Calculation of Claorific Value

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Gross Calorific Value H_o:

The gross or upper calorific value is the energy of a fuel which will be set free by a complete incineration process under the condition that the exhaust air is cooled down to constand 25° C. The water vapour produced during the incineration process condensate under this conditions and gives the heat of condensation to the environment.

Net calorific Value H_u:

The net or lower calorific value is the energy of a fuel which will be set free by a complete incineration process under the condition that the exhaust air is cooled down to const. 25° C. The water vapour produced during the incineration process stays virtual vaporous (that means without the heat condensation).

$H_{u,n}$ und $H_{o,n}$:

these values are related to the norm volume of 1 m³ dry gas (1013 hPa, 0 °C).

Analytic:

In waste management the gross calorific value H_o is de-termed from a water free sample as $H_{o(wf)}$.

$$H_{u(roh)} = H_{o(roh)} - k * F$$

with:

$H_{o(roh)}$ = $H_{o(wf)}$ * (100-WG) / 100
k = condensation heat of water under 25 °C = 24,41 J/g
F ≈ WG
WG = Water content
$H_{o(wf)}$ = water free gross calorific value

$$Hu(roh) = Ho(wf) * (100-WG)/100 - 24,41 * WG$$

Example:

The net calorific Value of Waste from different cities in kJ / kg. All data are an average over the total city. There can be great deviations between different areas of a city depending from the urban framework.

- Berlin ca 8.000
- Rome ca 7.600
- New York ca 9.500
- Bangkok ca 6.500
- Shanghai ca 6.800
- Accra ca 4.200
- Kathmandu ca 3.700
- Paris ca 8.500

Calculation on the Basis of the Waste Composition

The calculation of the net calorific value can be done on the basis of the composition of a waste stream. Some example data are given in table 1.

With the data from table 1 and the distribution of the elements and their water contents the net calorific value (Hu, roh) of the waste can be calculated using the element specific net calorific value under water free conditions (Hu,wf).

$$H_{u,roh,f} = \sum_{y=1}^{j} \left\langle \left\langle \left\langle \frac{H_{u,wf,y} * 100 - WG_{y,f}}{100} \right\rangle - k * WG_{y,f} \right\rangle * \frac{m_{y,f}}{100} \right\rangle$$

with:

$H_{u,roh,f}$	mixed net calorific value in the raw waste **f** [kJ/kg FS]
$H_{u,wf,y}$	net calorific value water free in a fraction **y** [kJ/kg TS]
$Wg_{y,f}$	water contend of a fraction **f** [wight.-% (FS)]
k	Spez. heat condensation of water under 25 °C (2,441 [kJ/kg])
$m_{y,f}$	Mass of a fraction y [wight.-% (FS)]
j	number of fractions [-]

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Tabelle 1: Chemical Composition of various waste fractions

	Fraction [1]	Water [2]	volatile matter [3]	Fix C [4]	Ash	Calorific Value H_u	Related to the combustible substance		Relation [3] to [4]	Chemical Composition of the water free Substance						
							Volatile matter	Fix C		C	H	O	N	S	Ash	Calorific Value $_u$
		%	%	%	%	kJ/kg	%	%		%	%	%	%	%	%	kJ/kg
1	News Paper	5,97	81,12	11,48	1,43	18.547,52	87,60	12,40	7,06	49,14	6,10	43,03	0,05	0,16	1,52	19.761,70
2	Brown Paper	5,83	83,92	9,24	1,01	16.893,74	90,10	9,90	9,08	44,90	6,08	47,84	0,00	0,11	1,07	17.961,37
3	Magazine Paper	4,11	66,39	7,03	22,47	11.806,78	90,40	9,60	9,44	32,91	4,95	38,55	0,07	0,09	23,43	12.748,81
4	corrugated card board	5,20	77,47	12,27	5,06	16.391,32	46,30	13,70	6,31	73,73	5,70	44,93	0,09	0,21	5,34	17.270,55
5	Plastic coated Paper	4,71	84,20	8,45	2,64	17.082,14	90,90	9,10	9,96	45,30	6,17	45,50	0,18	0,08	2,77	17.919,50
6	Waxed Paper	3,45	90,92	4,46	1,17	26.314,04	95,30	4,70	20,40	59,18	9,25	30,13	0,12	0,10	1,22	27.277,00
7	Food card board box	6,11	75,59	11,80	6,50	16.893,74	86,50	13,50	6,40	44,74	6,10	41,92	0,15	0,16	6,93	18.003,24
8	Recycled Paper	4,56	73,32	9,03	13,09	14.172,32	89,00	11,00	8,12	37,87	5,41	42,74	0,17	0,09	13,72	14.863,14
9	Vegetable waste	78,29	17,10	3,55	1,06	4.144,93	82,80	17,20	4,81	49,06	6,62	37,55	1,68	0,20	4,89	19.301,15
10	Citrus peel, cork	78,70	16,55	4,01	0,74	3.977,46	80,50	19,50	4,12	47,96	5,68	41,67	1,11	0,12	3,46	18.694,06
11	Cooked meat	38,74	56,34	1,81	3,11	17.731,10	96,90	3,10	31,10	59,59	9,47	24,65	1,02	0,19	5,08	28.888,92
12	Fat	0,00	97,64	2,36	0,00	38.267,35	97,60	2,40	41,40	73,14	11,54	14,82	0,43	0,07	0,00	38.267,35
13	Leather	7,46	57,14	14,26	21,16	16.851,87	80,00	20,00	4,00	42,01	5,32	22,83	5,98	1,00	22,86	18.191,65
14	Shoe sole	1,15	67,03	2,08	29,74	25.351,07	97,00	3,00	32,25	53,22	7,09	7,76	0,50	1,34	30,09	25.623,22
15	Vacuum Cleaner	5,47	55,68	8,51	30,34	14.863,14	86,70	13,30	6,54	35,69	4,73	20,08	6,26	1,15	32,09	15.700,50

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	Fraction [1]	Water [2]	volatile matter [3]	Fix C [4]	Ash	Calorific Value H½	Related to the combustible substance		Relation [3] to [4]	Chemical Composition of the water free Substance						
	bags															
							Volatile matter	Fix C		C	H	O	N	S	Ash	Calorific Value½
16	**Park Waste (including branches)**	69,00	25,18	5,01	0,81	6.280,20	83,40	16,60	5,02	48,51	6,54	40,44	1,71	0,19	2,61	20.347,85
17	**Spruce**	74,35	20,70	4,13	0,82	5.673,11	83,30	16,70	5,01	53,30	6,66	35,17	1,49	0,20	3,18	22.210,97
18	**Flower Waste**	53,94	35,64	8,08	2,34	7.661,84	81,50	18,50	4,41	46,65	6,61	40,18	1,21	0,26	5,09	18.694,06
19	**Grass**	75,24	18,64	4,50	1,62	4.793,89	80,50	19,50	4,14	46,18	5,96	36,43	4,46	0,42	6,55	19.384,88
20	**Leaves**	9,97	66,92	19,29	3,82	18.547,52	77,60	22,40	3,47	52,15	6,11	30,34	6,99	0,16	4,25	20.640,92

Table 2 Examples from various fuels

Fuel	Dnsity	Unit of Density	Calorific Value kWh/kg	Gross Calorific Value kWh/kg	CO_2 from Incineration kg/kg fuel	CO_2 from Production and Transport kg/kg fuel	CO_2 from Incineration kg/kWh	CO_2 from Production and Transport kg/kWh	Comment	Content C wight.-%	Content H wight.-%
Electricity	-	-	-	-	-	-	-	0,71		-	-
Natural gas	0,75	kg/Nm³	14,2		2,5	0,26	0,20	0,02	regional differences!	69	22,4
Fuel gas	0,85	kg/l	11,5	12,3	3,2	0,28	0,27	0,02		86	13,3
Propane gas			12,9	14,0		0,77	0,23	0,06			
Butane gas			12,7	13,8		0,76	0,24	0,06			
Hard coal			8,2		2,8	0,22	0,34	0,03		77	4,6
Brown coal			5,5		1,9	0,17	0,35	0,03	Briquette	52	4
Coke			7,7		2,6	0,29	0,39	0,04	Coke	70	4,3
Hardwood	480	kg/Rm	4,1		1,4	0,01	0,36	0,002	ca. 15% water content		
Softwood	300	kg/Rm	4,3		1,5	0,01	0,36	0,002	ca. 15% water content		
Wood briquette			5,3		1,5		0,36				
Woodchip	230	kg/Sm³	3,2		1,5		0,33				
Wood pellet	650	kg/Sm³	4,9		1,5		0,36				
Biogas	1,15	kg/Nm³	5,6		1,7	0,08	0,30	0,014	Large range	46	10
Gasoline	0,74	kg/l	11,8	12,8	3,2	0,70	0,26	0,06		86	14
Diesel	0,85	kg/l	11,6	12,4	3,2	0,34	0,28	0,03		86	13

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Fuel	Dnsity	Unit of Density	Calorific Value kWh/kg	Gross Calorific Value kWh/kg	CO_2 from Incineration kg/kg fuel	CO_2 from Production and Transport kg/kg fuel	CO_2 from Incineration kg/kWh	CO_2 from Production and Transport kg/kWh	Comment	Content C wight.-%	Content H wight.-%
Liquid gas			12,9	14,0		0,77	0,23	0,06	= Propane gas		
Natural Gas	0,75	kg/Nm³	14,2		2,5	0,26	0,20	0,02	"Auto gas"	69	22,4
Bio diesel	0,88	kg/l	10,3		2,8	1,11	0,27	0,11		77	12
Methanol	0,79	kg/l	5,42	6,2	1,38		0,255			37,5	12,5
Ethanol	0,79	kg/l	7,50		1,91	1,26	0,255	0,168	= Ethylalkohol, "Alkohol" / from digestion	52,2	13
Hydrogen	0,09	kg/Nm³	33,3	39,5	1,4		0,00				100
Oak	680	kg/Fm	4,9	5,3		0,01	0,43	0,002	absol. dry, 58,5% C	58	5,1
Beech	680	kg/Fm	4,9	5,3		0,01	0,36	0,002	absol. dry, 47,9% C	48	6,2
Spruce	430	kg/Fm	5,2	5,6		0,01	0,35	0,002	absol. dry, 49,7% C	50	6,3
Pine	510	kg/Fm	5,2	5,6		0,01	0,38	0,002	absol. dry, 53,2% C	53	5,9

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