Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Energie BFE

Anhang zum Schlussbericht 14. Januar 2014

Harmonisierung und Erweiterung der Bioenergie-Ökoinventare und -Ökobilanzen

ANHANG

EMPA
Materials Science & Technology

Auftraggeber:
Bundesamt für Energie BFE
Forschungsprogramm Biomasse und Holzenergie
CH-3003 Bern
www.bfe.admin.ch

Auftragnehmer:
Empa
Überlandstrs. 129
CH-8600 Dübendorf
www.empa.ch

Autorinnen dieses Anhangs:
Mireille Faist Emmenegger, Empa, mireille.faist@empa.ch
Rainer Zah, Empa, rainer.zah@empa.ch

BFE-Bereichsleiterin: Sandra Hermle
BFE-Programmleiterin: Sandra Hermle
BFE-Vertrags- und Projektnummer: 154368 / 103314

Für den Inhalt und die Schlussfolgerungen sind ausschliesslich die Autorinnen dieses Berichts verantwortlich.

Table of content

Abbreviations

AGB	Above Ground Biomass
bbl bit	barrel of bitumen
BGB	Below Ground Biomass
CHP	Combined Heat and Power
CO_2-eq	Carbon dioxide equivalent
DM	Dry Matter
DOM	Dead Organic Matter
EI 99	Eco-Indicator 99
FFB	Fresh Fruit Bunch
GHG	Greenhouse Gas
GWP	Global Warming Potential
ICE	Internal Combustion Engine
iLUC	Indirect Land Use Change
JME	Jatropha Methyl Ester
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LUC	Land Use Change
PM	Particulate Matter
RER	Europe
SCO	Synthetic Crude Oil
SCR	Short Rotation Croppice
SNG	Synthetic Natural Gas
SOC	Soil Organic Carbon
UBP	Umweltbelastungspunkte
v.km	Vehicle*kilometer

Influence of allocation methods on LCA results

1. Introduction

This annex of the report "Harmonisierung und Erweiterung der Bioenergie-Ökoinventare und -Ökobilanzen" (Faist Emmenegger et al., 2012) deals with goal 3-2 of the project, which is the study of how allocation methods can influence results of LCAs. The original project plan foresaw to use the new features in ecoinvent v3 and calculate the biofuel pathways with several allocation methods. Indeed, the new version of ecoinvent should have allowed applying the same allocation method on all processes in the database. However the actual ecoinvent version 3 supports only the economic allocation and system expansion, so that here the allocation method is applied only on foreground processes (i.e. from agriculture to biofuel production), leaving all background processes (production of auxiliaries, provision of energy etc.) originating from ecoinvent 2.2 with the original default allocation method.

2. Method

In the allocation analysis we compare three options:

- "ecoinvent default" allocation: this is the allocation methodology used in ecoinvent until v2. As far as possible, the flows are allocated on a physical basis. Where this is not possible, economic allocation is used. This means that different allocation approaches can be used within a dataset depending on the flow and the information available.
- full economic allocation: all inventory flows are allocated according to economic values of the product and co-products. This corresponds to the methodology applied by the Roundtable on Sustainable Biofuels (RSB).
- energetic allocation: all inventory flows are allocated according to energetic values of the product and co-products. This corresponds to the methodology applied by the Renewable Energy Directive (2009/28/EC, 2009).

The allocation approaches are only applied on the foreground processes, which are the conversion processes of the biofuel production chain. For the background processes, we use ecoinvent processes with their corresponding allocation (true-value).

We choose for this analysis relevant biodiesel and ethanol pathways. The following biofuel production inventory values have been calculated in SimaPro:

- Rapeseed methyl ester, Germany
- Rapeseed methyl ester, Switzerland
- Jatropha methyl ester, India
- Palm oil methyl ester, Malaysia
- Soybean methyl ester, Brazil
- Soybean methyl ester, USA
- Ethanol from sugar beets, Switzerland
- Ethanol from sugar cane, Brazil
- Ethanol from corn, USA
- Ethanol from rye, Europe
- Ethanol from sweet sorghum, China

The economic and energetic allocation factors have been taken from the ecoinvent report Nr. 17 "Life Cycle Inventories of Bioenergy" (Jungbluth et al., 2007) and for jatropha from Gmünder et al. (Gmünder, Singh, Pfister, Adheloya, & Zah, 2013) and ecoinvent v3. All flows have been considered, except the carbon flows. The allocation factor for carbon is always different from all other allocation factors and was not considered in this recalculation. This means also that, here, the allocation factor for the carbon flows of a certain product is the same across all three allocation methods. This has however no influence on the results as the biogenic carbon has no impact attached to it in all methods considered.

It was not possible to remodel the oil refineries datasets, so that no allocation scenarios for these pathways are calculated there.

We compare the results of the GWP 100a IPCC 2007 as well as of the UBP method. As the allocation is done on the level of the inventory flows, the calculation of other indicators is expected to yield the trends regarding to the differences between the methods.

3. Allocation factors

The two following tables give an overview of the allocation factors used for the calculations.

Table 1: Allocation factors ("true value", economic and energy) for the selected biodiesel pathways.

Biofuel	**Stage**	**Allocation Factors**		
		True Value	**Economic**	**Energy**
Jatropha methyl ester, India	Agriculture	All: 100%	All: 100%	All: 100%
	Oil mill	All: 81.7%	All: 81.7%	All: 42.6%
	Esterification	All: 92.1%	All: 92.1%	All: 96%
Palm oil methyl ester, Malaysia and Colombia	Agriculture	All: 100%	All: 100%	All: 100%
	Oil mill	All: 81.3%	All: 81.3%	All: 83.1%
	Esterification	All: 87.1%	All: 87.1%	All: 95%
Rapeseed methyl ester, Germany	Agriculture	All: 100%	All: 100%	All: 100%
	Oil mill	Electricity: 76.7%	All: 75.4%	All: 59.9%
		Rest: 75.4		
	Esterification	All: 86.9%	All: 86.9%	All: 95%
Rapeseed methyl ester, Switzerland	Agriculture	All: 100%	All: 100%	All: 100%
	Oil mill	Electricity: 75.4%	74%	58.20%
		Rest: 74%		
	Esterification	All: 87.1%	All: 87.1%	All: 95%
Soybean methyl ester, Brazil	Agriculture	All: 100%	All: 100%	All: 100%
	Oil mill	Electricity: 29.1%	All: 40.7%	All: 34.5%
		Heat (3 types): 26.2%		
		Rest: 40.7%		
	Esterification	All: 92%	All: 92%	All: 95%
Soybean methyl ester, US	Agriculture	All: 100%	All: 100%	All: 100%
	Oil mill	Electricity: 25.4%	All: 34.5%	All: 34.1%
		Heat (3 types): 24.7%		
		Rest: 34.5%		
	Esterification	All: 92%	All: 92%	All: 95%

Table 2: Allocation factors ("true value", economic and energy) for the selected ethanol pathways.

	Stage	Allocation Factors		
		True Value	**Economic**	**Energy**
Ethanol from corn, US	Agriculture	All: 100%	All: 100%	All: 100%
	Distillery	Heat - natural gas: 49.6%	All: 98.8%	All: 51.7%
		Electricity; heat - waste: 33.4%		
		Fermentation plant: 50.1%		
		Treatment sewage: 41.6%		
		Rest: 98.8%		
Ethanol from rye, conventional, RER	Agriculture	All: 90.3%	All: 90.3%	All: 58.7%
	Distillery	Heat (nat. gas): 49.4%	All: 98.1%	All: 51.7%
		Electricity: 33.2%		
		Ethanol fermentation plant: 49.7%		
		Heat (waste): 33.2%		
		Treatement sewage: 41.3%		
		Rest: 98.1%		
Ethanol from sugar beets, CH	Agriculture	All: 100%	All: 100%	All: 100%
	Fermentation	Cooling water; sugar beets; fermentation plant: 65.5%	All: 65.5%	All: 46.7%
		Phosphate; sulphate; sulphuric acid; tap water; heat - at cogen; heat - natural gas: 83%		
		Transport - lorry: 65.7%		
		Transport - rail: 66%		
		Electricity; heat - waste: 69.6%		
Ethanol from sugarcane, BR	Agriculture	All: 100%	All: 100%	All: 100%
	Distillery	All: 99.45%	All: 99.45%	All: 99.9%
Ethanol from sugarcane molasses, Brazil	Agriculture	All: 100%	All: 100%	All: 100%
	Distillery	Diammonium phosphate: 100%	All: 13.6%	All: 48.3 % (average)
		Sulphur dioxide, ammonium sulphate, chemicals organic, transport – lorry, water decarbonised: 11.1%		
		Tap water: 92.1%		
		Sulphuric acid: 11.3%		
		Soda powder: 11.5%		
		Sugar cane at farm, chemicals inorganic, lubricating oil, limestone: 10.8%		
		Hard coal: 11%		
		Treatment sewage: 12.6%		
		Rest: 13.6%		
Ethanol from sweet sorghum, China	Agriculture	All: 57.3%	All: 57.3%	All: 79.9%
	Distillery	Sweet sorghum: 90.7%	All: 92.1%	All: 42.4%
		Tap water: 91%		
		Sulphuric acid – liquid, ammonium sulphate, diammonium phosphate: 100%		
		Lubricating oil: 91.1%		
		Transport – 32t: 91.7%		
		Transport – 16t: 92.4%		
		Ethanol fermentation plant: 93.7%		
		Rest: 92.1%		

4. Results

4.1. Comparison of the datasets

In the following pictures, we compare the three calculated allocation systems on the selected pathways.

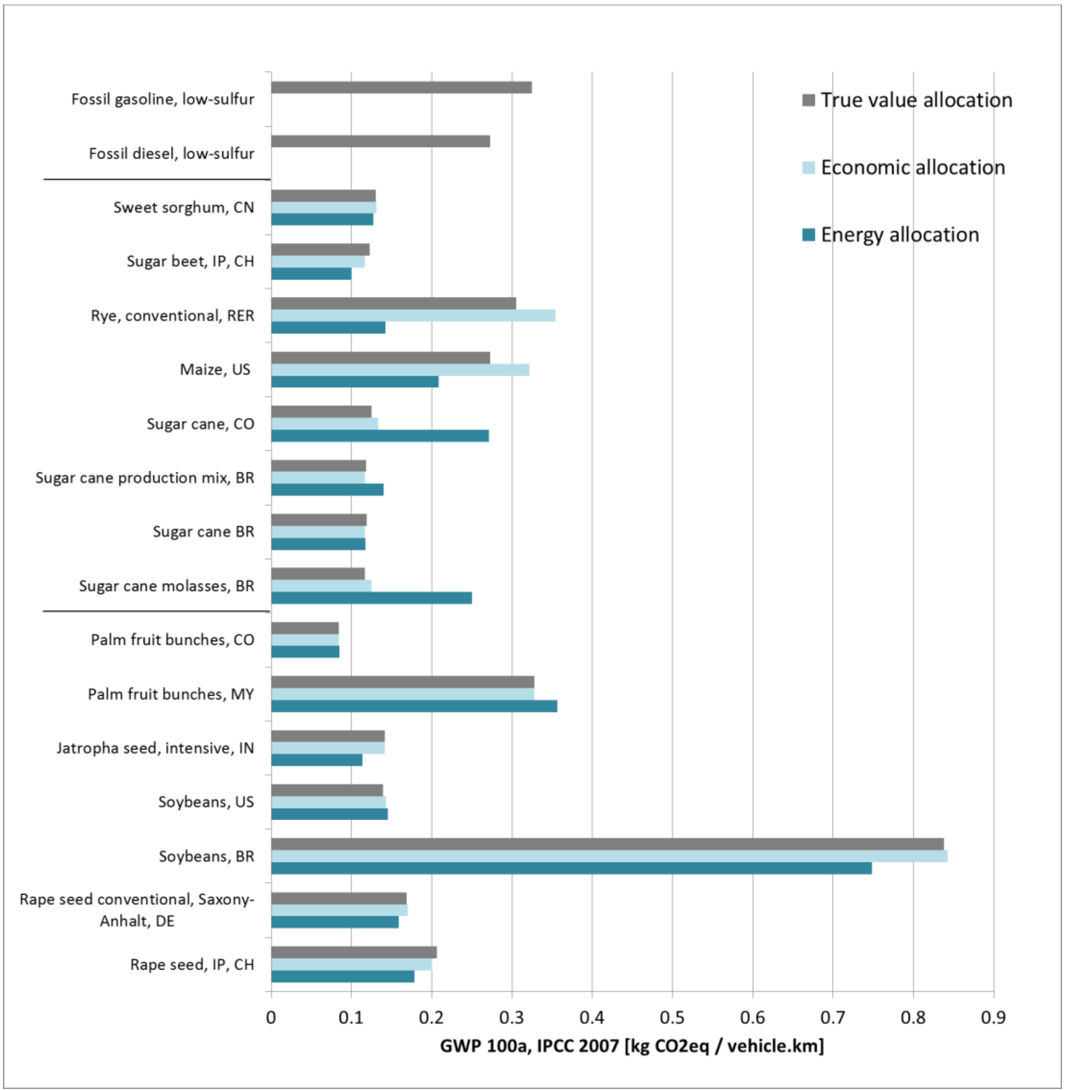

Figure 1: Comparison of results for GWP 100a IPCC 2007 in kg CO2-eq/v.km with three allocation methods: true value allocation (ecoinvent default), economic allocation and energy allocation.

The results of the three allocation modeling approaches show only very small variations for most pathways, except for rye, maize and sugarcane molasses within the ethanol pathways and for soybeans BR within biodiesel pathways.

Rye and maize ethanol production deliver the co-product DDGS, which has a high energy content (on a dry basis) but a rather low economic value. Allocation on energy basis allocates therefore a higher portion of the impacts as economic or true value allocation, which explains for the difference. The contrary is valid for sugarcane molasses ethanol.

A difference in the results of true value and economic allocation modeling occurs when several inventory flows are allocated on an energy or mass basis in the true value system modeling, as it is the case mainly in some ethanol pathways.

In the biodiesel pathways, the difference between soybean ME US and BR is due to the fact that the economic and energy allocation factors of the oil mill are almost the same in the US pathway, but have a little than 10% difference in the BR pathway. This means that for the US pathway, the higher allocation factor for energy in the esterification influences the results, while, in the contrary, the lower allocation factor for energy of the oil mill in the BR pathway leads to lower results.

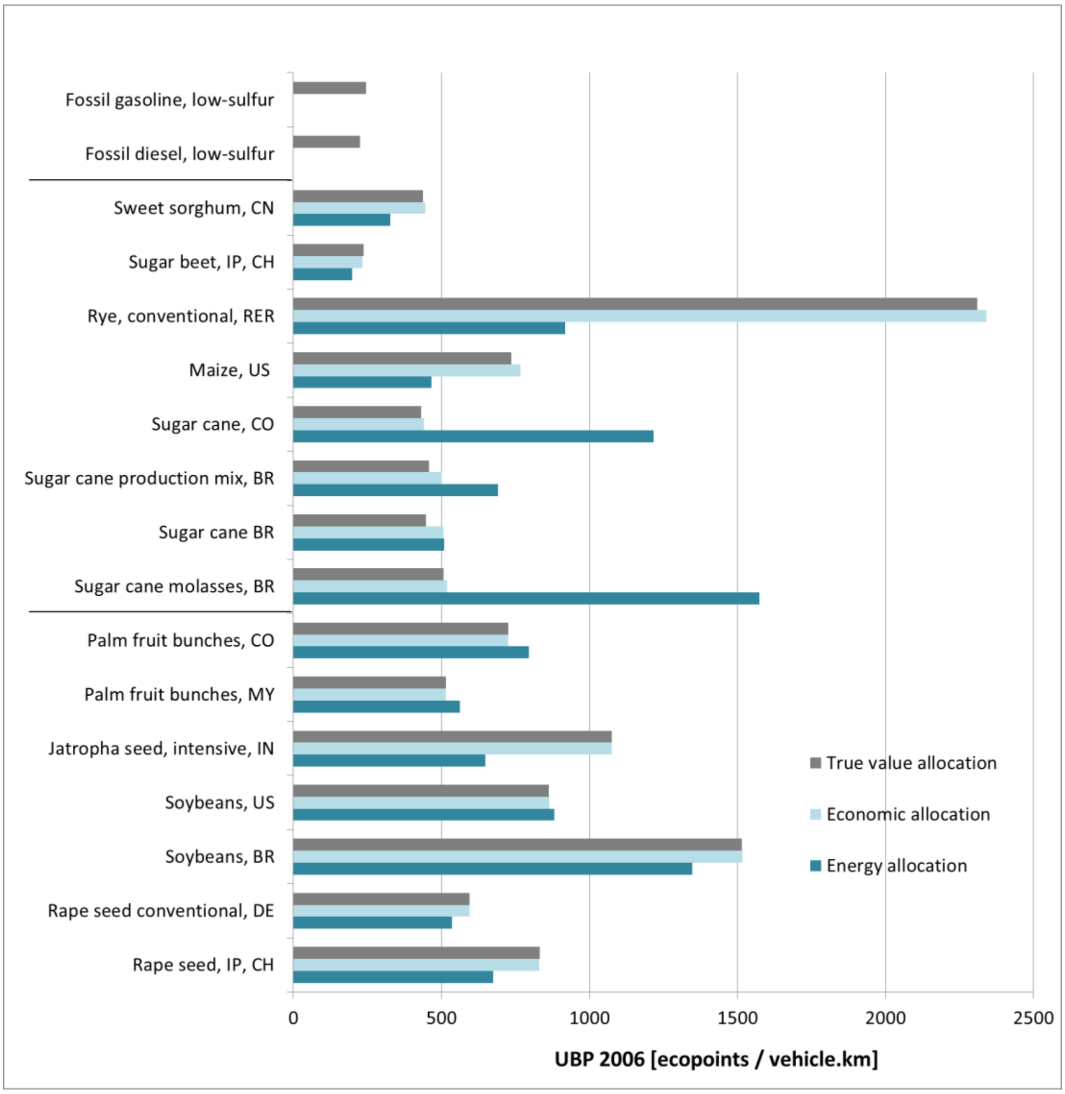

Figure 2: Comparison of results for the Swiss ecological scarcity method in ecopoints/v.km with three allocation methods: true value allocation (ecoinvent default), economic allocation and energy allocation.

The results of the three allocation modeling approaches show similar effects as when calculated for the GWP 100a. However, as the influence of the agricultural processes is high for the results of the Swiss ecological scarcity method, differences in the allocation factors which have an impact on the feedstock amount needed have a high repercussion on the overall results. For example, the feedstock amount for the jatropha metyl ester is 0.19 kg/vehicle*kilometer when using economic allocation, while it is only about half this value with the energy allocation (0.10 kg/vehicle*kilometer). On the contrary, sugarcane ethanol from molasses requires about 7 kg feedstock per vehicle*kilometer with energy allocation, whereas economic allocation results in a value of 1.6 kg feedstock per vehicle*kilometer.

4.2. Comparison with RED

In the following figure we compare the results of the modelling with energy allocation with the default values according to Annex V of the Renewable Energy Directive (RED).

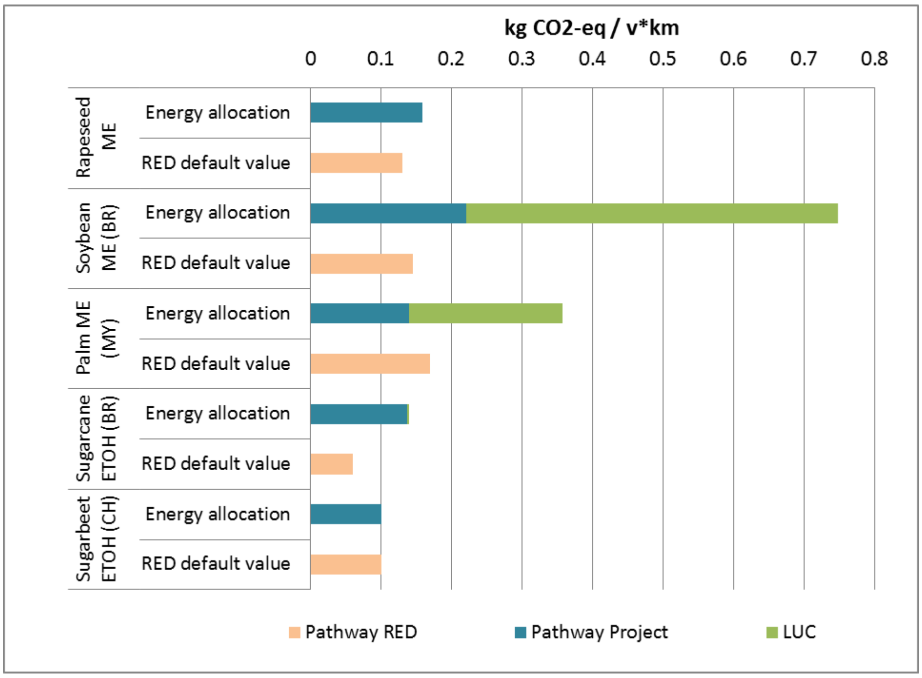

Figure 3: Comparison of results for GWP 100a IPCC 2007 in kg CO2-eq/v.km, energy allocation with the default values of the RED.

The results of the calculations with energy allocation are similar to the RED default values, except for palm, sugarcane and soybeans. In those pathways, land use change emissions are included, for which the RED default values do not account for but are calculated separately.

The differences between the RED default and the values of this project have manifold causes: different modelling of N2O emissions in the agriculture, different amounts in fertilizer use, and only average GHG emission factors for fertilizer in the RED methodology, among other.

5. Conclusions

Main outcomes of this comparison are following:

- The results are significantly lower in the ethanol pathways with energy allocation, except for sugarcane molasses pathways. One can observe a similar effect but not as pronounced in the methyl ester pathways.
- The better results in energy allocation only occur if allocation is made by taking as a co-product the LHV of *dried* DDGS. If allocation is performed after the separation of the co-products[1] ethanol and vinasse, the allocation factor related to ethanol is proned to be higher and therefore the GHG results as well, as vinasse has a very low LHV.
- As the allocation is based on the inventory flows, the calculation of other indicators yield similar trends. However, the methods do not weigh the impacts similarly, so that depending on the LCIA method, the differences are more or less pronounced.

[1] as advised in prEN 16214-4

6. References

2009/28/EC, E. (2009). DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL.

Faist Emmenegger, M., Gmünder, S., Reinhard, J., Bauer, C., Simons, A., & Doka, G. (2012). Harmonisation and extension of the bioenergy inventories and assessment. End report. Bern: Bundesamt für Energie BFE.

Gmünder, S., Singh, R., Pfister, S., Adheloya, A., & Zah, R. (2013). Environmental Impacts of Jatropha curcas Biodiesel in India. Journal of Biomedicine and Biotechnology, online ava.

Jungbluth, N., Chudacoff, M., Dauriat, A., Dinkel, F., Doka, G., Faist Emmenegger, M., … Sutter, J. (2007). Life Cycle Inventories of Bioenergy. ecoinvent report No. 17. Dübendorf, CH: Swiss Centre for Life Cycle Inventories.