Life cycle assessment and sustainability aspects of biodiesel

Niels Jungbluth
ESU-services Ltd., Uster, Switzerland

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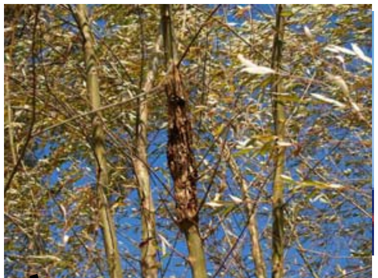
Overview

- General introduction to **L**ife-**C**ycle **A**ssessment methodology (LCA)
- Swiss LCA results on biodiesel
- Legislation on biofuels in Switzerland
- Recommendations

Life cycle assessment = from cradle to grave



Functional Unit: 1 pkm

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

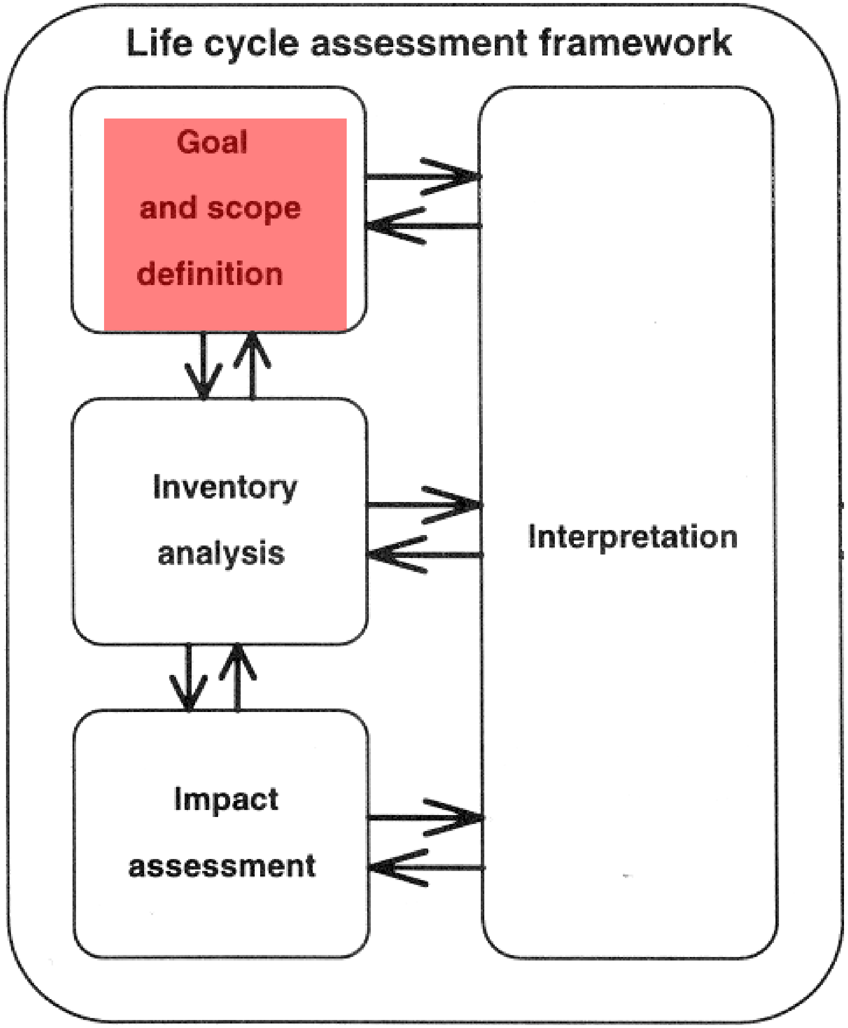
➢ Marketing and brand names do not help for a discussion on renewable fuels

Necessary classifications of fuels

- **Resources** used and how they have been produced
  - 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: Goal and scope



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

→ Per kilometre driven in Switzerland

Overview of investigated renewable fuels

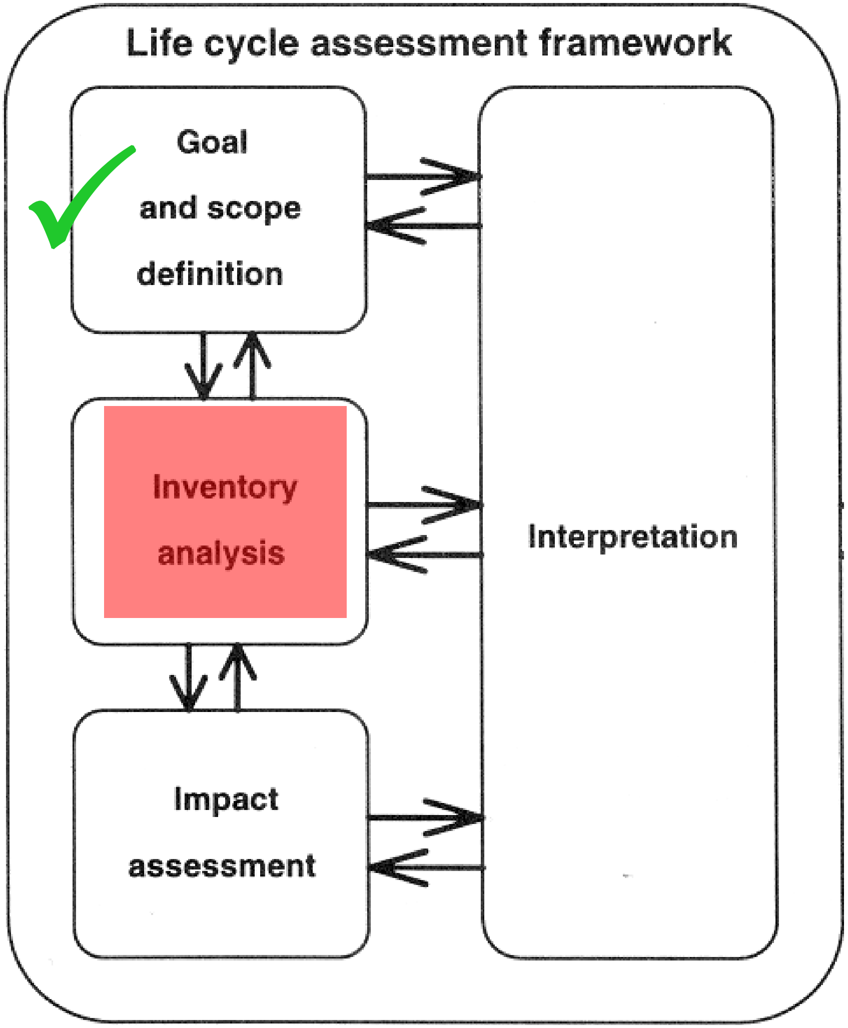
Biodiesel
Waste cooking oil
Rape seed CH/RER
soya oil US / BR
palm oil MY

Methanol
waste wood
industrial wood

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

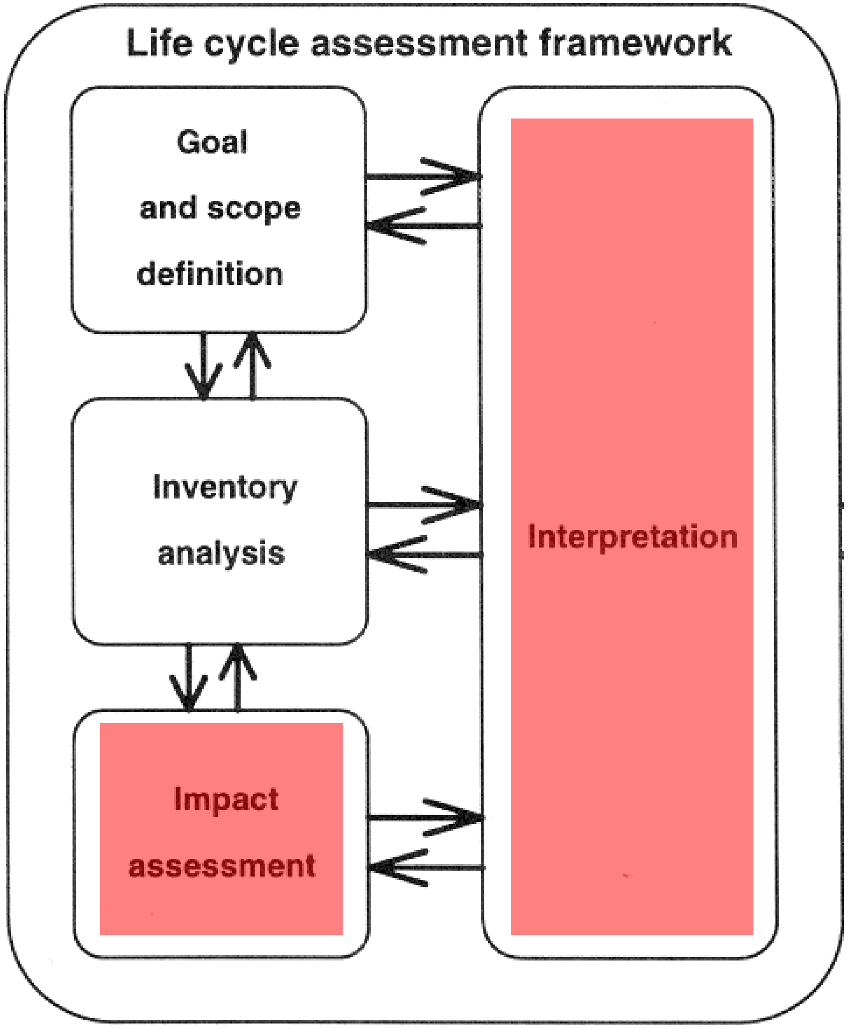
Methane 96%
biowaste
sludge
grass
manure
wood

Life Cycle Inventory Analysis



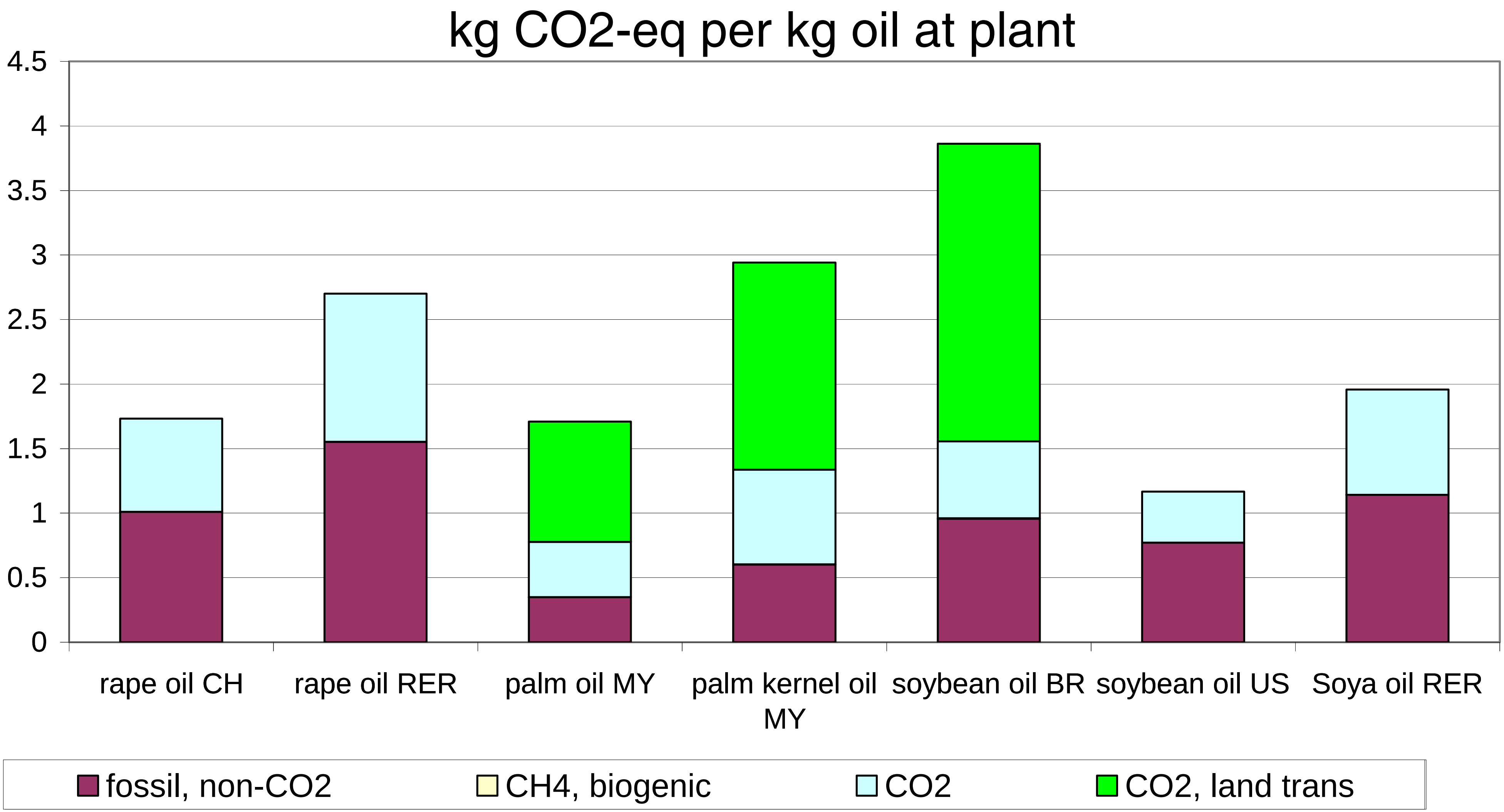
- Flow chart with short technical description
- Balance of material and energy flows:
  - Inputs and Outputs (e.g. biomass, chemicals, catalysts, products)
  - Emissions to air, water and soil
  - Resource uses (energy, water, land)
  - Wastes
- All data published on www.ecoinvent.org

ISO standard 14040: Interpretation



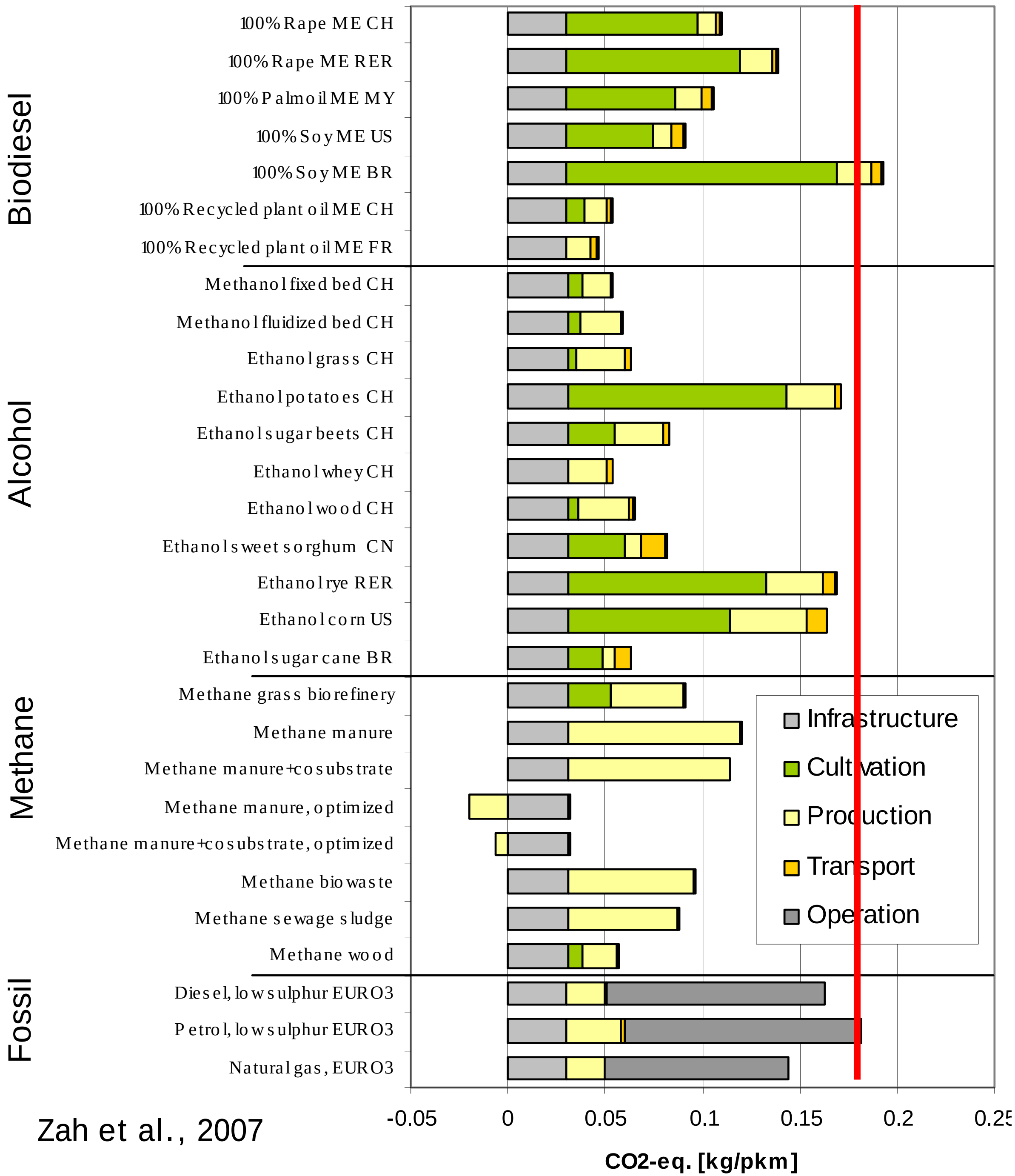
- Assessment of different types of environmental impacts
- Analysis of important factors
- Interpretation of results

Plant oil production: Carbon Footprint



Conclusions biomass production

- Regional differences for one crop need to be considered
  - Climate (water, sun, etc.)
  - Productivity (intensive vs. extensive)
  - Production standards (pesticides, fertilizer)
  - Specific issues (e.g. land use changes)
- Further differences depending on type of crop



Zah et al., 2007

GWP-Reduction of renewable fuels

Conclusions:

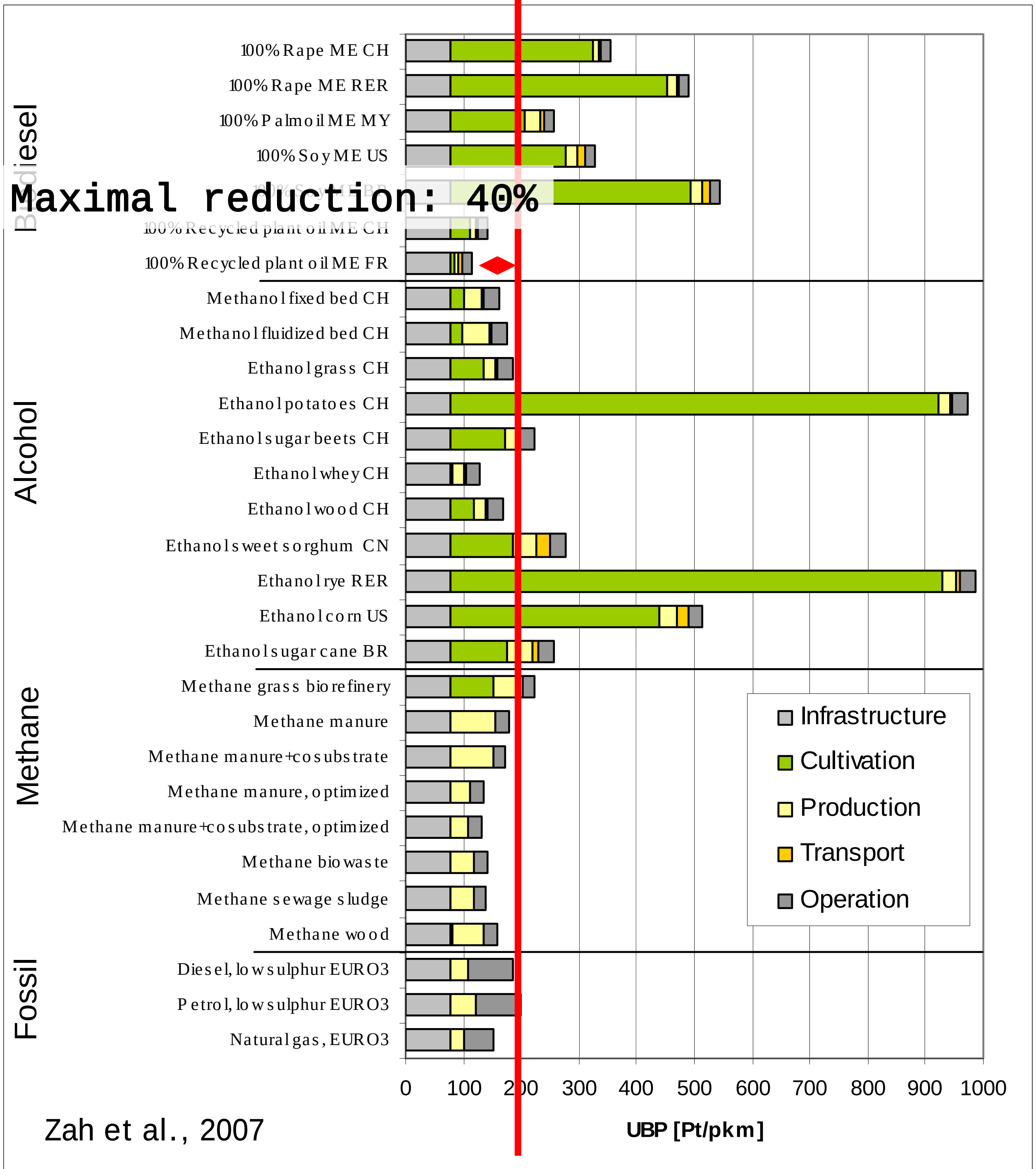
- 13 of 26 investigated fuels reduce the GWP significant (>50%)
- 5 of them are from waste
- Transportation and conversion not so relevant
- Worst fuel: Brazilian soya oil with more GWP than fossil reference (transformation of rainforest into agriculture)

GWP is one environmental effect...

	environmental impacts	carbon footprint (kg CO2-eq)	ecological footprint (m2a)	ecological scarcity 2006 (UBP)	ReCiPe (points)
resources	abiotic resources, incl. water	∅	∅	√	√
	nuclear energy	∅	√	√	√
	fossil energy	∅	∅	√	√
	land occupation	∅	√	√	√
	land transformation	∅	∅	∅	√
emissions	climate change	√	√	√	√
	ozone depletion	∅	∅	√	√
	toxicity	∅	∅	√	√
	summer smog	∅	∅	√	√
	acidification	∅	∅	√	√
	nutrification	∅	∅	√	√
	endocrine disruptors	∅	∅	√	∅
	noise, odour, litter	∅	∅	∅	∅
	ionising radiation	∅	∅	√	√
	waste (incl. radioactive waste)	∅	∅	√	∅

- There are several others serious impacts than only GWP
- All effects can be aggregated to one indicator

The whole picture



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.

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)

Improvement options

- Environmental sound production patterns for biomass balanced between intensive and extensive production (low input –high yield)
- High conversion efficiency and valuable by-products

- ➢ Don’t hope on miracles like plants growing without nutrients, water and soil (Jatropha)
- ➢ Don’t optimize only one parameter
  - ➢ Algae with high yield but complex infrastructure
  - ➢ BtL (broad range of biomass but flimsy conversion yield)

Legislative status in Switzerland

- Tax reduction for renewable fuels
  - Cradle to grave LCA one prerequisite
  - 40% GWP reduction
  - <125% of overall environmental impacts (UBP) than fossil reference
- Data provision by importers or producers of fuels in a questionnaire
- Simplified quick check (www.sqcb.org)
- Common background database and methodology: ecoinvent v2.0

Swiss regulation compared with EU Renewable Energy Directive (RED)

- Full life cycle included in calculation
- Scientific background from peer-reviewed LCA
- Coverage of several environmental impacts
- Consistent allocation rules mainly based on economic thinking
- 40% reduction over full life cycle compared to 35% reduction in fuel production and use only

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)
- LCA discussion forum on future biofuels
  www.lcainfo.ch/DF/DF36/Program.htm

Niels Jungbluth
jungbluth@esu-services.ch
www.esu-services.ch
ESU-services Ltd., Uster, Switzerland

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

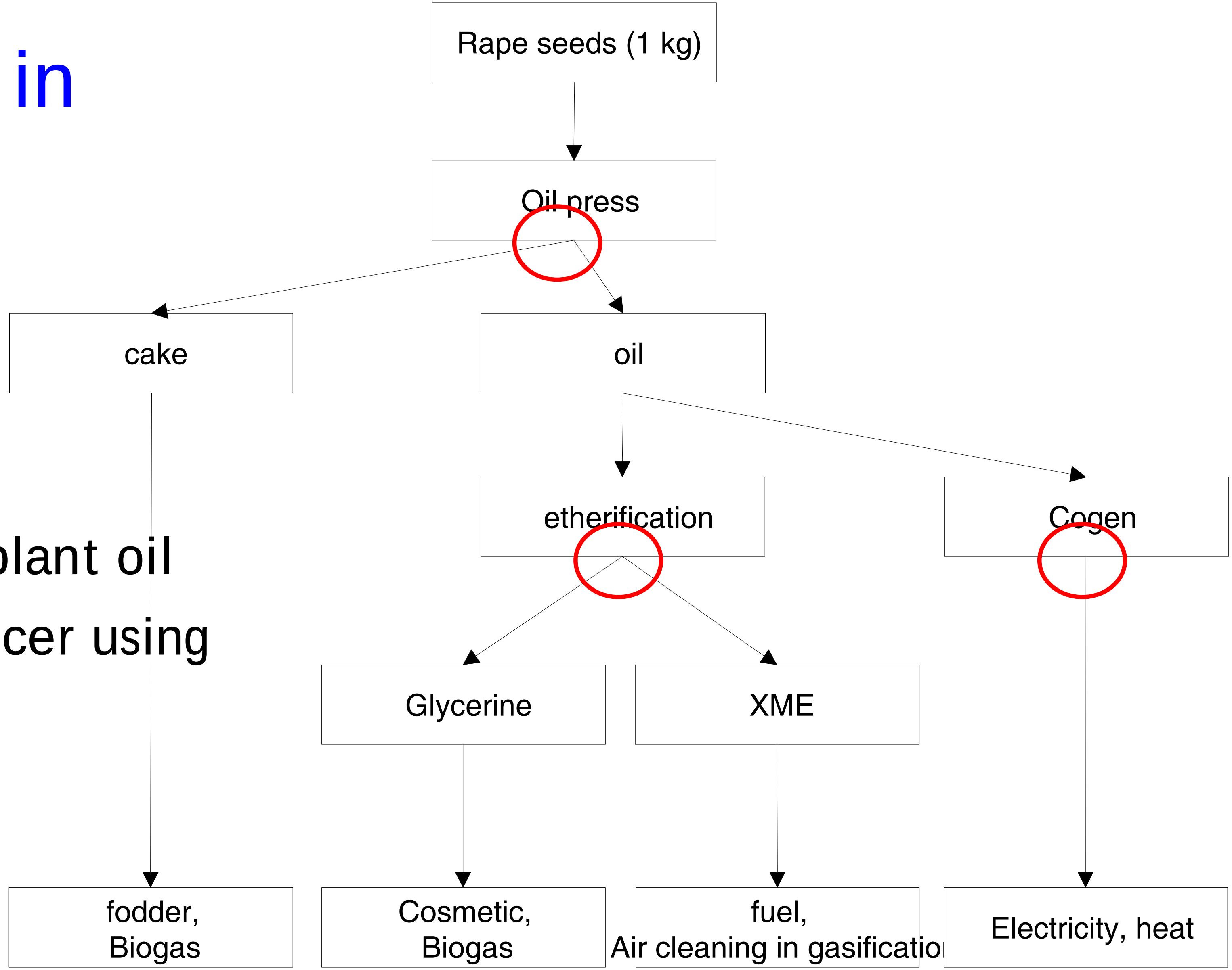
➢ Everyone is happy ☺

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.

Consistency in allocation

- Actors:
  - Farmer
  - Oil pressing
  - Cogen with plant oil
  - Biogas producer using glycerine
  - Fodder user
  - Fuel user



Main couple products in life cycle of biofuels

- First use – second use (e.g. used cooking oil that is sold)
- by-product as raw material for which disposal is necessary and paid
- Biomass production (straw – grains)
- Fuel conversion
  - oil – cake
  - XME – glycerine
  - Product – fertilizer
  - Biofuel - waste treatment service, proteins, etc.
- Biomass combustion (heat – electricity)
- Indirect effects (driver biofuel – harvested crop e.g. food)

Problems of energy allocation

- Impacts are fully allocated to second life cycle, e.g. old plant oils
- Energy forms might differ (fuel, heat, electricity)
- Energy not always a good descriptor, e.g. of waste treatment services, fertilizers production, etc.
- High water content will give low value even if other good properties, e.g. fertilizer

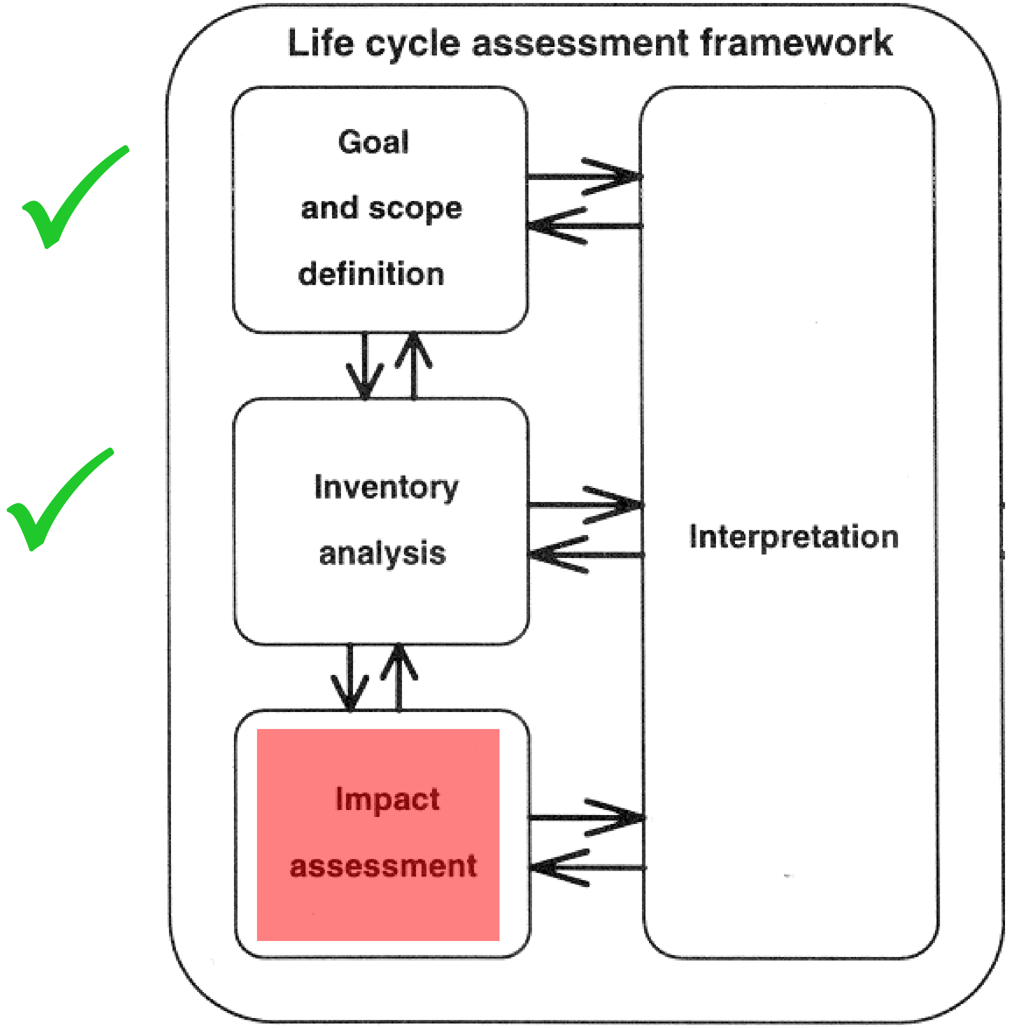
Land use change: Clear cutting of primary forests

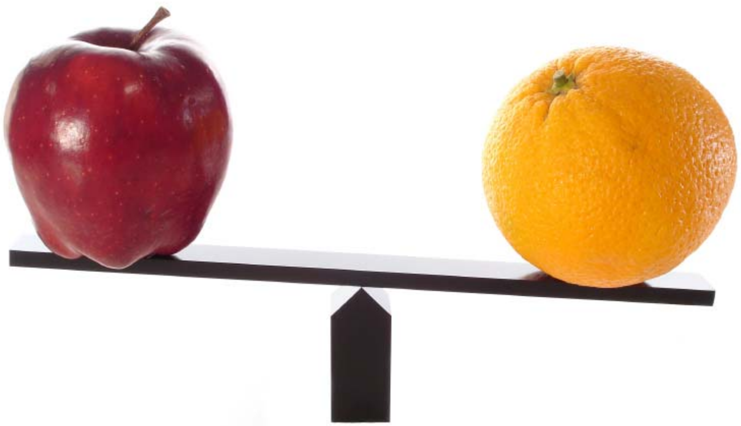
- Agricultural area is increased by clear cutting
- Land transformation leads to CO_2 emissions from soil and biomass
- Loss of biodiversity
- CO_2 from land transformation accounts for about 90% of Brazil CO_2 emissions

Principle of investigation

- Increase in agricultural area for the production in the reference year?
- Emissions per m^2 of clear cut land?
- Allocation of emissions between wood production and stubbed land
- Stubbed land assumed the main driver
- New elementary flow „CO_2, land transformation“ as used by IPCC for different possibilities of analysis
- No indirect effects – double counting in a database!

ISO standard 14040: LCIA





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**	

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

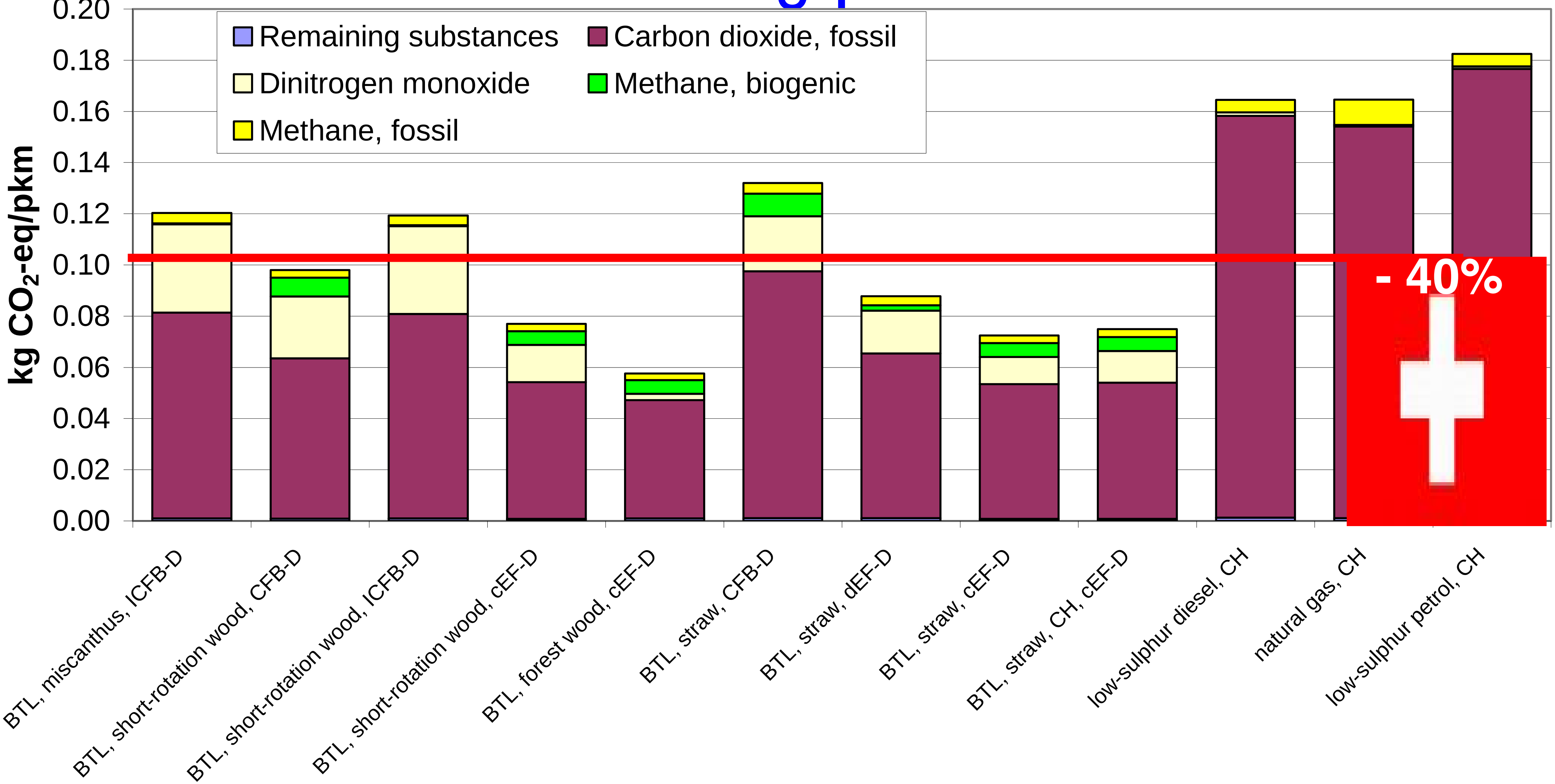
All effects can be aggregated:

- Eco-indicator 99
- Ecological Scarcity 2006
  or **U**mwelt**B**elastungs**P**unkte

BTL-fuel study

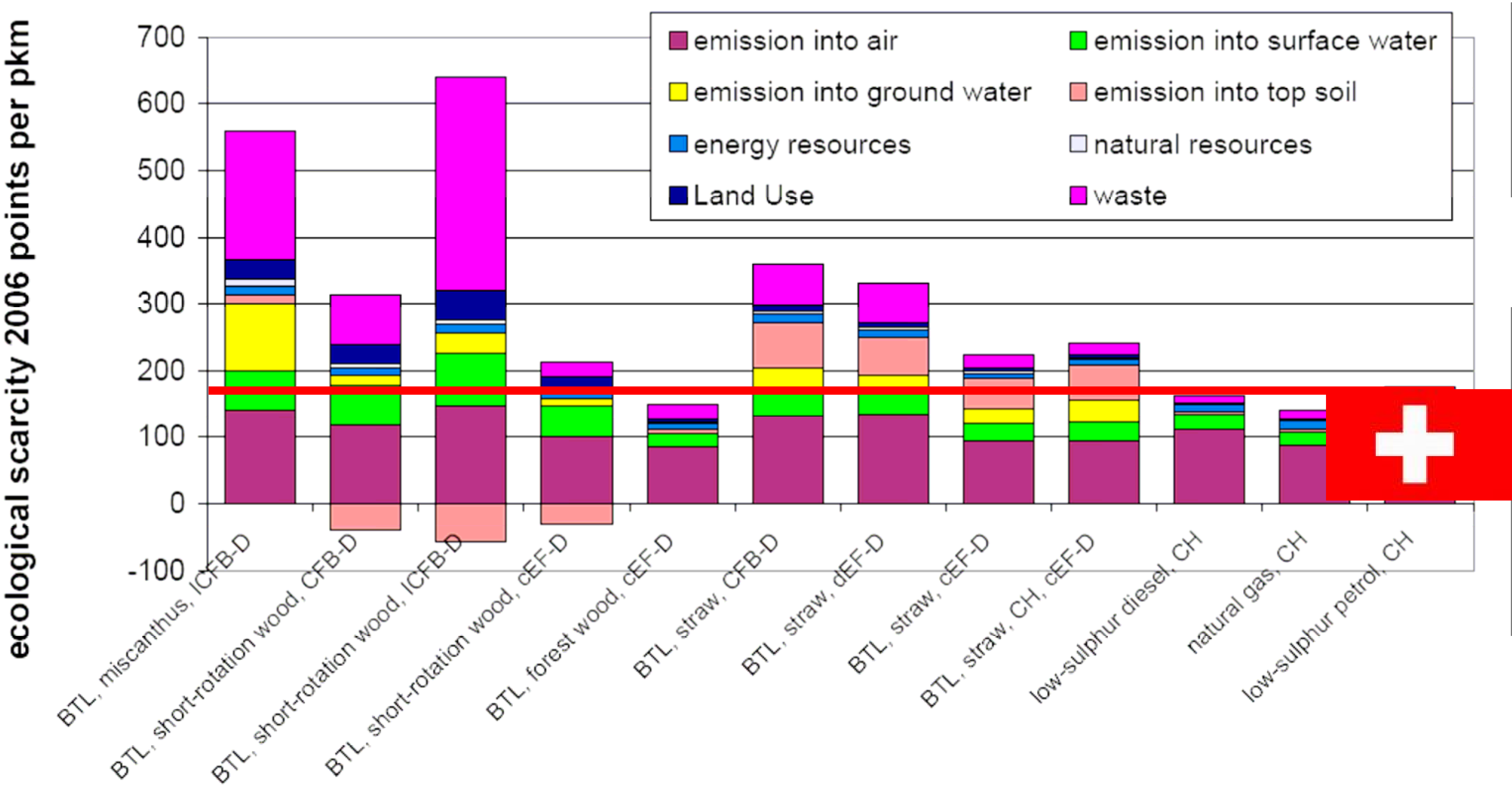
- Goal: assess total environmental impacts of different synthetic fuel pathways and conversion concepts
- Investigated BTL-fuels:
  - Miscanthus
  - Straw
  - Wood (Poplar / Salix) and from forest

Global warming potential BtL



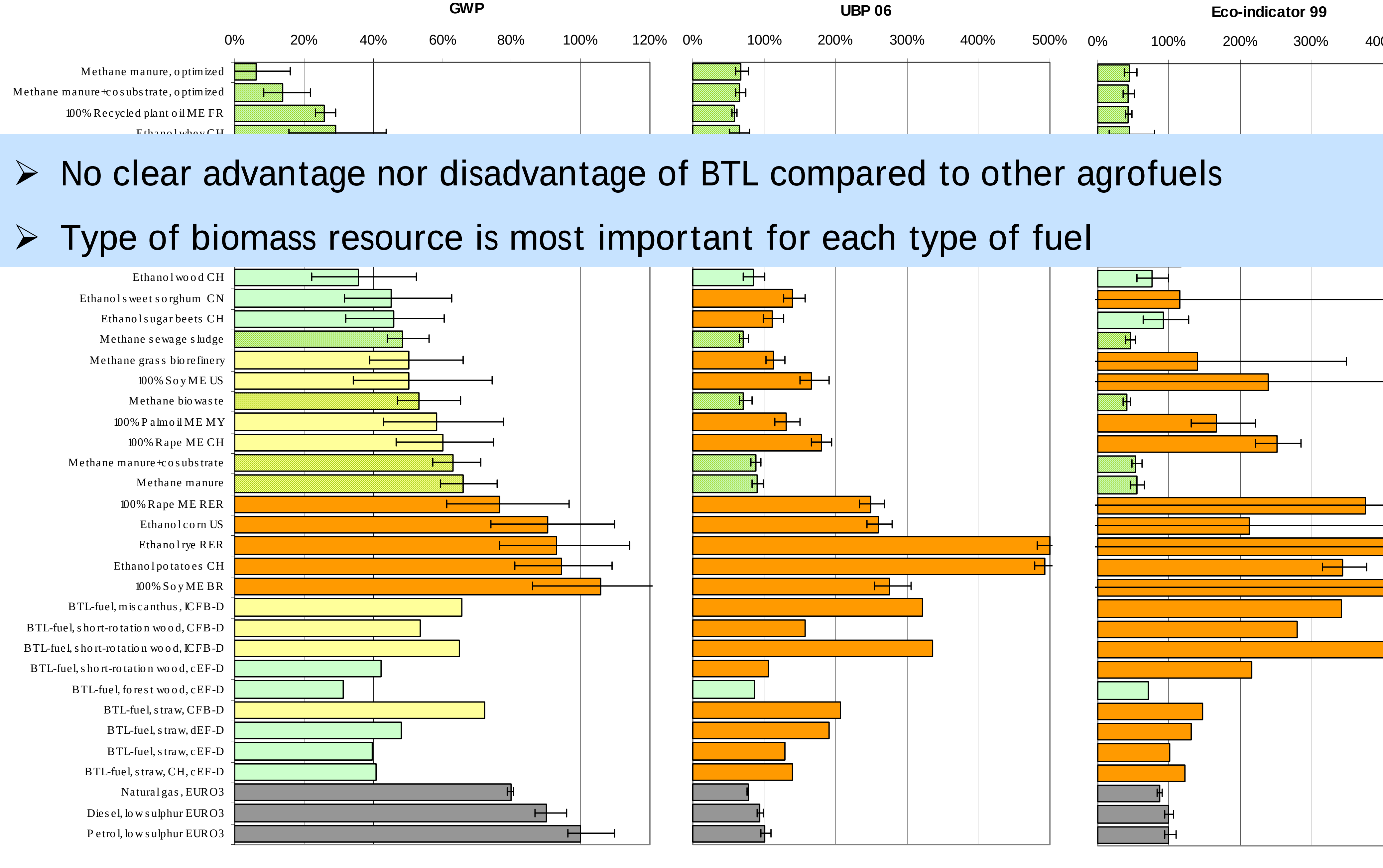
- GWP reduction between 28% and 69% → lower than what has been assumed so far

The whole picture: BtL overall env. impact



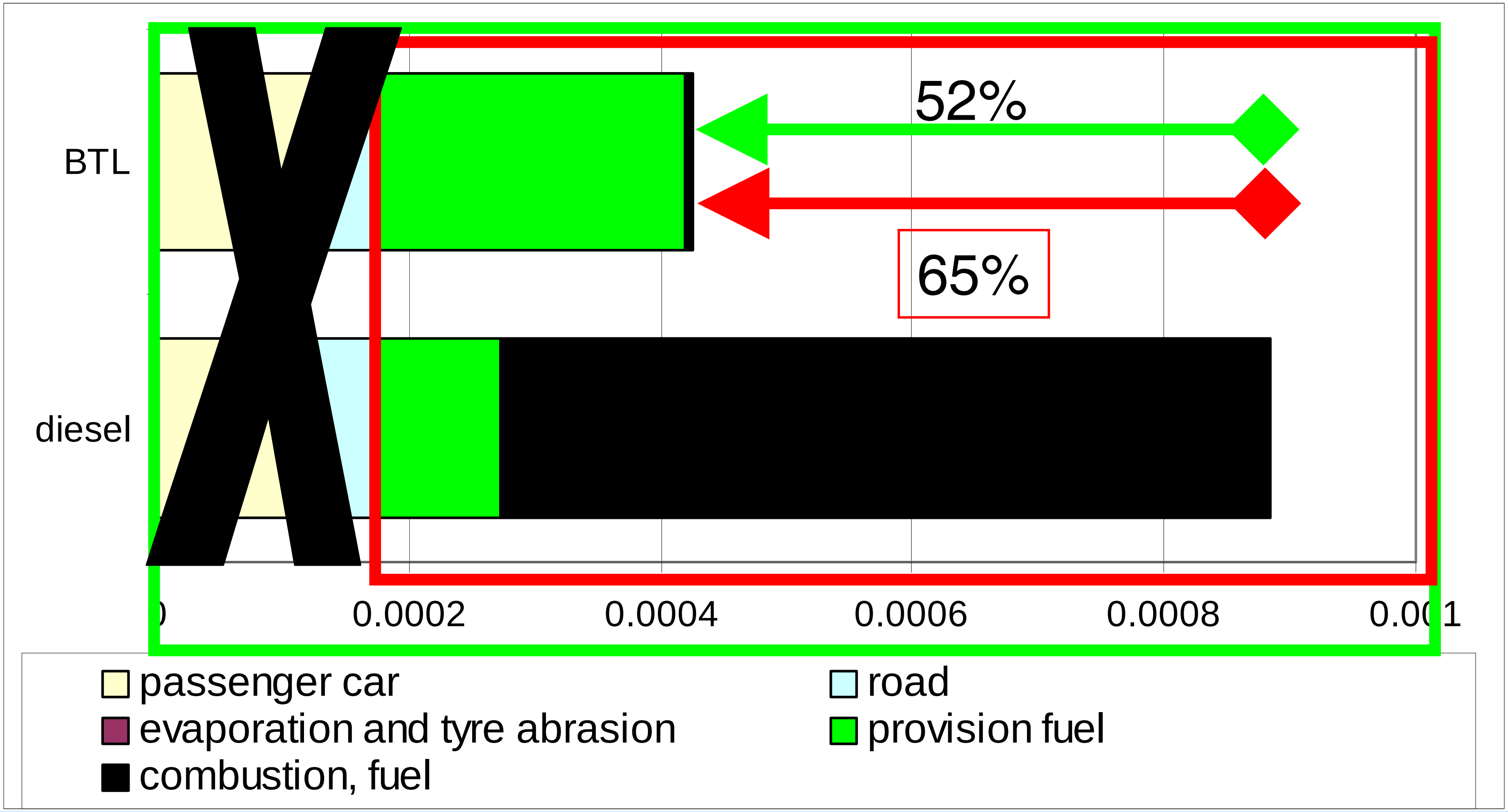
- Big differences between the production routes of the same biomass type

Comparison of all 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

GWP reduction of agrofuels

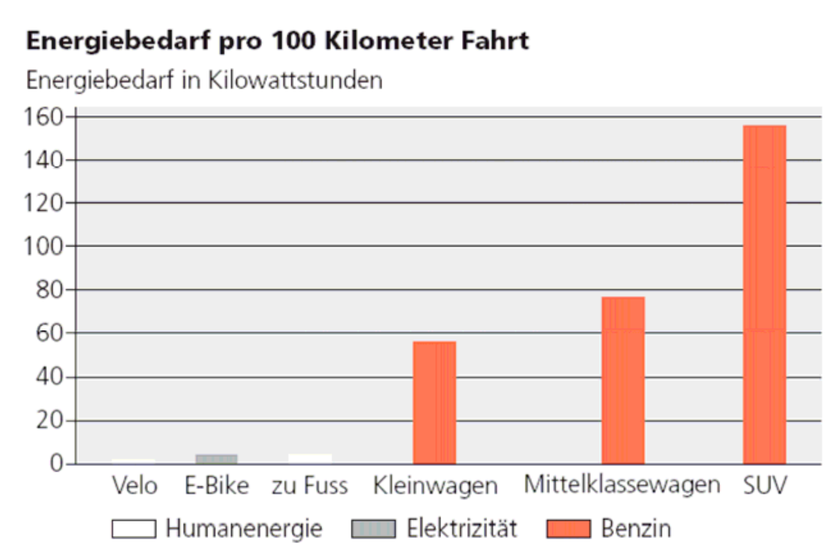


- Neglecting parts of the life cycle leads to different conclusions concerning reduction potentials expressed as a percentage

Again: How much better are renewable fuels?

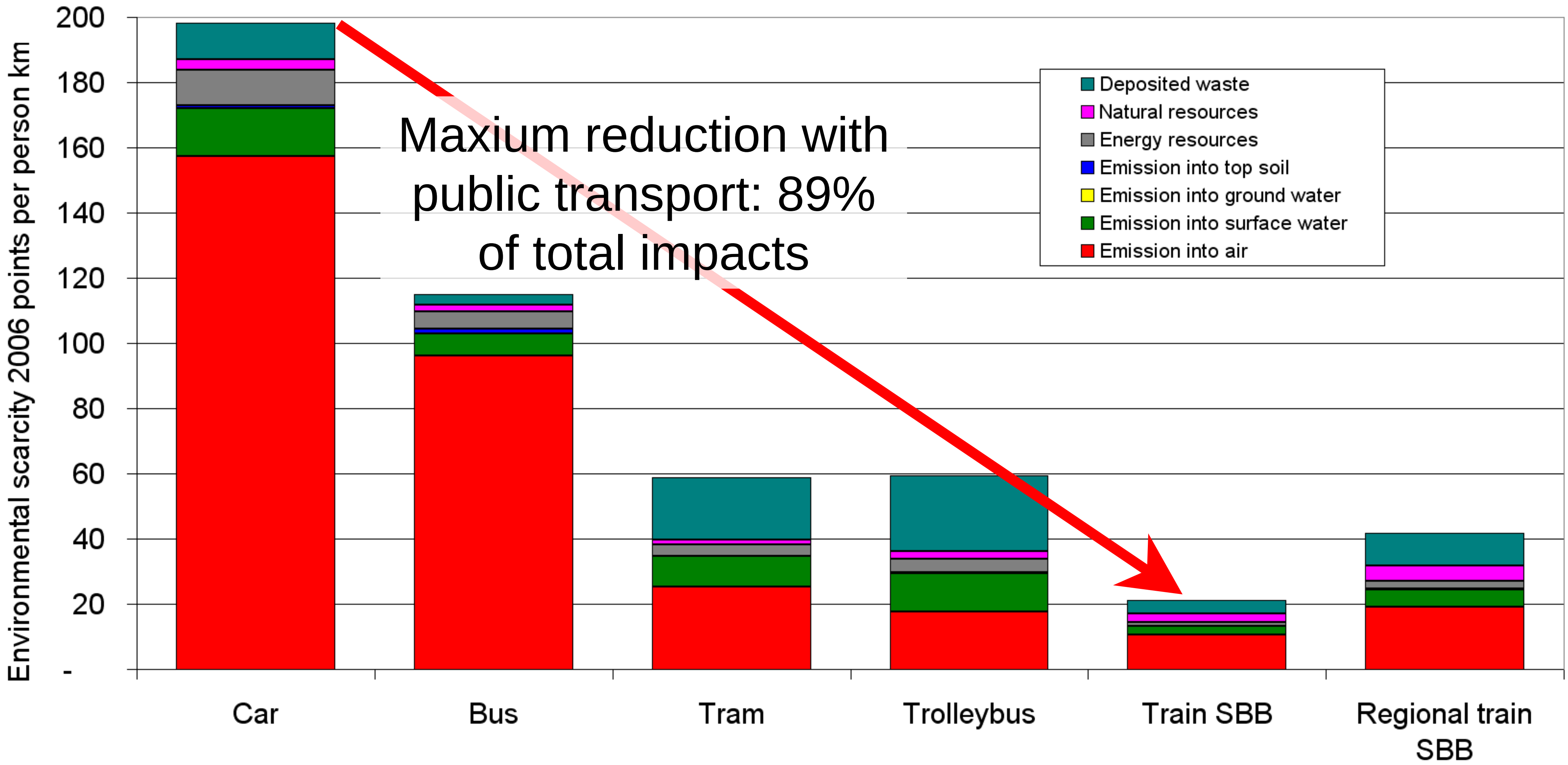
- Sorry, no easy answer... ☹
- Environmental performance depends on:
  - Scope of investigation
  - Choice of environmental indicators
  - Type & cultivation of biomass
  - Efficiency of conversion
  - Impacts of associated infrastructure as streets, manufacture of cars, etc.

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