Bioenergy GHG Emission Balances including Direct and Indirect Land Use Change Effects

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GHG Emissions of Bioenergy

- **Bioenergy life cycle GHG emission more or less understood:**
  - Uncertainty in N_2O (fertilizer for cultivation) and CH_4 (for biomethane)
  - Data variation in cropping (yield, fertilizer), conversion and background systems (electricity, process heat)
- **But land use change (LUC) impacts need consideration:**
  - GHG from direct + indirect land use changes
  - **Net result** can be positive or negative

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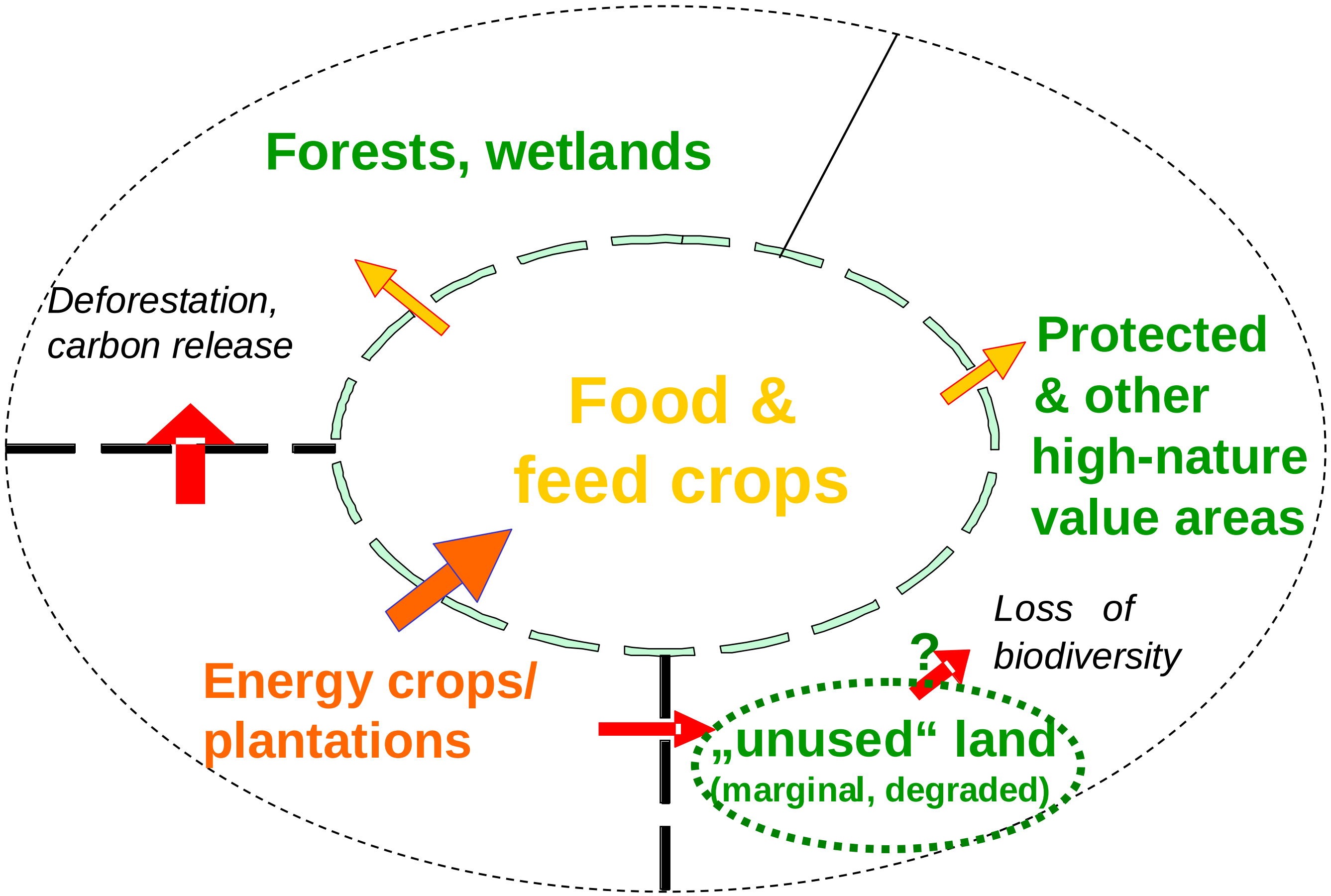
Indirect Effects (Displacement)



Source: based on Girard (GEF-STAP Biofuels Workshop, New Delhi 2005)

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GHG from indirect LUC

- **Displacement = generic problem of restricted system boundaries**
  - Accounting problem of partial analysis (only biofuels, no explicit modeling of agro + forestry sectors)
  - All incremental land uses imply indirect effects
- **Analytical and political implications**
  - Analysis: which displacement when & where?
  - Policy: which instruments? Partial certification schemes do not help, but have „spill-over“ effects
- **Future global GHG regime with cap for all sectors & countries: no leakage = no indirect effects!**

The iLUC Factor Approach (1)

…assumes that potential release of CO_2 from LUC caused by displacement is function of land used to produce agro products for exports, as displacement "works" via trade flows

…takes into account key countries trading agro-products being subject to displacement which can impact different land with different C stocks

…argues that trading countries are potentially incited to increase food/feed production to "balance" markets if increased feedstock production for biofuels displaces previous food/feed producing land

The iLUC Factor Approach (2)

…is <u>deterministic</u> and describes <u>average</u> impacts

... shares of displaced land for food/feed derived from share of land used in each country for agro commodity exports (country-specific yields, FAO data)

…share of land use in export countries determined using key commodity (rape, maize, palm, soy, wheat) in Brazil (BR), European Union (EU), Indonesia (ID), and United States of America (US)

…shares of land potentially affected derived from share of land used for selected commodity exports + assumptions on which LUC will be most likely (e.g. grassland to maize)

…IPPC-based LUC factors for C releases coupled with regional land use shares of each agro commodity

…from that, <u>average CO_2 emission factor per ha of displaced land</u> is derived, and discounted over time horizon of 20 years

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The iLUC Factor Approach (3)

Calculated <u>theoretical</u> global average iLUC factor: 20 t CO_2/ha/year – if displacement risk would be 100%. Real risk lower (biofuel feedstocks from set-aside/abandoned land, intensification etc.)

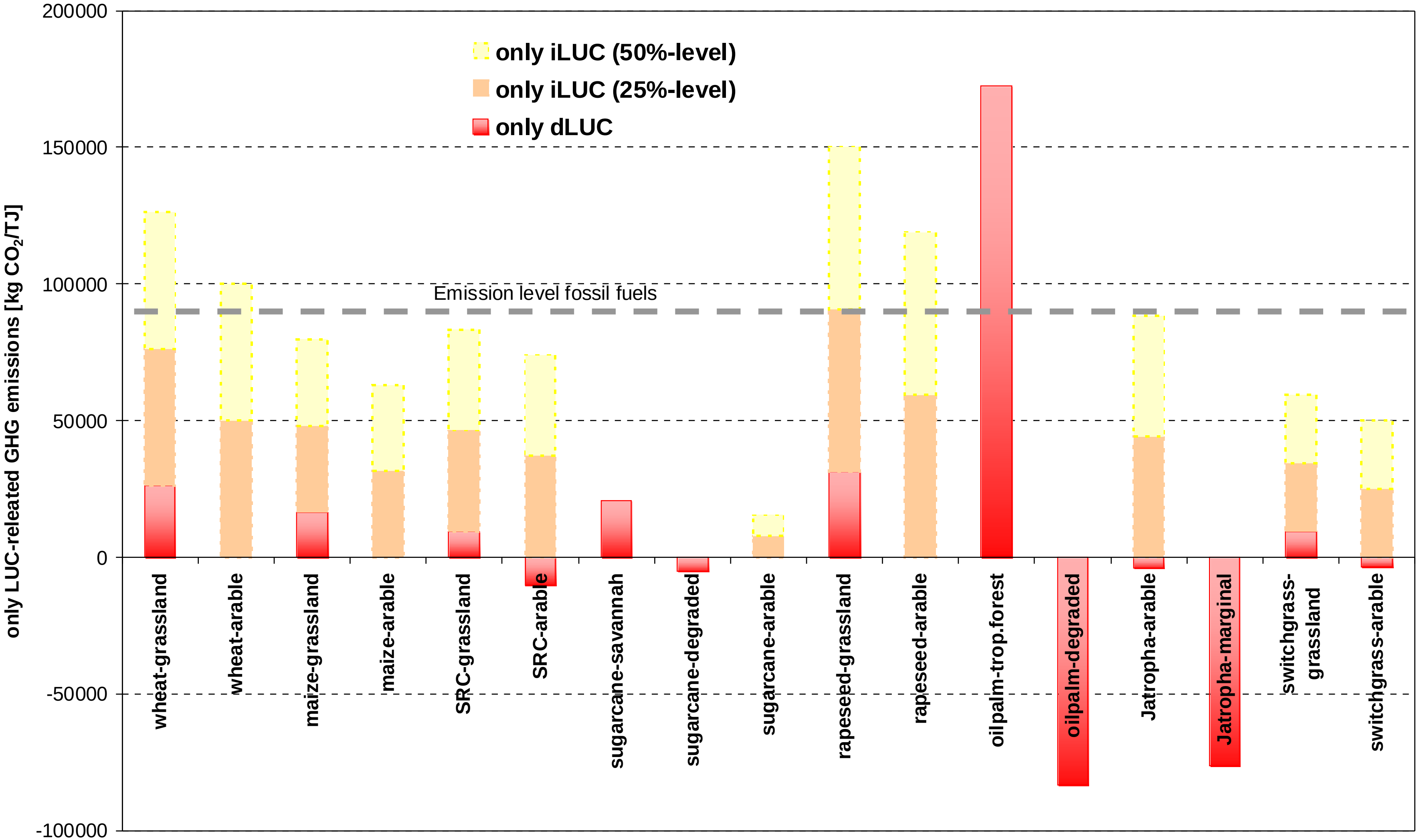
Indicative values for iLUC factor (reflecting order of magnitude) for

- "low" level, assuming 25% of all non-zero risk biofuels are subject to theoretical full iLUC factor = 5 t of CO_2/ha/year
- "medium" level, i.e. 50% of all non-zero risk feedstocks are subject to theoretical full iLUC factor = 10 t of CO_2/ha/year, and
- "maximum" level, representing a 75% share* of non-zero risk biofuel feedstocks = 15 t of CO_2/ha/year

Translating the iLUC factor to a given biofuel, divide by fuel-specific yield → energy-specific emission factor (t $CO_2/GJ_{biofuel}$).

***= maximum case is not 100% of theoretical iLUC factor as in the longer-term, 25% of all biofuels come from yield increases (average 1% per year until 2030)**

Direct + Indirect GHG from LUC



Data only for LUC-induced GHG emissions, <u>excluding</u> life-cycles

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Indirect GHG: “iLUC Factor“

Accounting for CO_2 from indirect LUC using the “iLUC factor“ for the GHG balance of biofuels*

	kg CO_{2eq}/GJ with iLUC factor			relative to fossil diesel/gasoline,		
	including conversion/by-products, without direct LUC			including conversion/by-products		
biofuel route, life-cycle	**max**	**med**	**low**	**max**	**med**	**low**
Rapeseed to FAME, EU	260	188	117	**201%**	**118%**	**35%**
palmoil to FAME, ID	84	64	45	-3%	-25%	-48%
soybean oil to FAME, Brazil	101	76	51	**17%**	-12%	-41%
sugarcane to EtOH, Brazil	48	42	36	-44%	-52%	-59%
maize to EtOH, US	129	101	72	**50%**	**17%**	-16%
wheat to EtOH, EU	144	110	77	**67%**	**28%**	-11%
SRC/SG to BtL, EU	109	75	42	**26%**	-13%	-51%
SRC/SG to BtL, Brazil, tropical	34	25	17	-61%	-71%	-80%
SRC/SG to BtL, Brazil, savanna	59	42	25	-32%	-51%	-71%

SRC = short-rotation coppice; SG= switchgrass; BtL = biomass-to-liquid, i.e. Fischer-Tropsch synthetic diesel

*= By-product allocation using lower heating value; iLUC factor is zero for residues/wastes and for biocrops from unused/degraded lands

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Total GHG: Biofuels (1)

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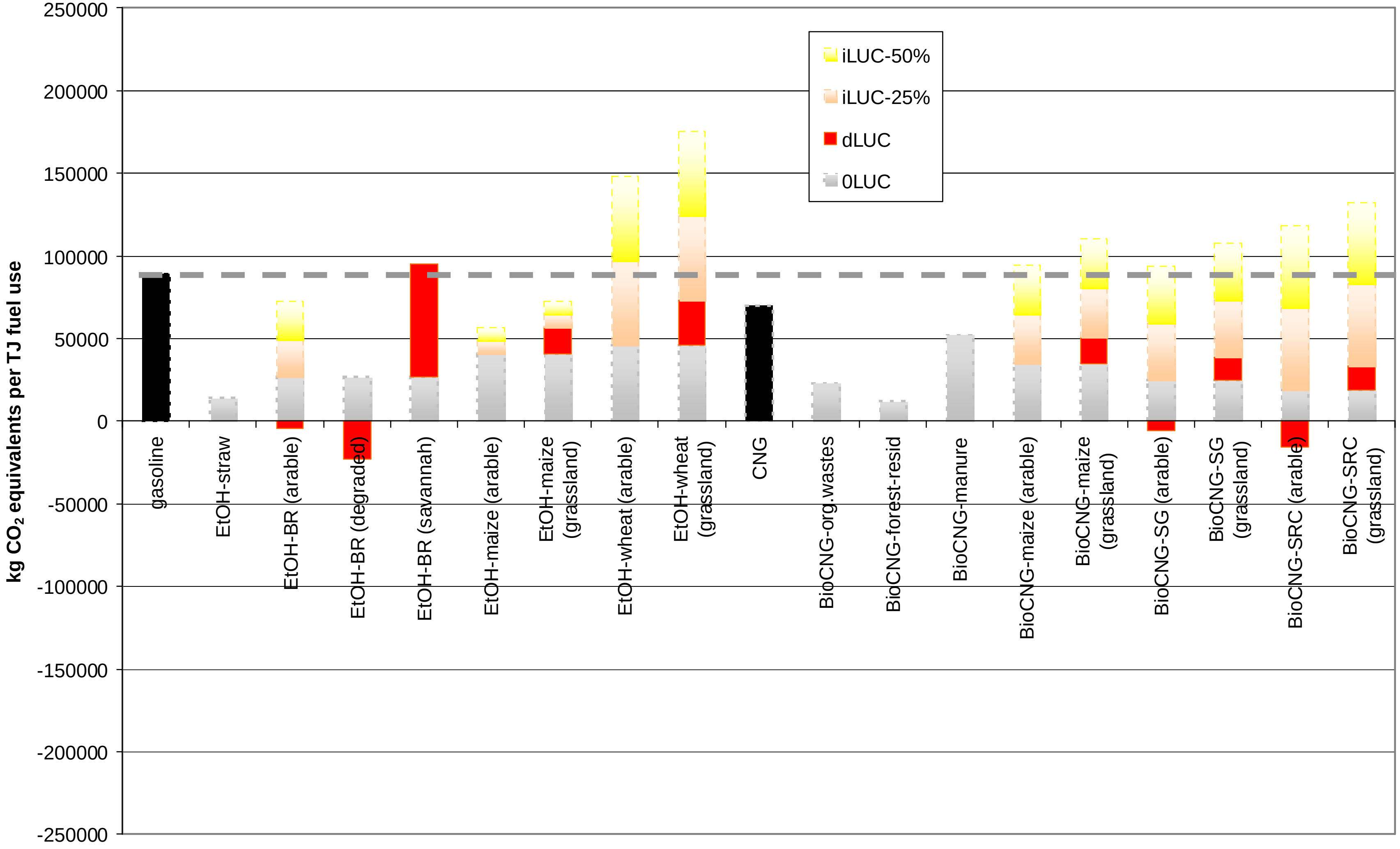

data from GEMIS 4.5; GHG emissions
from life-cycles + LUC, allocation by LHV

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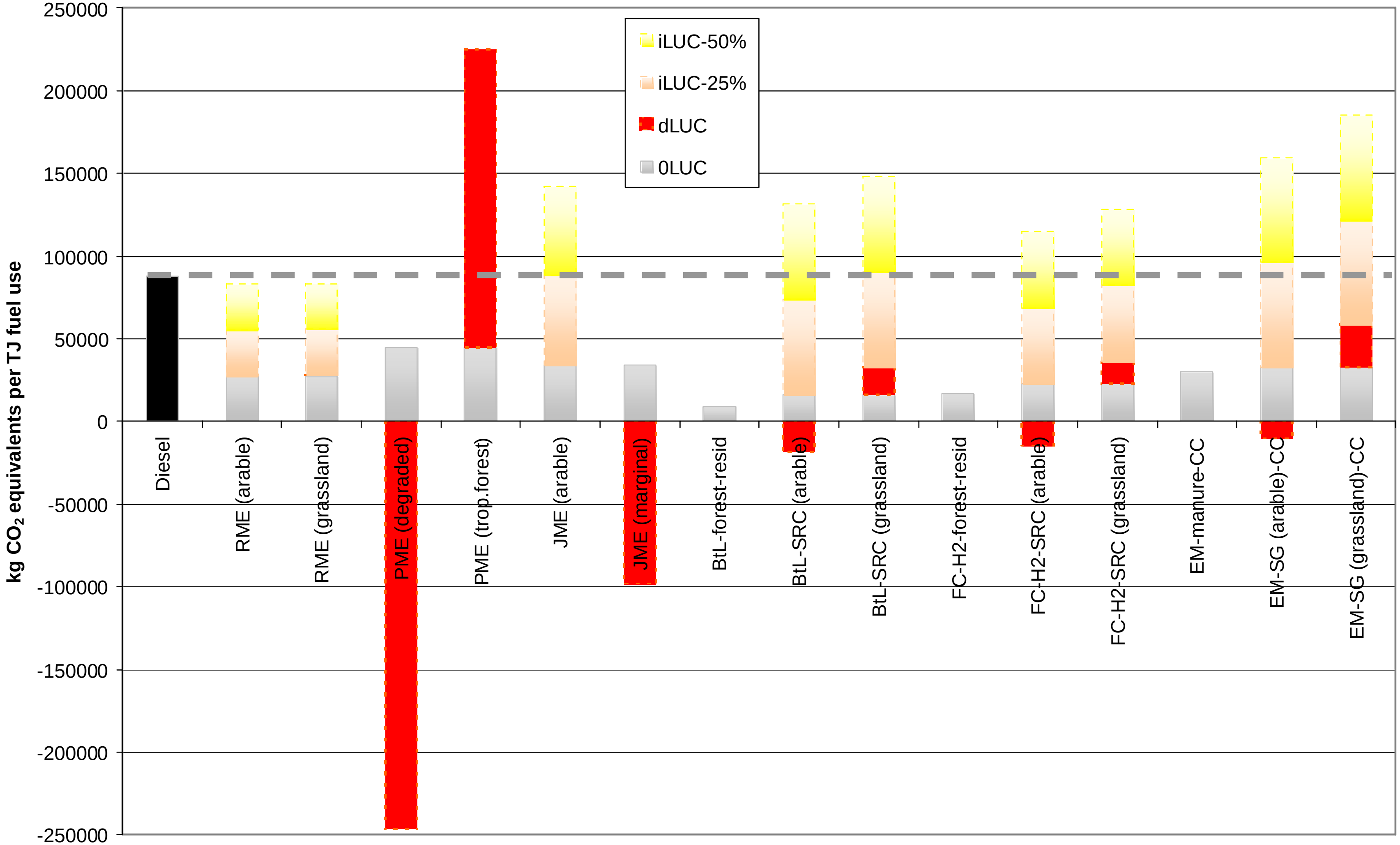
Total GHG: Biofuels (2)



data from GEMIS 4.5; GHG emissions
from life-cycles + LUC, allocation by LHV

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Conclusions

- GHG emissions from direct and indirect LUC **effect all uses of bioenergy** – electricity, heat, and transport fuels (also electricity for transport)
- GHG emissions of **direct** LUC relevant for C-rich soils; low impact for arable and some for grassland – but **indirect** effects!
- Risk hedging: favor residues/wastes, and unused/degraded land → **caution:** potential negative biodiversity and social tradeoffs

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