

Normatively Robust Mitigation Policy to Equitably Distribute the Remaining Carbon Budget

Abstract



Palok Biswas
Jazmin Zatarain Salazar
Jan H. Kwakkel

Equity in Climate Negotiations

Cop29 climate finance deal criticised as 'travesty of justice' and 'stage-managed'

Some countries say deal should not have been done and is 'abysmally poor' compared with what is needed



📷 Activists stage a protest following the closing ceremony in Baku amid anger over the deal and the negotiation process Photograph: Dominika Zarzycka/SOPA Images/REX/Shutterstock

Who Pays and How: The COP28 Dilemma of Debt and Equity

COP28 will take stock of the step change in ambition needed, but the gulf

nature

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NEWS | 10 November 2021

COP architects furious at lack of climate justice at pivotal summit

The New York Times

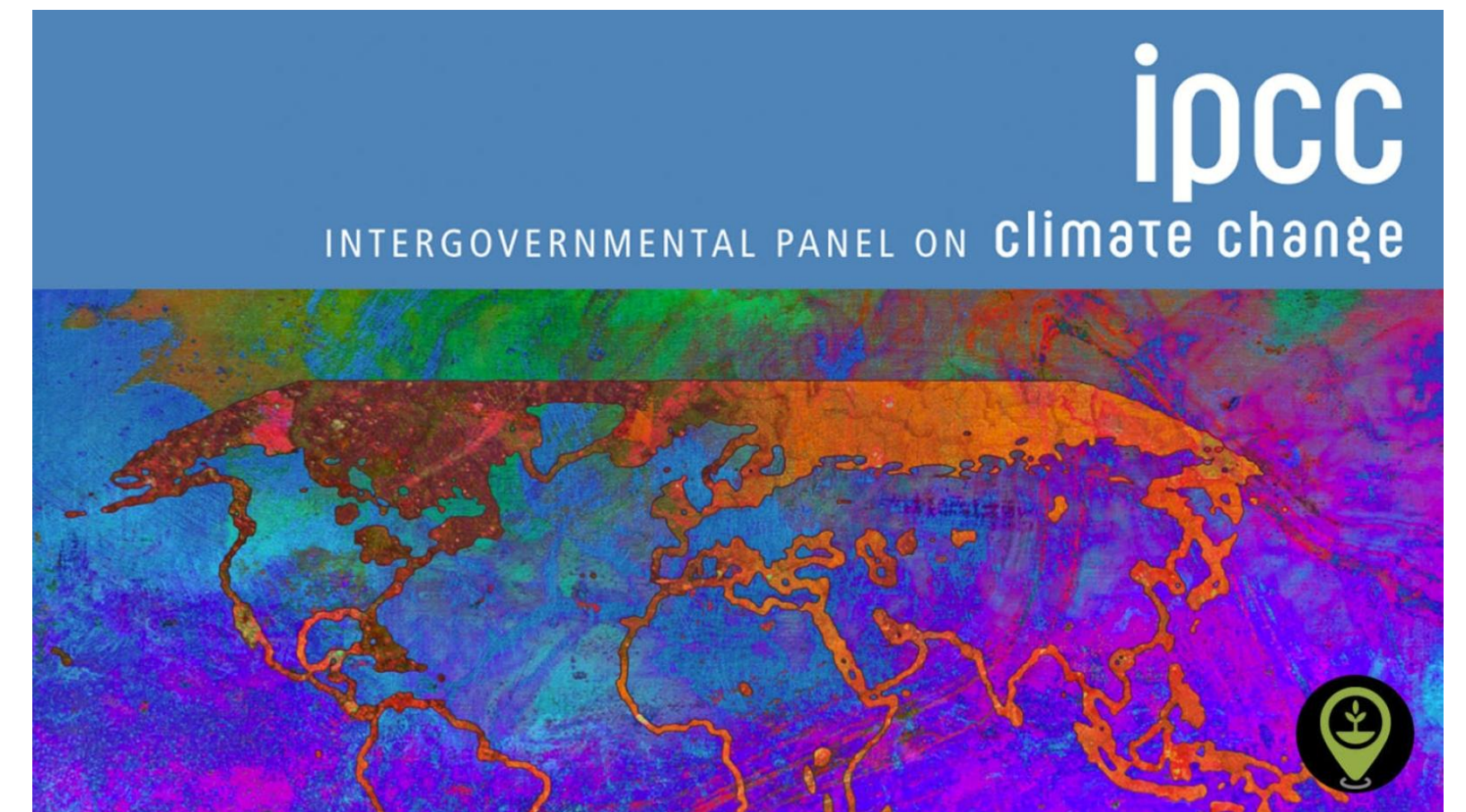
Countries Most at Risk Call Proposed Climate Agreement a 'Death Warrant'

The working draft made public at the U.N. summit in Dubai would not commit nations to phasing out the fossil fuels that are dangerously heating the planet.

Integrated Assessment Models

Integrated Assessment Models (IAMs) are the **dominant tool** used to design **global mitigation pathways** in **IPCC** reports¹.

IAMs *lack explicit consideration* for **distributive justice**².



1. Cointe et al. 2019
2. Budolfson et al 2021

Results in a **misalignment** between IAM
prescriptions and actual *decision needs*.

The Double Dilemma

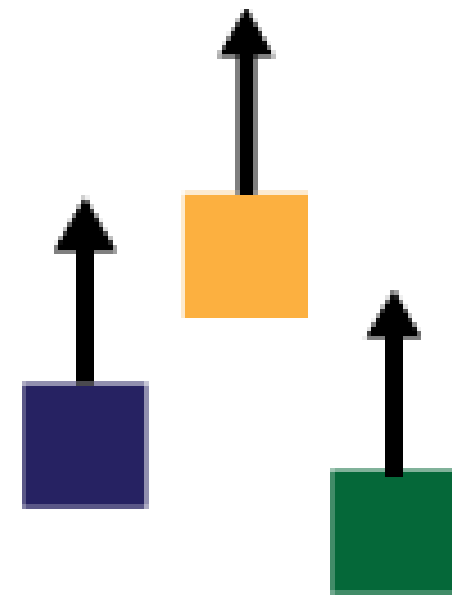
Deep Uncertainty

- Future socio-economic projections
- Economic *impacts* of climate damages

Normative Uncertainty

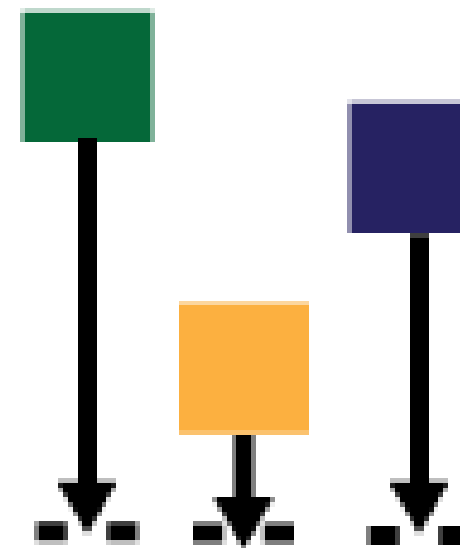
- Arising in a *multi-actor* setting with *perspectival diversity*.
- Different *theories* prescribe *different courses of action* in response to climate change.

Rival Ethical Framings



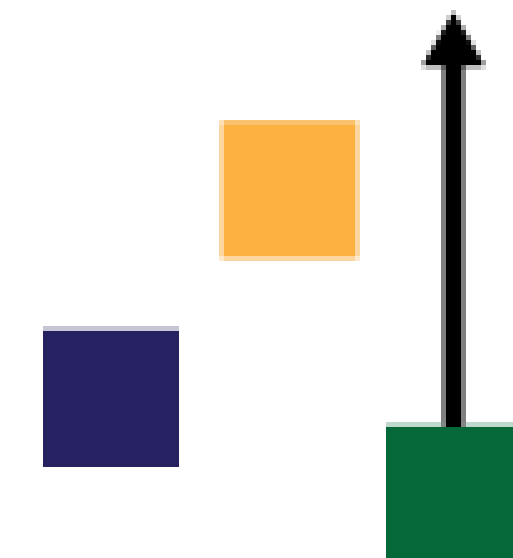
UTILITARIAN

Maximizes the sum of utility
without taking distribution into
account



LIMITARIAN

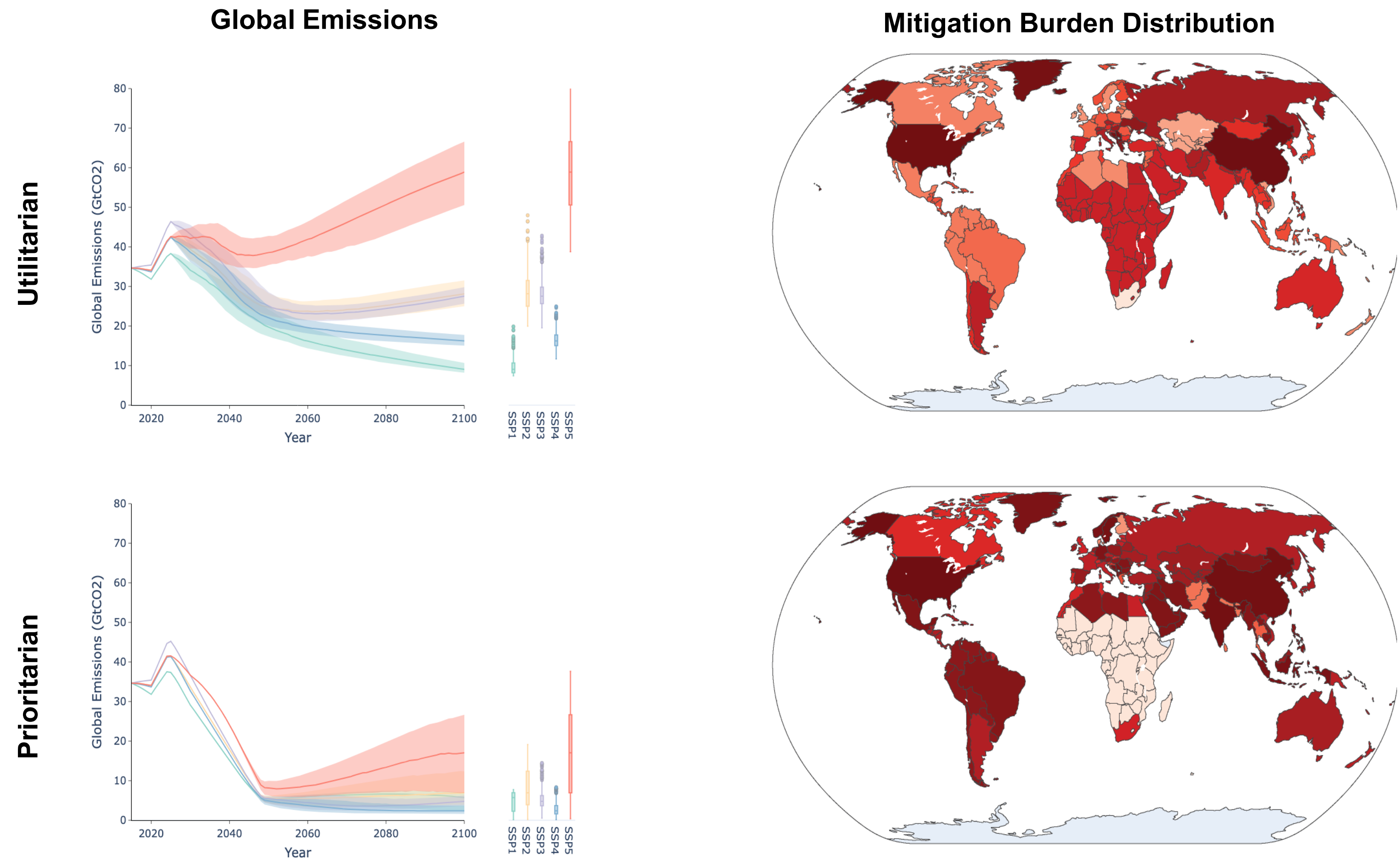
Puts an upper limit on well-
being; exceeding which is
unjust



PRIORITARIAN

Prioritizes the welfare of the least
well-off

Exploring Normative Uncertainty in IAMs



Normatively Robust Mitigation Policy to Equitably Distribute the Remaining Carbon Budget

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METHODS

RESULTS

Abstract

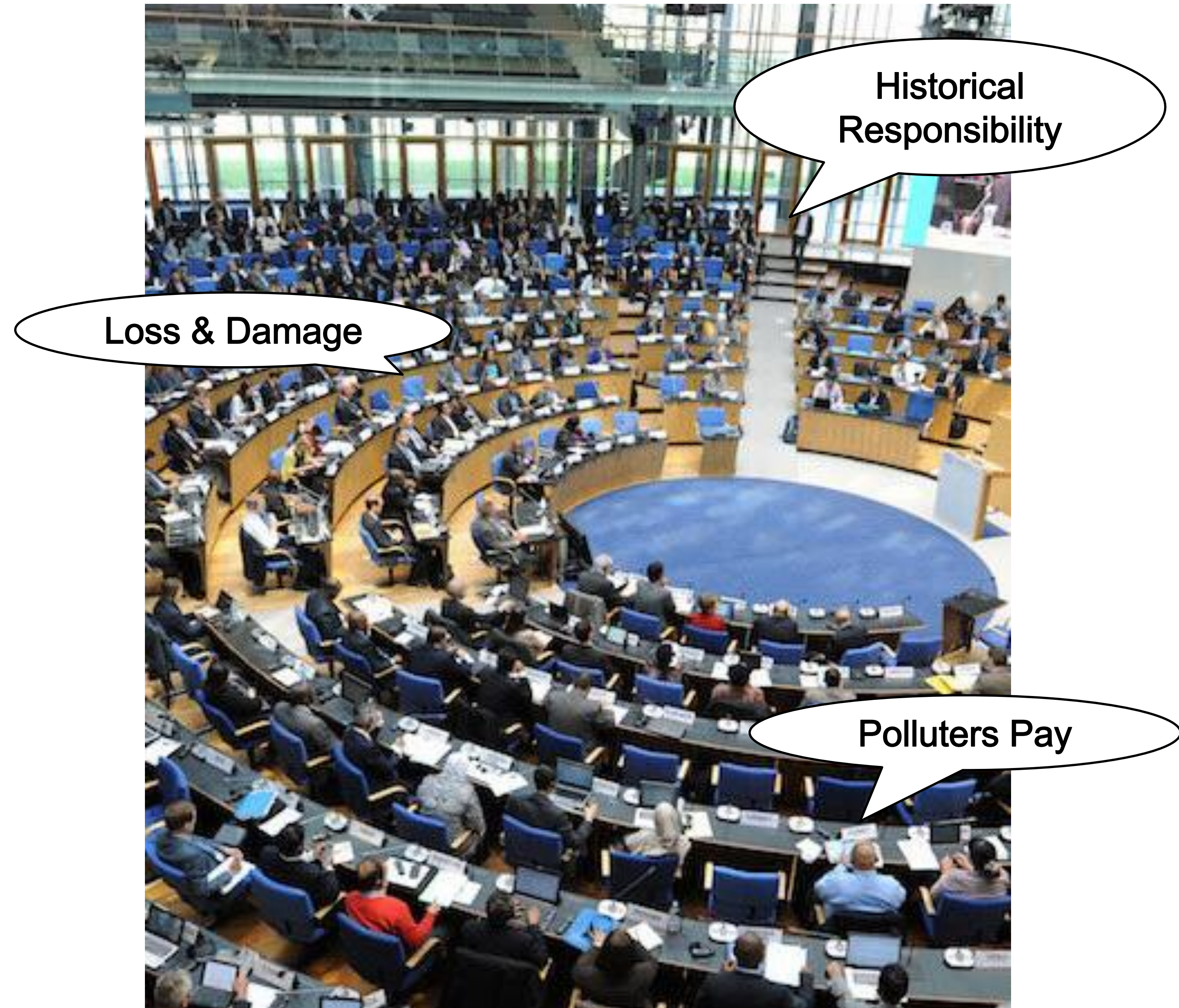


Challenges in COP Negotiations

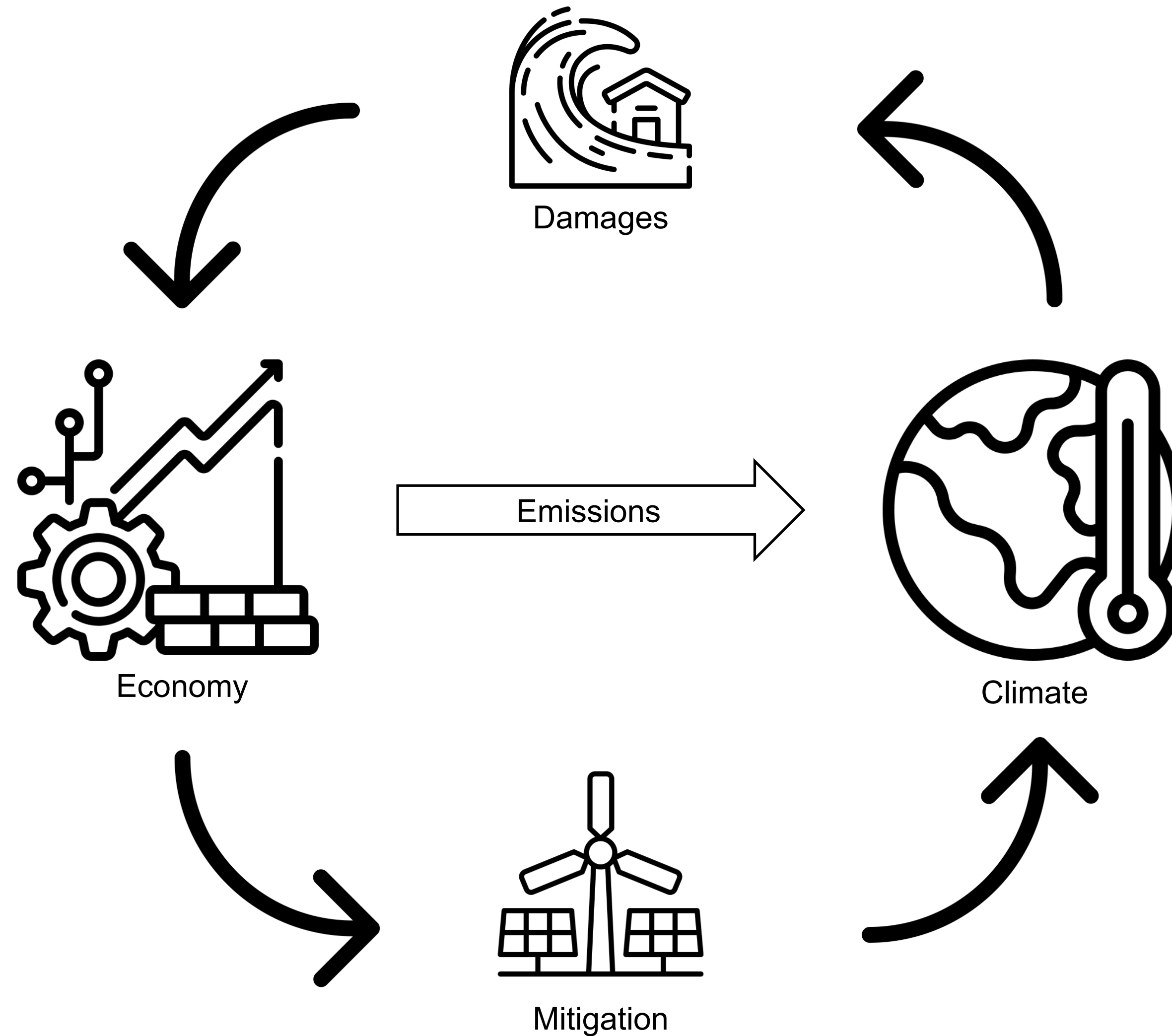
Multiple actors with diverse & conflicting interests

Uncertain future *economic & climate* projections

Stakeholders struggle to find common ground, leading to negotiation impasse



Integrated Assessment Models (IAMs)

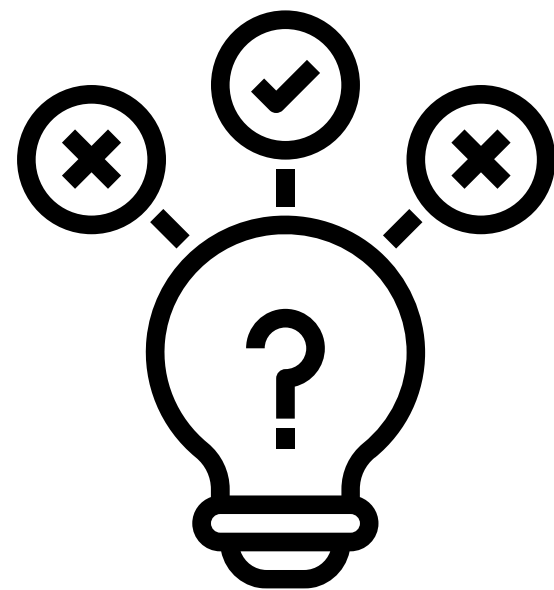


Consequences of Assumptions

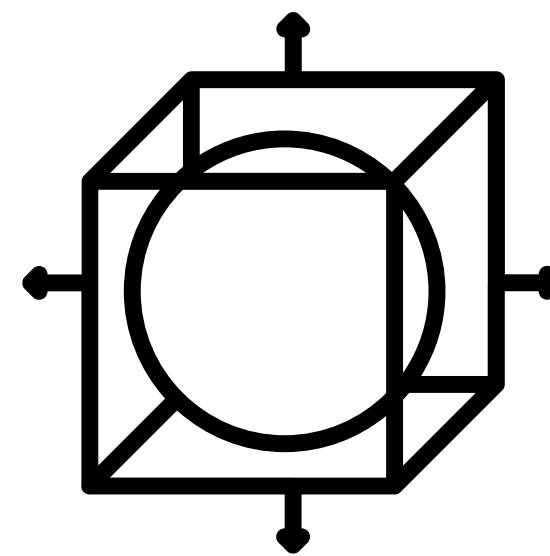
IAMs contain **different normative assumptions**

These assumptions have **different distributional consequences**

If overlooked, IAMs can **perpetuate inequalities**



Modeling Assumption



Model



Distributional Outcomes

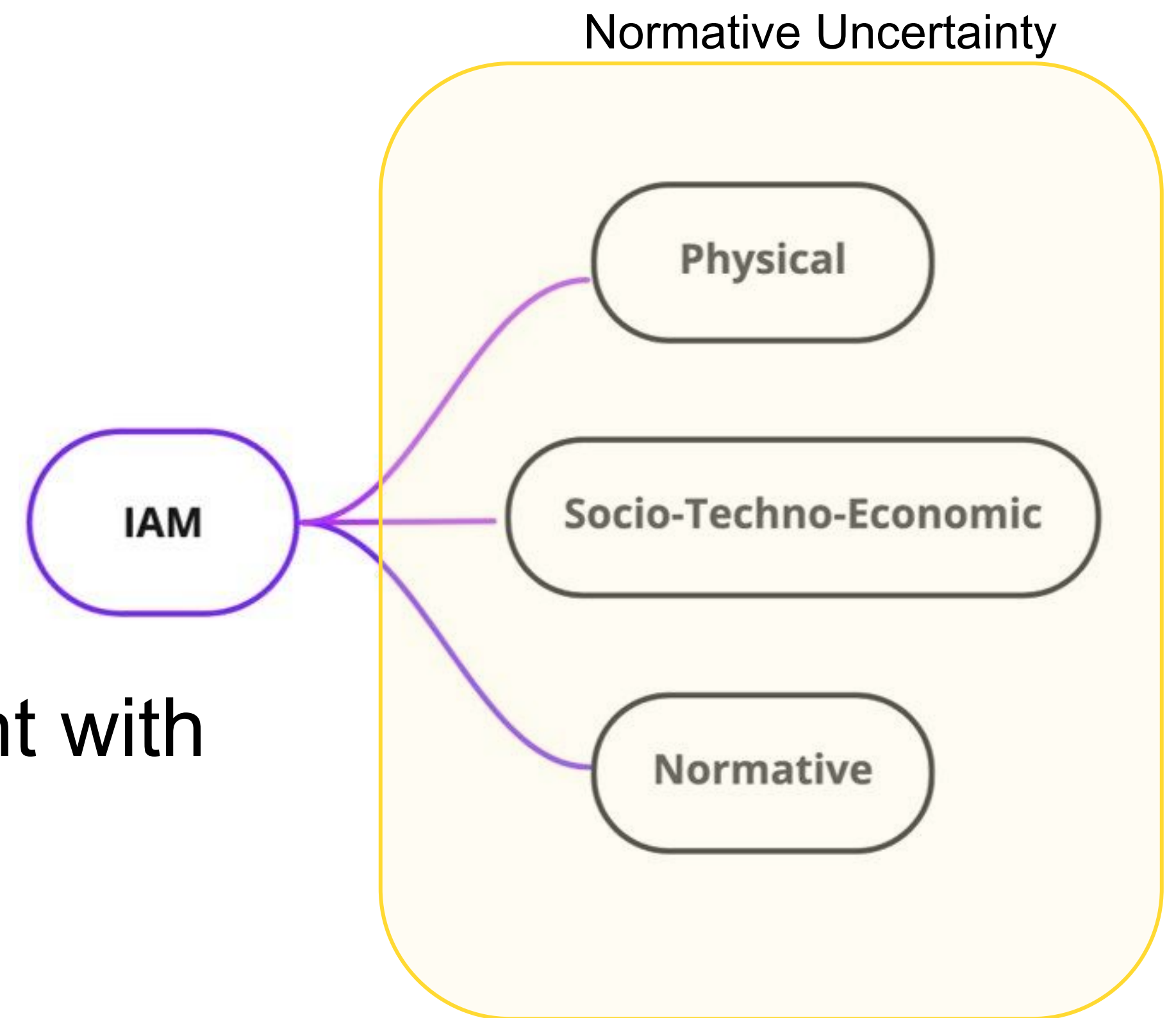
Normative Uncertainty in IAMs

Physical (*Climate*)

Socio-techno-economic

Normative

Normative components of IAMs, most fraught with uncertainty and yet the least understood¹



1. Tavoni & Valente, 2022

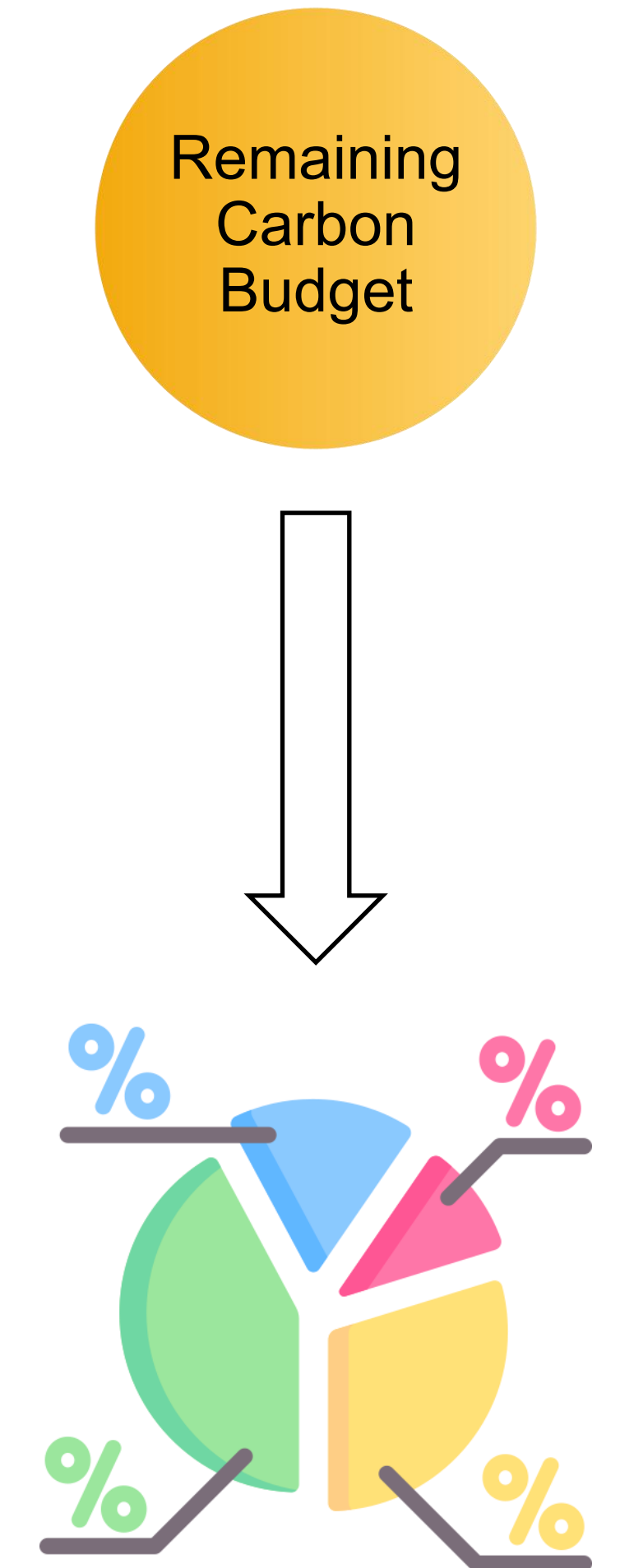
Distributive Justice in IAMs

Limitarianism:

- *Sets an upper cap on total global emissions* (the remaining carbon budget) to keep warming below 2°C.
- We use *emergent constraints*¹ to ensure this budget is robust under climate uncertainties.

Distribution with Utilitarianism & Prioritarianism:

- *Utilitarianism*: Allocates the carbon budget to maximize total global well-being.
- *Prioritarianism*: Prioritizes the needs of the least advantaged nations and generations.

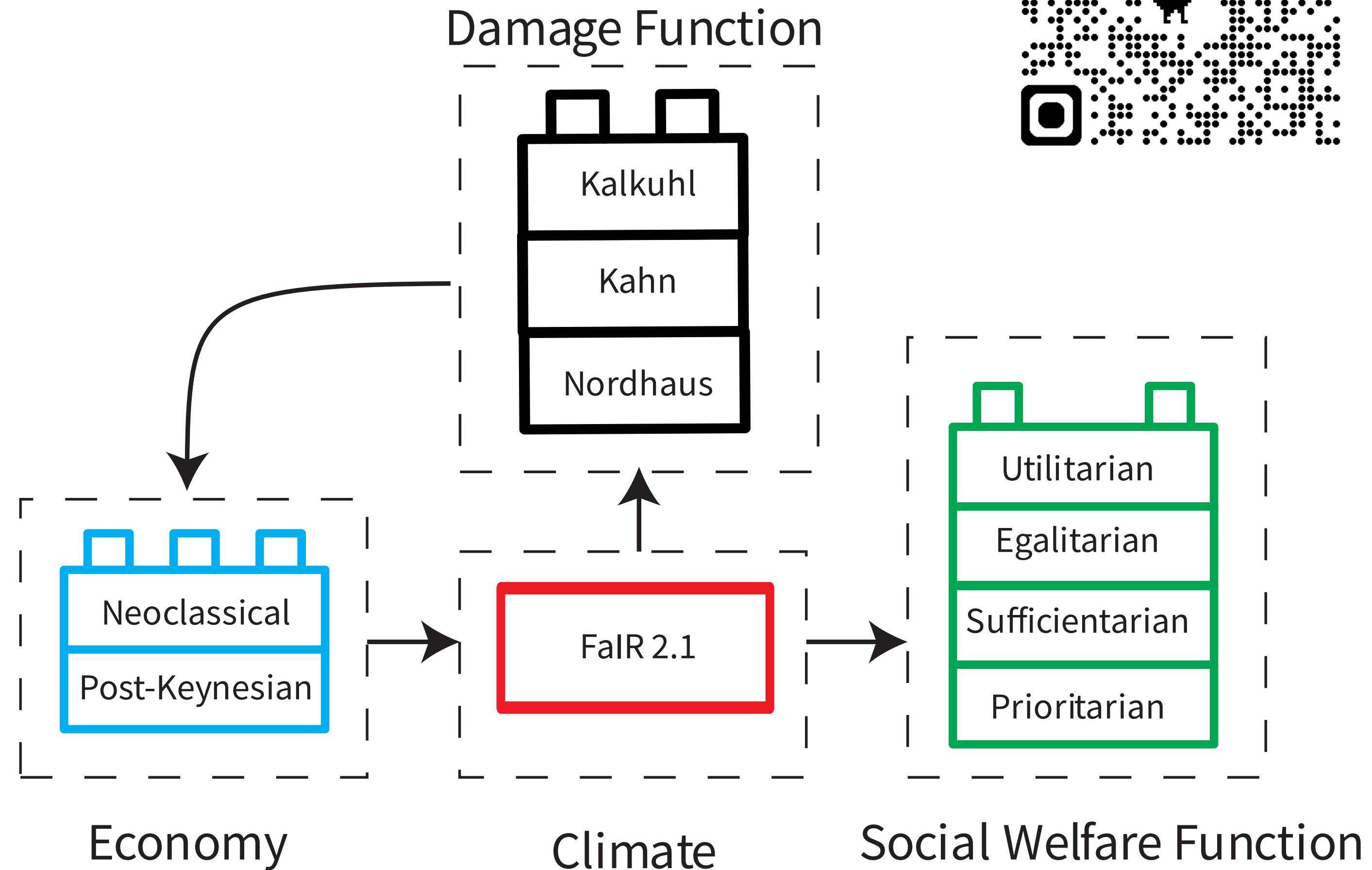


Methods

JUSTICE IAM Framework

Modular *Simulation-Optimization* Model Framework

Explores *distributional impacts* of *modelling assumptions*



Biswas et al. 2025. *In Review*.

DMDU Techniques to address Normative Uncertainty

Rival Ethical Framing

Social Welfare Functions rooted in different principles of *distributive justice*

...

Adaptive Policymaking

Closed-loop control problem using ***EMODPS*** framework

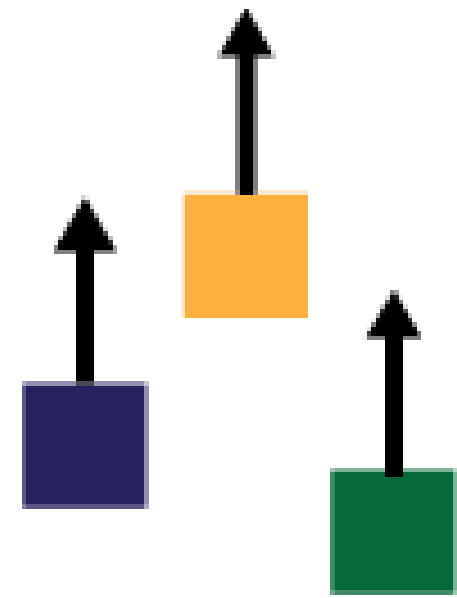
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Robustness Analysis

Using ***MORDM*** to assess the *robustness of policy options*

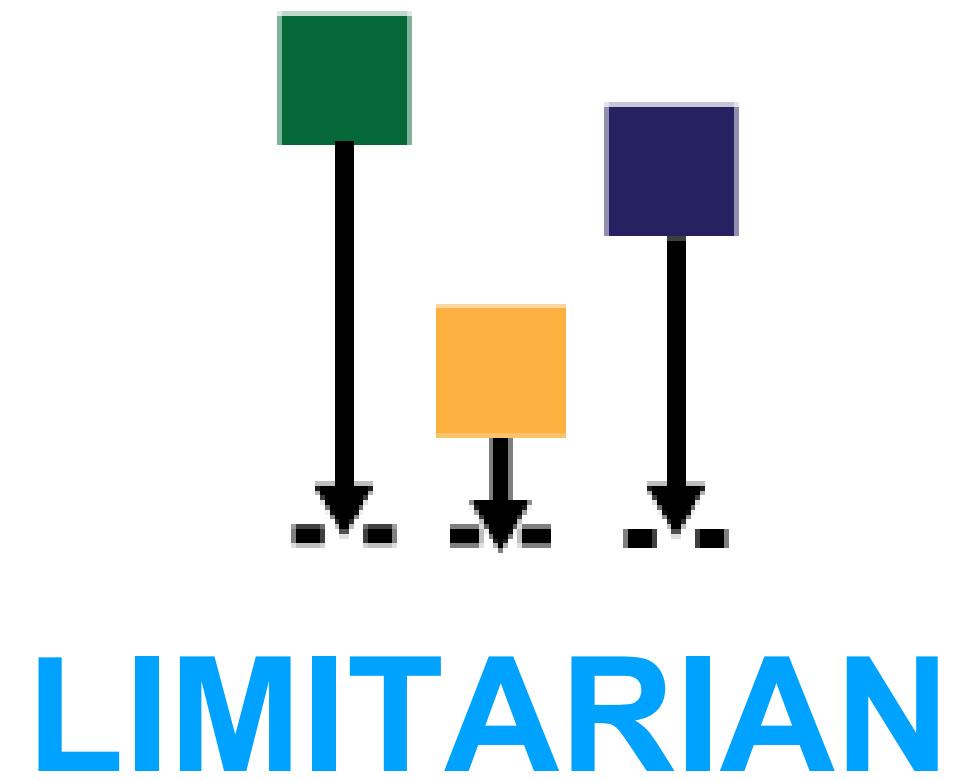
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1. Rival Ethical Framings

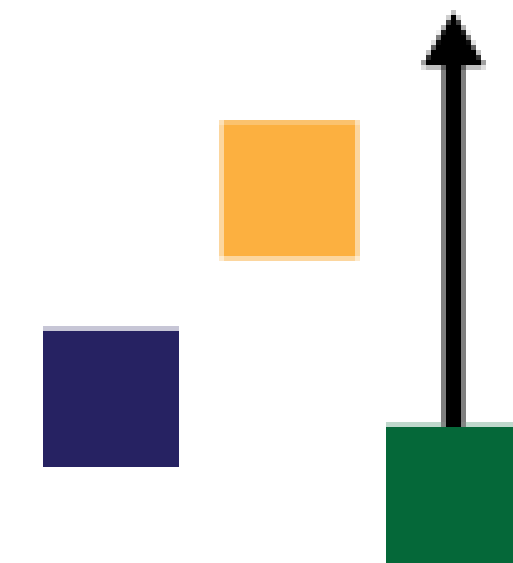


UTILITARIAN

Maximizes the sum of utility without taking distribution into account



Puts an upper limit on well-being; exceeding which is unjust



PRIORITARIAN

Prioritizes the welfare of the least well-off

1. Social Welfare Function

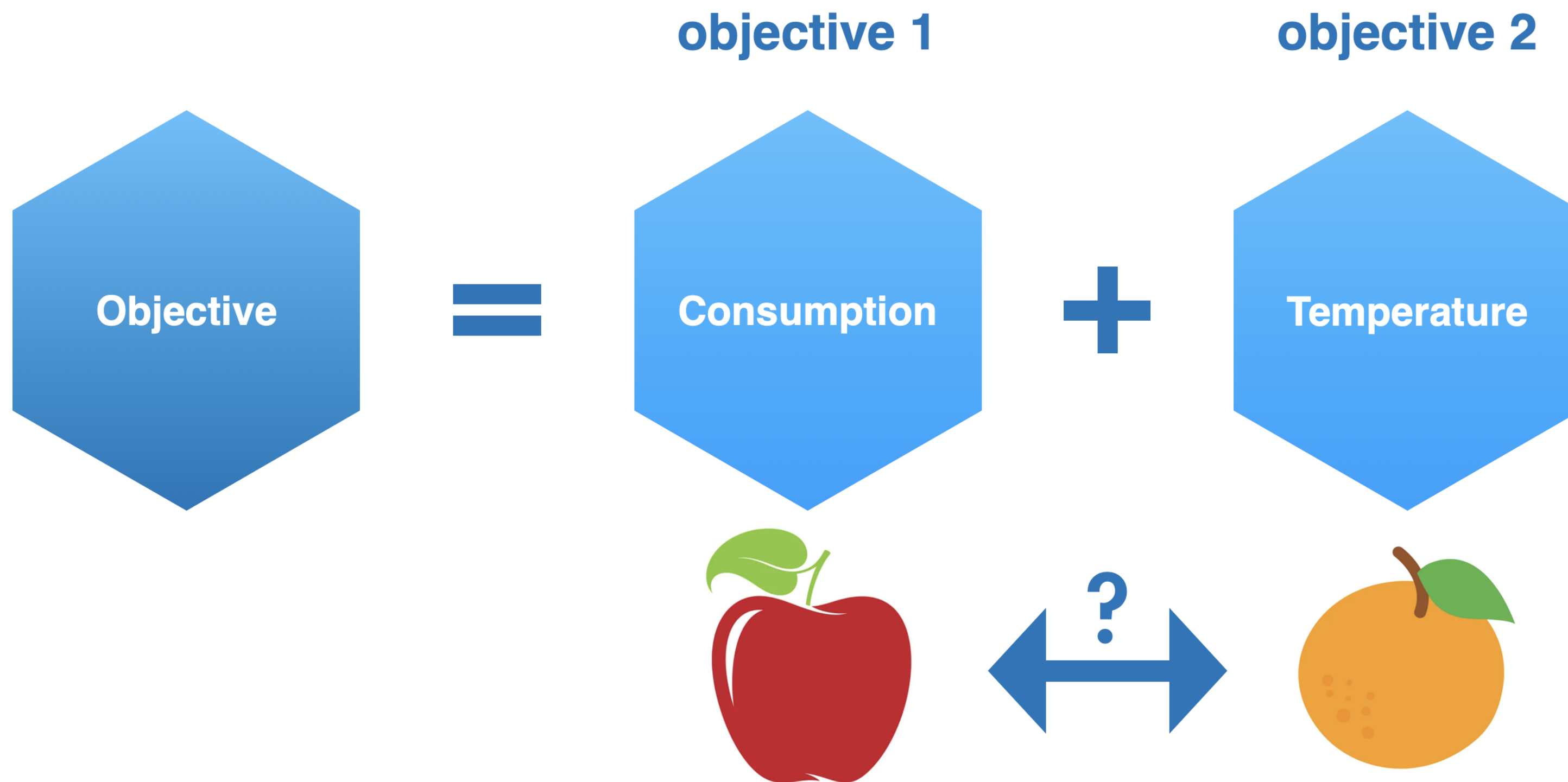
Normative Parameters

Normative Parameters	Description
ϕ_S	Risk Aversion
ϕ_N	Priority or Inequality Aversion
ϕ_T	Pure Rate of Time Preference
λ	Elasticity of Marginal Utility of Consumption
ψ	Equality Strictness
c^{Thresh}	Sufficiency Threshold
e^{Limit}	Limitarian Emission Limit

Biswas et al. 2025. *In Review.*

2. Disaggregation of Objectives

There exists **no single best** aggregation procedure to fully capture **diverse individual preferences** into a **single metric**¹



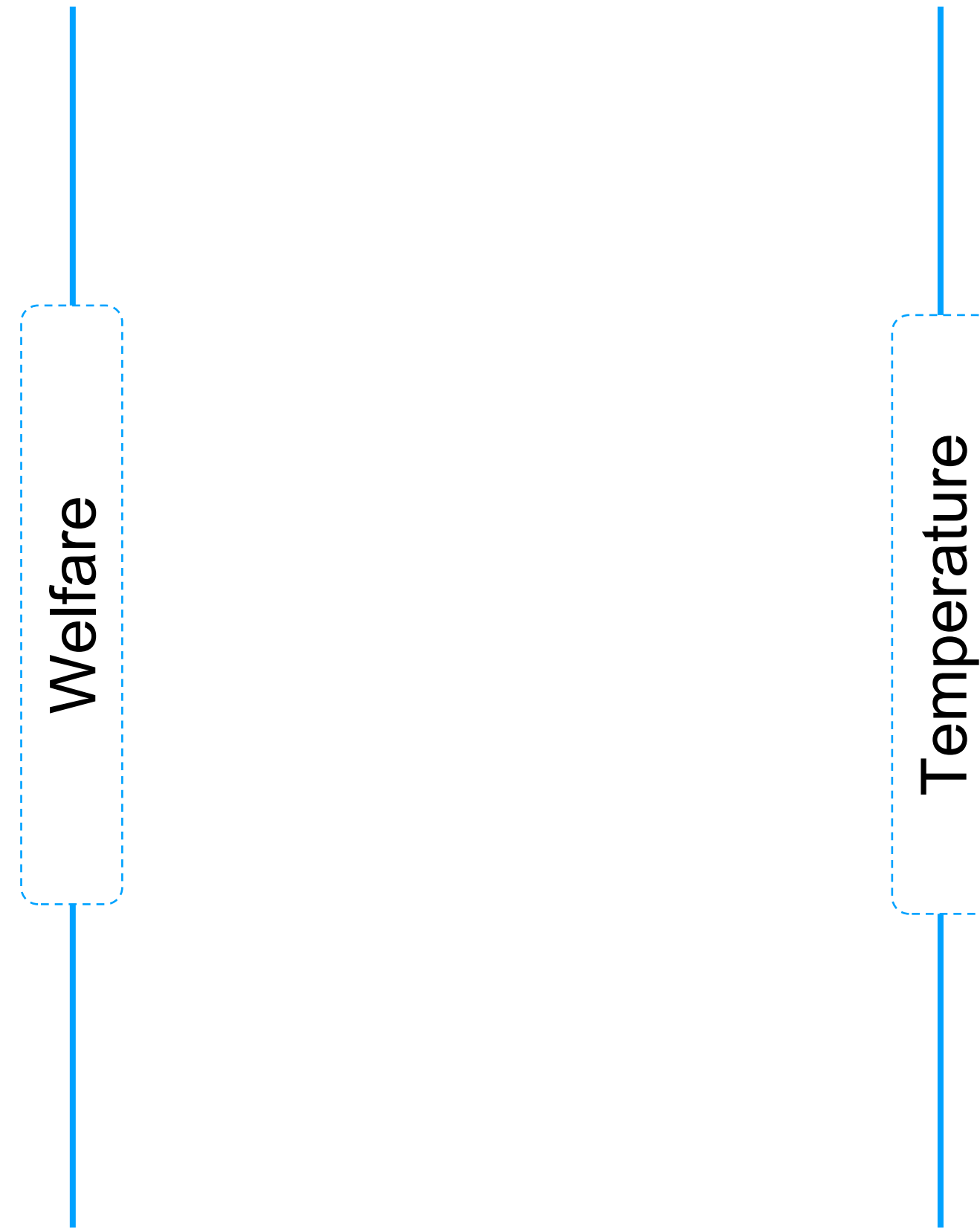
1. Arrow, 1950

2. Disaggregation of Objectives

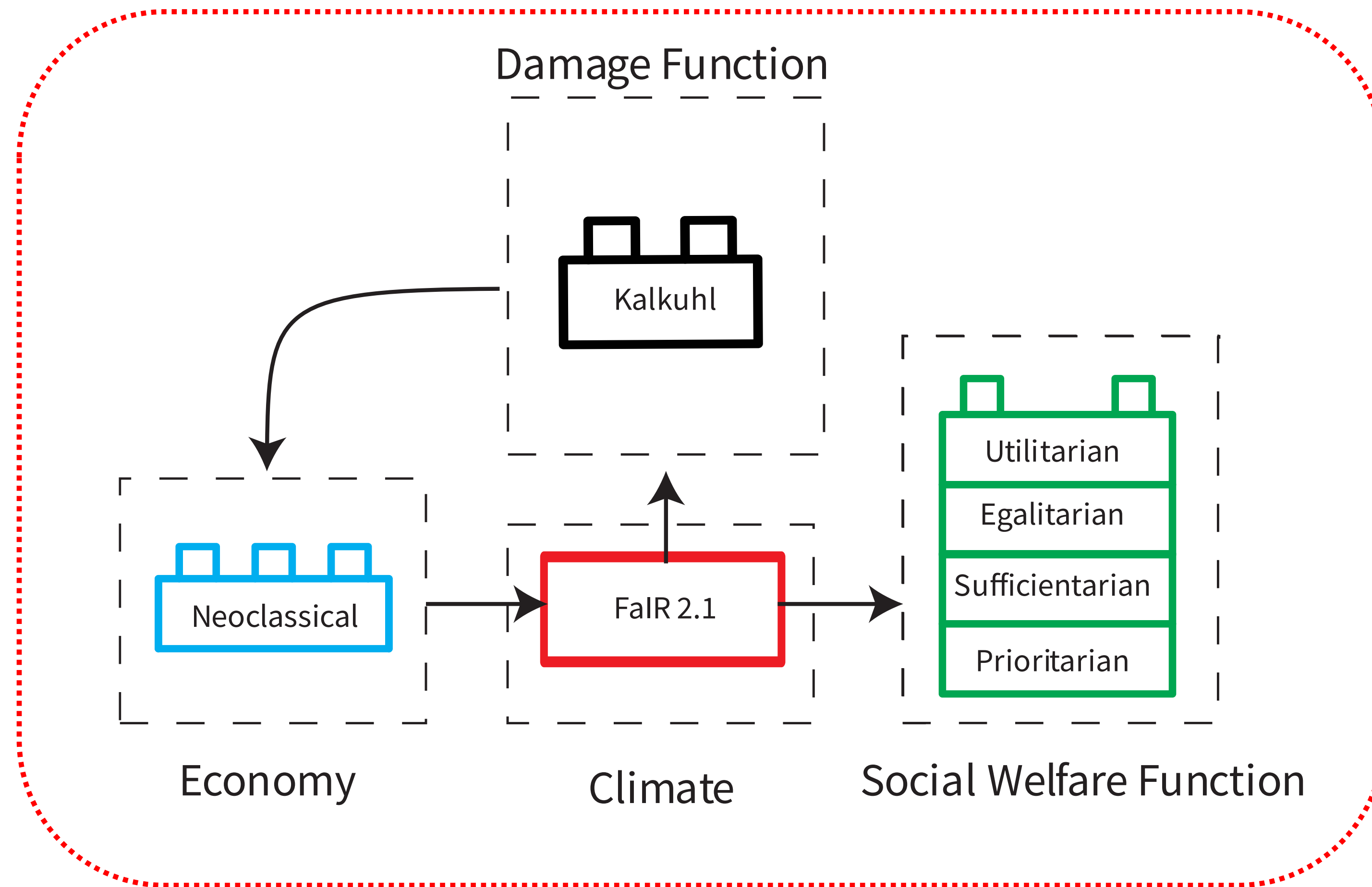


Welfare

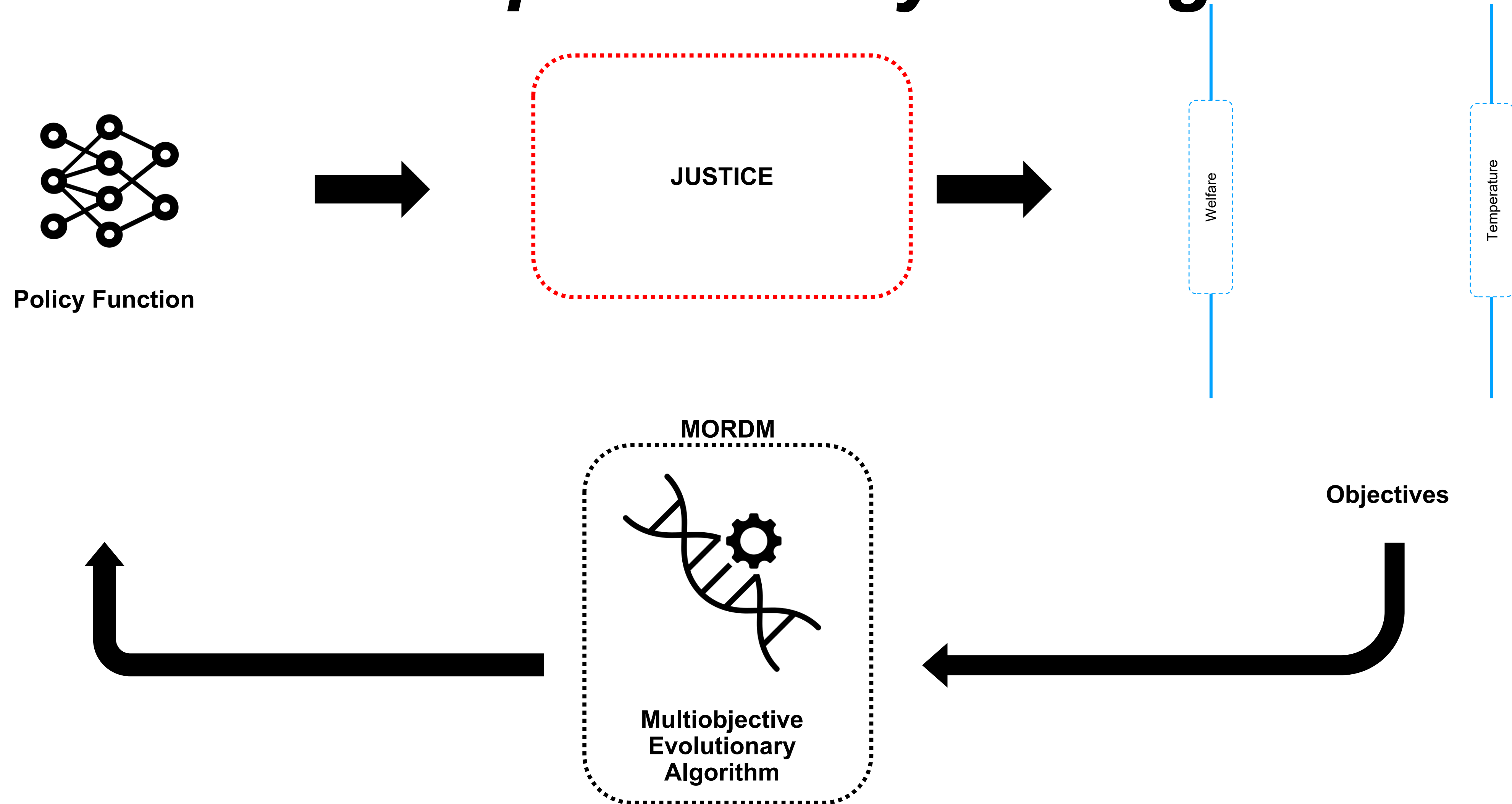
2. Disaggregation of Objectives



2. Evolutionary Multiobjective Direct Policy Search (EMODPS) – *Adaptive Policymaking*

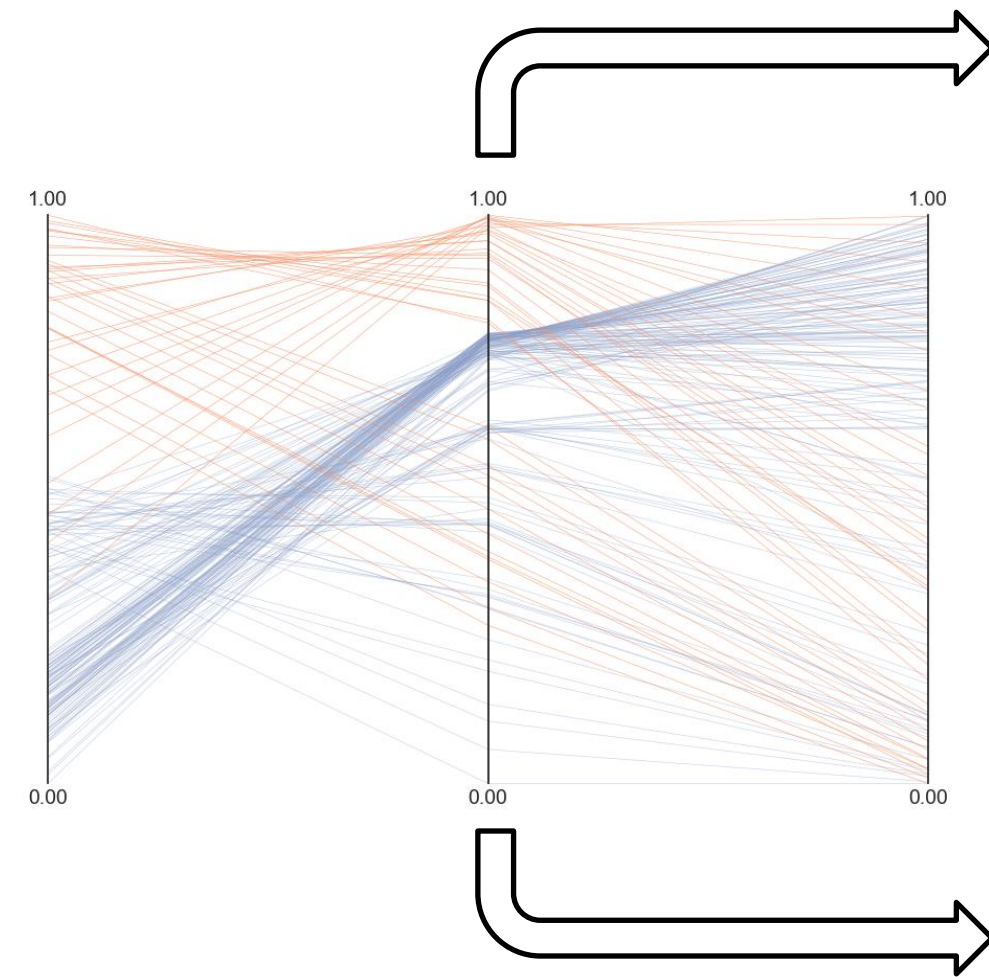


2. EMODPS – *Adaptive Policymaking*

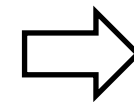
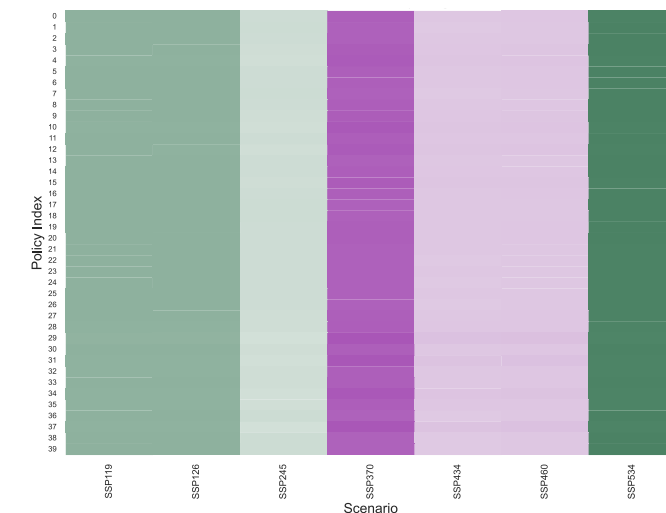


3. Multiobjective Robust Decision Making (*MORDM*)

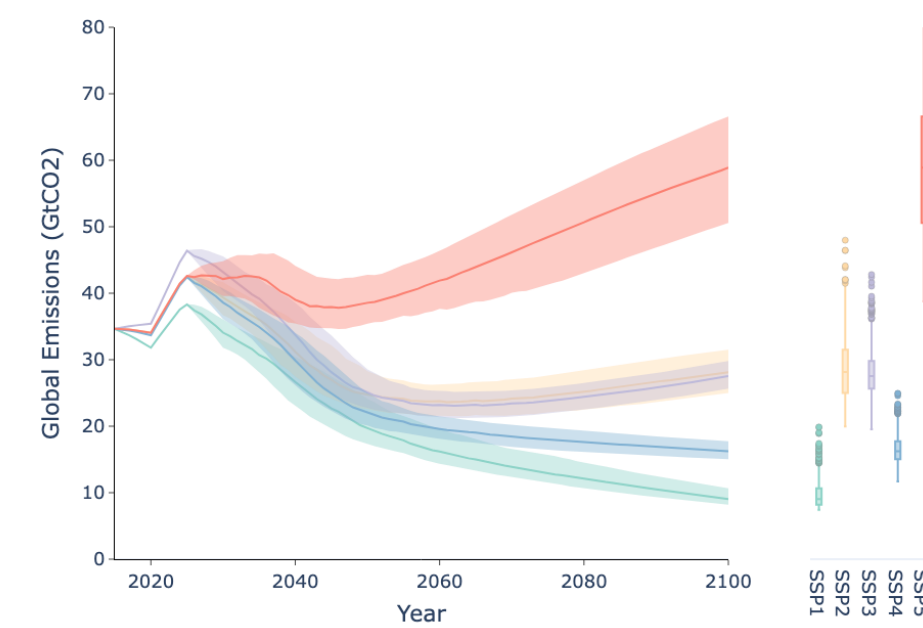
Multiobjective
Optimization



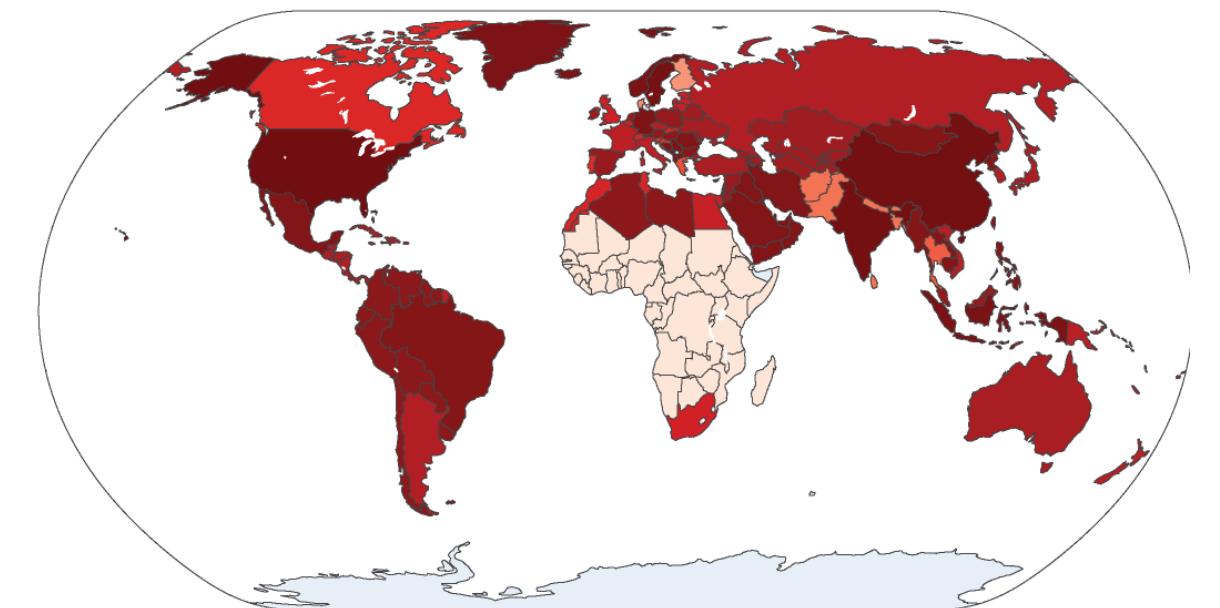
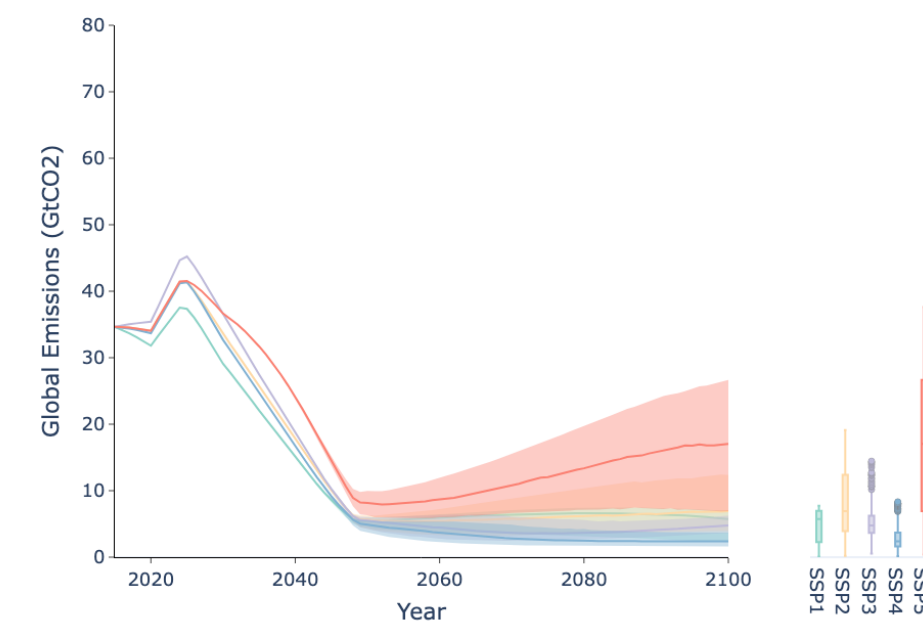
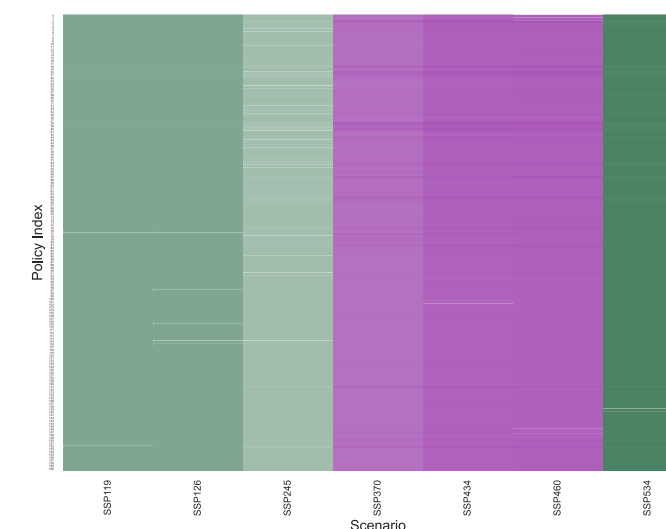
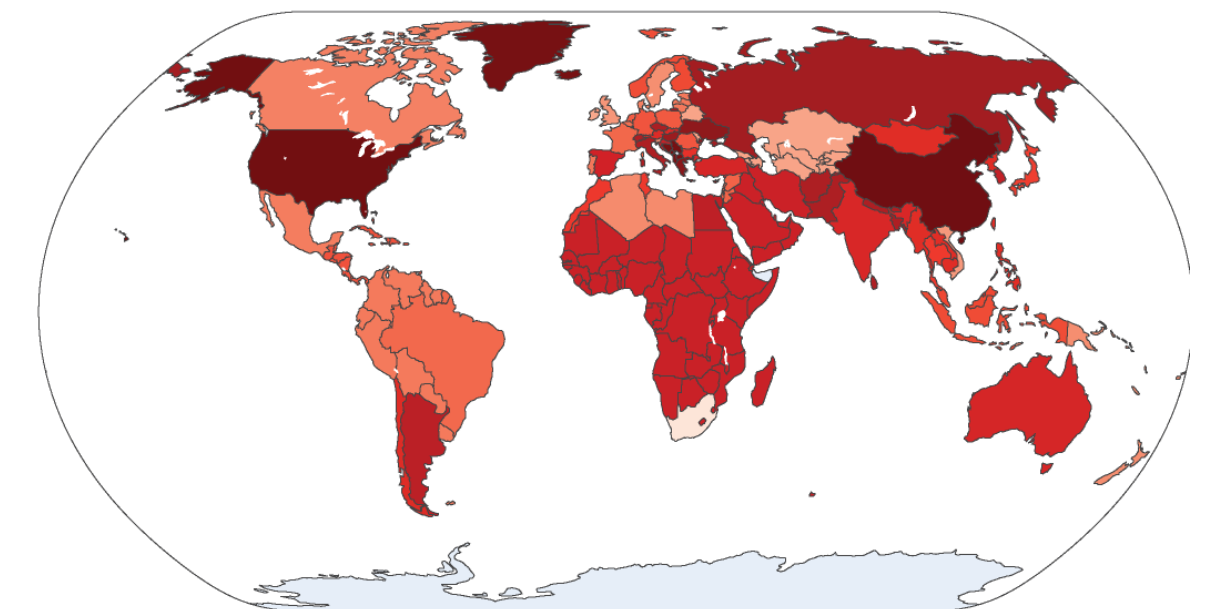
Robustness
Analysis



Emission Pathways

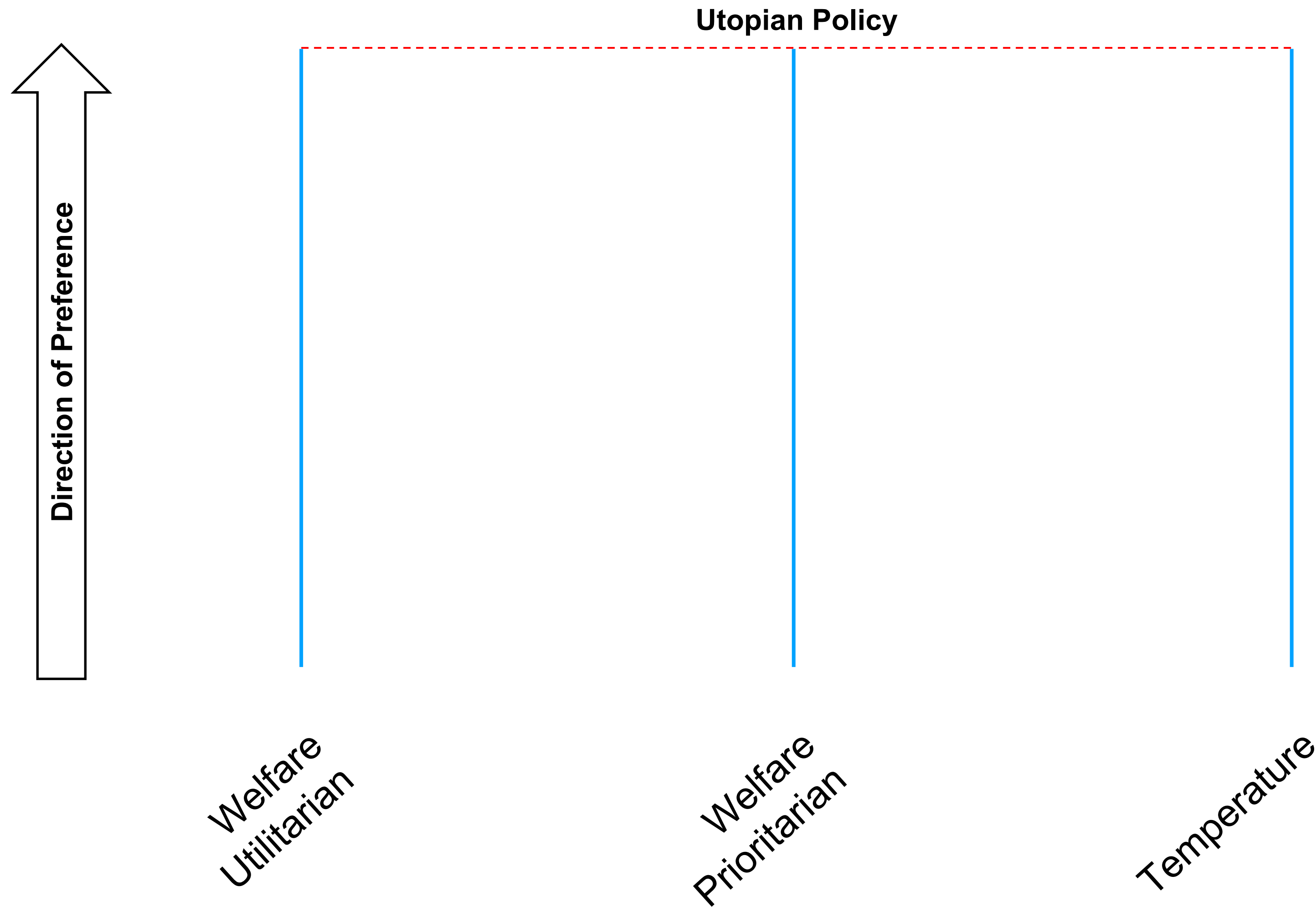


Burden Distribution

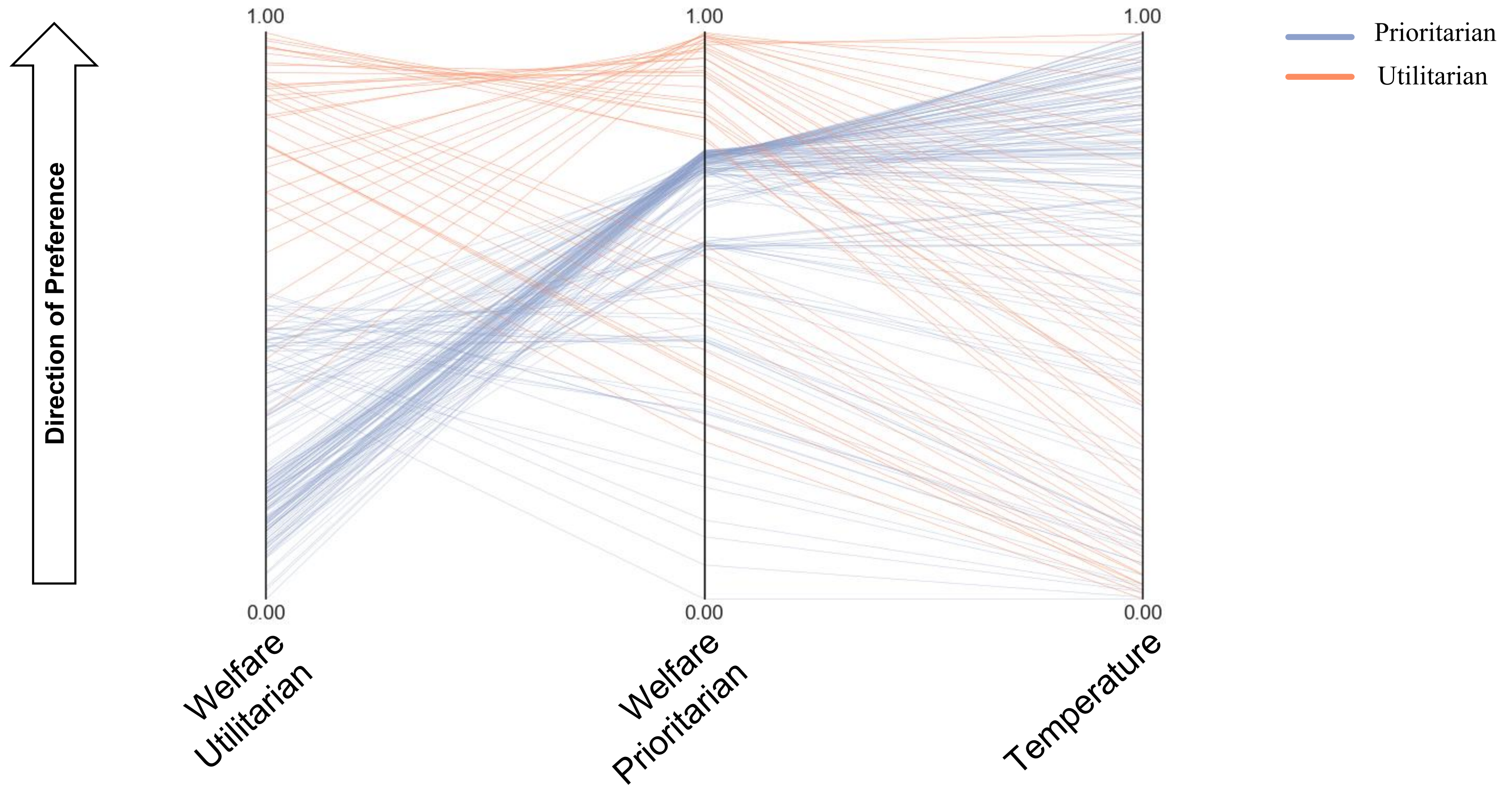


Results

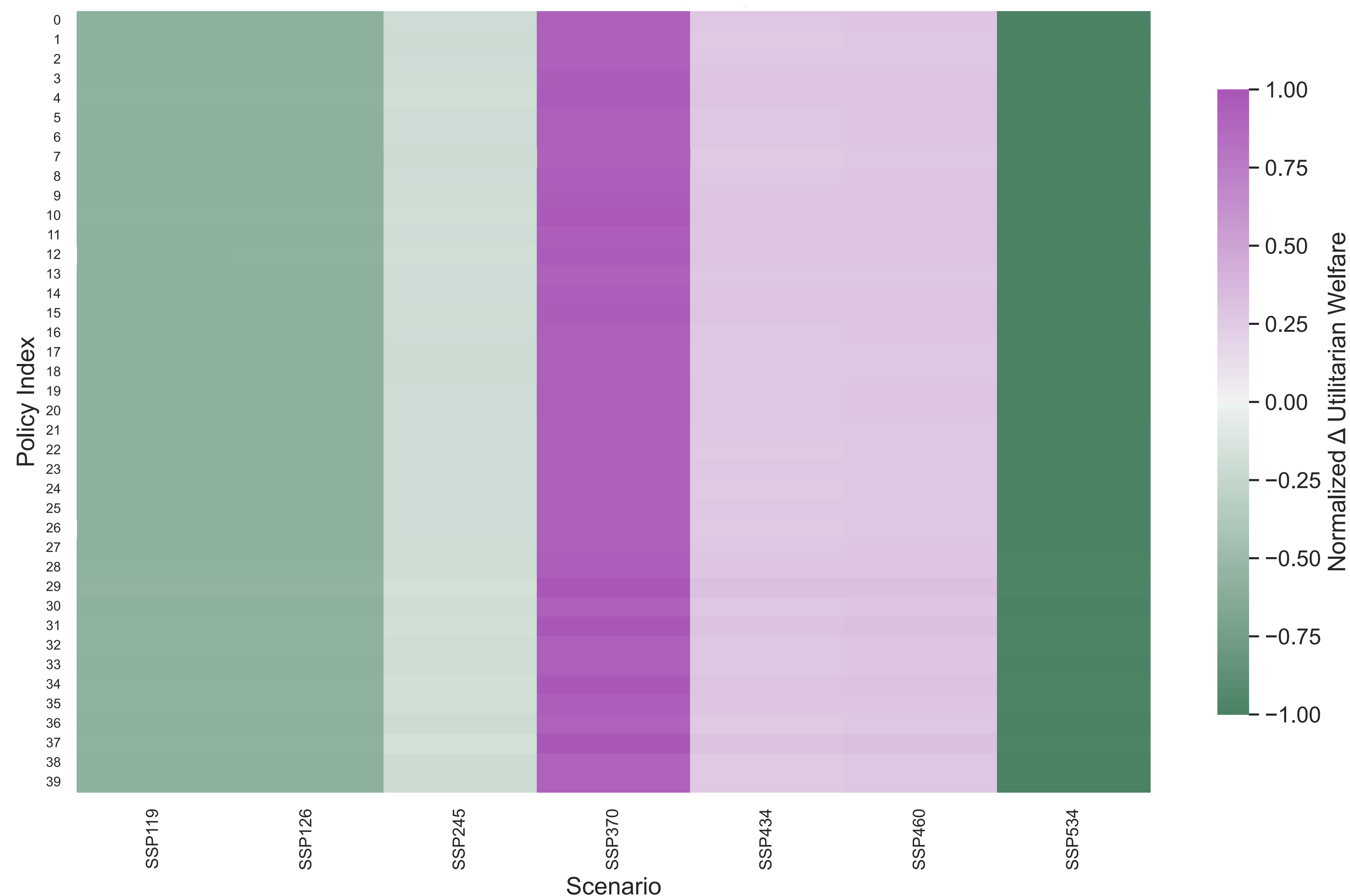
Multiojective Formulation



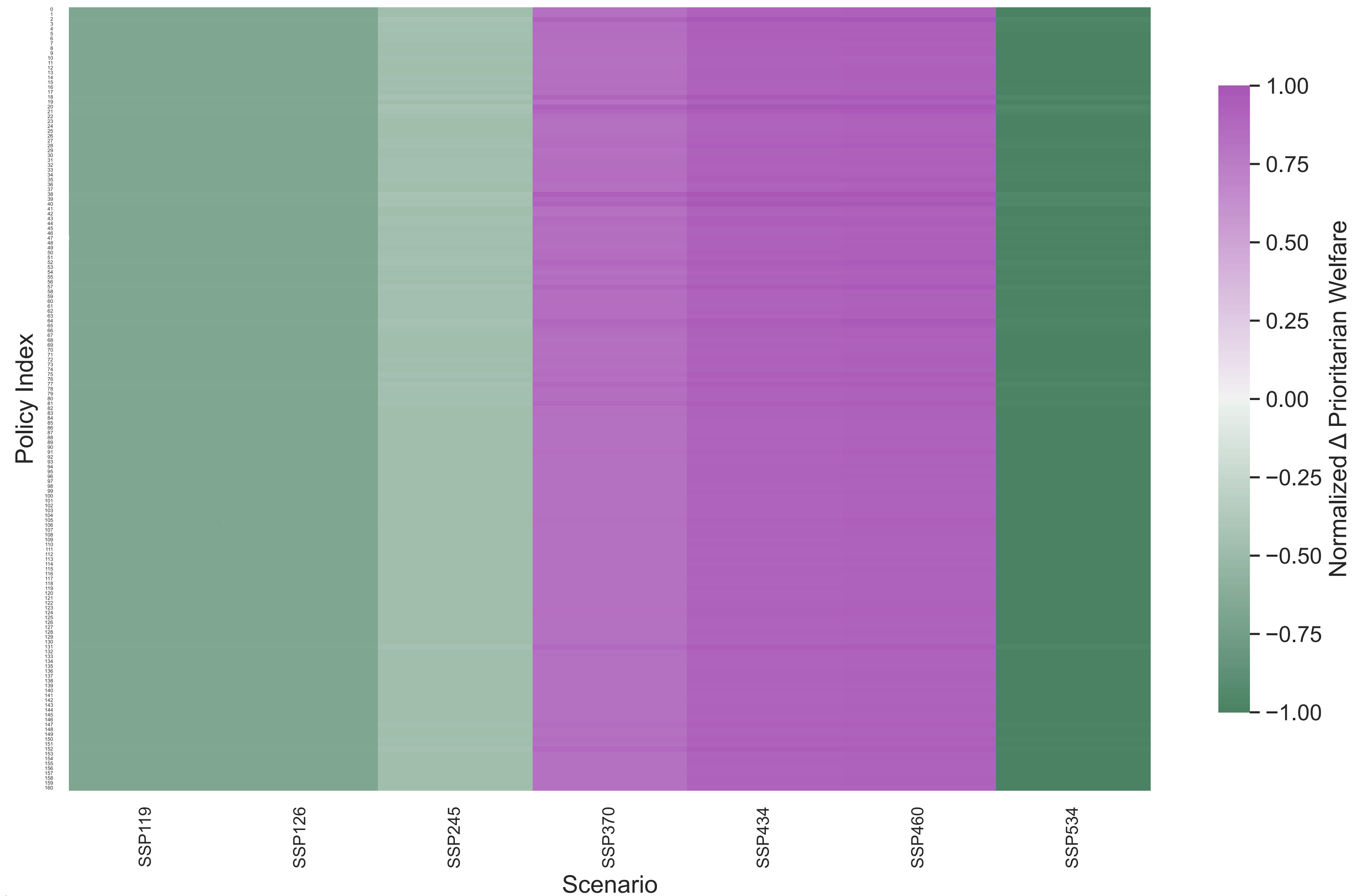
Trade-offs between Objectives



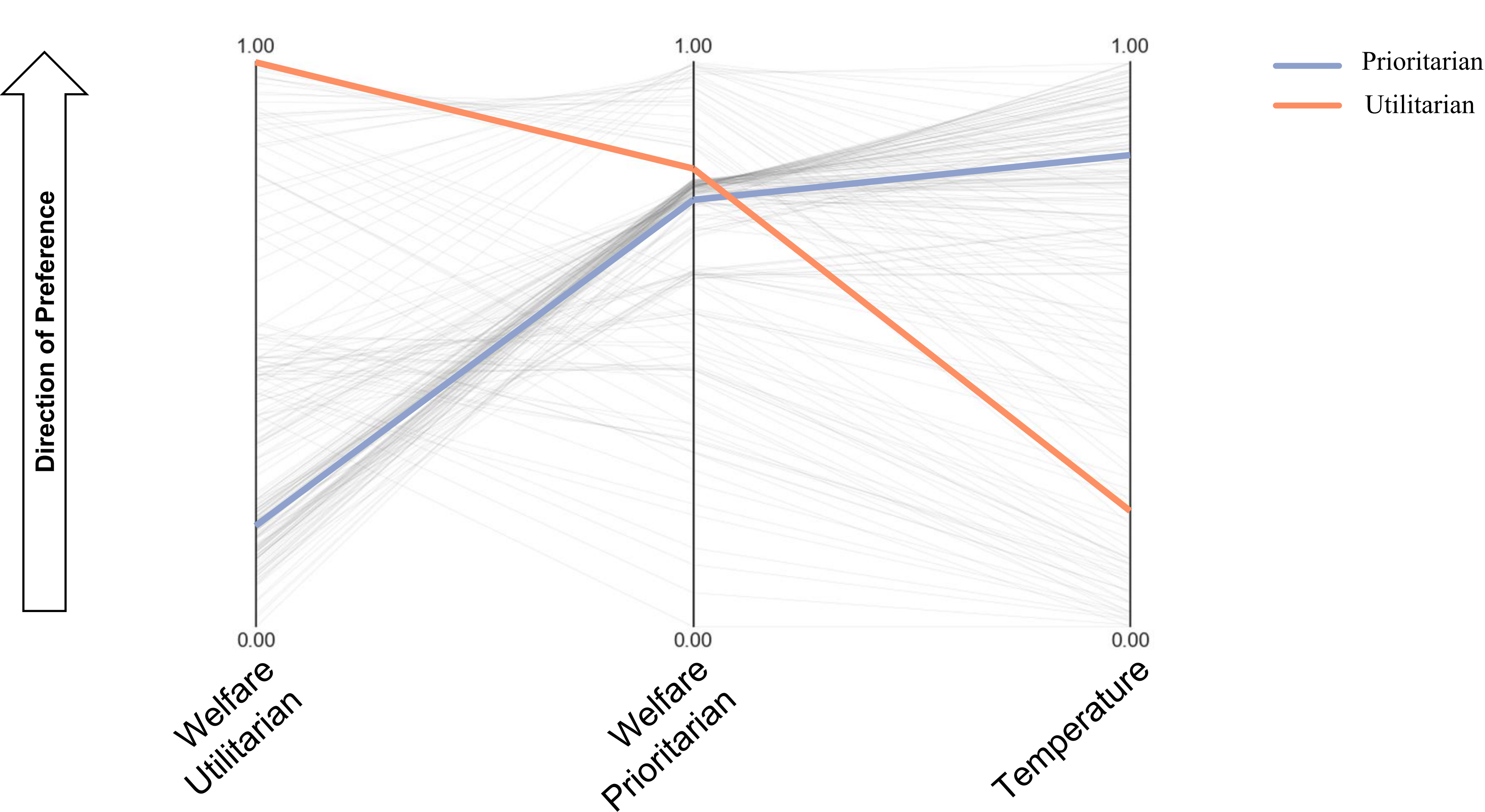
Regret Heatmap – Limitarian-Utilitarian



Regret Heatmap – Limitarian-Prioritarian

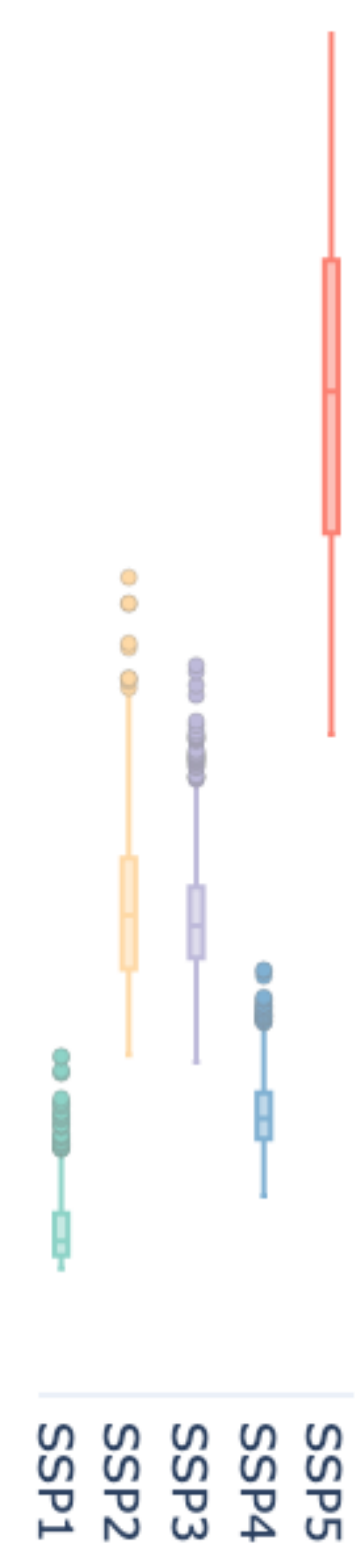
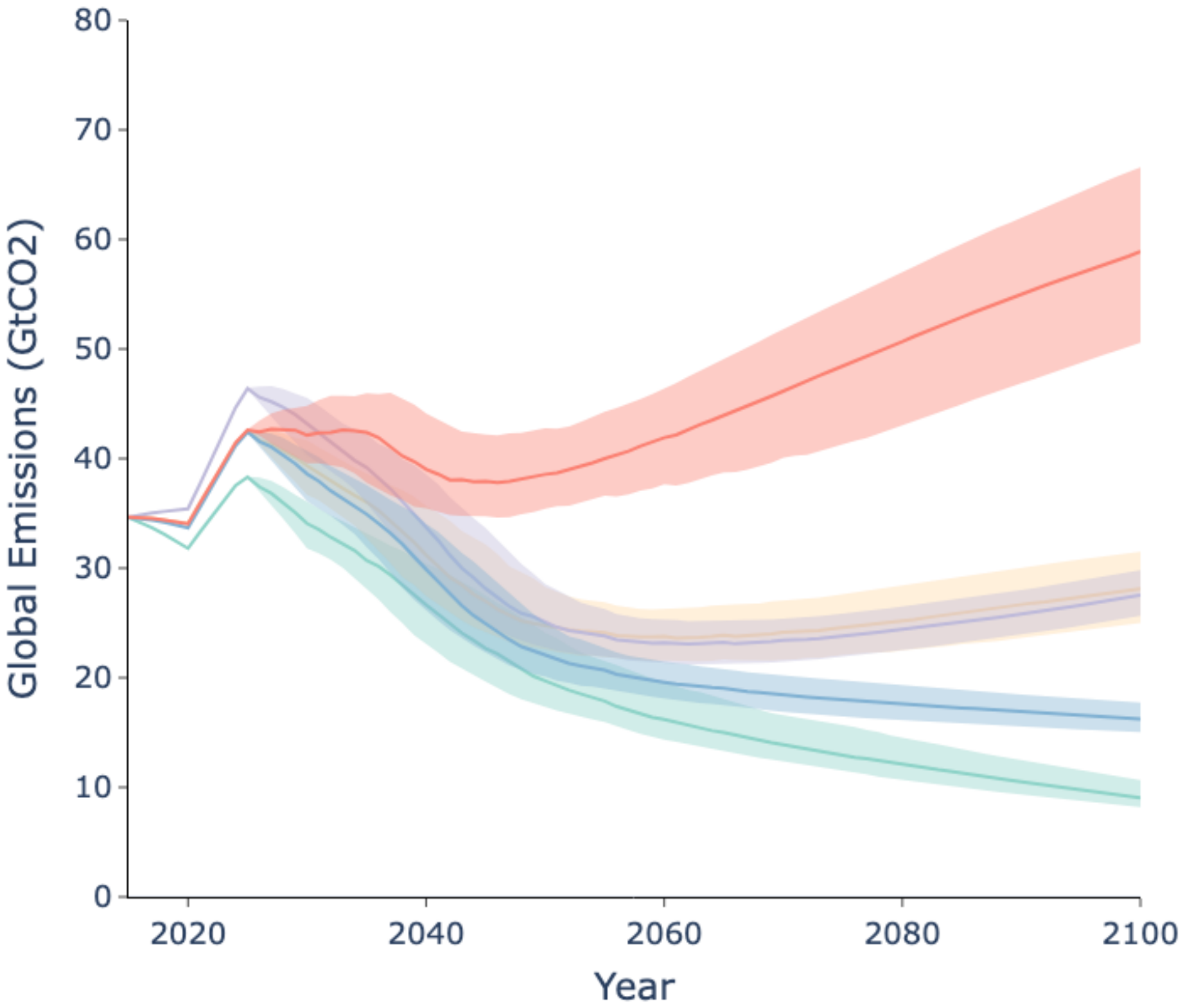


Filtering for Policies that Minimize the Maximum Regret

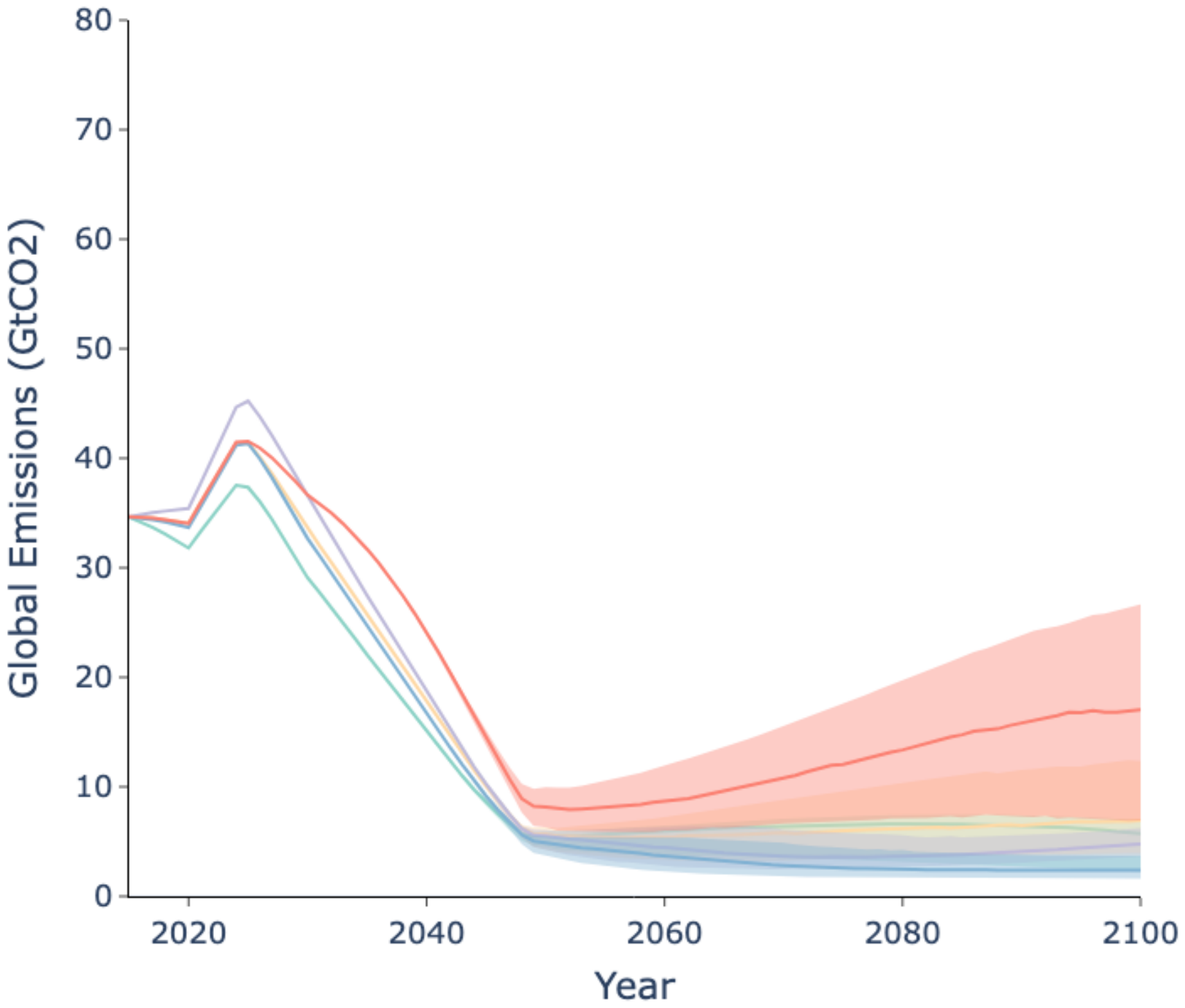


Global Emission Across SSP Scenarios

Limitarian-Utilitarian

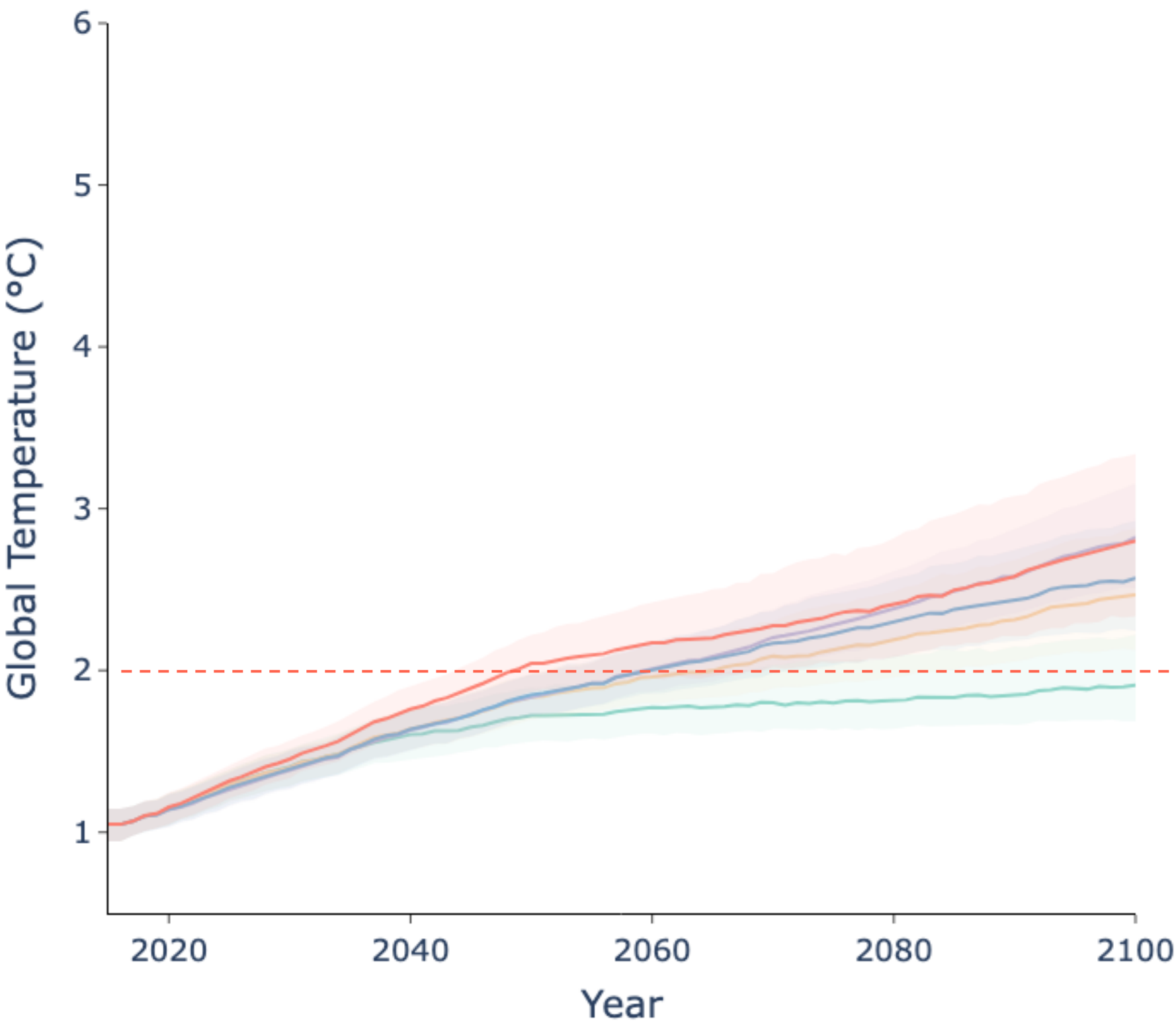


Limitarian-Prioritarian



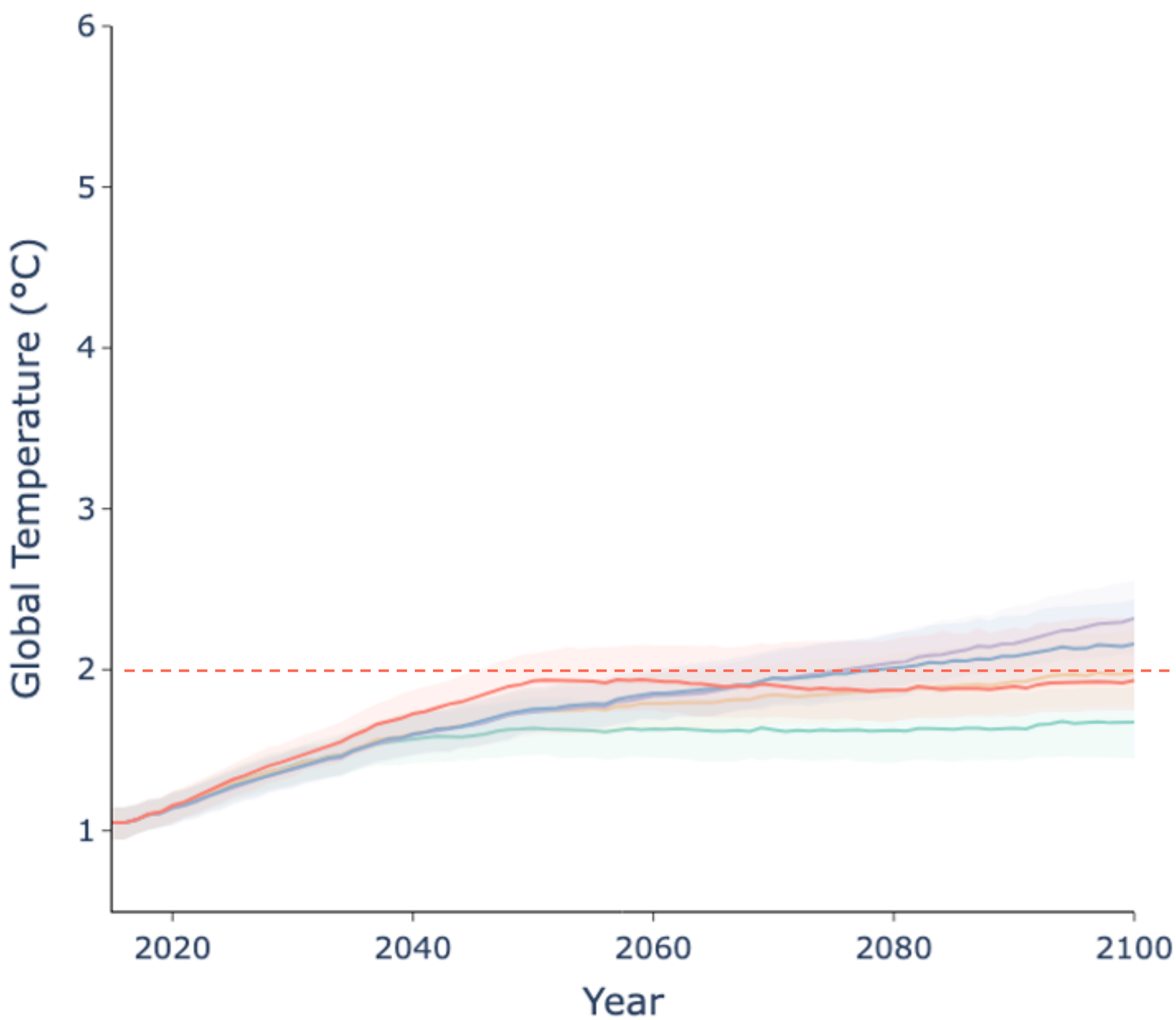
Global Temperature Across SSP Scenarios

Limitarian-Utilitarian



SSP1
SSP2
SSP3
SSP4
SSP5

Limitarian-Prioritarian

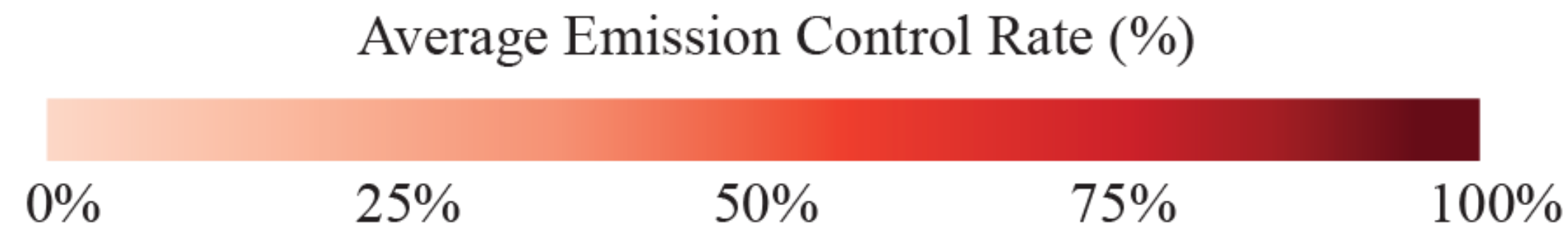
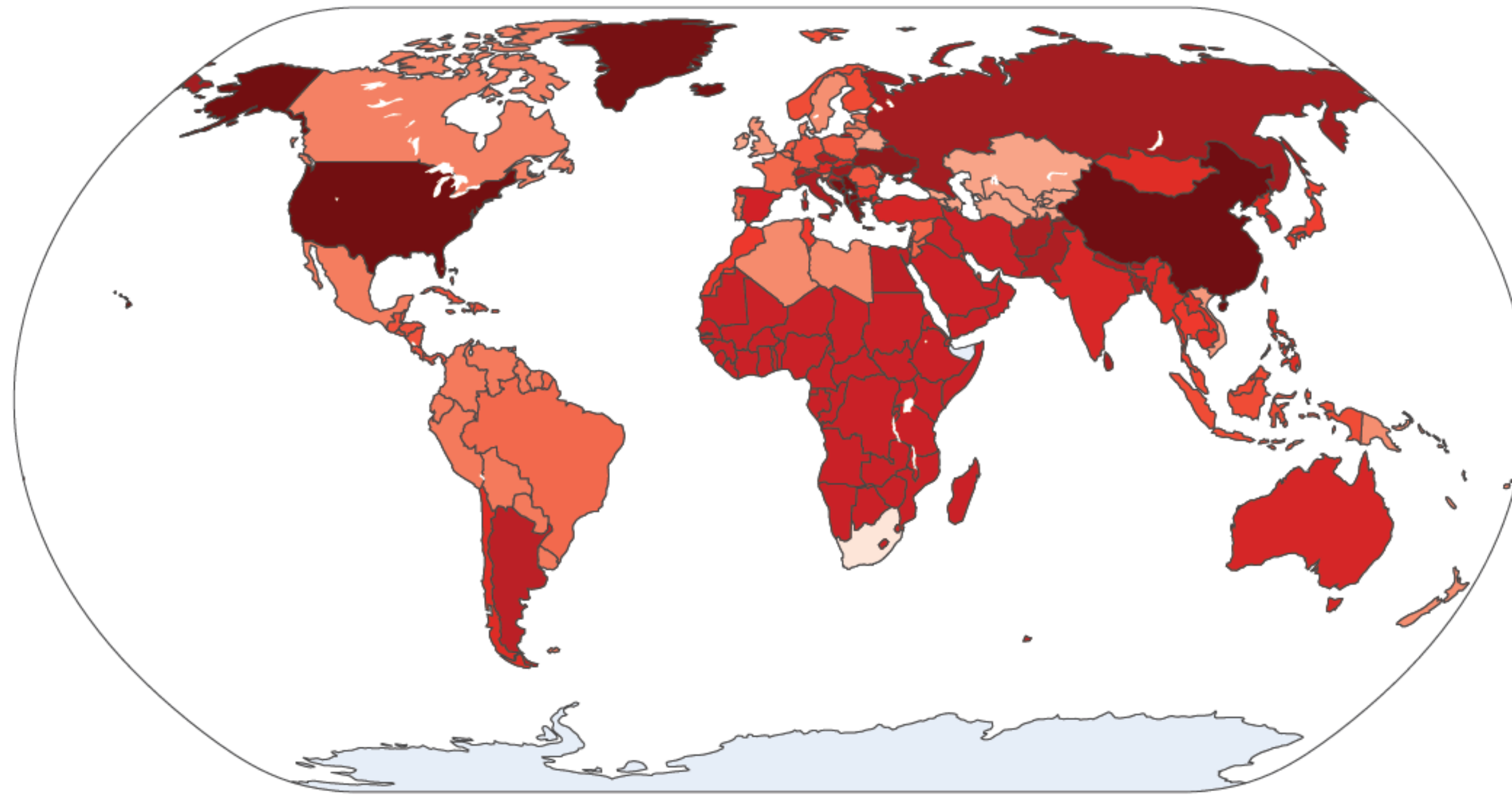


SSP1
SSP2
SSP3
SSP4
SSP5

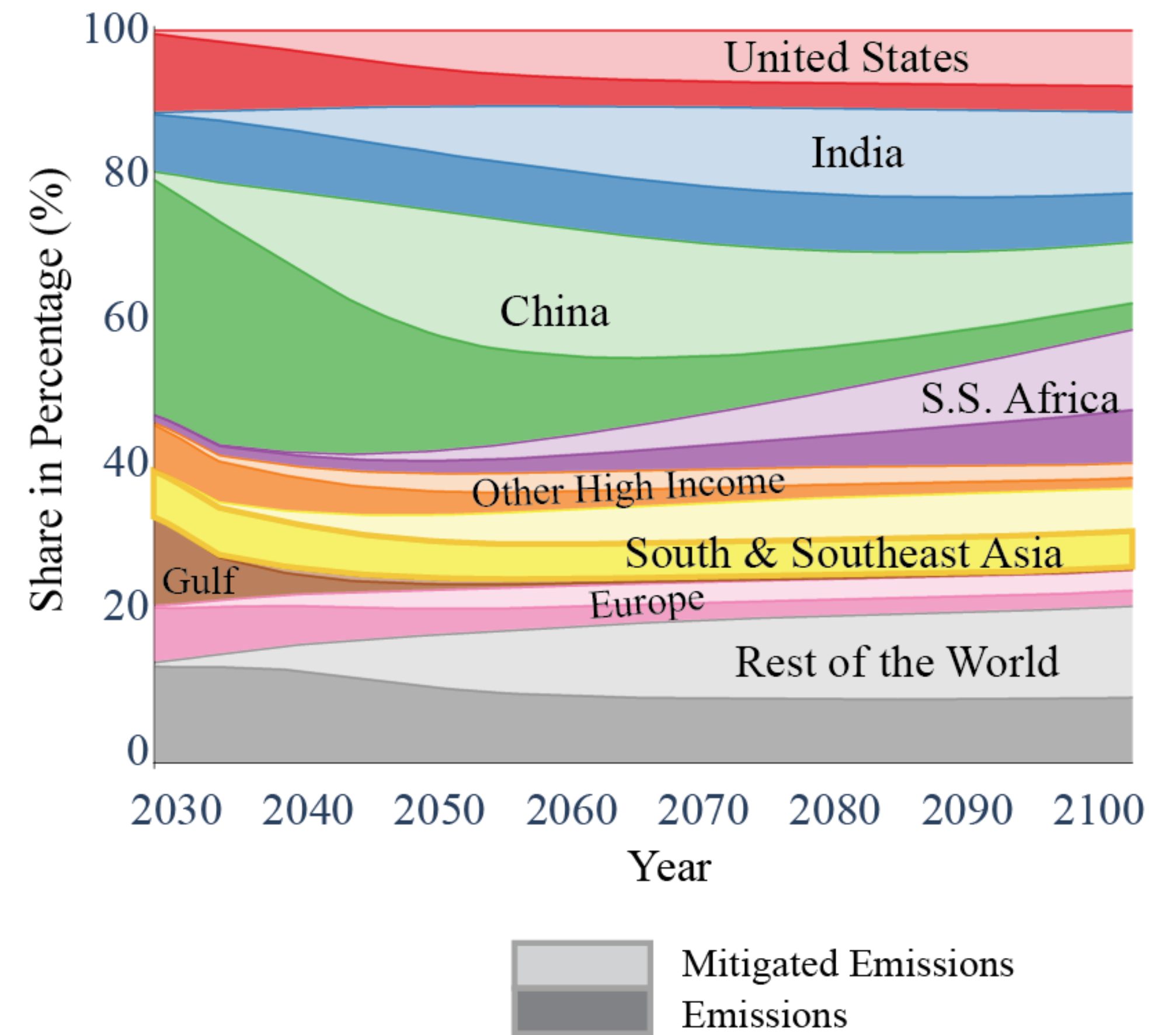
- SSP5
- SSP4
- SSP3
- SSP2
- SSP1

Regional Distribution of Mitigation Burden and Emission Budget – *Limitarian-Utilitarian*

Distribution of Emission Control Rate in 2050

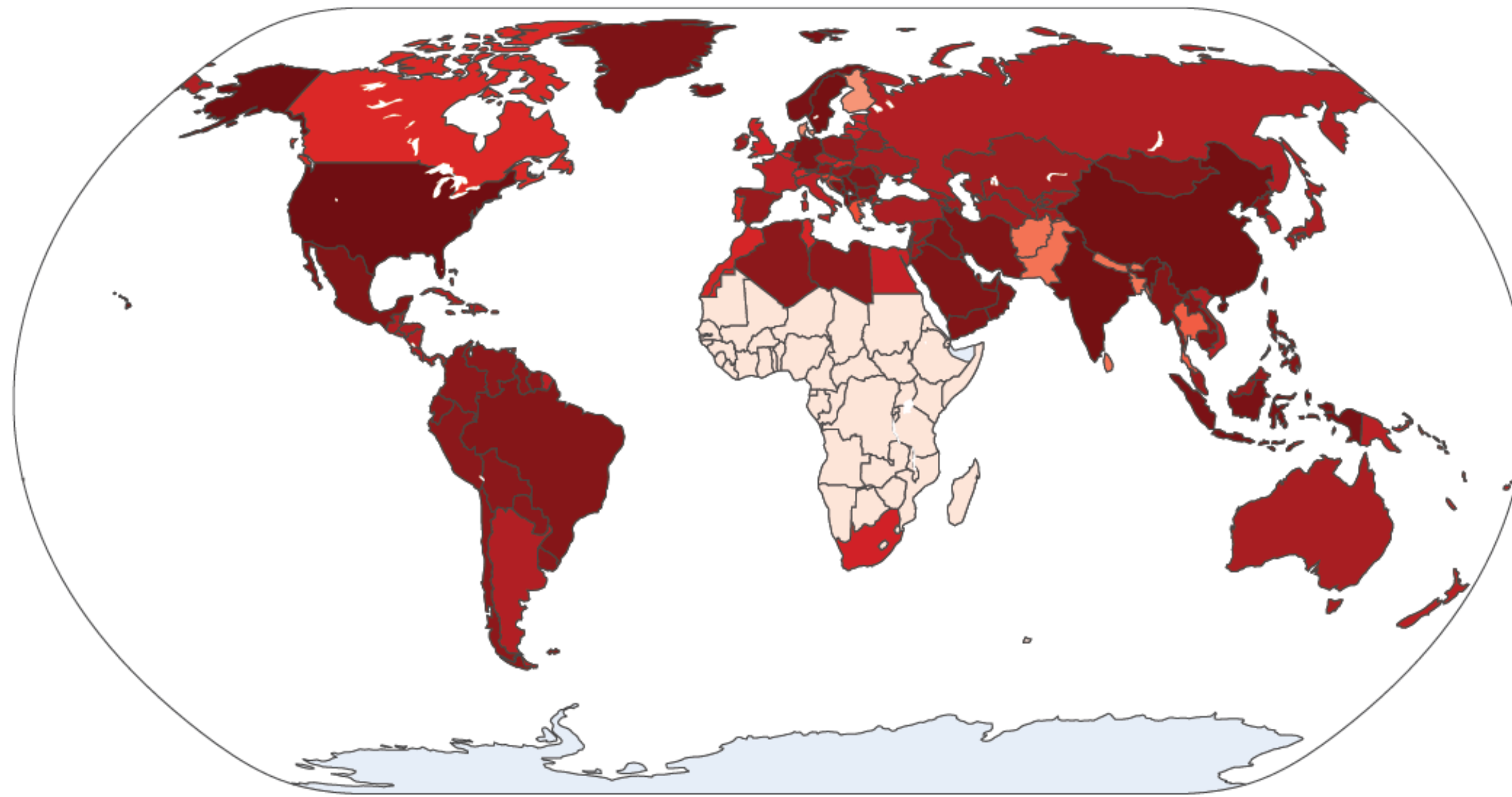


Emissions and Abated Emissions



Regional Distribution of Mitigation Burden and Emission Budget – *Limitarian-Prioritarian*

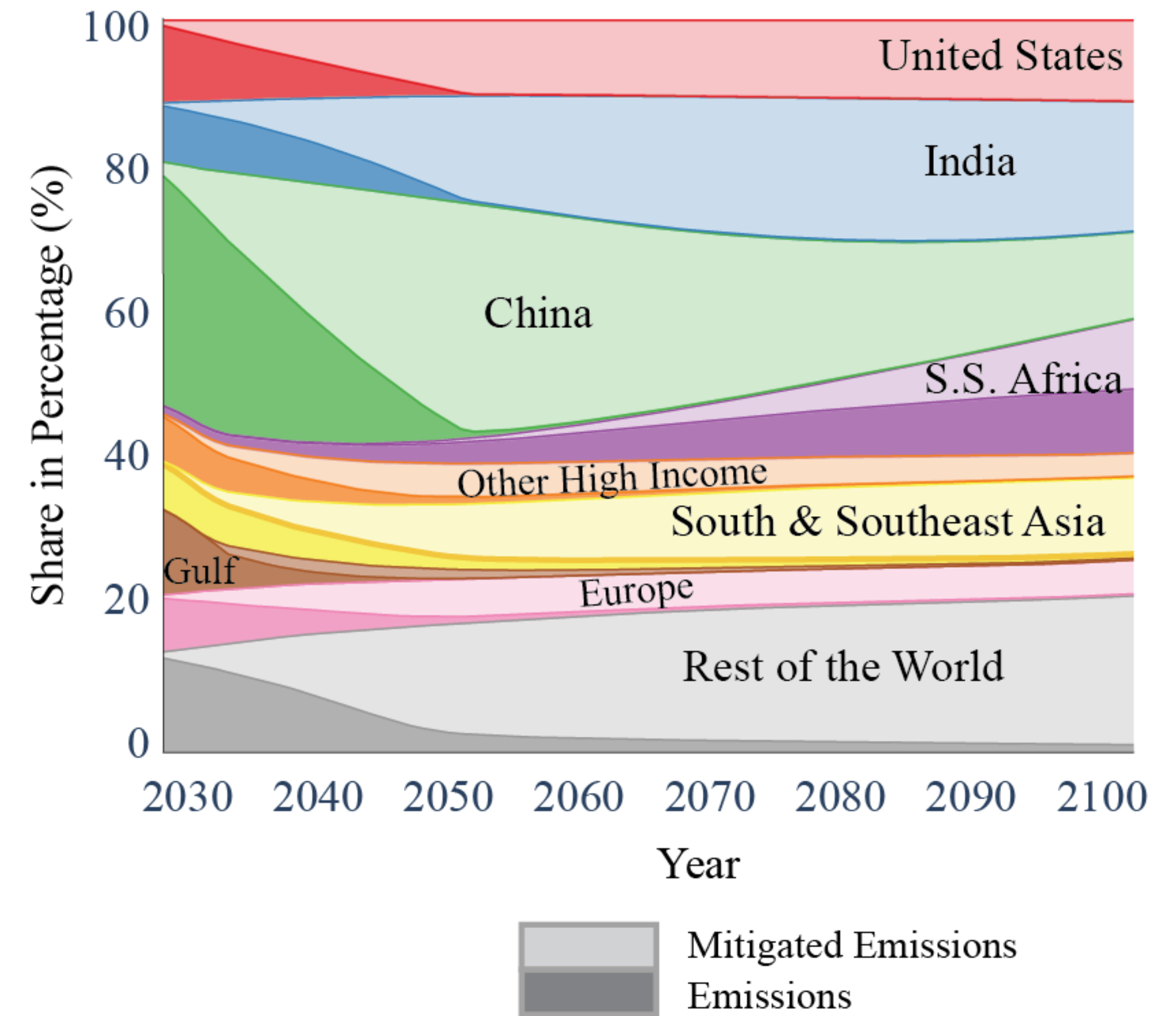
Distribution of Emission Control Rate in 2050



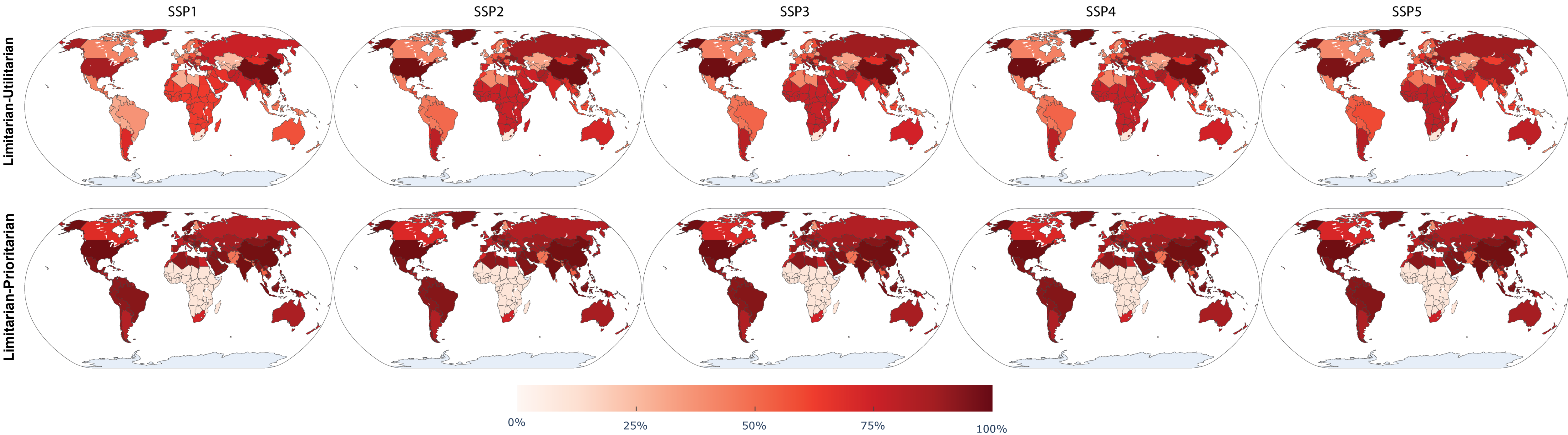
Average Emission Control Rate (%)



Emissions and Abated Emissions



Distribution is insensitive to SSP Scenarios



Distribution insensitive to SSP Scenarios



Take home message

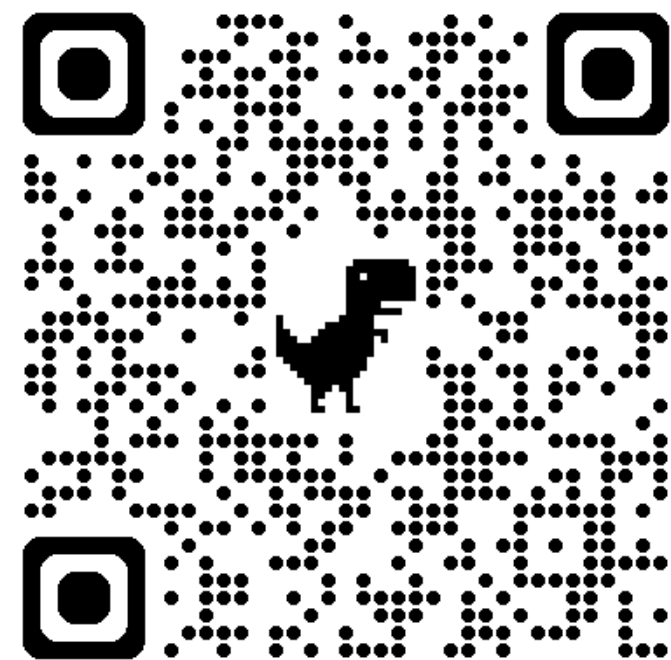
Ethical framing matters: It shapes both the *ambition* and *distribution* of mitigation efforts.

Integrating justice principles: Aligns *policy recommendations* with the *needs* and *values* of climate policymakers.

Exploring normative uncertainty: Builds *common ground* and fosters meaningful *dialogue*—supporting *fairer*, more *robust* climate policies.

Thank you!

JUSTICE IAM



Abstract



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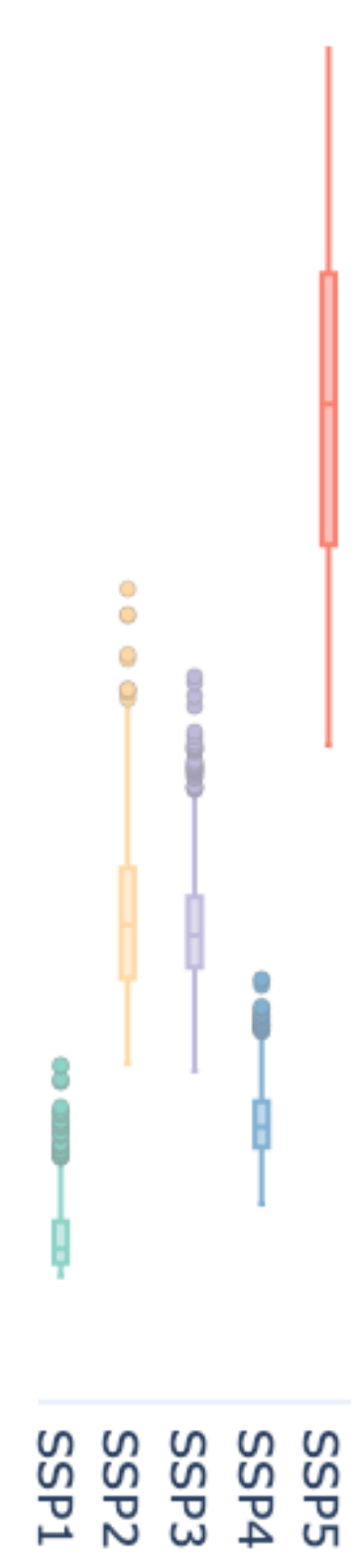
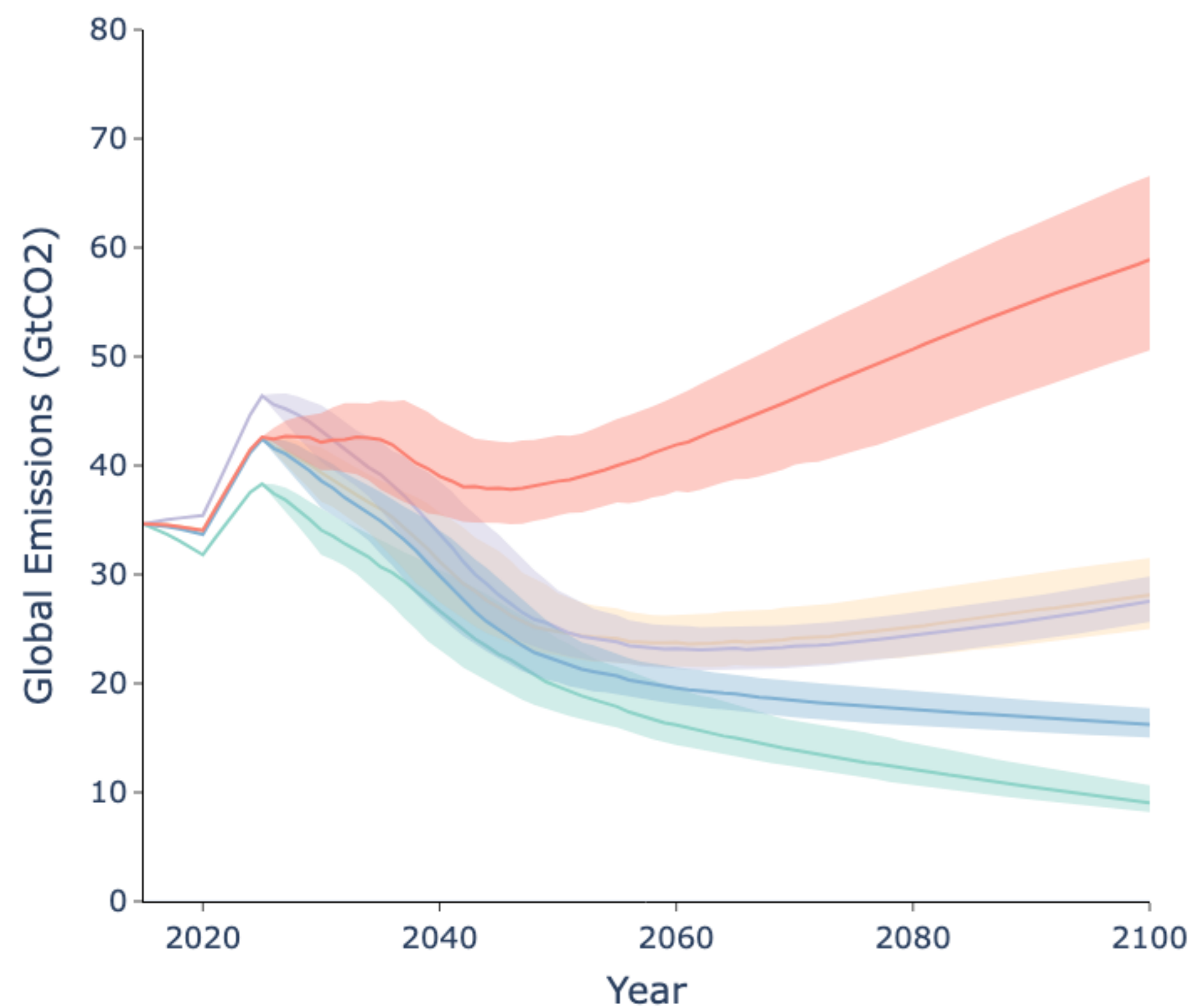


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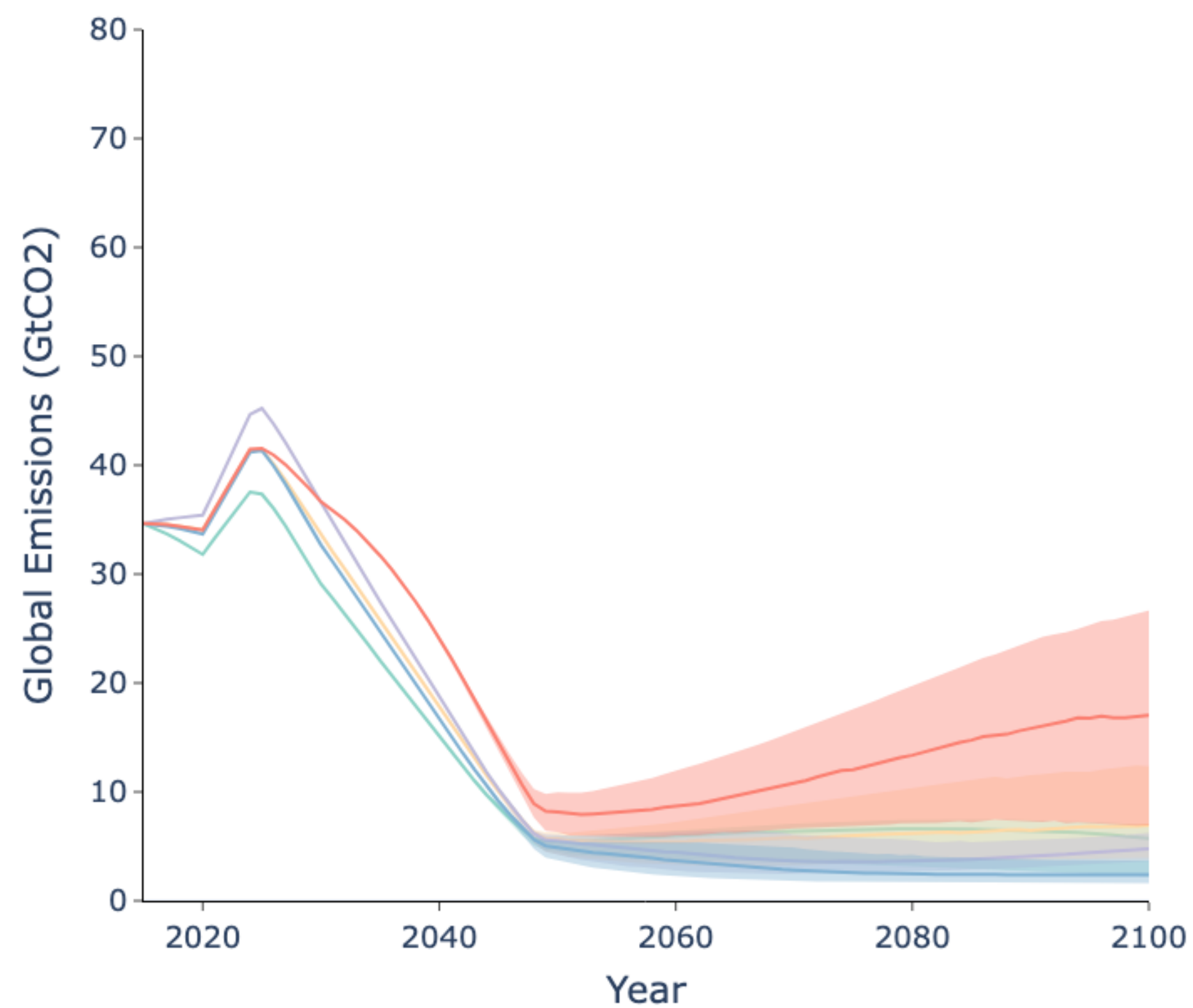


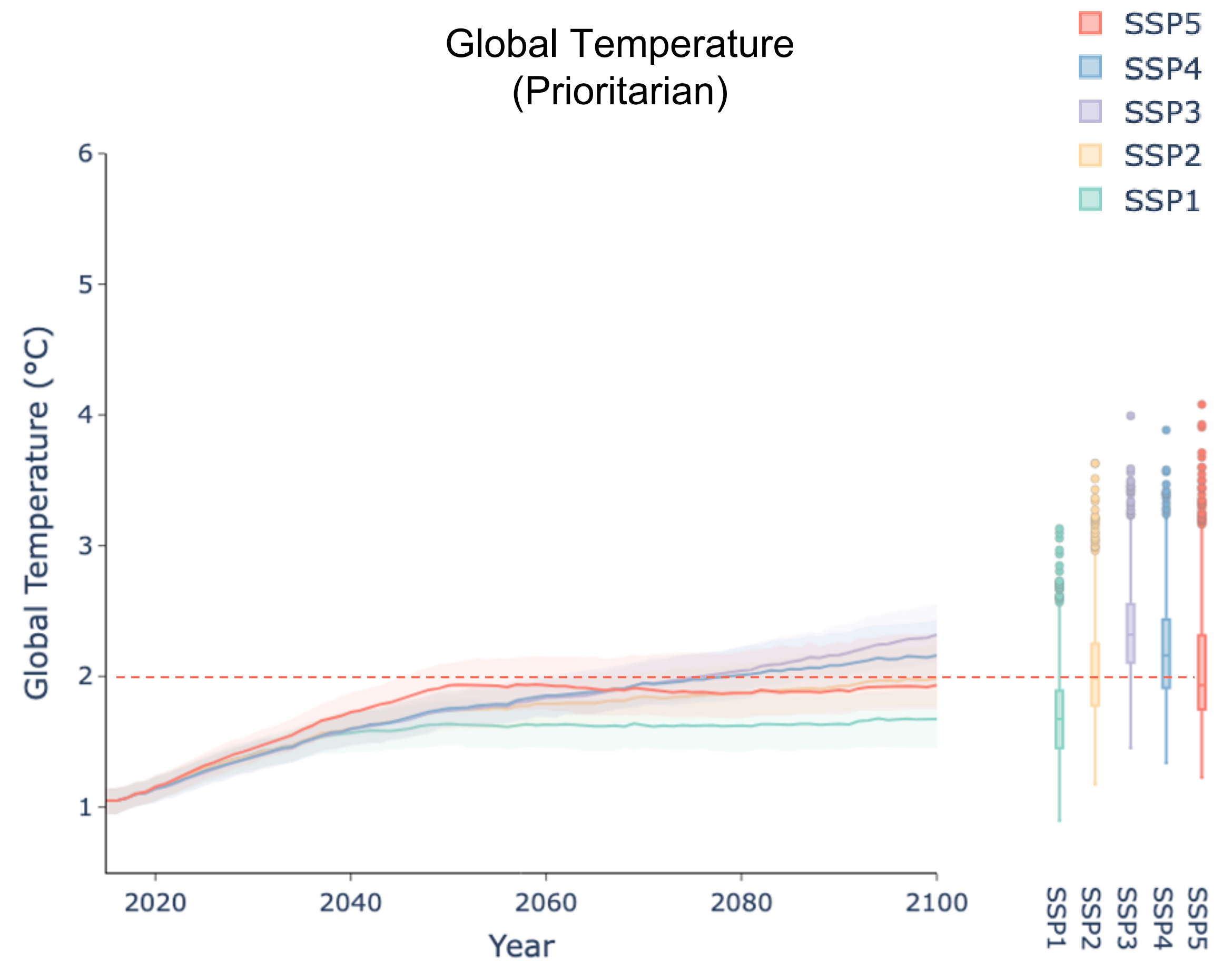
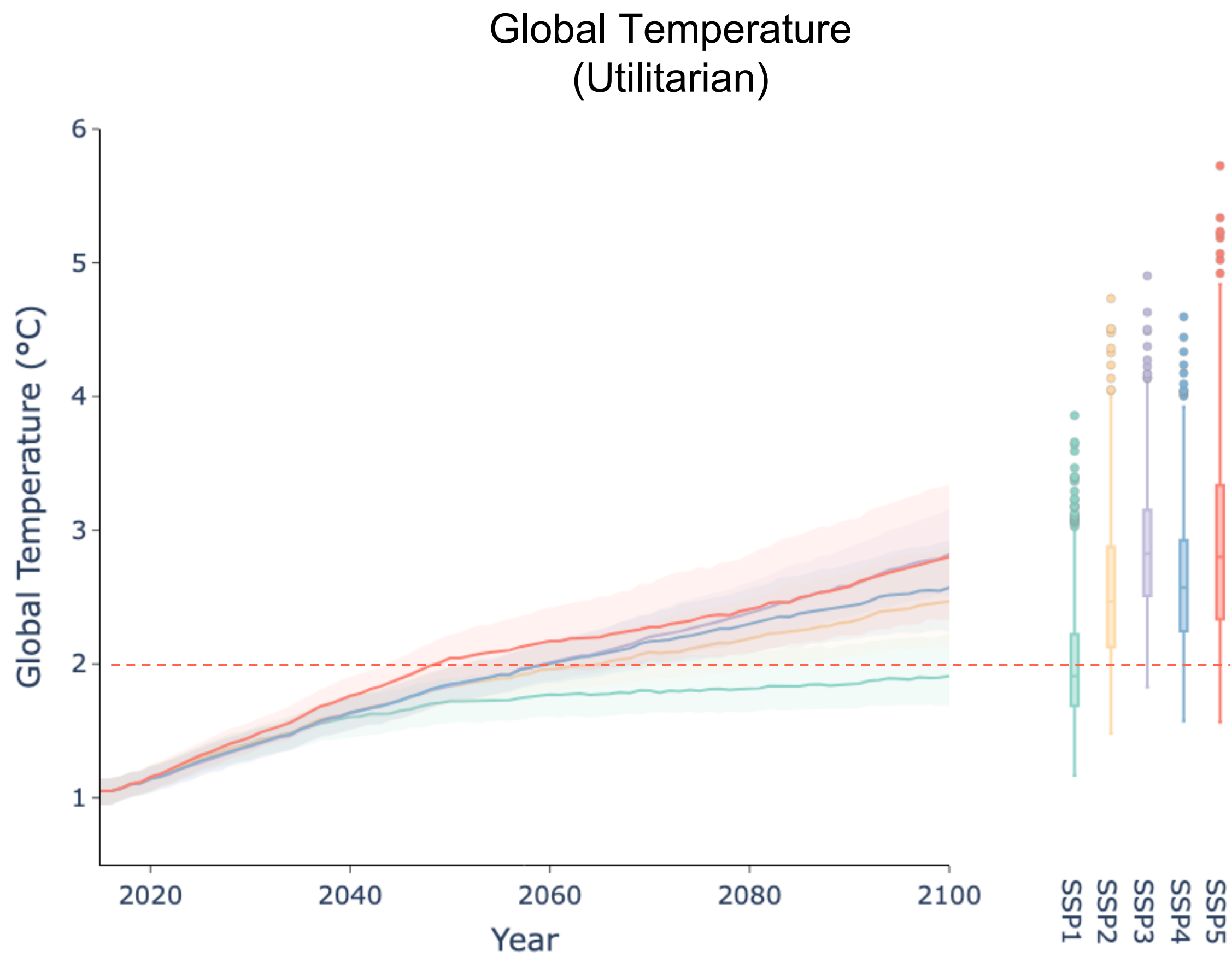
Palok Biswas

Global Emissions
(Utilitarian)



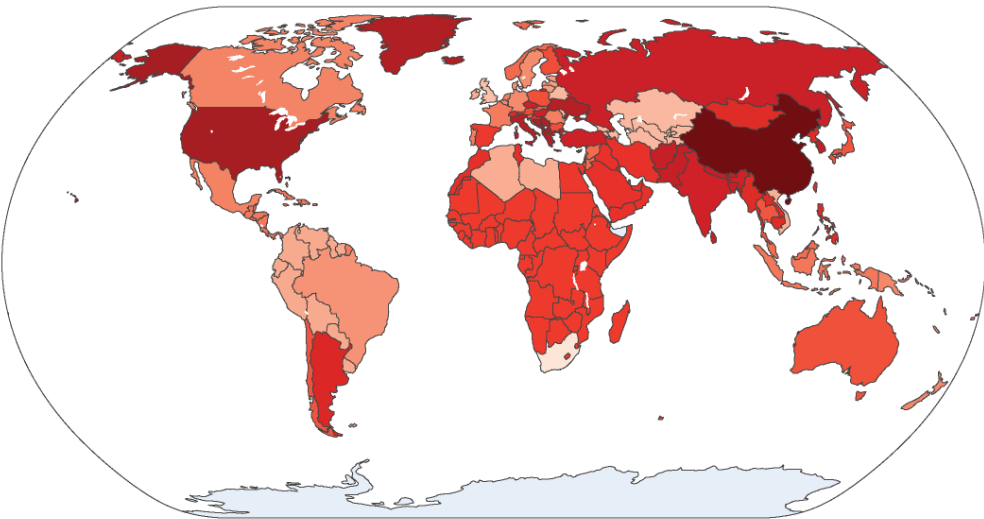
Global Emissions
(Prioritarian)



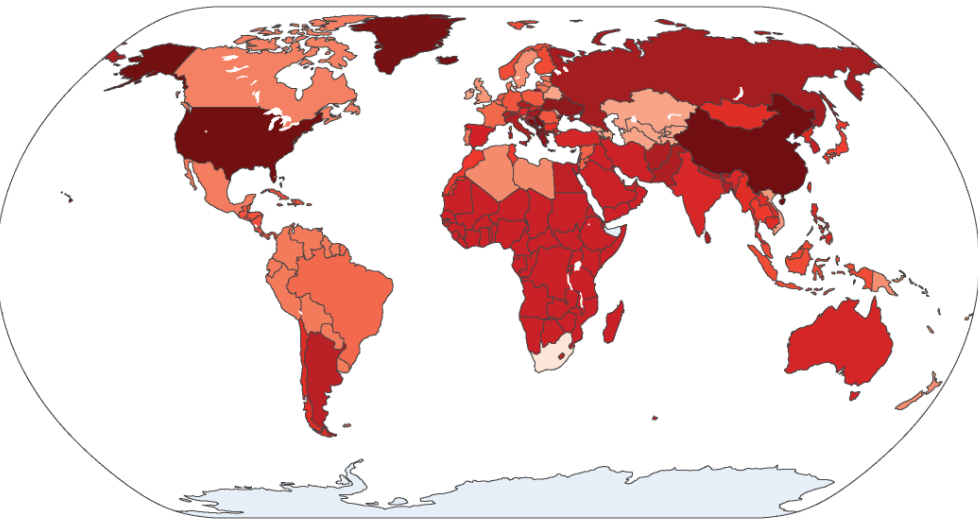


Limitarian-Utilitarian

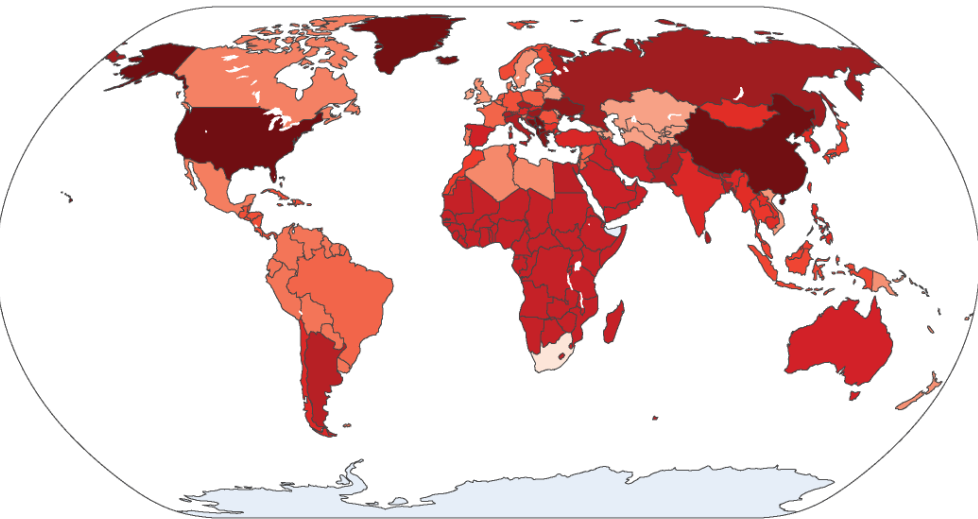
SSP1



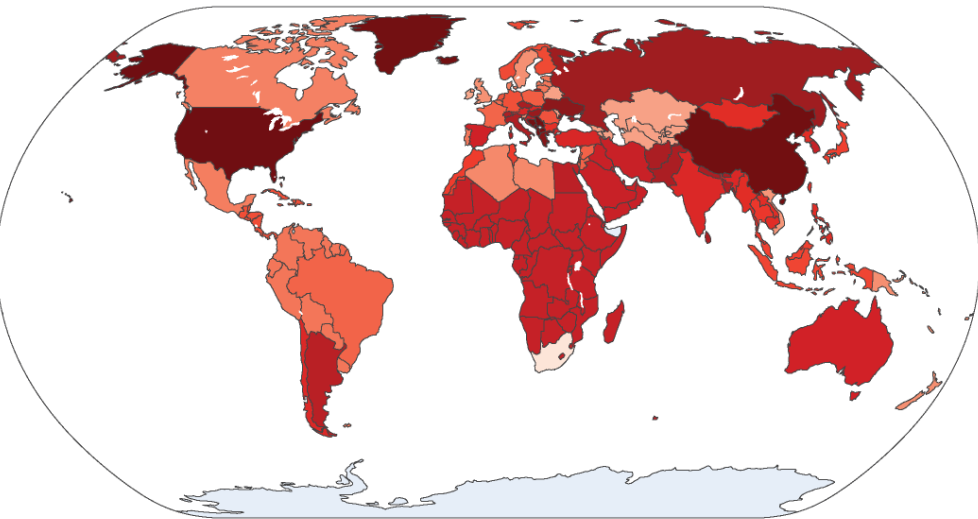
SSP2



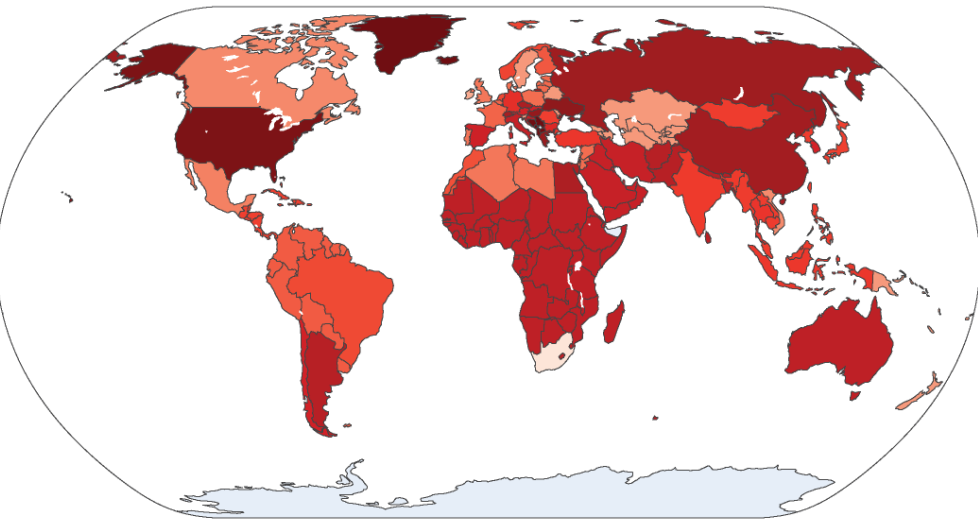
SSP3



SSP4



SSP5



Limitarian-Prioritarian

