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WELL-TO-TANK Appendix 1 - Version 4.0

Conversion factors and fuel properties

WELL-TO-WHEELS ANALYSIS OF FUTURE AUTOMOTIVE FUELS AND POWERTRAINS IN THE EUROPEAN CONTEXT

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WELL-TO-TANK (WTT) REPORT – APPENDIX 1

VERSION 4, JULY 2013

This report is available as an ADOBE pdf file on the JRC/IET website at:

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Conversion factors and fuel properties

All WTT data is stored in LBST's E^3 database and that software was used to calculate the energy and GHG balances of the pathways. The full details of each pathway can be found in the workbooks included in Appendix 4. A summary of the results can be found in Appendix 2.

This appendix gives conversion factors and details the fuel properties used in the study.

Table of contents

1 Useful conversion factors and calculation methods

1.1 General

1 kWh = 3.6 MJ = 3412 Btu
1 Mtoe = 42.6 PJ
1 MW = 1 MJ/s = 28.8 PJ/a (8000 h)

1 t crude oil ~ 7.4 bbl
1 Nm^3 of EU-mix NG ~ 0.8 kg ~ 40 MJ
(i.e. 1 Nm^3 of NG has approximately the same energy content as 1 kg of crude oil)

1.2 Factors for individual fuels

Gases

NG EU-mix	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	Nm_3/h
MW (MJ/s)		86.4	28.8	80.4	1929	643	102
GJ/d	0.012		0.333	0.930	22.3	7.4	1.18
PJ/a (8000 h)	0.035	3		2.79	67.0	22.3	3.53
kg/h	0.012	1.07	0.36		24	8	1.27
kg/d		0.04	0.01			0.33	0.05
t/a (8000 h)		0.13	0.04	0.13	3		0.16
Nm_3/h		0.85	0.28	0.79	19.0	6.3	

Methane	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	Nm_3/h
MW (MJ/s)		86.4	28.8	72.0	1728	576	101
GJ/d	0.012		0.333	0.833	20.0	6.7	1.17
PJ/a (8000 h)	0.035	3		2.50	60.0	20.0	3.50
kg/h	0.014	1.20	0.40		24	8	1.40
kg/d		0.05	0.02			0.33	0.06
t/a (8000 h)		0.15	0.05	0.13	3		0.18
Nm_3/h		0.86	0.29	0.71	17.1	5.7	

Hydrogen	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	Nm_3/h
MW (MJ/s)		86.4	28.8	30.0	719	240	336
GJ/d	0.012		0.333	0.347	8.3	2.8	3.89
PJ/a (8000 h)	0.035	3		1.04	25.0	8.3	11.66
kg/h	0.033	2.88	0.96		24	8	11.20
kg/d		0.12	0.04			0.33	0.47
t/a (8000 h)		0.36	0.12	0.13	3		1.40
Nm_3/h		0.26	0.09	0.09	2.1	0.7	

Liquids

Gasoline	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	m_3/d
MW (MJ/s)		86.4	28.8	83.1	1995	665	2.68
GJ/d	0.01		0.33	0.96	23.1	7.70	0.03
PJ/a (8000 h)	0.03	3		2.89	69.3	23.1	0.09
kg/h	0.01	1.04	0.35		24	8	0.03
kg/d		0.04	0.01			0.333	
t/a (8000 h)		0.13	0.04	0.13	3		
m_3/d		32.3	10.8	31.0	745	248	

Diesel	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	m_3/d
MW (MJ/s)		86.4	28.8	83.5	2005	668	2.41
GJ/d	0.01		0.33	0.97	23.2	7.73	0.03
PJ/a (8000 h)	0.03	3		2.90	69.6	23.2	0.08
kg/h	0.01	1.03	0.34		24	8	0.03
kg/d		0.04	0.01			0.333	
t/a (8000 h)		0.13	0.04	0.13	3		
m_3/d		35.9	12.0	34.7	832	277	

Methanol	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	m_3/d
MW (MJ/s)		86.4	28.8	180.9	4342	1447	5.48
GJ/d	0.01		0.33	2.09	50.3	16.75	0.06
PJ/a (8000 h)	0.03	3		6.28	150.8	50.3	0.19
kg/h	0.01	0.48	0.16		24	8	0.03
kg/d		0.02	0.01			0.333	
t/a (8000 h)		0.06	0.02	0.13	3		
m_3/d		15.8	5.3	33.0	793	264	

FT diesel	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	m_3/d
MW (MJ/s)		86.4	28.8	81.8	1964	655	2.52
GJ/d	0.01		0.33	0.95	22.7	7.58	0.03
PJ/a (8000 h)	0.03	3		2.84	68.2	22.7	0.09
kg/h	0.01	1.06	0.35		24	8	0.03
kg/d		0.04	0.01			0.333	
t/a (8000 h)		0.13	0.04	0.13	3		
m_3/d		34.3	11.4	32.5	780	260	

DME	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	m_3/d
MW (MJ/s)		86.4	28.8	126.6	3039	1013	4.54
GJ/d	0.01		0.33	1.47	35.2	11.72	0.05
PJ/a (8000 h)	0.03	3		4.40	105.5	35.2	0.16
kg/h	0.01	0.68	0.23		24	8	0.04
kg/d		0.03	0.01			0.333	
t/a (8000 h)		0.09	0.03	0.13	3		
m_3/d		19.0	6.3	27.9	670	223	

Ethanol	MW	GJ/d	PJ/a	kg/h	kg/d	t/a	m_3/d
MW (MJ/s)		86.4	28.8	134.3	3224	1075	4.06
GJ/d	0.01		0.33	1.55	37.3	12.44	0.05
PJ/a (8000 h)	0.03	3		4.66	111.9	37.3	0.14
kg/h	0.01	0.64	0.21		24	8	0.03
kg/d		0.03	0.01			0.333	
t/a (8000 h)		0.08	0.03	0.13	3		
m_3/d		21.3	7.1	33.1	794	265	

Solids

Hard Coal	MW	GJ/d	PJ/a	kg/h	kg/d	t/a
MW (MJ/s)		86.4	28.8	135.8	3260	1087
GJ/d	0.01		0.33	1.57	37.7	12.58
PJ/a (8000 h)	0.03	3		4.72	113.2	37.7
kg/h	0.01	0.64	0.21		24	8
kg/d		0.03	0.01			0.333
t/a (8000 h)		0.08	0.03	0.13	3	

Wood	MW	GJ/d	PJ/a	kg/h	kg/d	t/a
MW (MJ/s)		86.4	28.8	200.0	4800	1600
GJ/d	0.01		0.33	2.31	55.6	18.52
PJ/a (8000 h)	0.03	3		6.94	166.7	55.6
kg/h	0.01	0.43	0.14		24	8
kg/d		0.02	0.01			0.333
t/a (8000 h)		0.05	0.02	0.13	3	

1.3 GHG calculations

CO_2-equivalence coefficients [IPCC 2007]

Methane 25
Nitrous oxide 298

CO_2 emissions from combustion (assuming total combustion)

1 kg of a fuel with C% carbon emits:

1 x C% / 100 / 12 x 44 = (0.0367 x C%) kg of CO_2

1 MJ of a fuel with λ MJ/kg (LHV) and C% carbon emits:

1 / λ x C% / 100 / 12 x 44 = (0.0367 / λ x C%) kg of CO_2

2 Fuels properties

2.1 Gases

	Molar mass	LHV				C content	CO_2 emission factor*		
	g/mol	MJ/kg	MJ/Nm^3	kg/kWh	kWh/kg	% m	g CO_2/MJ	kg CO_2/kg	kg CO_2/Nm^3
Methane	16.0	50.0	35.7	0.072	13.89	75.0%	55.0	2.75	3.85
NG (EU-mix)	17.7	45.1	35.7	0.080	12.53	69.2%	56.2	2.54	3.21
NG (Russia)	16.3	49.2	35.8	0.073	13.67	73.9%	55.1	2.71	3.72
Hydrogen	2.0	120.1	10.7	0.030	33.36				
LPG	50.0	46.0		0.078	12.78	82.4%	65.7	3.02	1.35
Isobutane		45.6		0.079	12.68				
Isobutene		45.1		0.080	12.52				
Propylene		45.7		0.079	12.70				

* assuming total combustion

The EU-mix is the gas that is deemed to be available to a vehicle as CNG.

The Russian gas composition is used for marginal gas use in WTT pathways.

LPG composition assumed for this study

Component	% m/m	% v/v	MM	LHV (GJ/t)	C (%m/m)	H (%m/m)
C1	0.1	0.3	16	50.1	75.0	25.0
C2	2.4	4.0	30	47.5	80.0	20.0
C2=	0.5	0.9	28	47.2	85.7	14.3
C3	40.0	45.4	44	46.4	81.8	18.2
C3=	1.0	1.2	42	45.8	85.7	14.3
nC4	30.0	25.8	58	45.8	82.8	17.2
iC4	22.0	19.0	58	45.7	82.8	17.2
C4=	1.5	1.3	56	45.3	85.7	14.3
iC4=	1.5	1.3	56	45.1	85.7	14.3
nC5	1.0	0.7	72	45.4	83.3	16.7
Total	**100.0**	**100.0**	**50**	**46.0**	**82.4**	**17.6**

Total			
C2-	3.0		
C3	41.0		
C4	55.0	**CO2 emission factor**	
C5+	1.0	3.02	t CO2 / t
Olefins	4.5	65.7	kg CO2 / GJ

2.2 Liquids

	Density	LHV				C content	CO_2 emission factor*	
	kg/m3	MJ/kg	GJ/m3	kg/kWh	kWh/kg	% m	g CO_2/MJ	kg CO_2/kg
Crude oil	820	42.0	34.4	0.086	11.67	86.5%	75.5	3.17
Gasoline	745	43.2	32.2	0.083	12.00	86.5%	73.4	3.17
Diesel	832	43.1	35.9	0.084	11.97	86.1%	73.2	3.16
Naphtha	720	43.7	31.5	0.082	12.14	84.9%	71.2	3.11
Heavy fuel oil	970	40.5	39.3	0.089	11.25	89.0%	80.6	3.26
Syn diesel	780	44.0	34.3	0.082	12.22	85.0%	70.8	3.12
Syn naphtha	700	44.5	31.2	0.081	12.36	84.0%	69.2	3.08
Methanol	793	19.9	15.8	0.181	5.53	37.5%	69.1	1.38
DME	670	28.4	19.0	0.127	7.90	52.2%	67.3	1.91
Ethanol	794	26.8	21.3	0.134	7.44	52.2%	71.4	1.91
MTBE	745	35.1	26.1	0.103	9.75	68.2%	71.2	2.50
ETBE	750	36.3	27.2	0.099	10.07	70.6%	71.4	2.59
				Of which renewable		33.3%	23.8	
Plant oil (crude and refined)	920	37.0	34.0	0.097	10.28			
Biodiesel (methyl ester)	890	37.2	33.1	0.097	10.33	77.3%	76.2	2.83
Biodiesel (ethyl ester)	890	37.9	33.7	0.095	10.53	76.5%	74.0	2.81
HVO	780	44.0	34.3	0.082	12.22	85.0%	70.8	3.12
Tallow oil		37.0		0.097				
Glycerine		16.0		0.225	4.44			
Propylene glycol		20.0		0.180	5.56			
n-hexane		45.1		0.225	4.44			

* assuming total combustion

2.3 Solids

	Moisture content	LHV (dry matter)				C content	CO_2 emission factor*	
		MJ/kg		kg/kWh	kWh/kg	% m	g CO_2/MJ	kg CO_2/kg
Hard Coal		26.5		0.136	7.4	69.4%	96.0	2.54
Wood	30.0%	18.5		0.195	5.1	50.0%	99.1	1.83
Sugar beet	77.0%	16.3		0.221	4.5			
Sugar beet pulp	9.0%	16.1		0.224	4.5			
Sugar beet slops	9.0%	15.6		0.231	4.3			
Wheat grain	16.0%	17.1		0.211	4.8			
Barley grain	14.0%	17.0		0.212	4.7			
Rye grain	14.0%	17.1		0.211	4.8			
Maize/Corn grain	14.0%	17.3		0.208	4.8			
Wheat (whole plant)	16.0%	17.0		0.212	4.7			
Maize whole plant	65.0%	16.9		0.213	4.7			
Double crop (barley/corn)	70.0%	18.0		0.200	5.0			
Wheat straw	13.5%	17.2		0.209	4.8			
Rye straw	14.0%	17.4		0.207	4.8			
DDGS (Wheat, Barley, Rye)	10.0%	18.7		0.193	5.2			
DDGS (corn)	10.0%	19.8		0.182	5.5			
Sugar cane	73.0%	19.6		0.184	5.4			
Molasses, Vinasse	20.0%	14.0		0.257	3.9			
Rapeseed	9.0%	27.0		0.133	7.5			
Sunflower seed	9.0%	27.2		0.132	7.6			
Soya beans	13.0%	23.0		0.157	6.4			
Rapeseed meal	12.8%	18.4		0.196	5.1			
Sunflower meal	10.0%	18.2		0.198	5.0			
Soya bean meal	11.6%	19.1		0.188	5.3			
FFB (Fresh Fruit Bunch)	34.0%	24.0		0.150	6.7			
Palm kernel meal	10.0%	18.5		0.195	5.1			
Wet manure	85.0%	12.0		0.300	3.3			
Wood pulp	10.0%	15.9		0.227	4.4			
Black liquor	25.0%	12.1		0.298	3.4			
Nuclear fuel		3455.8		0.001	959.9			

* assuming total combustion

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