The Role of Negative Emission Technologies

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MIT Joint Program on the Science and Policy of Global Change

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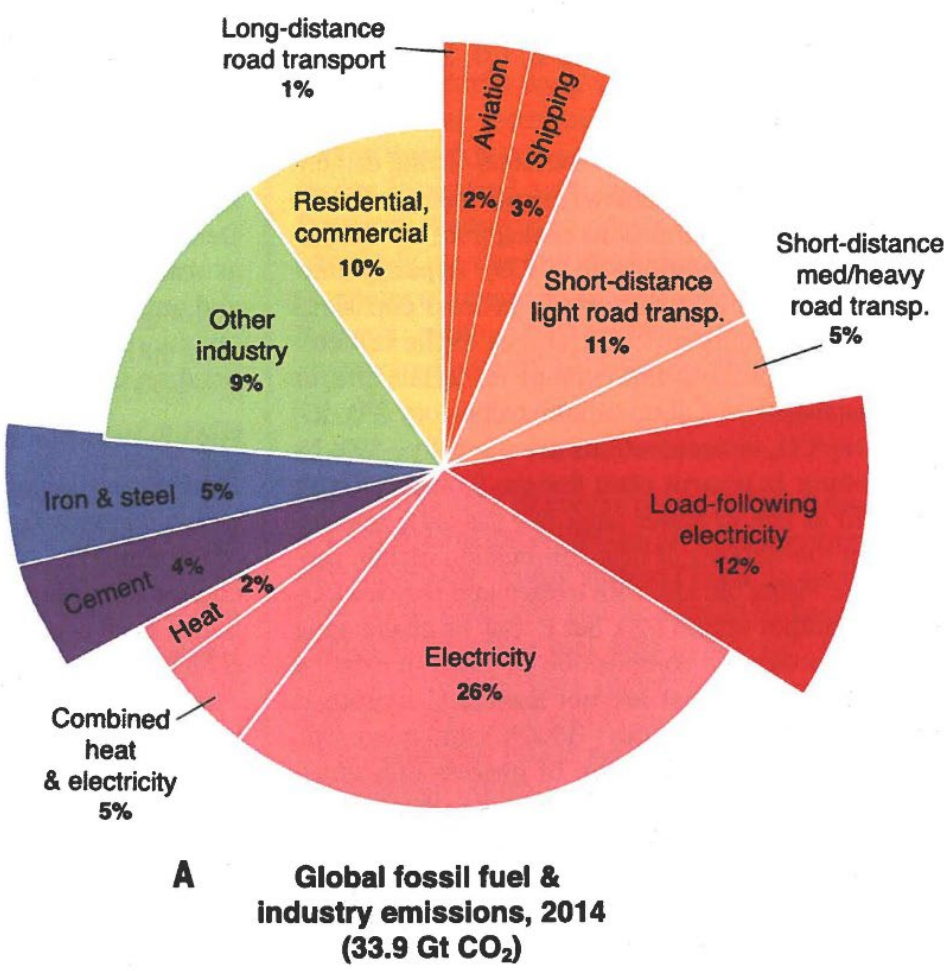
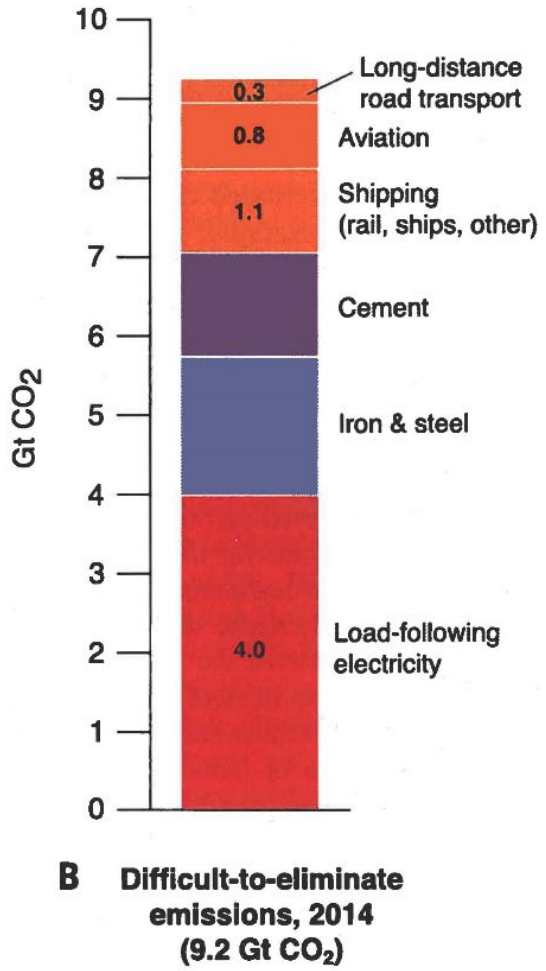
Based on work done with: Mathilde Fajardy, Howard Herzog, Niall Mac Dowell, Angelo Gurgel, Sergey Paltsev, Andrei Sokolov, Steve Rose, Martin Haigh, David Hone

Role of Negative Emission Technologies (NETs)

1) Offset difficult-to-eliminate emissions



A **Global fossil fuel & industry emissions, 2014 (33.9 Gt CO_2)**



B **Difficult-to-eliminate emissions, 2014 (9.2 Gt CO_2)**

Difficult-to-eliminate GHG emissions from other sectors (e.g., agriculture)

Total non-CO_2 GHGs in 2020 ~3 Gt CO_2e

Source: Davis et al., Science 360 1419 (2018)

Role of Negative Emission Technologies (NETs)

1) Offset difficult-to-eliminate emissions → **Net-Zero**

2) Carbon Removal → **Net-Negative**

3) Lower the costs of meeting a target → **Low-Carbon**

- Offset any emissions with marginal abatement cost > cost per ton negative emissions

Net-Zero	**Net-Negative**	**Low-Carbon**
Negative Emissions	Negative Emissions	Negative Emissions
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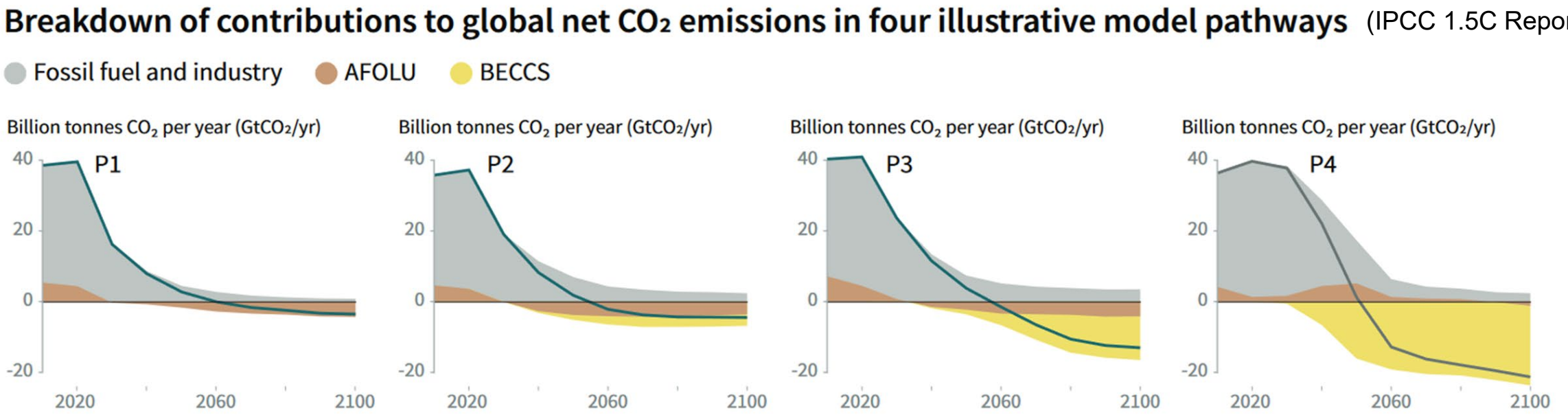
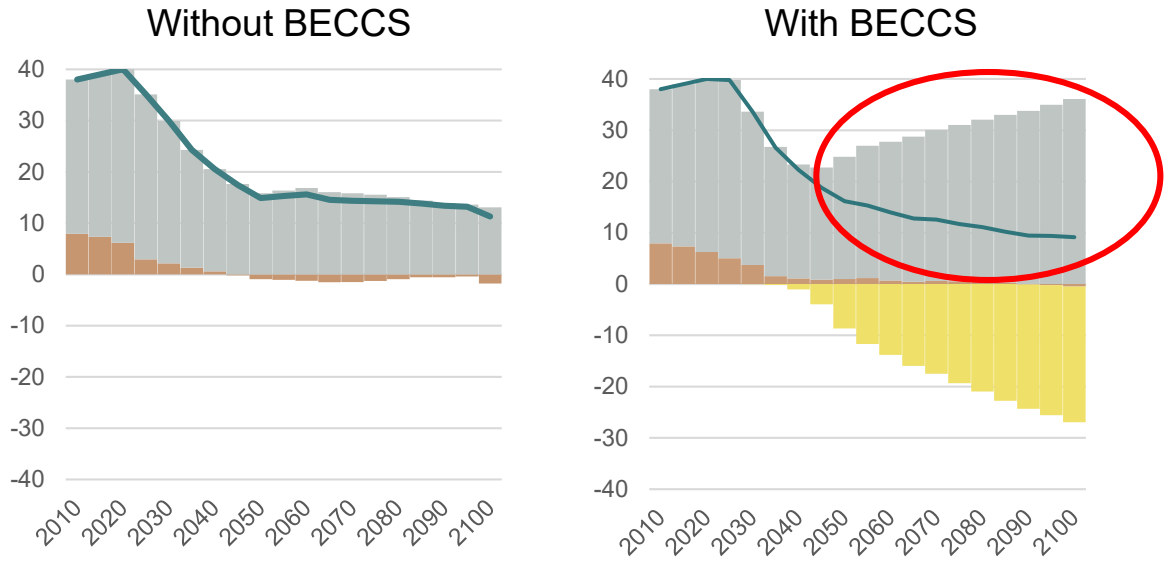
Released Emissions	Released Emissions	Released Emissions

Is low-carbon enough?

Net-Negative vs. Net-Zero vs. Low-Carbon



Additional Low-Carbon Pathways to 1.5C:



MIT-Imperial BECCS Study

Goal: Quantify potential scale of BECCS and its impact on the economy

- Considering technology and economics
- Excluding sustainability and political aspects

NEWS RELEASE

MIT News | Apr 04, 2021

Negative emissions, positive economy

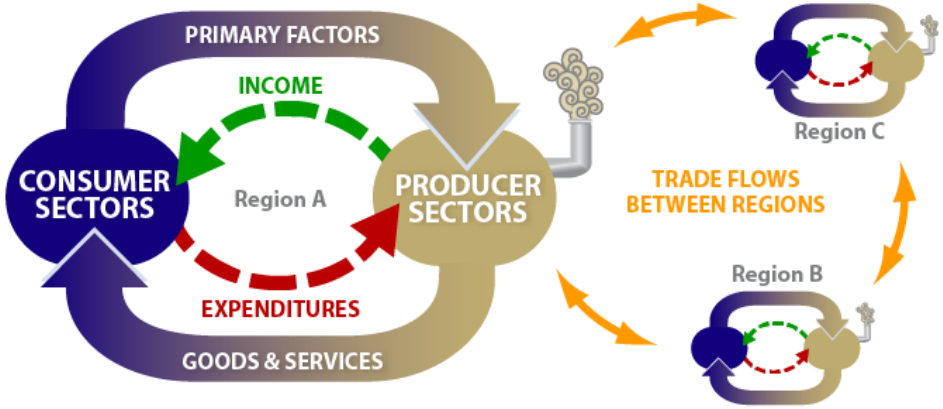
How bioenergy with carbon capture and storage (BECCS) could help stabilize the climate without breaking the bank

The long-term goals of the Paris Agreement—keeping global warming well below 2°C and ideally 1.5°C in order to avert the worst impacts of climate change—may not be achievable by greenhouse gas emissions-reduction measures alone. Most scenarios for meeting these targets also require the...

Fajardy M., J. Morris, A. Gurgel, H. Herzog, N. MacDowell and S. Paltsev (2021): The economics of bioenergy with carbon capture and storage (BECCS) deployment in a 1.5°C or 2°C world. *Global Environmental Change*, 68, 102262 (doi: 10.1016/j.gloenvcha.2021.102262) (https://www.sciencedirect.com/science/article/abs/pii/S0959378021000418)

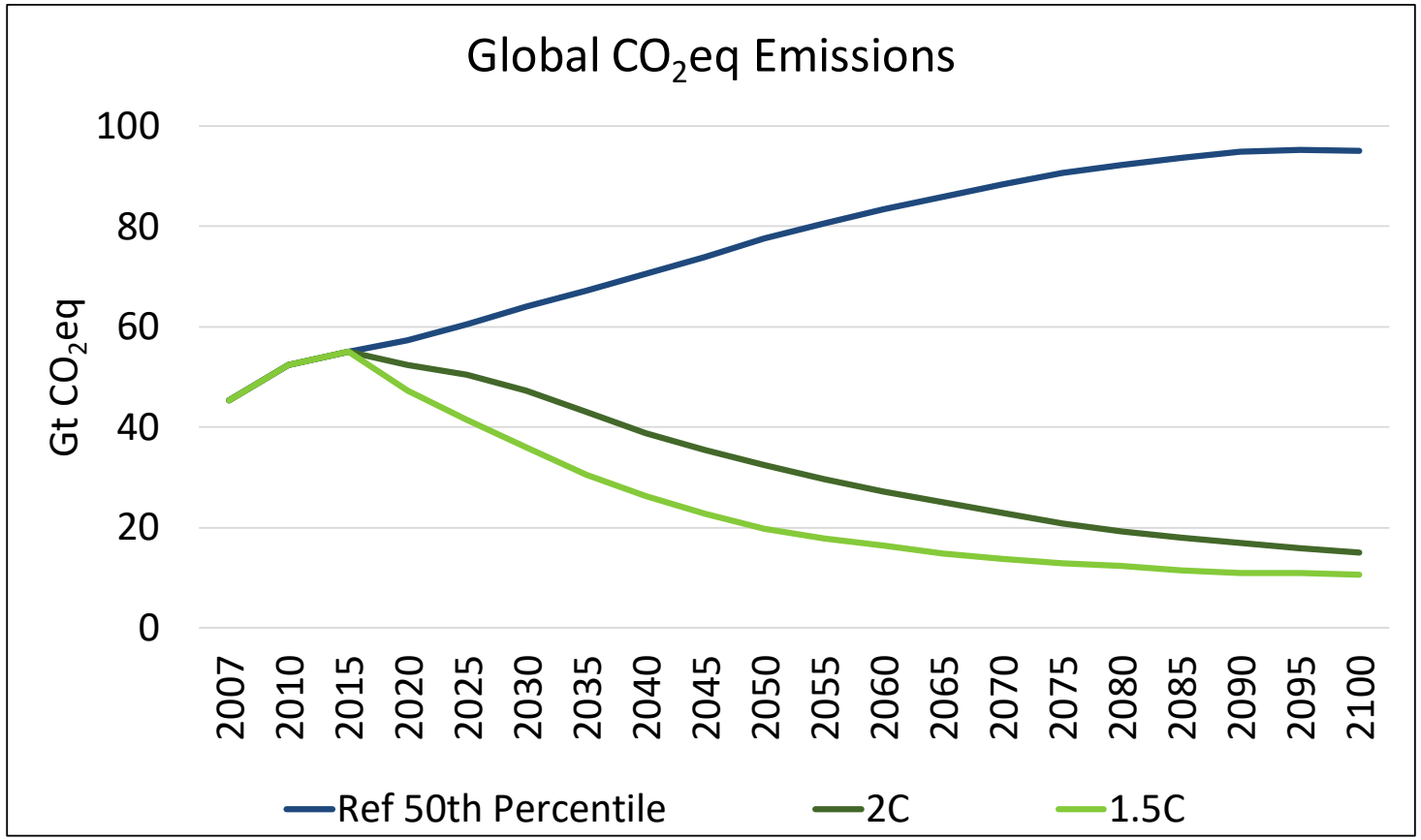
Approach

- Integrate a BECCS technology into MIT EPPA model and explore implications under 2C and 1.5C scenarios
- Model accounts for all major components of BECCS process:
  - Land availability
  - Crop production and transport
  - Biomass conversion to electricity with CO2 capture
  - Transport and underground storage of CO2
  - Endogenous land use change
  - Direct and indirect land use change emissions

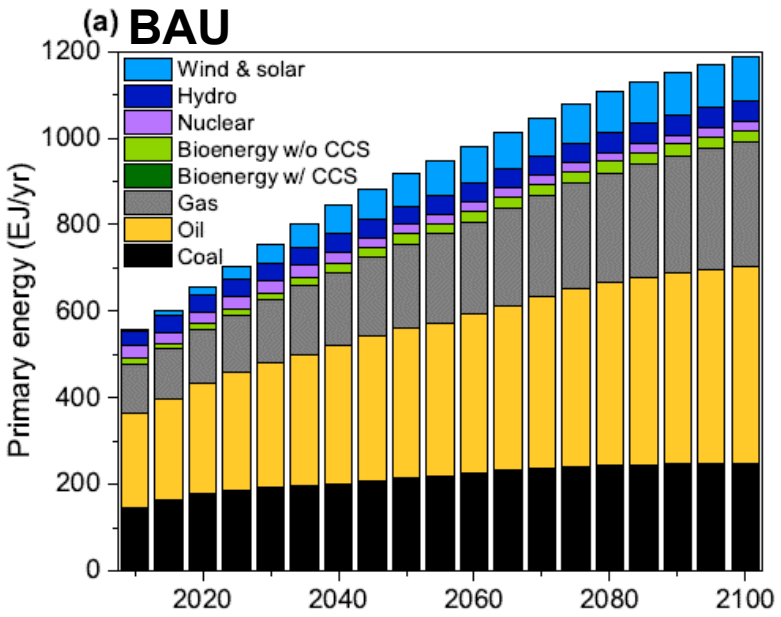


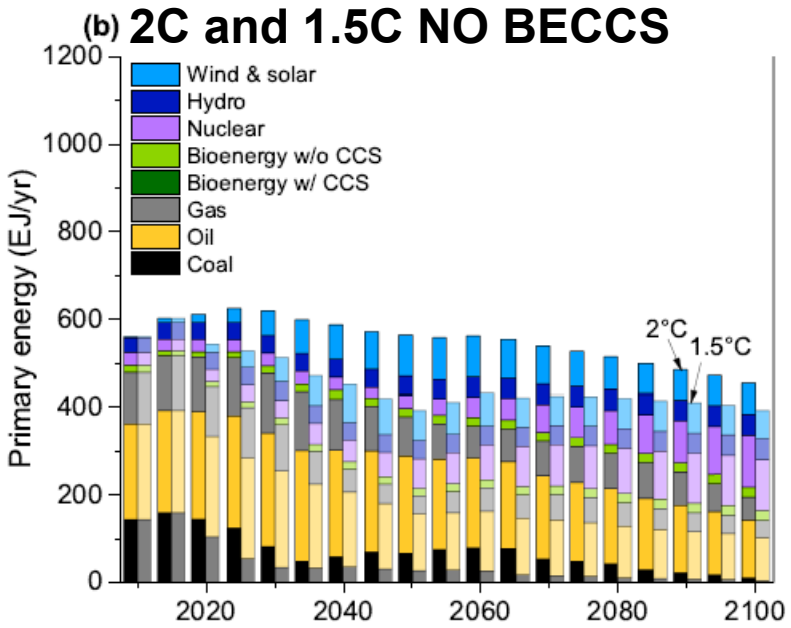
2°C and 1.5°C Policy Scenarios

Emissions **caps** with a **global carbon price** starting in 2020 to ensure that global mean surface air temperature in year 2100 does not exceed:
(a) 2°C above pre-industrial levels with a **66% probability**
(b) 1.5°C above pre-industrial levels with a **50% probability**



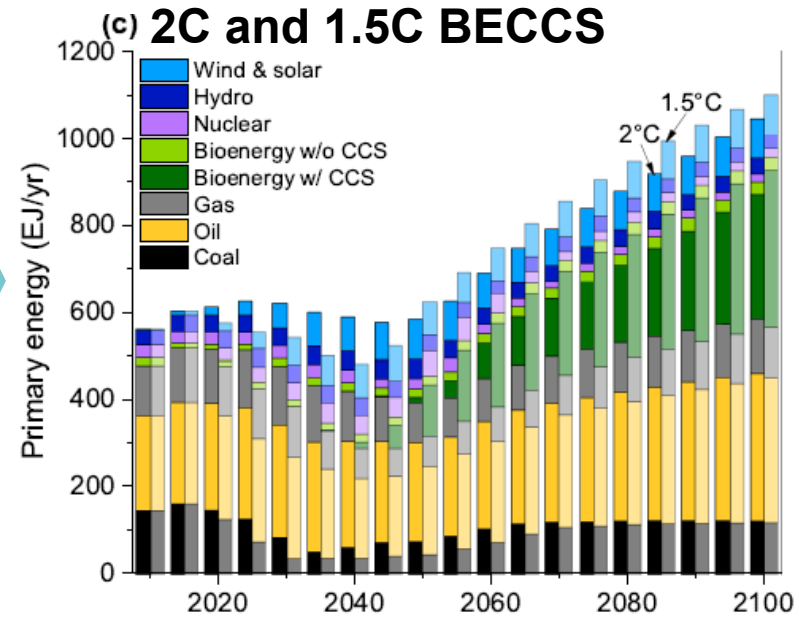
Total Primary Energy





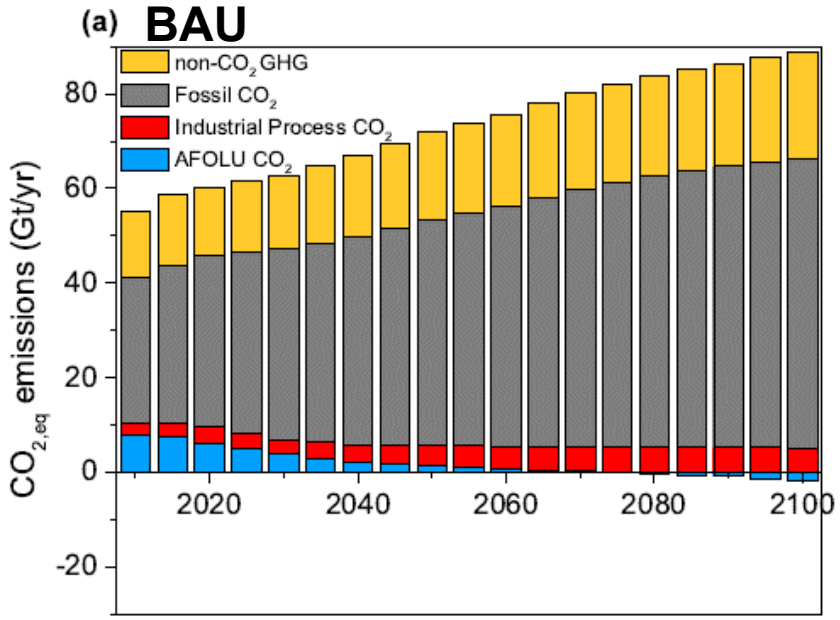
33-38% of BAU

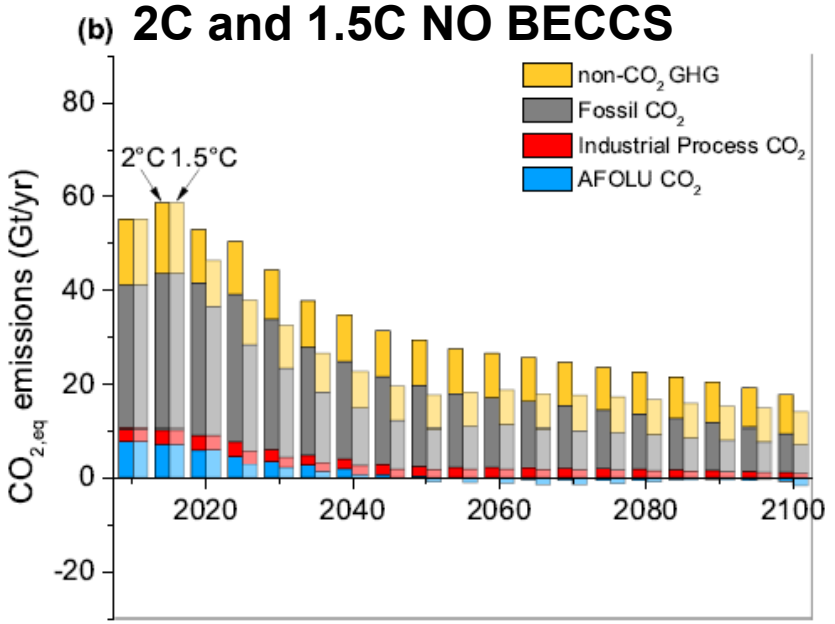
- Bioenergy: 30-140 EJ in 2050; 320-390 EJ in 2100
- 3x fossil fuels vs. NO BECCS
- Most coal and gas with CCS
- Emissions from oil use offset by BECCS



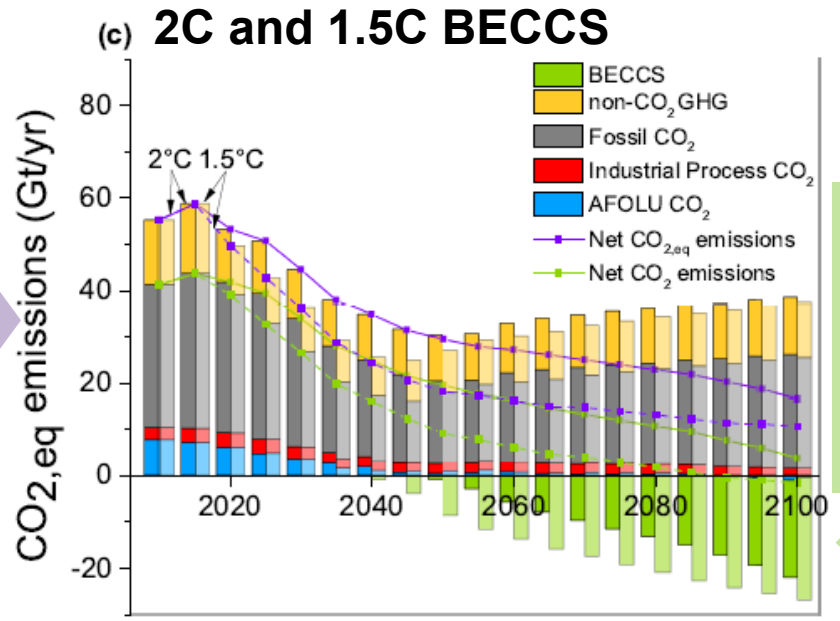
Just below BAU
30-36% Bio

Net CO_2eq Emissions





↓86-90% fossil CO_2
↓79-82% industrial process CO_2
↓64-70% non-CO_2 GHGs



- 21-26 $GtCO_2$/yr negative emissions by 2100
- Allows 3x more fossil CO_2 compared to NO BECCS

2020-2100: 620-1060 $GtCO_2$

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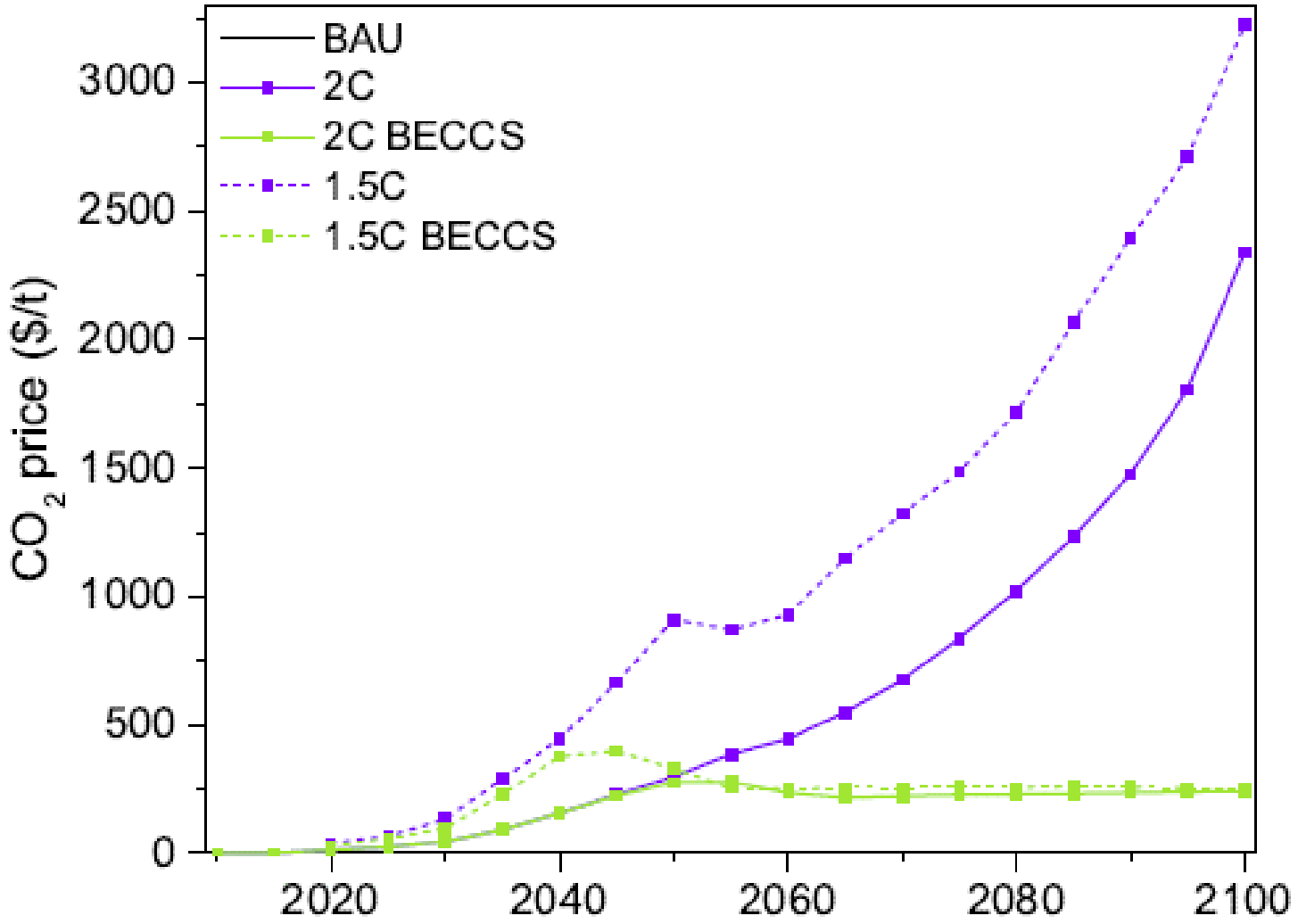
Global Carbon Price



BECCS effectively caps carbon price at about **$240/tCO$_2$eq,** an **order of magnitude less** than price without BECCS

BECCS Revenue: Electricity vs. Carbon Permits

What if?

1) **BECCS receives no CO_2 permits**
   → Zero BECCS deployment

2) **Cost of BECCS is doubled**
   → BECCS in 2100 decreases from 21 to 13 $GtCO_2/yr$

3) **"BAC" (biological air capture = BECCS without electricity production)**
   → BECCS in 2100 decreases from 21 to 19 $GtCO_2/yr$

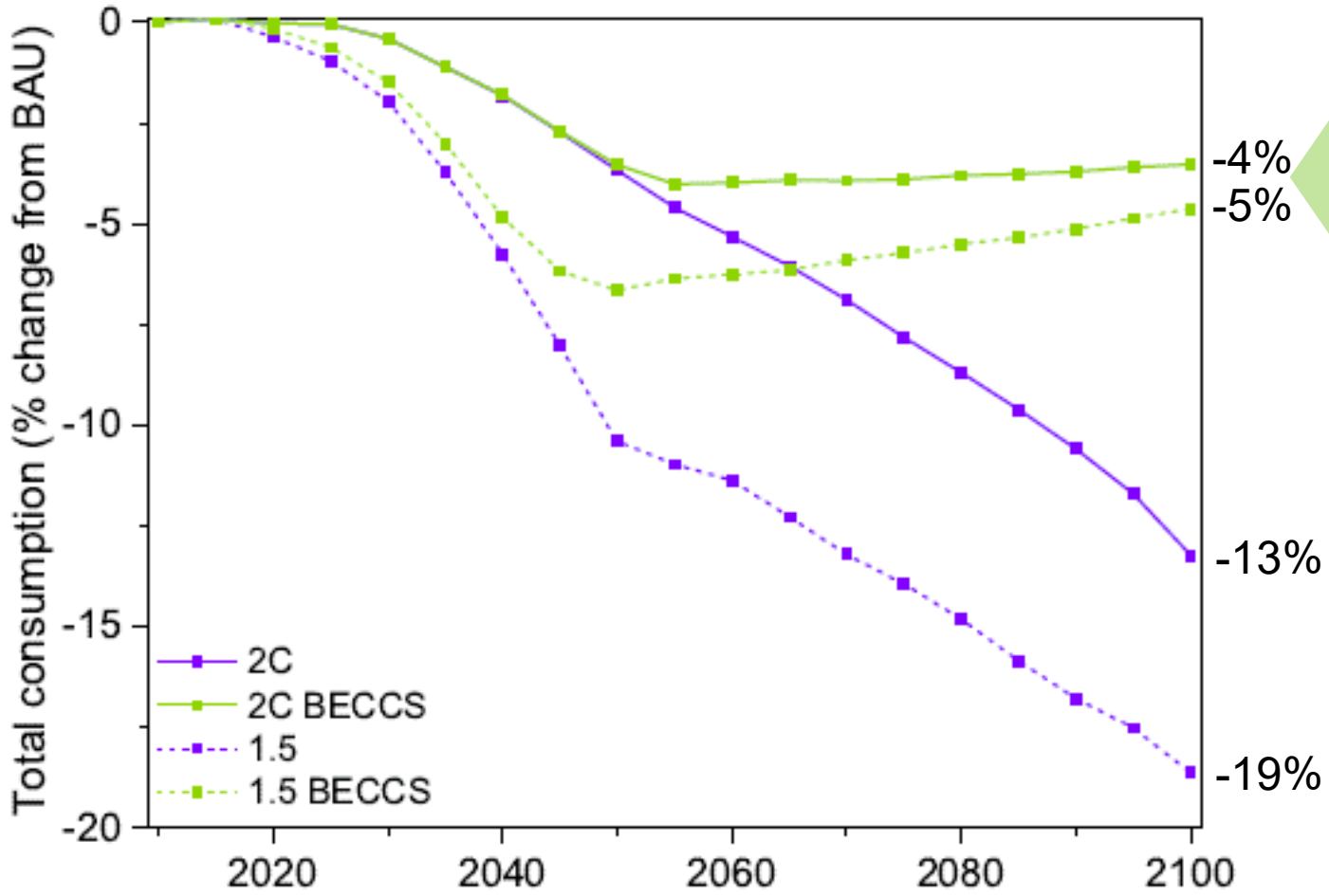
4) **"BAC" 22% cheaper than BECCS**
   → BECCS in 2100 back to 21$GtCO_2/yr$

Carbon permits drive deployment

Value of CO_2 removal > Value of electricity generation

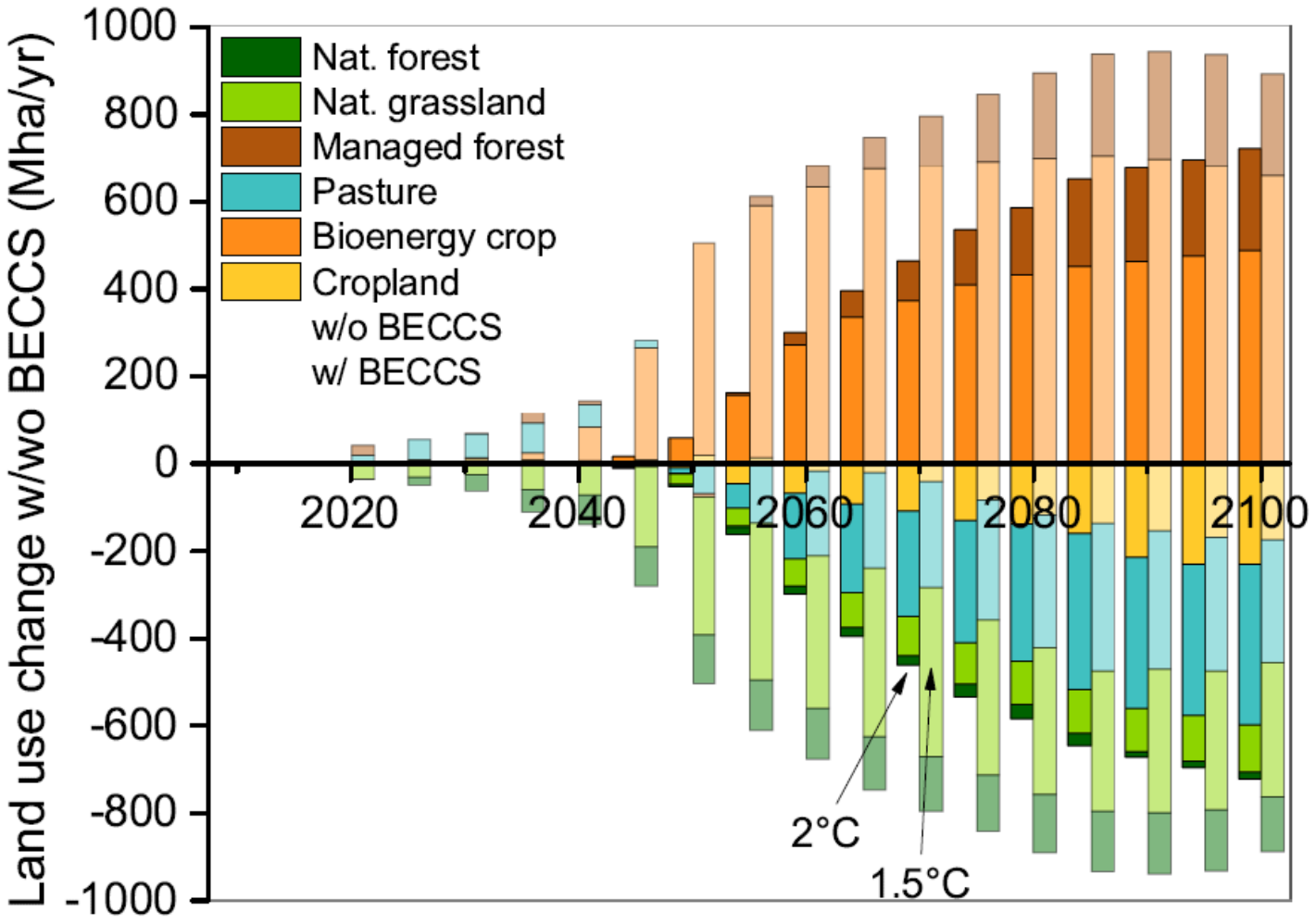
Global Policy Cost

Percentage change in economy-wide consumption relative to consumption in the BAU scenario



BECCS significantly reduces the cost of meeting long-term targets

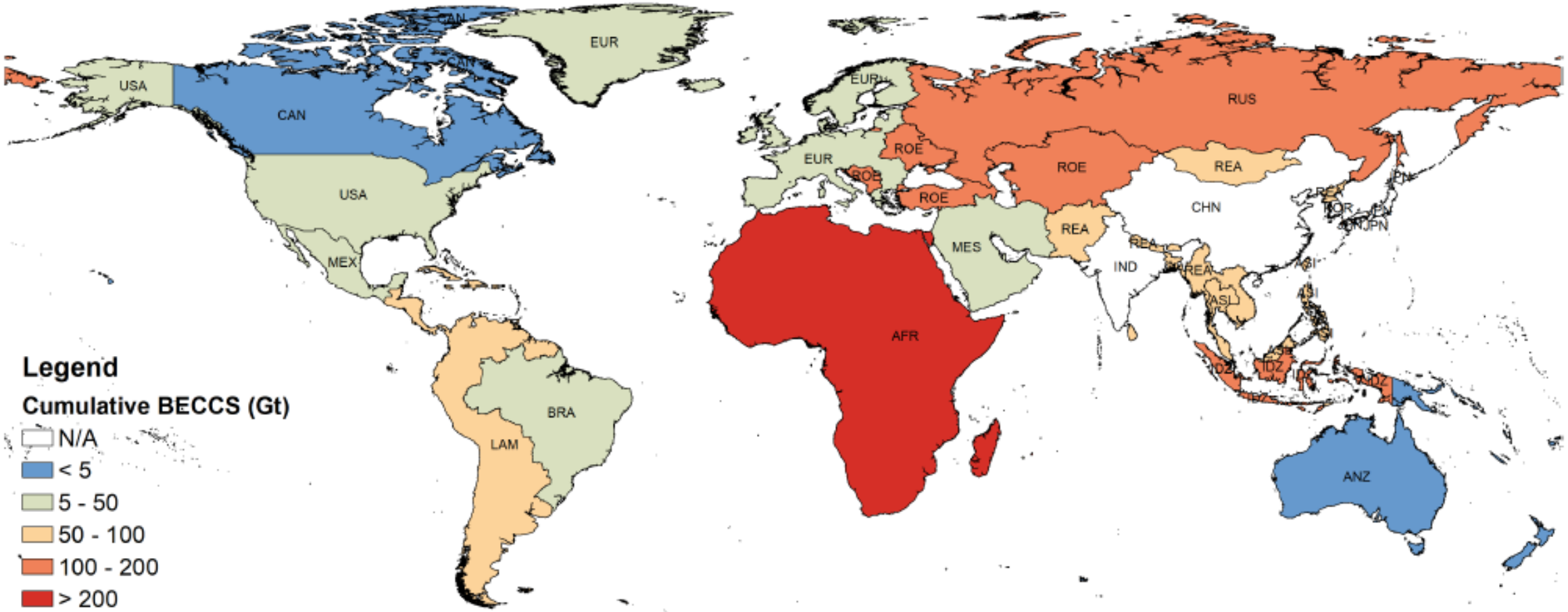
Global Land Use Change With vs. Without BECCS



2C BECCS: by 2100, additional 490 Mha for bioenergy, displacing mostly cropland and pasture

1.5C BECCS: by 2100, additional 650 Mha for bioenergy, displacing far more natural grassland and forest (in 2100, 430 Mha under 1.5C vs 120 Mha under 2C)

Regional Distribution of BECCS under 1.5ºC



Cumulative CO2 removal from BECCS under 1.5°C policy with BECCS.
84% of BECCS deployment occurs in developing nations, with 26% alone in Africa.

Importance of knowledge, technology and financial transfers to developing countries

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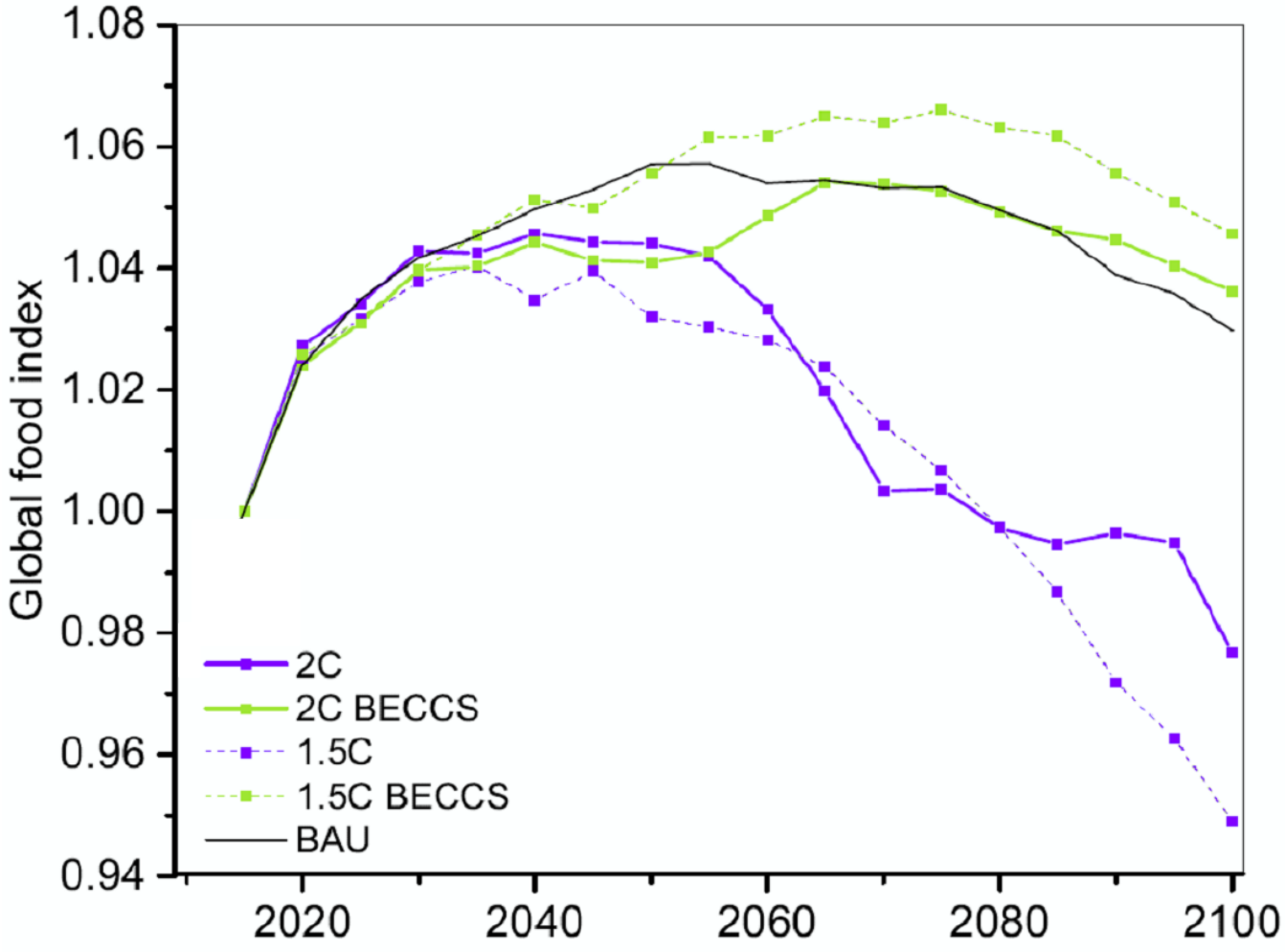
Global Food Price Index



With BECCS: price rises, ends up 0.6-1.5% higher than BAU in 2100

Competition for land: 490-650 Mha for bioenergy by 2100

Without BECCS: price falls, ends up 5-8% lower than BAU in 2100

BECCS with limited impact on global food prices

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Findings

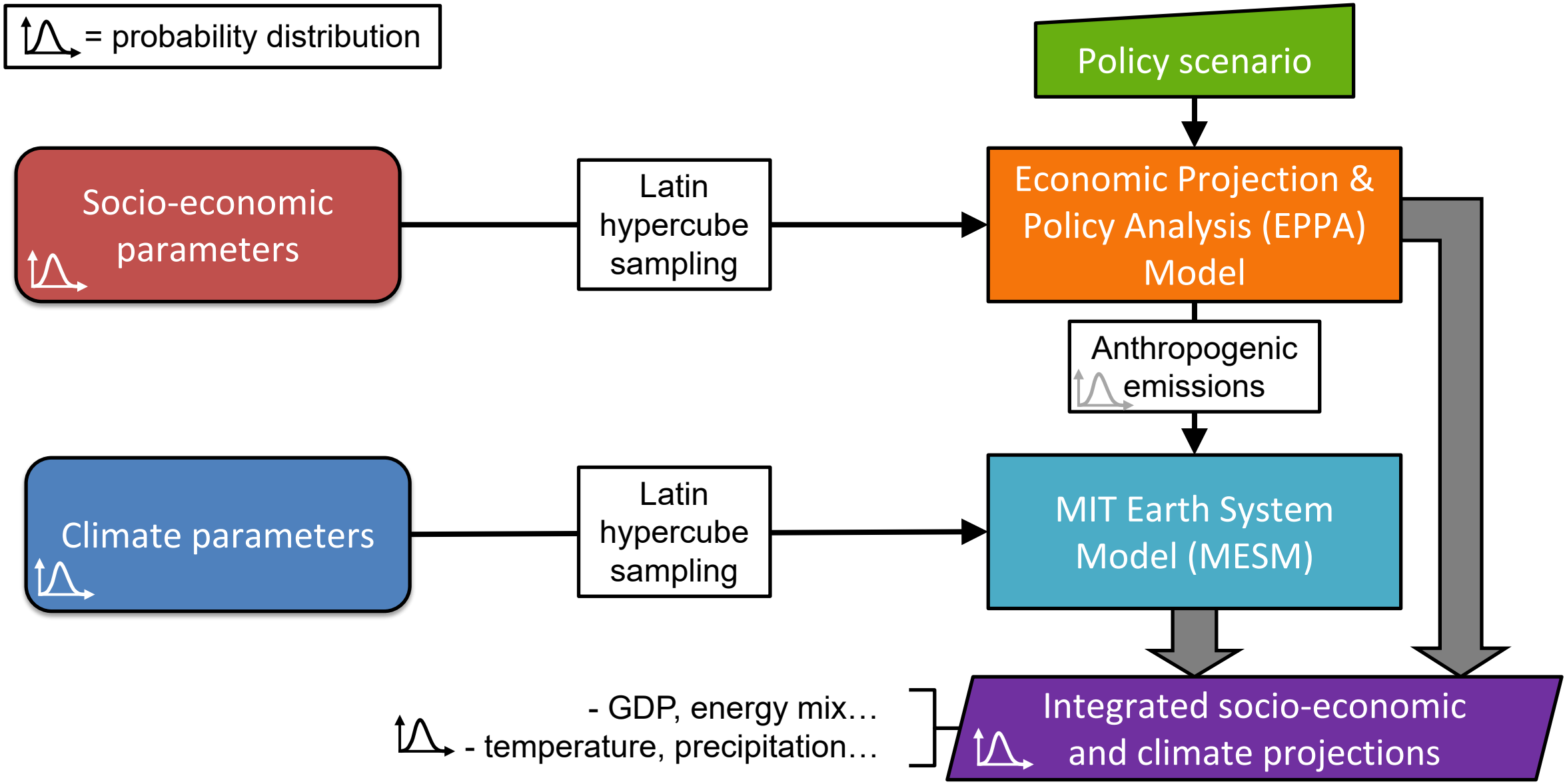
- BECCS can play a significant role in low-carbon futures
  - Lowers carbon price and policy cost, causes significant land use change, but only increases food prices by ~1.5%
- All technical components for large-scale BECCS currently exist
- Many challenges could limit BECCS deployment
  - Availability of sustainable biomass, availability of CO2 geologic storage sites, policy incentives, **development of a credible accounting and valuation system for negative emissions**, public acceptance, ecosystem impacts…

Stepping back….

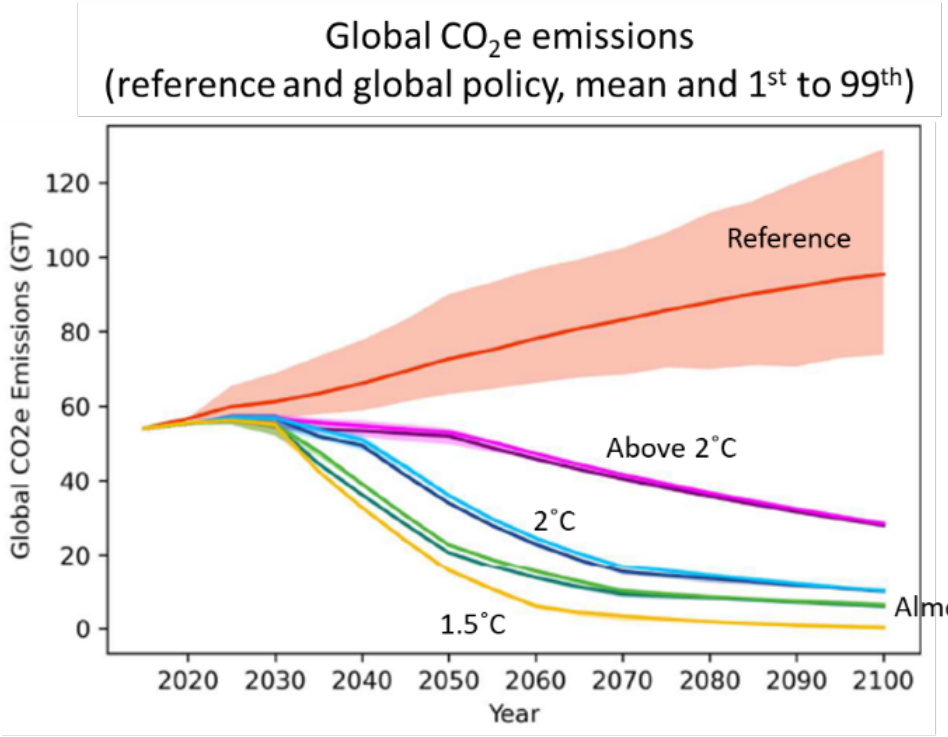
Is a world with near-zero emissions limits, global carbon pricing and large amounts of negative emissions realistic?

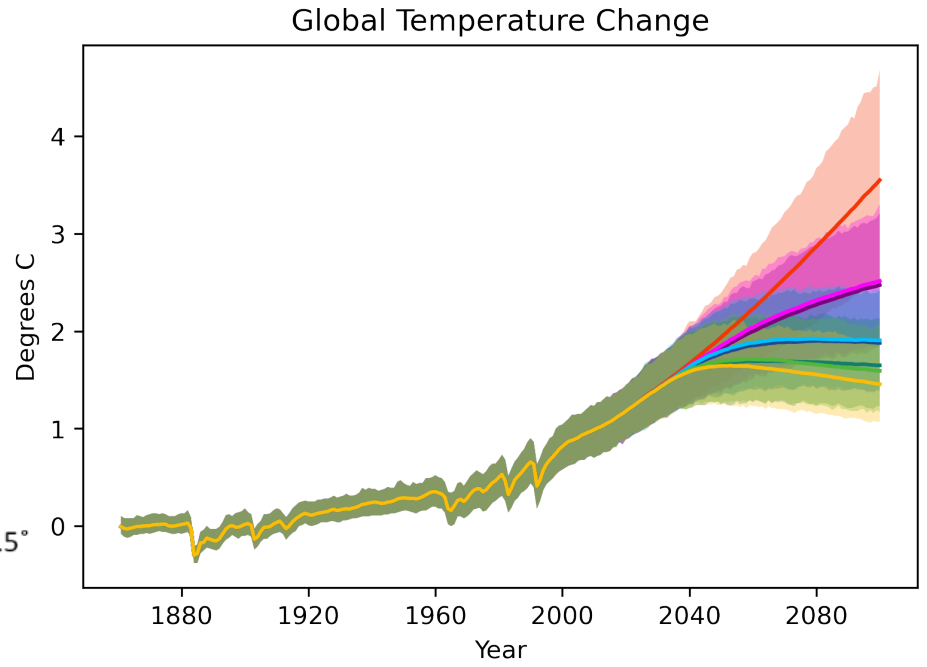
Is it risky to bet on such a world?

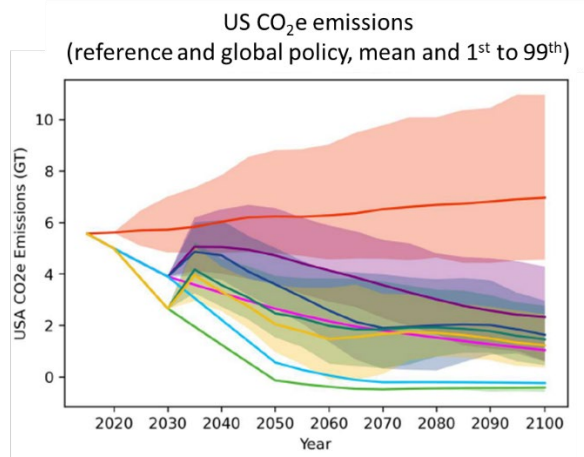
MIT Uncertainty Framework



MIT-EPRI Study: Uncertainty in Climate Policy Design







	CDR (BECCS & afforestation)	Land Mitigation Covered	International Permit Trading
Optimistic	Yes	Yes	Yes
Pessimistic	No	No	No

Preliminary. EPRI-MIT work in progress.

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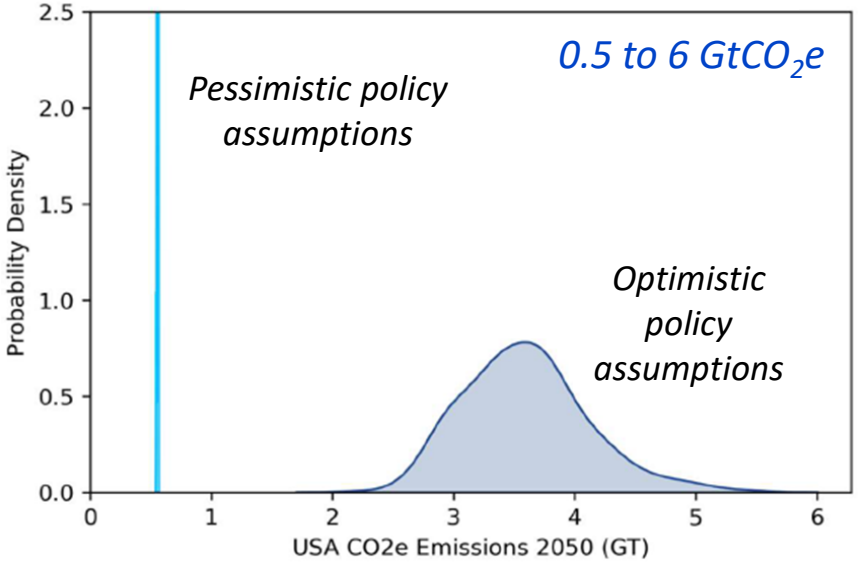
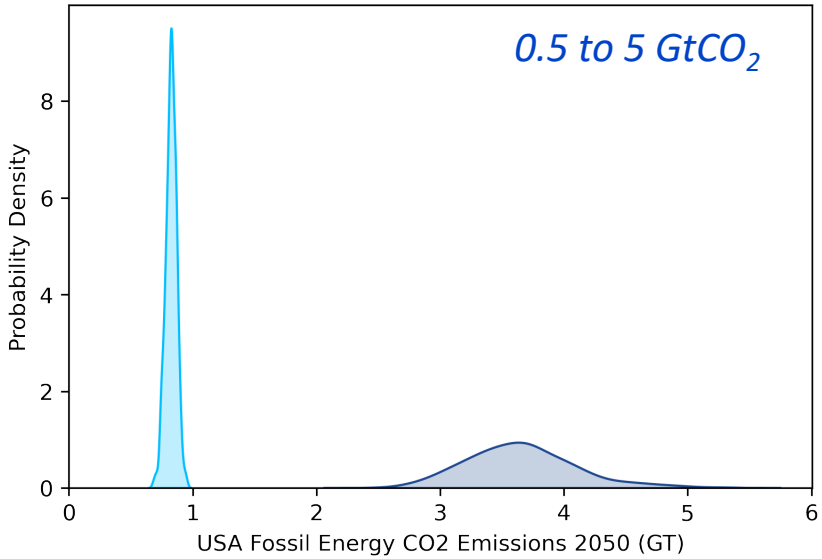
US 2050 uncertainty for a single 2˚C global emissions pathway

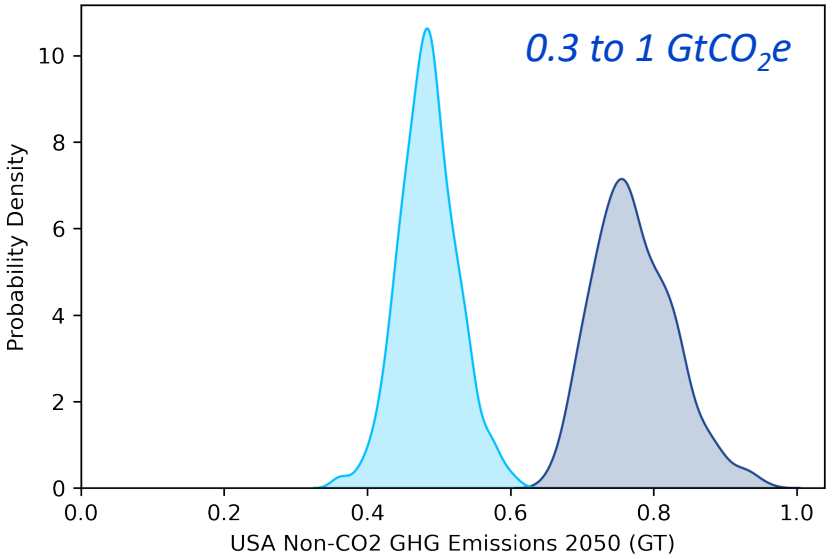
CO_2e Emissions



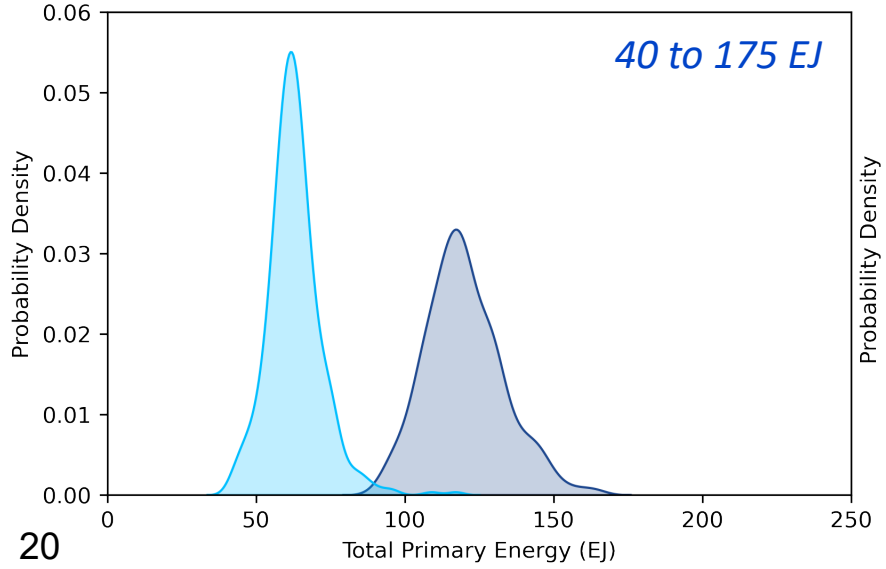
Fossil Energy CO_2 Emissions



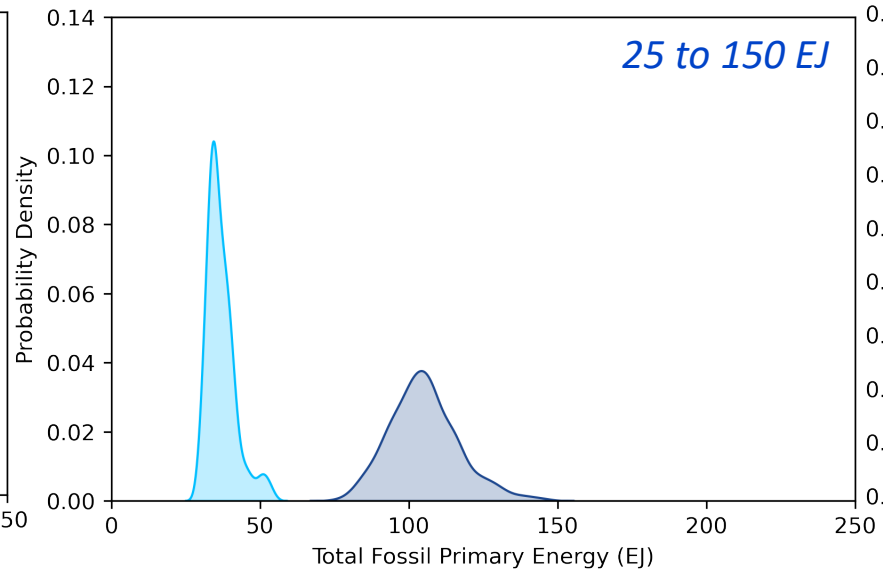
Non-CO_2 GHG Emissions



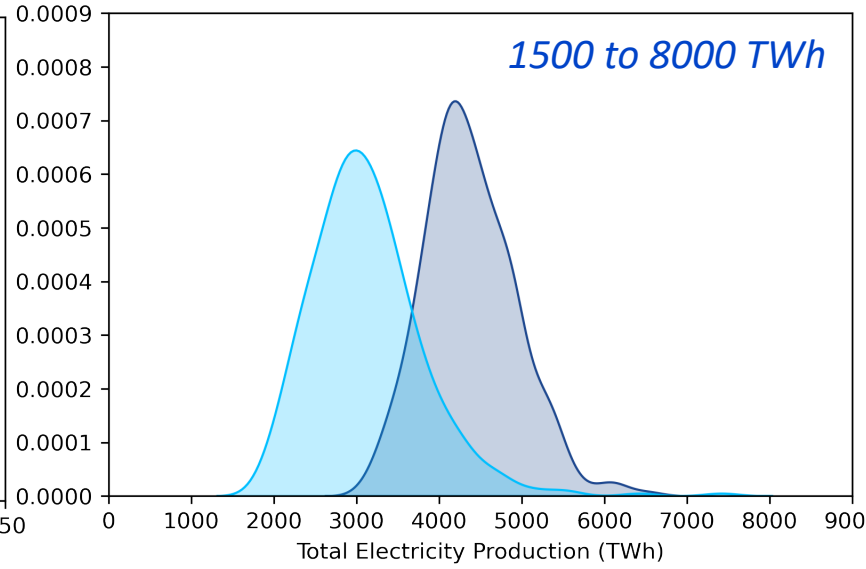
Total Primary Energy



Fossil Primary Energy

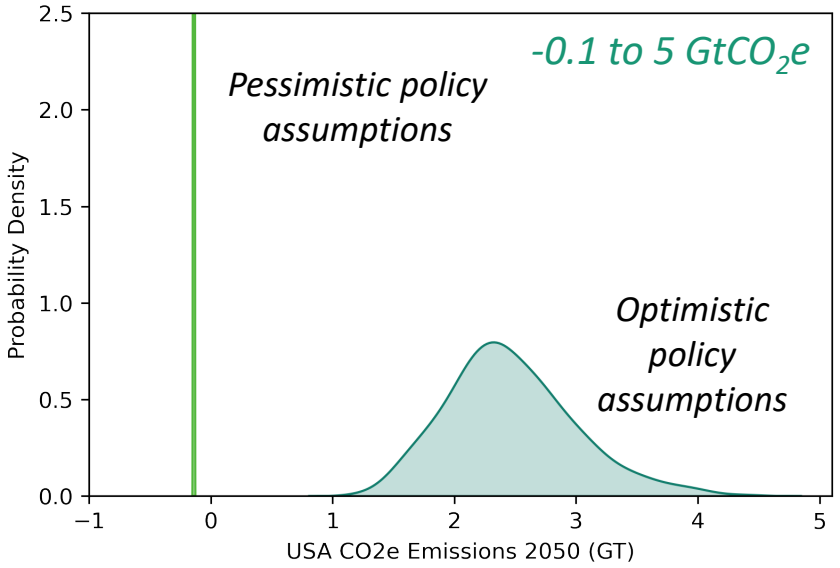


Electricity Generation

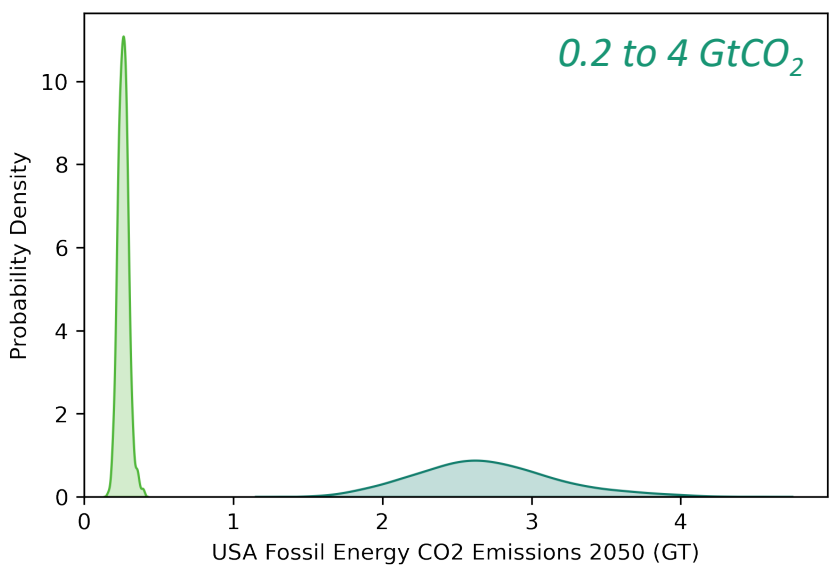


US 2050 uncertainty for a single Almost 1.5˚C global emissions pathway

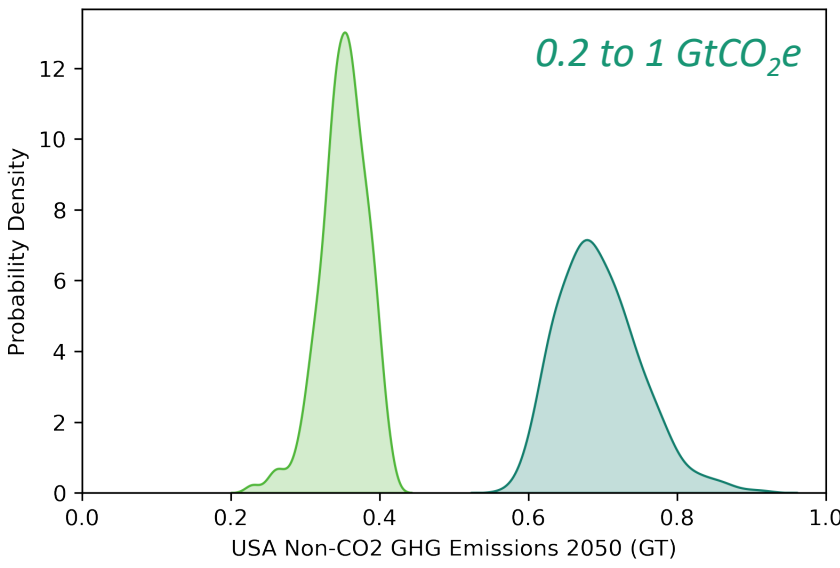
CO_2e Emissions



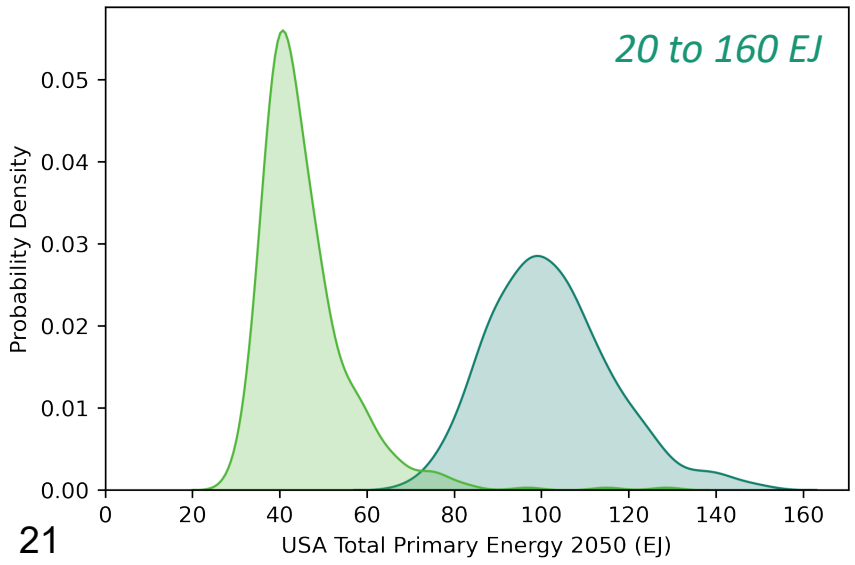
Fossil Energy CO_2 Emissions



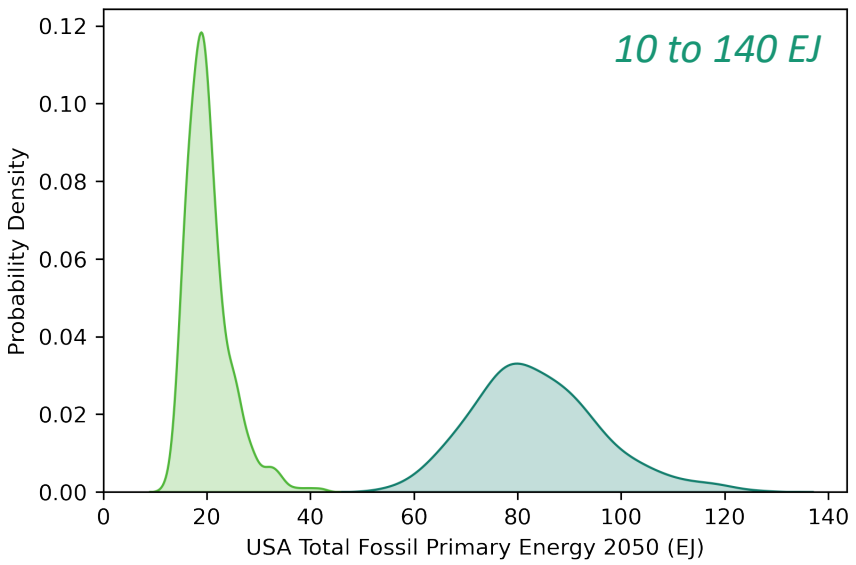
Non-CO_2 GHG Emissions



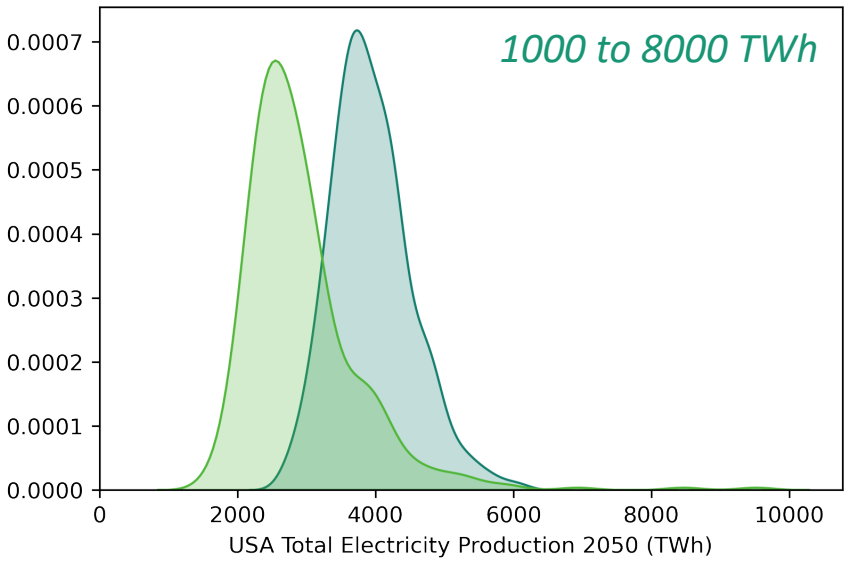
Total Primary Energy



Fossil Primary Energy

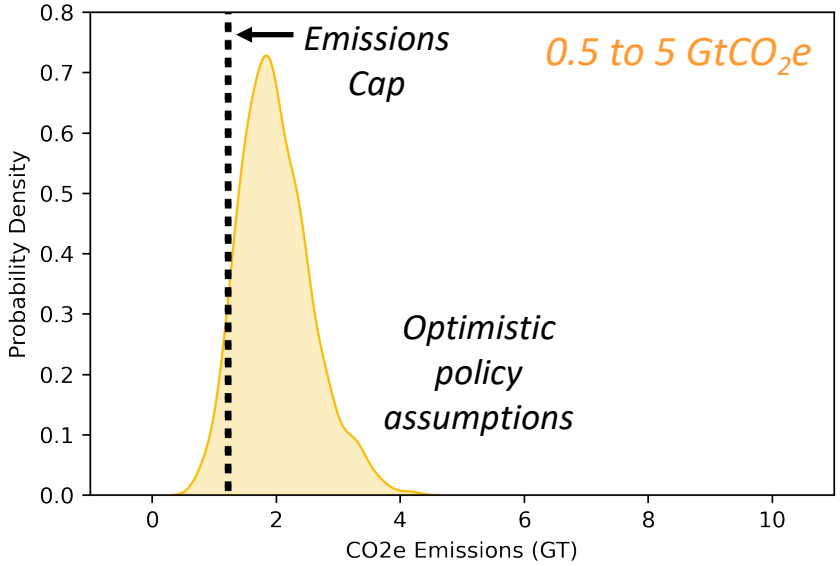


Electricity Generation

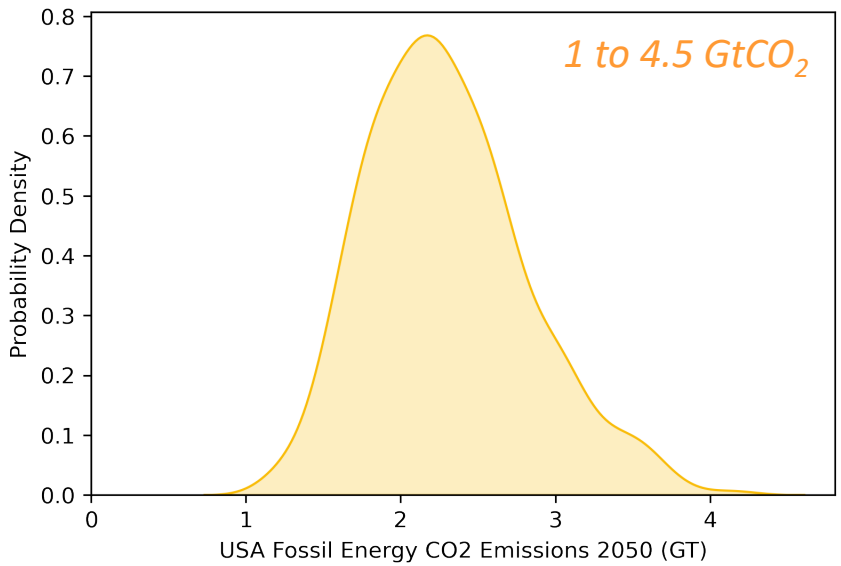


US 2050 uncertainty for a single 1.5˚C global emissions pathway

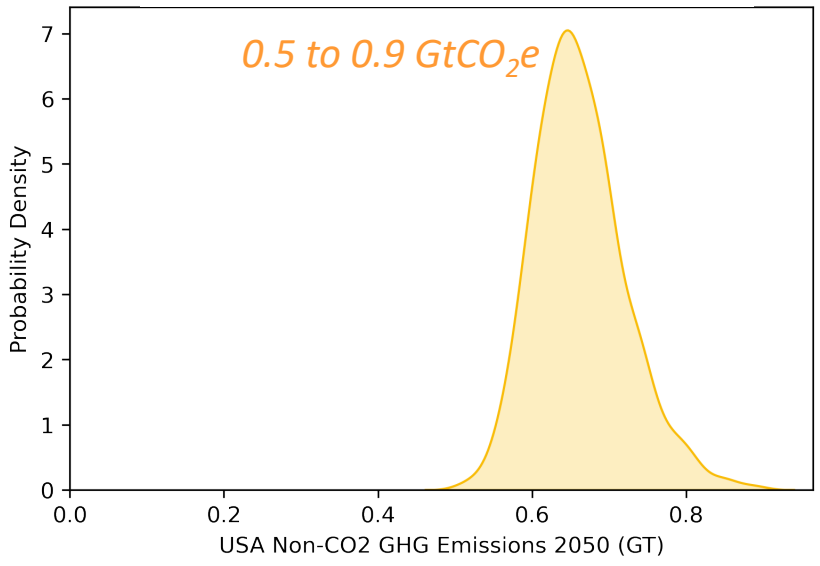
CO_2e Emissions



Fossil Energy CO_2 Emissions



Non-CO_2 GHG Emissions



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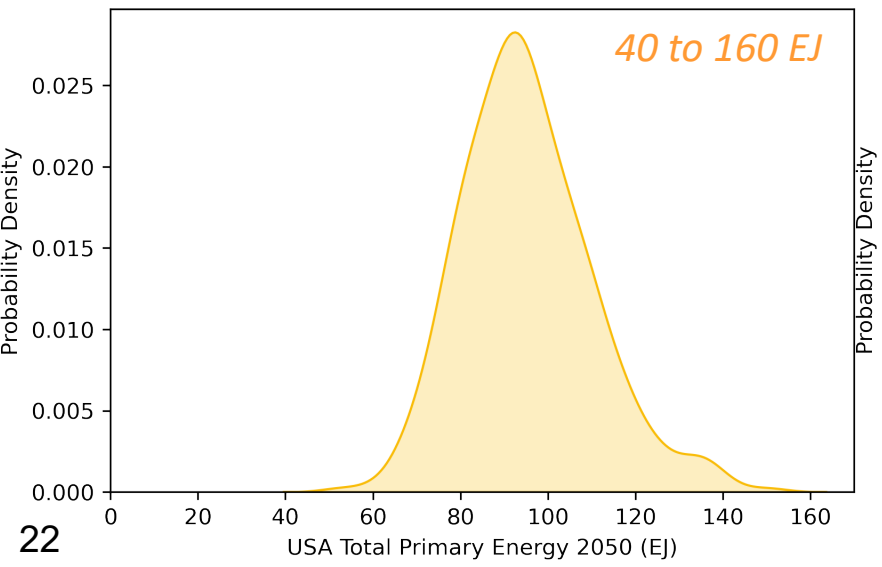
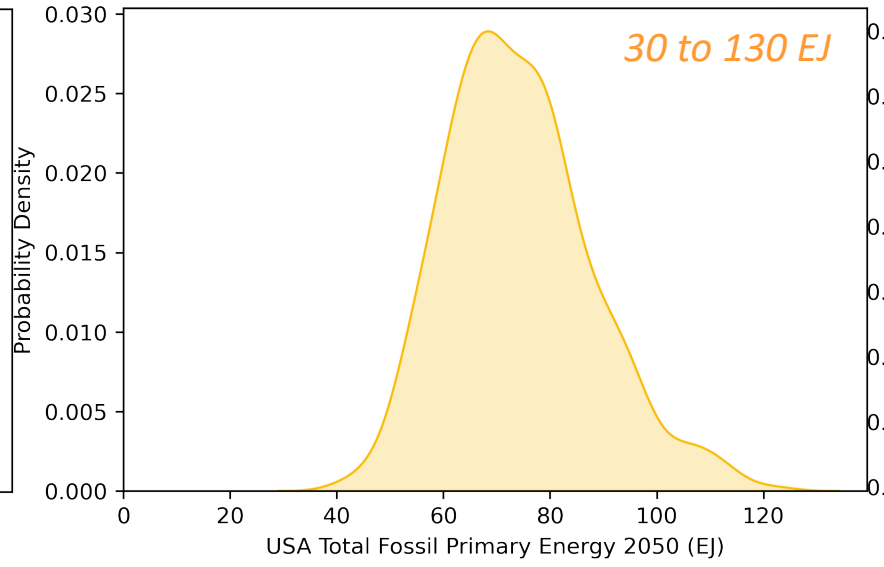
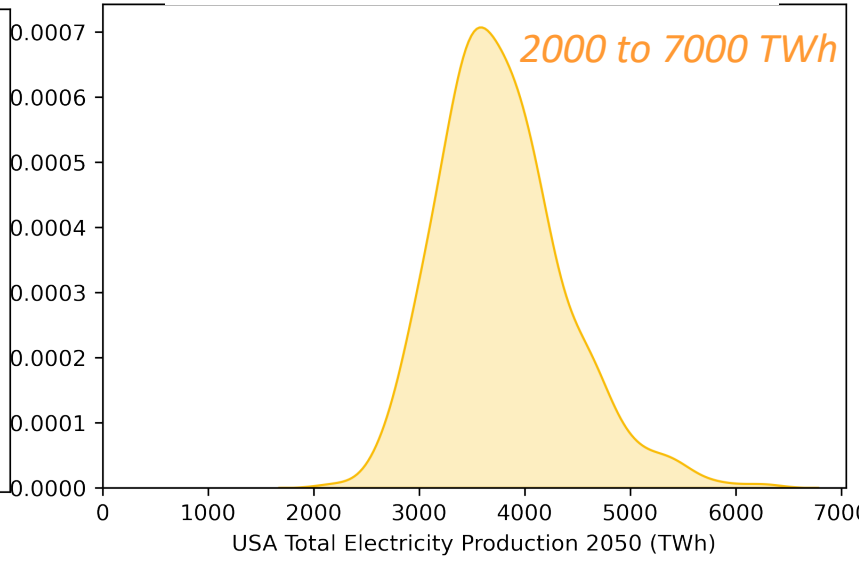


Fossil Primary Energy



Electricity Generation

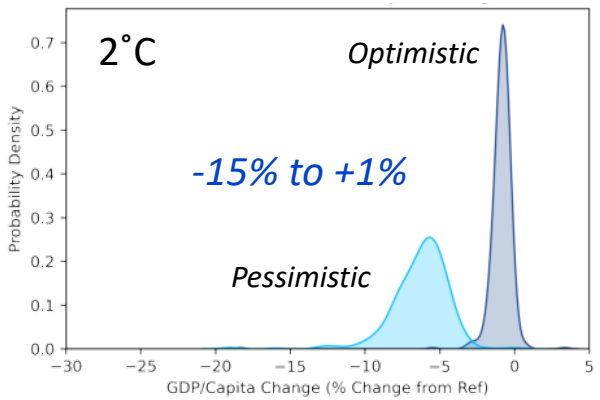


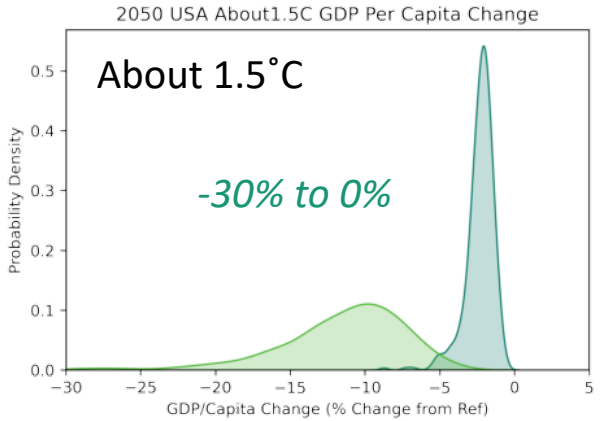
US 2050 cost uncertainty for different ˚C pathways

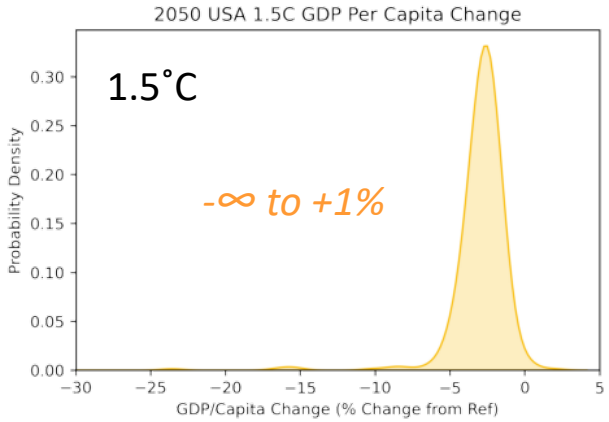
Substantial cost uncertainty – due primarily to pessimistic context, and the uncertainty increases with policy ambition

1.5˚C could not be solved with pessimistic assumptions

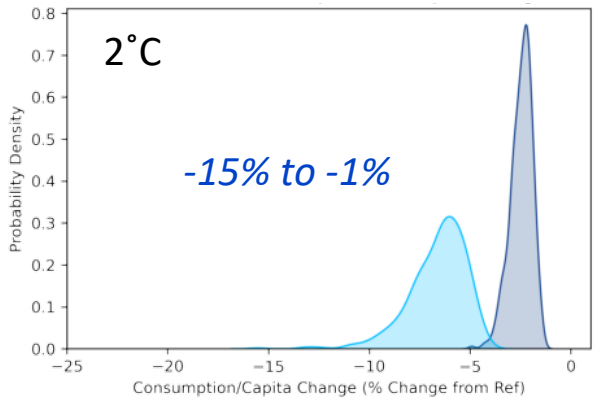
GDP per capita % change

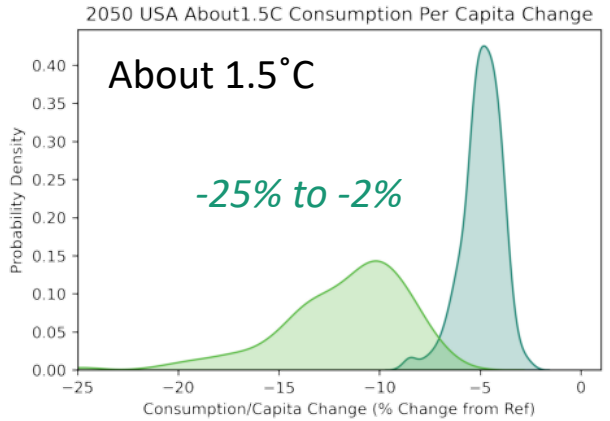


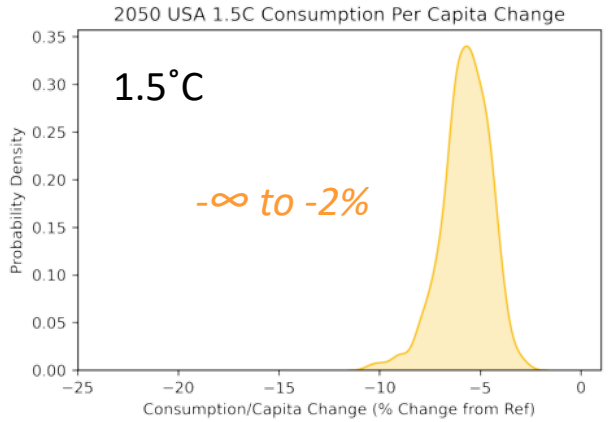




Consumption per capita % change

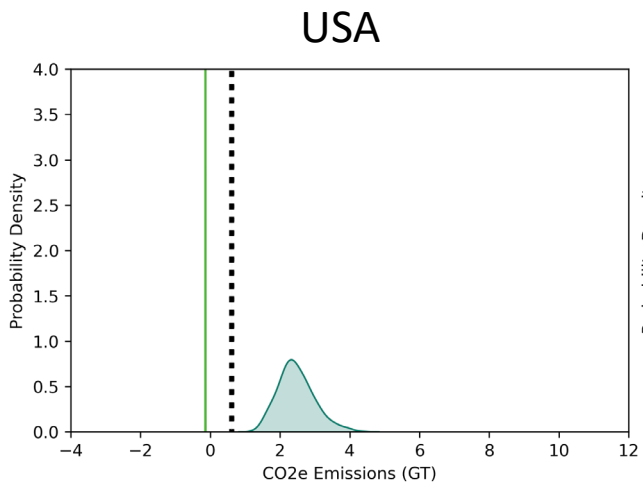


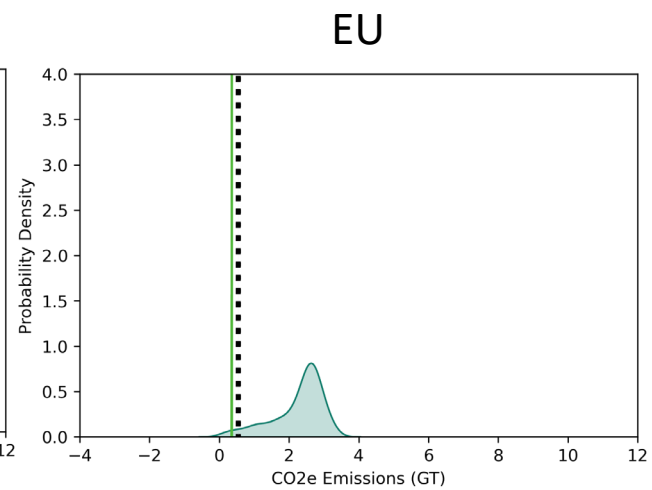


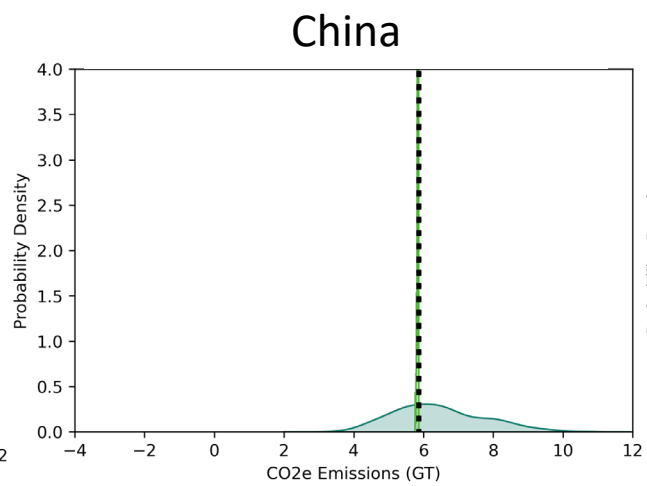


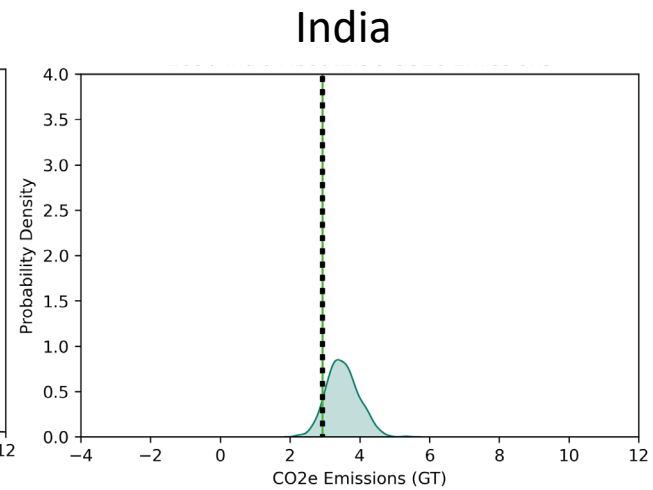
Preliminary. EPRI-MIT work in progress.

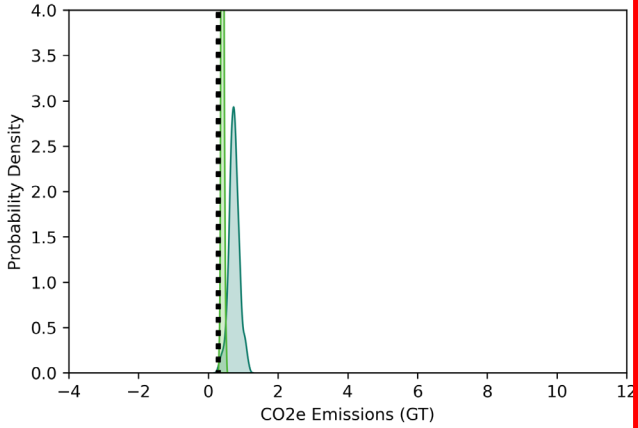
CO_2e emissions for selected regions under Almost 1.5˚C scenario

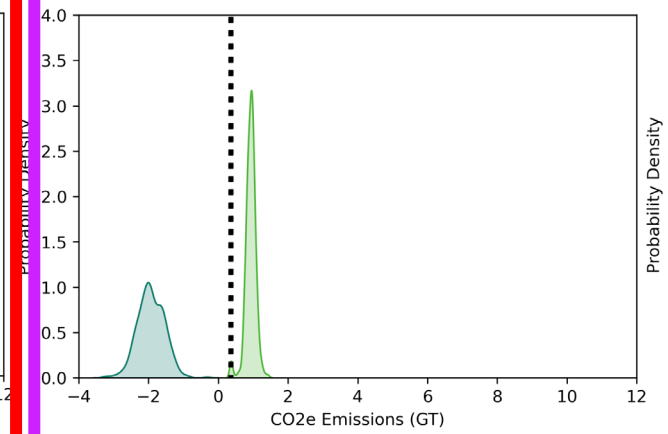


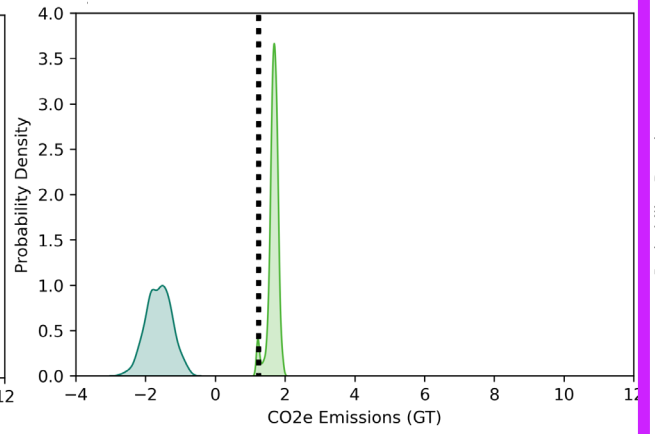


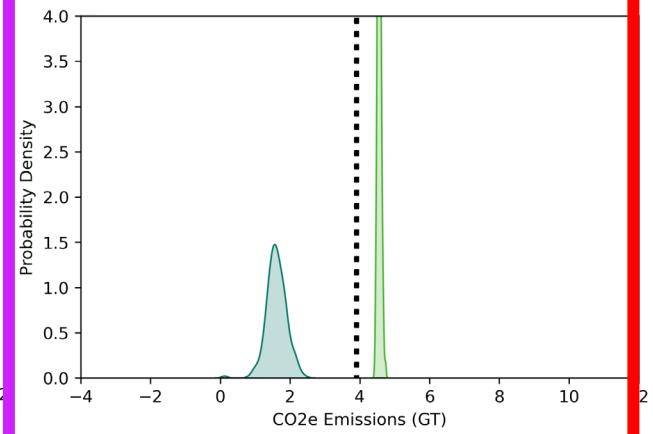








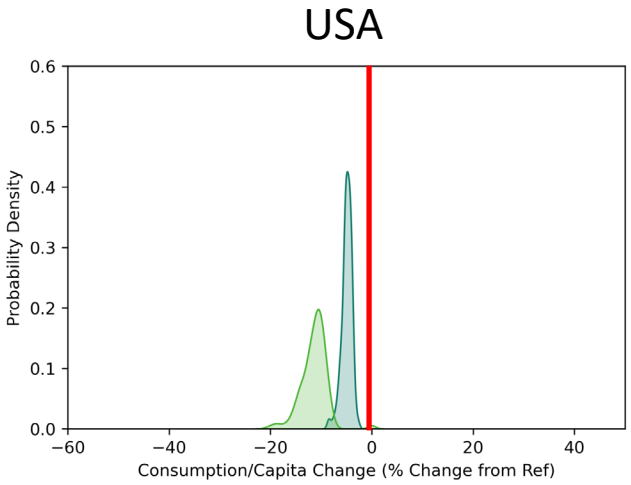


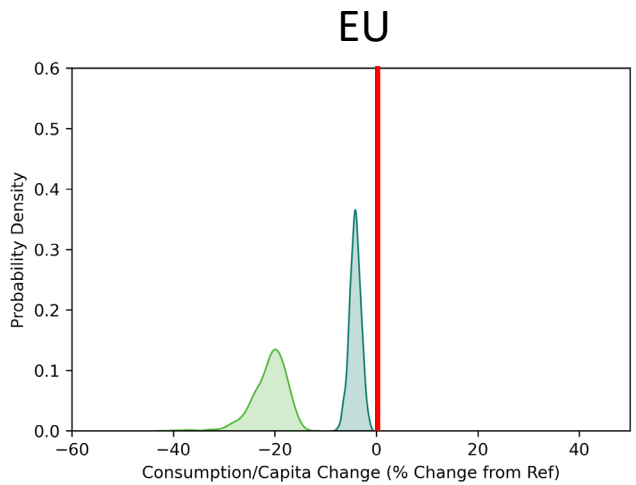


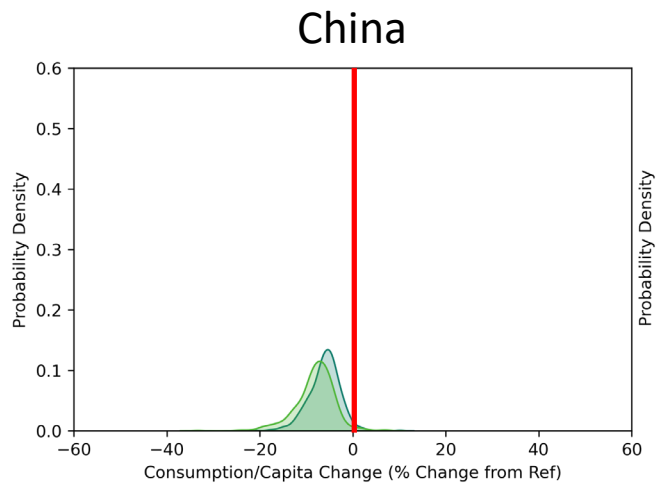
NET-NEGATIVE SELLERS

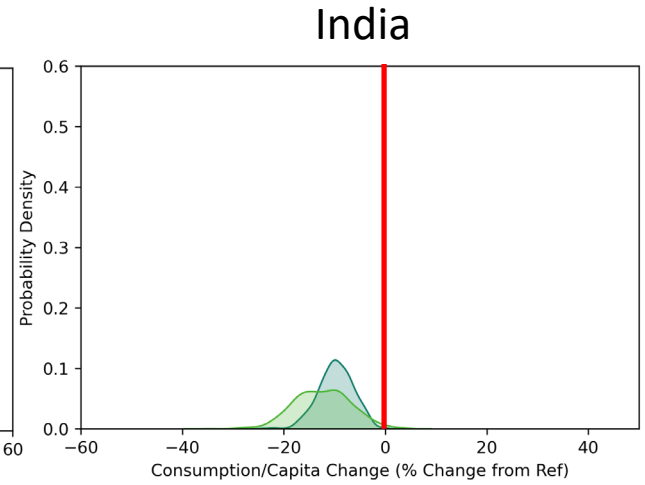
Preliminary. EPRI-MIT work in progress.

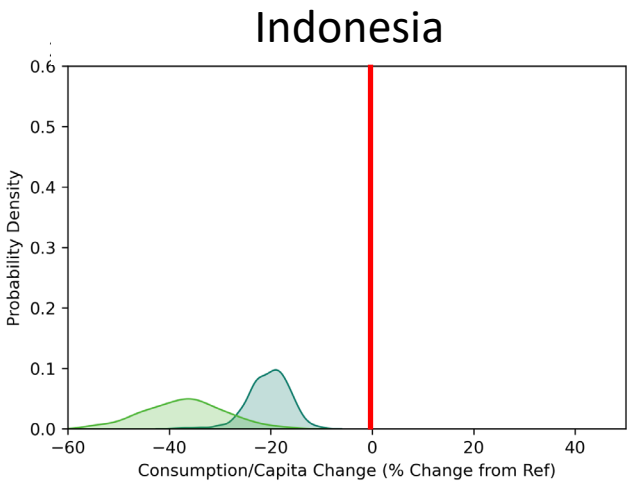
Consumption Impact for selected regions under Almost 1.5˚C scenario

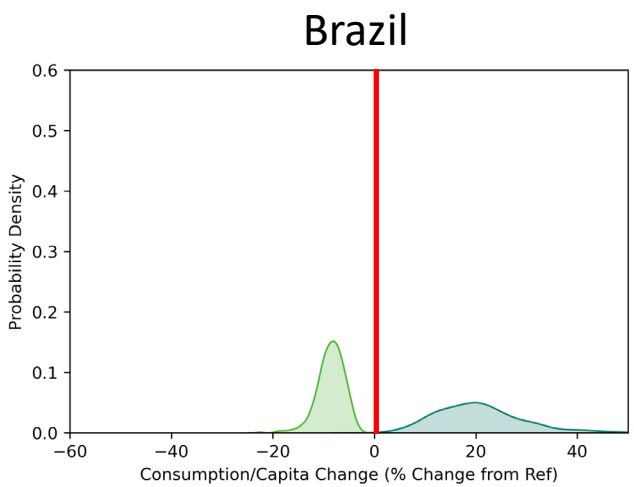


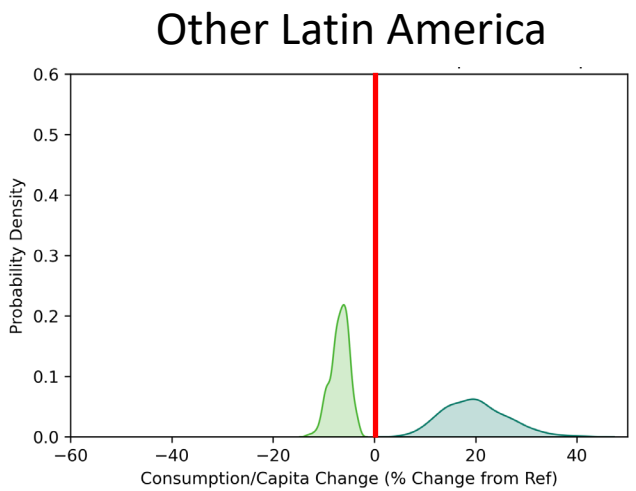


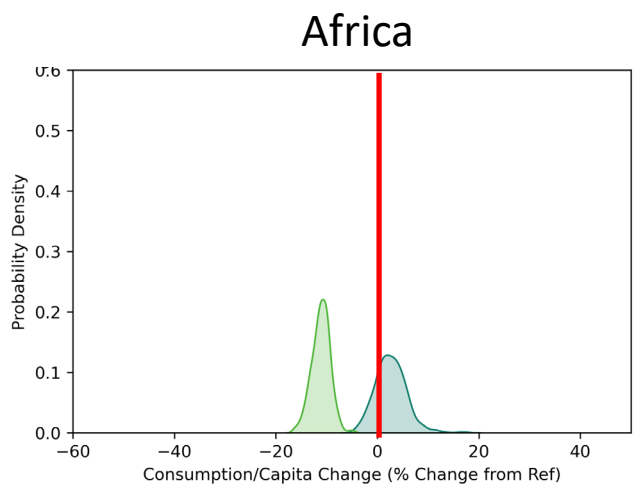










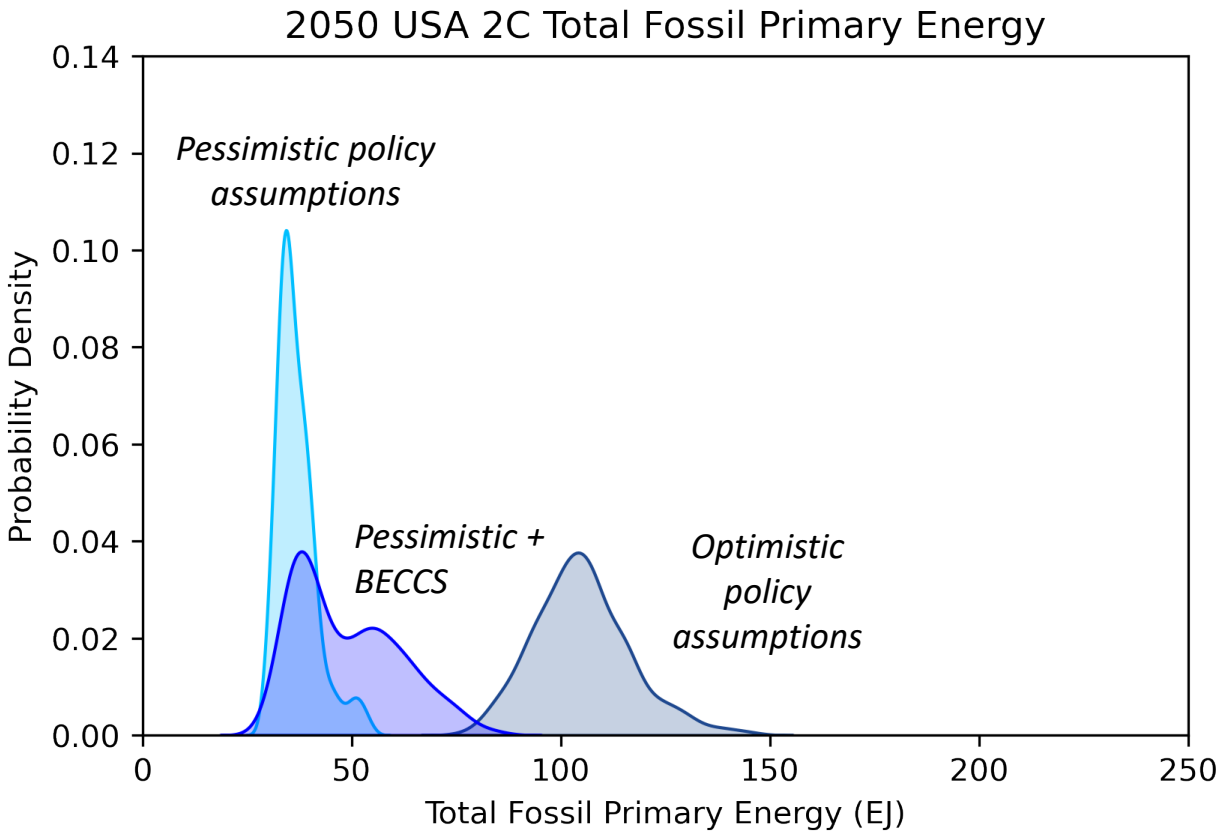


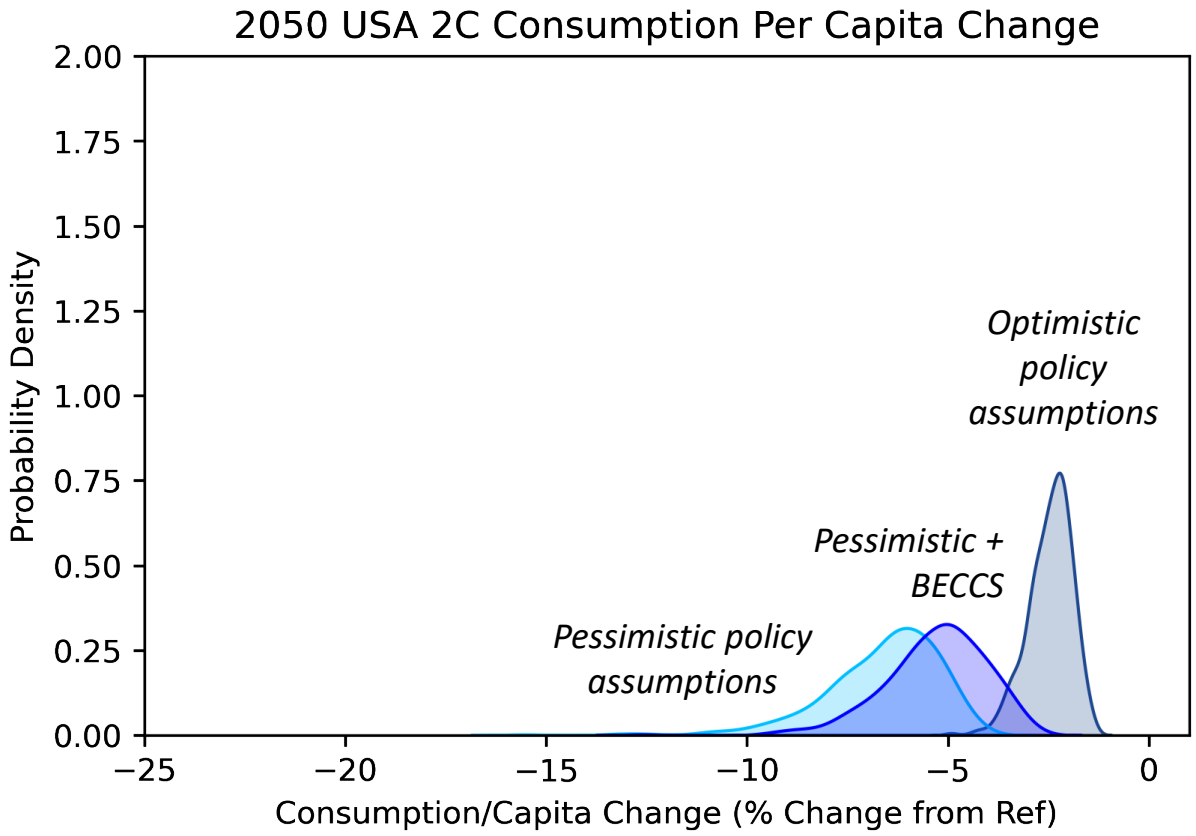
consumption/capita % change from Reference

Preliminary. EPRI-MIT work in progress.

What about an intermediate scenario? Pessimistic + BECCS

US 2050 uncertainty for 2˚C global emissions pathway





Preliminary. EPRI-MIT work in progress.

What if the world continues to address climate change in the way it has so far—through piecemeal actions and growing social and technological pressures?

Growing Pressures Scenario (MIT-Shell)

2020: No new coal generation in USA, EU, Canada, Australia & New Zealand

2030: No new coal generation in Japan; no coal use in final demand (heating and cooking)

2040: No new coal generation in Russia and former Soviet Union; slowing down new coal generation in the rest of the world; uptake of electric cars

2045: No new coal generation in China

2050: No new coal generation in rest of the world; No new gas generation in developed regions (USA, EU, Canada, Japan, Australia & New Zealand); Decline in cost of renewables reaches the floor (75% of 2020 cost)

2060: No natural gas in final demand (heating and cooking); EVs replace ICEVs globally

2070: No new gas generation in rest of world

2075: Cost-competitive long-term electricity storage; electrification of energy-intensive industries in developed regions

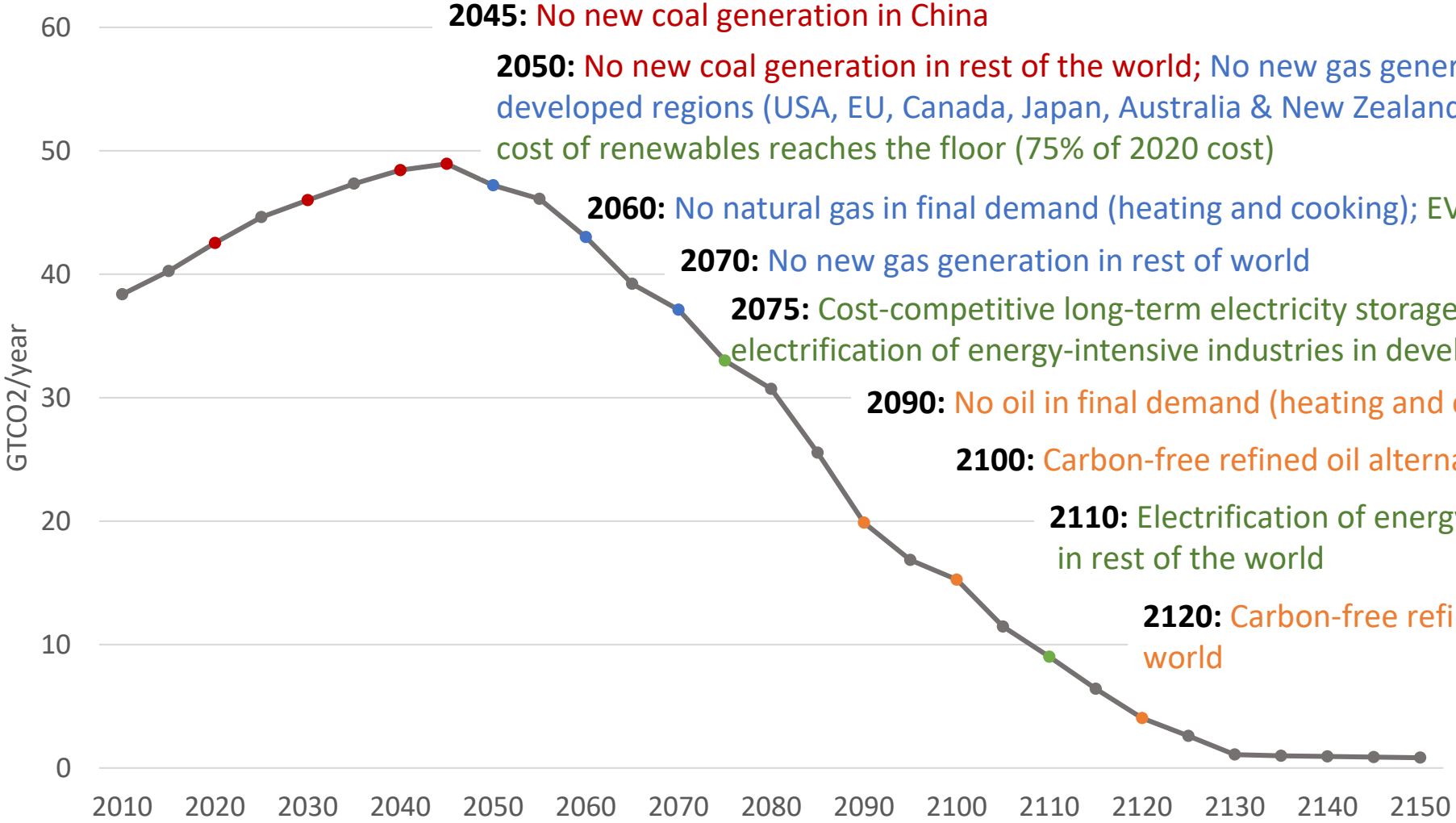
2090: No oil in final demand (heating and cooking); no more coal generation

2100: Carbon-free refined oil alternatives in developed regions

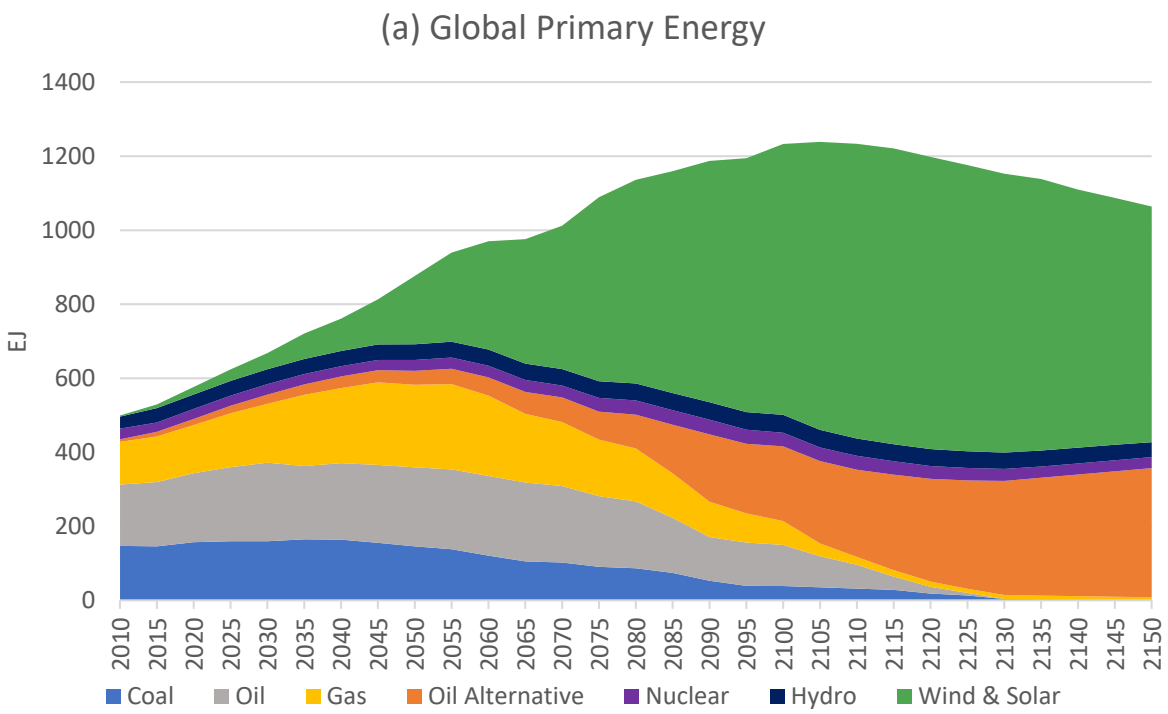
2110: Electrification of energy-intensive industries in rest of the world

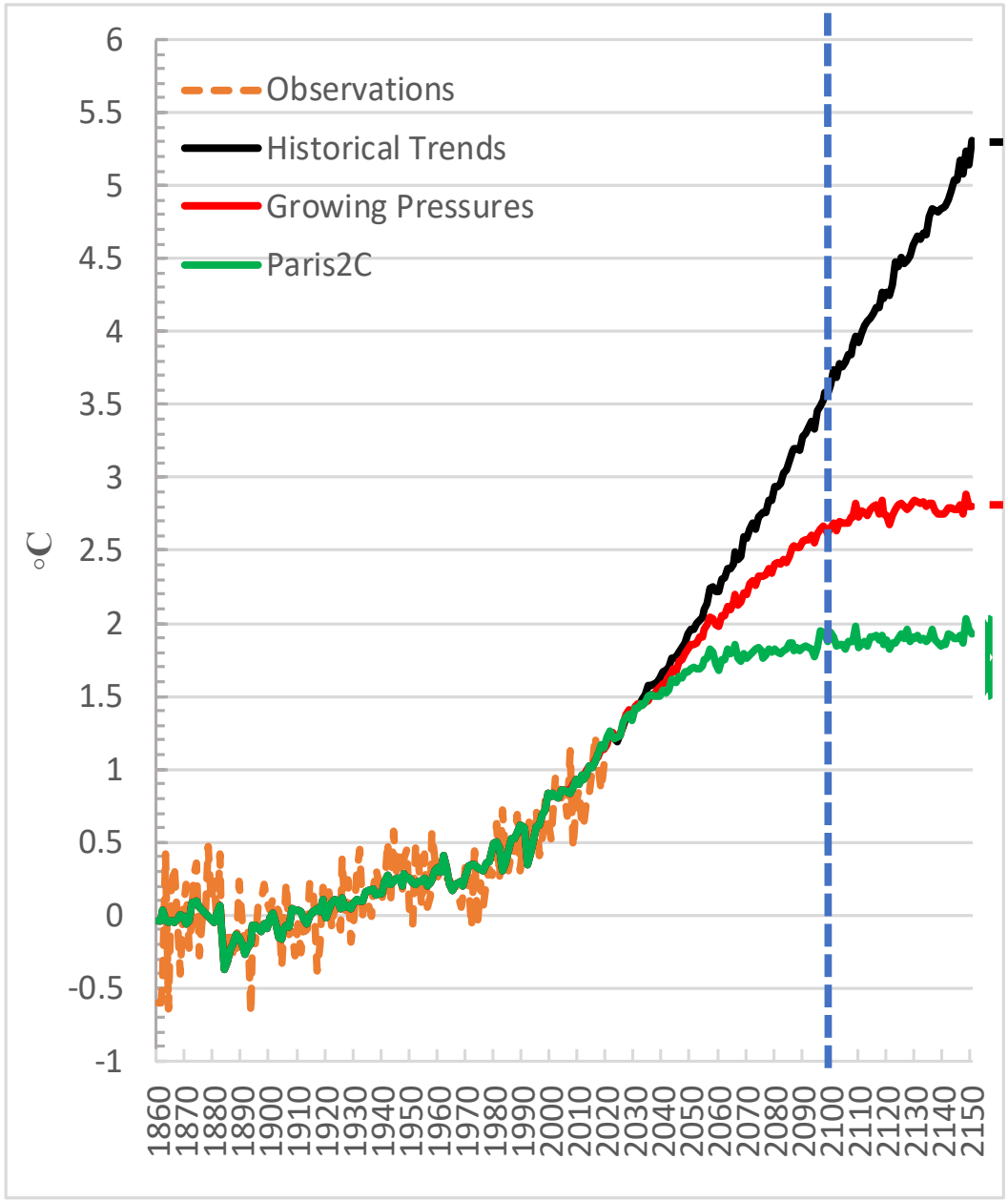
2120: Carbon-free refined oil alternatives in rest of the world

Change related to:
Coal
Gas
Oil
Electrification



Growing Pressures Scenario (MIT-Shell)





5.3°C in 2150

2.8°C in 2150

1.5-2°C in 2100 and beyond, Pari Agreement Goals

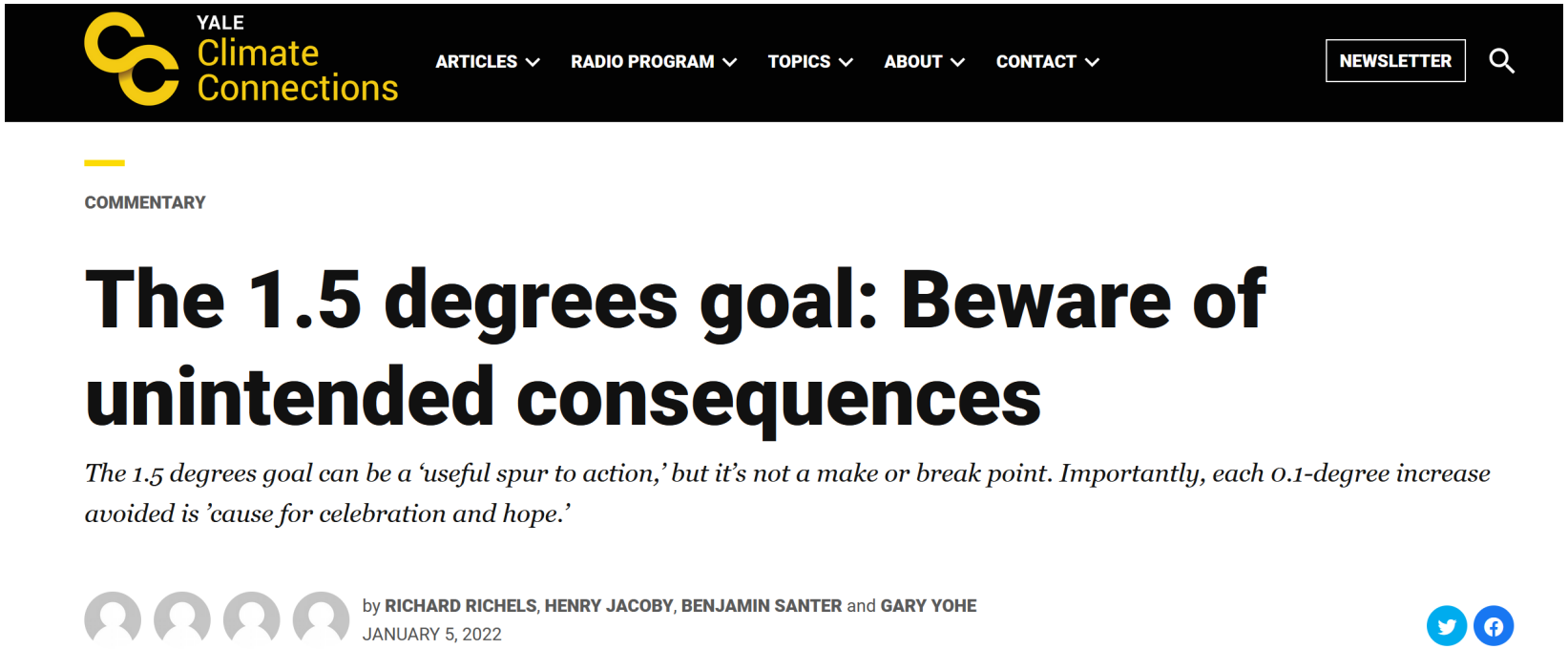
Stepping up actions (e.g. deploying carbon pricing, developing **negative emission technologies**, etc.) is crucial to accelerate the transition

Morris, J., D. Hone, M. Haigh, A. Sokolov and S. Paltsev (2022): Future energy: In search of a scenario reflecting current and future pressures and trends. Environmental Economics and Policy Studies, doi: 10.1007/s10018-021-00339-1 (https://link.springer.com/article/10.1007/s10018-021-00339-1)

MIT JOINT PROGRAM GLOBAL CHANGE

Closing Thoughts

- NETs have great potential in low-carbon futures–providing a more cost-effective pathway to meeting a given target, or enabling the achievement of a more stringent target
- There are still many challenges– MRV, sustainability, political acceptance…
- Net-zero, net-negative and 1.5C targets represent a major divergence from the policies we see being actually implemented today



Closing Thoughts

- NETs have great potential in low-carbon futures–providing a more cost-effective pathway to meeting a given target, or enabling the achievement of a more stringent target
- There are still many challenges– MRV, sustainability, political acceptance…
- Net-zero, net-negative and 1.5C targets represent a major divergence from the policies we see being actually implemented today
- Need to also explore other, more realistic scenarios
- Many uncertainties about the future, including about climate policy design
- Broad ranges of potential societies consistent with any individual global emissions pathway
    - Need to consider the full range for risk assessment and planning
- Must be prepared for future without a lot of negative emissions
    - Deep mitigation is needed
    - Importance of adaptation and resilience (e.g. how to best deal with / mitigate the consequences of not achieving 1.5C… or 2C)

Thank You

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