Influence of the chosen life cycle assessment approach on the results of the analysis:

an example with biofuels

Faculty of Technology
University of Novi Sad
Serbia

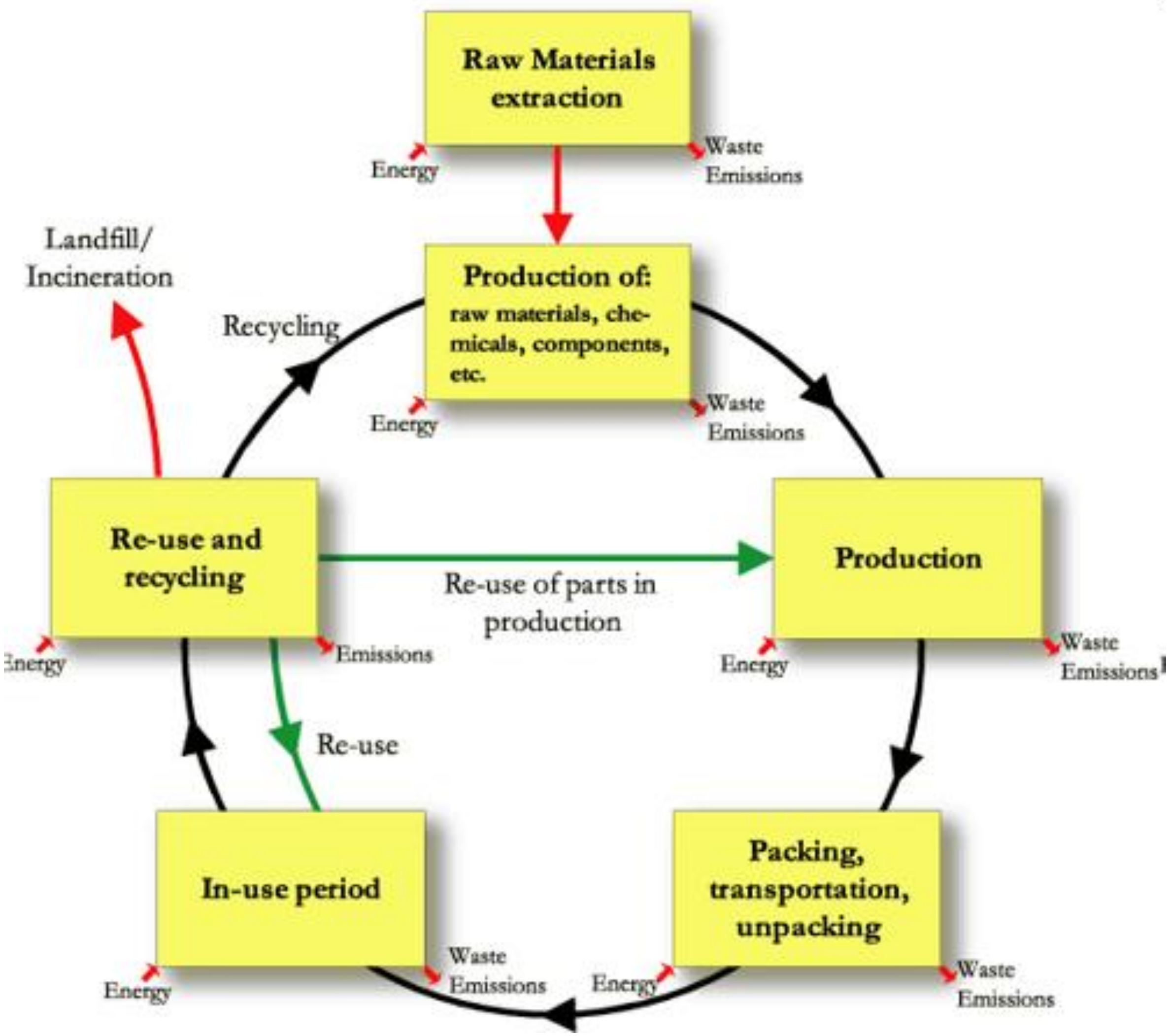
Ferenc E. Kiss

Prague, 16. September 2010

Life Cycle Assessment (LCA)

- Life-cycle assessment studies the environmental aspects and potential impacts of a product throughout its life from raw material acquisition through production, use and disposal (i.e. from cradle-to-grave)
- The procedures of LCA are part of the ISO14000 environmental management standards: in ISO 14040:2006 and 14044:2006.
- LCA is increasingly used by companies and government agencies

“Cradle-to-grave” concept



DIRECTIVES

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 April 2009

on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

(Text with EEA relevance)

ANNEX V

Rules for calculating the greenhouse gas impact of biofuels, bioliquids and their fossil fuel comparators

A. *Typical and default values for biofuels if produced with no net carbon emissions from land-use change*

Biofuel production pathway	Typical greenhouse gas emission saving	Default greenhouse gas emission saving
sugar beet ethanol	61 %	52 %
wheat ethanol (process fuel not specified)	32 %	16 %
wheat ethanol (lignite as process fuel in CHP plant)	32 %	16 %
wheat ethanol (natural gas as process fuel in conventional boiler)	45 %	34 %
wheat ethanol (natural gas as process fuel in CHP plant)	53 %	47 %
wheat ethanol (straw as process fuel in CHP plant)	69 %	69 %
corn (maize) ethanol, Community produced (natural gas as process fuel in CHP plant)	56 %	49 %
sugar cane ethanol	71 %	71 %
the part from renewable sources of ethyl-tertio-butyl-ether (ETBE)	Equal to that of the ethanol production pathway used	
the part from renewable sources of tertiary-amyl-ethyl-ether (TAEE)	Equal to that of the ethanol production pathway used	
rape seed biodiesel	45 %	38 %
sunflower biodiesel	58 %	51 %
soybean biodiesel	40 %	31 %
palm oil biodiesel (process not specified)	36 %	19 %
palm oil biodiesel (process with methane capture at oil mill)	62 %	56 %
waste vegetable or animal (*) oil biodiesel	88 %	83 %
hydrotreated vegetable oil from rape seed	51 %	47 %
hydrotreated vegetable oil from sunflower	65 %	62 %
hydrotreated vegetable oil from palm oil (process not specified)	40 %	26 %
hydrotreated vegetable oil from palm oil (process with methane capture at oil mill)	68 %	65 %
pure vegetable oil from rape seed	58 %	57 %
biogas from municipal organic waste as compressed natural gas	80 %	73 %
biogas from wet manure as compressed natural gas	84 %	81 %
biogas from dry manure as compressed natural gas	86 %	82 %

(*) Not including animal oil produced from animal by-products classified as category 3 material in accordance with Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules on animal by-products not intended for human consumption (1).

(1) OJ L 273, 10.10.2002, p. 1.

Results of previous studies

Source: Kiss, F. *Monetary valuation of environmental effects of production and usage of biodiesel in Serbia*, Unpublished project report, Goettingen, Februar 2009

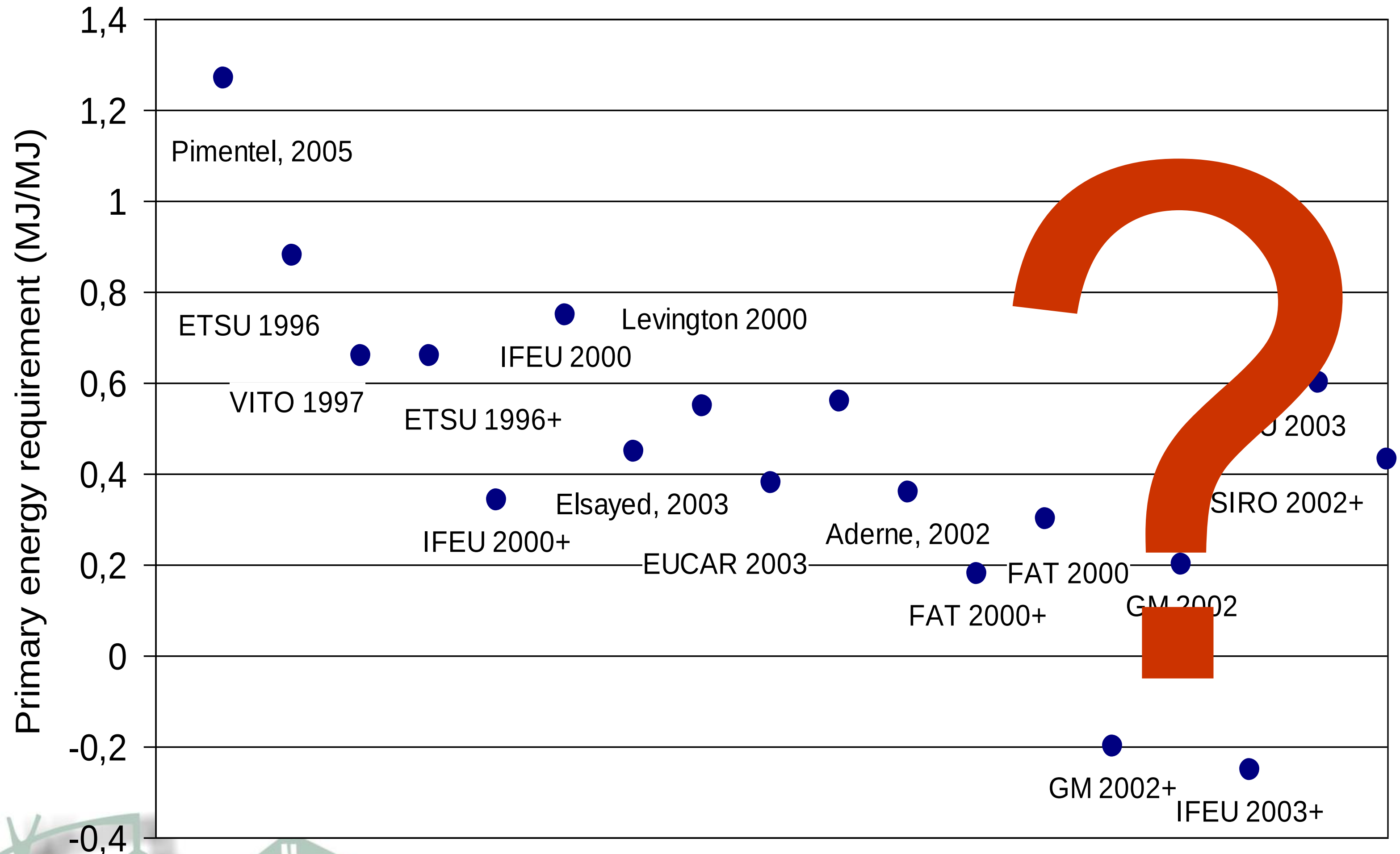
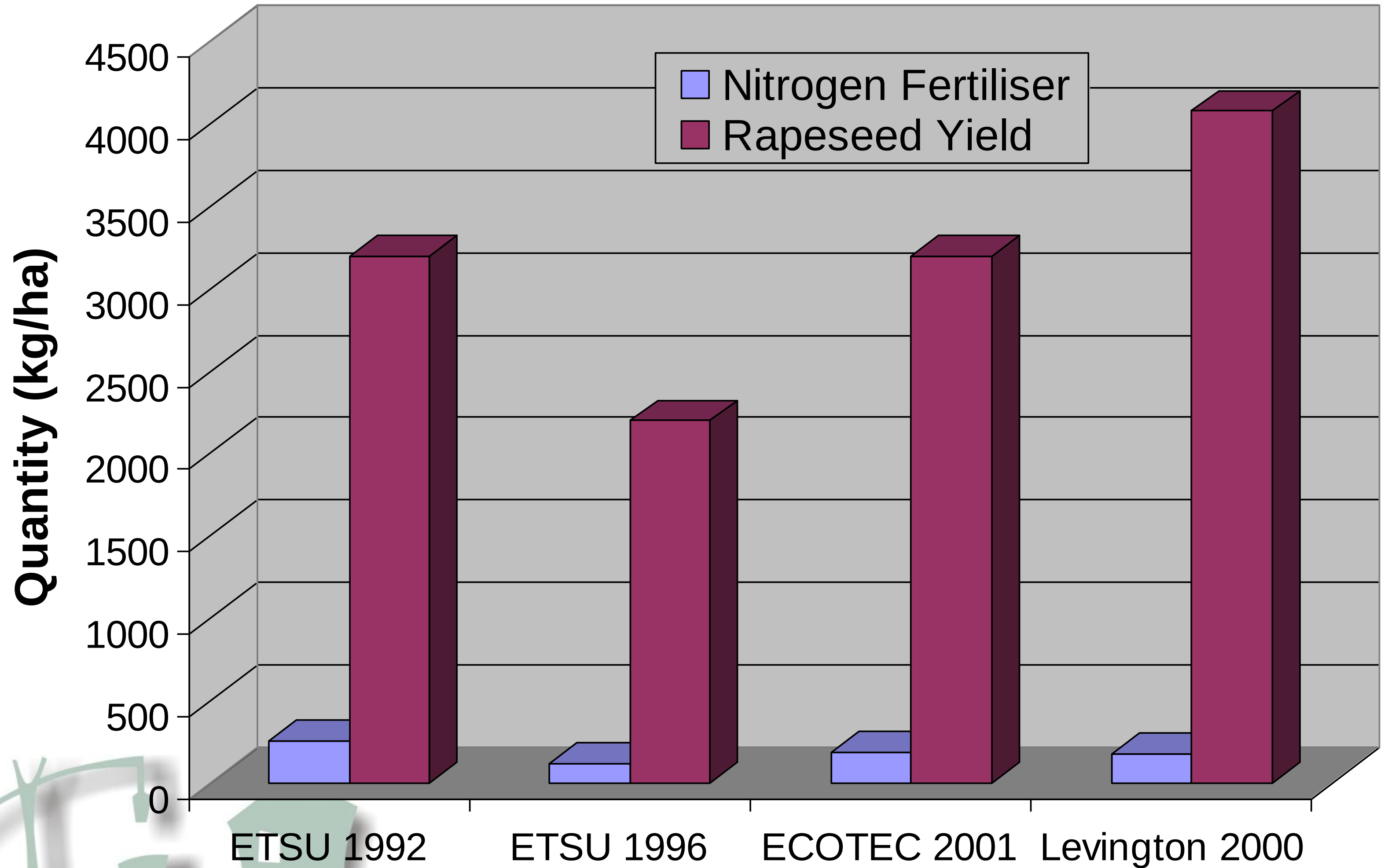


Fig. Comparison of energy requirements of biodiesel from previous studies

Input data

(example: application of N fertilizers and rapeseed yield)



Possible causes of the different LCI results

- (Functional unit)
- Agricultural referent system
- System boundaries
- Allocation procedure

Functional unit

- **Definition.** The functional unit defines the quantification of the identified functions of the product. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related *(EN ISO 14040:2006).*

- **Functional units in previous studies:** kg, ton, litre, MJ, km.

ISO 14040 Environmental management - Life cycle assessment - Principles and framework (2006)

Influence of the chosen functional unit on the results

(Example: blends of bioethanol and petrol)

Tab 1: Estimated environmental impacts when the functional unit is kg

Impact category	Unit	E10	E85
Crude Oil	g/**kg**	- 1.016	- 8[illegible]0
Global warming	g CO2 eq. / **kg**	- 1,88	[illegible]
Acidification	Moles H+ eq / **kg**	1,37	[illegible]
Eutrophication	g N eq. / **kg**	[illegible]	[illegible]

Tab 2: Estimated environmental impacts when the funct…

Kategorija uticaja	Jedinica me[illegible]	[illegible]	E85
Crude Oil	g/**km**	- 8,3	- 101,5
Global warming	g[illegible]	- 15,3	- 139,4
Acidification	Moles [illegible]	0,01	0,16
Eutrophication	g N eq. / [illegible]	0,01	0,14

Which functional unit should we use?

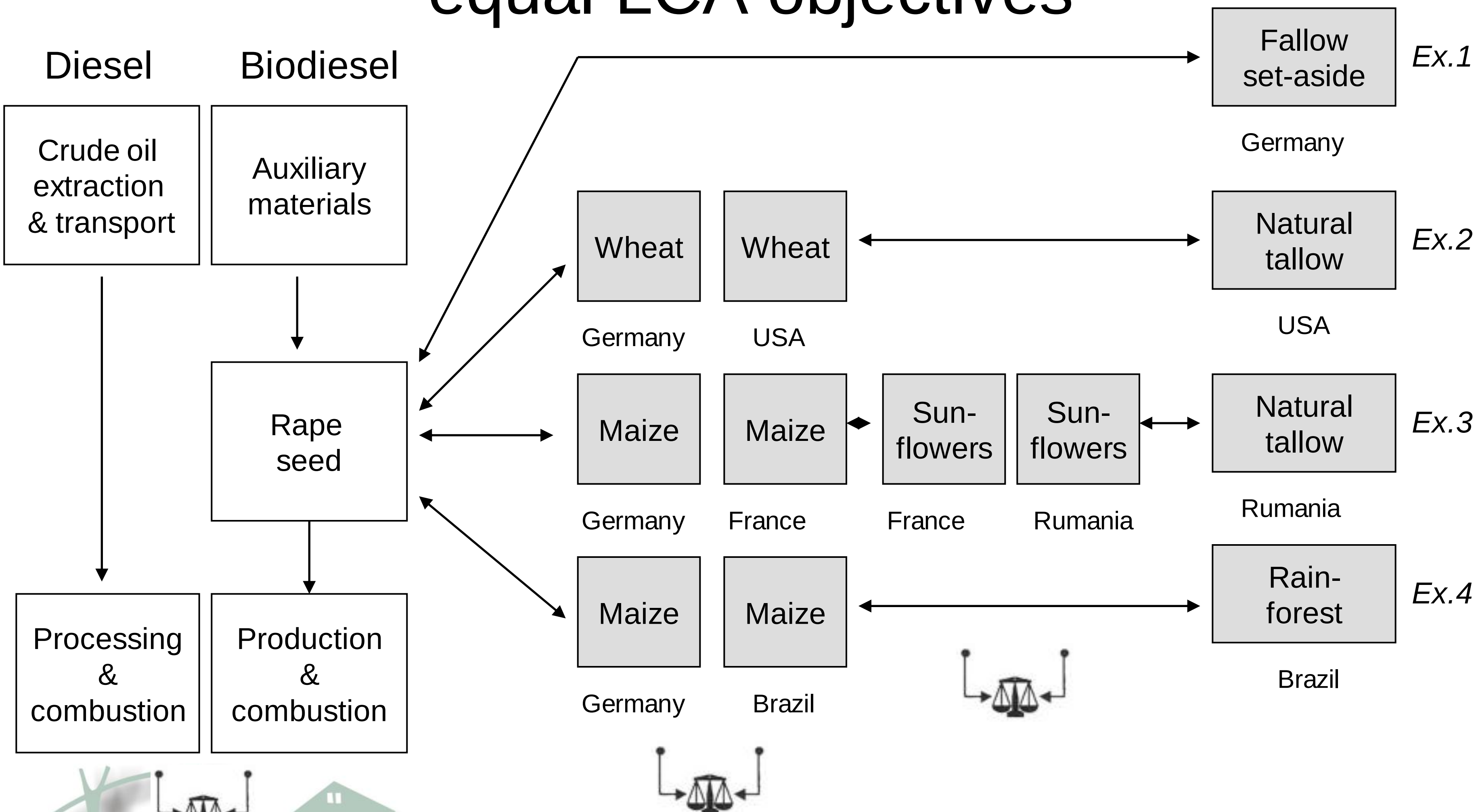
Kim S., Dale B: Ethanol Fuels: E10 or E85 – Life Cycle Perspectives Int J LCA 11 (2) 117 – 121 (2006)

Agricultural referent system

- **Definition.** Referent system are systems avoided or displaced by the main process under investigation. Used to determine credits from avoided activities.

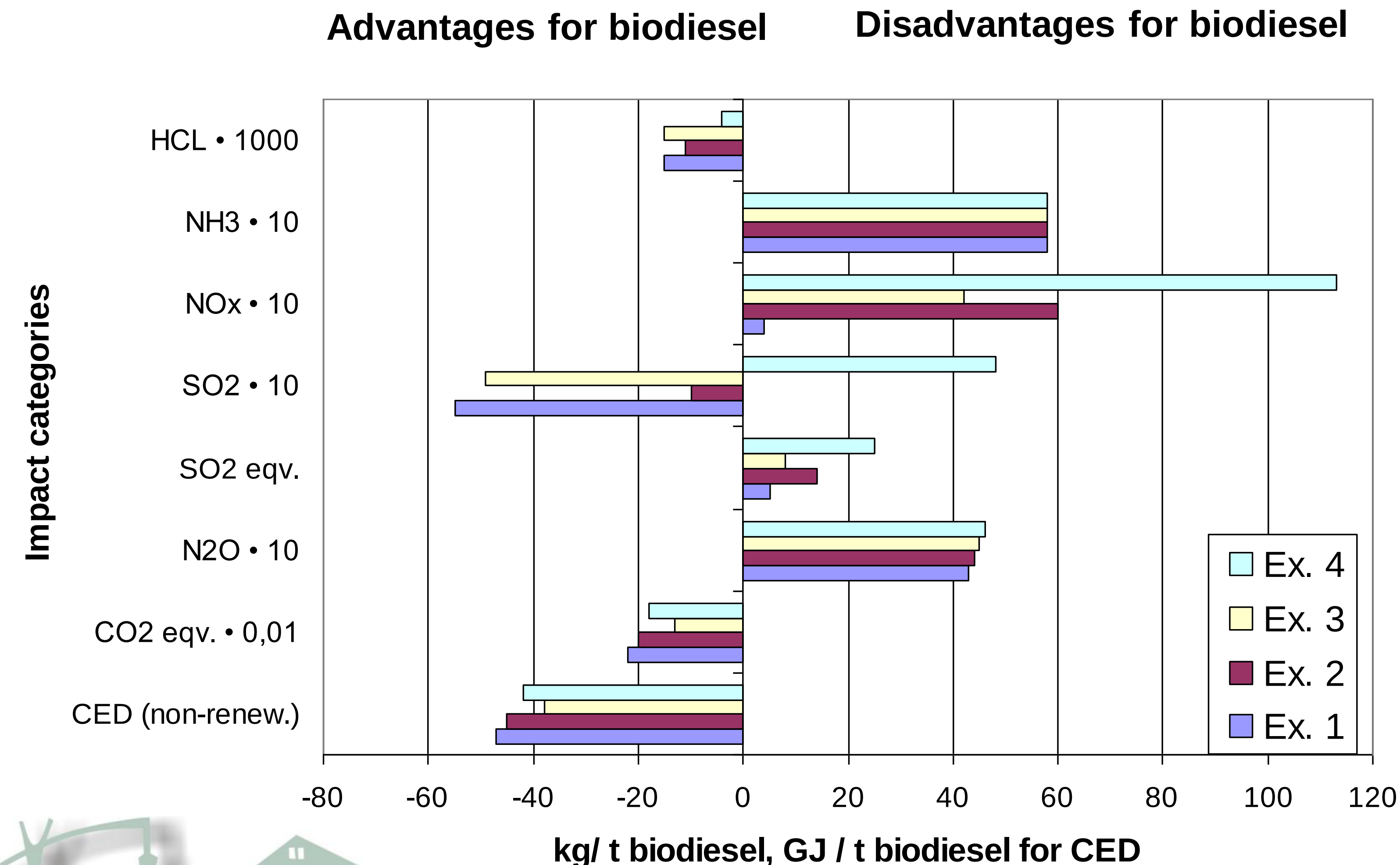
- **Referent system in previous studies:** there isn't any, set-aside land, wheat production.

Different agricultural reference system for equal LCA objectives



E.C. van Ierland and A. Oude Lansink (eds.). Economics of Sustainable Energy in Agriculture, 105–119.

Influence of different agricultural reference system options on LCA results

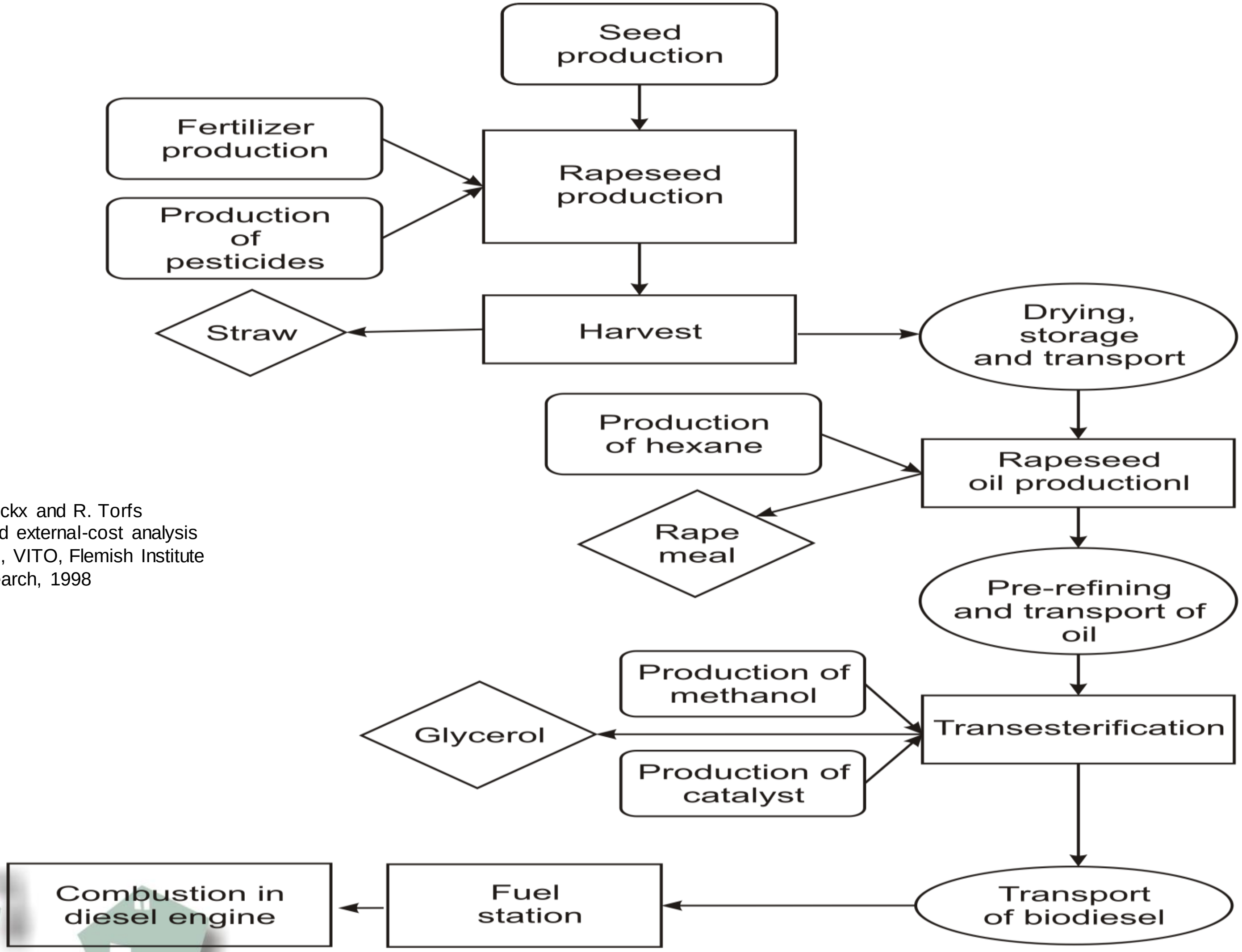


System boundary

- **Definition.** The system boundary defines the processes included in the system under investigation (EN ISO 14040:2006).
- **Biodiesel system boundary in previous studies:** from very simplified to very complex

Example 1

System boundary

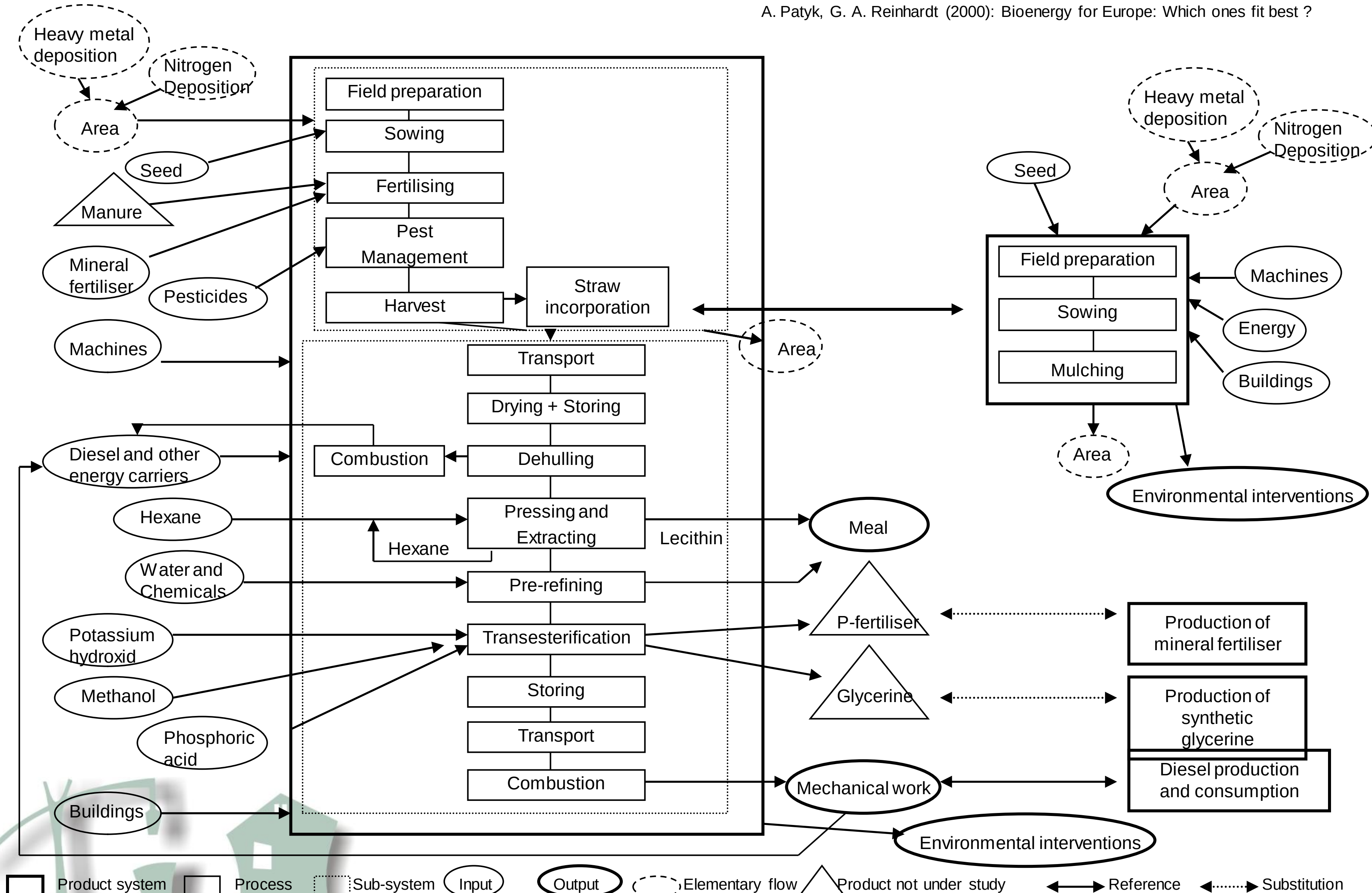


L. De Nocker, C. Spirinckx and R. Torfs
Comparison of LCA and external-cost analysis for biodiesel and diesel, VITO, Flemish Institute for Technological Research, 1998

System boundary

Example 2

A. Patyk, G. A. Reinhardt (2000): Bioenergy for Europe: Which ones fit best ?



System boundary

What is not included?

- Energy and material associated with building and maintaining fuel production and distribution infrastructure, transportation equipment, farm equipment…
- Human labor
- Land use
  - carbon in soil and biomass
  - nitrogen in soil
  - biodiversity

Mikhail Chester and Arpad Horvath. Environmental Life-cycle Assessment of Passenger Transportation: A Detailed Methodology for Energy, Greenhouse Gas and Criteria Pollutant Inventories of Automobiles, Buses, Light Rail, Heavy Rail and Air v.2. UC Berkeley Center for Future Urban Transport, University of California, 2008

Allocation

- **Definition.** In process chains which involve the provision of more than one product in is necessary to divide inputs and outputs between each product. This way this is achieved is referred to as allocation procedures.

- **Allocation in previous studies:**
  - Without allocation;
  - Inputs and outputs of the system are divided based on the energy content, mass, market prices of the products;
  - Substitution approach.

Allocation in previous studies

	Allocation in previous studies:		
	Rapeseed: Straw	Crude oil: Rape meal	Biodiesel: Crude glycerol
ETSU 1992	Energy content	Energy content	Energy content
ETSU 1996	No allocation	Substitution by soya meal	No allocation
VITO 1996	Mass	Market price	Market price
IFEU 1997	No allocation	Energy content	Energy content
ECOTEC 1999	No allocation?	No allocation?	No allocation?
Levington 2000	Energy content	Energy content	Energy content
ECOTEC 2000	No allocation?	No allocation?	No allocation?
ECOTEC 2001	No allocation?	No allocation?	Market price
CSIRO 2002	Energy content?	Energy content?	Energy content?

Influence of the allocation on LCI

Example with bioethanol

Table. Distribution of inputs and outputs on products based on their energy content and market prices

Allocation:	Energy content	Market price
Bioethanol	36 %	70 %
Distiller's waste	22 %	18 %
Straw	42 %	12 %

Table. Substitution approach

Substitution approach:		
1 kg Straw	– – →	0,87 kg wood
1 kg Distiller's waste	– – →	1,34 kg soya meal

Pål Börjesson: Life cycle assessment of biofuels; - how should we calculate? Agricultural biofuels and the media, World Bioenergy 2008. 27-29 May, Jönköping, Sweden

Influence of the allocation on LCI

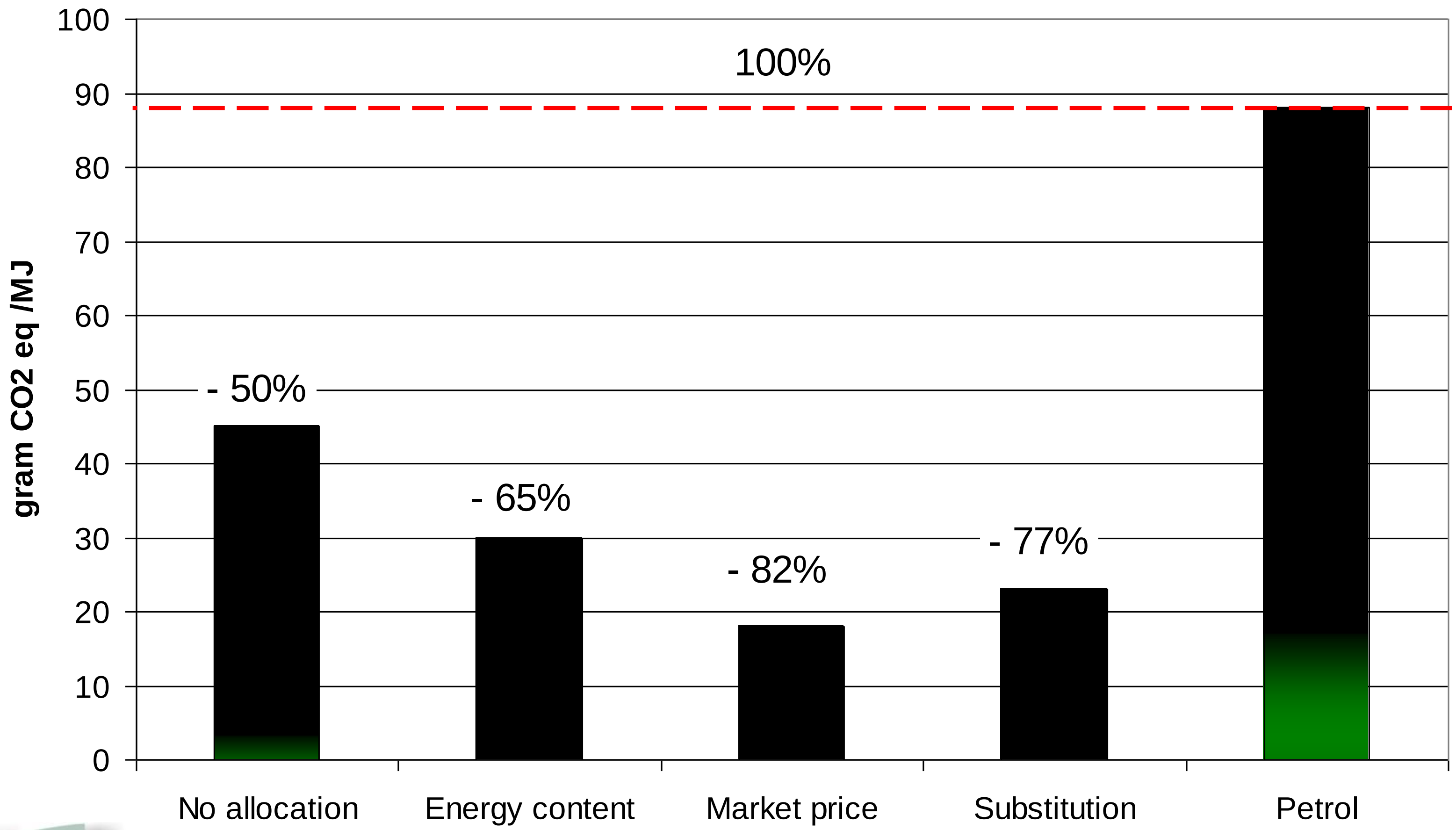


Fig. GHG emission per 1 MJ of bioethanol

Conclusion

- The ISO 14040:2006 allows a great amount of subjectivity in some methodological aspects.
- Results can be easily “adjust”.
- At this moment there is no solution.

- Do sensitivity analysis.

Thank you for your attention!

Ferenc E. Kiss
ferenc1980@gmail.com