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A joint initiative of the ETH domain and Swiss Federal Offices

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2nd International ecoinvent Meeting
Lausanne, March 14, 2008

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bioenergy and biomaterials: biofuels

Niels Jungbluth, ESU-services Ltd., www.esu-services.ch

Topics

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- Goal and scope of the project "Life cycle inventories of bioenergy"
- Allocation methodology
- Specific regional problems
  - Soy beans
  - Plant oils
  - Sugar cane
- Results of LCIA study
- Conclusions for inventories of biofuels

Problem setting "Ökobilanz von Energieprodukten"

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- Diverging results for bioenergy and biofuels in separate studies
- ecoinvent data v1.3 covered only a small part of bioenergy chains. No common database
- Aims to fully cover the most important bioenergy chains
- Main issue biofuels in Switzerland or imported
- Support for energy policy (fuel tax reductions)
- Examination for GHG reduction potential
- Investigation of several environmental aspects of "biofuels" supply chains

Participating organisations

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- Project leader: Niels Jungbluth, ESU-services Ltd.
- Financing:
  - Swiss Federal Offices for Energy (BFE), Agriculture (BLW) and Environment, Forests and Landscape (SAEFL)
  - Erdöl-Vereinigung, Zurich; Alcosuisse, Berne; Entsorgung und Recycling Zürich
- Inventory experts:
  - Carbotech AG, Basel
  - Chudacoff Oekoscience, Zürich
  - Doka Ökobilanzen
  - ENERS Energy Concept, Lausanne
  - INFRAS, Bern
  - Swiss Federal Institute of Technology Zürich (ETHZ)
- ecoinvent manager: Rolf Frischknecht, ecoinvent Centre

Goal and Scope

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- Time frame 2005 or new future technologies
- Investigation from well to Swiss wheel (cradle-to-grave)
- Products from multi-output processes are investigated with allocation factors that can be varied by the data user
- All direct co-products are included in the analysis
- Consistent investigation of energy, food, fodder and material products from biomass
- Clear differentiation of fossil and organic carbon
- Publication with ecoinvent data v2.0 late 2007 (www.ecoinvent.org)

Possible classifications of fuels

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- Chemical classification of energy carrier
  - methane, ethanol, methanol, hydrogen, oils, methyl ester, liquids (petrol, diesel), ETBE, MTBE
- Resources used
  - Non-renewable: crude oil, natural gas, coal, nuclear
  - Renewable: energy crops (edible, non-edible), algae, forest wood, biomass residues, sun, wind
- Type of conversion process
  - mechanical, chemical reaction, thermal treatment, fermentation, anaerobic digestion, gasification, Fischer-Tropsch synthesis, biotechnical
- Marketing:
  - Sunfuel, Sundiesel, Ökodiesel, Biodiesel, Naturgas, 1st, 2nd, 3rd generation

Resources, conversion techniques and "bioenergy" products investigated

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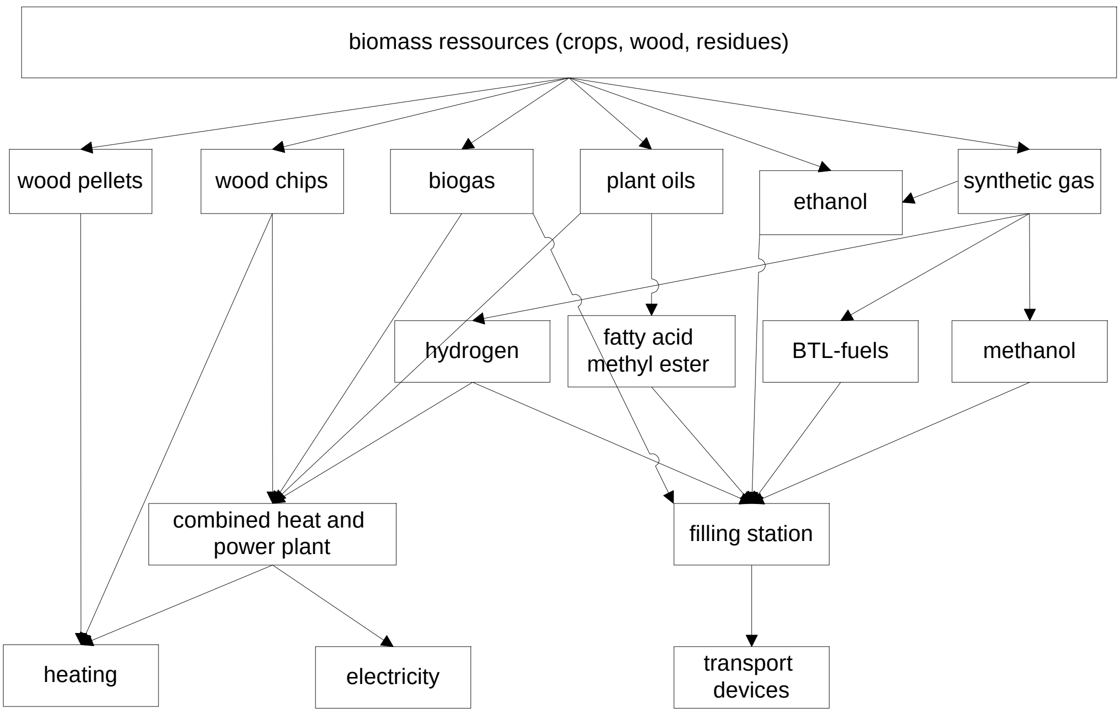
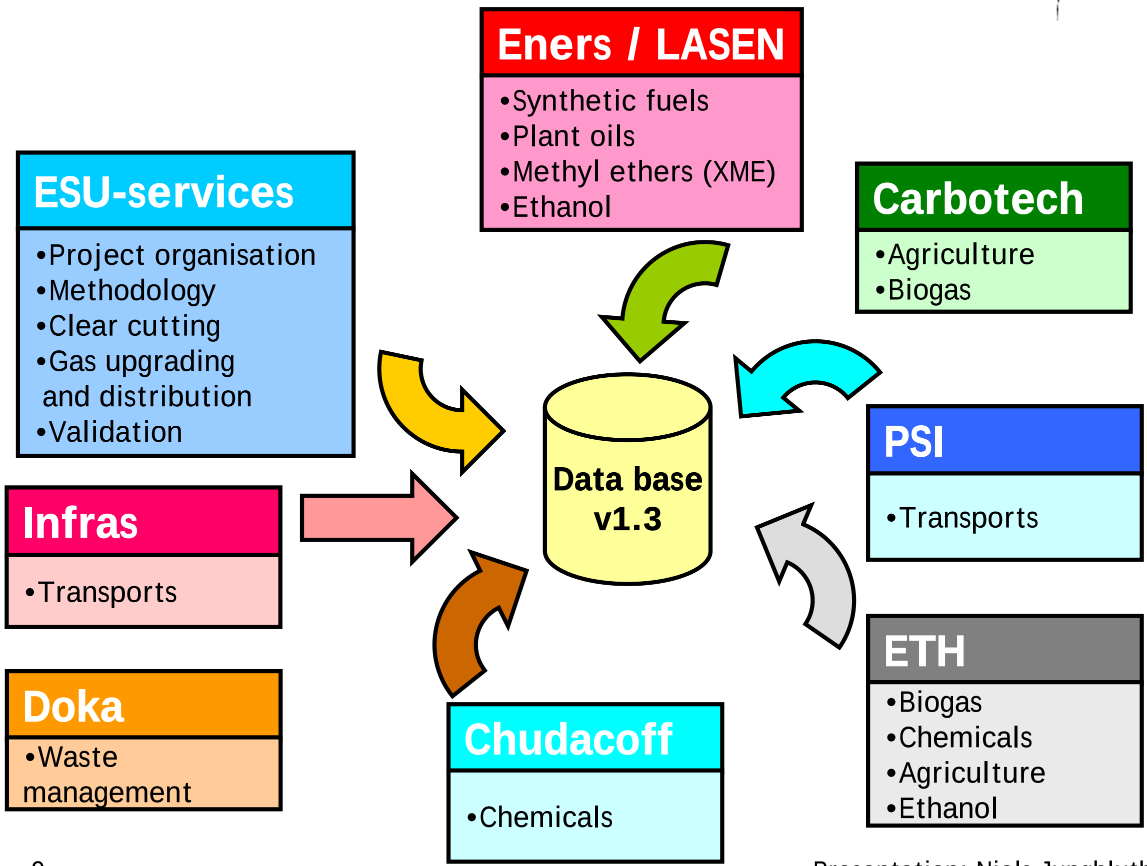


Data contributions



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Harmonization of data collection

- Clear definition of product properties
- Guidelines for allocation
- Standard assumptions for prices in allocation
- Standard distances for biomass transports
- Standard data for regional storage
- Carbon balance for biogenic fuels has been corrected in allocation according to product properties

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Investigated biofuels

Methanol
waste wood
Industrial wood

Ethanol 99.7%
wood
grass
potatoes
sugar beets
whey
sugar cane BR
maize
rye DE / RER

XME
Waste cooking oil
Rape seed CH/RER
soya oil US / BR
palm oil MY

Methane 96%
agriculture
biowaste
sludge
whey
grass
wood

Structuring of life cycles stages

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- Mix of different inputs, e.g.
  - Rape seeds IP and organic used in oil pressing
  - Different biogas processes used as input to grid
  - Mix of different ethanol pathways used as filling for car
- Modelling of average cases
- Data can be easily disaggregated if singe pathways are of interest
- Change of market situation must be considered in each study using the data

Transport services investigated in this project

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- Passenger cars
  - Compressed natural gas
  - Methane 96%
  - Ethanol 5%
  - Methanol 100%
  - Plant oil methyl ester 5%
  - ETBE 15%
  - EURO 3, 4, 5 for petrol and diesel
- Trucks
  - Rape seed methyl ester 100%

Allocation

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- Multi-output processes are stored in the database – BEFORE allocation
- Input- and output-specific allocation factors, i.e.
  individual allocation factor allowed per pollutant and input
- Allocation executed after import of dataset into database
  -> calculation of allocated unit processes
  -> matrix becomes invertible
- NO system expansion,
  NO credits
- All products included: fuel, electricity, heat, material, fertilizer, waste management, fodder, food, etc.
- Cut-off applied for outputs without economic value and wastes for recycling

Allocation: Example Biogas

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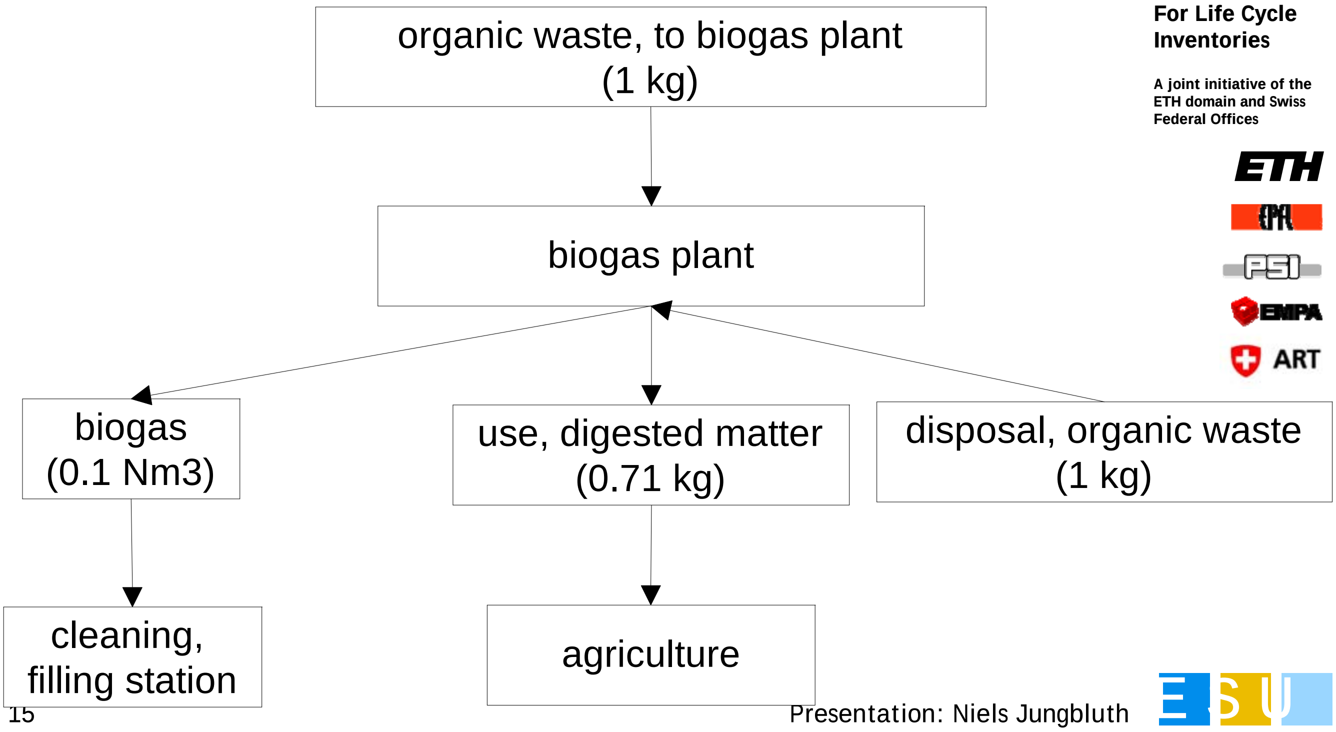


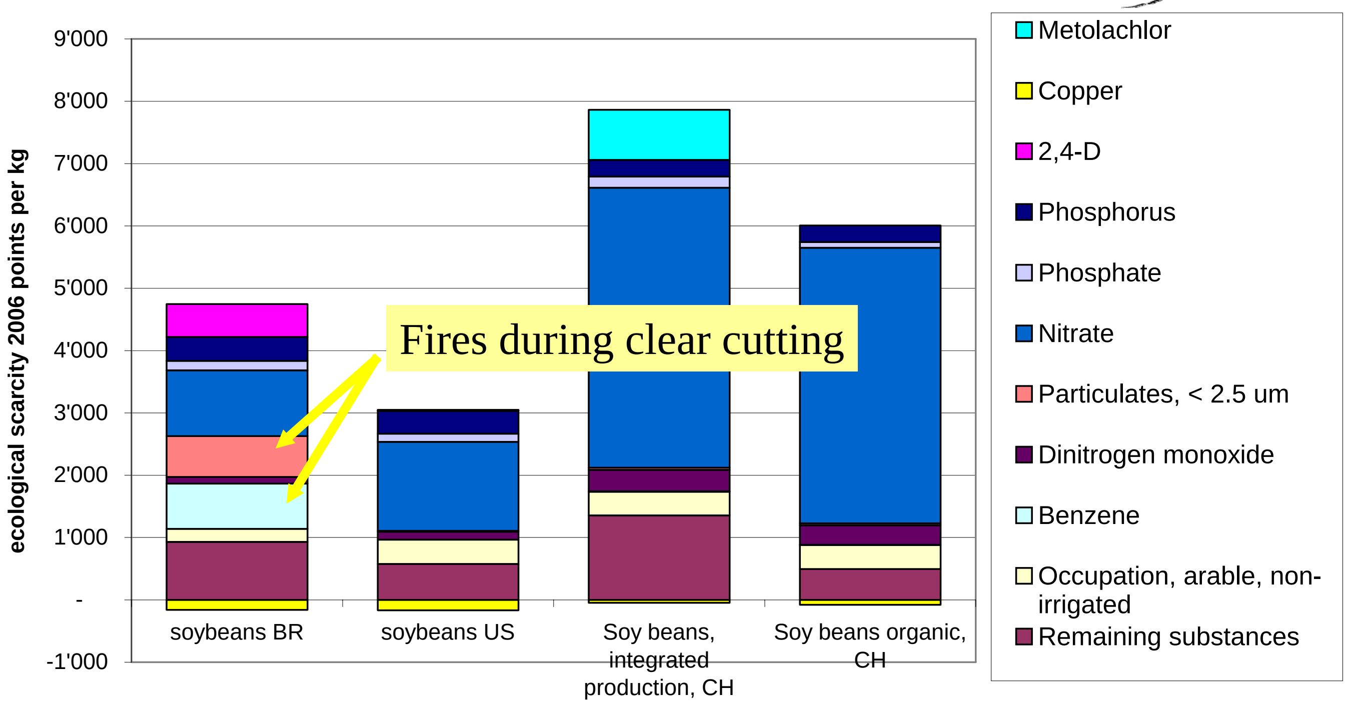
Raw data biogas

Name	Location	Unit	biowaste, to anaerobic digestion	biogas, from biowaste, at storage	disposal, biowaste, to anaerobic digestion	digested matter, application in agriculture
Location	0	0	CH	CH	CH	CH
InfrastructureProcess	0	0	0	-	-	-
Unit	0	0	kg	Nm3	kg	kg
biogas, from biowaste, at storage	CH	Nm3	1.00E-1	100.00	-	-
disposal, biowaste, to anaerobic digestion	CH	kg	1.00E+0	-	100.00	-
digested matter, application in agriculture	CH	kg	7.12E-1	-	-	100.00
heat, natural gas, at boiler condensing modulating >100kW	RER	MJ	5.94E-1	18.24	81.76	-
electricity, low voltage, at grid	CH	kWh	4.00E-2	18.24	81.76	-
disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	kg	1.00E-2	18.24	81.76	-
diesel, burned in building machine	GLO	MJ	1.80E-2	-	-	100.00
transport, lorry 16t	CH	tkm	1.50E-2	-	50.00	50.00
solid manure loading and spreading, by hydraulic loader and spreader	CH	kg	1.00E+0	-	50.00	50.00
Carbon dioxide, in air	-	kg	5.95E-1	55.00	-	45.00
Carbon dioxide, biogenic	-	kg	7.05E-1	18.26	81.79	- 0.05
Methane, biogenic	-	kg	8.53E-3	18.24	81.76	-

Soybean production and land transformation

17 Presentation: Niels Jungbluth

Soybean (ecological scarcity 2006)



- **Important differences in environmental profile**

Plant oil production

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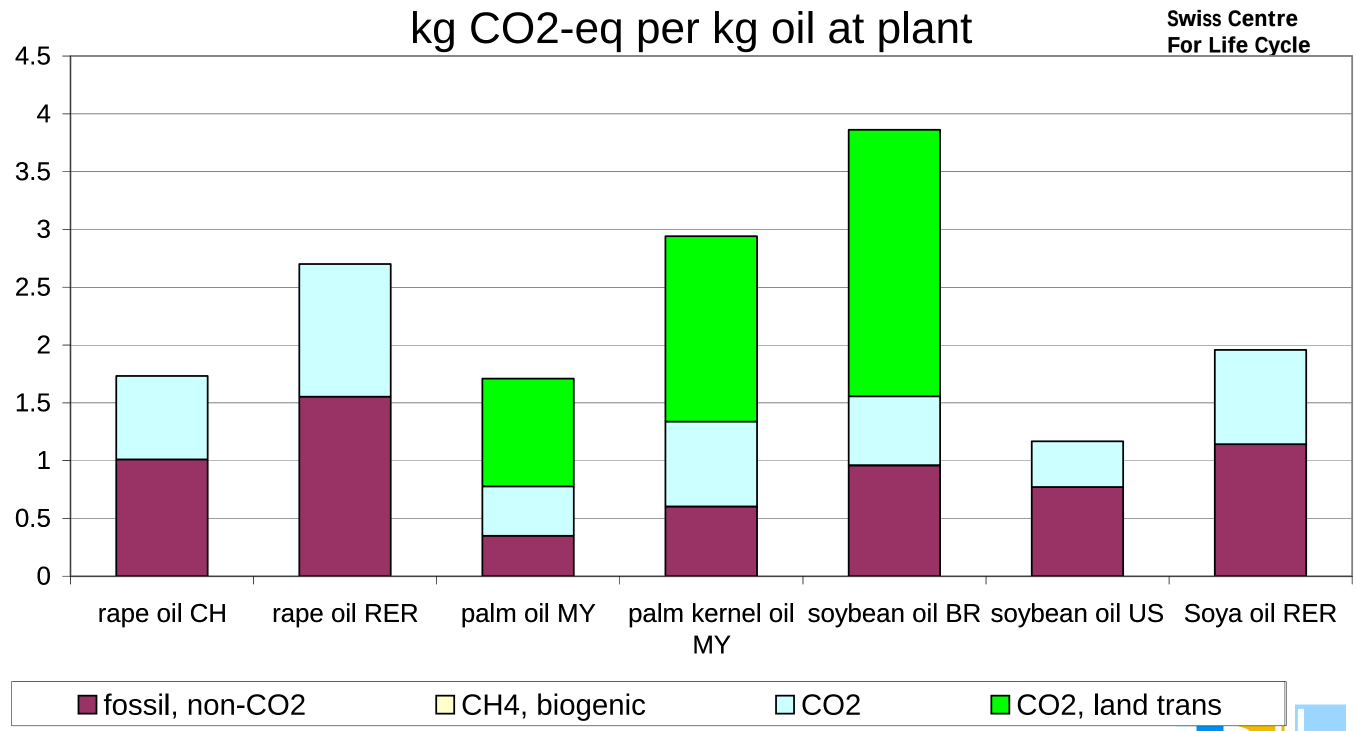


Production of sugar cane

agriculture



Harvest manual/ machinery

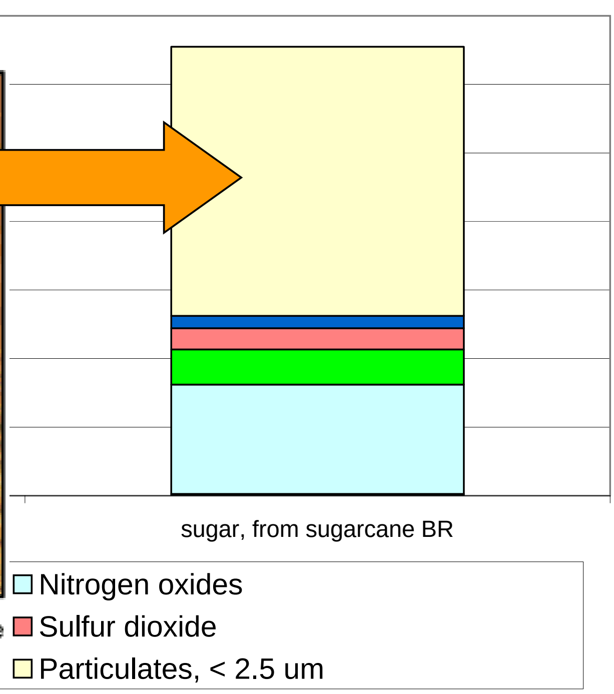


Sugar /Ethanol production



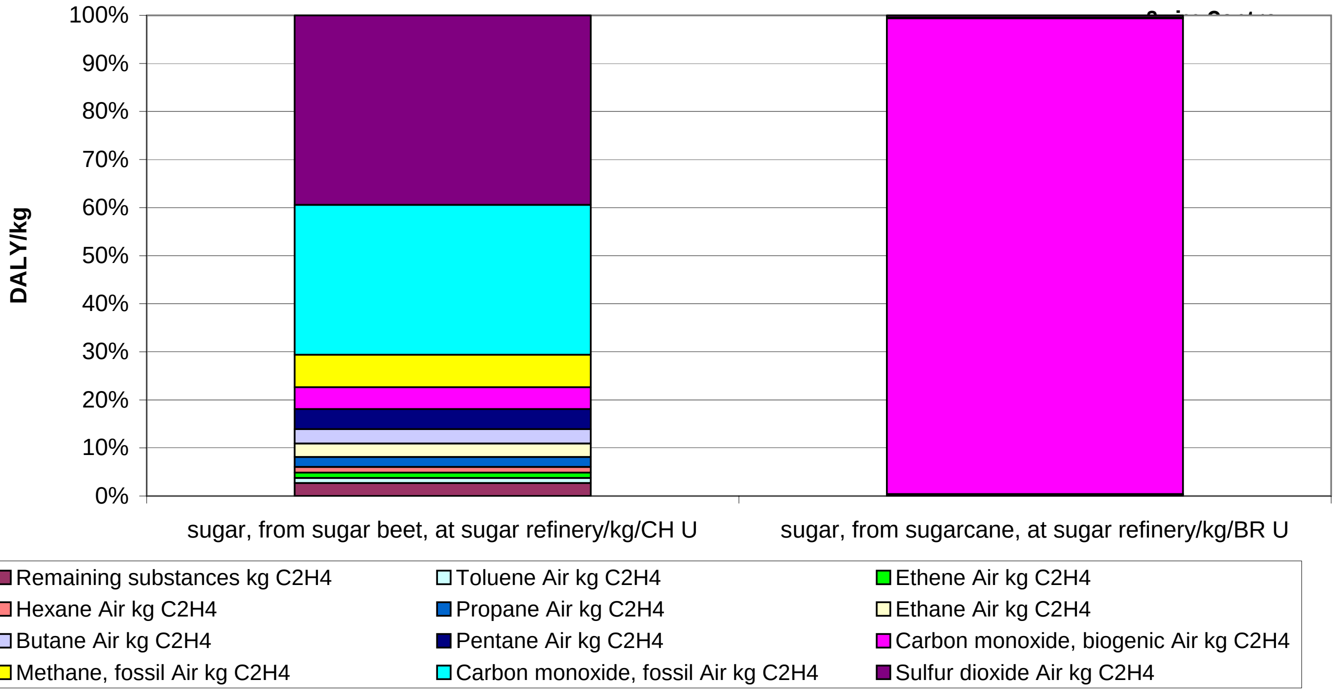
Sugar production

Figure 2 - The pre-harvesting burn in sugar cane field to eliminate most of the trash.

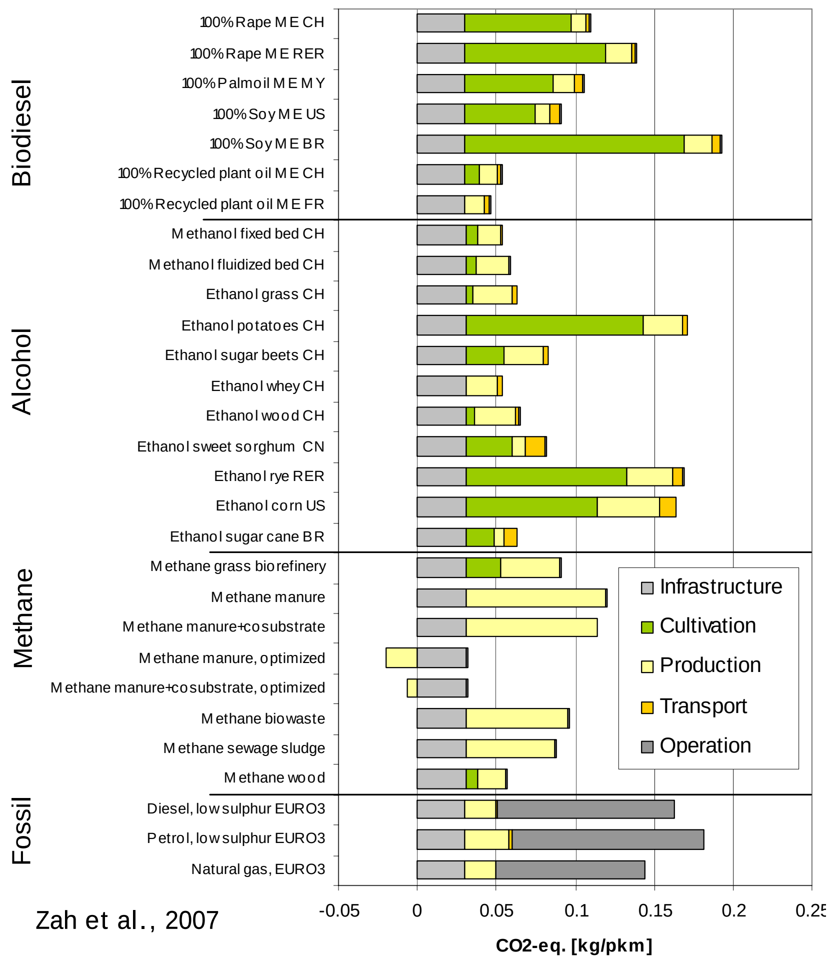


➢ **Respiratory effects, inorganic,Eco-indicator 99, (H,A) due to burning of residues**

Sugar production



➢ **Respiratory effects, organic, Eco-indicator 99, (H,A) due to burning of residues**

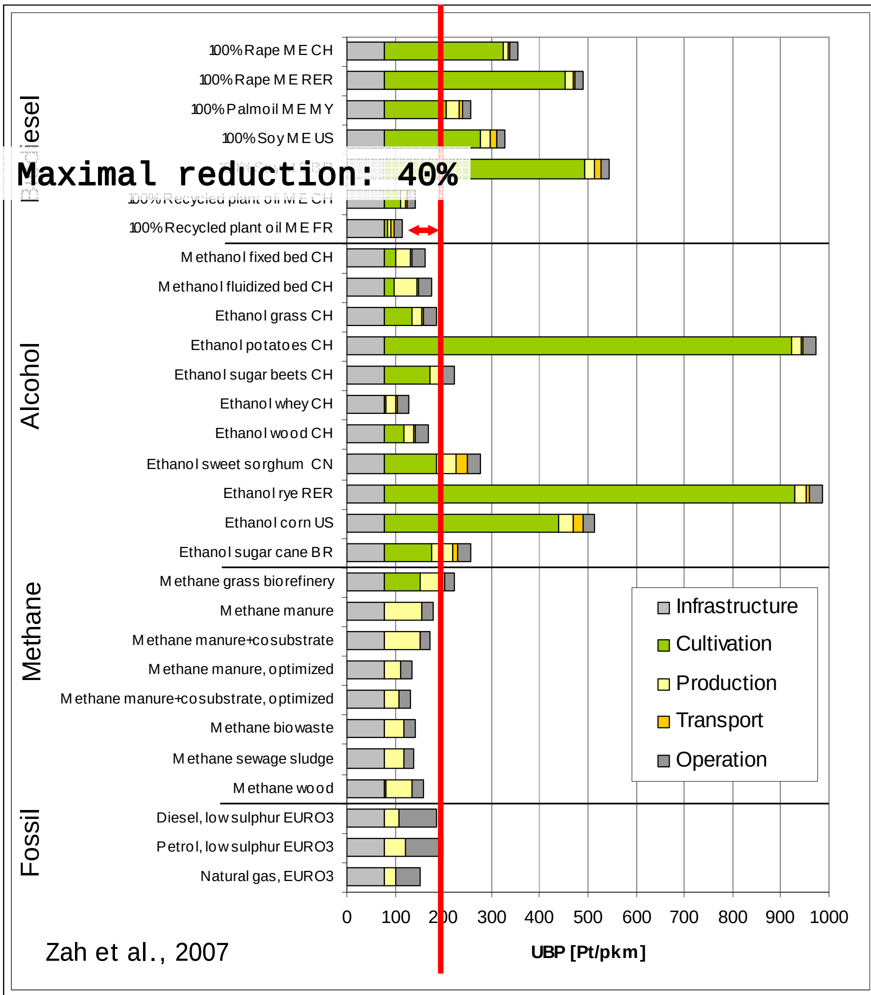


Zah et al., 2007

GWP-Reduction of Biofuels

Conclusions:

- 13 of 26 investigated biofuels reduce the GWP significant (>50%)
- 5 of them are from waste
- Worst biofuel: Brazilian soya oil with more GWP than fossil reference (transformation of rainforest into agriculture)



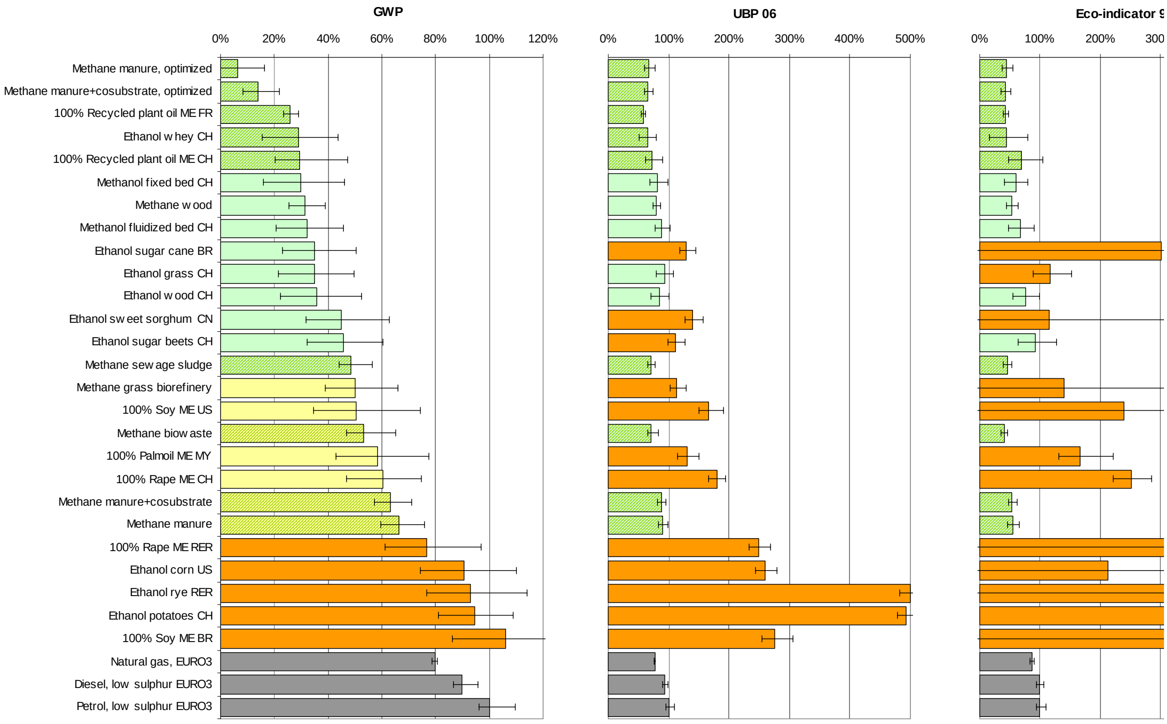
Zah et al., 2007

Environmental impacts (UBP 06)

Conclusion:

- Most important aspect of biofuels: cultivation
- About 40% of environmental impacts of transport services are infrastructure-related
- Maximal reduction has XME from recycled plant oil: 40%
- Or with other words: driving a car with XME from recycled plant oil still cause 60% of environmental impacts.

Biofuels comparison



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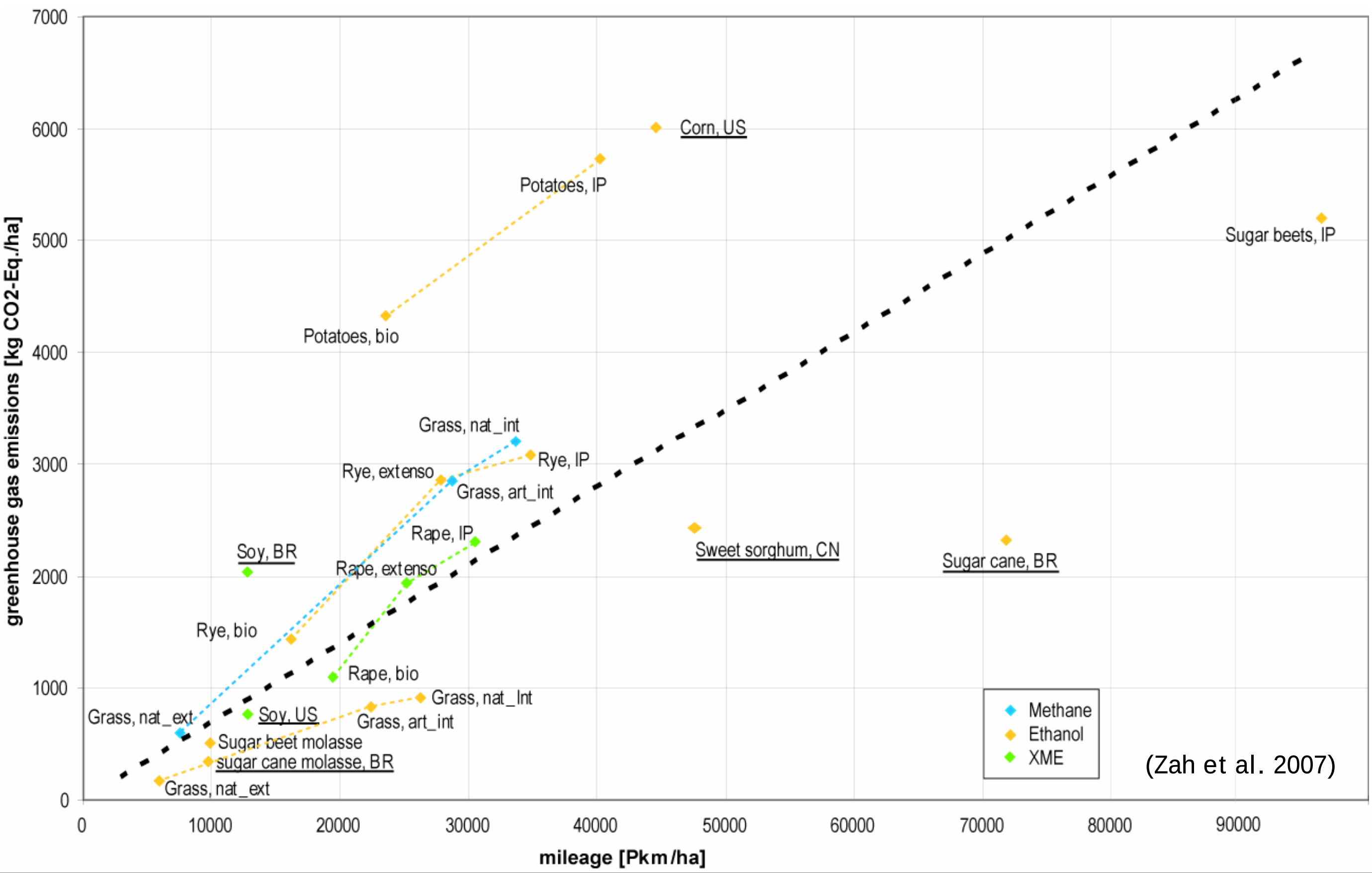
Zah et al. 2007

- **Tax exemption if 40% lower GWP and not higher environmental impacts than gasoline**

Trade-off of environmental impacts



Conclusion from biofuels study

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- A broad variety of investigated biofuels have a significant GWP-reducing potential
- Overall impact is lower in biofuels from waste. -> Step of cultivation is the most important one
- Transport-related impacts can‘t be neglected
- Many biofuels with agricultural biomass have higher overall impacts than fossil fuels

Limits of investigation

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- Emerging technologies with status 2005
- Different degree of development status
- No consequential LCA e.g. influence on food and fodder production
- No limits due to potentials of biomass production

Conclusions for inventory data

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- Products show environmental "Achilles' tendon" in different areas
  => Focus of investigation depends on product analysed
- "Biofuels" example:
  - burning of residues
  - CO_2 emissions due to land transformation
  => acknowledge and model regional differences
- ecoinvent data provide the necessary information

Conclusions (2)

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- Environmental impacts of biofuel pathways are dependent on the raw material
- No good or bad types of products
- Differences of biomass origin, type and processing must be taken into account
- ecoinvent data must be reworked if used in another context
- Data base provides good basis for such assessments

Outlook

- Full LCA based on investigated data published in the framework of the project (http://www.esu-services.ch/bioenergy.htm)
- Life cycle inventories of BTL-fuels are published in EcoSpold format in a European project (www.esu-services.ch/renew.htm)
- Ongoing discussion on guidelines for tax exemption will further increase the need for reliable LCI data
- Shift of focus from fuel to fuel consumption

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GWP is one environmental effect...

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... others serious effects are:

- photochemical oxidation
- acidification
- eutrophication
- ozone layer depletion
- human toxicity
- fresh water toxicity
- marine aquatic toxicity
- land competition
- abiotic depletion

All effects can be aggregated:

- eco-indicator 99
- UBP'06
  german: **U**mwelt**B**elastungs**P**unkte,
  english: Ecological Scarcity Point

Increase of agricultural area

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This area was cleared by soybean farmers in Novo Progreso. Brazilian Government figures show that the rate of clearing has increased.

Annual forest loss in Brazilian Amazon

nearly 20'000km^2
= 600m^2 per second

http://rainforests.mongabay.com/amazon/deforestation_calculations.html
http://sitemaker.umich.edu/section2group3/results_and_discussion

Clear cutting of primary forests

- Agricultural area is increased by clear cutting
- Land transformation leads to CO_2 emissions from soil and biomass
- Burning of residues with further emissions
- Loss of biodiversity
- CO_2 from land transformation accounts for about 90% of Brazil CO_2 emissions
- Particles from residue burning are an important problem in South-East Asia

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Principle of investigation

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- What is the increase in agricultural area for the production in the reference year?
- What is emitted per m² of clear cut land?
- Allocation of emissions between wood and stubbed land
- Stubbed land is the main driver
- New elementary flow „CO_2, land transformation“ as used by IPCC for different possibilities of analysis

Inventory Clear Cutting

Name	Location	InfrastructureProcess	Unit	clear-cutting, primary forest	round wood, primary forest, clear-cutting, at forest road	provision, stubbed land
Location				BR	BR	BR
InfrastructureProcess				0	0	0
Unit				ha	m3	m2
round wood, primary forest, clear-cutting, at forest road	BR	0	m3	5.21E+1	100	-
provision, stubbed land	BR	0	m2	1.00E+4	-	100
Wood, primary forest, standing	-	-	m3	1.82E+2	29	71
Transformation, from tropical rain forest	-	-	m2	1.00E+4	-	100
Transformation, to forest, intensive, clear-cutting	-	-	m2	1.00E+4	-	100
power sawing, without catalytic converter	RER	0	h	1.24E+1	100	-
Carbon dioxide, land transformation	-	-	kg	1.20E+5	-	100
Carbon monoxide, fossil	-	-	kg	7.84E+3	-	100
Methane, fossil	-	-	kg	5.14E+2	-	100

Inventory agricultural product

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Name	Location	Unit	soybeans, at farm
Location			BR
InfrastructureProcess			0
Unit			kg
Occupation, arable, non-irrigated		m2a	1.97E+0
Transformation, to arable, non-irrigated		m2	3.93E+0
Transformation, from forest, intensive, clear-cutting		m2	6.22E-2
Transformation, from arable, non-irrigated		m2	3.77E+0
Transformation, from shrub land, sclerophyllous		m2	1.03E-1
provision, stubbed land	BR	m2	6.22E-2

Soybean greenhouse gasses

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