   

Sustainability assessment of second generation bioethanol assessment

Dr Guido Reinhardt

International Conference on 2nd Generation Bioethanol Production

Brussels, 4 December 2013

Definitions

Biofuels	Definition	Examples
1st generation	E.g. produced from sugar, starch, vegetable oil, or animal fats using **conventional technology**	Biodiesel Vegetable oils Biogas Bioethanol
1 ½ generation	E.g. produced from oil using **advanced technology**	Hydrotreated vegetable oils or animal fats
2nd generation	E.g. produced from non-food biomass, such as lignocellulosis and waste biomass (stalks of wheat and corn, and wood) using **innovative technology**	Lignocellulosic ethanol Biomethanol BioDME Biohydrogen DMF BtL
3rd generation	E.g. produced from extracting oil of algae	Algae fuel

➔ Note: no unequivocal definition!

Examples for ethanol raw materials

For 1st generation Ethanol

Maize

Sugar cane

Wheat

Sugar beet

For 2nd generation Ethanol

Miscanthus

Straw

Switchgrass

Arundo

Definitions

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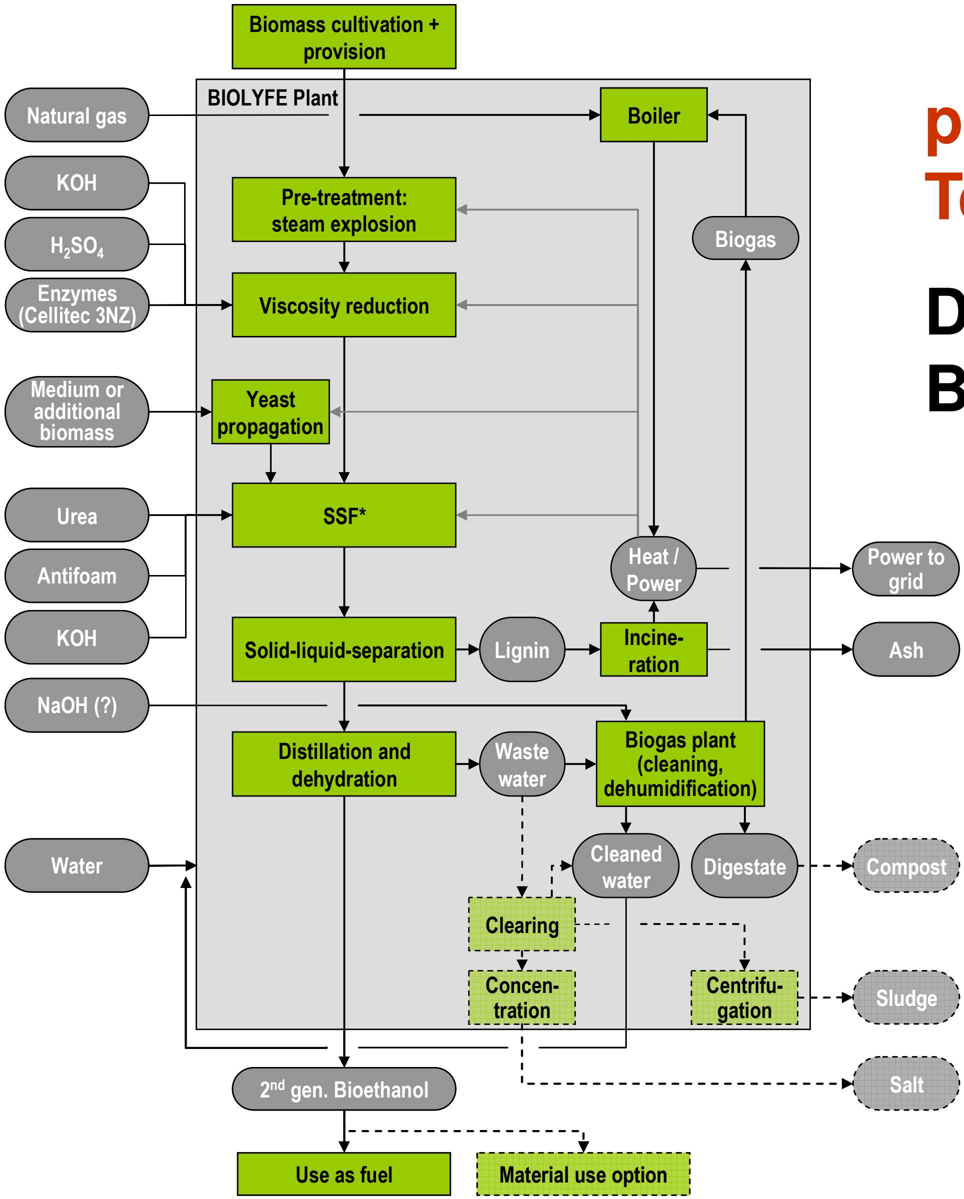

* Simultaneous saccharification and fermentation

proesa™ Technology

Developed by Biochemtex

Biofuels investigated in the Biolyfe project

Second generation Biolyfe ethanol

- Arundo ethanol
- Fiber sorghum ethanol
- Wheat straw ethanol

Alternative biofuels

- Arundo BTL
- Wheat ethanol
- Sugar beet ethanol
- Sugar cane ethanol
- Rapeseed biodiesel
- Corn ethanol
- Maize biomethane




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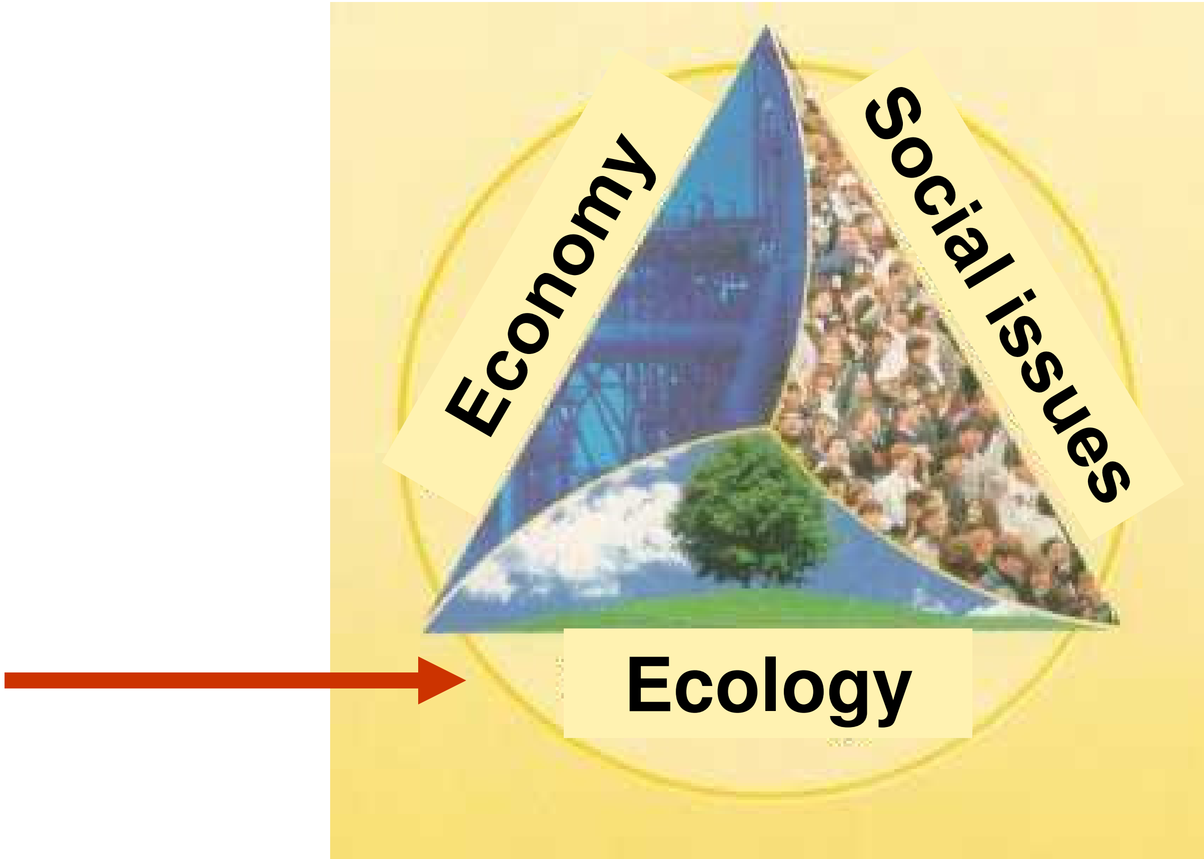
Sustainable development

Definition

"Meeting the needs of the present generation without compromising the ability of future generations to meet their needs."

Brundtland Commission 1987

The principle of sustainability



Environmental assessment:

→ **Life cycle assessment (LCA & RED*)**

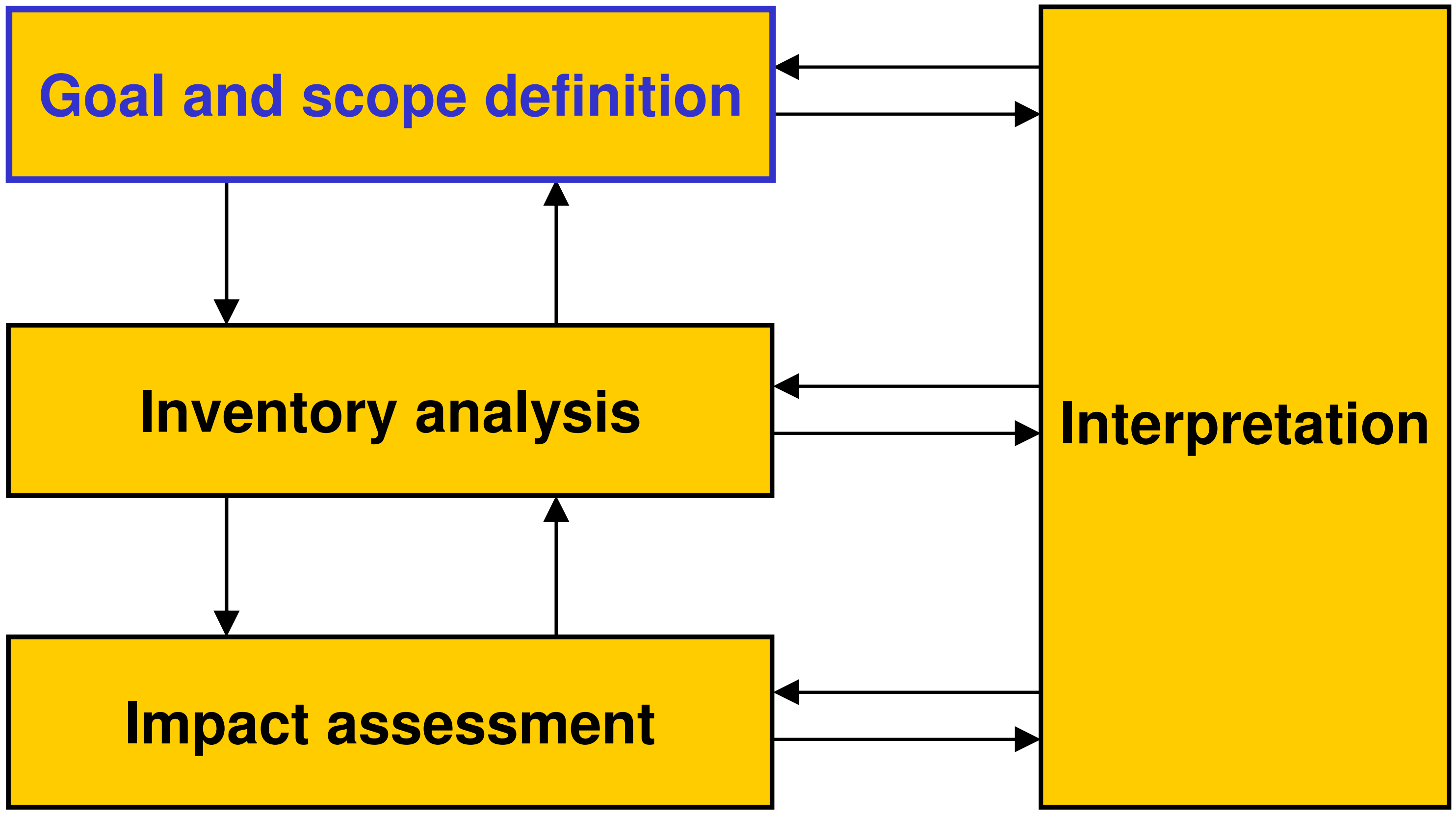
Life cycle environmental impact assessment (LC- EIA)

LCA	LC-EIA
→ Global impacts	→ Site-specific impacts

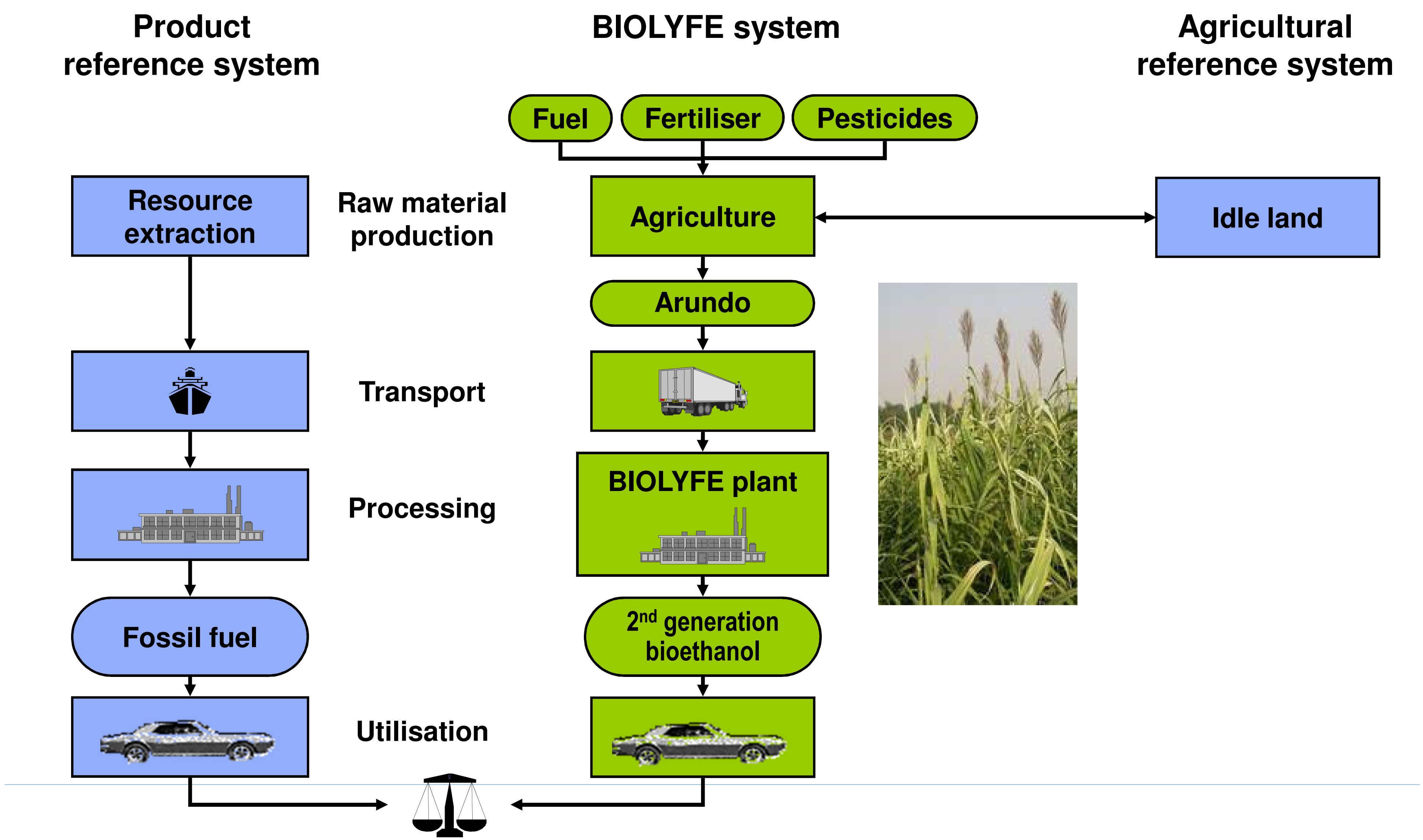
* RED: Renewable Energy Directive of the European Commission

Life cycle assessment (LCA)

ISO 14040 & 14044



Life cycle comparison

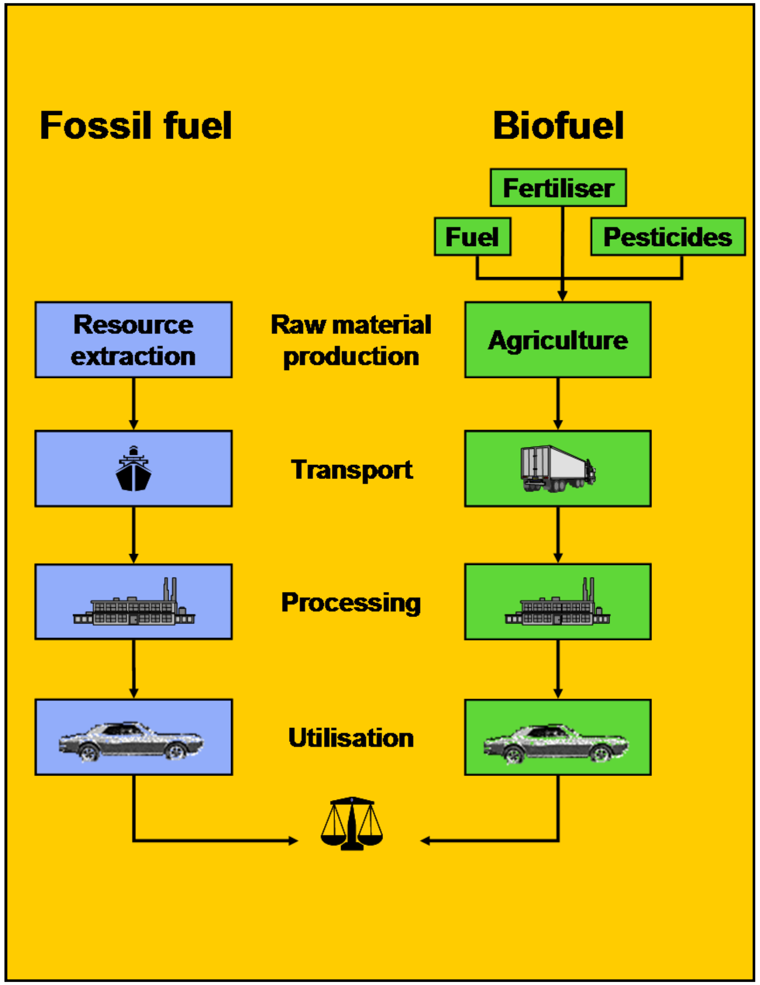


LCA: Inventory analysis

Inputs

e.g.:

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



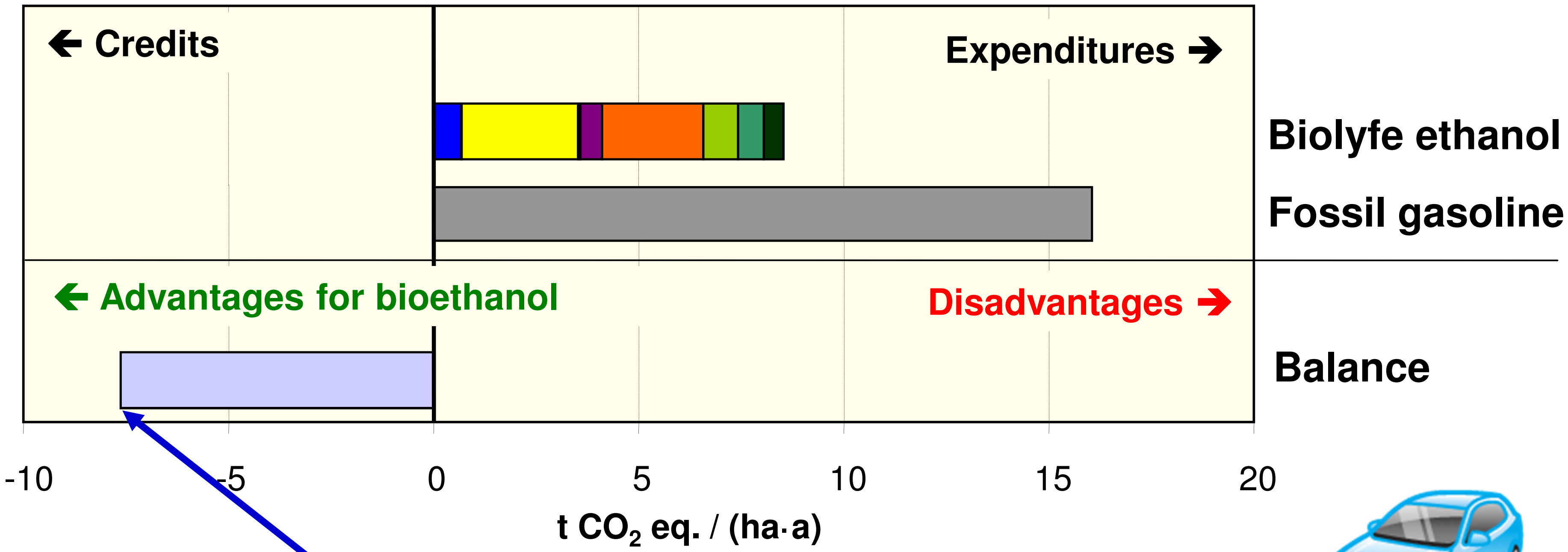
Outputs

e.g.:

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

Biolyfe ethanol from Arundo vs. gasoline

Greenhouse effect



Expenditures:

- Agriculture: diesel
- Agriculture: rest
- Conversion: material input
- Power
- Conversion: emissions from lignin combustion
- Agriculture: fertiliser

Equals a ride with a compact car of about 41.000 km, which is slightly more than the perimeter of the earth.

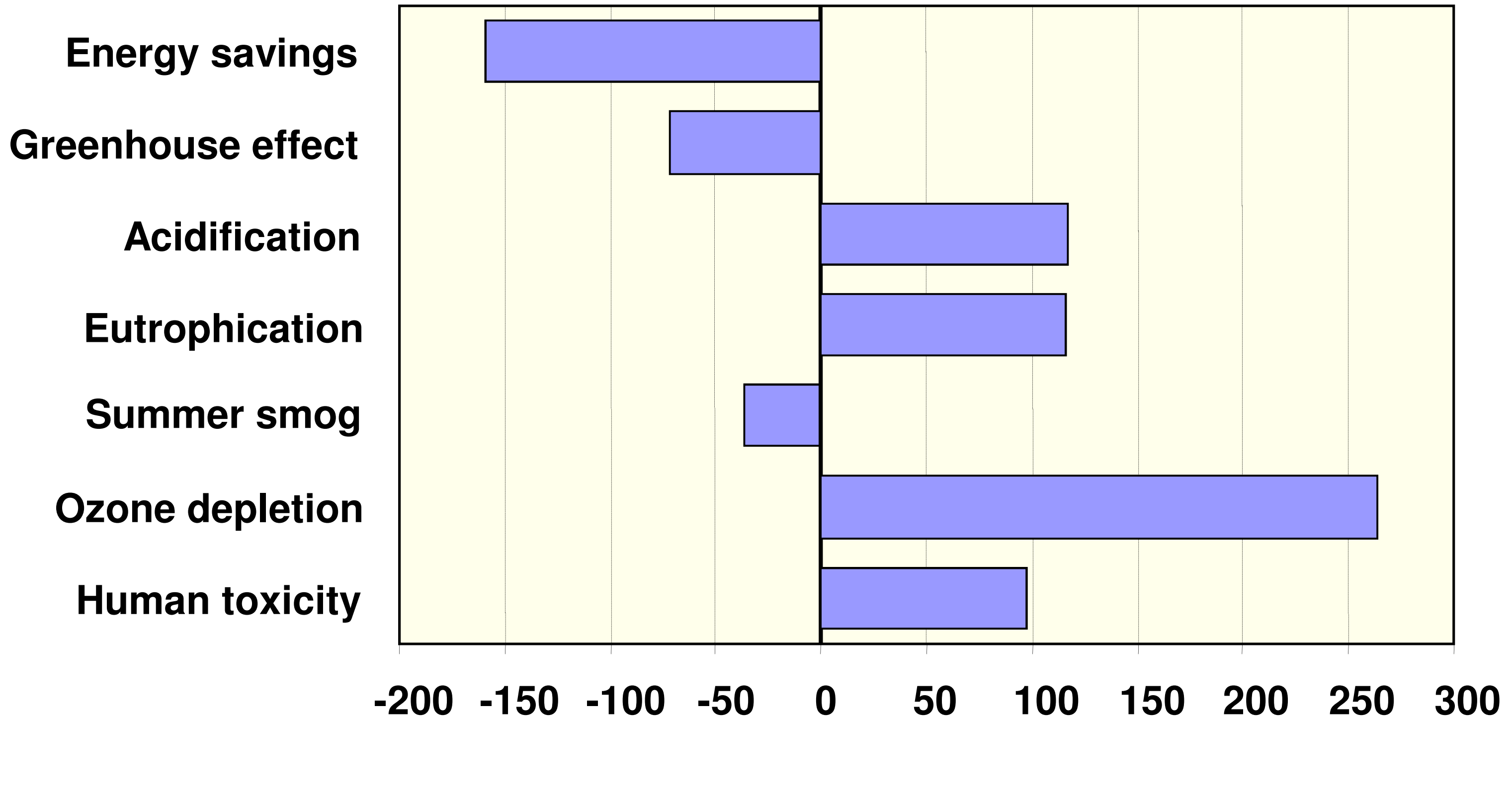
Source: IFEU 2013

LCA: Impact assessment

Impact category	Parameter	Substances (LCI)
Resource demand	Sum of depletable primary energy carriers Mineral resources	Crude oil, natural gas, coal, Uranium, … Lime, clay, metal ores, salt, pyrite, …
Greenhouse effect	CO_2 equivalents	Carbon dioxide, dinitrogen monoxide, methane, different CFCs, methyl bromide, …
Ozone depletion	F11 equivalents, (Nitrous oxide)	CFC, halone, methyl bromide, …
Acidification	SO_2 equivalents	Sulphur dioxide, hydrogen chloride, nitrogen oxides, ammonia, …
Eutrophication	PO_4 equivalents	Nitrogen oxides, ammonia, phosphate, nitrate
Photosmog	Ethylene equivalents	Hydrocarbons, nitrogen oxides, carbon monoxide, chlorinated hydrocarbons, …
Human and Ecotoxicity		Nitrogen oxides, carbon monoxide, hydrogen chloride, diesel particles, dust, ammonia, benzene, benzo(a)pyrene, sulphur dioxide, dioxines (TCDD), …

Biolyfe bioethanol from Arundo vs. gasoline

← Advantages for bioethanol Advantages for gasoline →

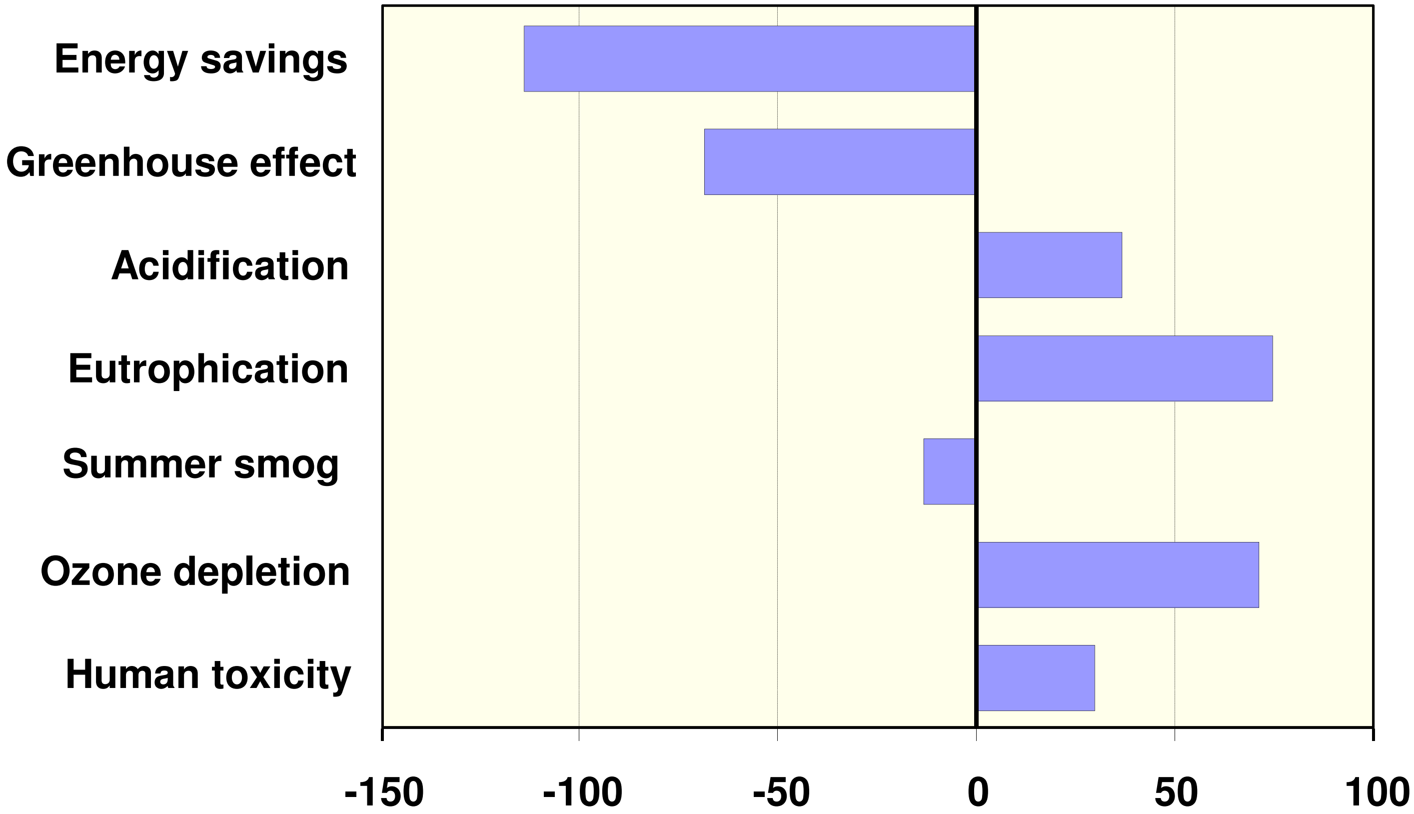


Arundo

Source: IFEU 2013

Bioethanol from sugar beet versus gasoline

← **Advantages for bioethanol** **Advantages for gasoline** →

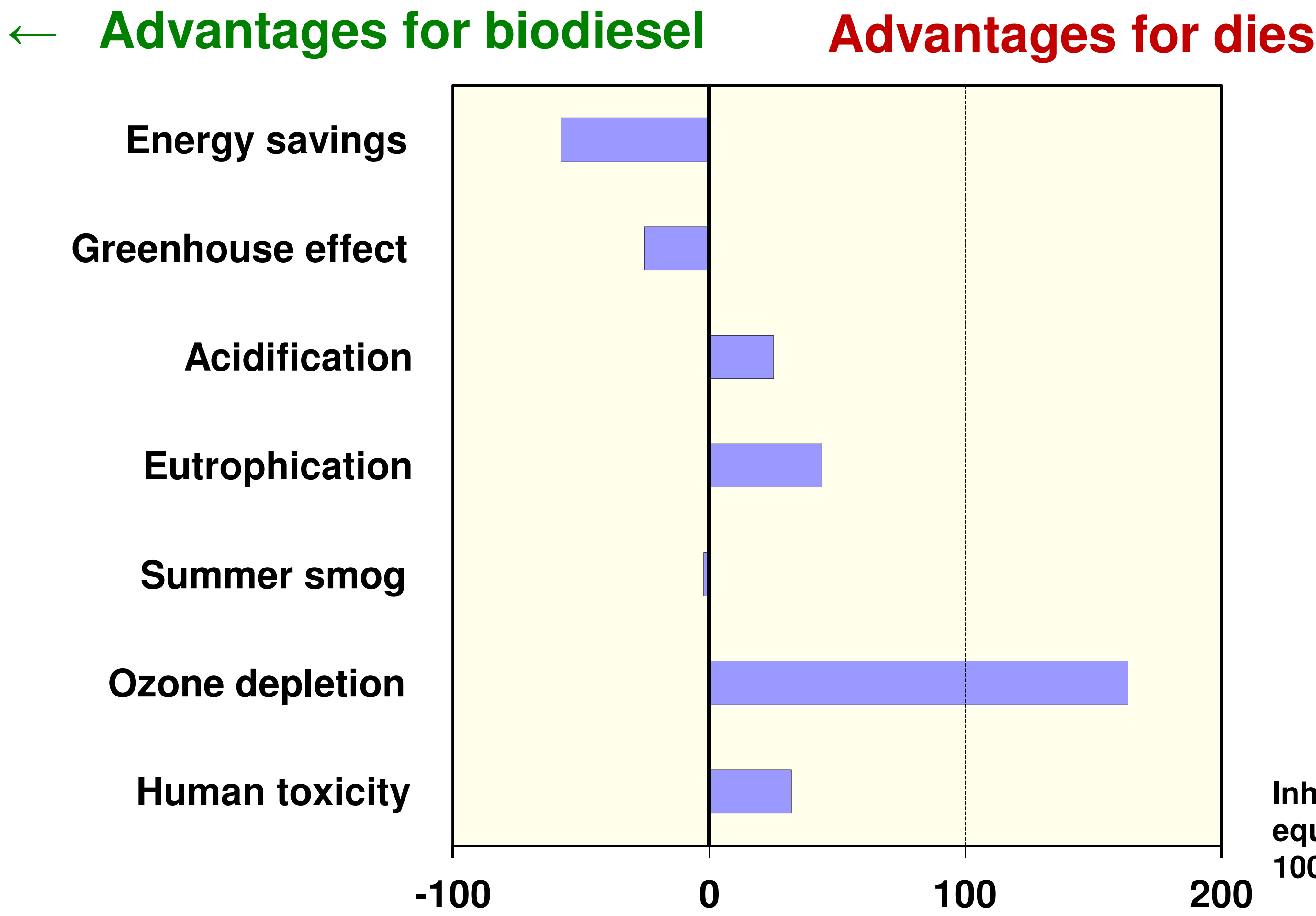


Sugar beet

Inhabitant equivalents per 100 ha and year

Source: IFEU 2013

Biodiesel from rape seed versus diesel



Rape seed

Source: IFEU 2013

Biolyfe bioethanol from Arundo vs. gasoline

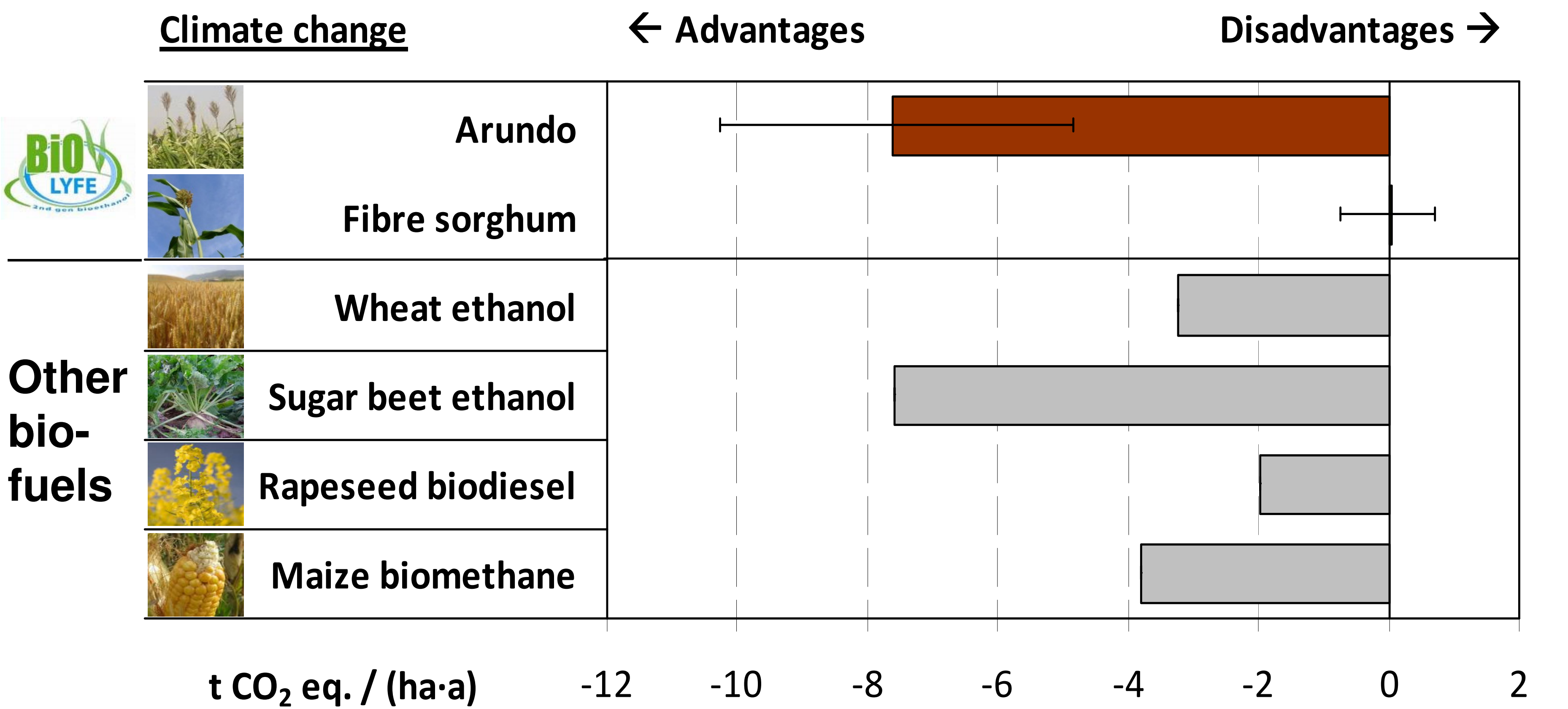
← Advantages for bioethanol Advantages for gasoline →

- ➔ **Life cycle assessment of Biolyfe ethanol: Environmental advantages and burdens**
- ➔ **Same pattern for most biofuels for transportation**
- ➔ **Need to identify all environmental implications and optimise the advantages and minimise the disadvantages**

-200 -150 -100 -50 0 50 100 150 200 250 300 Inhabitant equivalents per 100 ha and year

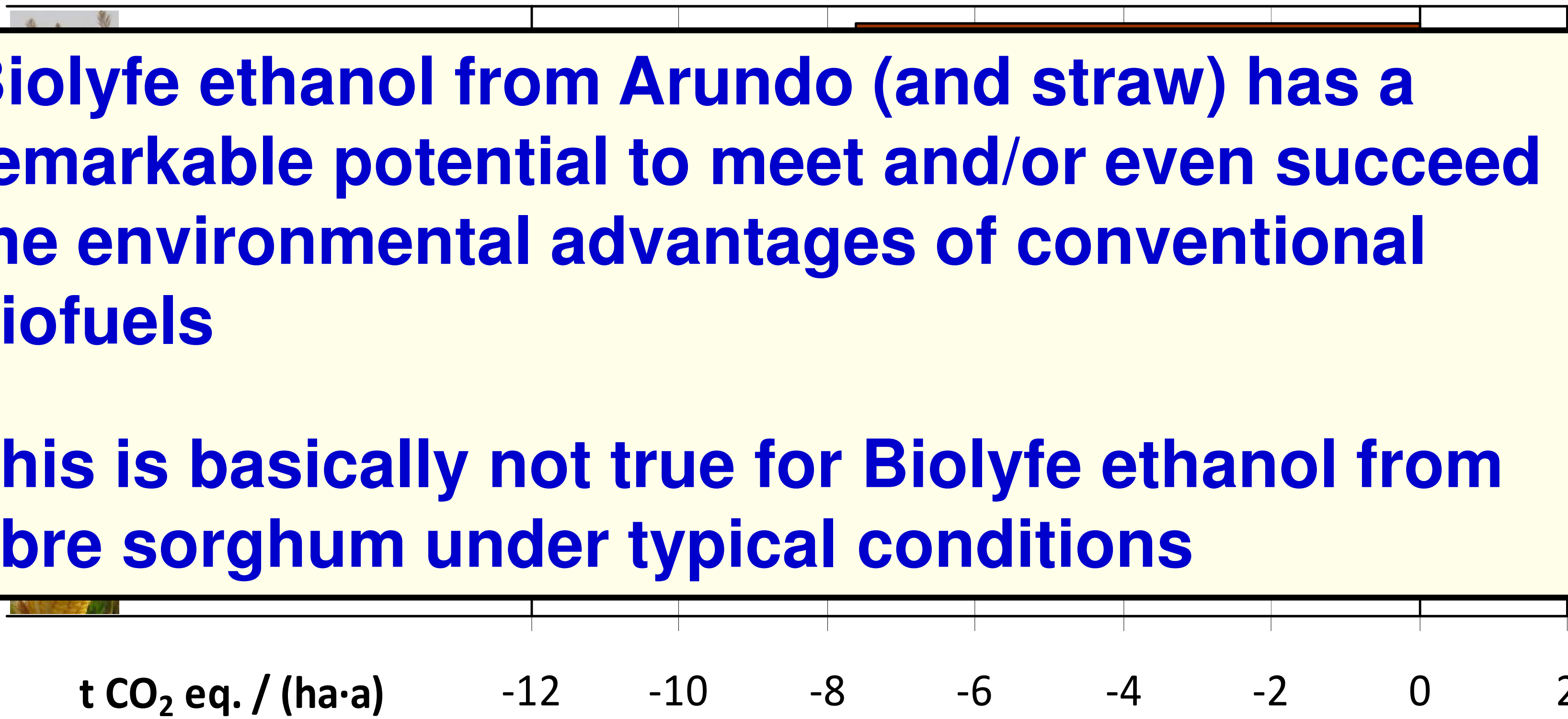
Source: IFEU 2013

Greenhouse gas balances for Biolyfe ethanol and other biofuels from different feedstocks



Source: IFEU 2013

Greenhouse gas balances for Biolyfe ethanol and other biofuels from different feedstocks



- ➔ **Biolyfe ethanol from Arundo (and straw) has a remarkable potential to meet and/or even succeed the environmental advantages of conventional biofuels**
- ➔ **This is basically not true for Biolyfe ethanol from fibre sorghum under typical conditions**

Source: IFEU 2013




Environmental assessment:

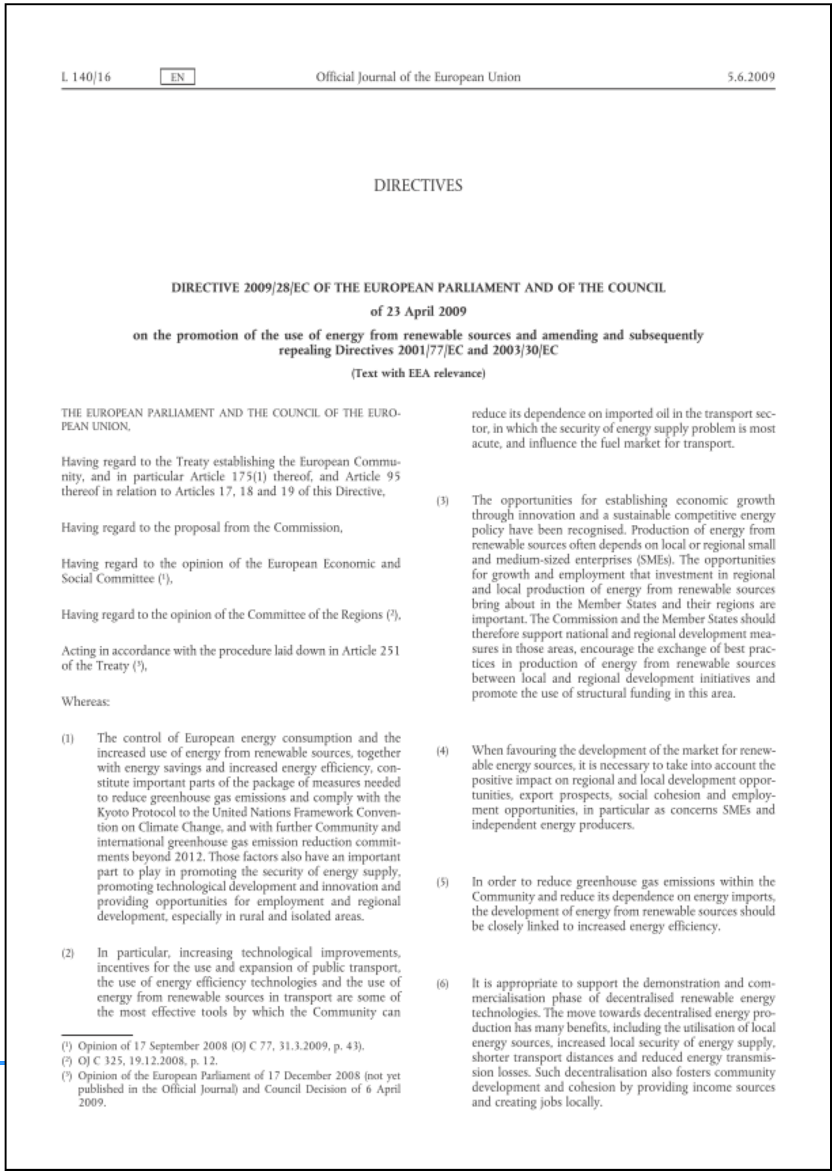
→ **Life cycle assessment (LCA & RED*)**

Life cycle environmental impact assessment (LC- EIA)

LCA	LC-EIA
→ Global impacts	→ Site-specific impacts

* RED: Renewable Energy Directive of the European Commission



L 140/16 EN Official Journal of the European Union 5.6.2009

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)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof, and Article 95 thereof in relation to Articles 17, 18 and 19 of this Directive,

Having regard to the proposal from the Commission,

Having regard to the opinion of the European Economic and Social Committee (1),

Having regard to the opinion of the Committee of the Regions (2),

Acting in accordance with the procedure laid down in Article 251 of the Treaty (3),

Whereas:

(1) The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012. Those factors also have an important part to play in promoting the security of energy supply, promoting technological development and innovation and providing opportunities for employment and regional development, especially in rural and isolated areas.

(2) In particular, increasing technological improvements, incentives for the use and expansion of public transport, the use of energy efficiency technologies and the use of energy from renewable sources in transport are some of the most effective tools by which the Community can reduce its dependence on imported oil in the transport sector, in which the security of energy supply problem is most acute, and influence the fuel market for transport.

(3) The opportunities for establishing economic growth through innovation and a sustainable competitive energy policy have been recognised. Production of energy from renewable sources often depends on local or regional small and medium-sized enterprises (SMEs). The opportunities for growth and employment that investment in regional and local production of energy from renewable sources bring about in the Member States and their regions are important. The Commission and the Member States should therefore support national and regional development measures in those areas, encourage the exchange of best practices in production of energy from renewable sources between local and regional development initiatives and promote the use of structural funding in this area.

(4) When favouring the development of the market for renewable energy sources, it is necessary to take into account the positive impact on regional and local development opportunities, export prospects, social cohesion and employment opportunities, in particular as concerns SMEs and independent energy producers.

(5) In order to reduce greenhouse gas emissions within the Community and reduce its dependence on energy imports, the development of energy from renewable sources should be closely linked to increased energy efficiency.

(6) It is appropriate to support the demonstration and commercialisation phase of decentralised renewable energy technologies. The move towards decentralised energy production has many benefits, including the utilisation of local energy sources, increased local security of energy supply, shorter transport distances and reduced energy transmission losses. Such decentralisation also fosters community development and cohesion by providing income sources and creating jobs locally.

(1) Opinion of 17 September 2008 (OJ C 77, 31.3.2009, p. 43).
(2) OJ C 325, 19.12.2008, p. 12.
(3) Opinion of the European Parliament of 17 December 2008 (not yet published in the Official Journal) and Council Decision of 6 April 2009.

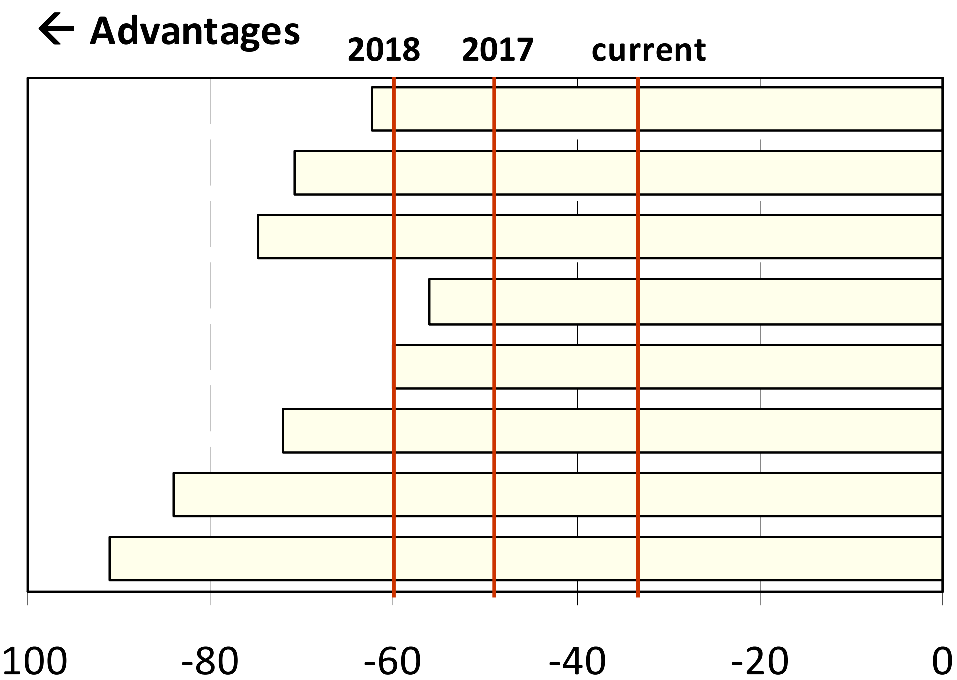
RED:

Renewable Energy Directive of the European Commission



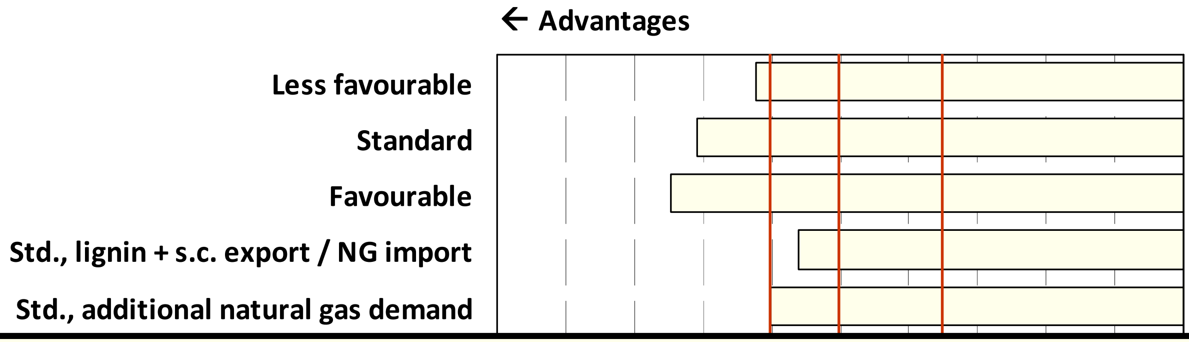

Greenhouse gas balances for Biolyfe ethanol according to the renewable energy directive (RED)

Wheat straw



Source: IFEU 2013

Wheat straw



- ➔ Biolyfe ethanol from straw can easily meet the long term RED requirements of 60 % GHG reduction.
- ➔ To meet 60 % GHG reduction with Biolyfe ethanol from Arundo is challenging though comparably easy achievable.
- ➔ To meet 60 % GHG reduction with Biolyfe ethanol from fibre sorghum needs extraordinary measures.
- ➔ In general, to meet 60 % GHG reduction with Biolyfe ethanol is achievable, though not a self running story in all cases.




Environmental assessment:

Life cycle assessment (LCA & RED*)

→ **Life cycle environmental impact assessment (LC- EIA)**

LCA	LC-EIA
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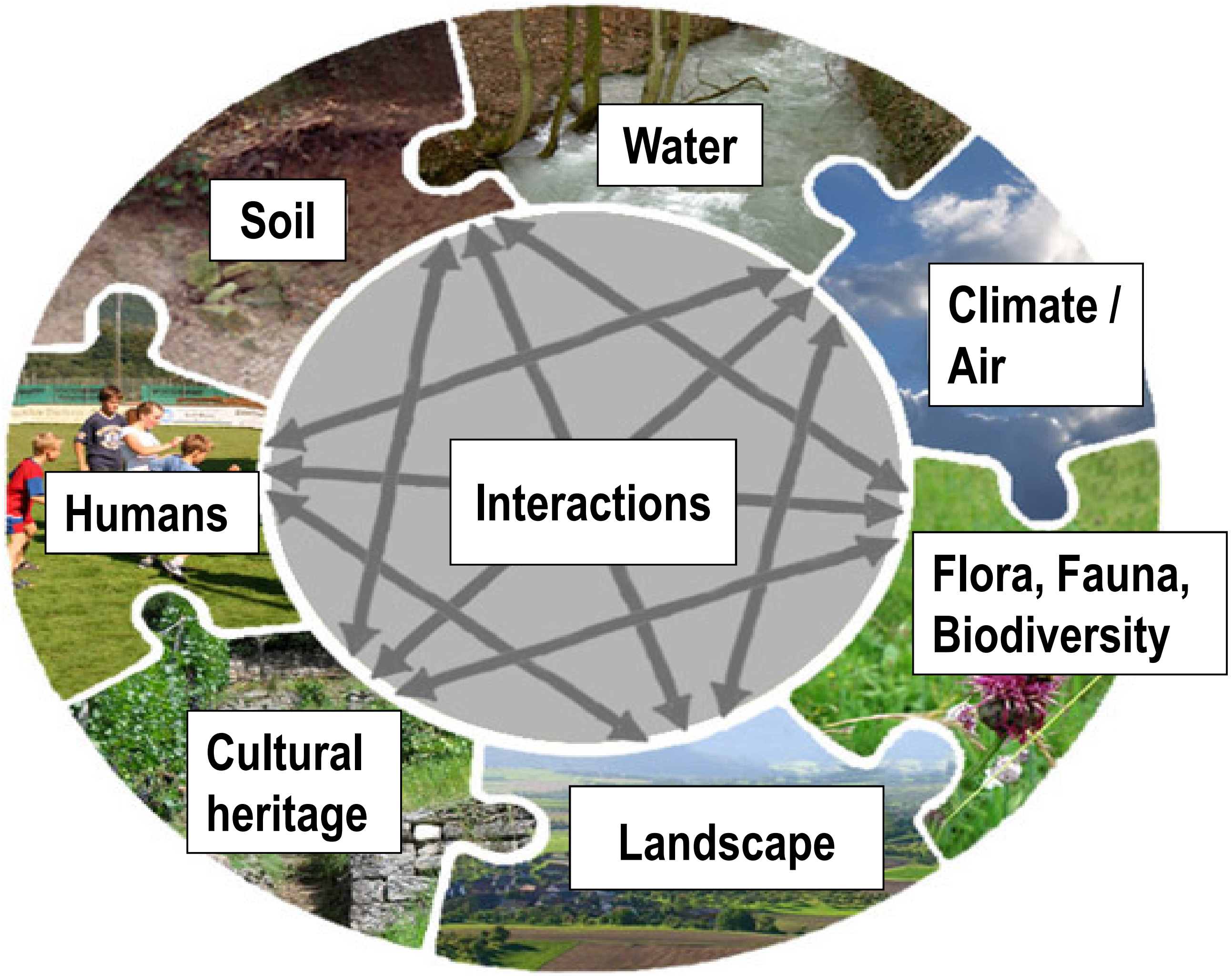
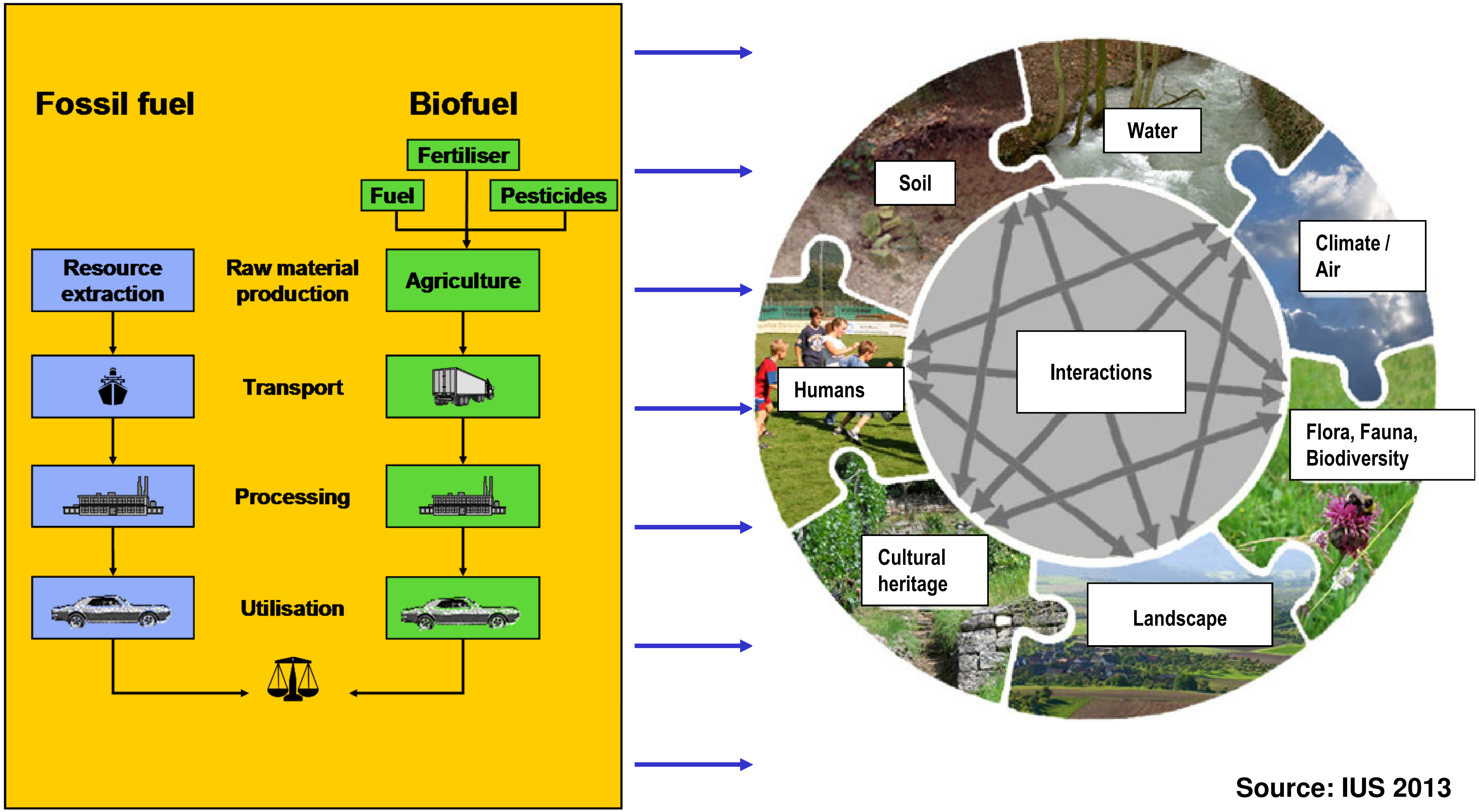
Description of the environment



Source: IUS 2013

LC-EIA: Life cycle environmental impact assessment



Source: IUS 2013

Principles of assessment (I)

Type of risk	Affected environmental factors								
	Soil	Ground water	Surface water	Plants/ Biotopes	Animals	Climate/ Air	Land-scape	Human health and recreation	Bio-diversity
S…									
… organic ma…									
Soil chemistry / fertilizer									
Eutrophication									
Nutrient leaching									
Water demand									
Weed control / pesticides									
Loss of land-scape elements									
Loss of habitat types									
Loss of species									

qualitative risk assessment

Source: IUS 2013

LC-EIA results: Wheat straw

Reference system: ploughed in

Type of risk	Affected environmental factors								
	Soil	Ground water	Surface water	Plants / Biotopes	Animals	Climate / Air	Land-scape	Human health and recreation	Bio-diversity
Soil erosion	neutral		neutral						
Soil compaction	neutral	neutral		neutral	neutral				neutral
Loss of soil organic matter	neutral			neutral	neutral				neutral
Soil chemistry / fertiliser	neutral	neutral							
Eutrophication	neutral	neutral	neutral	neutral	neutral				neutral
Nutrient leaching		neutral							
Water demand		neutral		neutral	neutral				neutral
Weed control / pesticides		neutral	neutral	neutral	neutral				neutral
Loss of land-scape elements				neutral	neutral	neutral	neutral	neutral	neutral
Loss of habitat types				**neutral / positive[1]**	**neutral / positive[1]**				**neutral / positive[1]**
Loss of species				**neutral / positive[1]**	**neutral / positive[1]**				**neutral / positive[1]**

1) Positive in case of long-stalked varieties since less weed control is necessary

Source: IUS 2013

Comparison of feedstocks

	Perennial crops		Annual crops				Residues
Feedstock	**Arundo donax**	**Sugar cane**	**Rapeseed**	**Sorghum**	**Sugar beet**	**Cereal**	**Cereal straw**
Type of risk / **Reference scenario**	non rsl	cerr.	rsl	rsl	rsl	rsl	conv. use
Soil erosion	B	C	C	C	E	C	C
Soil compaction	A	D	C	C	E	C	C
Soil organic matter	B	E	D	D	E	D	D
Soil chemistry / fertiliser	C	D	D	D	E	D	D
Nutrient leaching, Eutrophication	B	D	D	D	D	D	D
Water demand	D	D	C	D	E	C	C
Weed control / pesticides	B	E	E	E	E	E	E
Loss of habitat / species diversity	C	E	C	D	D	D	D
Loss of landscape elements	C	C	c	C	C	C	C

Impact category: A = minimum impact**; E** = maximum impact

non rsl: non-rotational fallow set-aside land, no cropping; **cer.:** cerrado (topical savannah);
rsl: rotational set-aside fallow land, no cropping; **conv. use:** conventional use

Source: IUS 2013

Life cycle environmental impact assessment (LC-EIA) results

	BIOLYFE scenarios				Alternatives to BIOLYFE					
	Arundo	Fibre sorghum	Wheat straw	Marginal land (Arundo)	BTL (Arundo)	Wheat ethanol	Beet ethanol	Cane ethanol (Brazil)	Rape seed biodiesel	Maize bio-methane
Environment										
Water	– –	–	0	–	– –	0	–	–	–	–
Soil	0	–	0	– –	0	–	– –	0	– –	– –
Fauna	0	–	0	– –	0	–	–	–	–	–
Flora	–	–	0	– –	–	–	– –	–	–	– –
Landscape	0	0	0	0	0	0	0	–	0	0

Ranking by 5 categories: ++ | + | 0 | – | – –

Source: IUS 2013

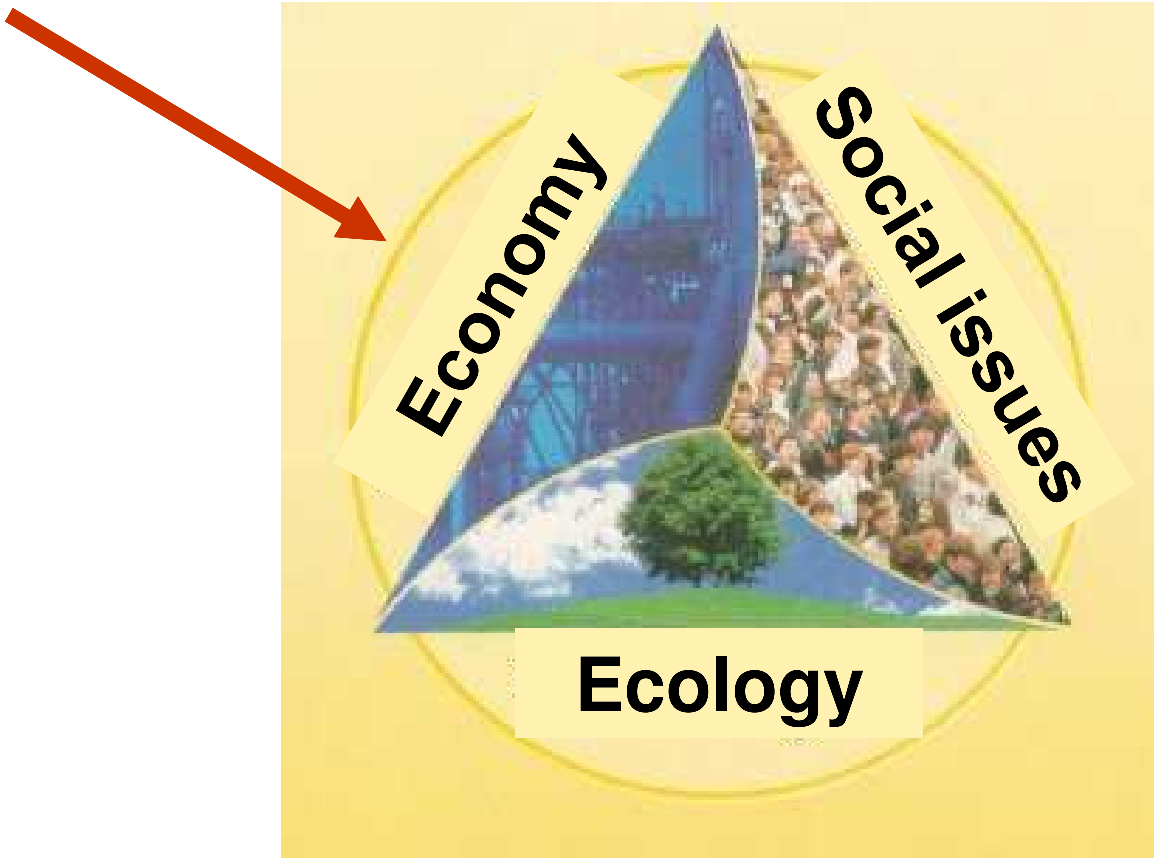
Life cycle environmental impact assessment (LC-EIA) results

- ➔ The so called LC-EIA "Life cycle environmental impact assessment" enlarges the spectrum of environmental assessment indicators.

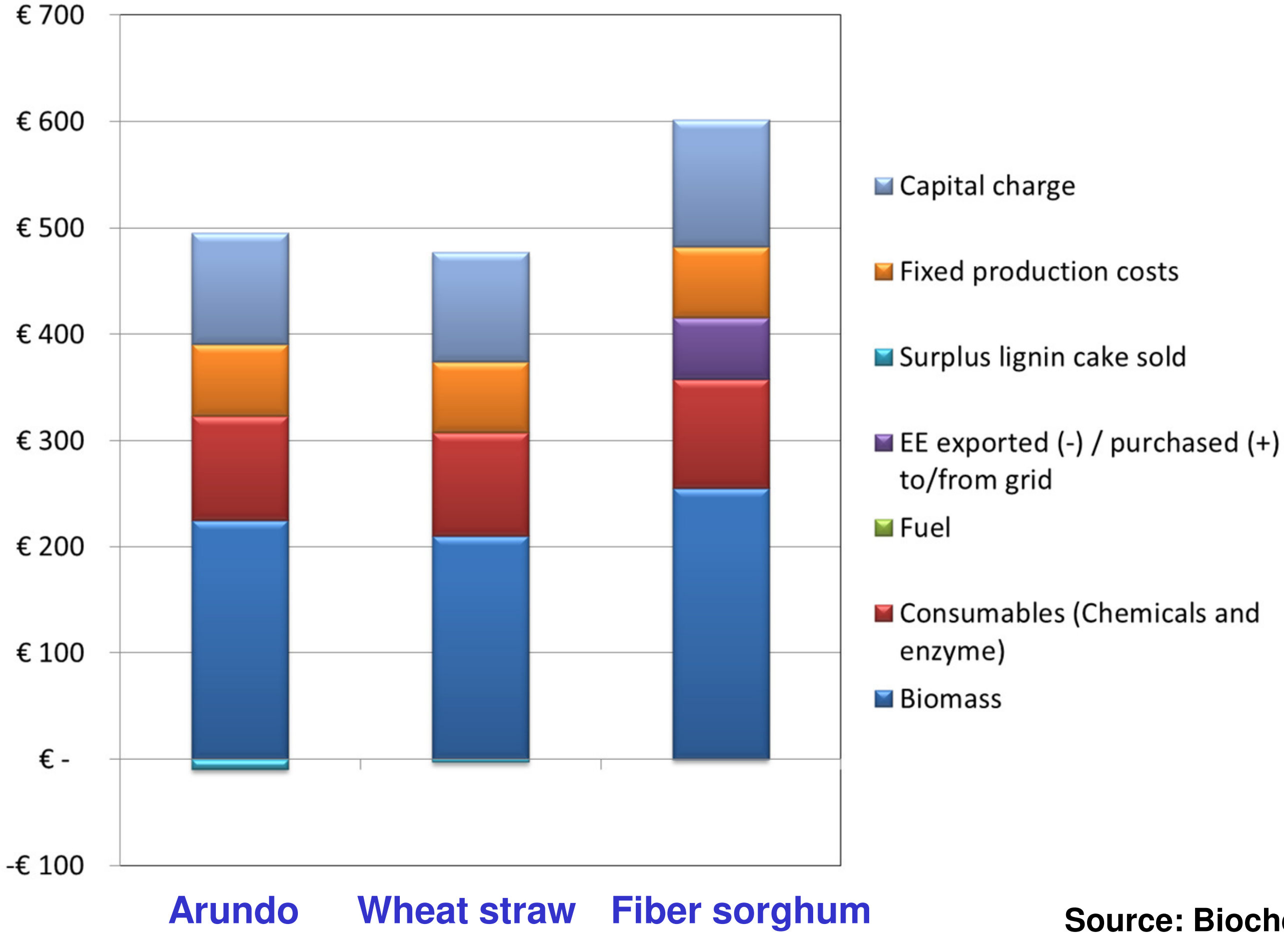
- ➔ It proves, that it works and it is worth it to include the LC-EIA as a supplementary environmental assessment tool to the standard "life cycle assessment".

- ➔ With respect to LC-EIA, Biolyfe ethanol from straw and Arundo compares to alternative biofuels in general quite positive.

The principle of sustainability

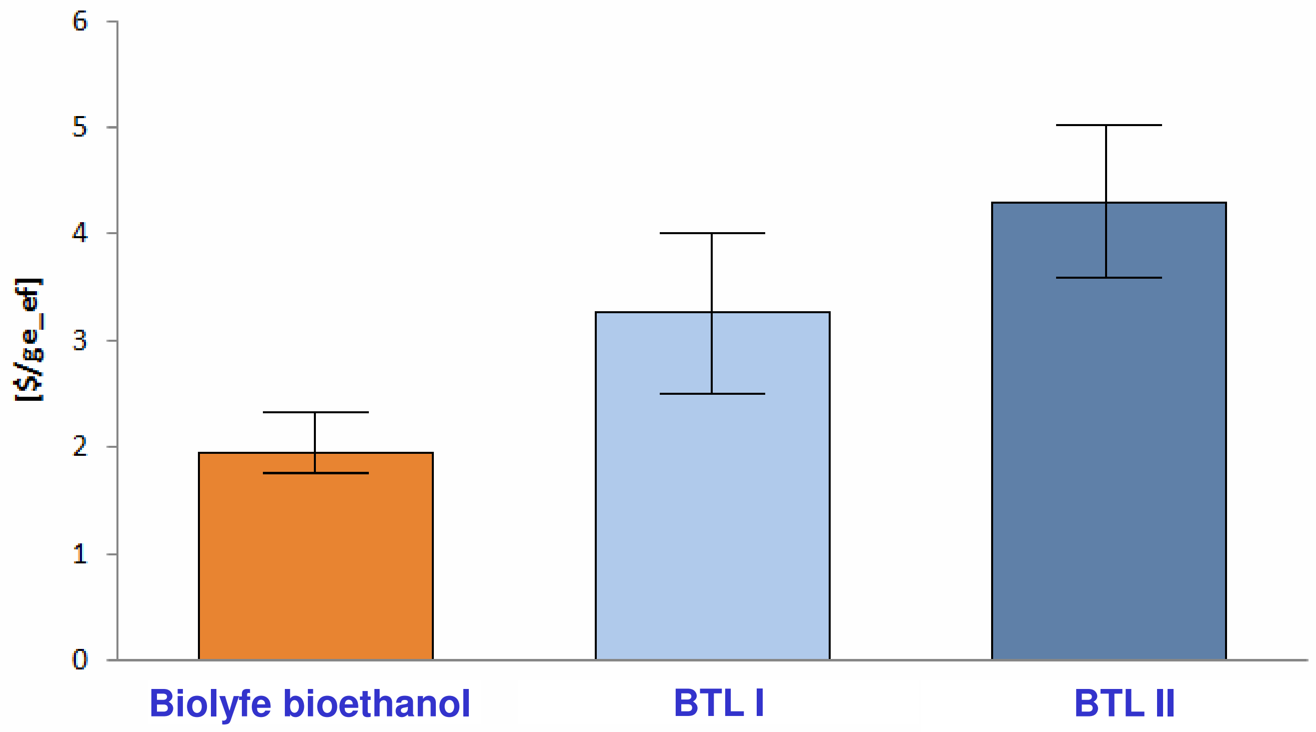


Production costs of Biolyfe bioethanol from different feedstocks



Source: Biochemtex 2013

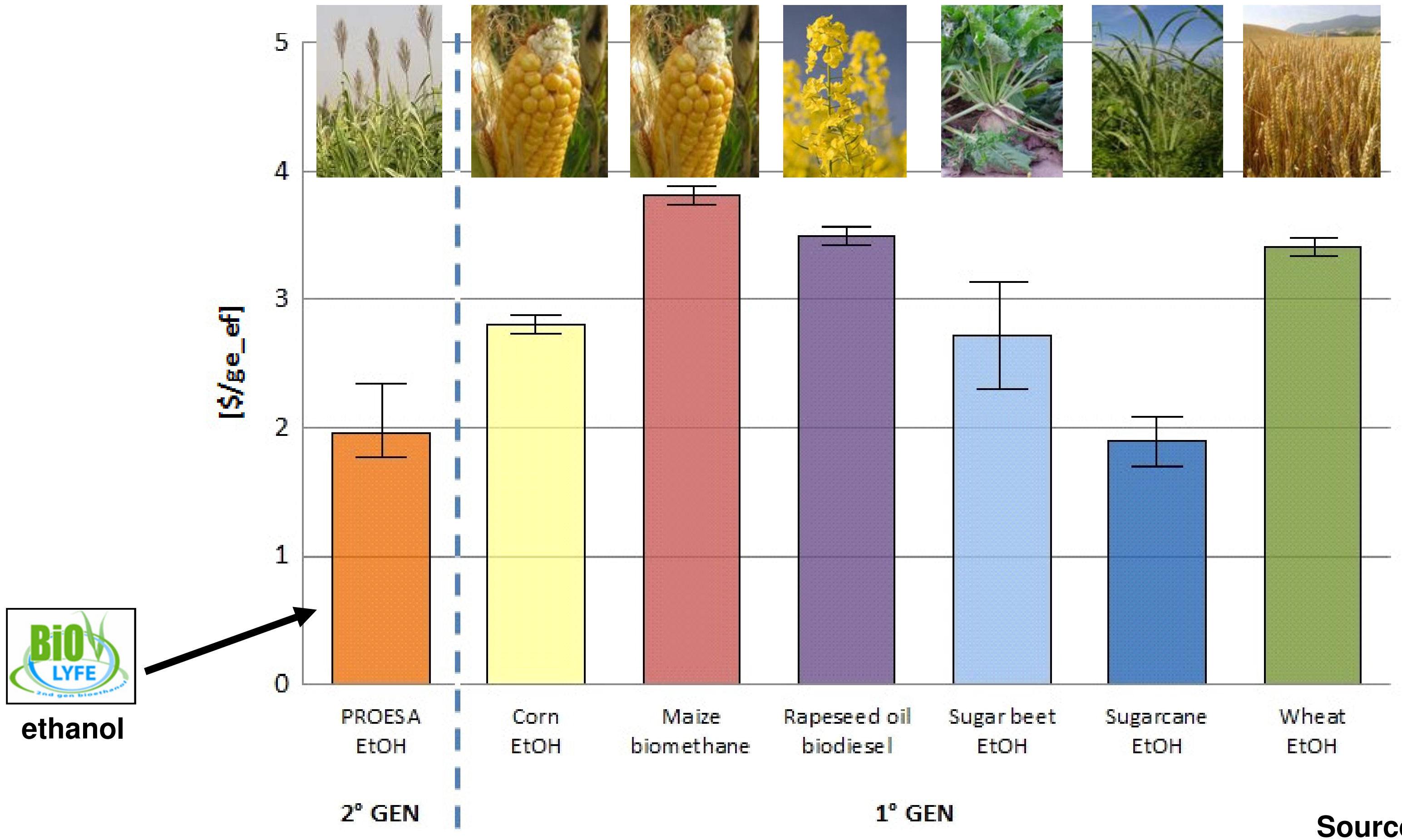
Production costs of Biolyfe bioethanol and several BTL* fuels



Source: Biochemtex 2013

* BTL: Biomass-to-liquid fuel

Production costs of Biolyfe ethanol and other biofuels from different feedstocks



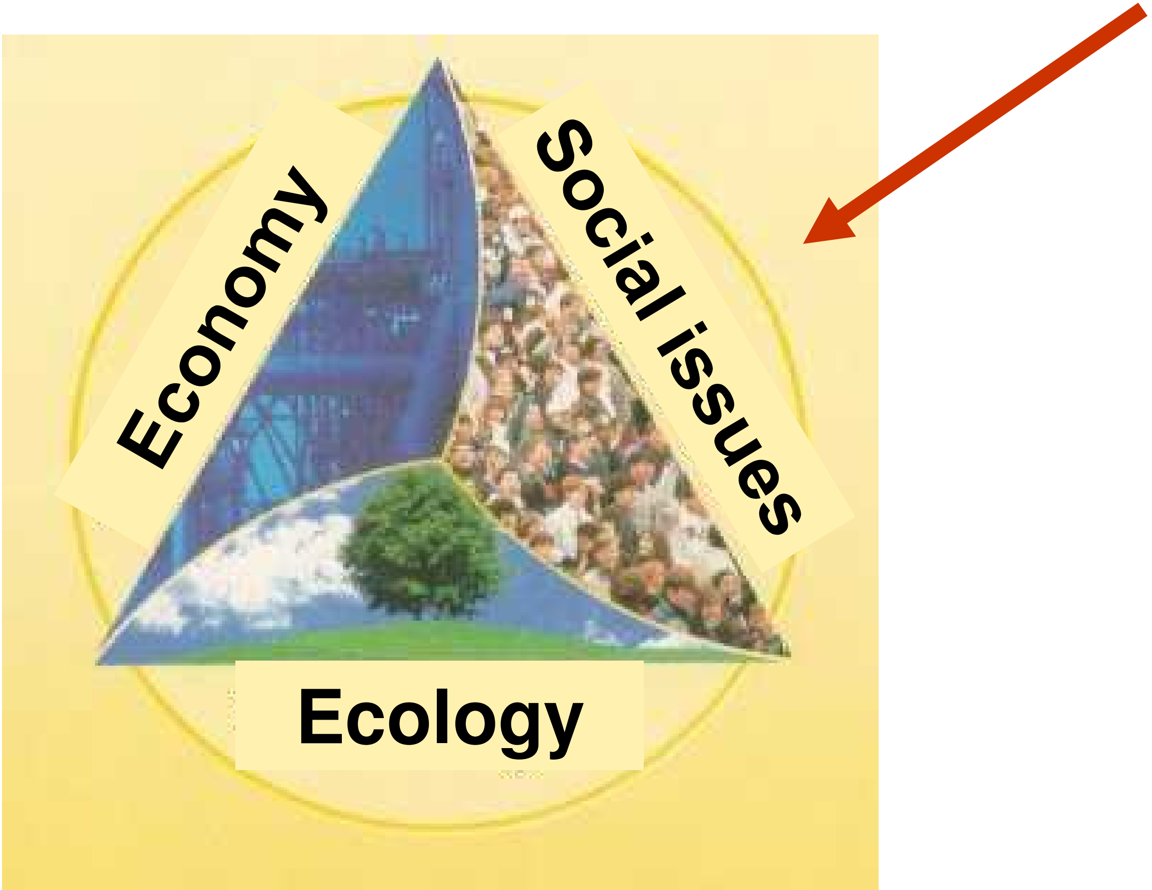
Source: Biochemtex 2013

Production costs of Biolyfe ethanol and other biofuels from different feedstocks

- ➔ **All biofuels investigated cannot compete with the production costs of fossil fuels as of today.**

- ➔ **According to Biochemtex calculations, the production costs of Biolyfe ethanol from Arundo and straw can easily compete with those of conventional biofuels and have even a big potential to be more competitive than most of them.**

The principle of sustainability



SWOT analysis

- **SWOT analysis evaluates Strengths, Weaknesses, Opportunities, and Threats (involved in a business venture).**
- **Factors which are internal to the system investigated are classified as strengths (S) or weaknesses (W).**
- **Factors which are external to the system investigated are classified as opportunities (O) or threats (T).**

	Positive	Negative
Internal	Strength	Weakness
External	Opportunity	Threat

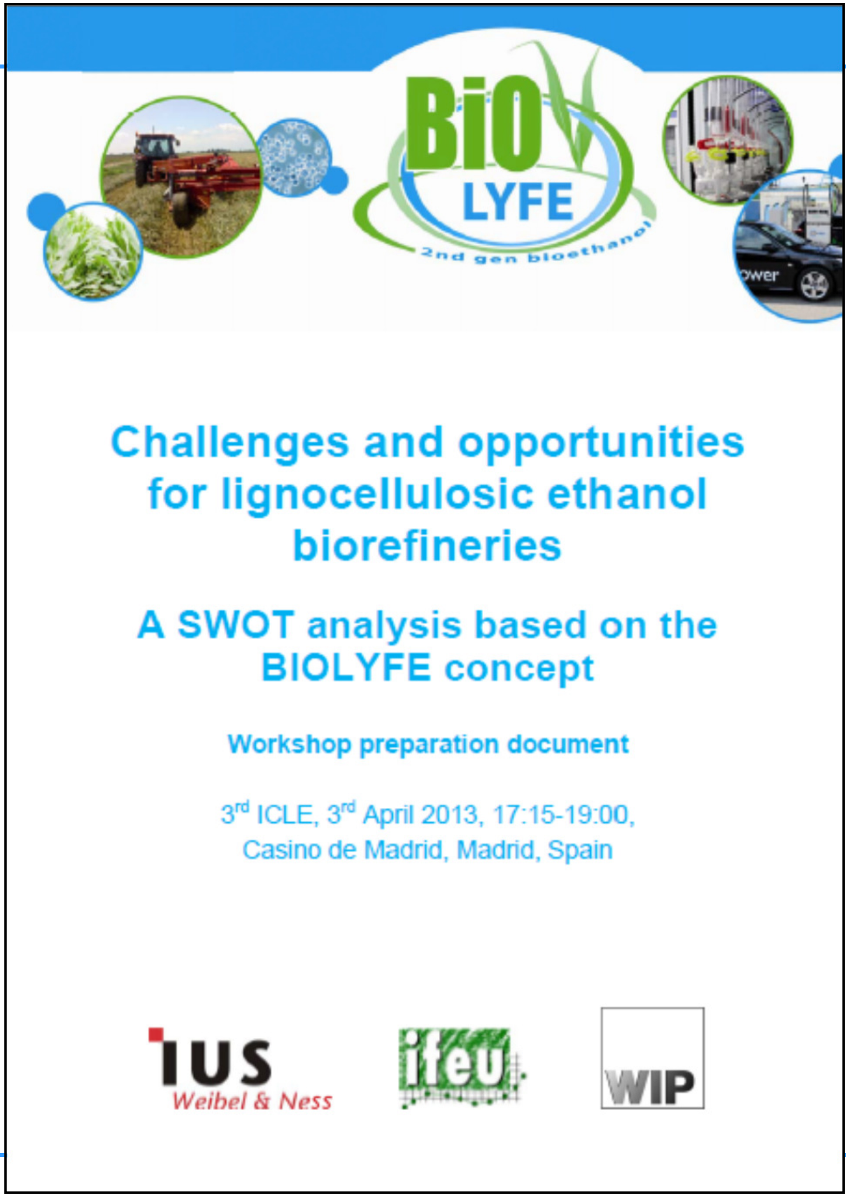
Example for SWOT results for biorefinery

Strengths	Weaknesses
• Adding value to the use of biomass • Maximising biomass conversion efficiency minimising raw material requirements • Production of a spectrum of bio-based products (food, feed, materials, chemicals) and bioenergy (fuels, power and/or heat) feeding entire bioeconomy • Strong knowledge infrastructure available to tackle technical and non-technical issues • Biorefinery is not new, it builds on agriculture, food and forestry industries • Stronger focus on drop-in chemicals facilitating market penetration	• Broad undefined and unclassified area • Involvement of stakeholders for different market sectors (agriculture, forestry, energy, chemical) over full biomass value chain necessary • Most promising biorefinery processes/concepts not clear • Most promising biomass value chains, including current/future market volumes/prices, not clear • Studying and concept development instead of real market implementation • Variability of quality and energy density of biomass
Opportunities	**Threats**
• Biorefineries can make a significant contribution to sustainable development • Challenging national and global policy goals, international focus on sustainable use of biomass for the production of bioenergy • International consensus on the fact that biomass availability is limited meaning that raw materials should be used as efficiently as possible – i.e. development of multi-purpose biorefineries in a framework of scarce raw materials and energy • International development of a portfolio of biorefinery concepts, including technical processes • Strengthening of the economic position of various market sectors (e.g. agriculture, forestry, chemical and energy) • Strong demand from brand owners for biobased chemicals	• Economic change and volatility in fossil fuel prices • Fast implementation of other renewable energy technologies feeding the market requests • Bio-based products and bioenergy are assessed to a higher standard than traditional products (no level playing field) • Availability and contractibility of raw materials (e.g. climate change, policies, logistics) • (High) investment capital for pilot and demo initiatives difficult to find, and undepreciated existing industrial infrastructure • Changing governmental policies • Questioning of food/feed/fuels (indirect land use competition) and sustainability of biomass production • Goals of end users often focused on single product

Source: IEA Bioenergy, Task 42 Biorefinery

Biolyfe International SWOT Workshop 2013

SEVENTH FRAMEWORK PROGRAMME


BiO LYFE
2nd gen bioethanol

Challenges and opportunities for lignocellulosic ethanol biorefineries

A SWOT analysis based on the BIOLYFE concept

Workshop preparation document

3rd ICLE, 3rd April 2013, 17:15-19:00,
Casino de Madrid, Madrid, Spain

IUS Weibel & Ness
ifeu
WIP

→ > 200 international delegates and experts

→ Finalization of SWOT Biolyfe analysis

SWOT results for BIOLYFE

SEVENTH FRAMEWORK PROGRAMME

Strengths:

- S1: **Renewable resource:** can be used as alternative to fossil fuels. Contributi
- S2: Can c opportuni
- S3: Can c
- S4: Introd **species c** systems.
- S5: **No di**

Weaknesses:

- W1: **Need for arable land** (in some cases: only marginal land) to cu Th co
- W ex
- W

Opportunities:

- O1: **Rising market opportunities for biofuels** as fossil fuels become scarcer
- O2: rese **ava**

Threats:

- T1: **Market price might be too low** compared to production costs (competition with other energy carriers).

➔ **Many SWOT indicators have been identified and assessed**

➔ **Need for prioritization and/or ranking of the results**

➔ **Dedicated extraction of results with respect of social assessment**




Social assessment

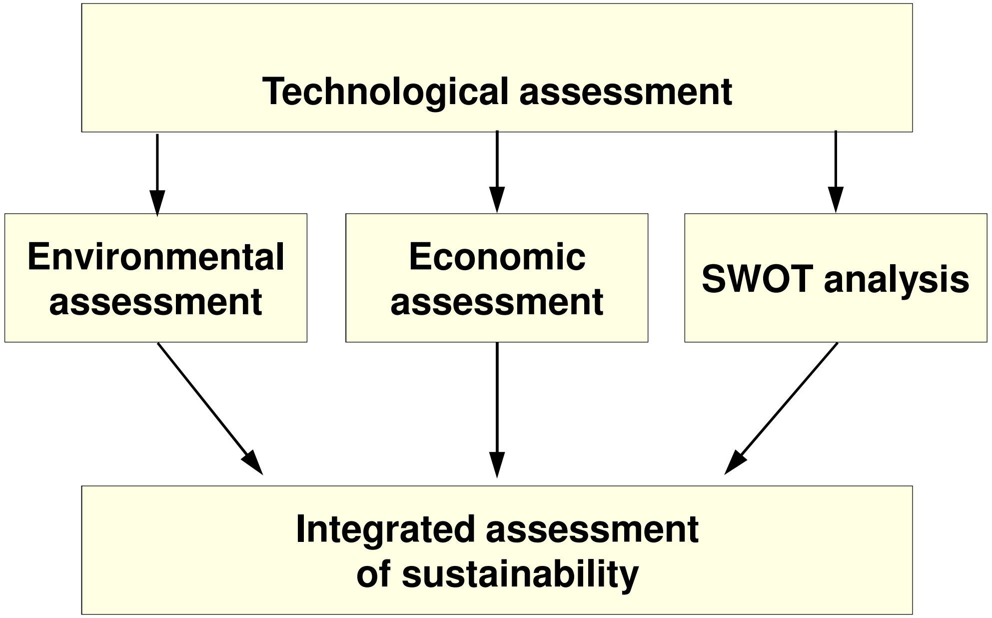
	BIOLYFE scenarios				Alternatives to BIOLYFE					
	Arundo	Fibre sorghum	Wheat straw	Marginal land (Arundo)	BTL (Arundo)	Wheat ethanol	Beet ethanol	Cane ethanol (Brazil)	Rape seed biodiesel	Maize bio-methane
Society										
Access to land (local comm. & farmers)	– –	– –	0	–	– –	– –	– –	– –	– –	– –
Access to jobs & income (local comm. & farmers)	+	+	++	++	+	+	+	0	+	+
Acceptance (local comm. & farmers)	– –	+	++	++	– –	+	+	+	+	+
Acceptance (general society)	–	– –	–	–	–	– –	– –	– –	– –	– –
Contribution to innovation (general society)	++	+	+	++	++	0	0	0	0	0

Ranking by 5 categories: ++ | + | 0 | – | – –

Source: IUS / IFEU 2013




Flow chart of “Integrated assessment of sustainability”



Integrated assessment of sustainability

		BIOLYFE scenarios				Alternatives to BIOLYFE					
		Arundo	Fibre sorghum	Wheat straw	Marginal land (Arundo)	BTL (Arundo)	Wheat ethanol	Beet ethanol	Cane ethanol (Brazil)	Rape seed biodiesel	Maize bio-methane
Technology											
Maturity	-	— —	—	—	— —	— —	0	0	0	0	0
Availability of infrastructure	-	— —	— —	—	— —	— —	0	0	0	0	0
Use of GMOs	-	—	—	—	—	0	0	0	0	0	0
Toxicity risks	-	+	0	+	+	0	0	0	+	0	0
Risk of explosions and fires	-	0	0	0	0	0	+	+	+	+	+
Environment											
Resource depletion: energy	GJ / t ethanol (eq.)	-20	-5	-21	-19	-25	-34	-14	-34	-39	-34
Climate change	t CO_2 eq. / t ethanol (eq.)	-1.1	0.0	-1.3	-1.1	-1.6	-2.1	-1.2	-2.7	-1.9	-1.2
Acidification	kg SO_2 eq. / t ethanol (eq.)	9	17	7	9	5	3	0	12	12	15
Terrestrial eutrophication	kg PO_4 eq. / t ethanol (eq.)	1.0	2.1	0.9	1.0	0.9	0.9	0.2	1.5	2.7	2.6
Aquatic eutrophication	kg PO_4 eq. / t ethanol (eq.)	2.1	7.6	3.1	2.0	N/D	N/D	N/D	N/D	N/D	N/D
Photochem. ozone formation	kg ethene eq. / t ethanol (eq.)	-1.1	-0.9	-1.2	-1.1	-0.9	-1.6	-1.2	[illegible]	[illegible]	-0.7
Ozone depletion	g CFC-11 eq. / t ethanol (eq.)	27	51	26	27	13	12	[illegible]	[illegible]	52	37
Respiratory inorganics	kg PM10 eq. / t ethanol (eq.)	6	11	5	6	2	[illegible]	[illegible]	[illegible]	5	7
Direct agricultural land use	ha·a / t ethanol (eq.)	0.15	0.20	0.00	0.23	[illegible]	[illegible]	[illegible]	0.24	0.94	0.33
Water	-	— —	—	0	—	[illegible]	[illegible]	—	—	—	—
Soil	-	0	—	0	[illegible]	[illegible]	—	— —	0	— —	— —
Fauna	-	0	—	0	[illegible]	[illegible]	—	—	—	—	—
Flora	-	—	—	0	[illegible]	—	—	— —	—	—	— —
Landscape	-	0	0	0	0	0	0	0	—	0	0
Economy											
Production costs	€ / t ethanol (eq.)	485	602	474	485	900	850	670	470	860	940
Cost difference to gasoline*	€ / t ethanol (eq.)	-115	-232	-104	-115	-530	-480	-300	-100	-490	-570
Fixed capital investment	Million €	89	103	88	100	N/D	N/D	N/D	N/D	N/D	N/D
CO2 avoidance costs	€ / t CO_2 eq.	101	N/A	82	103	323	224	250	38	263	456
Energy resource savings costs	€ / GJ	6	46	5	6	21	14	22	3	12	17
Society											
Access to land (local comm. & farmers)	-	— —	— —	0	—	— —	— —	— —	— —	— —	— —
Access to jobs & income (local comm. & farmers)	-	+	+	++	++	+	+	+	0	+	+
Acceptance (local comm. & farmers)	-	— —	+	++	++	— —	+	+	+	+	+
Acceptance (general society)	-	—	— —	—	—	—	— —	— —	— —	— —	— —
Contribution to innovation (general society)	-	++	+	+	++	++	0	0	0	0	0

Result example

Ranking by 5 categories: ++ | + | 0 | — | — —

Source: IUS / IFEU 2013




Conclusions I (selection)

- Biolyfe ethanol compares to gasoline with the same result pattern as most other biofuels sharing benefits with drawbacks.
- Compared to other biofuels, Biolyfe ethanol shows a remarkable set of benefits especially if produced from Arundo on marginal land and straw.
- Biolyfe ethanol is not a self running story: not all pathways are genuinely sustainable, though most of them have the potential to being directed into being best possible sustainable. For its further market introduction, there is still need for incentives for a certain transition period by e.g. political measures.




Conclusions II (selection)

- **It was proved that the methodology of the "integrated assessment of sustainability" works well and is very powerful.**
- **With this, it is worth it to expand the standards of environmental LCA and upcoming economic LCC and social sLCA supplementary with the environmental LC-EIA and SWOT. This should become a standard in future sustainability assessments.**
- **With respect to Biolyfe ethanol, it was shown, that there are some action fields for either improvement or optimisation such as**
  - to assure always a sustainable biomass production
  - optimise energy integration and most efficient energy use
  - improve enzyme efficiency and minimise enzyme production impacts
  - use BAT (best available technologies) in all process units
  - et cetera




Recommendations I (selection)

Many recommendations have been identified for several stakeholders such as for politicians, researchers, companies, and farmers. Some important include:

- **Politicians: If it is a political goal to introduce second generation fuels make sure to guarantee sufficient incentives for a certain transition period.**
- **Politicians: Develop and agree on both, a biomass allocation and land use allocation plan.**
- **Politicians: Implement compulsory regional planning tools.**




Recommendations II (selection)

- **Companies:**
  - Use only sustainable produced biomass
  - Use BAT in all processes
  - Optimise energy provision, integration and use et cetera
- **Farmers:**
  - Guarantee long term soil fertility when straw extraction
  - Guarantee sustainable biomass production et cetera
- **Researchers:**
  - For sustainability assessment use integrated tool
  - Optimise enzyme efficiency and production impacts
  - Optimise process integration for ethanol purification
  - Optimise the use of fermentation residues et cetera

Integrated sustainability assessment of BIOLYFE second generation bioethanol

(Deliverable 12.3: Final report)

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← **Further reading**




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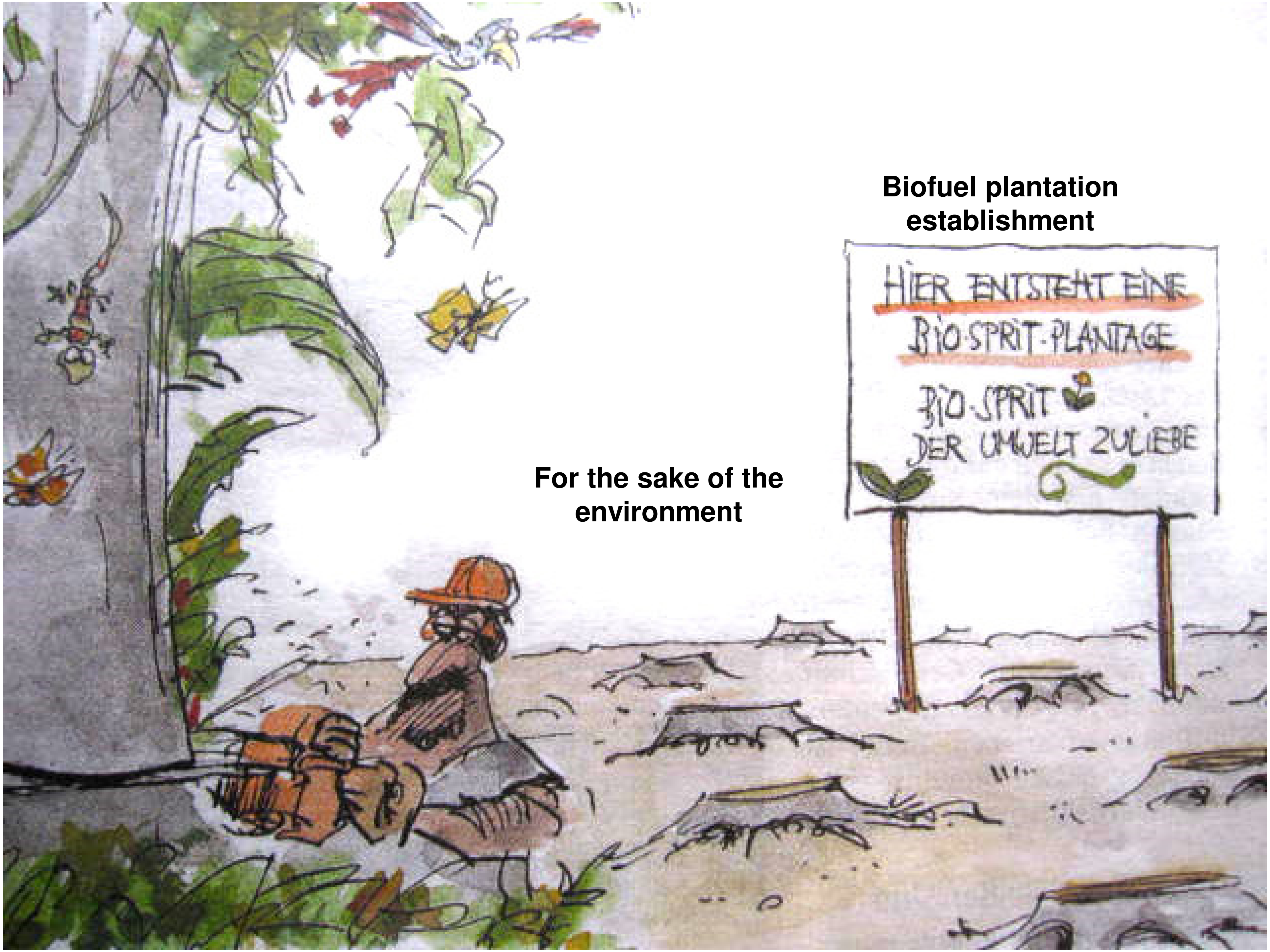
Concluding remark

Biolyfe ethanol has a remarkable potential to become a sustainable biofuel in the future. Still, it is not a self running story and quite some homeworks are still due for all stakeholders: politicians, researchers, industry and farmers.


Biofuel plantation establishment
HIER ENTSTEHT EINE
BIO-SPRIT-PLANTAGE
BIO-SPRIT
DER UMWELT ZULIEBE
For the sake of the environment




Thank you very much for your attention

Dr Guido Reinhardt

Questions ?

…… don‘t hesitate to ask !

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