Biogas versus other biofuels:

A comparative environmental assessment

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Biofuel comparisons

Biofuel	Fossil fuel
Coppice (poplar)	Light oil / natural gas – heat plant
Willow	Light oil / natural gas – heat plant
Miscanthus	Light oil / natural gas – CHP plant
Giant reed	Light oil / natural gas – CHP plant
Cocksfoot	Light oil / natural gas – heat plant
Whole crop wheat	Light oil / natural gas – heat plant
Biogas (liquid manure)	Light oil / natural gas – SCHP plant
Biogas (silage corn)	Light oil / natural gas – SCHP plant
Biogas (rape seed meal)	Light oil / natural gas – SCHP plant
RME	Diesel oil – passenger car / HDV
SME	Diesel oil – passenger car / HDV
Rapeseed oil	Diesel oil – passenger car / HDV
EtOH (sugar beet)	Gasoline (E5/E100) – passenger car
ETBE (sugar beet)	MTBE as an additive in gasoline
Biomethanol	Gasoline (M5/M10) – passenger car

Background

- **Bioenergy for Europe: which ones fit best? A comparative analysis for the community. Report. *Supported by the European Commission. DG XII,* 2000**
- **Development of the Clean Technologies Information Pool. *By order of: The World Bank*, 2002**
- **Environmental comparison of motor vehicles with different types of fuels and drive systems with special focus on fuel cells. *By order of: Office of Technology Assessment at the German Parliament (TAB),* 1999**
- **Environmental comparison of RME and rape seed oil. *Supported by the Federal Ministry for Consumer Protection, Nutrition, and Agriculture,* 2001**
- **LCA of bioenergy sources. Data, results, valuations. *Supported by the German Federal Environmental Foundation,* 2000**

Biofuels

Environmental advantages and disadvantages:

+

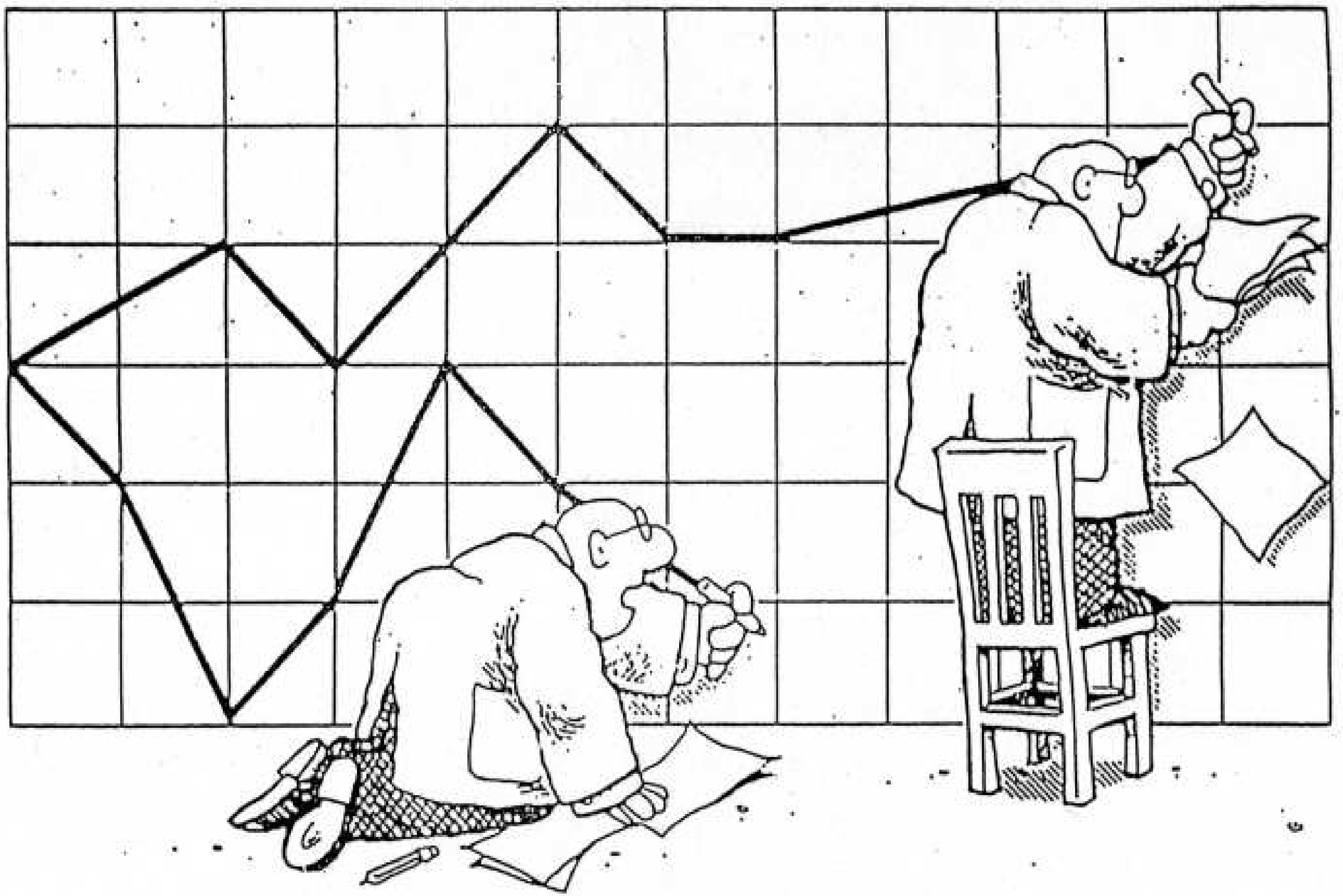
- CO_2 neutral
- Save energetic resources
- Not toxic
- Less transport
- etc.

–

- Land use
- Eutrophication of surface water
- Water pollution by pesticides
- Energy intensive production
- etc.

Total:
positive or negative

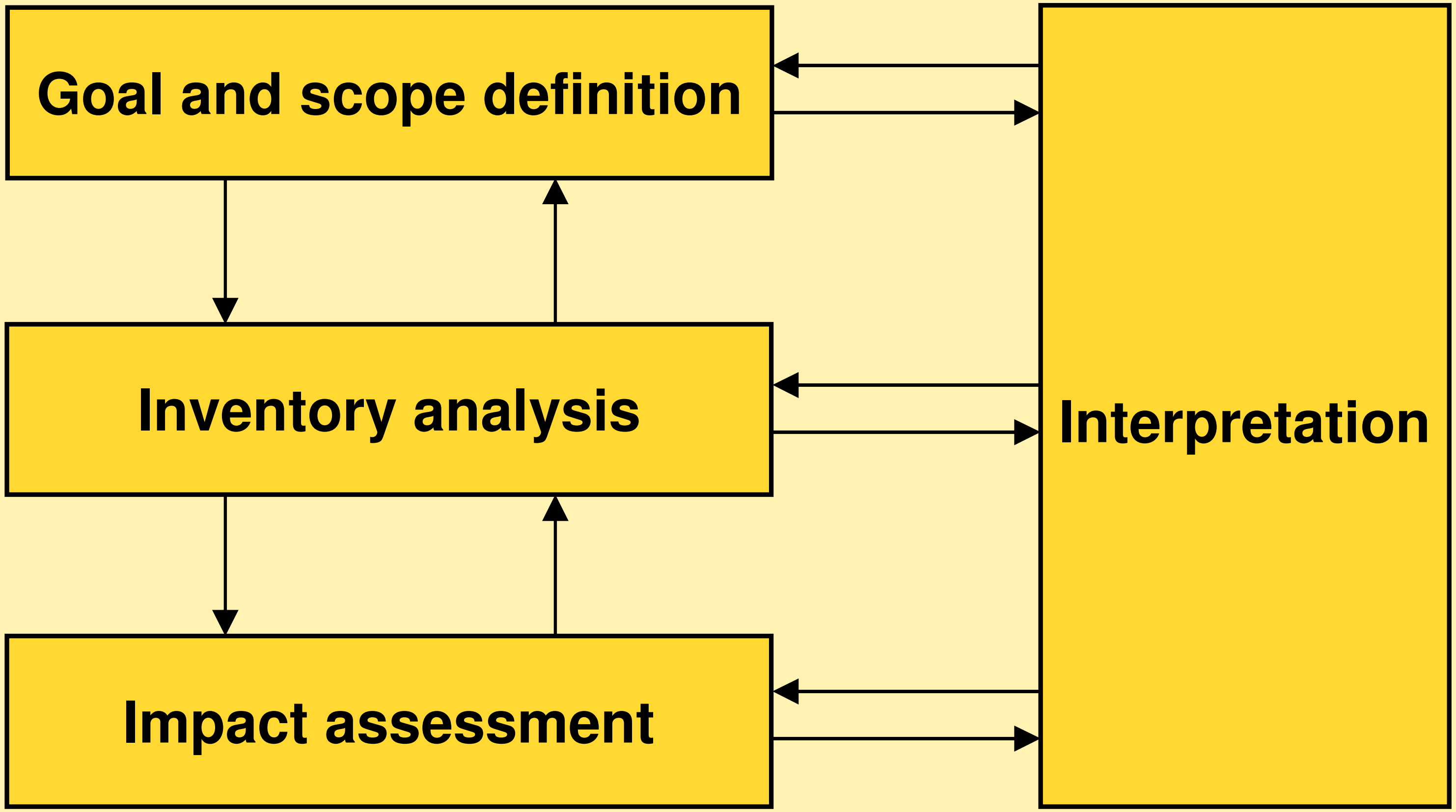
?



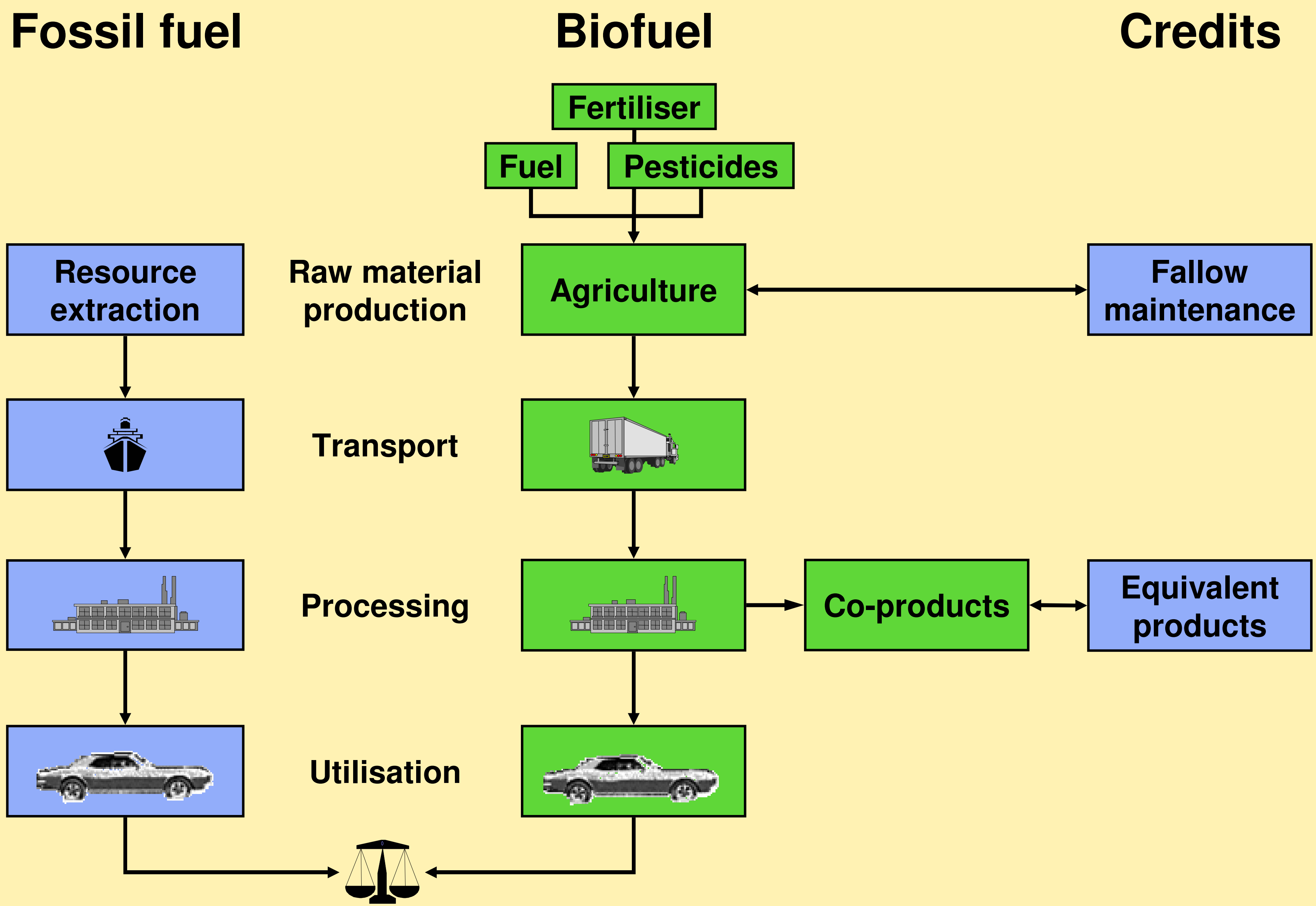
"HEY, I THOUGHT WE WERE WORKING WITH THE SAME DATA..."

Life Cycle Analysis (LCA)

ISO 14040-43



Goal and Scope Definition

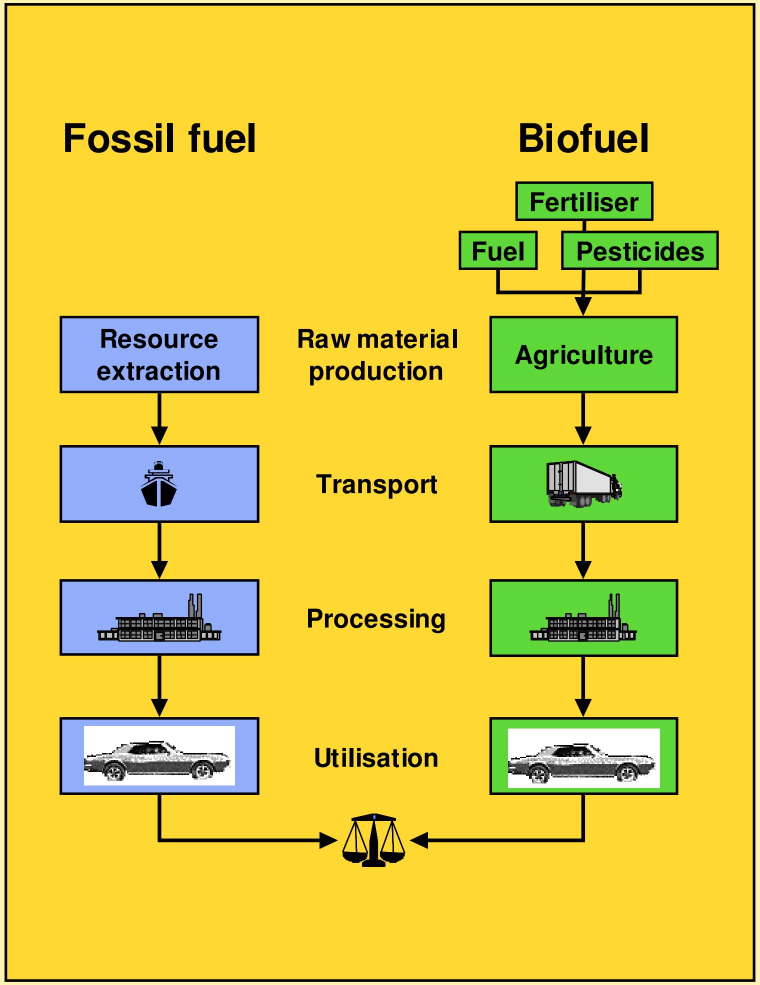


LCA: Inventory Analysis

Inputs

e.g.:

- natural gas
- crude oil
- brown coal
- hard coal
- uranium
- water



Outputs

e.g.:

- CO_2
- SO_2
- CH_4
- NO_X
- NH_3
- N_2O
- HCl
- CO
- C_6H_6
- VOC

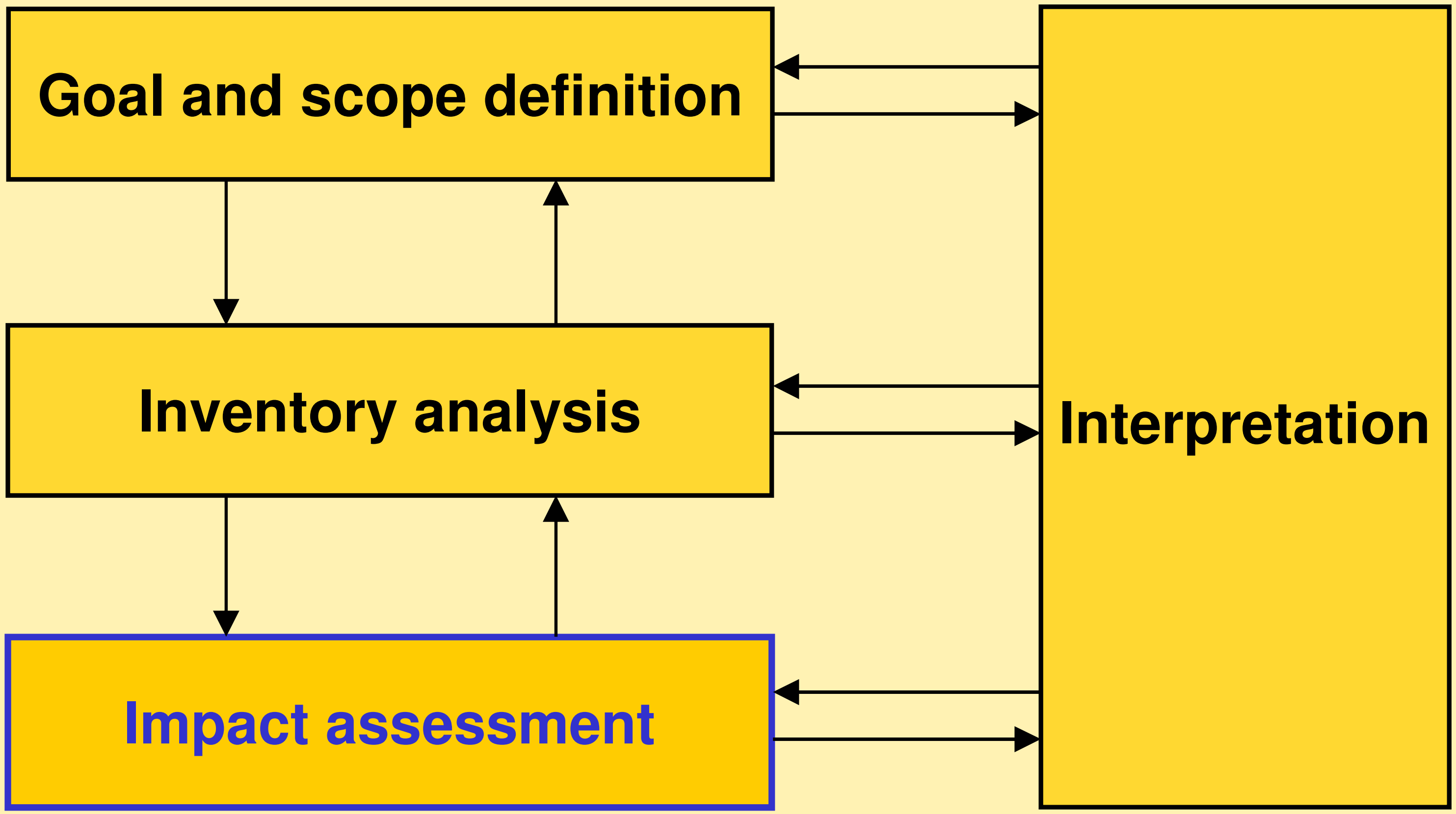
Life Cycle Inventory (LCI)

Inventory parameters	Unit	Rape seed oil
	per ha*a	
Crude oil	MJ	-62.279
Natural gas	MJ	5.697
Hard coal	MJ	313
Lignite	MJ	-148
Urane	MJ	-74
Water	MJ	7
Limestone	kg	45
Raw phosphate	kg	126
Sulphur	kg	8
Potassium	kg	811
Rock salt	kg	0
Clay	kg	0
CO_2 (fossile)	kg	-3.987
CH_4	kg	1

Inventory parameters	Unit	Rape seed oil
	per ha*a	
N_2O	kg	5
SO_2	kg	2
NO_x	kg	5
HCl	g	-10
NH_3	kg	4
CO	kg	2
NMHC	kg	-2
Diesel particulate	g	-405
Dust	g	-362
Formaldehyde	g	29
Benzene	g	-30
Benzo(a)pyrene	mg	2
TCDD	ng	-394

Life Cycle Analysis (LCA)

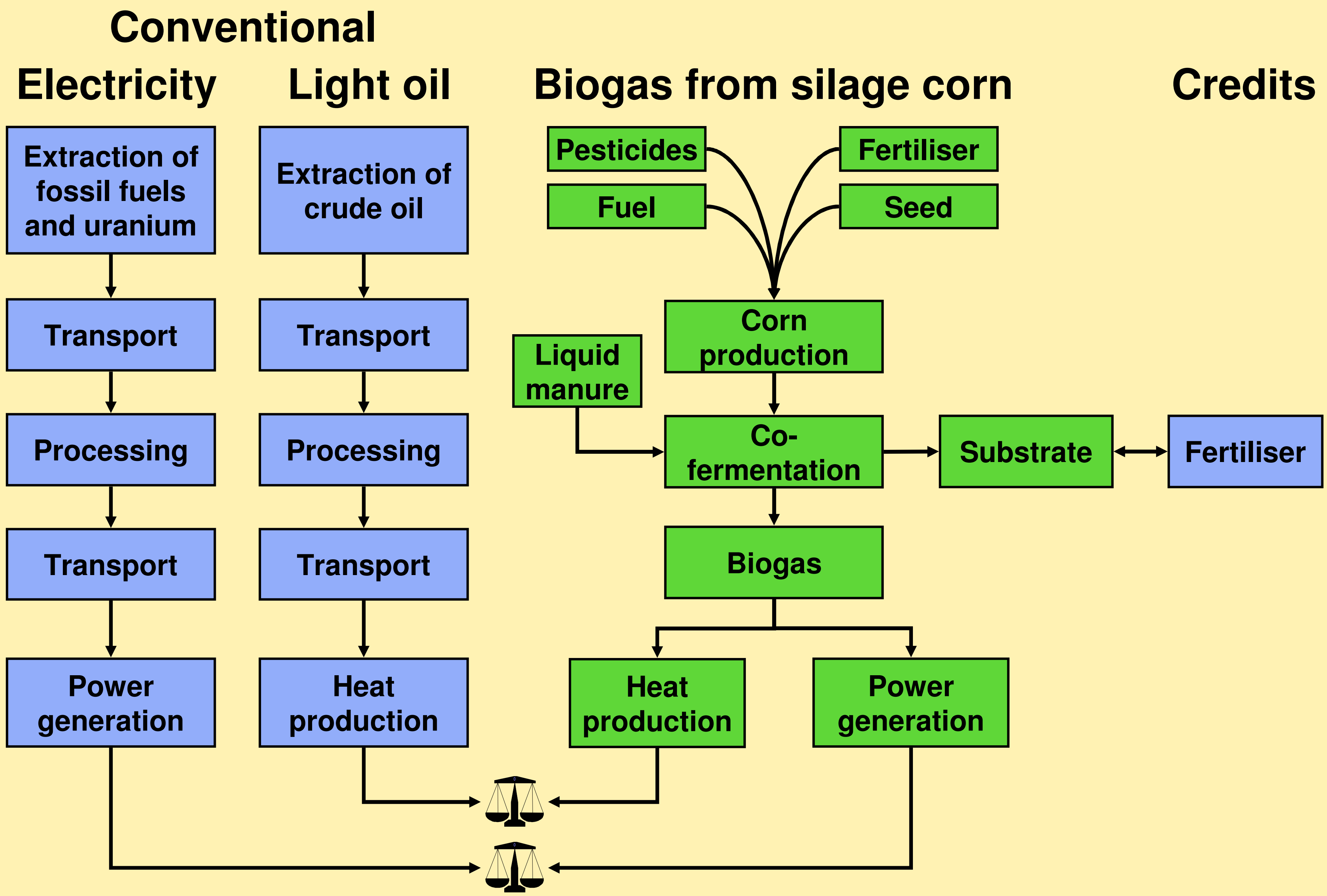
ISO 14040-43



Impact Assessment

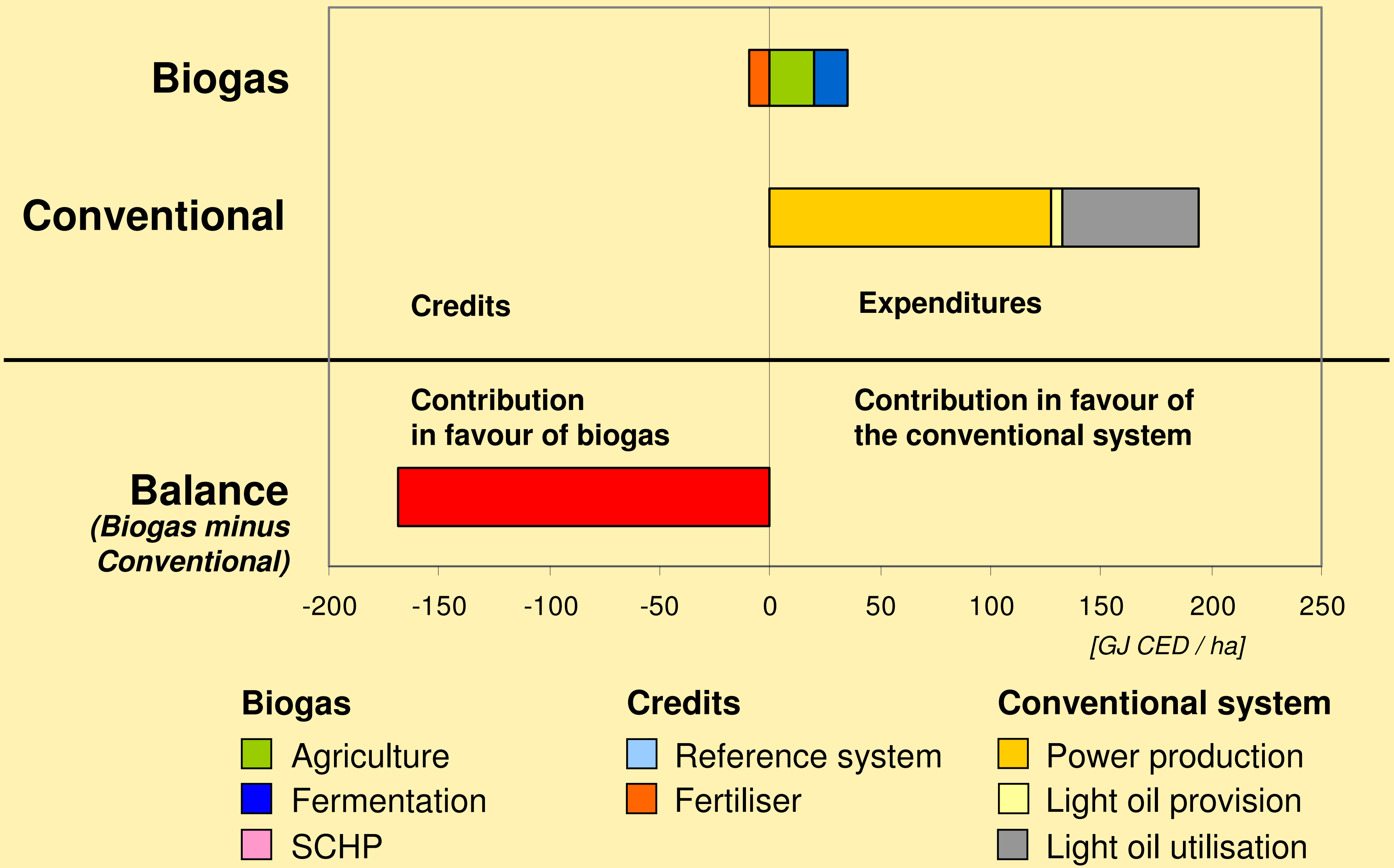
Impact category	Parameter	Substances (LCI)
Resource demand	Cumulated finite energy demand Mineral resources	Crude oil, natural gas, coal, uranium ore , … Limestone, clay, metal ores, rock salt, pyrite, …
Greenhouse effect	CO_2 equivalents	Carbon dioxide, nitrous oxide, methane, HCFCs, CFCs, methyl bromide, …
Ozone depletion	CFC equivalents, (nitrous oxide)	HCFCs, CFCs, halons, methyl bromide, …
Acidification	SO_2 equivalents	Sulphur dioxide, hydrochloric acid, nitrogen oxide, ammonia, hydrofluoric acid, …
Eutrophication	PO_4 equivalents	Nitrogen oxides, ammonia, phosphate, nitrate
Summer smog	Ethene equivalents	Hydrocarbons, nitrogen oxides, carbon monoxide, HCCs, …
Human and eco toxicity		Nitrogen oxide, carbon monoxide, hydrochloric acid, diesel particulate, dust, ammonia, benzene, benzo-a-pyrene, sulphur dioxide, Dioxines (TCDD), …

LCA of biogas from silage corn

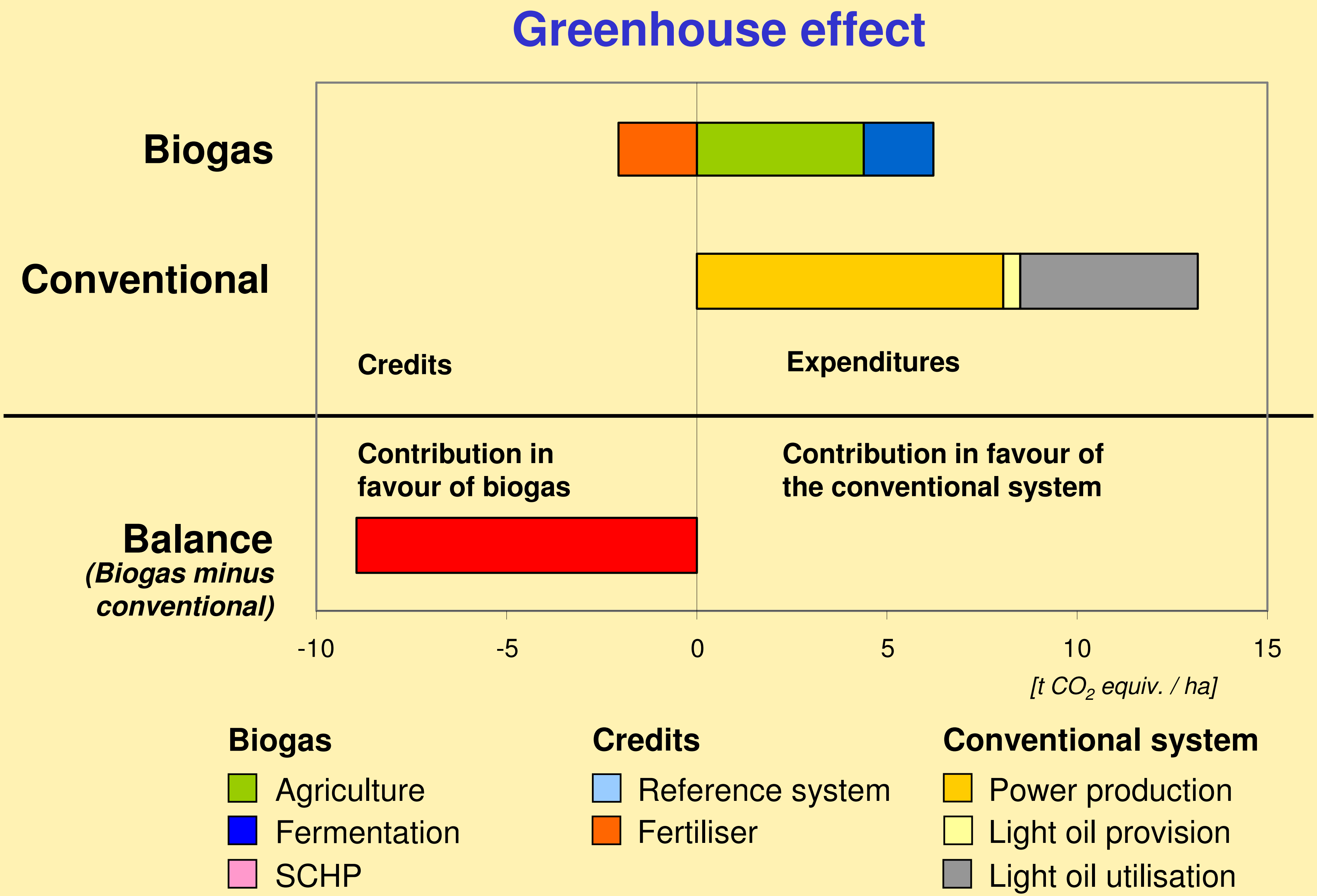


LCIA of biogas from silage corn

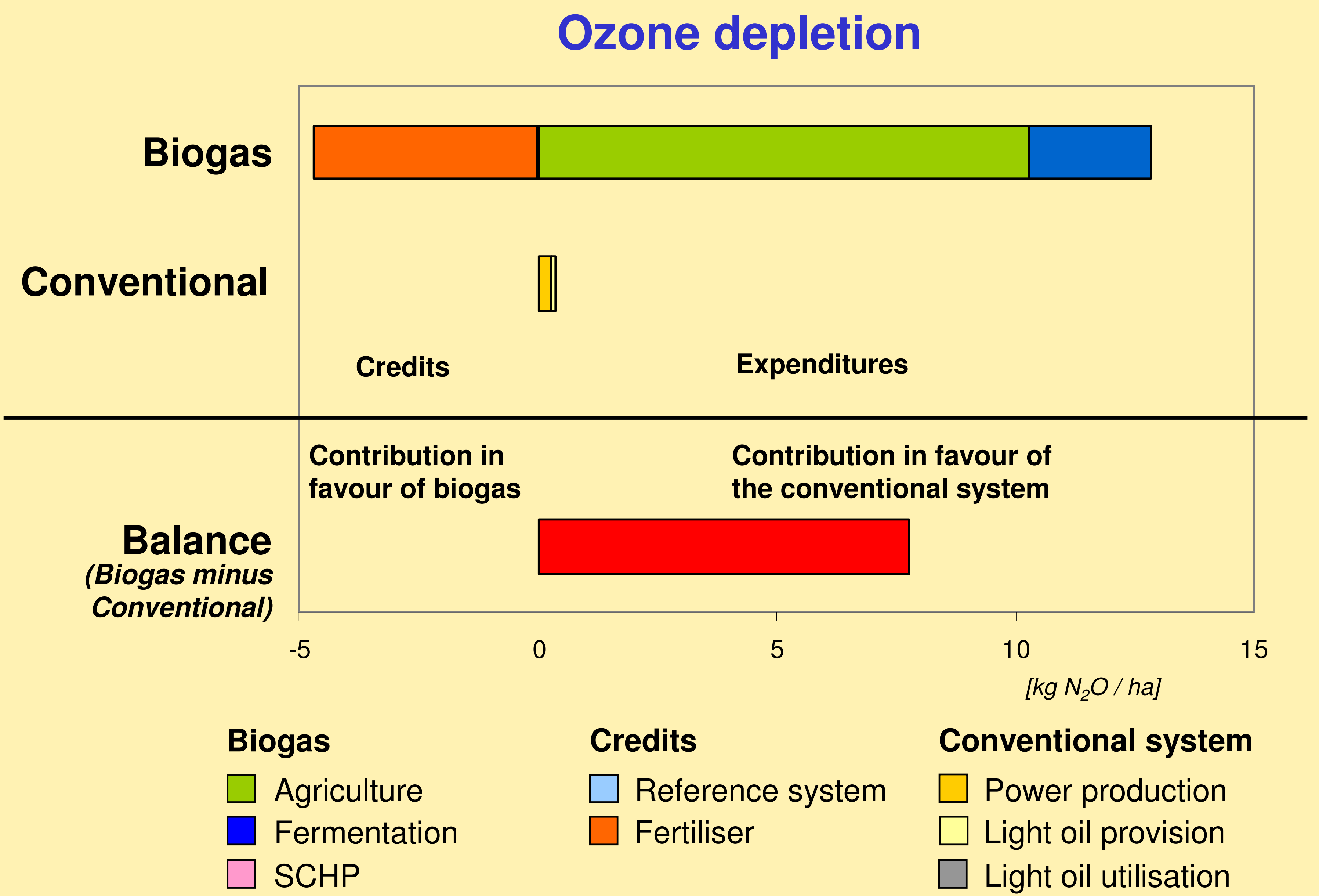
Resource demand



LCIA of biogas from silage corn



LCIA of biogas from silage corn



Biogas vs. fossil fuel

	Advantages for biogas	Disadvantages for biogas
Resource demand	savings of finite energy resources	consumption of mineral resources
Greenhouse effect	lower emissions of greenhouse gases	
Ozone depletion		more N_2O emissions
Acidification		higher acidification
Eutrophication		higher NO_X emissions risk: eutrophication of surface waters
Human- and ecotoxicity	less pollution of oceans due to extraction and transport of crude oil risk: less pollution by oil spillage after accidents risk: less toxicity / better biodegradability	risk: pollution of surface waters by pesticides risk: pollution of ground water by nitrate

LCA: Interpretation

Statistics about Heidelberg

Inhabitants	**130.000**
School buildings (including university)	**180**
Bridges	**5**
Dogs	**220**
Tourists per day	**5.500**
Total	**135.905**

LCA: Interpretation

Impact category	Parameter	Ecological significance
Resource demand	Cumulative energy demand (non-renew.)	important
Greenhouse effect	CO_2 equivalents	very important
Ozone depletion	Nitrous oxide	(very) important
Acidification	SO_2 equivalents	medium relevance
Eutrophication	PO_4 equivalents	medium relevance
Human- and Ecotoxicity	Nitrogen oxide	medium relevance
Human- and Ecotoxicity	Diesel particulates	very important

Biofuels vs. fossil fuels

Biofuel	Resource demand	Greenhouse effect	Ozone depletion	Acidifi-cation	Eutro-phication	Photo smog
Coppice (poplar)	+	+	–	–	–	+
Willow	+	+	–	–	–	–
Miscanthus	+	+	–	–	–	–
Giant reed	+	+	–	–	–	–
Cocksfoot	+	+	–	–	–	–
Whole crop wheat	+	+	–	–	–	–
Biogas (manure)	+	+	–	–	–	–
Biogas (silage corn)	+	+	–	–	–	–
Biogas (rape seed meal)	+	+	–	–	–	–
RME	+	+	–	–	–	+/ –
SME	+	+	–	+/ –	–	+/ –
Rapeseed oil	+	+	–	–	–	+/ –
EtOH (sugar beet)	+	+	–	–	–	+
ETBE (sugar beet)	+	+	–	–	–	+
Biomethanol	+	+	+/ –	+	–	+

+ Advantage for biofuel – Advantage for fossil fuel +/– Insignificant or ambiguous

Results: Biofuels vs. fossil fuels

1. All biofuels listed hold ecological advantages as well as disadvantages in comparison with fossil fuels.
2. In nearly all cases biofuels reveal advantages with respect to both saving non-renewable energy carriers and greenhouse effect.
3. Likewise, in most cases biofuels exhibit disadvantages in respect of acidification and eutrophication.
4. In the categories photo smog, ozone depletion and human and ecotoxicity the results are non-uniform.

Results: Biofuels vs. fossil fuels

5. An objective decision for or against a particular fuel cannot be made. However, based on a subjective value system a decision is possible.

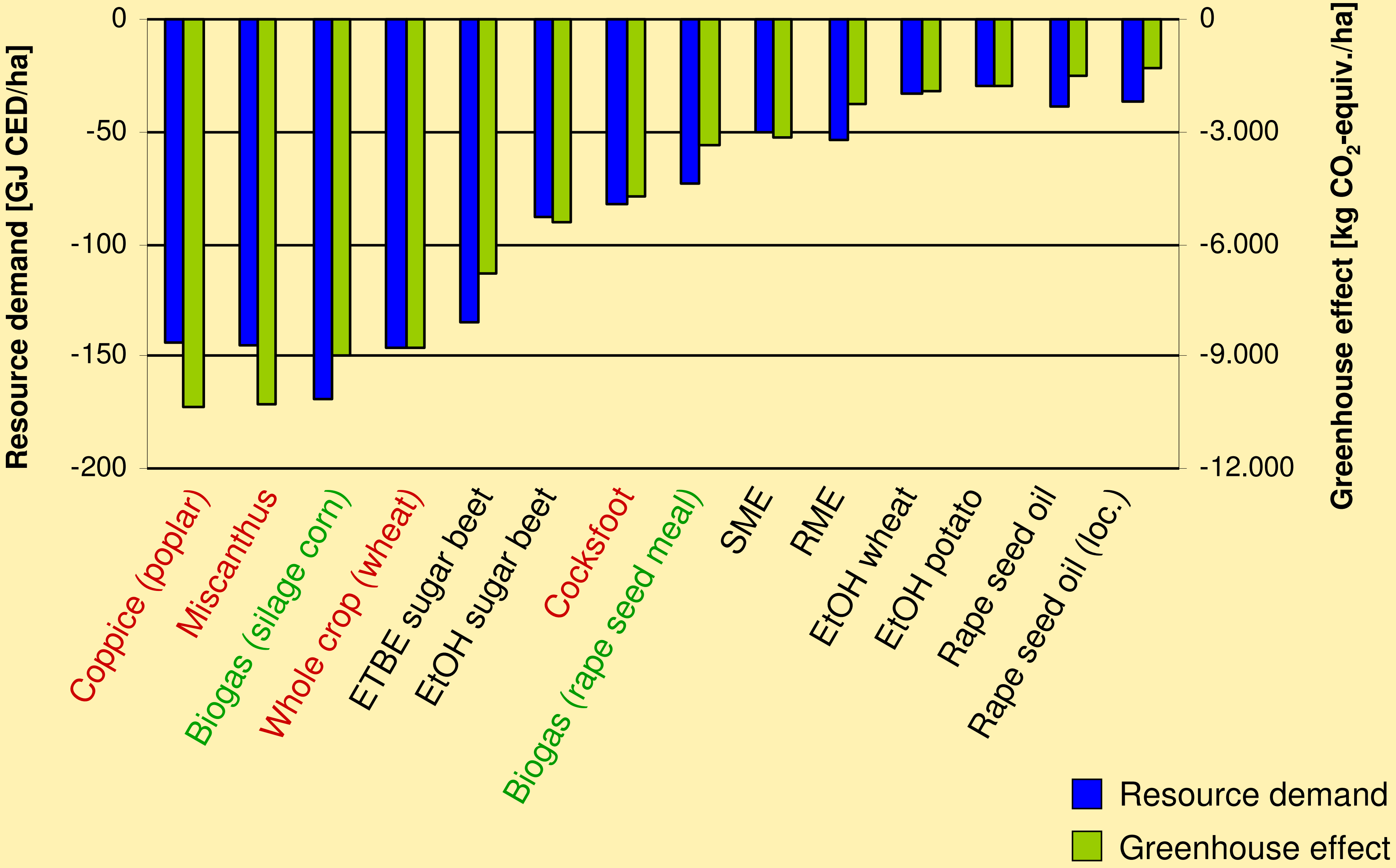
   If, for example, energy saving and greenhouse effect is given the highest priority, all of the biofuels studied perform better than the alternative fossil fuels.

Comparisons

→ **Biofuels vs. fossil fuels**

→ **Biofuels vs. biofuels**

Biofuels vs. biofuels



Results

- Solid biofuels usually perform better than liquid biofuels from energy crops.
- Biogas options based on energy crops lie within the range of liquid and solid biofuels.
- Biofuels from residues are to be interpreted separately.

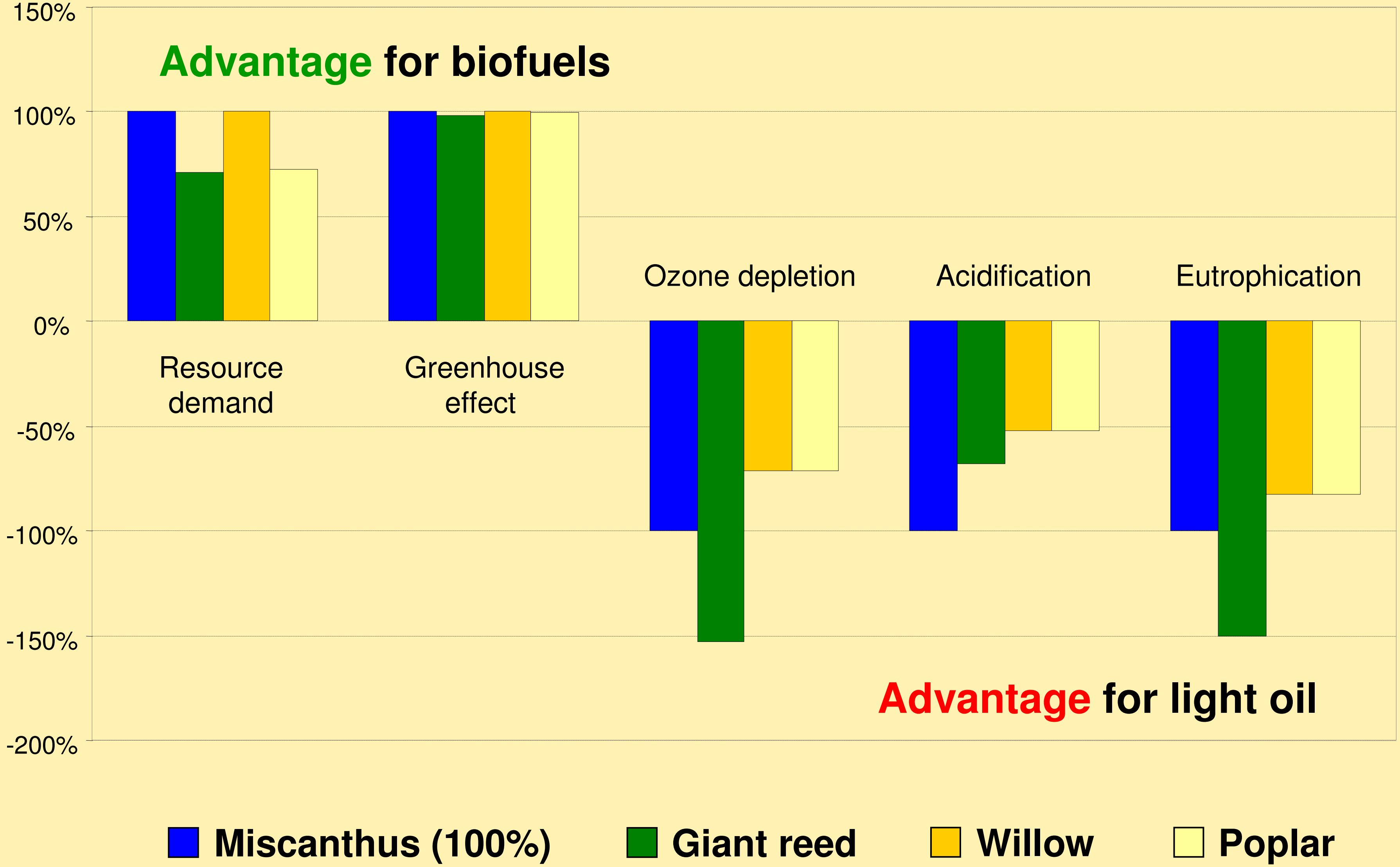
Comparisons

→ **Biofuels vs. fossil fuels**

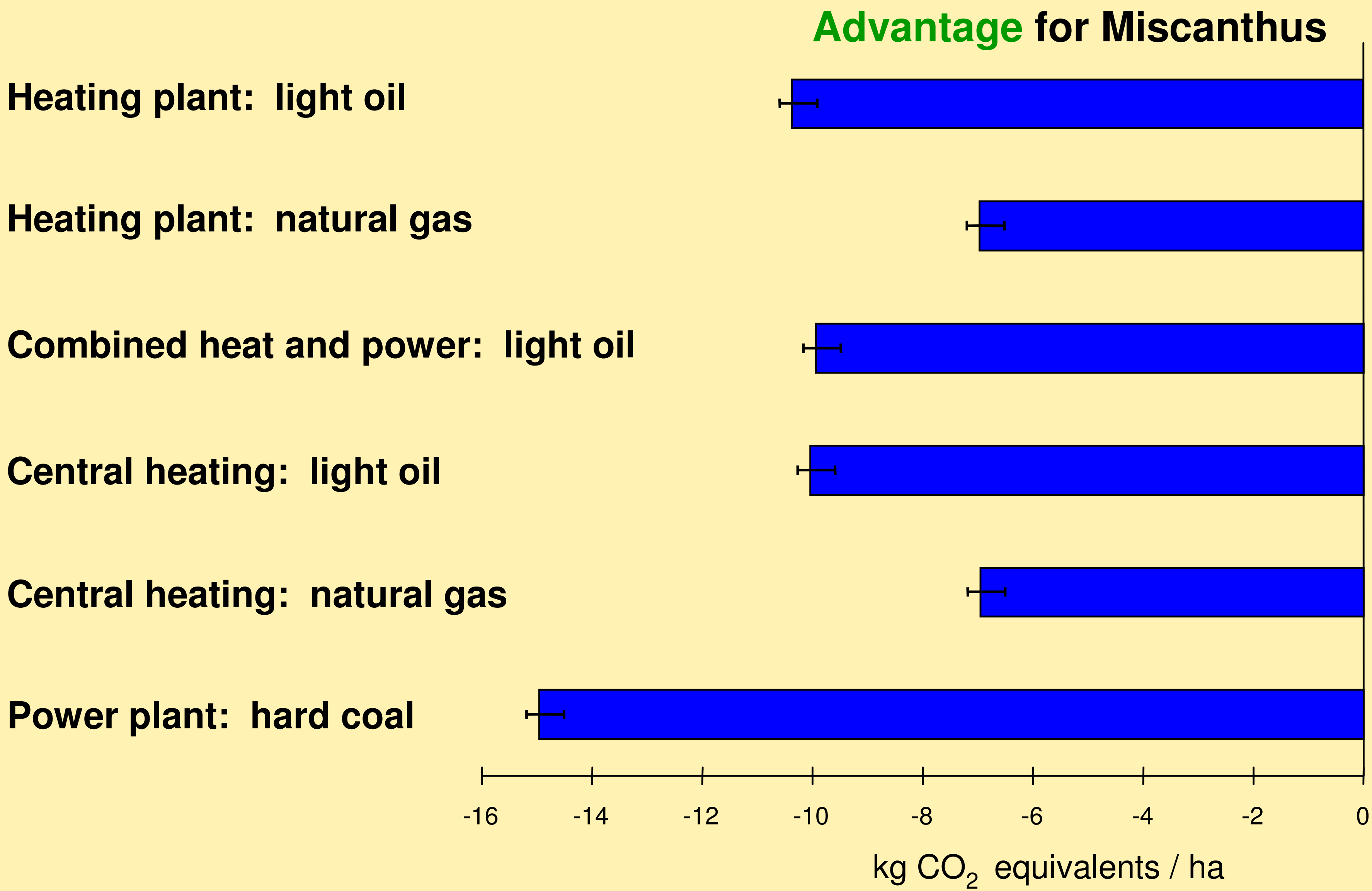
→ **Biofuels vs. biofuels**

- **solid biofuels**
- **biofuels for transportation**
- **biofuels from residues**

Solid biofuels vs. light oil



Miscanthus vs. fossil fuels



Results: solid biofuels

1. Willow and poplar (SRC) show ecological advantages over perennial grasses and wheat and triticale
2. Perennial grasses compared to wheat and triticale: no final conclusion as there are both, advantages and disadvantages
3. Compared to poplar, willow saves more fossil resources while there are no significant differences with the other categories
4. To have most ecological benefits, first choice is to substitute coal by biofuels, second is fuel oil

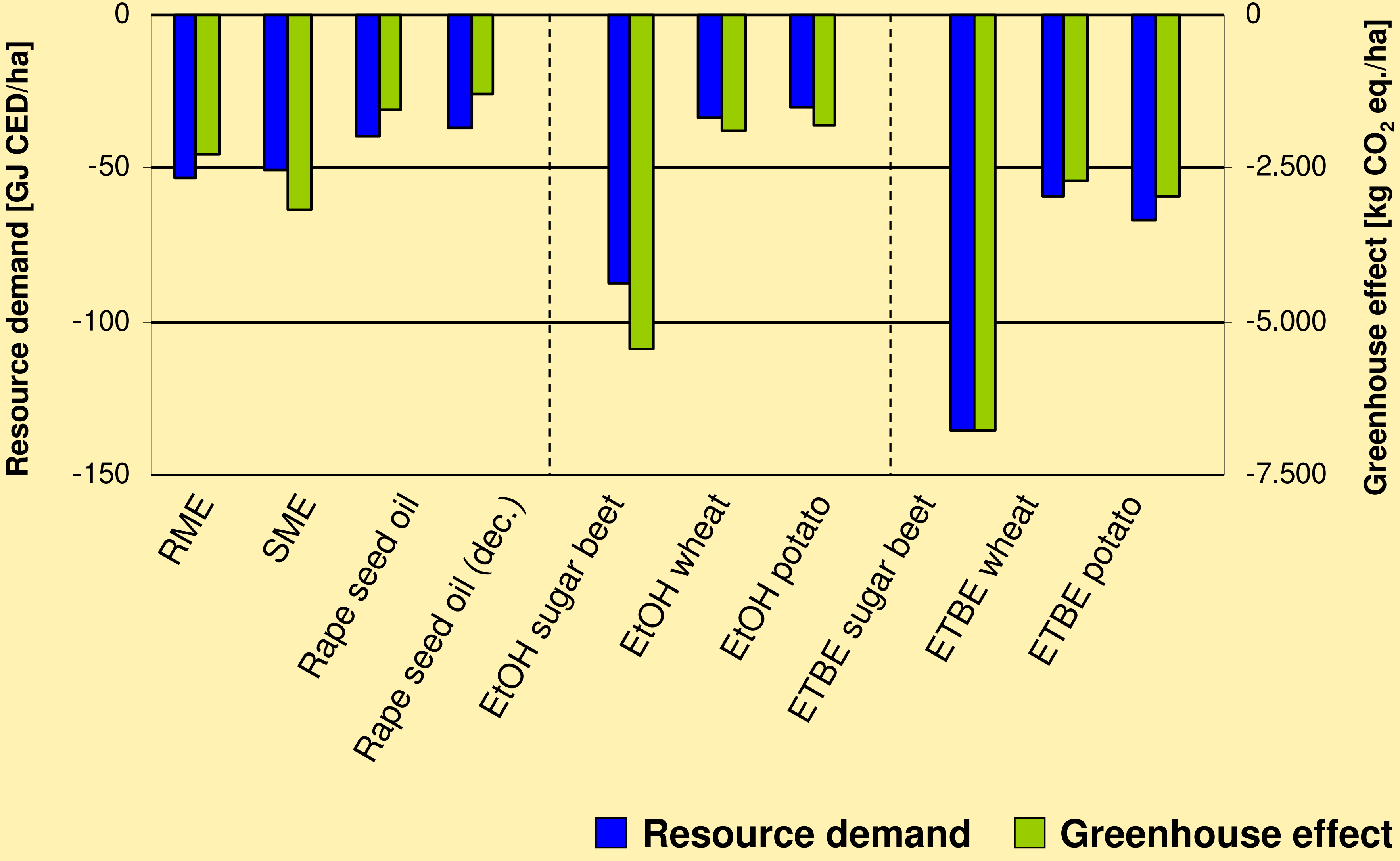
Comparisons

→ **Biofuels vs. fossil fuels**

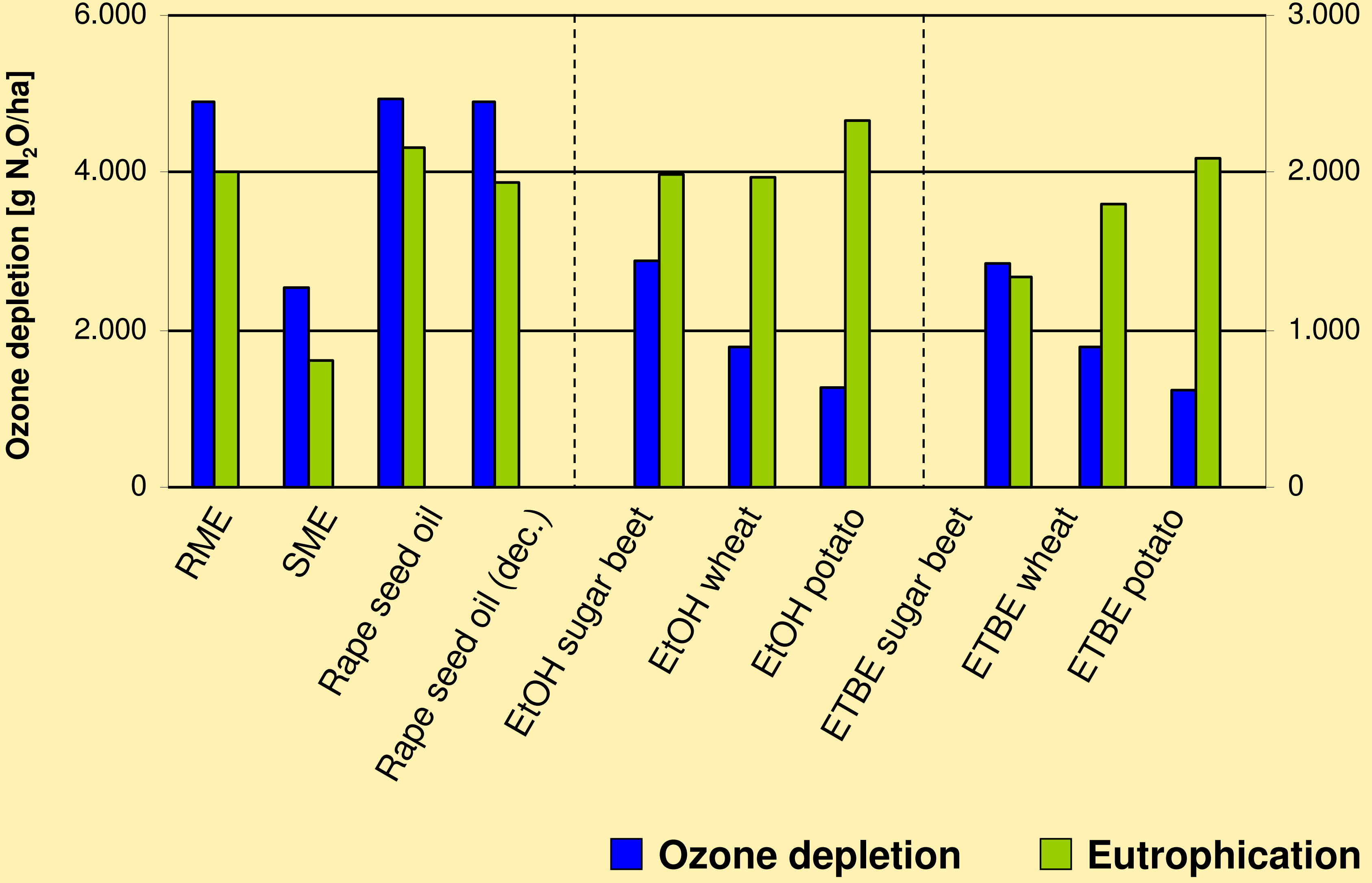
→ **Biofuels vs. biofuels**

- **solid biofuels**
- **biofuels for transportation**
- **biofuels from residues**

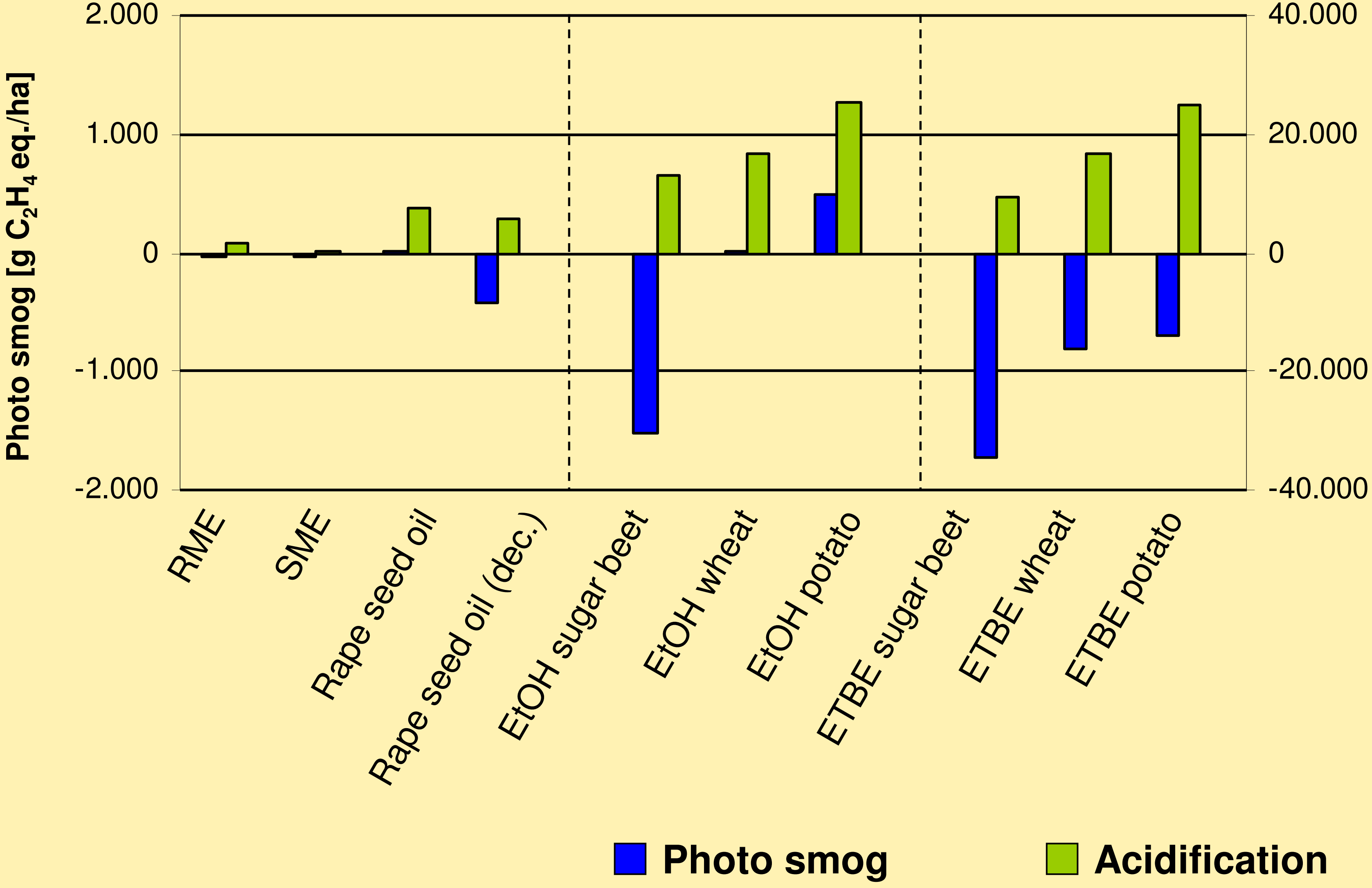
Biofuels versus Biofuels



Biofuels versus Biofuels



Biofuels versus Biofuels



Results: Biofuels vs. biofuels

1. SME shows better results than RME
2. RME turns out to be better than pure rape seed oil
3. Central pressing of rape seed oil shows better results compared to local pressing
4. Investigated options for Bioethanol and ETBE (particularly ETBE from sugar beet) are significantly better than biofuels from vegetable oil (SME, RME, pure rape seed oil)

Results: Biofuels vs. biofuels

5. ETBE shows better results than Ethanol
6. Ethanol from sugar beet shows advantages compared to wheat and potato
7. Wheat comes out second best, potato shows least favourable results in all categories apart from N_2O
8. For synfuels and sunfuels as well as for the various ways to generate bioethanol from residual organic biomass resp. lignocellulose reliable life cycle assessments are currently unavailable. Screening life cycle assessments resp. preliminary screenings however indicate considerable ecological potentials.

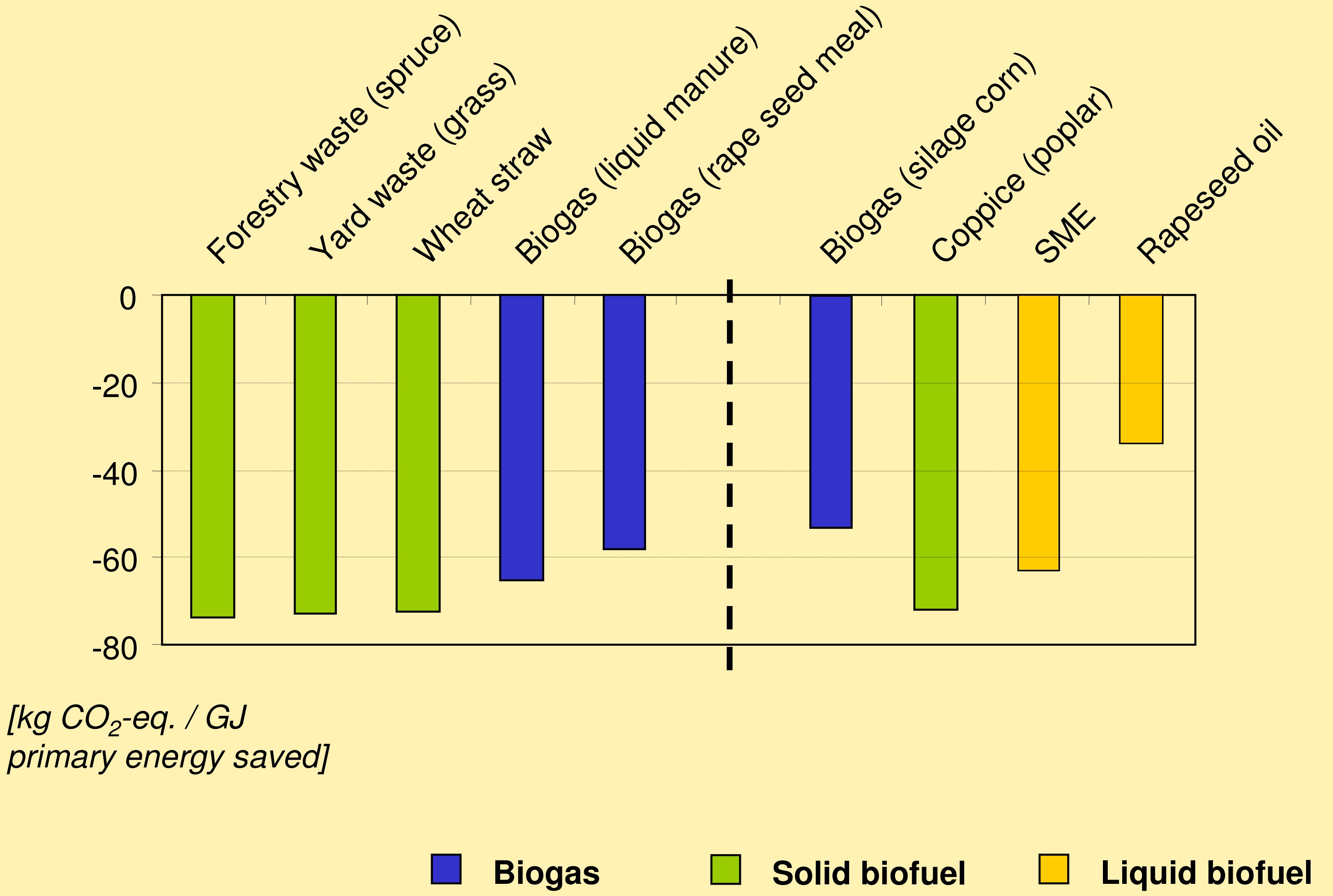
Comparisons

→ **Biofuels vs. fossil fuels**

→ **Biofuels vs. biofuels**

- **solid biofuels**
- **biofuels for transportation**
- **biofuels from residues**

CO_2 efficiency



Results: Biofuels from residues

1. With respect to CO_2 efficiency solid biofuels perform better than both liquid biofuels and biogas in most cases.
2. Nevertheless, the performance of biogas lies in a large range.
3. Additional advantage compared to energy crops: No land is necessary to produce them.

Biogas or other modes of use ?

Biogas from energy crops or co-products

Biogas from corn

Biogas from rape seed meal

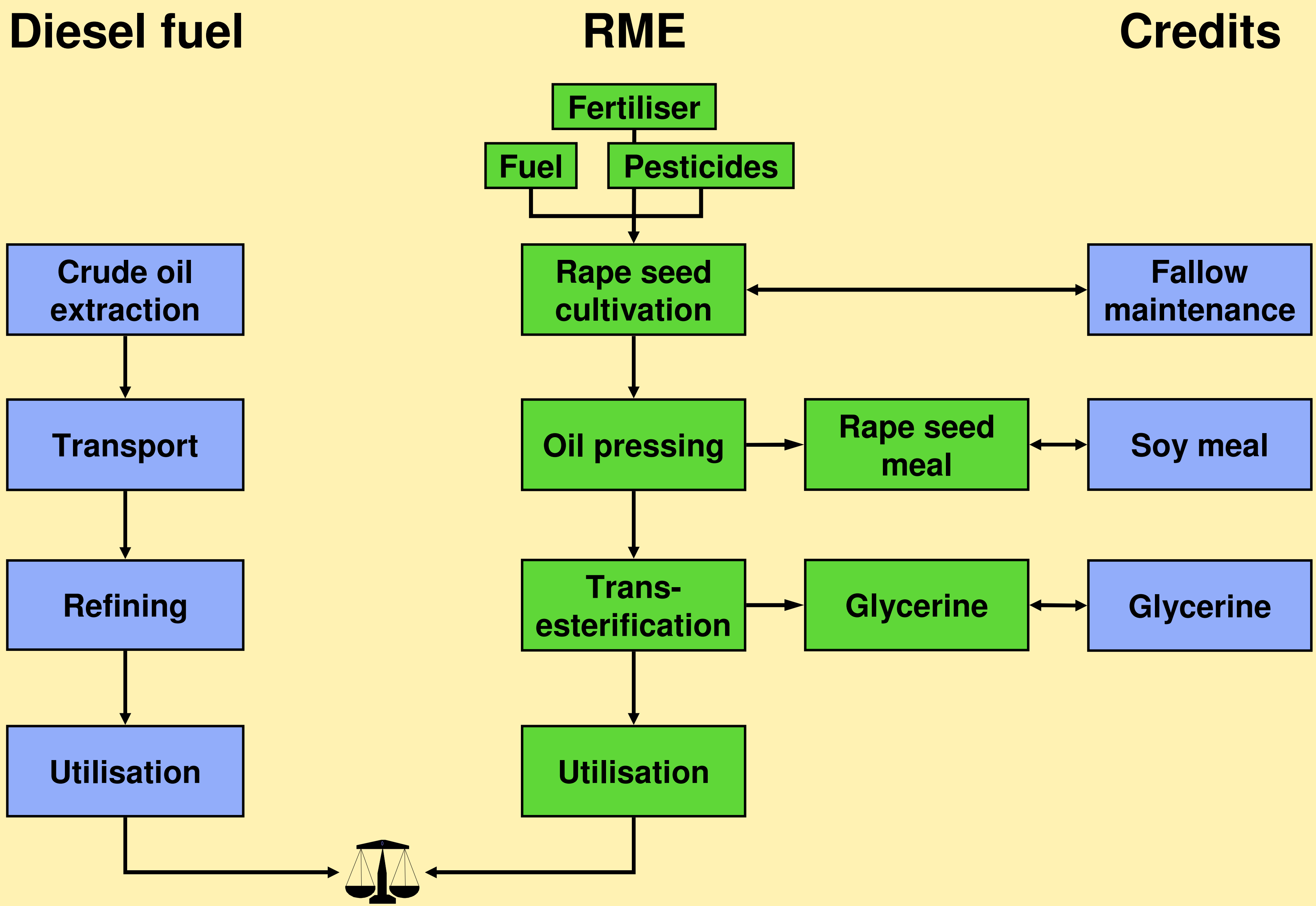
← versus →

Other modes of use

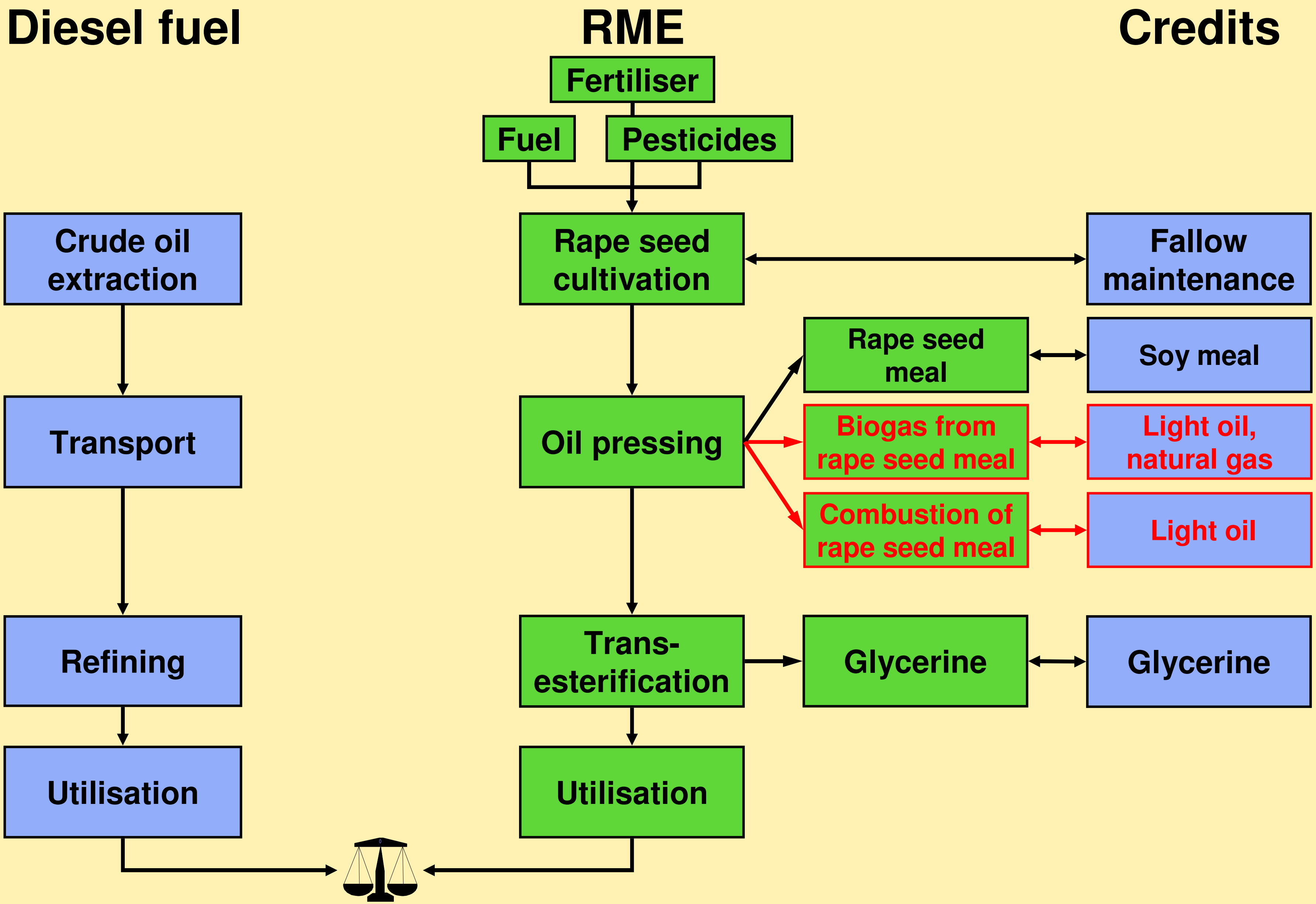
Corn: direct combustion

Rape seed meal: combustion or animal feed

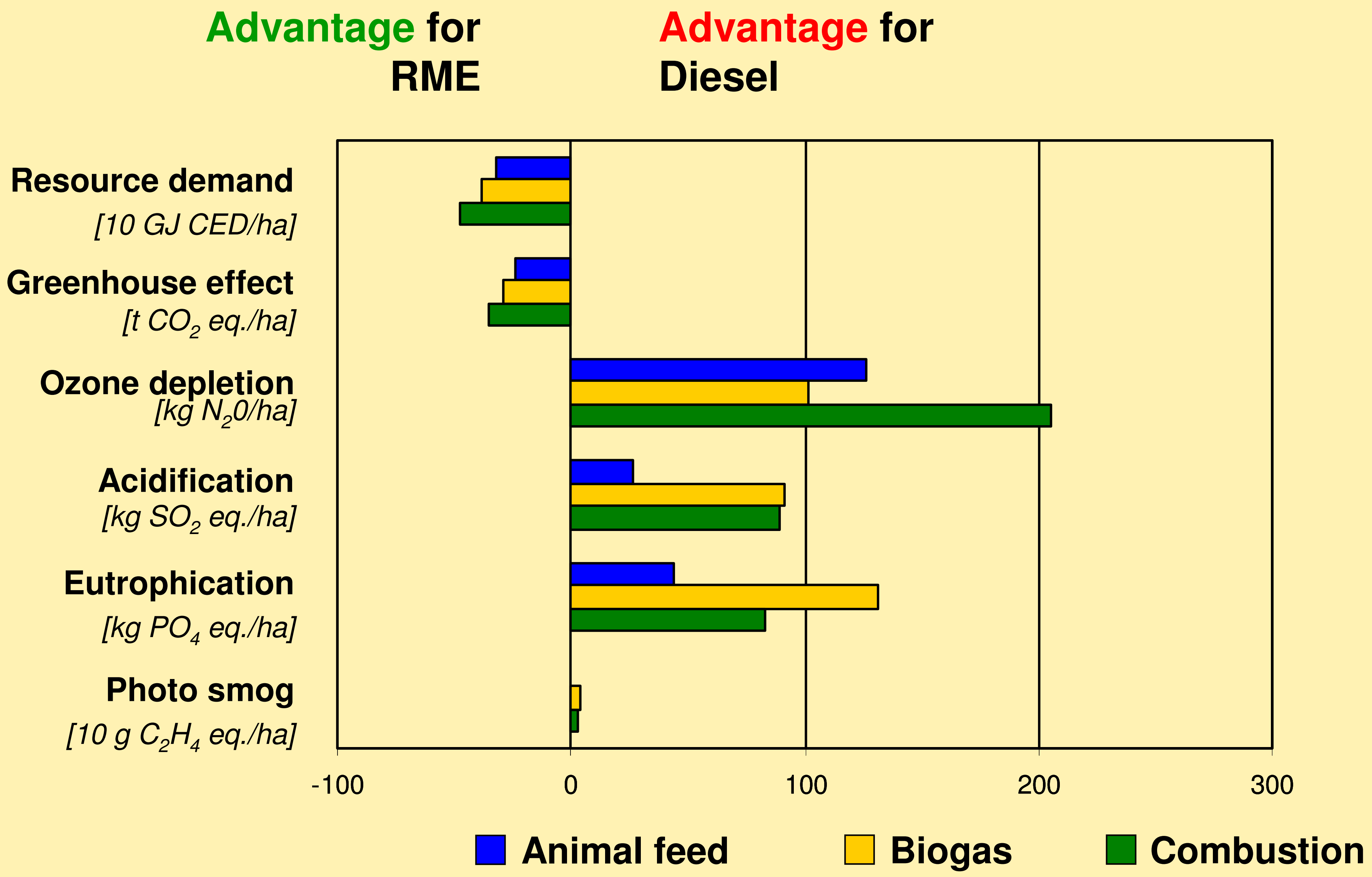
RME vs. Diesel



RME vs. Diesel



RME vs. Diesel



Results: Biofuels vs. fossil fuels

1. All biofuels have advantages and disadvantages compared to fossil fuels
2. An objective decision in favour of one or another fuel is not possible but can be done using subjective value systems
3. When giving energy savings of fossil resources and greenhouse gases highest ecological importance, all investigated biofuels compare favourably to their fossil alternatives

Results: Biofuels vs. biofuels

- Solid biofuels usually perform better than liquid biofuels from energy crops.
- Biogas options based on energy crops lie within the range of liquid and solid biofuels. Detailed analyses are necessary to determine their impacts. Some biogas options may have a high environmental potential.

Results: Solid biofuels

- Wood chips show ecological advantages over perennial grasses and wheat
- Compared to poplar, willow saves more fossil resources while there are no significant differences with the other categories
- To have most ecological benefits, first choice is to substitute coal by biofuels, second is fuel oil

Results: Liquid biofuels

- Ranking of biofuels from energy crops: ETBE / EtOH, SME / RME, plant oil
- Both, bio-DME and bio-methanol, show much better results than biofuels from agriculture.
- For synfuels and sunfuels as well as for the various ways to generate bioethanol from residual organic biomass resp. lignocellulose reliable life cycle assessments are currently unavailable.

Conclusions I

- Biogas - like other forms of bioenergy - has the potential to save non-renewable energy carriers and thus to reduce greenhouse gas emissions.

- Biogas - again similar to other bioenergies - affects the environment with respect to other impact categories like acidification, eutrophication, photo smog and ozone depletion.

Conclusions II

- In most cases, from the environmental point of view, direct combustion of the biomass may be preferred to biogas production.
- However, a number of non-ecological reasons like for instance logistics, manageability etc. may argue for the use of biogas.

Conclusions III

- Biogas can compete easily with the most excellent solid biofuels and at the same time provides a number of possible applications.
- Due to large number of possibilities to generate and to utilise biogas, the environmental implications have to be quantified for each case separately.

Conclusions IV

- Life Cycle Assessment as a balancing tool may help to maximise the positive and minimise the negative environmental effects via sensitivity analysis as well as weak-point analysis for the entire biogas life cycle from provision to utilisation.

…… and finally:

Thank you very much

for your attention

Tak for det

The Team

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