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Credits on the Green House Gas CO_2 by using the released Energy from thermal Waste Treatment Plants

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The aim of this presentation is to show the specific CO2equ savings:

by replacing the demand of primary fuels for the <u>electricity</u> and/or <u>heat</u> production by dedicated facilities

by energy from recent or future Waste-to-Energy (WtE) plants for the same purposes

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Content

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General

By all thermal production/ combustion processes in the presence of CARBON (C) Carbon Dioxide CO2 is produced

CO2 is classified as a Green House Gas and with its fossil fraction primaryly responsable for the global warming potential (GWP in LCA)

$CO2_{fossil}$ release should therefore be reduced as far as possible and be replaced e.g. by renewable energies or better conversion efficiencies

$CO2_{biogenic}$ release from biomass is classified as environmentally neutral and renewable

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GWP and CO2 equivalences

GWP expressed as CO2equ is primarily produced by CO2 fossil (equivalence factor EF = 1)

GWP is also related to other gas emissions e.g.:
methane (CH4) (EF = 21),
nitrogen oxide compounds as NOx (EF = 8),
nitrous oxide N2O (EF = 310),
carbon monoxide (CO) (EF = 3),
ammonia (NH3) (EF = not defined),
non-methane volatile organic compounds (NMVOCs) (EF = 11) *see Johnke, B (1999/2004)*

In the Intergovernmental Panel on Climate Change (IPCC) fourth Assessment Report (AR4)
methane (CH4) (EF = 25),
nitrous oxide N2O (EF = 298) *see Hull, C (2009)*

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Ratio between CO2 and other GWP emissions, resulting by multiplying EF with the emission content in the released flue gas of a combustion process in CO2equ:

for dedicated power and/or heat producing facilities
CO2 : other GWP emissions
in general 97-98% : 2-3% *Johnke 1999/2004*

for WtE plants
CO2 : other GWP emissions
in general 99,6% :0,4% *Johnke 1999/2004*

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CO2equ fossil by primary fuels

To determine the potential of CO2equ savings the specific CO2 production related to the energy input of the imported primary fuel (e.g in k(M)g CO2/G(T)J or k(M)Wh) is needed

The determination of the heat related specific CO2 releases is of good accuracy because the primary fuels are in general homogenious in their composition and NCV

For the different possible primary fuels used in a dedicated power plant the specific CO2 releases are shown in the following table

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		treated brown coal,lignite	hard coal	heavy fuel oil	light fuel oil	natural gas per 1000 m3
net calorific value (NCV)						
min[1)]	GJ/Mg	19,4	25,3	-	-	33
max[1)]	GJ/Mg	22,0	28,6	-	-	36
NCV average[1)]	**GJ/Mg**	**19,5**	**26,5**	**39,5**	**42,6**	**34,5**
CO2 emission factor						
min[1)]	Mg CO2/GJ	0,098	0,093	-	-	-
max[1)]	Mg CO2/GJ	0,101	0,096	-	-	-
average[1)]	**Mg CO2/GJ**	**0,099**	**0,094**	**0,078**	**0,074**	**0,056**
average[2)]	Mg CO2/GJ	**-**	**0,095**	**-**	**0,077**	**0,056**
average[3)]	Mg CO2/GJ	**0,110**	**0,094**	**-**	***(0,056??)***	**0,052**
average[4)]	Mg CO2/GJ	**0,111**	**0,093**	**-**	***0,074***	**0,056**
CO2 average [1) -4)]	**Mg CO2/GJ**	***0,107***	***0,094***	***0,078***	***0,075***	***0,055***

(Reimann 2012)

1) Bundesgesetzblatt Jahrgang 2007 Teil I Nr. 40, "Zuteilungsverordnung von Emissionsfaktoren" Anhang I, Bonn am 17.August 2007
2) www.volker-quaschning.de/datserv/Co2-spez/index.php
3) Obermoser O. et.al. "Determination of reliable CO2 emission factors for WtE plants" wm&r nr 27:907-913 in 2009
4) Bilitewski, B. " Ökologische Effekte der Müllverbrennung durch Energienutzung", presentation, Berlin 06.11.2006

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Municipal Solid Waste (MSW)

In contrary to primary fuels
MSW contains beside

- **fossil fractions (e.g. plastic) producing CO2 fossil**
- **many biogenic fractions (e.g. paper, organics) releasing CO2 biogenic are not GWP relevant**

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CO2equ fossil by waste (MSW)

To determine the potential of CO2equ savings the specific CO2 production related to the energy input <u>of the waste</u> (e.g in k(M)g CO2/G(T)J or k(M)Wh) is needed

Because the composition of the waste and its NCV are in general different the results of the specific CO2 release is in a bright range

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For the determination of the fossil (respectively biogenic) spec. CO2 production related to the varying composition of waste and its NCV the determination of the CARBON (C) content in the waste is needed

3 standardized methods based on CEN 343 (2008) prEN15440 are available to determine the amount of fossil CARBON (C_{fossil}) from MSW and Solid Recovered Fuels SRF, even if the results show significant uncertainty

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Sorting analyse (input analyse)

Selective dissolution method (input analyse)

Radiocarbon "14C" method (input analyse)

A new but not yet officially standardised method is the so called "balance method" using operational data of a WtE plant in combination with a calculation method at the output of a plant (in the chimney) for the determination of fossil and biogenic organic matter (output analyse) ***(see Rechberger,H (2007))***

By the result from the following table it can be summarized that for MSW the specific $CO2_{fossil}$ as reasonable average is:

based on a ratio of <u>37%/63%</u> of fossil / biogenic fraction *(not published EPE protocol for 6 EU Countries)*

and a mean NCV of about <u>10 GJ/Mg</u> for European MSW *(CEWEP Energy Report III data not yet published)*

the specific $CO2_{fossil}$ factor for MSW can - as long as reliable analyses show no other results - be assumed between

<u>0.034 – 0.036 Mg/GJ</u> as average <u>0.035 Mg/GJ</u>

or <u>0.340 – 0. 360 Mg/Mg MSW</u>

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CO2 fossil from MSW		fossil/ biogenic fraction	related NCV of MSW	mixed municipal solid waste (MSW) < 25%CW	house-hold waste (HW)	MSW<50% commercial/ industrial waste (CW; IW) > 50% and SRF
		ratio	GJ/Mg MSW	Mg CO2/GJ	Mg CO2/GJ	Mg CO2/GJ
average[1)]		**not reported**	**8.4**		**0.030**	
average[1)]	from 6 different plants	**not reported**	**12,1-14,9**			**0.037- 0.049**
average[2)]		**not known**	**9**		**0.033**	
average[3)]		***50/50*** **(38/62)**	**9**	***0.046***	**0.035**	
average[4)]		**not known**	**9**	***0.046***		
average[5)]		**45/55**	**10**		**0.038**	
average[6)]	from 6 different reports	**average 36/64**	**average 10**	**0.036**		
CO2 fossil as average of total				**0.036**	**0.034**	**0.0436**

(Reimann 2012)

1) Obermoser O. et.al. "Determination of reliable CO2 emission factors for WtE plants" wm&r nr 27:907-913 in 2009
2) EpE "Protocol for the Quantification of Greehouse Gases Emissions from Waste Management Activities" Version 3.0, Paris, December 2008
3) Johnke, B. "Emissions from Waste Incineration" Background Paper 2003
4) Olofsson, M. " WtE from an environmental point of view", 2nd CEWEP Congress 6-8 September in Amsterdan 2004
5) Van Berlo, M. "Unleaxhing the power of Waste" Concept for Publication, Amsterdam, March 2008
6) Manders, J. "Life cycle Assessment of the treatment of MSW in "average" European Waste-to-Energy plants", presentation in Malmö, 24.11.2009
7) CEWEP Energy Report III (status 2007-2010) data not yet published

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CO2equ fossil for electricity production

To determine the substitution potential of CO2equ the specific CO2equ fossil production for electricity production with primary fuels (e.g in k(M)g CO2/G(T)J or k(M)Wh) is needed

Because the composition of the individual primary fuel and its NCV do not show high deviations the results of the specific CO2 release is in a quite small range and often certified by official data

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In general different primary fuels are included for the electricity production in a so called ELECTRICITY MIX which in general varies from country to country (e.g. saving own sources, financial (market) reason, political demands, import/export of electricity, long running delivery contracts etc)

The results in the following table are based on the ENERGY MIX for EU 27 for the year 2009

by IEA 2011

These results are therefore only of general character, but usable for GWP statistics and substitution potential in EU 27

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Specific CO2 emissions of different energy sources used for electricity production and for the EU electricity mix based on data of

Status 2009, EU 27			mean electricity efficiency	energy carrier spec. CO2 prod (see slide 7)	spec. CO2 prod eff. related as averages	spec. CO2 production efficiency and % electricity mix related as averages	
primary fuel	Electricity MIX [1] GWh	% of total	% of energy input	Mg CO2/TJ input	Mg CO2/TJ el	Mg CO2/TJ el	Mg CO2/MWh el
coal and peat	849,327	26.5					
hard coal (76%) [2]	*645,489*	20.1	37[3]	94	254	51	0.184
lignite (24%) [2]	*203,838*	6.4	36[3]	99	275	17	0.063
oil	95,972	3.0	*38*	74	195	6	0.021
gas	725,961	22.6	*38*	56	147	33	0.120
biofuels	91,742	2.9	*0*	0	0	0	0.000
waste CHP	32,696	1.0	14,9[4]	35	235	2	0.009
nuclear	893,991	27.9	35	23	66	18	0.066
hydro	359,106	11.2	*38*	8	21	2	0.008
geothermal	5,547	0.2	*0*	0	0	0	0.000
solar PV	14,058	0.4	15	120	800	4	0.013
solar thermal	22	0.0	0	0	0	0	0.000
wind	132,666	4.1	20[3]	12	60	2	0.009
tide	497	0.0	0	0	0	0	0.000
other sources	8,281	0.3	*38*	0	0	0	0.000
total	**3,209,866** [2]	**100.0**			**2,053**	**137**	**0.492**

(Reimann 2012)

[1] International Energy Agency (IEA) "Electricity/Heat in European Union 27 in 2009 (www.iea.org/stats/electricitydata.asp)

[2] EUROCOAL, Brüssel (2007)

[3] www.braunkohle.de (2012)

[4] CEWEP Energy Report III (2007-2010) not yet published

Specific CO2 release in a country should be calculated in the same way as in the Table but with the individual ELECTRICITY MIX

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Specific CO2 emission in case that out the recent electricity mix nuclear power is replaced only by coal, based on IEA data of 2009

Status 2009, EU 27			mean electricity	energy carrier	spec. CO2 prod	spec. CO2 production	
primary fuel	Electricity MIX [1]		efficiency	spec. CO2 prod (see slide 7)	eff. related as averages	efficiency and % electricity mix related as averages	
	GWh	% of total	% of energy input	Mg CO2/TJ input	Mg CO2/TJ el	Mg CO2/TJ el	Mg CO2/MWh el
coal and peat	1,743,318	54.3					
hard coal (76%) [2]	*1,324,922*	41.3	37[3]	94	254	105	0.378
lignite (24%) [2]	*418,396*	13.0	36[3]	99	275	36	0.129
oil	95,972	3.0	*38*	74	195	6	0.021
gas	725,961	22.6	*38*	56	147	33	0.120
biofuels	91,742	2.9	*0*	0	0	0	0.000
waste CHP	32,696	1.0	14,9[4]	35	235	2	0.009
hydro	359,106	11.2	*38*	8	21	2	0.008
geothermal	5,547	0.2	*0*	0	0	0	0.000
solar PV	14,058	0.4	15	120	800	4	0.013
solar thermal	22	0.0	0	0	0	0	0.000
wind	132,666	4.1	20[3]	12	60	2	0.009
tide	497	0.0	0	0	0	0	0.000
other sources	8,281	0.3	*38*	0	0	0	0.000
total	**3,209,866** [1]	**100.0**			**1,987**	**191**	**0.686**

(Reimann 2012)

[1] International Energy Agency (IEA) "Electricity/Heat in European Union 27 in 2009 (www.iea.org/stats/electricitydata.asp)

[2] EUROCOAL, Brüssel (2007)

[3] www.braunkohle.de (2012)

[4] CEWEP Energy Report III (2007-2010) not yet published

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In case that in the ELECTRICITY MIX the use of nuclear power will be excluded (e.g. as in GERMANY) and for the replacement of this missing energy supply coal would be used with the recent electricity efficiencies the CO2 emissions would increase for this most negative scenario from:

0.492 to 0.686 Mg CO2 fossil/MWh el up to 40%

In case that in the ELECTRICITY MIX the use of nuclear power will be excluded (e.g. as in GERMANY) and for the replacement of this missing energy supply coal would be used but with technically feasible electricity efficiencies as in modern power plants (for hard coal: instead 37% now 46%; for lignite: instead 36% now 43%) the CO2 emissions would increase for this improved negative scenario from:

0.492 to 0.591 Mg CO2 fossil/MWh el up to 20%

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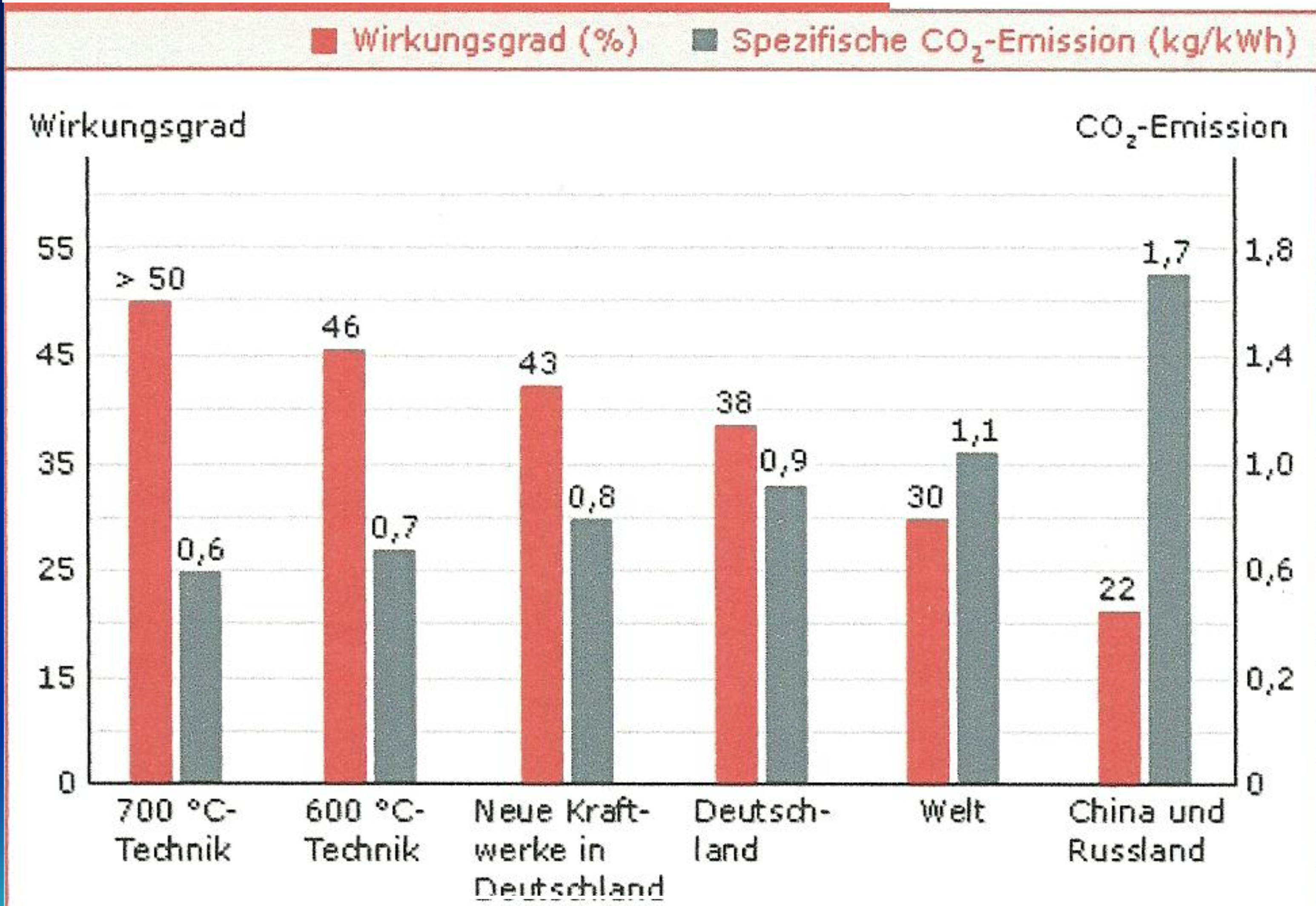
Comparison of recent and future CO2 fossil reduction potential by coal fired power plants related to technically feasible electrical efficiency



http://www.eon.com/Geschäftsfelder/stromerzeugung/kohle/hocheffiziente-kohleerzeugung/kraftwerke-im-vergleich.html

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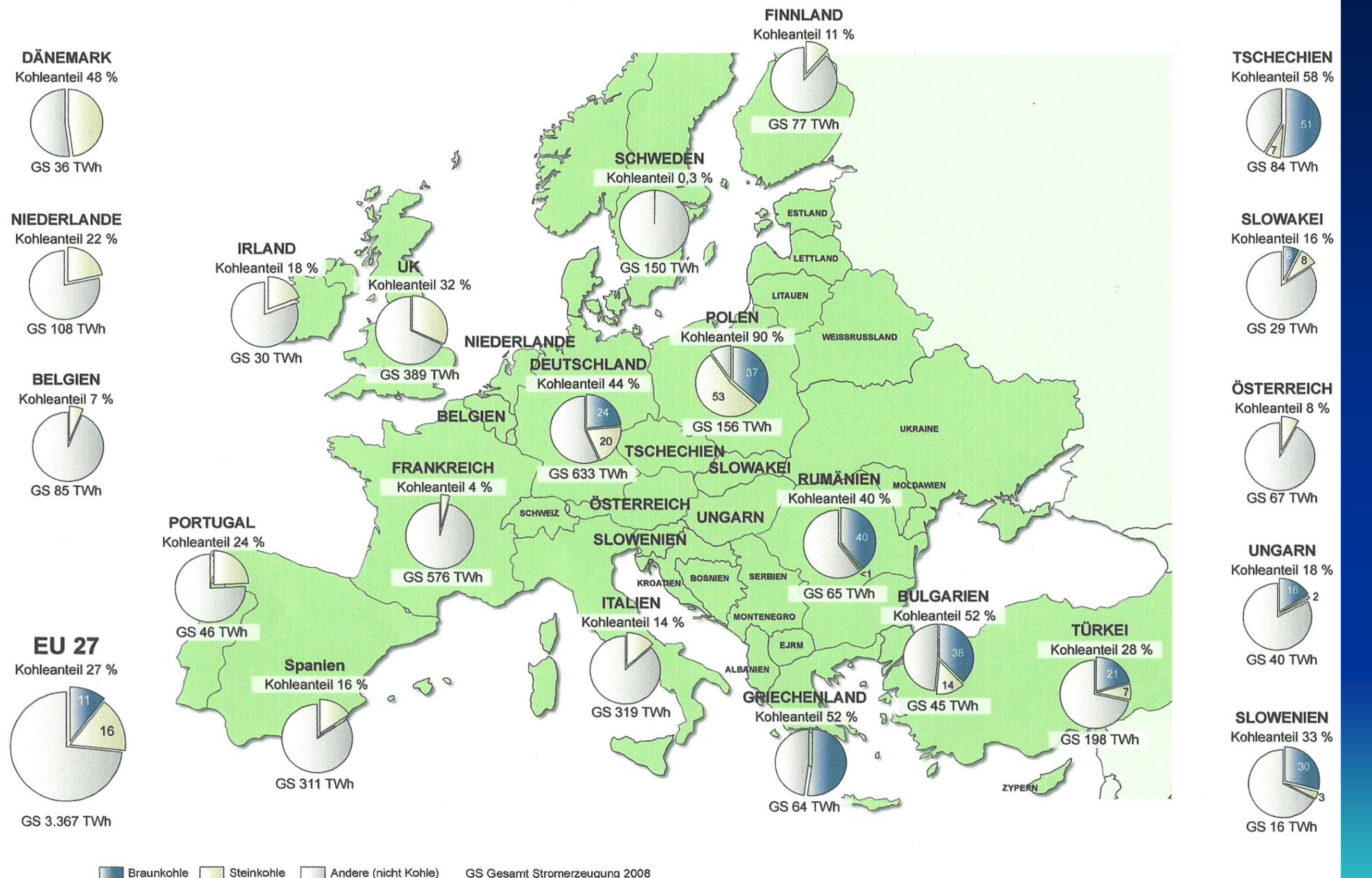
Anteil der Kohle an der Stromerzeugung ausgewählter Länder in Europa



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Specific CO2 emissions of different energy sources used for electricity production for CZ electricity mix based on Statista data of 2008

	Status 2008, CZ		mean electricity	energy carrier	spec. CO2 prod	spec. CO2 production	
primary fuel	Electricity MIX [1]		efficiency	spec. CO2 prod (see slide 7)	eff. related as averages	efficiency and % electricity mix related as averages	
	GWh	% of total	% of energy input	Mg CO2/TJ input	Mg CO2/TJ el	Mg CO2/TJ el	Mg CO2/MWh el
coal and peat	4,536,000	54.0					
hard coal (76%) [2]	588,000	7.0	37[2]	94	254	18	0.064
lignite (24%) [2]	3,948,000	47.0	36[2]	99	275	129	0.465
oil	0	0.0	*38*	74	195	0	0.000
gas	672,000	8.0	*38*	56	147	12	0.042
nuclear	2,688,000	32.0	35	23	66	21	0.076
other sources	504,000	*6.0*	*15*	*10*	*29*	*2*	*0.006*
total	**84,000** [1]	**100.0**			**965**	**182**	**0.654**
total if no nuclear but instead coal used	**84,000** [1]	**100.0**			**965**	**236**	**0.850**

1) Quelle: Tschechische Republik, Statista.comm (2011)

2) www.braunkohle.de (2012)

Specific CO2 release in CZ calculated in the same way as in the Table for EU 27 by taking the individual ELECTRICITY MIX into account

In both scenarios about 0.14 Mg CO2 equ more will/would be released than for EU 27. The reason for this deviation is, that the fraction of coal in the ELECTRICITY MIX of CZ is about 100% higher than in EU 27.

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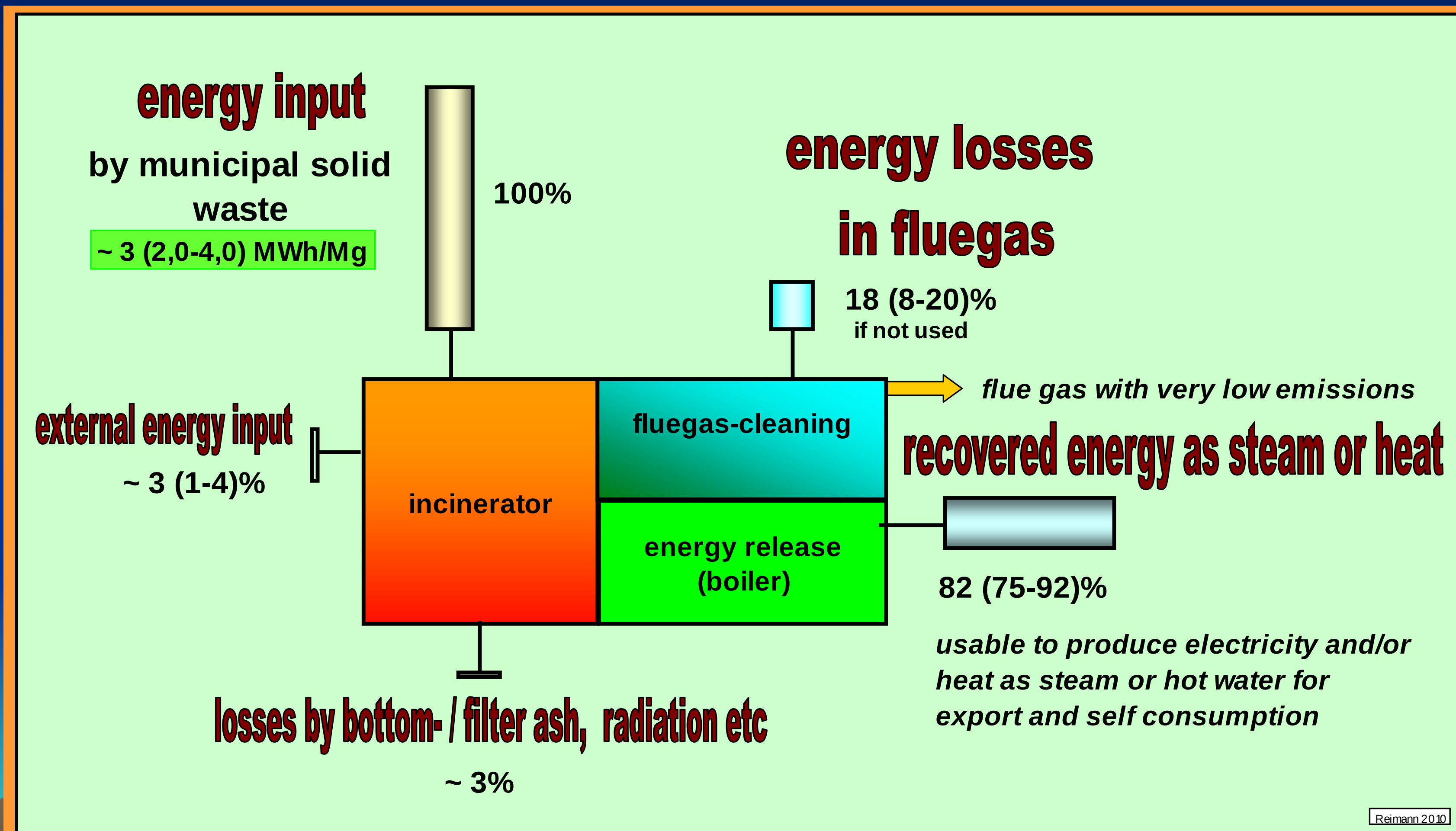
Energy balance of WtE plants

Waste-to-Energy (WtE) plants generate electricity and heat by the thermal treatment of mixed municipal solid waste (MSW).



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Substitution factors for MSW

CO2 fossil substitution potential for electricity and heat production, metal recovery and primary fuel demand by MSW incineration

Literature research and determination	CO2 fossil substitution by **electricity** production from MSW	CO2 fossil substitution by **heat** production from MSW	CO2 fossil substitution by **metal credit from MSW**	CO2 fossil **production** by use of primary fuels for the comb. process
	Mg CO2 fossil /MWhel	Mg CO2 fossil /MWhth	Mg CO2 fossil /Mg MSW	Mg CO2 fossil /Mg MSW
CEWEP LCA Report 2008[1)]	0.533	0.264	0.053	0.044
Prognos 2008[1)]	0.541	0.312	-	
FNADE 2008[1)]	0.560	0.242	-	-
Cassumptions for NL by VA 2009[1)]	0.572	0.227	0.053	-
Profu 2009 (Nordic)[1)]	0.640	0.300	-	
MHKW Amsterdam[2)]	0.594	0.256	0.113	0.038
CEWEP 2007-2010[3)]	-	-	-	0.035[3)]
CO2 fossil as average of total	**0.573**	**0.267**	**0.073**	**0.041**
Data based on IEA 2009[4)] see detailed calculation	**0.492**	**0.254**	***0.053***	***0.035*** [3)]

(Reimann 2012)

1) Manders, J. "Life cycle Assessment of the treatment of MSW in "average" European Waste-to-Energy plants", presentation in Malmö, 24.11.2009
2) Van Berlo, M. "Unleaxhing the power of Waste" Concept for Publication, Amsterdam, March 2008
3) CEWEP Energy Report III (status 2007-2010) data not yet published
4) International Energy Agency (IEA) "Electricity/Heat in European Union 27 in 2009" (www.iea.org/stats/electricitydata.asp)

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Determination of CO2 credits for WtE plants

CHP CO2equ emissions by combustion of MSW	unit	CO2 fossil by incineration	CO2 fossil by imported fuels	CO2 fossil by other GH gases than CO2 (+0.4%)		total specific CO2equ pollution
specific CO2equ pollution; NCV 10.3 GJ/Mg MSW	Mg CO2equ /Mg MSW	0.361	0.013	0.014		0.387
CHP **CO2equ credits by energy conversion from MSW**	**unit**	**CO2 for electricity production**	**CO2 for heat production**	**CO2 for other GH gases than CO2 (+2.5%)**	**CO2 for metal recovery**	**total specific CO2equ credit**
specific energy production from MSW *data from CEWEP Energy Report III not yet published*	MWhx /Mg MSW	0.452	0.761		0.053	
specific CO2 substitution potential	Mg CO2equ /MWhx	0.492	0.254	0.019	0.053	
CO2equ credits from MSW	Mg CO2equ /Mg MSW	0.222	0.193	0.019	0.053	0.487
	Credit in case of CHP = 0.487 - 0.387				Mg CO2equ /Mg MSW	0.100

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CO2equ credit in case of using the released energy from the waste treatment plant for Combined Heat and Power production (CHP) based on the data of this presentation and of the CEWEP Energy Report III which is not yet published

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primarily electricity prod. CO2equ emissions by combustion of MSW	unit	CO2 fossil by incineration	CO2 fossil by imported fuels	CO2 fossil by other GH gases than CO2 (+0.4%)		total specific CO2equ pollution
specific CO2equ pollution; NCV 9.55 GJ/Mg MSW	Mg CO2equ /Mg MSW	0.334	0.013	0.013		0.361
primarily electricity prod. CO2equ credits by energy conversion from MSW	**unit**	**CO2 for electricity production**	**CO2 for heat production**	**CO2 for other GH gases than CO2 (+2.5%)**	**CO2 for metal recovery**	**total specific CO2equ credit**
specific energy production from MSW *data from CEWEP Energy Report III not yet published*	MWhx /Mg MSW	0.581	0.115		0.053	
specific CO2 substitution potential	Mg CO2equ /MWhx	0.492	0.254	0.019	0.053	
CO2equ credits from MSW	Mg CO2equ /Mg MSW	0.286	0.029	0.019	0.053	0.387
	Credit in case of primarily electricity production				Mg CO2equ /Mg MSW	0.026

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CO2equ credit in case of using the released energy from the waste treatment plant for primarily power production (el.) based on the data of this presentation and of the CEWEP Energy Report III which is not yet published

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primarily heat production CO2equ emissions by combustion of MSW	unit	CO2 fossil by incineration	CO2 fossil by imported fuels	CO2 fossil by other GH gases than CO2 (+0.4%)		total specific CO2equ pollution
specific CO2equ pollution; NCV 11.0 GJ/Mg MSW	Mg CO2equ /Mg MSW	0.385	0.040	0.015		0.440
primarily heat production CO2equ credits by energy conversion from MSW	**unit**	**CO2 for electricity production**	**CO2 for heat production**	**CO2 for other GH gases than CO2 (+2.5%)**	**CO2 for metal recovery**	**total specific CO2equ credit**
specific energy production from MSW *data from CEWEP Energy Report III not yet published*	MWhx /Mg MSW	0.164	2.431		0.053	
specific CO2 substitution potential	Mg CO2equ /MWhx	0.492	0.254	0.019	0.053	
CO2equ credits from MSW	Mg CO2equ /Mg MSW	0.081	0.617	0.019	0.053	0.770

Credit in case of primarily heat production	Mg CO2equ /Mg MSW	**0.330**

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Credit in case of all 3 recovery systems weighted	Mg CO2equ /Mg MSW	**0.128**

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CO2equ credit in case of using the released energy from the waste treatment plant for primarily heat production (th) and the total WtE plants not classified into different groups based on the data of this presentation and of the CEWEP Energy Report III which is not yet published

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Conclusion

CO2 fossil as the most problematic emission gas for the environment and should be minimized in all thermal processes as far as technically possible and economically acceptable

Municipal Solid Waste (MSW) belongs with its biogenic fraction (Biomass) and with this fraction to the group of Renewable Energy.

The total C-content is in a bride range of 0.240-0.300 as average 0.250 Mg C/Mg MSW.

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MSW has got a heterogeneous structure and consists of different waste fractions (e.g. household, bulky, commercial or industrial waste or SRF).

This heterogeneity is e.g. indicated by a high range of Net Calorific Value (NCV) between 6 - 17 as average 10 GJ/Mg MSW in Europe.
NCV is primarily depending on the CARBON (C) and Hydrogen (H) content in the MSW.

The total C-content consists of a biogenic fraction 50% to 77% as average 63% of C total which produces environmentally neutral CO2=biogenic CO2=CO2 neutral.

The remaining part of about 37% of C total is fossil and polluting the environment not taking credits into account with 0.340 - 0.360 MgCO2 fossil/Mg MSW.

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Needed primary fuels for special processes (e.g. start up/shut down process, keeping the incineration temperature at e.g. 850°C) are producing additional 0.035 Mg CO2 fossil/Mg MSW

By the conversion of the energy from MSW into useable heat and/or electricity these amounts of energy can be avoided in dedicated power/ heat plants, operated with primary fuels producing fossil CO2 emissions.

By this substitution effect WtE plants receive a CO2 credit in case that the avoided CO2 emissions for electricity and heat in dedicated plants are higher than the CO2 fossil produced by MSW incineration.

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Avoided CO_2 fossil emissions for the production of heat and electricity are different from country to country because inter alia depending on the local composition of the ENERGY MIX, political conditions, efficiencies of used technology, market (financial) situation, base load energy, use of own resources, nuclear power: yes or no.

Detailed calculation are necessary **as shown in this presentation**

As an additional CO_2 fossil saving the recovery of metals, about 0.053 Mg CO_2 fossil/Mg MSW can be taken into account.

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In the calculation model for the CO2 fossil credits by MSW incineration in this presentation it is obvious that independent of the kind of energy substitution WtE plants will receive under the recent condition in EU in any case a CO2 credit.
WtE plants primarily <u>heat with only a little electricity production get higher CO2 credits than normal CHP and only electricity producing WtE plants.</u>

Approaches and results for the detailed calculation methods of CO2 fossil production by primary fuel, related to different ENERGYMIX as well as the CO2 fossil substitution potential by MSW as mentioned in the conclusion are part in this presentation.

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Thank you for your attention