NEGATIVE EMISSIONS: CONSTRAINTS TO GT SCALE

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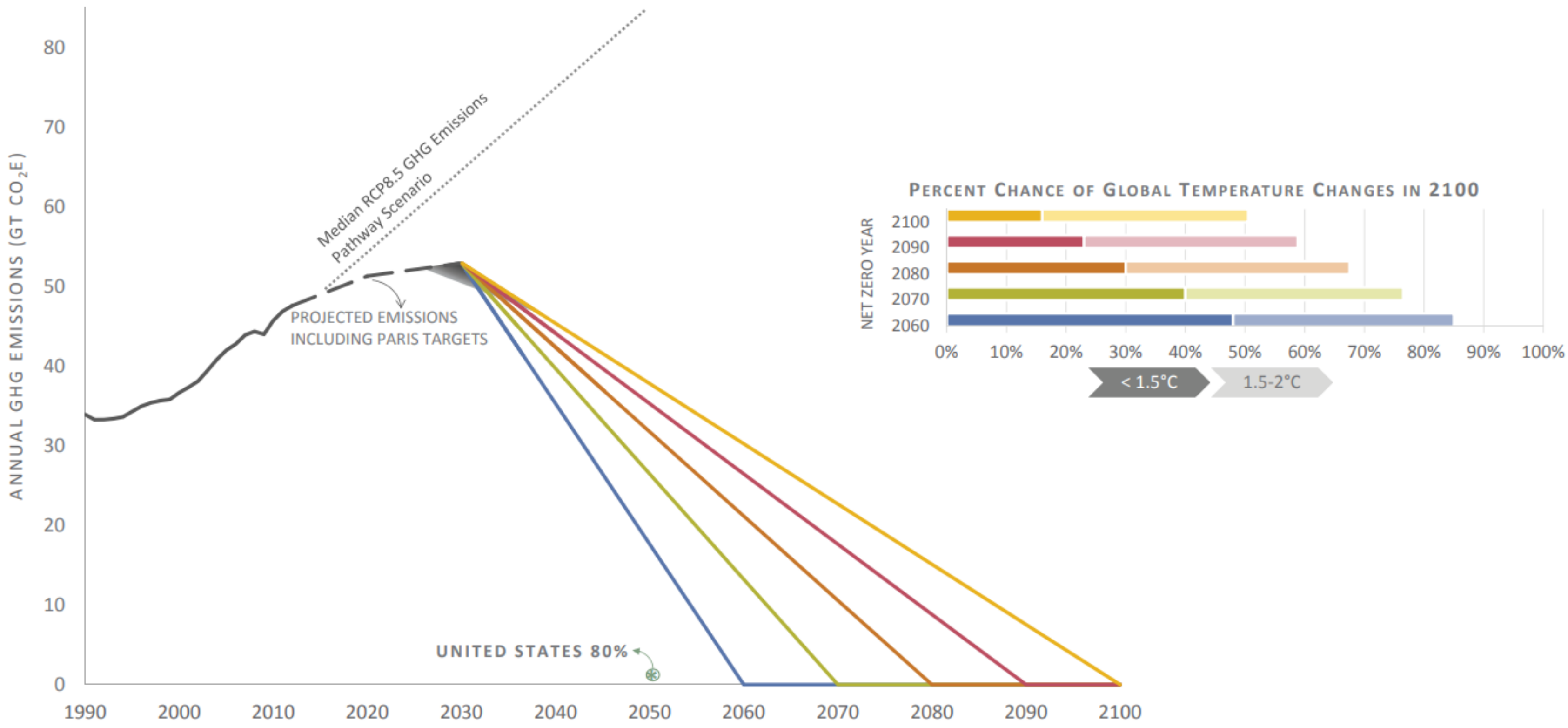
FIGURE E11: GLOBAL TRAJECTORIES TO NET-ZERO GHG EMISSIONS AND PROBABILITY OF GLOBAL TEMPERATURE CHANGES



U.S. Mid-Century Strategy:

It is no longer possible to hold warming "well below 2 degrees C", let alone 1.5C, simply by cutting global emissions more rapidly

HOW MUCH CO_2 REMOVAL DO WE NEED?

IS IT FEASIBLE?

NEGATIVE EMISSIONS TECHNOLOGIES

Technology	Benefits	Drawbacks
Natural carbon capture (sequestered in soils, biomass)	• Scalable, economical now • Potential to increase biomass supply	• Finite potential • Reversible • Monitoring costs and complexity • Potential economic, env. Impacts
Bioenergy plus CCS (BECCS)	• Feasible with existing technologies • Displaces FF	• Finite potential • Not demonstrated at scale • Costly • Potential economic, env. impacts
Direct Air Capture (DAC)	• Unlimited scale? • Minimal land requirements	• Energy intensive • Most costly option • Very early stage development
Rock weathering etc.	• Very large scale potential • Low cost?	• Very early stage development • Potential risks

Duke et al., draft

MY TASK

How much can BECCS contribute to the 800-2,200 Gt CO2 cumulative need for CDR, considering all environmental and economic constraints?

Estimate “especially conservative” global biomass availability by 2050, 2100 for BECCS

MAJOR CONSTRAINTS

FRESH WATER

NUTRIENTS

LAND USE

(BIODIVERISTY)

ALBEDO

There may be other near-term constraints like seeds, capital, expertise…

WHAT ARE "CONSTRAINTS"?

PHYSICAL CONSTRAINTS

- **Physical limits to resource through-puts, stocks**
- Often are a function of existing technologies and costs anyway
- But easier to frame and model

ECONOMIC CONSTRAINTS

- **Limits to acceptable environmental, commodity costs**
- Based in social justice
- Reached far before any physical constraints?

Recommend going forward we focus on economic constraints rather than physical constraints.

Not currently the case in the literature.

LAND USE DEMAND

- **Bioenergy**: IPCC scenarios for below 2 degrees C utilize 100-300 EJ of bioenergy, up to 7 times greater than current global use, requiring up to 700 million hectares of productive land.

- **Forests**: 320-970 million hectares of forest expansion could also be needed.

- **Cropland**: Even with increasing crop yields, global cropland could increase by 9-12 percent, or 180 million hectares.

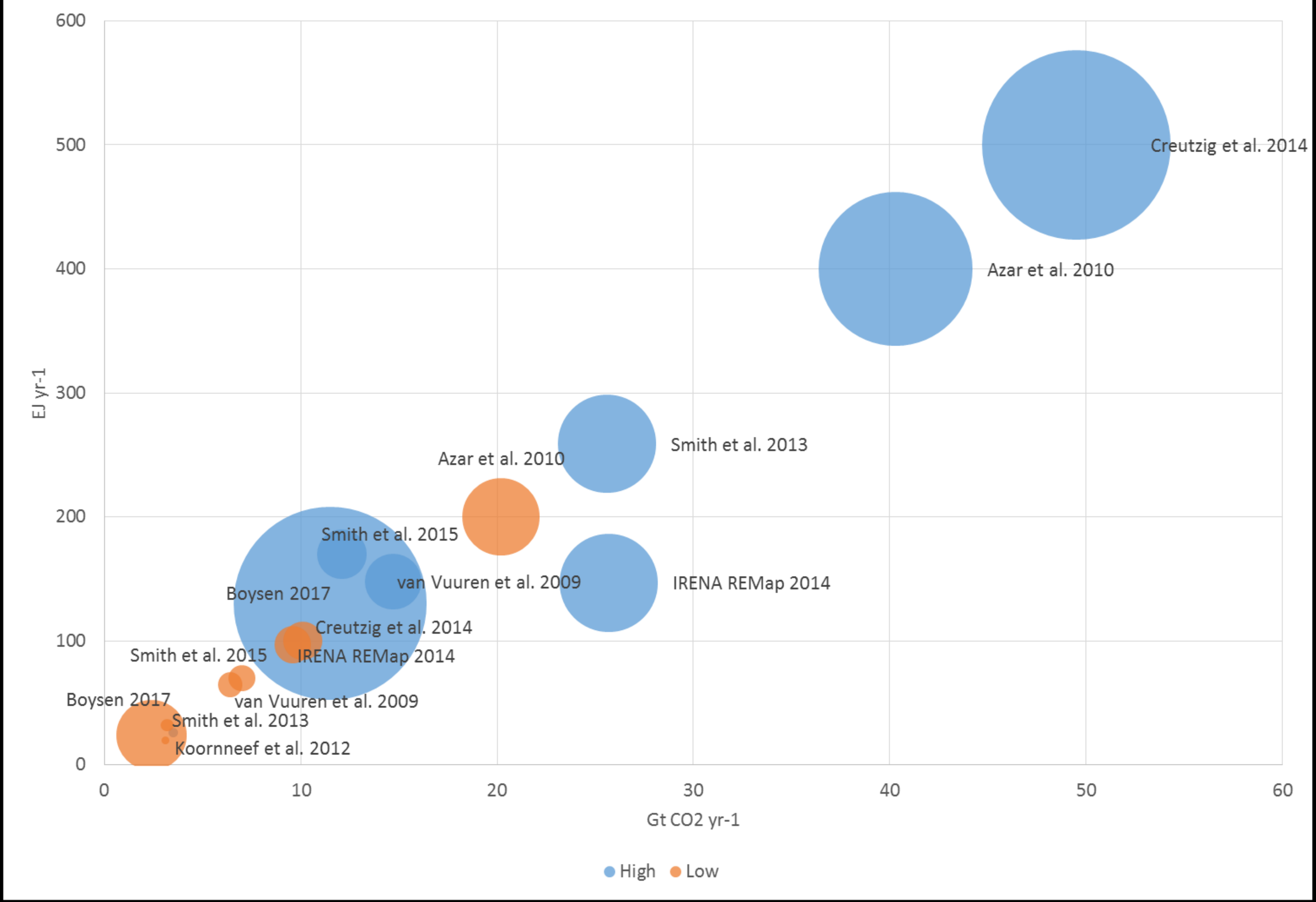
- **Settlement**: Growing urban and commercial areas, projected to triple between now and 2030 could further exacerbate land use pressures.

- What will be the net result of increasing land demand? How to define "bad outcomes"? How to avoid bad outcomes?

Smith et al. 2015
Haberl et al. 2011

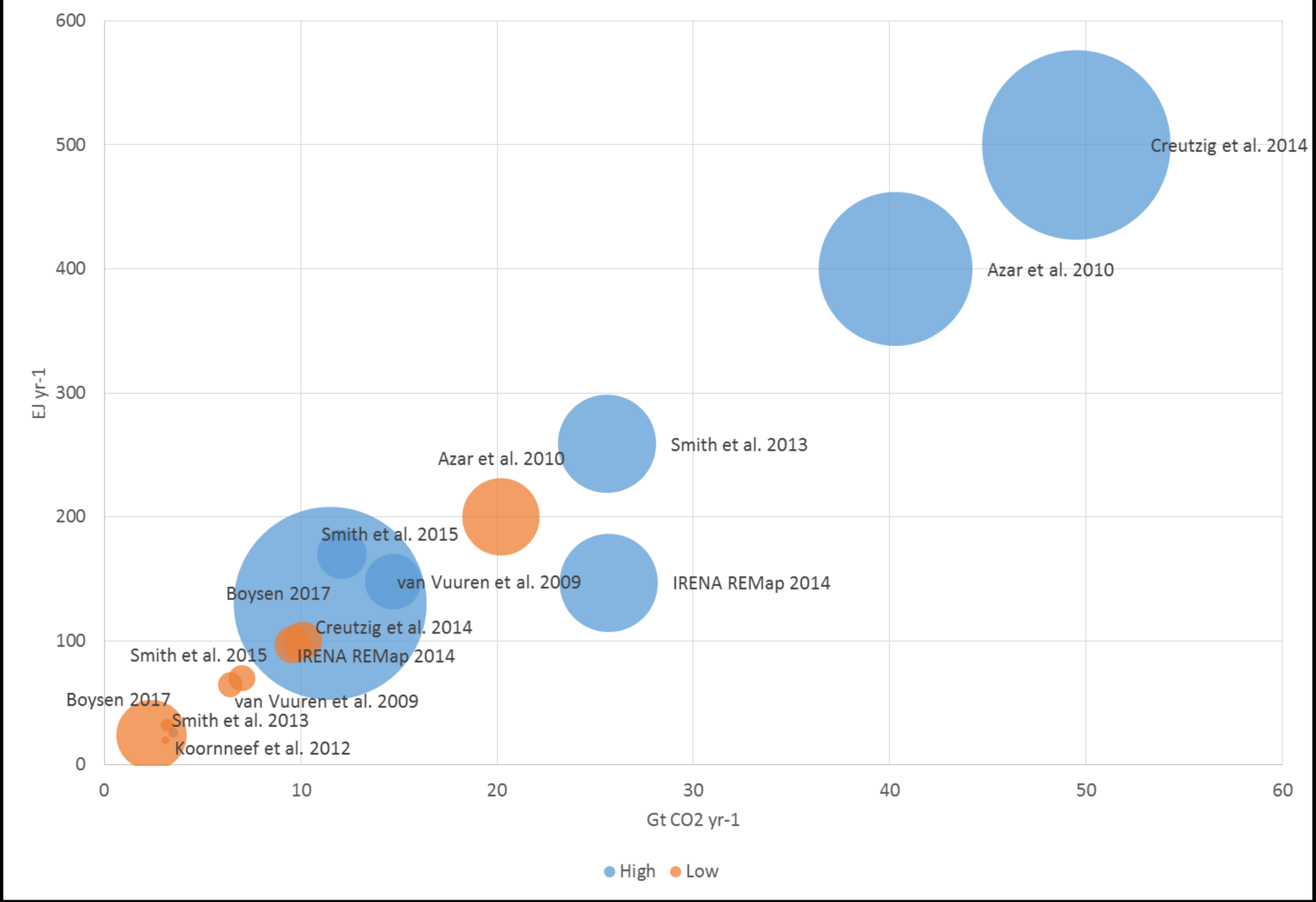
		Land use constraints				Environmental constraints	
	Scenario(s)	Food production	Forest expansion	Conservation	Settlement	Water use	Nitrogen
Boysen et al. 2017	LPJmL: 10-25% conversion of ag, natural lands; abandoned crop/pasture	3,000 kcal/cap/day, 7 billion population	Steffen et al. 2015 (no forest expansion)	N/A	N/A	Rain-fed vs. unlimited irrigation	Double planetary boundary
Smith et al. 2015	BECCS deliver all CDR required for 450	380-700Mha				2-2.5 m^3 per t Ceq (evaporative)	10-20 kg N per t Ceq
Van Vuuren et al. 2009	IMAGE: abandoned ag land and natural grasslands	FAO medium economic growth, 9.4 billion	N/A	Bio-reserves expanded 12-25%	N/A	WaterGap analysis	N/A
Smith et al. 2013	Biomass and afforestation on “spare land”	FAO medium case	6.1 – 16.5 gT CO2/yr	N/A	N/A		N/A
IRENA REMap 2014	Assumes only current cropland/pasture available	FAO projections?	N/A	N/A	N/A	N/A	N/A
Azar et al. 2010	IMAGE/GET/MESSAGE: MAC for BECCS vs. no CCS tech	N/A	N/A	N/A	N/A	N/A	N/A
Popp et al. 2014	GCAM/IMAGE/REMIND: Scenarios for 450, 550	N/A	GCAM has highest forest value/elasticity	N/A	N/A	IMAGE assumes no irrigation	All models price N2O from ag

Duke et al., draft



High and low global BECCS potential estimates across 8 studies

Bubbles represent area of land use for biomass , ranges from 140 million to 2.7 billion hectares



Estimates driven by:

- Biomass feedstock types included (wastes, residues, energy grasses, thinnings/roundwood)
- Energy grass yields
- Input constraints – largest driver is amount of land considered "available" for biomass production

ROTATIONAL ANALYSIS

	Assumptions	Hectares (1000)	Low yield (6 mt/ha)	High yield (12 mt/ha)
			BECCS sequestration ($Gt\ CO_2/yr$)	
Cultivated pasture rotation	30% of cultivated pasture (1.6% of total global pasture)	55,226	0.6	1.2
Economically marginal cropland	10% of total cropland	16,2908	0.2	0.4
Temporary fallow	100% of temp fallow	82,999	0.9	1.8
Early planted forest rotation	7% of planted forest (first 7 years of 100 yr. rotation)	19,858	0.2	0.4
Invasive brush removal	All encroached grassland in U.S. southwest	8,090	0.1	0.2
Salt-affected soils restoration	All soils impacted by salt	12,000	0.1	0.3
Mined land restoration	Low-end extrapolation of all U.S. post-mined land	1,000	0.01	0.02
Total		195,463	2.2	4.3

Global land areas derived from FAO, 2017 except invasive brush removal from NRCS 2010 and mined land BLM 2014, EPA 2015

CHALLENGES

- Only considers land use constraint
  - Water constraints partially implicit in limiting to cultivated pasture and planted forest
  - No nutrient, economic constraints considered
- Untested agronomic feasibility – complex rotational strategies create risk, higher costs
- Potential yields untested in some cases
- Does not consider alternative mitigation strategies on these areas
- How would policy enable/require this?

PRIMARY RESEARCH NEEDS

- Agronomic pilots and economic analysis for rotational strategies, invasive species utilization, "marginal" land
- Ongoing investments in yield improvement
- Algae, advanced biomass RD&D

MODELING RECOMMENDATIONS

- IAM inter-comparison analysis using comprehensive constraints across all categories
- Develop scenarios observing different levels of economic constraints – what mitigation is feasible?
- Clear reporting of food prices, land rents, other input prices for all mitigation scenarios
- Make sure to compare food price under mitigation scenarios vs. BAU climate impact
- For policy makers and modelers: don’t think about bioenergy and forestry separately

LET'S JUST GET STARTED

THANK YOU