ifeu – Institute for Energy and Environmental Research Heidelberg, Germany

Environmental Assessment of Energy Sorghum

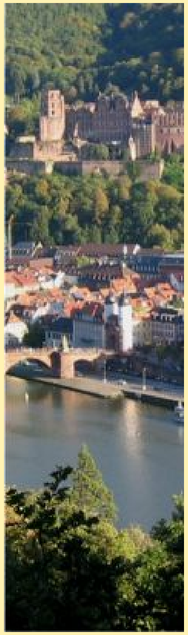
Dr Guido Reinhardt &

Dr Christine Cornelius

SWEETFUEL Regional Stakeholder Workshop

Hamburg, 26 June 2014

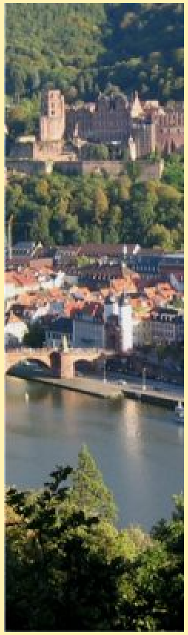
Who we are - What we do



IFEU - Institute for Energy and Environmental Research Heidelberg, since 1978

- **Independent scientific research institute**
- **Organised as a private non profit company with currently about 50 employees**
- **Research / consulting on environmental aspects of**
  - Energy (including Renewable Energy)
  - Transport
  - Waste Management
  - Life Cycle Analyses
  - Environmental Impact Assessment
  - Renewable Resources
  - Environmental Education

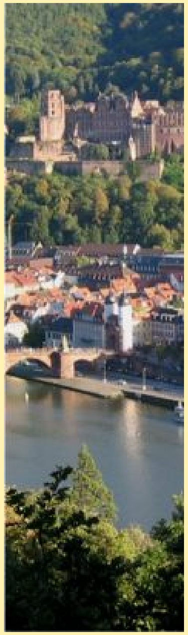
Who we are - What we do



IFEU focuses regarding the topic of biomass

- Research / consulting on environmental aspects of
  - transport biofuels
  - biomass-based electricity and heat
  - biorefinery systems
  - biobased materials
  - agricultural goods and food
  - cultivation systems (conventional agriculture, organic farming, etc.)
- Potentials and future scenarios
- Technologies / technology comparisons
- CO_2 avoidance costs
- Sustainability aspects / valuation models

Who we are - What we do



IFEU - Institute for Energy and Environmental Research Heidelberg, since 1978

- **Our clients (on biofuel studies)**
  - World Bank
  - UNEP, GIZ, UNIDO, UNFCCC, FAO etc.
  - European Commission
  - National and regional Ministries
  - Associations (national and international)
  - Local authorities
  - NGOs: WWF, Greenpeace, Friends of the earth etc.
  - Companies (DaimlerChrysler, German Telekom, etc.)
  - Foundations

> 20 years of experience

F + E-Vorhaben des Umweltbundesamtes
Nr. 104 08 508/02

Endbericht

Energie- und CO_2-Bilanz von Rapsöl und Rapsölester im Vergleich zu Dieselkraftstoff

ifeu – Institut für Energie- und Umweltforschung Heidelberg
Fachbereich „Verkehr und Umwelt“

Dezember 1991

First full life cycle balance on biodiesel in Europe

1991

Background

Sweet Sorghum – an alternative energy crop

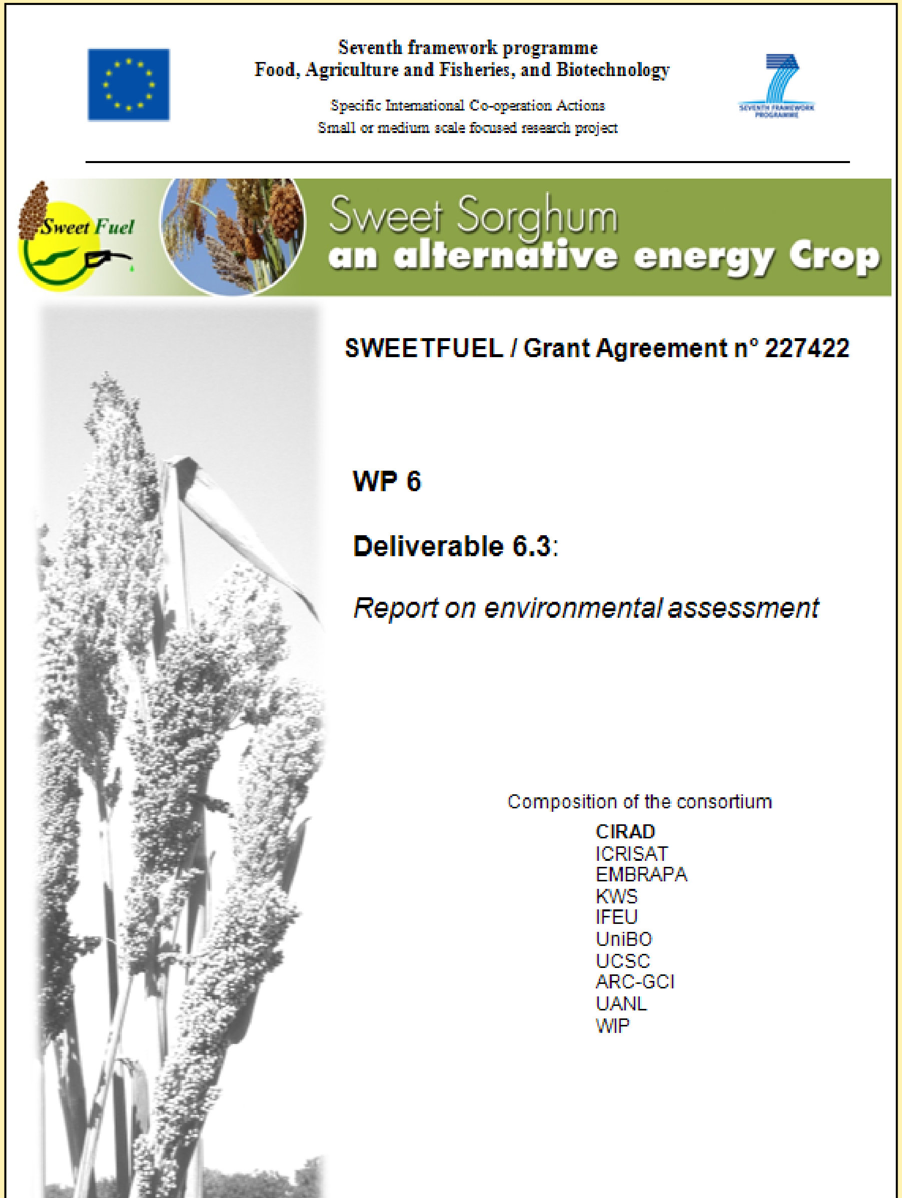
- **Project Number: 227422**
- **Funded by EU FP7 Programme**
- **Project leader: CIRAD**
- **Partners: ICRISAT, EMPRABA, IFEU, KWS, UNIBO, UCSC, ARC-CGI, UANL, WIP**

Objective:

Develop bio-ethanol production in temperate and semi arid regions from sweet sorghum through genetic enhancement and improvement of cultural and harvest practices

http://www.sweetfuel-project.eu/

Background



Seventh framework programme
Food, Agriculture and Fisheries, and Biotechnology

Specific International Co-operation Actions
Small or medium scale focused research project

Sweet Fuel

Sweet Sorghum
an alternative energy Crop

SWEETFUEL / Grant Agreement n° 227422

WP 6

Deliverable 6.3:

Report on environmental assessment

Composition of the consortium

CIRAD
ICRISAT
EMBRAPA
KWS
IFEU
UniBO
UCSC
ARC-GCI
UANL
WIP

Report on environmental assessment

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The SWEETFUEL project is funded by the EU FP7 Programme

Sorghum variants

➔ Sweet sorghum

Sorghum cultivars with juicy stems and high juice sugar content in their stalks; potentially used as an energy and / or food crop

➔ Biomass sorghum

Sorghum cultivars with high lignocellulosic biomass yield, potentially used as energy crop

- **Fibre sorghum**

  Sorghum cultivars with a high content of fibre; potentially used as fibre or energy crop

- **Grain sorghum**

  Sorghum cultivars with high grain yield established as food and feed crop

Outline

- Background
- ➔ Biomass sorghum pathways
- Sweet sorghum pathways
- Conclusions and recommendations
- Outlook

Biofuels for transportation

Environmental advantages and disadvantages:

+

- CO_2 neutral
- Save energetic resources
- Organic waste reduction
- Less transport
- etc.

–

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

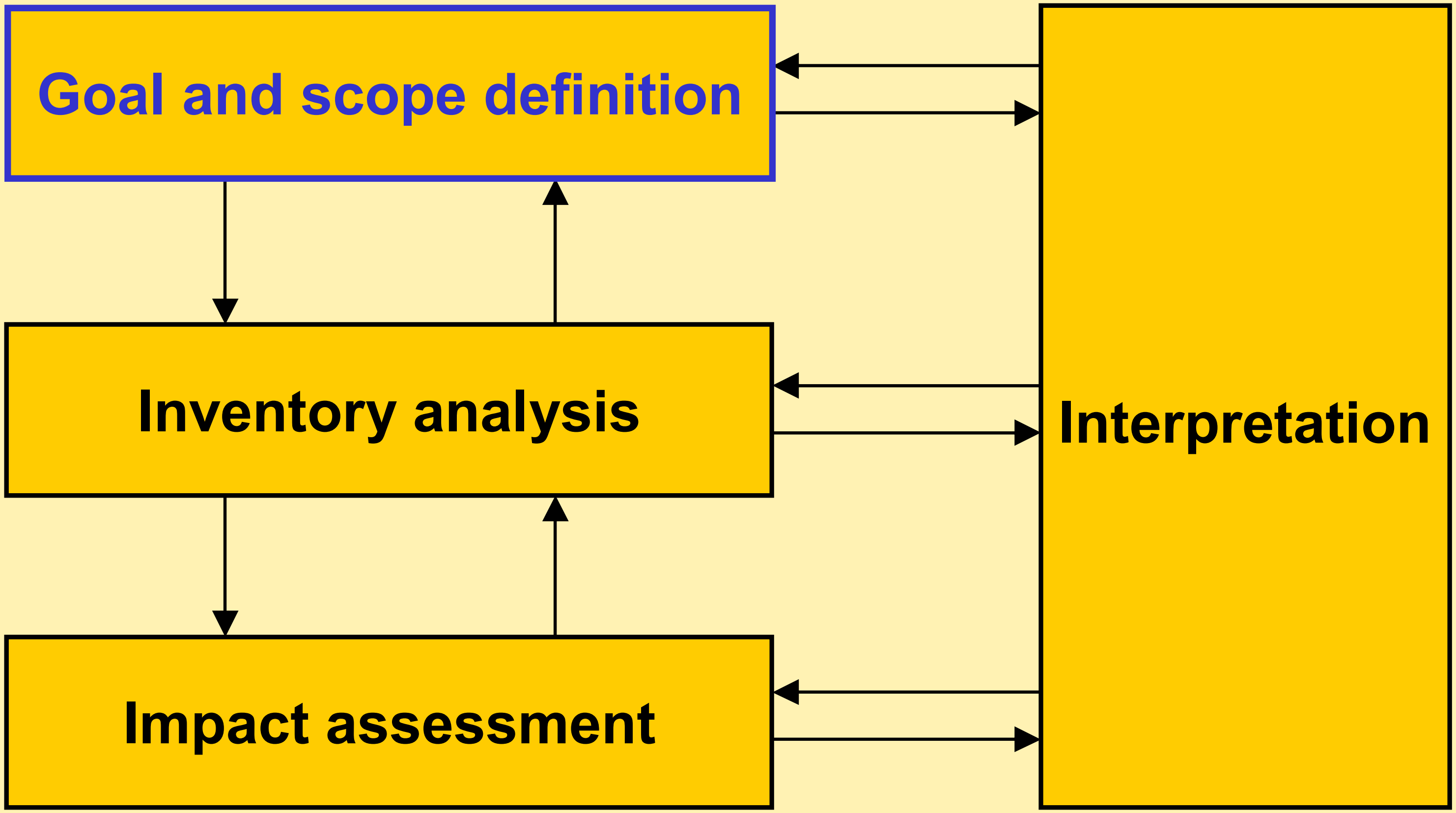
Total:

positive or negative

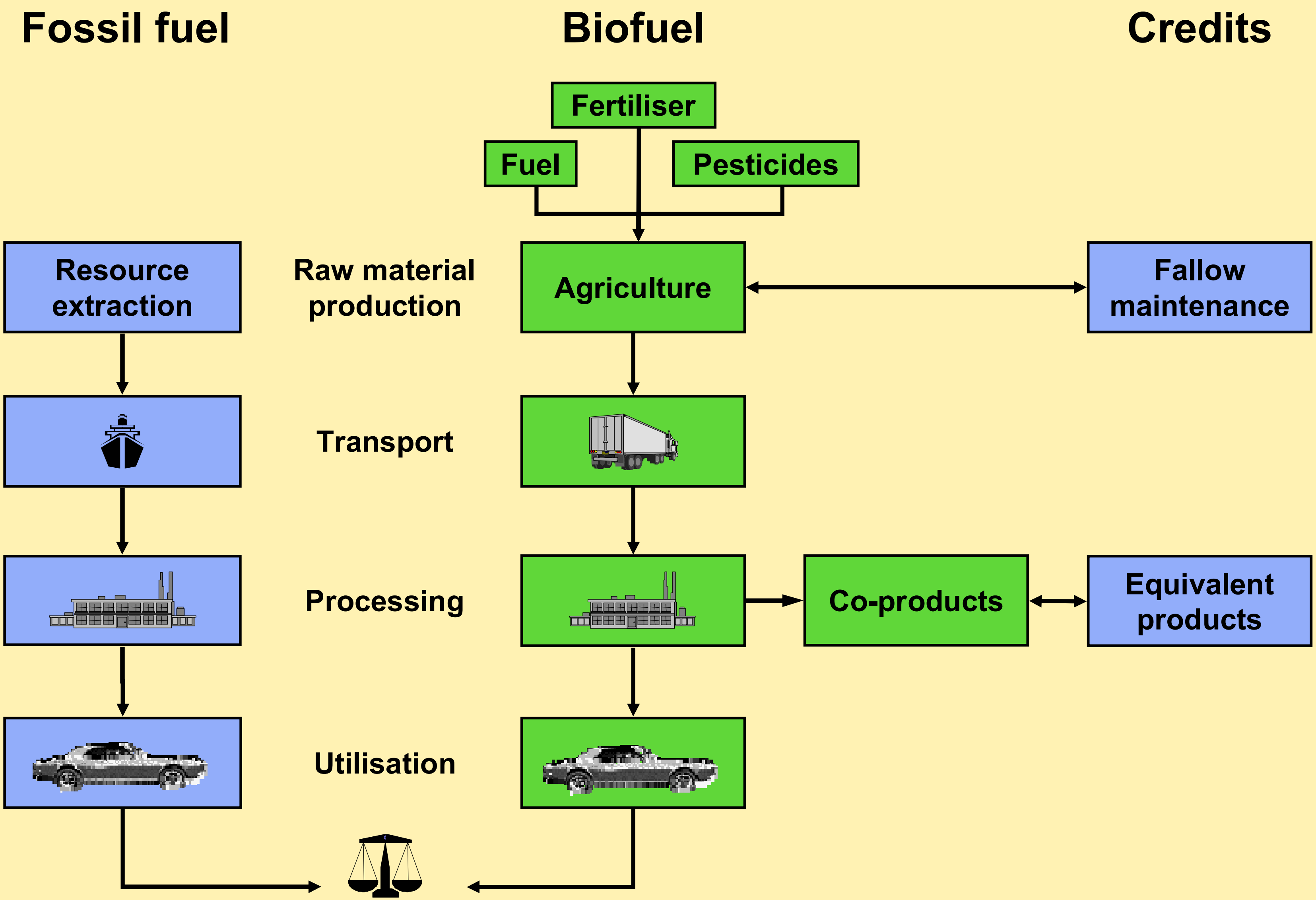
?

Life cycle assessment (LCA)

ISO 14040 & 14044



Life cycle comparison

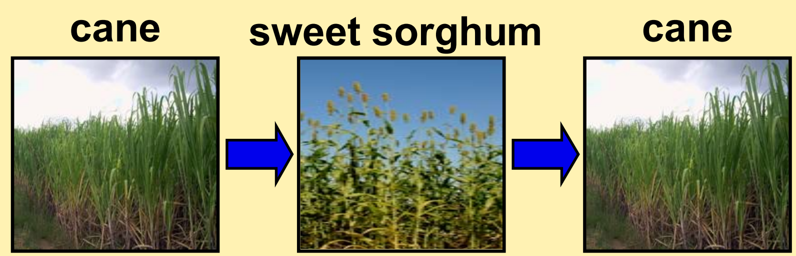


Environmental assessment

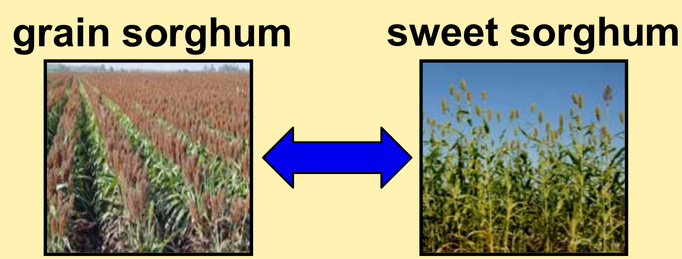
Energy Sorghum scenarios

- **Biomass Sorghum: Biogas**
  Cultivation of biomass sorghum on idle land, biogas or biomethane production, temperate climate zones

- **Sweet Sorghum: Cane fallow**
  Intercropping between two sugar cane cycles instead of peanuts / soy, subtropical to tropical climate

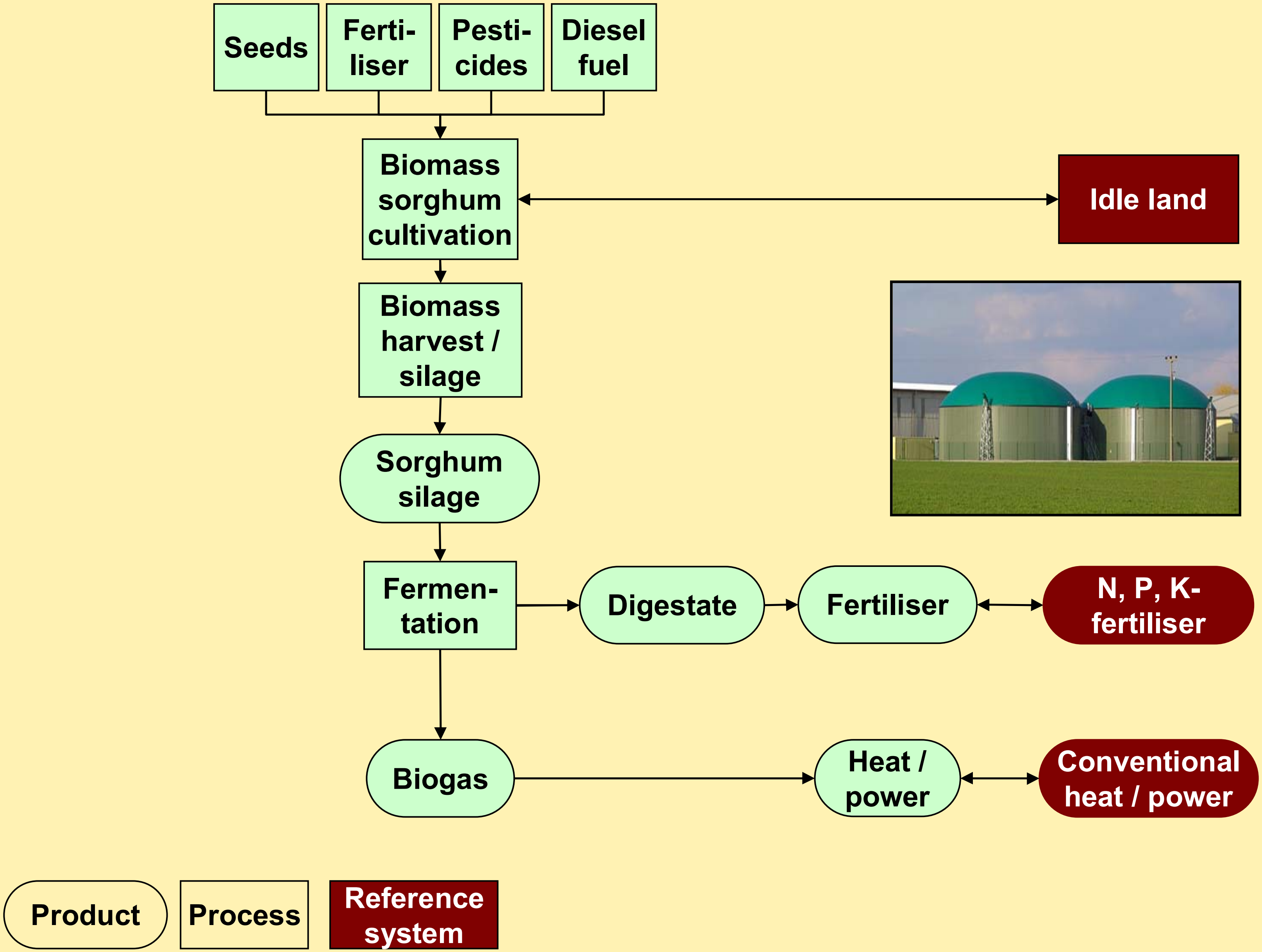


- **Sweet Sorghum: Grain – food**
  Replacement of grain sorghum cultivation, semi-arid climate



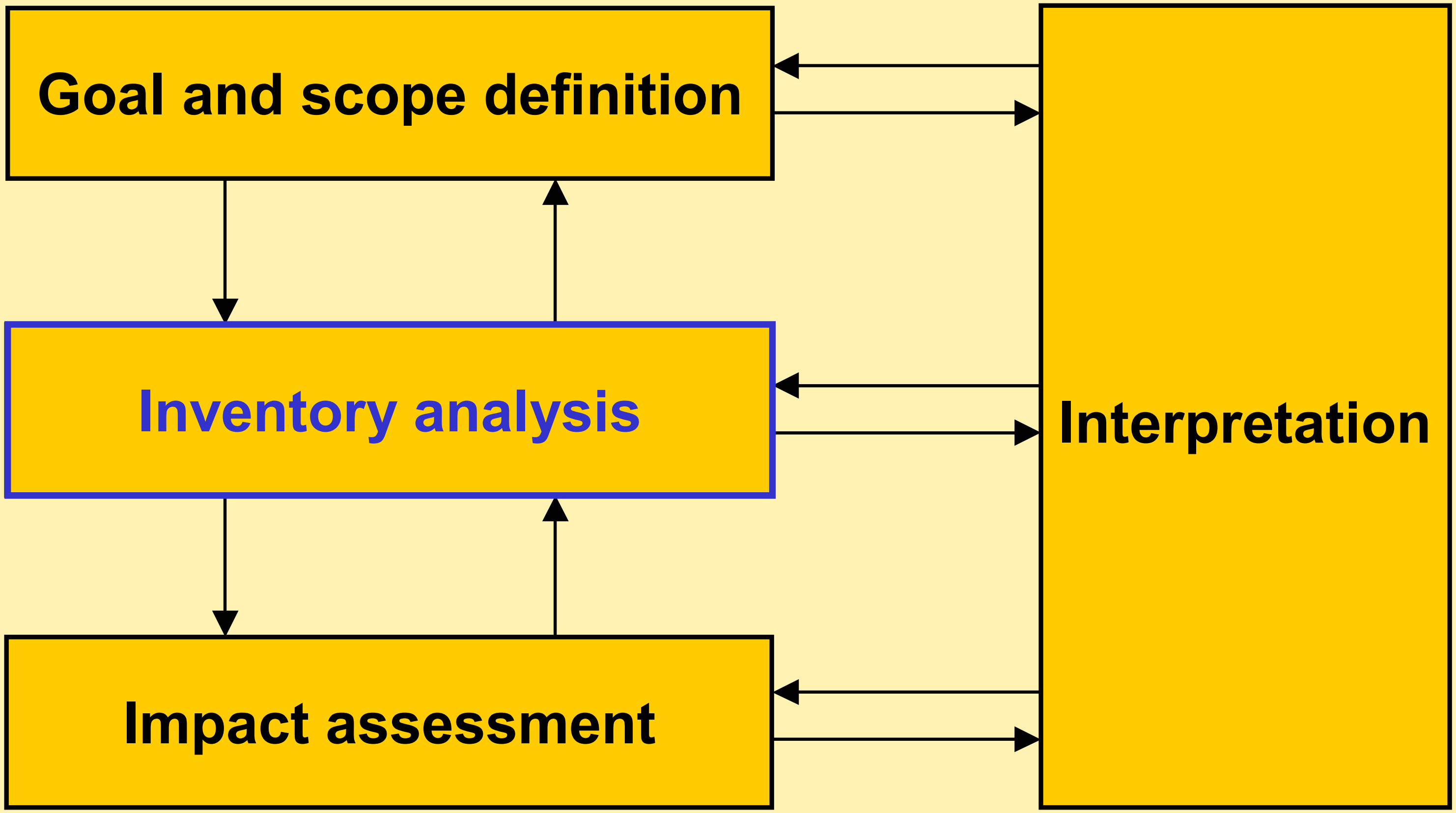
- **Sweet Sorghum: Syrup**
  Replacement of e.g. cotton cultivation, decentralised syrup production, centralised ethanol production, subtropical to tropical climate

Scenario: Biogas



Life cycle assessment (LCA)

ISO 14040 & 14044

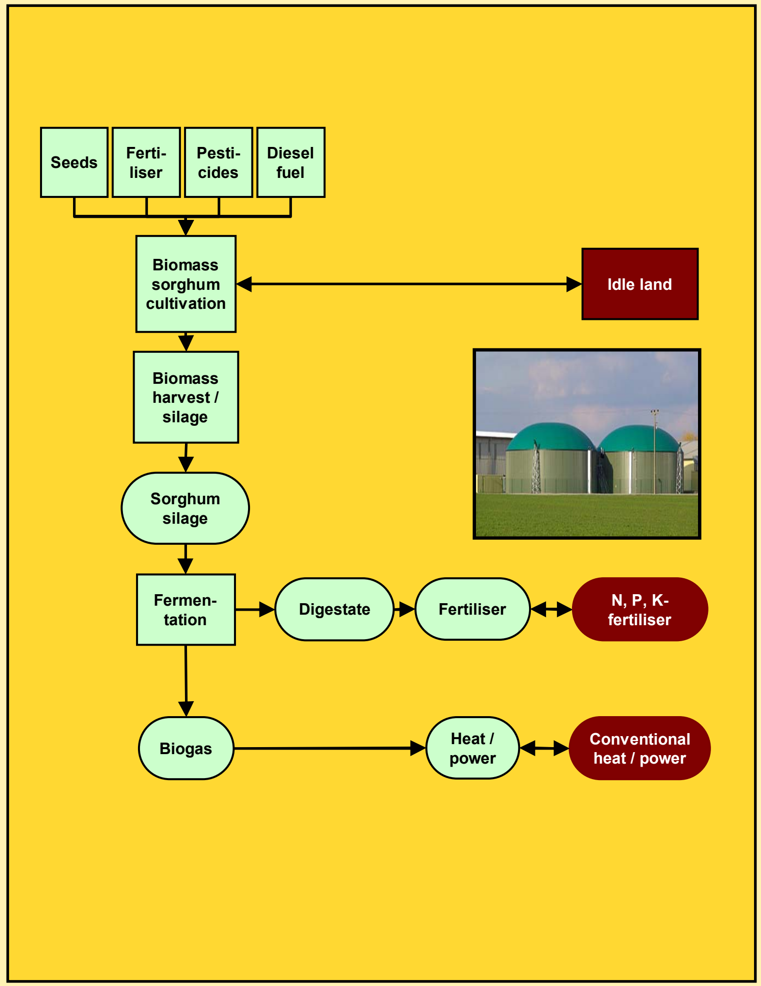


LCA: Inventory analysis

Inputs

e.g.:

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



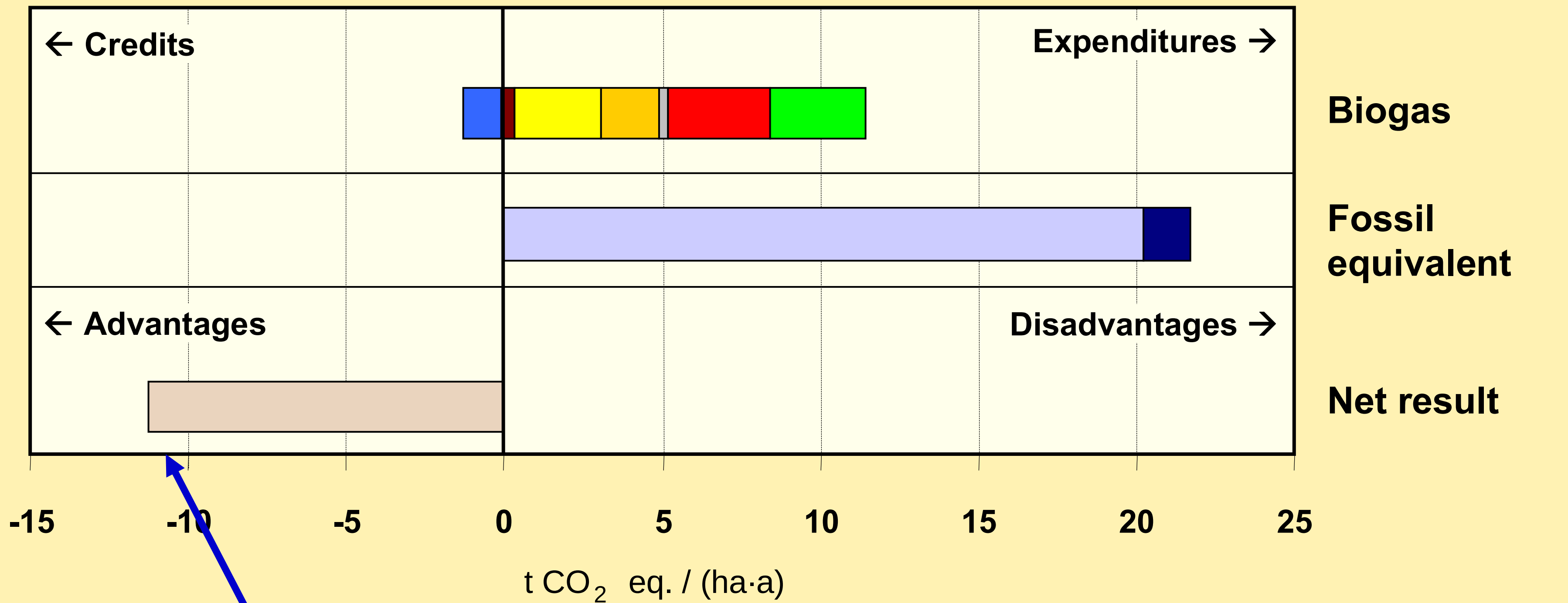
Outputs

e.g.:

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

Sorghum biogas versus natural gas

Greenhouse gas (GHG) balance

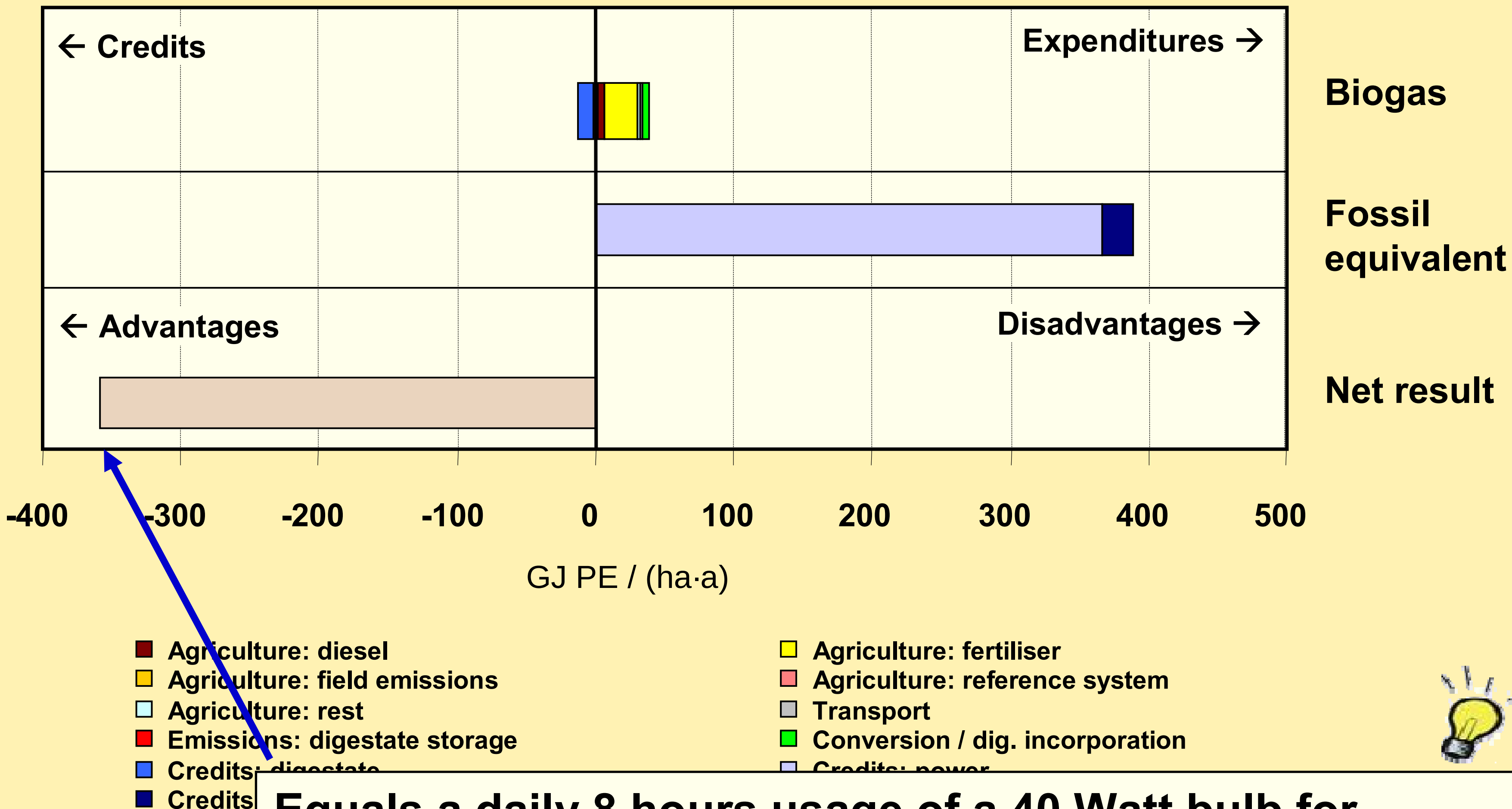


- Agriculture: diesel
- Agriculture: field emissions
- Agriculture: rest
- Emissions: digestate storage
- Credits: dige
- Credits: heat
- Agriculture: fertiliser
- Agriculture: reference system
- Transport
- Conversion / dig. incorporation

Equals a ride with a compact car of about 61.000 km, which is 1,5 times the perimeter of the earth.

Sorghum biogas versus natural gas

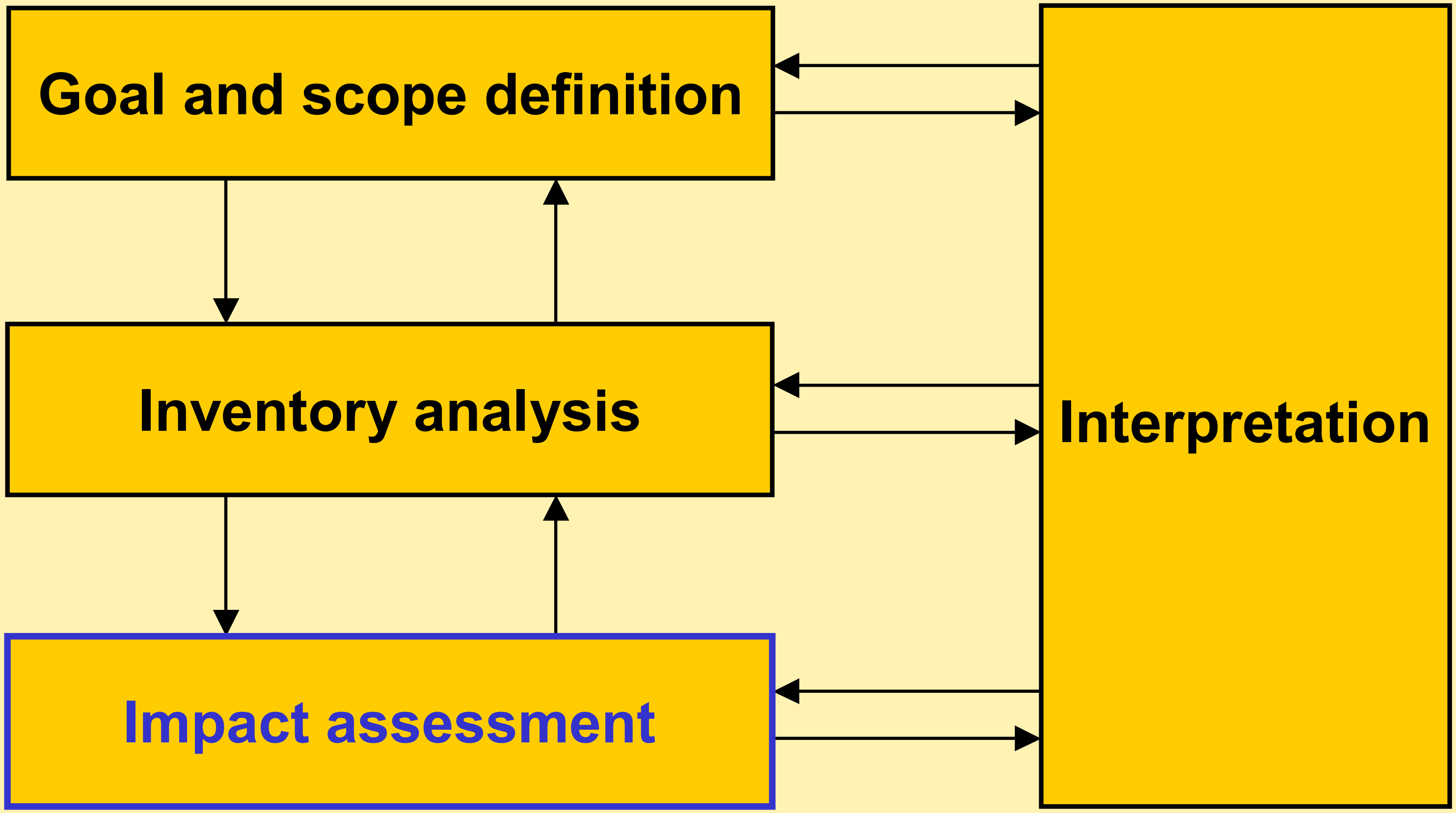
Non-renewable energy demand



Equals a daily 8 hours usage of a 40 Watt bulb for roundabout 286 years

Life cycle assessment (LCA)

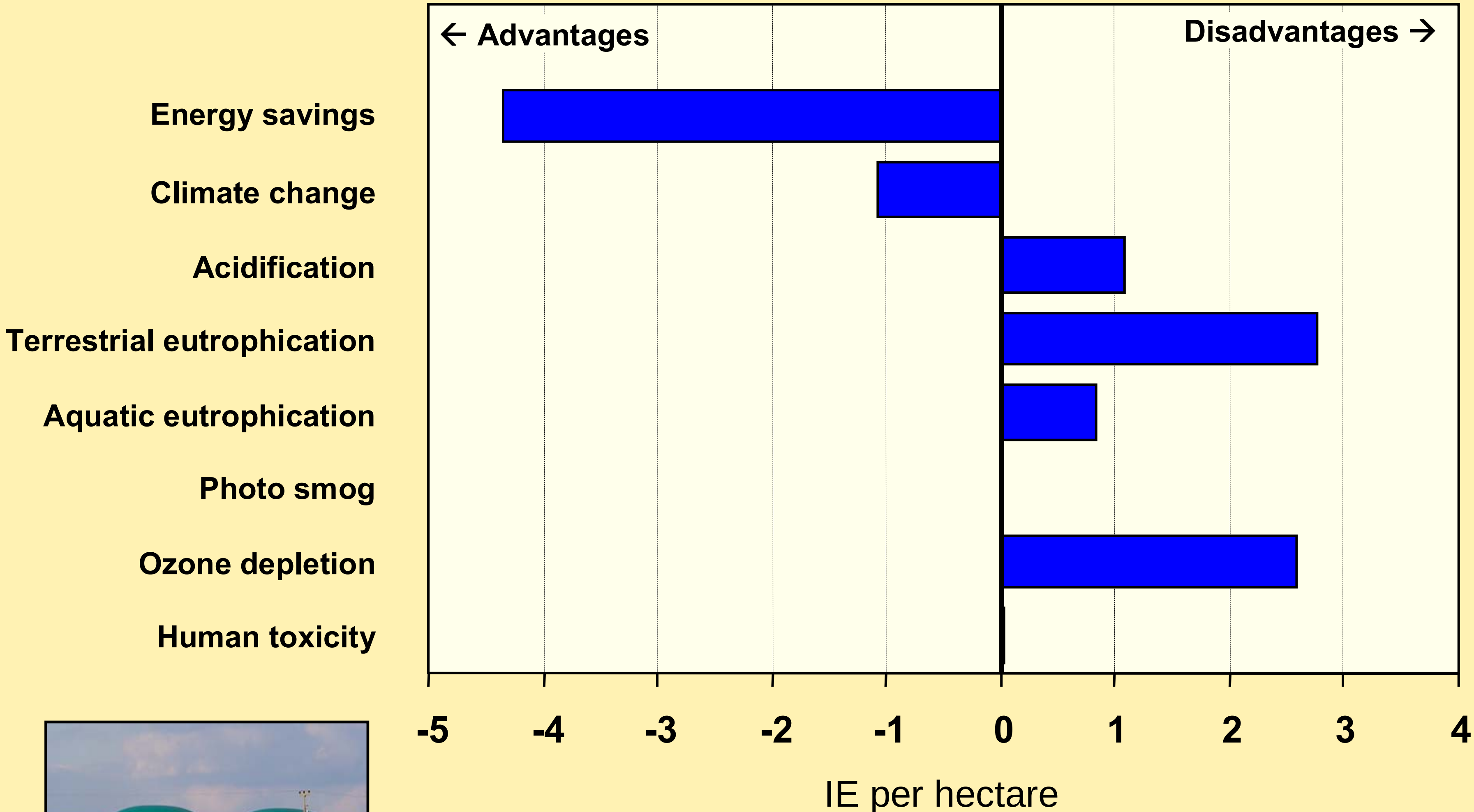
ISO 14040 & 14044



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), …

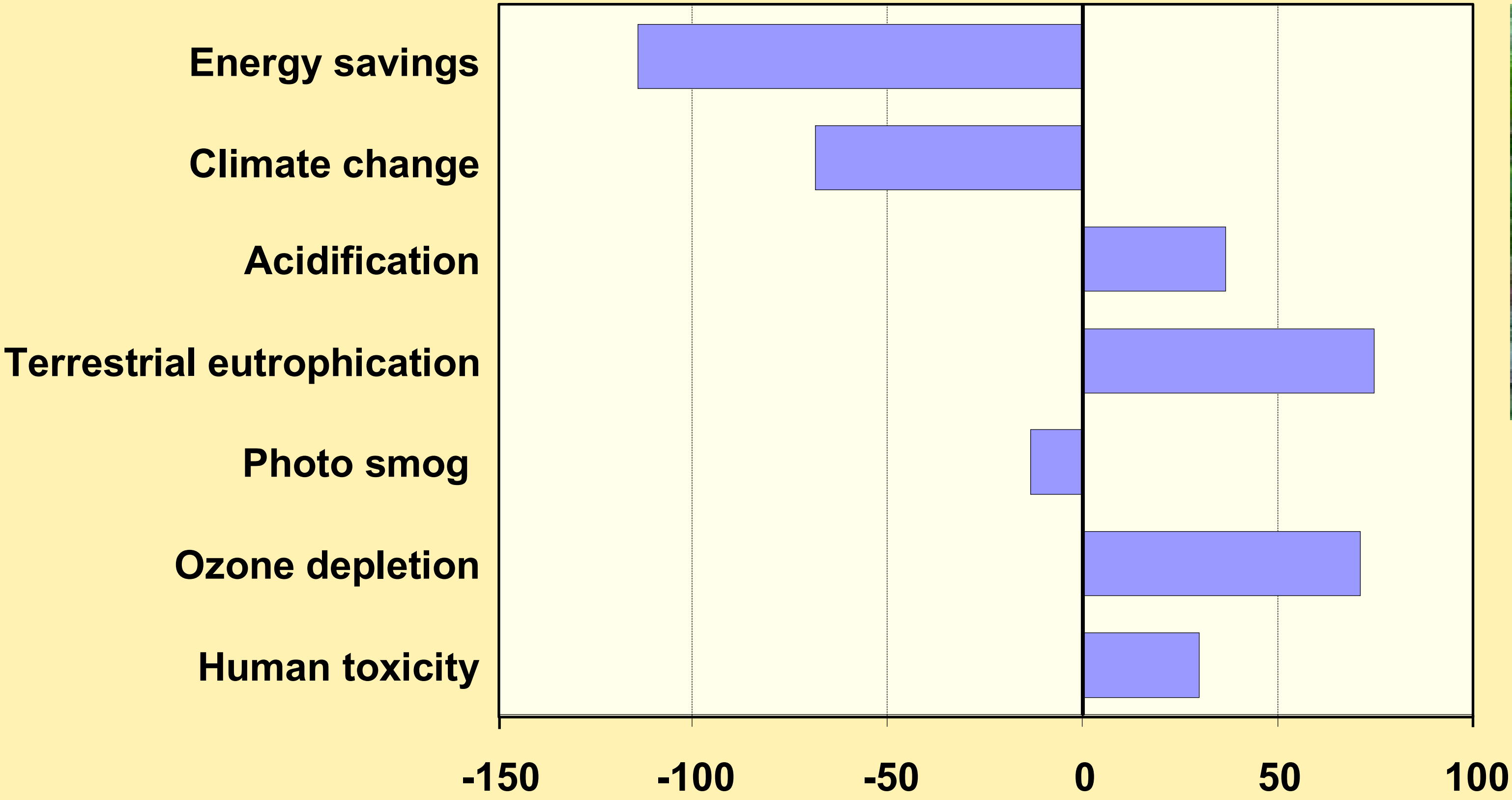
Biogas from sorghum: all impact categories



Source: IFEU 2014

Bioethanol from sugar beet versus gasoline

← Advantages for bioethanol   Advantages for gasoline →

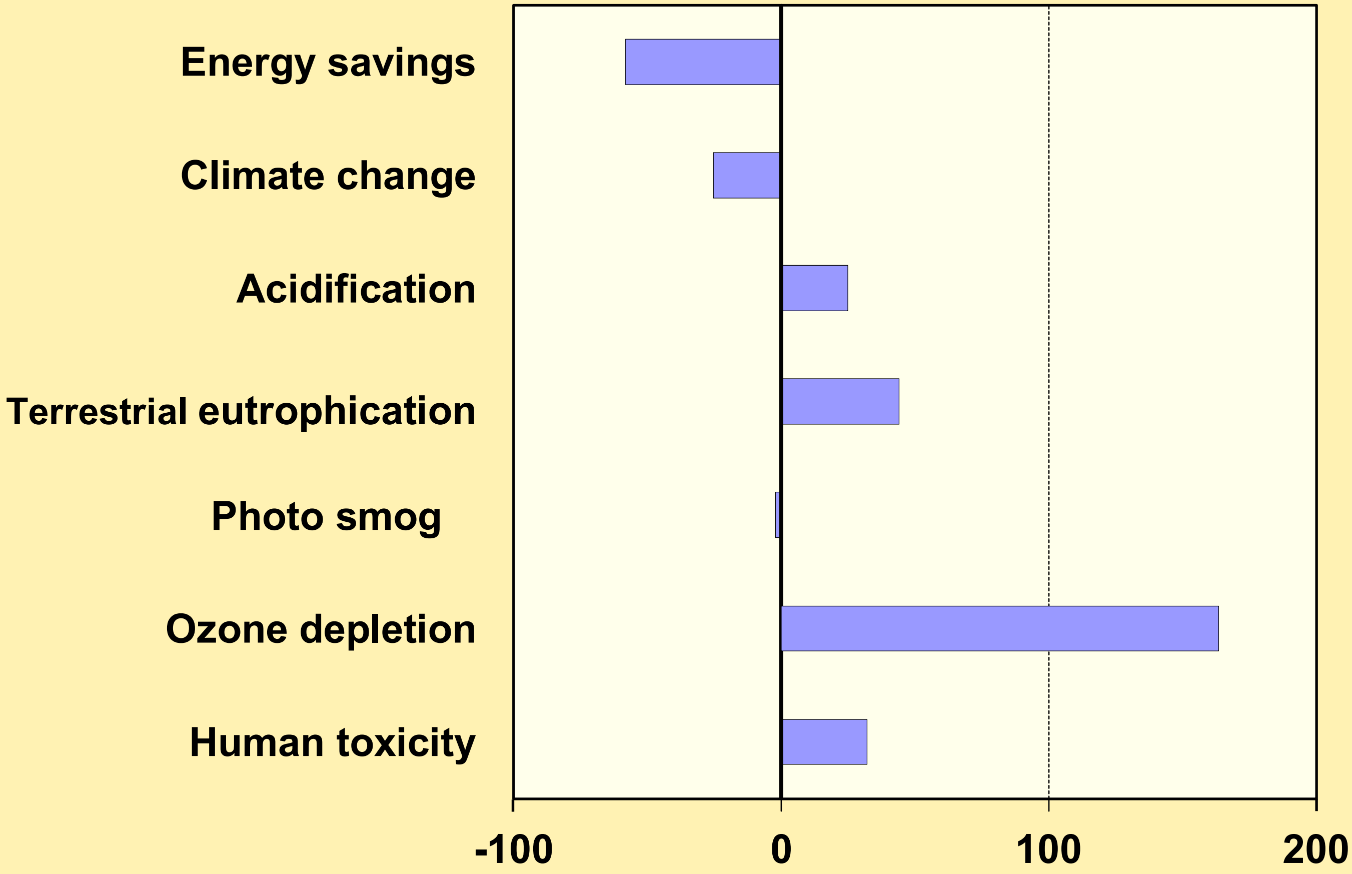


Sugar beet

Source: IFEU 2014

Biodiesel from rape seed versus diesel

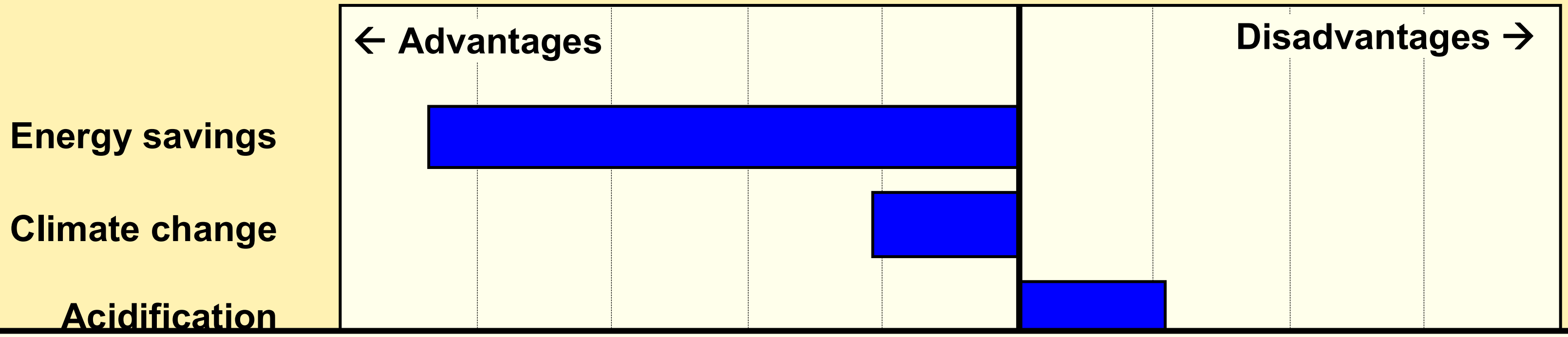
← Advantages for biodiesel Advantages for diesel →



Rape seed

Source: IFEU 2014

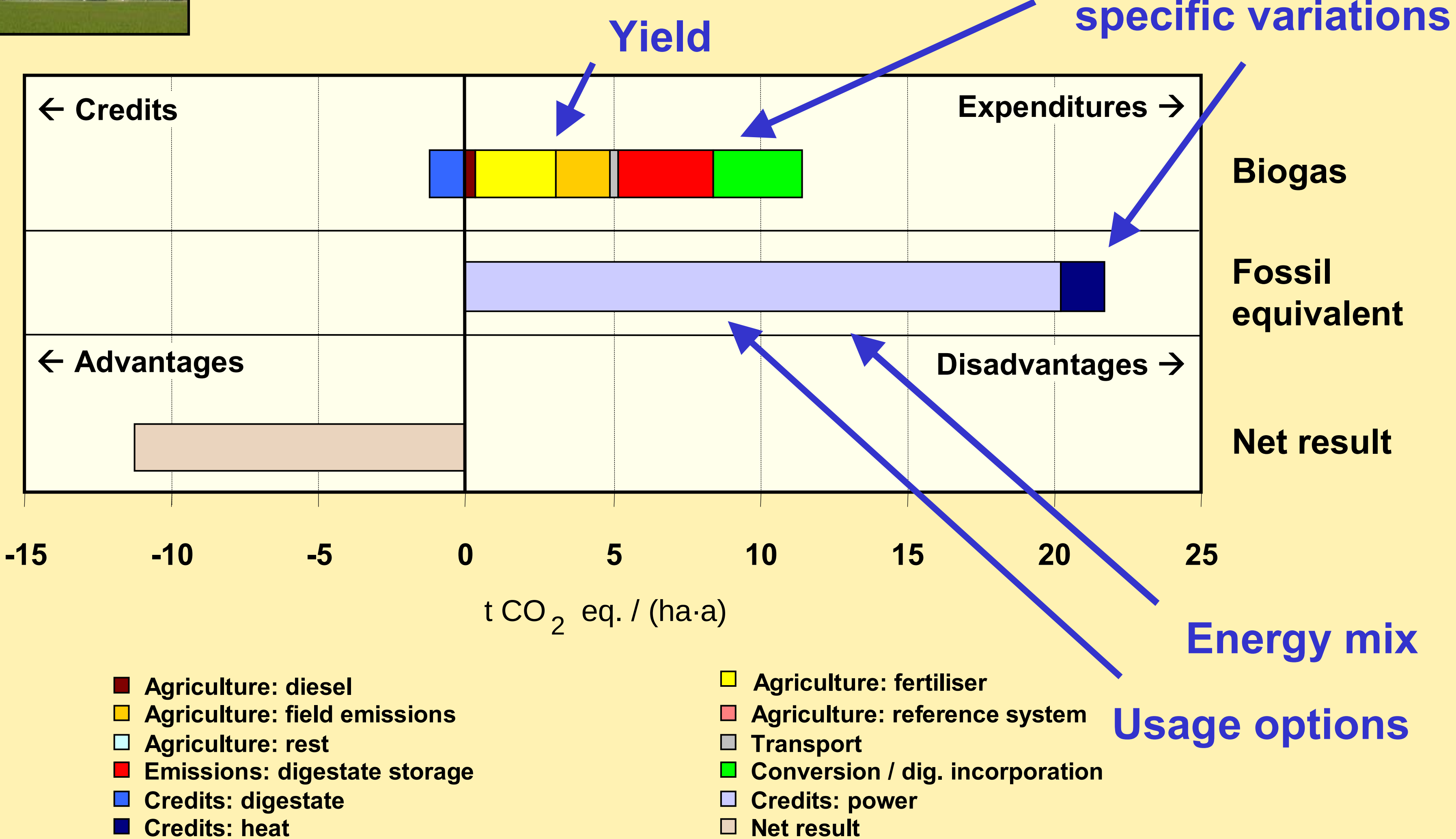
Biogas from sorghum: all impact categories



- ➔ **LCA: Environmental advantages and burdens**
- ➔ **Same pattern for most biofuels**
- ➔ **Biofuels are not "bio" just because they are biofuels**
- ➔ **Need to identify all environmental implications and optimise the advantages and minimise the disadvantages**

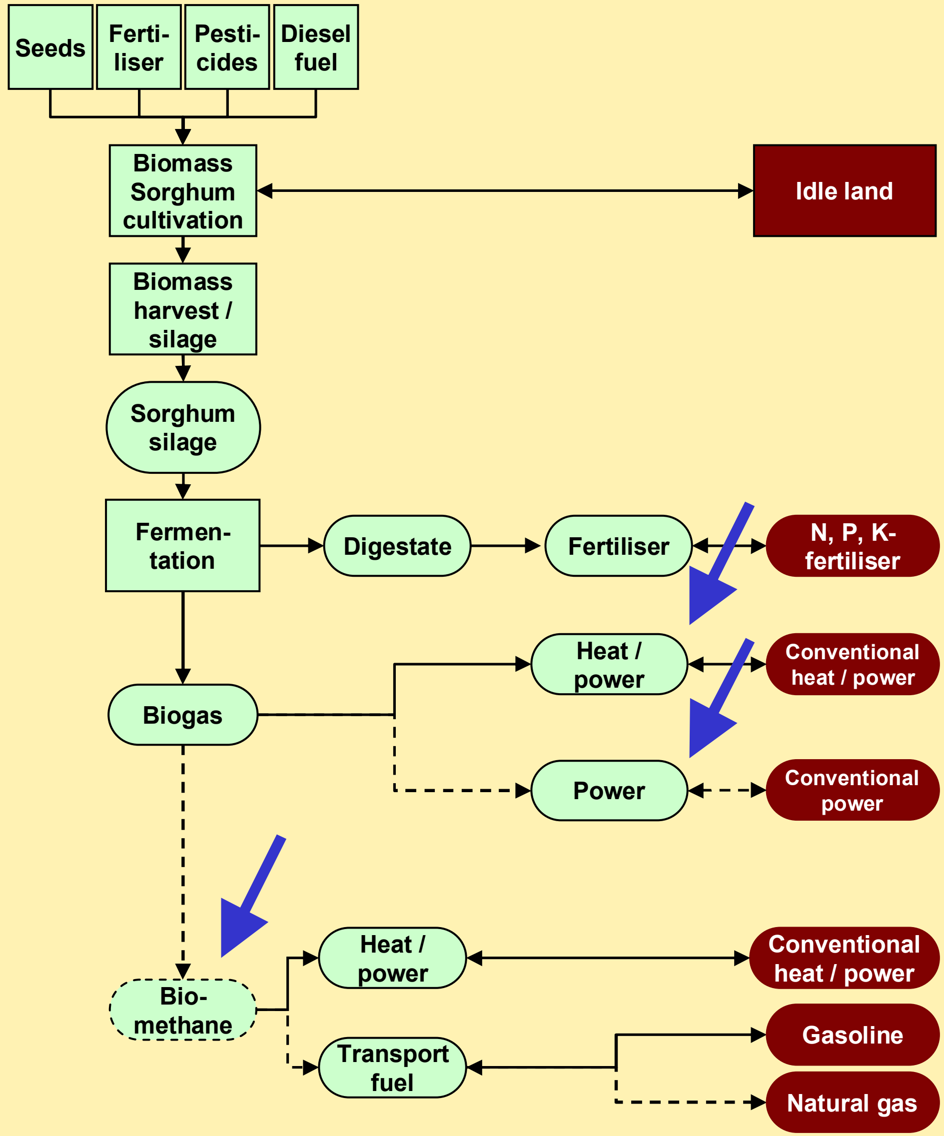
Environmental assessment: biogas from sorghum

Greenhouse gas emissions



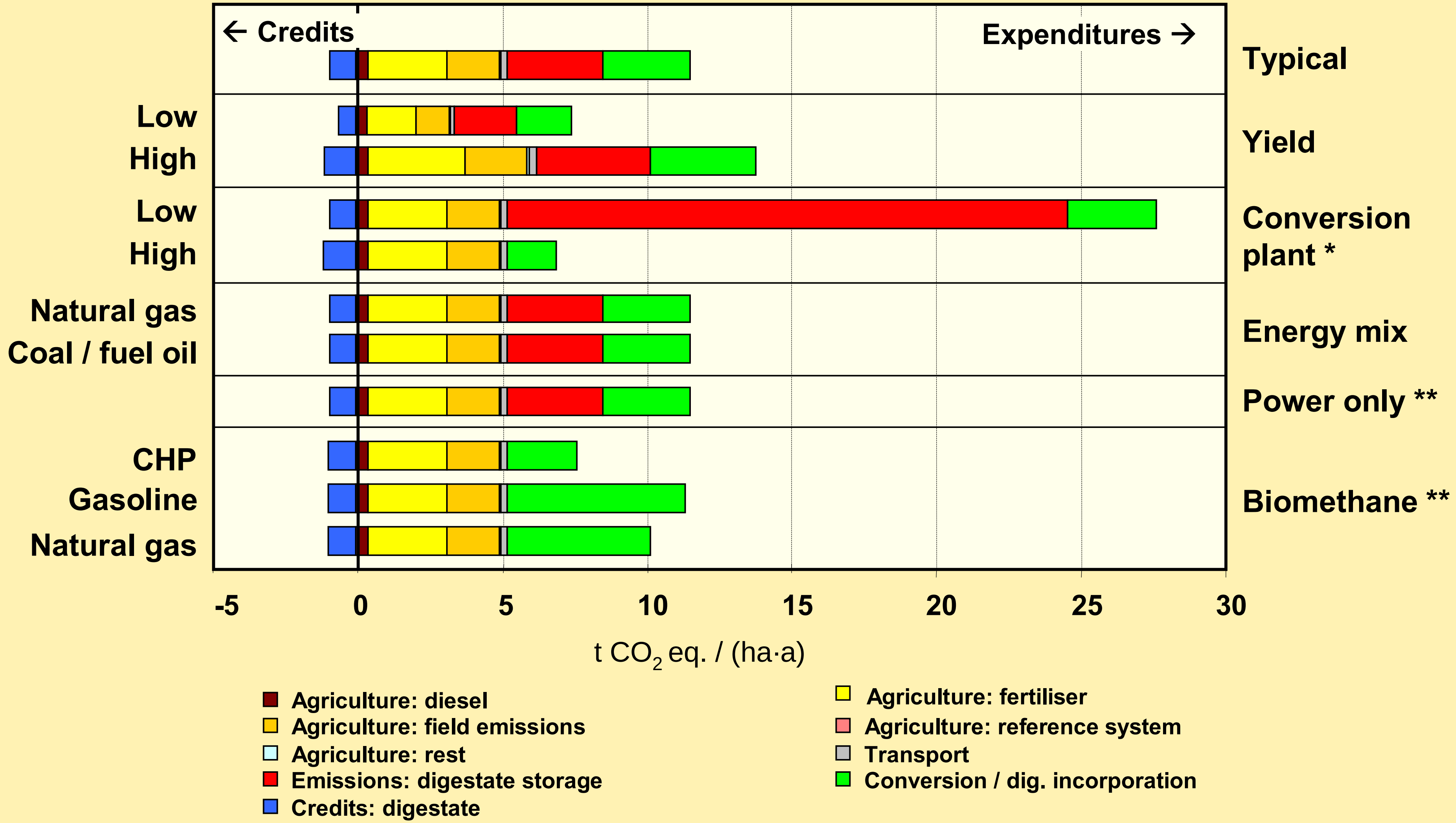
Source: IFEU 2014

Scenario: Biogas



Product
Process
Reference system

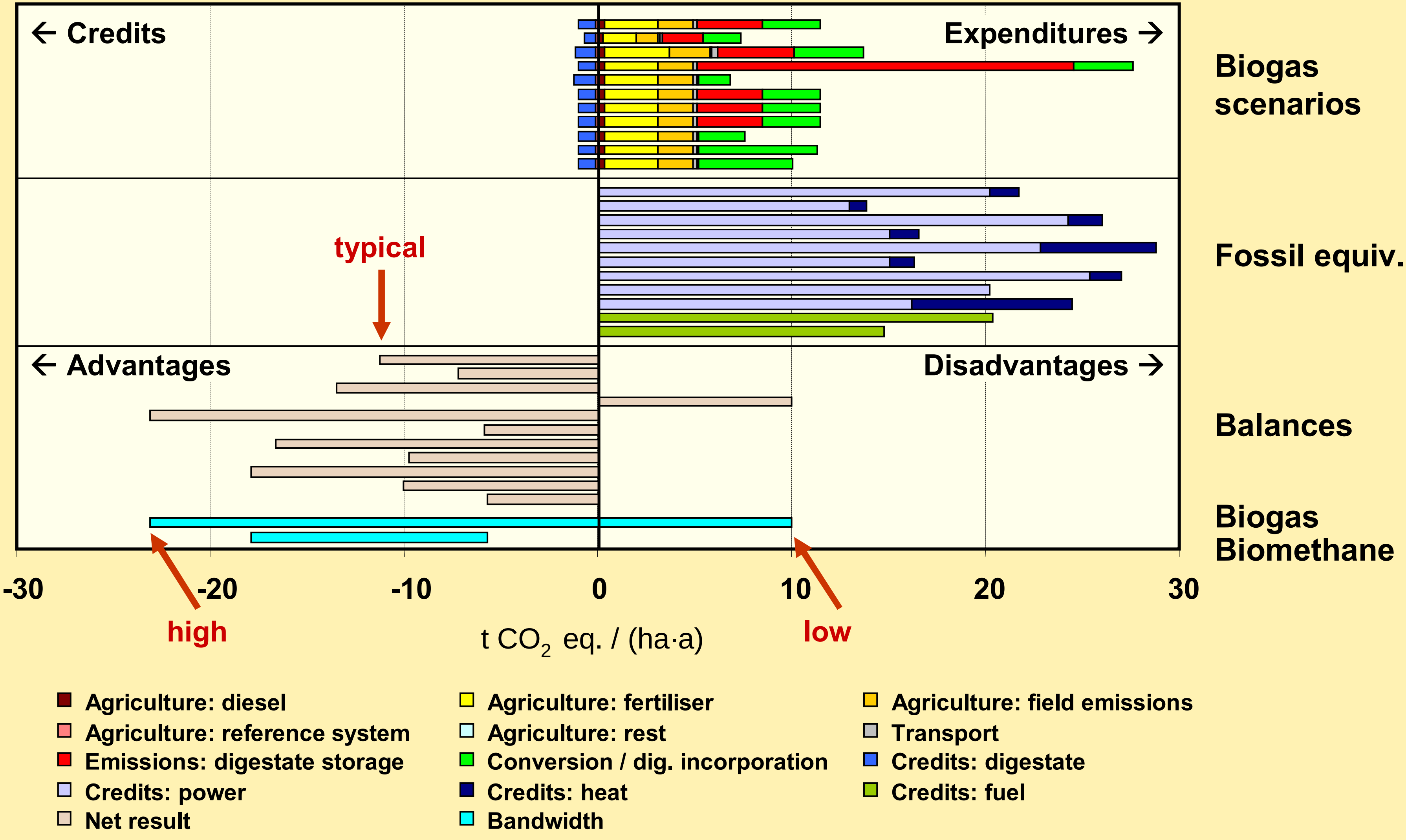
GHG balances of sorghum biogas scenarios



* efficiency, type of digestate storage, amount of CH_4 emissions, time of digestate incorporation; ** biogas use options

Source: IFEU 2014

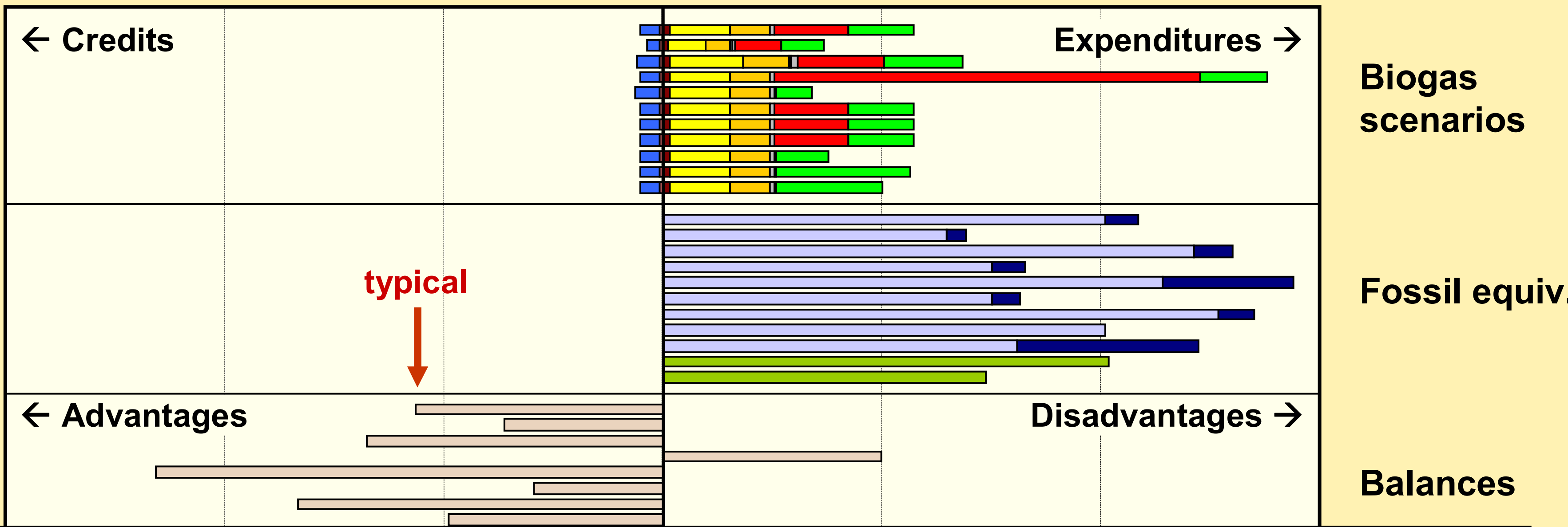
GHG* balances of sorghum biogas scenarios



* GHG: Greenhouse gases

Source: IFEU 2014

GHG balances of sorghum biogas scenarios



- ➔ Not only one result for biomass sorghum LCA, but many
- ➔ Remarkable bandwidth of results depending on specific conditions
- ➔ Remarkable potential for optimisation

Net result Bandwidth

Source: IFEU 2014

GHG balances of sorghum biogas scenarios

Specific results:

- ➔ The higher the biomass yields the more greenhouse gases can be saved. Breeding efforts should focus on optimised crop cultivars. Cultivation methods should aim towards highest yields possible.
- ➔ Digestate storage tanks should be covered and being sealed gas-tight.
- ➔ The digestate should be incorporated into the soil as fast as possible.
- ➔ If biogas is further refined into biomethane, the use of biomethane in a combined heat and power unit should be favoured over a use as natural gas substitute or fuel.

Source: IFEU 2014

Biomass sorghum: scenarios

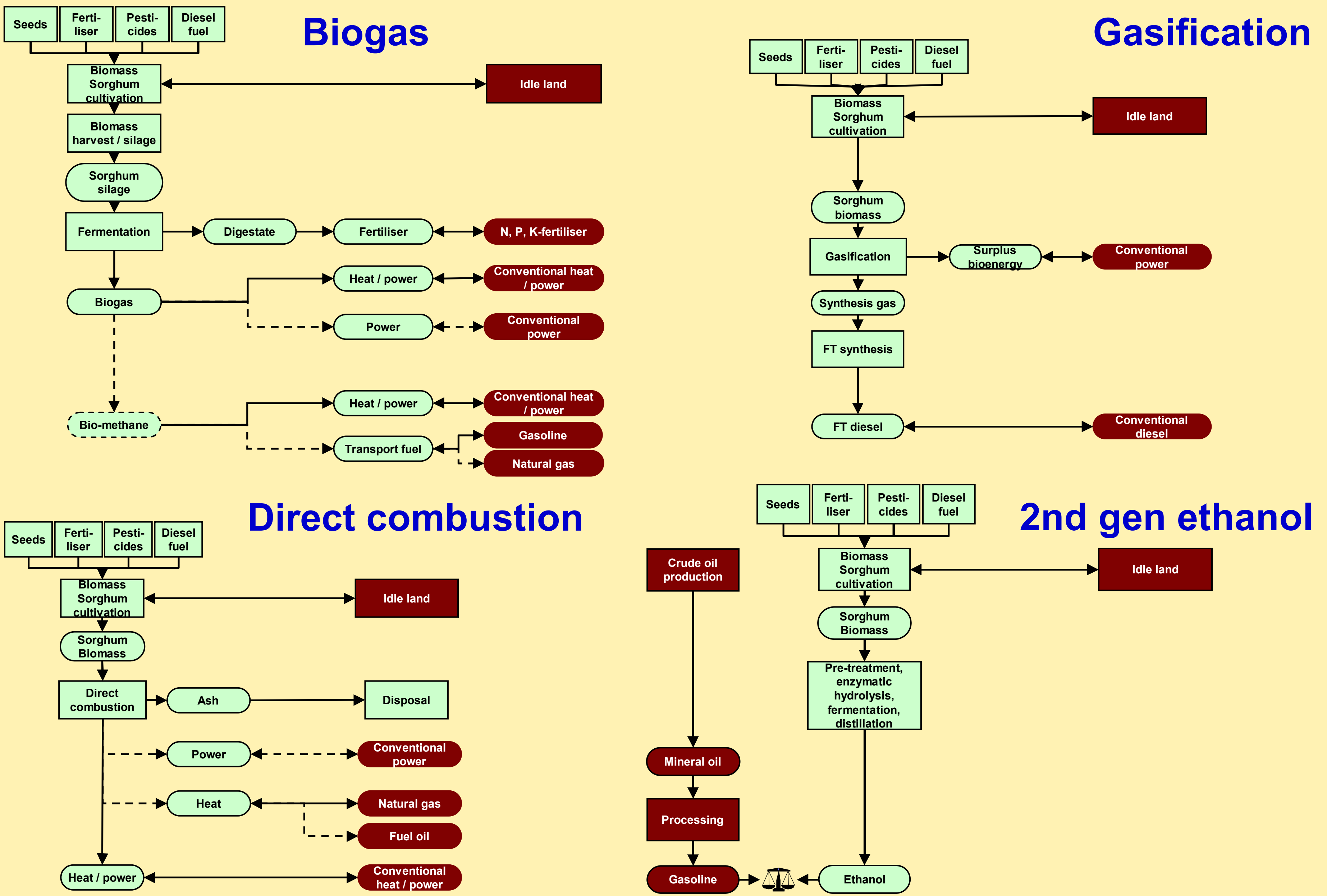
- Main biogas scenario

➔ Alternative use of biomass sorghum

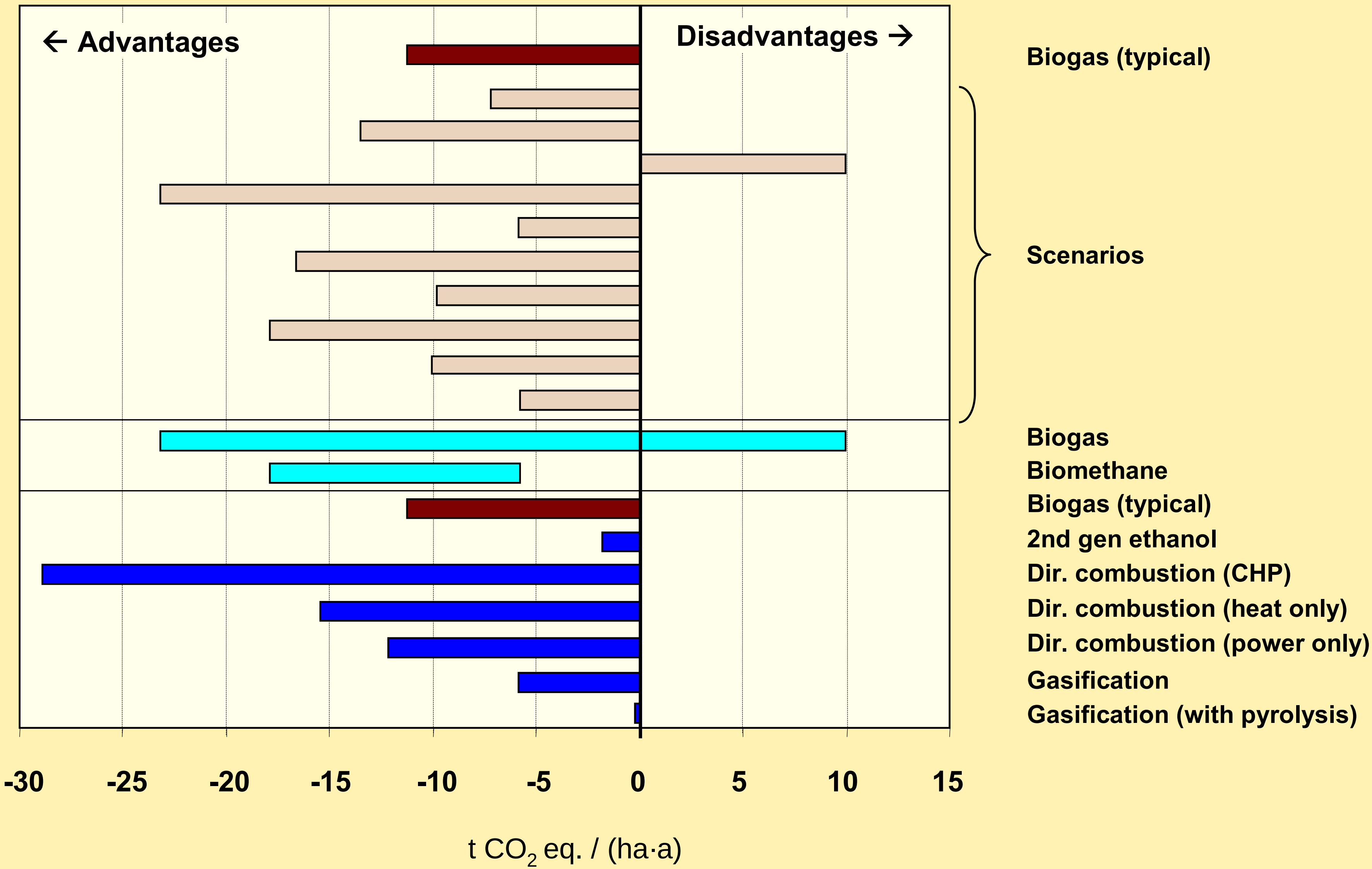
  - 2nd gen ethanol (from lignocellulose)
  - Direct combustion (CHP, heat only, power only)
  - BTL*: Gasification (via and without pyrolysis)

* BTL: Biomass to liquids = synthetic biofuels

Alternative biomass sorghum use options

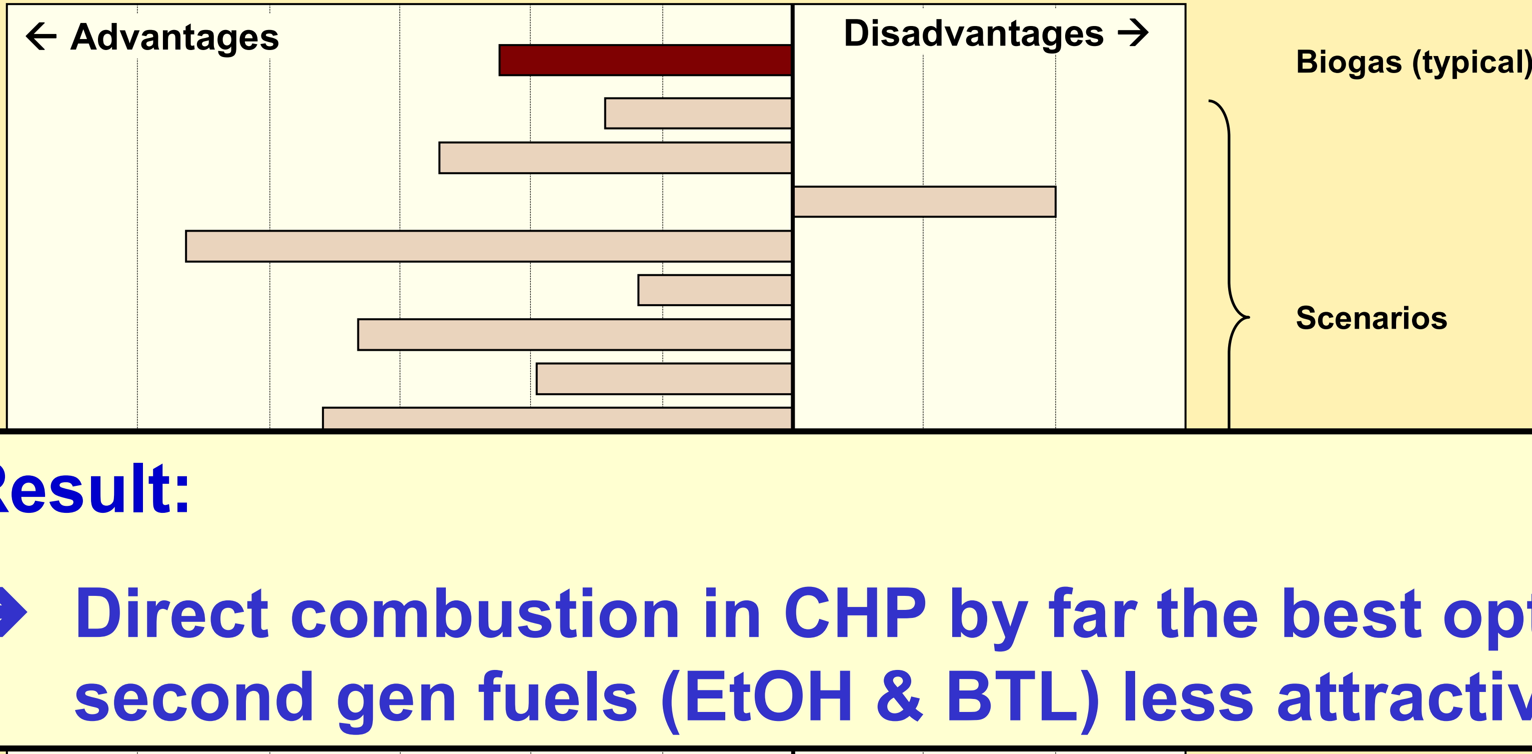


Alternative biomass sorghum use options



Source: IFEU 2014

Alternative biomass sorghum use options



Result:

➔ Direct combustion in CHP by far the best option, second gen fuels (EtOH & BTL) less attractive

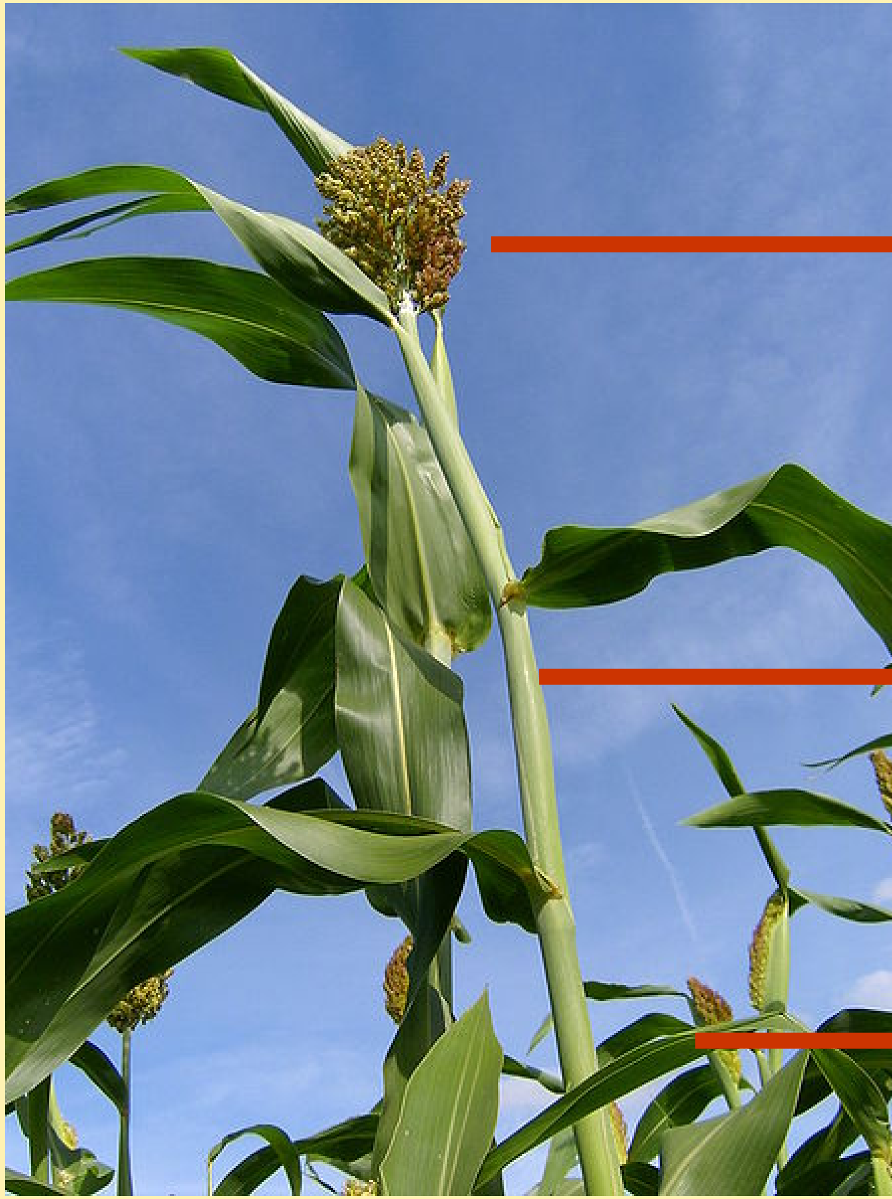
Recommendation :

➔ Direct combustion should be favoured if heat and power can be produced, otherwise realise optimised biogas pathways.

Outline

- Background
- Biomass sorghum pathways
- ➔ Sweet sorghum pathways
- Conclusions and recommendations
- Outlook

Different uses of Sweet Sorghum



Grains

Juice

Bagasse

Leaves

Environmental assessment

Energy Sorghum scenarios

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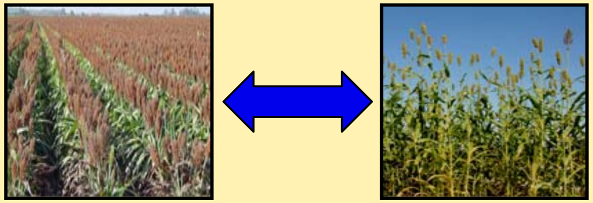
  Cultivation of biomass sorghum on idle land, biogas or biomethane production, temperate climate zones

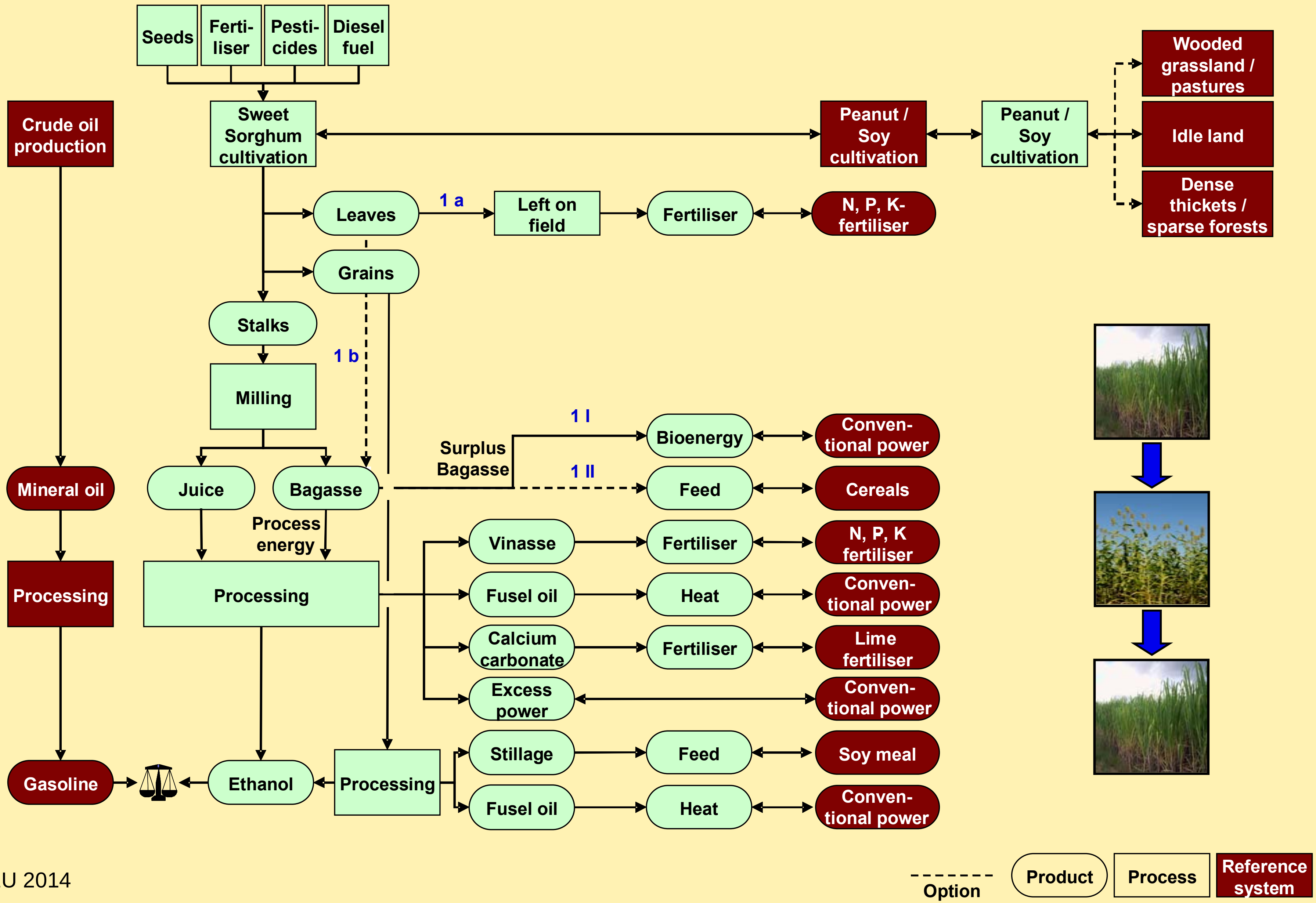
- **Sweet Sorghum: Cane fallow**
  Intercropping between two sugar cane cycles instead of peanuts / soy, subtropical to tropical climate

- **Sweet Sorghum: Grain – food**
  Replacement of grain sorghum cultivation, semi-arid climate



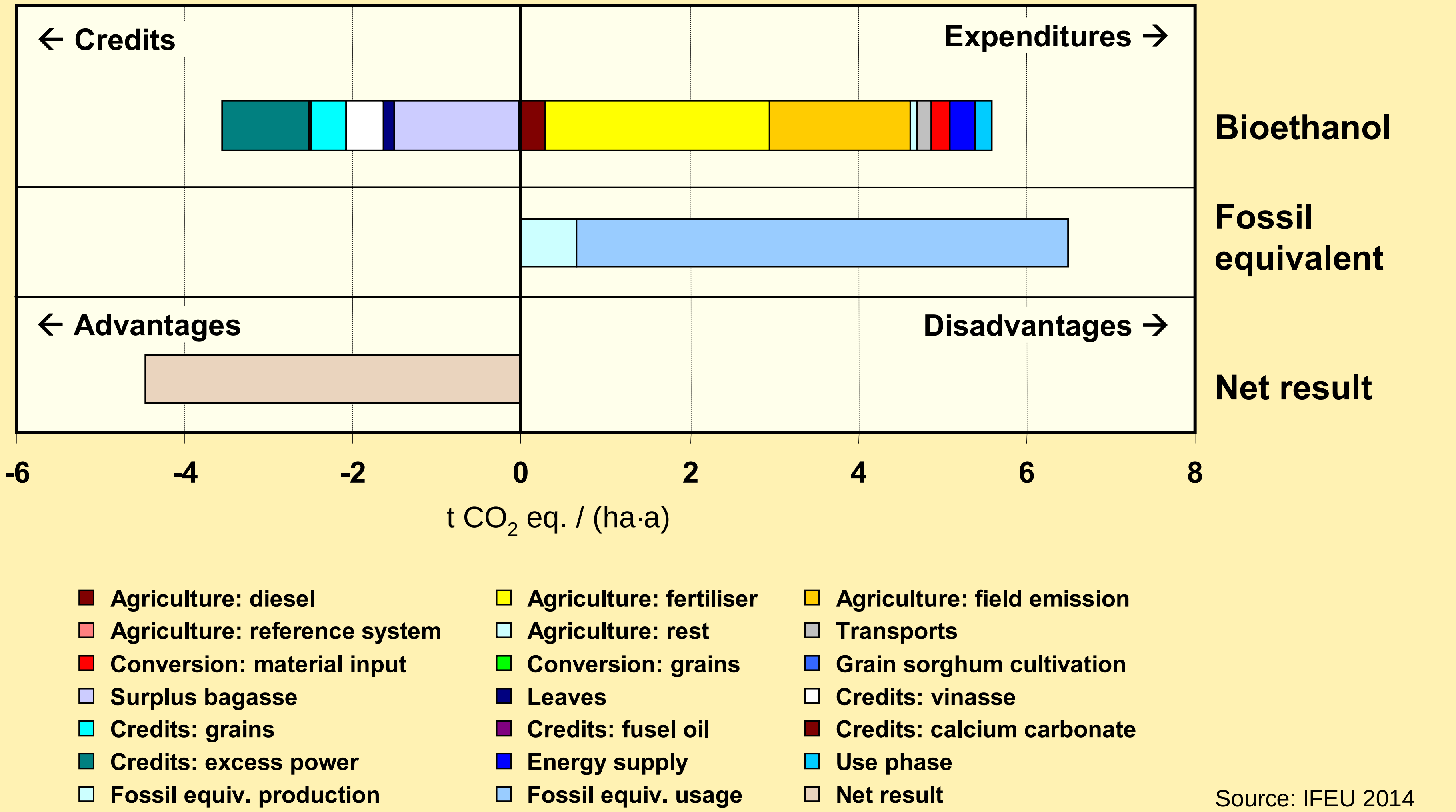
- **Sweet Sorghum: Syrup**
  Replacement of e.g. cotton cultivation, decentralised syrup production, centralised ethanol production, subtropical to tropical climate

Environmental assessment: cane fallow



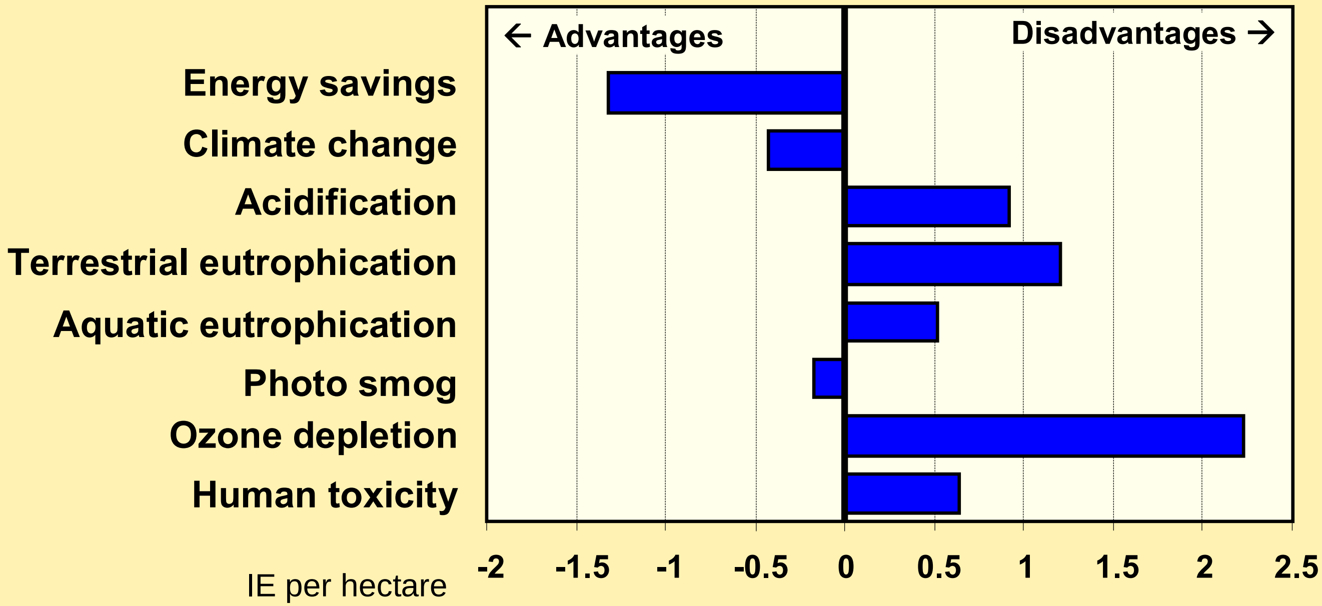
Environmental assessment: cane fallow

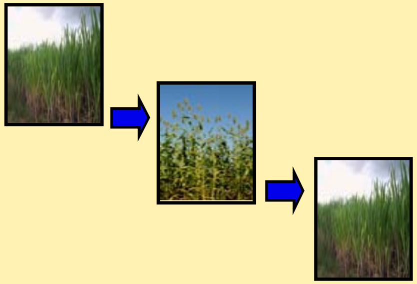
Greenhouse gas balance



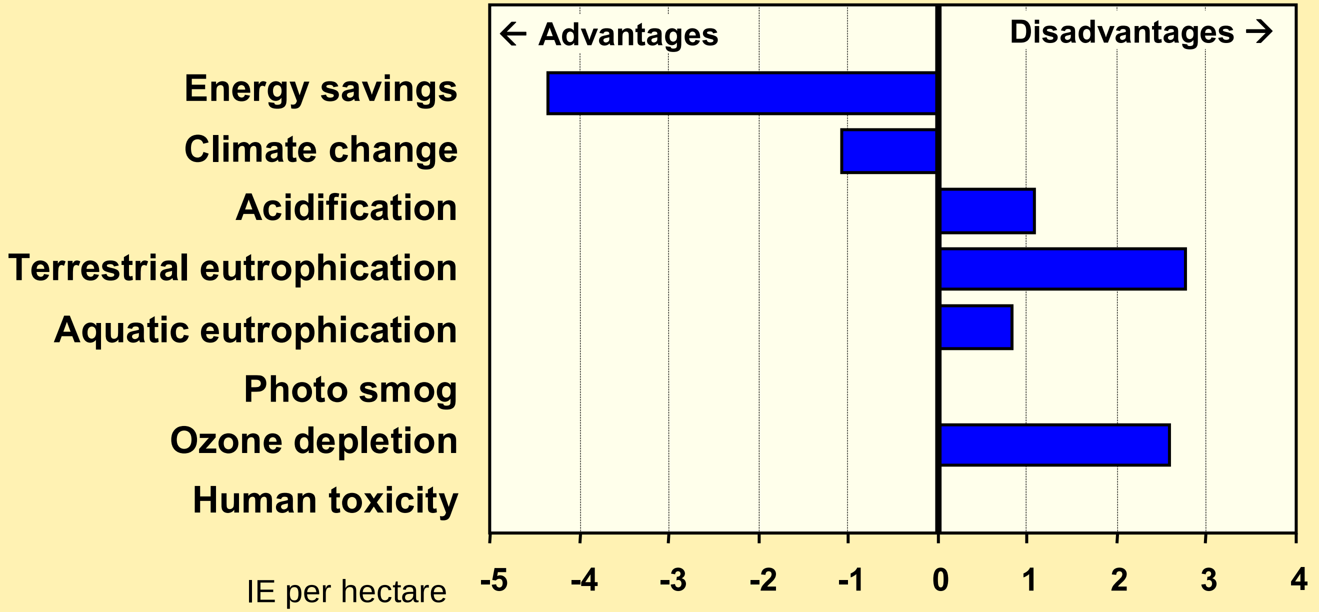
Source: IFEU 2014

Cane fallow: All impact categories





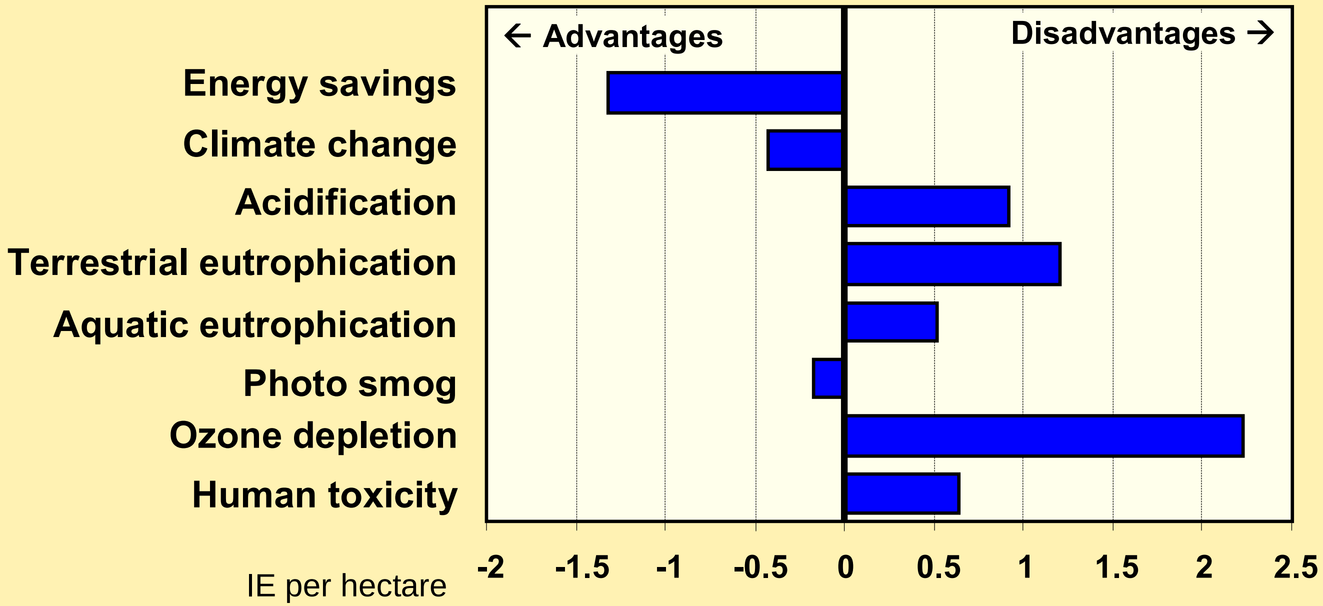
Sweet sorghum: cane fallow

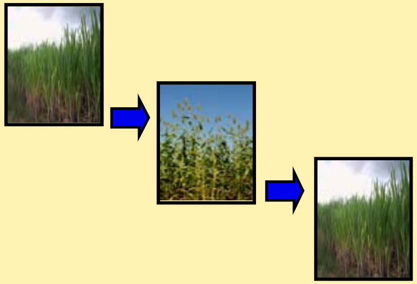


Biomass sorghum: biogas production

Source: IFEU 2014

Cane fallow: All impact categories





Sweet sorghum: cane fallow

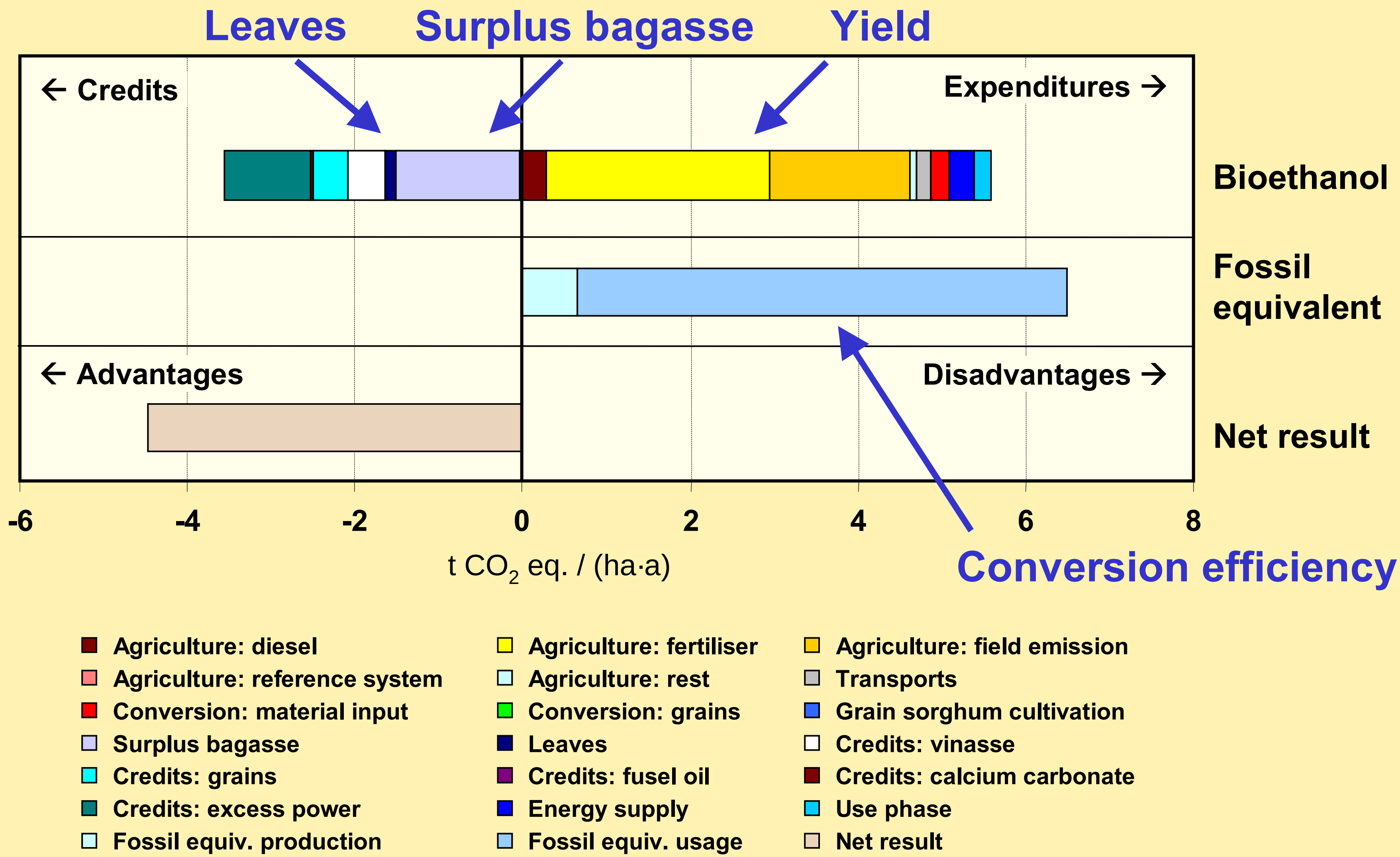
- ➔ **LCA: Environmental advantages and burdens**
- ➔ **Same pattern for sweet and biomass sorghum**
- ➔ **Need to identify all environmental implications and optimise the advantages and minimise the disadvantages**

IE per hectare -5 -4 -3 -2 -1 0 1 2 3 4

Source: IFEU 2014

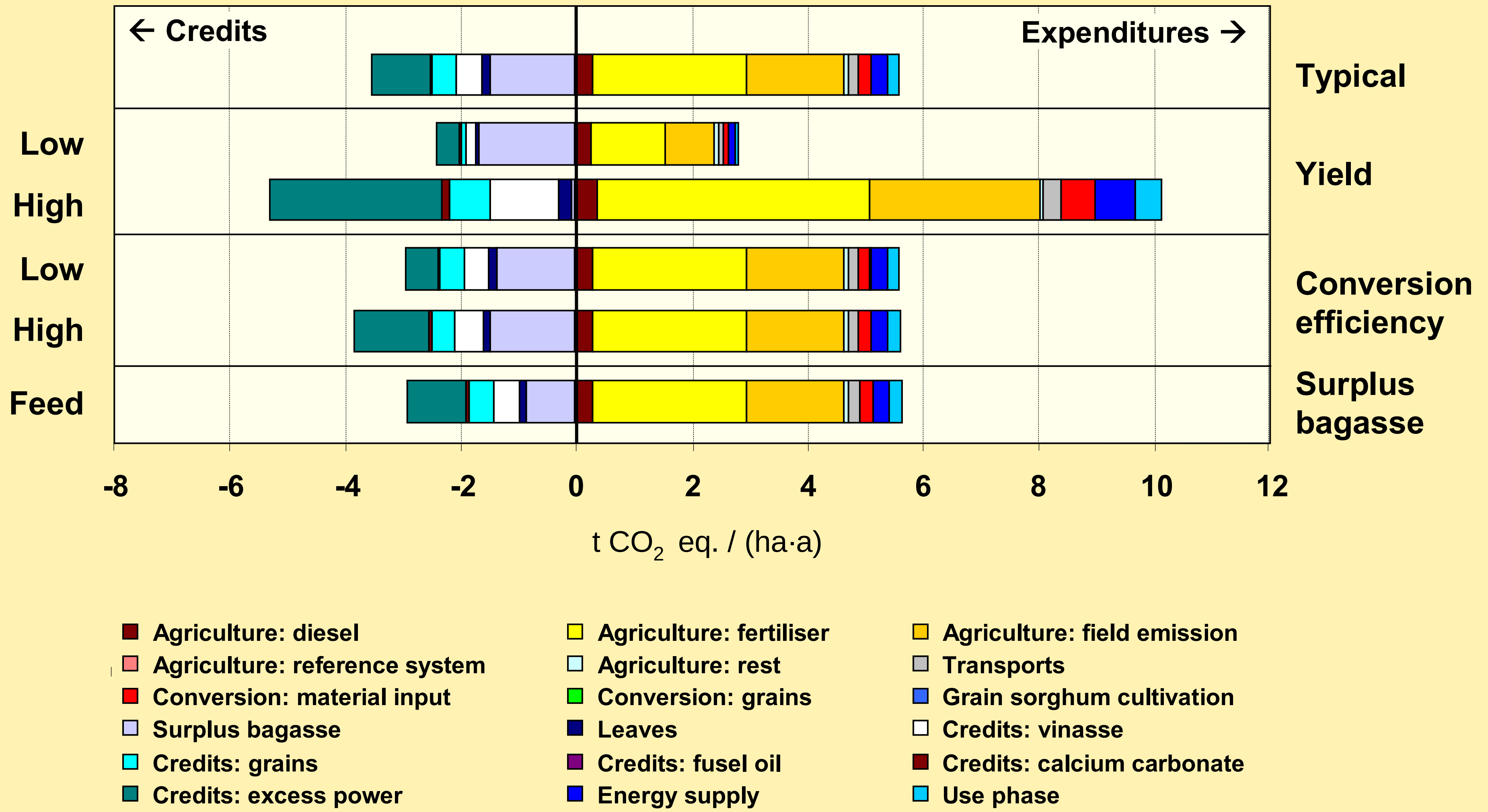
Environmental assessment: cane fallow

Greenhouse gas balance



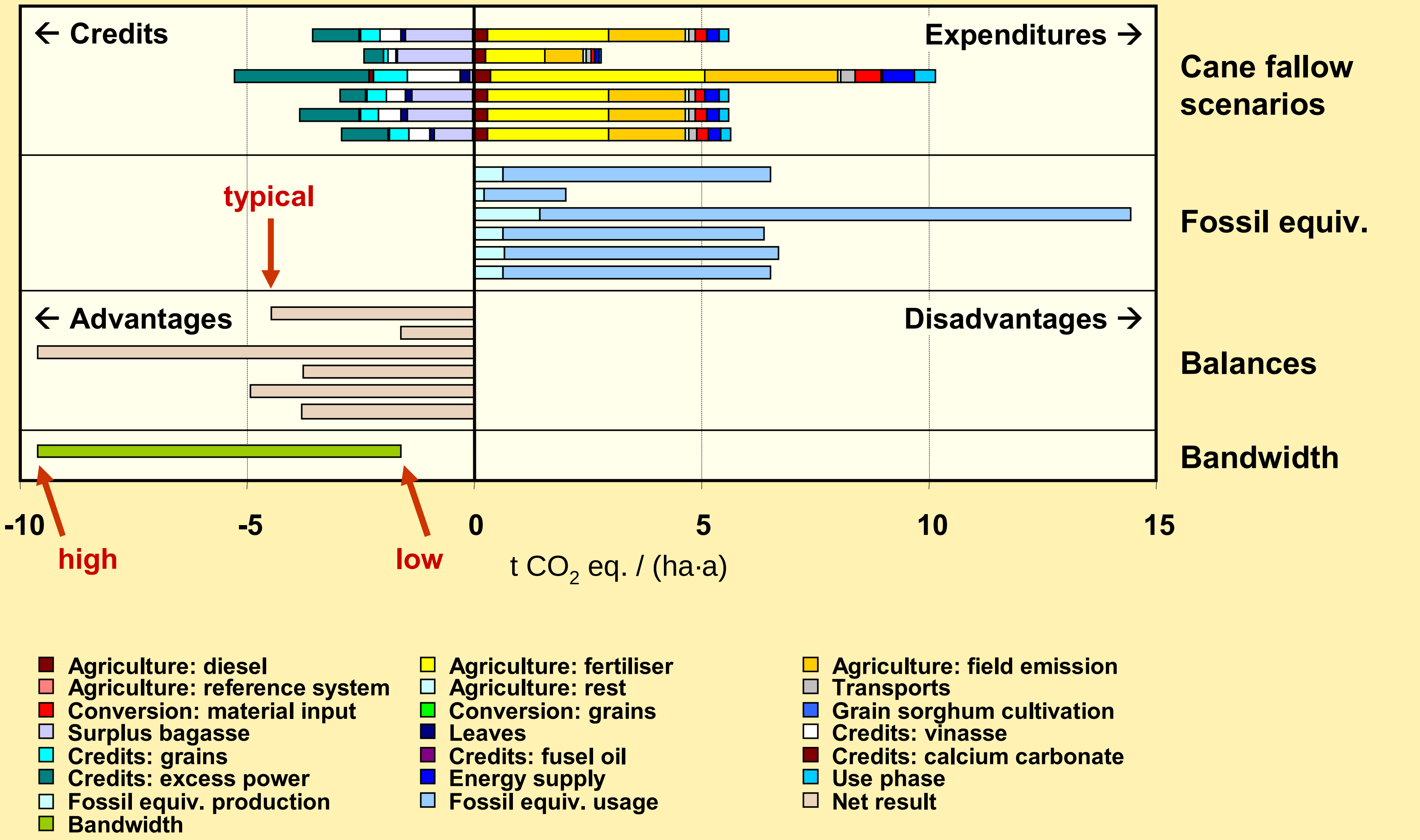
Source: IFEU 2014

Cane fallow: greenhouse gas balances



Source: IFEU 2014

Cane fallow: greenhouse gas balances



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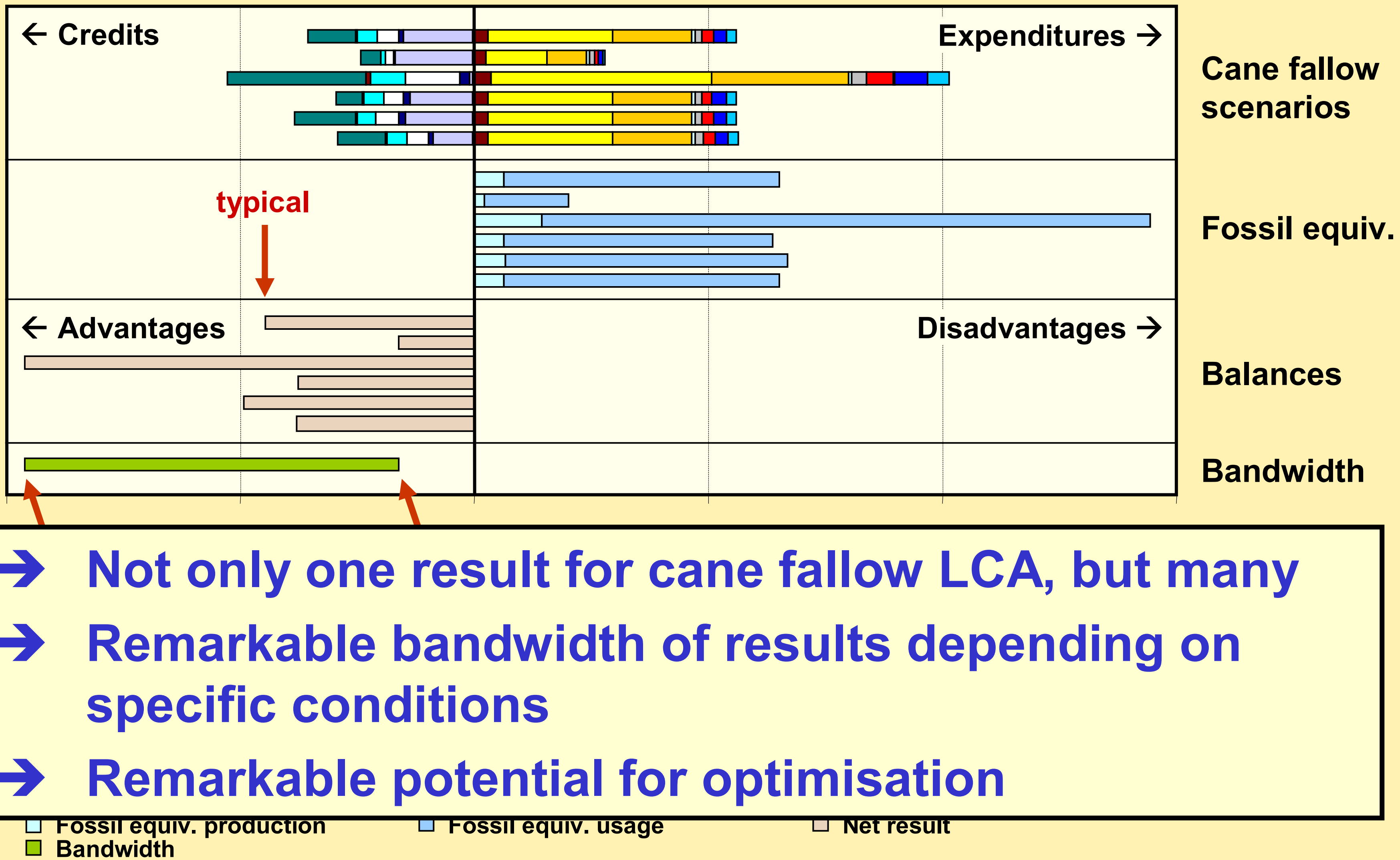
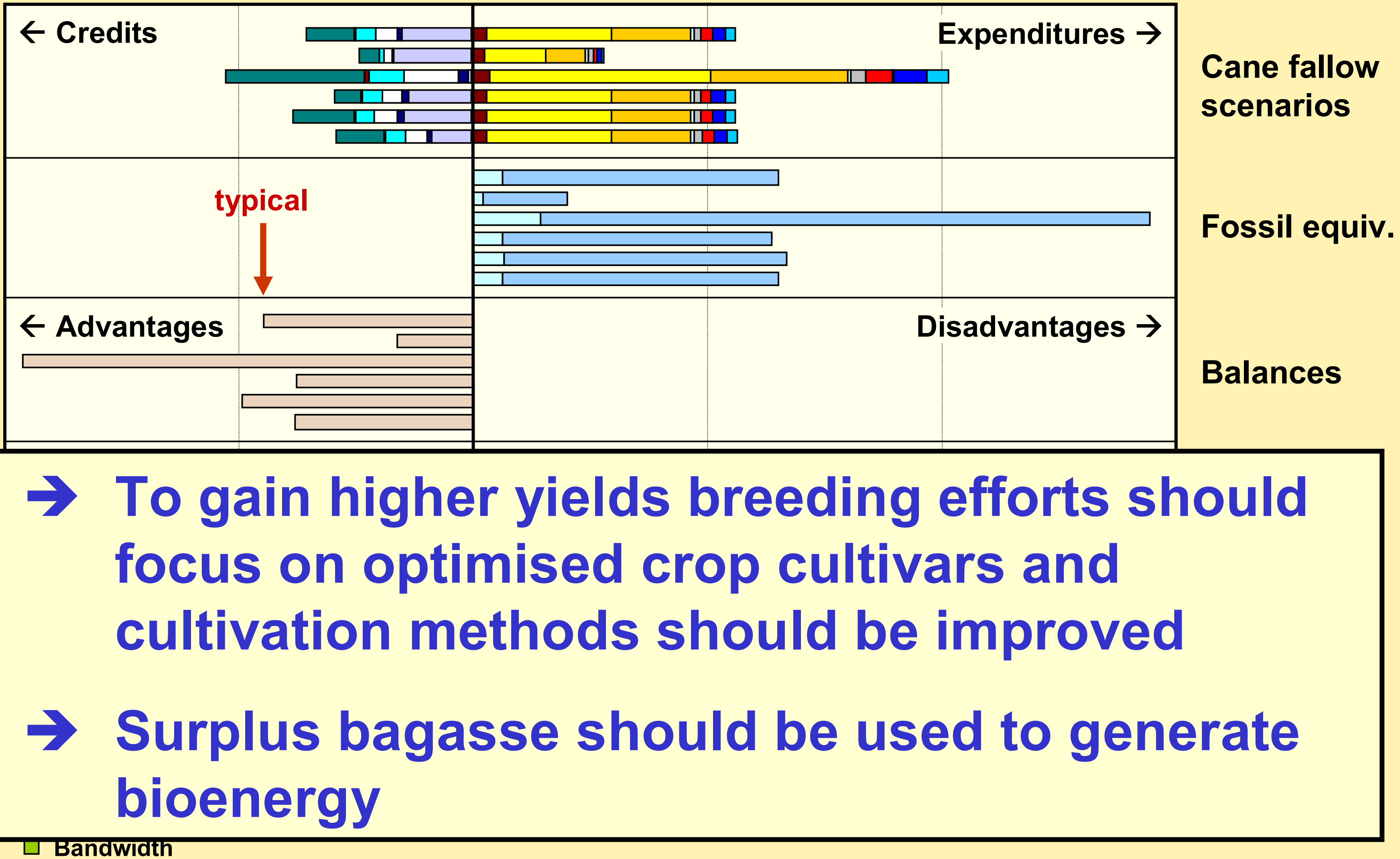
Cane fallow: greenhouse gas balances



- ➔ Not only one result for cane fallow LCA, but many
- ➔ Remarkable bandwidth of results depending on specific conditions
- ➔ Remarkable potential for optimisation

Source: IFEU 2014

Cane fallow: greenhouse gas balances

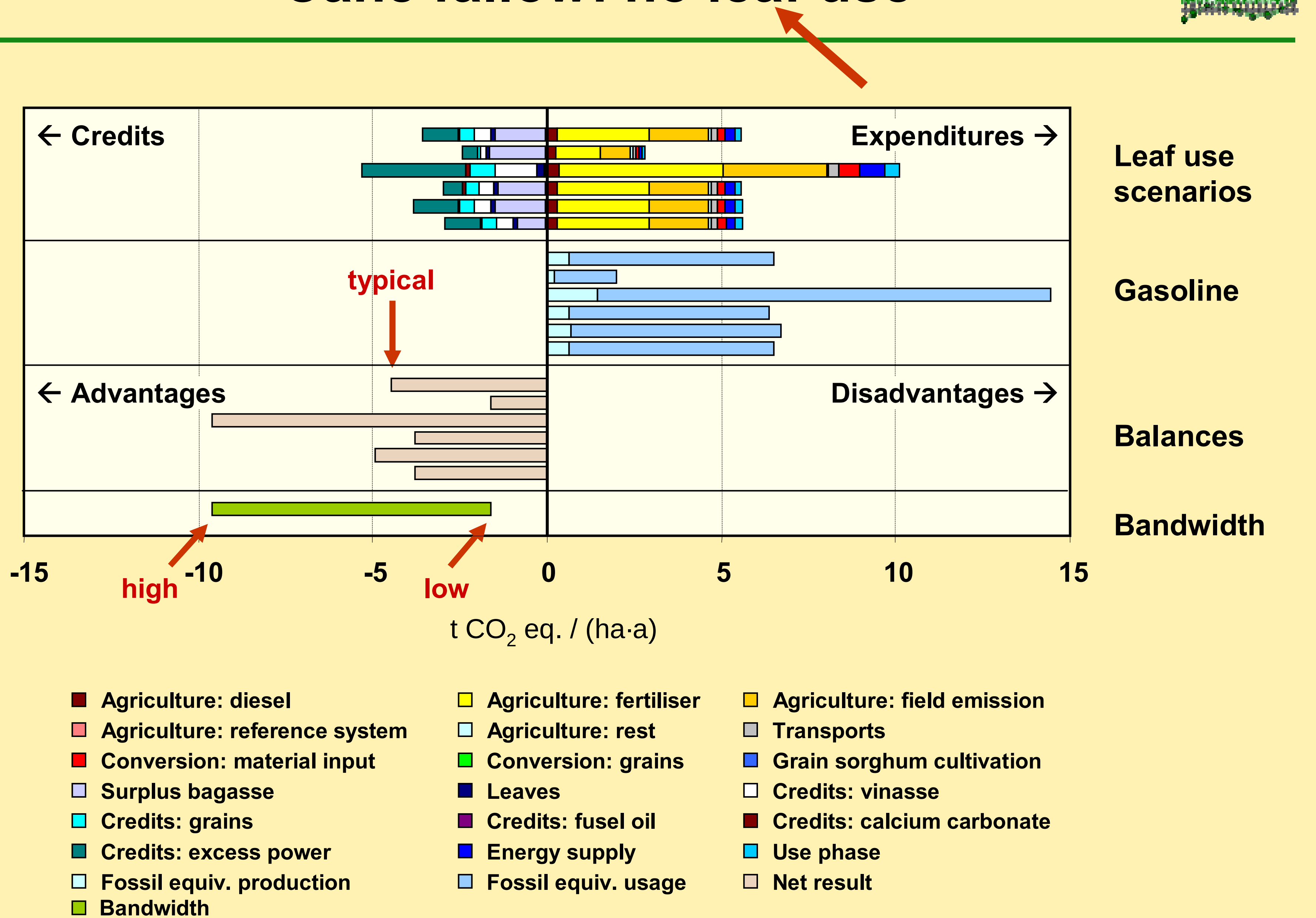


➔ To gain higher yields breeding efforts should focus on optimised crop cultivars and cultivation methods should be improved

➔ Surplus bagasse should be used to generate bioenergy

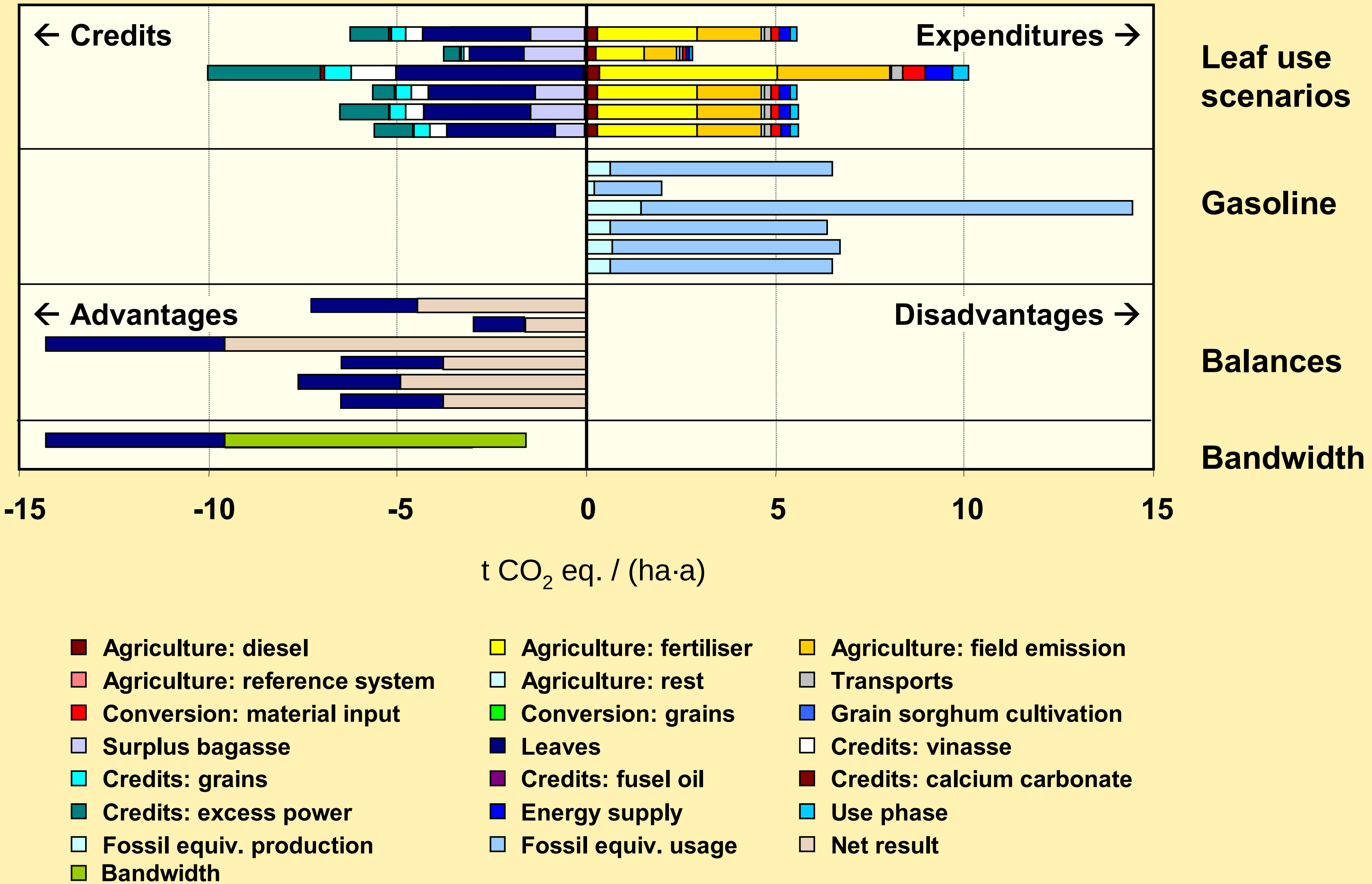
Source: IFEU 2014

Cane fallow: no leaf use



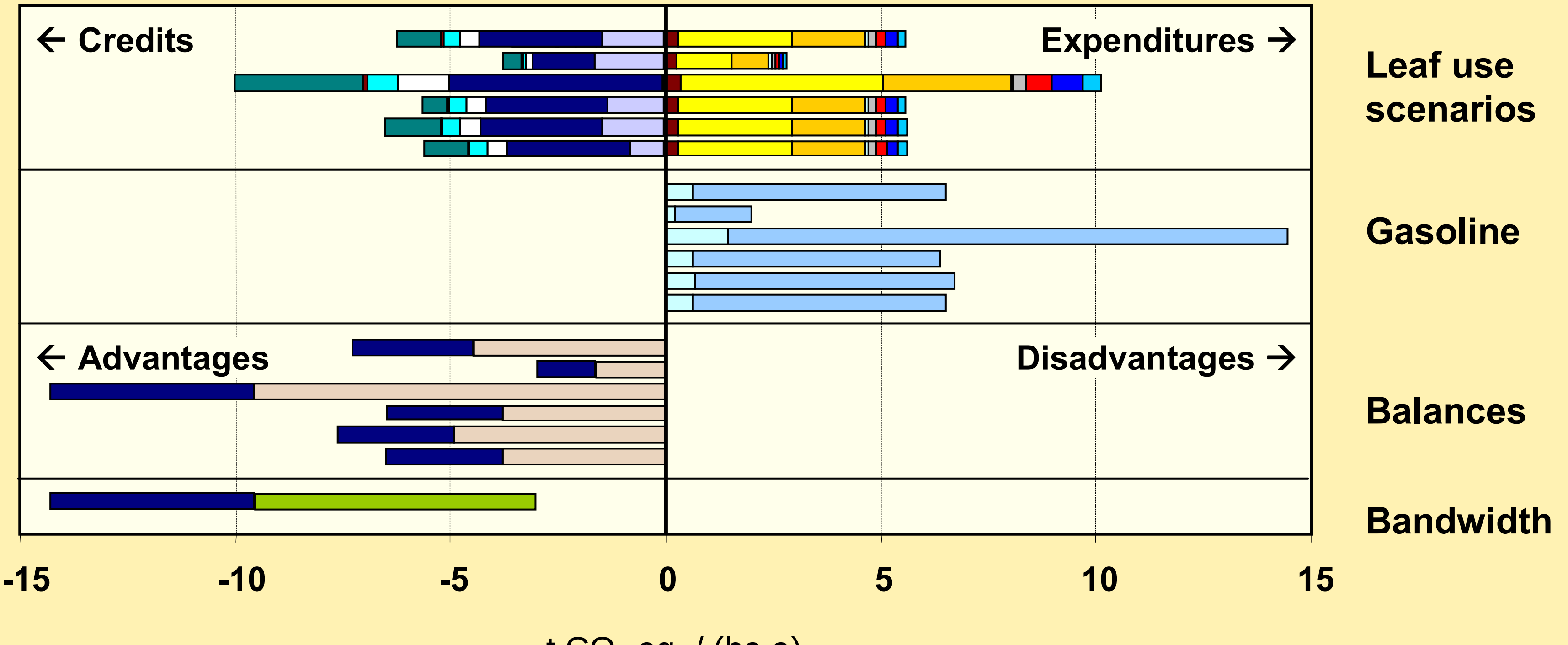
Source: IFEU 2014

Cane fallow: leaf use



Source: IFEU 2014

Cane fallow: Leaf use



➔ Big improvement of results if leaves are used

- Agriculture: reference system
- Conversion: material input
- Surplus bagasse
- Credits: grains
- Credits: excess power
- Fossil equiv. production
- Bandwidth
- Agriculture: rest
- Conversion: grains
- Leaves
- Credits: fusel oil
- Energy supply
- Fossil equiv. usage
- Transports
- Grain sorghum cultivation
- Credits: vinasse
- Credits: calcium carbonate
- Use phase
- Net result

Source: IFEU 2014

Environmental assessment

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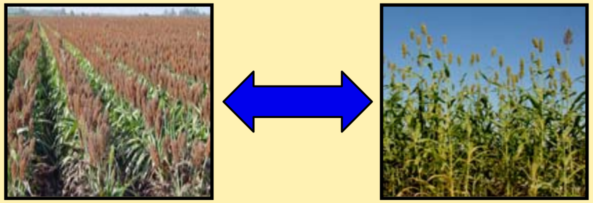
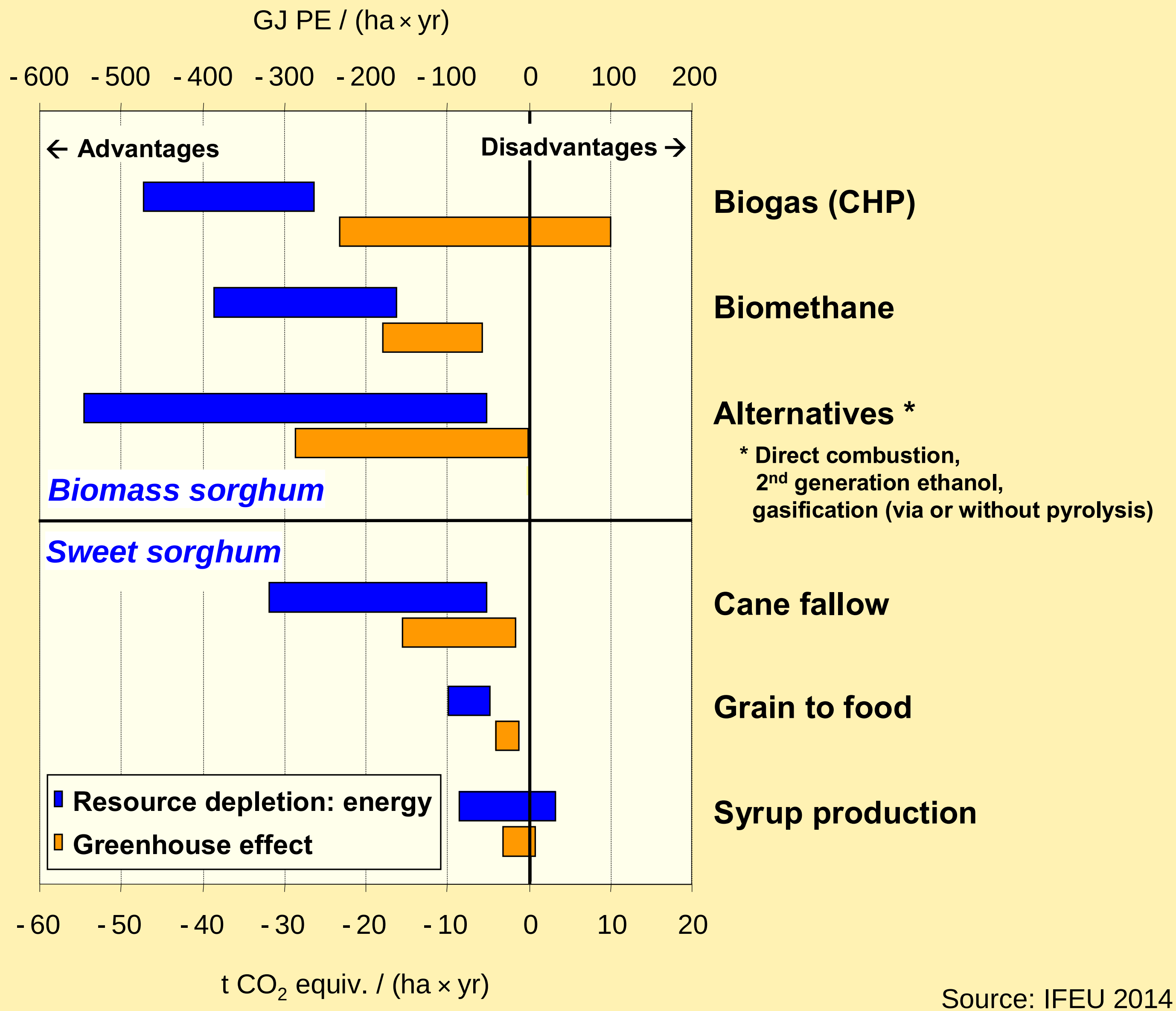


➔ **Sweet Sorghum: Syrup**
Replacement of e.g. cotton cultivation, decentralised syrup production, centralised ethanol production, subtropical to tropical climate

LCA results of sweet and biomass sorghum



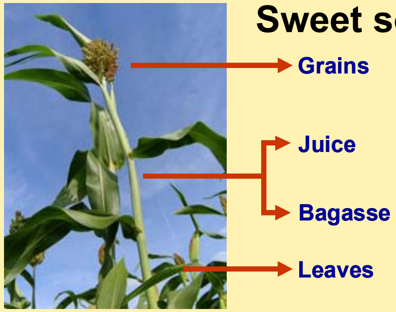
Source: IFEU 2014

Outline

- Background
- Biomass sorghum pathways
- Sweet sorghum pathways
- ➔ Conclusions and recommendations
- Outlook

Conclusions 1/3

Biomass sorghum to biogas



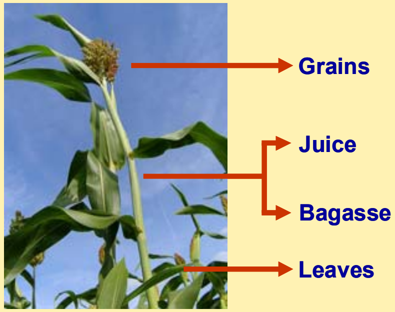
Sweet sorghum to bioethanol

- ➔ LCA: Environmental advantages and burdens
- ➔ Same pattern for most biofuels
- ➔ Biofuels and bioenergy are not “bio” just because they are bio-based
- ➔ Need to identify all environmental implications and optimise the advantages and minimise the disadvantages

Conclusions 2/3

Biomass sorghum to biogas

Sweet sorghum to bioethanol



- ➔ Not only one result for energy sorghum LCA, but many
- ➔ Remarkable bandwidth of results depending on specific conditions
- ➔ Remarkable potential for optimisation

Conclusions 3/3

Specific for biomass sorghum for biogas:

- ➔ The higher the biomass yields the more greenhouse gases can be saved. Breeding efforts should focus on optimised crop cultivars. Cultivation methods should aim towards highest yields possible.
- ➔ Digestate storage tanks should be covered and being sealed gas-tight.
- ➔ The digestate should be incorporated into the soil as fast as possible.
- ➔ If biogas is further refined into biomethane, the use of biomethane in a combined heat and power unit should be favoured over a use as natural gas substitute or fuel.

Specific recommendations

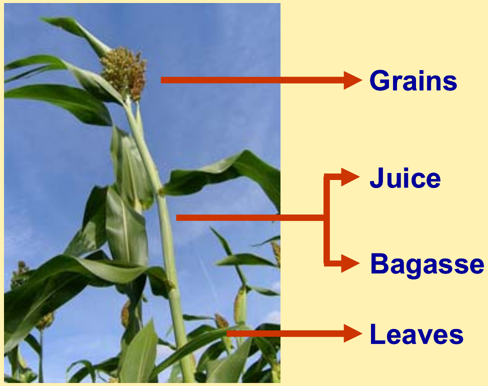
Biomass sorghum:

➔ Direct combustion should be favoured if heat and power can be produced, otherwise realize optimised biogas pathways.

Sweet sorghum:

➔ Surplus bagasse should be used to generate bioenergy.

➔ Techniques and strategies should be developed to harvest and use leaves sustainably.



Recommendations

- **Research**: To gain higher yields and to minimise nitrogen loss, breeding efforts should focus on
  - optimised crop cultivars and
  - improvement of cultivation methods
- **Implementation**: Need to perform a life cycle assessment (LCA) for each specific sorghum pathway concept to identify their environmental optimisation options
- Supplement LCA by life cycle environmental impact assessment (LC-EIA) and full sustainability assessment

Outline

- Background
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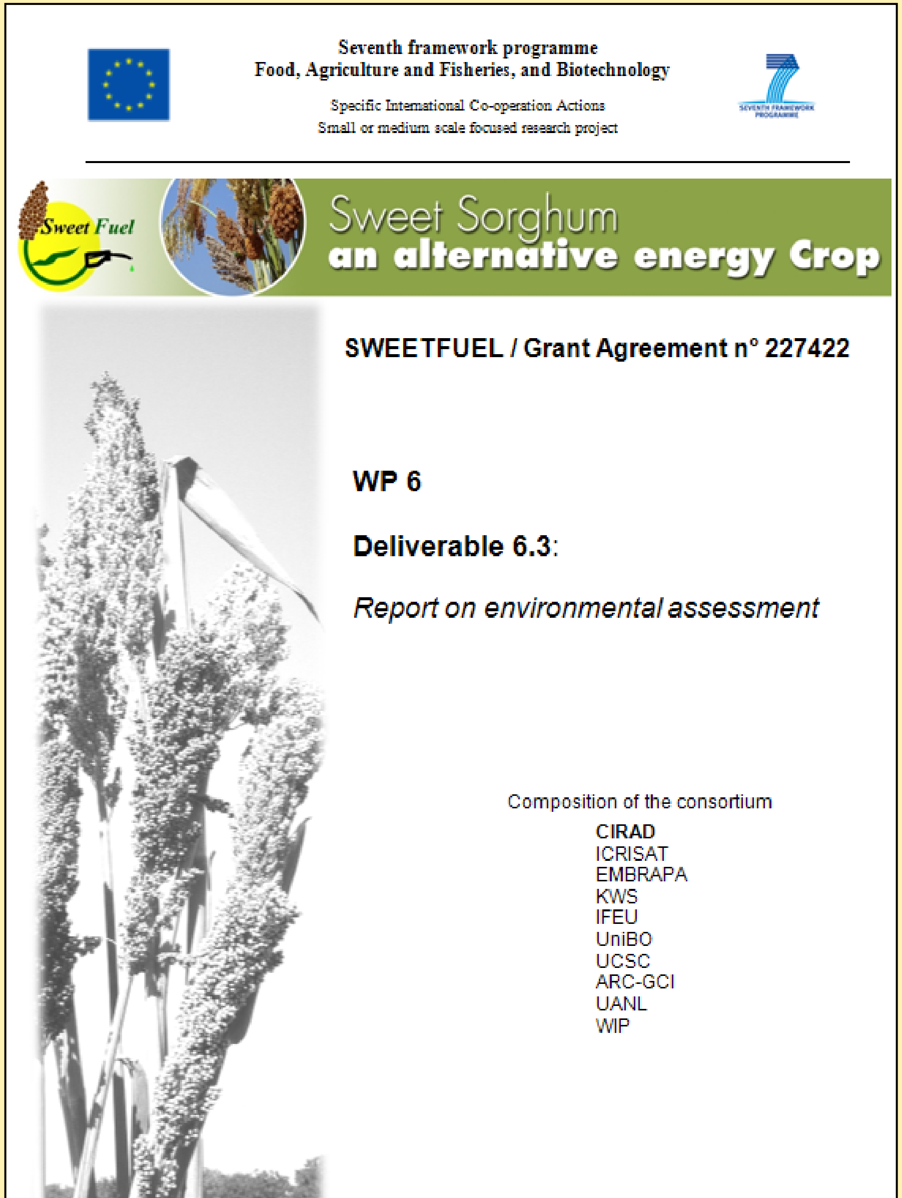
- Sweet sorghum pathways
- Conclusions and recommendations

→ Outlook

Further reading


Seventh framework programme
Food, Agriculture and Fisheries, and Biotechnology

Specific International Co-operation Actions
Small or medium scale focused research project

Sweet Fuel

Sweet Sorghum
an alternative energy Crop

SWEETFUEL / Grant Agreement n° 227422

WP 6

Deliverable 6.3:

Report on environmental assessment

Composition of the consortium

CIRAD
ICRISAT
EMBRAPA
KWS
IFEU
UniBO
UCSC
ARC-GCI
UANL
WIP

Report on environmental assessment

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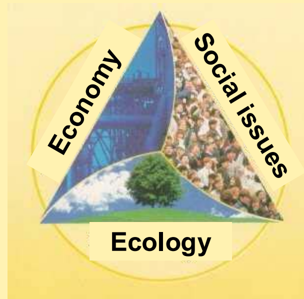
Download from SWEETFUEL homepage:

www.sweetfuel-project.eu

The principle of sustainability

Integrated sustainability assessment



Technological assessment

Life cycle assessment

Life cycle environmental impact assessment

Economic assessment

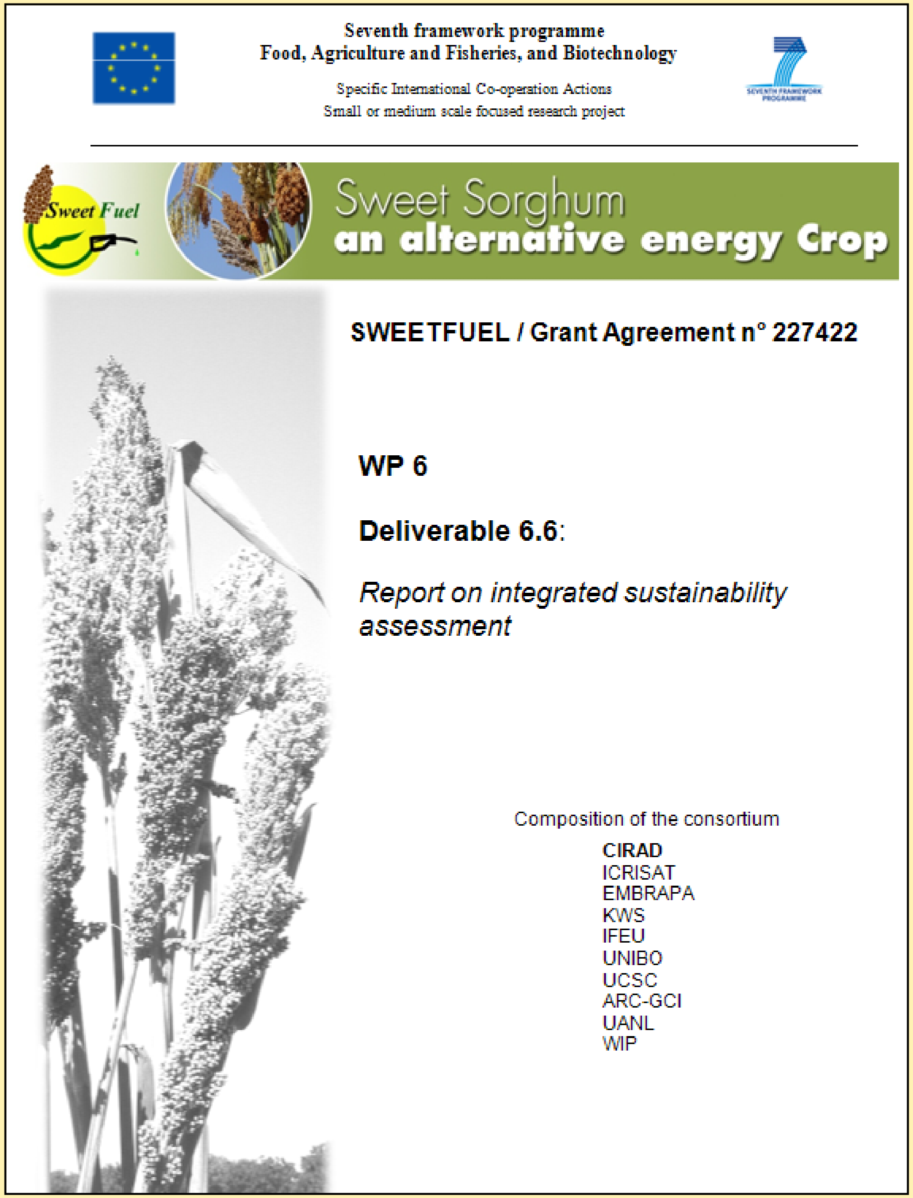
SWOT * analysis

Social, legal and policy aspects

Integrated assessment of sustainability

* Strengths, Weaknesses, Opportunities, Threats

Outlook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WP 6

Deliverable 6.6:

Report on integrated sustainability assessment

Composition of the consortium

CIRAD
ICRISAT
EMBRAPA
KWS
IFEU
UNIBO
UCSC
ARC-GCI
UANL
WIP

Report on *integrated sustainability* assessment

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