Life cycle assessment of biofuels

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Overview

- Aims and motivation
- General introduction to **L**ife-**C**ycle **A**ssessment methodology (LCA)
- LCA Results

Why a boom of biofuels?

- Climate protection, because carbon neutral
- Environmentally friendly, because natural production
- Resource protection, because renewable
- Independence from criminal crude oil countries
- Benefits for local economy
- Fits in the business model of car manufacturers
- Good application for genetically modified organisms

➢ Everyone is happy ☺

Objectives of the LCA studies

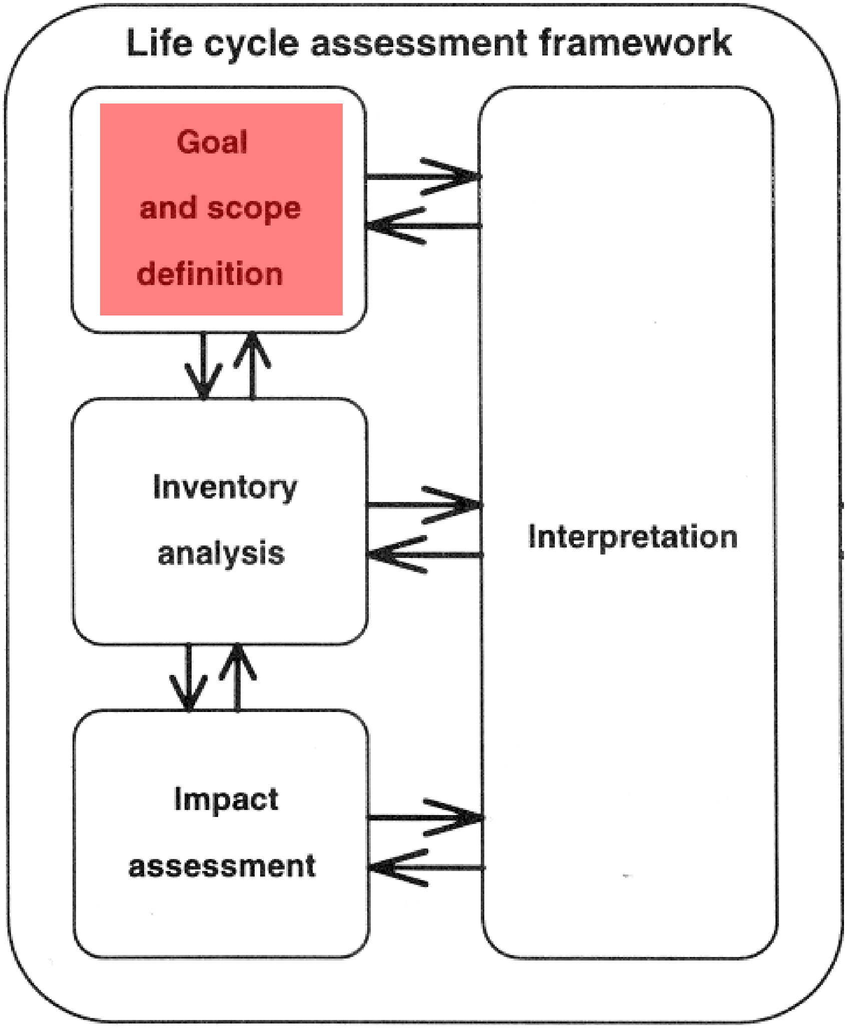
Life cycle assessment of different agrofuels

- What are the environmental impacts of using renewable fuels compared to fossil diesel?
- Which type of fuel has the best environmental performance?

Life cycle assessment = from cradle to grave

Functional Unit: 1 pkm

ISO standard 14040: LCA



- System boundary:
  from cradle to grave
- Functional Unit:
  - 1 Person transported over a distance of 1km

Classification of fuels: Marketing and brand names

- Sunfuel, Sundiesel: synthetic fuels from Choren process)
- Ökodiesel, Biodiesel: mainly used for XME with biomass from different origin
- Naturgas: natural gas mixed with >10% biogas
- Kompogas: brand name of biogas plants
- 1st, 2nd, 3rd generation: unclear definition e.g. based on today market share, resource types or edibility or conversion processes

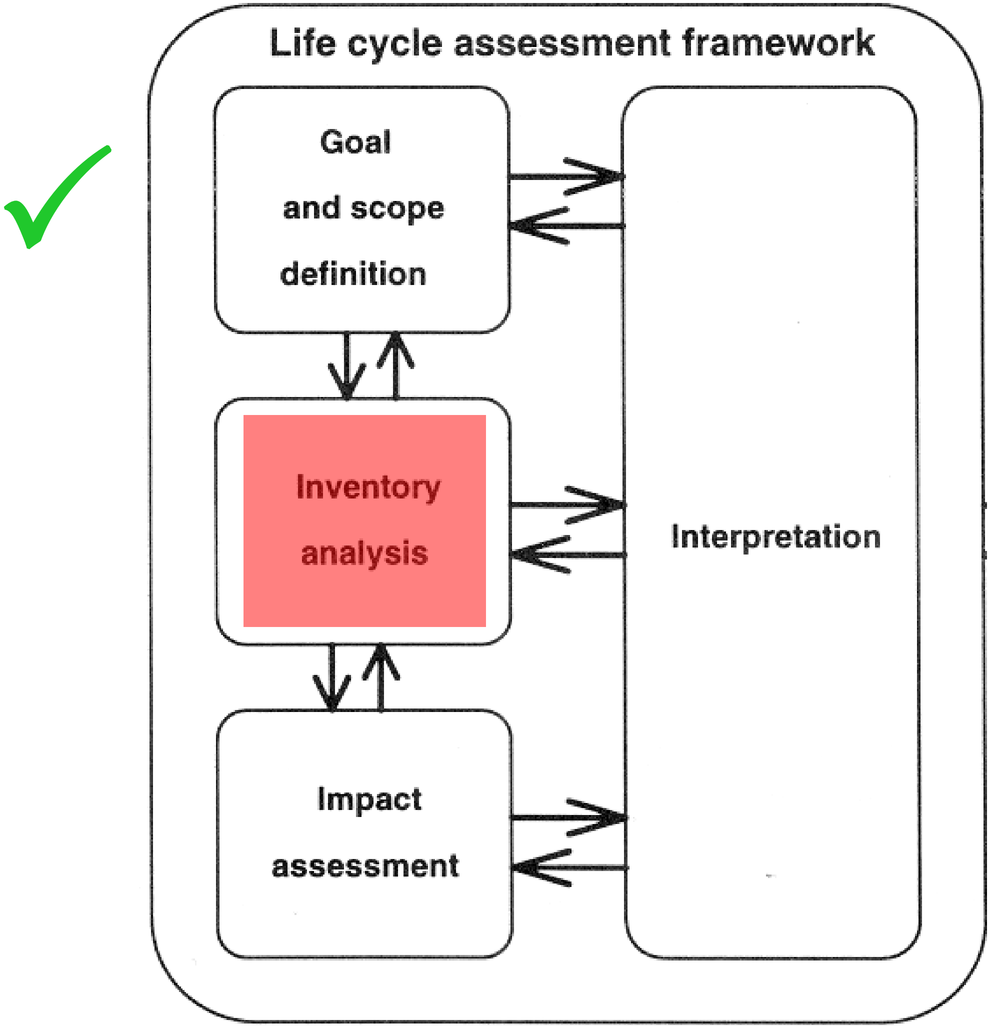
➢ Marketing and brand names do not help for a discussion on renewable fuels

Classifications of powertrain fuels

- **Resources** used
  - Non-renewable: crude oil, natural gas, coal, nuclear
  - Renewable: energy crops (edible, non-edible), algae, forest wood, biomass residues (e.g. straw), industrial residues (e.g. Black Liquor), sun, wind
- Conversion **process** technologies
  - mechanical, chemical reaction, thermal treatment, fermentation, anaerobic digestion, pyrolysis, gasification, Fischer-Tropsch synthesis, biotechnical
- Chemical classification of the **product**
  - methane, ethanol, methanol, dimethylether (DME), hydrogen, oils, methyl ester, liquids (petrol, diesel, BtL, GtL), ETBE, MTBE

➢ Fuels can only be classified by a combination of resource, process and product

ISO standard 14040: LCA



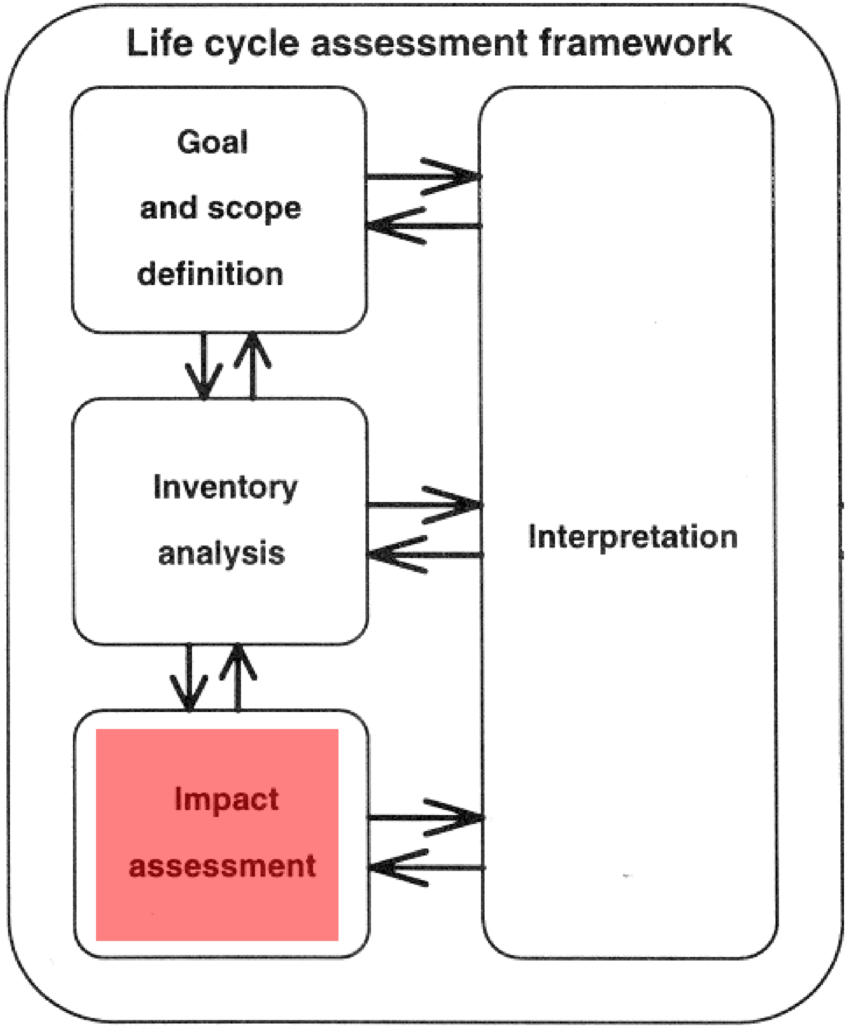
Life cycle inventory analysis

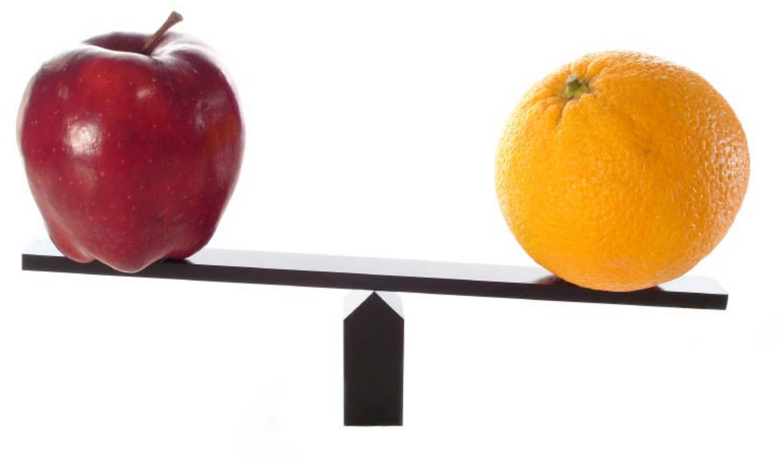
- Flow chart with short technical description
- Balance of all material and energy flows:
  - Inputs and Outputs (e.g. biomass, chemicals, catalysts, products)
  - Emissions to air, water and soil
  - Resource uses (energy, water, land)
  - Wastes

Environmental relevant goods for driving with agrofuels

- **Fuel**
  - biomass production
  - fuel conversion
  - fuel distribution
- **Powertrain and car**
  - Manufacture
  - Maintenance
  - Disposal
- **Streets / tunnel / bridges**
  - Construction
  - Maintenance
  - Disposal

ISO standard 14040: LCA





Life Cycle Impact Assessment (LCIA)

	Example:
Cumulative LCI results	CO_2, CH_4: Greenhouse gases,
↓ Classification	Global warming potential (GWP)
↓ Characterisation	CO_2=1; CH_4=23kg CO_2-equivalent.
↓ Normalization	GHG-emission Europe:6.5 Mia. t CO_2-eq.
↓ Grouping	Sorting and ranking
↓ Weighting	Aggregation based on weighting principles
↓ **Environmental indicator**	

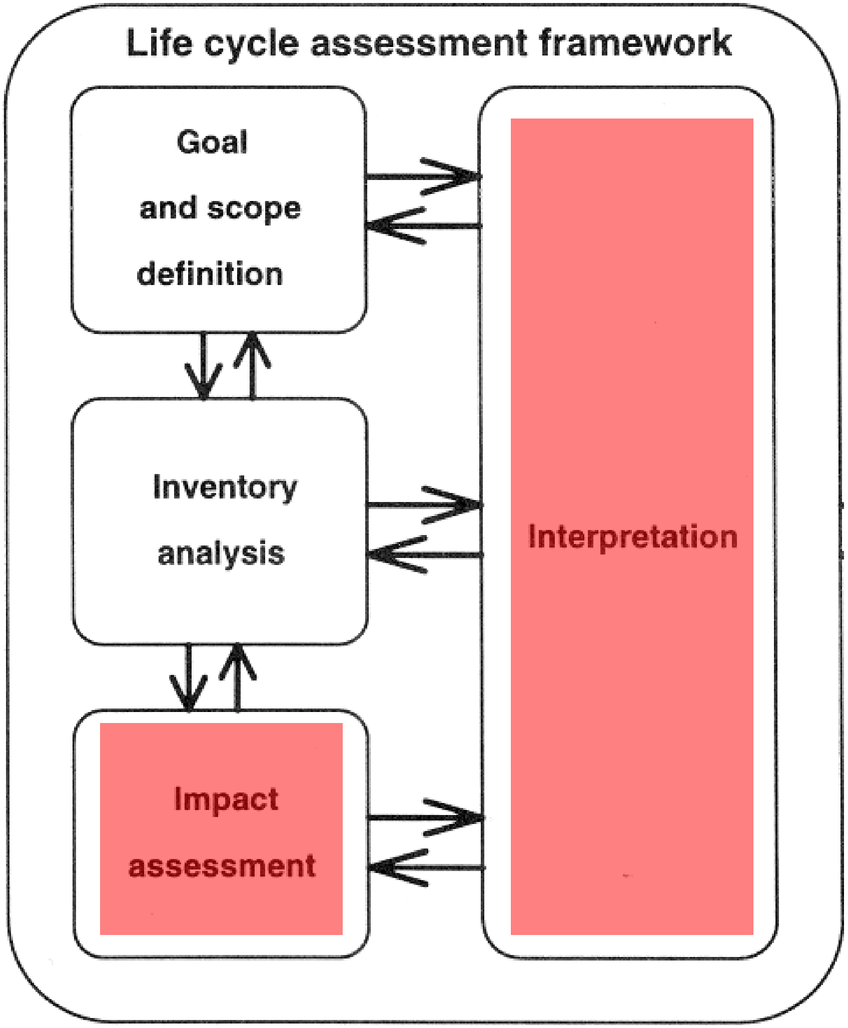
Environmental impacts covered by different LCIA methods

	environmental impacts	cumulative energy demand (CED)	global warming potential (GWP)	ecological scarcity 2006	eco-indicator 99
resourc	abiotic resources	√	∅	√	√
	biotic resources	∅	∅	√	∅
	land use	∅	∅	√	√
emissions	climate change	∅	√	√	√
	ozone depletion	∅	∅	√	√
	human toxicity	∅	∅	√	√
	ecotoxicity	∅	∅	√	√
	photochemical oxidant formation	∅	∅	√	√
	acidification	∅	∅	√	√
	nutrification	∅	∅	√	√
	odour	∅	∅	∅	∅
	noise	∅	∅	∅	∅
	ionising radiation	∅	∅	∅	√
	waste (incl. radioactive waste)	∅	∅	√	∅

Summary on LCA methodology

- Life cycle assessment (LCA) is for quantifying the environmental impacts of products and services
- The focus of an investigation is from the extraction of resources to the final disposal. (from “cradle-to-grave”)
- Reliable, transparent and consistent LCI data are crucial for such analyses.

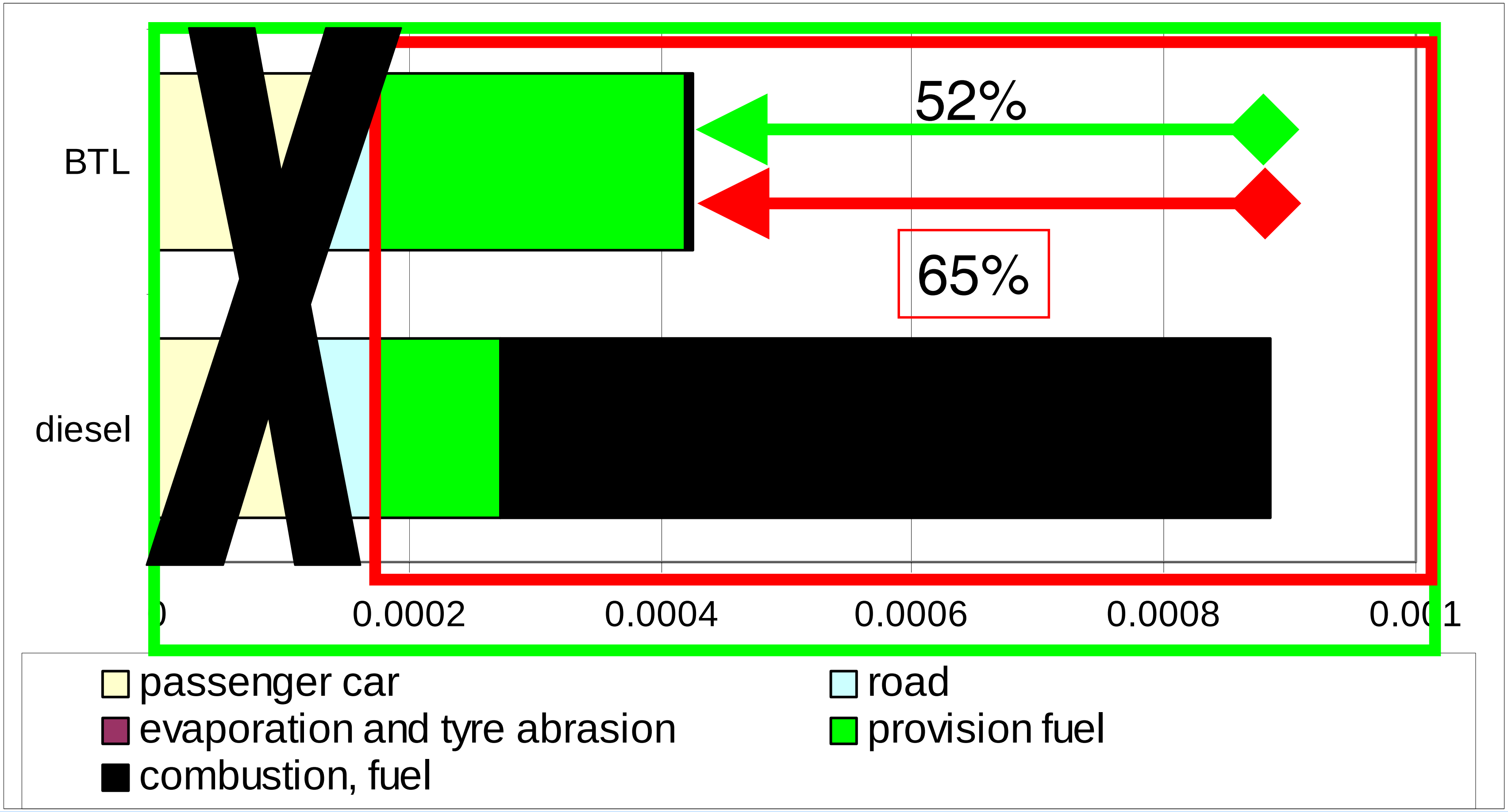
ISO standard 14040: LCA



- Results agrofuel studies
- Interpretation of results

How much better are renewable fuels?

GWP reduction of agrofuels



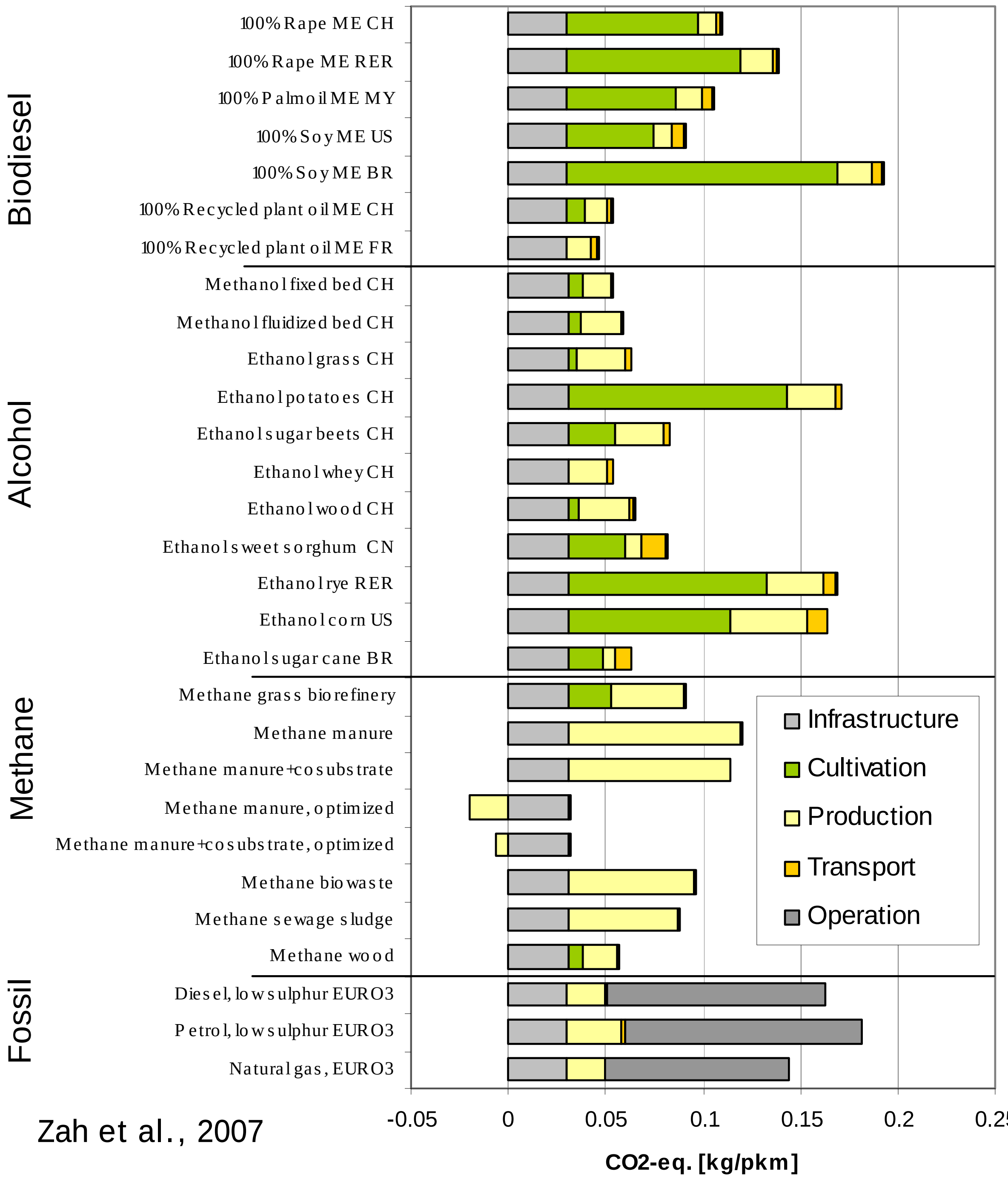
- Neglecting parts of the life cycle leads to different conclusions concerning reduction potentials expressed as a percentage

1st renewable energy study (Switzerland)

- Scope: from cradle-to-grave
- Goal: assess total environmental impacts of different pathways for a possible tax redemption
- Overview of investigated renewable fuels:

Methane 96%	**Ethanol 99.7%**	**Methanol**	**Biodiesel**
biowaste	wood	waste wood	Waste cooking oil
sludge	grass	industrial wood	Rape seed CH/RER
grass	potatoes		soya oil US / BR
manure	sugar beets		palm oil MY
wood	whey		
	sugar cane BR		
	maize		
	rye DE / RER		
	sweet sorghum		

GWP-Reduction of renewable fuels



Zah et al., 2007

Conclusions:

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



GWP is one environmental effect…

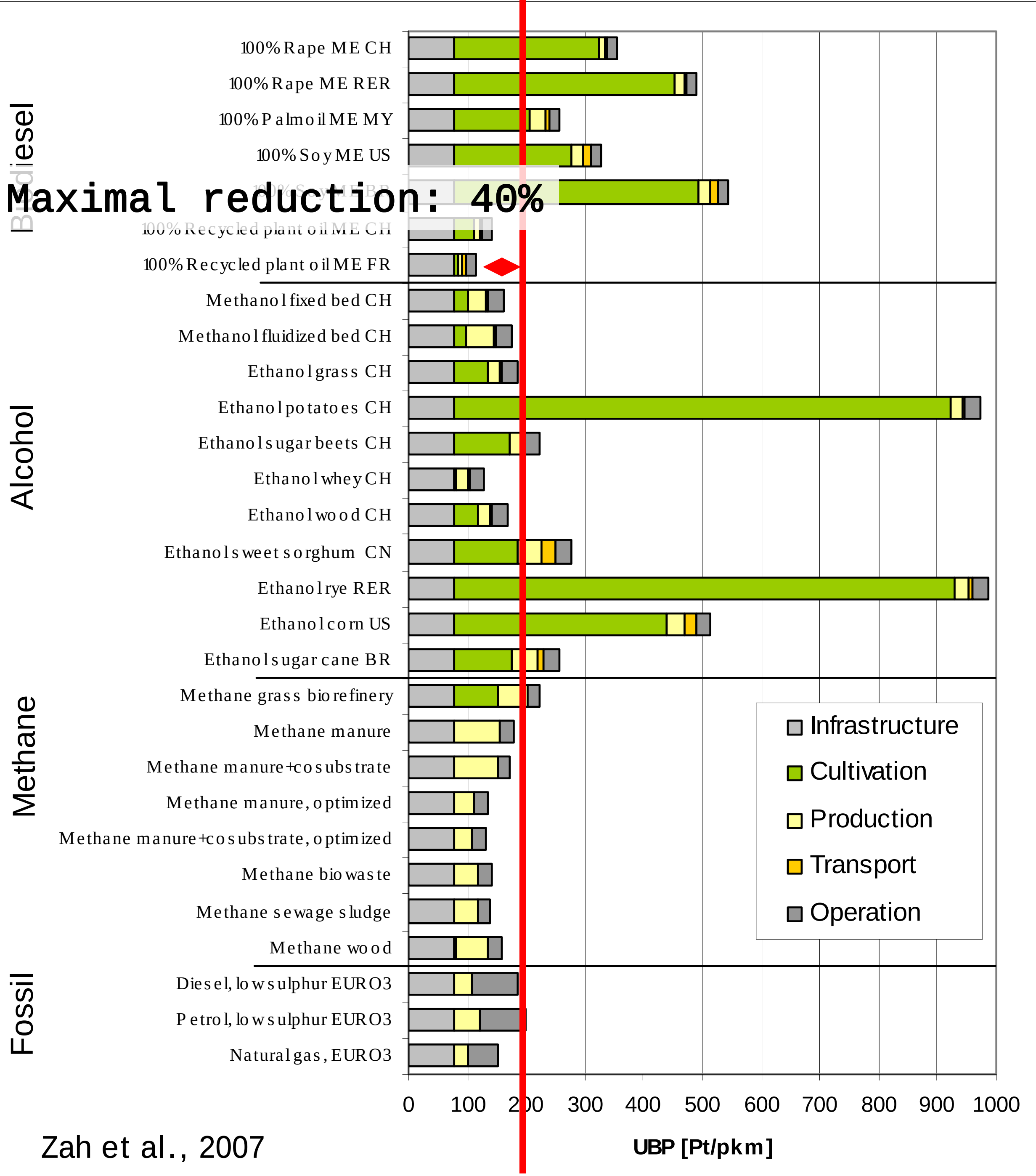
… others serious effects are:

- 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
- Ecological Scarcity 2006 or **U**mwelt**B**elastungs**P**unkte

The whole picture



Zah et al., 2007

Conclusion:

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

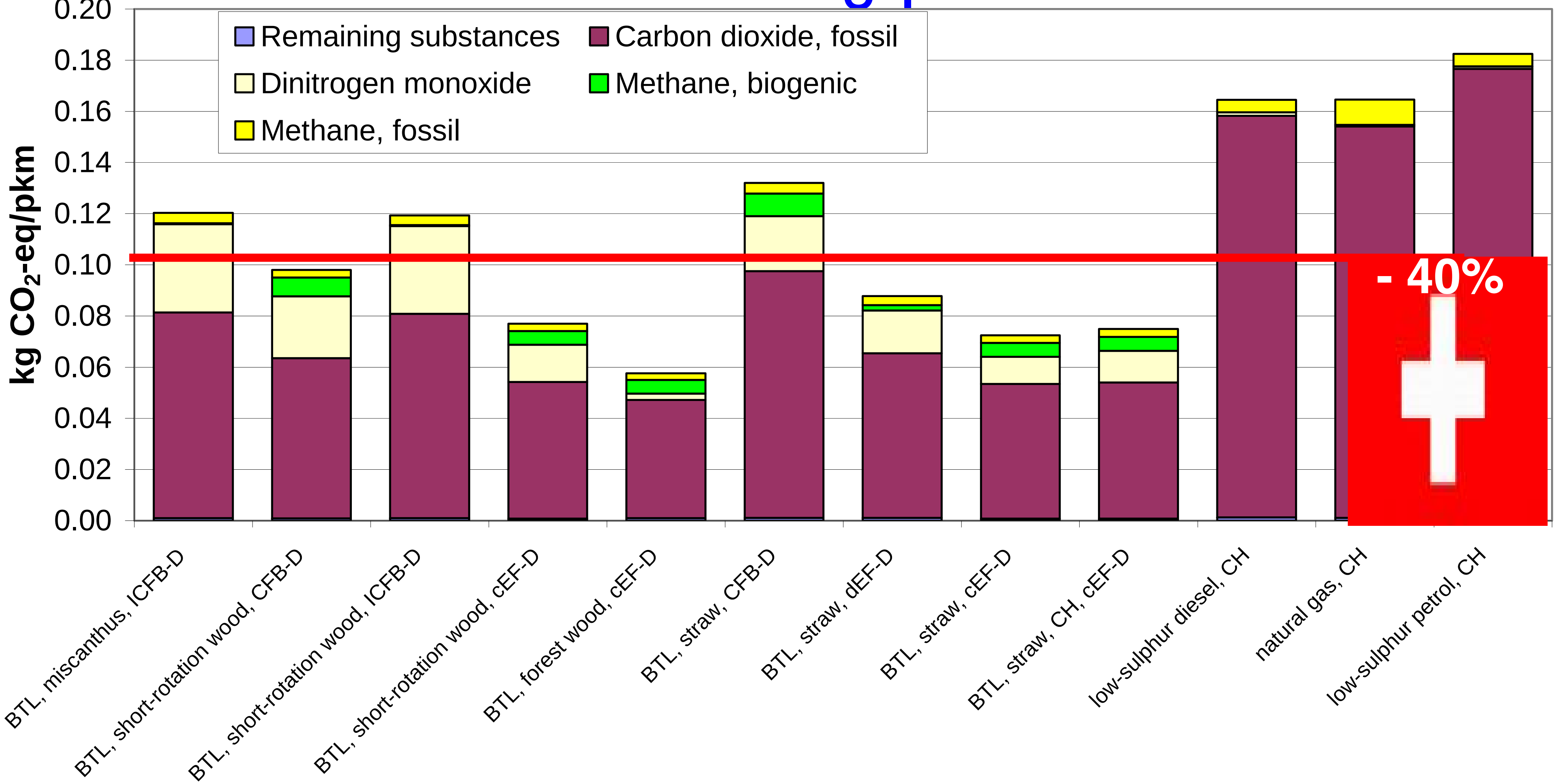
Conclusion from 1st study

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

BTL-fuel study

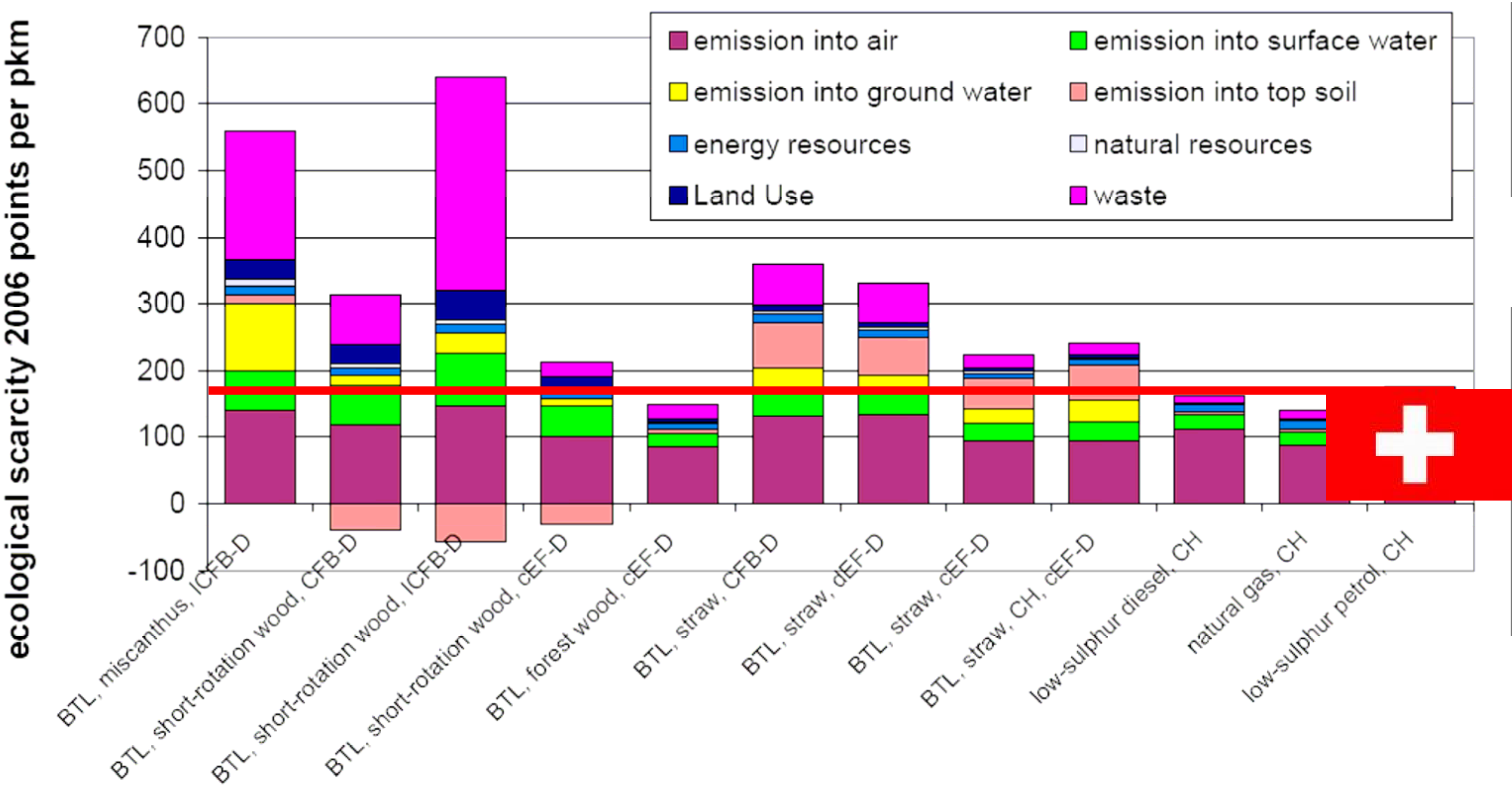
- Goal: assess total environmental impacts of different <u>synthetic</u> fuel pathways and conversion concepts
- Investigated BTL-fuels:
  - Miscanthus
  - Straw
  - Wood (Poplar / Salix) and from forest

Global warming potential



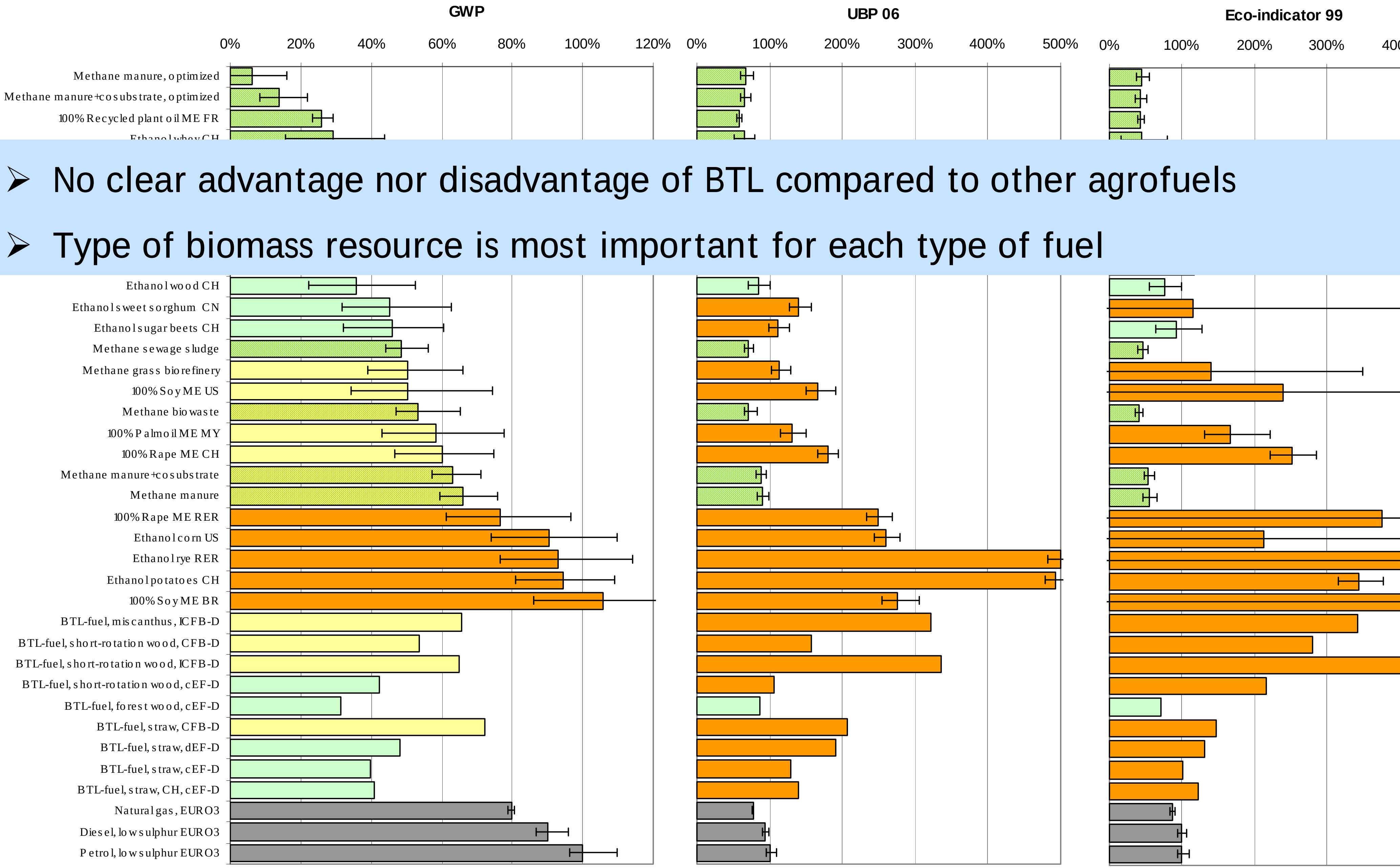
- GWP reduction between 28% and 69% → lower than what has been assumed so far

The whole picture: overall env. impact



- Big differences between the production routes of the same biomass type

Comparison of renewable fuels



- No clear advantage nor disadvantage of BTL compared to other agrofuels
- Type of biomass resource is most important for each type of fuel

Again: How much better are renewable fuels?

- Sorry, no easy answer… ☹
- Environmental performance depends on:
  - Scope of investigation
  - Choice of environmental indicators
  - Type & cultivation of biomass
  - Efficiency of conversion
  - Impacts of associated infrastructure as streets, manufacture of cars, etc.

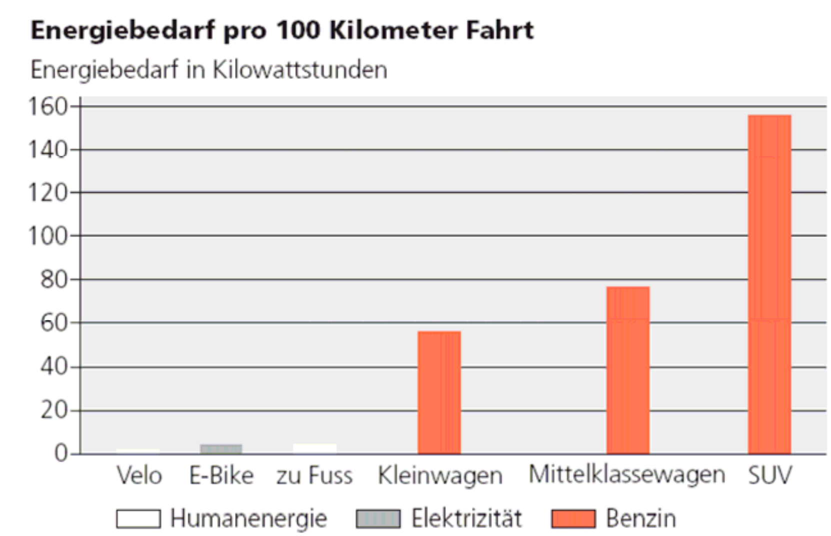
Conclusions on agrofuels from an environmental point of view

- Renewable fuels can help to save the climate, but they are never climate neutral
- Many agrofuels have higher total environmental impacts than fossil fuels
- The type of biomass is more important than the type of fuel
- The use of waste-products for fuel-production makes sense
- Agrofuels cannot reduce the environmental impacts from important non-fuel emissions (e.g. infrastructure)

Legislative status in Switzerland

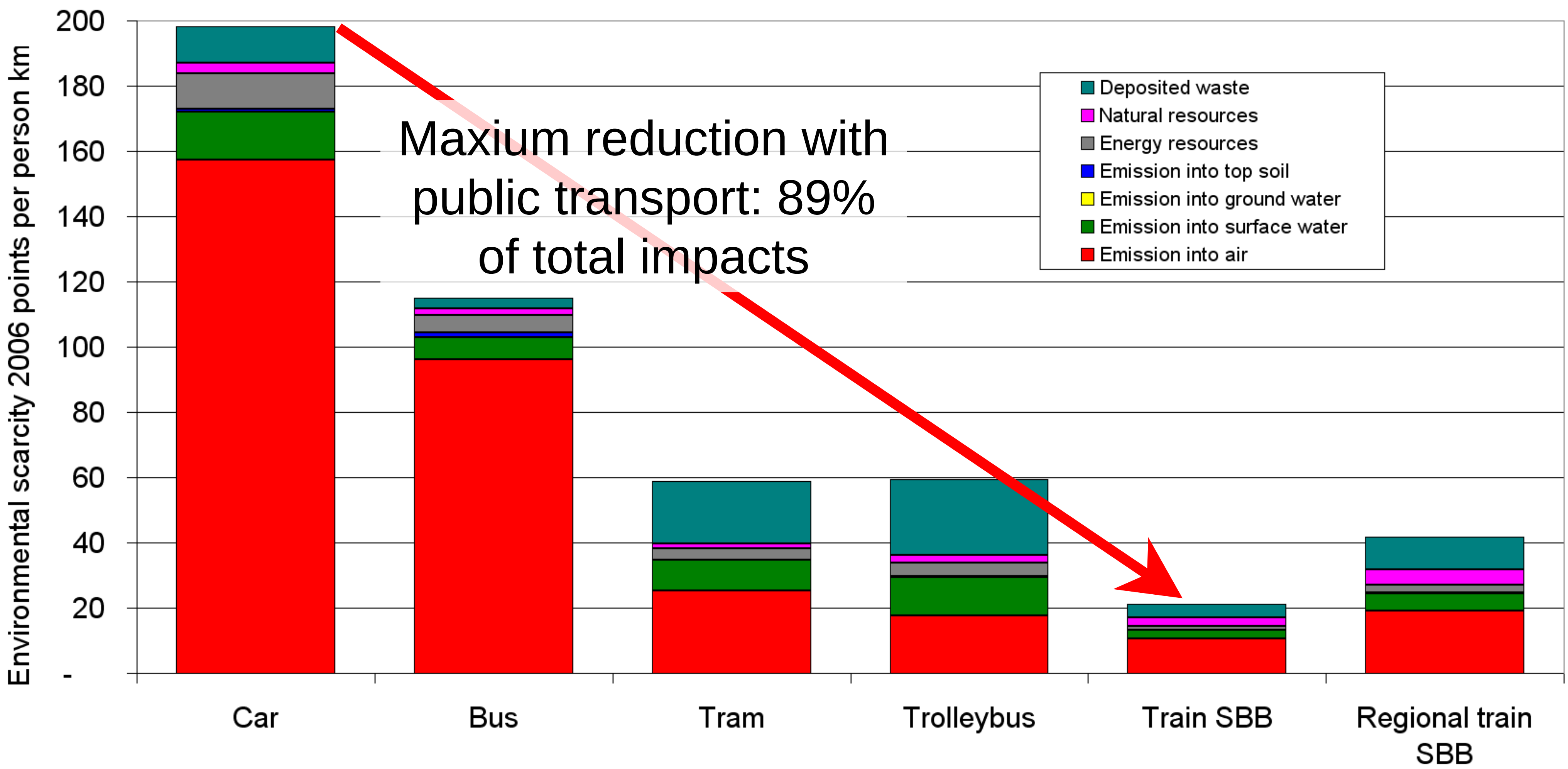
- Full LCA is basis for tax reduction for renewable fuels
  - 40% GWP reduction
  - <125% of overall environmental impacts (UBP) than fossil reference
  - Cradle to grave LCA one prerequisite
- Data provision by importers or producers of fuels not from waste
- Common background database and methodology: ecoinvent v2.0

How far can I get with fuel from



- Depending on the car: 5’000 – 30’000 km per soccer field
- By bicycle and food: 12’500 km (veal), 65‘000 km (wine), 400‘000 km (wheat), 600’000 km (potatoes)

Real alternatives to petrol?



Recommendations for mobility

1. **Use bicycle or public transport**
2. **Drive a car with suitable number of seats and space for loading (→ Carsharing)**
3. **Buy a car with low fuel consumption**
4. Drive with fuels from waste
5. Other agrofuels with proof of origin and possibly a label

Thank you for your attention!

Publications:

- LCA of Bioenergy Products (http://www.esu-services.ch/bioenergy.htm)
- LCA of Biomass-To-Liquid fuel production (www.esu-services.ch/renew.htm)
- LCA of Biomass-To-Liquid fuel use (www.esu-services.ch/btl)

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