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Bioenergy – a lesser of two evils?

Glen Peters (CICERO)

IEA Bioenergy Task 38 and Chalmers University of Technology, 16/05/2017

CO_2 perturbation and associated global warming potentials following emissions from biofuel based on wood

Are biofuels "carbon" or "climate" neutral?

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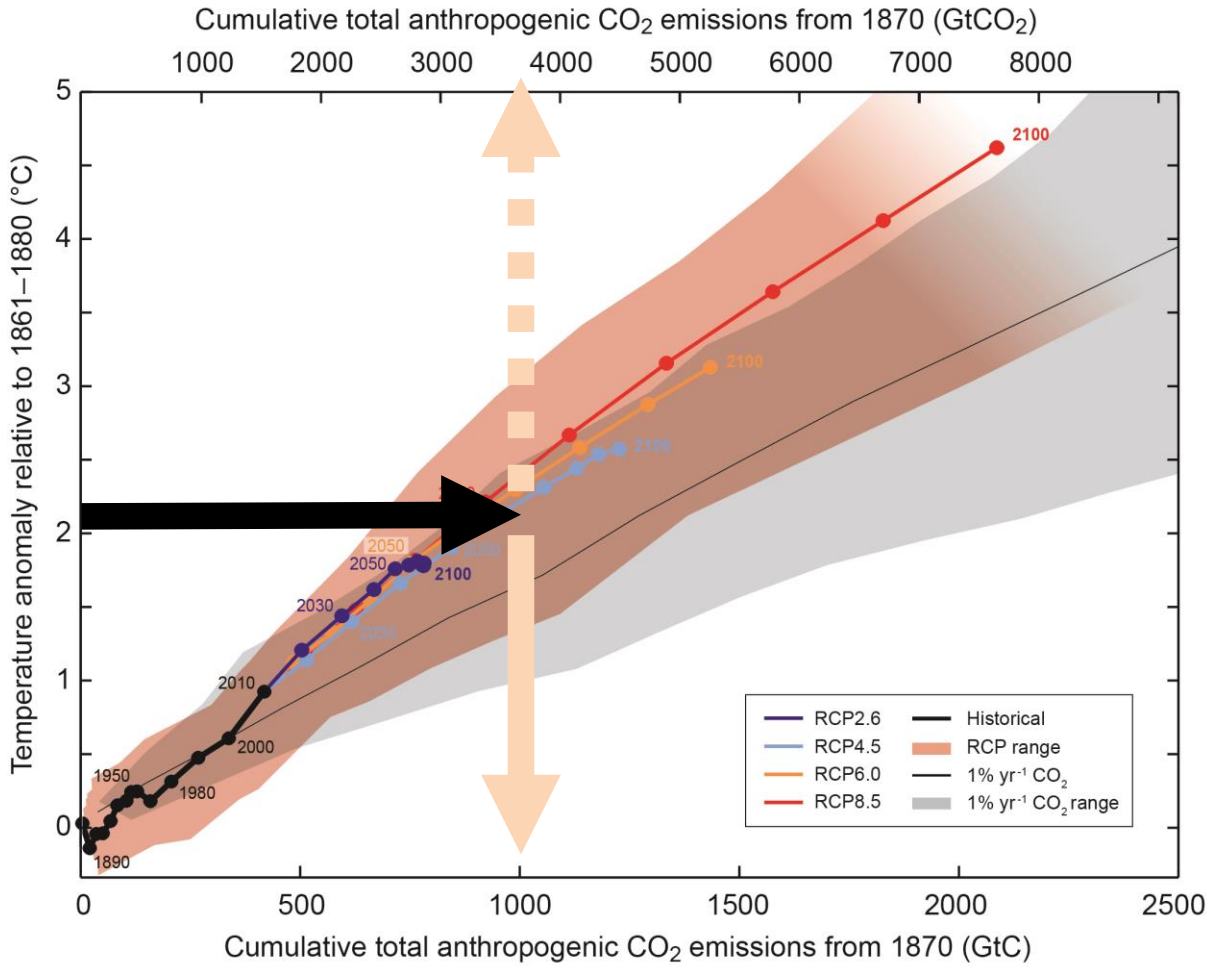
Emission scenarios

What do 2°C scenarios say about bioenergy?

The power of cumulative emissions

There is a *near-linear* relationship between cumulative emissions and global average temperature increase



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Source: IPCC Synthesis Report

Cumulative CO_2, temperature, probabilities

An important, but extremely complex table…
(See several blogs discussing the ins and outs of this table)

Table 2.2 | Cumulative carbon dioxide (CO_2) emission consistent with limiting warming to less than stated temperature limits at different levels of probability, based on different lines of evidence. *{WGI 12.5.4, WGIII 6}*

Cumulative CO_2 emissions from 1870 in $GtCO_2$									
Net anthropogenic warming [a]	<1.5°C			<2°C			<3°C		
Fraction of simulations meeting goal [b]	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only [c]	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios [d]	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. [e]	4150 to 5750	5250 to 6000
Cumulative CO_2 emissions from 2011 in $GtCO_2$									
Complex models, RCP scenarios only [c]	400	550	850	1000	1300	1500	2400	2800	3250
Simple model, WGIII scenarios [d]	No data	550 to 600	600 to 1150	750 to 1400	1150 to 1400	1150 to 2050	n.a. [e]	2350 to 4000	3500 to 4250
Total fossil carbon available in 2011 [f]: 3670 to 7100 $GtCO_2$ (reserves) and 31300 to 50050 $GtCO_2$ (resources)									

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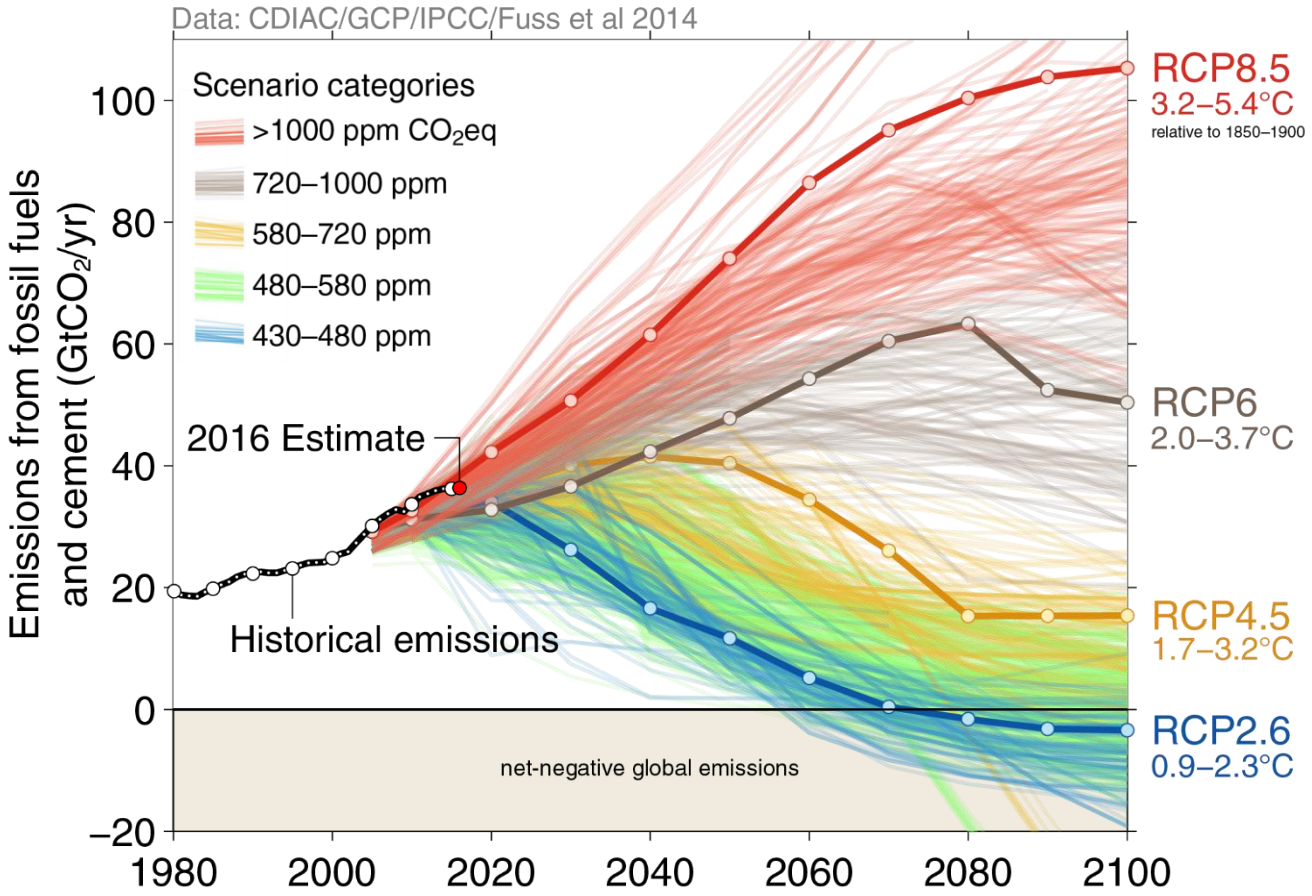
Source: IPCC Synthesis Report (Table 2.2); Blog 1; Blog 2; Blog 3

There are many options to stay below 2°C

IPCC assessed about 1200 scenarios, and about 120 different 2°C scenarios!
Different scenarios cover different models, policy start dates, technology portfolios, etc



Light lines: The IPCC Fifth Assessment Report assessed about 1200 scenarios using Integrated Assessment Models (IAMs)
Dark lines: Detailed climate modelling was done on four Representative Concentration Pathways (RCPs)
Source: Fuss et al 2014; CDIAC; IIASA AR5 Scenario Database; Global Carbon Budget 2016

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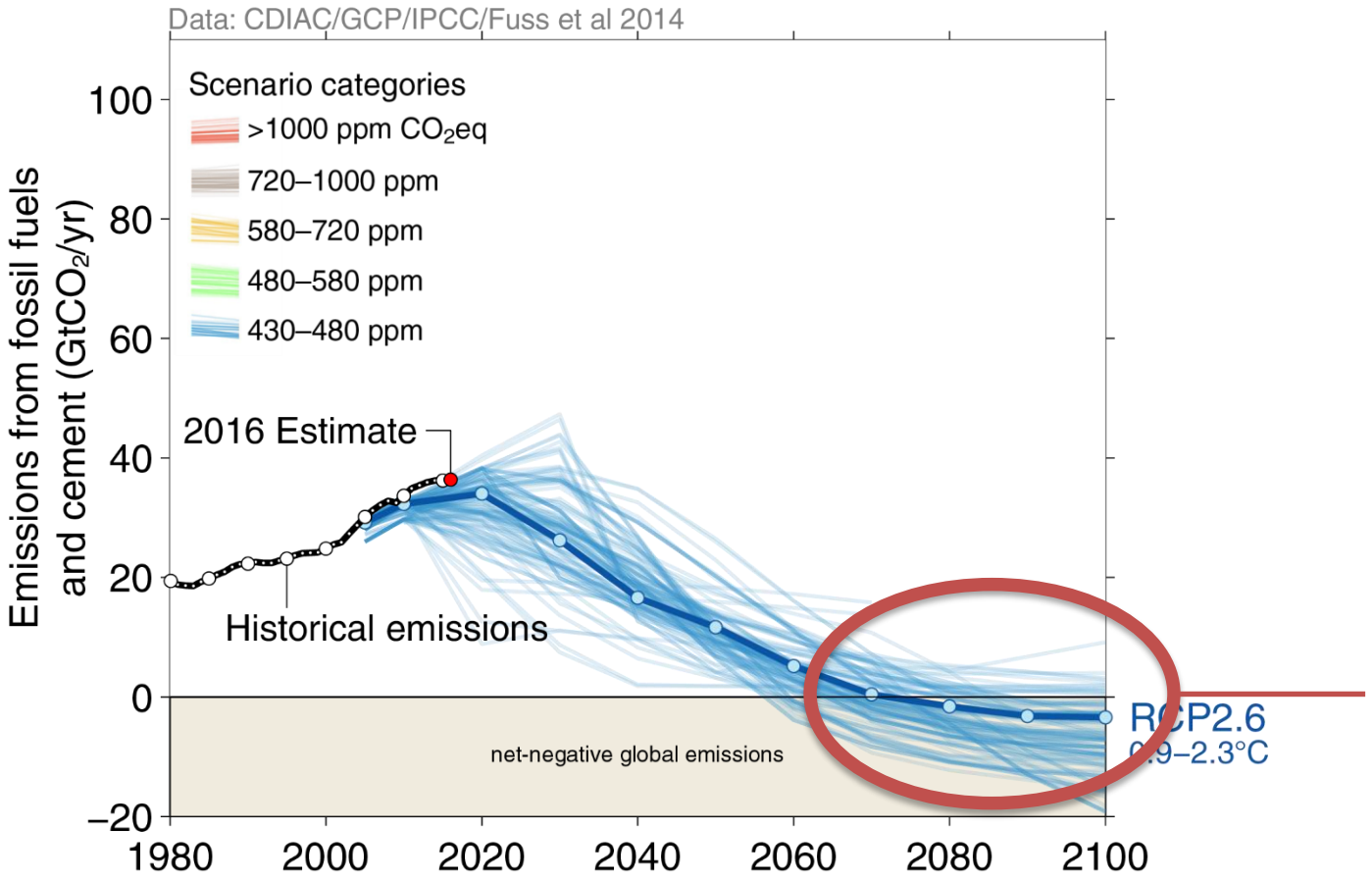
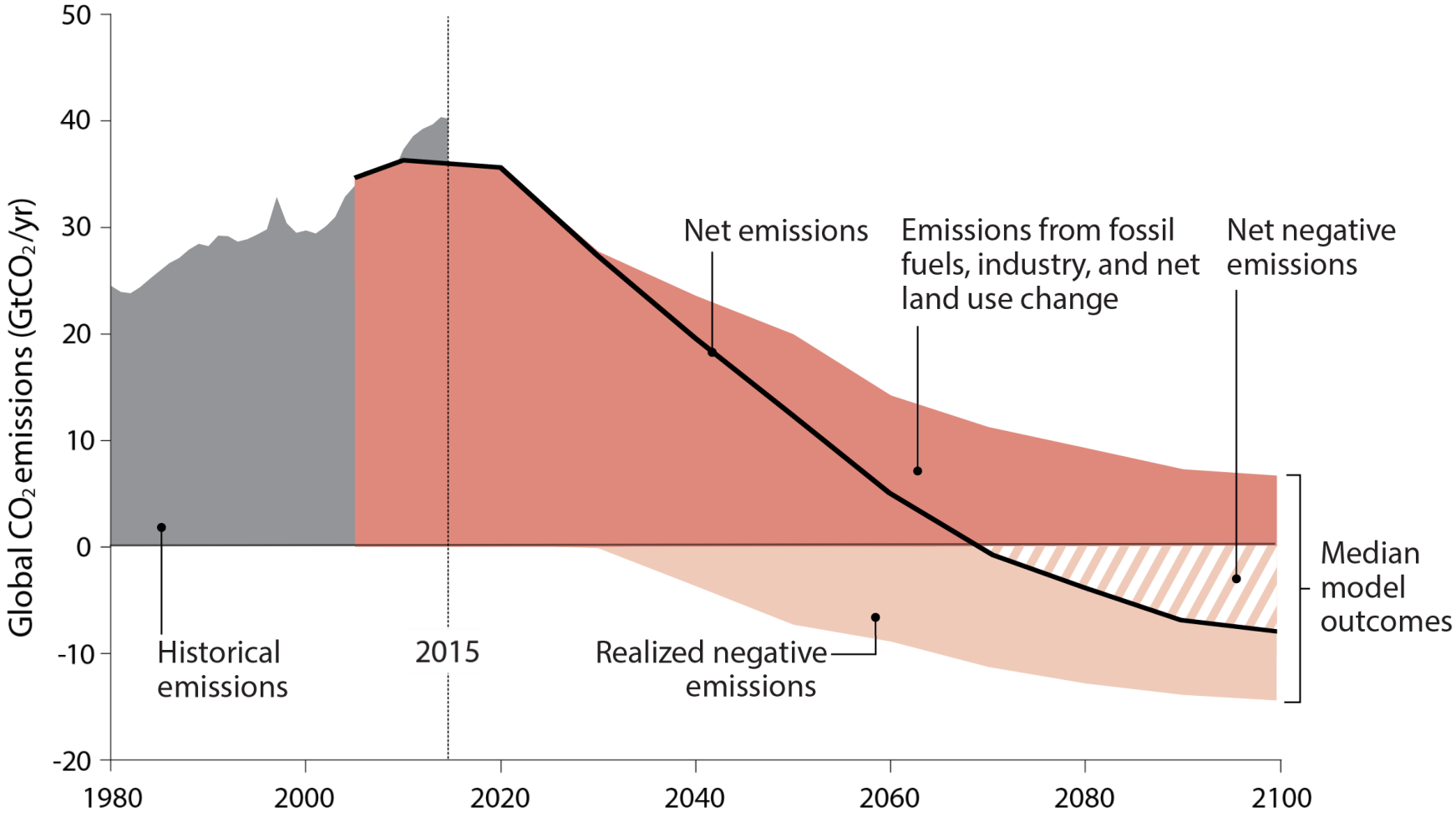


"Negative emissions" are a fundamental feature with fundamental consequences…

Light lines: The IPCC Fifth Assessment Report assessed about 1200 scenarios using Integrated Assessment Models (IAMs)
Dark lines: Detailed climate modelling was done on four Representative Concentration Pathways (RCPs)
Source: Fuss et al 2014; CDIAC; IIASA AR5 Scenario Database; Global Carbon Budget 2016

The importance of “Negative Emissions”

CO_2 removal starts in 2020-2030 and rises to 15 billion tonnes CO_2 per year in 2100
Less CO_2 removal requires more rapid reductions in fossil fuel and industry emissions



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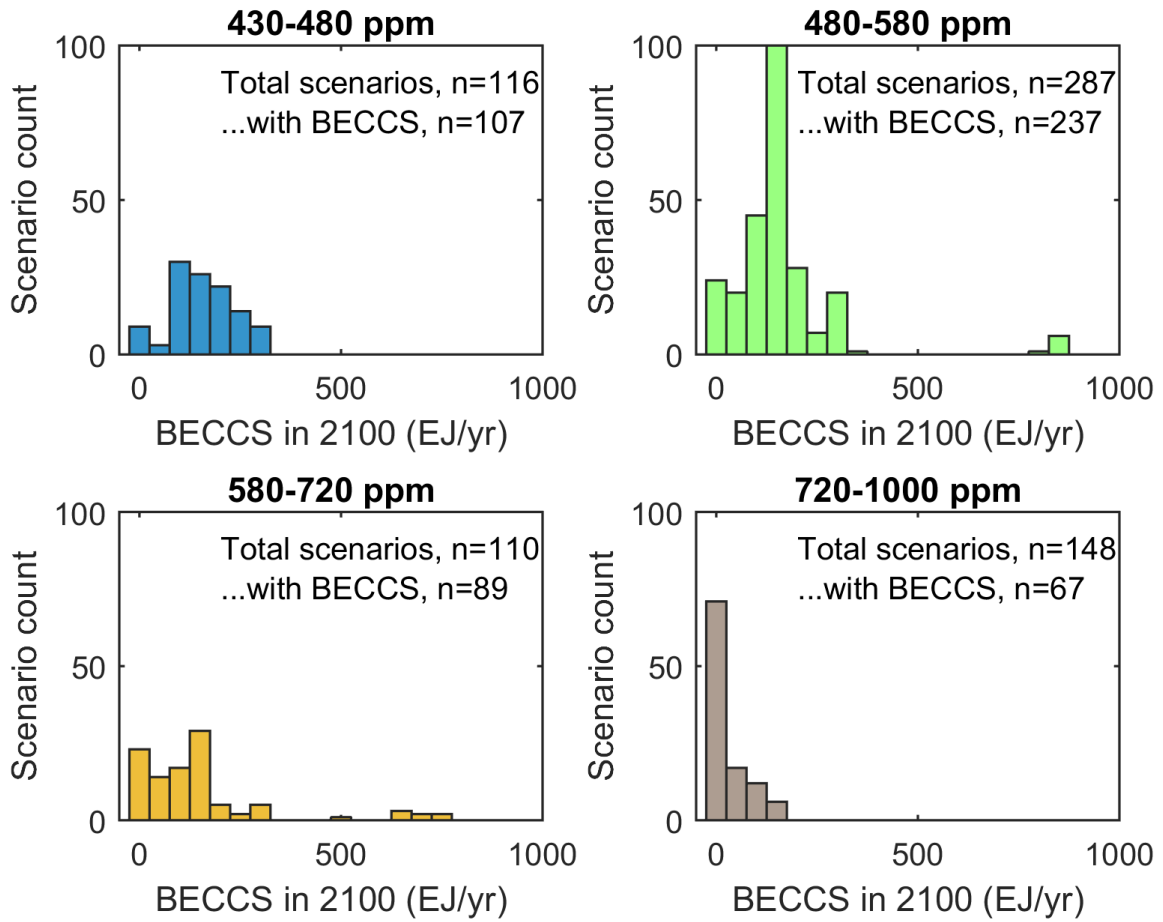
Source: Anderson & Peters (2016)

BECCS by forcing level in 2100

BECCS is not just for 2°C, but whenever there is mitigation BECCS is used in scenarios



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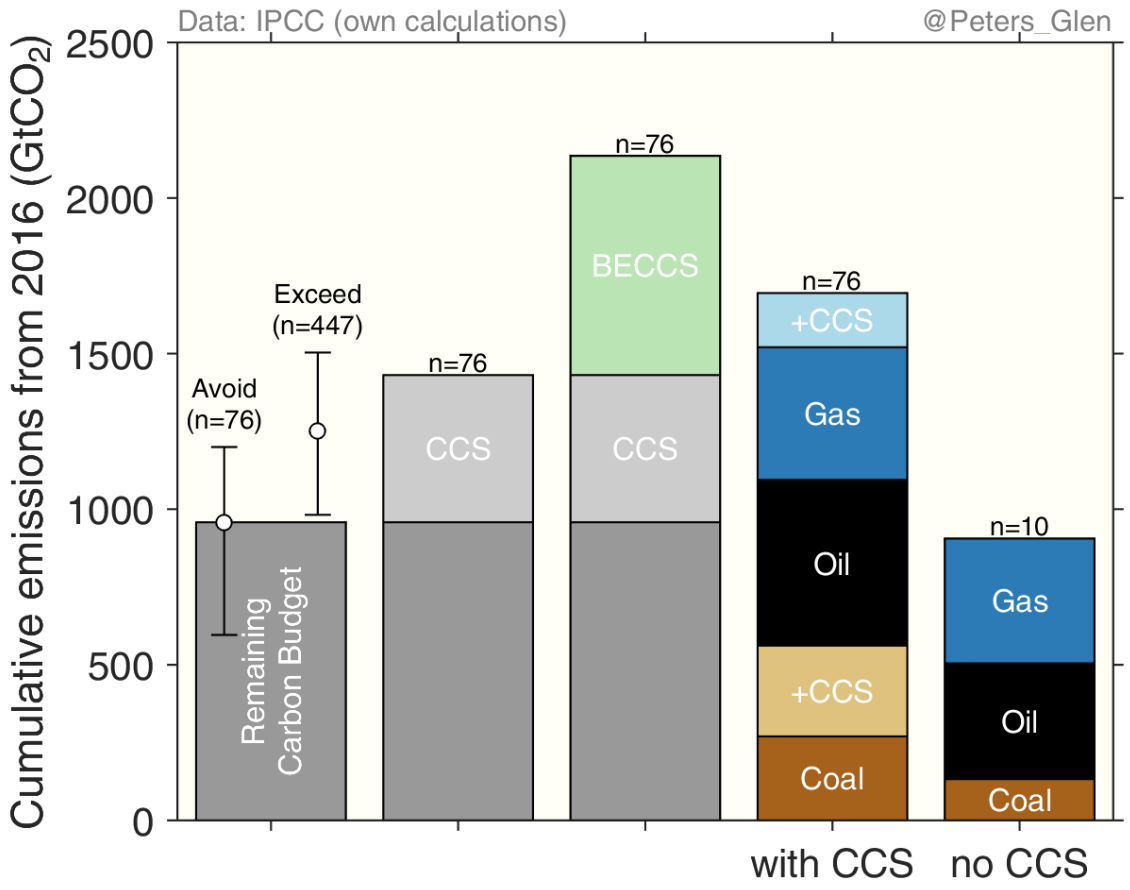
Source: IIASA AR5 Scenario Database (own calculations)

Consequences of CCS and BECCS

Carbon Capture and Storage (CCS) and “Negative Emissions” allows the budget to be exceeded

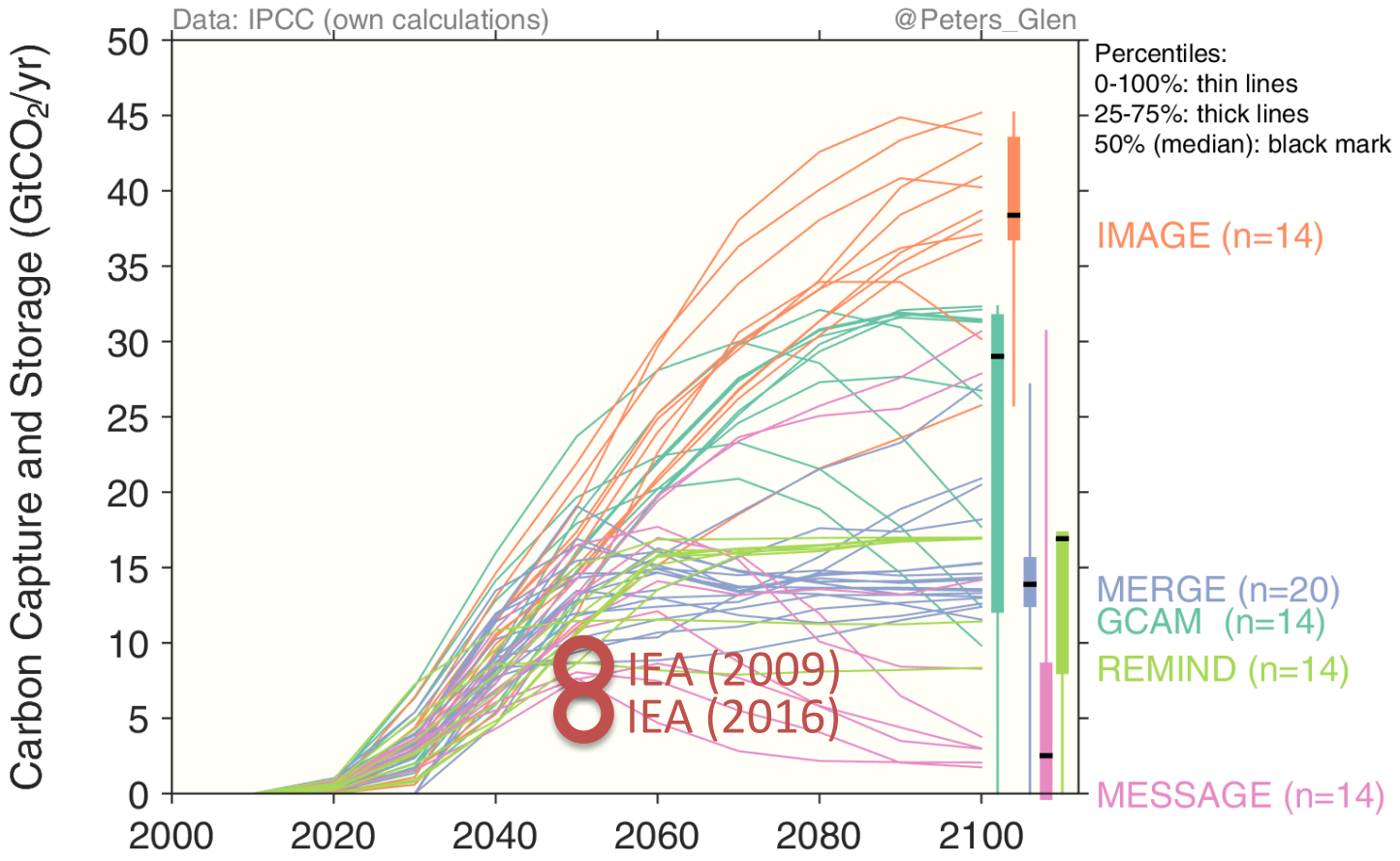


Note: Totals are not always consistent because medians are not additive, and some columns have different numbers of scenarios

Source: Peters (2016)

Carbon Capture and Storage

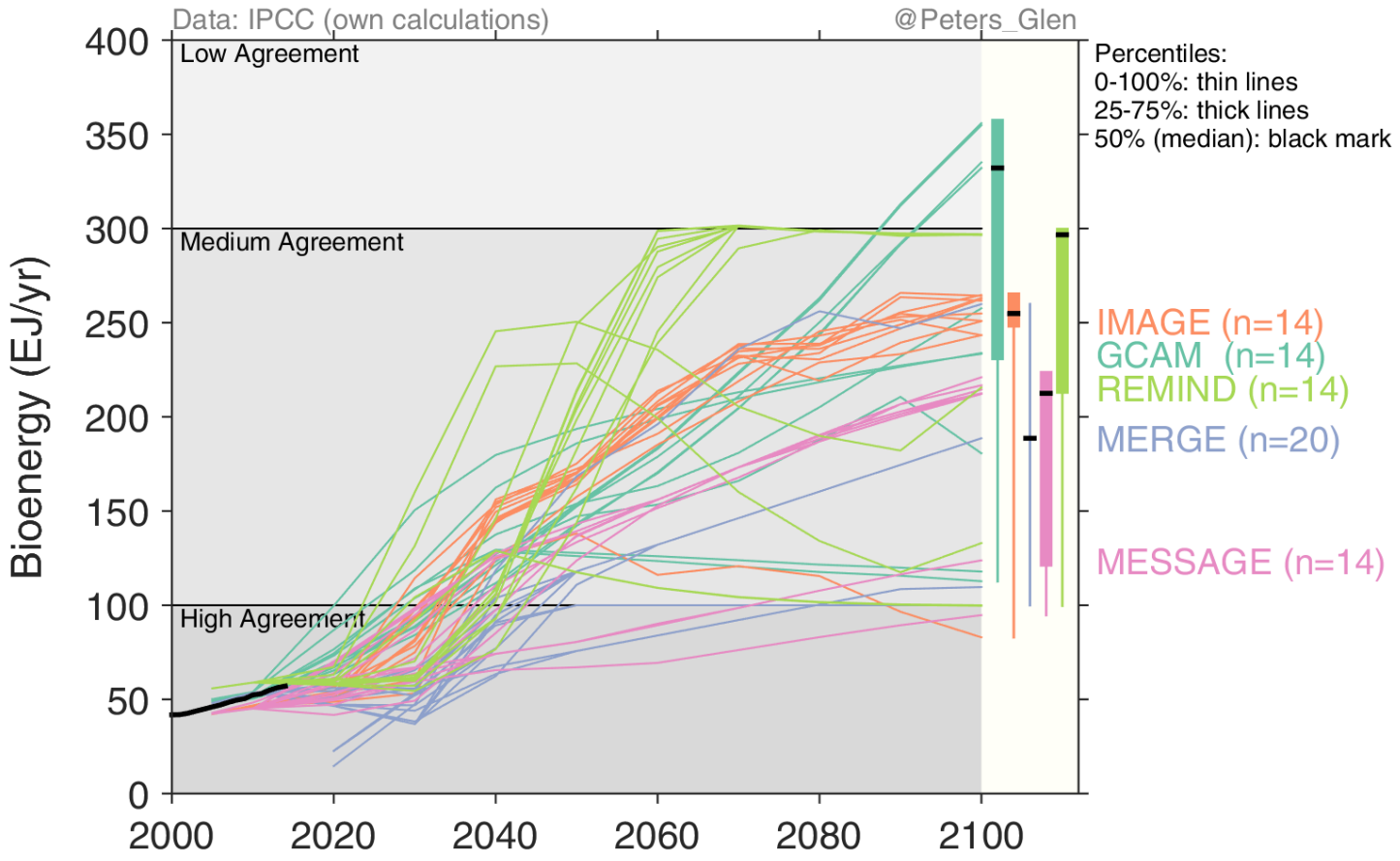
A typical CCS facility today is about 1MtCO_2/yr storage (e.g., Sleipner) → 1000 facilities per 1GtCO_2
Scenarios assessed by the IPCC use more CCS than IEA (though, IEA is a 50% scenario)



Today, there is capture *capacity* of 28MtCO_2/yr, but only about 7.5MtCO_2/yr is verified as stored (IEA).
Source: Based on IIASA AR5 Scenario Database

Bioenergy

Today, robust scientific debate over 1EJ/yr, scenarios are 100-300EJ/yr between 2050 and 2100
Need to have a clear and accessible narrative on why 100-300EJ/yr is carbon neutral



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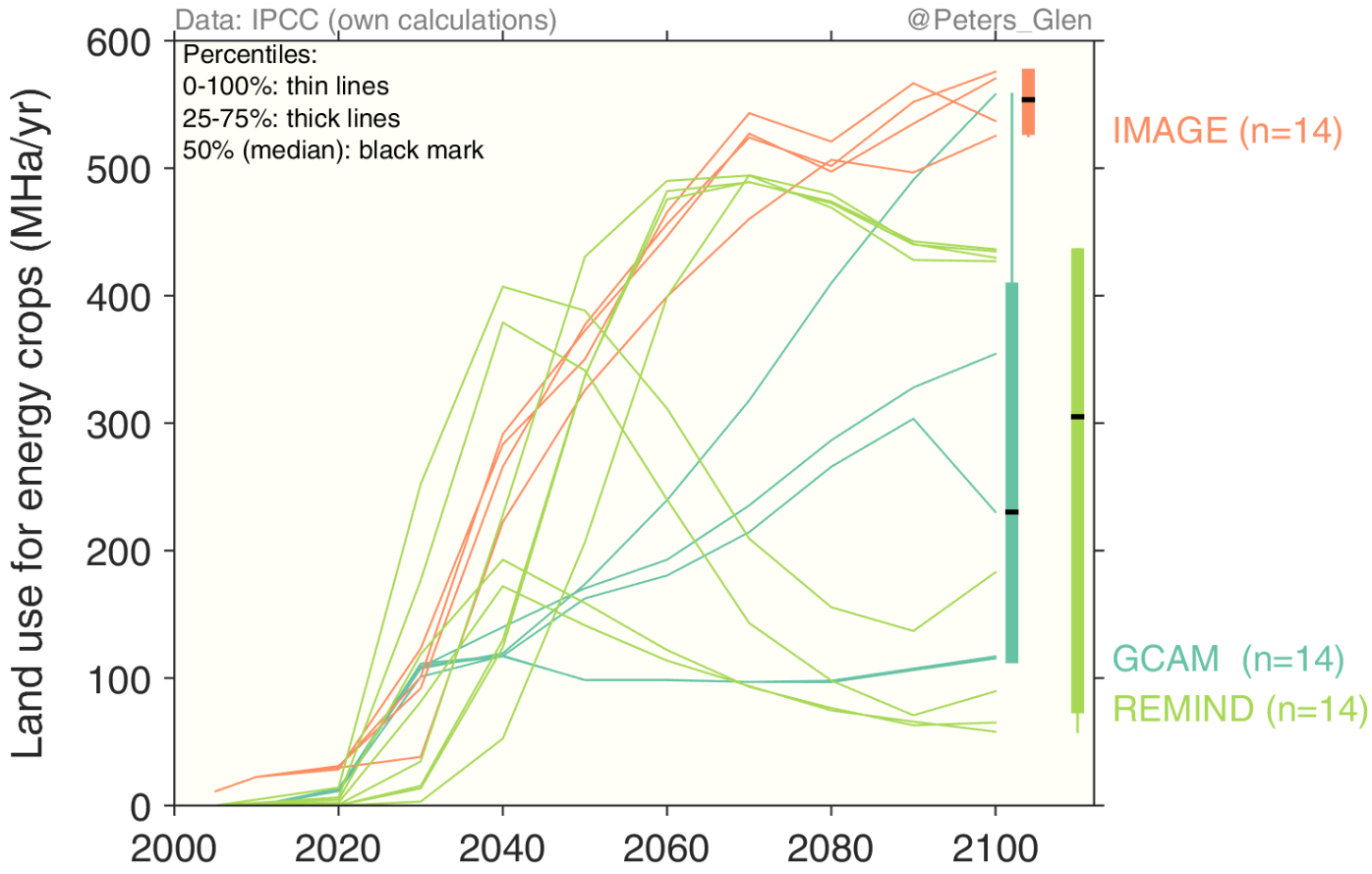
Source: Based on IIASA AR5 Scenario Database

Land use for energy crops

This is direct output from the AR5 scenario database, land areas comparable to the size of India
Some in the IAM community have critiqued figures like this as misleading.



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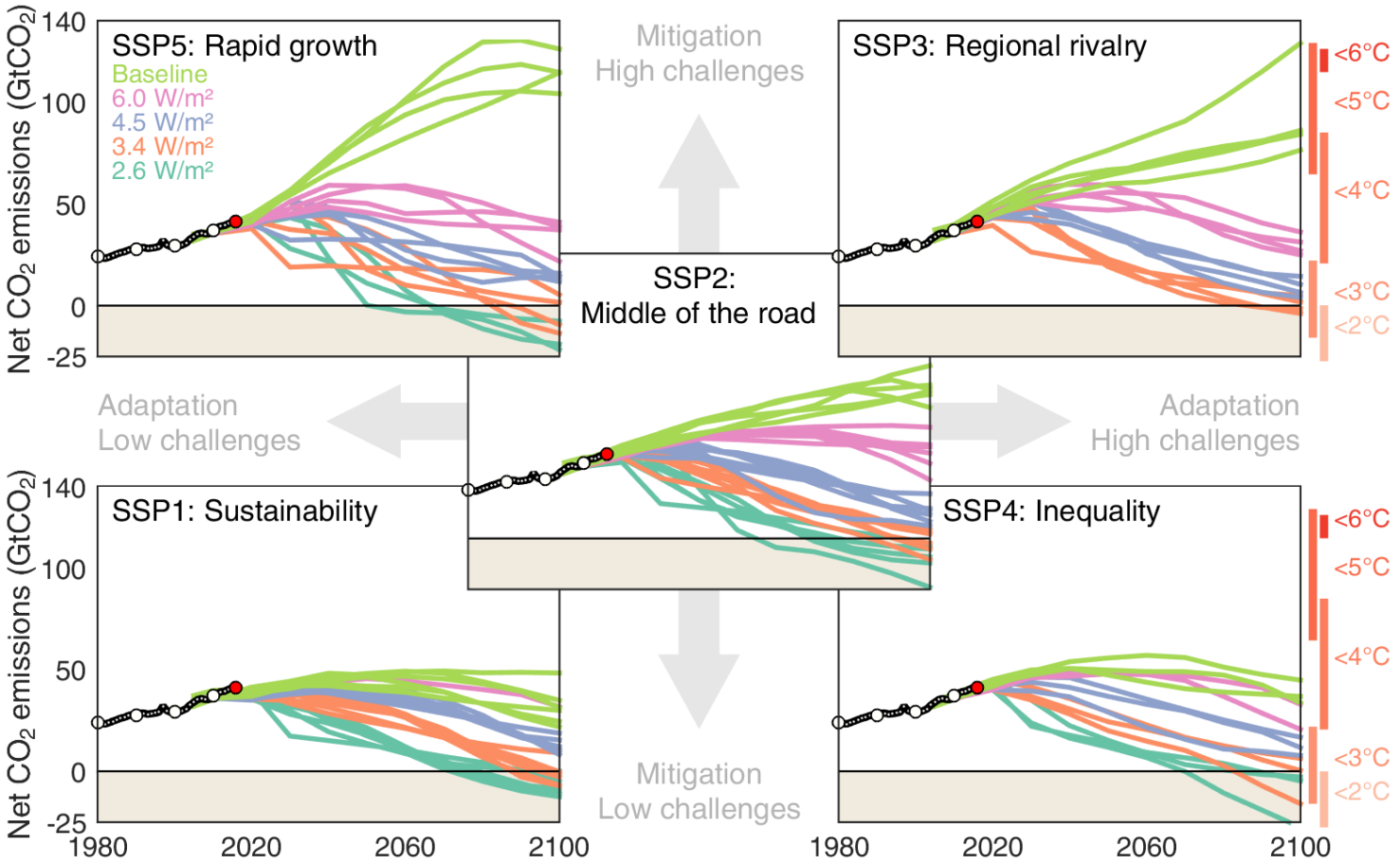
Source: Based on IIASA AR5 Scenario Database

New generation of emission scenarios

In the lead up to the IPCC's Sixth Assessment Report new scenarios have been developed to more systematically explore key uncertainties in future socioeconomic developments



Five Shared Socioeconomic Pathways (SSPs) have been developed to explore challenges to adaptation and mitigation. Shared Policy Assumptions (SPAs) are used to achieve target forcing levels (W/m^2).

Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2016

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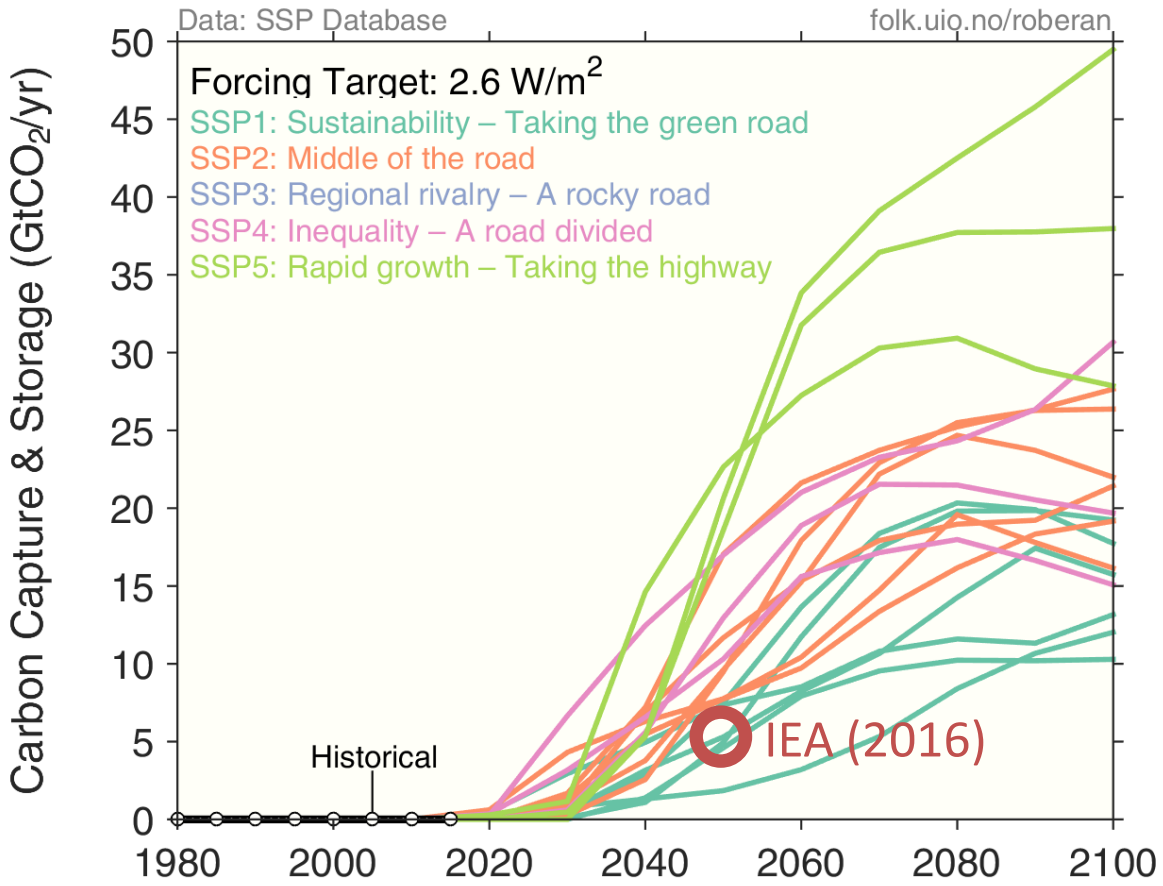
CCS in new generation of scenarios

Shared Socioeconomic Pathways (SSPs) are different narratives for global development
Nevertheless, CCS is just as high in the next generation of scenarios to be assessed by the IPCC



This data was estimated, as it is not available in the public SSP database

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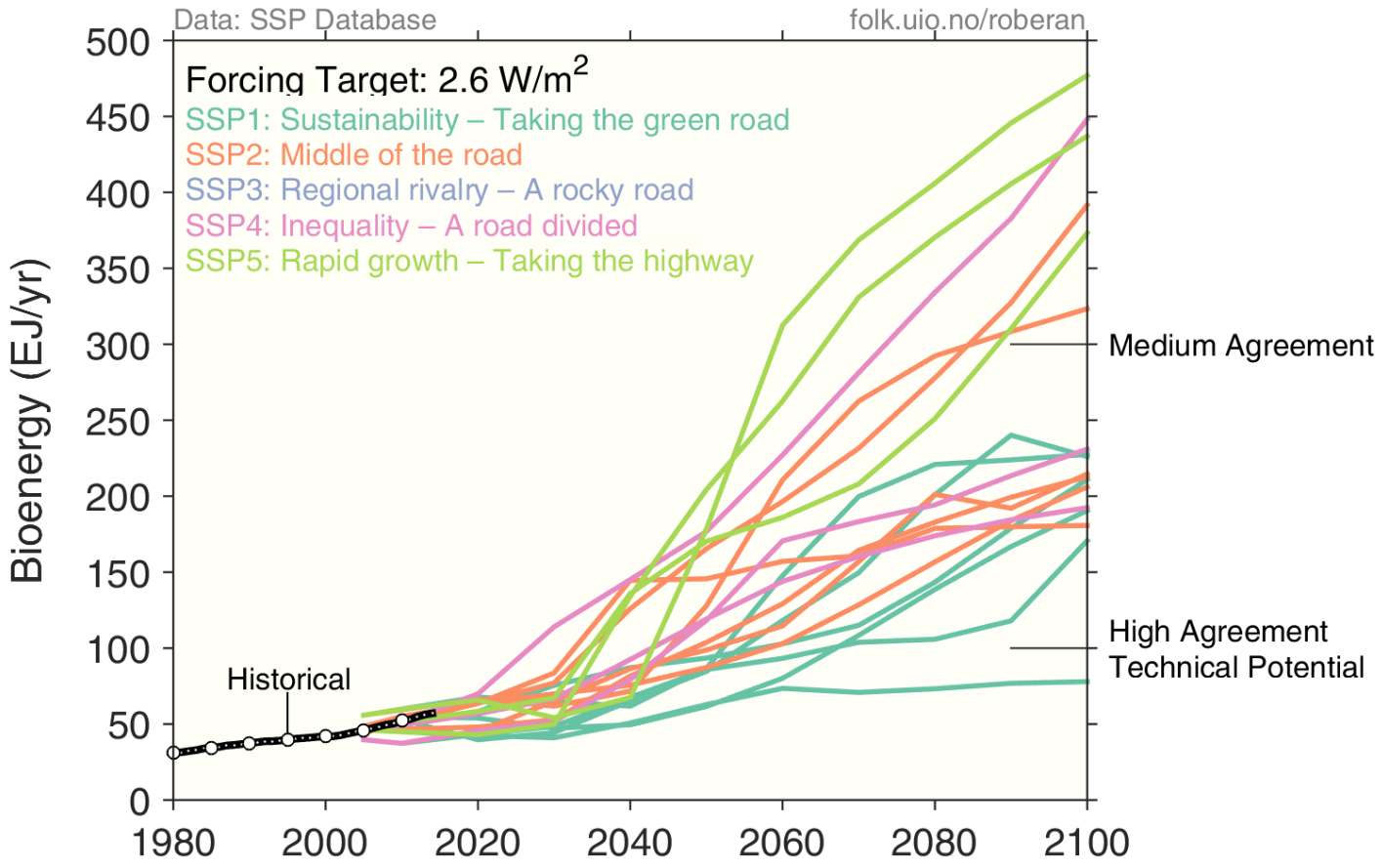
Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2016

Bioenergy in new generation of scenarios

The next generation of scenarios seems to use more bioenergy
Levels may be reasonable, but more robust debate needed on scale and impact of bioenergy



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Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2016

Why is bioenergy “carbon neutral”?

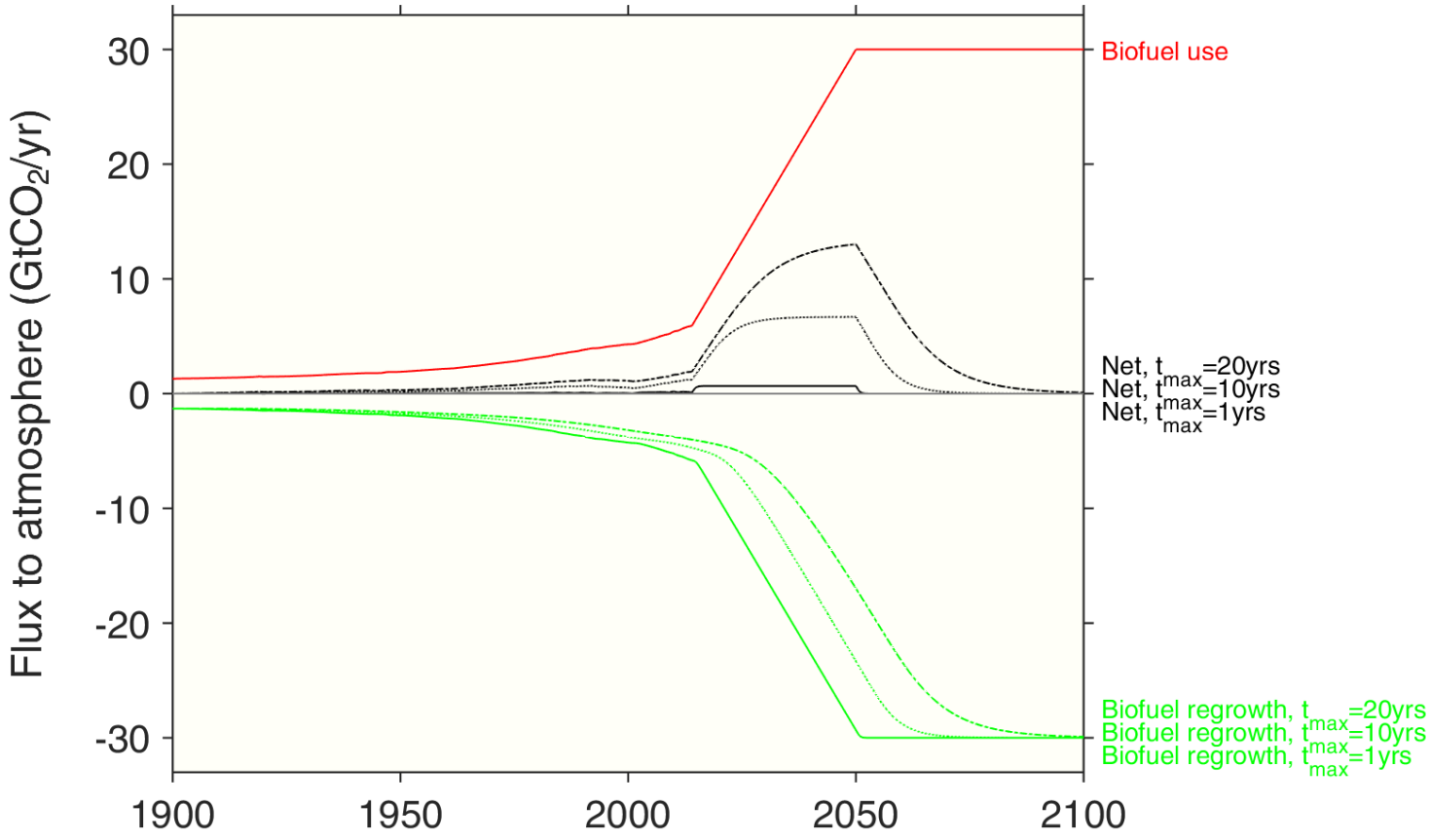
A lessor of two evils?

Thought experiments

- Start with historical bioenergy use, and assumed future
- Use simple growth curves
  - Log-normal
  - Linear with a “long” tail to mimic soil losses.
- Look at fluxes in and out of carbon pool
  - Using simple convolution approach
  - Assumes biomass standing (I think ok over history)
- All a thought experiment

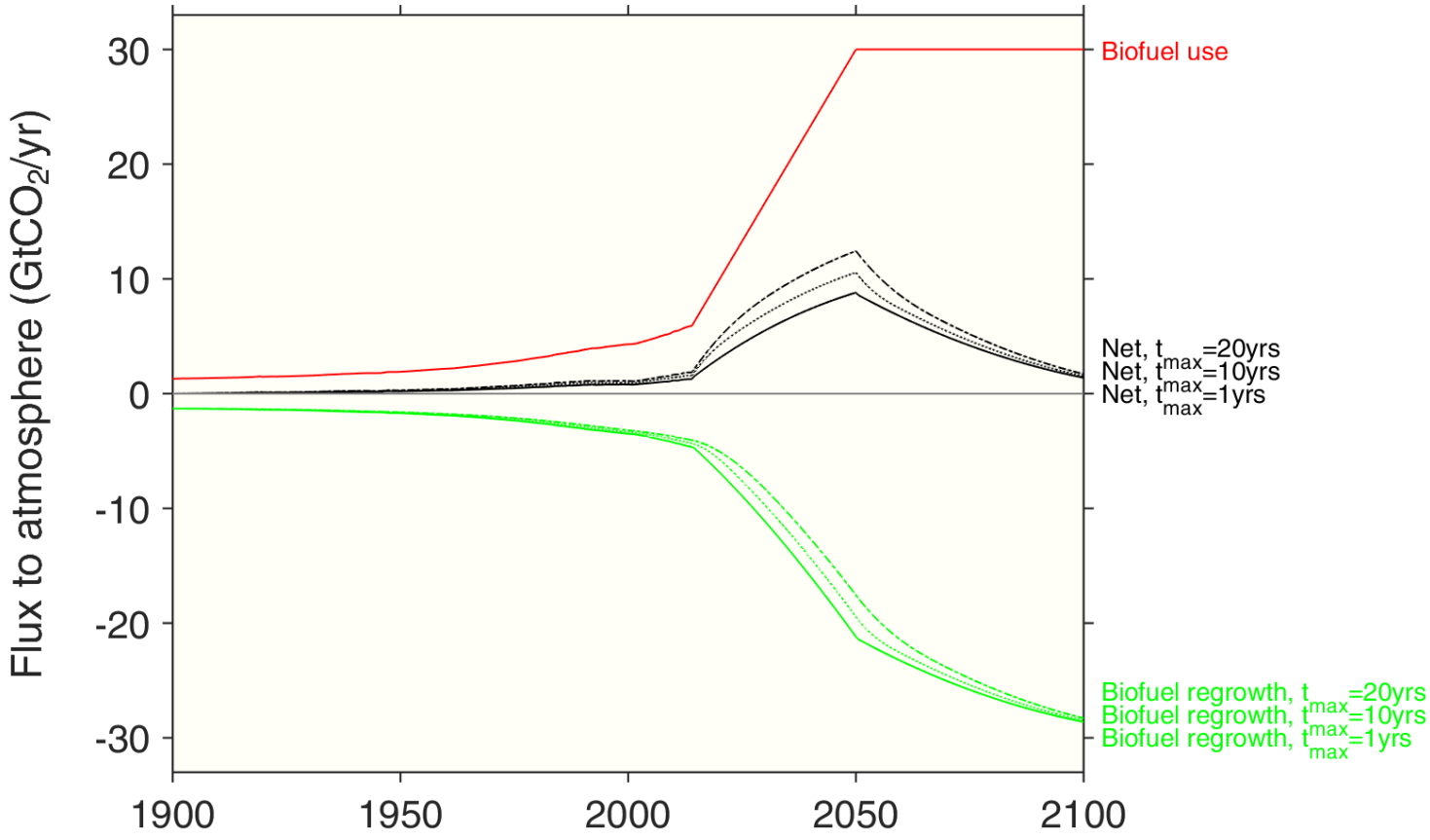
Bioenergy use and growth (standard)

Historical bioenergy use with future scenario (red), growth curves with three different peaks
Net carbon flux depends on growth curve and ramp rate, eventually carbon neutral



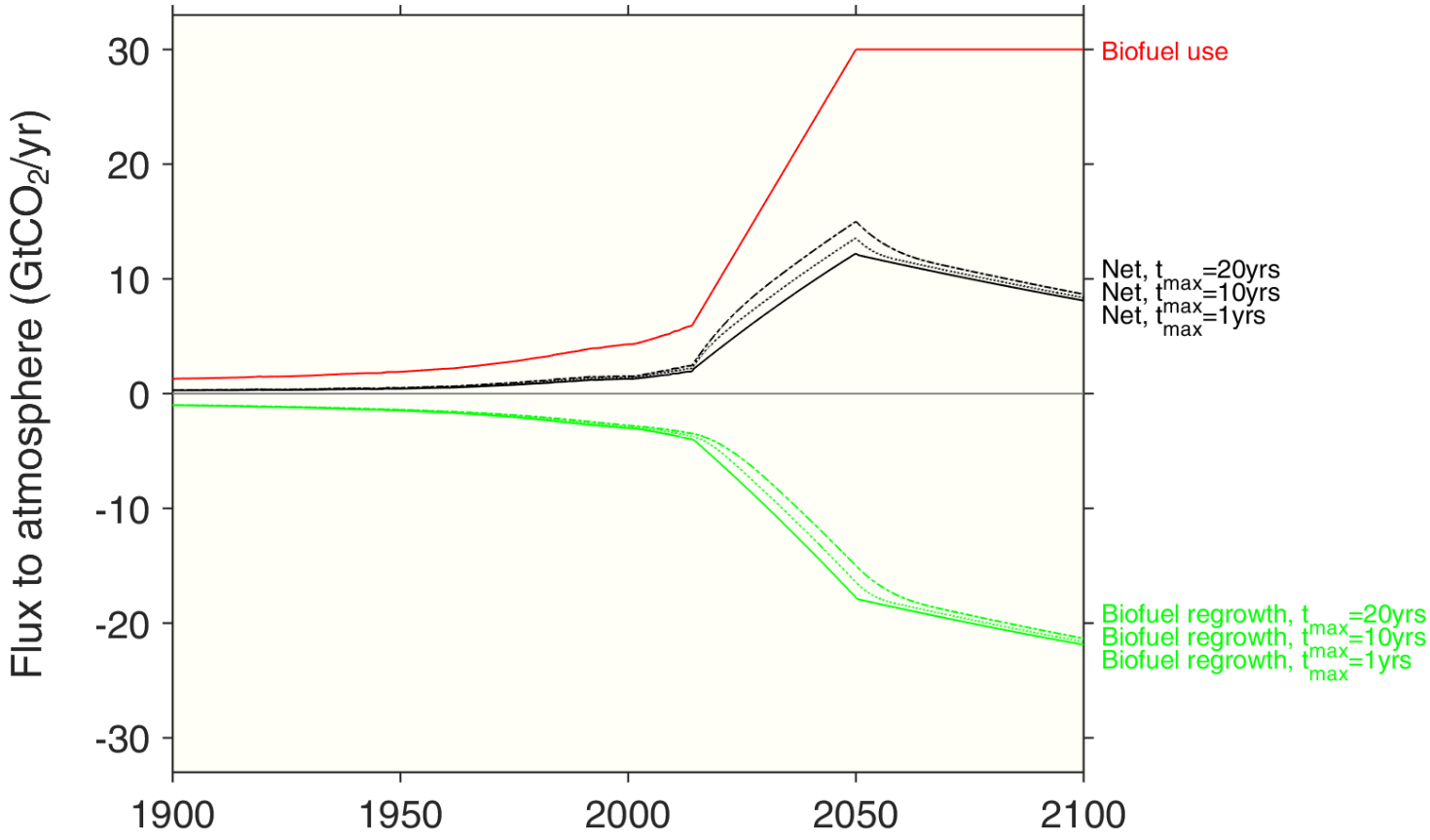
Bioenergy use and growth (tail)

Many argue there is overall loss of carbon, at least, much slower recovery. Growth curve to zero after 100 years. Means it takes longer to reach a carbon neutral balance.



Bioenergy use and growth (long tail)

Many argue there is overall loss of carbon, at least, much slower recovery. Growth curve to zero after 300 years. Means it takes longer to reach a carbon neutral balance.



Carbon neutrality

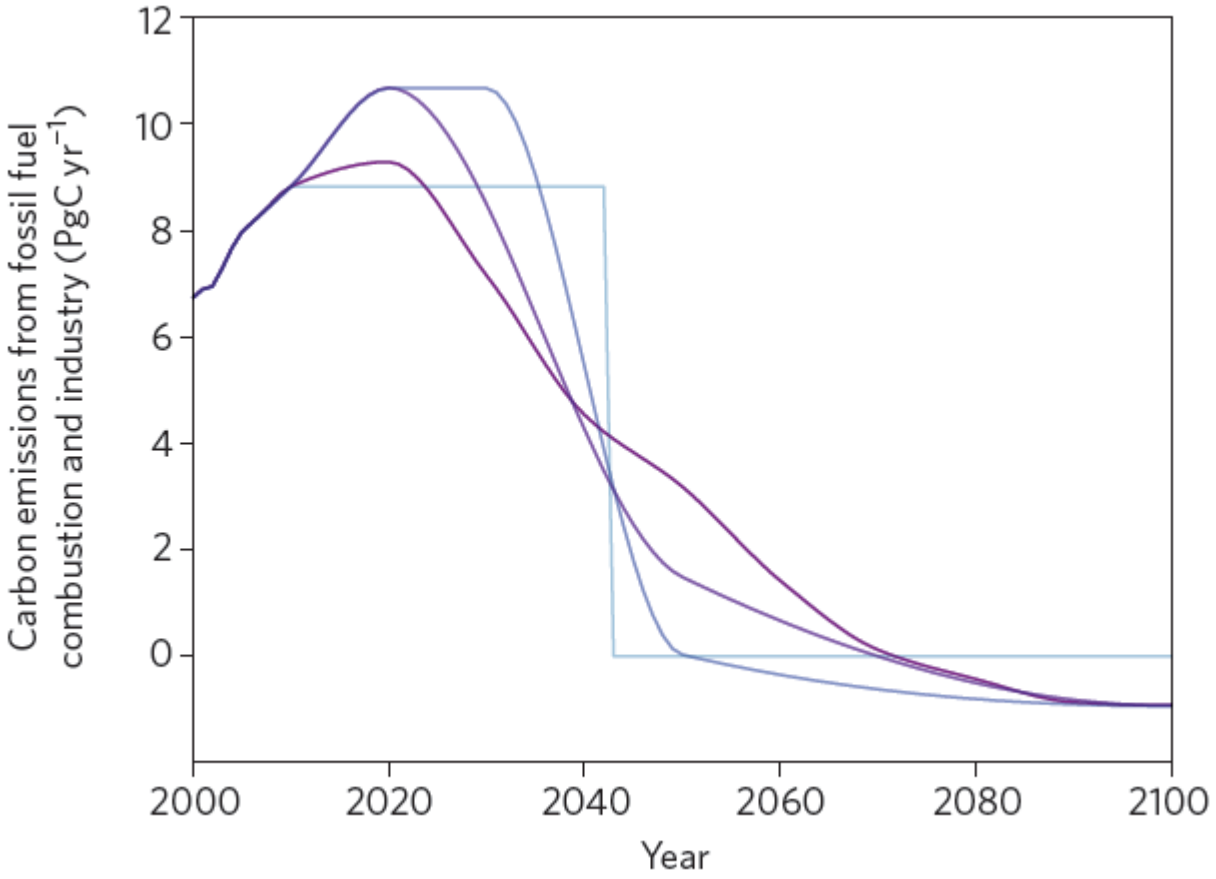
- If not carbon neutral, then the system would diverge.
  - Cumulative fossil fuel and land use emissions: 2050GtCO_2
  - Cumulative bioenergy use: 400GtCO_2
- Either we don't understand the climate system, or bioenergy is carbon neutral *after a time frame*

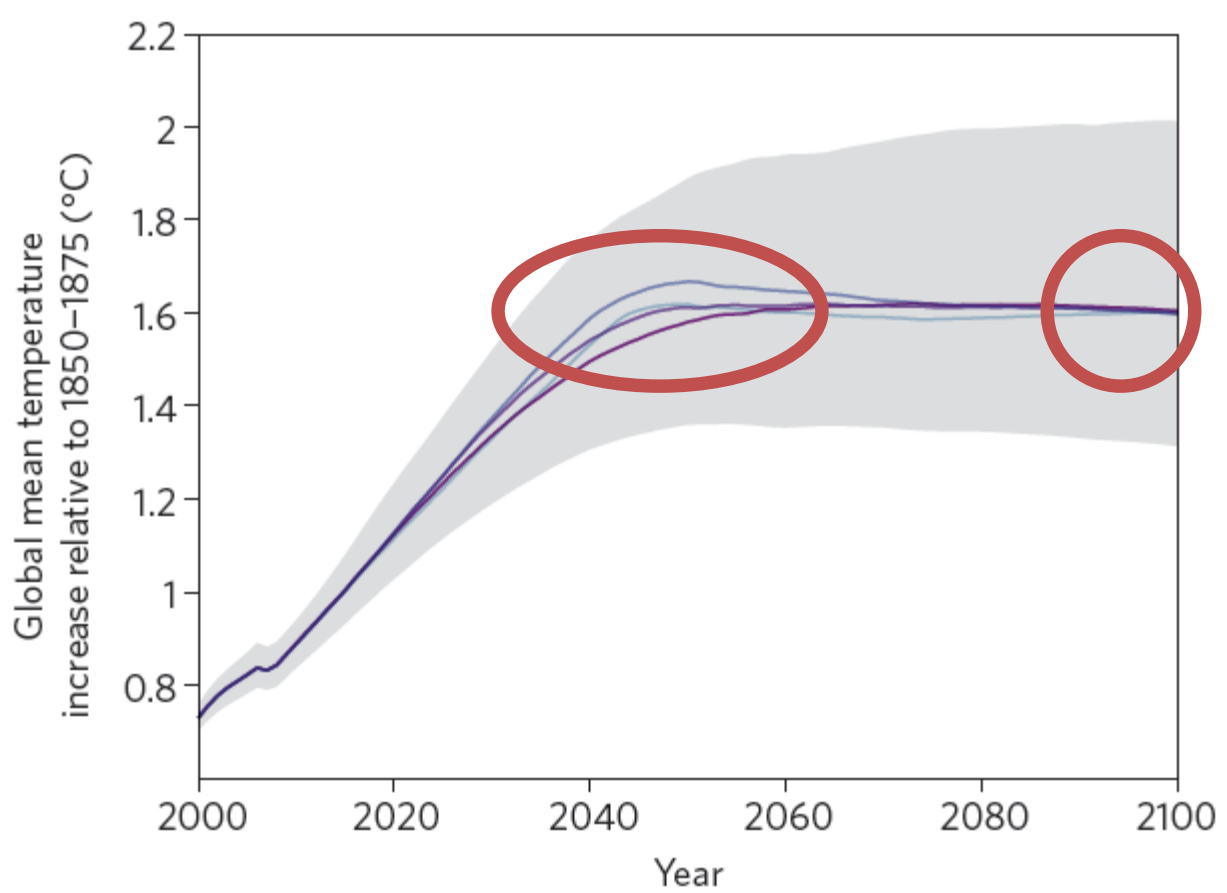
- But, there is elevated CO_2 for a time period…

Cumulative emissions

The pathway *does* matter!

Cumulative emissions is a very aggregated concept. Yes, temperature proportional to cumulative CO_2, but…
If worried about tipping points, you would take early reductions!





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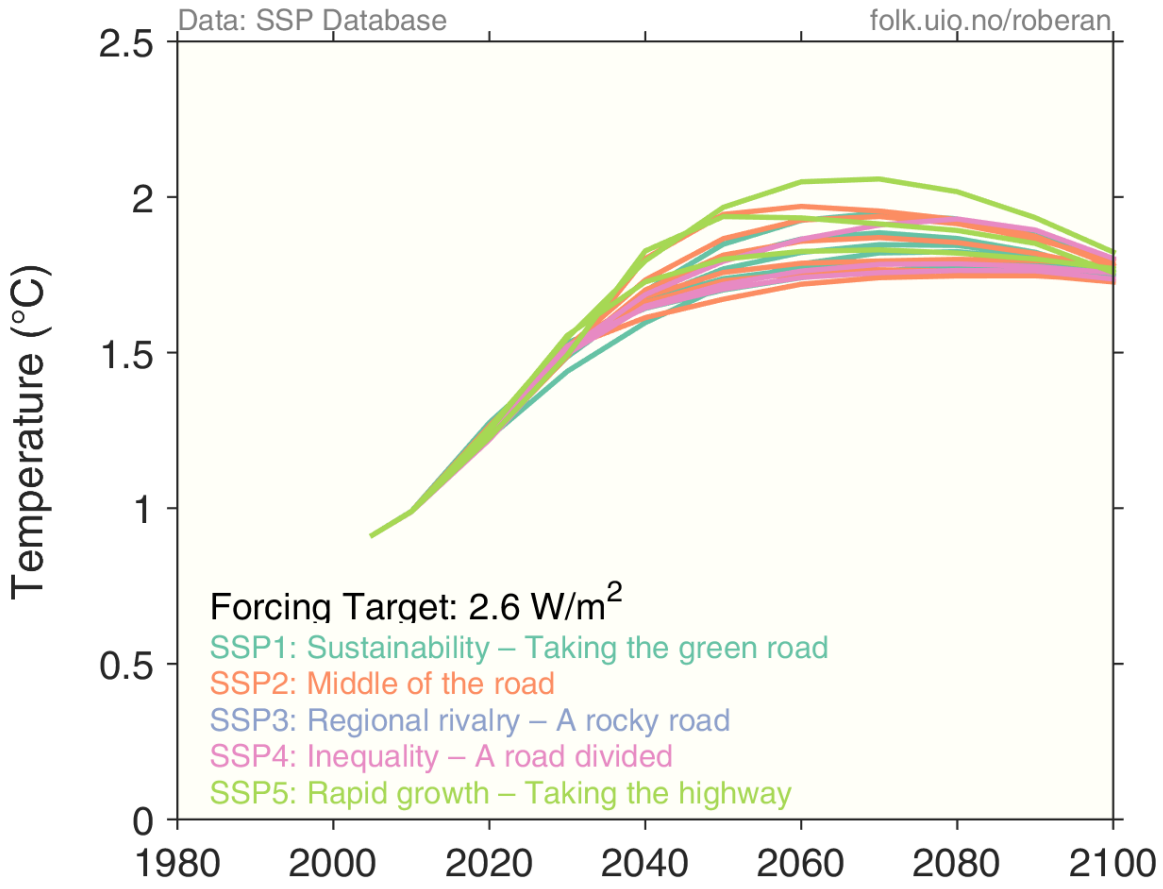
Source: Rogelj et al (2016)

Temperature overshoot

The existence of net-negative emissions really ensures temperature overshoot, but modest overshoot
Median in 2100 is 1.76°C, median 2000-2100 is 1.84°C, maximum overshoot is 0.2°C (2.06-1.82)



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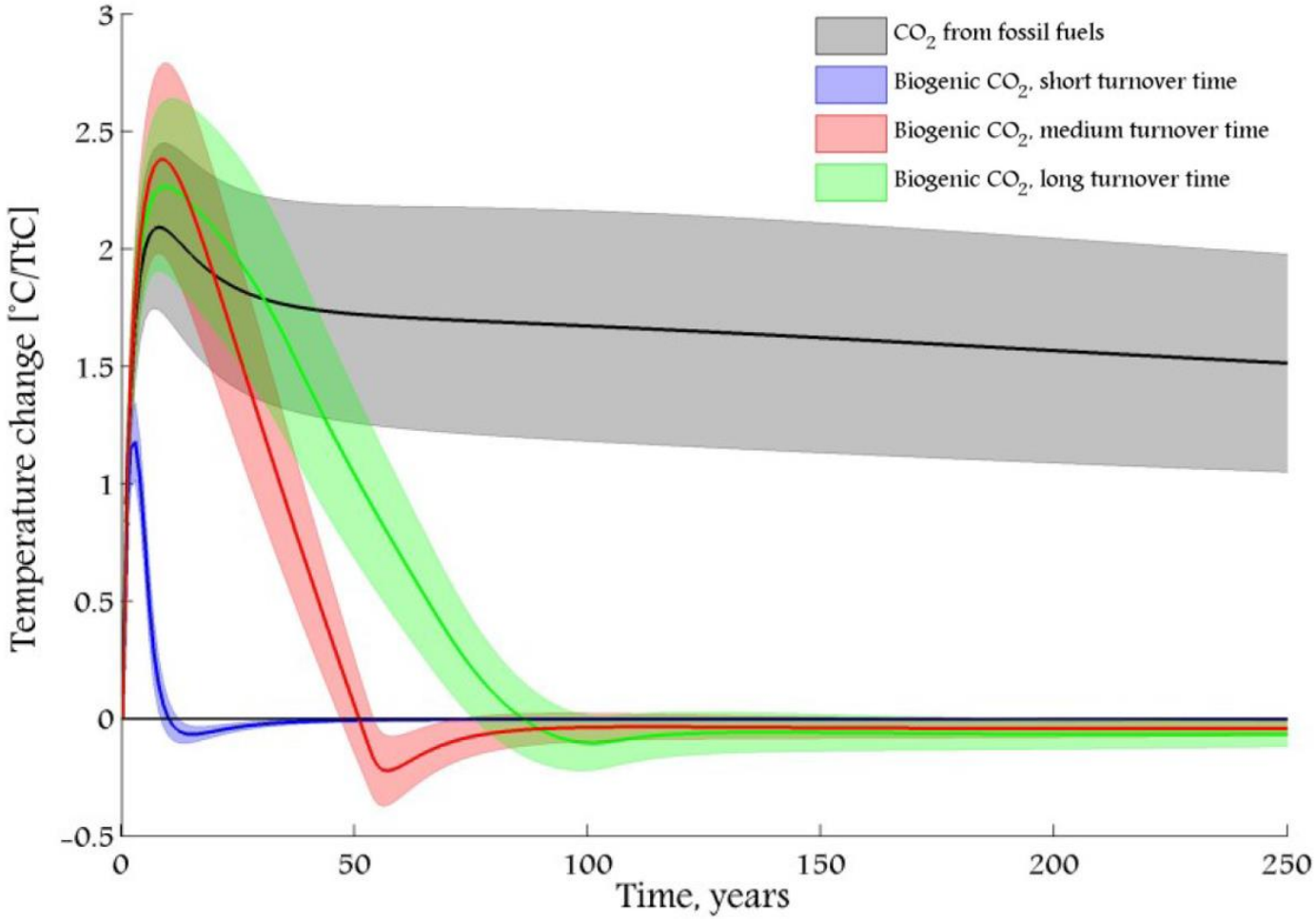
Source: Riahi et al. 2016; IIASA SSP Database; Global Carbon Budget 2016

GTP for biomass

Cumulative emissions are zero, temperature is (eventually) zero, but pathway obviously matters!
Temperature is negative after a period, how should we interpret this (Artifact? Realistic?)



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Source: Cherubini et al (2014)

Experimental Set Up

Set up	Instantaneous Forcing and Temperature	Integrated Forcing and Temperature
Single plot, harvest first	Warming $T<T_1$ Cooling $T>T_1$	Warming
Single plot, harvest second	Cooling $T<T_2$ Warming $T>T_2$	Cooling
Infinite plots, harvest first	Warming	Warming
Infinite plots, harvest second	Cooling	Cooling

All else equal, all options better than fossil fuels…

Experimental Set Up

Set up	Instantaneous Forcing and	Integrated Forcing and
Single		
Single		
Infinite plots, harvest first	Warming	Warming
Infinite plots, harvest second	Cooling	Cooling

Landscape view perspective, if zero stock-change over time:

- Moving from forest to forestry warms, but better than fossil fuels
- Moving from cropland to forestry cools

All else equal, all options better than fossil fuels…

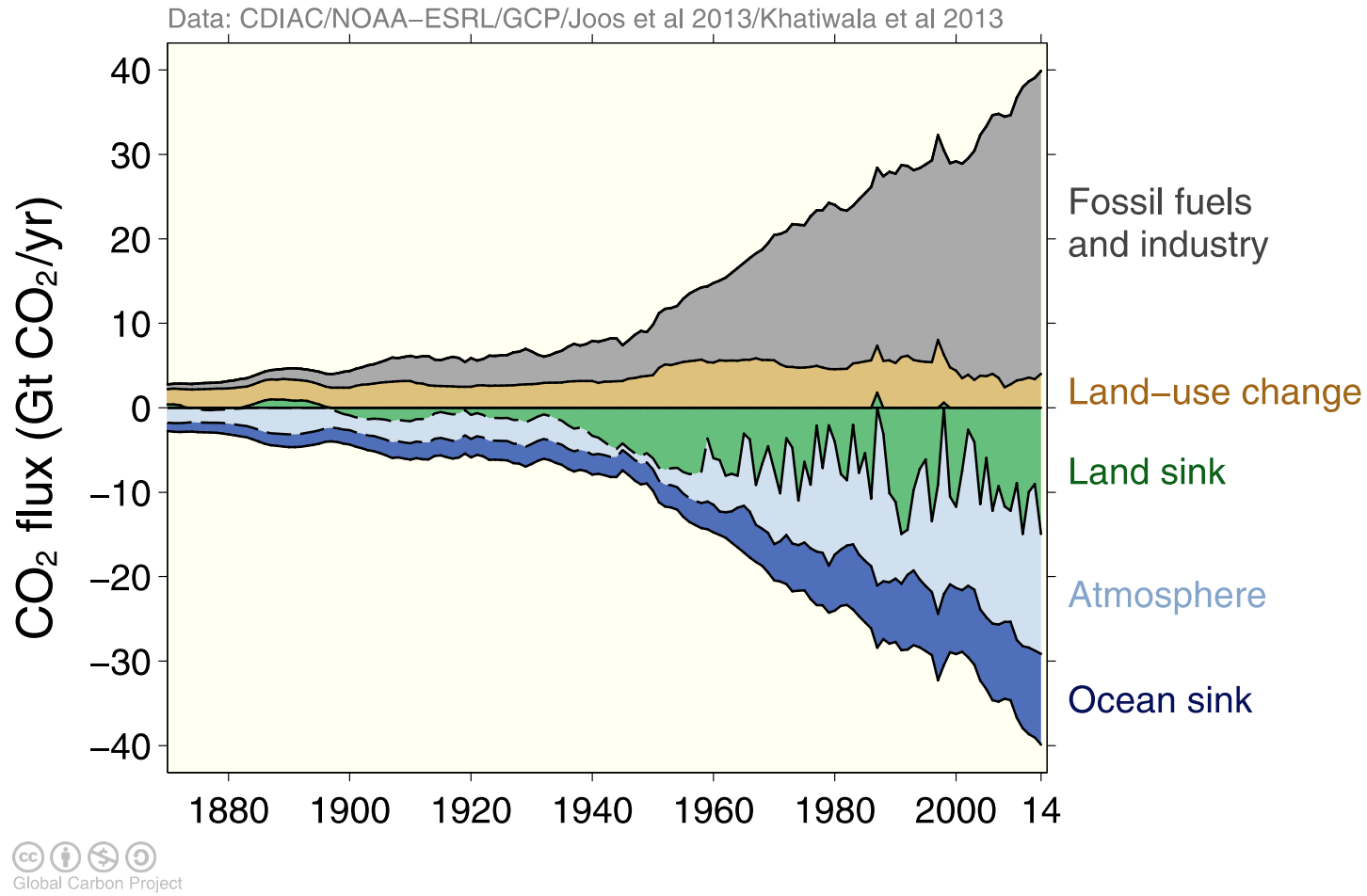
LCA is (generally) marginal processes

- If bioenergy was “small”, say 10% of energy mix
  - Then a “reasonable” payback period is ok
- If the LCA was 300EJ/yr bioenergy
  - Then one really needs to look at the transition (earlier figures)
- It is well accepted (or should be)
  - Use multiple metrics… C, sum(C), RF, sum(RF), T, sum(T)
  - Do a trade-off analysis
- How non-linear does the system have to be for a small overshoot to matter?

Accounting issues

Global Carbon Budget

Carbon dioxide sources from fossil fuels, industry, and land-use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean



Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2015; Global Carbon Budget 2015

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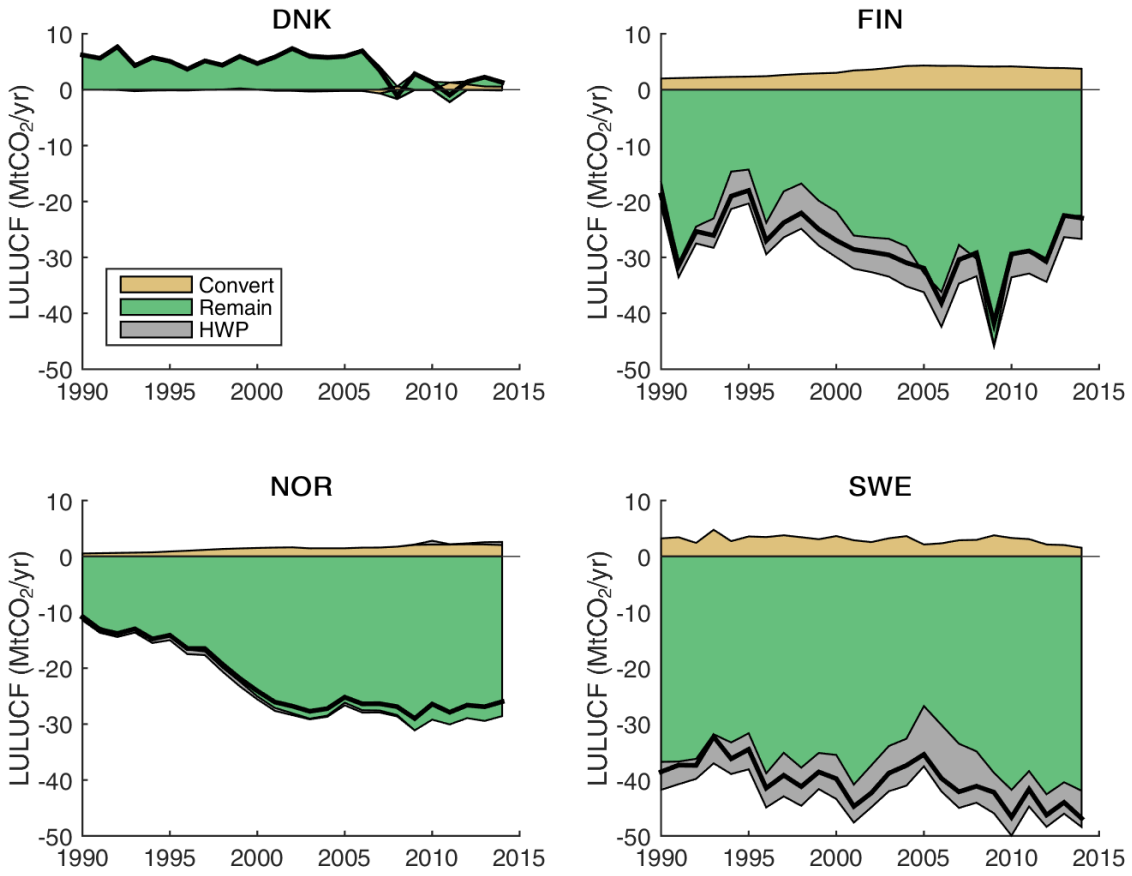
CO_2 from LULUCF

UNFCCC and carbon cycle community have very different definitions

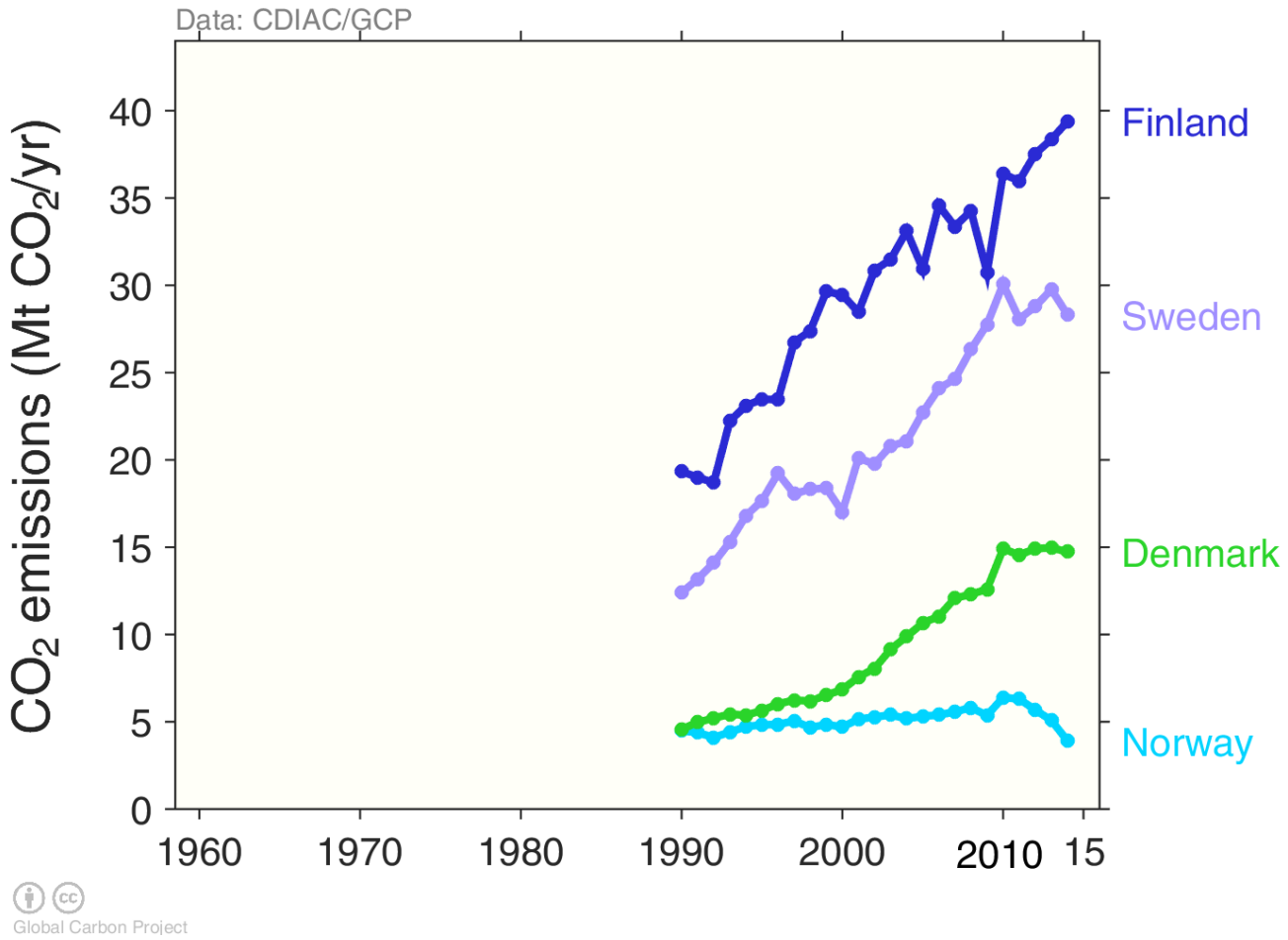
Convert: Land-use change; Remain: A subset of the land sink; HWP: Harvested Wood Products



Source: CDIAC; UNFCCC National Inventory Reports; own calculations

CO_2 from biomass (memo)

CO_2 from biomass is a sizeable share of CO_2 flux in the Nordics, assumed carbon-neutral with flux in LULUCF sector
Could this lead to an attribution problem in regional carbon budgets?



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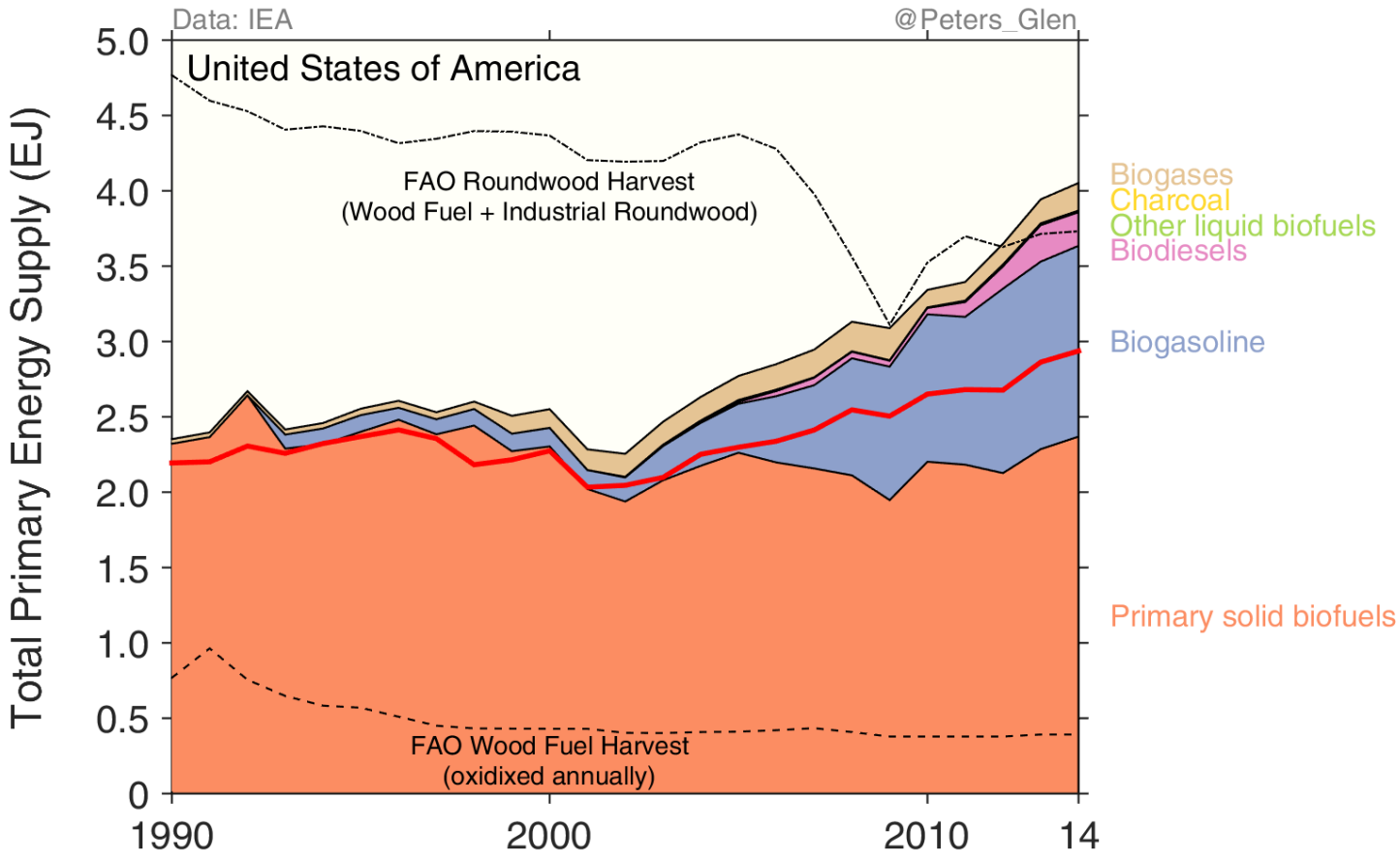
Source: UNFCCC National Inventory Reports; own calculations

Data inconsistencies

IEA and UNFCCC bioenergy use a similar, but a long way to bridge with FAO data
FAO is often used in carbon cycle models



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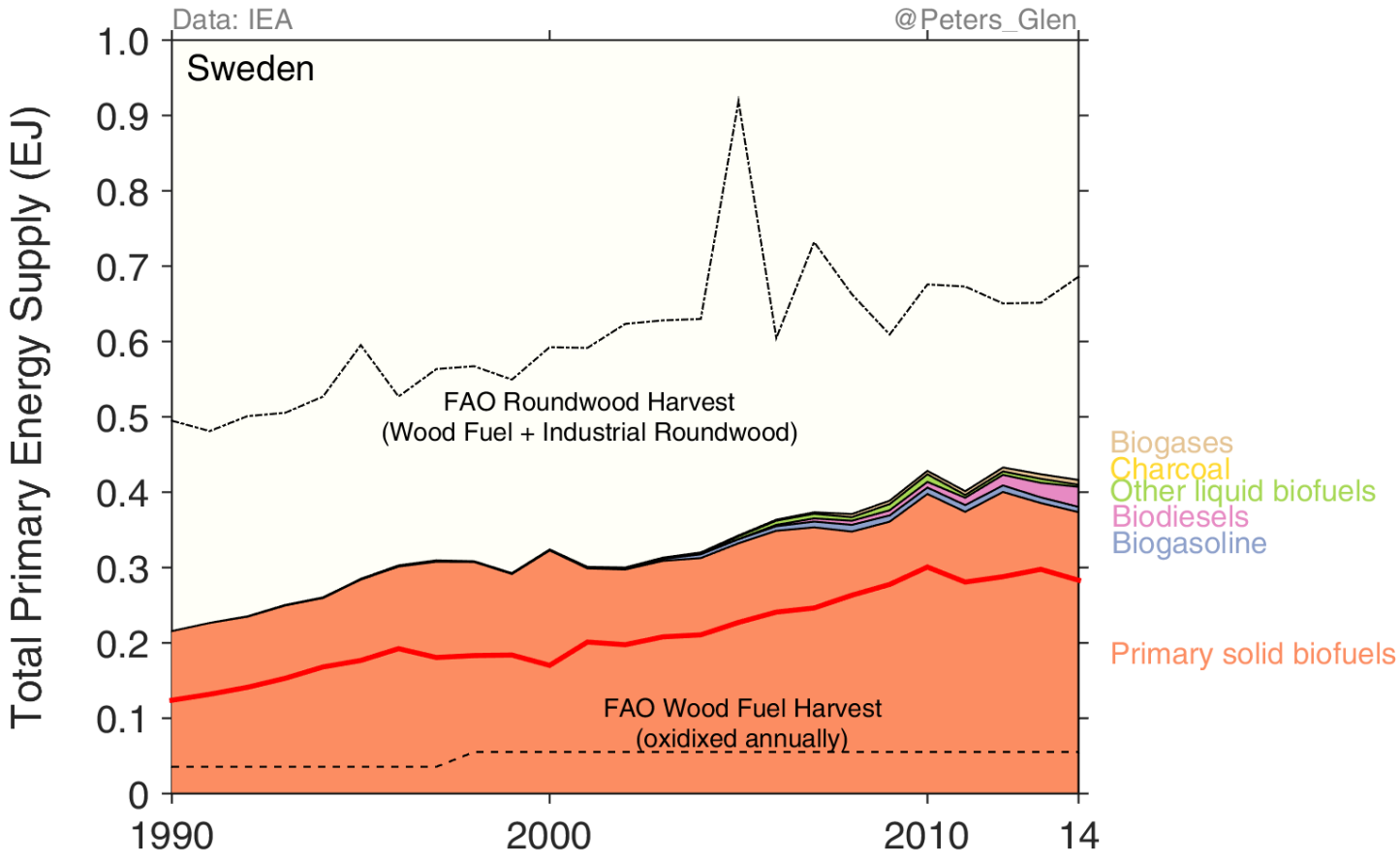

Source: UNFCCC National Inventory Reports; own calculations

Discussion

Discussion

- Emissions scenarios use about 300EJ/yr bioenergy
  - Five times higher than today's usage
  - Carbon implications if LUC and in transition phase
- Cumulative emissions a robust concept
  - Timing does matter at a small scale
  - Need to think about scale, and metric trade-offs
- Modelling systems not well adapted to large-scale bioenergy

Trade-offs

- We seem set on “well below 2°C”. Ok, but trade-offs
- Bioenergy leads to increase in food prices?
  - This does not affect the carbon balance
  - Advanced biofuels may not effect food prices
    - (e.g., we deploy electric cars even if based on coal power)
  - Counterfactual? 3°C and greater impacts on food prices?
    - (Mitigation models general don’t trade off with climate impacts)
  - Alternatives: Wind (birds/land), coal with CCS, nuclear, …
- We need a narrative to discuss trade-offs…

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