## CLIMATE POLICY

Can Paris pledges avert severe climate change?

Reducing risks of severe outcomes and improving chances of limiting warming to 2°C

By **Allen A. Fawcett,**[1] **Gokul C. Iyer,**[2]* **Leon E. Clarke,**[2] **James A. Edmonds,**[2] **Nathan E. Hultman,**[3] **Haewon C. McJeon,**[2] **Joeri Rogelj,**[4] **Reed Schuler,**[5] **Jameel Alsalam,**[1] **Ghassem R. Asrar,**[2] **Jared Creason,**[1] **Minji Jeong,**[2] **James McFarland,**[1] **Anupriya Mundra,**[2] **Wenjing Shi**[2]

Paris Agreement

► The heart of the Paris architecture is the **INDC (Intended Nationally Determined Contribution).**

- The INDCs are the contributions parties are making towards meeting the goals of the agreement in light of their national circumstances.

► Evolving commitments

- 2018 and every 5 years thereafter
  - A global stocktake will assess what the NDCs accomplish in light of the goals of the Agreement
- 2020 and every 5 years thereafter
  - COP meeting with new NDCs submitted 9-12 months in advance covering the next 10 years, ratcheting up ambition compared to previous NDCs.
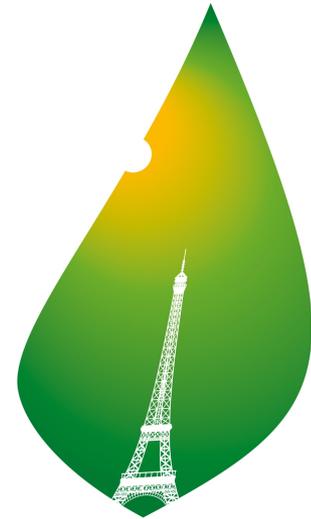
COP21·CMP11

PARIS 2015

UN CLIMATE CHANGE CONFERENCE
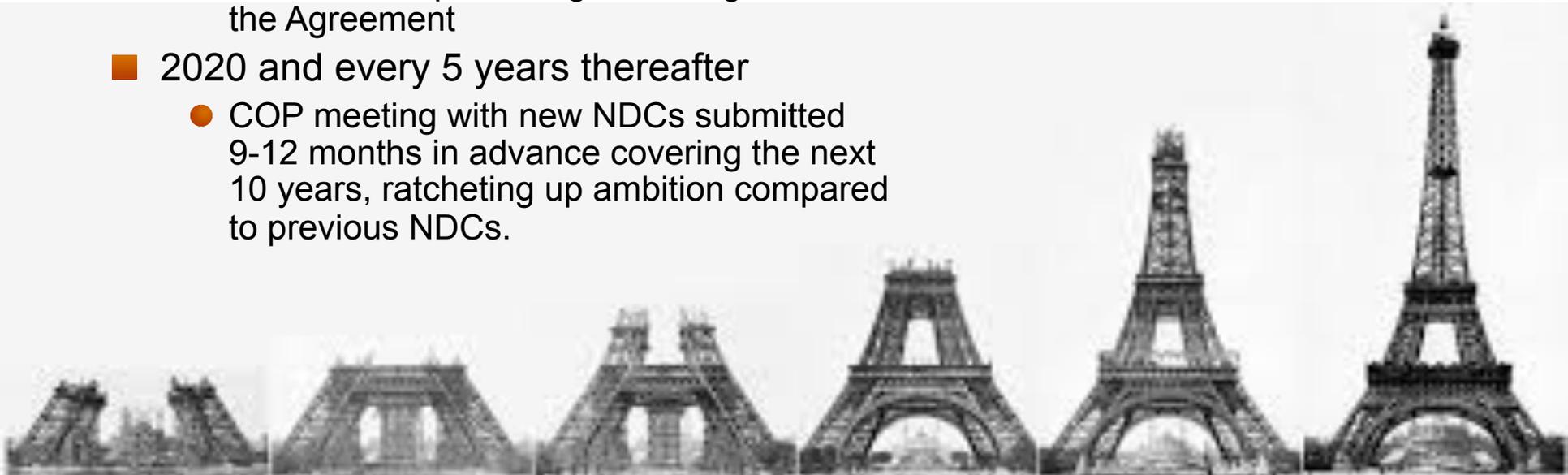
Paris Agreement

► **Article 2**

1. "This agreement…aims to strengthen the global response to the threat of climate change…by:

   (a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change..."

► **Article 4**

1. "In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible...and to undertake rapid reductions thereafter…so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"

2. "Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions."

3. "Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

9. "Each Party shall communicate a nationally determined contribution every five years..."

19. "All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies…"

A New Paradigm

▶ The international architecture that emerged from Paris represents a new approach

- Kyoto
  - Top down approach based on cap-and-trade
  - Capped emissions in Annex I parties only
  - Included non-Annex I parties only through CDM
- Paris
  - Bottom up approach based on INDCs
  - All parties are contributing INDCs
  - Paris is creating a durable framework for Parties' to update their INDCs and increase ambition over time.

U.S. & China Nov. 2014 Joint Announcement and the INDC development process

▶ "Today, the Presidents of the United States and China announced their respective post-2020 actions on climate change, recognizing that these actions are part of the longer range effort to transition to low-carbon economies, mindful of the global temperature goal of 2°C."

▶ "The United States and China hope that by announcing these targets now, they can inject momentum into the global climate negotiations and inspire other countries to join in coming forward with ambitious actions as soon as possible, preferably by the first quarter of 2015."
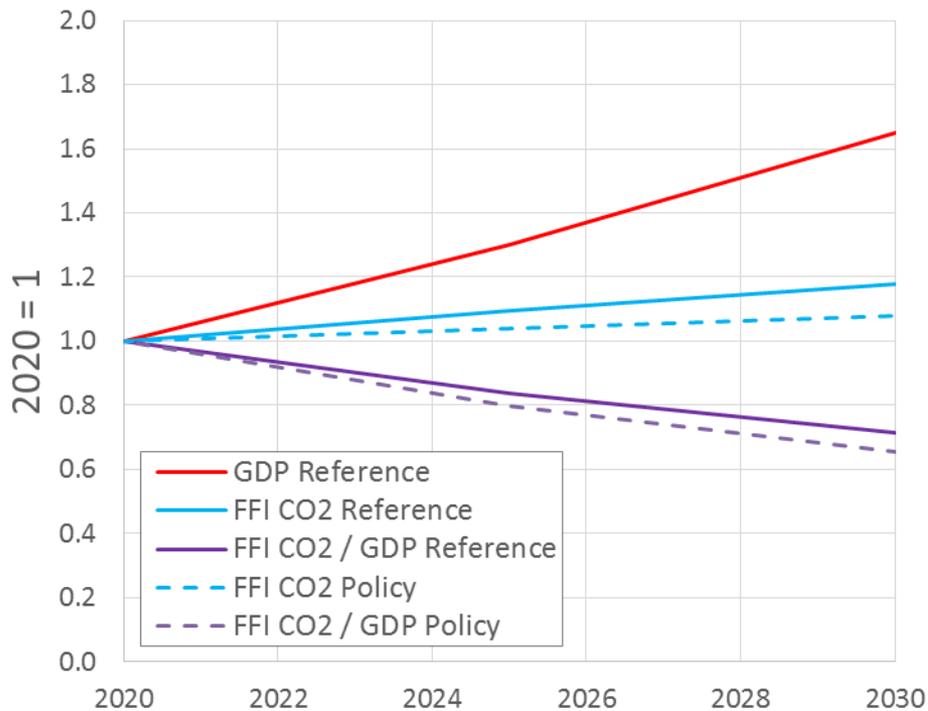
China INDC

Intended nationally determined contribution

- To achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early;

- To lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level;

- To increase the share of non-fossil fuels in primary energy consumption to around 20%; and

- To increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level.

China INDC, Decarbonization Rates, and CO$_2$ Projections

China - GDP and CO$_2$

Legend:
- GDP Reference
- FFI CO2 Reference
- FFI CO2 / GDP Reference
- FFI CO2 Policy
- FFI CO2 / GDP Policy

► In the GCAM baseline scenario for the China, from 2020 to 2030:
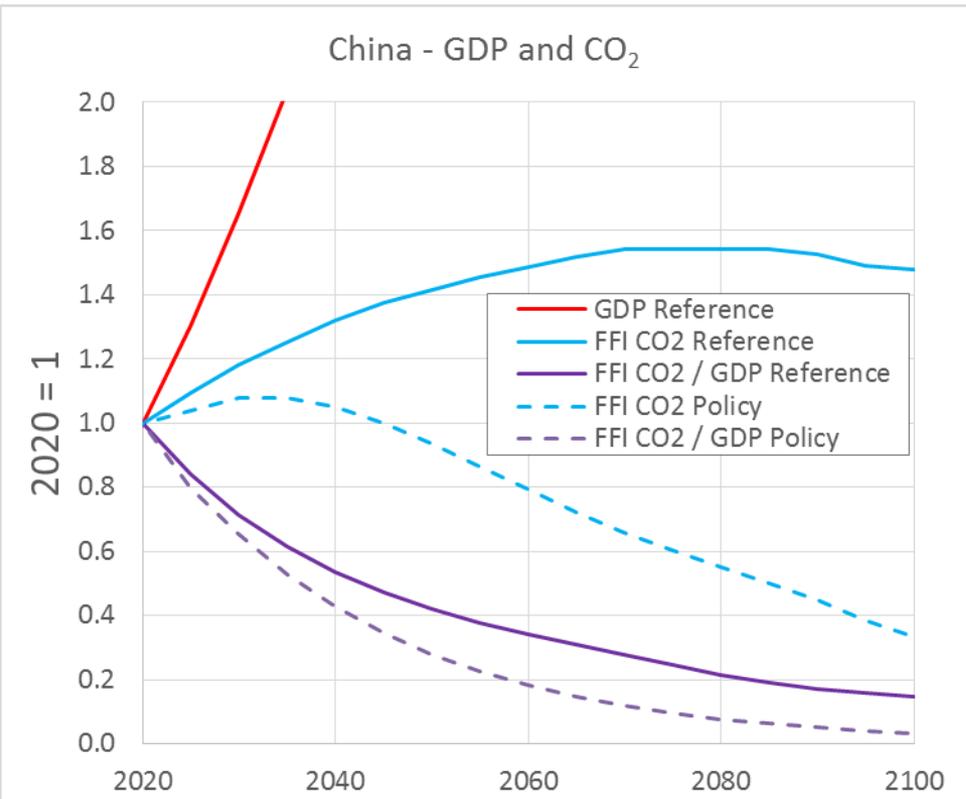- GDP increases 65%
  - 5.1% annual growth rate
- FFI CO2 **increases 18%**
  - 1.7% annual growth rate
- FFI CO2/GDP falls 29%
  - 3.3% annual decarbonization rate

► In the GCAM policy scenario that meets the China INDC goal,* from 2020 to 2030:
- GDP increases 65%
  - 5.1% annual growth rate
- FFI CO2 **increases 8%**
  - 0.8% annual growth rate
- FFI CO2/GDP falls 35%
  - 4.2% annual decarbonization rate

* The peak by 2030 and the 20% non-fossil share of primary energy are both considered in this GCAM scenario.

China INDC, Decarbonization Rates, and CO$_2$ Projections

China - GDP and CO$_2$

Legend:
- GDP Reference
- FFI CO2 Reference
- FFI CO2 / GDP Reference
- FFI CO2 Policy
- FFI CO2 / GDP Policy

▶ If China maintains the decarbonization rate required to meet the INDC goal.

▶ In the GCAM baseline scenario for the China, from 2020 to 2100:
  ■ GDP increases 912%
    ● 2.9% annual growth rate
  ■ FFI CO2 **increases 48%**
    ● 0.5% annual growth rate
  ■ FFI CO2/GDP falls 85%
    ● 2.4% annual decarbonization rate

▶ In the GCAM policy scenario that extends the INDC decarbonization rate, from 2020 to 2100:
  ■ GDP increases 912%
    ● 2.9% annual growth rate
  ■ FFI CO2 **decreases 67%**
    ● -1.4% annual growth rate
  ■ FFI CO2/GDP falls 98%
    ● 4.2% annual decarbonization rate

U.S. INDC

The United States intends to achieve an economy-wide target of reducing its greenhouse gas emissions by 26%-28% below its 2005 level in 2025 and to make best efforts to reduce its emissions by 28%.

► The target is fair and ambitious.

- Additional action to achieve the 2025 target represents a substantial acceleration of the current pace of greenhouse gas emission reductions.

► The 2025 target is consistent with a path to deep decarbonization.

- This target is consistent with a straight line emission reduction pathway from 2020 to deep, economy-wide emission reductions of 80% or more by 2050.

- The target is part of a longer range, collective effort to transition to a low-carbon global economy as rapidly as possible.

► The target reflects a planning process that examined opportunities under existing regulatory authorities to reduce emissions in 2025 of all greenhouse gases from all sources in every economic sector.

U.S. 2016 Biennial Report

Figure 6 **U.S. Emissions Projections—2016 *Current Measures* Compared with Potential Reductions from *Additional Measures* Consistent with the *Climate Action Plan***

Also shown are previous projections from the 2006, 2010, and 2014 U.S. Climate Action Reports, which demonstrate the dramatic ratcheting down of projected U.S. emissions over the past decade.
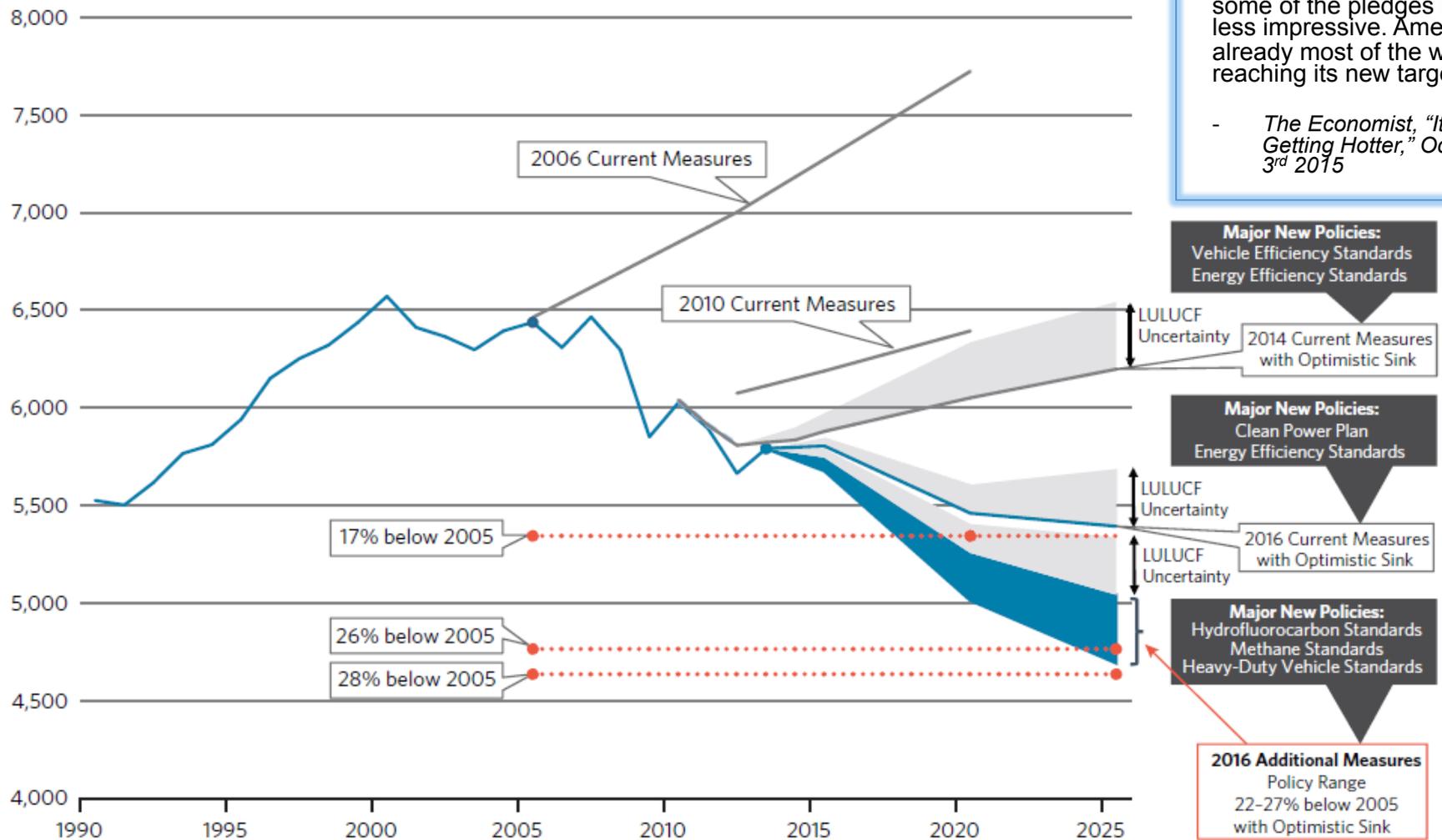
"On closer scrutiny, though, some of the pledges look less impressive. America is already most of the way to reaching its new target."
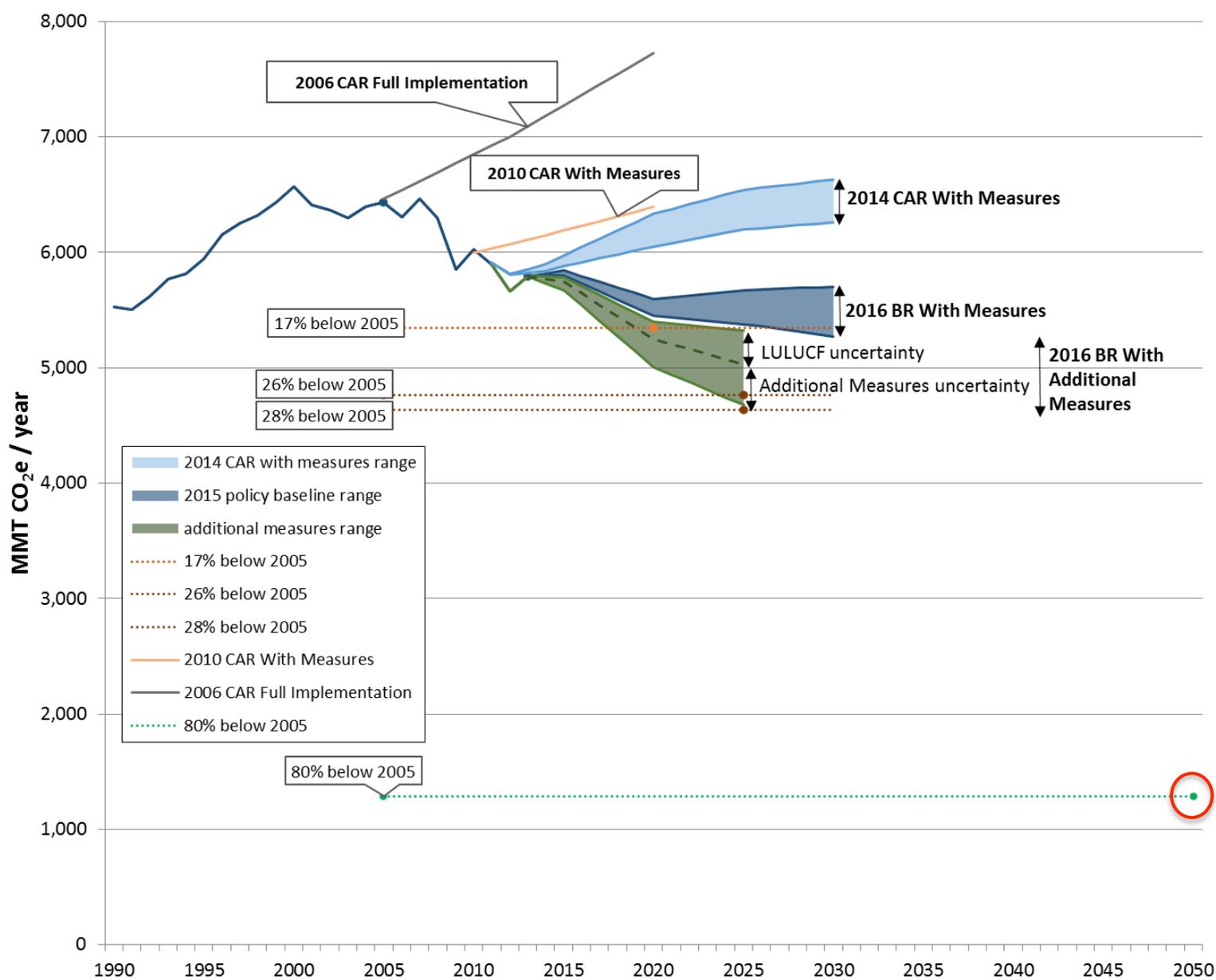
- *The Economist, "It's Getting Hotter," October 3rd 2015*

2006 Current Measures

2010 Current Measures

Major New Policies:
Vehicle Efficiency Standards
Energy Efficiency Standards

LULUCF Uncertainty

2014 Current Measures with Optimistic Sink

Major New Policies:
Clean Power Plan
Energy Efficiency Standards

LULUCF Uncertainty

2016 Current Measures with Optimistic Sink

LULUCF Uncertainty

Major New Policies:
Hydrofluorocarbon Standards
Methane Standards
Heavy-Duty Vehicle Standards

17% below 2005

26% below 2005

28% below 2005

2016 Additional Measures
Policy Range
22–27% below 2005
with Optimistic Sink

U.S. Net Emissions (Mt CO₂e)

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U.S. 2016 Biennial Report

U.S. INDC, Decarbonization Rates, and CO_2 Projections

USA - GDP and CO_2

- GDP Reference
- FFI CO2 Reference
- FFI CO2 / GDP Reference
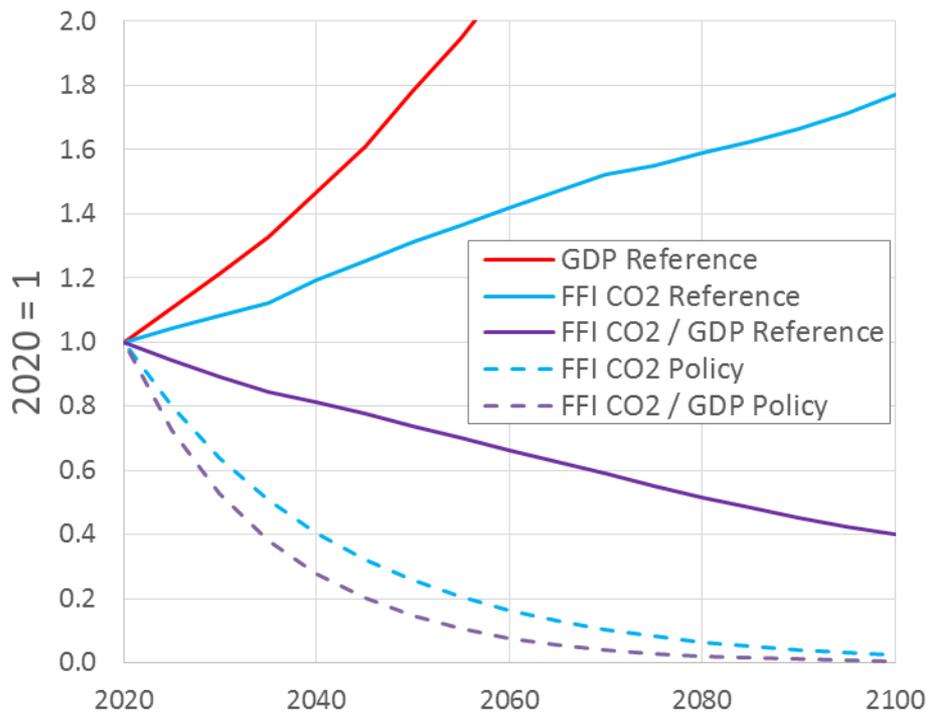- FFI CO2 Policy
- FFI CO2 / GDP Policy
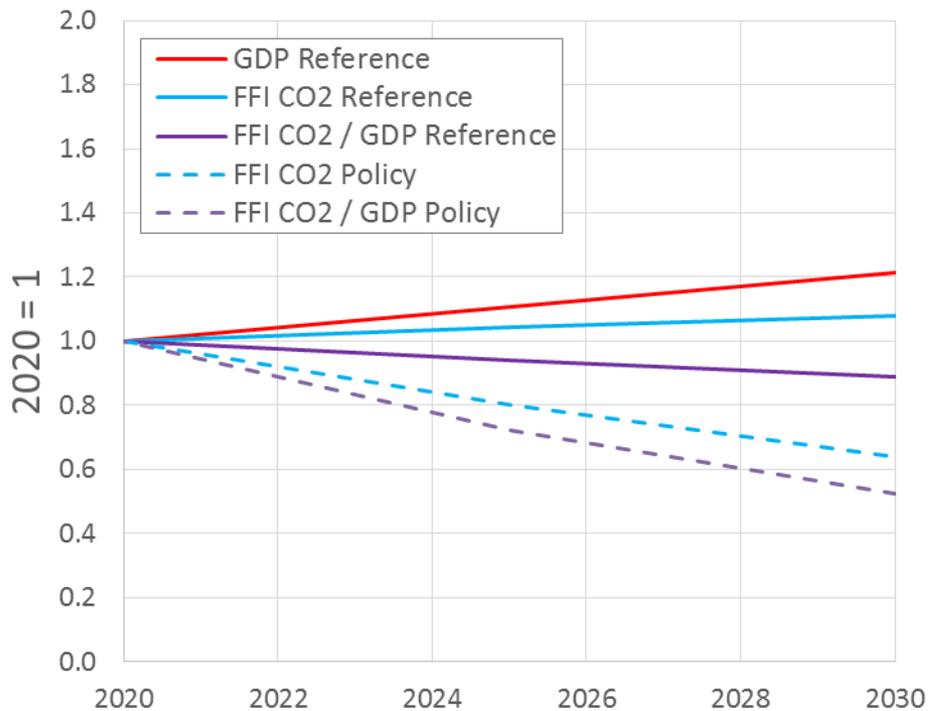
► In the GCAM baseline scenario for the U.S., from 2020 to 2030:
- ■ GDP increases 21%
  - ● 2.0% annual growth rate
- ■ FFI CO2 increases 8%
  - ● 0.8% annual growth rate
- ■ FFI CO2/GDP falls 11%
  - ● 1.2% annual decarbonization rate

► In the GCAM policy scenario that meets the U.S. INDC goal,* from 2020 to 2030:
- ■ GDP increases 21%
  - ● 2.0% annual growth rate
- ■ FFI CO2 decreases 36%
  - ● -4.4% annual growth rate
- ■ FFI CO2/GDP falls 47%
  - ● 6.2% annual decarbonization rate

* Using the straight line path from the 2020 17% target, through the 28% 2025 goal, to a 80% reduction in 2050 as discussed in the U.S. INDC.

U.S. INDC, Decarbonization Rates, and CO$_2$ Projections

USA - GDP and CO$_2$

Legend:
- GDP Reference
- FFI CO2 Reference
- FFI CO2 / GDP Reference
- FFI CO2 Policy
- FFI CO2 / GDP Policy

► If the U.S. maintains the decarbonization rate required to meet the INDC goal.

► In the GCAM baseline scenario for the U.S., from 2020 to 2100:
  ■ GDP increases 343%
    ● 1.9% annual growth rate
  ■ FFI CO2 increases 77%
    ● 0.7% annual growth rate
  ■ FFI CO2/GDP falls 60%
    ● 1.1% annual decarbonization rate

► In the GCAM policy scenario that extends the INDC decarbonization rate, from 2020 to 2100:
  ■ GDP increases 343%
    ● 1.9% annual growth rate
  ■ FFI CO2 decreases 97%
    ● -4.5% annual growth rate
  ■ FFI CO2/GDP falls 99%
    ● 6.2% annual decarbonization rate

INDC Commitments
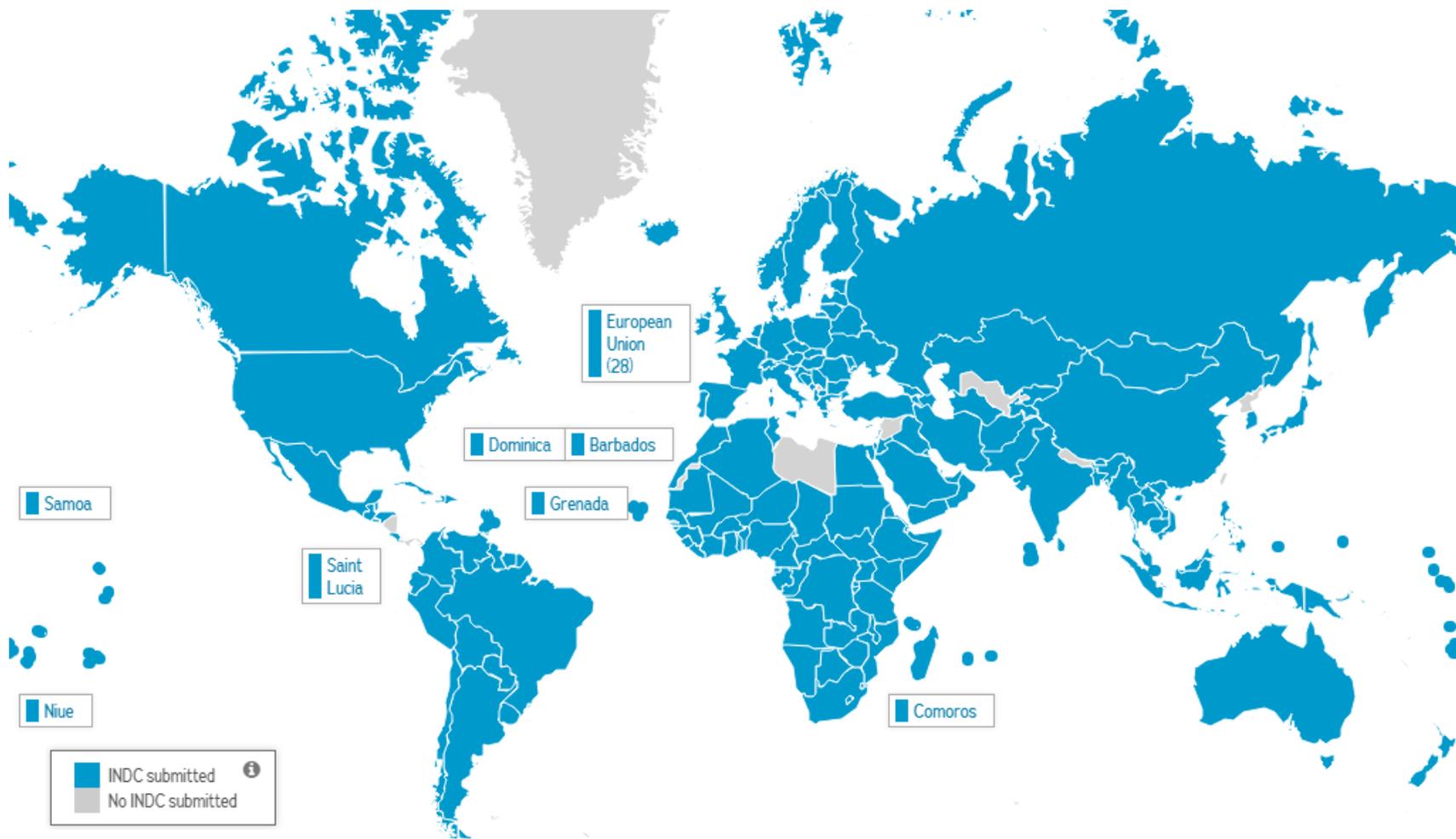
WRI. CAIT Climate Data Explorer. 2015. CAIT Paris Contribution Map. Washington, DC: World Resources Institute. Available at: http://cait.wri.org/indcs/#/map. 12 Dec 2015

► 160 INDCs representing 187 countries have been submitted.

► These countries represent 98.6% of current global GHG emissions.

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- ▶ A multi-year effort by a team from PNNL, EPA, UMD, State, and IIASA supporting the INDC process in the lead up to Paris.

- ▶ We analyze Paris from a risk management perspective and pose two key questions:

  - ■ How much does Paris and the INDCs reduce the probability of the highest levels of temperature change?

  - ■ How much do they improve the odds of achieving the international goal of limiting temperature change to 2°C?

- ▶ In order to answer these questions we need to:

  - ■ Estimate what emissions would look like without Paris

  - ■ Assess the emissions reductions that would be driven by the INDCs

  - ■ Project a range of futures that are enabled by Paris and the INDCs

  - ■ Estimate probabilistic temperature outcomes over the 21st century for this range of scenarios with and without Paris and the INDCs

Can Paris pledges avert severe climate change?

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A Emissions pathways
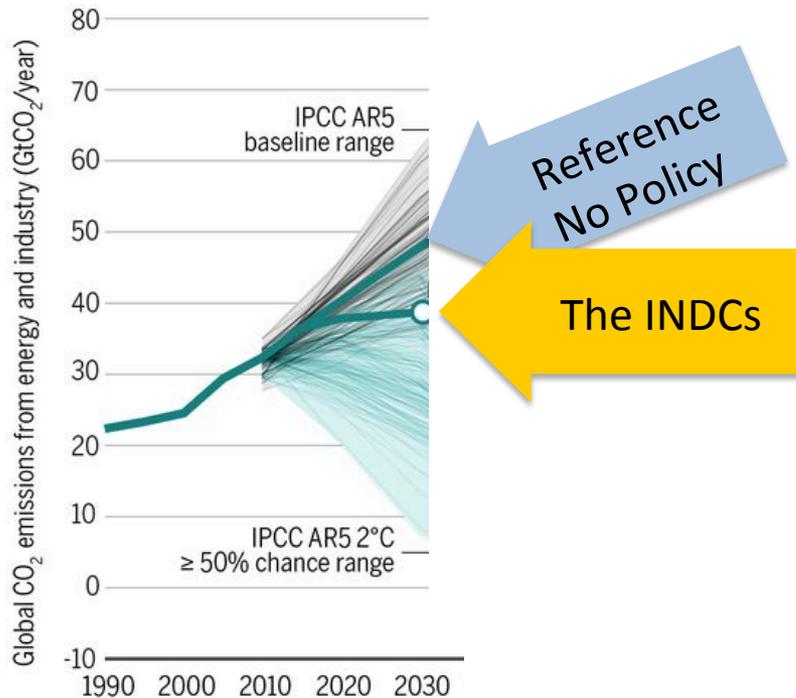
- ▶ The INDCs are defined no further than the year 2030

- ▶ Yet, a major question that is being asked is, what are the climate implications of the INDCs?

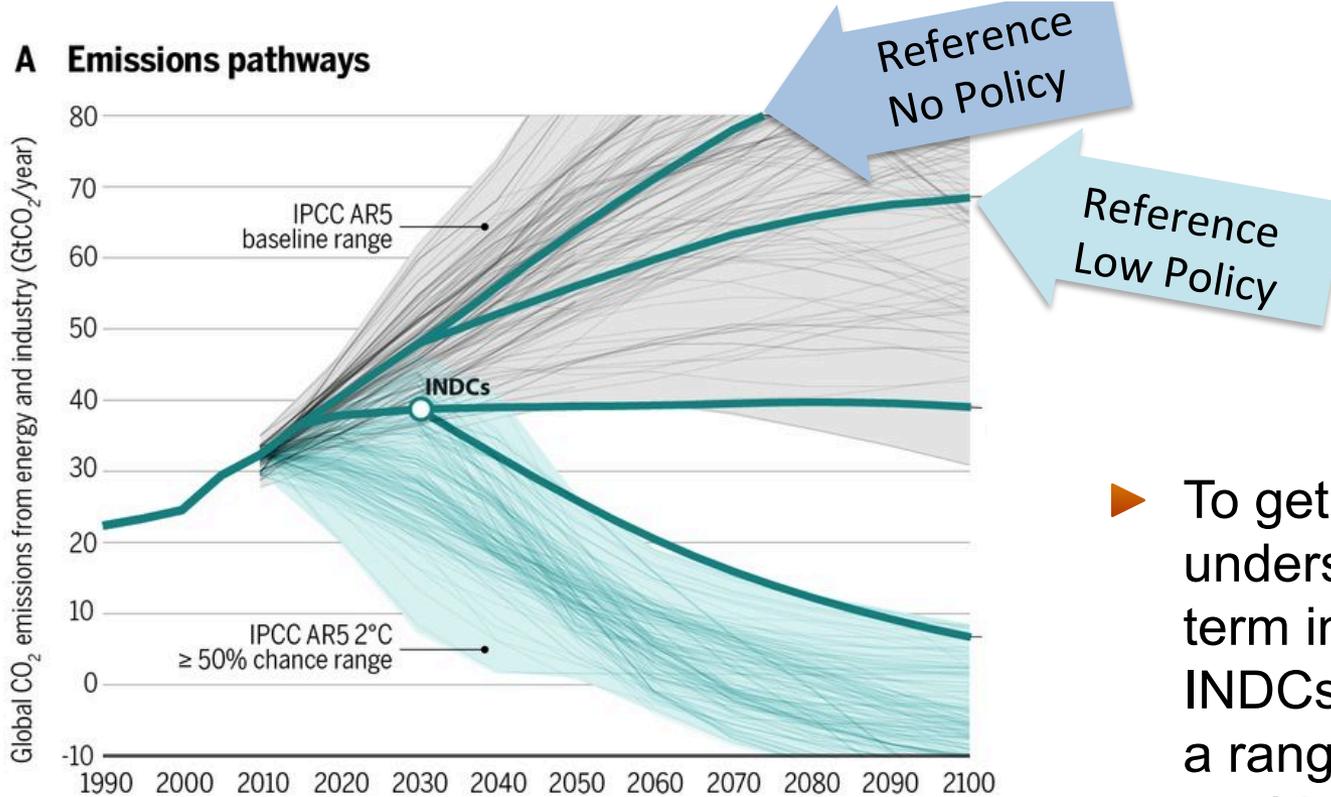- ▶ That answer depends on the next 70 or more years.

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A **Emissions pathways**

Reference No Policy

Reference Low Policy

IPCC AR5 baseline range

INDCs

IPCC AR5 2°C ≥ 50% chance range

Global CO$_2$ emissions from energy and industry (GtCO$_2$/year)

► To get a better understanding of the long term implications of the INDCs we need to consider a range of scenarios that could occur in the period between 2030 and 2100.

Science
AAAS

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Can Paris pledges avert severe climate change?

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A Emissions pathways

- ▶ We extend the INDCs under two alternative assumptions:
  - ■ Paris - Continued Ambition
  - ■ Paris - Increased Ambition

- ▶ To extend the INDCs, we assume that countries continue to decarbonize their economies after 2030 (reduce CO2/GDP) at the pace required to meet their INDC goals in 2030.

- ▶ The range between our two scenarios is generated by varying the minimum decarbonization rate that countries are assumed to achieve after 2030 from 2% in the continued ambition scenario to 5% in the increased ambition scenario.

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A Emissions pathways

- ► We contrast our baseline scenarios with the range of baseline scenarios from the IPCC AR5 database

- ► We contrast our Paris scenarios with the range of scenarios from the IPCC AR5 database that have at least a 50% chance of limiting global mean surface temperature change to 2°C above pre-industrial time.
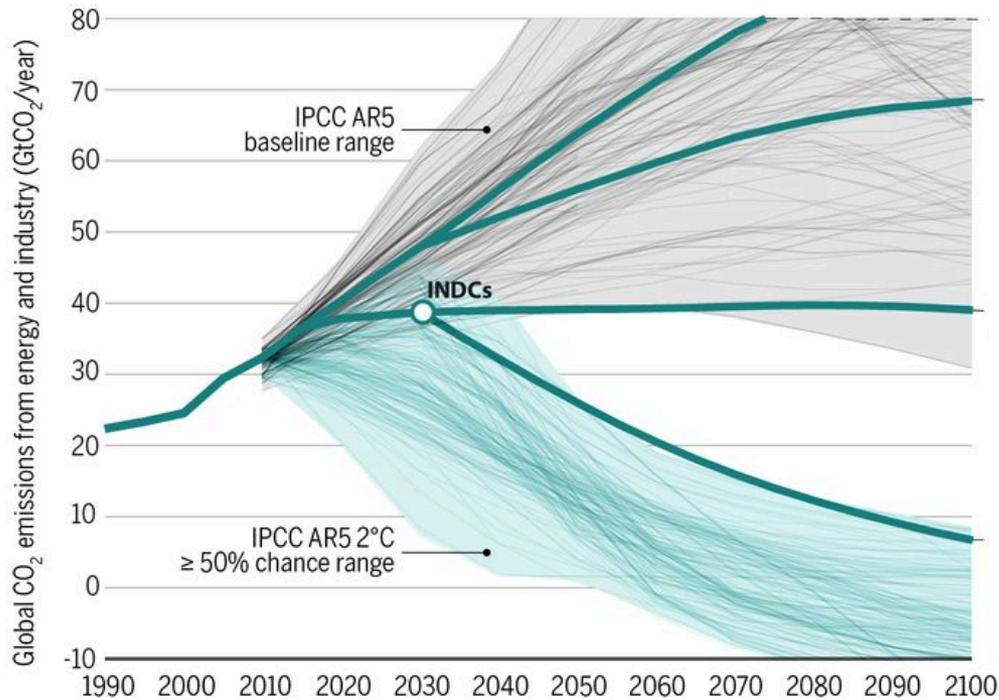
Allen A. Fawcett et al. Science 2015;science.aad5761

www.sciencemag.org/content/350/6265/1168

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A Emissions pathways

IPCC AR5 baseline range

INDCs

IPCC AR5 2°C ≥ 50% chance range

Global CO_2 emissions from energy and industry ($GtCO_2$/year)

► Our 4 deterministic emissions scenarios are run with GCAM

- GCAM generates the no-policy reference scenario

- GCAM fills in non-fossil fuel CO_2 emissions and generates the non-CO_2 emissions paths.

► We run each of our scenarios through a probabilistic version of MAGICC, a reduced form physical Earth system model, using a Monte Carlo simulation to get the distribution of temperature probabilities.

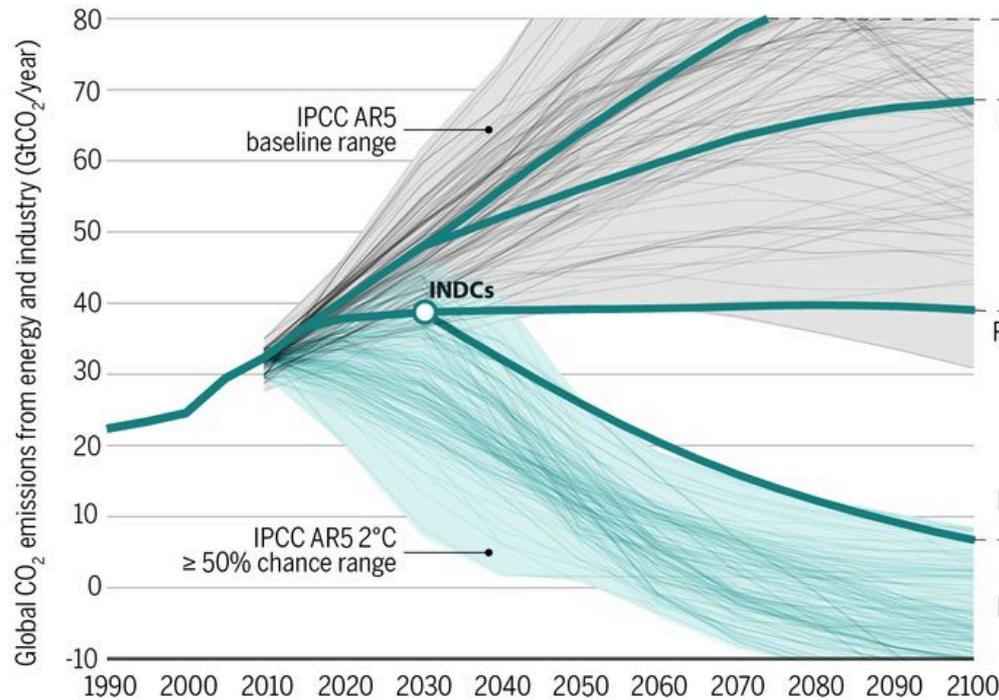**Allen A. Fawcett et al. Science 2015;science.aad5761**
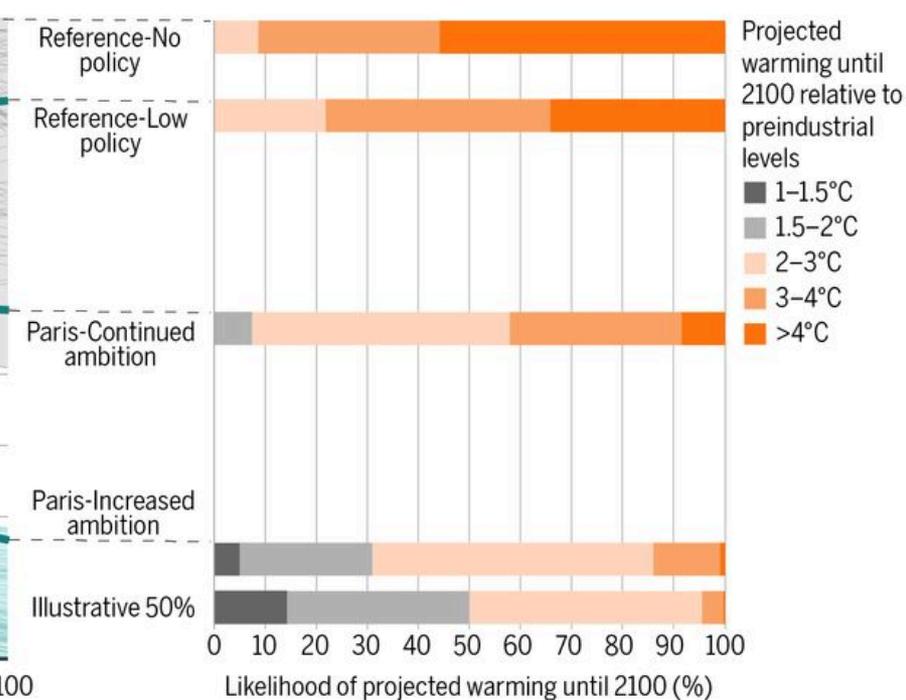www.sciencemag.org/content/350/6265/1168

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Can Paris pledges avert severe climate change?

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**A Emissions pathways**

B Temperature probabilities

- ► While the INDCs are defined no further into the future than 2030, along with the Paris framework they nonetheless reshape the range of options available to future decision makers.
- ► We need to assess the contribution of Paris from a risk management perspective.
- ► If the INDCs are followed by similar increases in ambition after 2030, then they could lead to substantial reductions in the likelihood of global average temperature change greater than 4°C.
- ► The INDCs also leave the door open to increased ambition which would increase the likelihood climate less than 2°C
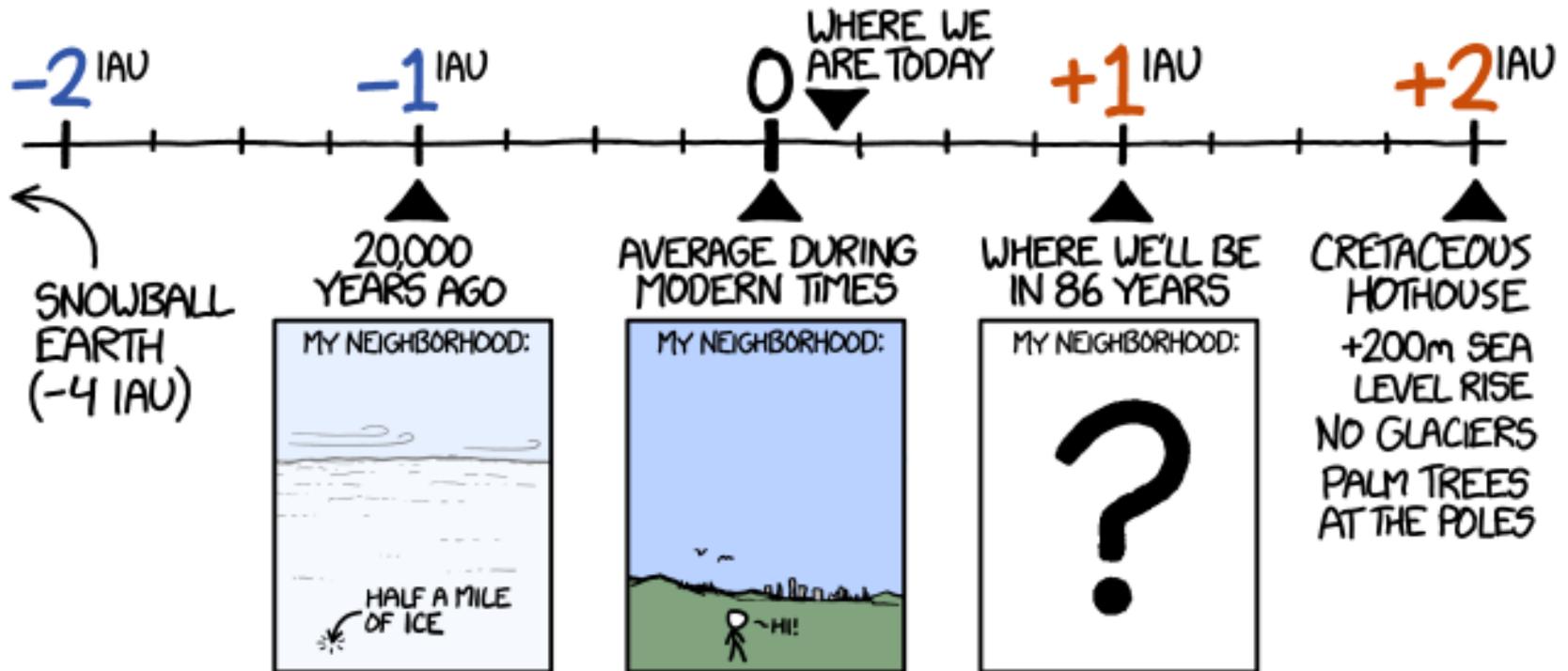
DISCUSSION

Appendix
Supplementary Materials

Decarbonization Rates – Ambition & Feasibility
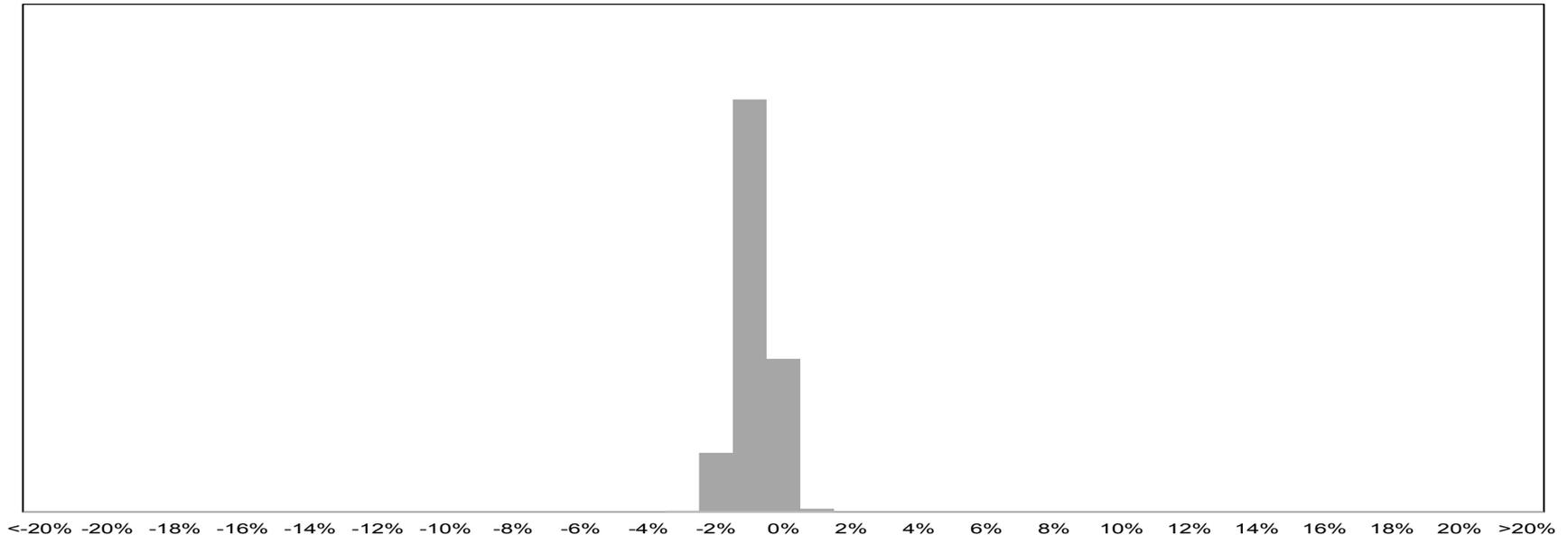
<-20% -20% -18% -16% -14% -12% -10% -8% -6% -4% -2% 0% 2% 4% 6% 8% 10% 12% 14% 16% 18% 20% >20%

▶ Distribution of 10-year running average of global rates of change in CO_2/GDP (change in global CO_2/global GDP) from 2020 to 2100 in baseline scenarios (that is, scenarios with no new GHG mitigation policies) from the IPCC's Fifth Assessment Report.
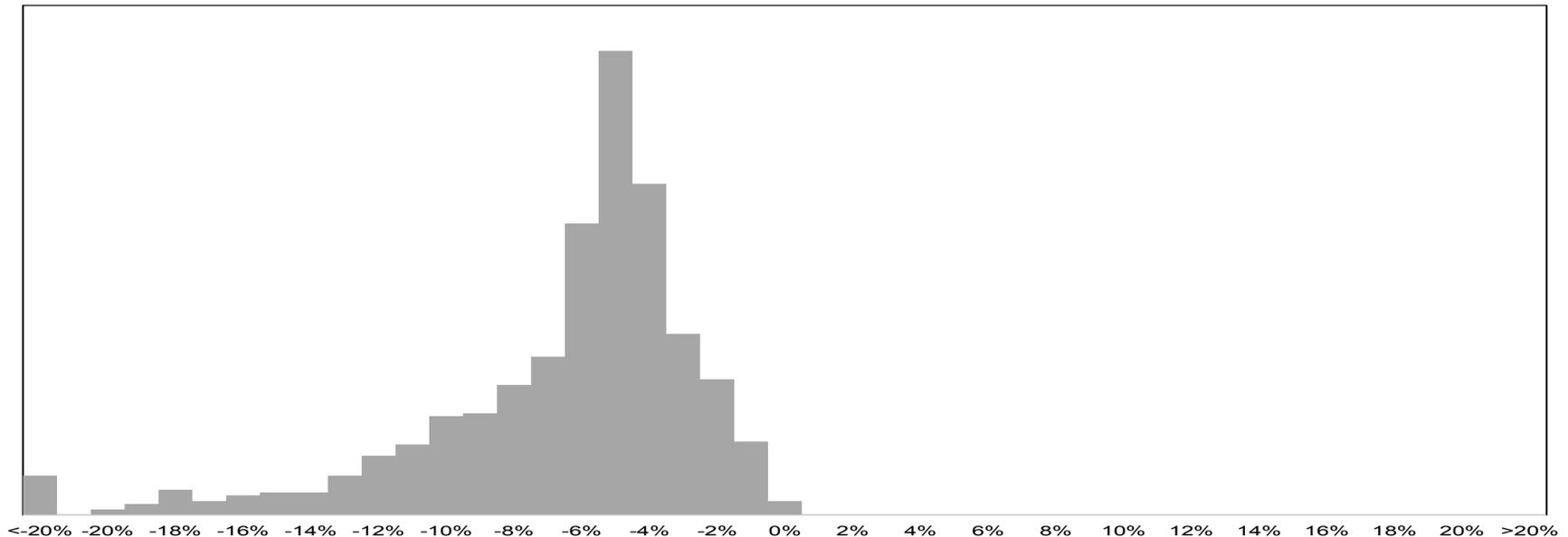
▶ Negative rates of change are referred to as "decarbonization rates".

Decarbonization Rates – Ambition & Feasibility

Distribution of 10-year running average of global rates of change in CO_2/GDP, with x-axis from <-20% to >20% in 2% increments, peaking around -4% to -6%.
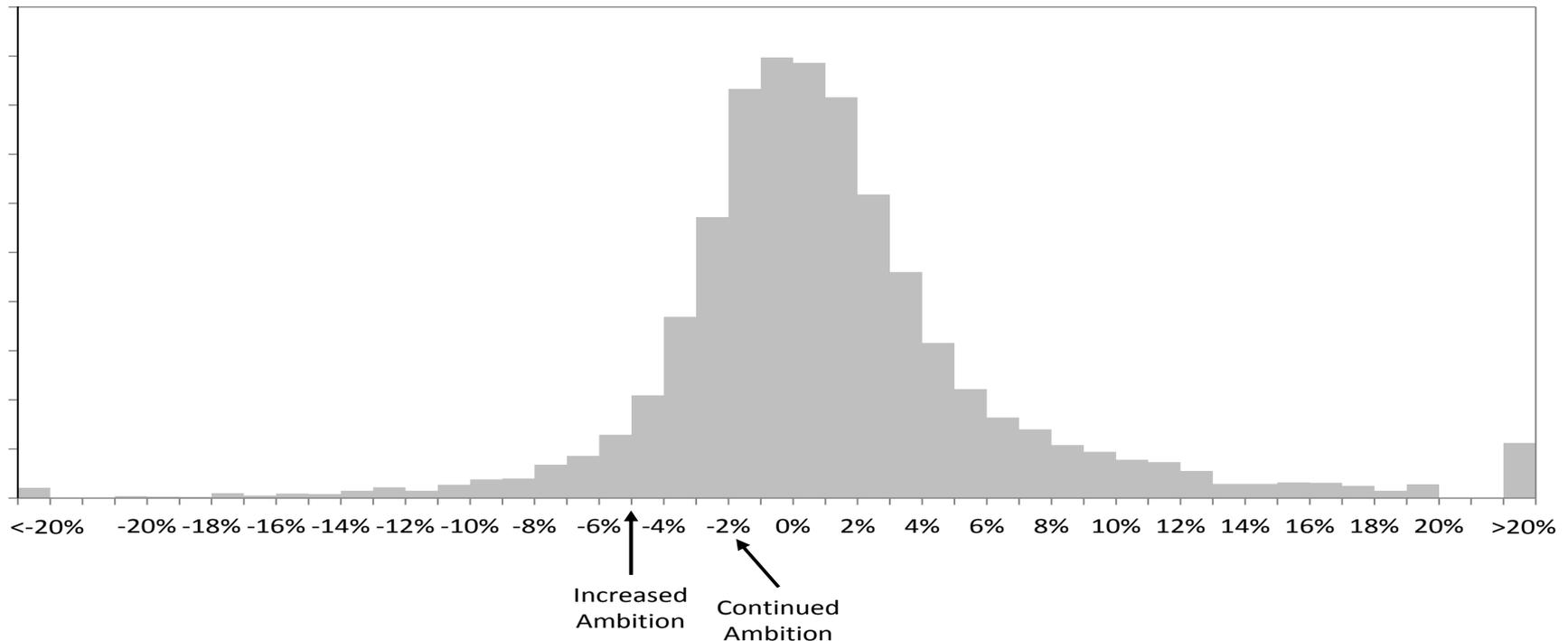
- ▶ Distribution of 10-year running average of global rates of change in CO_2/GDP (change in global CO_2/global GDP) from 2020 to 2100 in scenarios that limit global temperature change to less than 2°C with at least 50% chance from the IPCC's Fifth Assessment Report.
- ▶ Negative rates of change are referred to as "decarbonization rates".
- ▶ Periods with negative emissions are excluded from the distribution.
    - ■ This exclusion might bias the distribution towards low decarbonization rates since the negative emissions scenarios will be the ones with the lower rates initially.

Decarbonization Rates – Ambition & Feasibility

- ▶ Historical distribution of 10 year running average of country level rates of change in CO_2/GDP (1900-2008)
- ▶ Negative rates of change are referred to as "decarbonization rates".
- ▶ Rates with absolute values larger than 20% are associated with newly established countries and countries that ceased to exist.
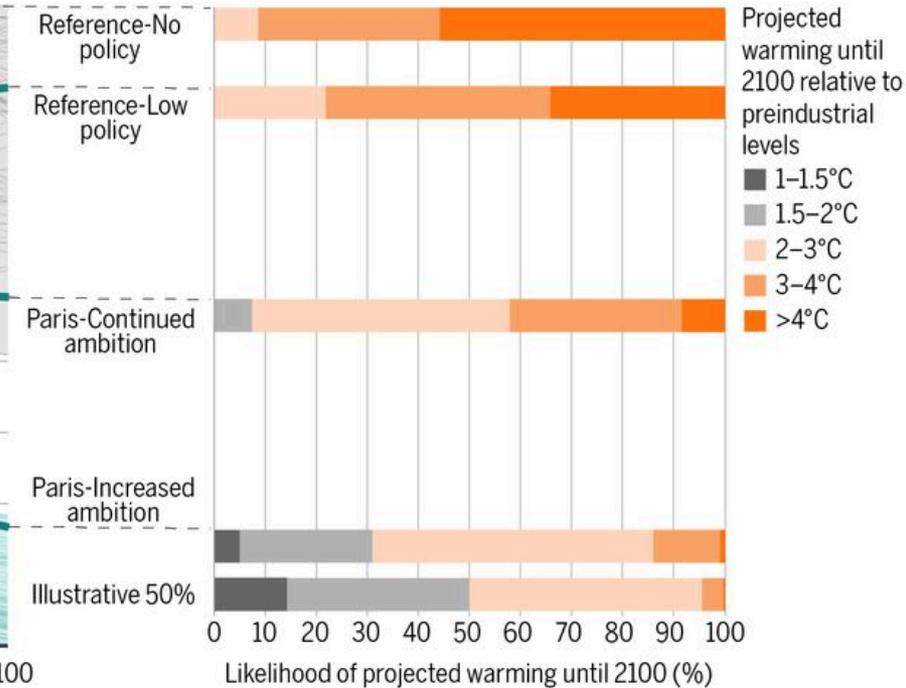
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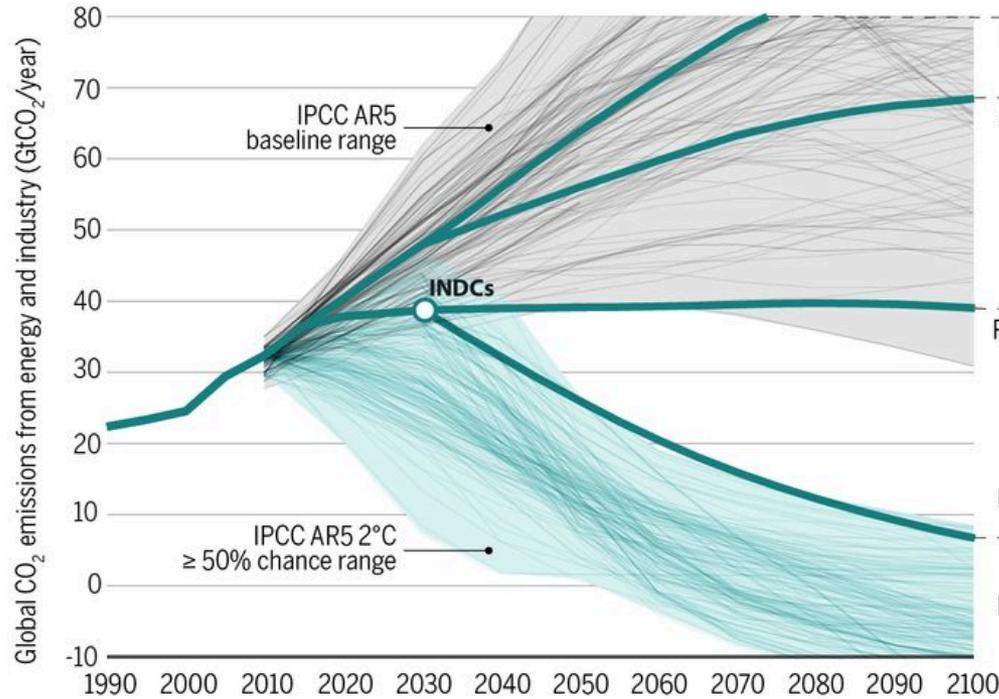
Global CO_2 emissions and probabilistic temperature outcomes of Paris. (**A**) Global CO_2 emissions from energy and industry (includes CO_2 emissions from all fossil fuel production and use and industrial processes such as cement manufacture that also produce CO_2 as a byproduct) for the four emissions scenarios explored in this study. The IPCC AR5 emissions ranges are from (12). The IPCC AR5 baseline range comprises scenarios that do not include new explicit GHG mitigation policies throughout the century. The IPCC AR5 2°C ≥ 50% range comprises scenarios that limit global warming until 2100 to less than 2°C with at least a 50% chance. The faint lines within the IPCC ranges represent the actual emissions trajectories that determine the range (12). (**B**) Likelihoods of different levels of increase in global mean surface temperature change during the 21st century relative to preindustrial levels for the four scenarios. Although (A) shows only CO_2 emissions from energy and industry, temperature outcomes are based on the full suite of GHG, aerosol, and short-lived species emissions generated by the GCAM (9) simulations (see SM). The Illustrative 50% scenario in (B) corresponds to an emissions pathway that achieves a 50% chance of maintaining temperature change below 2°C until 2100 (see SM). Other 50% pathways could lead to a range of temperature distributions depending on cumulative CO_2 emissions and representations of other GHGs.

Scenarios

Scenario	2020	2021-2030	2031-2100 Countries that have committed to unconditional emissions reductions in their INDCs	2031-2100 Countries that have not submitted INDCs or committed to unconditional emissions reductions in their INDCs
Reference-No Policy	No new policies or measures designed primarily to mitigate greenhouse gas emissions			
Reference-Low Policy	No new greenhouse gas mitigation policy		Low minimum decarbonization rate	Low minimum decarbonization rate
Paris-Continued Ambition	Copenhagen	INDC	Larger of either decarbonization rate implied by INDC, or low minimum decarbonization rate	Low minimum decarbonization rate
Paris-Increased Ambition	Copenhagen	INDC	Larger of either decarbonization rate implied by INDC, or high minimum decarbonization rate	High minimum decarbonization rate

Low Reference – No Policy
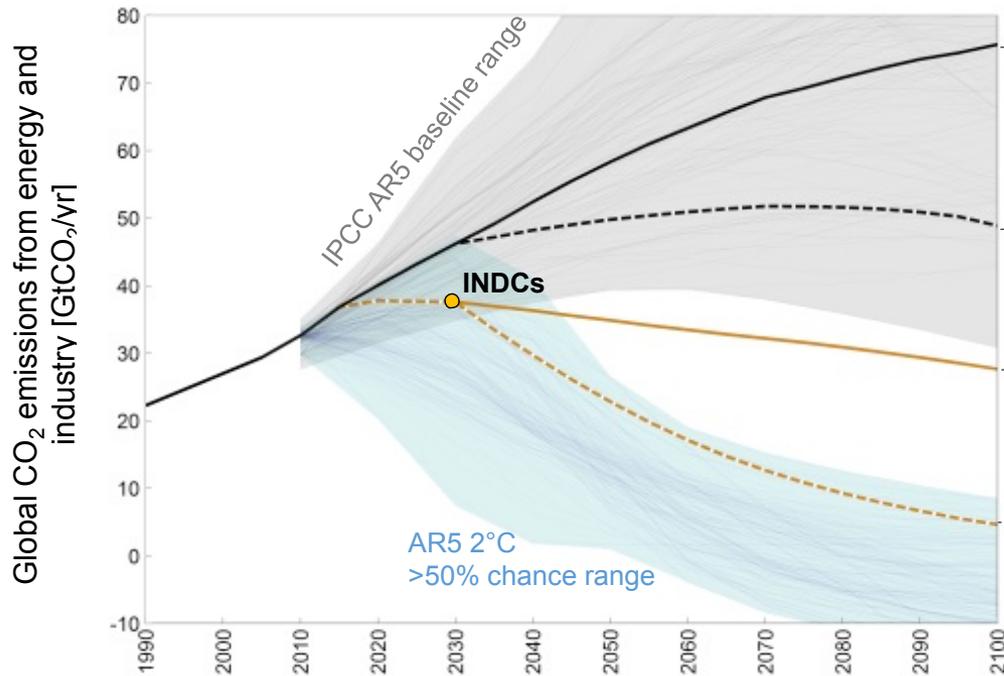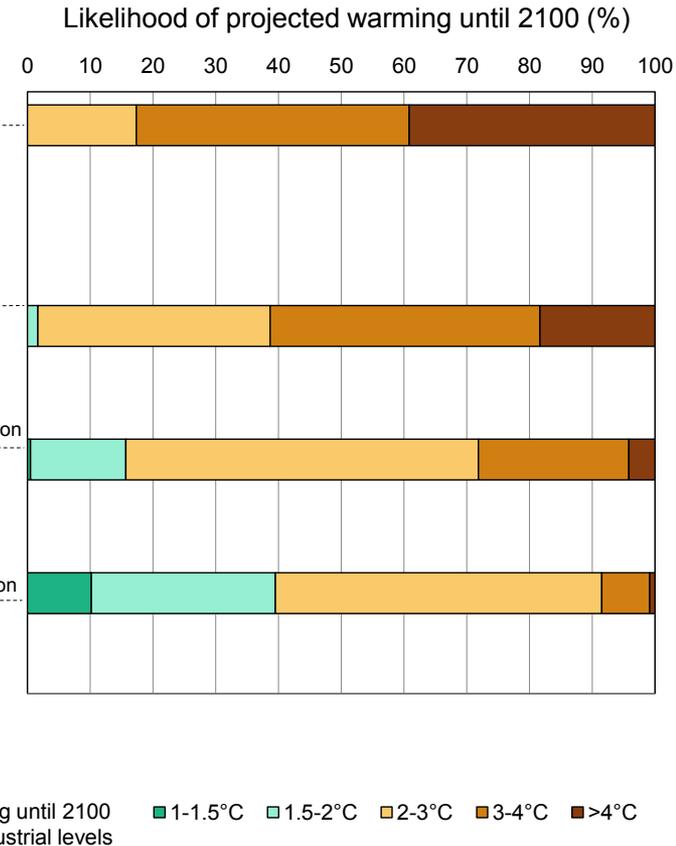
In this study we construct relatively simple sensitivity cases by decreasing and increasing regional labor productivity growth rates by 0.5% (over the entire 21st century) compared to the "*Medium Reference-No Policy*" case (which corresponds to the one used in the main analysis) such that the resulting emissions and radiative forcing trajectories span the IPCC AR5 range

Medium Reference – No Policy
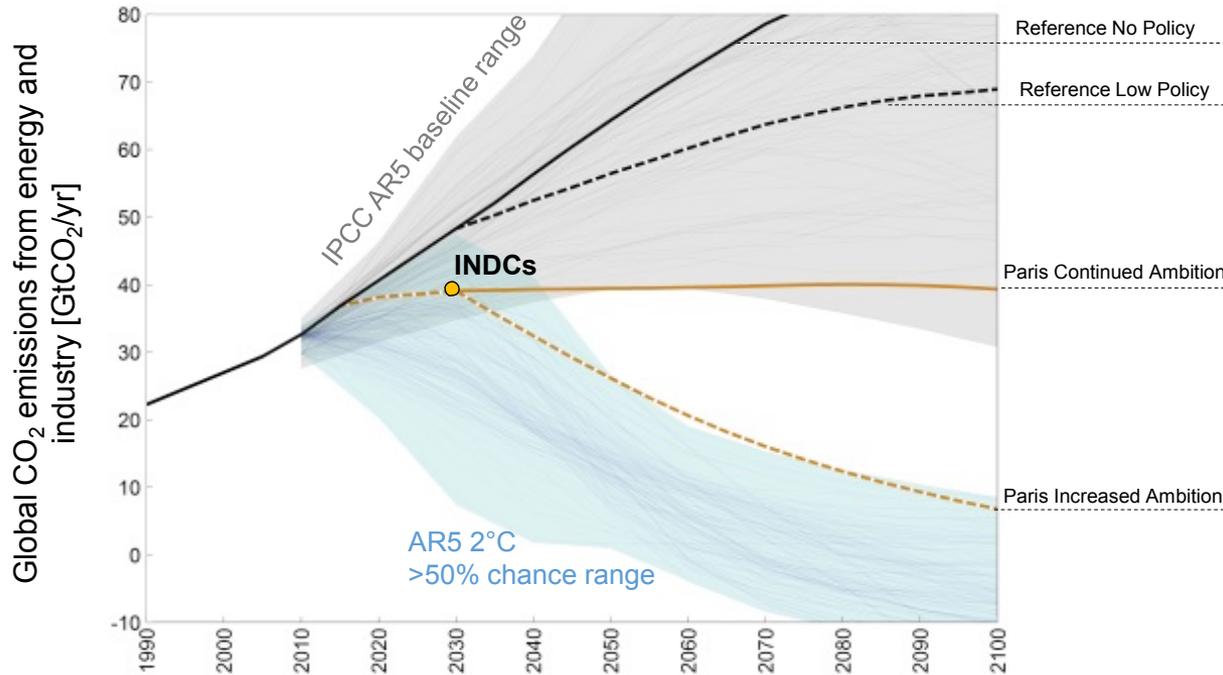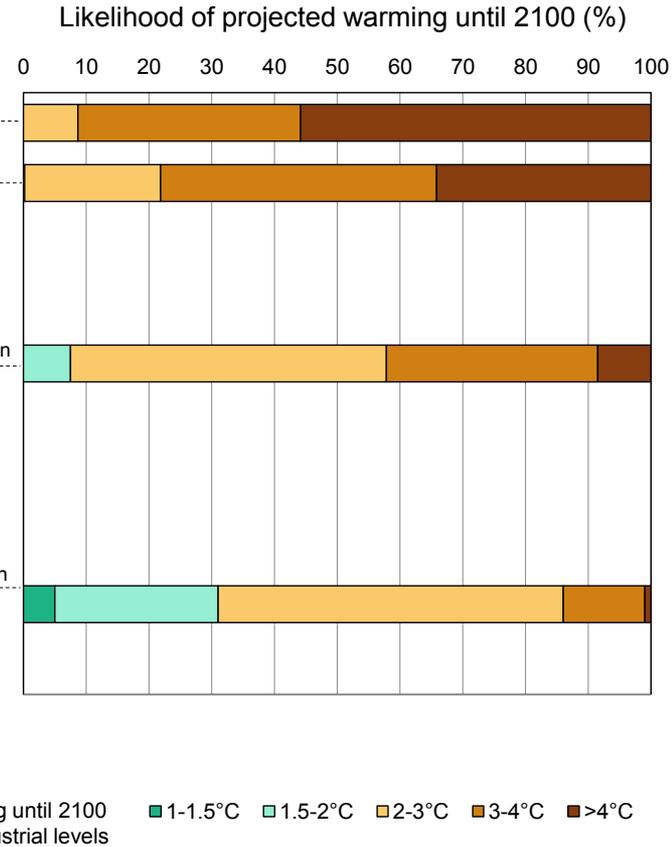

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High Reference – No Policy

A — Global CO₂ emissions from energy and industry [GtCO₂/yr]; IPCC AR5 baseline range; INDCs; AR5 2°C >50% chance range

B — Likelihood of projected warming until 2100 (%): Reference No Policy, Reference Low Policy, Paris Continued Ambition, Paris Increased Ambition

Projected Warming until 2100 relative to pre-industrial levels: 1-1.5°C, 1.5-2°C, 2-3°C, 3-4°C, >4°C
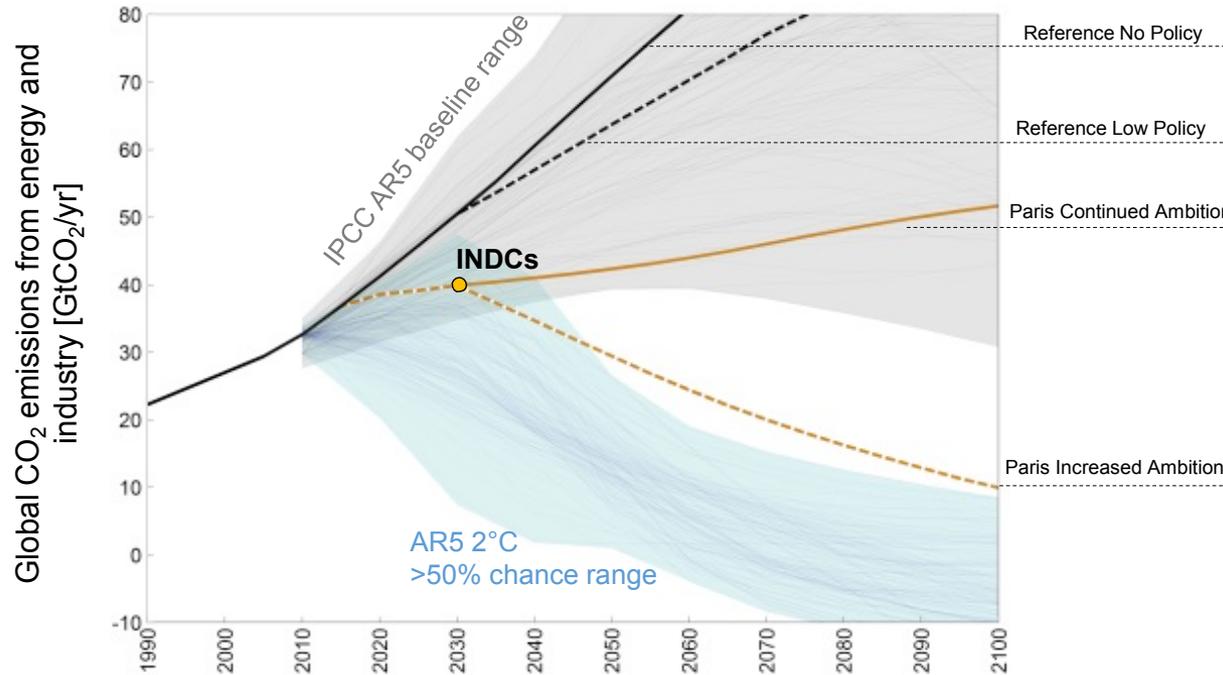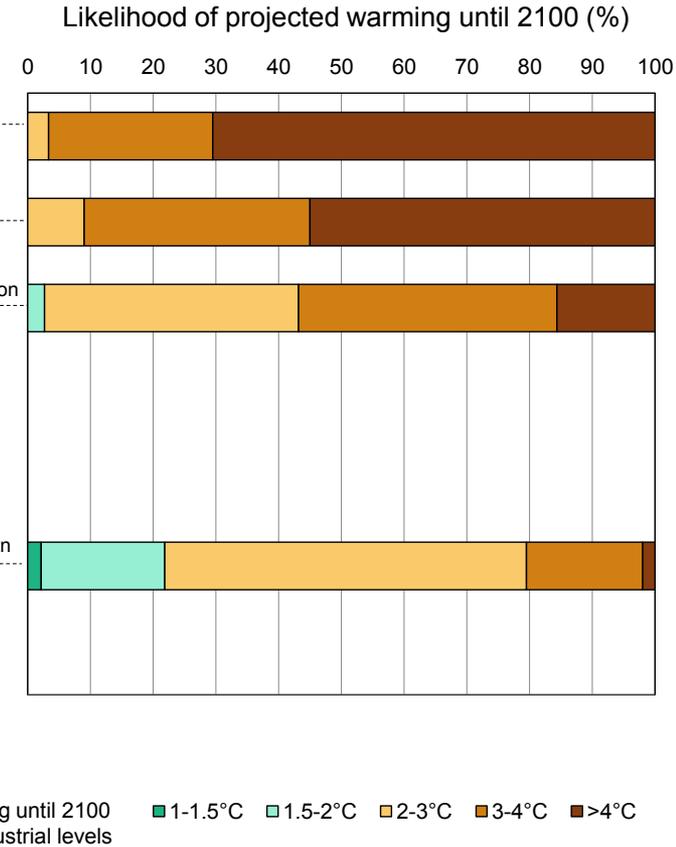
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A

global CO_2 emissions from energy and industry [$GtCO_2$/yr]

year

B

levels of projected warming
until 2100 relative to pre-industrial levels

1-1.5°C   1.5-2°C   2-3°C   3-4°C   >4°C

2°C probability variation: 22-40%

4°C probability variation: 0-2%

Paris
Increased Ambition

High baseline

Medium baseline

Low baseline

likelihood of projected warming until 2100 [%]