Environmental implications associated with sweet sorghum production and use for biofuels

Nils Rettenmaier

EUROCLIMA Workshop
Campinas, Brazil, 30 November 2011

Background

ifeu –
Institut für Energie- und Umweltforschung Heidelberg gGmbH

Assessment of energy and greenhouse gas inventories of Sweet Sorghum for first and second generation bio-ethanol

Susanne Köppen
Guido Reinhardt
Sven Gärtner

Commissioned by the Food and Agriculture Organization (FAO)

Heidelberg, March 2009

„Assessment of energy and greenhouse gas inventories of Sweet Sorghum for first and second generation bio-ethanol“

Report commissioned by the Food and Agriculture Organization (FAO), Rome

Authors:
Susanne Köppen, Guido Reinhardt, Sven Gärtner

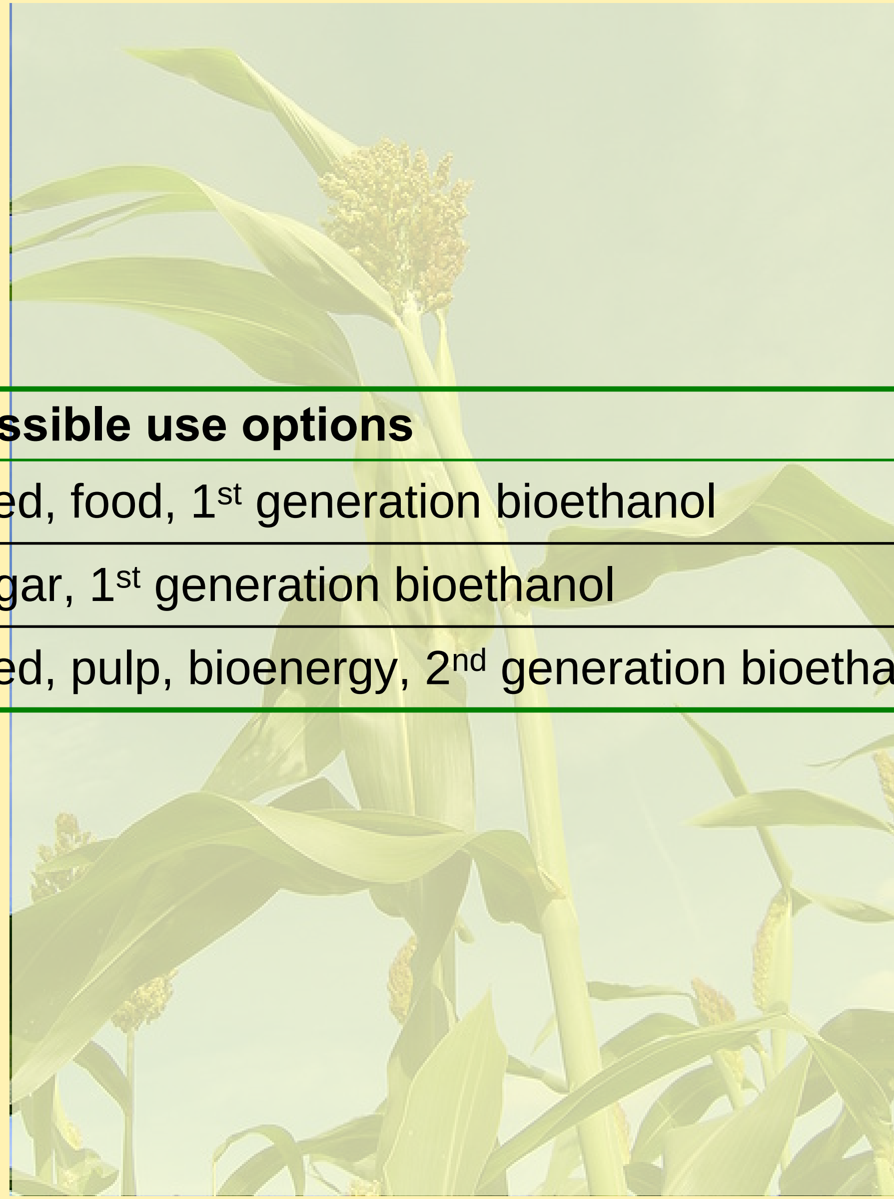
Final report:
March 2009

Characteristics of Sweet Sorghum

Sorghum bicolor

- **Geographical distribution:**
  - **in semi-arid to humid climates; 40° N to 40° S**
- **Physical characteristics:**
  - **Annual; grows from seeds; stalk contains a sugar-rich juice (sucrose, fructose, glucose); panicles produce up to 4 000 starch containing grains.**
  - **C4 crop, very drought resistant; good adaptability to poor soil types and to saline soils; very short vegetation period and thus is ideal for double cropping.**

Characteristics of Sweet Sorghum

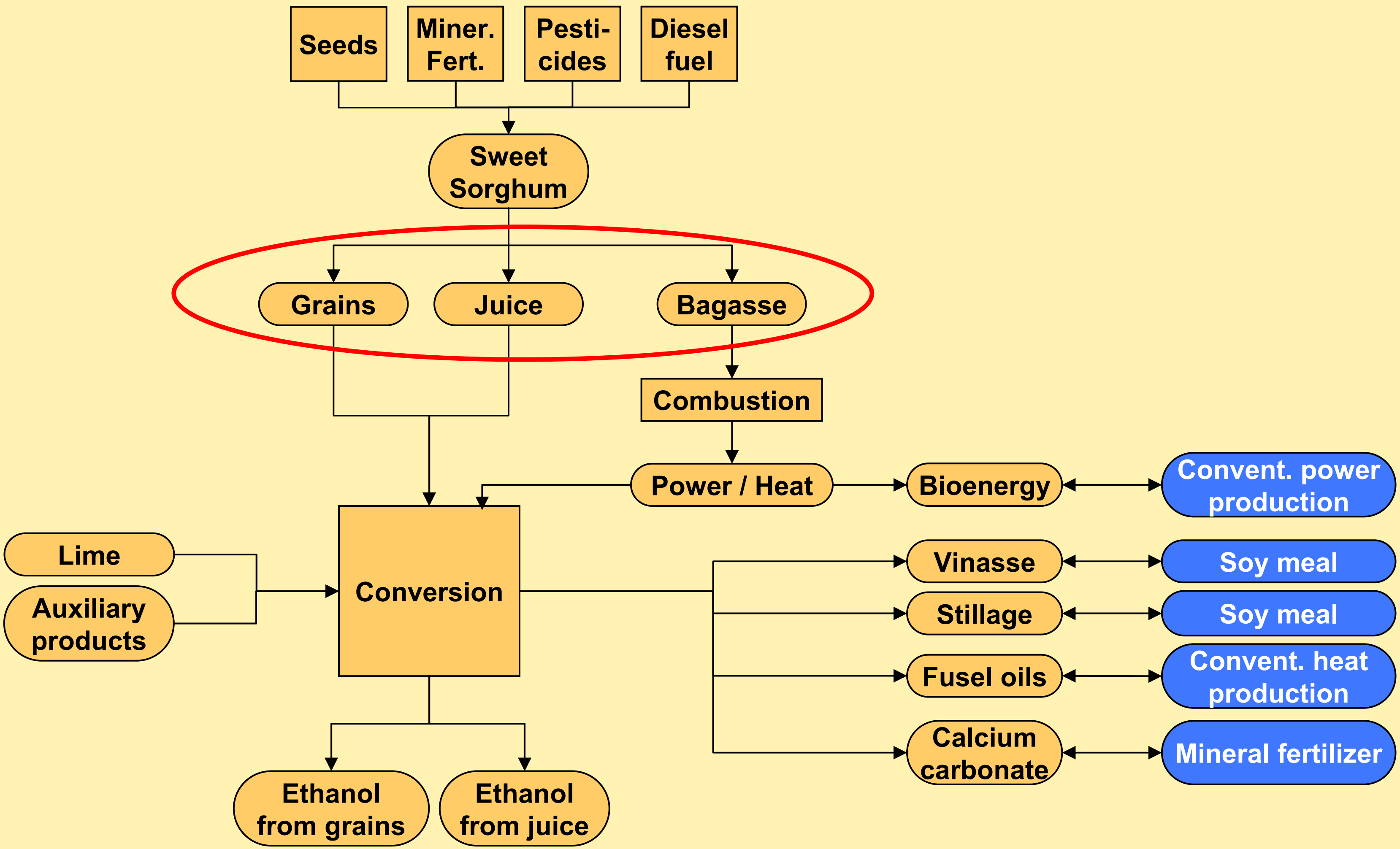


Crop part	Possible use options
Grains	Feed, food, 1st generation bioethanol
Juice	Sugar, 1st generation bioethanol
Bagasse	Feed, pulp, bioenergy, 2nd generation bioethanol, compost, fertilizer

Outline

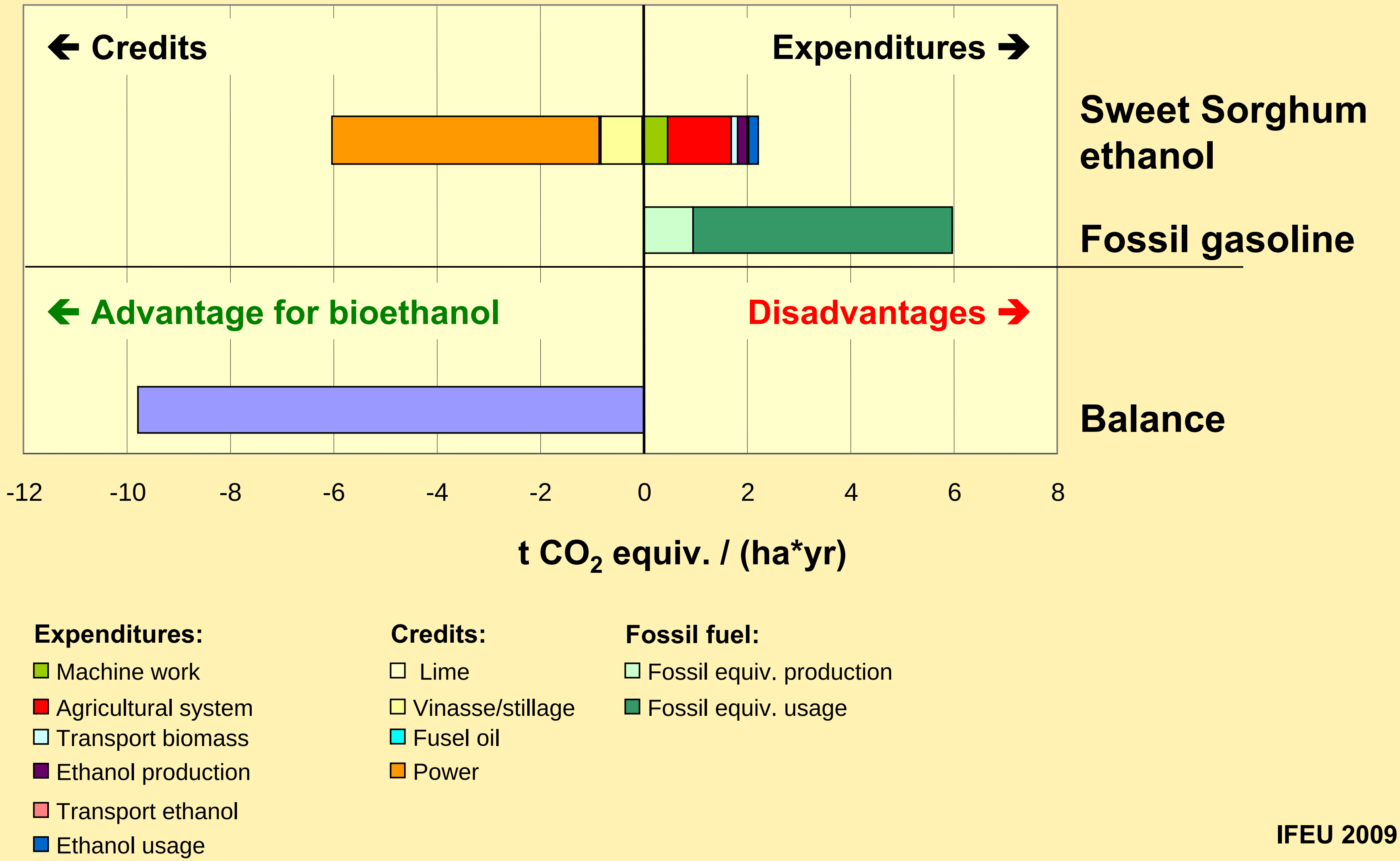
- Introduction
- Life cycle assessment (LCA) methodology
- **Energy and GHG balances of Sweet Sorghum EtOH**
  - **Sweet Sorghum vs. fossil fuel – main scenarios**
  - Sweet Sorghum vs. fossil fuel – sensitivity analyses
  - Sweet Sorghum vs. other ethanol crops
- Additional environmental impacts
- Conclusions
- Outlook: The SWEETFUEL project

Sw. sorghum ethanol vs. fossil fuel



Sw. sorghum ethanol vs. fossil fuel

Greenhouse effect



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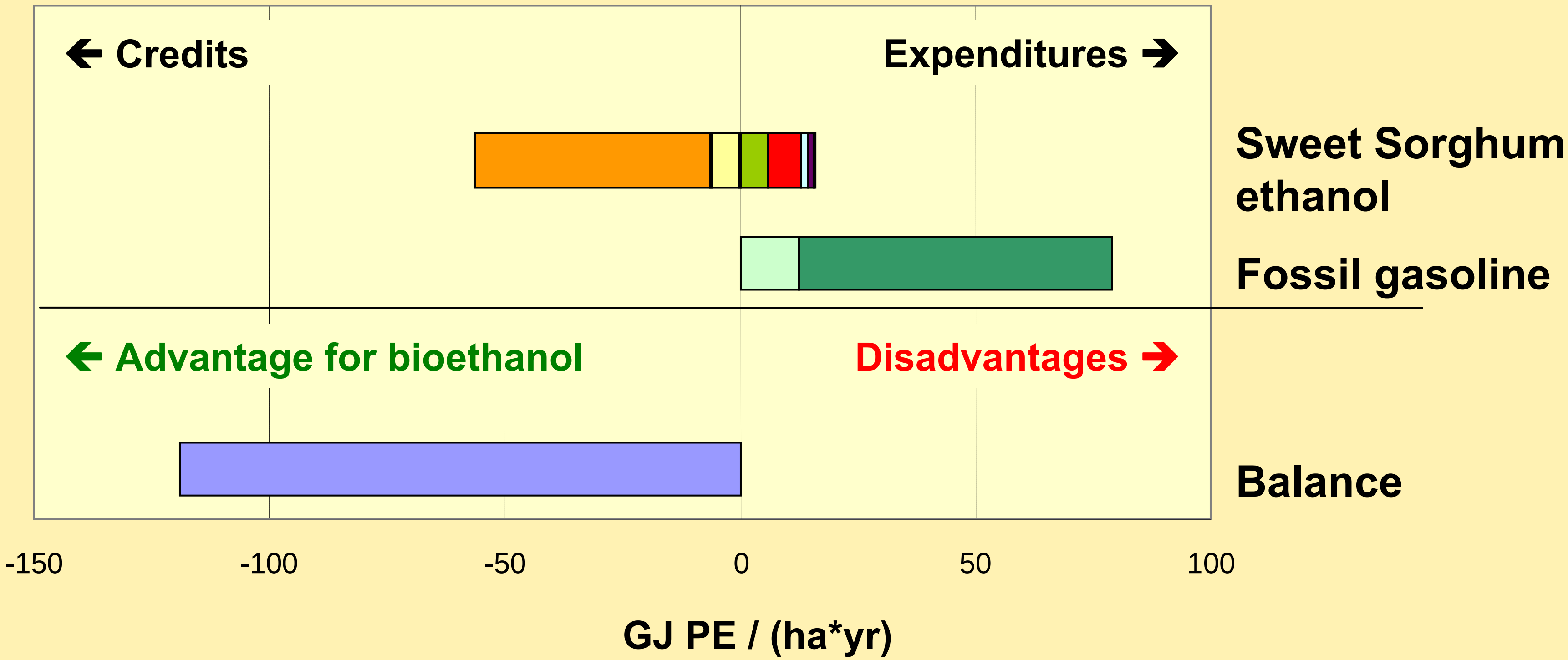
Sw. sorghum ethanol vs. fossil fuel

Energy savings



Expenditures:
- Machine work
- Agricultural system
- Transport biomass
- Ethanol production
- Transport ethanol
- Ethanol usage

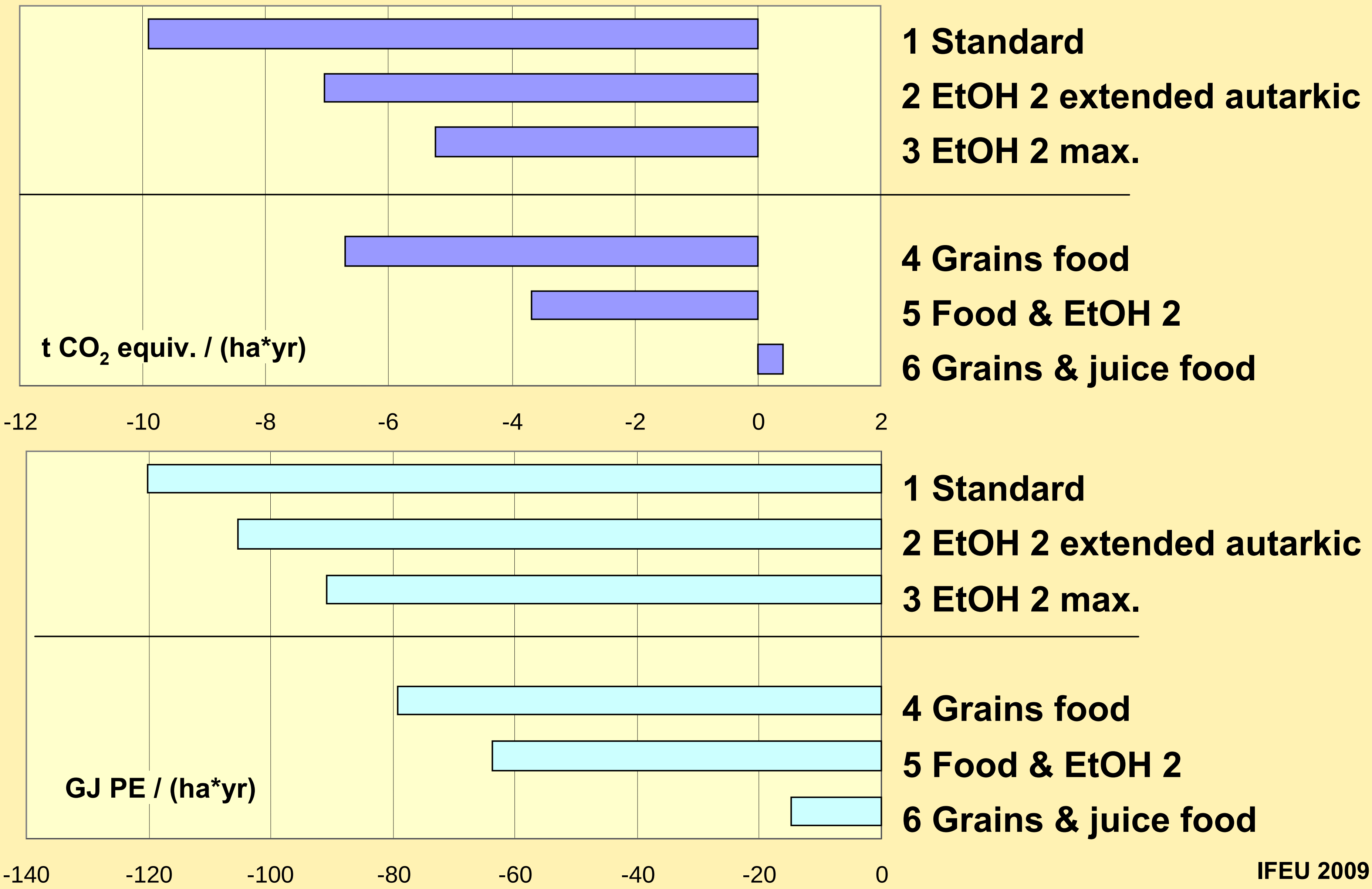
Credits:
- Lime
- Vinasse/stillage
- Fusel oil
- Power

Fossil fuel:
- Fossil equiv. production
- Fossil equiv. usage

Overview on scenarios

N°	Scenario	Juice	Grains	Bagasse
1	Standard	1st gen. bioethanol	1st gen. bioethanol	Process energy & bioelectricity
2	EtOH 2 extended autarkic	1st gen. bioethanol	1st gen. bioethanol	2nd gen. bioethanol (autarkic)
3	EtOH 2 maximum fossil	1st gen. bioethanol	1st gen. bioethanol	2nd gen. bioethanol (fossil fuel input)
4	Grains food	1st gen. bioethanol	Food	Process energy & bioelectricity
5	Food & EtOH 2	1st gen. bioethanol	Food	2nd gen. bioethanol (autarkic)
6	Grains & juice food	Food (fossil fuel input)	Food	2nd gen. bioethanol (autarkic)

Sw. sorghum ethanol vs. fossil fuel



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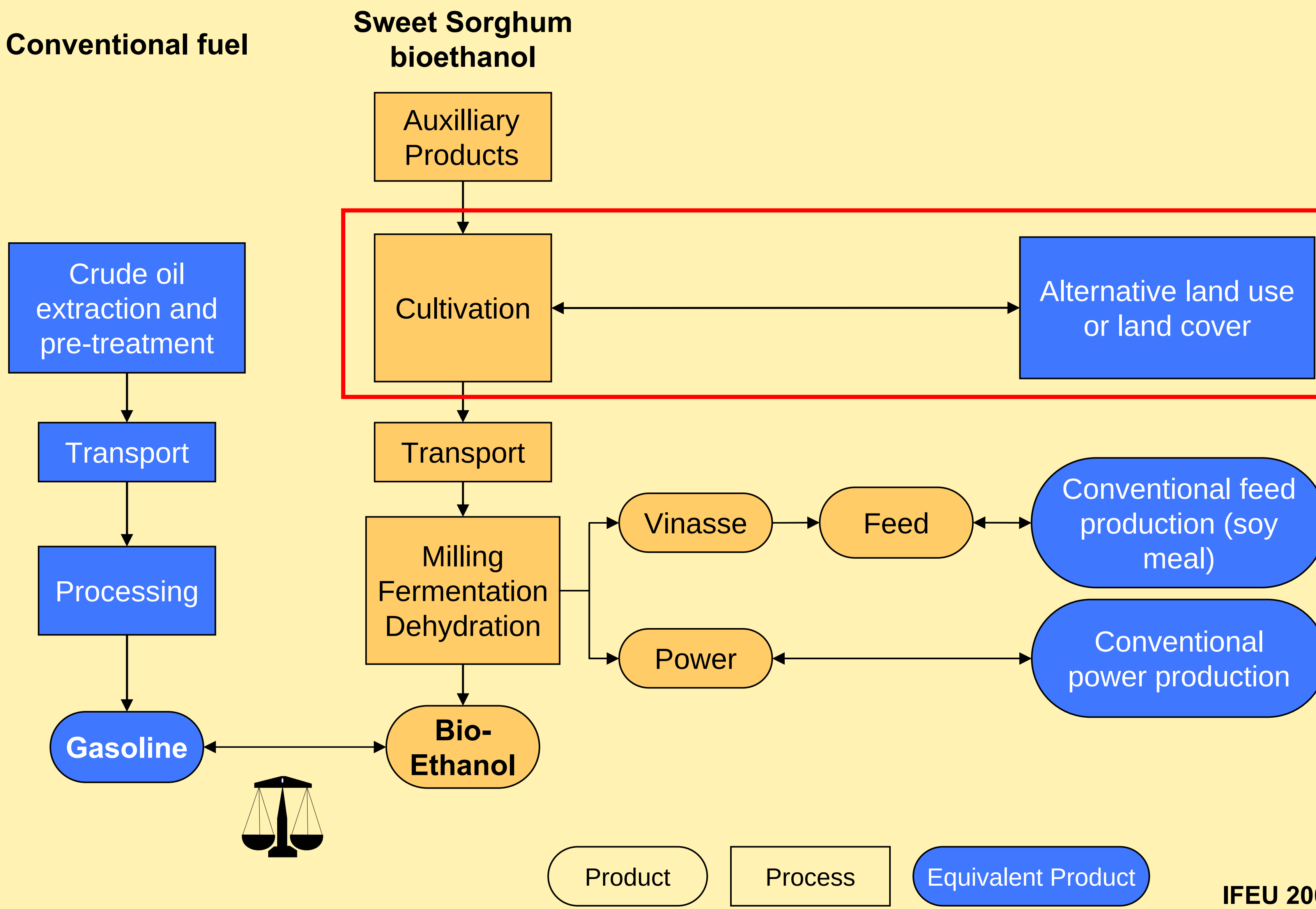
1. Agricultural reference system



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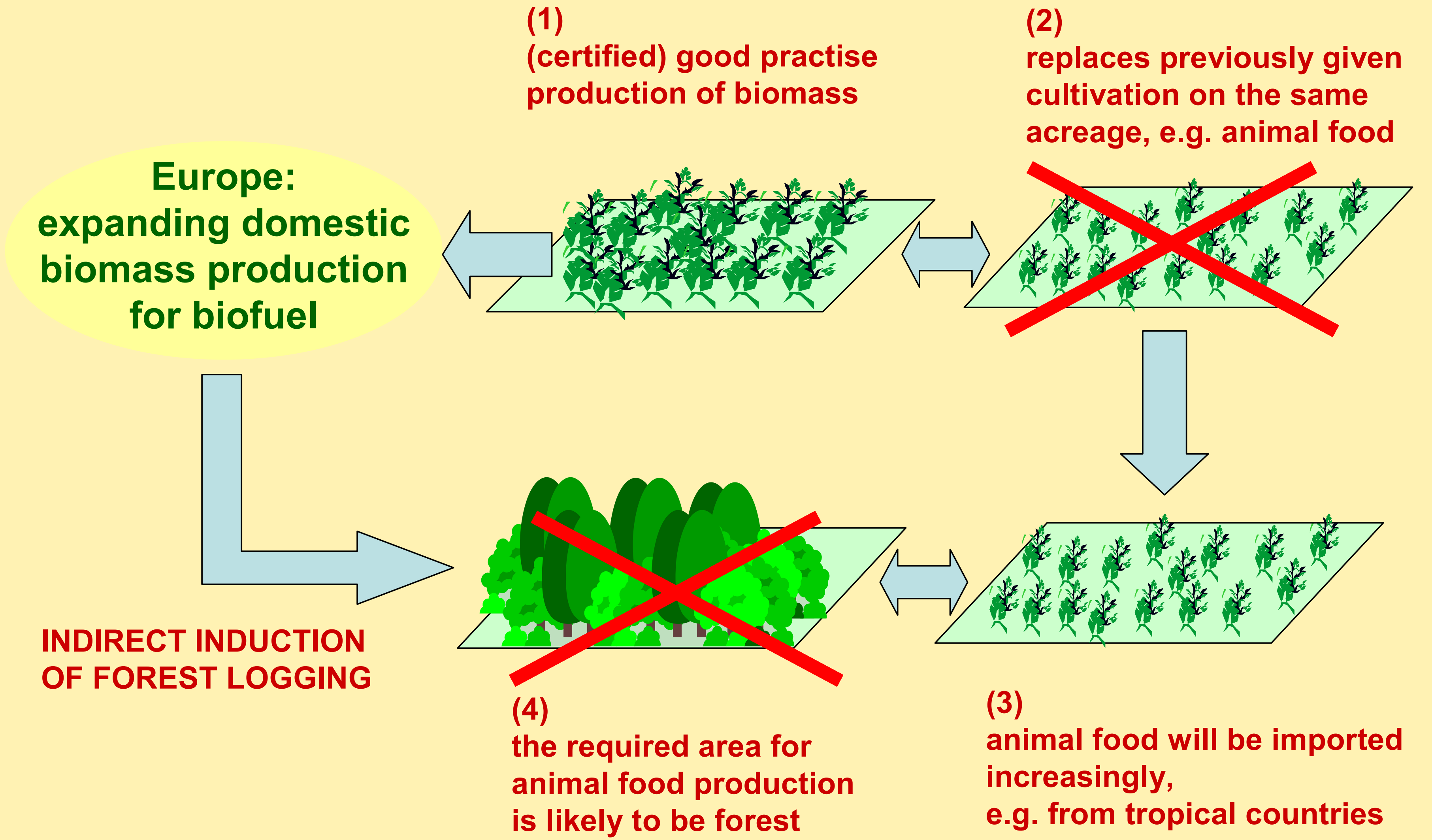

Fehrenbach et al. 2008

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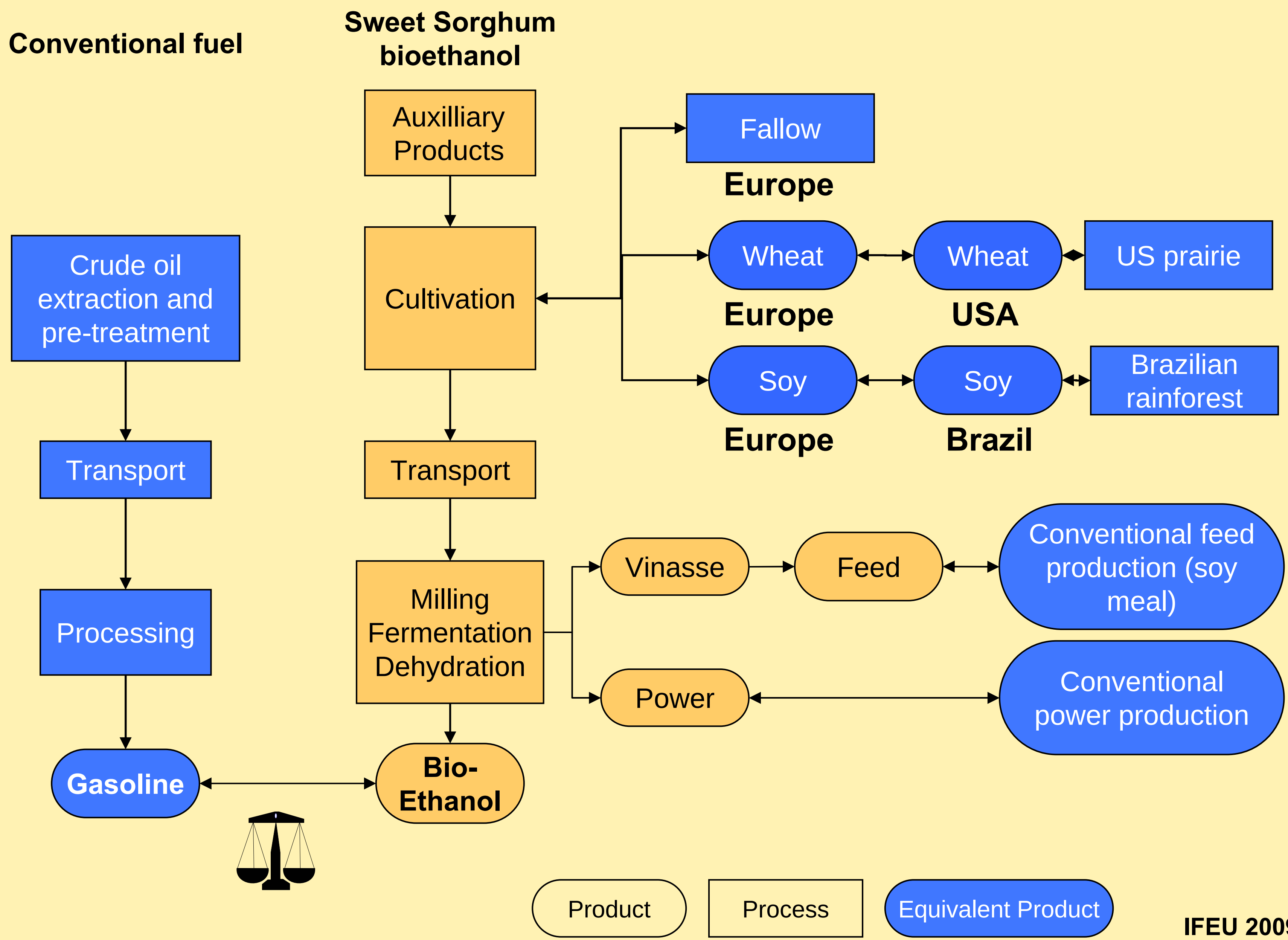

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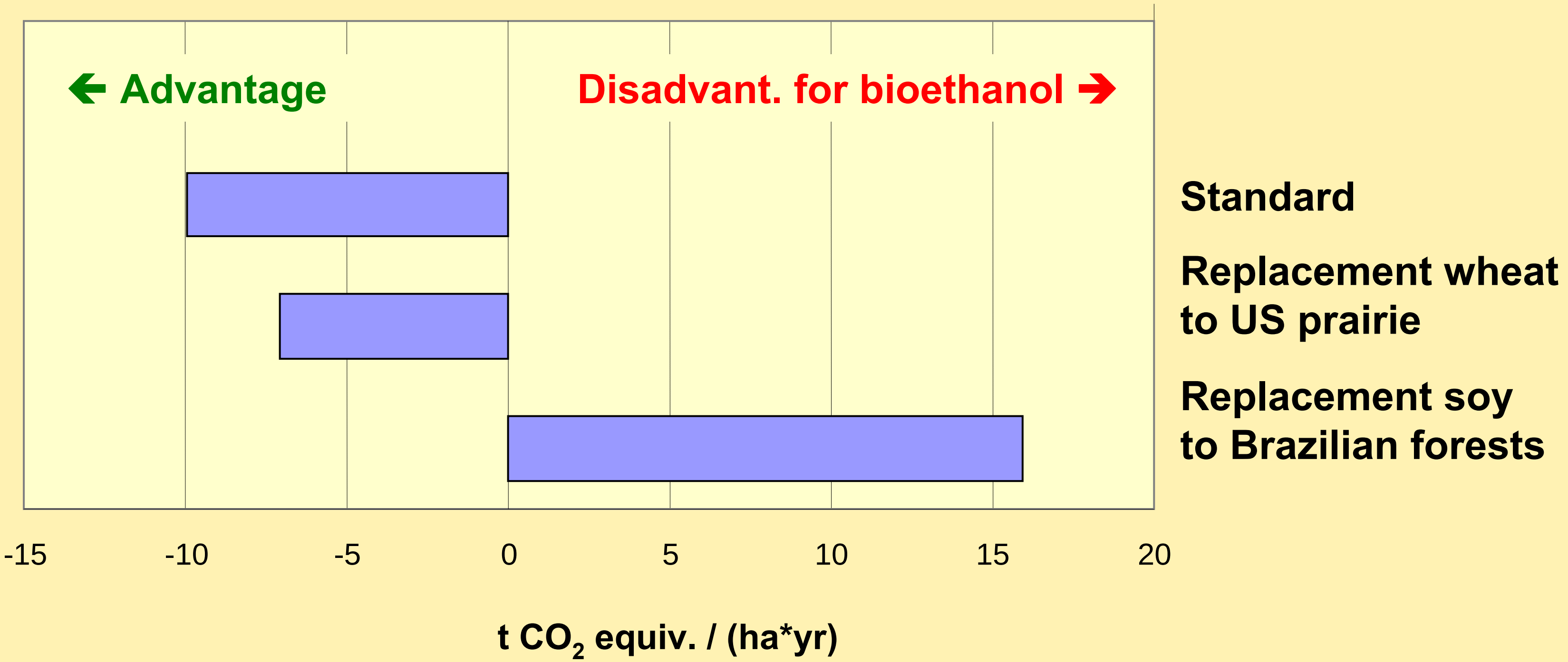
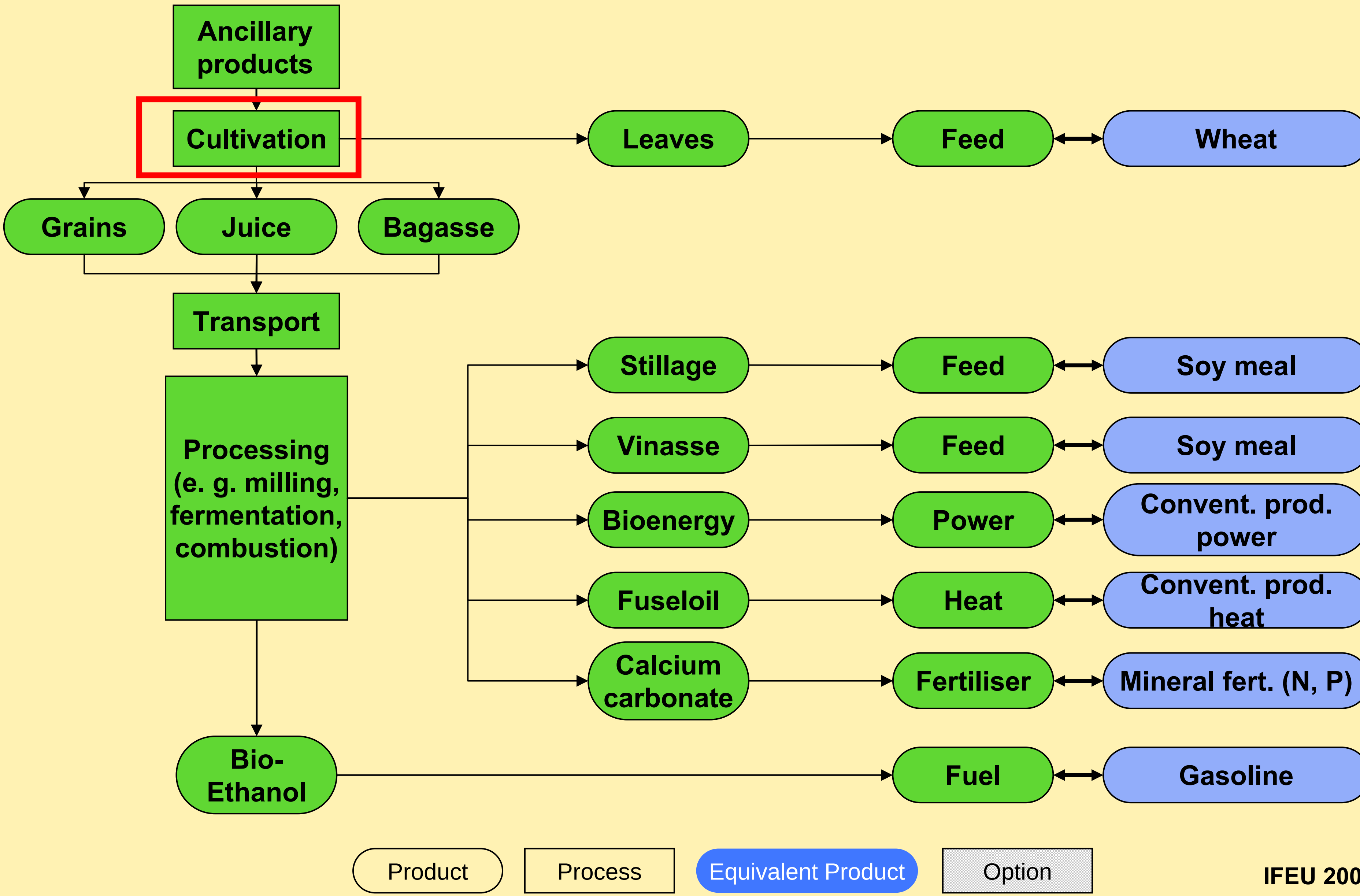
1. Agricultural reference system

Greenhouse effect



2. Different yields



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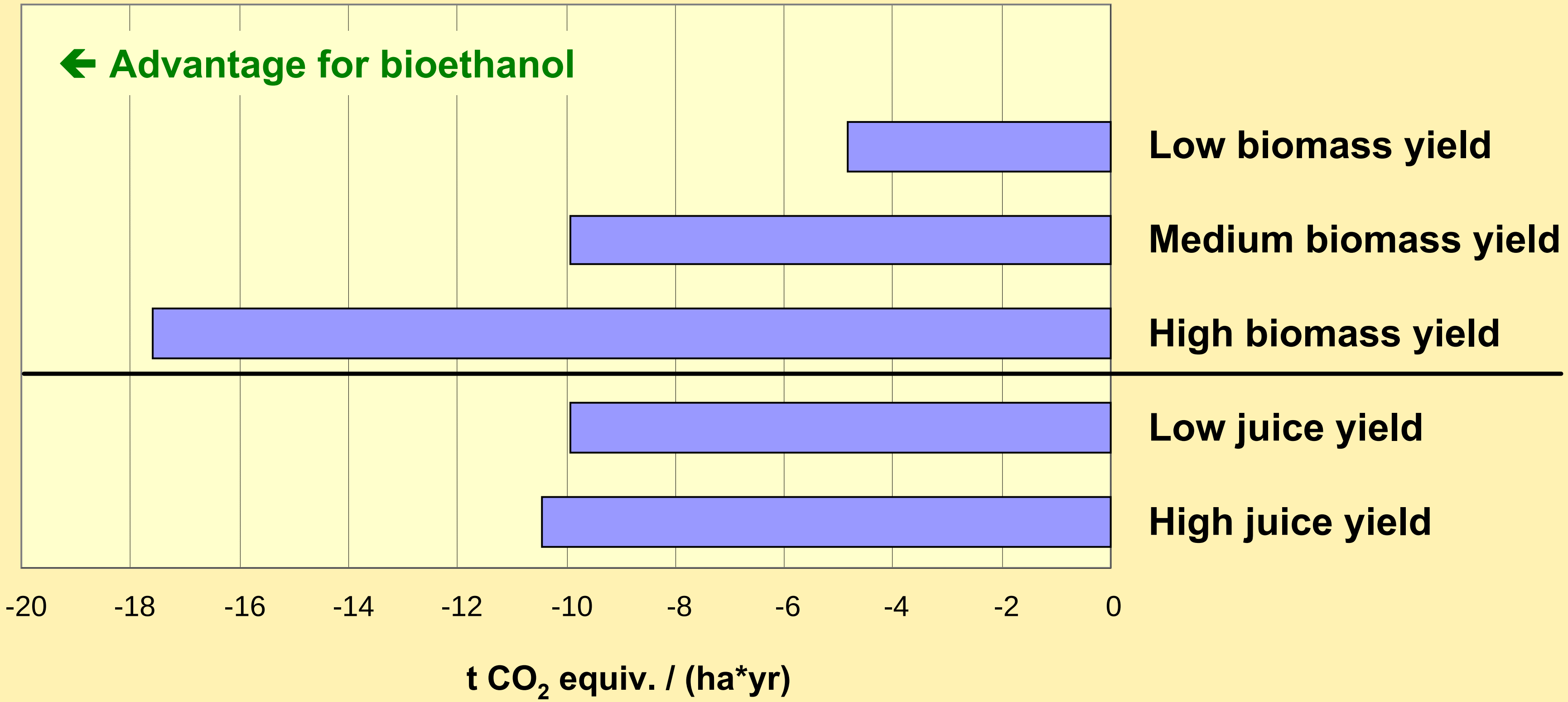
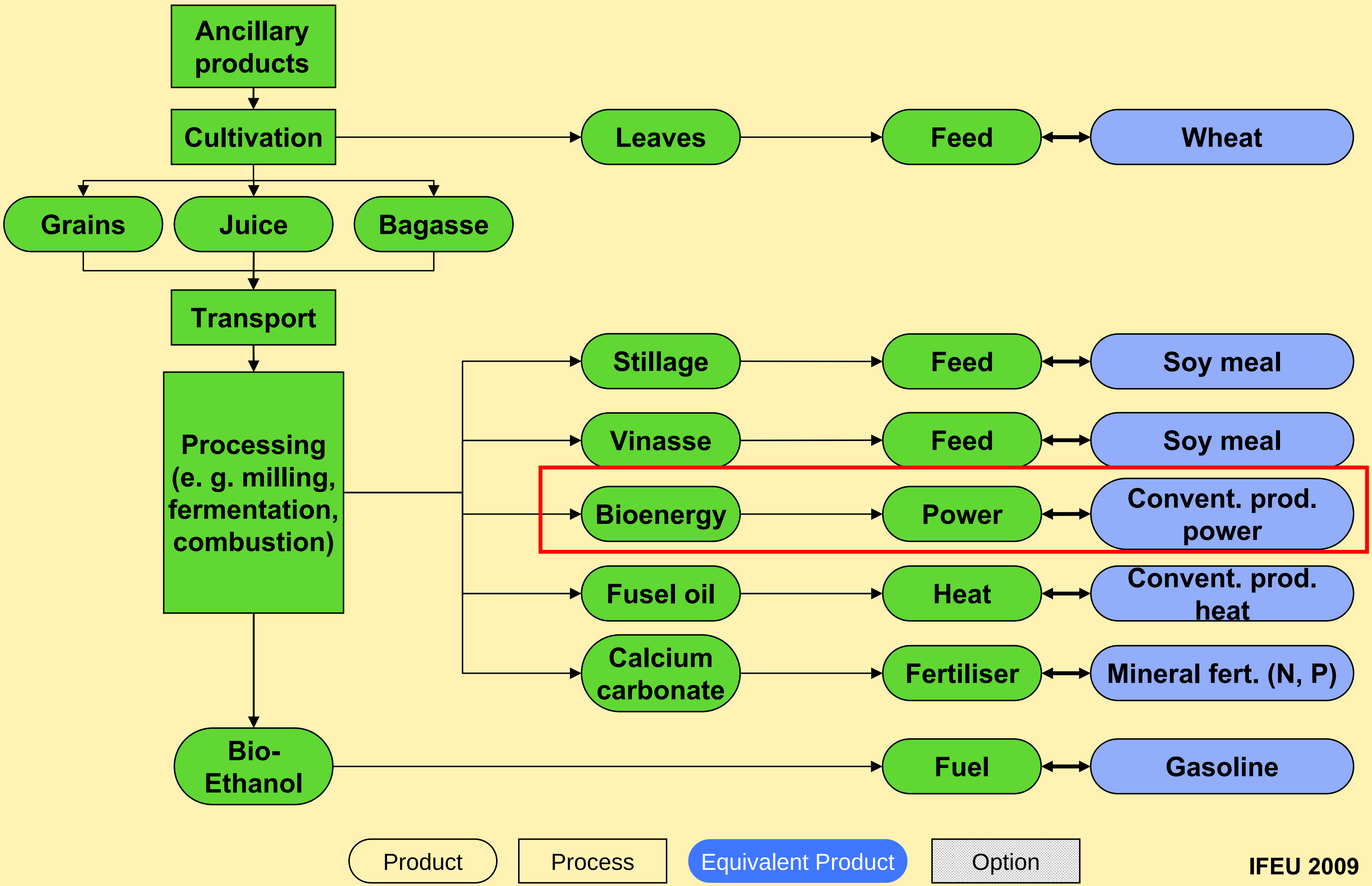


3. Substituted energy carriers



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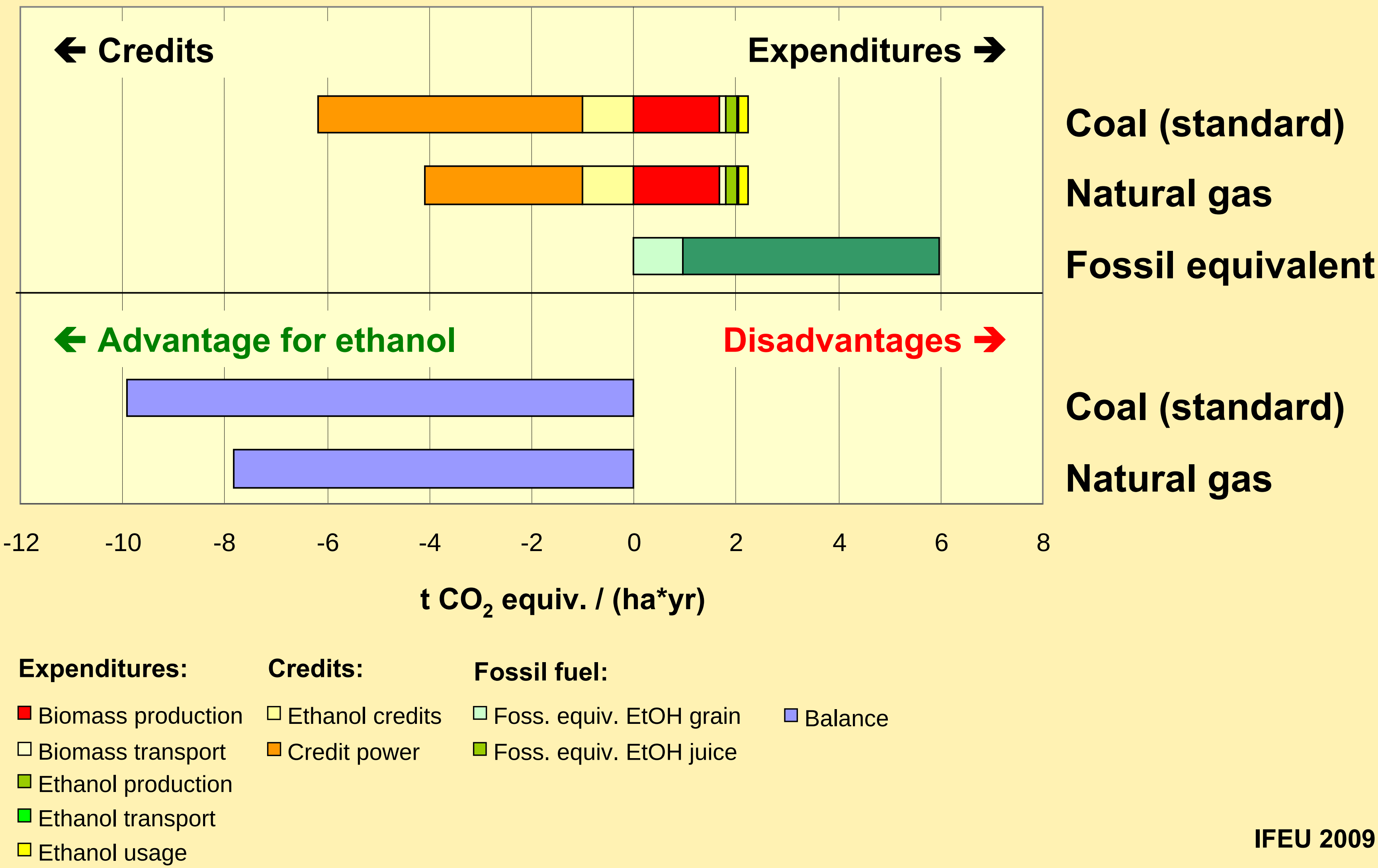

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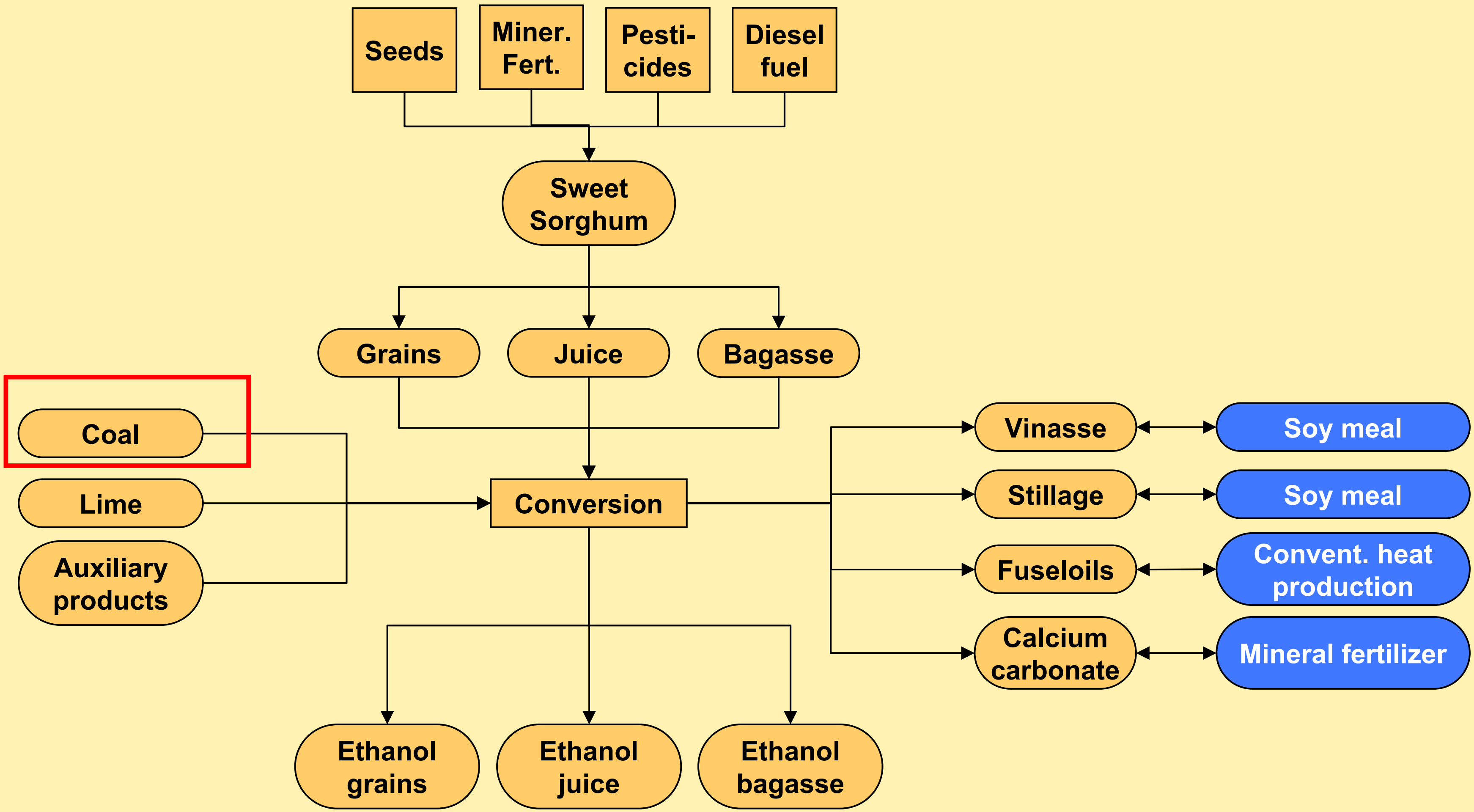
4. External energy carriers

Scenario ‚EtoH 2 max.‘



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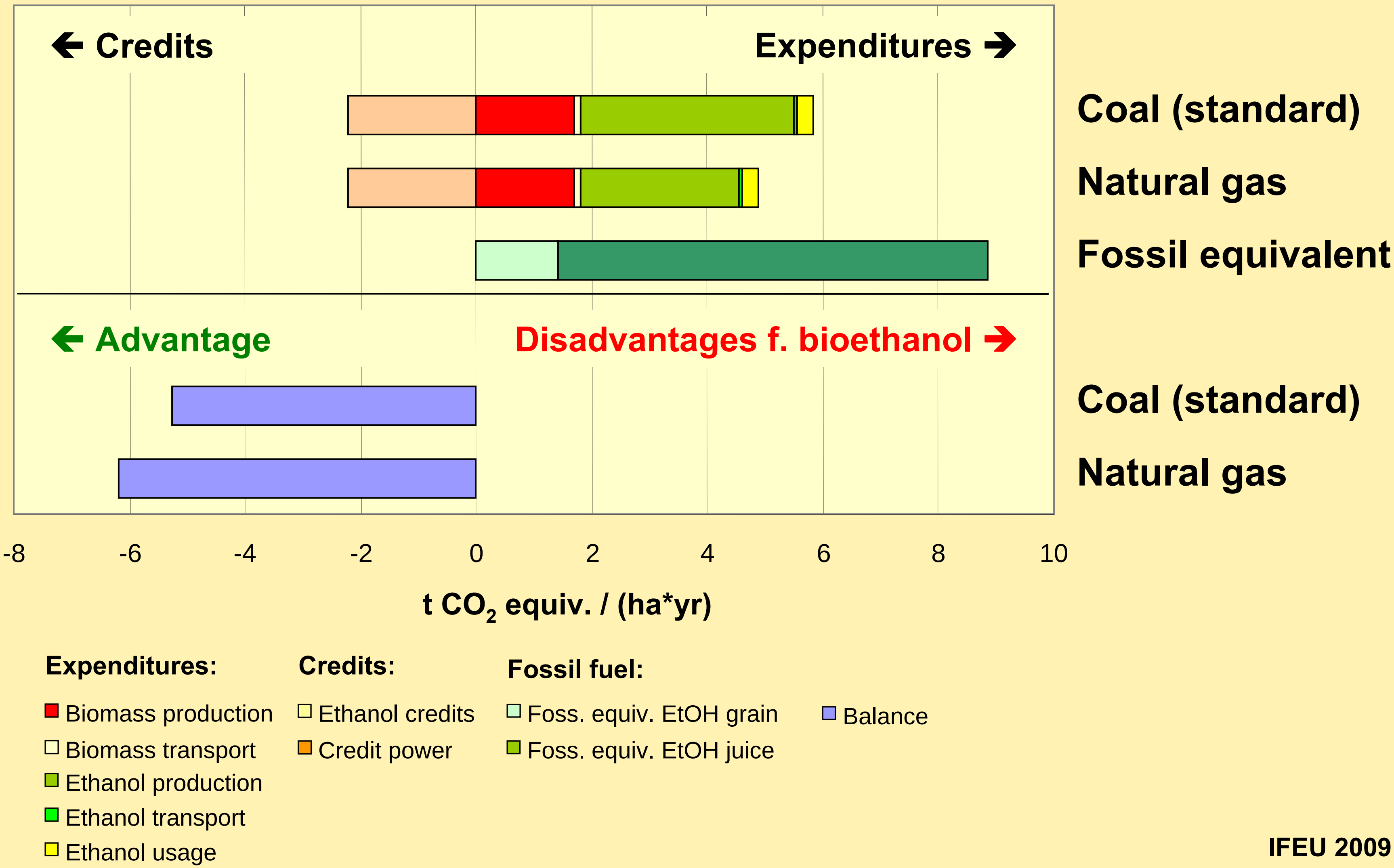

IFEU 2009

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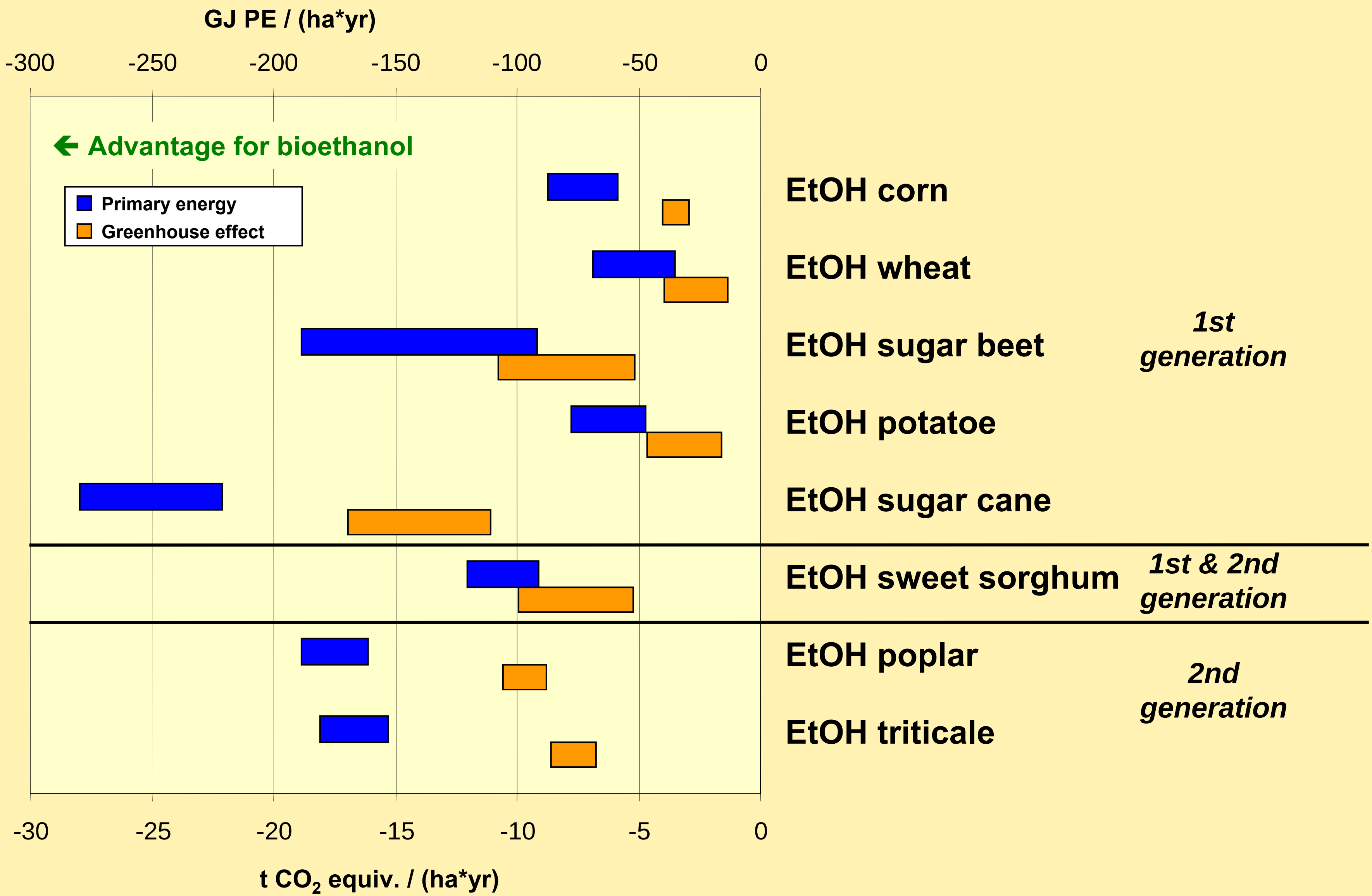
Comparison with biofuel



IFEU 2010

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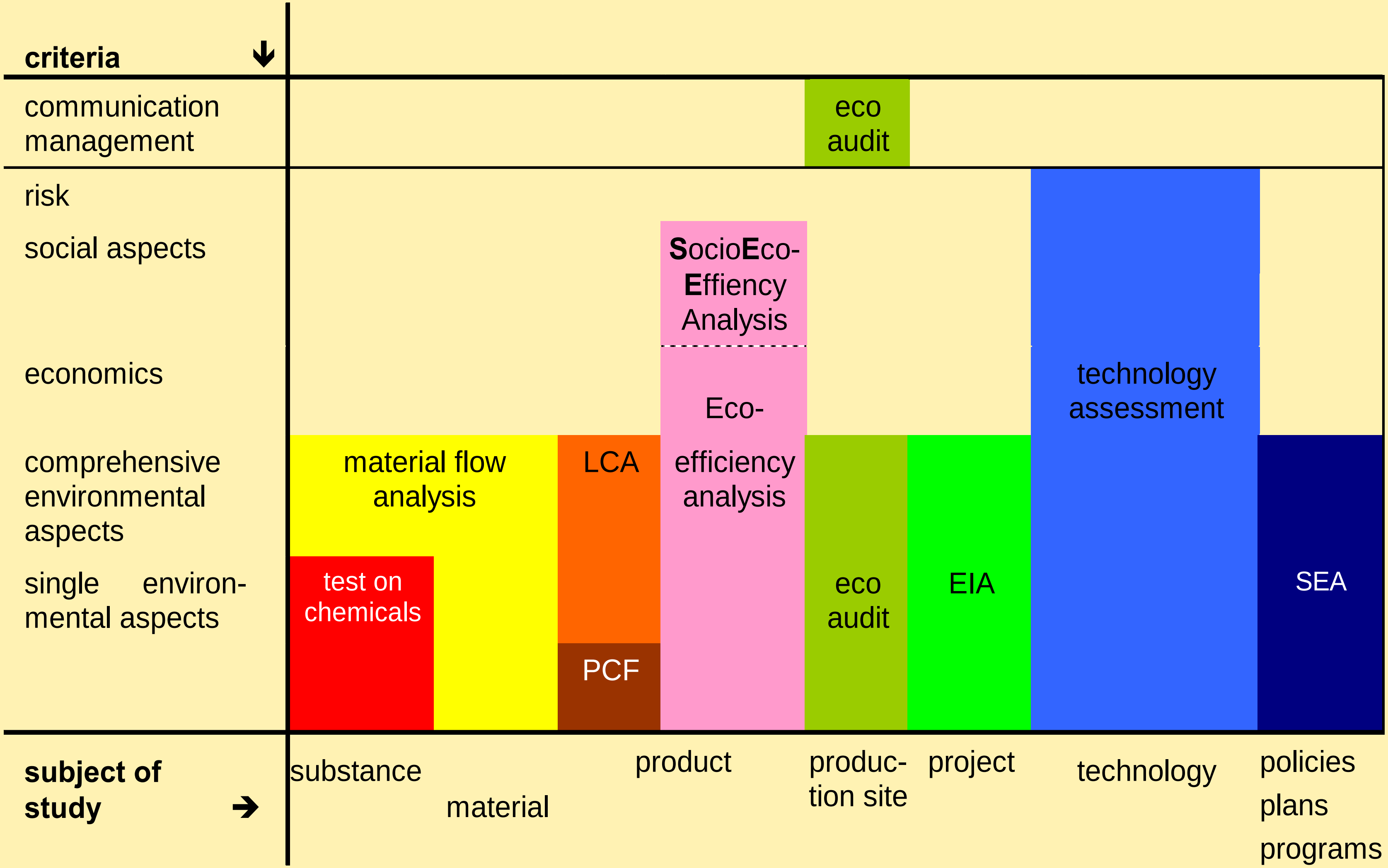
Environmental impacts of biofuels

- Like with any other product, a number of environ-mental impacts are usually associated with the production and use of biomass for biofuel.
- The main environmental concerns related to biofuels are land use and associated impacts on natural environment and resources such as GHG emissions, biodiversity, water and soil.
- A number of assessment techniques are available for environmental assessment which differ in the subject of study and show strengths and weaknesses

Review of environmental studies



➔ LCA is less suitable for site-specific env. impacts

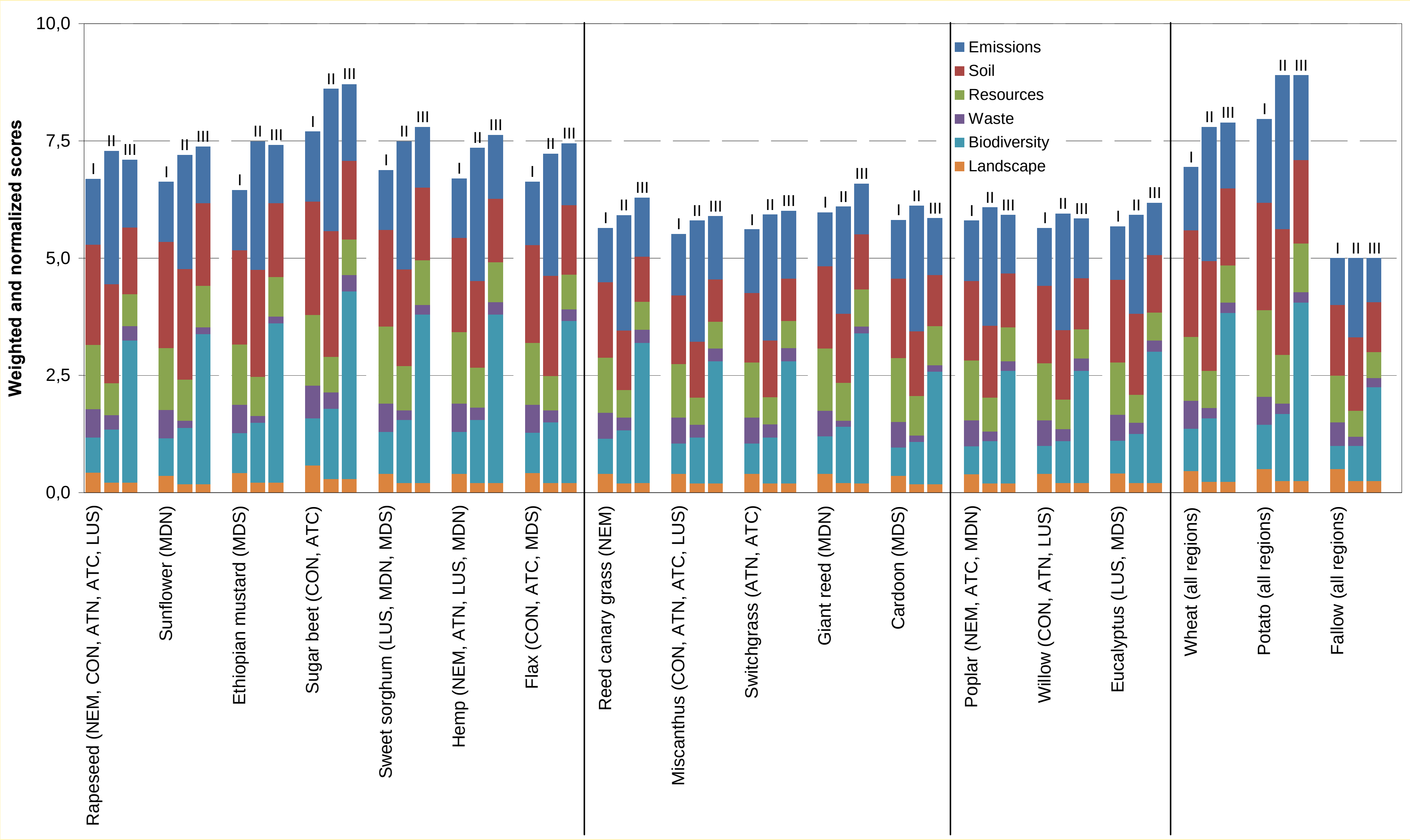
Other environmental impacts

Impact parameter	Sweet Sorghum production systems	
	Large-scale	**Small-scale/ low input**
Acidification	**-**	**-**
Eutrophication	**-**	**0 to -**
Ozone depletion	**-**	**-**
Photo smog	**-**	**-**
Soil erosion/ soil compaction	**- / -**	**- / 0**
Water consumption	**+**	**+**
Impact on ground and surface water	**0 to -**	**0**
Impact on soil	**+ to -**	**+ to -**
(Agro-)Biodiversity	**0 to -**	**0 to +**
+ positive; 0 no impact; – negative		

LCA

EIA

Example: EIA of energy crops in EU



Fernando et al. 2010

Conclusions

- **Sweet Sorghum bioethanol can contribute significantly to the conservation of fossil energy resources and to the mitigation of greenhouse gases.**

- **Also combination of 1st and 2nd generation bioethanol leads to savings of energy and greenhouse gases**

- **If grains are used as food, bioethanol from the stalk's sugar juice still shows clear advantages to fossil fuels.**

➔ Only crop to combine food and bioenergy production with available technologies

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Conclusions

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- **Also combination of 1st and 2nd generation bioethanol leads to savings of energy and greenhouse gases**
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➔ Only crop to combine food and bioenergy production with available technologies

Conclusions

- **If both sugar and grains are used as food, all energy and greenhouse gas expenditures can be compensated by ethanol production from the bagasse (2nd generation).**

Conclusions

- Optimization potentials:
  - If 1st and 2nd generation bioethanol are to be combined, part of the bagasse should be used for process energy generation
  - Land use change: indirect land use change due to the replacement of food or feed crops can lead to significant carbon emissions and thus to a disadvantageous greenhouse gas balance; Sweet sorghum should not compete with food/feed production

Conclusions

- **Optimization potentials:**
  - **Yields: higher biomass yields can lead to higher savings in energy and greenhouse gases**
  - **Energy carrier: the higher the specific emissions of greenhouse gases are in the replaced energy carriers, the better results can be obtained by replacing it.**

- **In comparison with other ethanol crops no clear advantage or disadvantage; depends on specific boundary conditions**

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Outlook

Sweet Sorghum – an alternative energy crop

- **EU FP7 project (no. 227422)**
- **Duration: 01/2009 – 12/2013 (60 months)**
- **Total budget: 4.9 M € (EC contrib.: 3.0 M €)**
- **Coordinator: CIRAD**
- **Partners: ICRISAT, EMPRABA, KWS, UNIBO, UCSC, ARC-CGI, UANL, WIP**

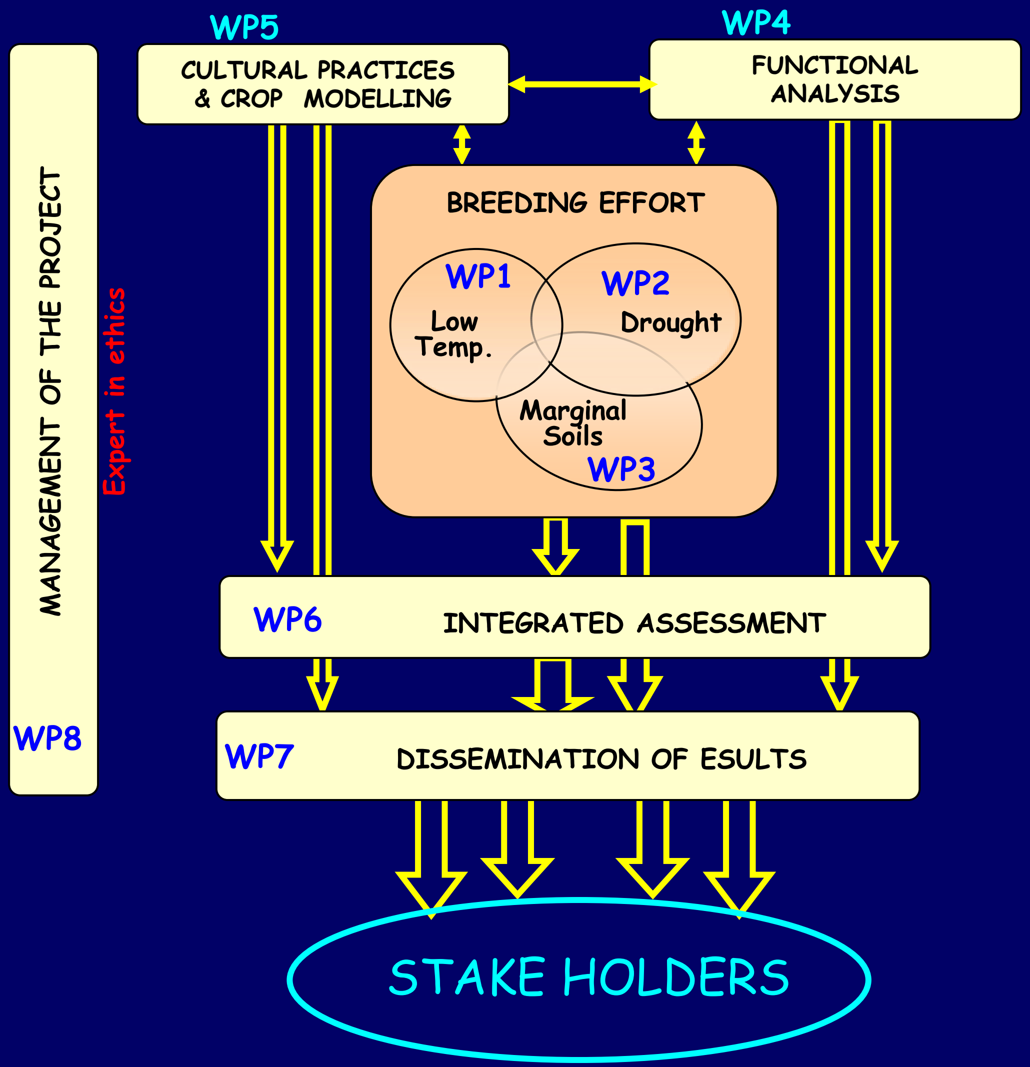
- **Objective:**
  - **Develop bio-ethanol production in temperate and semi- arid regions from sweet sorghum through genetic enhancement and improvement of cultural and harvest practices**

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

Sweet sorghum : an alternative energy crop

Project Number: 227422   Web site: www.sweetfuel-project.eu

Organisation of WPs



Breeding objectives

Specific objectives of breeding programmes **WP1**, **WP2** and **WP3** are to develop new sorghum lines or hybrids.
The target ideotype depends on the target environment as well as the system of transformation

Target ideotype for WP1
Sorghum with high biomass, good adaptation to low temperature and good digestibility (low content of lignin, *bmr* trait)
⇨ suitable for 2nd generation bioethanol

Target ideotype for WP2
Double purpose sorghum (grain + sugars) suitable for humane and/or animal feeding, with a good drought adaptation, juicy stalks with high sugar content and good digestibility
⇨ suitable for 1st generation bioethanol

Target ideotype for WP3
Double purpose sorghum (grain + sugars) suitable for humane and/or animal feeding, with a good adaptation to marginal soils (acidity, high Al, low P) and good digestibility
⇨ suitable for 1st generation bioethanol

Project Number: 227422 Web site: www.sweetfuel-project.eu

Other objectives

Other specific objectives of SweetFuel are:

WP6

Provide a multicriteria evaluation of the sustainability of the bioethanol production from sweet sorghum on a social, economic and environmental point of view

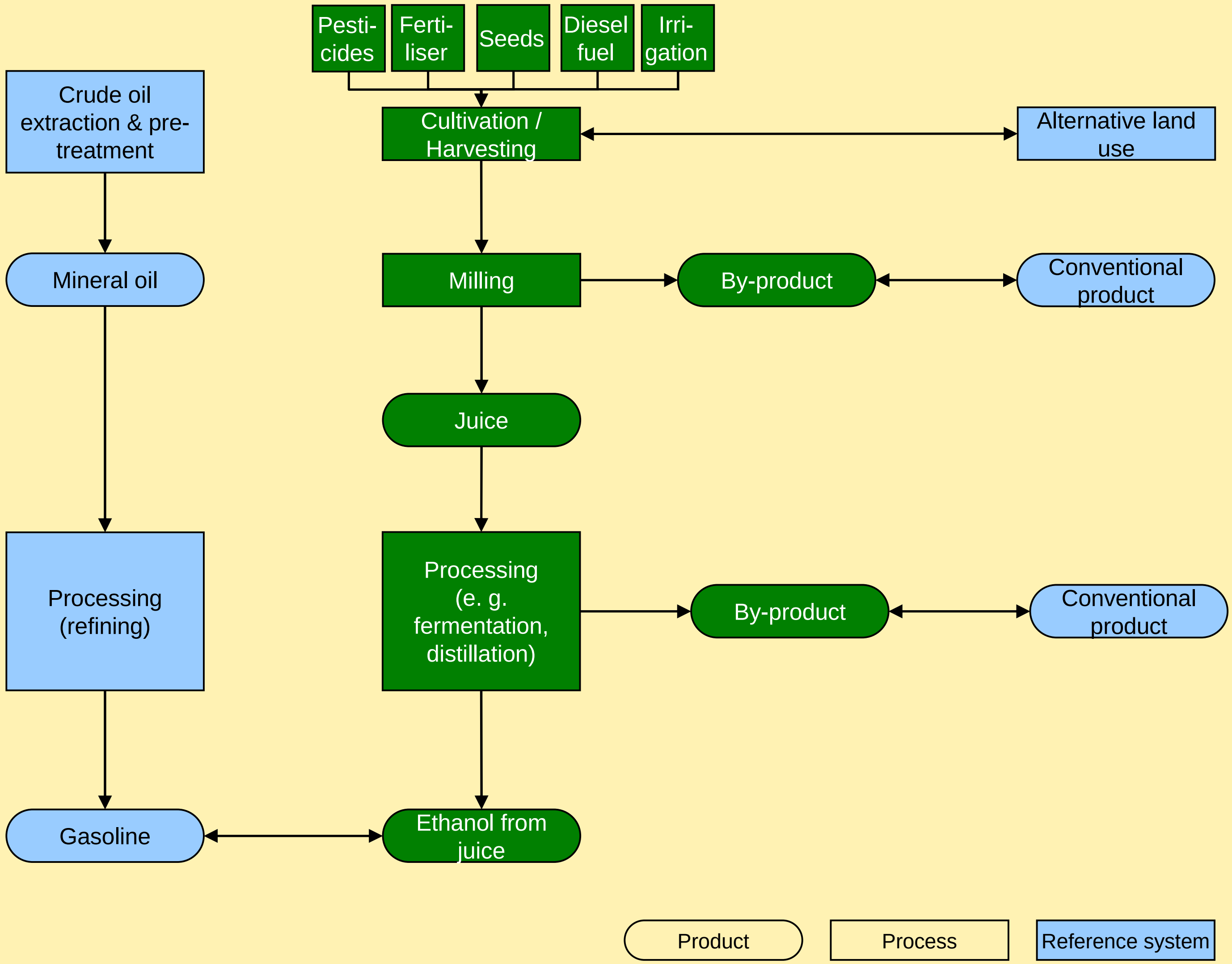
Task 6.1 — **Definitions and settings & Technological assessment**
Task leader: CIRAD

Tasks 6.2 – 6.4

Environmental assessment	Economic assessment	SWOT analysis
Task leader: IFEU	Task leader: ICRISAT	Task leader: WIP

Task 6.5 — **Integrated assessment of sustainability**
Task leader: IFEU

Basic life cycle comparison

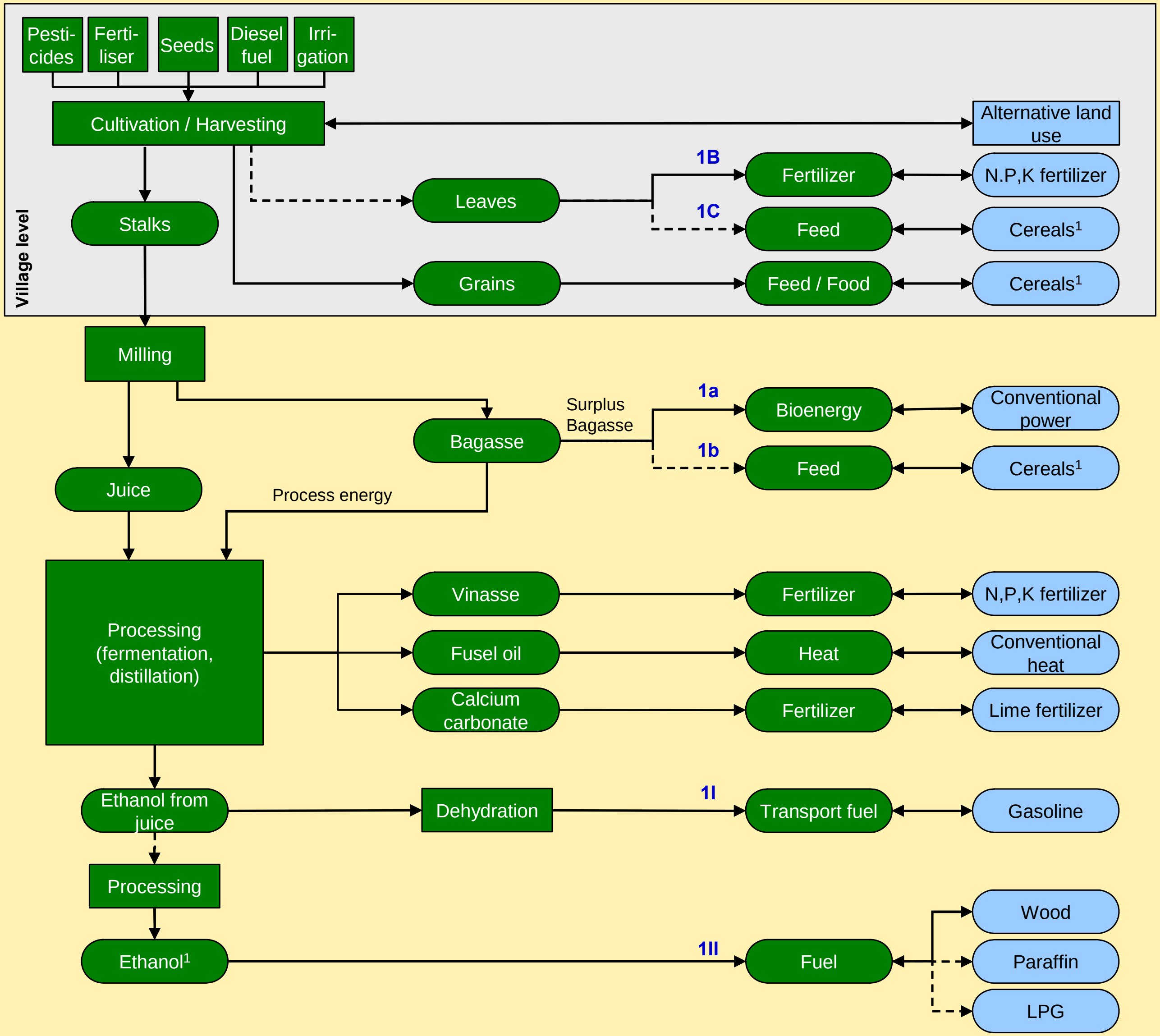


SWEETFUEL scenarios

Semi-arid / tropical climate – centralised

- Sweet sorghum crops are cultivated in villages and transported to central units where further processing steps follow
- Grains for feed / food in order to set off food security problems
- Bagasse used for process energy generation in ethanol production

Tropical climate – centralised



1 needs to be discussed / clarified **Scenario** Option Process Product Reference system

SWEETFUEL scenarios

Semi-arid / tropical climate – decentralised

- Two levels of decentralisation:
  a) Syrup is cultivated from sweet sorghum juice in villages and transported to central ethanol units

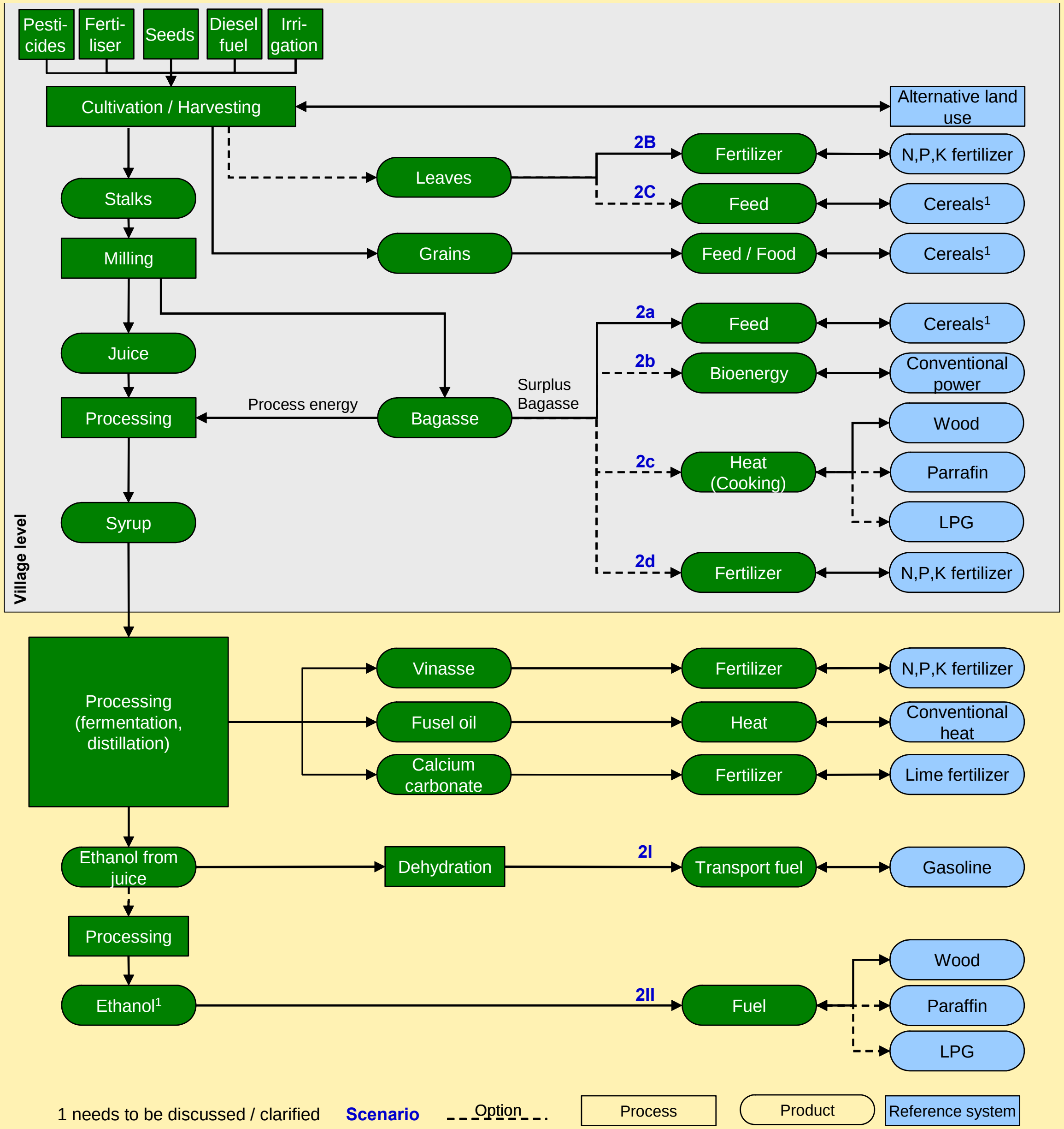
     Bad infrastructure for biomass transportation might require partial local production and syrup is more advantageous for ethanol production as longer storable

  b) All production steps until ethanol processing are realized at village level

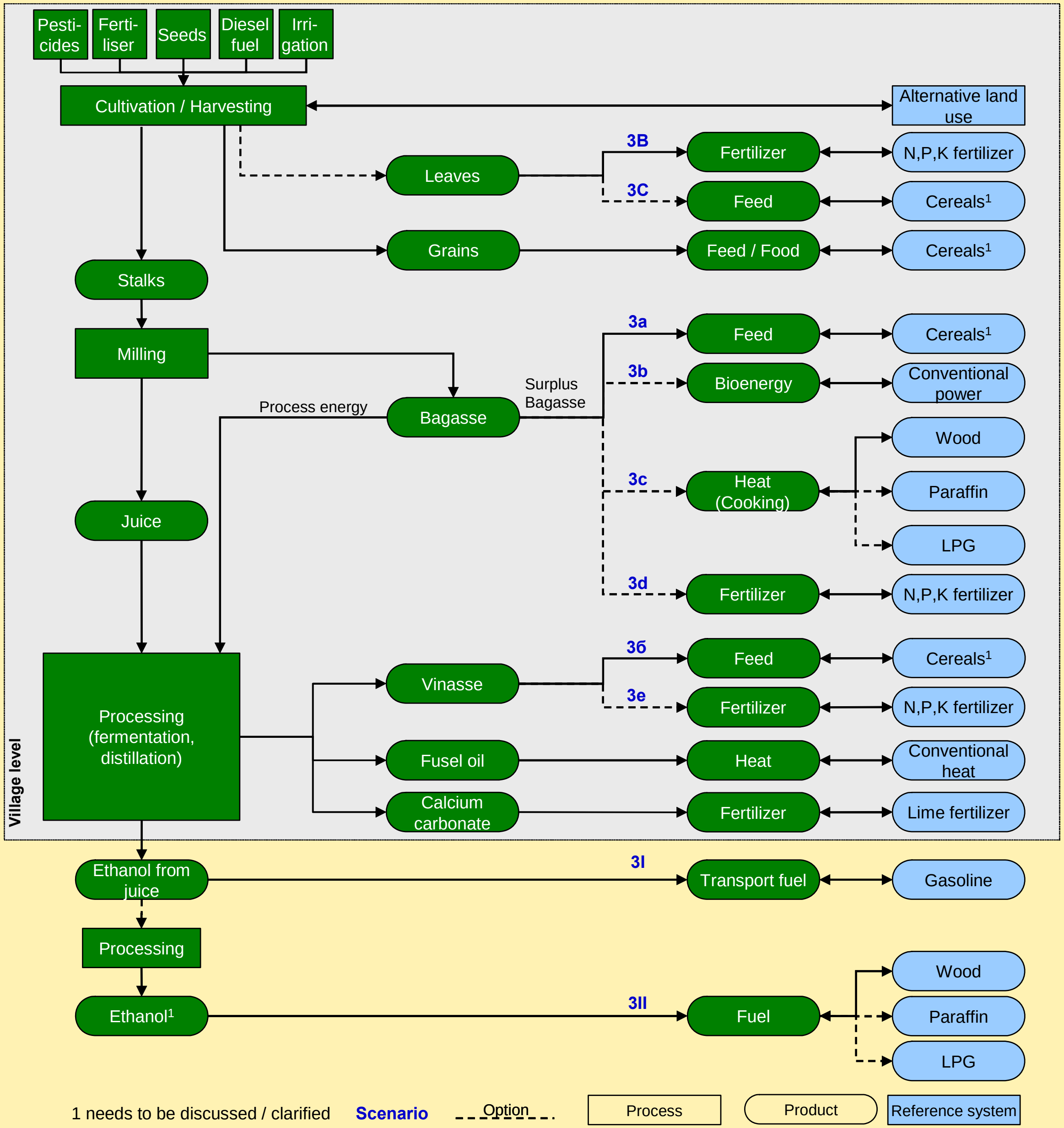
     Opportunity to gain access to own energy and to provide a healthier energy source than wood or paraffin; contribution to rural development

- Grains for feed / food in order to set off food security problems
- Bagasse used for process energy generation in syrup and ethanol production

Tropical climate – decentralised I



Tropical climate – decentralised II



SWEETFUEL scenarios

Temperate climate

- Only large scale centralised production
- Whole crop is used ➔ focus on high biomass yield instead of high sugar / juice yields
- Focus on 2nd generation production technology
- Four pathways are assessed:
  a) Biogas production
  b) 2nd generation ethanol production from lignocellulose
  c) Direct combustion
  d) Gasification for BtL-production

Thank you for your attention !

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Downloads:

www.ifeu.de

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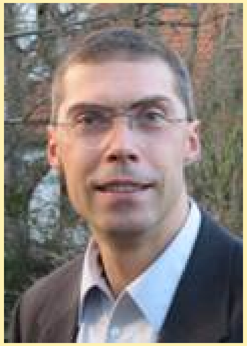
Susanne Köppen



Guido Reinhardt