Biofuels and their Discontents

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Thanks!













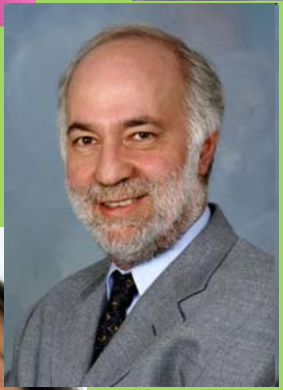



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The research presented here was partially supported by the California Air Resources Board and does not necessarily represent positions of ARB or the University of California.

Overview

- Policy context: EISA/LCFS/RTFO etc.
- GWI as an implementation tool
  GHG/MJ vs. warming vs. social cost: these are different
  ILUC and physical property measurement
- Lessons from decision theory:
  - Implementation GWI values are acts
  - Physical GWI, and system response, are states of the world
- The cost of error function for biofuels GWI

Asking the right question

- How can we enrich farmers, Monsanto, and ADM?
- How should we reduce the GW index of liquid transportation fuel?
- What's the best use of biomass for energy?
- What's the best use of biomass?
  - *What does* best *mean*?
- What's the best use of a hectare of land?

Policy context dictates the question, and the answers are not usually the same

Policy Context

- Agricultural subsidies and tariffs
- EISA/EPA, EC (statute)
  - **Volume** mandate
  - Biofuels in categories (advanced, etc.) on the basis of GWI
  - LUC in statute, may be overridden by climate bill
- California LCFS/ARB (exec. order)
  - **Average carbon intensity** limit
  - All fuels assigned a GWI
  - LUC included

LCFS has caused institutional learning

- Consequential life cycle assessment is not a simple matter, and may only be possible for a policy (eg, the LCFS with regulatory GWI values) and not for a substance (eg, corn ethanol)

- Climate policy in one jurisdiction has to be analyzed with attention to events in others

- There is no escape from economics

- There is no escape from science

- There is no scientific escape from policy judgment

GWI in the LCFS

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

$$AFCI_{jt} = G_p Q_p + G_b Q_b$$

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

p = petroleum, *b* = biofuel

P = price of credits (+/- sold or bought) (or fine)

Much of the current debate is about the operational definition of G_b

Operational Definition

The *operational definition* of a quantity or measurement includes the protocol by which it is observed.

*eg: the "height" of a building can be determined (**with different results for each**) by*

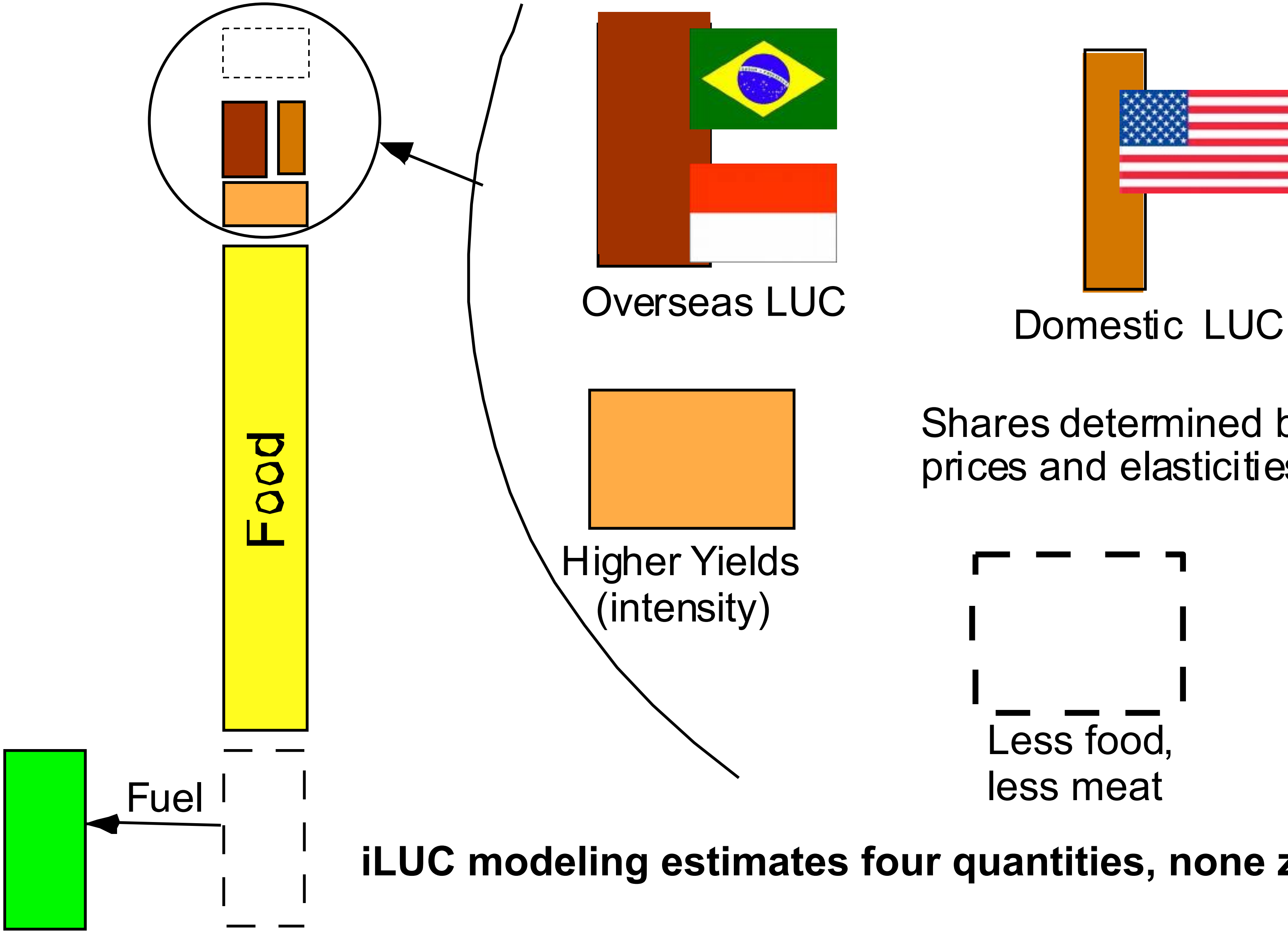
- *altimeter*
- *tape measure*
- *trigonometry*
- *dropping a clock from the top*

ILUC dominoes

- Biodiesel refiner outbids Kraft for soybean oil
- Kraft buys palm oil from Indonesia for Miracle-Whip
- Indonesian grower plants palm on cleared forest
- Indonesian logger clears more forest (on peat land?)

  - Ethanol refiner outbids ADM for corn (price increase)
  - Corn farmer shifts from soybeans to corn
  - Brazilian grower plants soybeans on pasture
  - Brazilian ranger moves cattle to cleared forest
  - Brazilian logger clears more forest

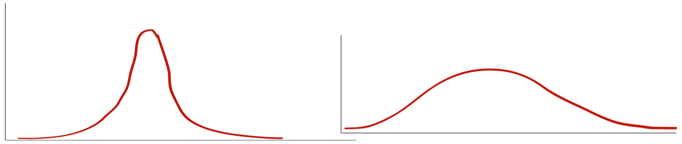
Price increases drive process



iLUC modeling estimates four quantities, none zero

ILUC in the LCFS

- 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:



$$AFCI_{jt} = G_p Q_p + \{G^d{}_b + iLUC\} Q_b$$

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

p = petroleum, *b* = biofuel

LCFS Example

Reduction required (Gasoline 96 ⟶ 86)	10%
Blend limit for ethanol	20%
GWI_b required	**45**

What is G_x?

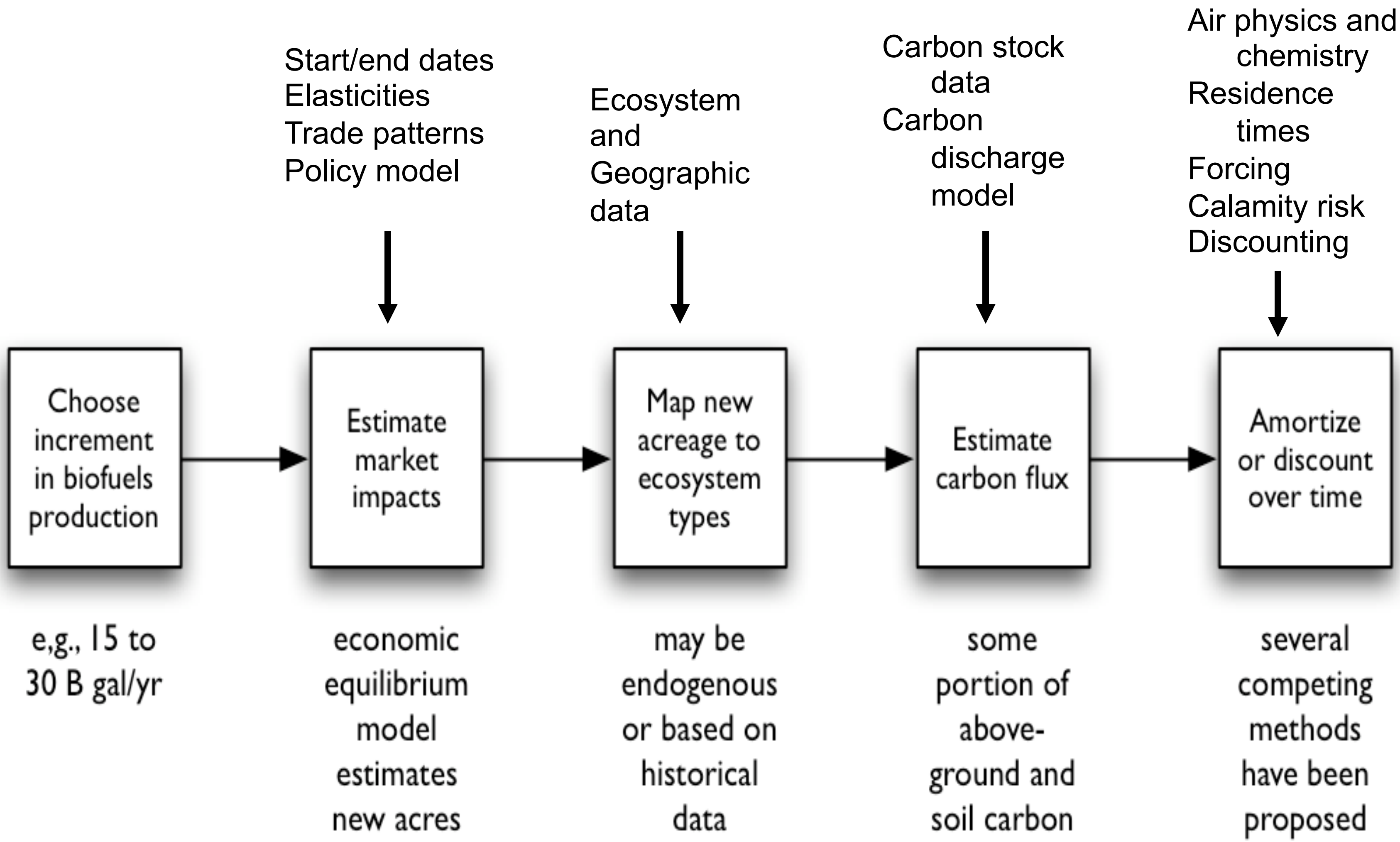
- Implicitly, the additional GHG released if *one MJ of fuel x is made and used and "nothing else" is different*

but

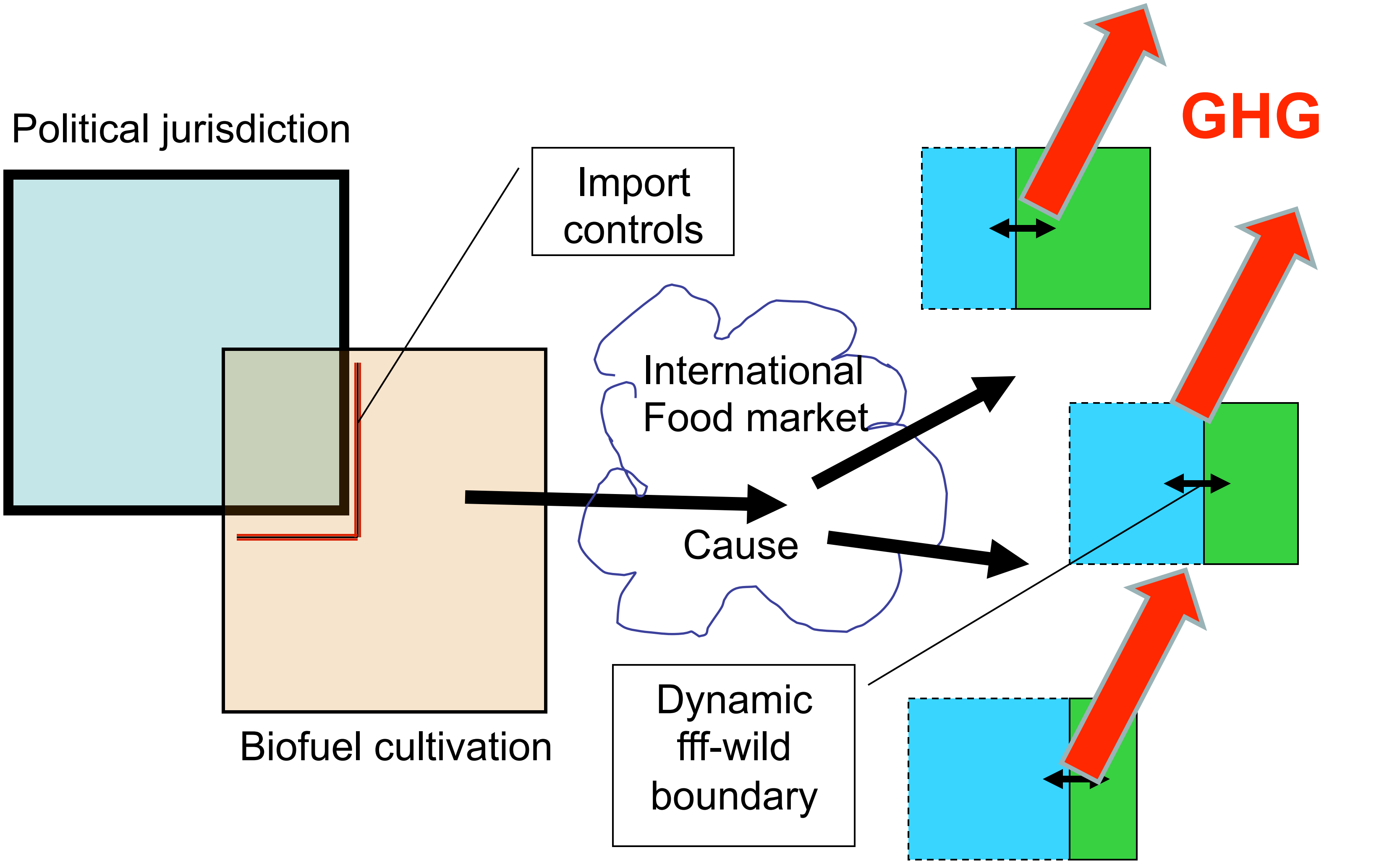
- This can never actually happen
- GHG is not the same as GW
- GW is not the same as social cost

A brief review of ILUC estimates

Note: “direct” emissions are also uncertain



CGE ILUC Model Process



What policies and practices *in producing and consuming jurisdictions* can reduce iLUC?

Almost nothing except yield.

US Corn Ethanol ILUC Estimates: 30 yr straight-line amortization

Study	Target year	Shock size (10^9 L)	ILUC factor (g CO_2e MJ^{-1})	Range (g CO_2e MJ^{-1})
Searchinger et al. 2008	2016	56	104	20 – 200[a]
Hertel et al. 2010	2001[b]	50	27	15 – 90[c]
Dumortier et al. 2009	2018/19	30	n/a	21 – 118[d]
USEPA 2010	2012	7.5	81	62 – 104[e]
	2017	14	58	43 – 76[e]
	2022	10	34	25 – 45[e]
Al-Riffai et al. 2010	2020[f]	0.47	36	36 – 53[g]
Tyner et al. 2010	2015[h]	13.4	14	14-22[i]

Mean = 51

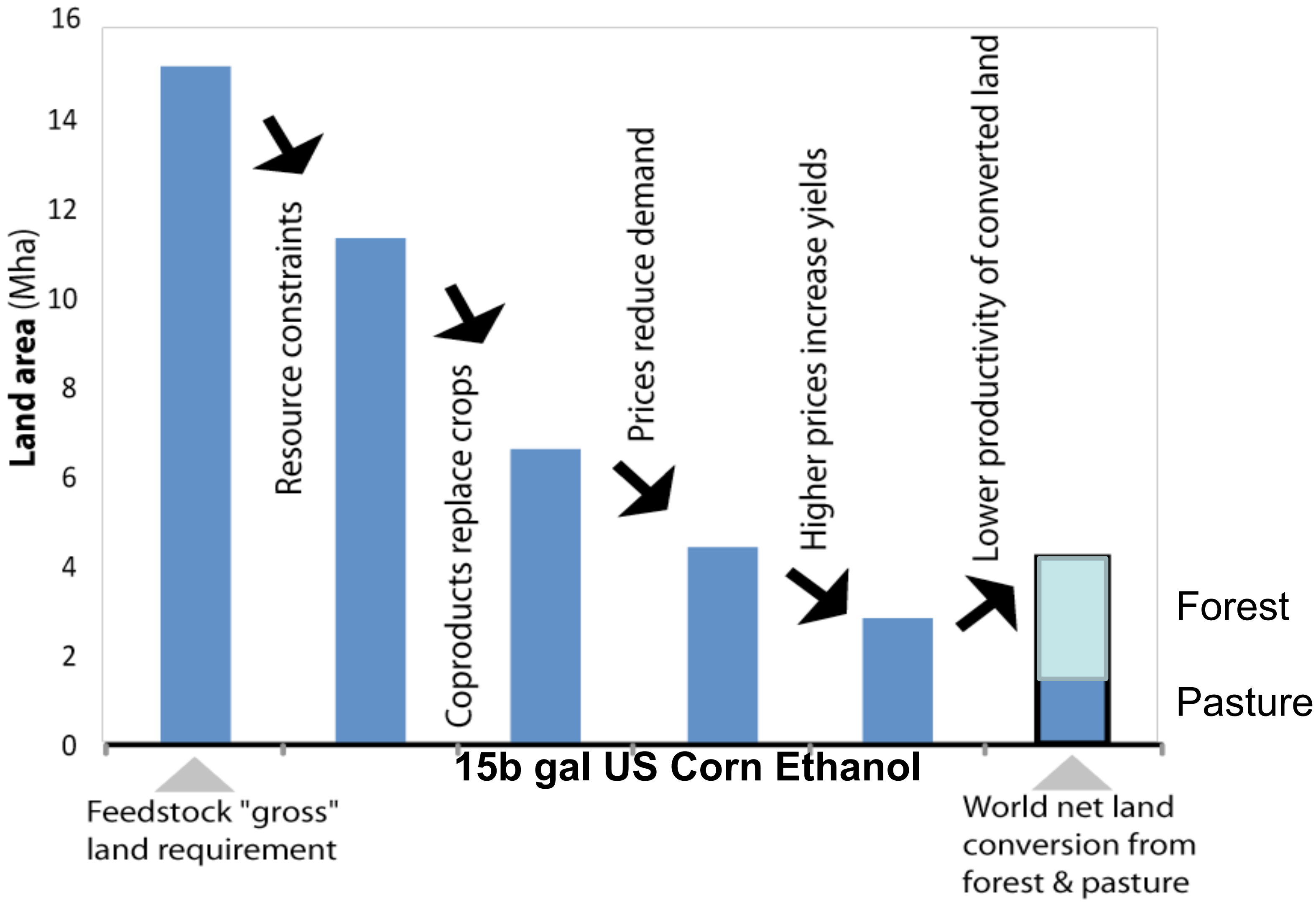
[a] Calculated from reported sensitivity results.
[b] Analysis was performed using the GTAP-6 database, based on 2001 data, but the results were adjusted *post facto* to account for the 10% greater average corn yield in 2010.
[c] Range is based on a combination of high and low values for various uncertain economic model parameters.
[d] Range is based on evaluating alternative model assumptions.
[e] Range is 95% CI around mean considering only the uncertainty in satellite data analysis and carbon accounting.
[f] Analysis was performed using the GTAP-7 database, based on 2004 data, using the model to project out to 2020.
[g] Effect of additional 10^6 GJ after meeting 5.6% mandate. Higher value is for greater trade liberalization.
[h] 2006 GTAP database, yield increases assumed
[i] Range is from different model assumptions only.

From Plevin et al 2010

How might these ILUC results be too high/low?

- Higher lower (climate change) yields of all crops
- Different allocations of "makeup" to different natural lands
- Better C stock & land use data
- Better coproduct accounting
- Counting C recapture after production
- Albedo changes (eg, snow on cleared temperate forest land)
- Nitrogen cycle (increase from fertilizer decrease from cattle)
- Time and warming effect
- Better modeling of forests and unmanaged land
- Other greenhouse gases (eg, cattle, rice methane)
- Production period
- More conversion from lower-C land types (pasture)
- Increased cattle intensity/better practice
- Higher/lower price elasticity of yields

Land use change is not 1:1 with feedstock land use



(from Hertel et al 2010)

Uncertainty

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From Plevin et al 2010

Lesson Ia

- There is no support for believing ILUC = 0

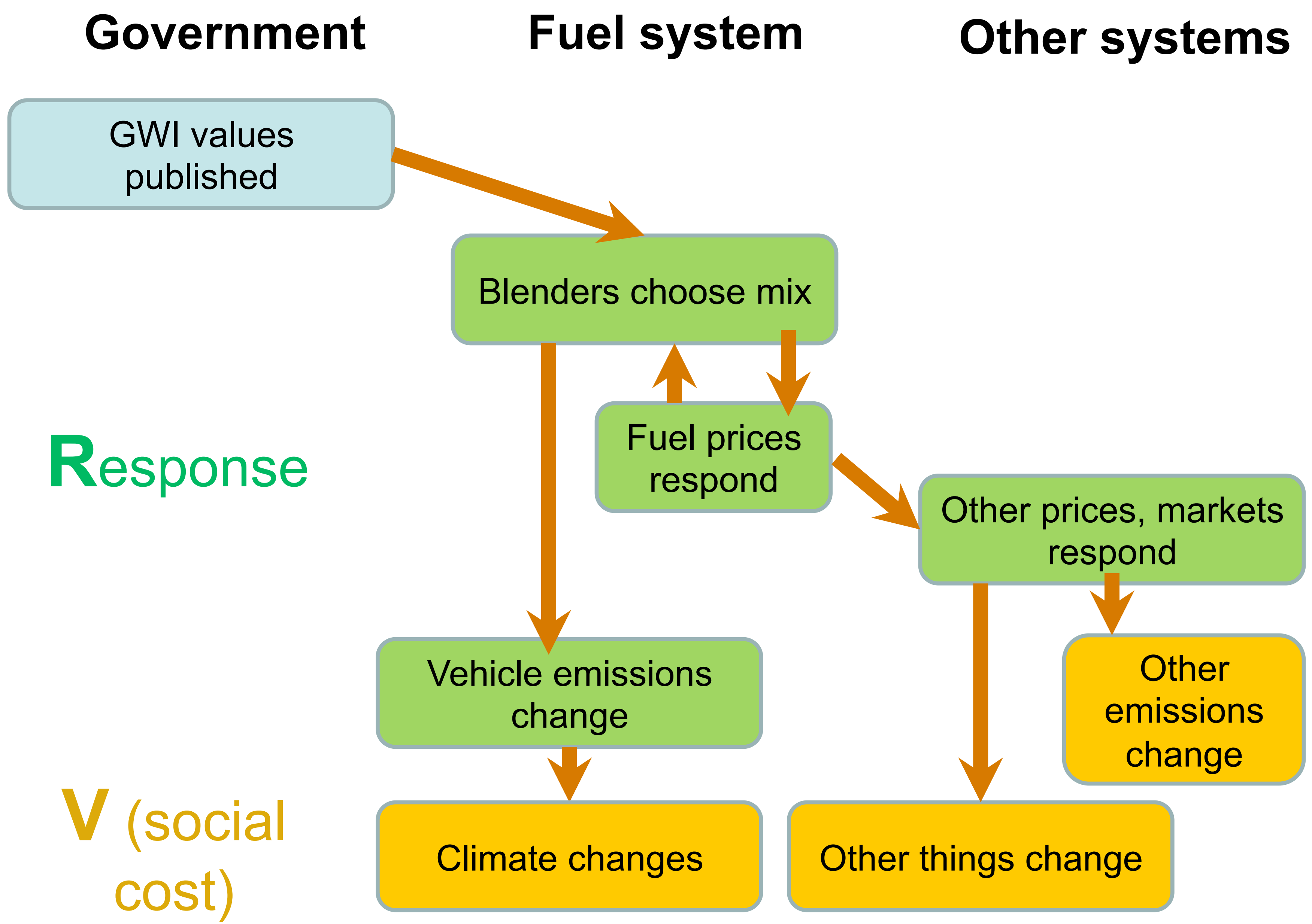
Lesson Ib

- ILUC will be uncertain for the foreseeable future; other indirect GW terms more so.

Regulation and observation

- The physical GWI of a fuel *i* (G^*_{i}) includes both lab-measurable, high-accuracy, high-precision terms and modeled, precision, high-variance terms (like ILUC)

- The administrative GWI (G_i) in a particular regulatory context is **not the same** as G^*_i


Government
Fuel system
Other systems
GWI values published
Blenders choose mix
Fuel prices respond
Other prices, markets respond
Response
Vehicle emissions change
Other emissions change
V (social cost)
Climate changes
Other things change

Decision Theory

- Act: 'Implement' a vector of values $\{G_i\}$ for fuels *i*, that blenders will respond to.

What LCFS doesn't recognize:

- State of world: $[\{G^*_i\}, R\{G_i\}]$, where
  - G^* is actual value,
  - ***R*** is response of system.
- Max $E(V(\{G_i\}, [\{G^*_i\}, R\{G_i\}]))$, where
  - ***V*** is net benefit
  - G^*, R have probability distributions

Decision Theory

- Act: 'Implement' a vector of values $\{G_i\}$ for fuels *i*,
  that blenders will respond to.

What policy doesn't recognize (yet?):

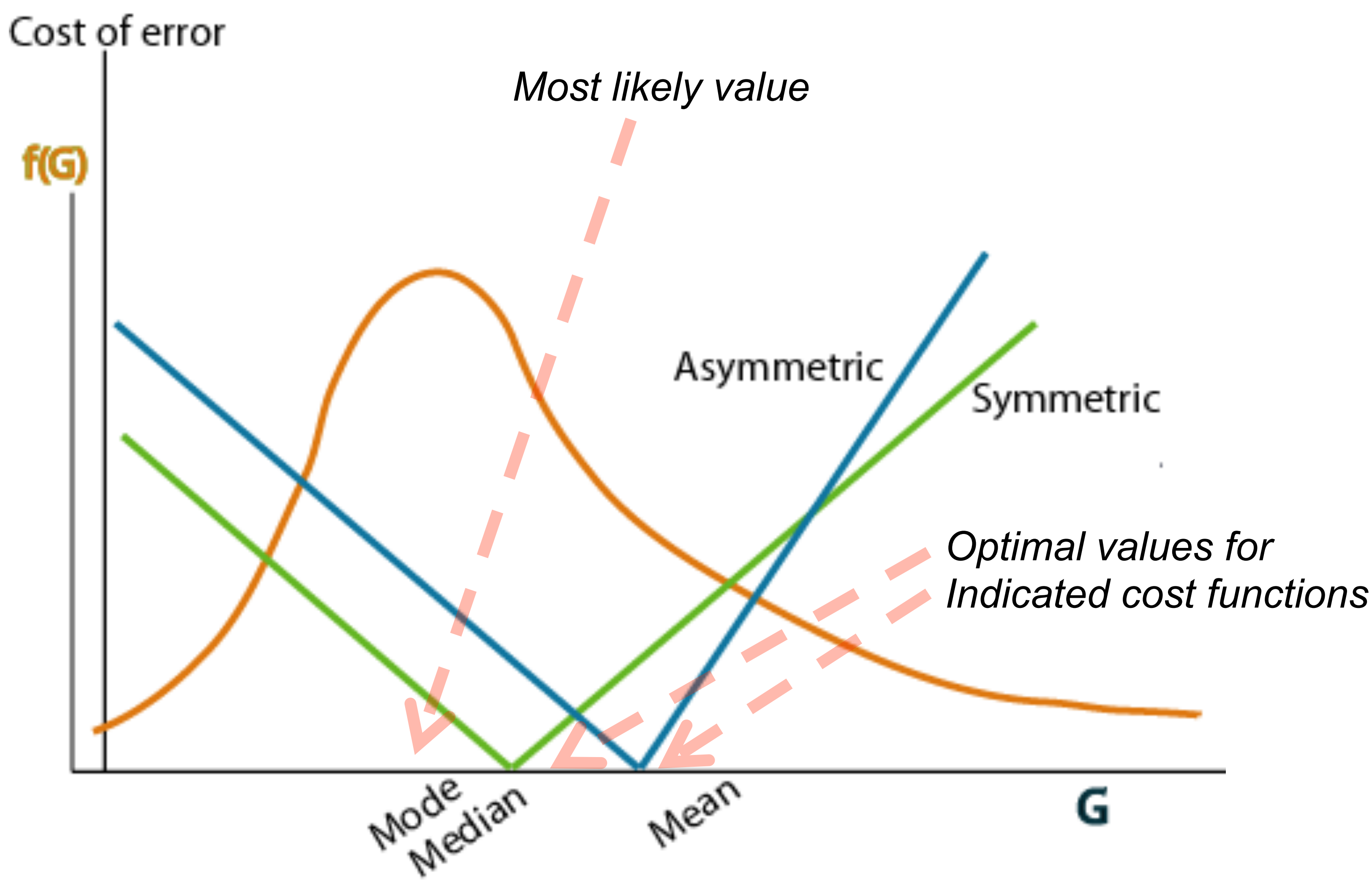
- State of world: $[\{G^*_i\}, R\{G_i\}]$, where
  - G^* is actual value,
  - R is response of system.
- Max $E(V(\{G_i\}, [\{G^*_i\}, R\{G_i\}]))$, where
  - V is net benefit
  - G^*, R have probability distributions

V , R
What should policy maximize?
What kind of cost matters?
What is the cost of being "wrong" about G^*_i in each direction?

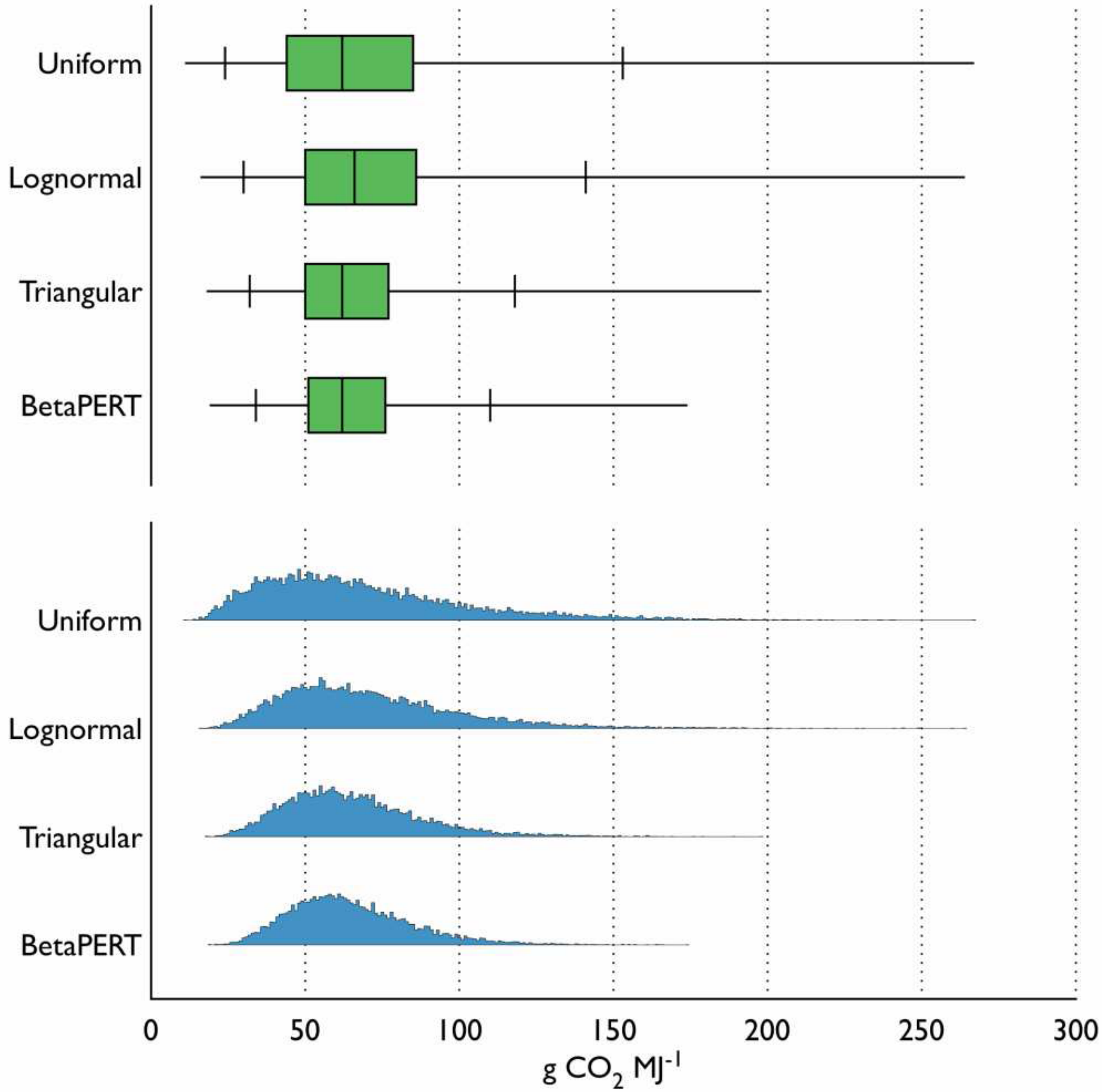
E
How should policy recognize uncertainty?

Key decision questions

- Are high values of G_i^* more likely than small ones (long right tail)?
- Is it worse to overestimate G_i^* by 10 g than to underestimate it?
  - Irreversible ILUC releases
  - Biodiversity
  - Future biofuel infrastructure development
  - Undercut advantage for greener [bio]fuels
  - Etc.

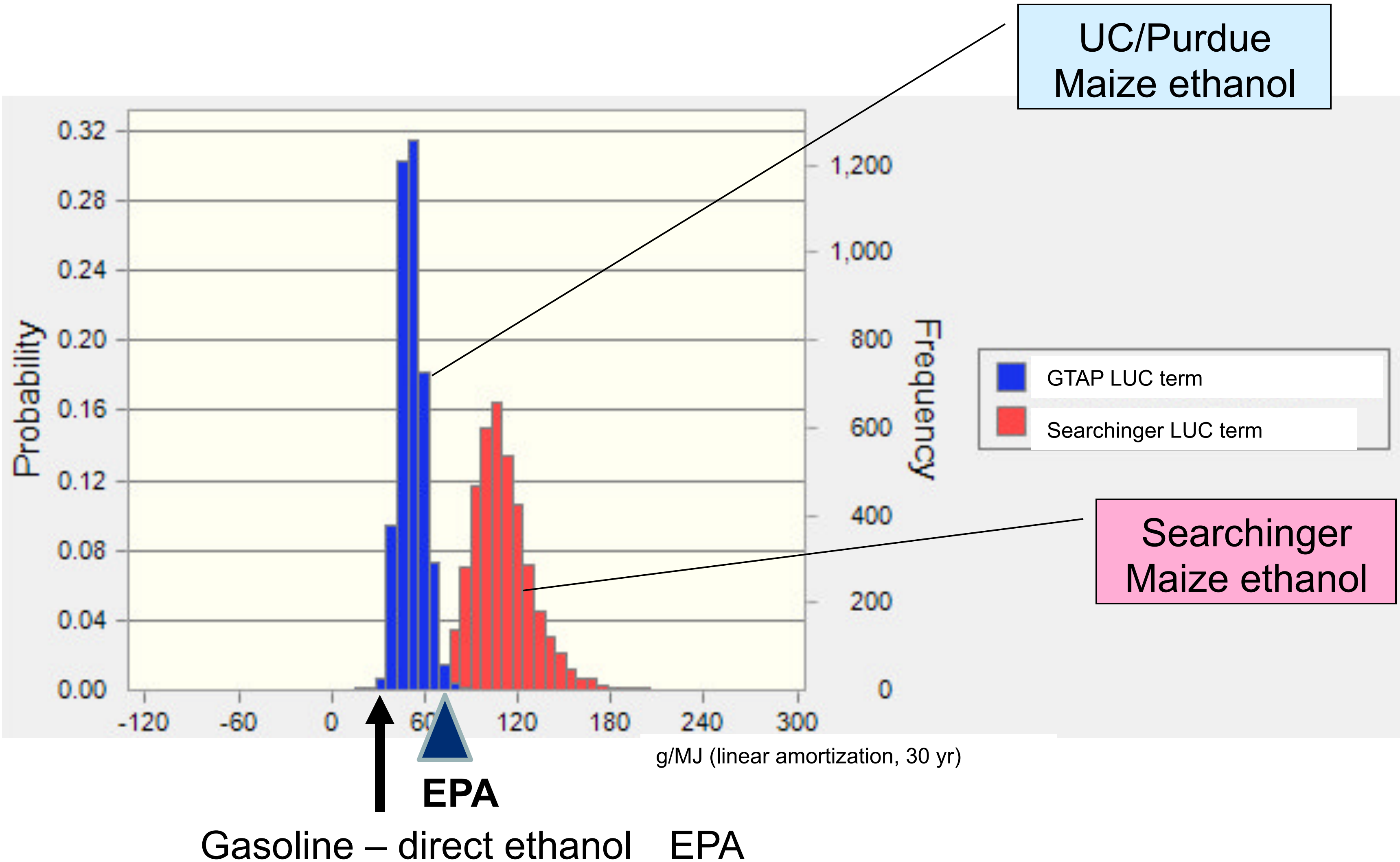


Cost of error
Most likely value
f(G)
Asymmetric
Symmetric
Optimal values for
Indicated cost functions
Mode
Median
Mean
G



From Plevin et al 2010

Model Uncertainty and Parameter Uncertainty



Theory-practice gaps

- No unitary decisionmaker, varying data reference sets, so conflicting pdf's
- *V* function varies across experts, stakeholders: politics
- *V* has not been sufficiently studied
- Three grounds of legitimacy:
  – Process
  – Scientific
  – Political

What action should be optimized?

(1) "Best" estimate of GWI for a pathway, assuming 1:1 substitution of fuels.

(2) "Best" value to use in regulation, assuming the world's most likely reaction to it .

These are not necessarily the same number, no matter what "best" means. Maximize:

$$O = E\left\lfloor V\left(\left\{G_i\right\},\left\{G*_i\right\},R\{G_i\}\right)\right\rfloor$$

Other regulatory practice accommodates uncertainty and distinctive cost-of-error functions

- Food and drug
- Structural and civil engineering
- Traffic safety
- Banking and finance
- Etc

Not all offer good examples, but all illustrate options to adapt.

Heuristics

- Let individuals choose, with information
- Choose on the "safe side" (~safety factor) considering shape of *V*
- Minimax loss or similar rule
- Choose central estimator and let the chips fall where they may
- Robust policy (choices insensitive to variation) such as "no seed-based biofuel".

Key issues

- PDF of G* is asymmetric, with long right tail (Plevin et al)
- *V* may be
  - symmetric: same cost for “too much GHG” from over- or underuse of biofuel
  - Asymmetric: irreversible effects only on one side, etc.
  - Non-linear

Lesson II

- Even assuming GHG discharge minimization is the objective, optimal G_i (policy implementation) requires attention to the shape of the distribution of G^*_i and to the cost of being wrong.

Actually, we don't even care about GHG *per se* (perhaps for ocean acidification) but about warming; what does that say about *V*?

Considerations for the cost of error

- ILUC discharges are irreversible on a scale of decades, no matter how short a period of biofuel production causes them.
- An ungreen biofuel economy now may develop infrastructure for the green “advanced” biofuel (algae, cellulosic) economy of the future
- Other dimensions of social cost (employment, biodiversity, water, etc.) should be included? (A climate policy is not a Christmas Tree for every good cause)
- If a narrow view is taken -- climate effects only -- should rebound (“indirect petroleum use change”) be counted?

Time and discharge profiles

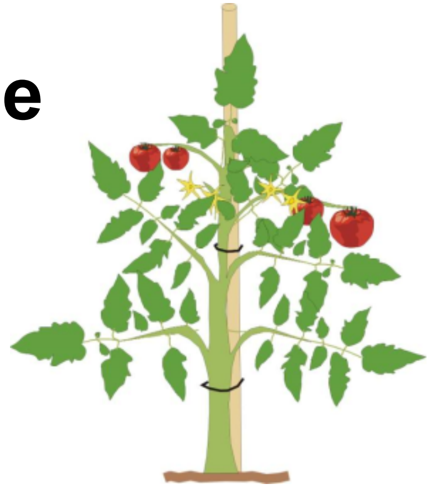
Time issues

- Realistic production period
  - For each fuel
  - Until substitutes are more attractive in the market
- If we calculate cumulative warming, not just emissions,*recognizing when discharge occurs,* summing GHG discharges for each fuel is misleading.
- Distinguish afforestation (slow) from deforestation (fast) discharges/recharges
- Discount economic quantities, not physical ones

Discounting

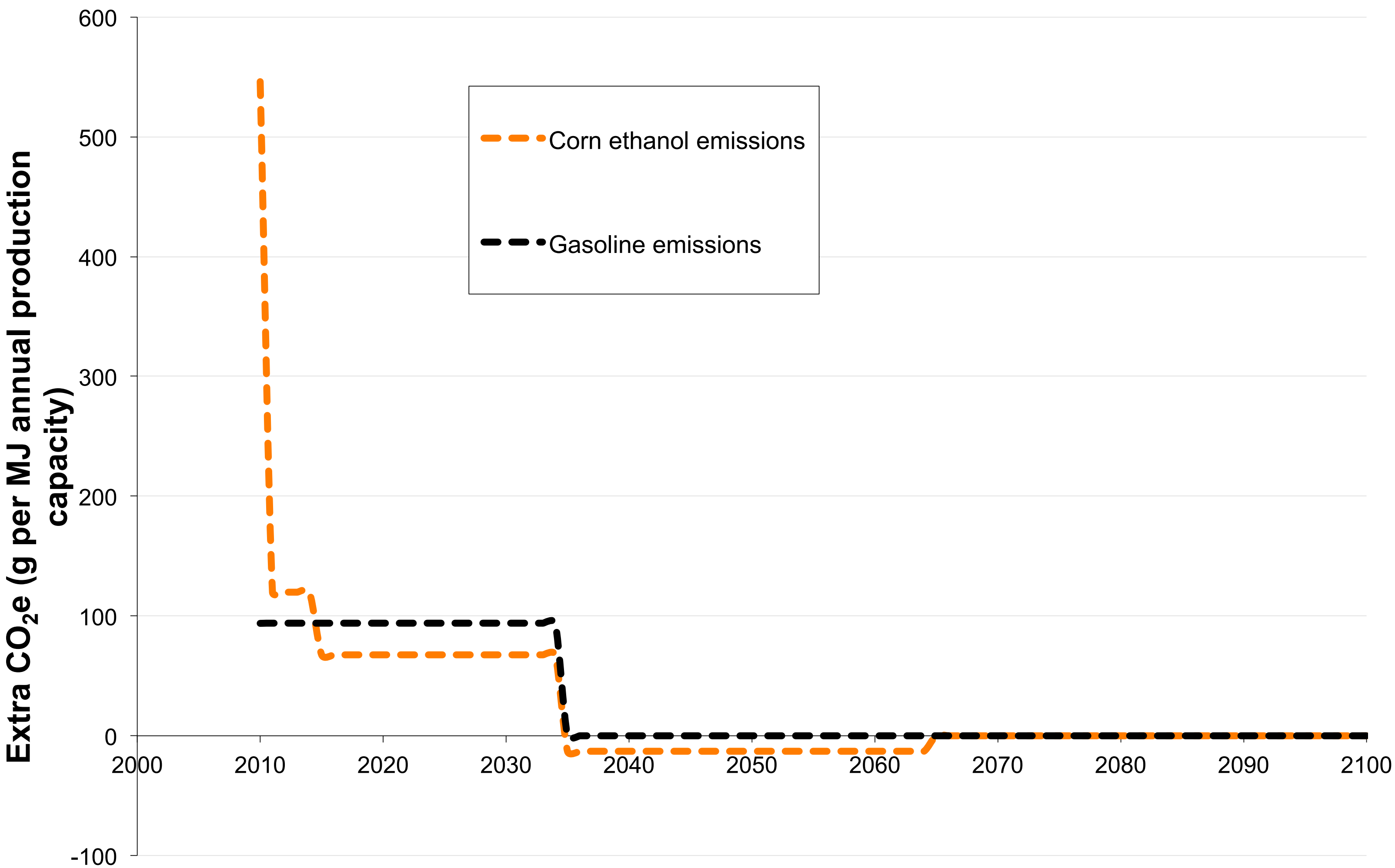
What is the “present quantity” in January of a bucket of water for use in…

June



January

Corn ethanol: 25 yrs production, 60g direct emissions, 776 g LUC, 30 yrs recovery of 50% of LUC



http://rael.berkeley.edu/BTIME

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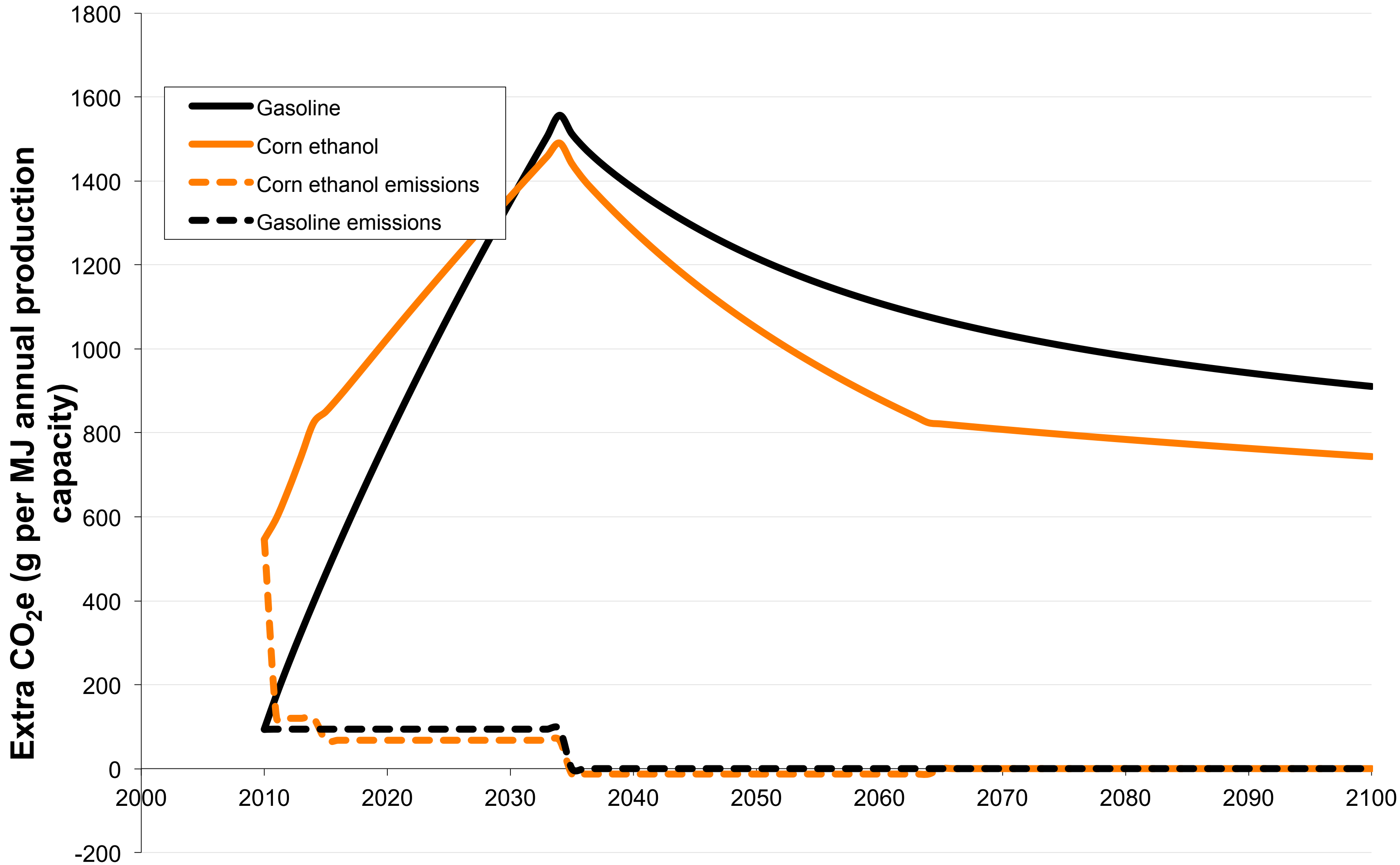

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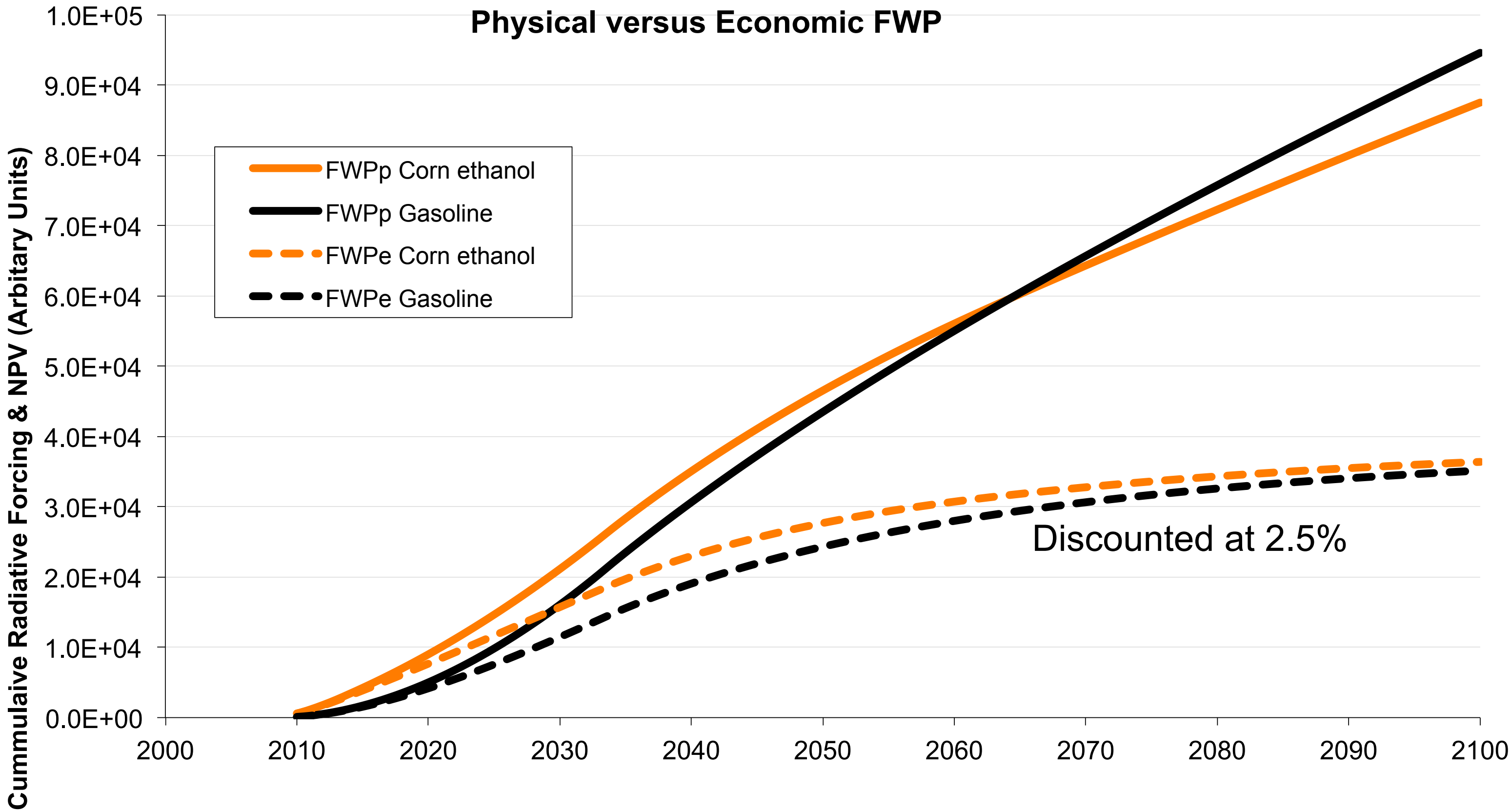
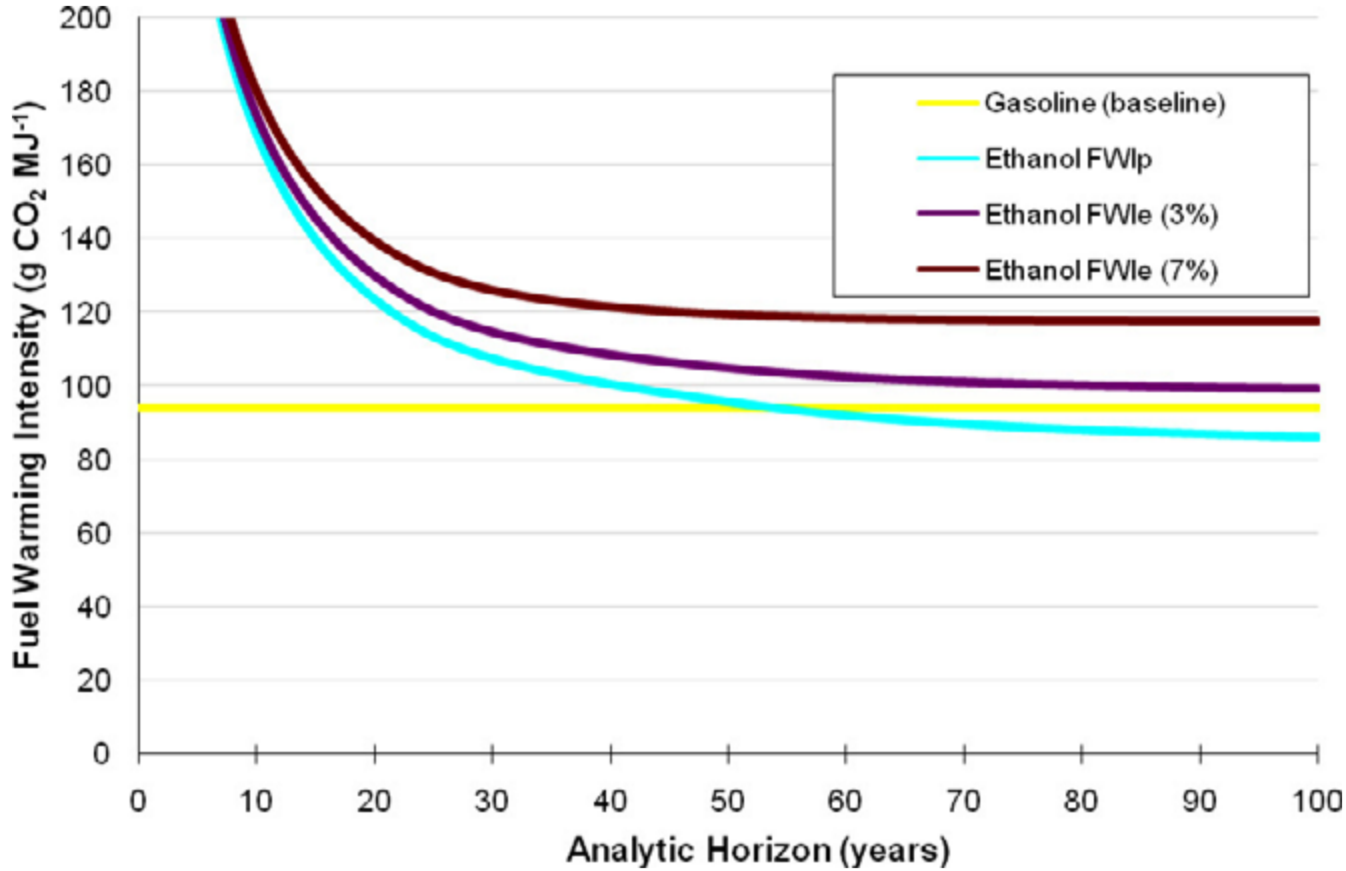


FWP(t) is total warming up to time t



Fuel Warming Intensity (g CO_2 MJ^{-1})
200
180
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
Analytic Horizon (years)
Gasoline (baseline)
Ethanol FWIp
Ethanol FWIe (3%)
Ethanol FWIe (7%)

Lesson III

- If fuel policy is about global warming, GWI values must recognize discharge time profiles and incorporate at least a discount rate.

Food effects

Nutrition consequences

- UC/Purdue/GTAP 2010: With food constant, ILUC is 50% higher for corn alone
- Effects will not be uniform across populations, nor from different fuels

Emerging issues

Should LCA look to the past or the future?

- Consider a kg of hydrocarbon. If it's burned for fuel, its C goes into the air. If not, it will sit underground indefinitely. What is its GWI?

Does it matter whether it is biogenic or fossil originally?

Source only matters if future has a causal link back to creation.

Enforcement

- ILUC discharges occur in places with generally adequate environmental laws but
  - Underfunded enforcement
  - High corruption indices
  - Inadequate ownership/registration systems
- 80-90% of new cropland in the tropics between 1980-2000 came from forest

ILUC is bigger than biofuels

- Technologies with large initial discharges (eg, nuclear)
- Land uses competing with food
  - Highways
  - Suburban housing
  - Parks
  - Meat

Summary

- Regulatory optimal value is probably not the same as scientific "most likely" estimate
- GHG discharge total is not the same as warming or social cost
  - Time profiles matter
  - Reversibility matters
- Uncertainty in estimates is refractory
- Policy regularly accommodates uncertainty
- Land use change and the effects of time are more general than biofuels

Your thoughts?