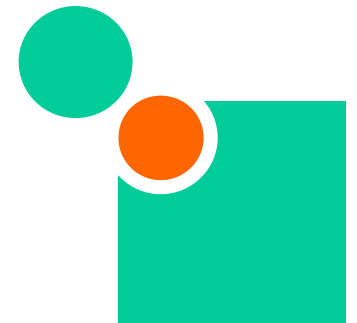


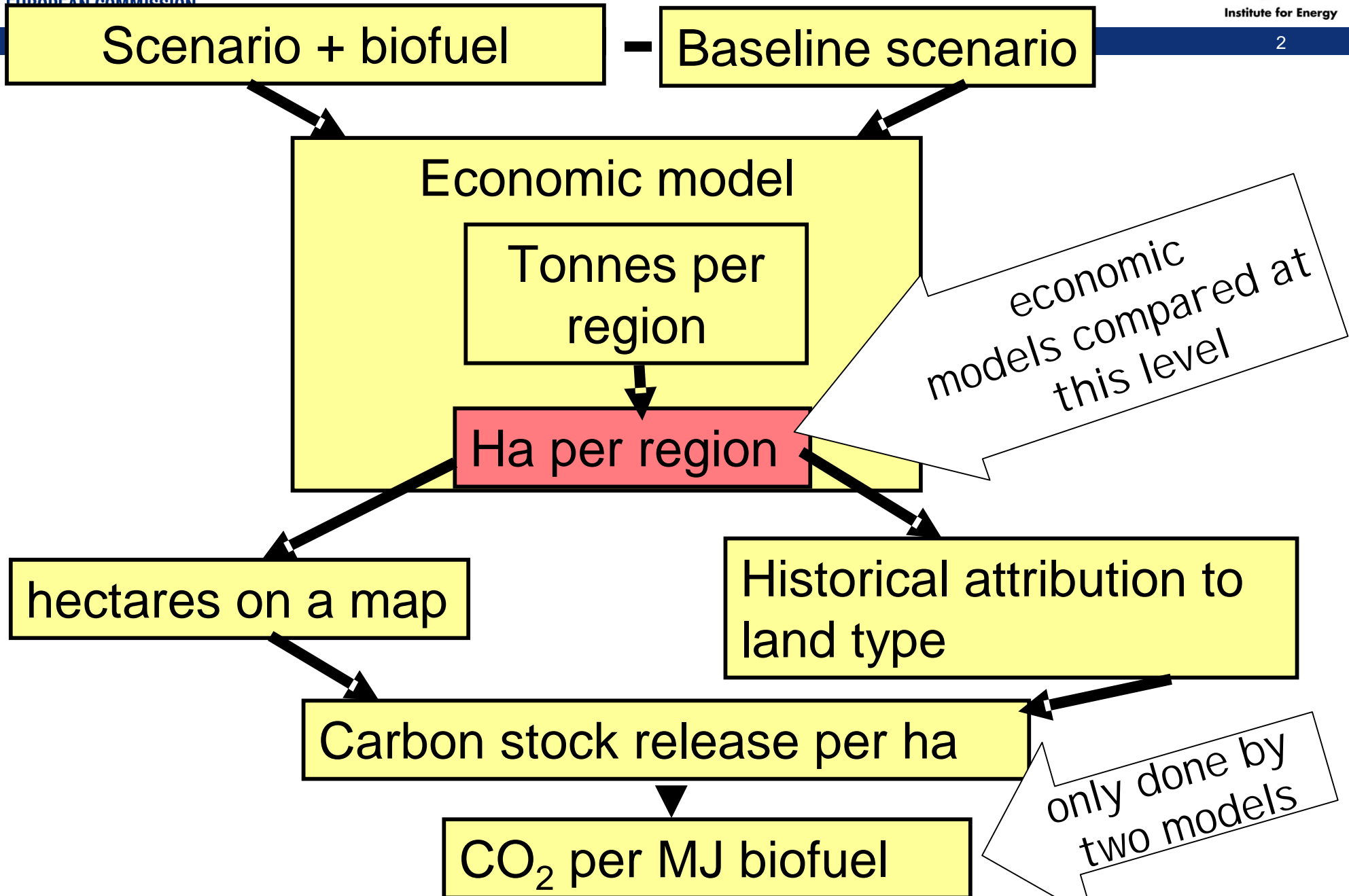
Indirect Land Use Change from increased biofuels demand

Comparison of models and results for marginal biofuels production from different feedstocks

**Robert Edwards,
Declan Mulligan and Luisa Marelli**

Brussels, October 26th, 2010





- **WHY MARGINAL SCENARIOS?**
- **Comparison of model results**
- ***How and why* do model results differ?**
- **A rough estimate of GHG emissions from the area results**
- **strong effects neglected by models**

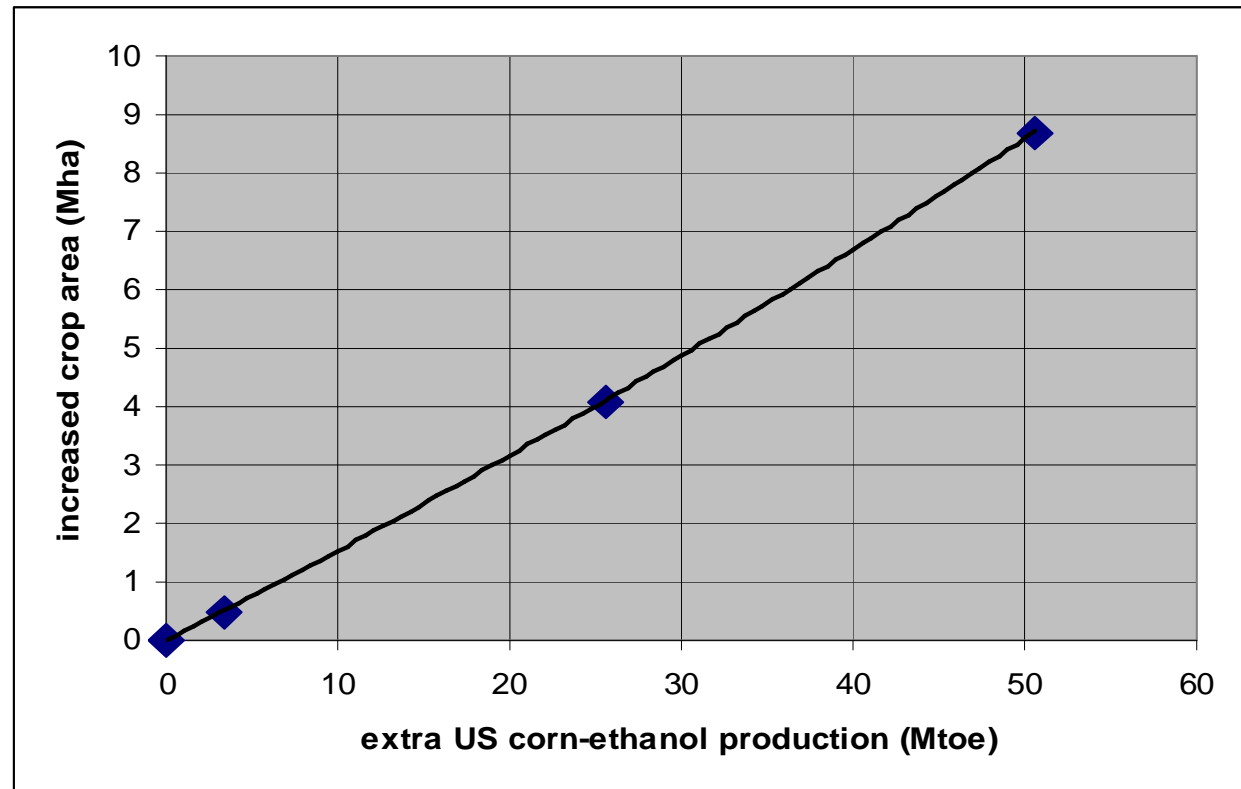
WHY MARGINAL SCENARIOS?

- To compare model results we at least need to compare the results per unit quantity of biofuel, vs. baseline
- If model results are roughly linear for different shocks, they should be additive for:-
 - different biofuels
 - different crops and by-products
- Legislators need to understand how ILUC differs between biofuels from different feedstocks and regions
- If an ILUC factor is used, we need to know this quantitatively for all biofuels/feedstocks

Most models are practically linear for a given feedstock mix

FAPRI-CARD, AGLINK-COSIMO, IMPACT, CAPRI
..... linear by structure (in most situations).

GTAP-based models (GTAP, LEITAP...)
...linear for small changes (“shocks”) in demand
...even for large shocks
they seem almost linear..
(slight upward curve
with increasing extra area)



n.b. in IFPRI -MIRAGE non-
linearity is due mostly to
changes in ratio of ethanol
and biodiesel

Comparison of model results...

JRC elicited estimates of marginal LUC ha per extra (“marginal”) Mtoe of:

- ethanol from EU crops
- biodiesel from EU crops
- ethanol in US
- Some models also gave results for: palm oil biodiesel
sugar cane ethanol

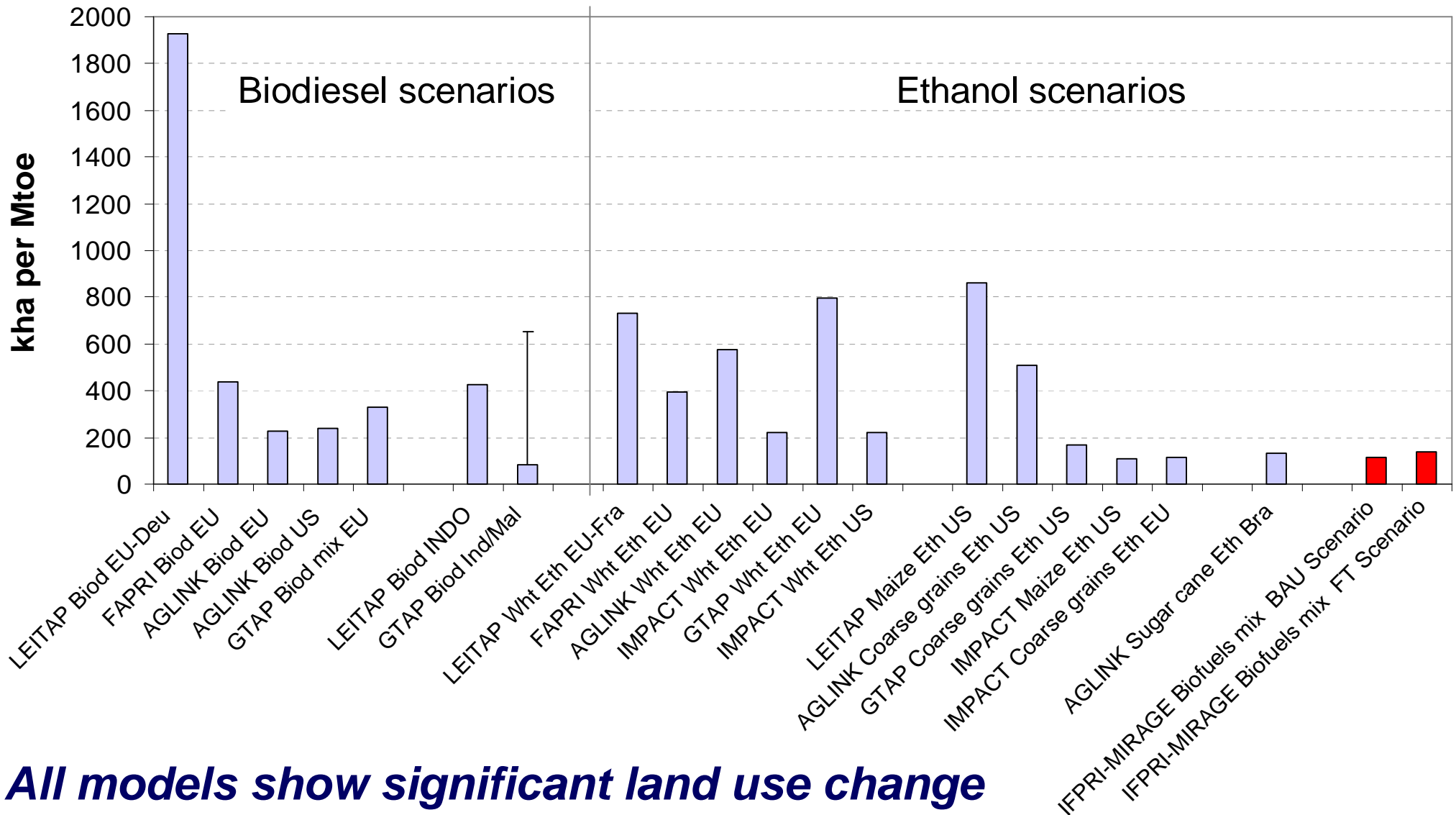
...All using the models’ existing parameters
...and compared to the model’s **existing** baseline.

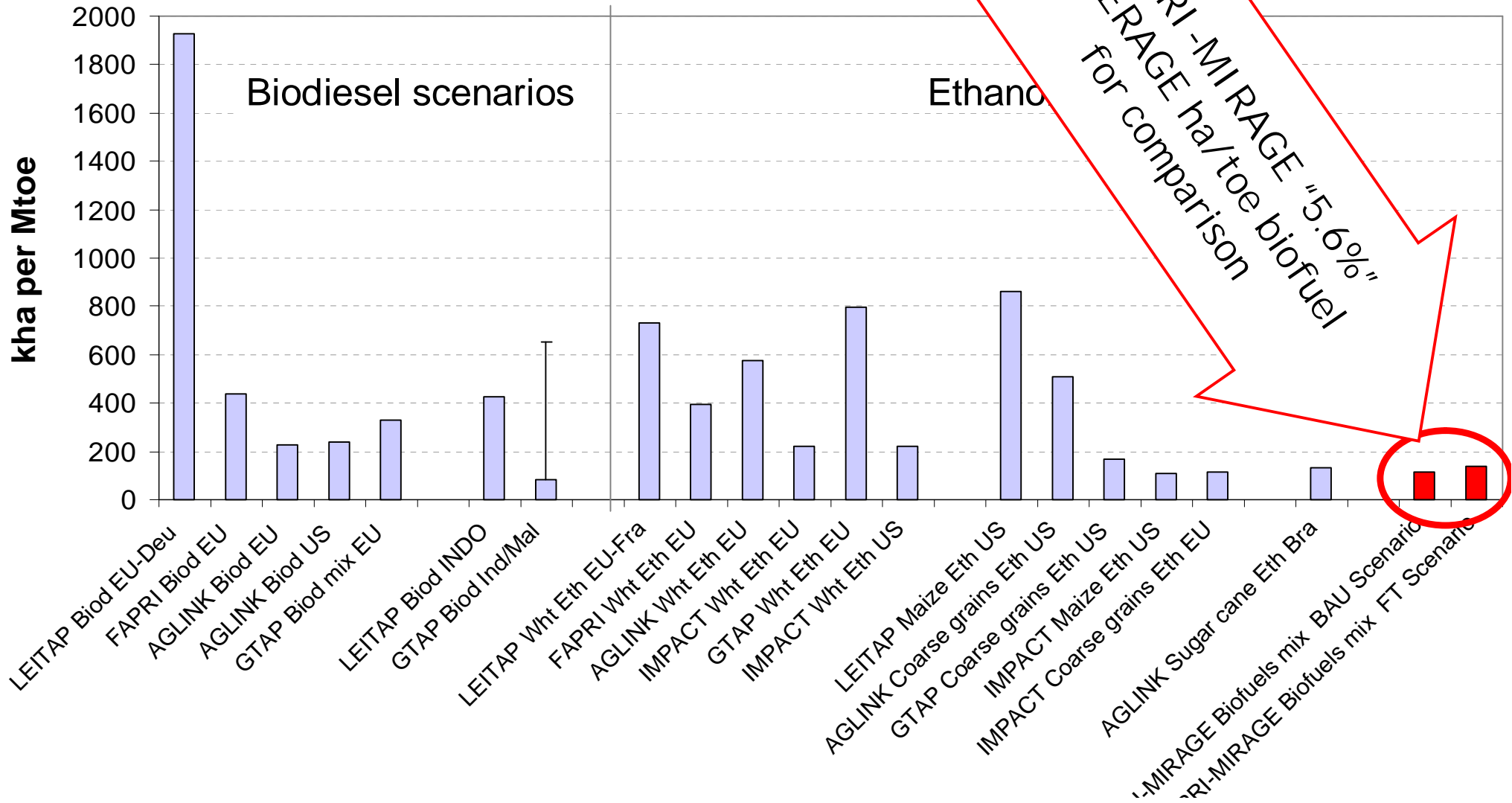
Institution: model

comparison with I FPRI -MIRAGE 5.6% scenario
was put in afterwards (in red)

FAPRI: CARD
LEI: LEITAP
PURDUE: GTAP
LEI/IPTS: CAPRI (EU-only)

IFPRI: IMPACT
OECD: AGLINK-COSIMO
LCAssociates- GTAP





All models show significant land use change

details...

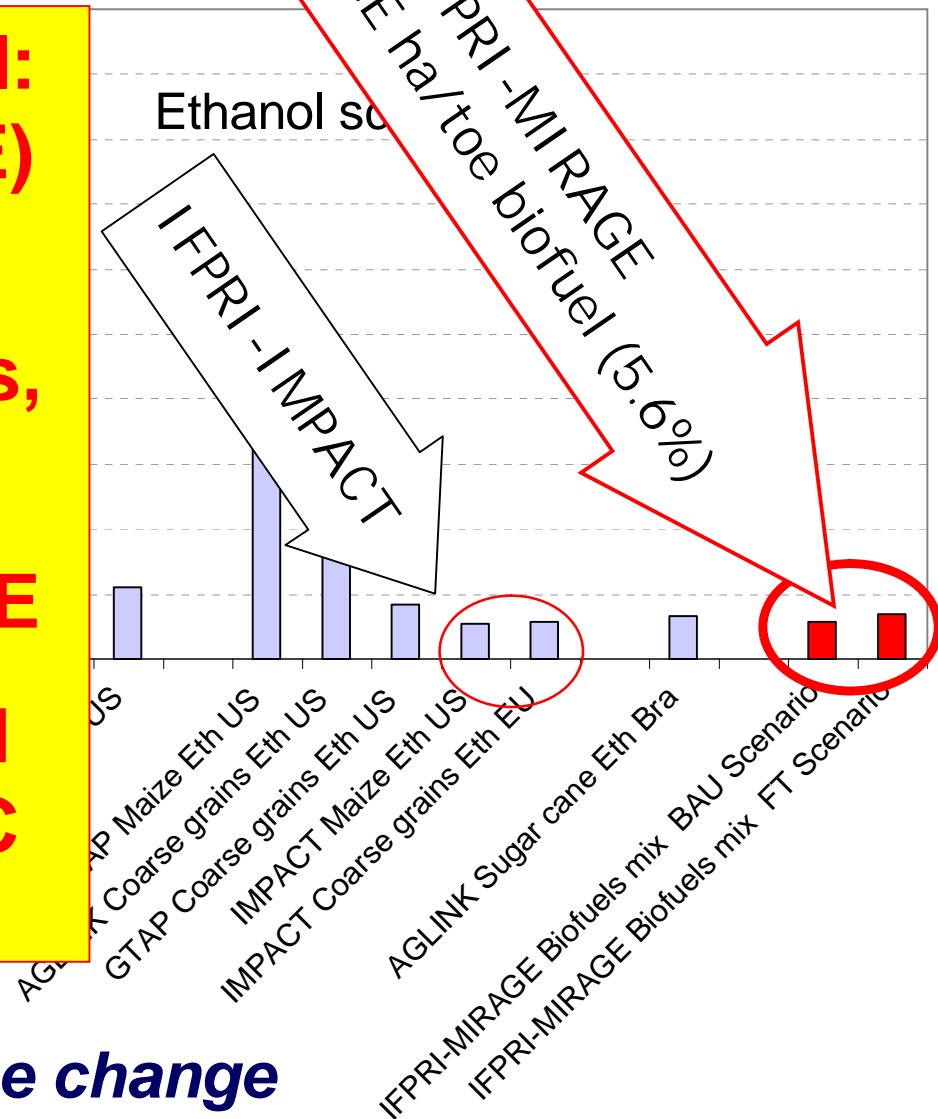
How and why do model results differ?

- 1. to what extent crop production is shifted to countries with lower yield**
- 2. how much price increases area compared to yield (IFPRI has higher ILUC savings from yield increases)**
- 3. how much crops are released by reduced food+feed consumption**
- 4. how by-products are counted (LEITAP)**

There are 2 models from IFPRI: MIRAGE (study for DG-TRADE) and IMPACT (for JRC)

Both show the lowest ha/toe's, due to

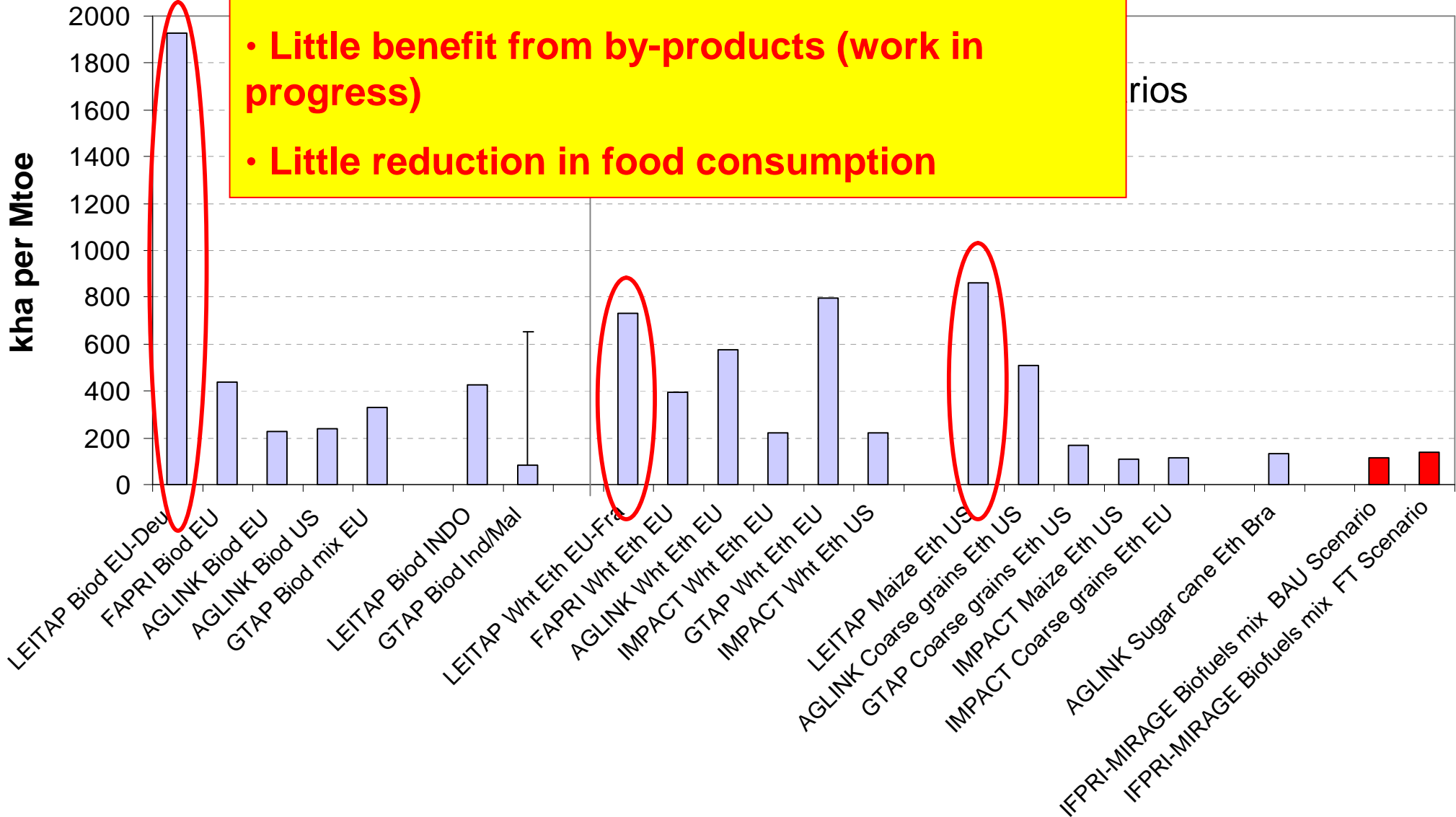
- high % sugar cane in MIRAGE
- relatively large price-induced yield increases, reducing ILUC area



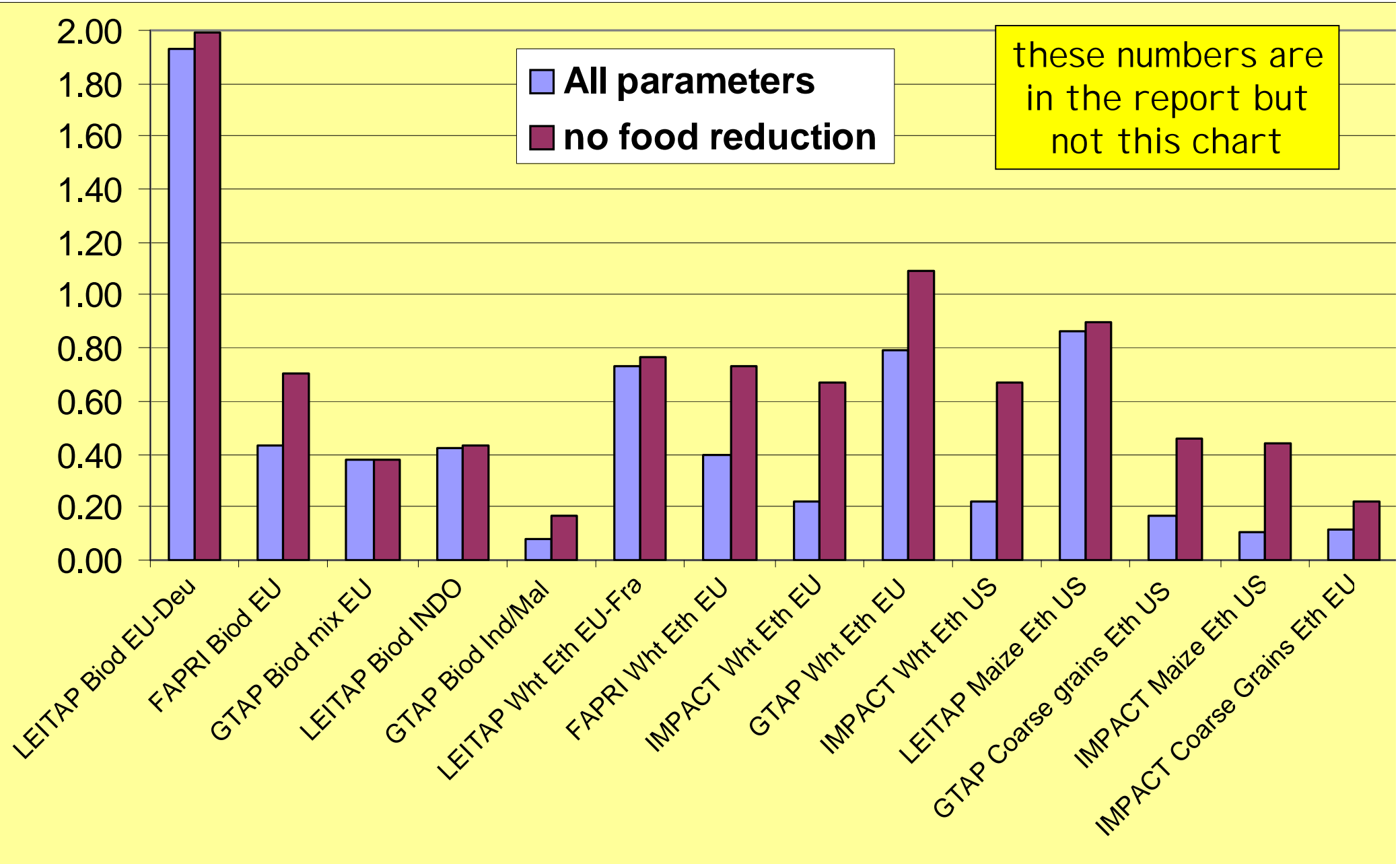
All models show significant land use change

LEITAP shows the highest results, due to...

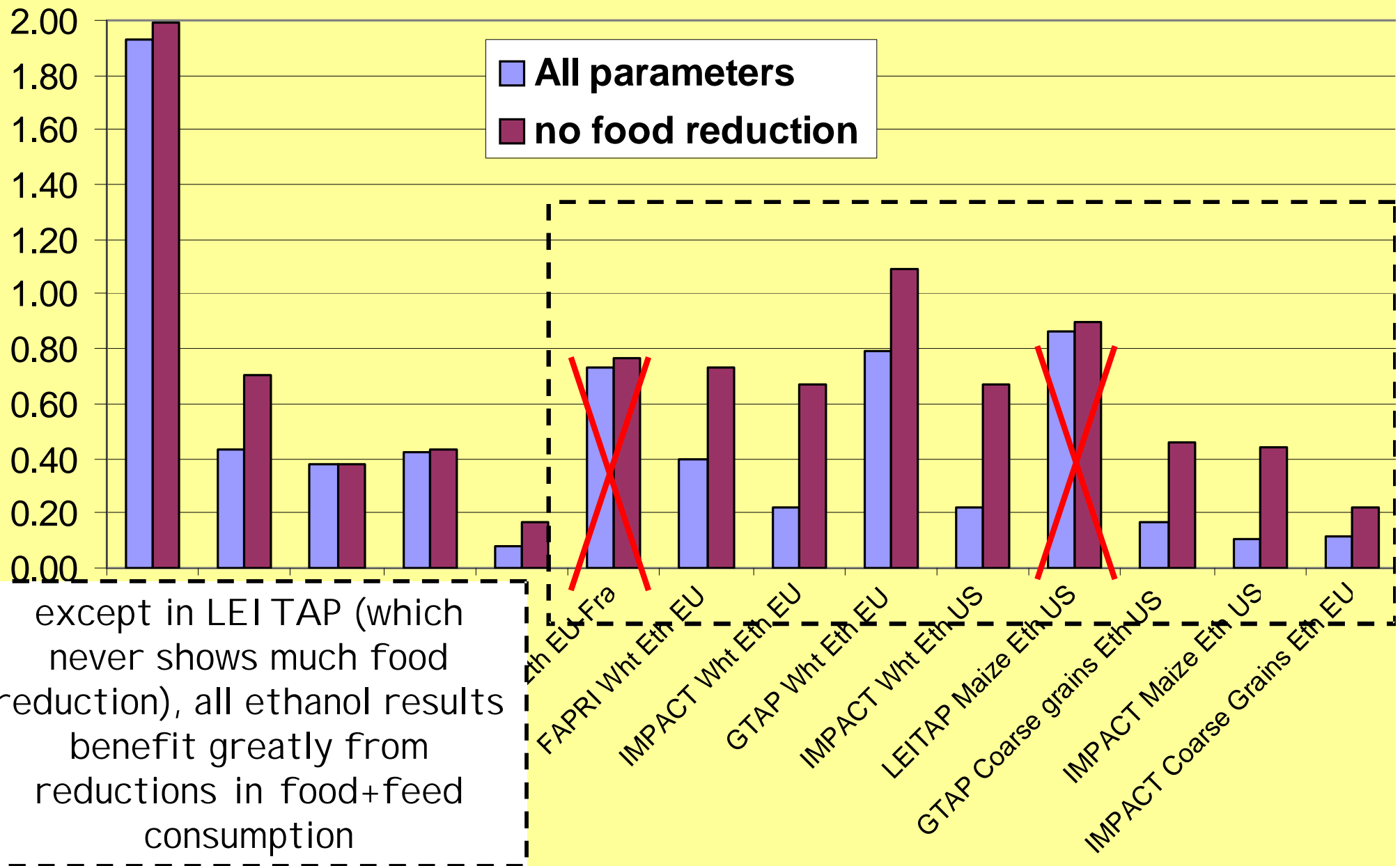
- Little benefit from by-products (work in progress)
- Little reduction in food consumption



LUC ha/toe with and without reduction from food/feed consumption



LUC ha/toe with and without reduction from food/feed consumption



Model	Scenario	% of total LUC change	
		Within scenario region	ROW
AGLINK-COSIMO	EU Biodiesel	25%	75%
	EU Wheat Ethanol	35%	65%
	US Biodiesel	1%	99%
	US Maize Ethanol	9%	91%
	Brazil Sugar cane Ethanol	123%	-23%
CARD-FAPRI	EU wheat ethanol	103%	-3%
	EU rapeseed biodiesel	8%	92%
GTAP	EU Wheat Ethanol	44%	56%
	US Corn Ethanol	41%	59%
	EU Biodiesel (mix)	41%	59%
	Malay_Ind Biod	42%	58%
IMPACT	EU Coarse grains	24%	76%
	EU Wheat	15%	85%
LEITAP	US Maize Ethanol	90%	10%
	Wheat Ethanol Fra	55%	45%
	Biodiesel Deu	26%	74%
	Biodiesel INDO	124%	-24%

For EU and US biofuels, most of the LUC takes place in the Rest-Of-the-World

...unless you force the wheat to be grown in EU, like FAPRI /CARD-EU-wheat scenario,

LEITAP US-maize ethanol

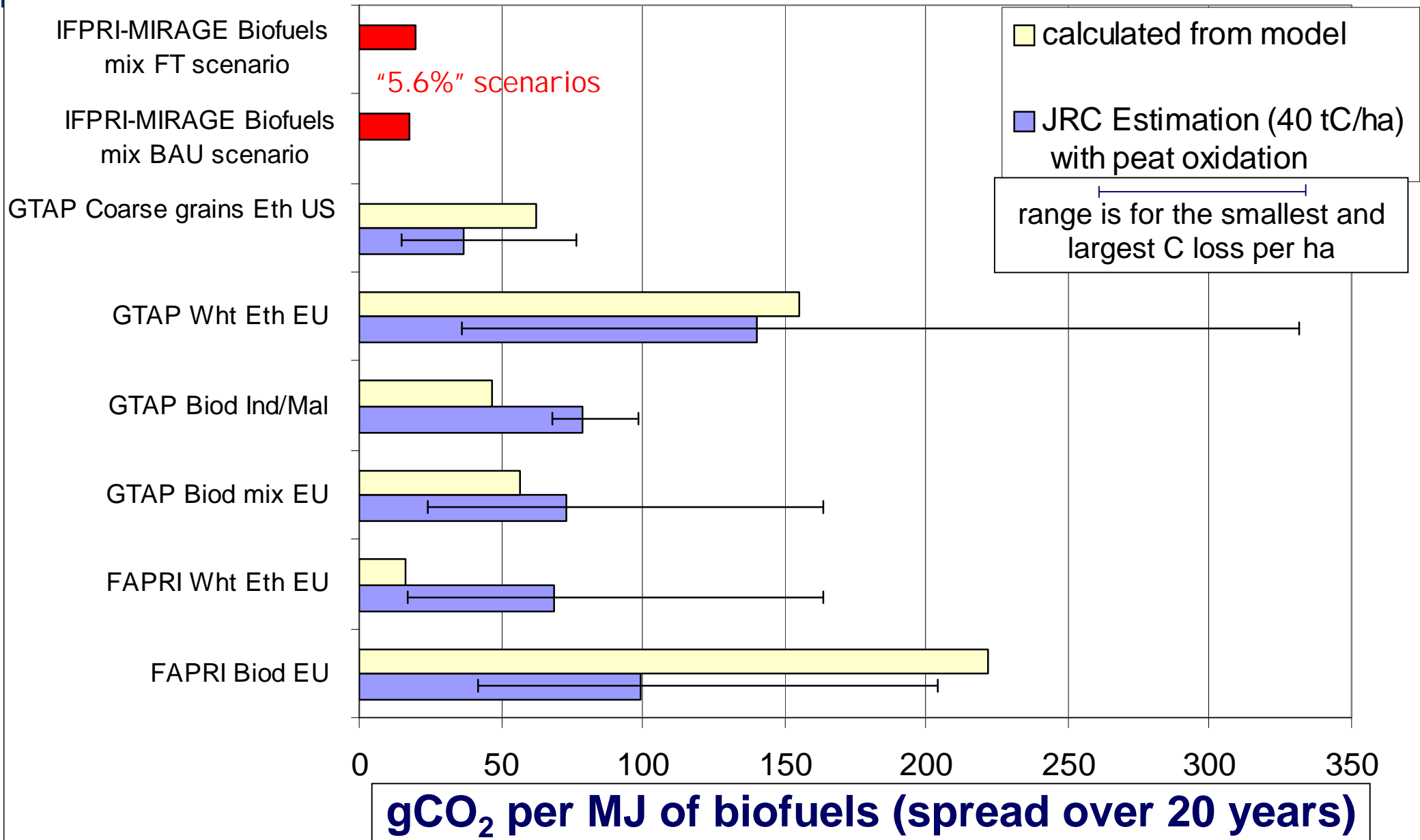
LUC change			
	ROW		
%	75%		
%	65%		
%	99%		
%	91%		
%	-23%		
%	-3%		
%	92%		
%	56%		
%	59%		
%	59%		
%	58%		
%	76%		
%	85%		
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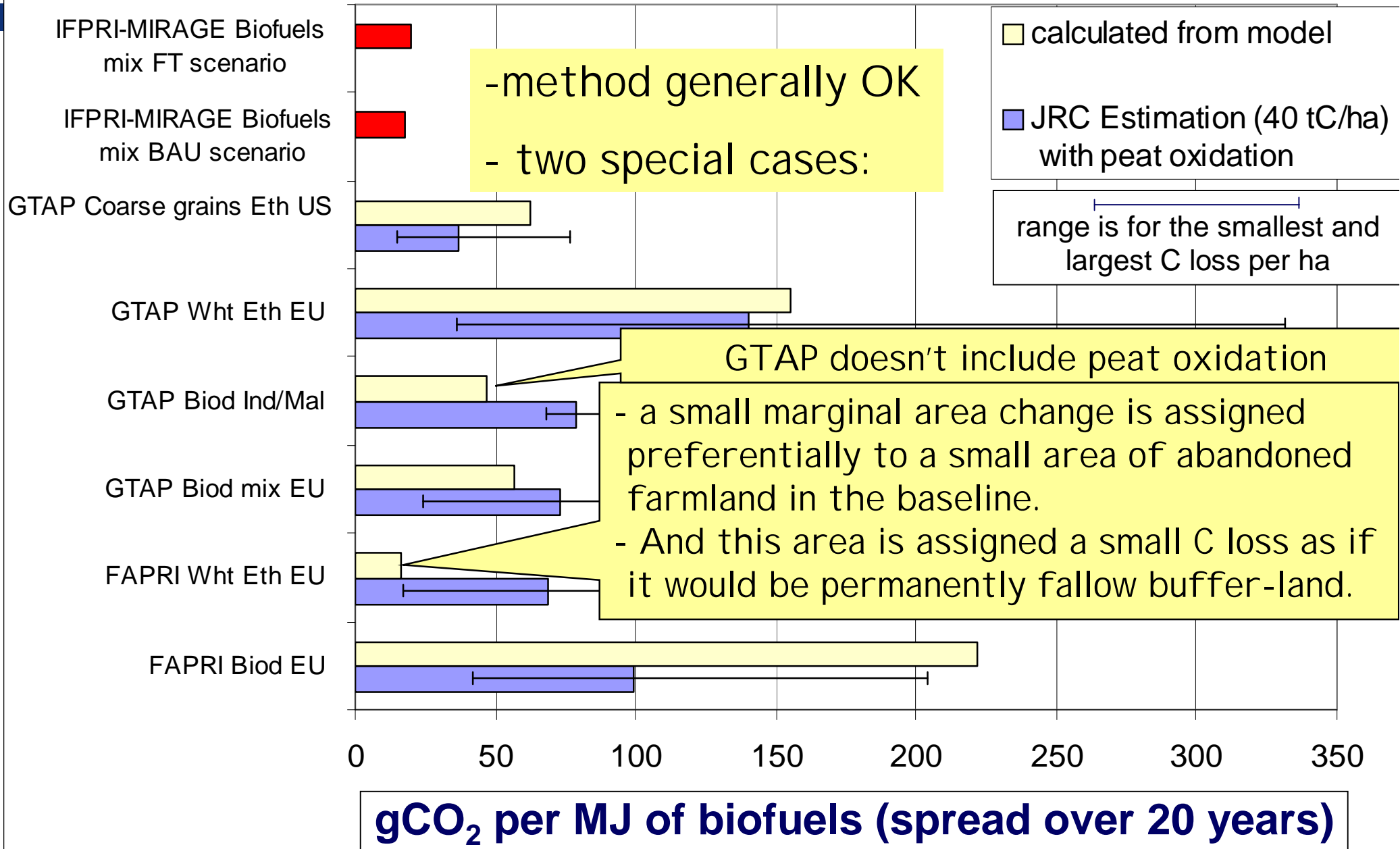
	EU Wheat	15%	85%
LEITAP	US Maize Ethanol	90%	10%
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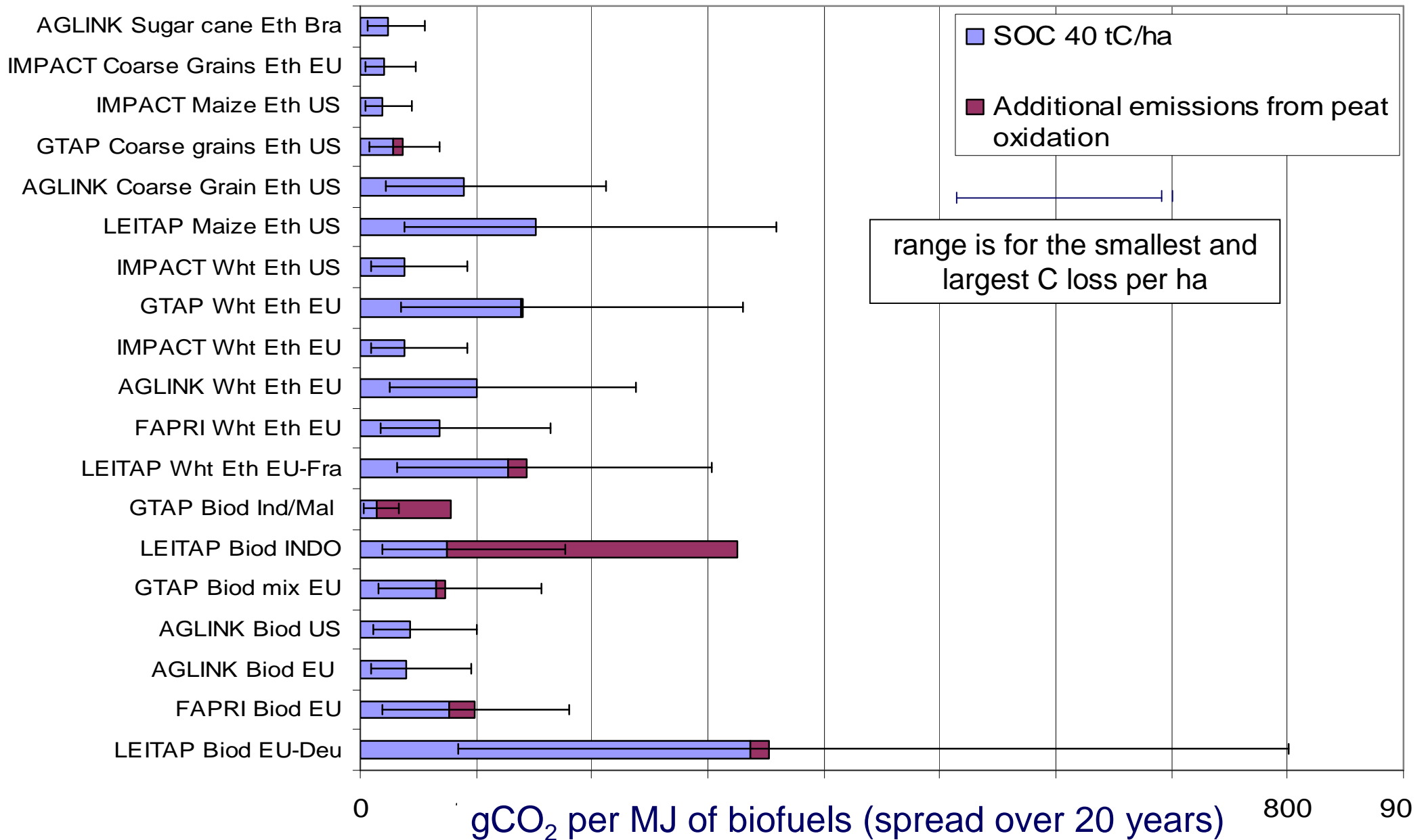
**A rough estimate of GHG emissions
due to ILUC, from the model area
results..**

- 1. We multiplied the ha/toe of extra crop area from each model by a range of C loss from soils+biomass:-**
 - lowest value for soils (10 tC/ha)**
(= abandoned cropland in FAPRI/GREEN-AGSIM,
(average value for IFPRI-MIRAGE “5.6% scenario ~32tC/ha*”)
 - low-typical (40 tC/ha)**
(IPCC say 38-95 tonnesC/ha for temperate land)
 - highest (95 tC/ha) (Searchinger 2008 including tropical)**
- 2. We converted the emissions to gCO₂/MJ of biofuel spread over 20 years**
- 3. We showed separately an estimate of the contribution from tropical peat oxidation (@19 tonnesCO₂/ha/y)**

* the slides as presented incorrectly suggested this value was close to 10 tC/ha.







- **All the models show significant ILUC effects for all feedstocks.**
- **These results are higher than those reported for the “5.6%” EU biofuels mix* by the IFPRI-MIRAGE model commissioned by DG-TRADE**
 - * partly because this mix is principally sugar-cane ethanol
- **Most ILUC effects occur in “rest of the world”**
- **The results of the models (esp. for ethanol) would be significantly higher if they did not include emissions savings from reduced food consumption.**
- **But models neglect several strong effects, causing them to underestimate ILUC emissions...**

Strong effects neglected by the models

- 1. neglecting emissions from tropical peat drainage**
- 2. yield at the crop frontier vs. average yield**
- 3. extra emissions from yield intensification**
- 4. ignoring effects on pasture area**

- **Ignored by all the models which JRC commissioned**
- **Very underestimated in the IFPRI-MIRAGE results for DG-TRADE:**
 - it used IPCC carbon stocks which are not for deep-drained peat (oil-palm)
...averaged with an estimate of the *minimum possible* peat emissions
 - used the ~% of *existing* plantations on peat, not the % of *new* ones.

We think models underestimate the effect of EU biofuels on future palm oil demand, because they have to use short-term data on substitutability of vegetable oils.

But here are our estimates of the extra emissions based on the model results of palm oil area as presented...

Extra emissions from peat oxidation @ 19 tonnes CO₂/ha/y of palm oil

oil palm area change	kHa per Mtoe	tCO ₂ /toe	gCO ₂ /MJ
Biodiesel scenarios			
LEITAP Biod EU-Deu	33	1	15
FAPRI Biod EU	51	1	23
AGLINK Biod EU			
AGLINK Biod US			
GTAP Biod mix EU	16	0	7
LEITAP Biod INDO	561	11	252
GTAP Biod Ind/Mal	143	3	64

How models go from tonnes to ha

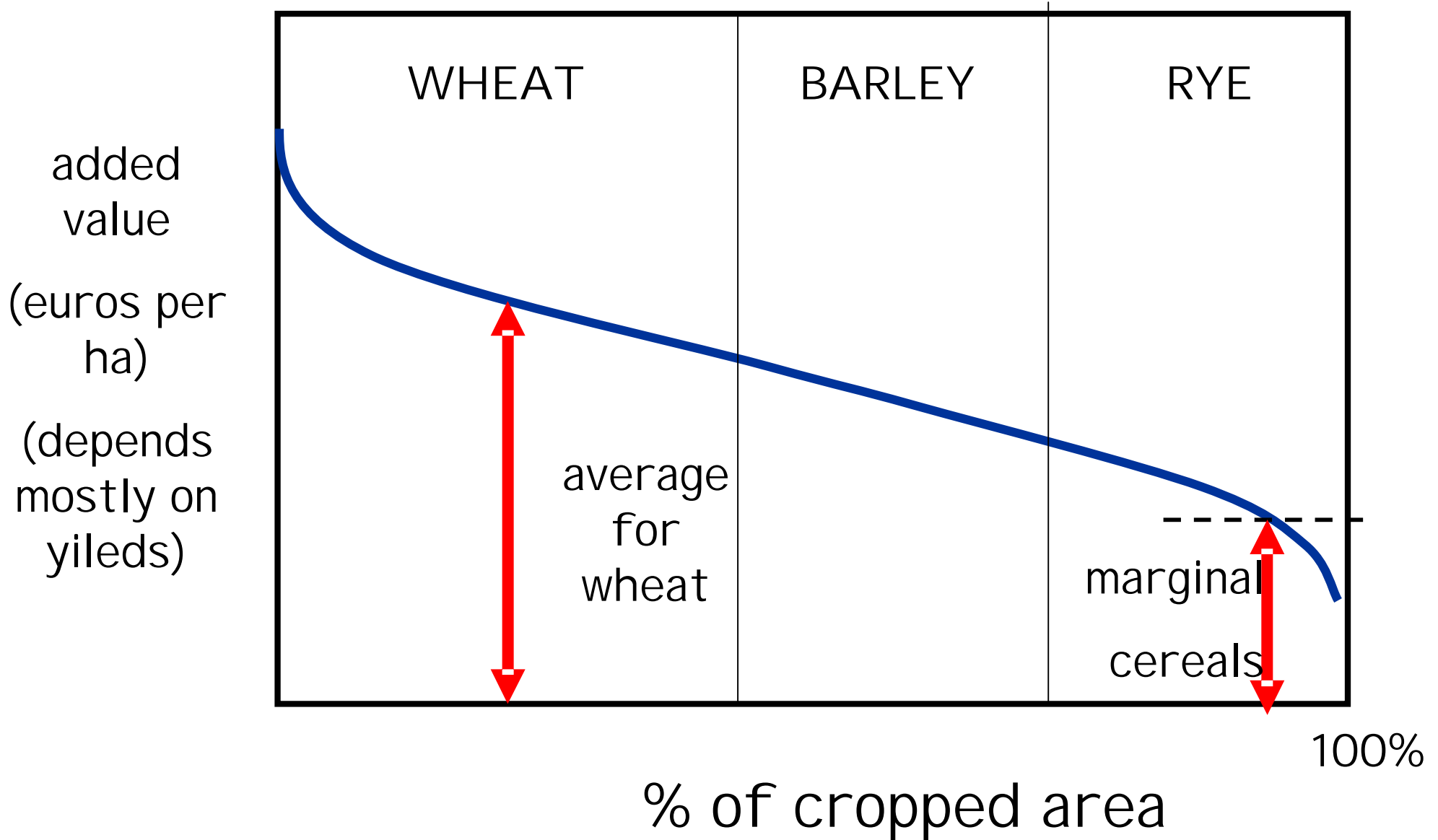
- Model output is basically change in tonnes of crop per country
- How many hectares of extra cropland?
- Most models say...

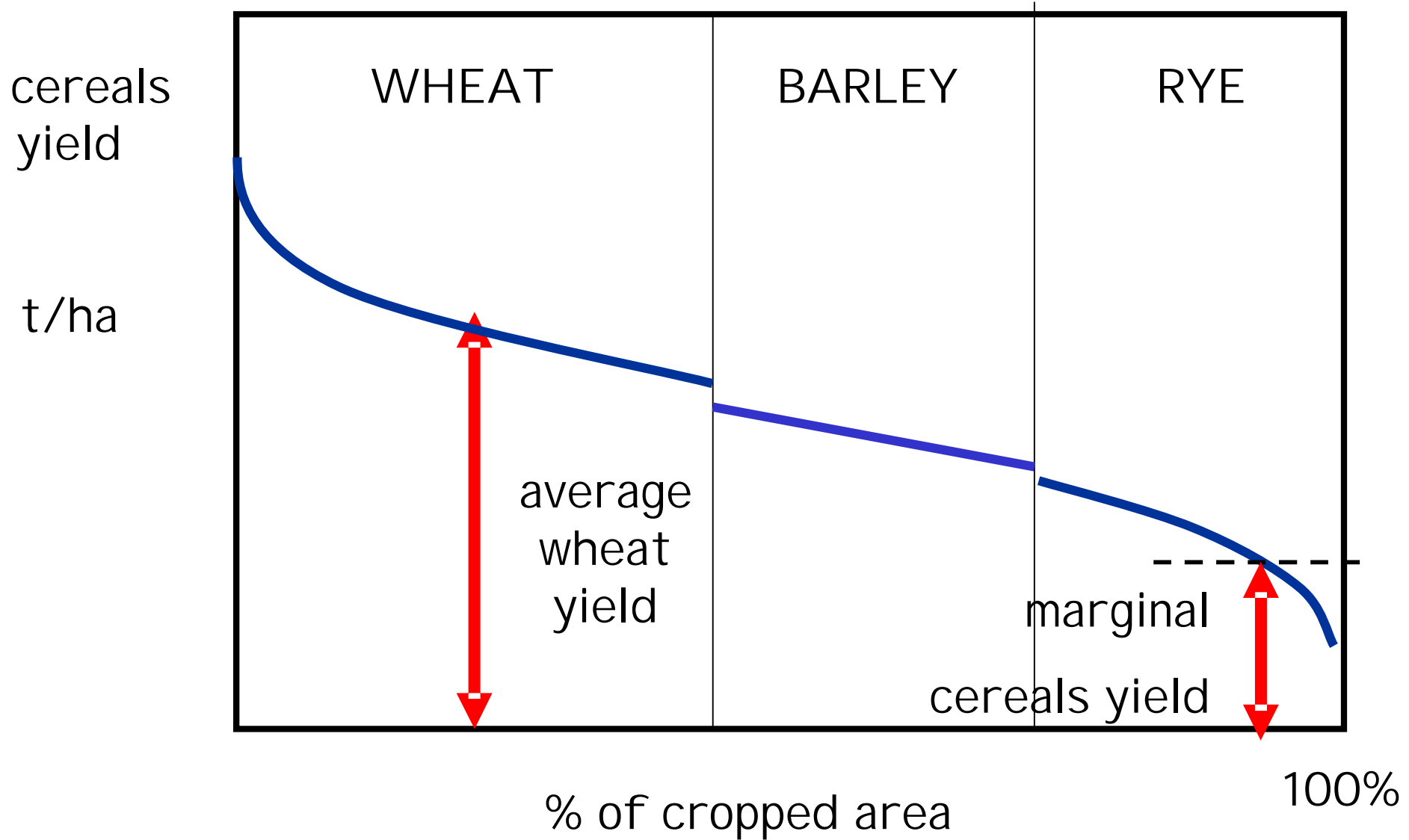
(extra hectares per crop)

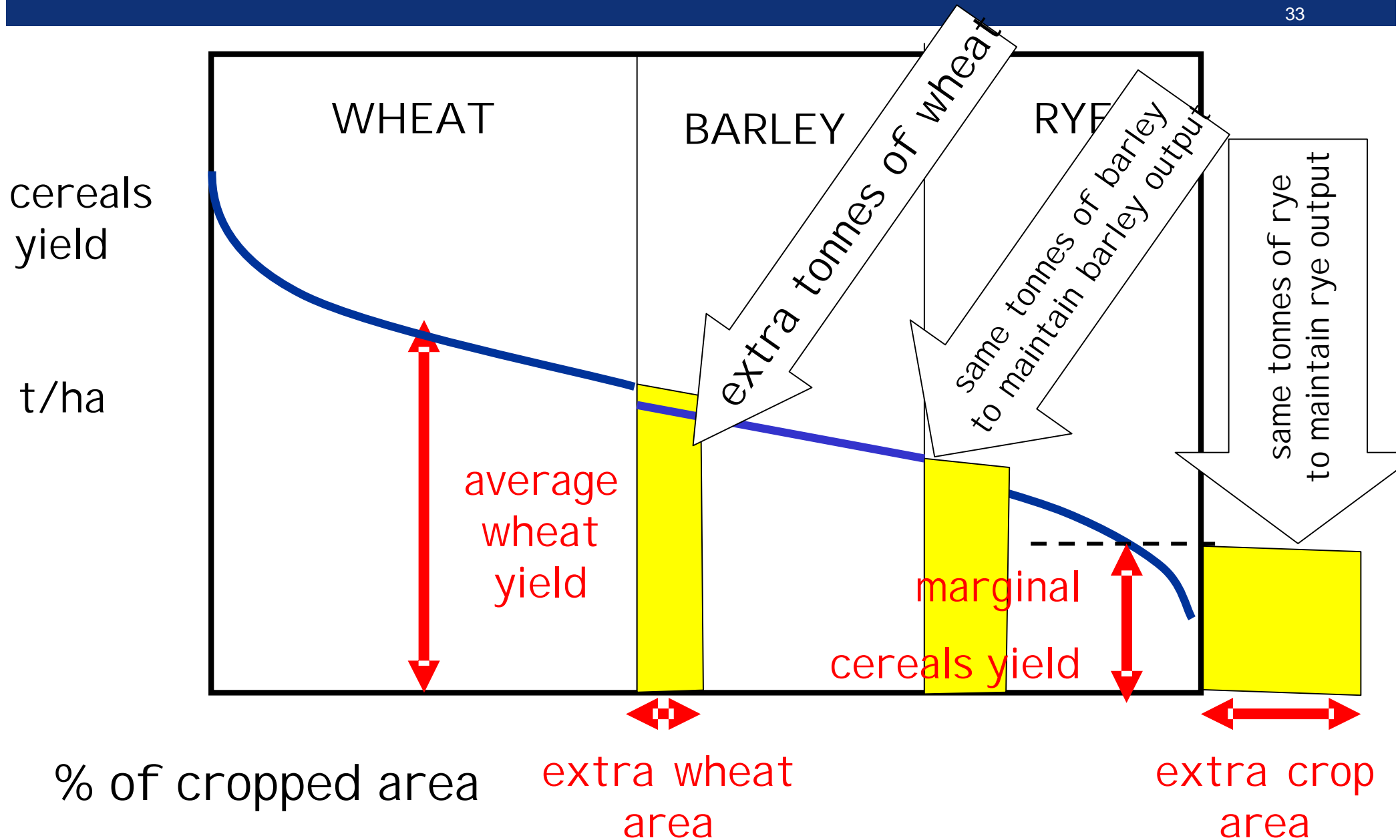
= (extra tonnes)/(yield of crop)

...and then add the hectares.

- Some marginal models have the average yield (for example, of barley) depending slightly on area of wheat
- Some models include small factors (e.g. FAPRI 0.97) for marginal/average yield of the same crop in the same country
- *Only GTAP* assumes constant yield-at-the-frontier independent of the crop displaced: 0.66 of the average yield for all crops in the region
- That means the other models would predict ~double the ILUC effect from rye as from wheat, because rye has ~half the yield!
That is because they ignore crop displacements...







- ILUC depends on the ratio of the yield-of-crops-at-the-frontier to average-yield

- Depends on the size of the region you are considering

the evidence is that

- - in EU the yield at the frontier of cropping is much less than the average wheat yield
- - in the US the ratio for maize is ~0.66
- - in Brazil the ratio for one soybeans is ~1

- $0.7 \times 0.7 \times 0.38 = 0.19$, so ILUC could be 5 times higher!
- On the other hand, in Brazil new land “has ~ same yield”:

The discussion in our report shows:

- **it is almost certain that the increased yield due to price increase (not due to *time*) will cause an increase in farming emissions per tonne of production. These extra emissions are not considered in models, although the yield increase is!**
- **The effect of price on *rate-of-improvement of yield* can at best lead to only a moderate yield increase over 10 years, and anyway might not decrease emissions per tonne of production.**

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- **These results are higher than those reported for the “5.6%” EU biofuels mix* by the IFPRI-MIRAGE model commissioned by DG-TRADE**
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- **Most ILUC effects occur in “rest of the world”**
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THE END

SPARE SLIDES TO ANSWER QUESTIONS

MORE ABOUT PEAT

- Undisturbed tropical peat forest is a carbon sink
- But it must be thoroughly drained to allow it to support oil palms.
- The ground level then subsides as peat oxidizes into the air.
- JRC estimated these emissions to be 57 tonnes CO₂ per ha per year (new data suggests it's double this)
- At least 1/3 of new palm oil plantations are on peat
- This does not include emissions caused by drainage of surrounding forest, including fires (peat fires emissions were overestimated after 1999, but not peat oxidation emissions)

DISCUSSION

YIELD INCREASES

Discussion from JRC workshop:

Two **yield-price** effects:

1 Crop-price effect on yield

- = yield elasticity on price
- short-term (1-5 years)
- all models include it
- but they don't consider the extra emissions from extra inputs (much discussion)

2 Crop-price effect on *rate of yield improvement* (research spending effect)

- biofuels mandates redirect research to increasing yields rather than reducing costs
- so effect on farm emissions per tonne is not clear
- 20 y time-lag before research results are seen in yields

1. Reversible effect of price on yield (yield elasticity on price)

- yields from higher inputs
- what is $d(\text{emissions})/d(\text{ton crop})$?

According to classical agro-economics,

$$\frac{\frac{\partial(\text{Nitrogen})}{\partial(\text{ton crop})}}{\frac{\partial(\text{Nitrogen})}{\partial(\text{ton crop})}} = \frac{\text{price of crop}}{\text{price of nitrogen}}$$

= 5 to 12 times the average nitrogen per tonne crop

BUT other inputs also increase yield with less emissions: this dilutes the marginal emissions per ton

...but for marginal emissions per ton to be *less* than average ones,

<< 1/5 to 1/12 of the extra spending must go on N

- One CANNOT find this by naively correlating historical yield data against fertilizer, because of co-linearity (autocorrelation) problems
- It attributes yield gains due to time-learning to demand increase
- SO IT GREATLY UNDERESTIMATES EXTRA FERTILIZER USE CAUSED BY PRICE INCREASES
- (real crop price DECREASES with time, so one could equally argue that decreasing price increases yields!)

2. Irreversible effect of sustained higher crop price on rate-of-yield-increase, due to...

How big is this effect?

The driver for investment improving net return/ha is net -
return/ha

The driver for higher yield is crop price

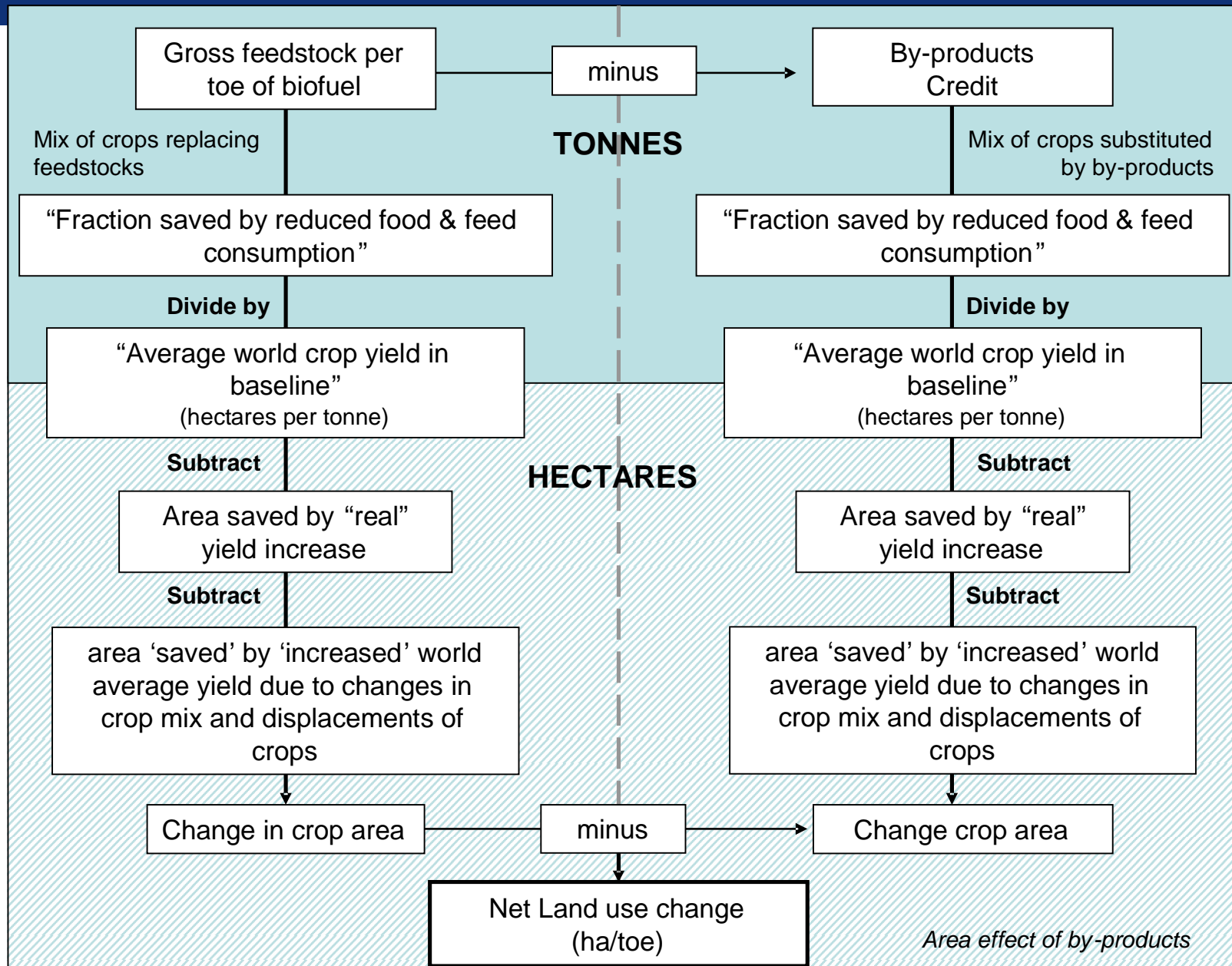
e.g. 10% sustained crop-price increase:

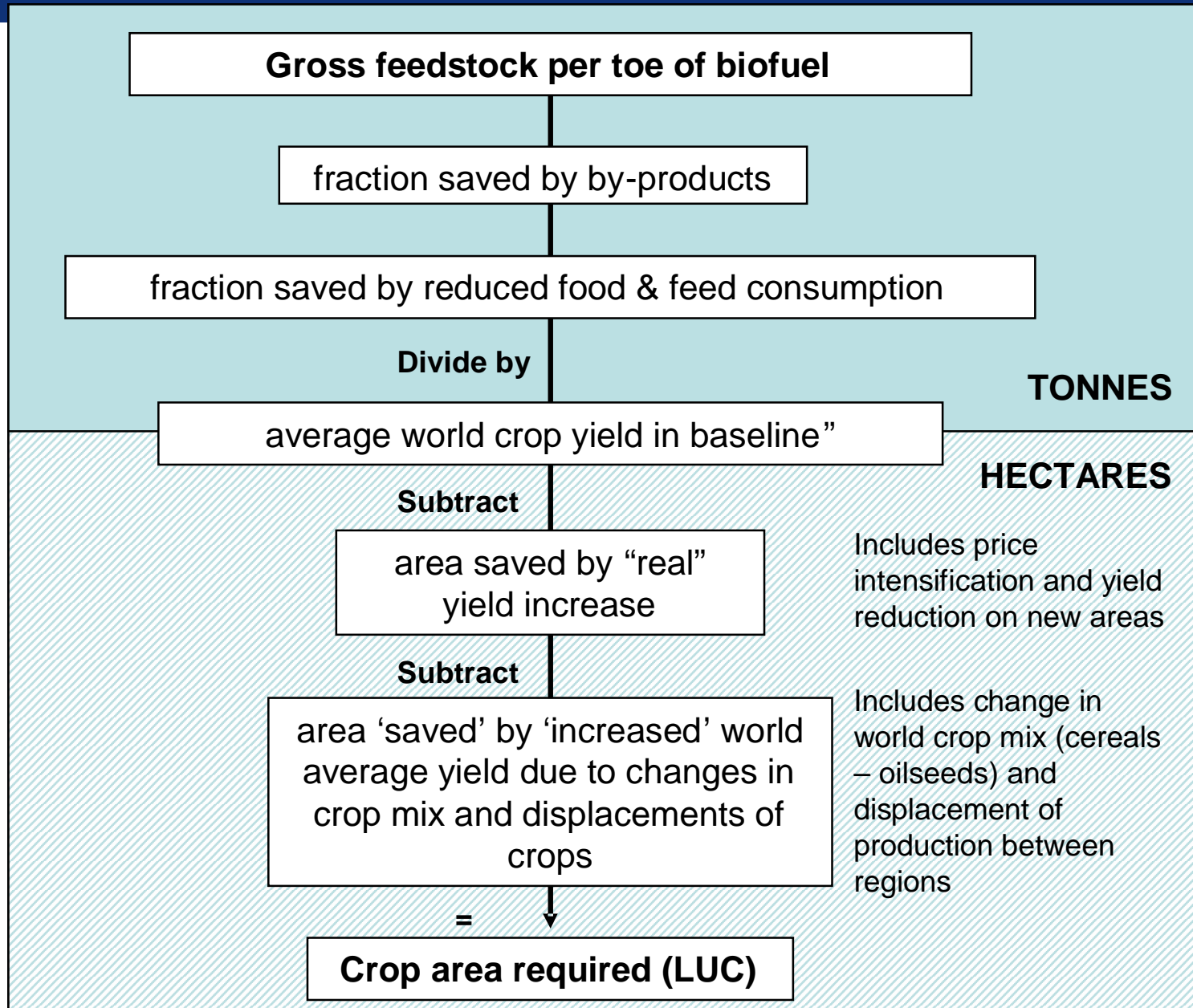
say $d(\text{yield})/dt$ increases proportionally to price increase,
from 1 to 1.1% per year (i.e. NO diminishing returns;
instant effect),

over 10 years yield goes up 11.6% instead of 10.4%:

effective contribution to yield elasticity on price after 10 years is 0.12
the effect can only be moderate

JRC-IE ANALYSIS METHOD





PER TOE BIOFUEL		EU Wheat Ethanol		EU Rapeseed Biodiesel					
	Gross tonnes of feedstock	5.40	adjustment		3.0	adjustment		A	fraction of gross feedstock saved by by-products
I			-	31%		-	61%		
	...net of by-products (tonnes)	3.71			1.16			B	fraction of net feedstock supplied by reduction in food use
II			-	34%		-	97%		
	...net of reduction in food use (tonnes)	2.45			0.03			C	baseline production/baseline area (tonnes/ha)
III			÷	3.7		÷	3.7		
	corresponding hectares at average baseline-yield-of-all-crops	0.66			0.01			D	baseline area * (fractional yield increase (per region per crop) weighted by baseline area (per region per crop)) (ha/toe)
IV			-	0.07		-	0.12		
	...net of area from increased yield on baseline crop distribution (ha)	0.59			-0.11			E	fractional change in (total crops/total area) x baseline area (ha/toe)
V			-	0.20		-	-0.5		
	...minus the area 'saved' by 'increased' yields due to crop/regional displacements (ha)	0.39			0.40			LUC (ha/toe)	
VI									

Feedstock per toe biofuel - little variance between models

A Fraction of extra crops saved by by-products

Modellers could generally only report directly the effect of by-products on the demand of the *principal feedstock*. Does not include replacement of *other* crops by by-products.

B Fraction of extra crops (after correction for by-products) saved by reduced food consumption

includes crops fed to animal for meat/dairy production

C Average Crop Yield

This is only in the table for comparison

D Area saved by 'real' yield increase

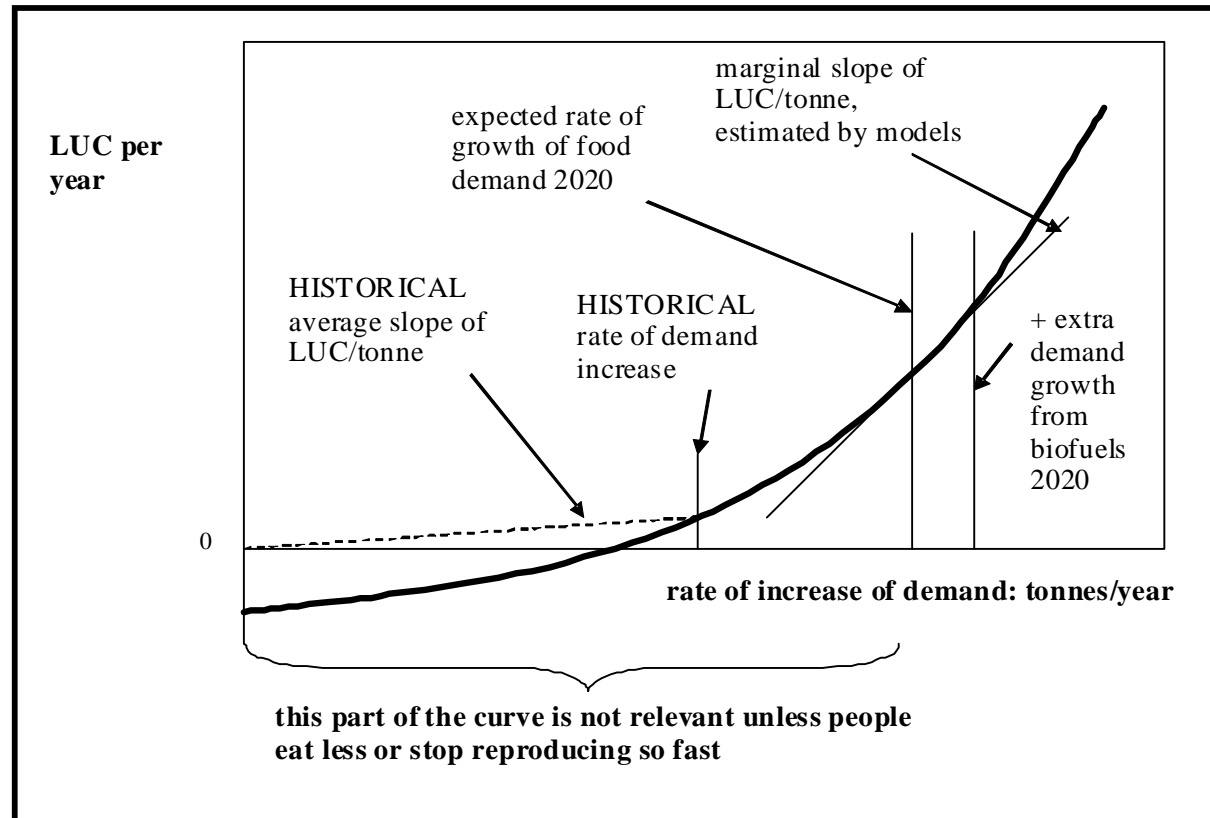
increase in average yield for all the crops in all regions, weighted by the baseline area-distribution of the crops

E Area saved by crop displacements

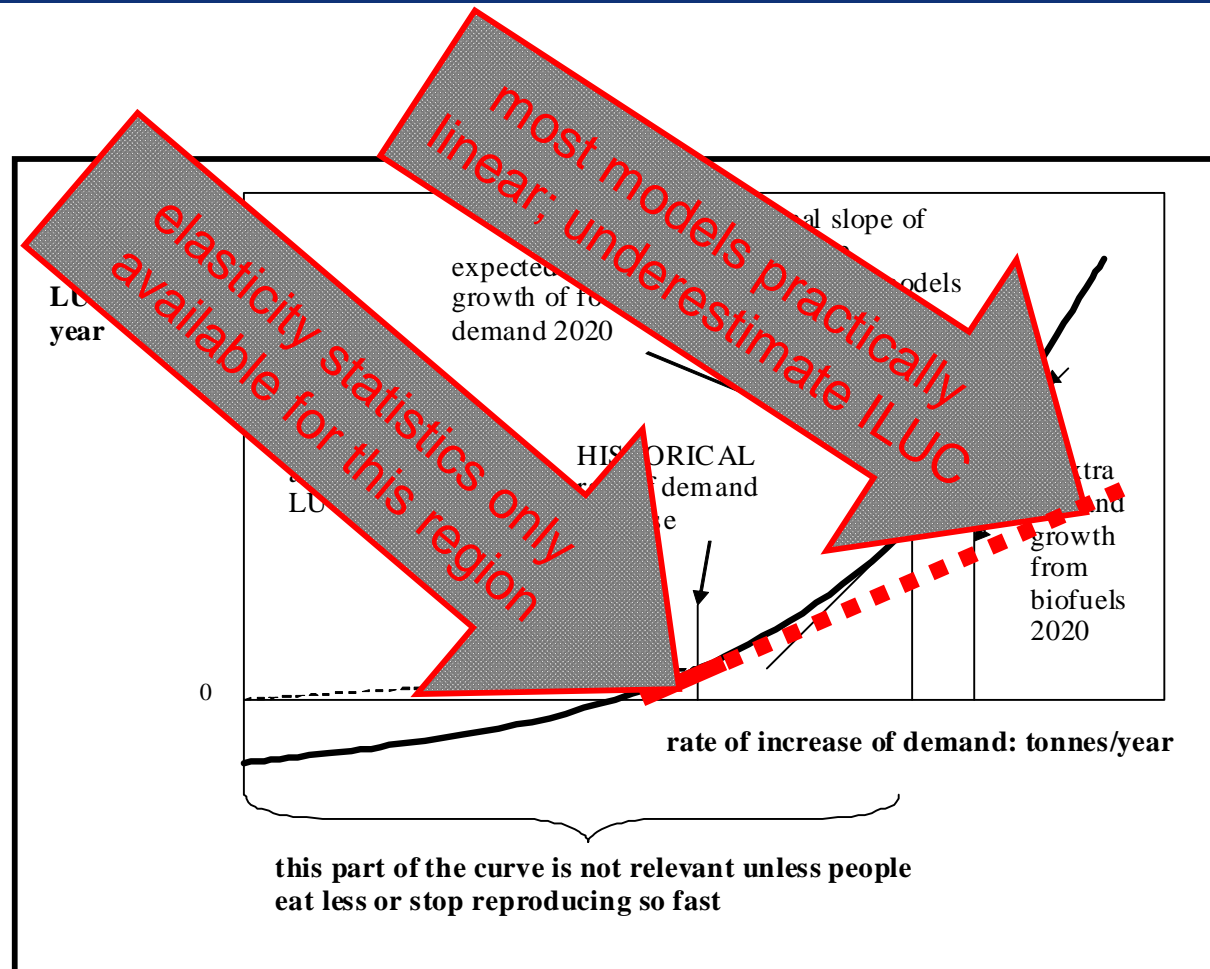
Change in crop mix on existing land. Area of a particular crop may diminish in one country and rise in another one which has a different yield

Model and scenario		Feedstock (tonnes)	Feedstock adjustments (%)						Area without yield "savings" (ha)	Area adjustments (ha)			LUC (ha/toe)		
			By-products		Food consumption reduction		Average yield			Area "saved" by Yield increase	Area "saved" by crop displacement				
FAPRI-CARD	EU Wheat Ethanol	5.4	-	31%	-	34%	3.7	=	0.66	-	0.07	-	0.20	=	0.39
	EU Rapeseed Biodiesel	3.0	-	61%	-	97%	3.7	=	0.01	-	0.12	-	-0.51	=	0.40
GTAP	EU Wheat Ethanol	5.2	-	32%	-	46%	5.5	=	0.34	-	0.03	-	-0.48	=	0.79
	US Coarse grains Ethanol	4.6	-	31%	-	52%	5.5	=	0.27	-	0.12	-	-0.01	=	0.16
	EU Biodiesel (mix)	2.4	-	52%	-	1%	5.5	=	0.21	-	0.25	-	-0.42	=	0.38
	Malay_Ind Biodiesel	5.1	-	22%	-	12%	5.5	=	0.63	-	0.23	-	0.32	=	0.08
IMPACT	US Maize Ethanol	4.6	-	0%	-	36%	5.1	=	0.58	-	0.45	-	0.02	=	0.11
	US Wheat Ethanol	4.9	-	0%	-	47%	5.1	=	0.51	-	0.54	-	-0.26	=	0.22
	EU Coarse grains Ethanol	4.8	-	0%	-	11%	5.1	=	0.83	-	0.92	-	-0.21	=	0.12
	EU Wheat Ethanol	4.9	-	0%	-	47%	5.1	=	0.51	-	0.54	-	-0.26	=	0.22
LEITAP	Maize Ethanol US	5.0	-	7%	-	4%	4.2	=	1.07	-	0.02	-	0.18	=	0.86
	Wheat Ethanol Fra	5.5	-	1%	-	3%	4.2	=	1.26	-	0.15	-	0.38	=	0.73
	Biodiesel Deu	3.0	-	1%	-	9%	4.2	=	0.64	-	0.36	-	-1.64	=	1.93
	Malay_Ind Biodiesel	3.0	-	0%	-	1%	4.2	=	0.71	-	0.004	-	0.28	=	0.43
Calculations:		Feedstock (tonnes)	fraction of gross feedstock saved by by-products (tonnes)		fraction of net feedstock supplied by reduction in food use (tonnes)		baseline production /baseline area (tonnes/ha)	Would-be extra area without yield changes	baseline area *average of fractional yield increase (per region per crop) weighted by baseline area (ha/toe)	Area saved by total net yield effects - D (ha/toe)		LUC ha/toe			

LINEARITY DISCUSSION



...ILUC is probably not linear, but models generally are (or nearly so), because of lack of data for non-linearities. Linearity means marginal effects are additive for different feedstocks.



...ILUC is probably not linear, but models generally are (or nearly so), because of lack of data for non-linearities. Linearity means marginal effects are additive for different feedstocks.

DISCUSSION: INDIRECT? EFFECTS

In traditional LCA, biofuels can only appear to save GHG because of the “renewable carbon” credit: emissions from burning carbon in the crop are not counted.

That works fine if you establish a new biofuel plantation by irrigating a desert. But if you **divert** an existing crop from food to biofuel...

crop to biofuels

vs.

crop to food, fossil fuel

Now there is no additional absorption of carbon: crop absorbs carbon in both the biofuel and reference scenarios, so the carbon credit cancels out.

There are now no direct GHG savings from biofuels, because all the other direct emissions from biofuel (tailpipe emissions, refining emissions...) are the same or higher for biofuels

Now the only way biofuels can save GHG is by indirect effects

- either someone else absorbs more carbon by growing replacement food (than was absorbed before on his land)
- or the food is not replaced, and someone eats less

So accounting for indirect effects is essential in order to establish whether using existing crops for biofuels saves GHG.

What are usually called “indirect emissions” are a fix to correct the mistake in traditional LCA methodology when applied to crops grown on already-used land.

Biofuel from crop

fossil fuel + crop for food

Car exhaust CO₂

≈

Car exhaust CO₂

Refining emissions

>

Refining emissions

Farming emissions

=

Farming emissions

CO₂ absorbed in the crop

=

CO₂ absorbed in the crop

Direct effects give no GHG saving

Somebody else absorbs net CO₂ by farming operations to replace the missing food

Net CO₂ absorbed in the existing land use

or
Somebody else stops eating the missing food and releasing its carbon as CO₂

biofuels can only save CO₂ emissions because of indirect effects