Are any biofuels really green?

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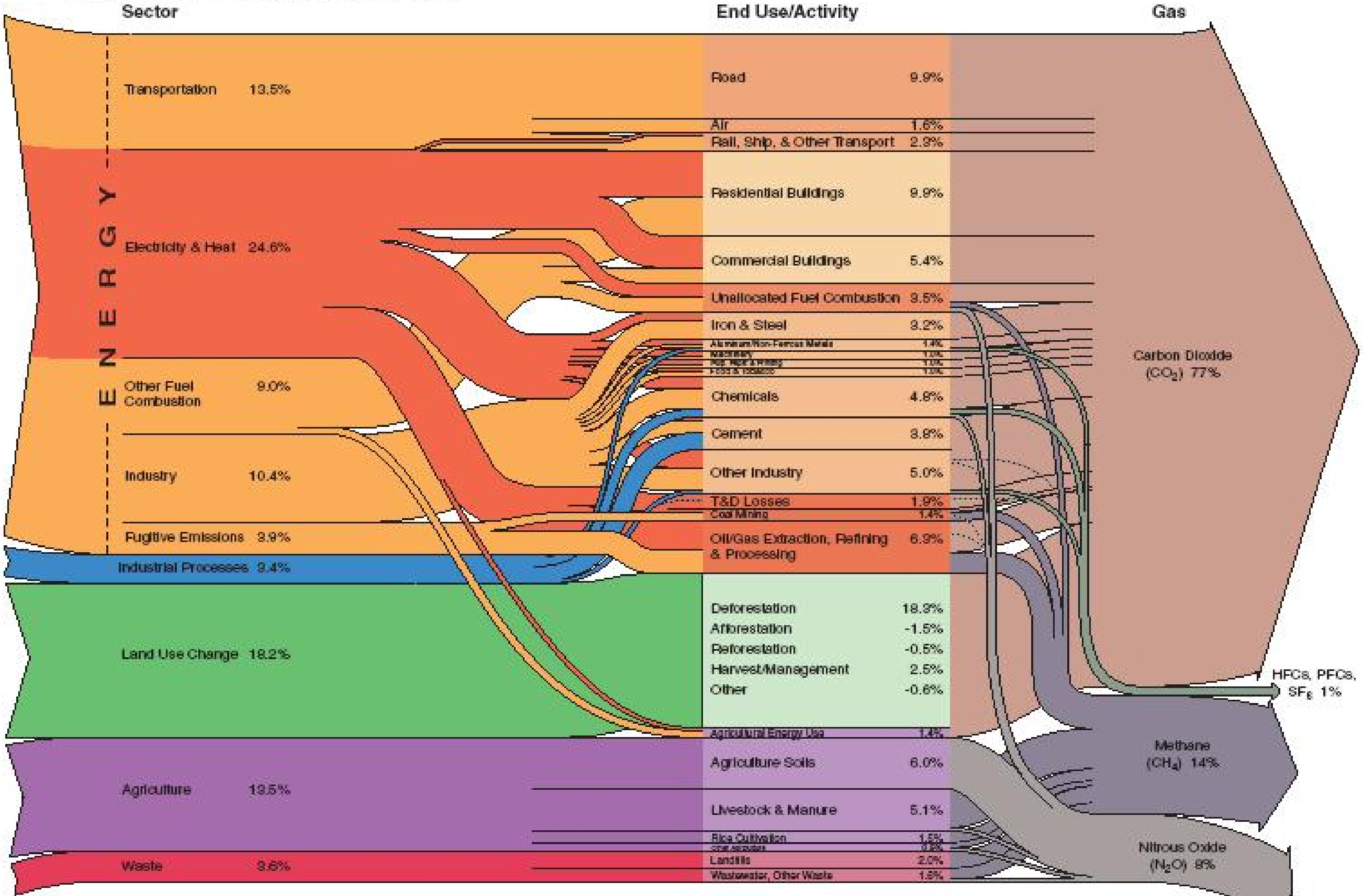
World GHG Emissions Flow Chart



Sources & Notes: All data is for 2000. All calculations are based on CO_2 equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41,755 $MtCO_2$ equivalent. Land use change includes both emissions and absorptions; see Chapter 16. See Appendix 2 for detailed description of sector and end use/activity definitions, as well as data sources. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

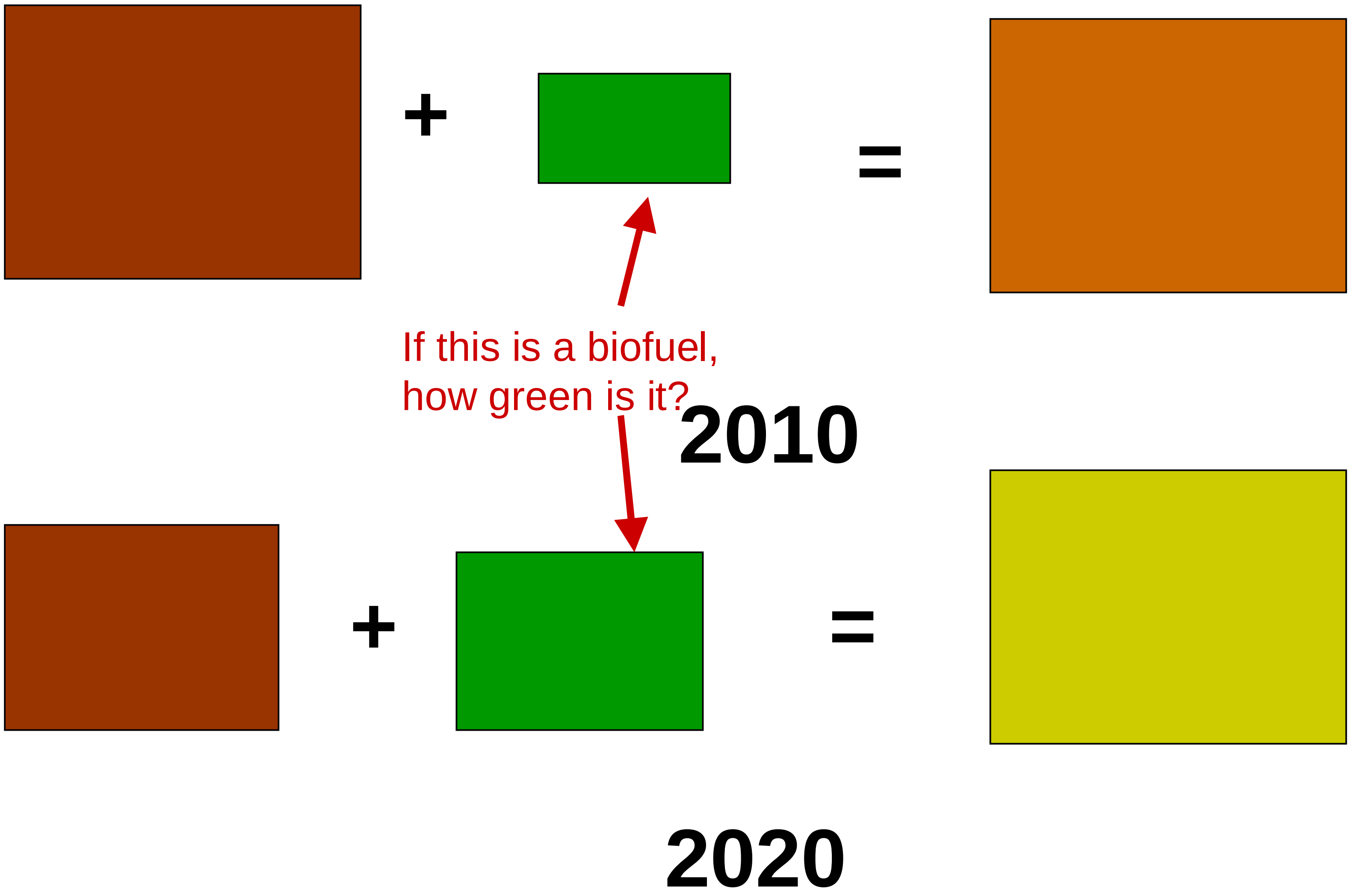
Overview

Feedstock	Product			
	Ethanol	**Otherols**	**Diesel**	**Mass**
Maize				
Wastes				
Perennials				
Sugar crops				
Other crops				
Algae				

US Policy Context

- Renewable Fuels Content
  - 7.6% in 2008
  - 36 x 10^9 gal by 2036
- Ethanol subsidies and import tariff
- Agricultural subsidies (including maize)
- Life cycle analysis required for RFC
- State LCFS policies, esp. California

LCFS liquid fuel concept



LCFS in practice

- For producer *j* in year *t* who blends Q_i units of fuel with GHI index G_i, the fine (or sale of credits) when the standard is S_t will be:

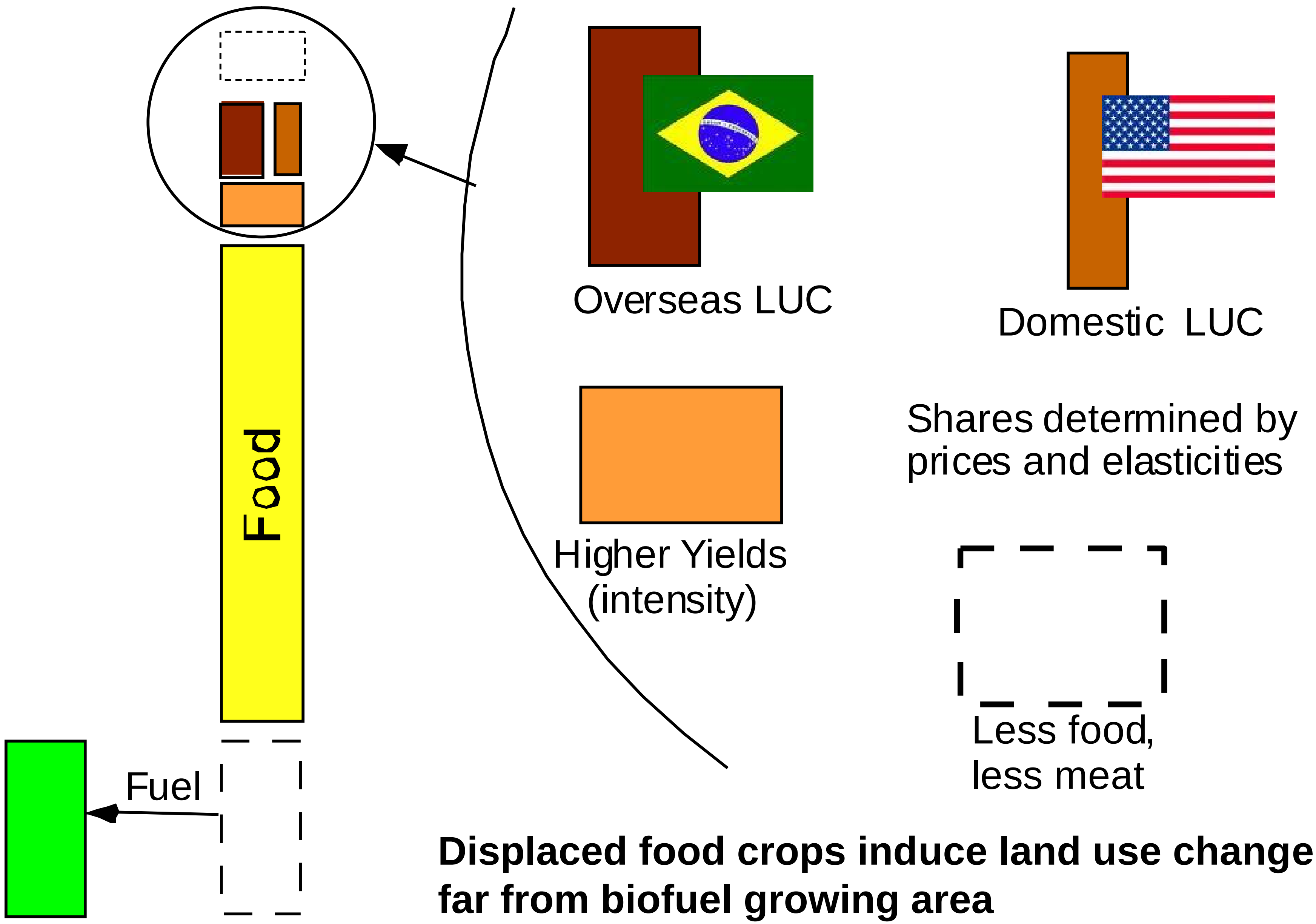
$$AFCI_{jt} = G_1 Q_1 + G_2 Q_2 + \ldots$$

$$C_{jt} = \left(S_t - AFCI_{jt}\right) PQ_t$$

Policy implementation comprises (mostly) establishing operational definitions for these variables.

Overview of LUC

- Ethanol from crop plants will induce additional cultivation somewhere in the world, or reduce grain consumption as food.
- Three kinds of change will occur:
  - People will eat less, or eat less meat.
  - Agriculture will become more intensive
  - Land will be converted from something else to crops
- The second and third release GHG not counted in the LFC analysis of the ethanol crop itself
  - As far as we can tell now, these releases are very large (research is still scanty).
  - The smallest estimates available for land use change alone put corn ethanol and all biodiesels well above gasoline in unit GWP.
- Simply increasing corn ethanol content in vehicle fuel should not be considered the “typical” means of compliance with LCFS.



Displaced food crops induce land use change far from biofuel growing area

Land use change (LUC) may cause large GHG emissions

U.S. corn farmer switches from corn/soy to corn/corn

U.S. soy exports go down and world soy prices rise

Additional land in Brazil (for instance) is put into soy production

Soy farmers everywhere use more inputs to increase yields

Indirect LUC emissions

Indirect process emissions

Process emissions

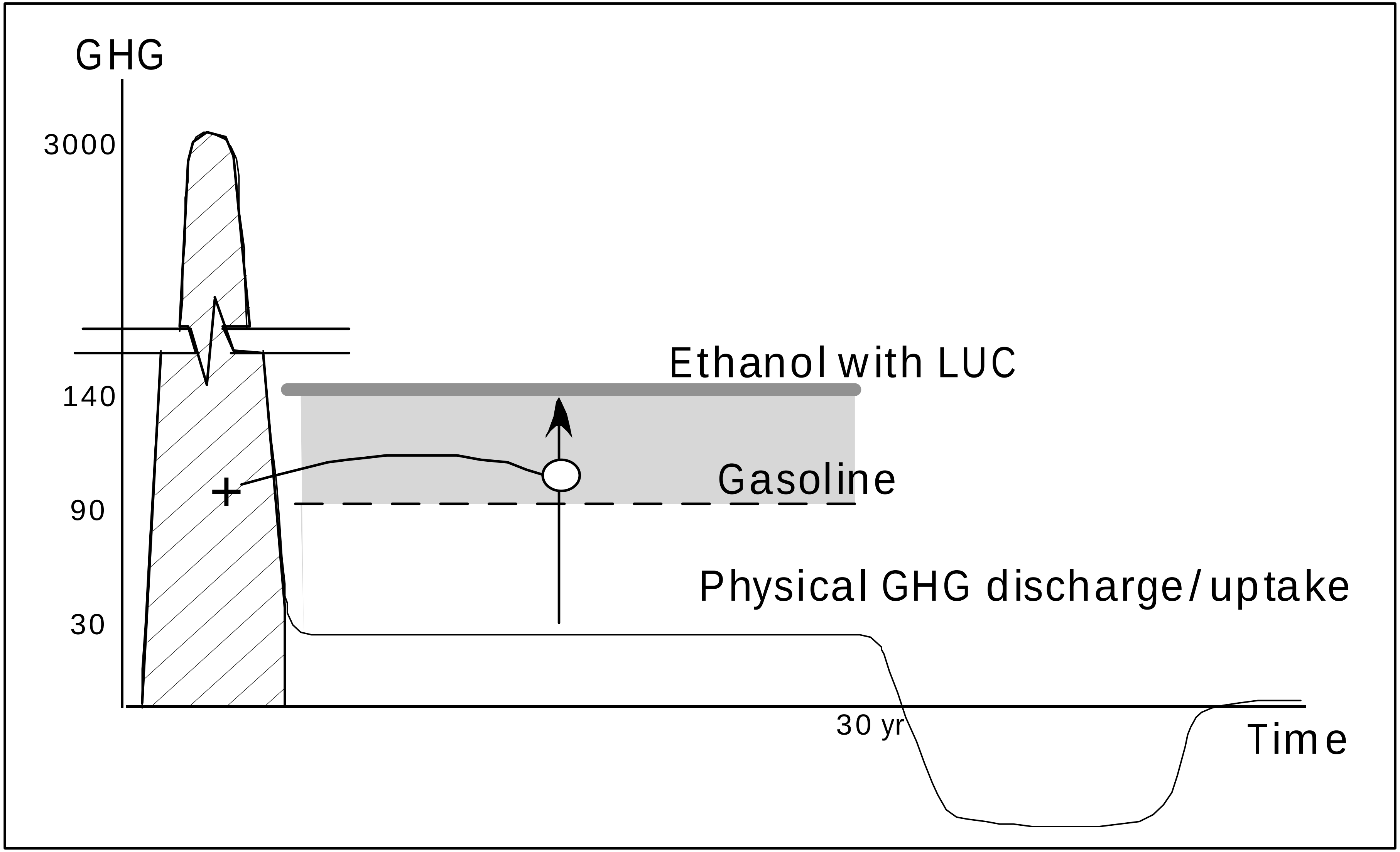


Figure 1: Physical discharge of GHG and land use change. Values rounded from Searchinger *et al*.

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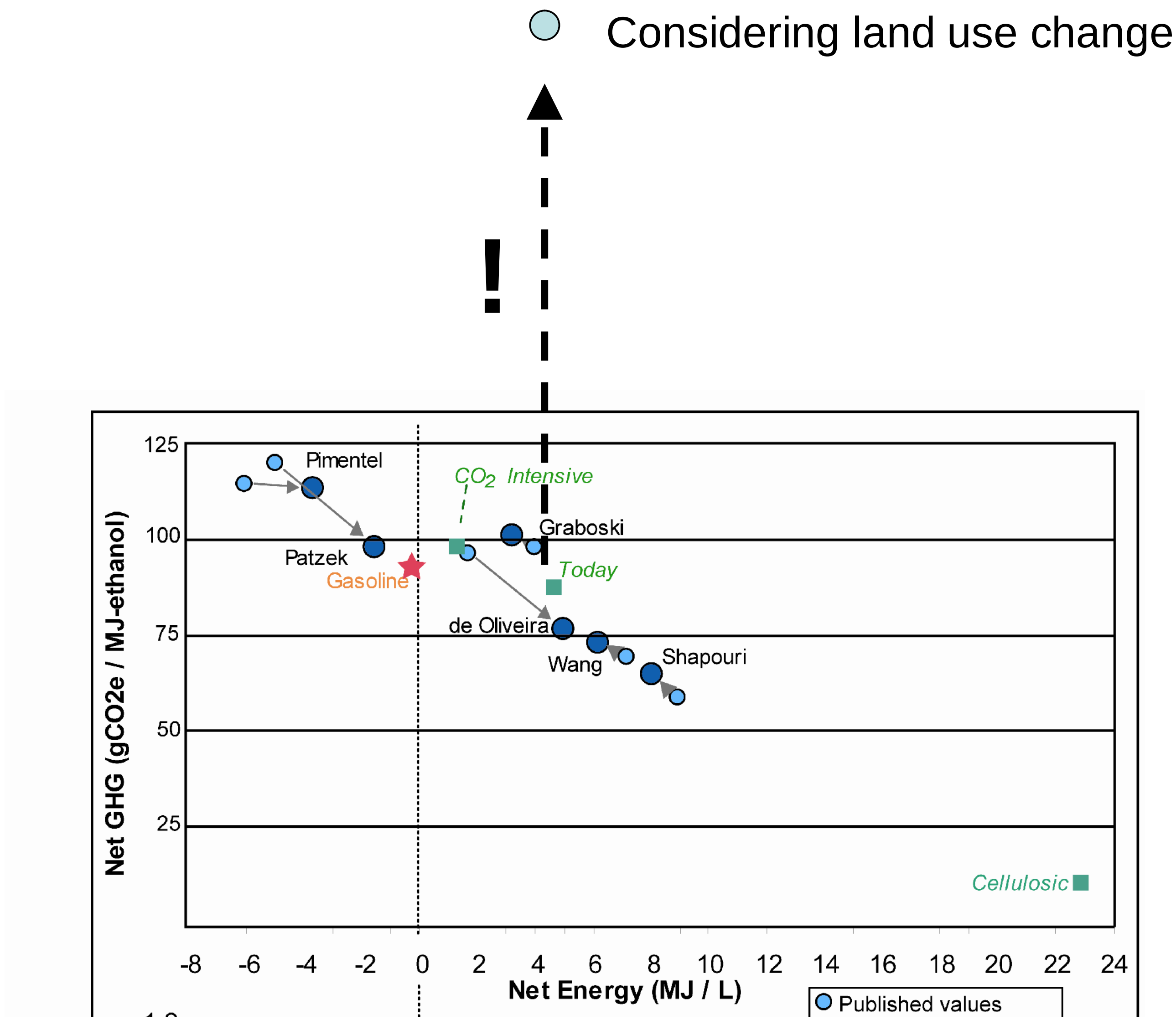
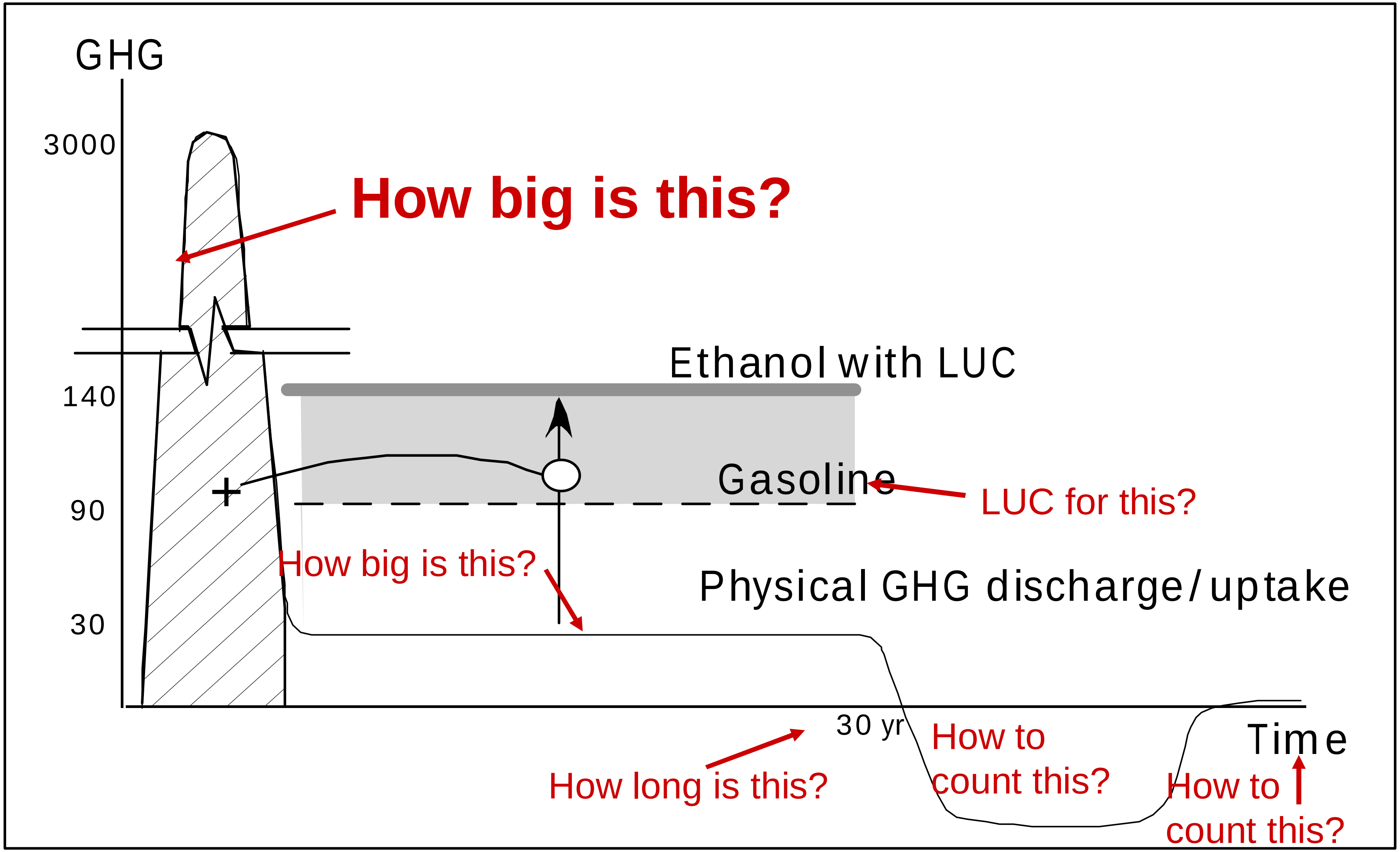

Considering land use change
!
Net GHG (gCO2e / MJ-ethanol)
125
100
75
50
25
Pimentel
Patzek
Gasoline
CO2 Intensive
Graboski
Today
de Oliveira
Wang
Shapouri
Cellulosic
-8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24
Net Energy (MJ / L)
Published values

Table 1. Comparison of corn ethanol and gasoline greenhouse gasses with and without land use change by stage of production and use (Grams of GHGs CO_2 eq. per MJ of energy in fuel) (*29*).

Source of Fuel*	Making Feedstock	Refining Fuel	Vehicle Operation (Burning Fuel)	Net Land Use Effects: Feedstock Uptake from Atmosphere (GREET)	Net Land Use Effects: Land Use Change †	Total GHGs*	% Change in Net GHGs vs. Gasoline
Gasoline	+4	+15	+72	0	–	+92	–
Corn Ethanol (GREET)	+24	+40	+71	-62	–	+74 +135 without feedstock credit	-20% +47% without feedstock credit
Corn Ethanol + Land Use Change	+24	+40	+71	-62	+104	+177	+93%
Biomass Ethanol (GREET)	+10	+9	+71	-62	–	+27	-70%
Biomass Ethanol + Land Use Change	+10	+9	+71	-62	+111	+138	+50%

*Figures in total may not sum perfectly due to rounding in each column.
†Amortized over 30 years

From Searchinger 2008



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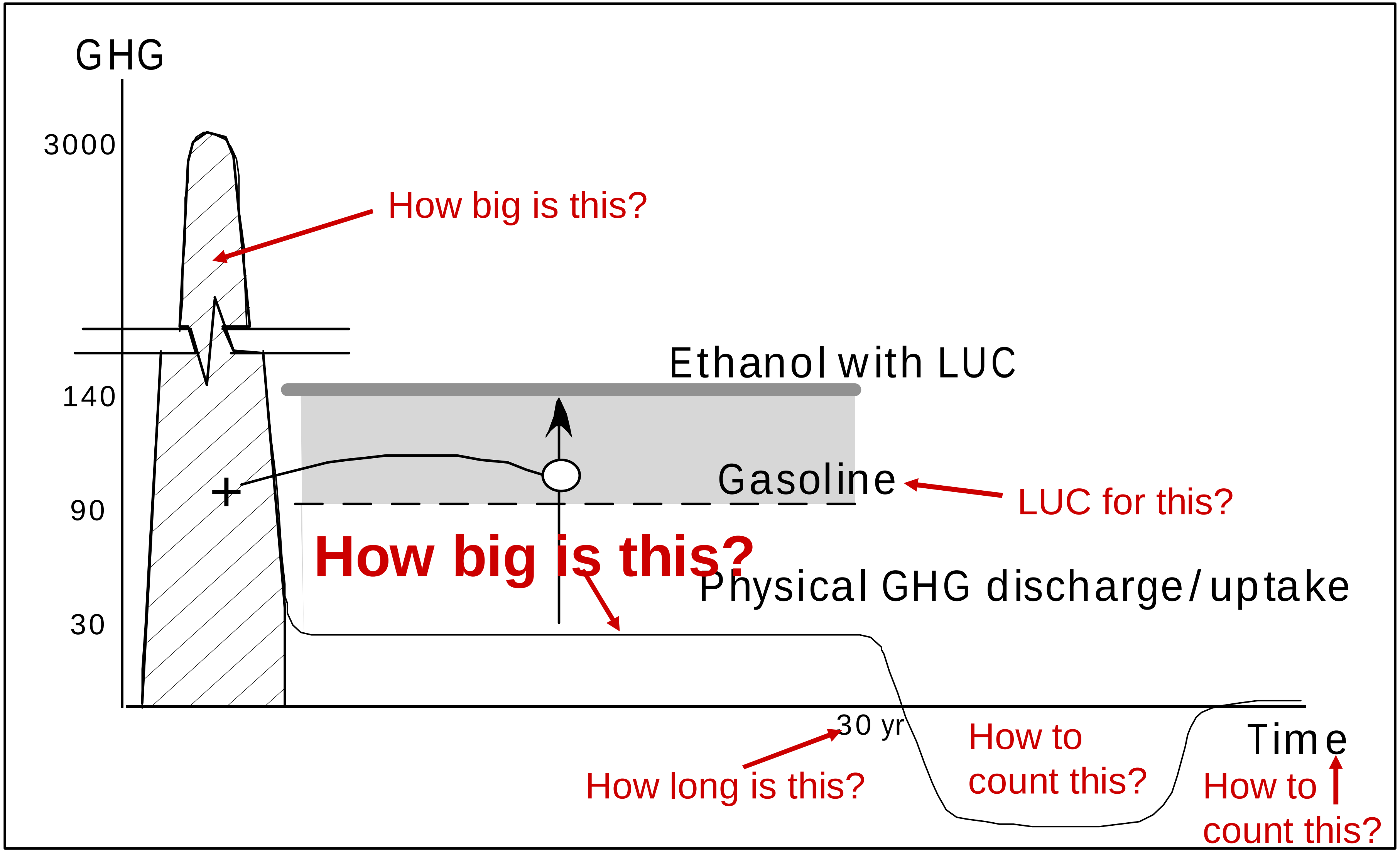
How big is the initial release?

- Larger/smaller biofuel yields per acre means less/more land converted.
- More complete economic models may predict more/less land converted in each of category.
- Better biological models may change per-acre C release estimates for different land types and locations.
- Biofuels on non-food-crop land have very small LUC effects.

Marginal vs. average yields

- Yields of all crops increase over time
  - This is irrelevant to LUC issue on *ceteris paribus* principle.
- Yields from land not used are lower than current averages (best land used first)
  - This means LUC estimated with declining marginal yields will be higher.



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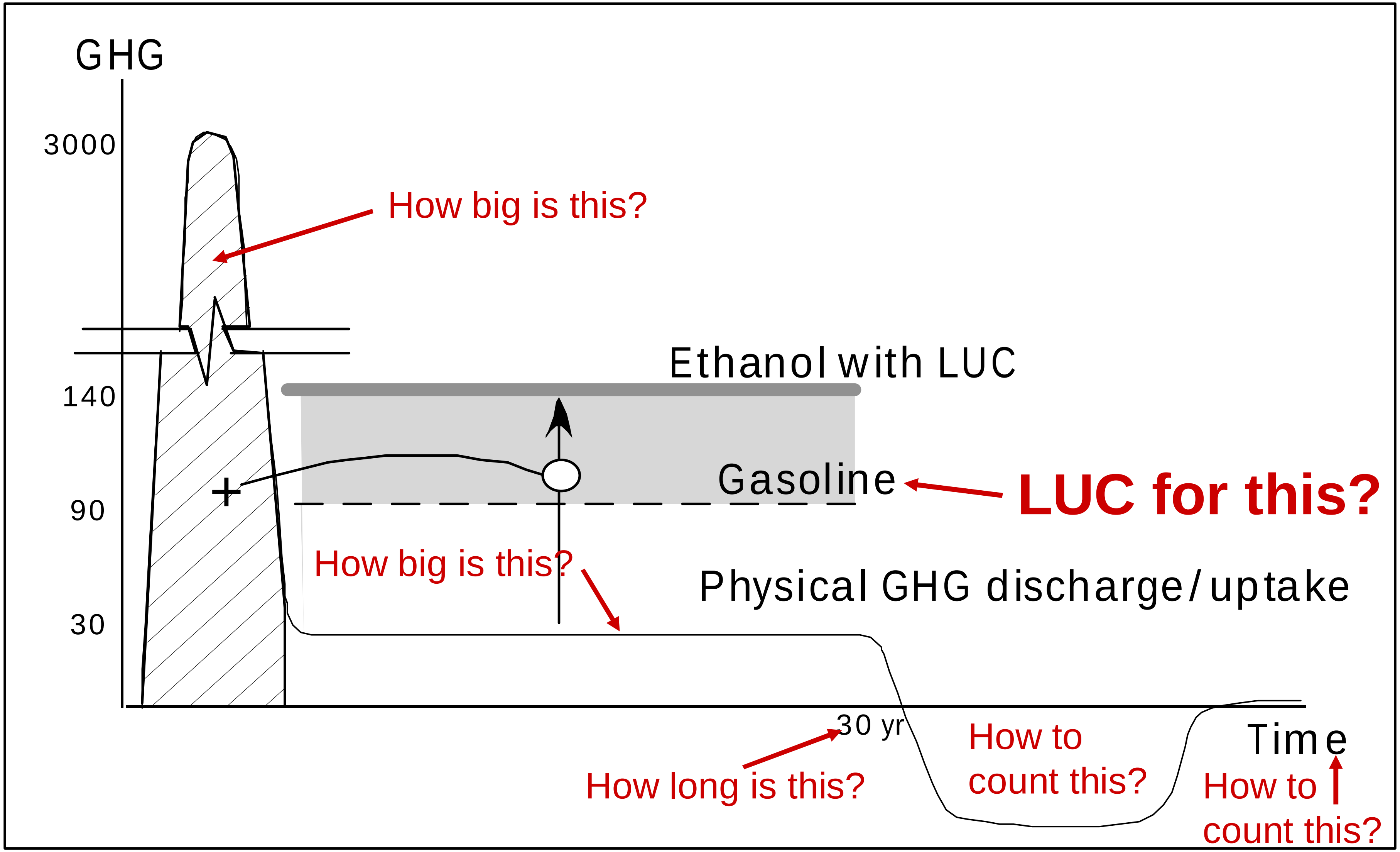
How large are crop production GHG releases?

- Different crops have very different production GHG effects
  - Mixed perennials on waste land: very low
  - Corn-only intensive: very high
- Better agriculture practice has lower GHG releases
  - But irrelevant under *ceteris paribus* principle



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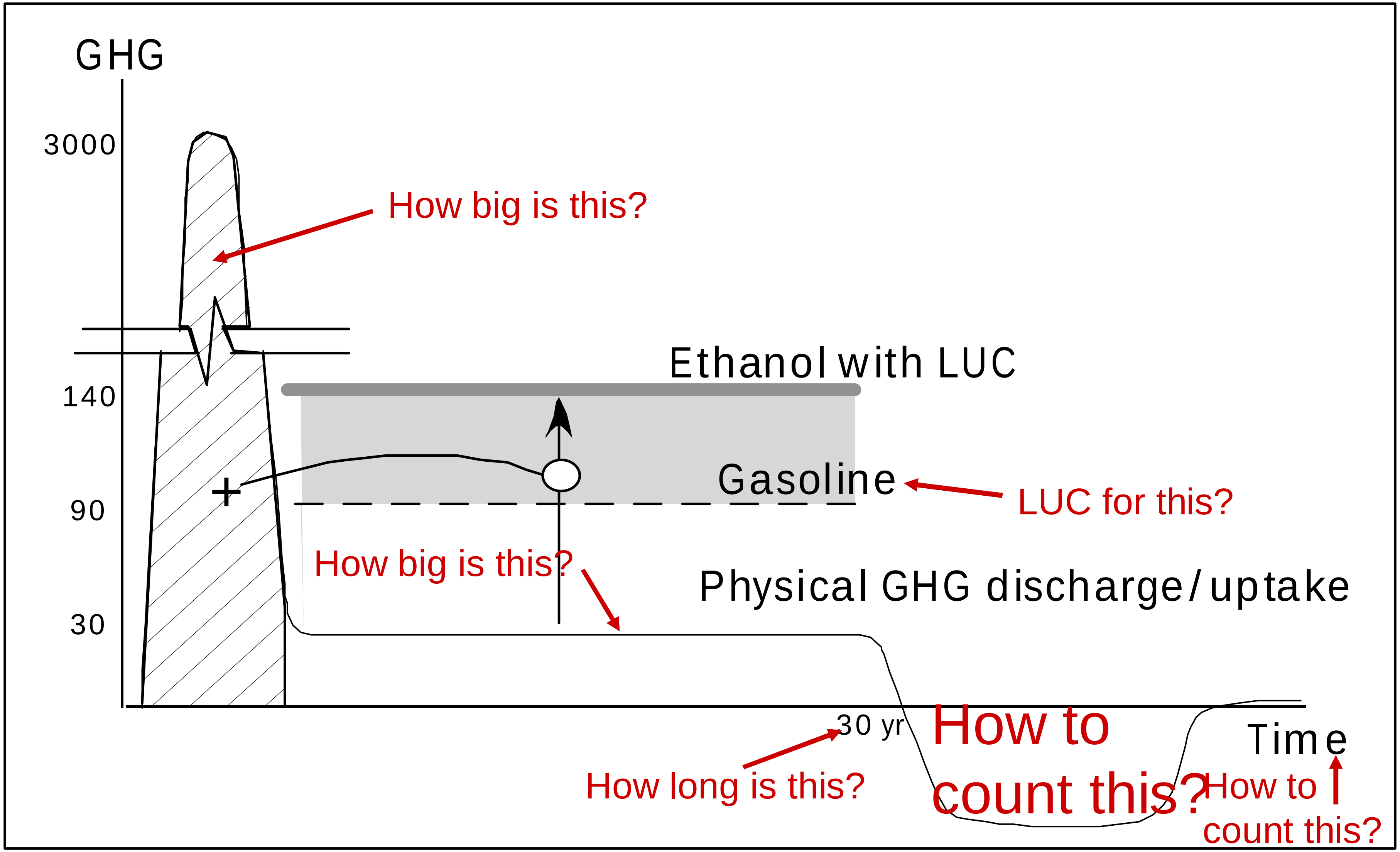
What about gasoline LUC?

- Conventional petroleum land use is very small (depends on extraction rate)
  - Offshore oil
  - Desert oil
- Tar sands, shale petroleum uses much more land but not much, and low C.
- Surface coal mining is extremely destructive but still much less than biofuel (depends on extraction rate)



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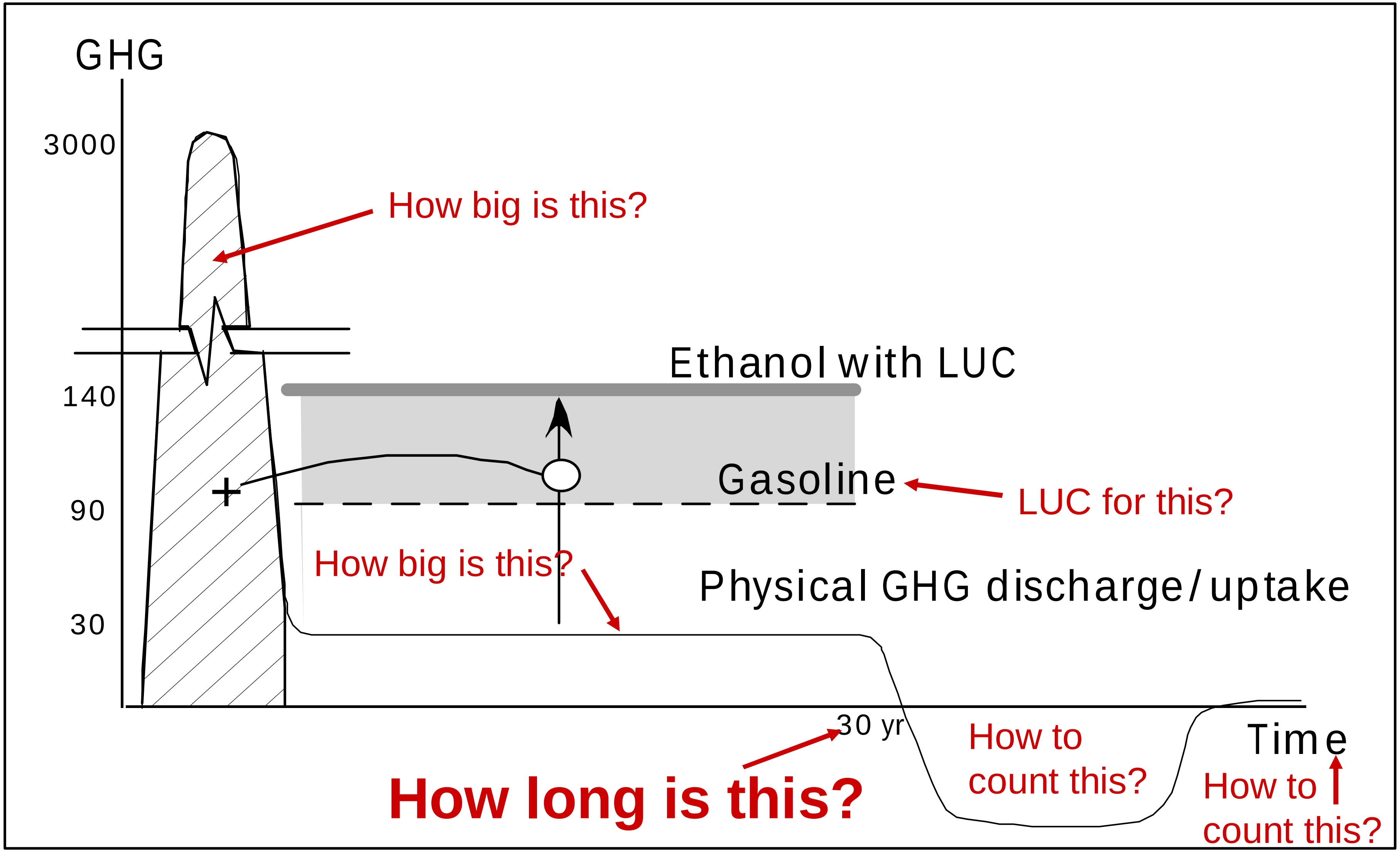
What about reversion?

- Eventually, land converted to crops is no longer used and returns to some ecological equilibrium with carbon sequestration.
- But biofuel LUC also delays conversion of current cropland *back* to natural vegetation.
- If it is “counted” without discounting, LUC term in GWI is about zero.



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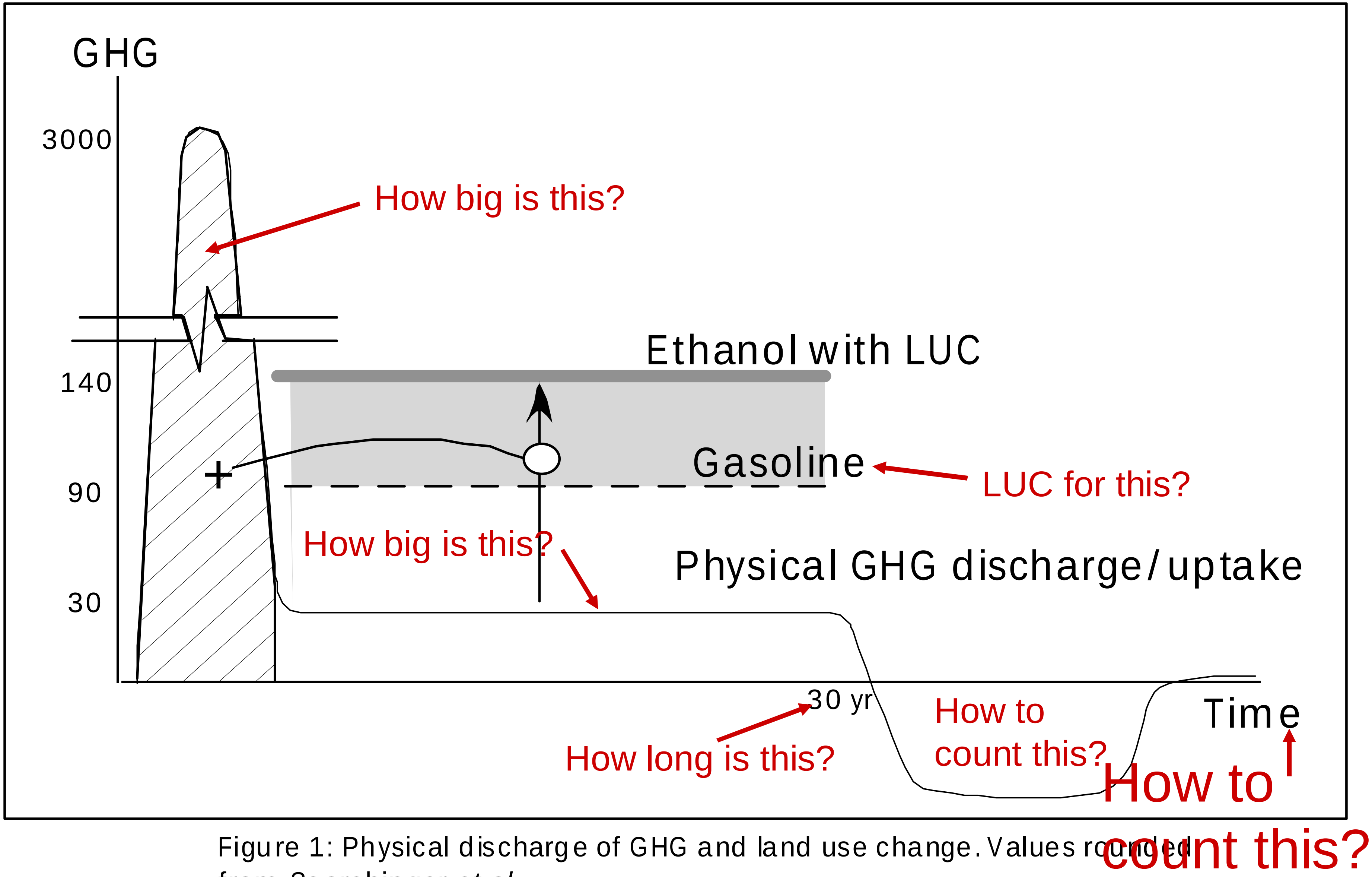
What production period applies?

- The longer biofuel production continues, the lower the unit “charge” for LUC GW.
- This period is conceptually terminated by new energy technologies, or major irreversible GW consequences.
- Current estimates indicate that production would have to be on the order of a century to bring many biofuels’ GWI below gasoline.



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What about time?

- Searchinger (and others) do not discount
- Discounting is a complicated issue:
  - Economic discounting of events involving goods traded in markets
  - “Derating” of physical phenomena
- *Any recognition of time value* increases currently estimated deficits of crop biofuels relative to fossil fuel.

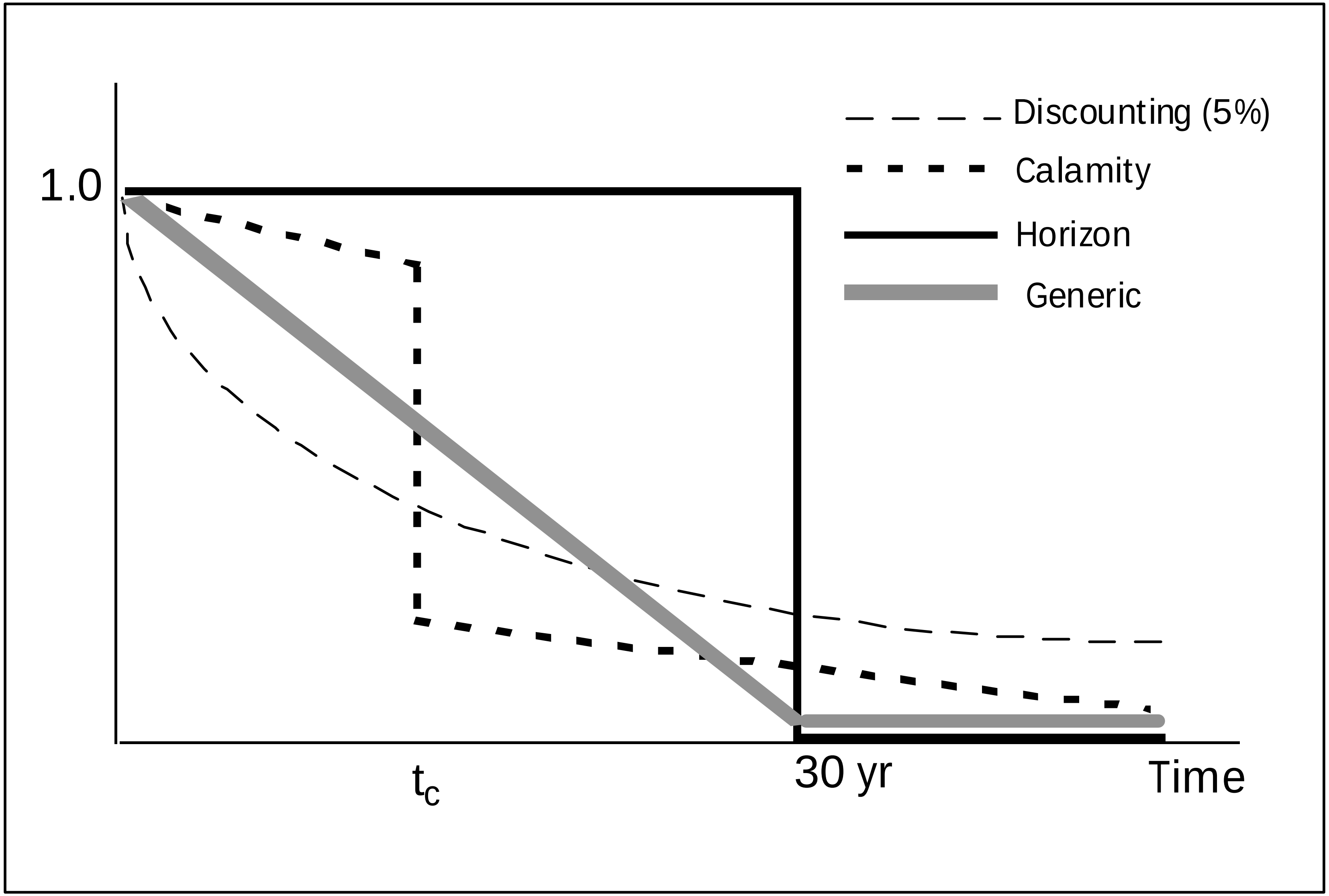


Figure 2: Possible social cost of physical GHG release functions. Conventional economic discounting is shown for comparison (see text)

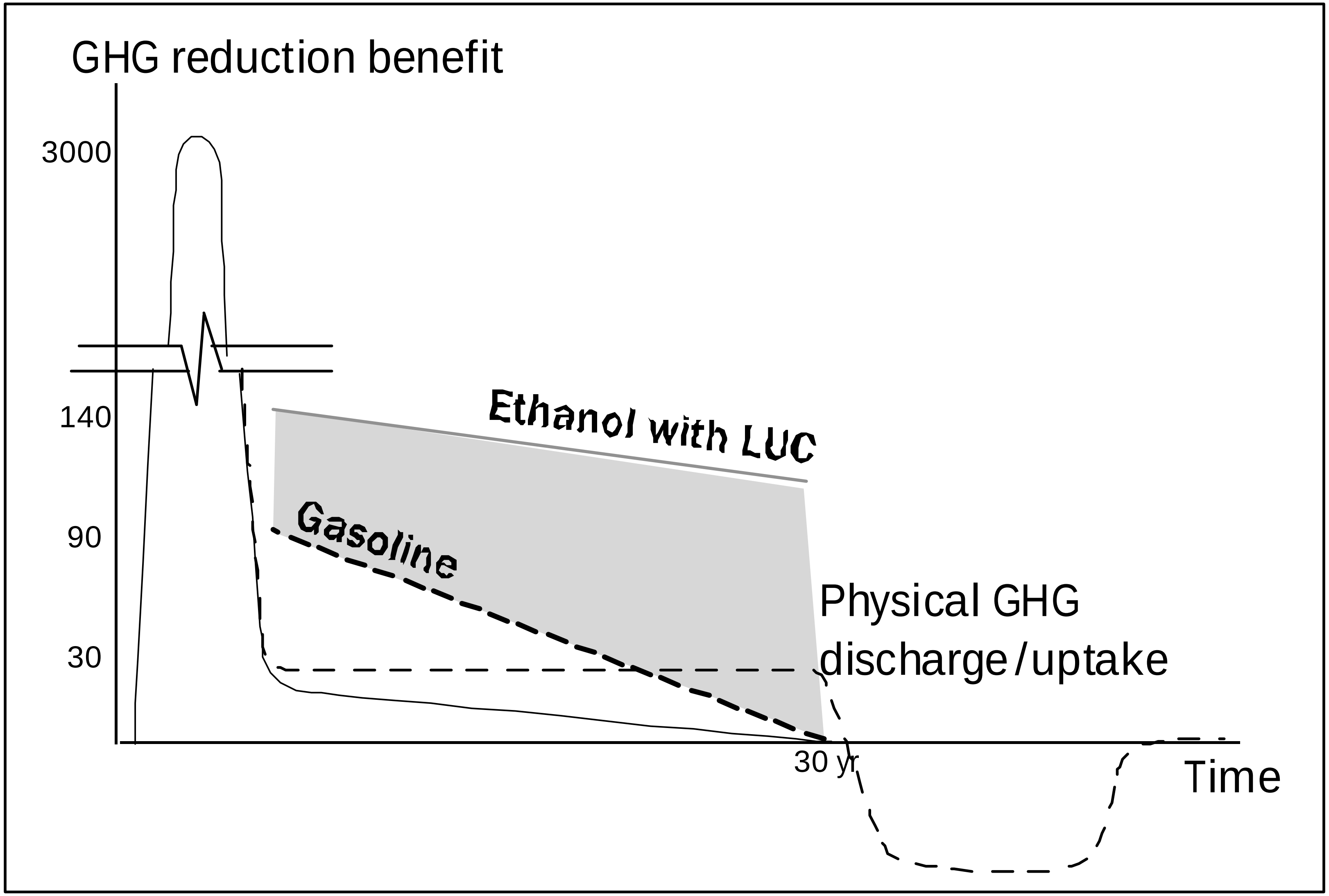


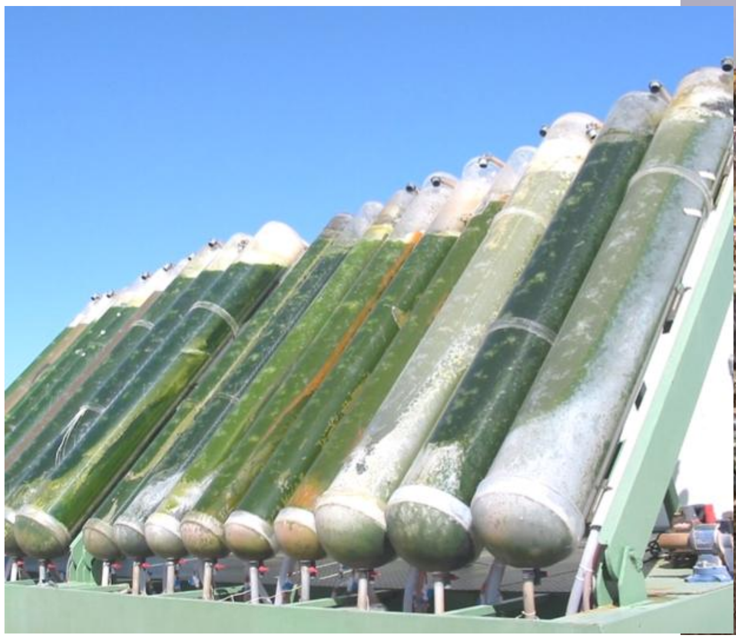
Figure 3: Social benefit of reducing physical discharge of GHG including land use changes, with derating according to the Generic function (see Figure 2). Values rounded from Searchinger *et al*.

Ethanol

- From maize
  - Conventional, rudimentary, close to gasoline cost
  - **Probably not RF**
- From cellulose crops
  - Waiting for technology
  - **May not be RF**
- From waste
  - Waiting for technology
  - **Probably RF**
- Usability issues

Advanced biofuel technologies will be needed to produce fuels without causing LUC

- Most biofuel feedstocks that do not cause LUC are cellulosic
- Other feedstocks are even more advanced



What's left?

- From waste: ~8% of gasoline
  - Enzymes to crack cellulose
  - Thermal gasification + microbes + membrane separation (eg, Coskata)
  - Mass burn
- Mixed perennials on waste land
- Cane, variousols
- Algae: too soon to tell, but very expensive now. Must be on desert (closed system) or open water.

Other considerations for crop biofuels

- Industrial monocrops
- Biodiversity, economic diversity
- Climate and blight/pest risk
- Capital intensive, low-wage labor
- Biofuel curse?

• Is the GHG intensity of a biofuel an RV with a PDF?

• What statistic should be used for its GHG index in a regulatory context?

• What does the cost-of-being-wrong function look like?