Sustainability requirements for biofuels - German Perspectives

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GHG Accounting Methodology and Default Data according to the Biomass Sustainability Ordinance (BSO)

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Legal Background

Biofuel Quota Act (Jan 07) determines mandatory quotas for biofuels and requires evidence on:

→Sustainable cultivation

→Protection of natural habitats

→A minimum rate of CO_2 mitigation

Biomass Sustainability Ordinance (BSO, draft from Dec. 07) determines criteria biofuels have to meet for to ifines ist die Voraussetzung zur Anrechnung zur Quote nach BioKraftQuG

Basics

Basic methodological elements worked out

- by a task force of representatives from BMU, BMELV, UBA, FNR, FAL, Öko-Institut and IFEU.
- within the scope of the research project "criteria for a Sustainable Use of Bioenergy on a Global Scale"

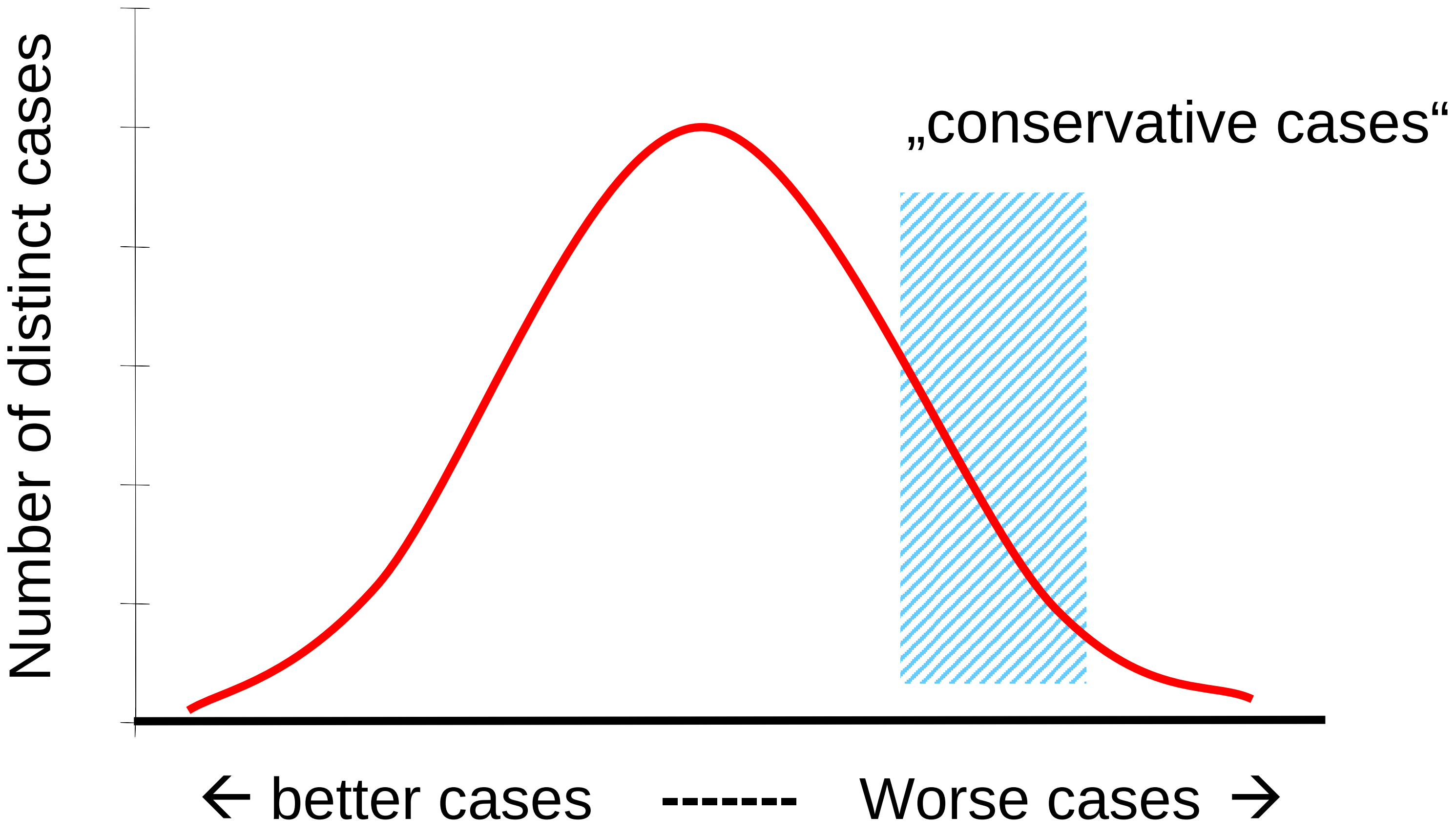
Task force started work on May 2007.

Principles of GHG balance

- **The whole production chain shall be considered.**
- **Default values have to be applied in case specific data are not provided and verified.**
- **The emission of GHG shall be calculated in the unit kg CO_2 equivalent / GJ of fuel.**
- **GHG conversion factors to CO_2-e according to the Kyoto Protocol.**
- **Co-products are considered according to there energy content: Allocation by lower heating value.**
  no pre-chain for waste input.
  Co-products that stay on the agricultural land (e.g. straw) are not allocated.

Default values

… shall be based on conservative but realistic cases for Germany (in Germany used biofuels).



Default-Werte

Modules referring to the single steps of the production chain

1. direct land use change
2. Production of biomass
3. Transport of biomass
4. Conversion step 1
5. Transport between conversion steps
6. Conversion step 2
7. Transport to refinery, storage, admixture

Default values

- Default values have to be applied in case specific data are not provided and verified.
- These shall be based on conservative but realistic cases for Germany (in Germany used biofuels)
- Modules referring to the single steps of the production chain

- **Reference values are taken from the WtW study (JEC):**
  Petrol: 85 kg CO_2-e/GJ
  Diesel: 86,2 kg CO_2-e/GJ

Consideration of co-products

Allocation by the lower heating value:

Reasons:

- Robust unambiguous approach, .
- Coefficients are empirical, provable and available (at least from standard tables).
- Energy (GJ) is the major issue concerning biofuel BioKraftQuG.

☹ In some cases the LHV is unclear (varying water content).

Lower heating values

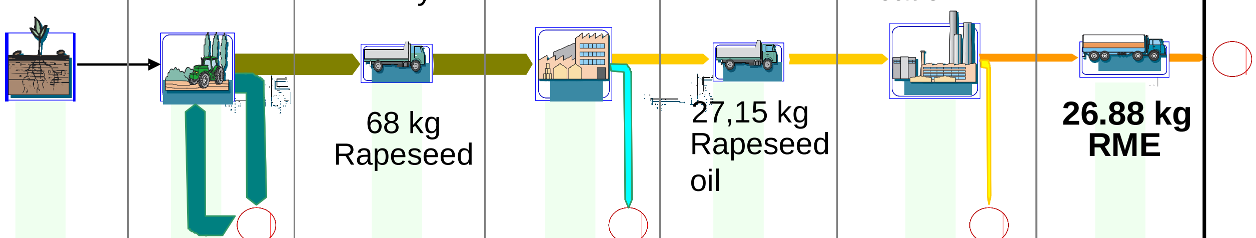
		Lower heating value Hu		Water content
		MJ/kg DS	MJ/kg OS	%
Agricultural products				
Wheat	Complete plant	17.1	13.5	18.4%
	Grains	17.0	13.7	16.9%
	Straw	17.2	13.3	19.8%
Maize	Complete plant	16.5	14.3	11.6%
	Grains	21.4	17.4	16.7%
	Straw	17.7	13.7	19.8%
Sugarcane	Complete plant	17.0	11.0	30.8%
	Crop harvest	17.0	11.0	30.8%
Sugar beet	Complete plant beet	17.0	2.1	76.4%
	Crop harvest			
Rapeseed	Complete plant	21.8	17.0	19.6%
	Grains	26.5	21.8	16.2%
	Residue	17.0	14.7	11.8%
Soybeans	Complete plant	18.0	14.5	17.1%
	Beans/seed	20.0	17.0	13.3%
	Residue	17.0	13.0	20.5%
Palm oil	Seed head	24.6	22.3	8.5%
	Fruits	31.7	31.5	0.6%
	empty seed heads	17.5	14.0	17.5%

Semi-manufactured products			
Destiller’s dried grains (DDGS)	21.8	16.0	23.9%
Molasses (45% sucrose)	19.0	7.2	55%
Bagasse (50% DS)	16.6	7.1	50%
Extracted beet slices	16.3	2.1	75.5%
Melasse, vinasse	17.0	7.2	50%
Rapeseed oil	37.2	-	0%
Soybean oil	36.6	-	0%
Palm oil	36.5	-	0%
Rapeseed extraction cakes	19.0	15.0	18.6%
Soy extraction cakes	19.0	15.0	18.6%
Oil fibers	17.5	14.0	17.5%
Palm nuts	28.0	28.0	0%
Glycerine (un-processed)	17.0	13.4	18.5%
Final product			
Ethanol	26.7	-	0%
RME	37.2	-	0%
SYME	37.0	-	0%
PME	36.6	-	0%
Hydrogenated vegetable oil	44.0	-	0%

DS: dry substance

OS: original substance with consideration to the given (default) water content

example for allocation: RME



	Direct land use	Biomass production	Transport of biomass	Conversion step 1	Transp. betw. Conv. steps	Conversion step 2	Transport to refinery	
	Arable land 200 m^2	Rapeseed cultivation	100 km Lorry	Oil mill	100 km Truck	Transesteri-fication	150 km Truck	1 GJ RME
		68 kg Rape straw	68 kg Rapeseed	**40.8 kg** Extrac-tion cake	27,15 kg Rapeseed oil	**2.5 kg** Glycerine	**26.88 kg RME**	**Total Sum**
GHG emission	**54.9**	**48.8**	**0.7**	**12.1**	**0.2**	**8.0**	**0.3**	**125 kg CO_2-Eq.**
Allocation factor	**59.7%**	**59.7%**	**59.7%**	**62.3% x 96% = 59.7%**	**96%**	**96%**	**100%**	
Allocated GHG emission	**32.8**	**29.1**	**0.4**	**7.6**	**0.2**	**7.6**	**0.3**	**allocated sum 78.1 kg CO_2-Eq.**

module: conversion step 2

		Ethanol wheat, Europe	Ethanol maize, North America	Ethanol sugarcane, Latin America	Ethanol sugar beet, Europe	FAME rapeseed oil, Europe	FAME soybean oil, Latin + N. America	FAME Palm oil, Southeast Asia	Hydro-genated vegetable oil
Step 2		Fermentation	Fermentation	Fermentation	Fermentation	Transesterif.	Transesterif.	Transesterif.	Hydrogenation
Core product		Ethanol:	Ethanol	Ethanol	Ethanol	RME	SYME	PME	
Output core product [a)]	kg/GJ Hu	37.45	37.45	37.45	37.45	26.88	27.03	27.32	
	% of input	29.50%	32.50%	44.60%	44.60%	99%	99%	99%	
Output DDGS, vinasse[a)]	% of input	40.60%	44.70%	10.40%	10.40%				
Output Glycerin [a)]	% of input					9.30%	9.30%	9.30%	
Input Methanol [a)]	% of input					10.90%	10.90%	10.90%	
energy consumption									
Electricity	kWh/kg core pr.	0.402	0.402	0.345	0.1	0.046	0.046	0.046	
thermal energy	MJ/kg core pr.	9.76	9.76	9.16	9.76	1.36	1.36	1.36	
Fuel		lignite	gas/fuel oil	Bagasse	lignite	gas/fuel oil	gas/fuel oil	gas/fuel oil	
surplus electricity	kWh/kg EtOH								
Total electricity prod.	*kWh/kg EtOH*			*0.345*					
Auxillaries									
NaOH (g/kg)	g/kg					6	6	6	
HCl (g/kg)	g/kg					5	5	5	
Emission									
Methanol	kg CO_2-Eq./kg core prod.					0.1364	0.136	0.136	
electricity		0.2534	0.2436	0.0093	0.063	0.0290	0.0290	0.0290	
heat/steam		1.418	0.8756	0.0206	0.876	0.122	0.122	0.122	
auxiliaries		0	0	0		0.00849	0.00849	0.00849	
SUM		**1.671**	**1.119**	**0.0299**	**0.939**	**0.296**	**0.296**	**0.296**	
Emission related on GJ									
not allocated	kg CO_2-Eq./GJ	**62.6**	**45.6**	**1.12**	**35.2**	**7.95**	**8.0**	**8.08**	**10.5**
allocated [b)]	kg CO_2-Eq./GJ	**34.3**	**25.0**	**0.99**	**31.0**	**7.63**	**7.67**	**7.75**	**9.7**

a) Sum of output mass flows does not match with input mass flow because of losses due to CO_2 creation (fermentation), evaporation and effluent discharge.
b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

module: conversion step 1

		Sugarcane, Latin America	Sugar beet Europe	Rapeseed oil, Europe	Soybean oil, Latin America	Soybean oil, North America	Palm oil, Southeast Asia
Emissions	kg CO_2-eq./kg core product						
Electricity Mill/Sugar production		0.003	0.045	0.060	0.092	0.283	0.003
power refinery				0.004	0.002	0.005	0.0002
Excess power		0.029					0.0183
Thermal: mill/ sugar prod.		0.008	0.057	0.349	0.594	0.594	0.006
Thermal: refinery				0.032	0.034	0.034	0.001
Resources				0.002	0.002	0.002	0.003
TOTAL		***0.0395***	***0.102***	***0.447***	***0.724***	***0.918***	***0.031***
POME pond emissions	kg CH_4/ kg Oil						0.028
	kg CO_2-eq./kg Oil						0.511
Total	**kg CO_2-eq./kg** core product	**0.04**	**0.102**	**0.447**	**0.724**	**0.918**	**0.5421**
Total without refinery		0.01		0.411	0.688	0.879	0.523
Refinery				0.036	0.036	0.039	0.001
Excess power		0.029					0.018
Emission based on GJ							
Refinery	kg CO_2-eq./GJ			1.0	1.0	1.1	0.023
Excess	kg CO_2-eq./GJ	2.44					0.51
Total							
not allocated	kg CO_2-eq./GJ	**3.32**	**8.6**	**12.1**	**19.8**	**25.1**	**14.96**
allocated	kg CO_2-eq./GJ	**0.78**	**5.47**	**7.64**	**7.34**	**9.199**	**6.9**

a) DS: Molasses; percentage is based on dry sugar bulk
b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

module: conversion step 1

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module: biomass production

		Wheat Europe	Maize North America	Sugarcane trop. Latin America	Sugar beet Europe	Rapeseed Europe	Soybean trop. Latin Am.	Soybean North America	Palm oil South East Asia
core biomass		grains	grains	cane	beets	rapeseeds	soy beans	soy beans	oil fruits
Yield	t/(ha*a)	7.31	8.77	68.7	56	3.5	2.5	2.4	10.5
co-products		straw	straw	harvest residues	harvest residues	straw	Legum.-N [a)]	Legum.-N [a)]	Empty fruit benches
allocation applied		no	no	no	no	no	yes	yes	no
emission from land									
N_2O	kg/(ha*a)	2.25	2.1	2.02	2.04	2.67	1.18	1.18	1.375
CH_4	kg/(ha*a)	0	0	19.7	0	0	0	0	0
Diesel consumption	kg/(ha*a)	48.9	81.5	56.4	90.8	54.7	48.9	48.9	167
fertilizer consumption									
N	kg/(ha*a)	143	132	58.3	130	170	5	4	87.5
P_2O_5	kg/(ha*a)	58.5	70	36.7	56	63	10	11.9	10.5
K_2O	kg/(ha*a)	43.9	44	100	95	35	20	22	131.3
CaO	kg/(ha*a)	7.3	11	367	27	22.2	0	275	26.2
Pesticides	kg/(ha*a)	4.5	3.0	2	2.1	1.23	1.25	1.25	1.23
Irrigation		no	for 25%	no	no	no	no	nein	no
Diesel	kg/(ha*a)		10						
Drying									
Electricity	kWh/kg grains	0.011	0.011	-	-	0.0117	0.0072	0.0072	-
fuel oil	MJ/kg grains	0.4	0.4	-	-	0.4	0.17	0.17	-
Emission									
Field	kg CO_2-eq. /(ha*a)	698	643	986	633	828	366	366	426
Diesel use	kg CO_2-eq. /(ha*a)	186	310	215	346	208	186	186	636
fertilizer prod.	kg CO_2-eq. /(ha*a)	1,038	981	601	990	1,219	58	58	681
PSM-prod.	kg CO_2-eq. /(ha*a)	56	37.11	25	26	15	15	15	15
Diesel irrigation	kg CO_2-eq. /(ha*a)		38						
electricity drying	kg CO_2-eq. /(ha*a)	51	82	0	0	26	5	15	0
fuel oil drying	kg CO_2-eq. /(ha*a)	314	376	0	0	150	46	44	0
SUM		**2,342**	**2,468**	**1,826**	**1,995**	**2,447**	**676**	**763**	**1,759**
Emission by biofuel									
not allocated	kg CO_2-eq./GJ	**40.7**	**32.4**	**22.1**	**17.8**	**48.8**	**41.0**	**48.2**	**13.9**
Allocated	kg CO_2-eq./GJ	**22.3**	**17.8**	**19.5**	**11.3**	**29.1**	**12.9**	**15.1**	**6.6**

a) Nitrogen produced during soybean growing and accumultaed in the soil (70 kg/ha) is considered to be a co-product and allocated by the energetic value of N fertilizer (49 MJ/kg N).

b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

Module: land use change

Difference divided by 20 years

		wheat Europe	Maize / corn North America	Sugar cane trop. Latin America	Sugar beet Europe	rapeseed Europe	soybean trop. Latin America	soybean North America	Palm oil South East Asia
previous use		grassland	grassland	Savannah	grassland	grassland	savannah	grassland	trop. rain forest
Change of C-storage									
biomass total	t C/ha	**70**	**70**	**134.0**	**70**	**70**	**134.0**	**70**	**265**
above ground	t C/ha	6.3	6.3	66.0	6.3	6.3	66.0	6.3	165
below ground	t C/ha			21.0			21.0		40
Soil	t C/ha	63.0	63.0	47.0	63.0	63.0	47.0	63.0	60
Use		**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**cultivated land**	**plantation**
biomass total	**t C/ha**	**55**	**55**	**55**	**55**	**55**	**53**	**55**	**110**
above + below ground	t C/ha	5	5	7.5	5	5	5	5	50
Soil	t C/ha	50	50	47.5	50	50	48	50	60
Changement [a)]	**t C/ha**	**-15**	**-15**	**-79**	**-15**	**-15**	**-81**	**-15**	**-155**
time span	a	20	20	20	20	20	20	20	20
	t C/(ha*a)	0.75	0.75	3.95	0.75	0.75	4.05	0.75	7.75
Result (emission)	**t CO_2 /(ha*a)**	**2.75**	**2.75**	**14.5**	**2.75**	**2.75**	**14.8**	**2.75**	**28.4**
required area									
not allocated	ha/GJ	0.0174	0.0131	0.0121	0.0089	0.0200	0.0607	0.0632	0.0079
Allocated	ha/GJ	0.0095	0.0072	0.0107	0.0057	0.0107	0.0168	0.019	0.0038
emission referring to biofuel									
not allocated	**kg CO_2-eq./GJ**	**47.8**	**36.1**	**175.5**	**24.5**	**54.9**	**901.1**	**173.8**	**223.9**
allocated	**kg CO_2-eq./GJ**	26.2	19.8	154.7	15.6	32.8	282.4	54.5	106.6

a) negative values are given in case of a loss of carbon storage

b) Taking the allocation into consideration according to the lower heating value via the production chain down to the final product (ethanol, FAME)

Overview Default values

Biofuel / Biomass / origin / step of production chain	Ethanol: Wheat Europe	Ethanol: Maize (corn) North America	Ethanol: Sugarcane Latin America	Ethanol: Sugar beet Europe	Biodiesel (FAME): Rapeseed Europe	Biodiesel (FAME): Soybean Latin America	Biodiesel (FAME): Soybean North America	Biodiesel (FAME): Palm oil Southeast Asia
direct land use change	*26.2* [a)]	*19.8* [a)]	*158.8* [a)]	*15.6* [a)]	*32.8* [a)]	*289.6* [a)]	*54.5* [a)]	*112.8* [a)]
production of biomass	22.3	17.8	19.5	11.3	29.1	12.9	15.2	6.6
transport of biomass	0.7	0.7	1.5	1.7	0.4	0.5	0.5	0.1
conversion step I	-	-	0.8	6.6	7.6	7.3	9.2	6.90
transport between conversion steps	-	-	-	-	0.2	3.8	3.4	4.3
conversion step II	34.3	25.0	1.0	48.9	7.6	7.7	7.7	7.7
transport to fuel storage for admixture	0.4	4.8	5.5	0.4	0.3	0.3	0.3	0.3
Total without LUC	**57.7**	**48.2**	**28.3**	**68.8**	**45.3**	**32.4**	**36.3**	**25.9**
Total with direct LUC	*83.9* [a)]	*68.0* [a)]	*187.1* [a)]	*84.4* [a)]	*78.1* [a)]	*322* [a)]	*90.7* [a)]	*138.7* [a)]

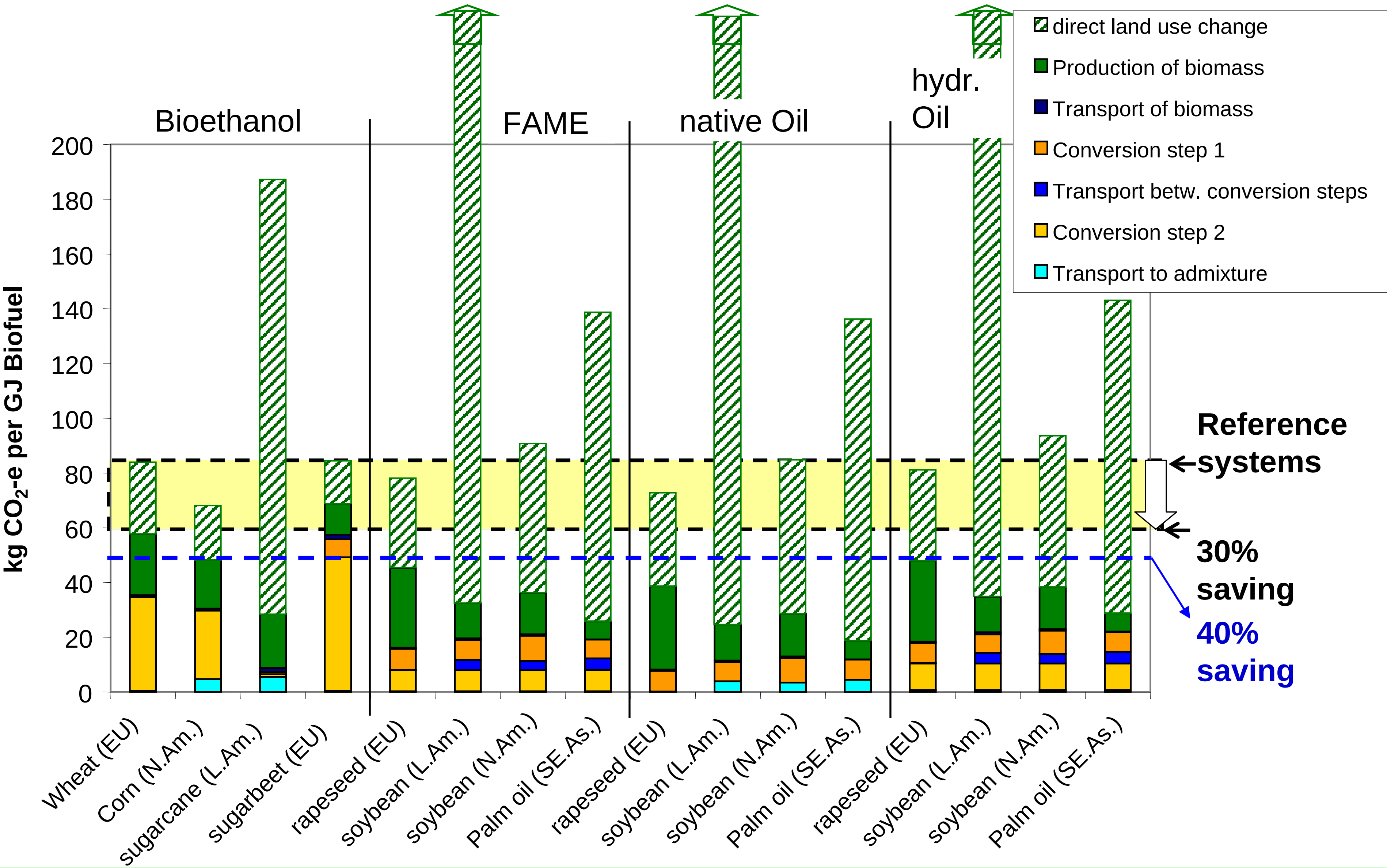
a) worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

Overview default values 2

Biofuel / Biomass / origin — step of production chain	straight vegetable oil				Hydrogenated vegetable oil			
	rapeseed oil	**soybean oil**		**palm oil**	**rapeseed oil**	**soybean oil**		**palm oil**
	Europe	Latin America	North America	Southeast Asia	Europe	Latin America	North America	Southeast Asia
direct land use change	*34.2* [a)]	*298.8* [a)]	*56.2* [a]	*117.4* [a)]	*33.2* [a]	*293.4* [a]	*55.2* [a]	*114.3* [a]
production of biomass	30.4	13.1	15.5	6.9	29.5	13.0	15.4	6.7
transport of biomass	0.5	0.6	0.6	0.1	0.4	0.8	0.5	0.1
conversion step I	7.6	6.9	9.0	7.4	7.3	6.8	8.6	7.2
transport between conversion steps	-	-	-	-	0.2	3.8	3.5	4.3
conversion step II	-	-	-	-	9.7	9.7	9.7	9.7
transport to fuel storage for admixture	0.2	3.9	3.5	4.4	0.7	0.7	0.7	0.7
Total without LUC	**38.6**	**24.5**	**28.5**	**18.8**	**47.9**	**34.8**	**38.3**	**28.7**
Total with direct LUC	***72.8*** [a)]	***323.3*** [a)]	***84.7*** [a]	***136.2*** [a)]	***81.1*** [a)]	***328.2*** [a)]	***93.5*** [a]	***143.1*** [a)]

a) worst case situation, contradicts generally criteria for sustainability (conversion of areas with high carbon storage) only to apply as long direct land use cannot be verifiably excluded; when excluded, indirect land use change has to be considered.

Default values 3



Thank you for listening

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