Life Cycle Assessment as a support tool for bioenergy policy

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Outline: Applying LCA for quantifying the climate effects of bioenergy

- Urgent need for replacing fossil fuels in order to mitigate climate change; bioenergy systems promising strategy
- Life Cycle Assessment as a decision-support tool for bioenergy
- Quantified benefits of bioenergy systems very variable and depend on methodological choices
- Unresolved methodological issues inthe LCA of bioenergy systems
- Insights and Prospects: LCA's uncertainty and relevance

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Counter-intuitive lessons from hard systems analysis

What’s better?

- Composting	vs	Incineration
- Reusable nappies	vs	Disposable nappies
- Recycled bags	vs	Plastic bags
- Recycled paper	vs	Virgin paper
- Organic food	vs	Conventional food
- Local food	vs	Imported food
- Biofuels/bioenergy	vs	Fossil fuels

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The Life Cycle concept: a systems approach

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Source: EC-JRC

Life Cycle Thinking and Assessment

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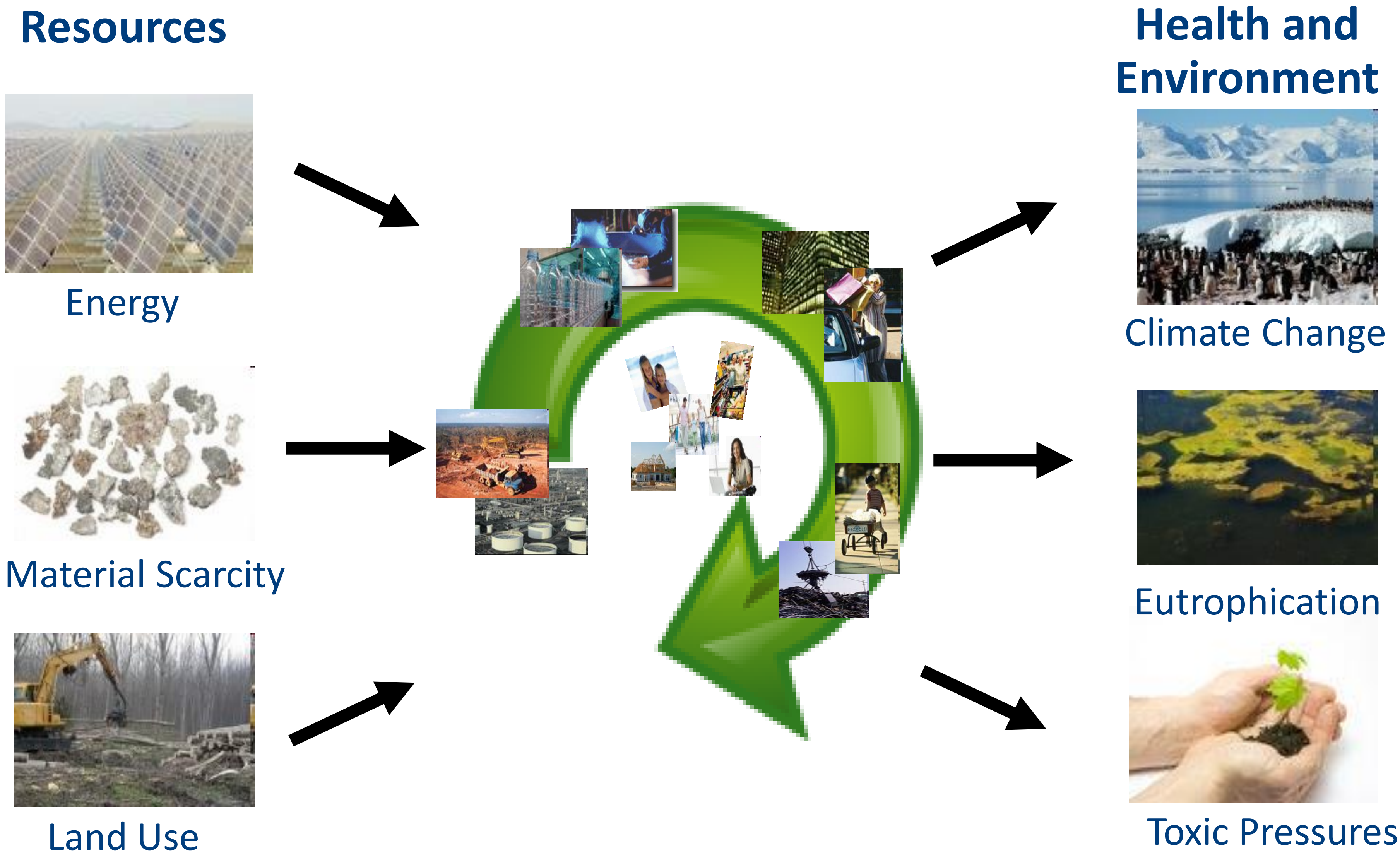

Source: EC-JRC

Aggregation to single score indicator

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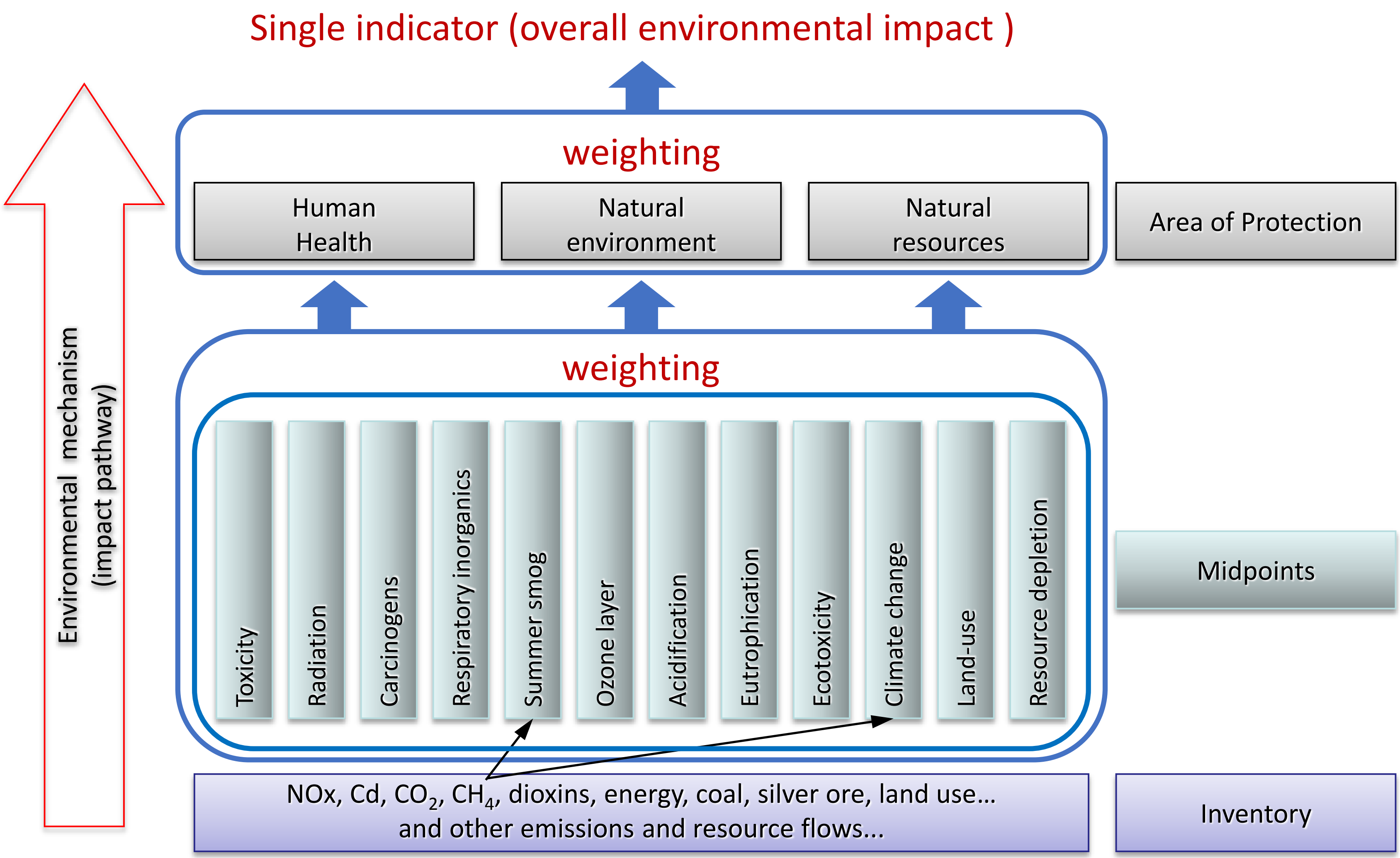
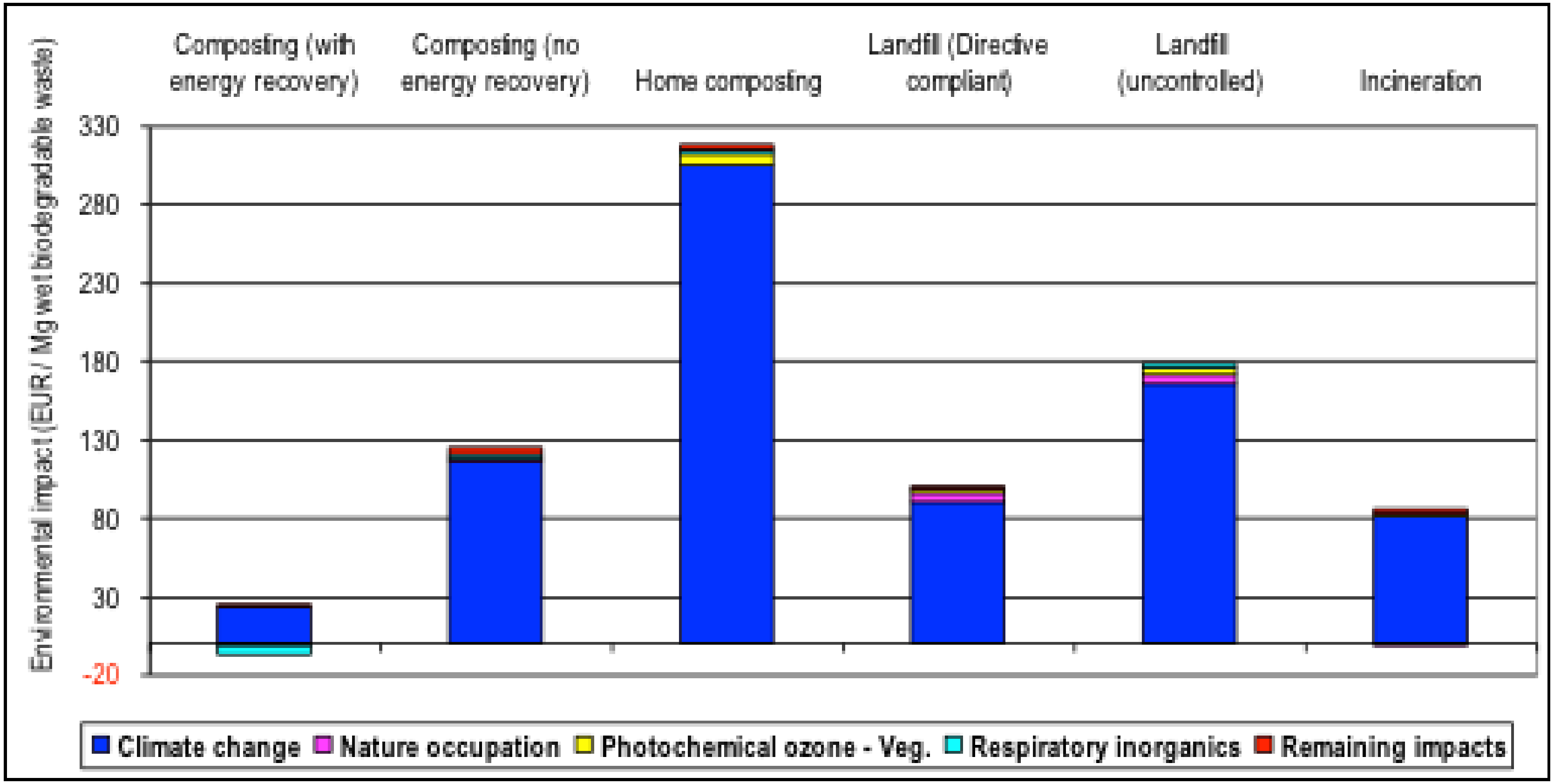


Environmental impacts for different treatment options for MSW



Source: JRC, 2008

Necessity of Life Cycle Thinking in Policy and Business

- Avoid shifting-of-burdens
  - from one stage to another in product life-cycles
  - among countries, to/from outside EU
  - across different environmental and health impacts and resources use
  - from one generation to the next
- Fair basis for comparisons
  - holistic assessments
  - equivalent functionality

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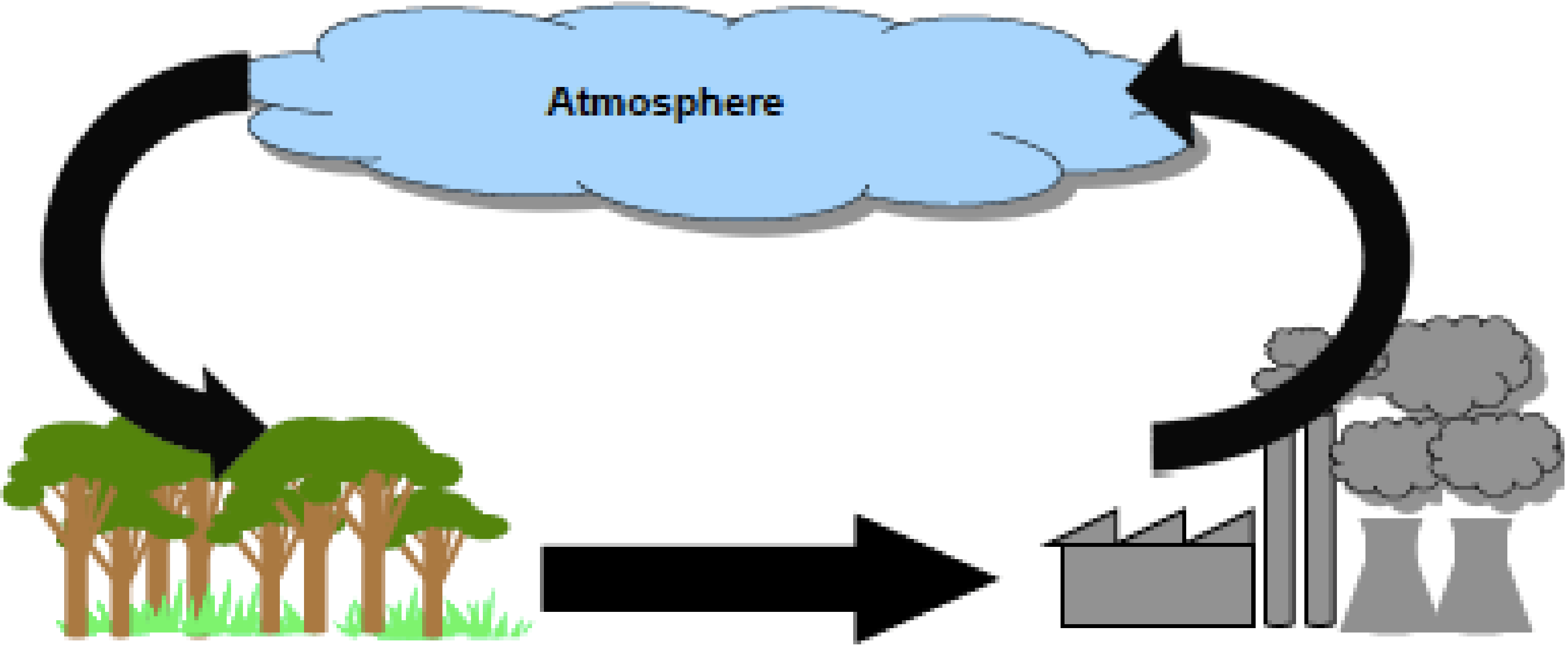
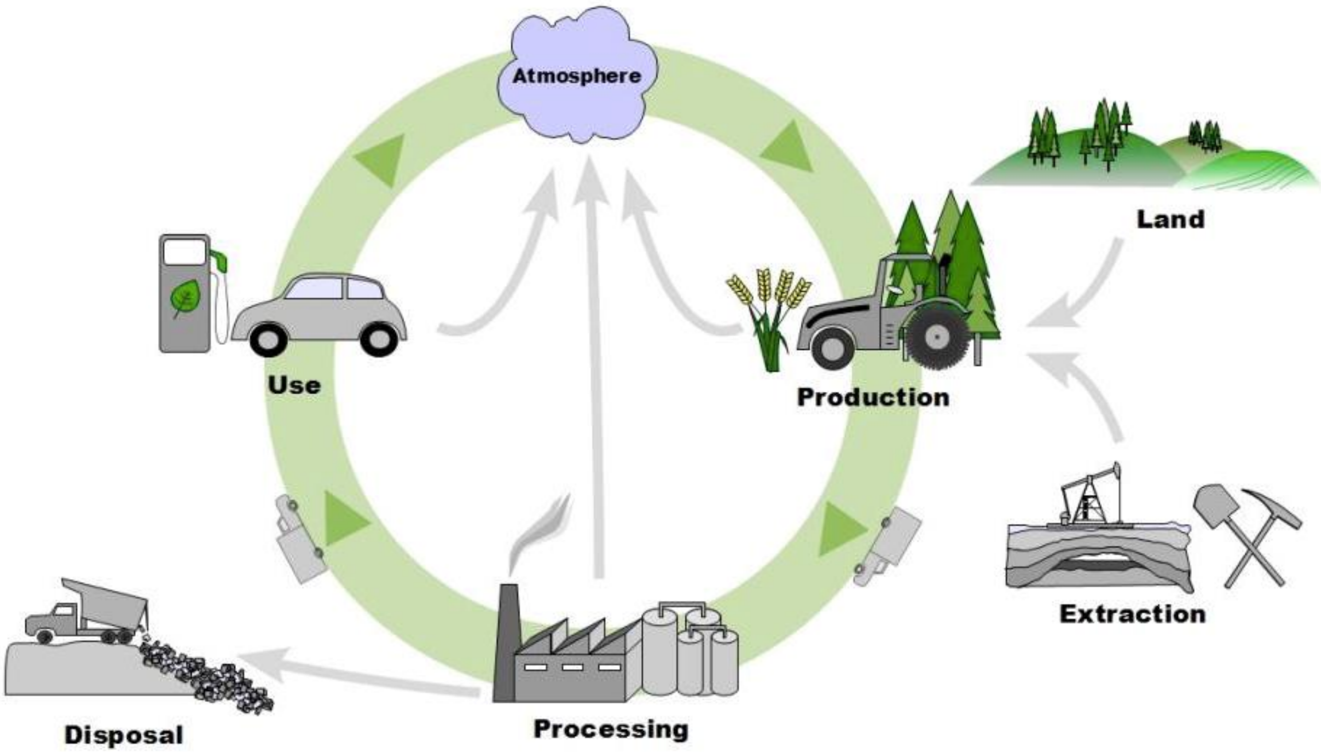
Is bioenergy carbon neutral?



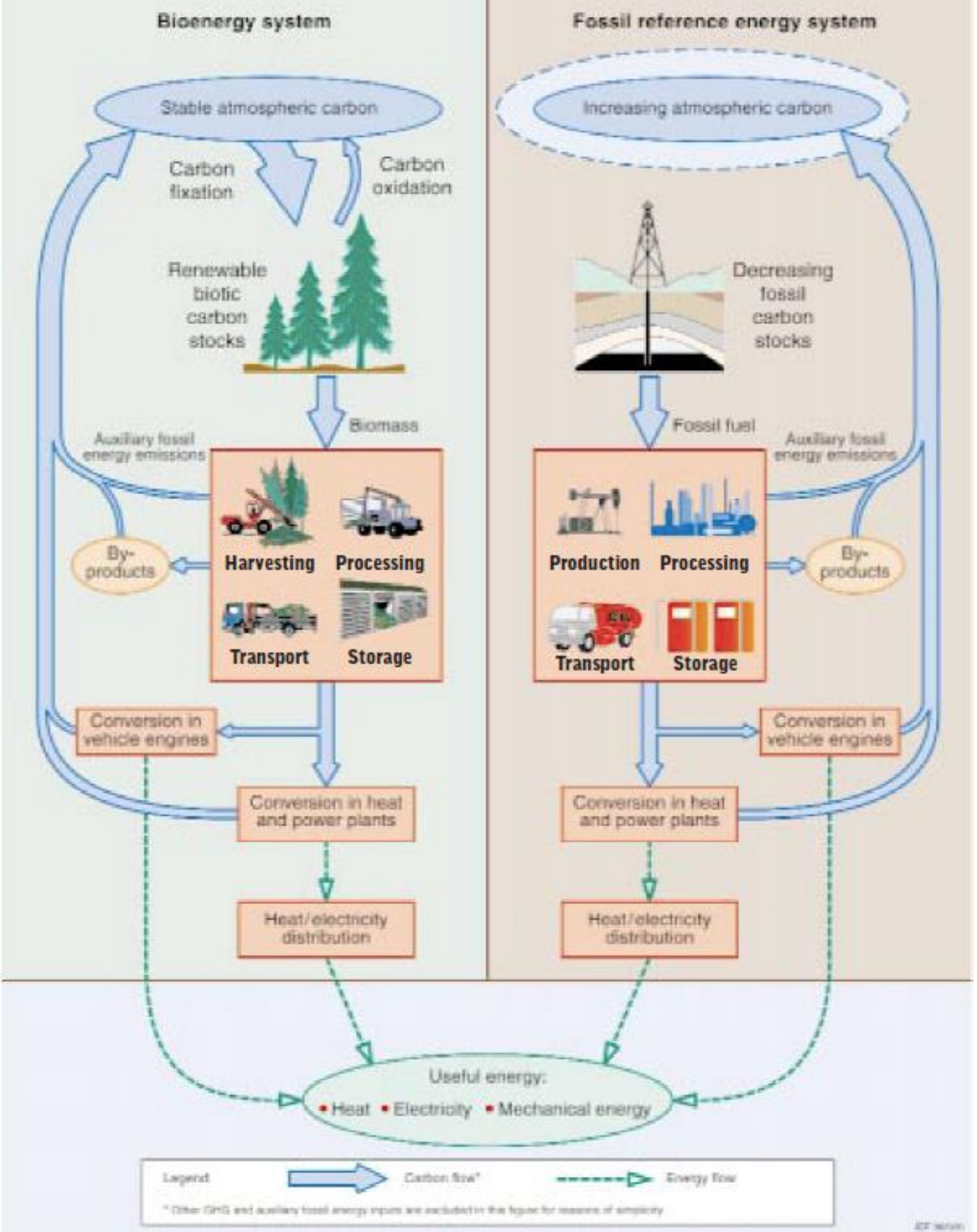
Source: IEA Bioenergy Task 38

Not carbon neutral because



- **Life cycle emissions**
- **Non-CO2 GHGs**
- **C-stock change**
- **ILUC**
- **Albedo**

Source: IEA Bioenergy Task 38



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Source: Schlamadinger *et al.* 1997 in IEA Bioenergy Task 38

LCA methodology in Renewable Energies Directive

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$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{ccs} - e_{ccr} - e_{ee},$$

where

E = total emissions from the use of the fuel;

e_{ec} = emissions from the extraction or cultivation of raw materials;

e_l = annualised emissions from carbon stock changes caused by land use change;

e_p = emissions from processing;

e_{td} = emissions from transport and distribution;

e_u = emissions from the fuel in use;

e_{ccs} = emission savings from carbon capture and sequestration;

e_{ccr} = emission savings from carbon capture and replacement; and

e_{ee} = emission savings from excess electricity from cogeneration.

Typical and default values for biofuels

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Biofuel producion pathway	Typical greenhouse gas emission saving (%)	Default greenhouse gas emission saving
Sugar beet ethanol	61	52
Wheat ethanol	32	16
Corn (maize) ethanol	56	49
Sugar cane ethanol	71	71
Rape seed biodiesel	45	38
Sunflower biodiesel	58	51
Soybean biodiesel	40	31
Palm oil biodiesel	36	19
Pure vegetabe oil from rape seed	58	57

Source: European Commission Renewable Energies Directive (2009)

Large variability in published GHG emissions for bioenergy

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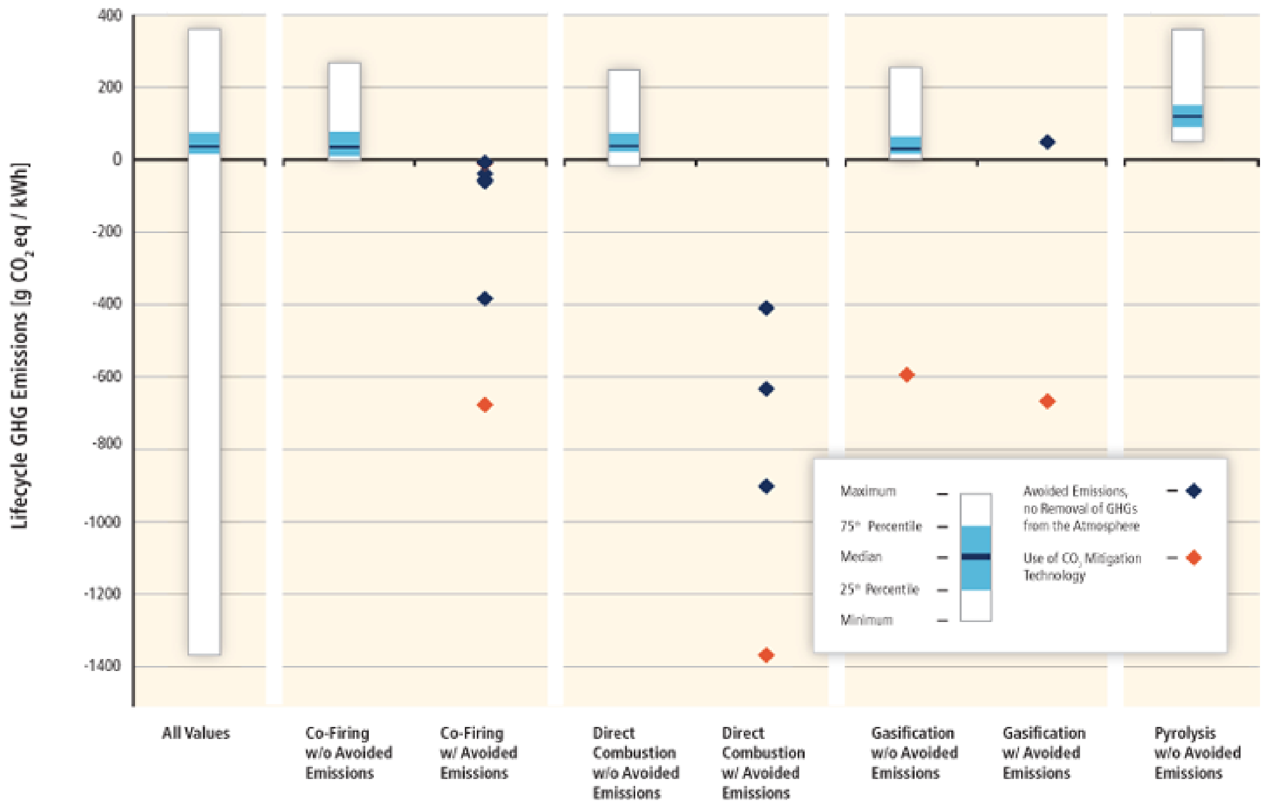

Estimates:	228	54	7	102	4	45	2	14
References:	53	19	4	26	3	20	1	3

Source: Chum et al. (2011) Bioenergy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

Unresolved Issues

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- System modelling approaches: attributional and consequential
    - Handling co-production: allocation or substitution
    - Reference systems
        - baseline land use
        - indirect Land Use Change (ILUC)
        - associated carbon flows

- Climate change metrics: Biogenic Carbon and time accounting

Attributional and consequential modelling

- UNEP/SETAC (2011). Shonan LCA database guidance principles:
  - **Attributional approach**: System modelling approach in which **inputs and outputs are attributed** to the functional unit of a product system by linking and/or partitioning the unit processes of the system **according to a normative rule**.
  - **Consequential approach**: System modelling approach in which activities in a product system are linked so that **activities are included in the product system** to the extent that they are expected to change **as a consequence of a change in demand** for the functional unit.

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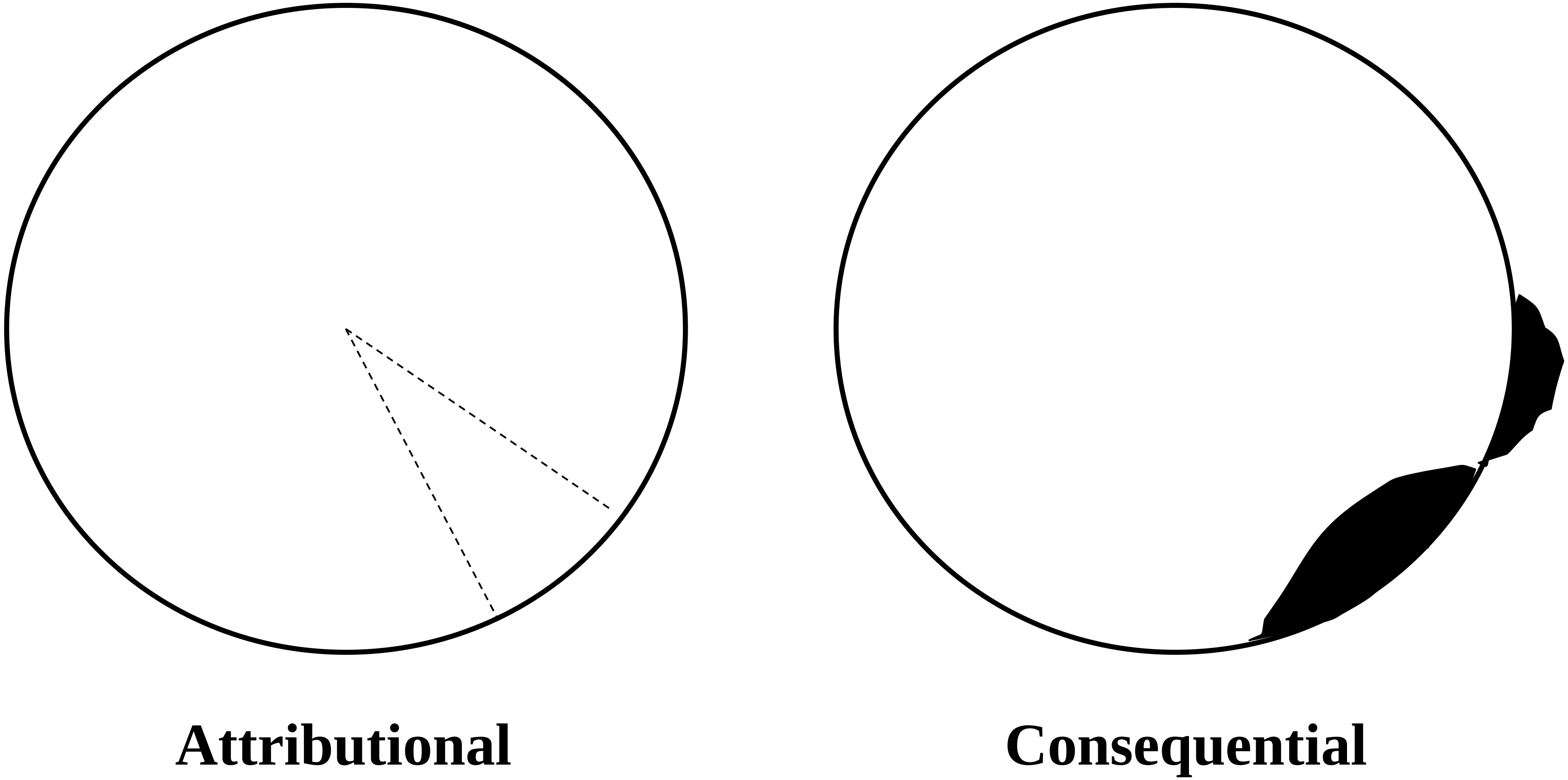
Attributional and consequential modelling



Source: Weidema (2003)

Bioenergy and GHG Accounting: Reference system

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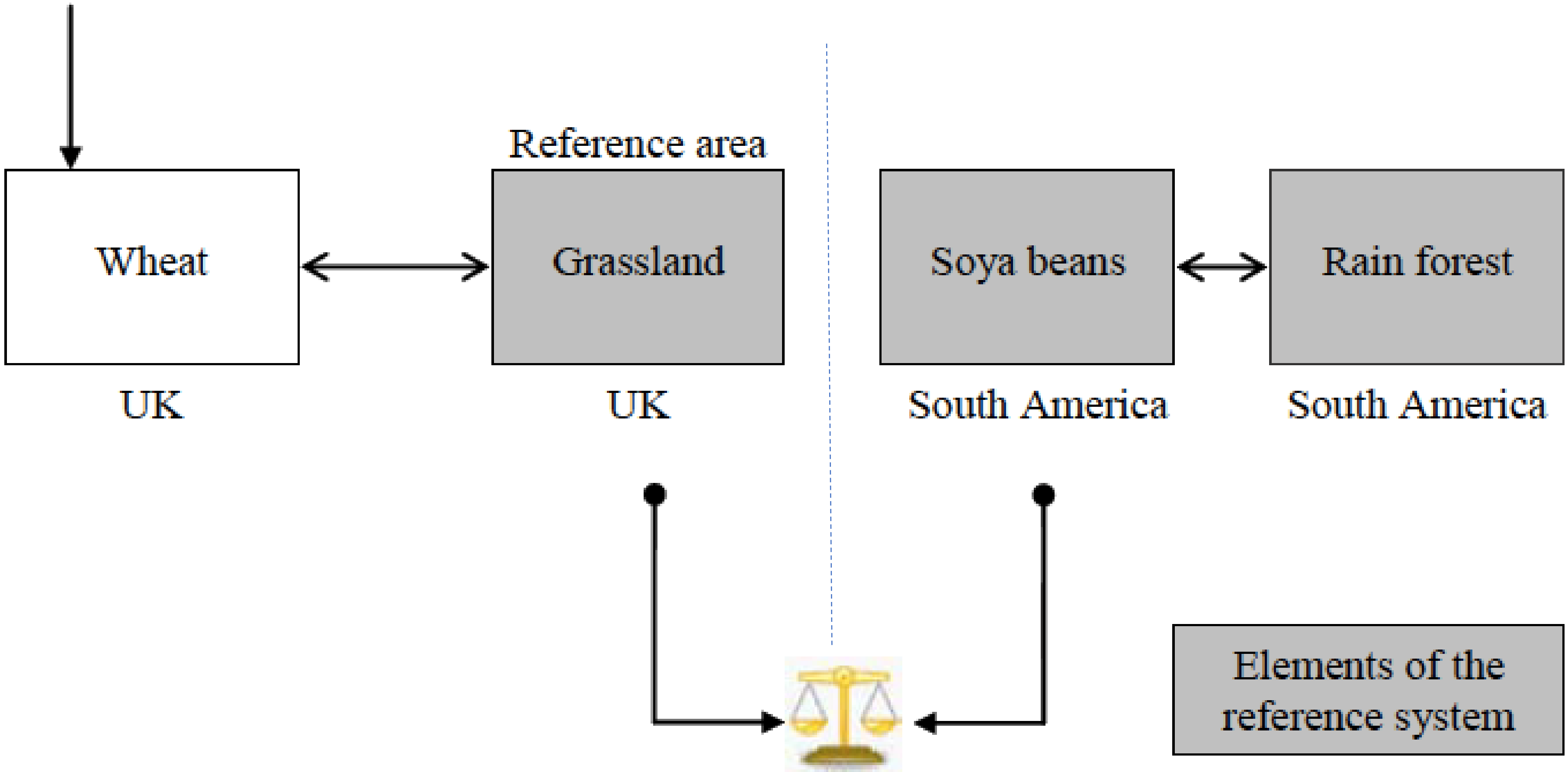
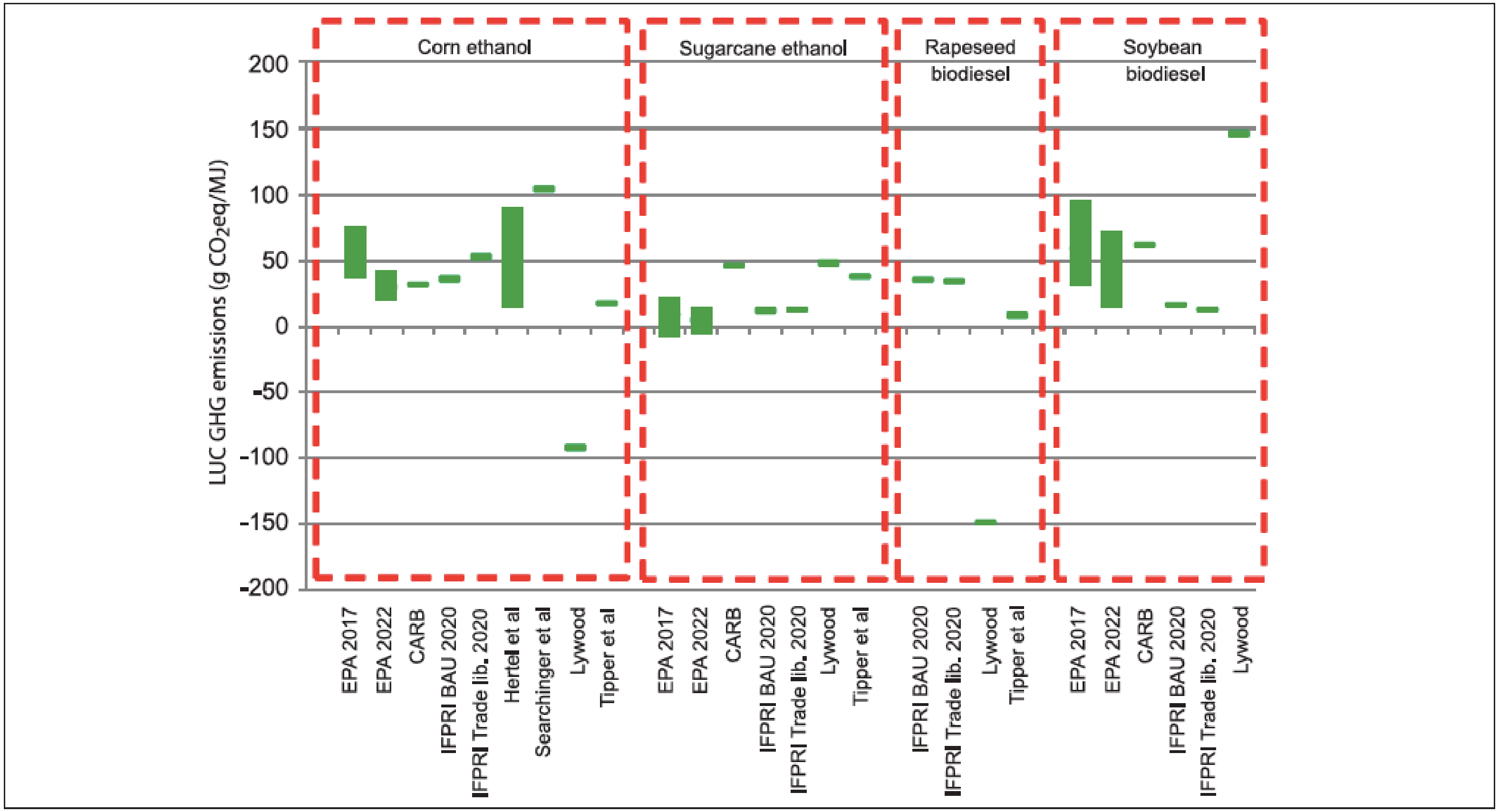
	Sources of Energy				Remarks
Scenario for meeting energy demand	**Fossil Feedstocks**	**Natural Ecosystems**	**Managed Land**	**Under-utilised Resources (e.g. land)**	
Status quo	+ 1				Climate Change
Deforestation		+ 1.5			Climate Change
Diversion (no compensation)			-1 + 1 = 0		Food Security
Diversion (with compensation; iLUC)		+ 1	-1 + 1 = 0		Climate Change
Diversion (with compensation; Intensification	+ 0.5		-1 + 1 = 0		Climate Change
Additional biomass growth (C sequestration)				-1 + 1 = 0	Efficient resource use
Carbon Capture and Storage	+1-1=0				
BECCS (Bioenergy with CCS)				-1+1-1=-1	

Indirect land use change (ILUC)



Source: Brandão (2008)

Are models suitable for determining ILUC factors?



Source: Berndes, G., Bird, N. & Cowie, A., 2011. Bioenergy, land use change and climate change mitigation. Background Technical Report, Paris: International Energy Agency (IEA).

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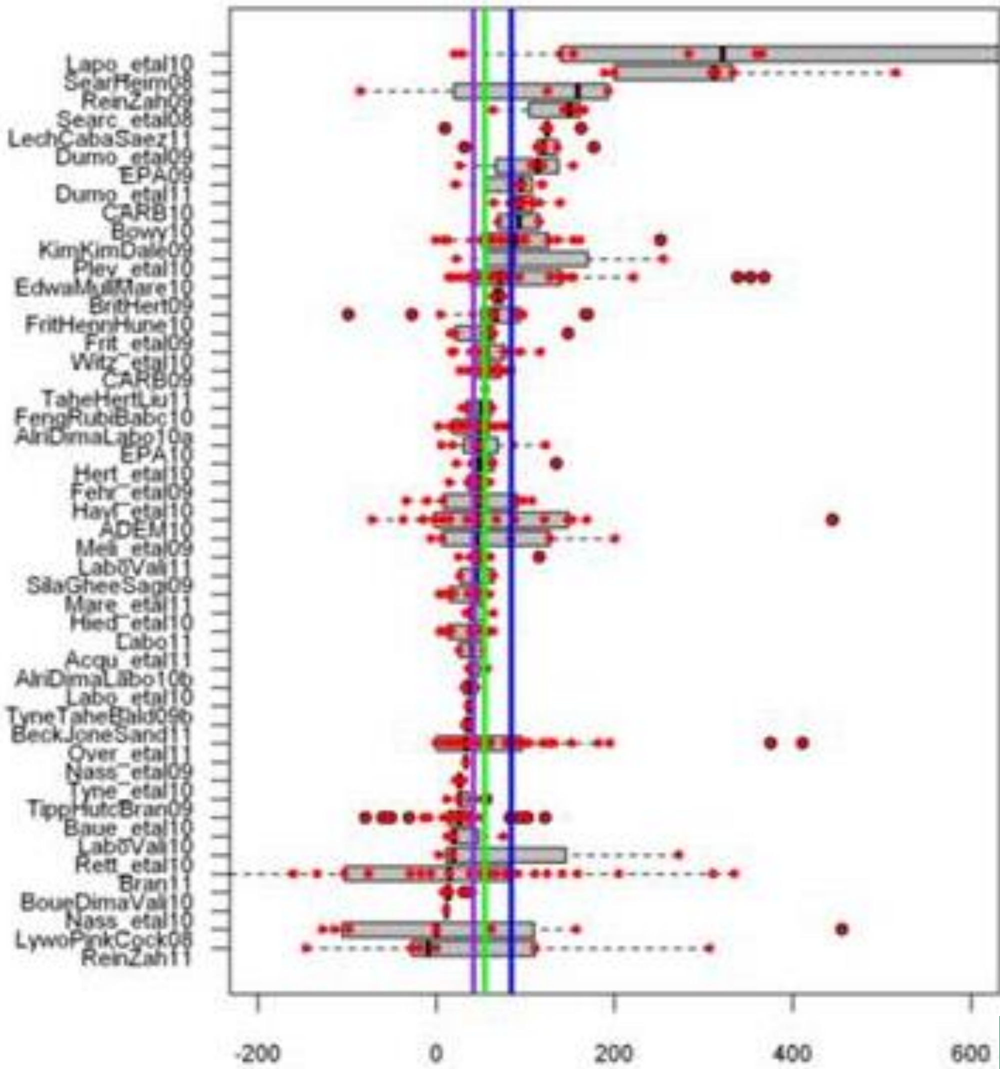
Are models suitable for determining ILUC factors?



Source: Valin et al. 2015

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When the new ILUC proposal was launched on 17 October 2012, EU Climate Commissioner Connie Hedegaard said that some biofuels currently receiving EU subsidies were "as bad as, or even worse than the fossil fuels that they replace."

Estimated indirect land-use change emissions from biofuels

- Cereals and other starch rich crops – 12 g CO2-eq./MJ
- Sugars – 13 g CO2-eq./MJ
- Oil crops – 55 g CO2-eq/MJ

- Fossil fuel comparator – 83.8 g CO2-eq./MJ (2008)
  - 2012: 90.7 for diesel
  - 2012: 89.2 for gasoline
  - 2012: 90.3 for weighted average (3:1)

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EC Default values + iLUC factors

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- Palm Oil – 105 g CO_2-eq./MJ
- Soybean – 103 g CO_2-eq./MJ
- Rapeseed – 95 g CO_2-eq./MJ

No GHG saving!

- Sunflower – 86 g CO_2-eq./MJ
- Palm Oil with methane capture – 83 g CO_2-eq./MJ
- Wheat (process fuel not specified) – 64 g CO_2-eq./MJ

<35% GHG saving

- Wheat (as process fuel natural gas used in CHP) – 47 g CO_2-eq./MJ

35-50% GHG saving

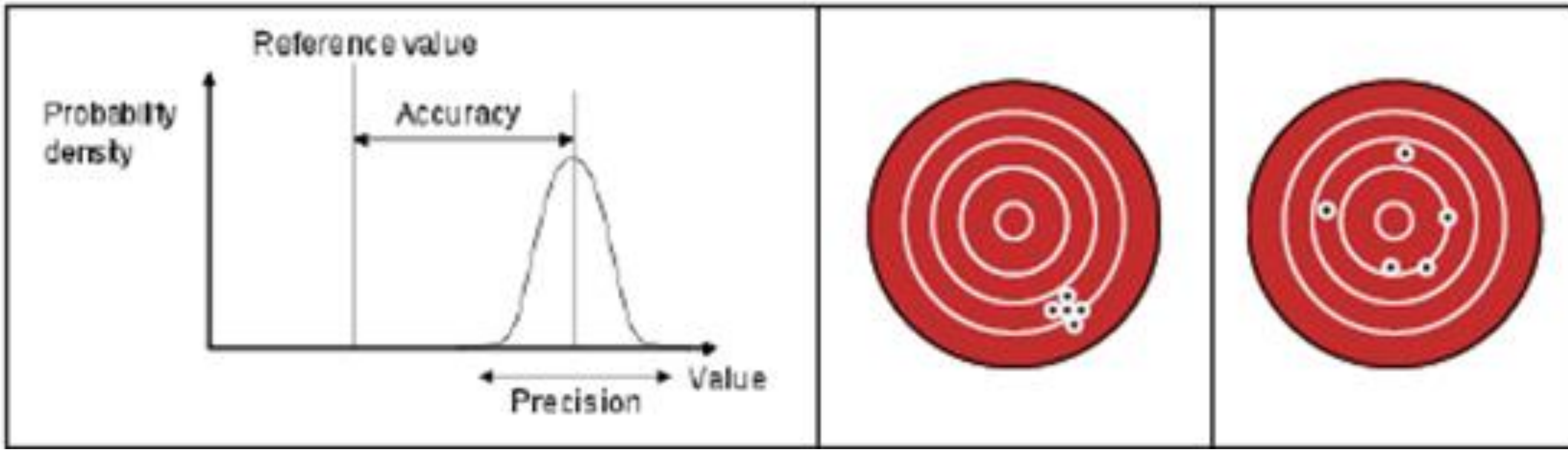
- Corn (Maize) – 43 g CO_2-eq./MJ

50-60% GHG saving

- Sugar Cane – 36 g CO_2-eq./MJ
- Sugar Beet – 34 g CO_2-eq./MJ
- Wheat (straw as process fuel in CHP plants) – 35 g CO_2-eq./MJ
- 2G Ethanol (land-using) – 32 g CO_2-eq./MJ
- 2G Biodiesel (land-using) – 21 g CO_2-eq./MJ
- 2G Ethanol (non-land using) – 9 g CO_2-eq./MJ
- 2G Biodiesel (non-land using) – 9 g CO_2-eq./MJ

>60% GHG saving

Precision vs. Accuracy



Source: Brandão et al. (2014) The Use of Life Cycle Assessment in the Support of Robust (Climate) Policy Making. Journal of Industrial Ecology

High Precision
Low Accuracy
Biased results

High Accuracy
Low Precision
Representative Results

"It is much more important to be able to survey the set of possible systems approximately than to examine the wrong system exactly.
It is better to be approximately right than precisely wrong."

Tribus and El-Sayed (1982)

Outlook: LCA for decision support

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- LCAs relevance for policy support growing
  - Several international developments and ongoing initiatives
  - Better methods, databases, software
  - Lack of consensus
  - Increasing harmonisation needed in LCA practice
  - Need for integrating with economic (and social) results to inform the design of policy instruments
- LCA of biobioenergy systems
  - Methodological choices in LCA determine results
  - Delimitation of system boundary and indirect effects important
  - All models are wrong, some are useful
  - Not all bioenergy systems are created equal → Biomass/biofuels not necessarily better
  - Helps us in identifying the best and worst offenders
  - Bioenergy may still play a role in mitigating climate change
  - Message for policy makers: promote the good system, discourage the bad and ugly
- Non-shifting of burdens

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Thank you

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Policy implications for iLUC estimations by economic-equilibrium modelling

- Does the modelling provide a good basis for determining the significance of iLUC?
- Are the impacts significant?
- Can we differentiate between bioethanol/biodiesel, feedstocks, geographical areas and production methods?
- iLUC effect is significant and crop-specific
- EC Directives ineffective
- iLUC factor to crop-specific biofuels

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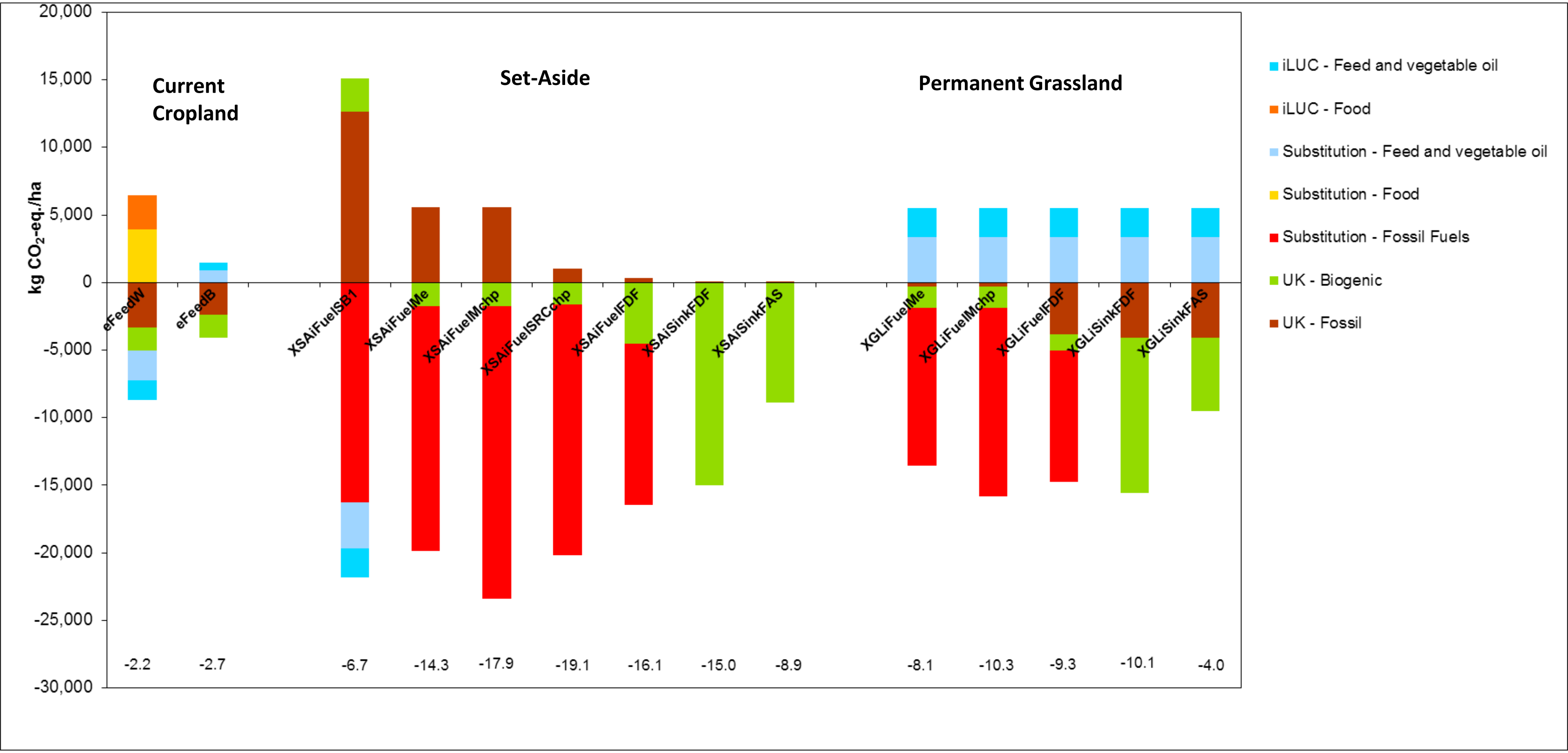
Food, feed, fuel, timber or carbon sink? Optimal land-use strategies



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Why apply economic-equilibrium models?

- To estimate how a sector balances
- To estimate how an economy balances
- To estimate how the whole world balances

- This is important because it avoids the shifting of burdens in the form of indirect and rebound effects!

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How and why do model results differ (Monforti, 2011)?

- LUC effects vary considerably across feedstocks
- For the same feedstock, models differ in terms of LUC [ha/toe] according to:
  - How much area increases compared to yield (IFPRI has higher ILUC savings from yield increases)
  - Marginal yield
  - How much crops are made available by reduced food and feed consumption
  - To what extent crop production is shifted to countries with lower yield
  - How by-products are accounted for (LEITAP has much lower ILUC savings from by-products)

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Critical issues in iLUC modelling

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1. GHG emissions from LUC
   – Land requirements
   – Reference system
2. Ascribing LUC to their drivers
   – Amortisation
3. Dealing with modelling uncertainties
   – Treatment of by--products
   – intensification vs. expansion vs. displacement

Crop displacement (Edwards et al. 2010)

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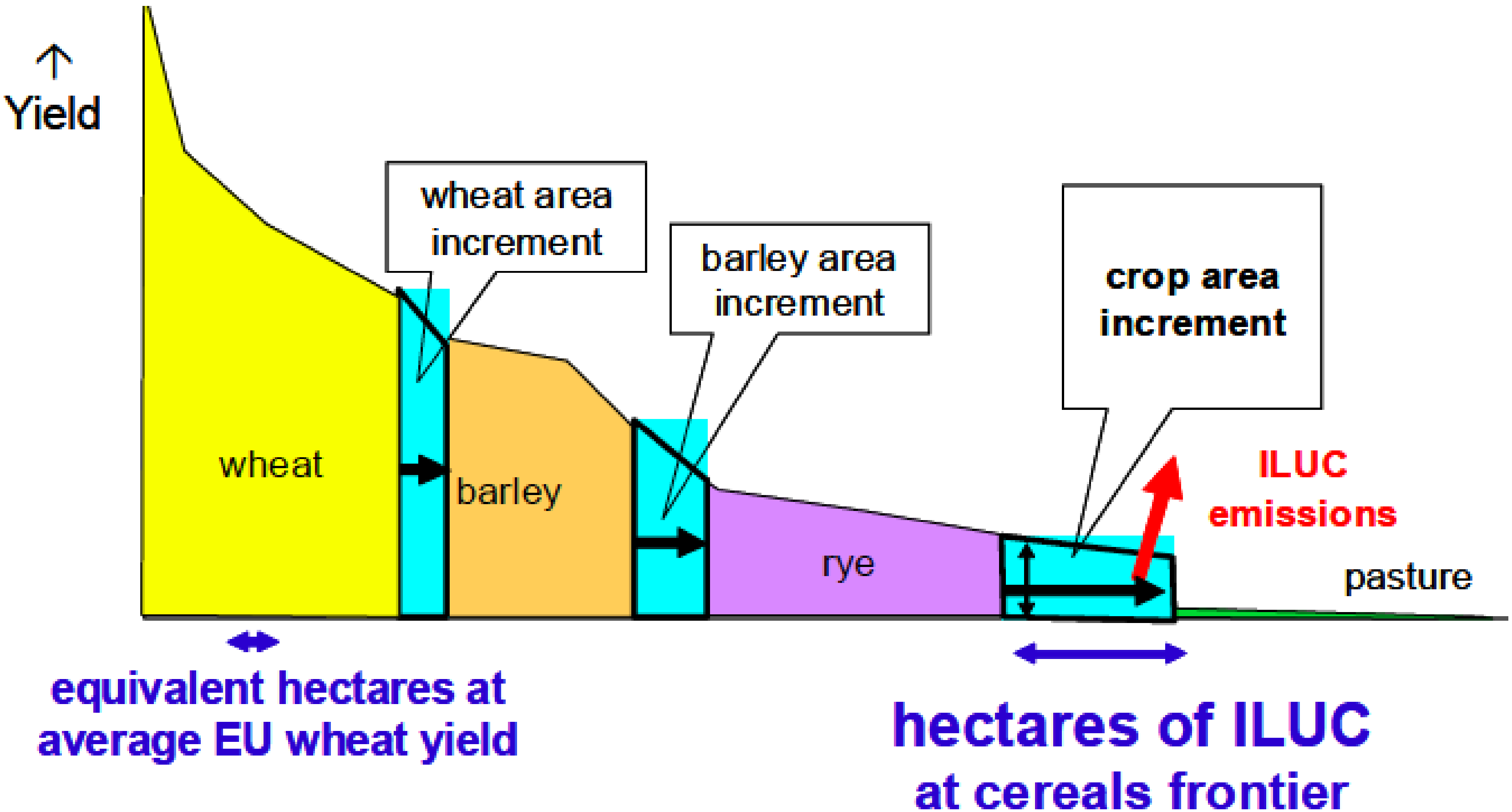

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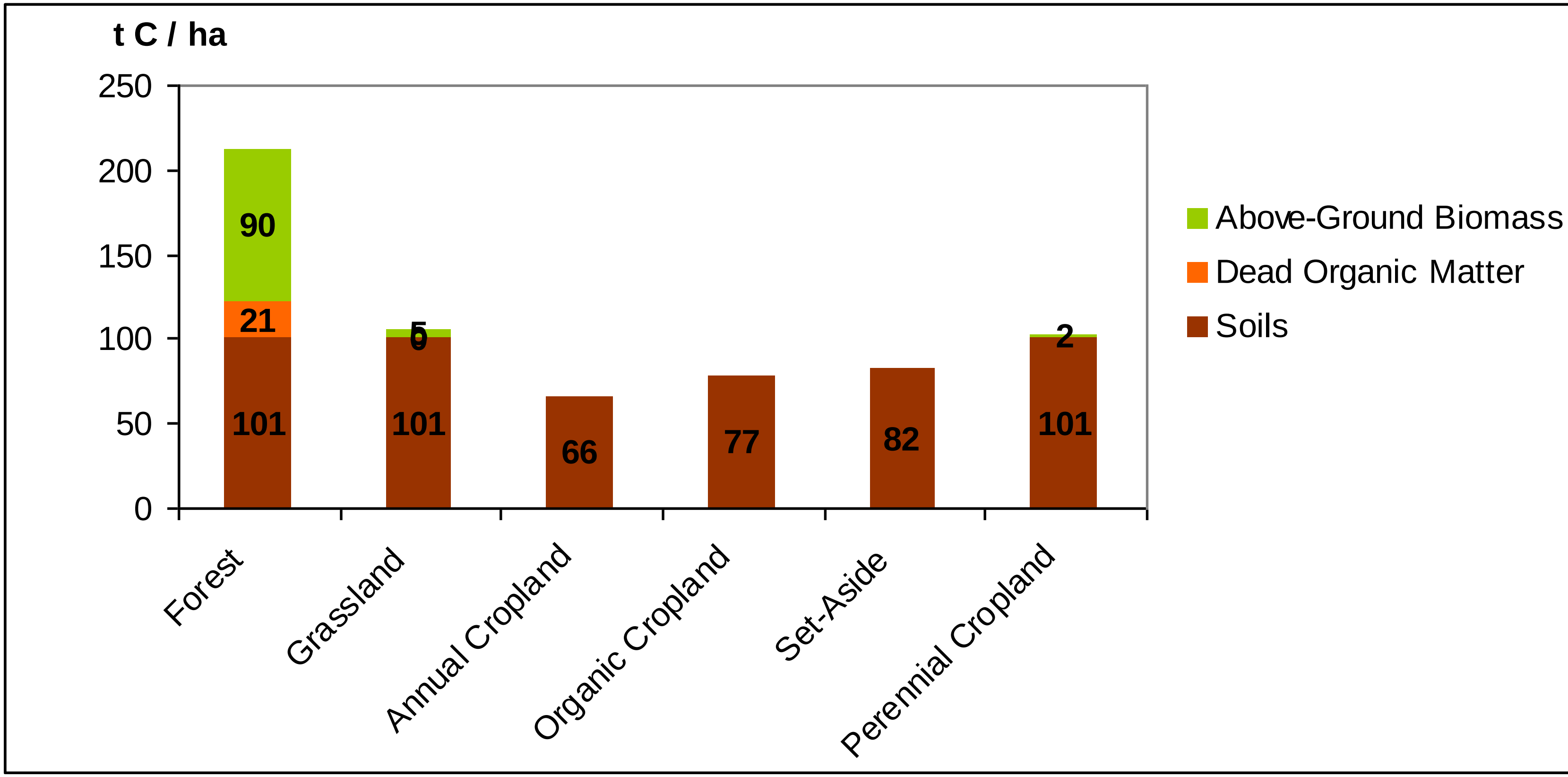
Carbon stocks in UK



Source: : Azeez (2009), IPCC (2003; 2006)

Implications of choice