Biofuels Policymaking for Refractory Uncertainty

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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 is not just about GW

- **WHEREAS** California's dependence on a single type of transportation fuel whose price is highly volatile imperils our economic security, endangers our jobs, and jeopardizes our industries; and

- **WHEREAS** diversification of the sources of transportation fuel will help protect our jobs and economy from the consequences of oil price shocks; and

- **WHEREAS** alternative fuels can provide economic development opportunities and reduce emissions of greenhouse gases, criteria pollutants, and toxic air contaminants.

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:

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

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

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

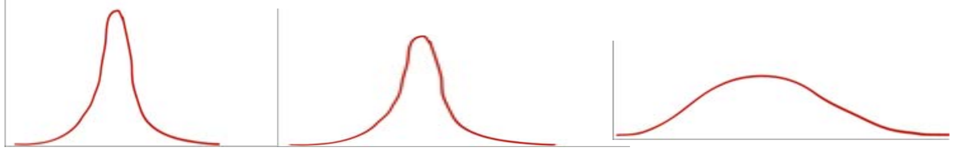
The *operational definition* of a quantity or measurement includes the protocol by which it is observed.

*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 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:



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

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

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

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

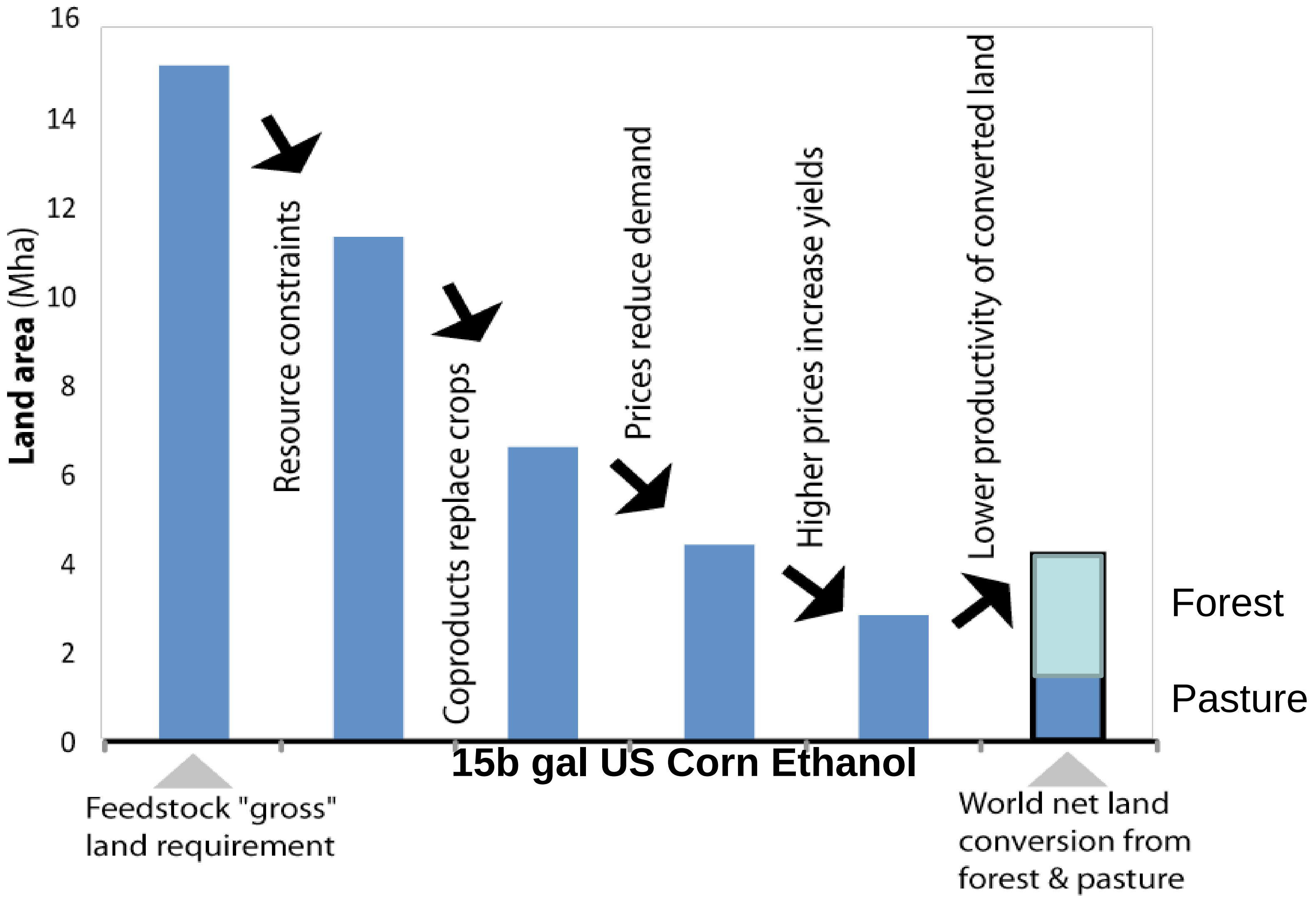
[a] Calculated from reported sensitivity results.
[b] Analysis was performed using the GTAP-6 database, based on 2001 data, but the results were adjusted *post facto* to account for the 10% greater average corn yield in 2010.
[c] Range is based on a combination of high and low values for various uncertain 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

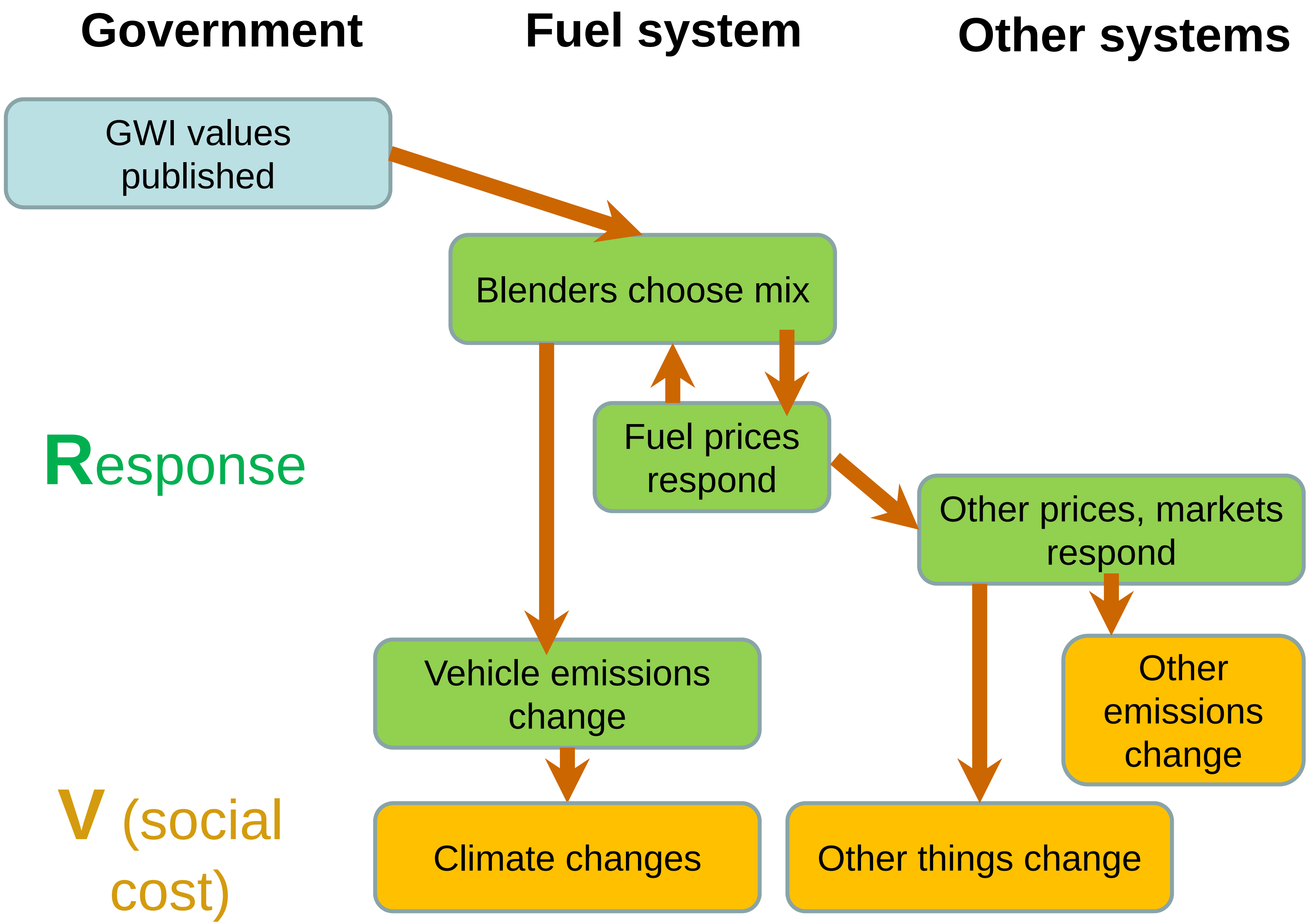
Lesson Ib

- 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, low-accuracy, 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?):

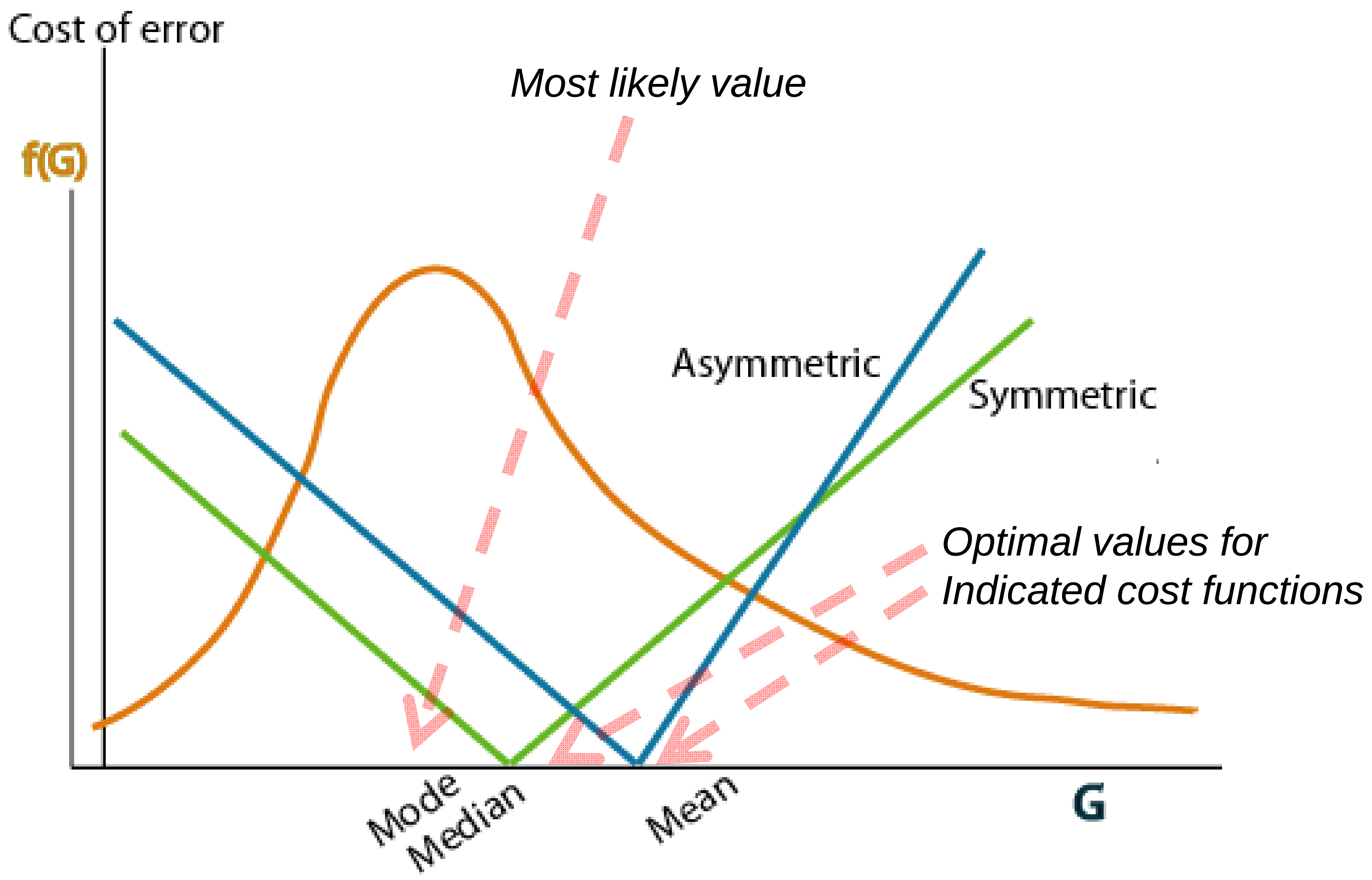
- State of world: $[\{G^*_i\}, R\{G_i\}]$, where
  - G^* is actual value,
  - R is response of system.
- Max $E(V(\{G_i\}, [\{G^*_i\}, R\{G_i\}]))$, where
  - V is net benefit
  - G^*, R have probability distributions

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

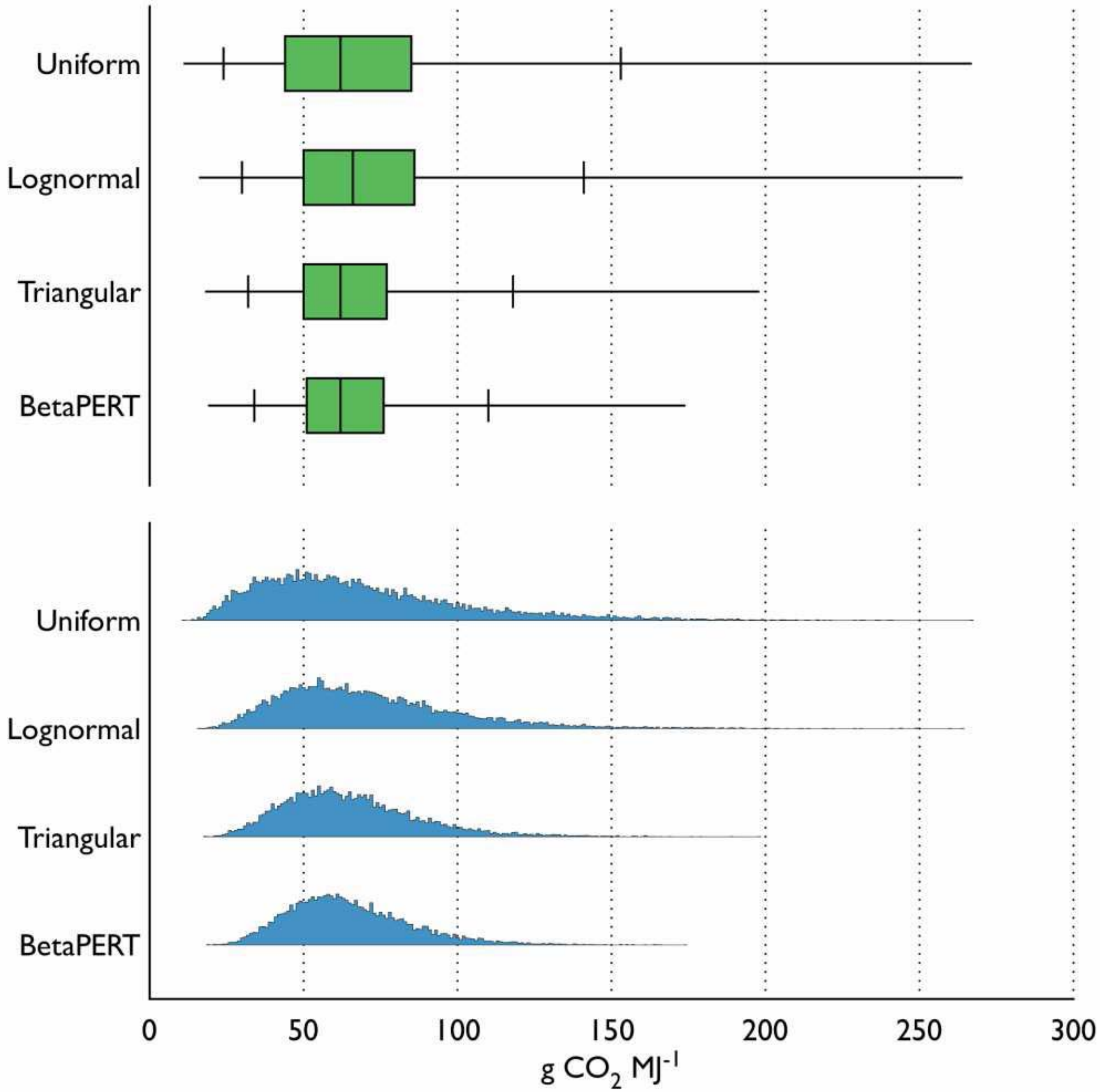
E
How should policy recognize uncertainty?

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.

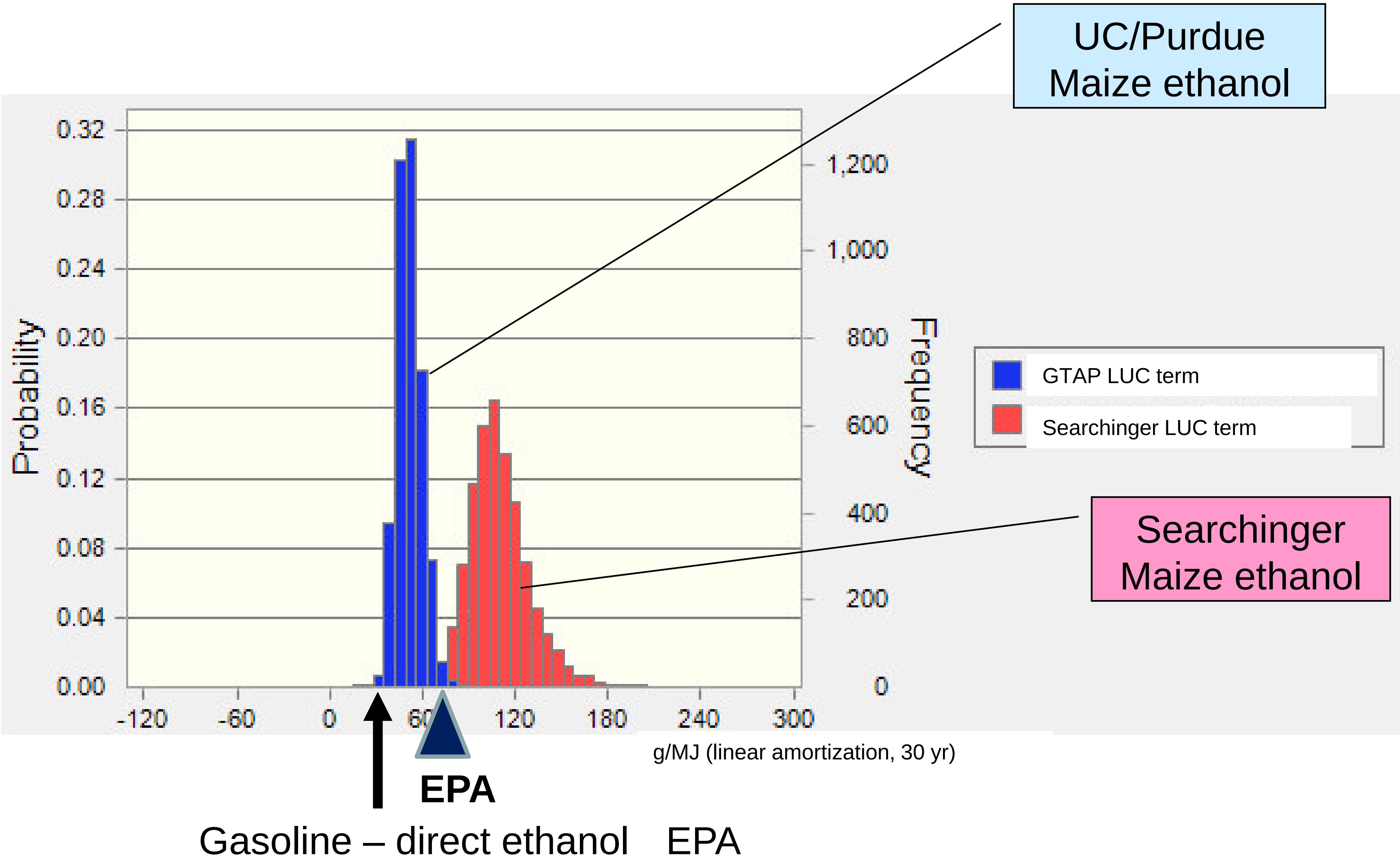


Cost of error
Most likely value
f(G)
Asymmetric
Symmetric
Optimal values for
Indicated cost functions
Mode
Median
Mean
G



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:

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

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

(see O’Hare et al 2010)

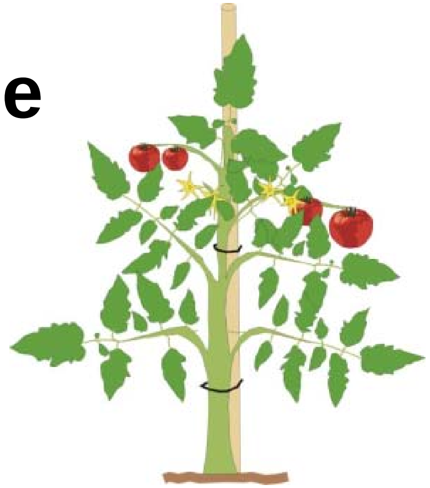
Time issues

- 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

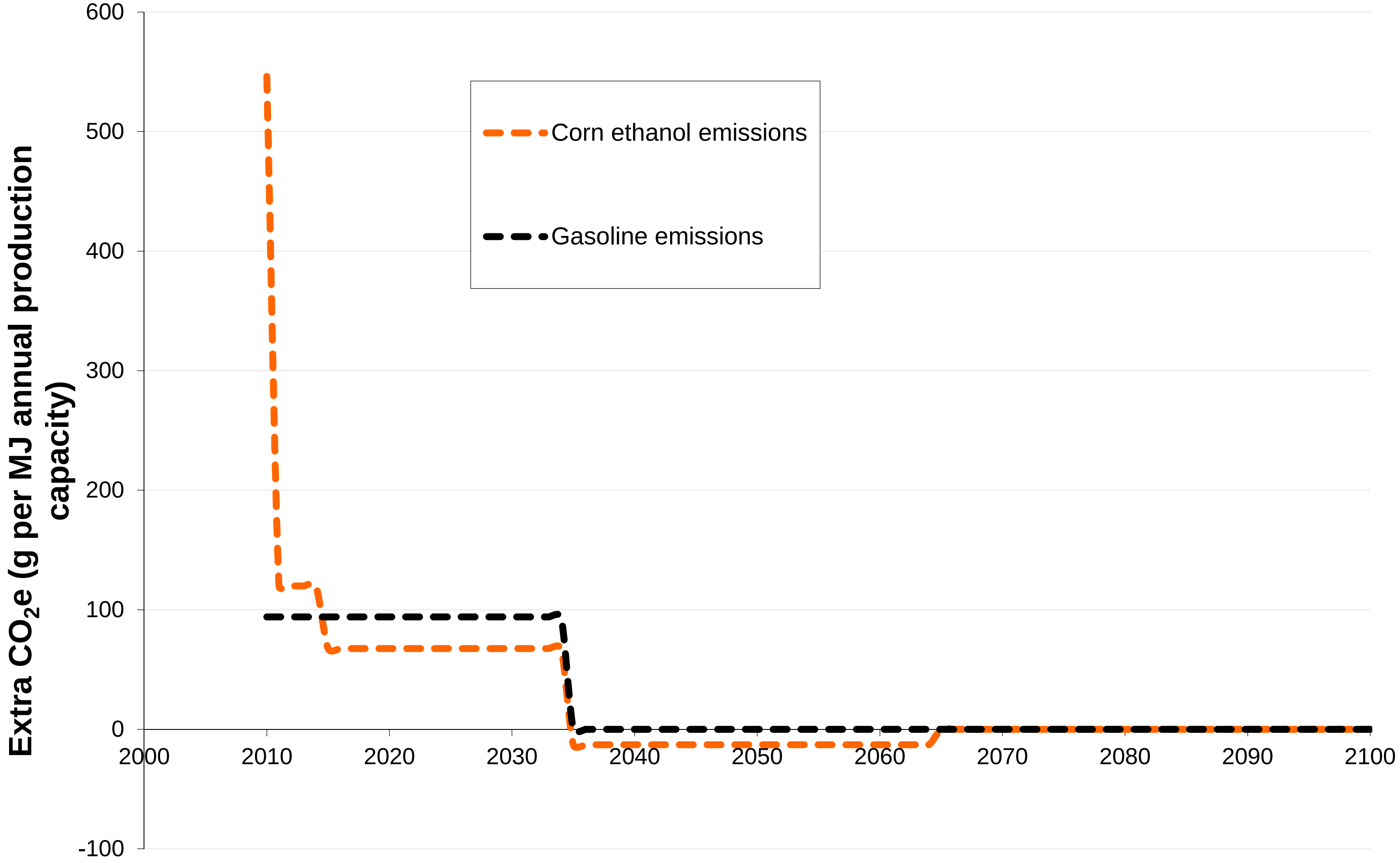
What is the “present quantity”
in January of a bucket of
water for use in…

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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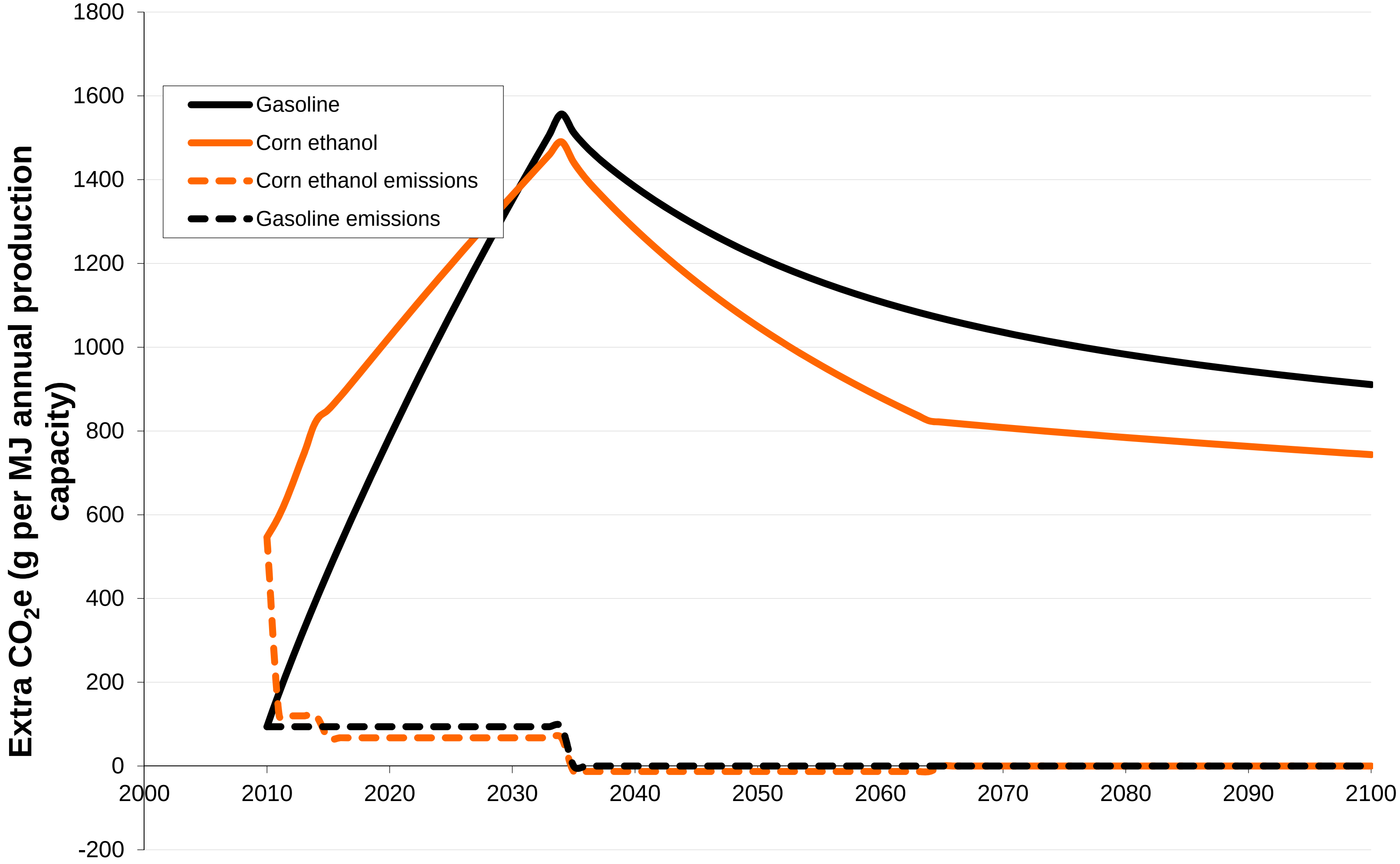

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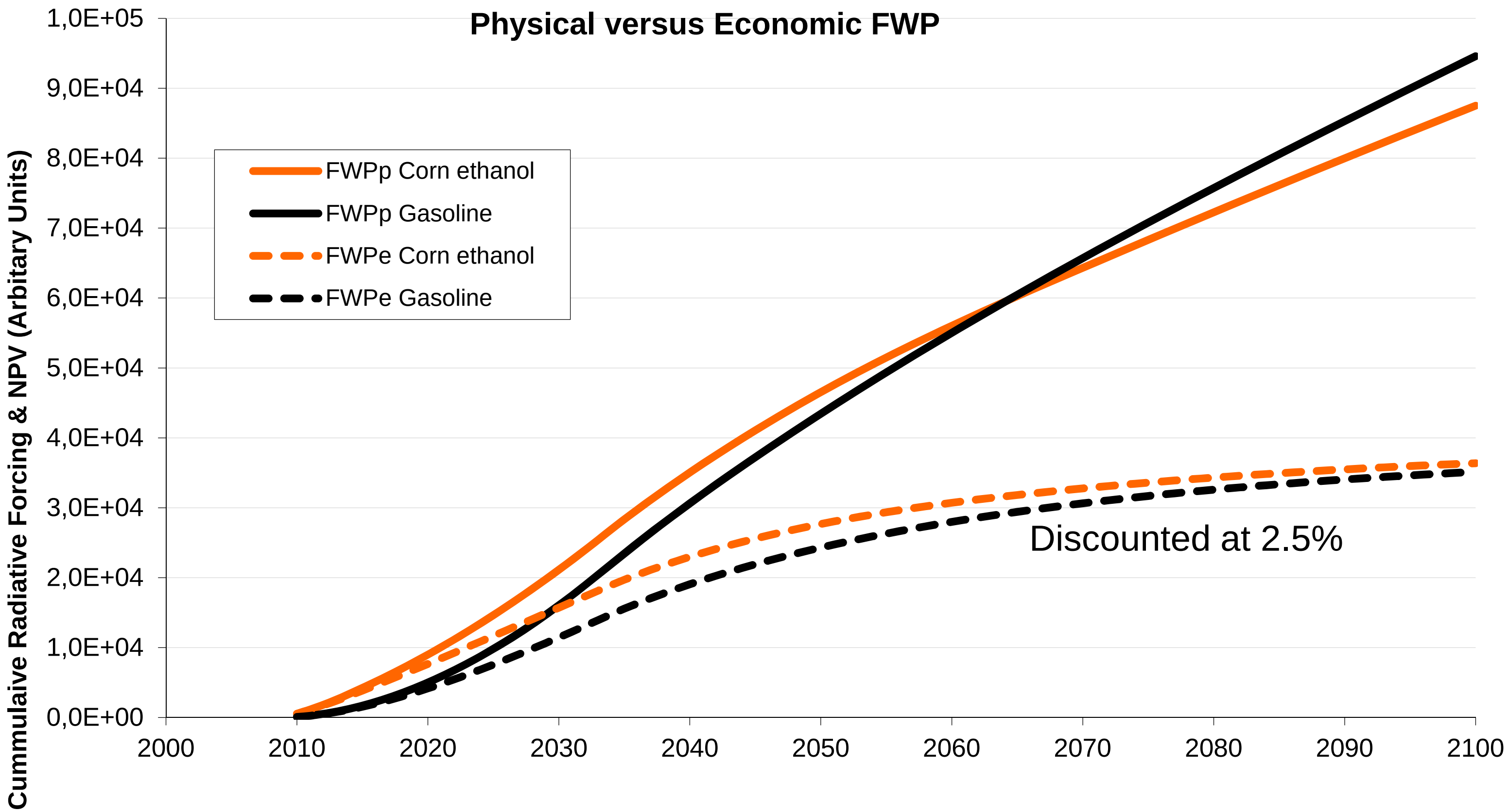
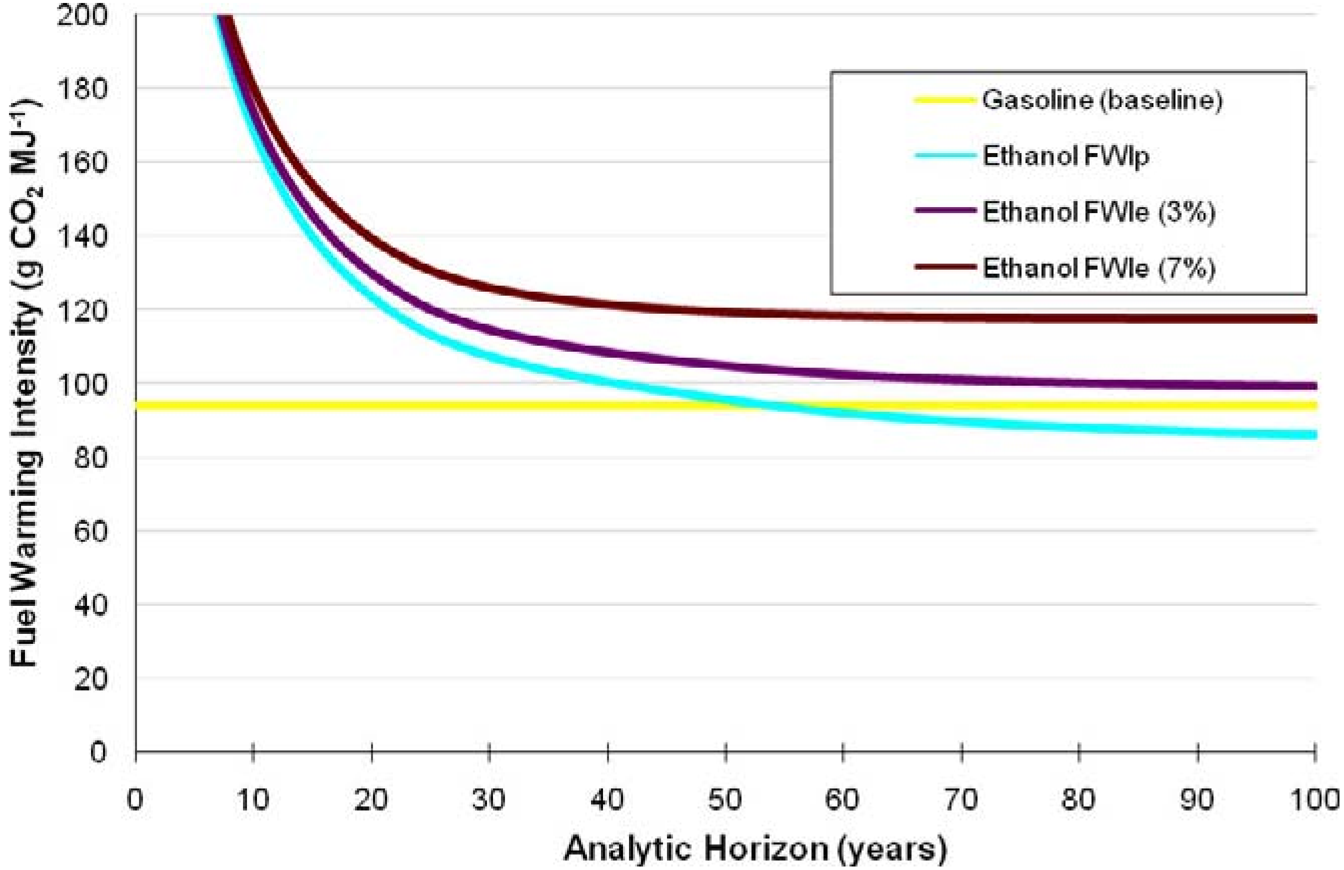


FWP(t) is total warming up to time t


Fuel Warming Intensity (g CO2 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%)

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

References

O’Hare, M. , R.J. Plevin, J.I. Martin, A.D. Jones, A. Kendall, E. Hopson, “Proper accounting for time increases crop-based biofuels’ greenhouse gas deficit versus petroleum”. *Env. Res. Lett.* 4 (2009)

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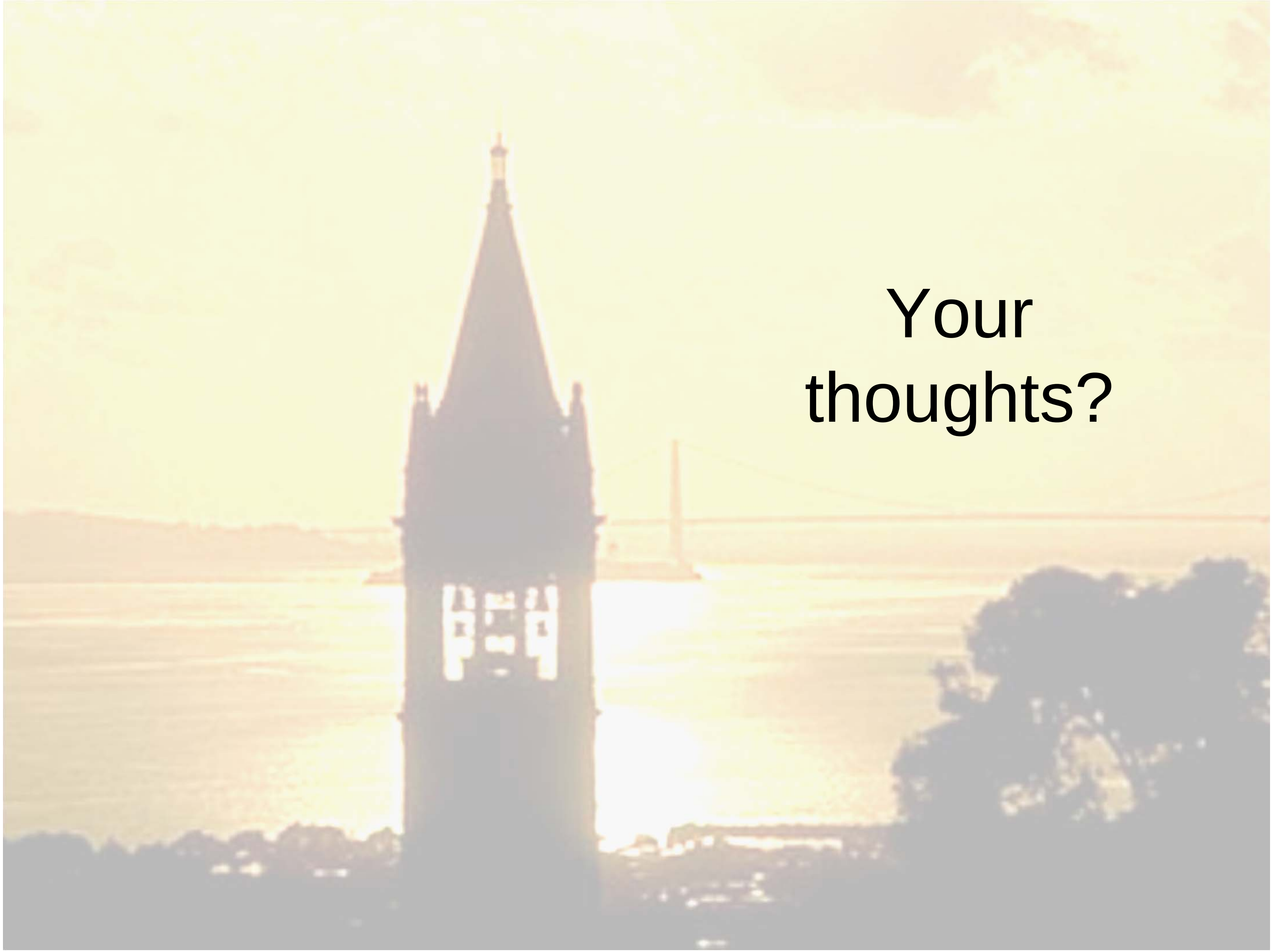
Your
thoughts?