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Making Policy in the Absence of Certainty:

Risk-Aware Consideration of Indirect Land Use Change (ILUC) Estimates for Biofuels

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Colin Murphy Ph.D
Deputy Director – UC Davis Policy Institute for Energy, Environment, and the Economy
Co-Lead – UC Davis Low Carbon Fuel Policy Research Initiative

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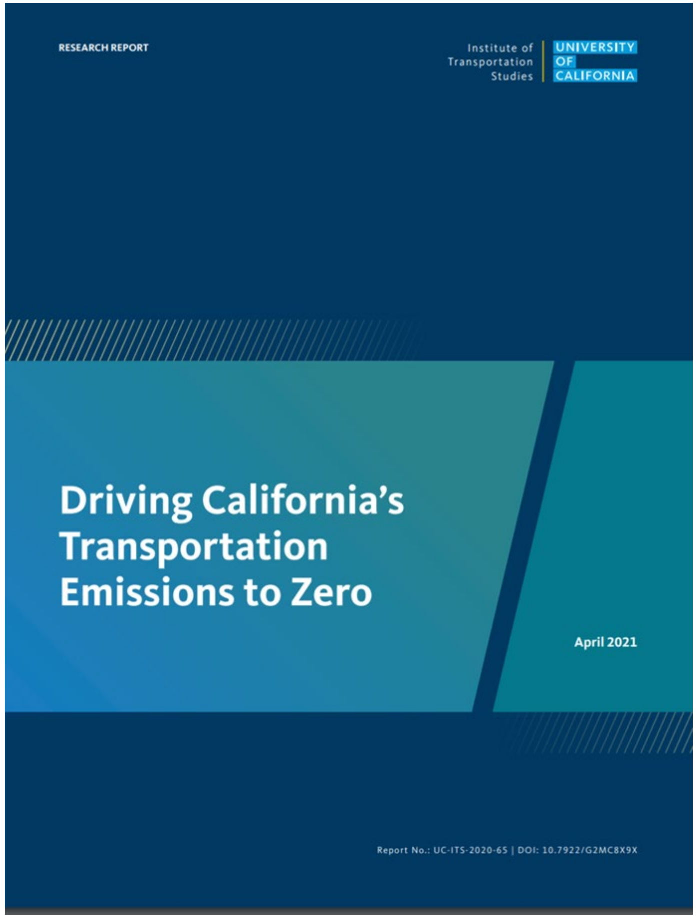
The Need for Fuel Policy:

- EVs are the key tool for decarbonizing road transportation
- Even under most ambitious EV deployment scenarios, they don't deploy fast enough to meet mid-century carbon neutrality targets.
    - In CA ~1.75 billion gal/year of gasoline demand remained in 2045
- Aviation, marine, etc. likely to require liquid fuels over long term
- Biofuels remain only alt fuel tech that has proven scalability….
- BUT sustainability and land use impacts probably limit growth potential
- Life cycle analysis is required to avoid unwanted impacts



Driving California's Transportation Emissions to Zero

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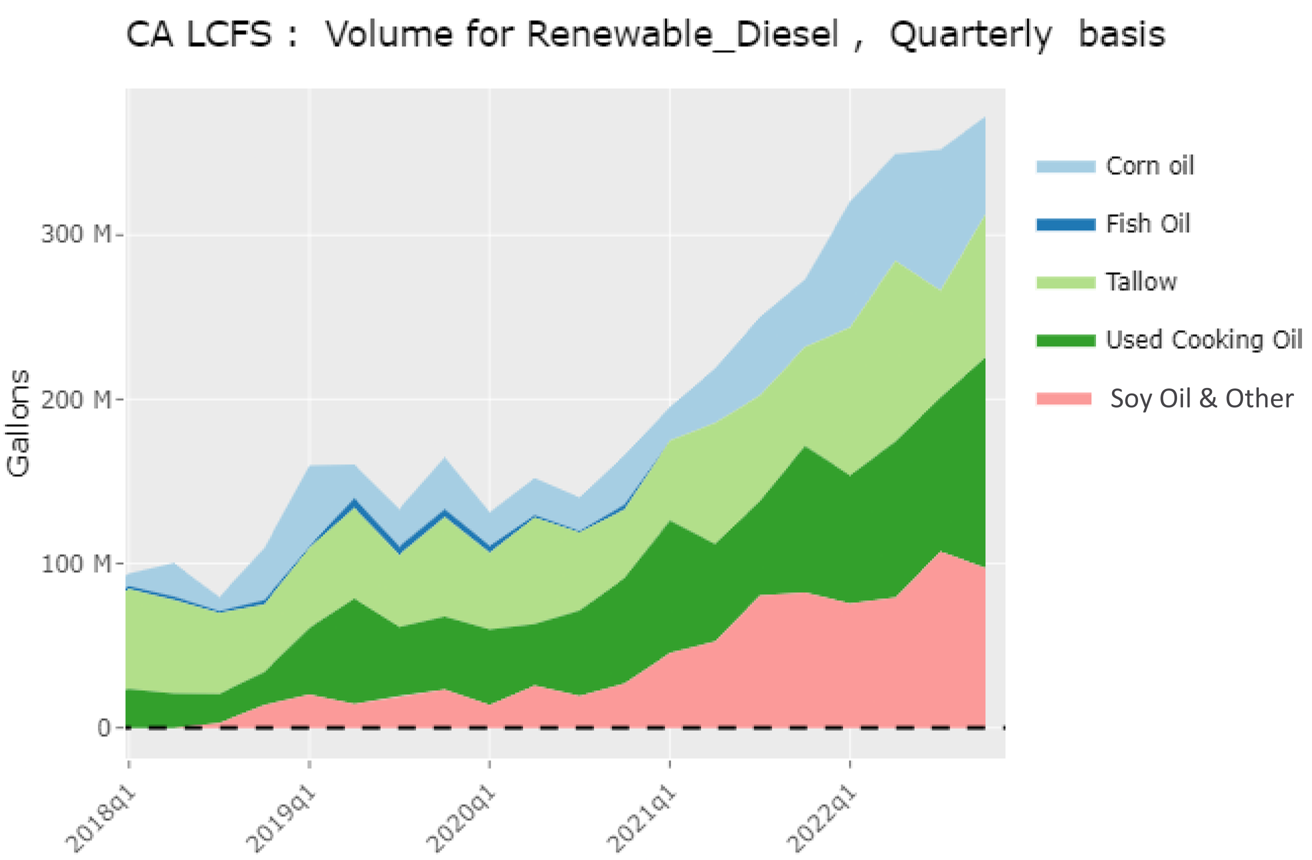
Crop Oils Entering Fuel Market at Scale

- Hydrotreated Renewable Diesel has grown rapidly. Alternative aviation fuel (aka "SAF") using similar process has also emerged.
  - Mostly waste feedstocks to date

- LCFS provides much higher incentive for fuels made from waste/residue oils.

- Significant expansion of hydrotreated fuel production capacity projected in North America over coming 5-10 years. 4-6 billion gallons of annual capacity expected.
  - Soybean oil will play larger role as feedstock.



Sources of feedstock for renewable diesel in California. Source: UCD LCFS Web Data Tool, data from CARB quarterly summary.

Indirect Land Use Change (ILUC) Overview

- Biofuels can use common agricultural commodities, such as corn or soybean oil as feedstock
- These are also consumed by humans, animals or other industrial sectors.
- When these commodities are used for biofuels, consumers seek replacements or substitutes, increasing aggregate demand for agricultural commodities
  - This typically results in higher prices for feedstock commodities
- Alternative framing: Biofuel feedstock production can compete against other uses for arable land, leading to higher demand for arable land
- Higher demand and/or prices increase the incentive to expand production. This often entails conversion of non-cultivated land into cultivated land.
- Conversion of non-cultivated land typically results in solid carbon, in soil and standing biomass being released as CO_2, methane, or other GHGs.
- “Wastes” typically have less ILUC impact, but probably not zero, because many were used for other production processes (e.g. used cooking oil as part of animal feed)

Range of ILUC Estimates

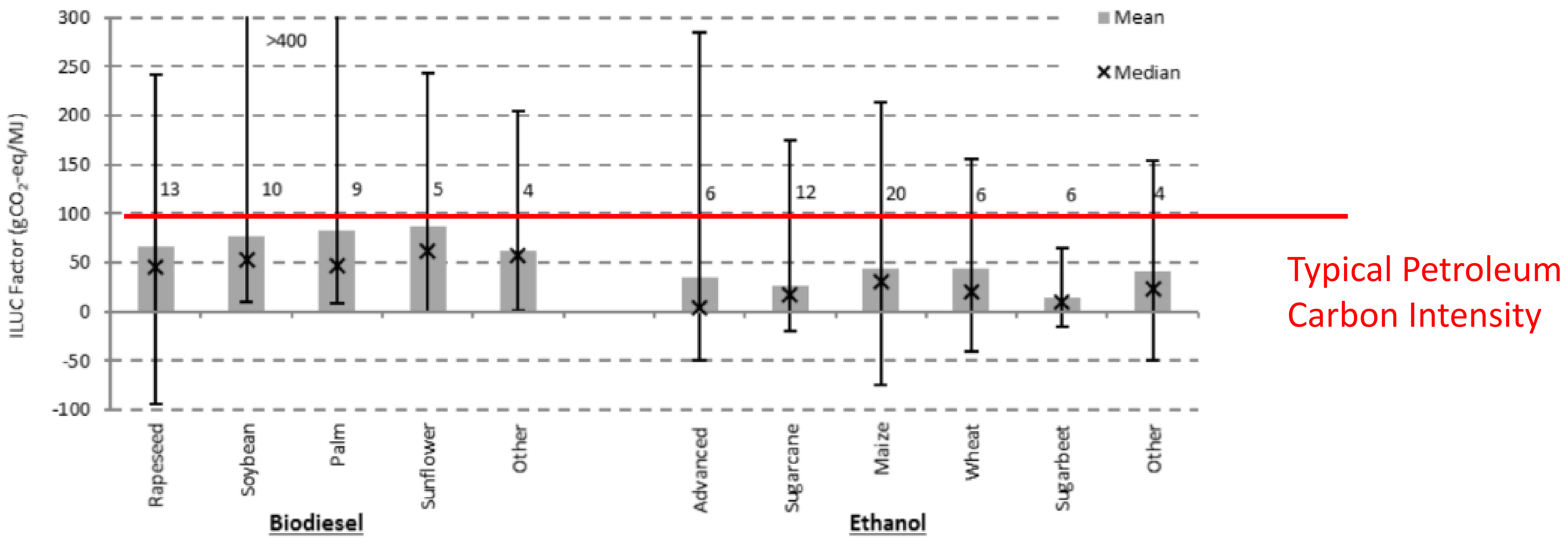


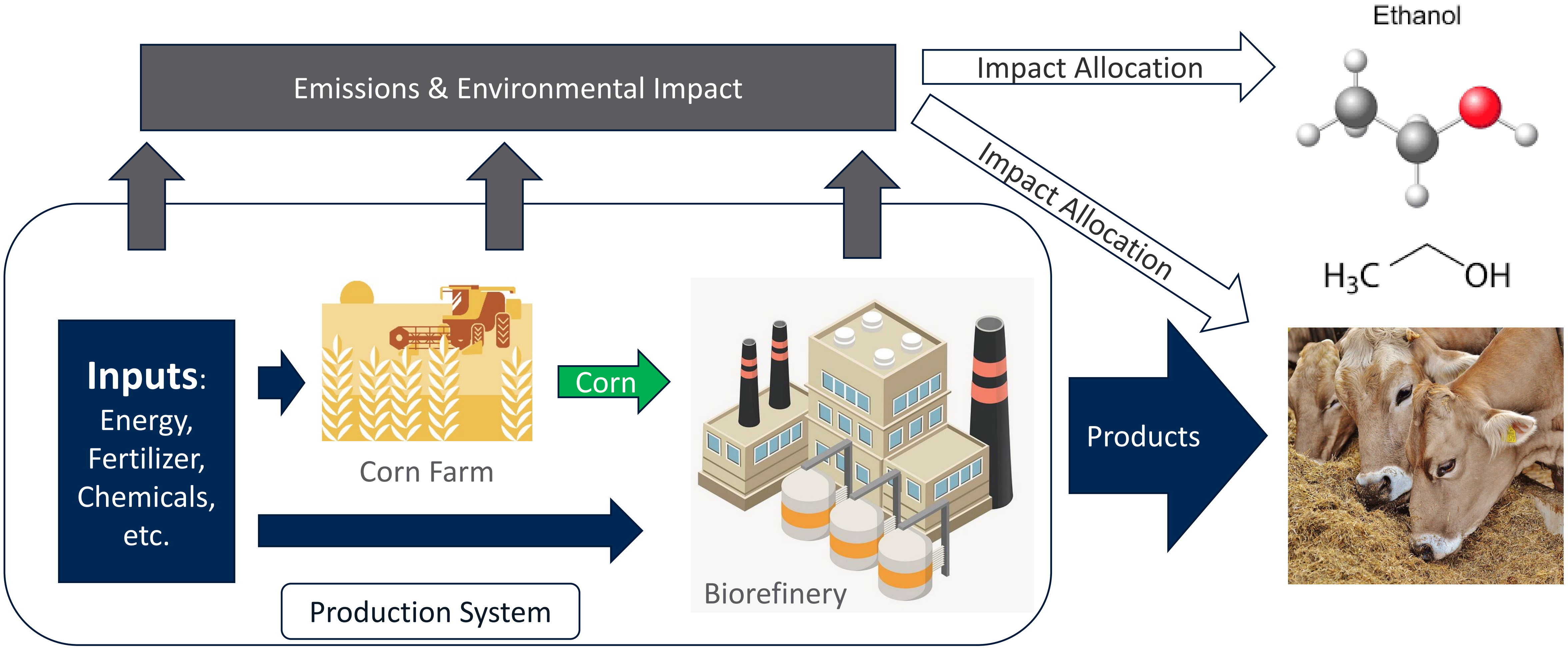
Figure 1 Summary of ILUC factors found in literature for biodiesel and ethanol. Grey bars: Mean, Black crosses: Median, Whiskers: Maximum-Minimum, number of studies quantifying ILUC factors written above each column. All ILUC factors have been harmonized to represent a 20 year amortization period. Note: a given study may include multiple scenarios or feedstocks.

Source: Woltjer *et al.* (2017)

Why so Uncertain?

- Not for lack of research effort - Google Scholar search for “Indirect Land Use Change” and “biofuel” returns 9,740 results since 2008.
- ILUC reflects decisions made by growers, who are geographically, economically, culturally, and technologically diverse, and react to market signals differently.
- ILUC is not a single, static number, it’s affected by many transient factors:
    - E.g. Drought or war in agricultural producing areas drive up crop prices, increasing incentive to clear land for cultivation ➔ Increased ILUC risk

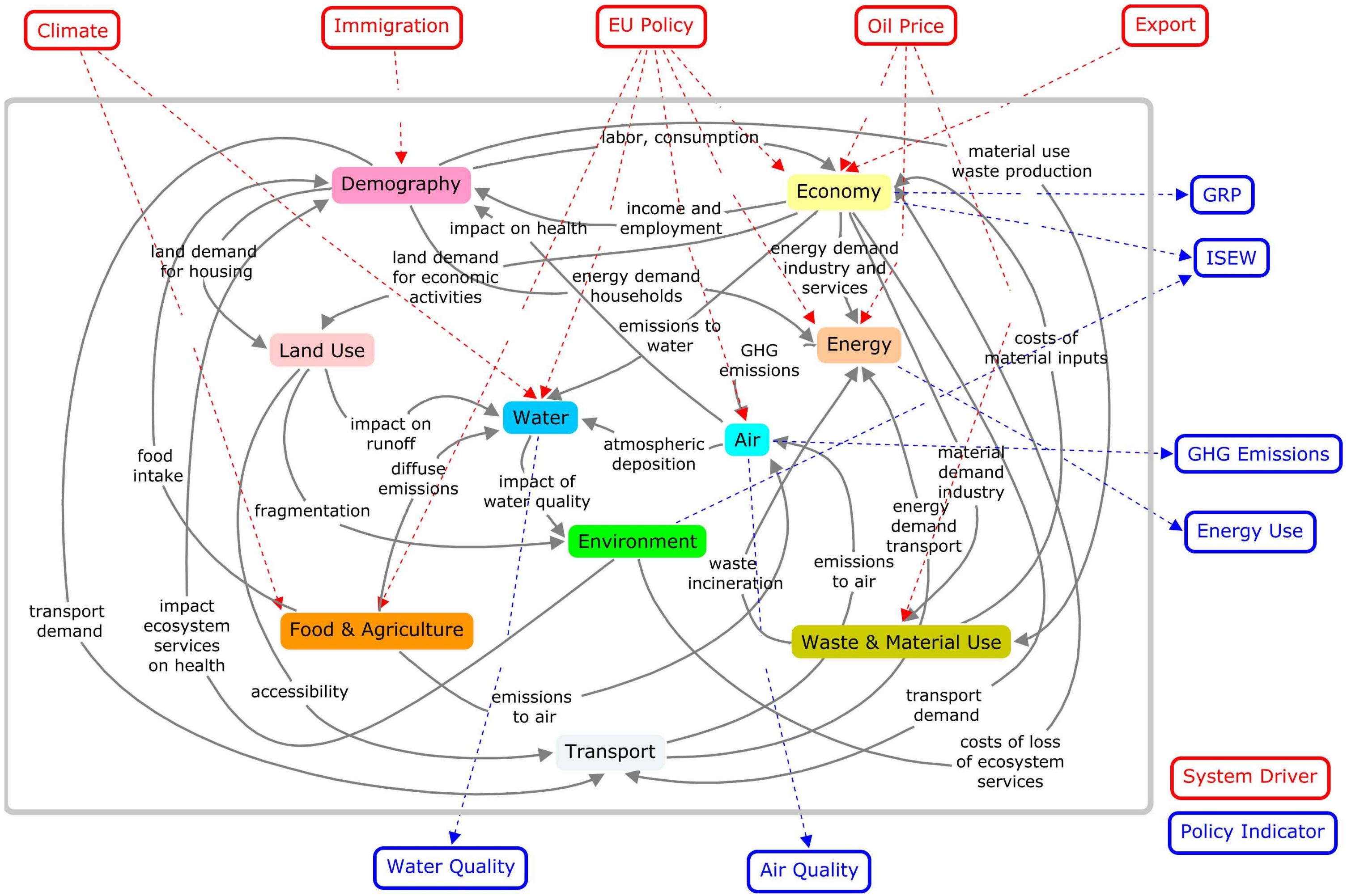
LCA Is Not Perfectly Objective



Complexity!

Factors Affecting ILUC

- Commodity prices
- Economic growth
- Population growth
- Biofuel promotion policies
- Land protection policies
- Weather/climate
- Changes in agronomy
- Social/cultural changes
- Trade policies
- War/instability



Example of system dynamics model of land use and agriculture effects. Provided as an example of the complexity around agricultural land use. Source

Calibration Data Challenges

- Structurally correct models require calibration and validation against real-world data.
- Critical ILUC data focuses on how markets and growers respond to changes in agricultural commodity prices and supplies.
    - Data are limited, often proprietary, and usually only available to researchers with a lag of 1-2 years
    - Expected biofuel growth is unprecedented
    - Ag data are notoriously noisy, due to natural variation and measurement uncertainty
- Historical data cannot reflect impacts of climate change or climate policy on agriculture

What we know:

- GHGs matter, so good fuel policies consider life cycle GHGs.
- ILUC is a major driver of life cycle GHG impact
- Static point estimates of ILUC impact are unreliable, but hard to execute policy without.
- Any policy relying on static point estimates of ILUC to assess GHGs is based on an inaccurate assessment, and incentives will not precisely match the theoretical ideal.

Model-based point estimates of ILUC are going to be wrong.

But there are a lot of different ways to be wrong.

What's the right way to be wrong?

Different Models Set Uncertainty Range

Different models take different approaches to modeling, e.g. system boundaries, scope, and assumed counterfactuals

Not all results or modules are easily or directly comparable

Where possible, a comparable range of outcomes can be observed

Table 7.7-1: Carbon intensity of soybean oil biodiesel (kgCO₂eq/MMBTU) calculated using emissions reported by each model[213]

	Models with Energy Markets				Models without Energy Markets		
		ADAGE	GCAM	GTAP		GLOBIOM	GREET
Sector/stage-specific emissions	Energy from Fossil Fuels	-28	-40	-46	Biofuel Production	x	13
	Crop Production	7	21	-6	Crop Production	11	x
					Feedstock Production	x	9
	Livestock Sector	0.7	-1.3		Livestock Sector	3	x
	Other	1	0		Fuel Use	x	0.4
	Land Use Change	295	62	10	Land Use Change	23	10
Totals	Agriculture, forestry, and land use	303	82	4	Agriculture, forestry, and land use	38	19
	Global GHG Impact	276	42	-42	Global GHG Impact	x	x
	Supply Chain GHG Emissions	x	x	x	Supply Chain GHG Emissions	x	32

"x" means not reported by that model.
Source: EPA ILUC Inter-Model Comparison

Uncertainty, and Risk

Thinking Through ILUC

ILUC causality: Increased demand for agricultural commodities causes someone somewhere clears land for agriculture, releasing carbon embodied in soil & standing biomass into the atmosphere.

Carbon loss in this way is quite quick.

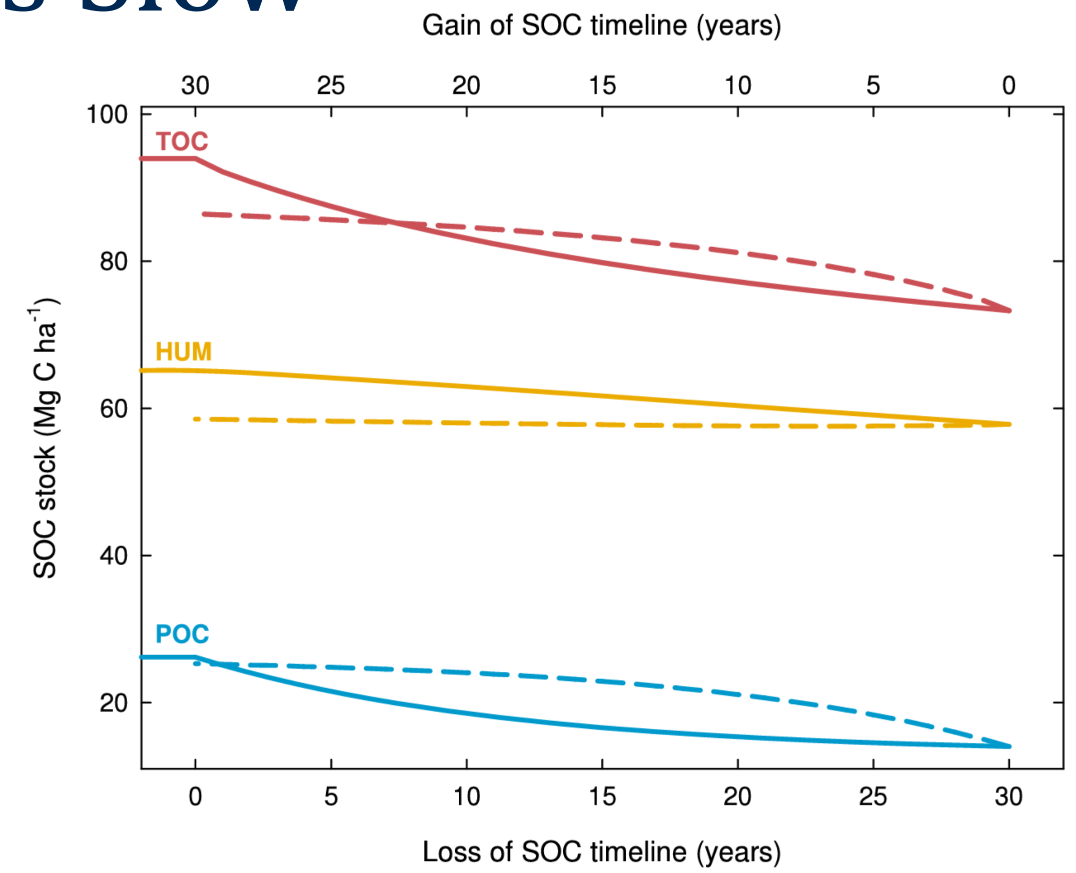
- Standing biomass lost to burning (instantaneous conversion to CO_2) or decomposition (most lost within 1-2 years)
- Soil carbon loss is fast in first few years after conversion
  - Zhang (2021) estimates for conversion of Midwest U.S. grassland to cultivation, 25% of soil carbon is lost in 5 years, with changes much slower after that

Carbon Accumulation is Slow

Recovery or accumulation of ecosystem carbon is slow – often decades or more

We need to achieve carbon neutrality by mid-century, we don't have decades to recover from land use change emissions.

Lost soil and ecosystem carbon is often effectively permanent *on timescales relevant to avoiding worst effects of climate change*.



Loss and gain of soil organic carbon (SOC) after change in management practices over time, broken into rapidly cycling particulate organic carbon (POC), slow cycling humic carbon (HUM) and total organic carbon (TOC). Loss trajectories are solid lines, moving from left to right, recovery are dotted lines moving right to left. Source: Sanderman & Baldock (2010)

Comparing Proximate GHG Impacts

Policy Overly Limits Biofuels

Harm: Lost GHG mitigation opportunity.

Example: 1 billion gallons of soybean oil renewable diesel (assumed 65 g CO2e/MJ) that displaces petroleum diesel saves ~3.4 million tonnes of CO2.* Possible economic / job creation benefits of production.

Policy Overly Supports Biofuels

Harm: Excessive land use change.

Example: 1 billion gallons of soybean oil renewable diesel requires ~ 15 million acres, roughly the area of West Virginia (assuming 66 gallon per acre net yield).

Based on Zhang, *et al (2021)*: Conversion of this area from Midwest grassland to conventional corn/soy rotation releases 2.6 million tonnes CO2/year.* (Higher for forests) Also, ecosystem and/or cultural value.

* These are highly approximate estimates, with many simplifying assumptions.

Some Risks are Asymmetric

Policy Overly Limits Biofuels

Relatively few non-linear risks from under-consuming biofuels.

Policy changes can increase biofuel consumption within a few years

Lower stranded asset risk, politically easier to add incentives

Policy Overly Supports Biofuels

Conversion of forests or peat soil landscapes dramatically increases carbon lost per acre.

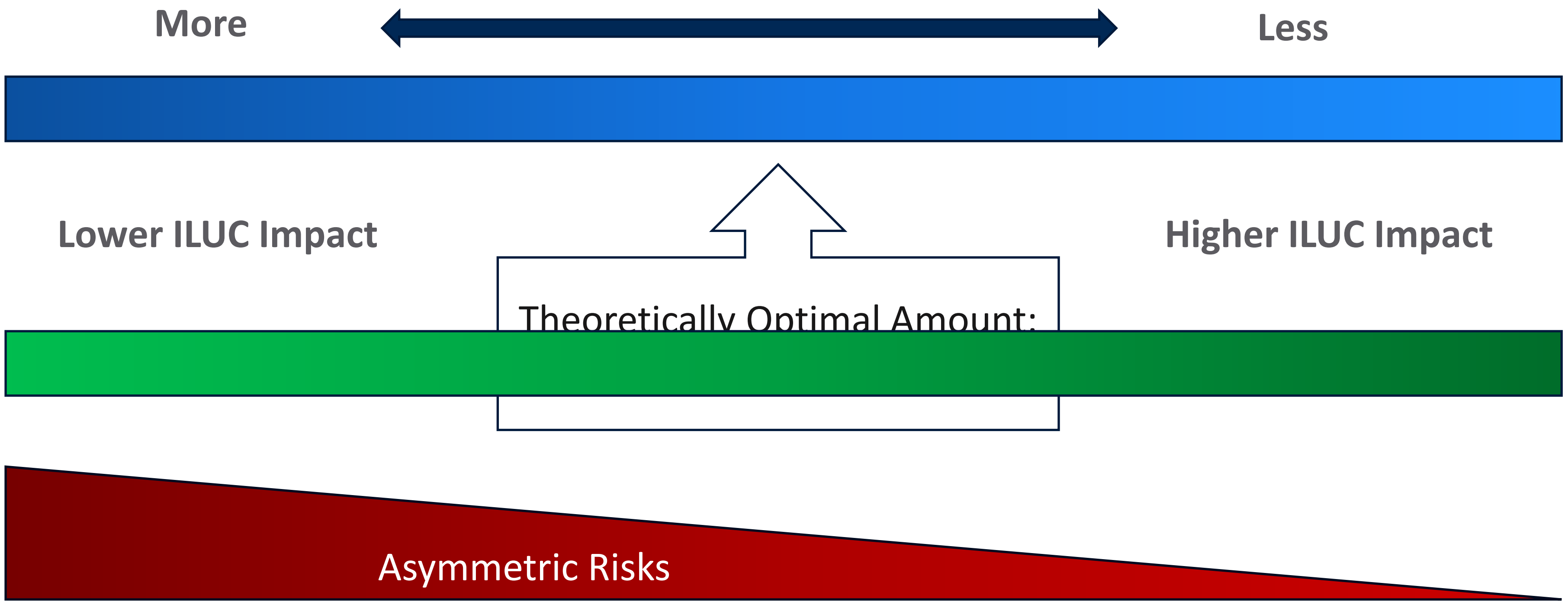
- E.g. Southeast Asian loss of peat soil rainforest to palm oil plantations as a result of 2000's EU biofuel policy.

High-yield land typically cultivated first, so ILUC impacts may increase as demand grows

Greater stranded asset risk, politically harder to withdraw policy support

Finding the Right Balance

Policy Support for Biofuel



Reversibility of carbon loss, nonlinear GHG effects, ecosystem/cultural value loss, stranded asset risk, political risk

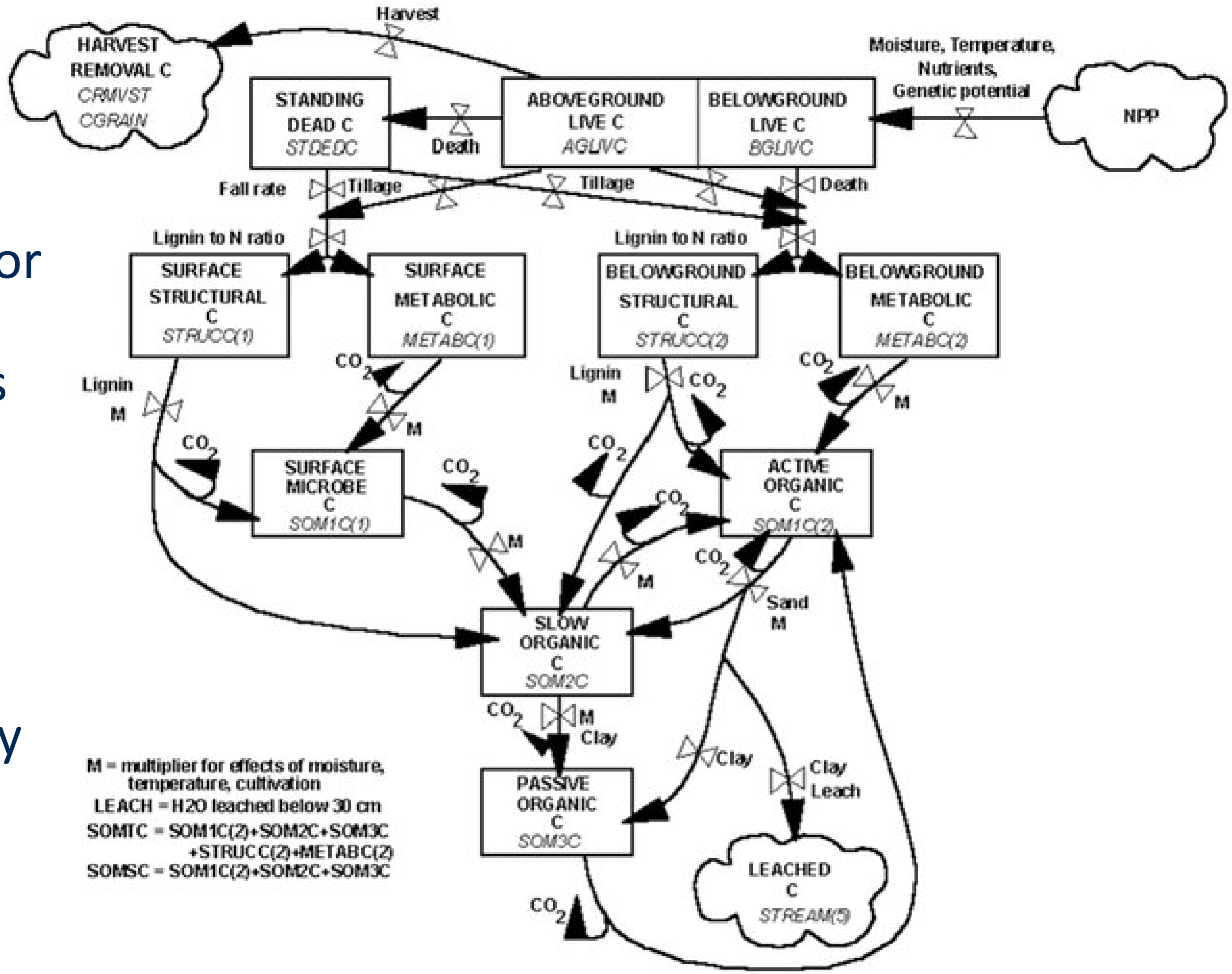
Doing ILUC Policy Right

- Support continued research to narrow uncertainty range on ILUC estimates
- Support collaborative technical engagement and consensus-building processes (e.g. National Academies biofuel LCA or CORSIA GHG assessment and sustainability workgroupss). Give all stakeholders, especially historically marginalized ones, a full voice
  - Develop consensus where possible, esp. around modeling methods
- Use an ensemble of multiple models to understand range of impacts.
  - Different approaches by different models helps paint full composite picture
  - Many groups have a vested interest in high/low ILUC outcomes, so it's likely that there will be results at high and low end of plausible ILUC range.
- Picking value at upper end of ILUC uncertainty range reduces chance of inaccurate ILUC impact estimate exposing us to worst risks

Related Questions re: Biofuel Policy

Soil Carbon

- Soil is a complex and dynamic system, affected by many factors.
- Models often only well-calibrated for the narrow set of soil/weather/crop/agronomic conditions of fields their calibration data comes from.
- We are confident that some agricultural practices can increase soil carbon.
- Existing models struggle to precisely quantify soil carbon changes over a wide variety of landscapes.



Soil Carbon’s Unique Challenges

- Reversion risk – Growers could build soil carbon over many years of regenerative agriculture, but it can be rapidly lost if practices change.
- Natural variability – Temperature, precipitation, pests, etc. can affect soil carbon
- Soil carbon equilibrium – Changes in agronomic practices can cause carbon to accumulate, but eventually a new equilibrium is reached.
- Market segmentation – At present biofuels consume a small fraction of total agricultural production (40% of corn, much less of all other crops). Biofuel policies affect only a small subset of growers.

Effective soil carbon policy must mitigate these risks. It should not rely solely on existing models until they demonstrate accuracy across wider range of crop/landscape types, and have robust protection against reversion risk, without creating implicit incentive to grow feedstock instead of food.

Is Current Land for Feedstock a Sunk Cost?

Would subsidies for biofuel feedstock from land currently used for that purpose actually result in additional ILUC emissions?

- Need to differentiate between supporting growth and maintaining existing capacity.
  - RFS has (to date) served as a functional cap on total crop-based biofuel consumption.
  - As long as biofuel policy does not expand production faster than net feedstock yield (i.e. yield minus non-fuel demand growth) then ILUC pressure should be low
- BUT: Demand for agricultural commodities will expand with population and economic growth.
- If demand for biofuel feedstock goes down, feedstock growers are likely to shift to other crops, reducing pressure to convert land elsewhere.

Good resources

Considerations for addressing indirect land use change in Danish biofuel regulation (EU Consultant Report)

EPA Inter-Model Comparison Technical Report

National Academies Current Methods for Life Cycle Analyses of Low-Carbon Transportation Fuels in the United States

Animal, Vegetable, or Mineral (Oil)? (Cerulogy)

Sanderman & Baldock (2010) Accounting for soil carbon sequestration in national inventories: a soil scientist's perspective

Driving California's Transportation Emissions to Zero by 2045

Questions, thoughts, and discussion welcome!

Colin Murphy Ph.D.

cwmurphy@ucdavis.edu

policyinstitute.ucdavis.edu

Twitter: @scianalysis

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