

# JOINT GLOBAL CHANGE RESEARCH INSTITUTE



## Standardized Scenarios, SRES, RCPs, SSPs, SPAs: the design and use of scenarios in modeling and policy analysis

March 15, 2023

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Joint Global Change Research Institute





# Roadmap

What and why of scenarios

The SSP-RCP framework

Examples of applications

Issues and future directions

What are scenarios, why do we use them?

# Scenarios.

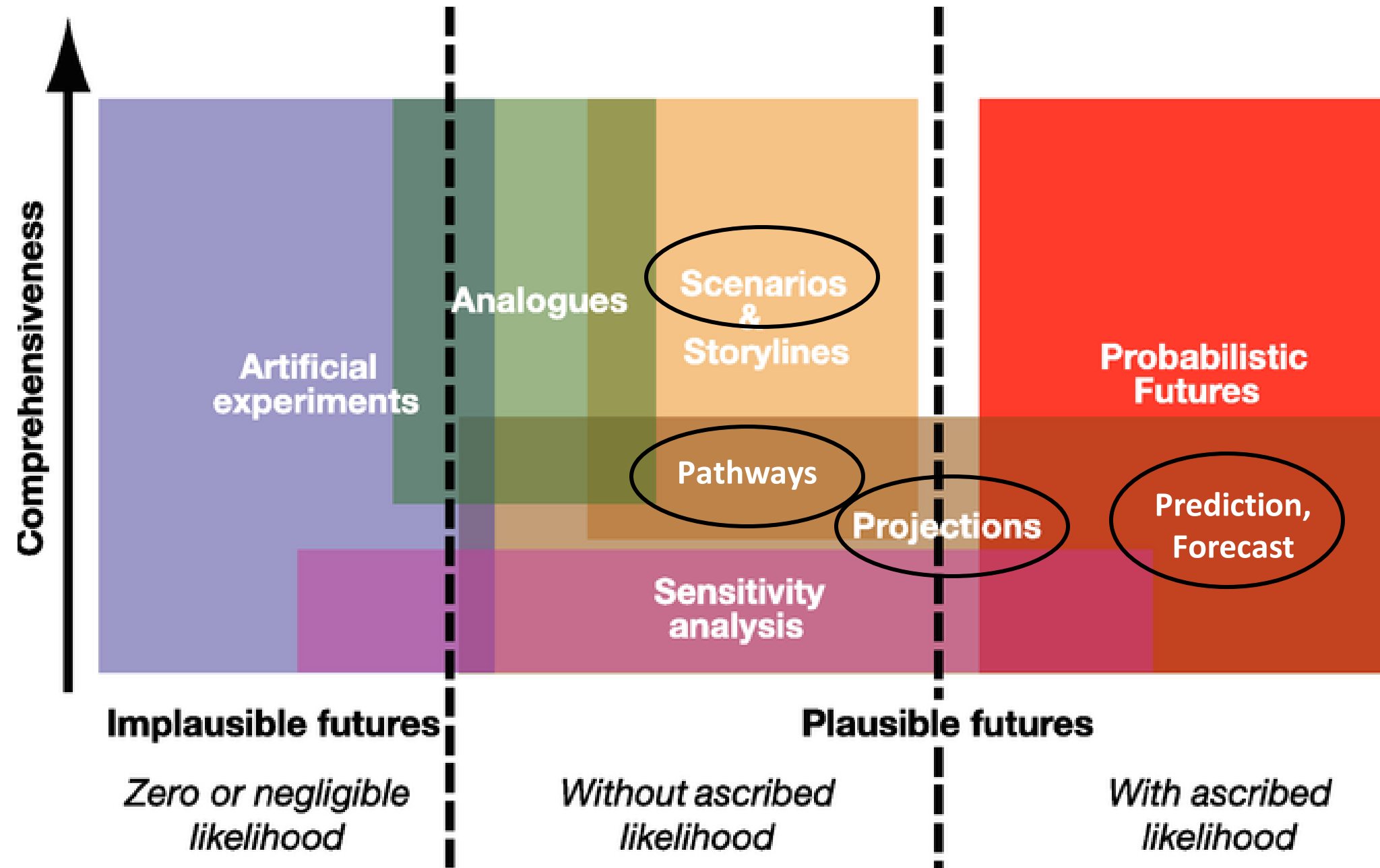
A scenario is a coherent, internally consistent, and **plausible** description of a possible future state of the world.

Scenarios are **not predictions or forecasts** (which indicate outcomes considered most likely), but are alternative images without ascribed likelihoods of how the future might unfold.

They may be **qualitative, quantitative, or both**.

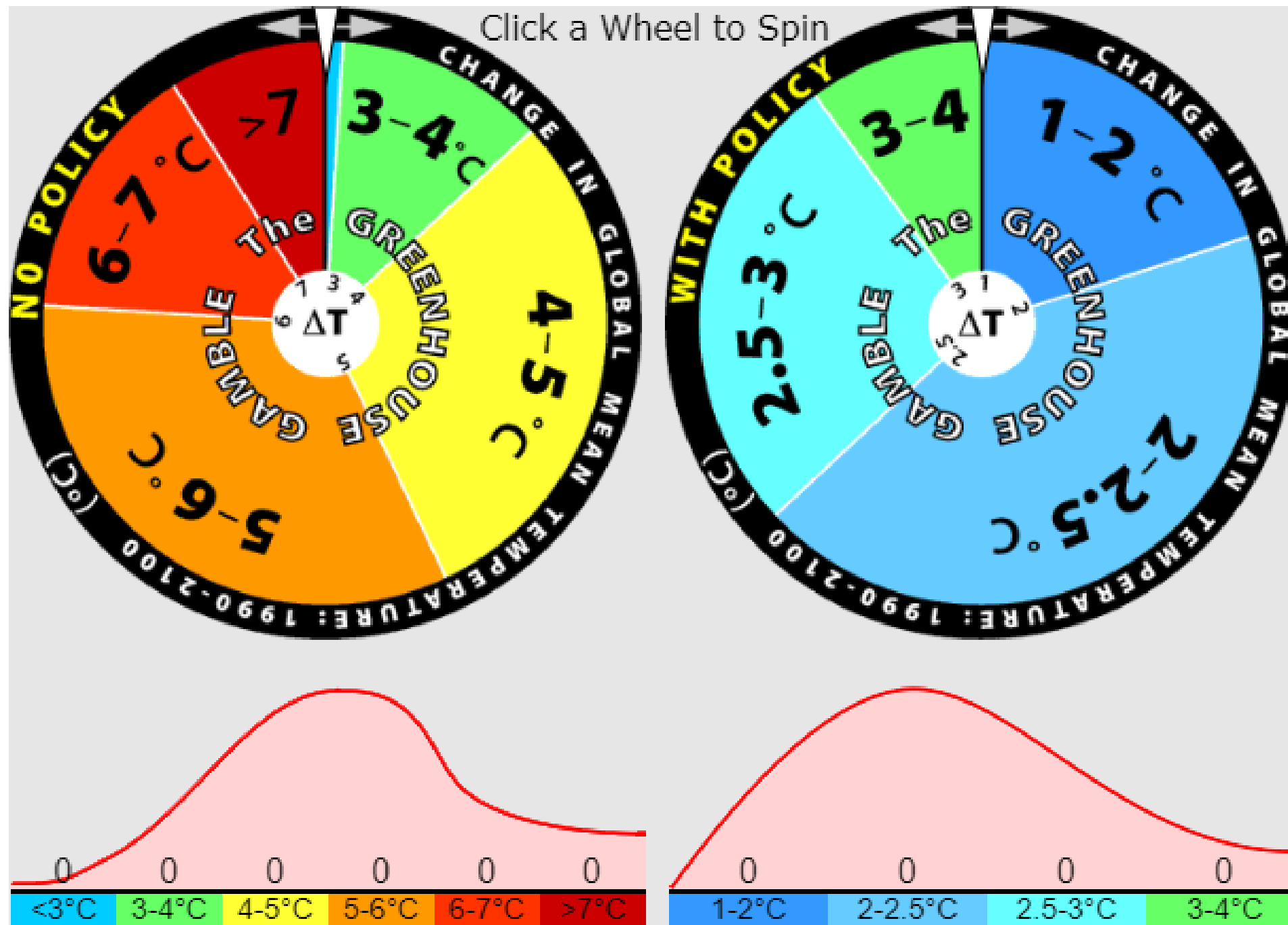
An **overarching logic** often relates several components of a scenario, for example a storyline and/or projections of particular elements of a system.

# Characterizations of the future



Carter et al., 2007. Ch 2, IPCC Fourth Assessment Report, WG2.

# MIT “Greenhouse Gamble” ([site](#))



# Scenario process vs. product

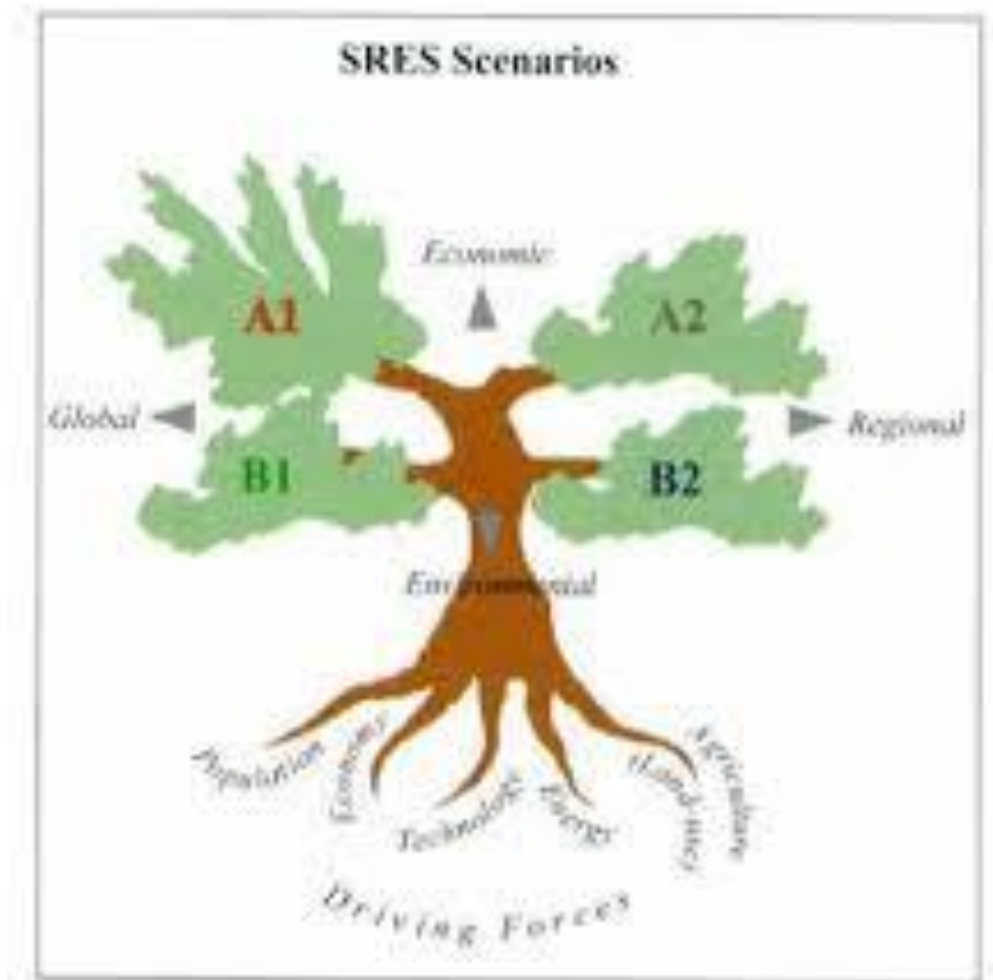
“Process” scenarios:

Shell 1973 Energy Scenarios foreseeing possibility of oil price shock



“Product” scenarios:

IPCC Special Report on Emissions Scenarios (SRES, 2000)



# A long line of community scenarios for climate change research

## Rationale:

Deep uncertainty

Facilitate integrated research and assessment

## Key roles:

Frames research

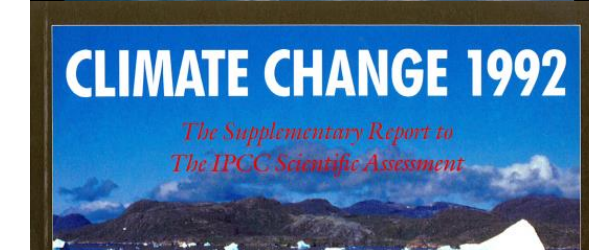
Shapes scientific assessments

Science-policy interface

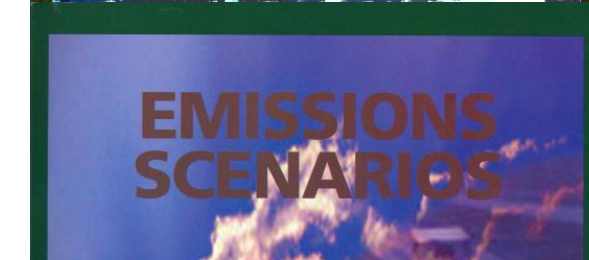
SA90, 1990



IS92, 1992



SRES, 2000



SSPs,  
2014-2017





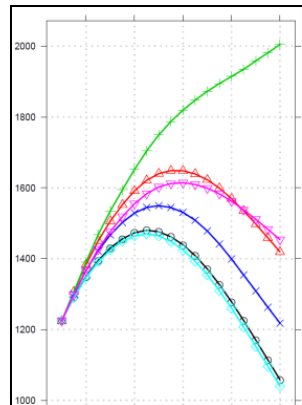
# The SSP-RCP scenario framework

# Shared Socioeconomic Pathways (SSPs)



## Narrative

Qualitative description  
of broad patterns of  
development  
Logic relating elements  
of narrative to each  
other



## Quantitative elements

National:  
Population  
Education  
Urbanization  
GDP

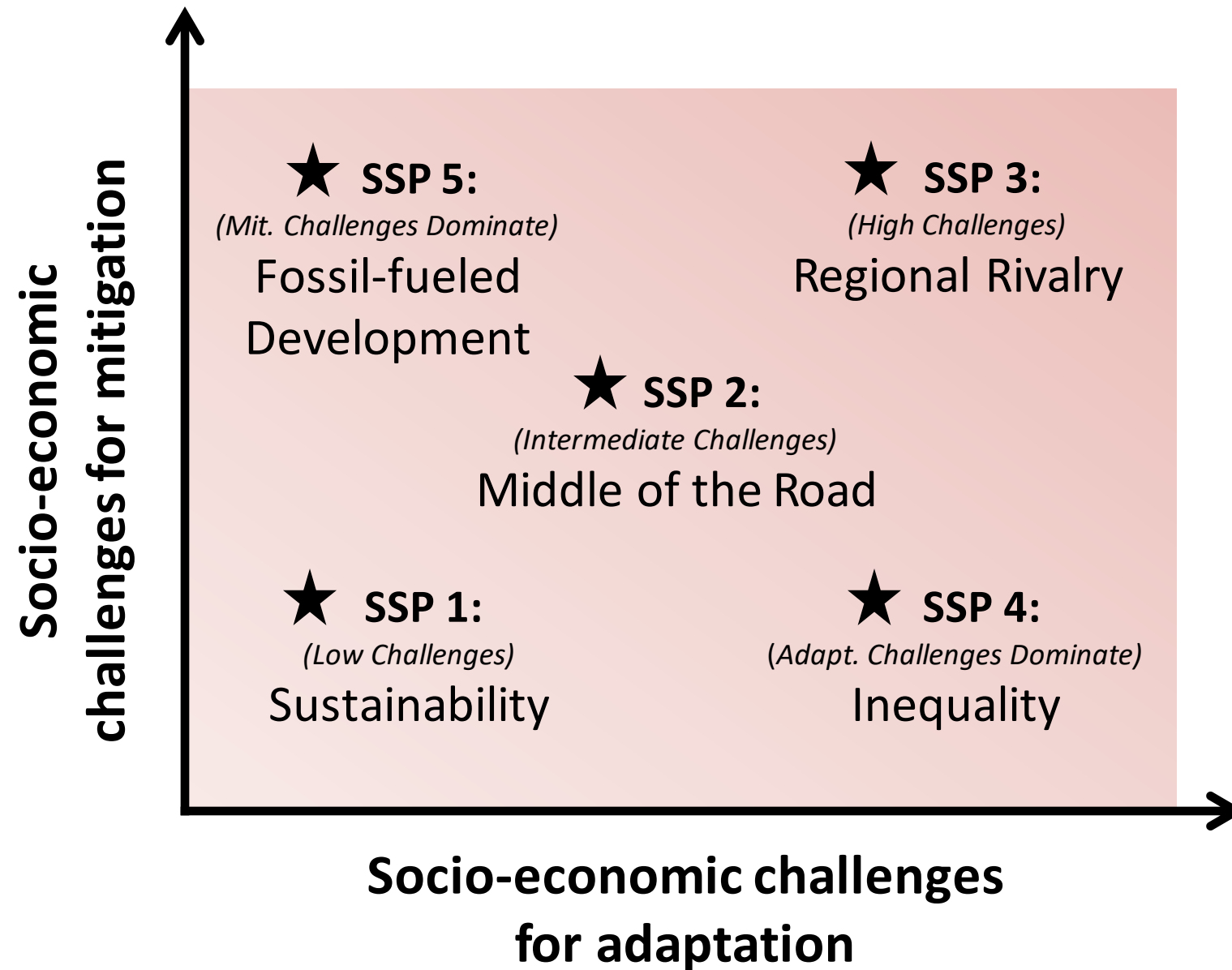
## SSPs

- 1: Sustainability
- 2: Middle of the Road
- 3: Regional Rivalry
- 4: Inequality
- 5: Fossil-fueled Development

SSP narratives, quantitative elements: **2017 special issue of *Global Environmental Change*.**

SSP Database, hosted by IIASA.

# Shared Socioeconomic Pathways (SSPs)



# SSP Narratives



## **SSP3: Regional Rivalry**

Multi-pole Cold War

Conflict, focus on security

Barriers to trade, migration

Little investment in health, education

Slow technological progress

Weak institutions

Slow income growth

## **SSP5: Fossil-fueled development**

Rise of the global middle class

Rapid technological progress

Large investments in human well being  
(health, education)

Well functioning institutions

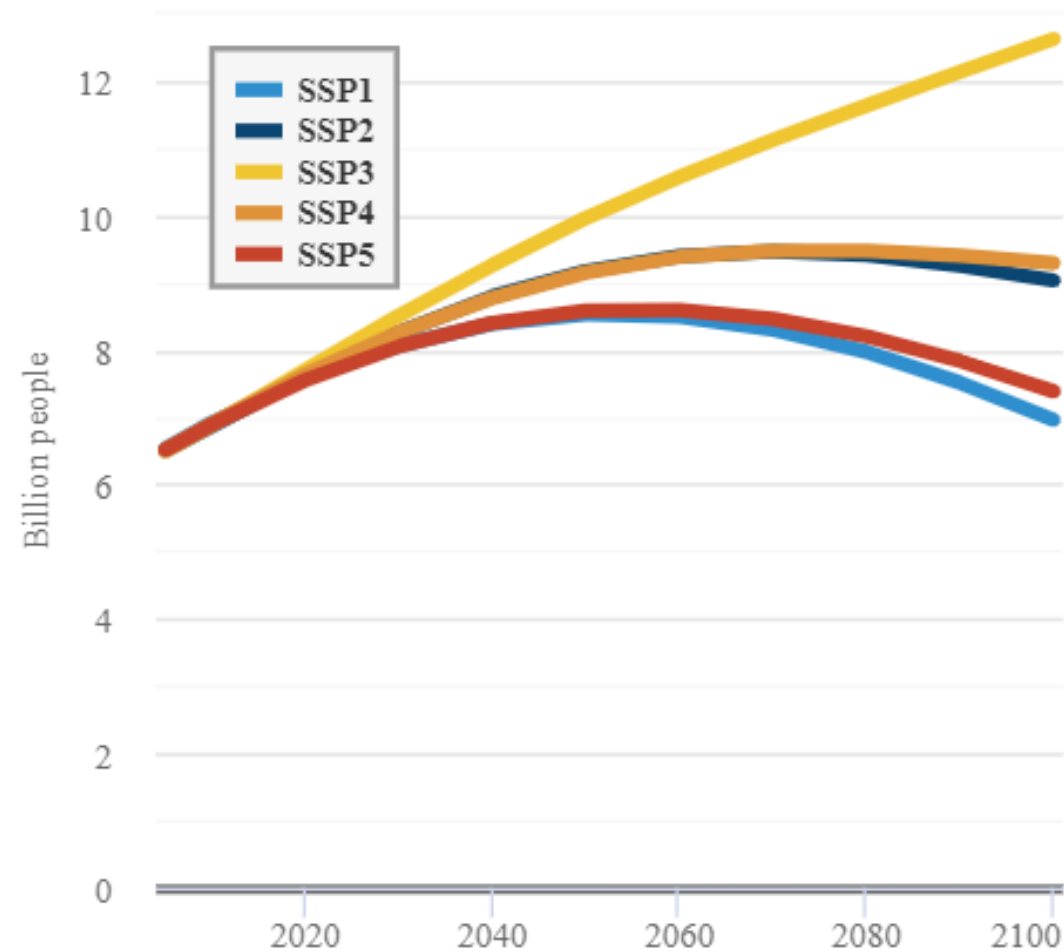
Rapid economic growth

Fossil-centered energy system

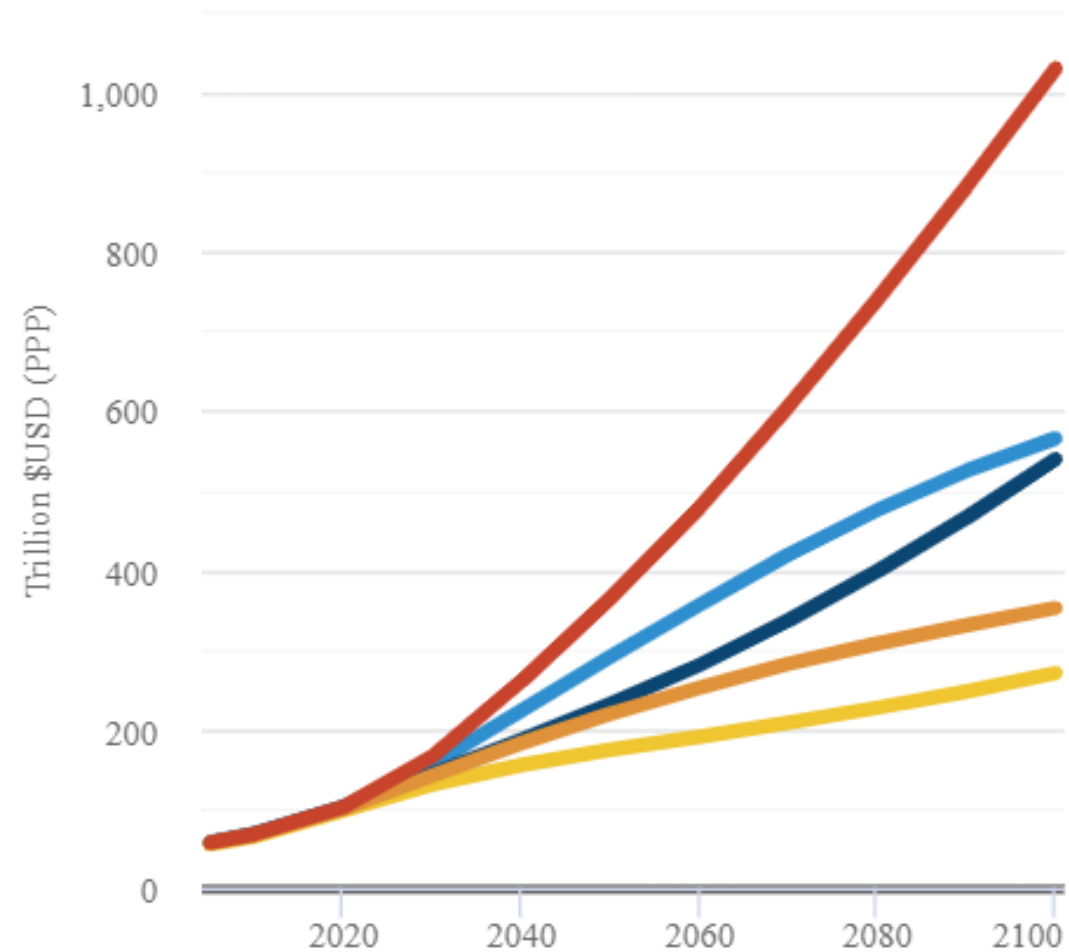


# SSP global population and GDP projections

Global population

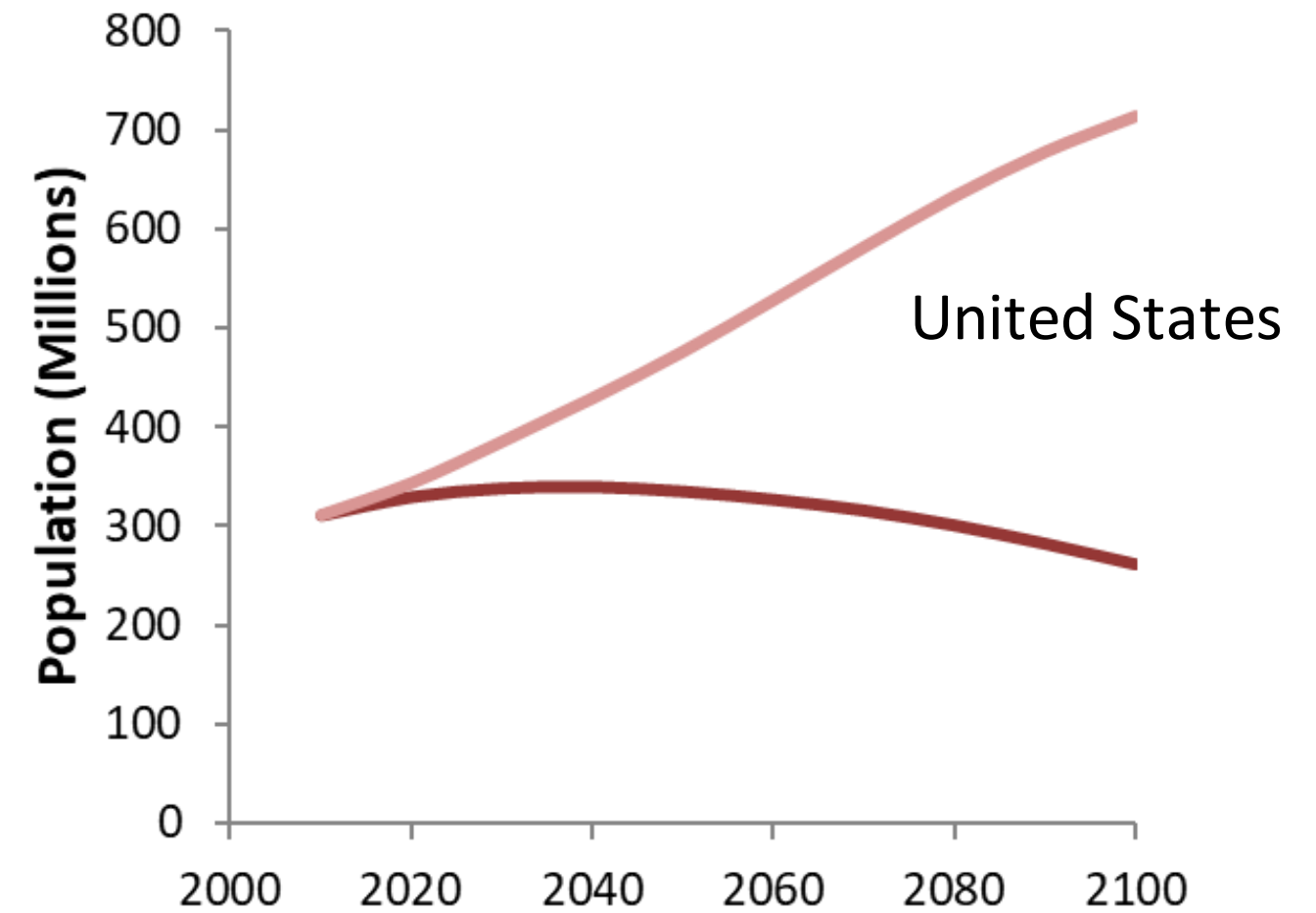
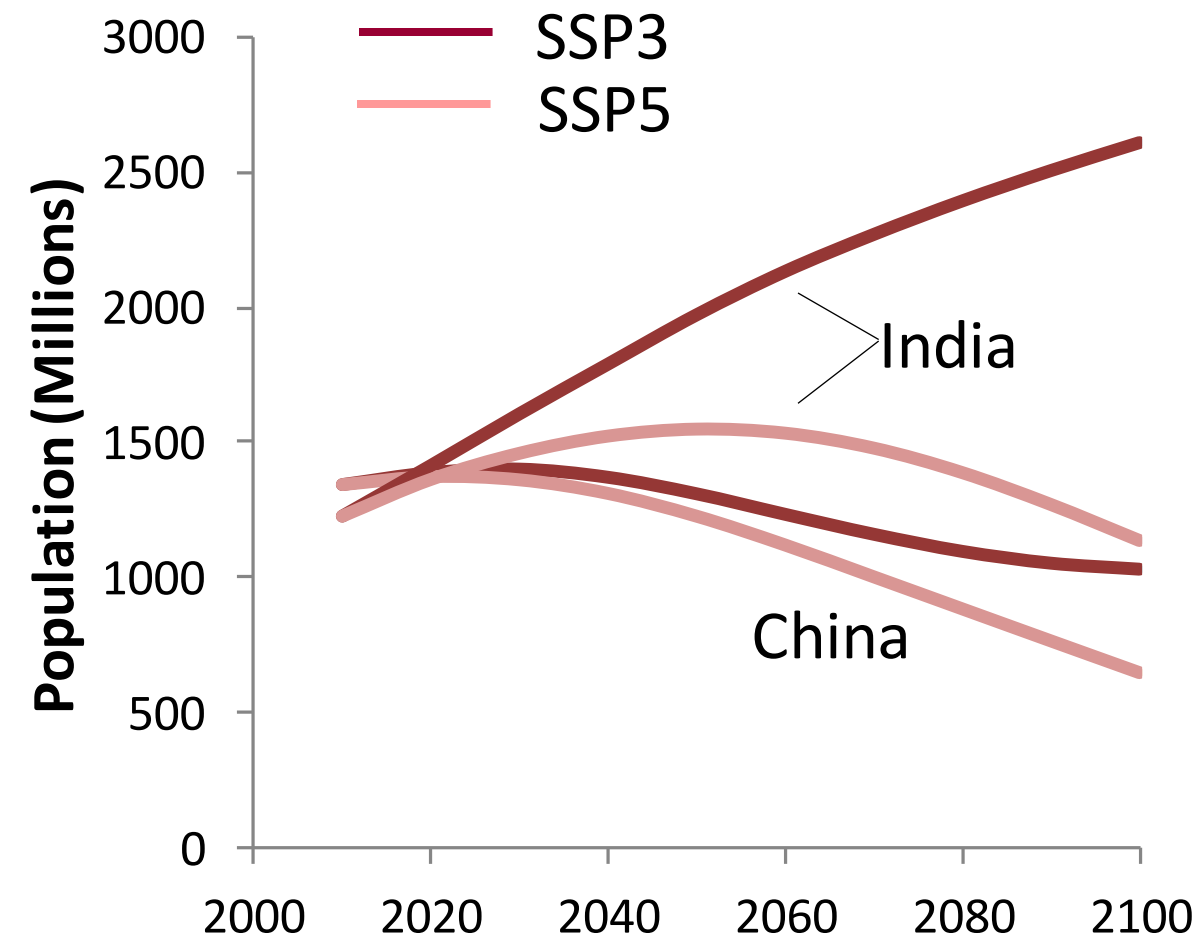


Global GDP



Carbon Brief, 2018, based on SSP database. 

# SSP Population: Asia, US



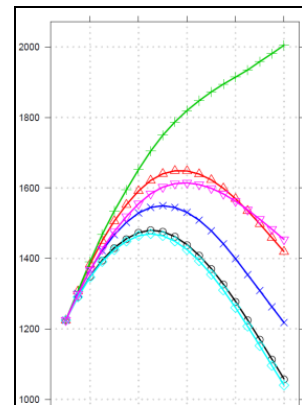
Based on KC and Lutz, 2015.

# SSP-based emissions projections

## SSPs 1-5

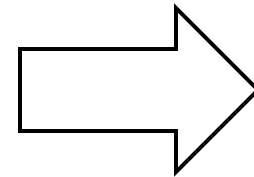


**Narratives**



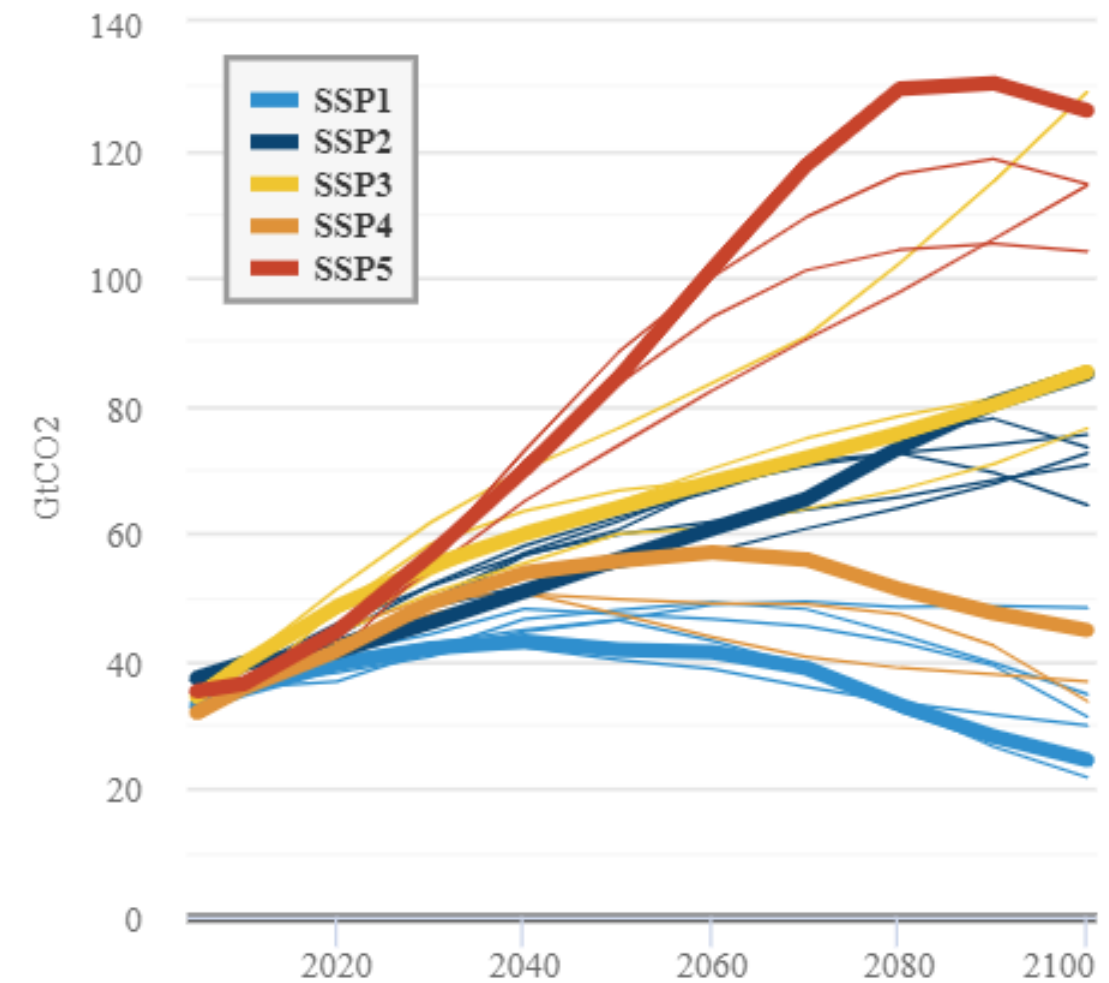
**Quantitative Elements**

Integrated  
Assessment  
Models



## Emissions

CO<sub>2</sub> emissions for SSP baselines

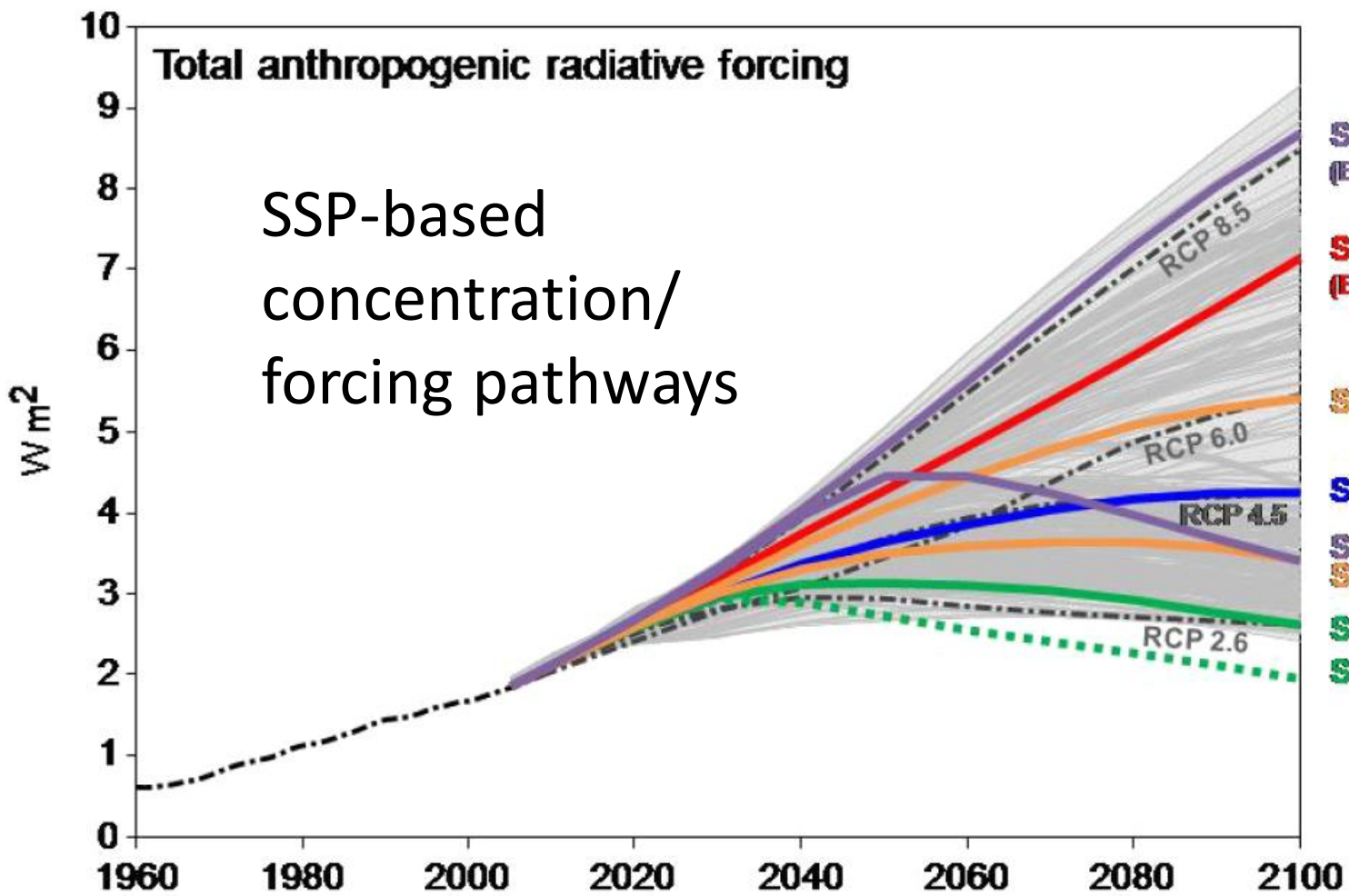


# SSP-based climate projections

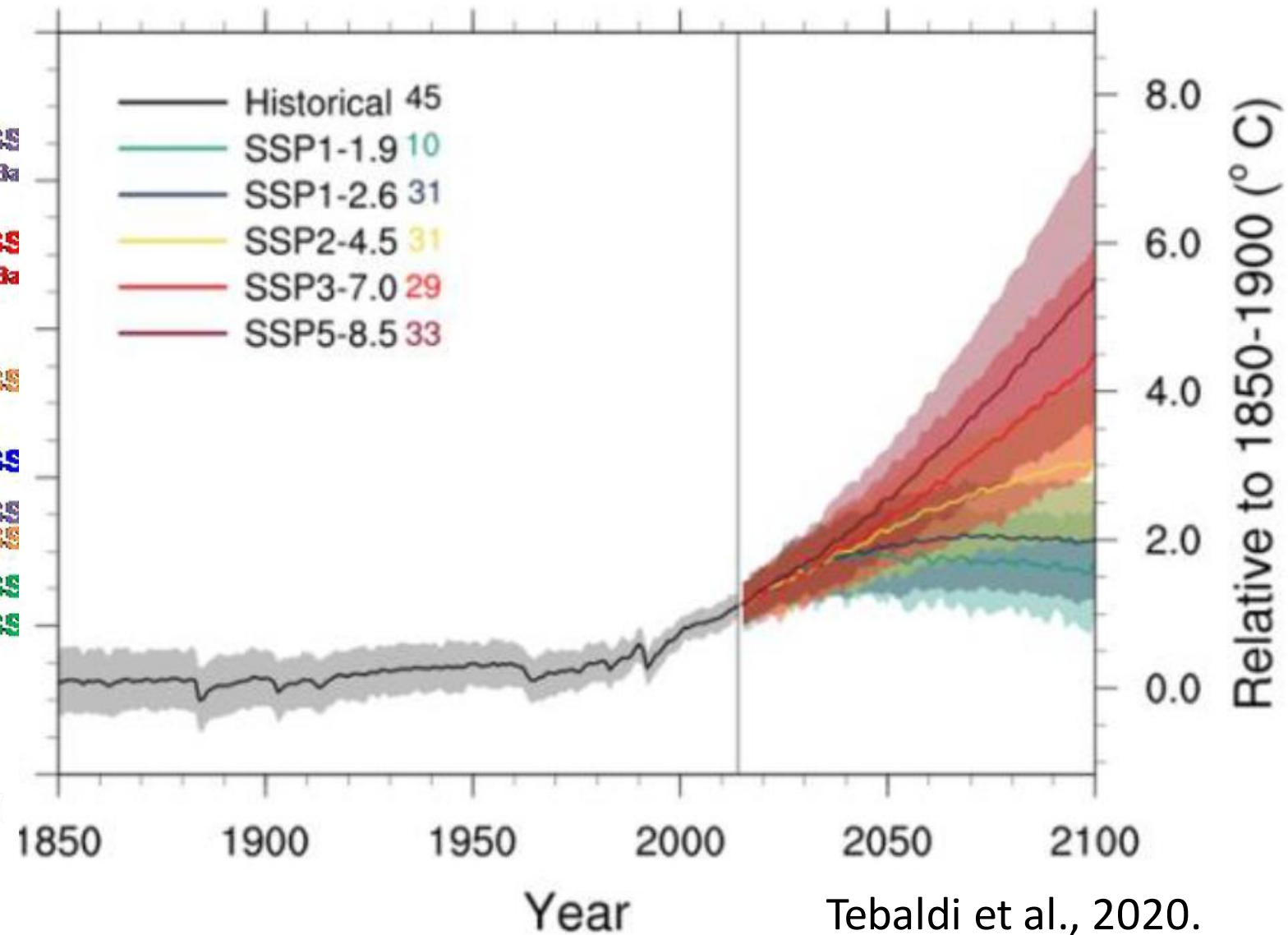
Radiative forcing  
(from concentrations)



Global Mean Temp. Change  
(CMIP6)



O'Neill et al., 2016; Riahi et al., 2017.



Tebaldi et al., 2020.

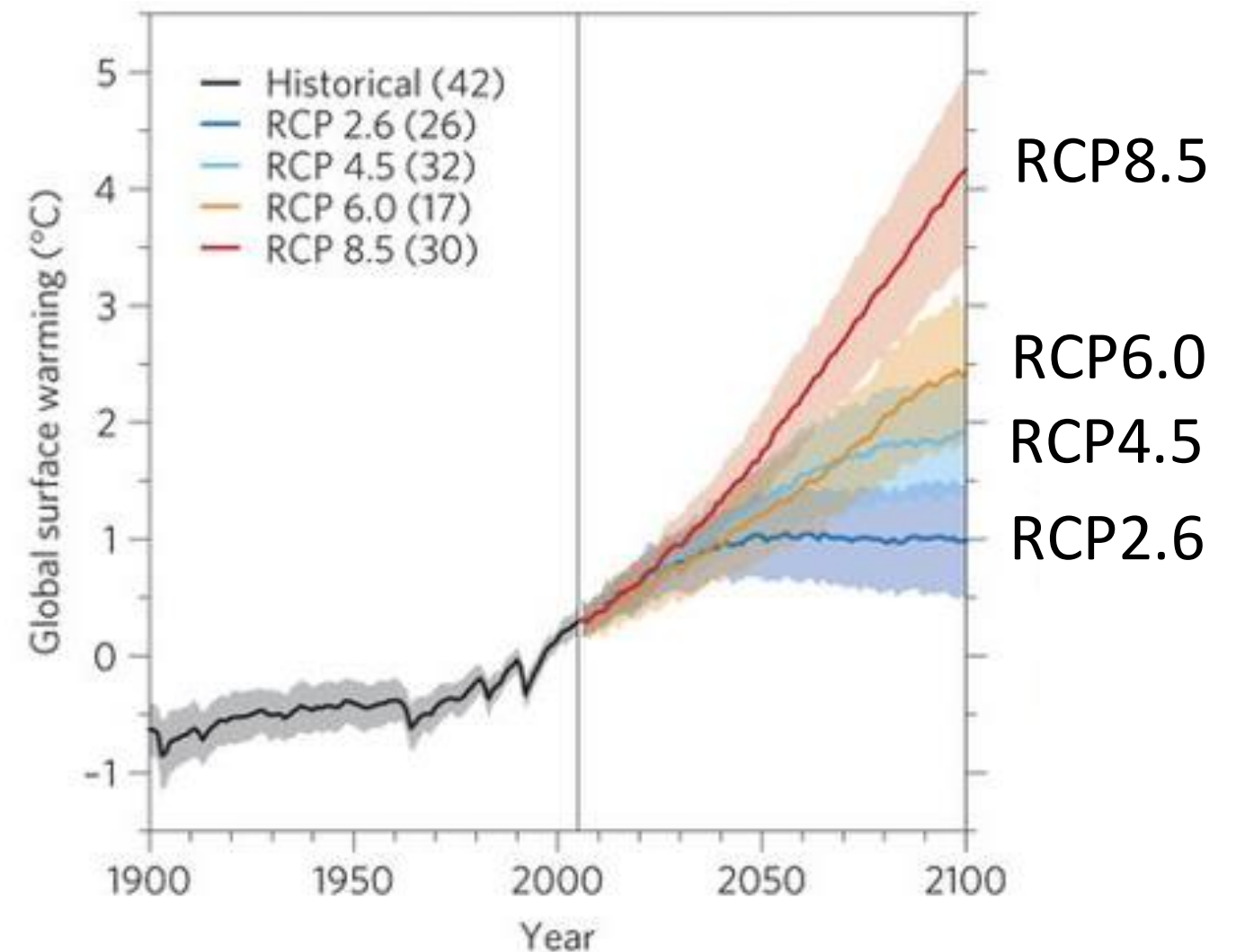
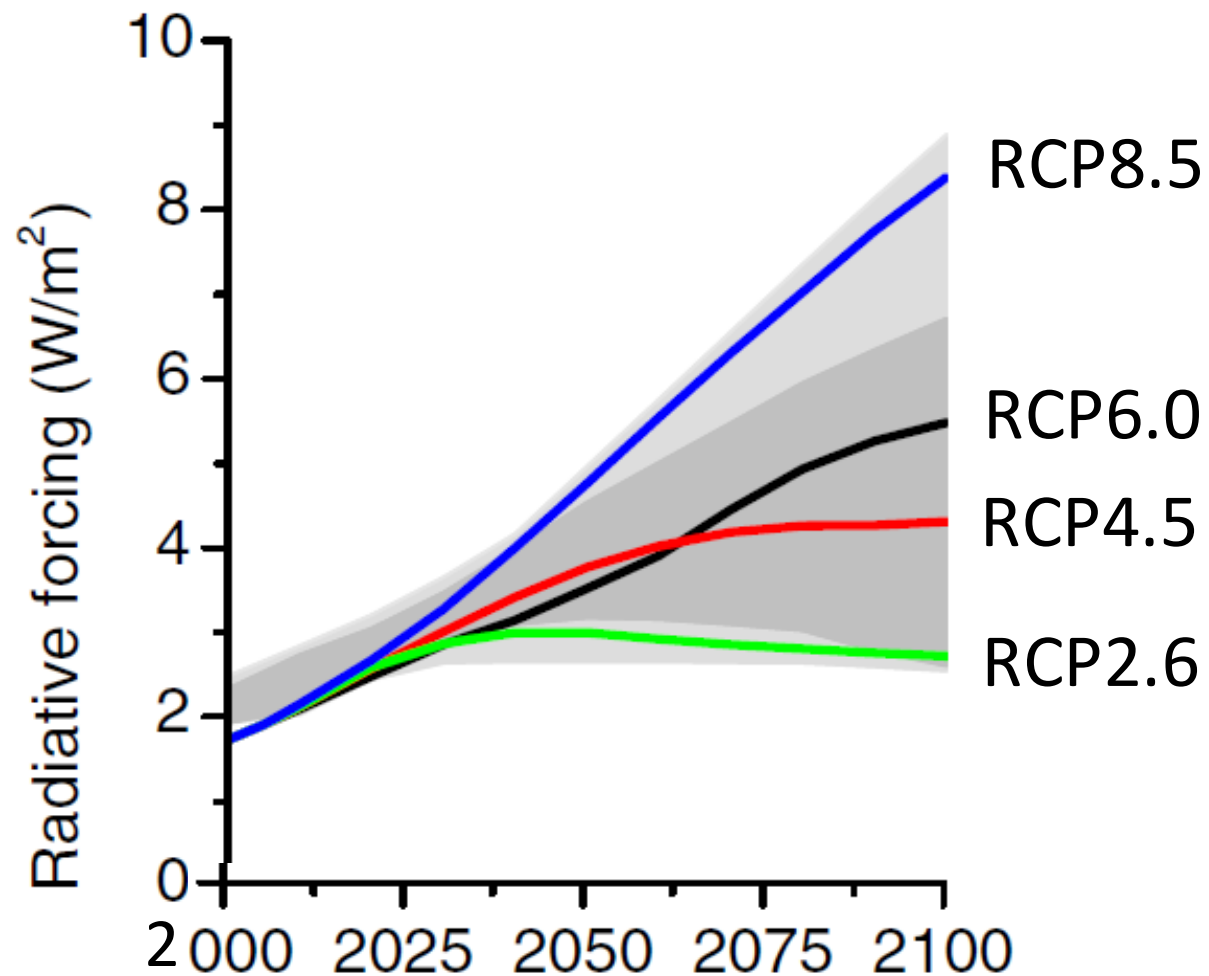


# Representative Concentration Pathways (RCPs)

Radiative forcing  
(from concentrations)

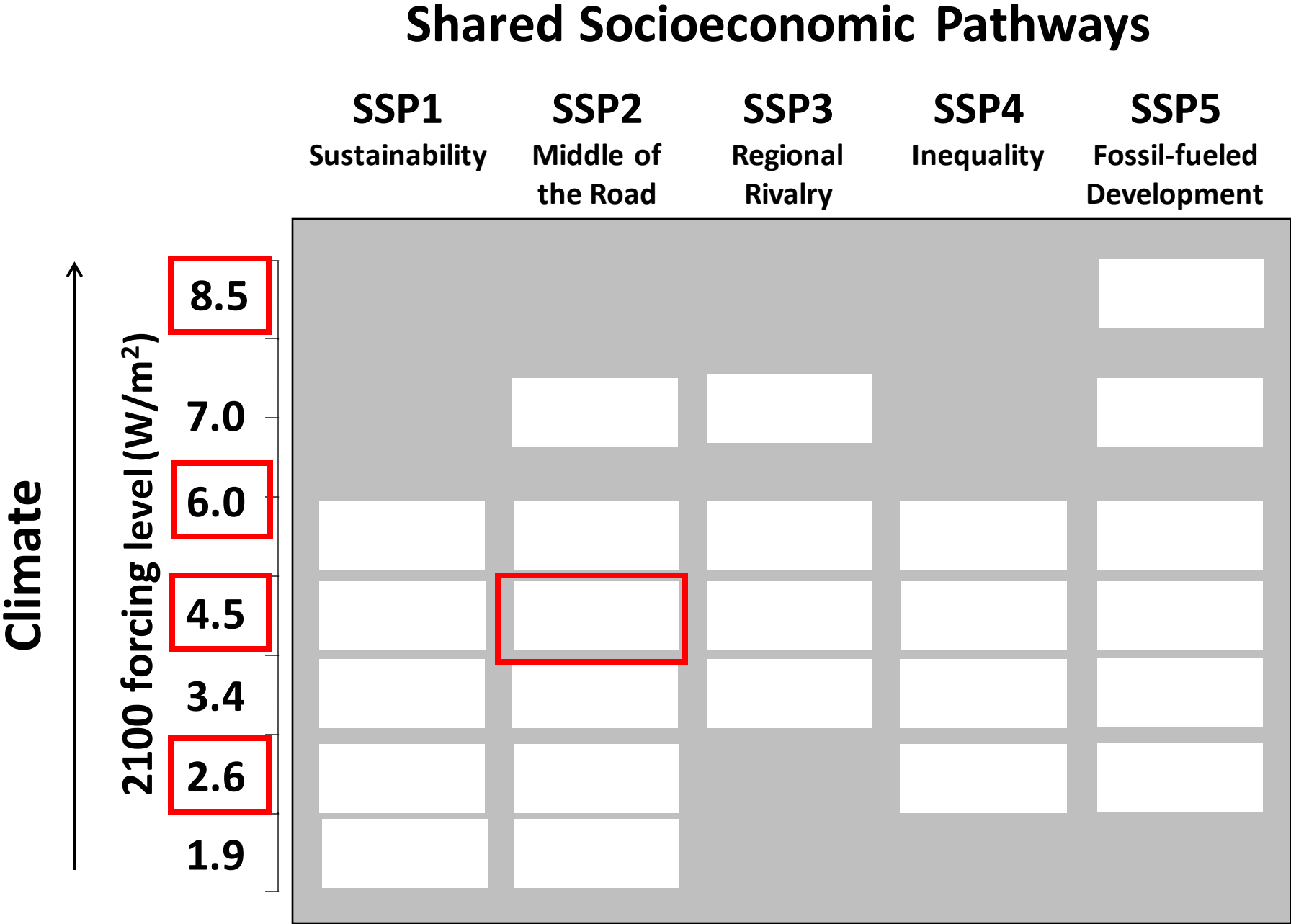


Global Mean Temp. Change  
(CMIP5)



# The “matrix architecture”

 Original RCP levels



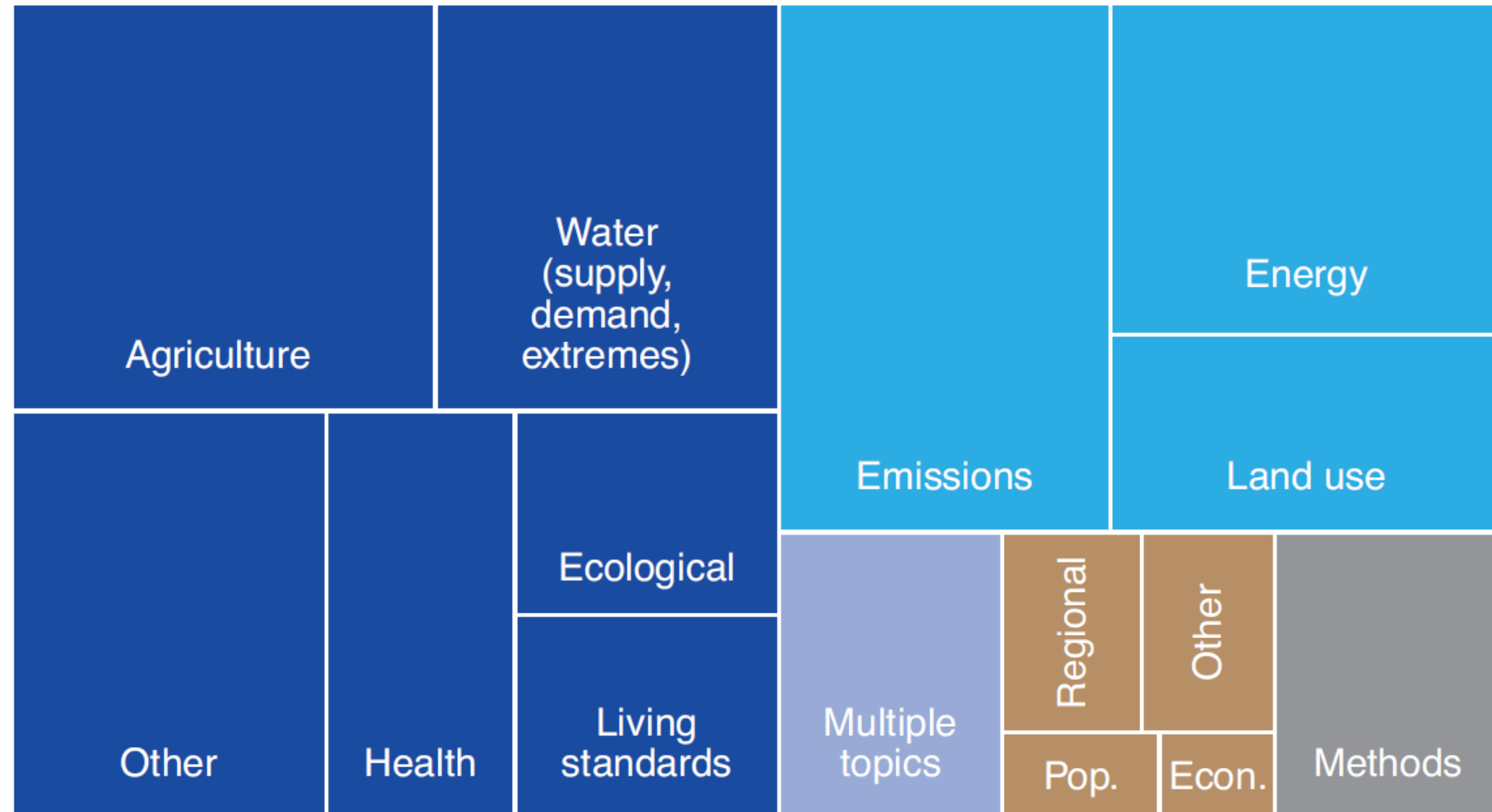
Applications of the framework

# SSP applications in the literature, 2012-2019

~1900 total analyses  
through 2021

Use SSPs, in some  
cases RCPs as well

Categorized by  
primary topic of  
focus





# Example application (resilience matters!)

## Key SSP elements

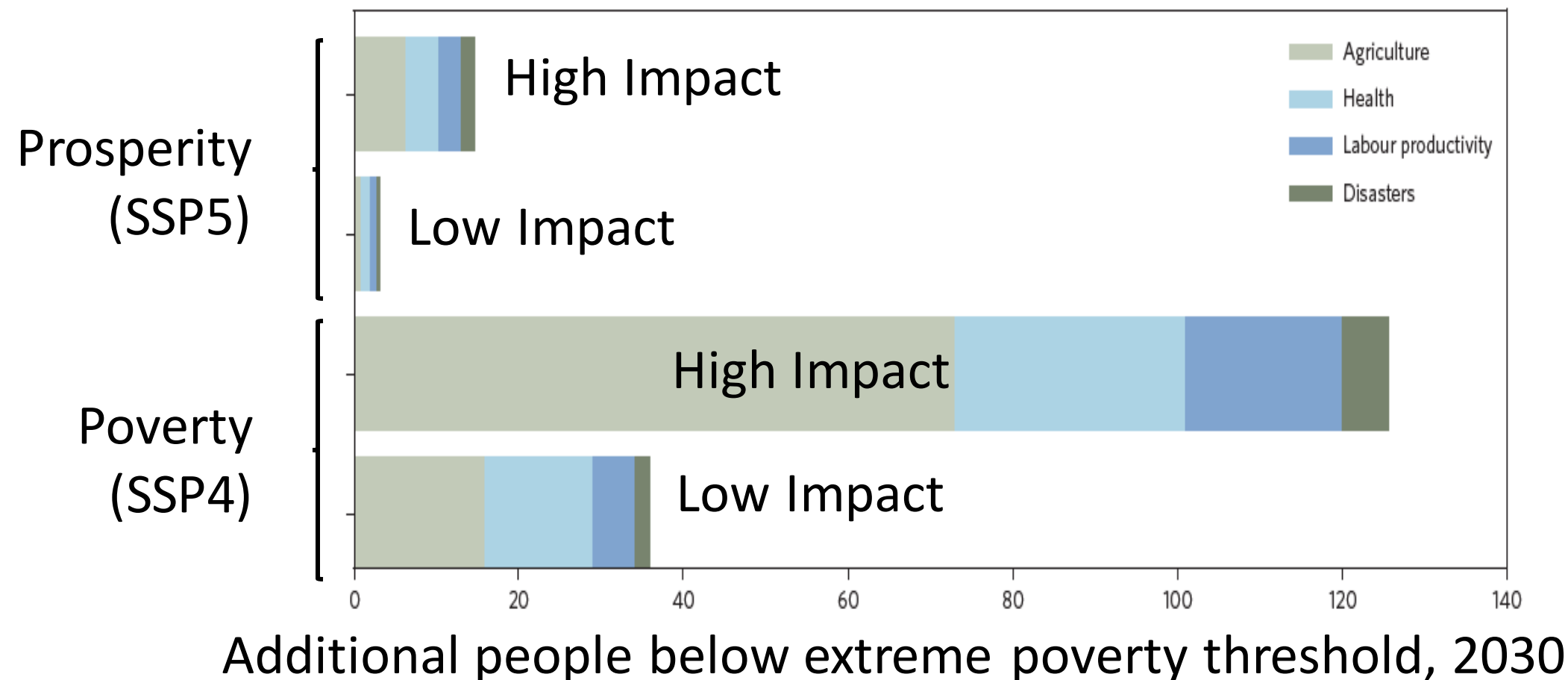
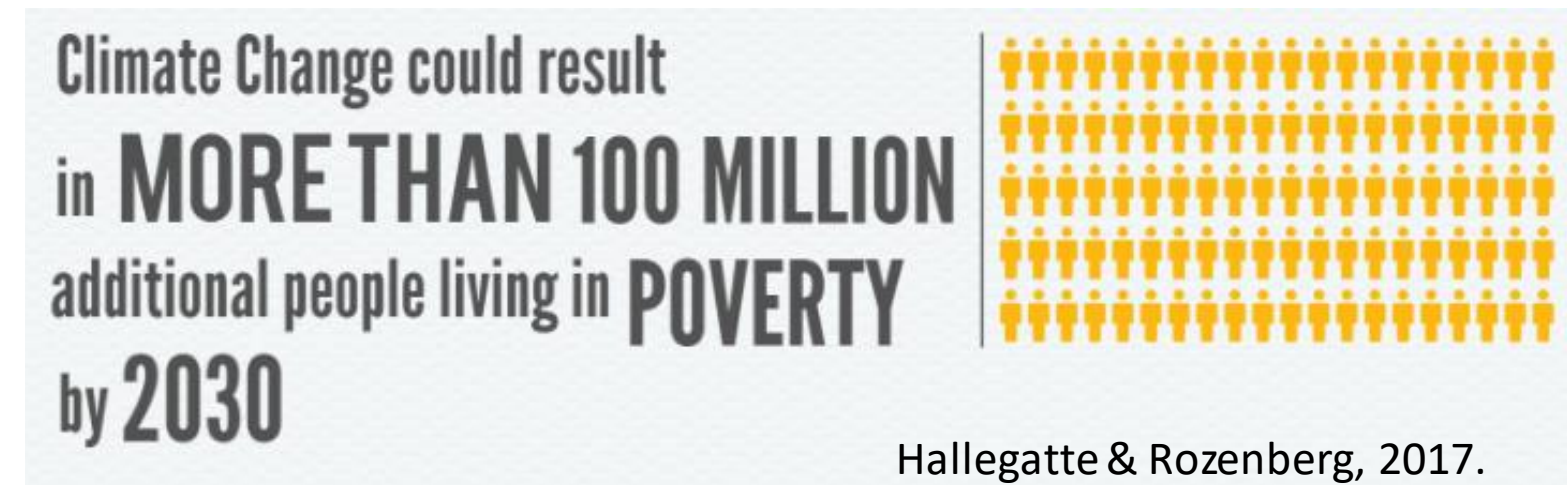
Education

Sectoral shift

Income distribution

## Conclusion

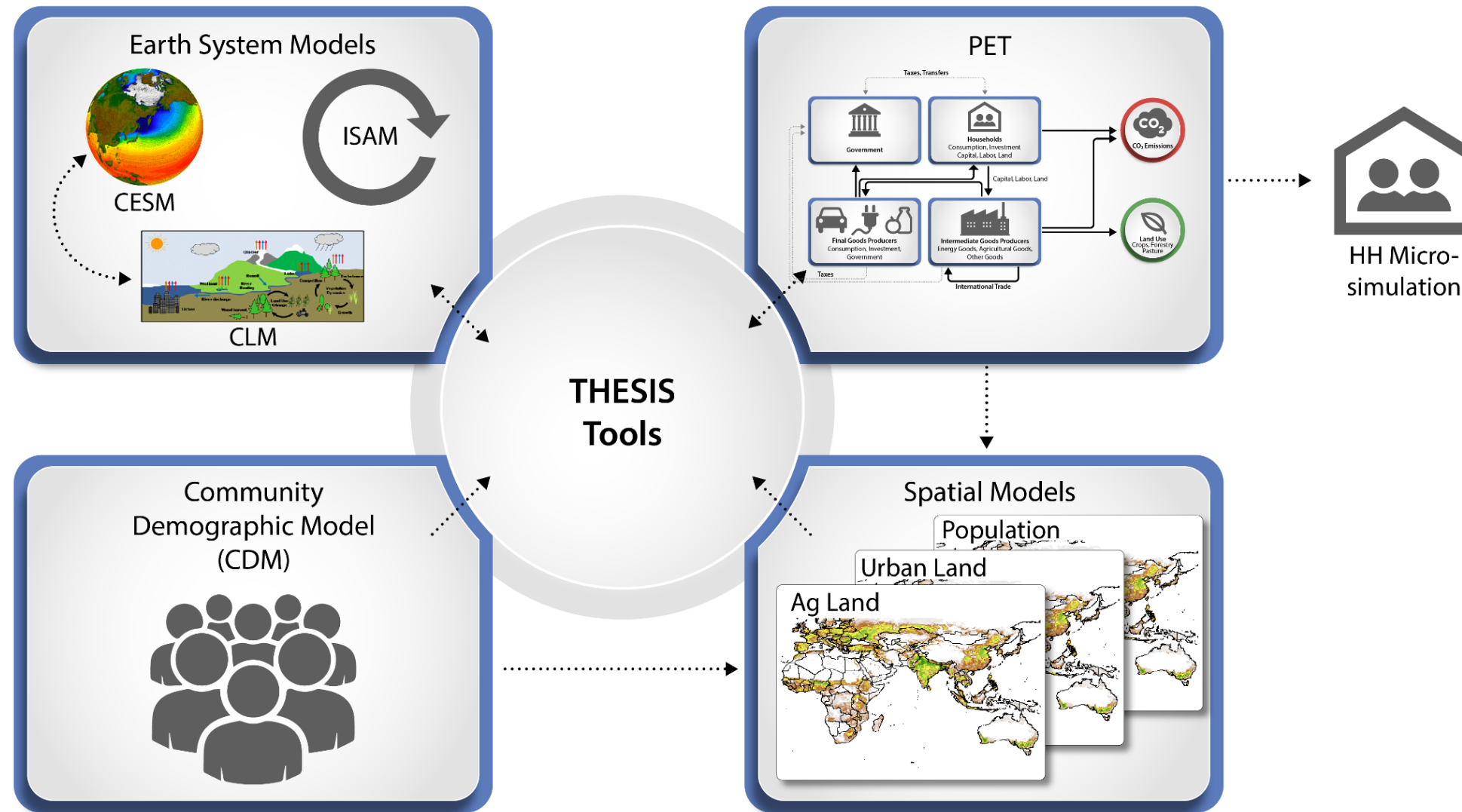
Resilience critical to  
climate change risk



# Integrated climate-society research

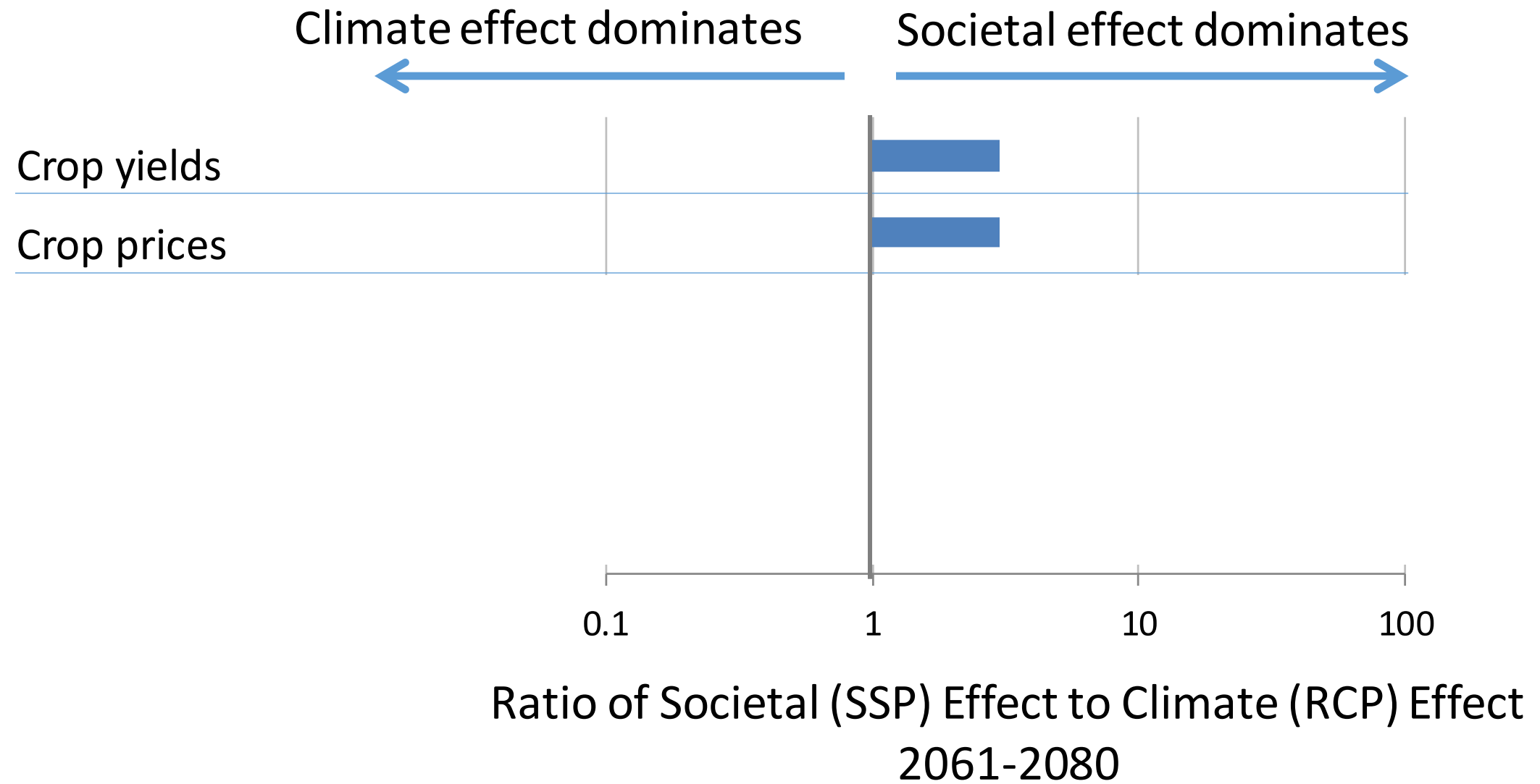
RCPs

SSPs

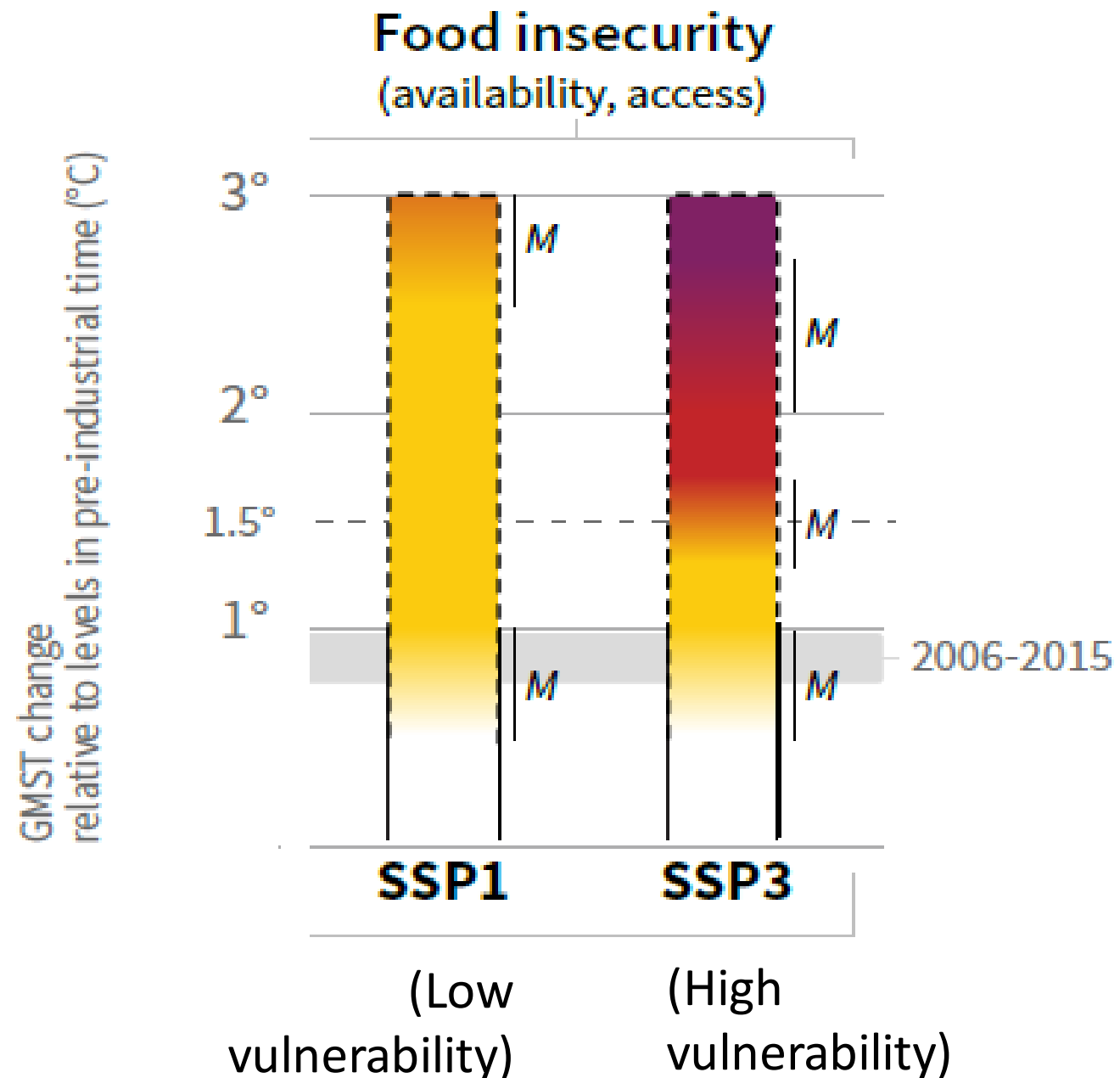


iPETS  
integrated  
assessment  
model  
framework

# Agricultural impacts: climate or society?



# IPCC food security risk assessment



IPCC Special Report  
on Climate Change  
and Land (2019)



# Examples of SSP extensions

Income distribution

Spatial population

Spatial urban land

Governance

Health

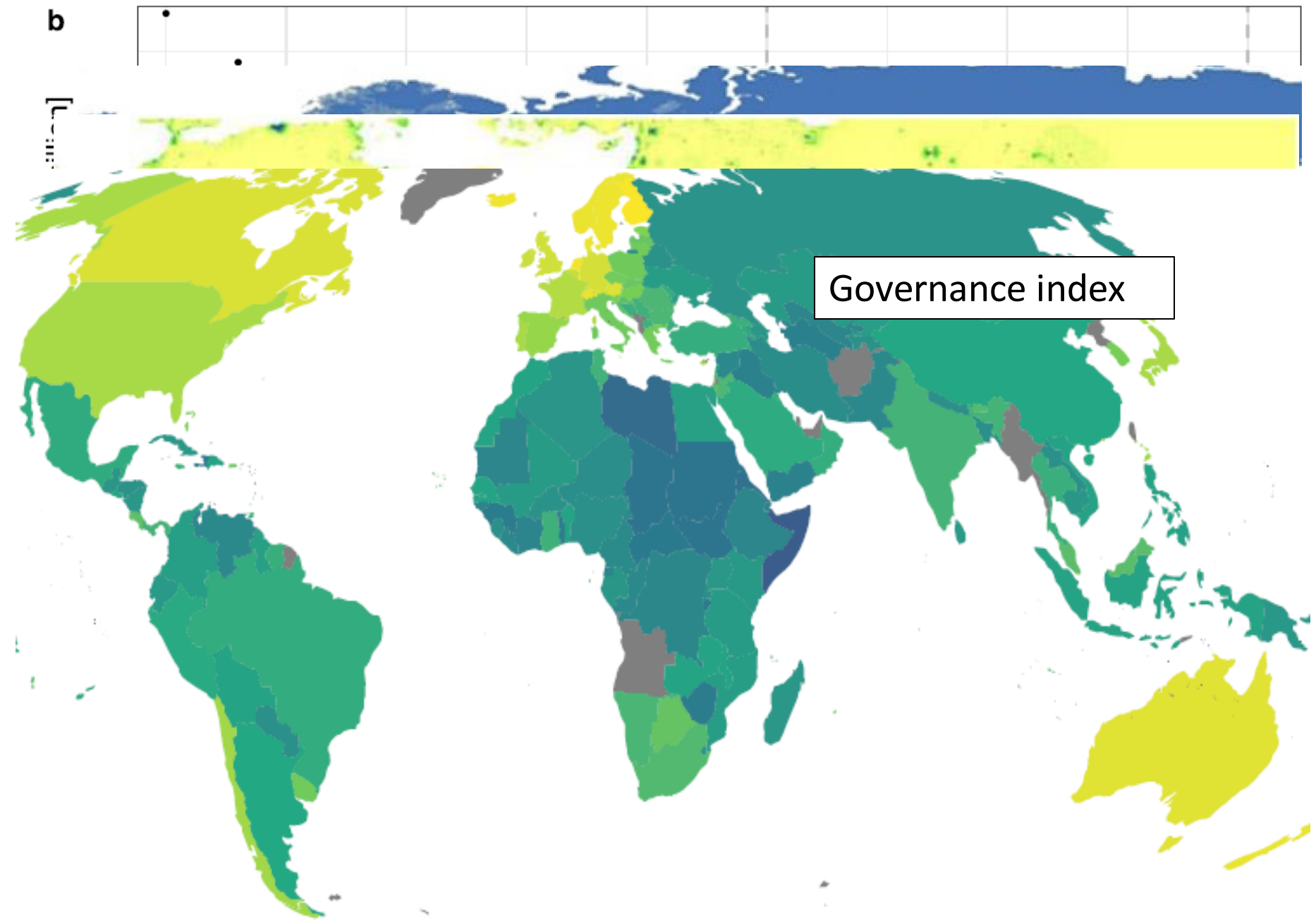
Oceans

Forestry

Air pollution

Water

Regions: Europe, US  
Southeast, Japan



# Example: Exposure to extreme heat

Two RCPs (8.5, 4.5) for climate futures

CESM ensemble simulations

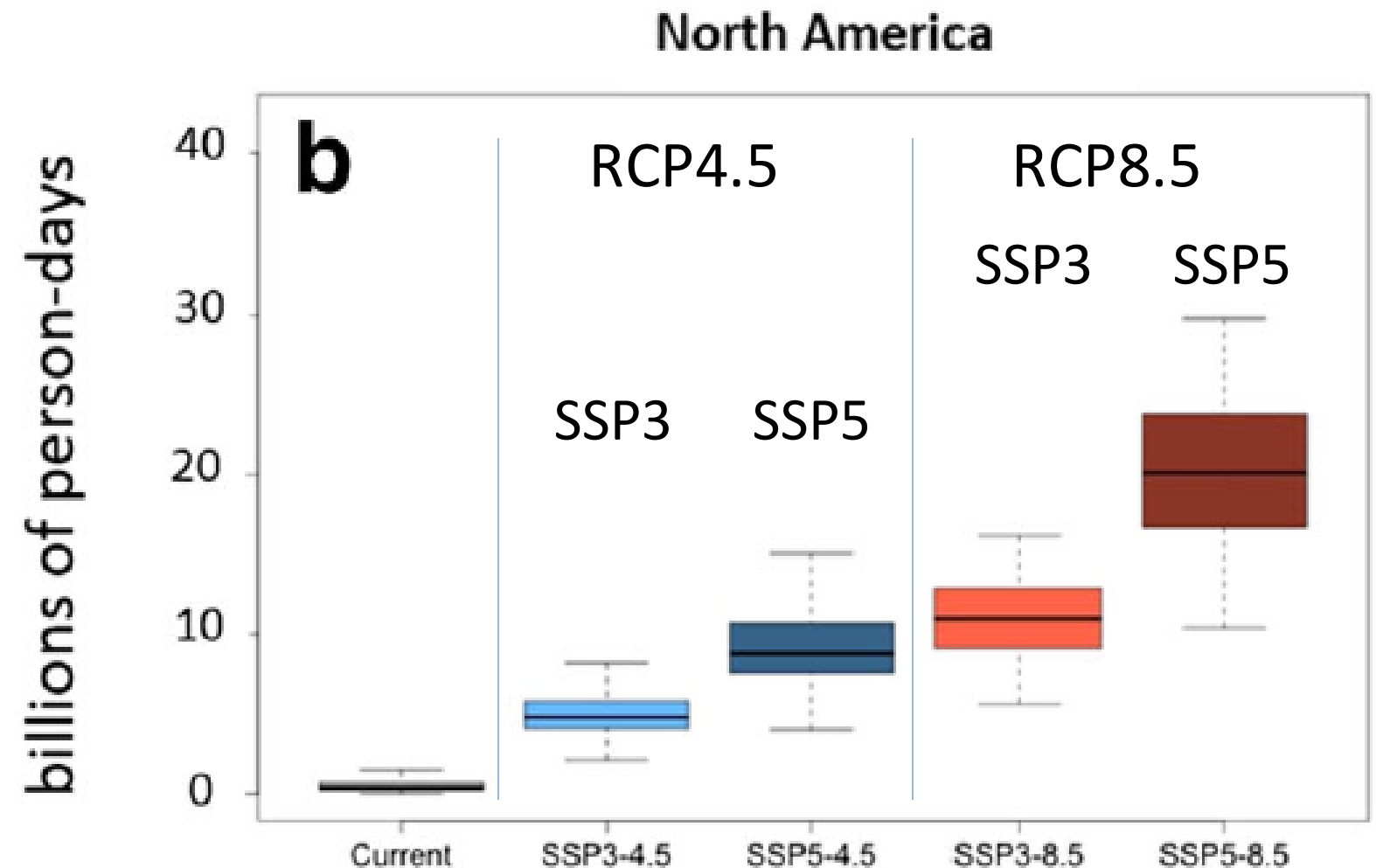
Two SSPs (3, 5)

Low, high population growth

Can translate to:

Temperature level (3.7, 2.5 C global mean warming)

Time period (2061-2080)



Needs and next steps

# Selected needs and recommendations

## Modify current framework

- Extend SSPs to include additional indicators of vulnerability and resilience

- Extend SSPs to better support adaptation pathway development

## Improve scenario development process

- Make process more inclusive

- Establish regular update process

## Connect to users and other research communities

- Develop sanctioned regional scenarios

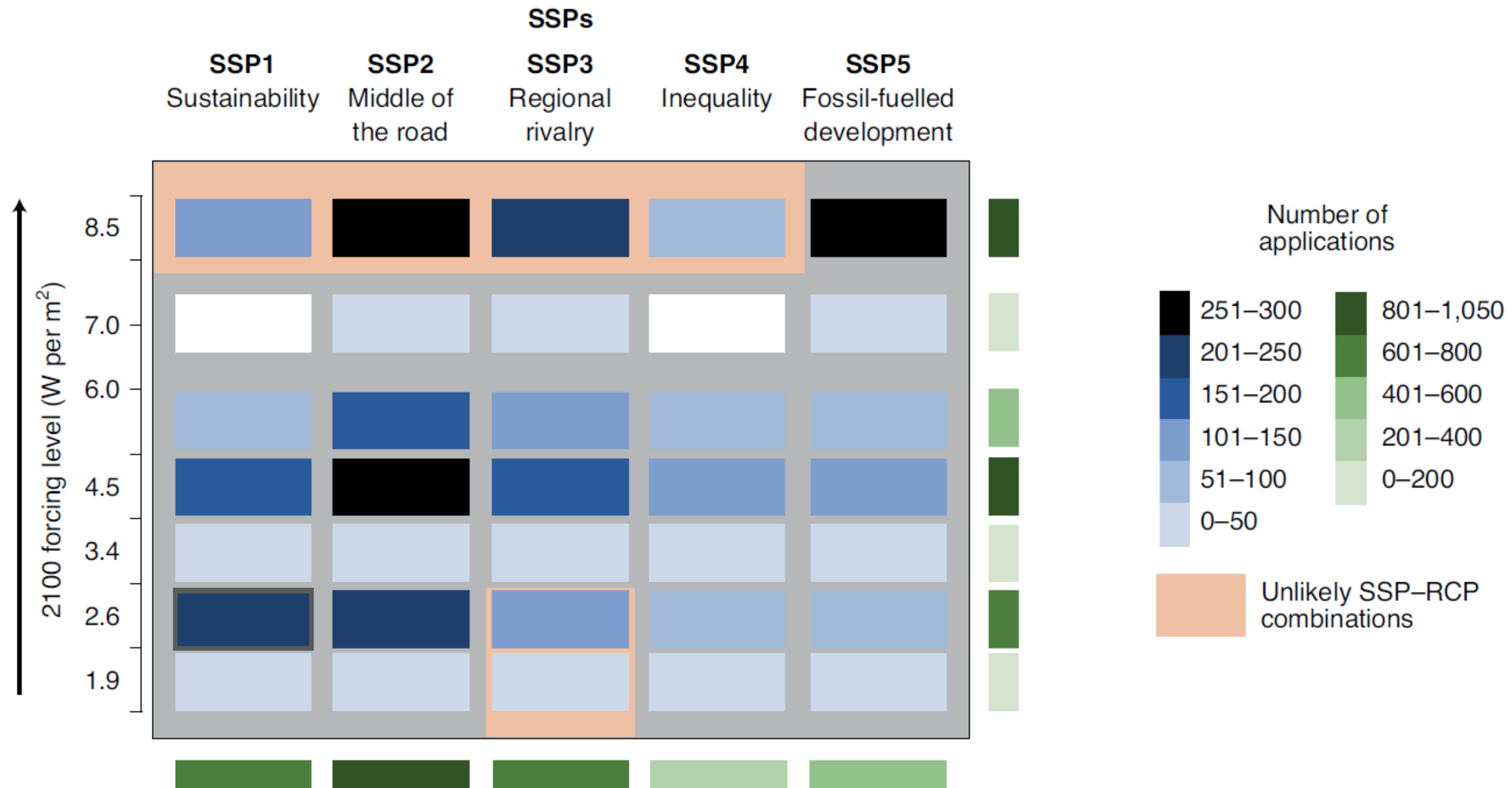
- Further develop and maintain the SSP-literature database

## New Research

- Evaluate uncertainty range, possible missing scenarios

- How to best account for possible future shocks

# SSP applications in the literature, 2014-2019



O'Neill et al., 2020.



# Scenario use (& misuse?)

COMMENT • 29 JANUARY 2020

## **Emissions – the ‘business as usual’ story is misleading**

Stop using the worst-case scenario for climate warming as the most likely outcome – more-realistic baselines make for better policy.

**Zeke Hausfather** ✉ & **Glen P. Peters** ✉

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# Scenario uncertainty and political debate



Zinke is right about the big picture. The USGCRP modeled climate impacts using four different emission scenarios called representative concentration pathways (RCPs). However, as the report acknowledges, “NCA4 focuses on RCP8.5 as a ‘higher’ scenario, associated with more warming, and RCP4.5 as a ‘lower’ scenario with less warming” (p. 6). So, in nearly every case, the general reader sees a range of impacts that go from bad to worse.

Although the report does not describe RCP8.5 as a “baseline” or “no action” scenario, readers are left with the overwhelming impression that the worst impacts are highly probable absent “significant global mitigation action.” But RCP8.5 is not a realistic baseline scenario. It projects higher emission levels in 2100 than about 90 percent of baseline scenarios in the literature. That makes RCP8.5 darn close to being a worst-case scenario.

Lewis, 2018, CEI.



**Michael Liebreich**

@MLiebreich

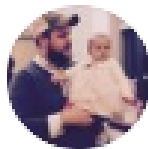


Replying to [@past\\_is\\_future](#) [@rustneversleepz](#) and 2 others

RCPs = Representative Concentration Pathways. In the case of RCP 8.5, mainly used for generating headlines, scaring gullible folk and children, and giving climate contrarians a reason to ignore the need for urgent action on emission mitigation.

10:51 AM · Aug 4, 2019 · [Twitter for Android](#)

1 Retweet 12 Likes



**Peter Jacobs** [@past\\_is\\_future](#) · Aug 4



Replying to [@MLiebreich](#) [@rustneversleepz](#) and 2 others

Cool, so you actually have no idea what RCPs are used for and are just regurgitating denialist nonsense, as everyone has been pointing out this whole time.

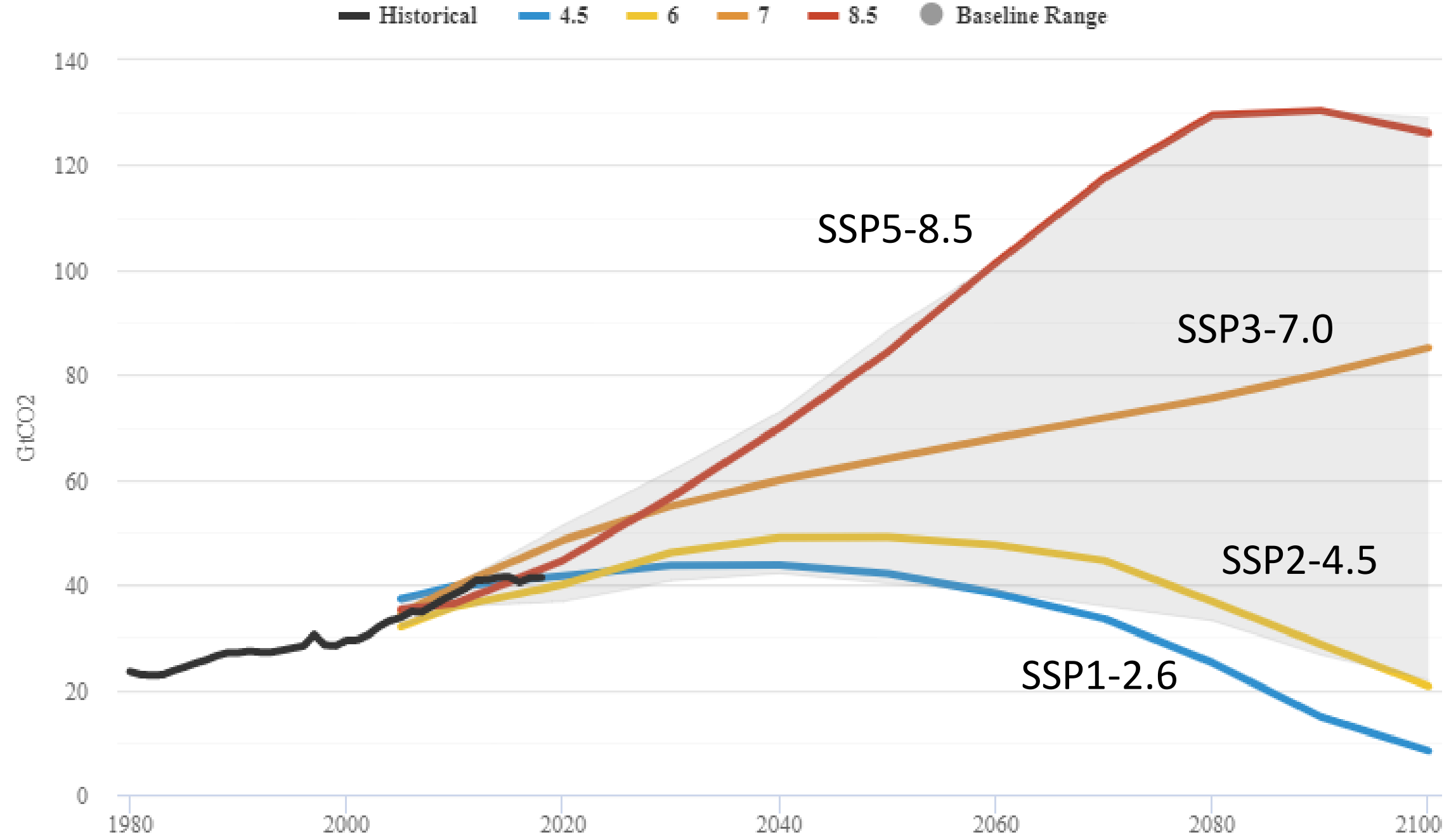


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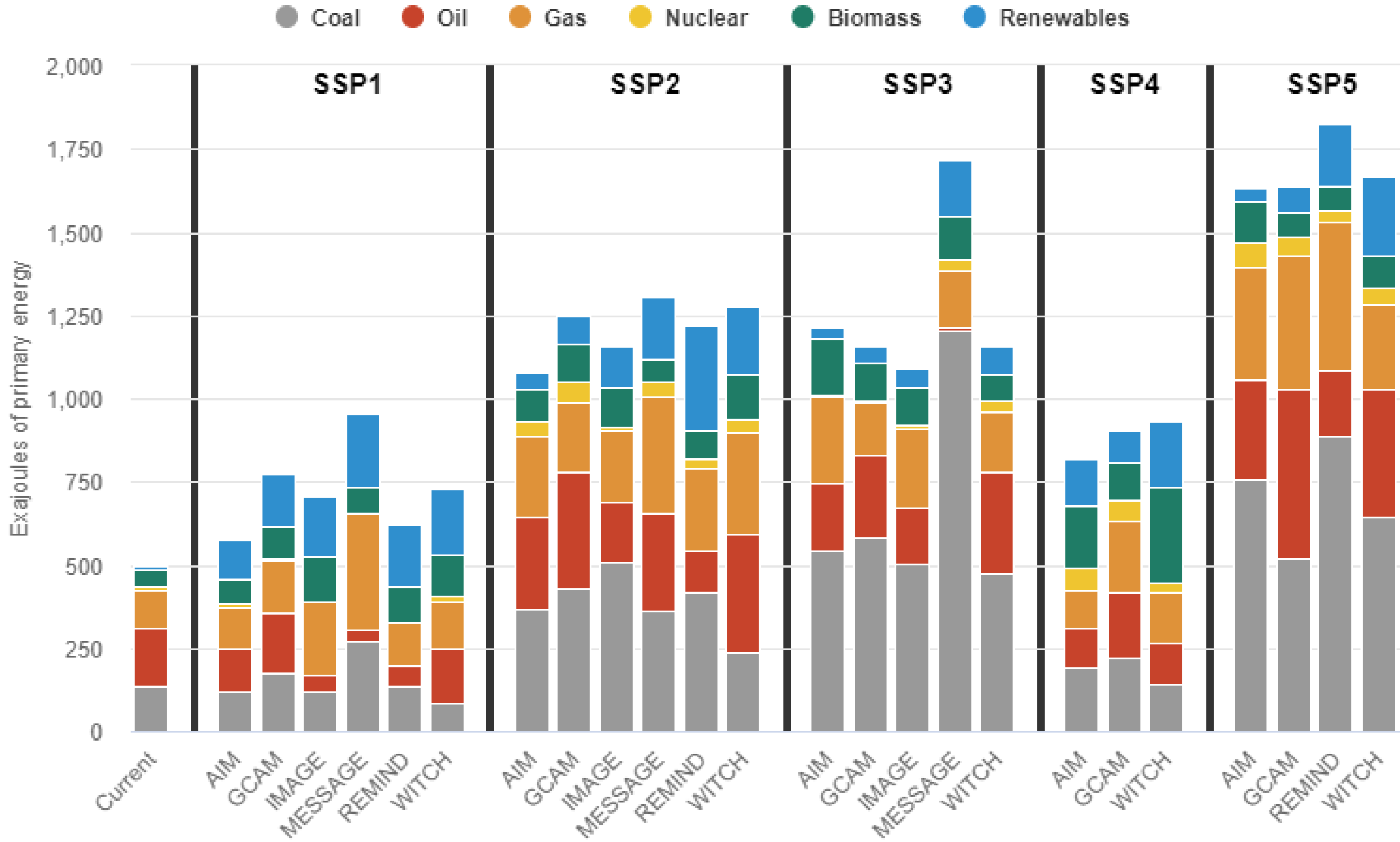


Twitter thread literally went on for weeks!

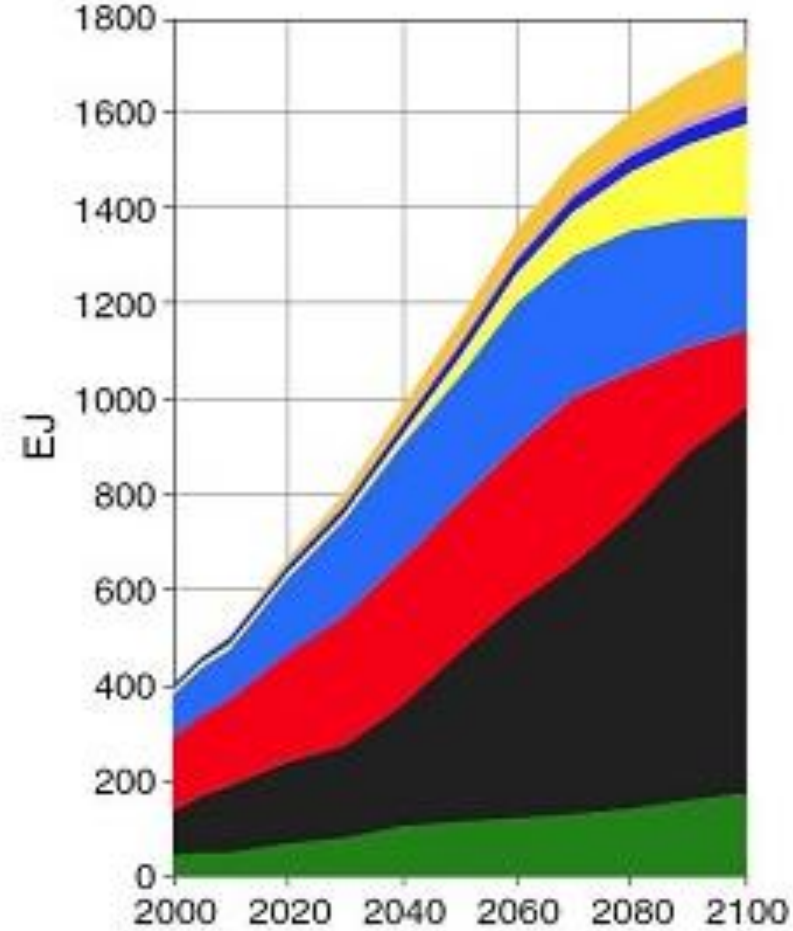
## SSP baseline and CMIP6 scenarios



Primary energy in 2100 by model for SSP baseline scenarios





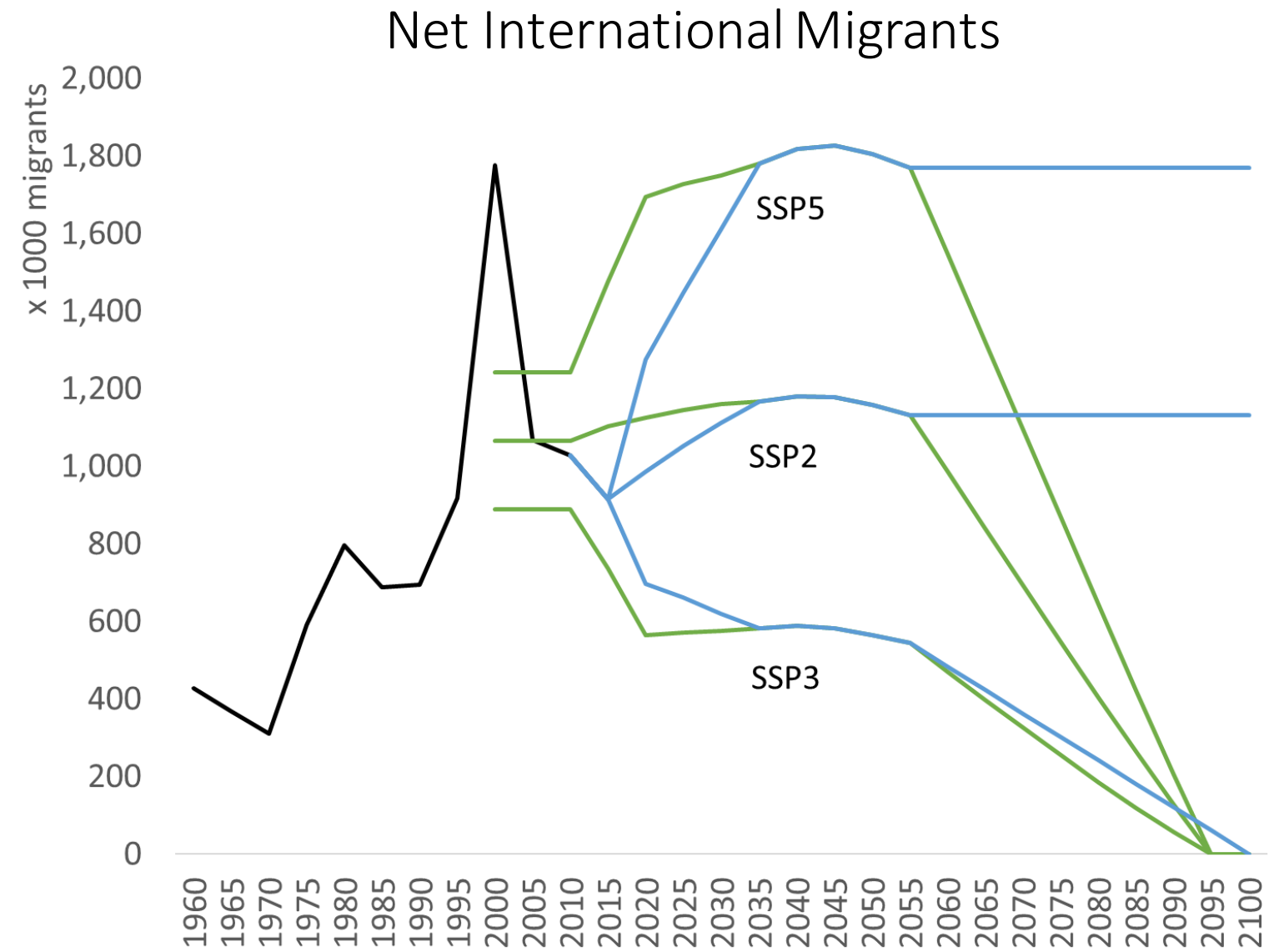
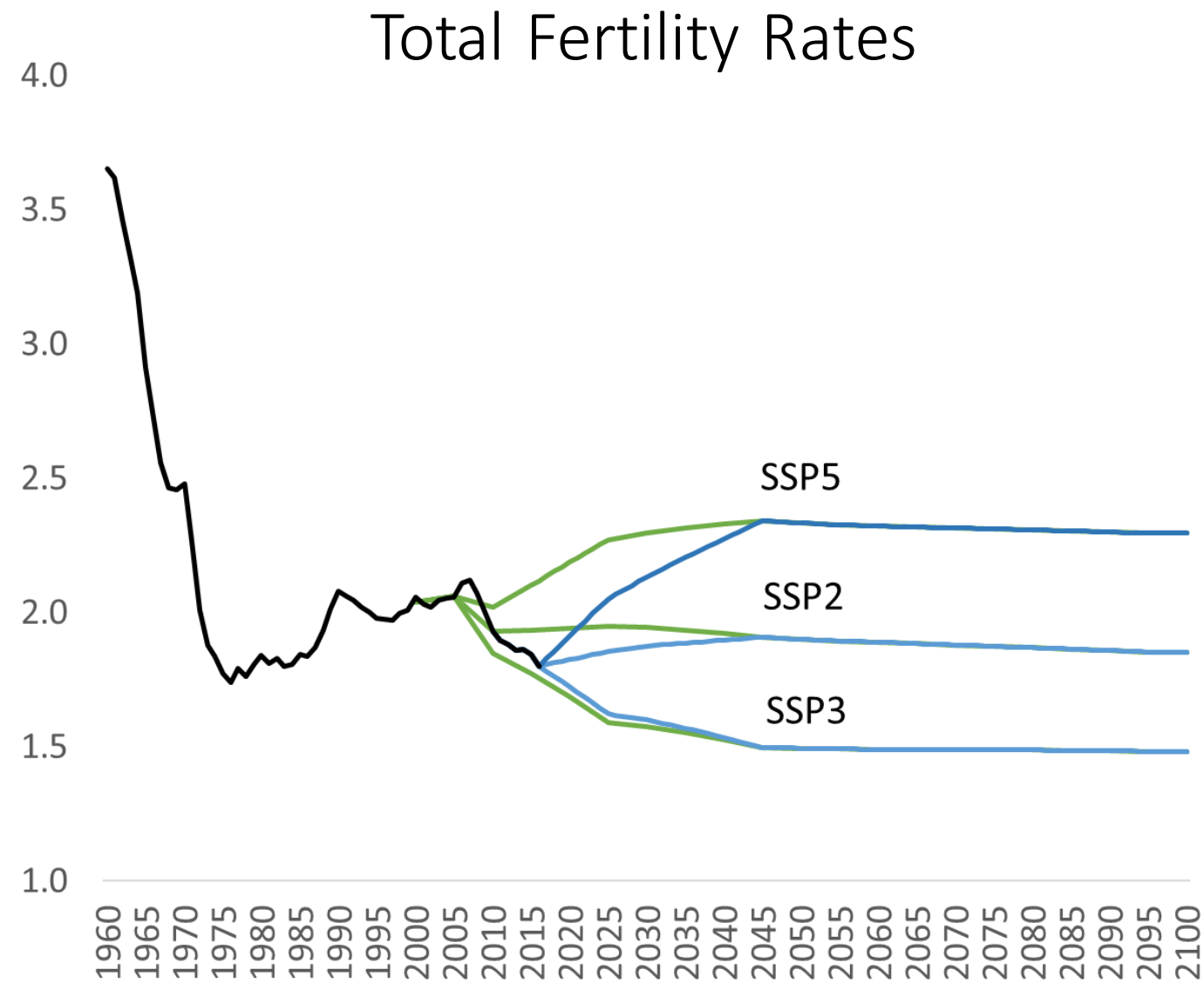


RCP 8.5 Energy supply

The core defect of RCP8.5 can be stated in two words: natural gas. RCP8.5 derives from an earlier emission scenario called A2 used by the Intergovernmental Panel on Climate Change (IPPC) in its 2007 Fourth Assessment Report (AR4). The analysts who developed A2 did not foresee the coming U.S. shale boom. RCP8.5 tacitly assumes that coal becomes the world's dominant energy source in the 2040s and continues to expand market share relative to gas through the rest of the century. Coal, of course, is the most carbon-intensive fossil fuel, emitting about twice as much carbon dioxide as natural gas per unit of energy consumed.

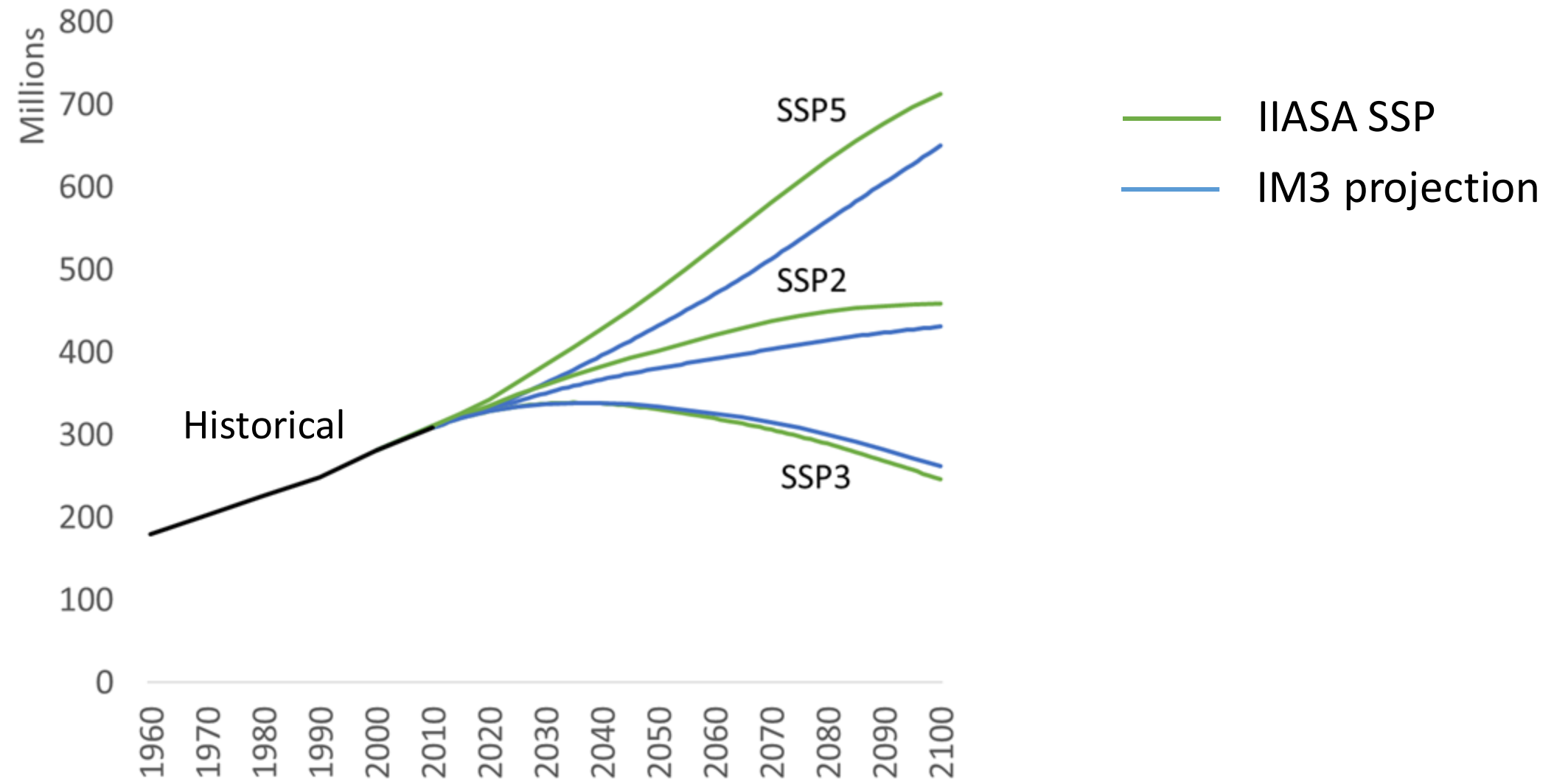
Lewis, 2018, CEI.

# Updating US population projections



— historical data    — IIASA SSPs projection    — new IM3 projection

# Results: US Total Population

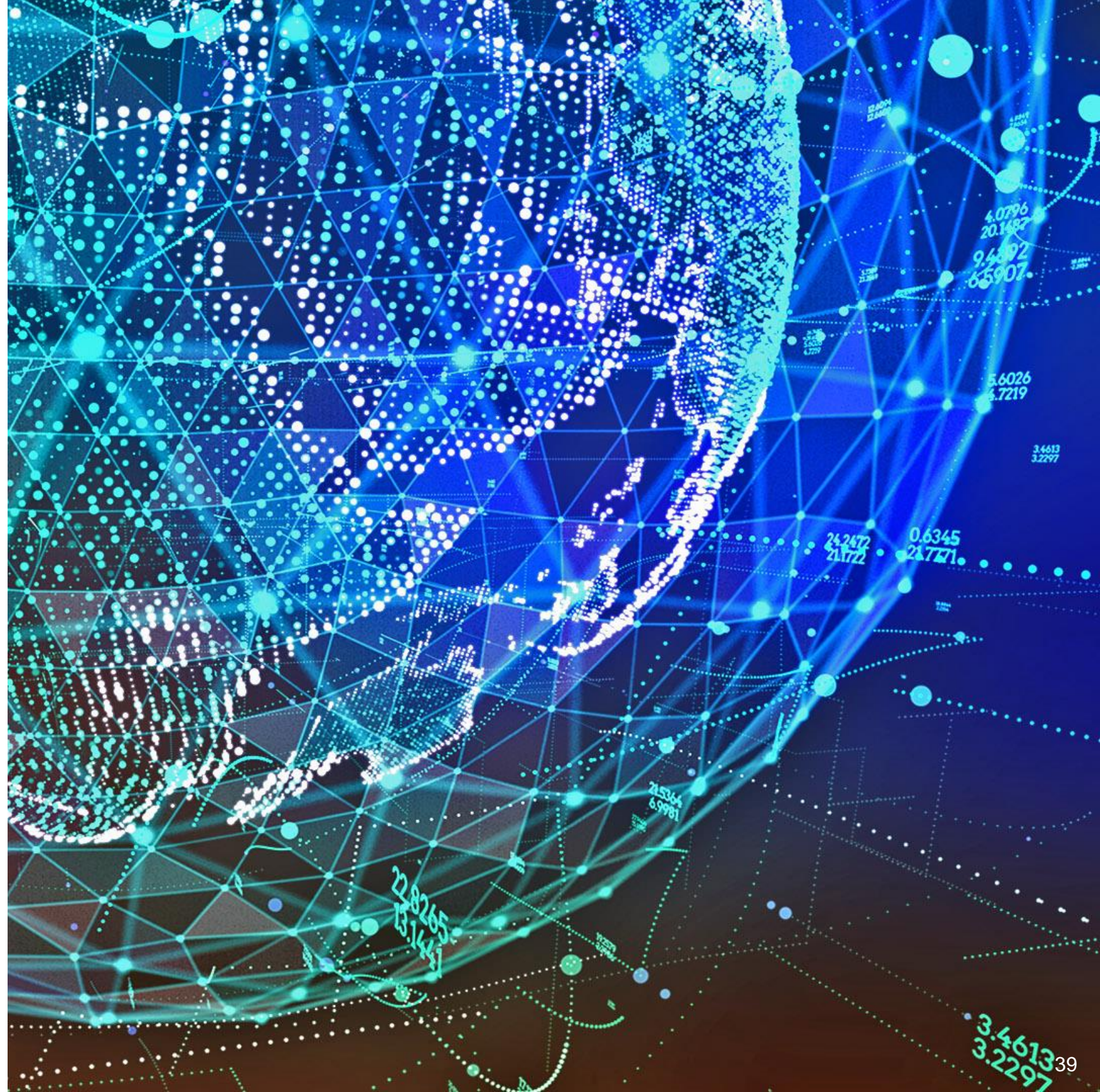




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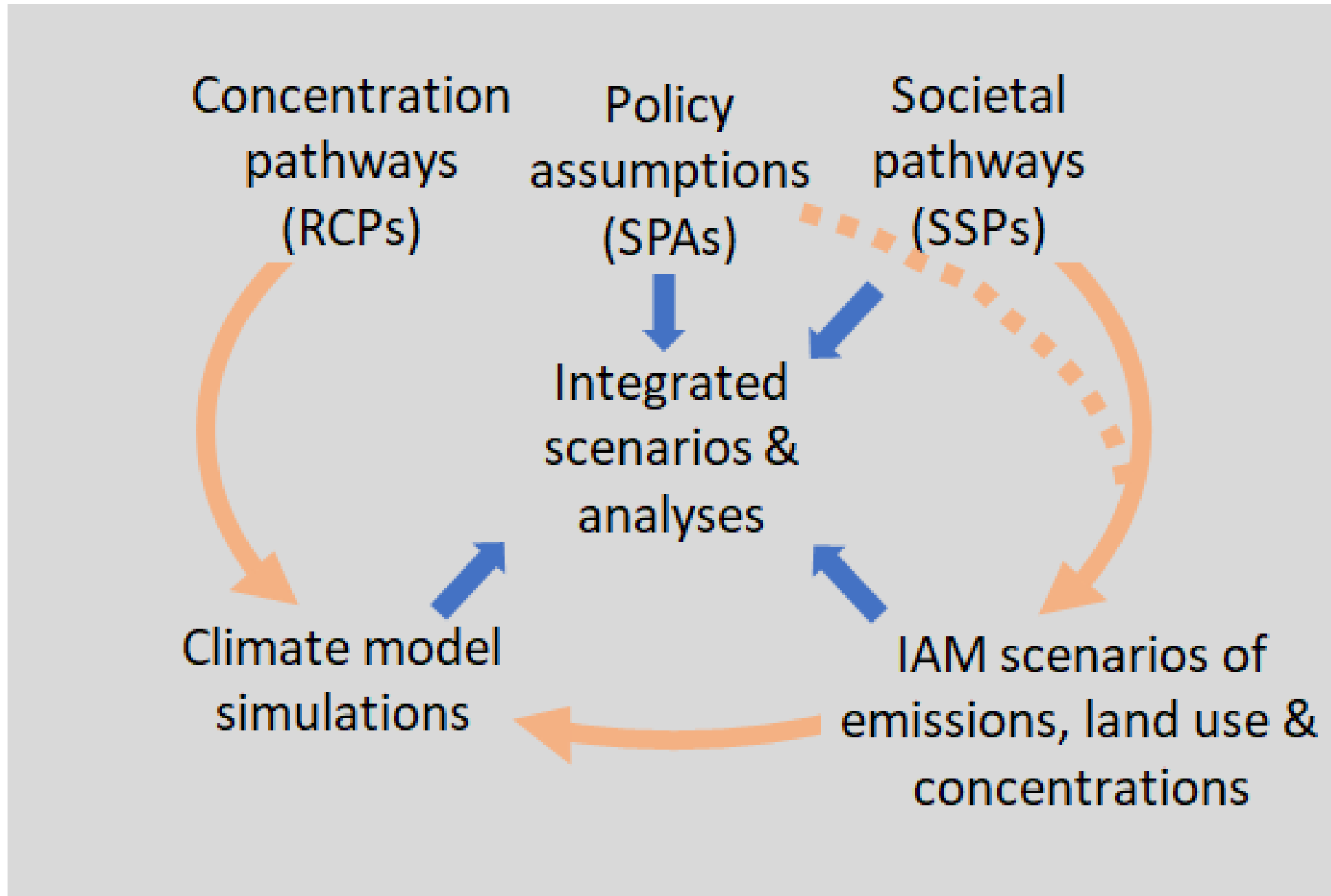
Thank you





Extra slides

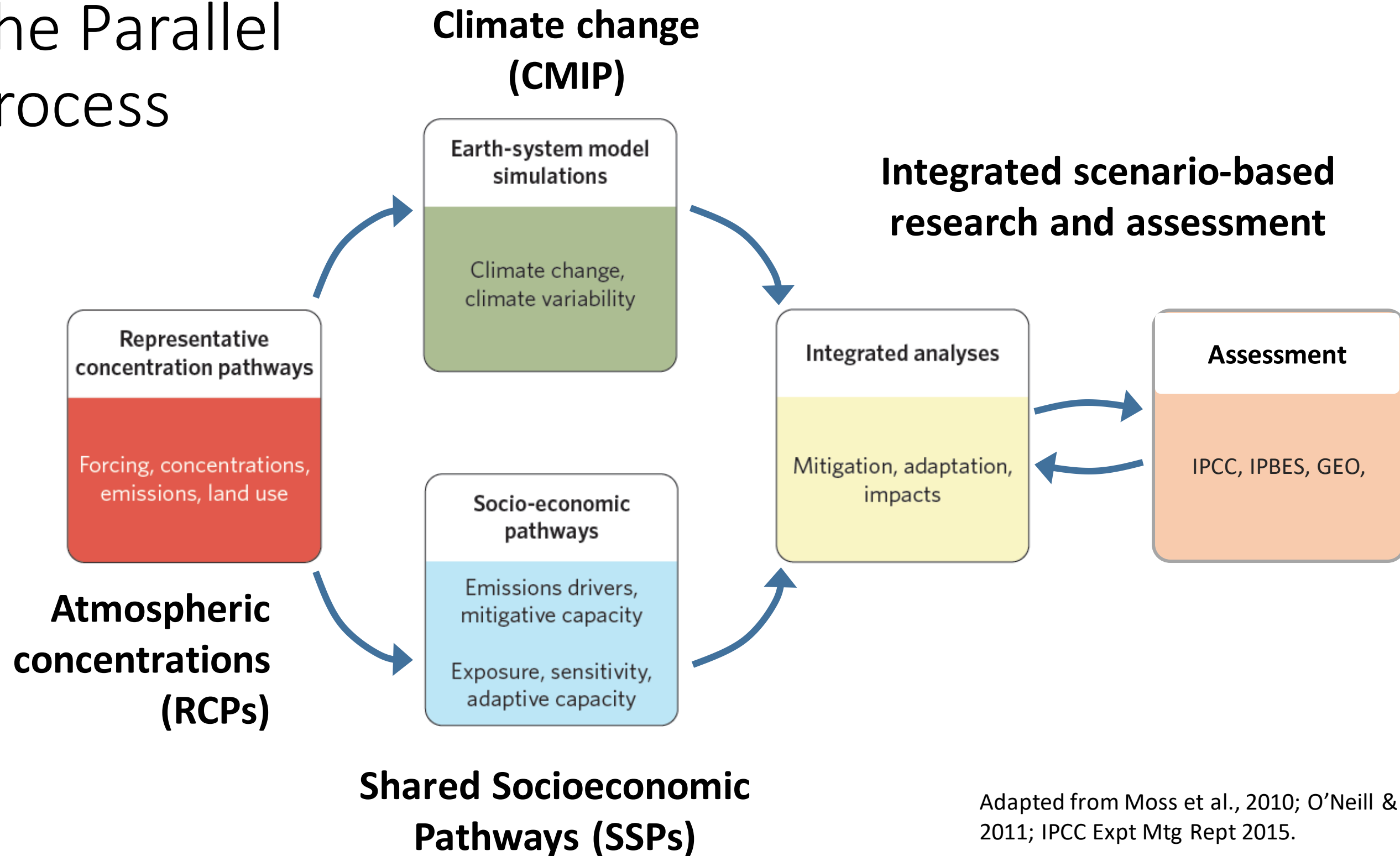
# The SSP-RCP scenarios framework



O'Neill et al.,  
2020.

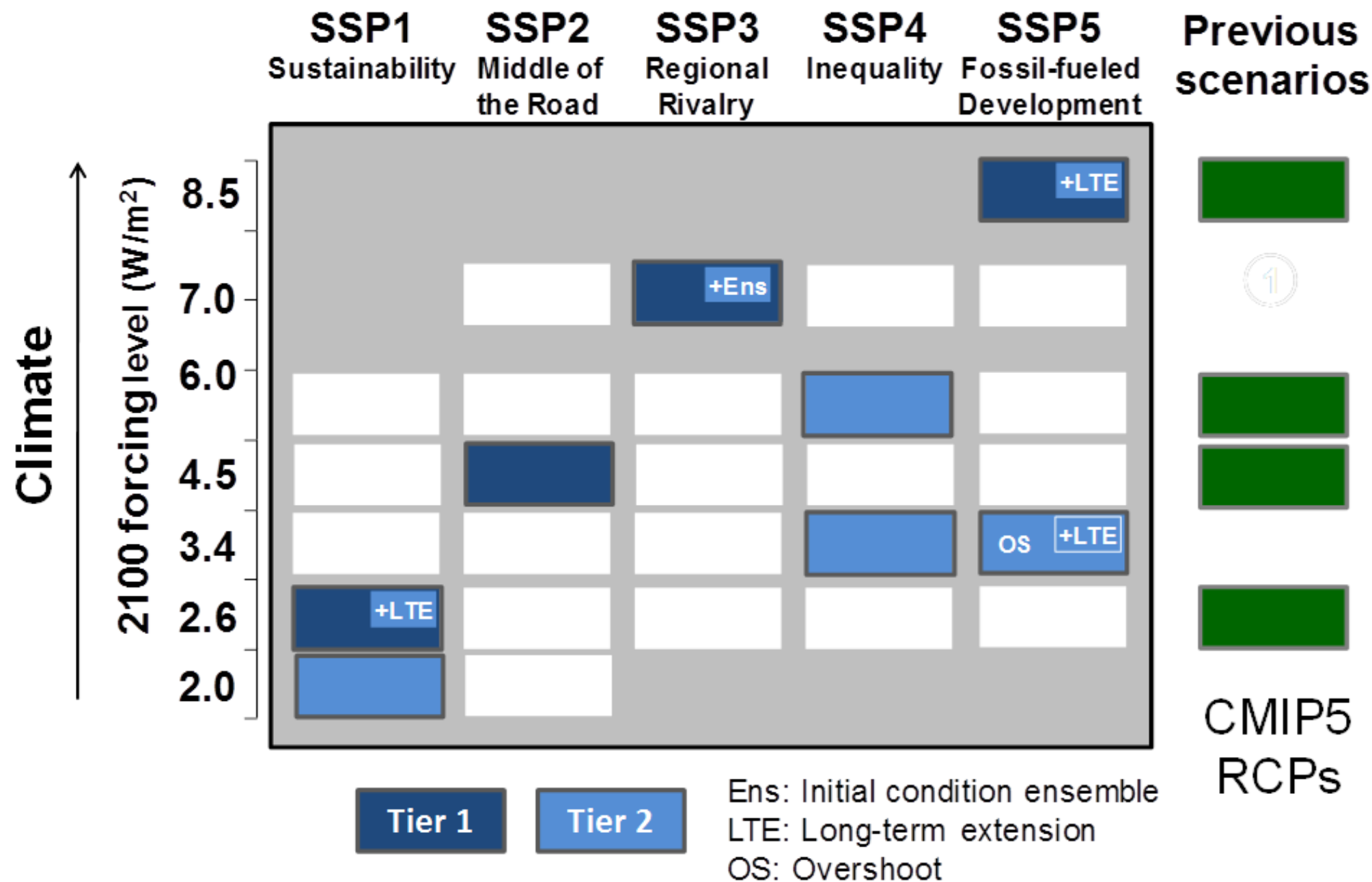


# The Parallel Process

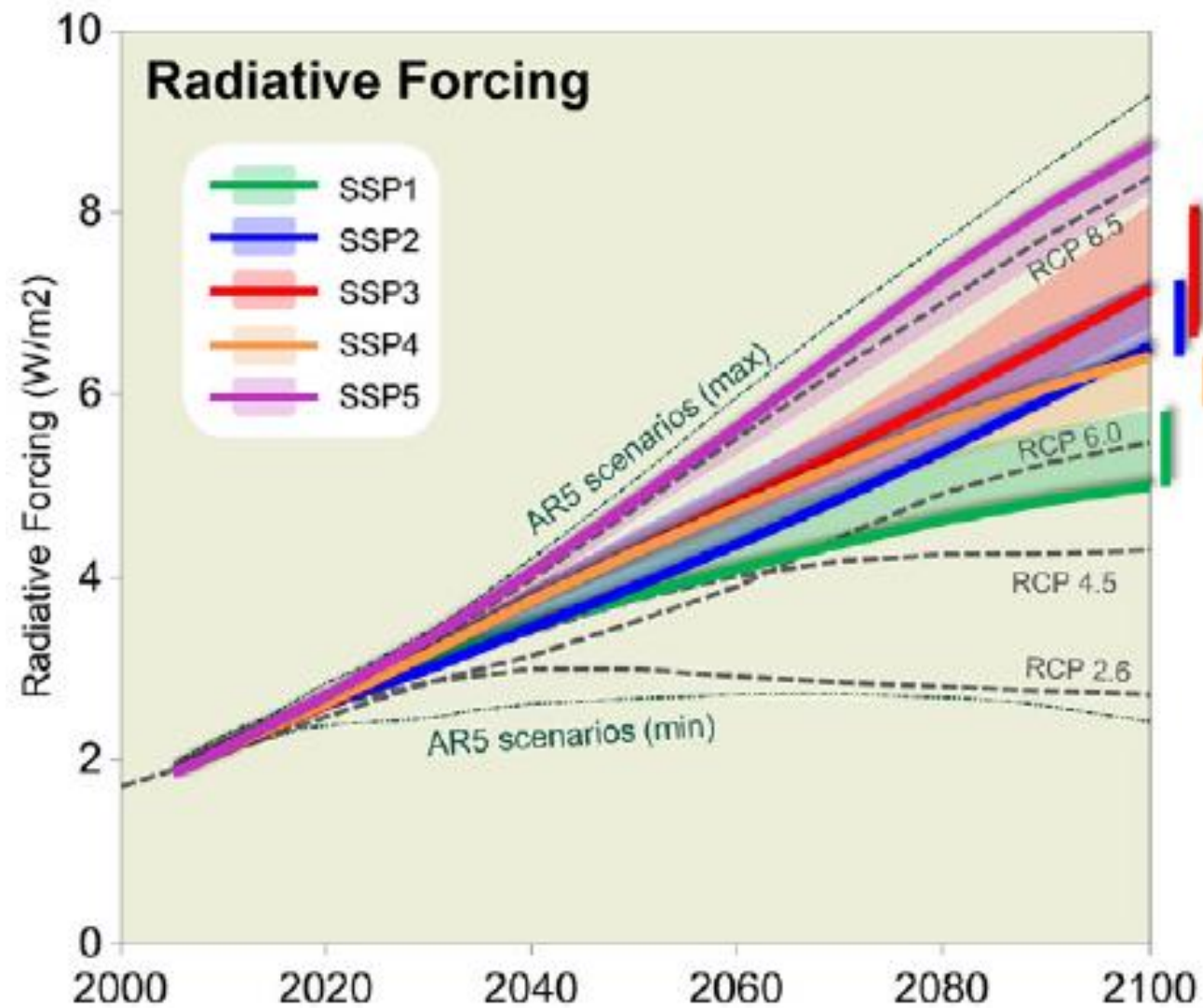


Adapted from Moss et al., 2010; O'Neill & Schweizer, 2011; IPCC Expt Mtg Rept 2015.

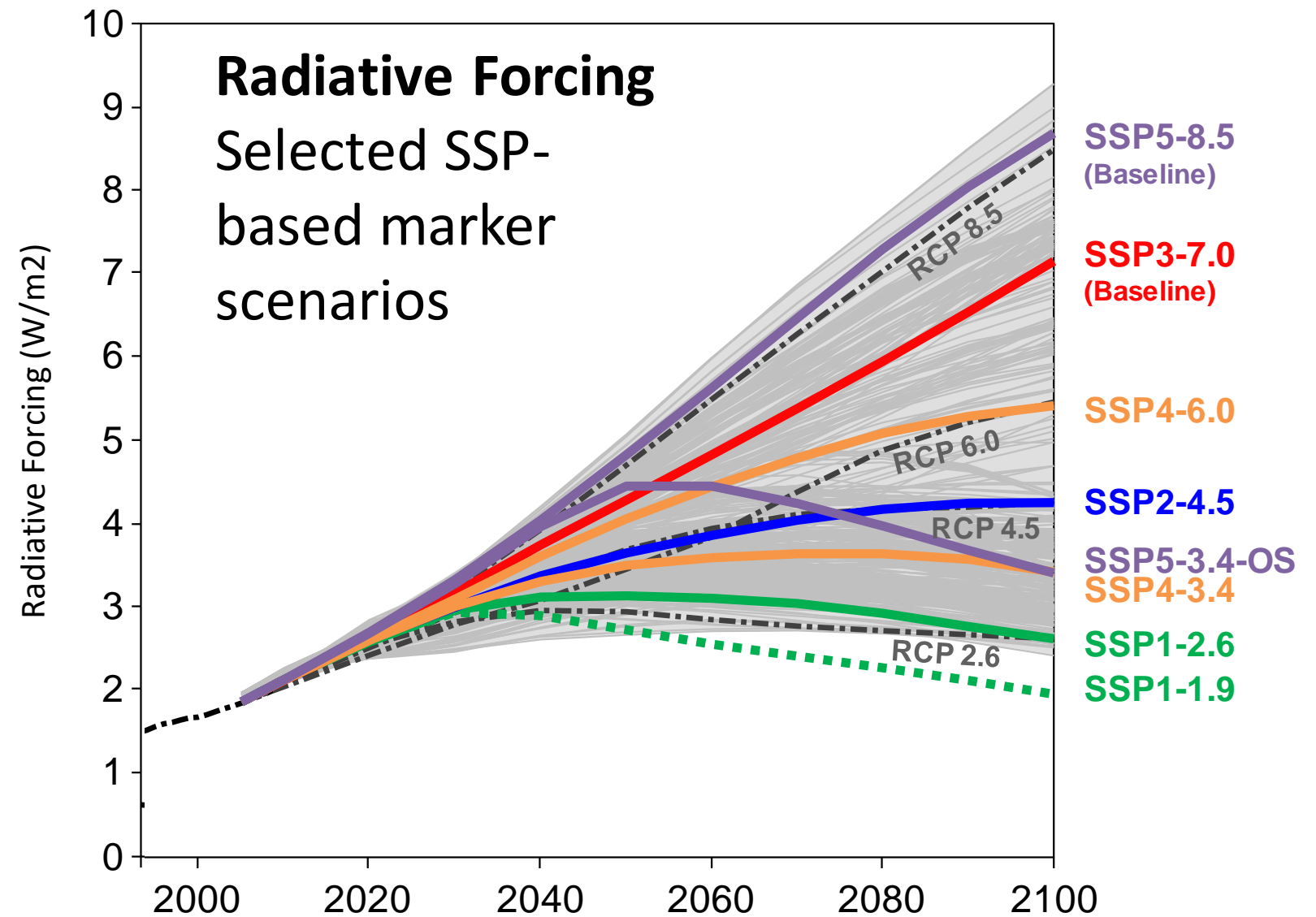
# Shared Socioeconomic Pathways



# IAM scenarios based on SSPs and policy assumptions

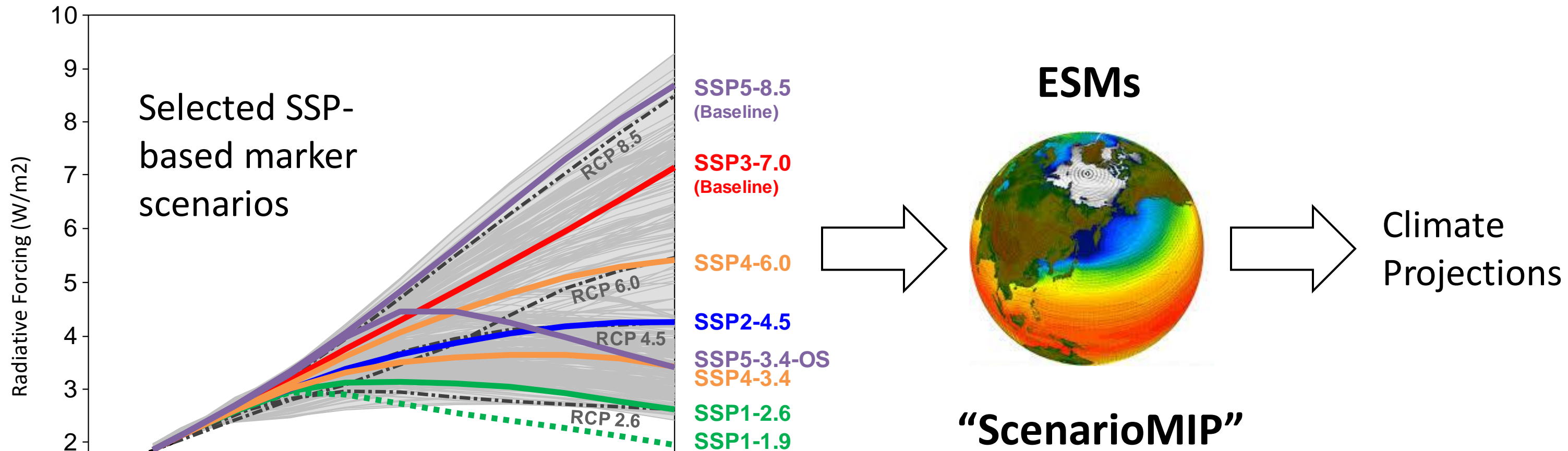


Riahi et al., 2017.



O'Neill et al., 2016.

# Applications: Climate projections (CMIP6)



O'Neill et al., 2016.

# Poverty results (extr. poverty = <\$1.90/day)

**TABLE 0.1** Climate change threatens to worsen poverty, but good development can help

| Policy choices      | Climate change scenario                     |  |                        |   |
|---------------------|---|--|------------------------|---|
|                     | No climate change                           | Low-impact scenario  |                        | High-impact scenario                              |
|                     | Number of people in extreme poverty by 2030 | Additional number of people in extreme poverty due to climate change by 2030 |                        |   |
| Prosperity scenario | 142 million                                 | +3 million   |                        | +16 million                                       |
|                     | 3%, WB goal                                 | Minimum<br>+3 million  | Maximum<br>+6 million  | Minimum<br>+16 million<br>Maximum<br>+25 million  |
| Poverty scenario    | 900 million                                 | +35 million  |                        | +122 million                                      |
|                     | 11%   | Minimum<br>–25 million   | Maximum<br>+97 million | Minimum<br>+33 million<br>Maximum<br>+165 million |

Source: Rozenberg and Hallegatte, forthcoming.

Note: The main results use the two representative scenarios for prosperity and poverty. The ranges are based on 60 alternative poverty scenarios and 60 alternative prosperity scenarios.