RESOURCES for the FUTURE

The Social Cost of Carbon:

Advances in Long-term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates

Kevin Rennert, Brian Prest, William Pizer, Richard Newell, David Anthoff, Cora Kingdon, Lisa Rennels, Roger Cooke, Adrian Raftery, Hana Ševčíková, Frank Errickson

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Background

Social Cost of Carbon:

- The social cost of carbon (SCC) is an estimate, in dollars, of the economic costs (or “damages”) of an incremental ton of CO_2 emissions
- The SCC underpins policy analysis across a wide range of applications in the federal government and elsewhere

Rennert et al. (2021), BPEA

Background

The National Academies (NASEM) recommended improving the representation of key input variables and characterizing uncertainty

- Integrated modular framework
- Socioeconomics
- Physical climate system
- Damage functions
- Discounting approach

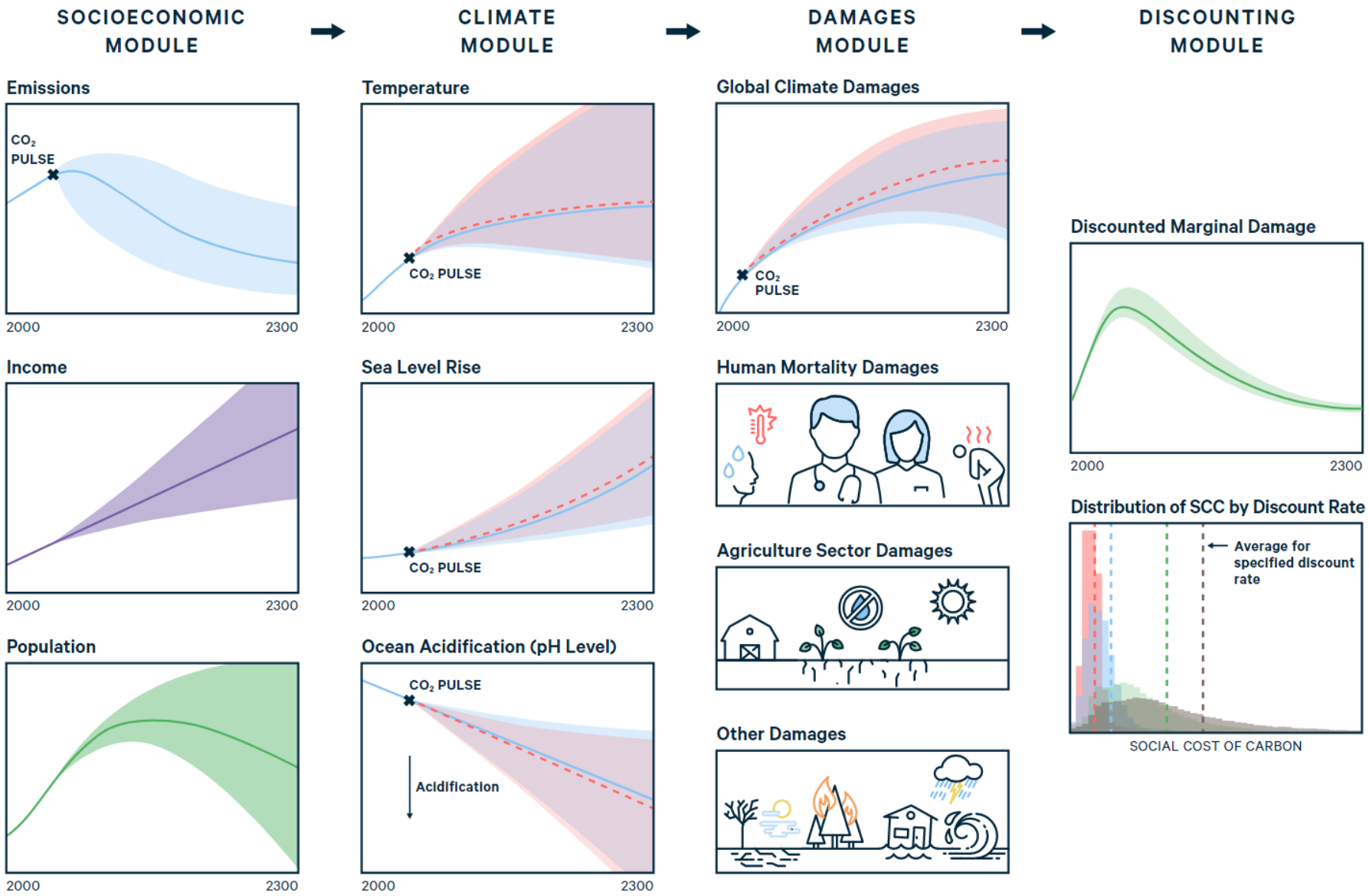
Rennert et al. (2021), BPEA

Background

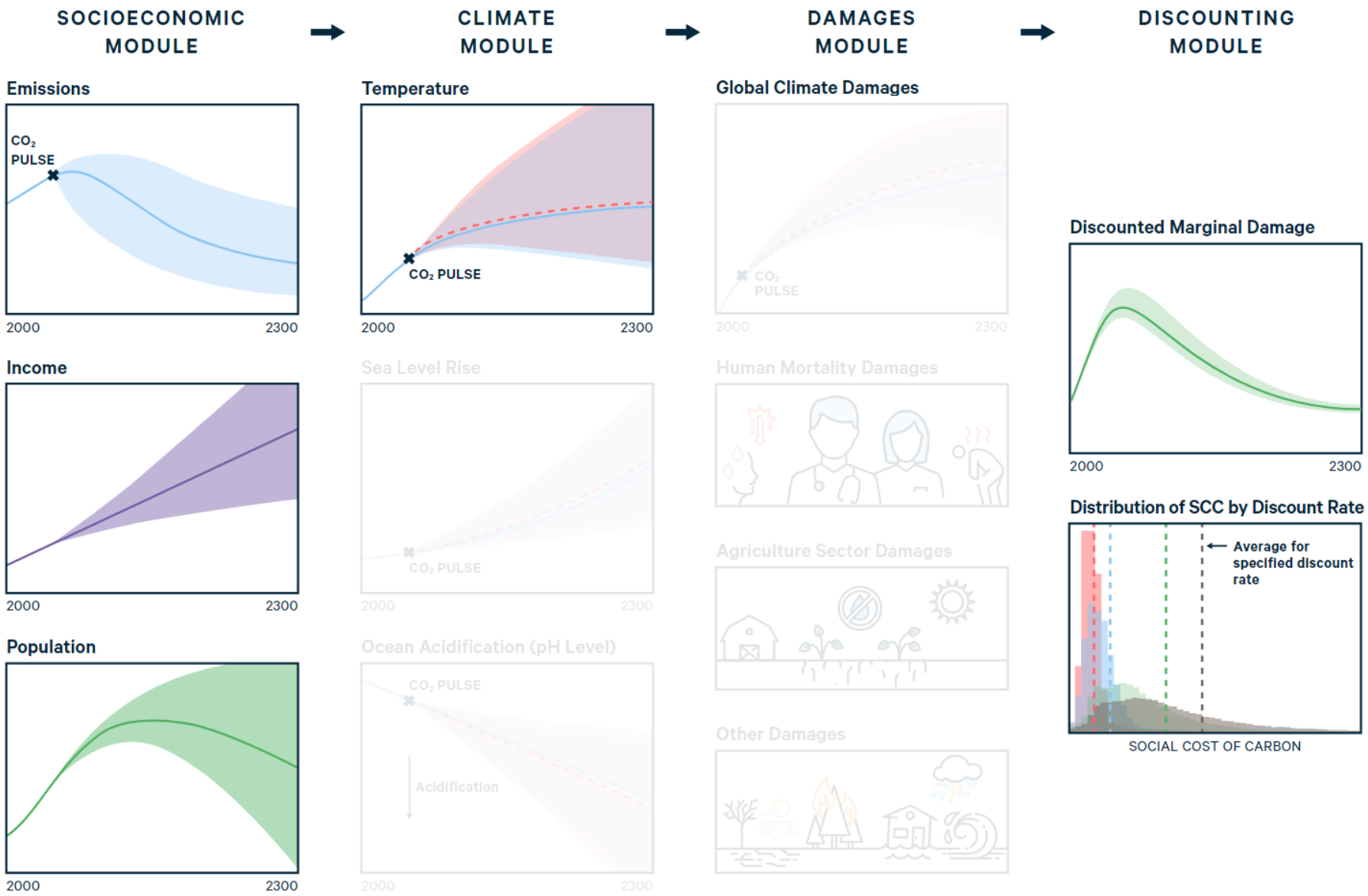
The Biden administration is currently updating its SCC estimation methodology to incorporate best available science, with **updated estimates anticipated for January 2022**

Rennert et al. (2021), BPEA

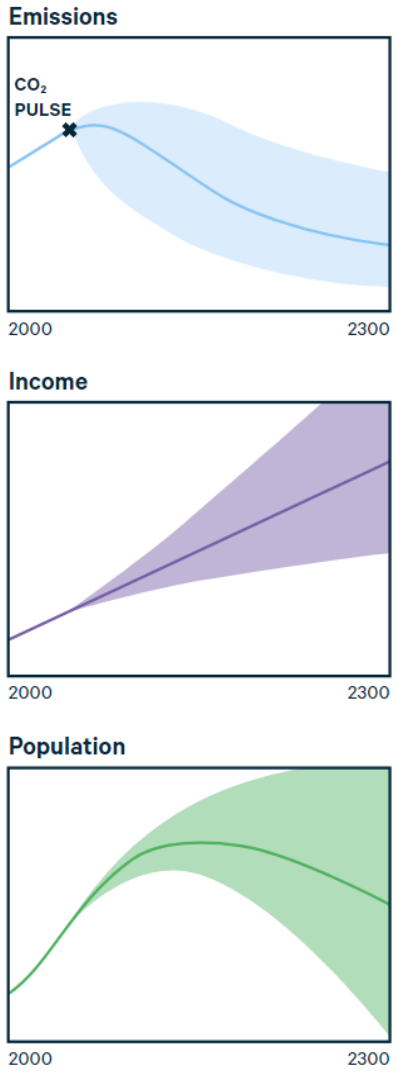
Modular framework for calculating the SCC



Modular framework for calculating the SCC



SCC calculations present challenging requirements for socioeconomic projections



- **Very long time-horizon**
  - CO_2 is very long lived in the atmosphere (centuries to millennia)
- **Complex uncertainty**
  - Future damages will depend on improvements in technologies, mitigation policies, regional/sectoral shares of the global economy
  - Adaptation levels should be tied to GDP
- **Regional detail**
  - Effects of climate change vary regionally, so ideally socioeconomics would provide regional detail to support damage calculations

RFF Socioeconomic Projections (RFF-SPs) address these challenges

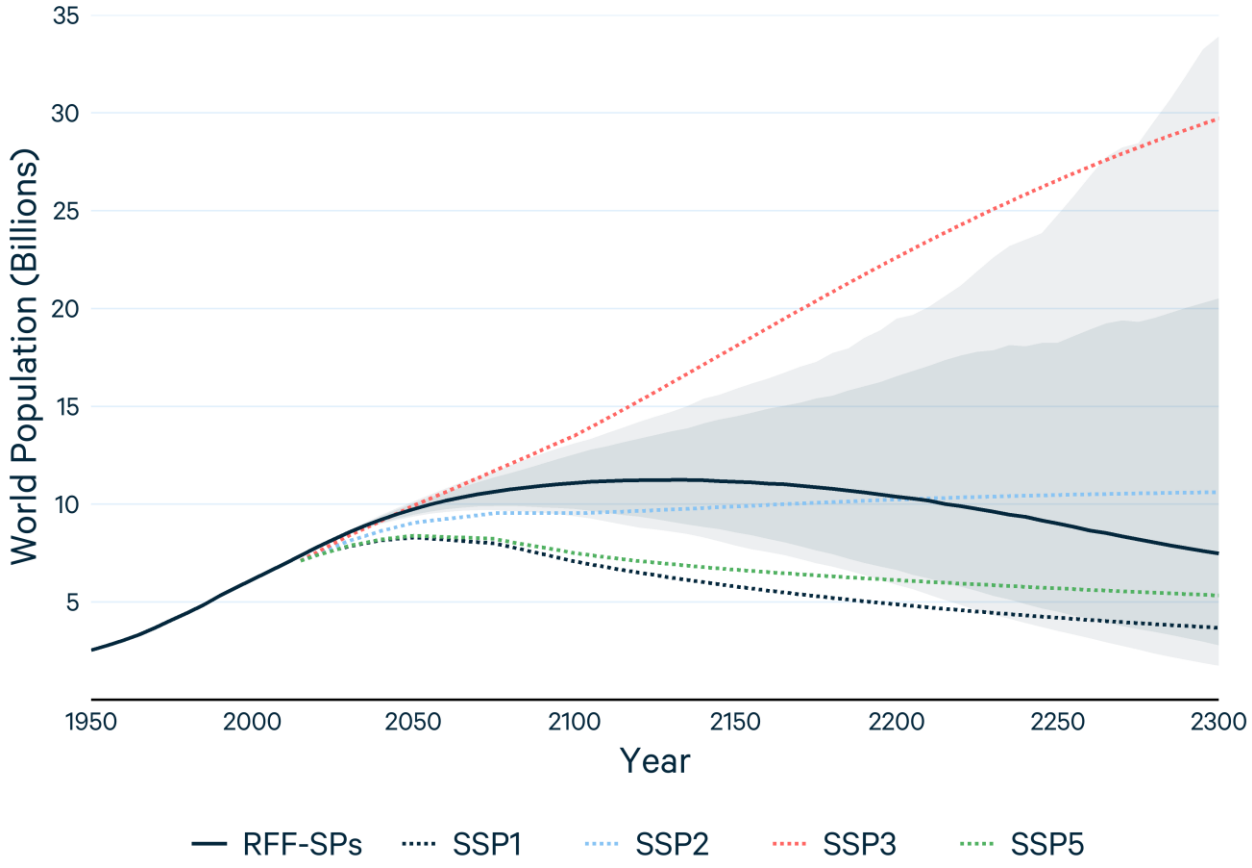
- **RFF-SPs:**
  - Are multi-century, probabilistic projections of country-level population and GDP per capita, and global emissions
  - Account for future policies and dependencies between the variables
  - Incorporate both statistical and structured expert judgment methods to account for the extended time horizon
  - Fully implement near-term NASEM recommendations

- The *Shared Socioeconomic Pathways** (SSPs) offer a natural point of comparison
  - The SSPs were designed to inform the IPCC and provide (non-probabilistic) socioeconomic scenarios with associated narratives to 2100

*Riahi et al. 2017, Kikstra et al. 2021

RFF-SPs: Population (country level)

- *Methods:* Extend the fully probabilistic statistical approach used by the UN for official population forecasts, incorporating improvements from a panel of nine leading demographers*
- *Results:* Median world population peaks at ~11B mid-next century, declines to ~7.5B in 2300, but with wide uncertainty (98% interval from 1.7 to 33.9 billion)
- Median is most comparable to SSP2; uncertainty range is significantly narrower than SSP spread through 2200



Shaded areas represent 90% and 98% prediction intervals

*Raftery and Ševčíková (forthcoming)

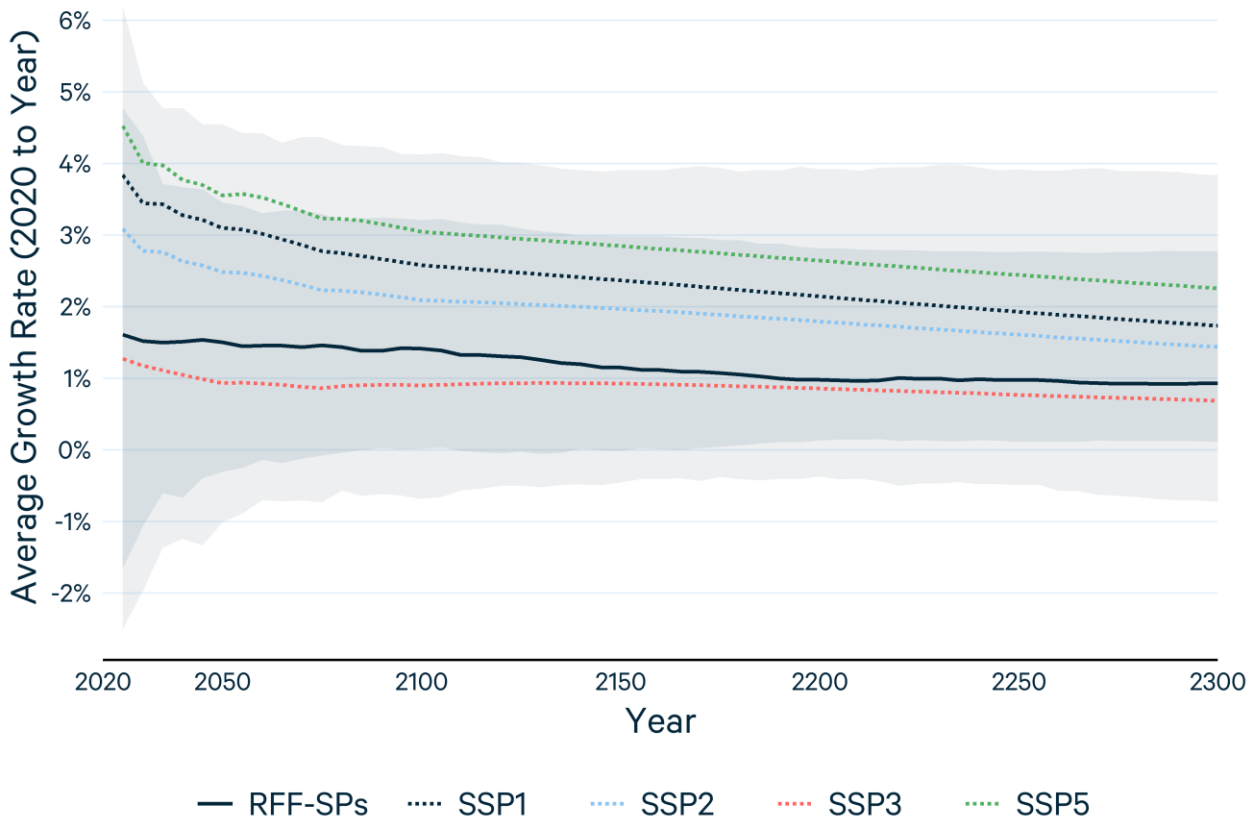
Rennert et al. (2021), BPEA

RFF-SPs: Economic Growth (country level)

- *Methods:* Country-level econometric growth projections to 2300*, constrained using expert uncertainty from RFF *Economic Growth Survey*

- *Results:*
  - Both sources view extremely high (>4%) and low (~0%) long-run growth as highly unlikely, but possible
  - Median projection from experts shows much lower long-run growth than statistical model

- SSPs all fall within 90th percentile range of RFF-SPs; do not fully span the low end of the range



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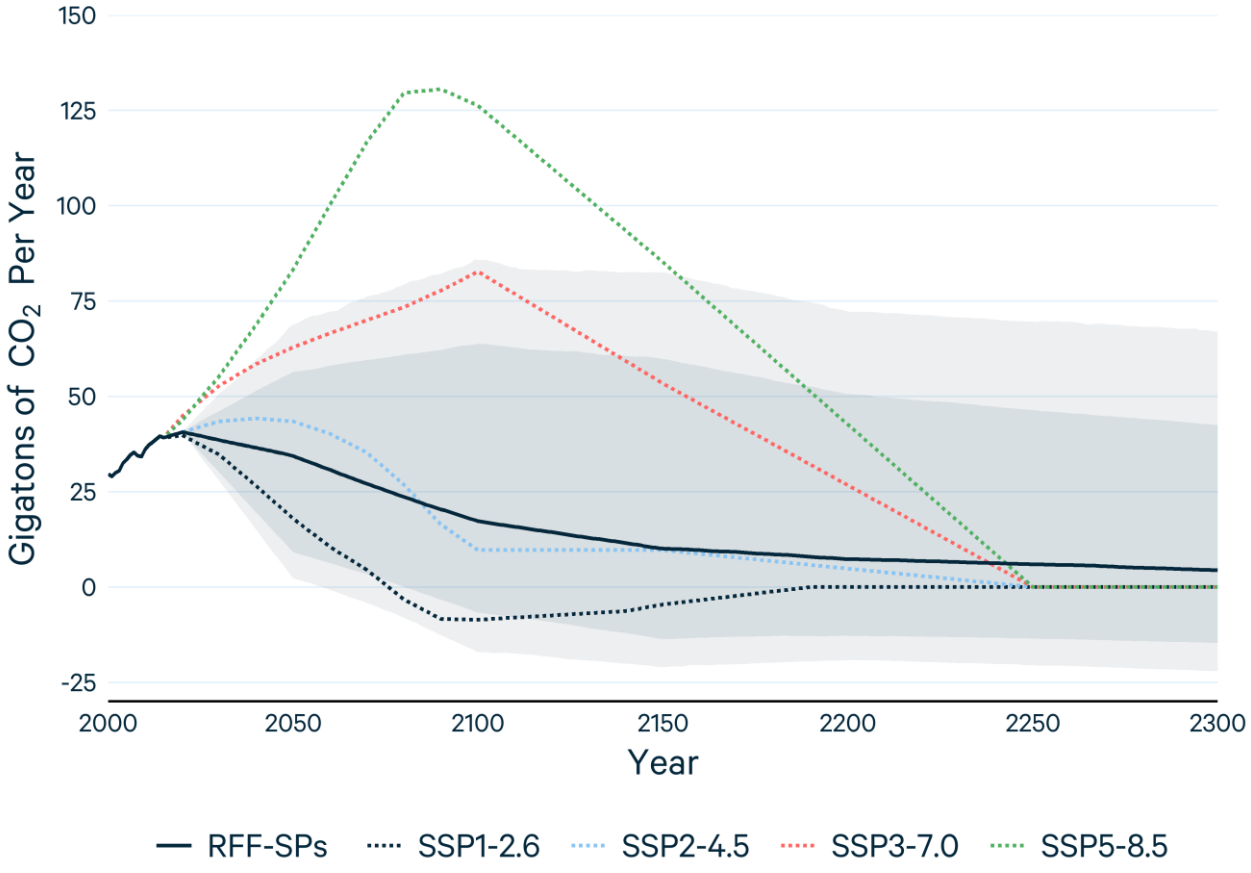
* Müller, Stock, Watson (forthcoming)

Rennert et al. (2021), BPEA

RFF-SPs: Emissions (global)

- *Methods:* RFF *Future Emissions Survey* quantified uncertainty for 4 categories of future emissions, including uncertainty on future policy. CO_2 distributions were conditioned on future economic growth.
- *Results:* Median projections indicate ~60% reduction of CO_2 by 2100, with wide uncertainty, including net-zero emissions.
- SSPs 1 and 3 are outliers through 2100 compared with RFF-SPs, SSP5 is well outside the range. Requirement for all SSPs to go to zero emissions during 2100-2250 is generally inconsistent with expert projections.



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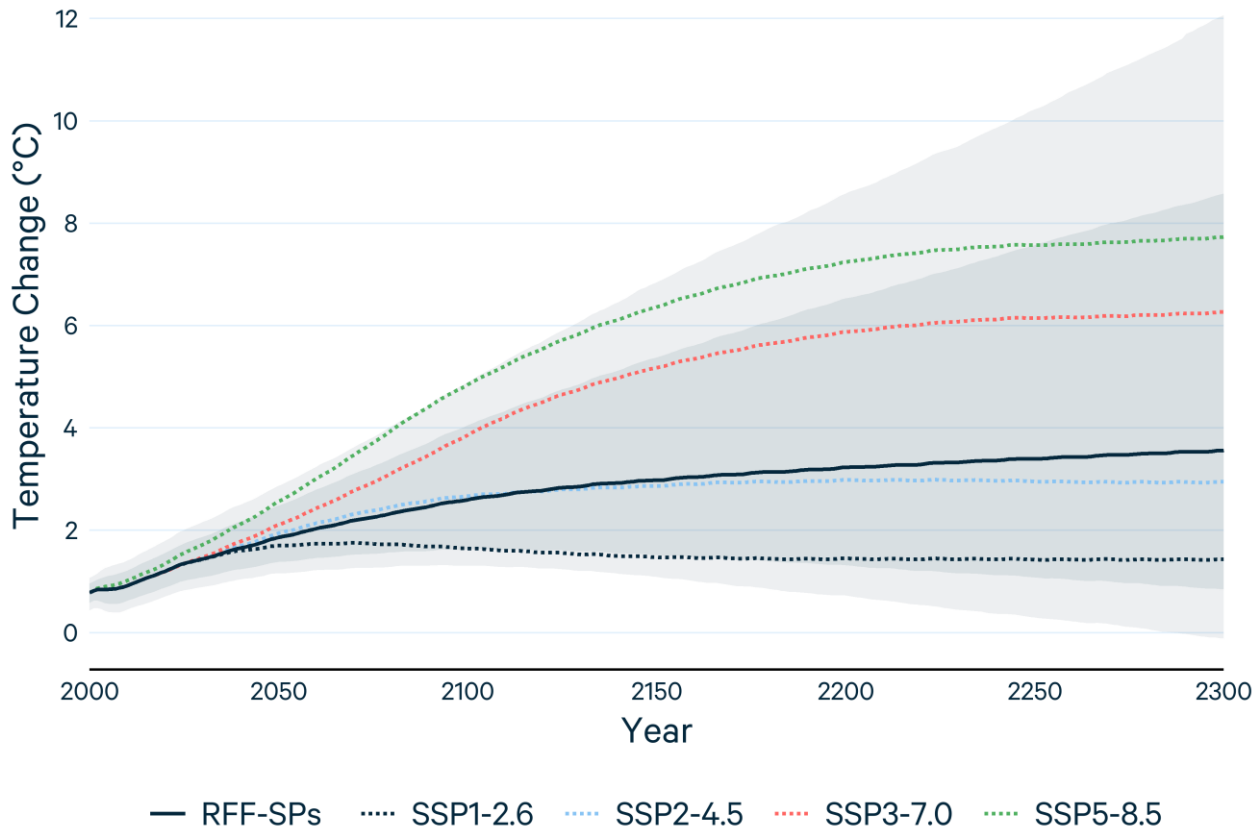
Rennert et al. (2021), BPEA

Temperature projections using RFF-SPs

- *Methods:* Emissions from RFF-SPs were sampled and used as an input to the FaIR 2.0* climate model

- *Results:*
  - Median temperature pathway ~3° C increase from pre-industrial level by 2100, continues to increase to 2300
  - ~10% chance of staying below 2° C by 2100; negative emissions allow for pathways that peak then decline

- SSP temperature pathways roughly span RFF-SP range through 2150, but narrow as SSP emission pathways go to zero (by construction)



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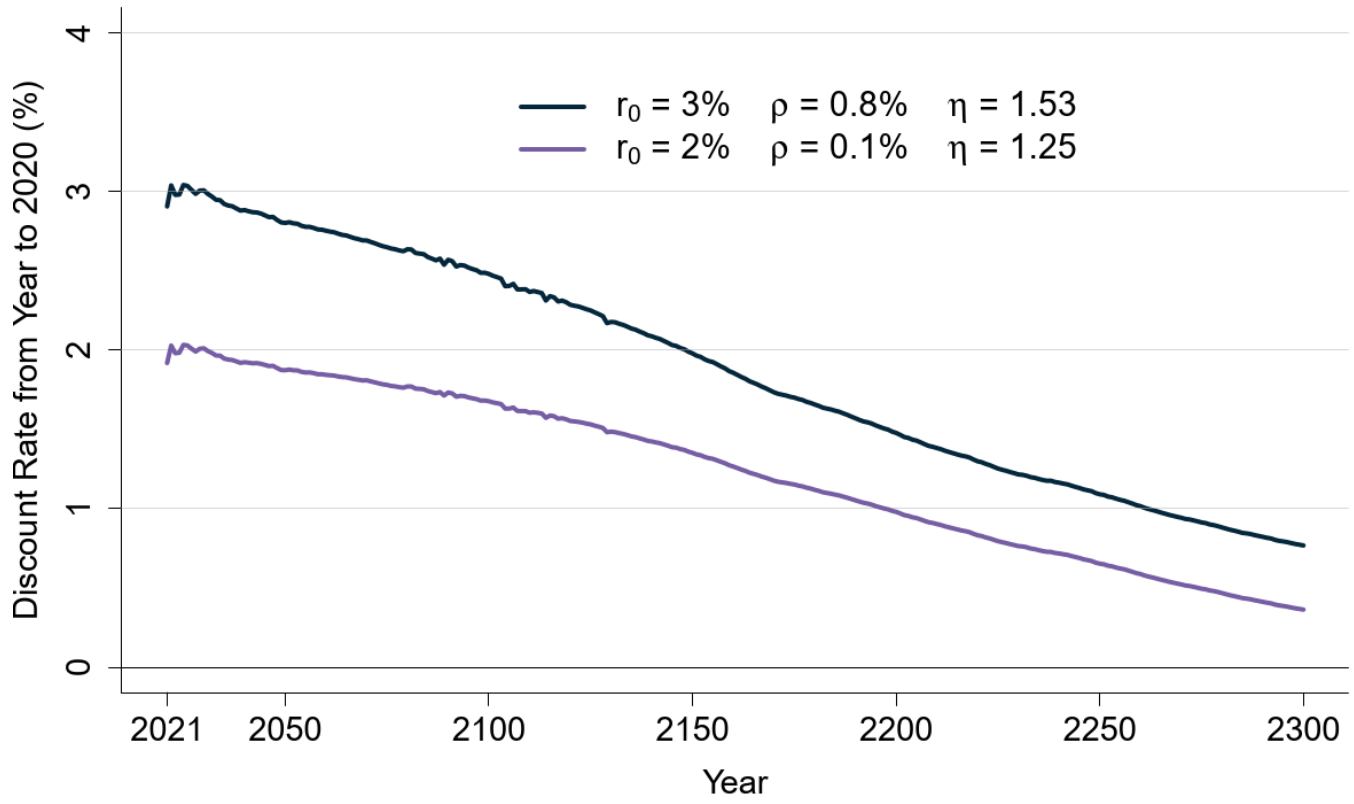
Rennert et al. (2021), BPEA

** Leach et al. 2021*

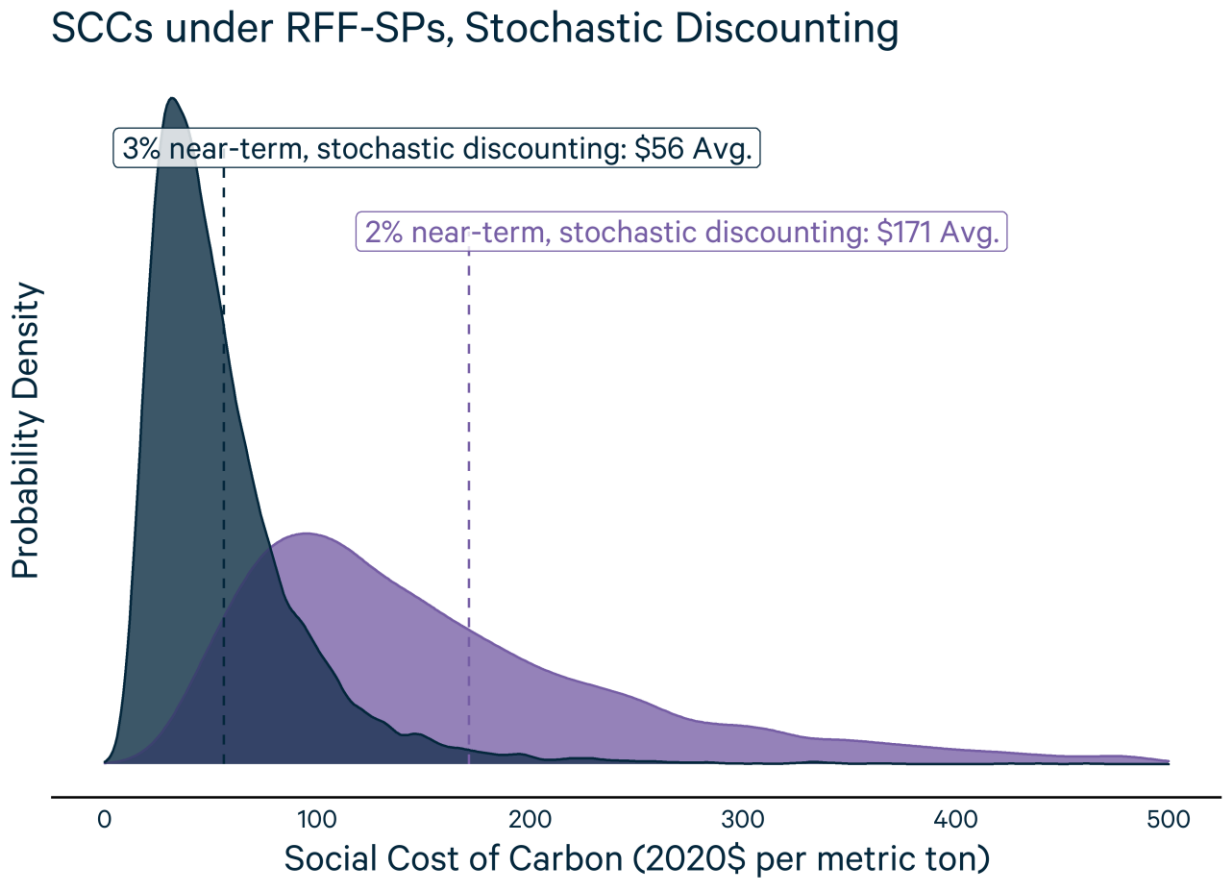
Stochastic discounting with growth: $r = \rho + \eta g$

- *NASEM recommendations:*
  - Discount rate should be consistent with policy rates (e.g., 3%) in the near term while also linked to growth uncertainty in the long term
- *Methods:*
  - Calibrate ρ and η parameters to match near-term rates (e.g., 3%) while also reconciling evidence on long-run interest rate behavior* and economic growth uncertainty**
- *Results:*
  - Empirically calibrated ρ and η values for use in estimating the SCC, linking discounting to growth



*Bauer & Rudebusch (2021)
**Müller, Stock, & Watson, forthcoming

Illustrative SCCs in 2020, with DICE damage function and FaIR climate model



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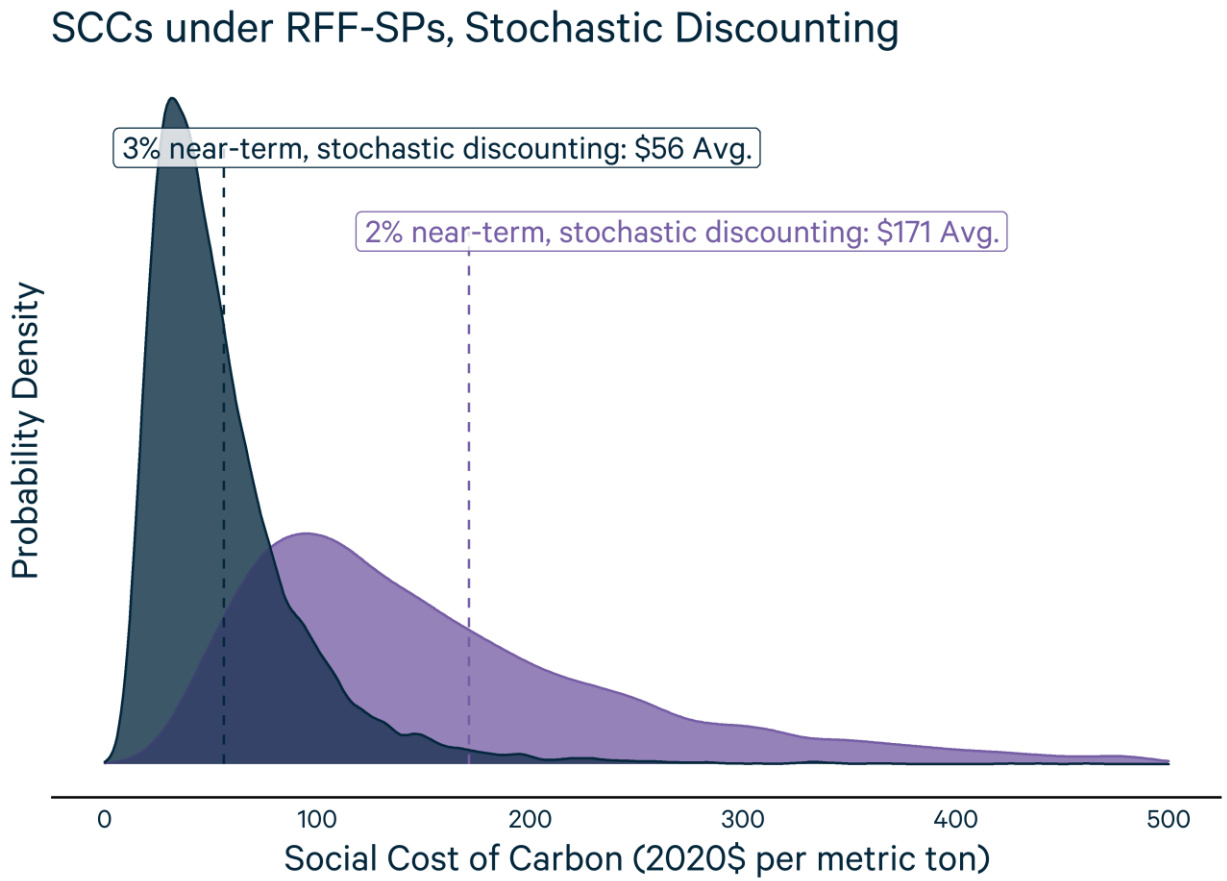

IWG 2020 SCC with Constant Rate Discounting (2020$/metric ton CO_2)

Model	3%	2%
DICE	46	112
FUND	23	68
PAGE	83	182
Average of models	51	121

Rennert et al. (2021), BPEA

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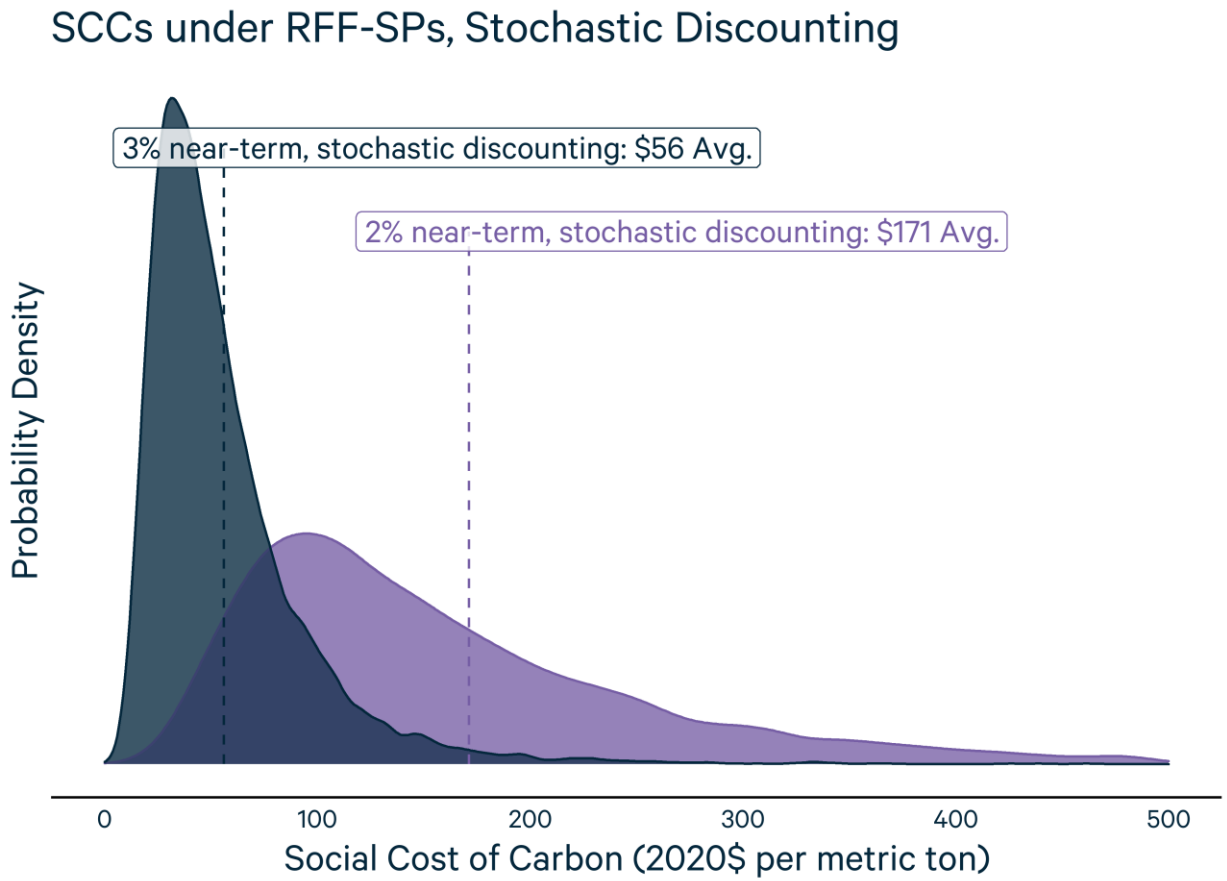

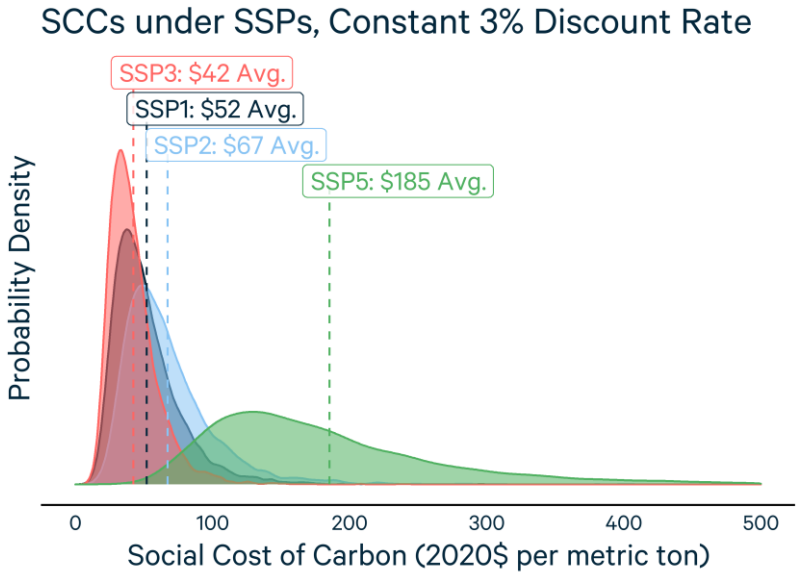

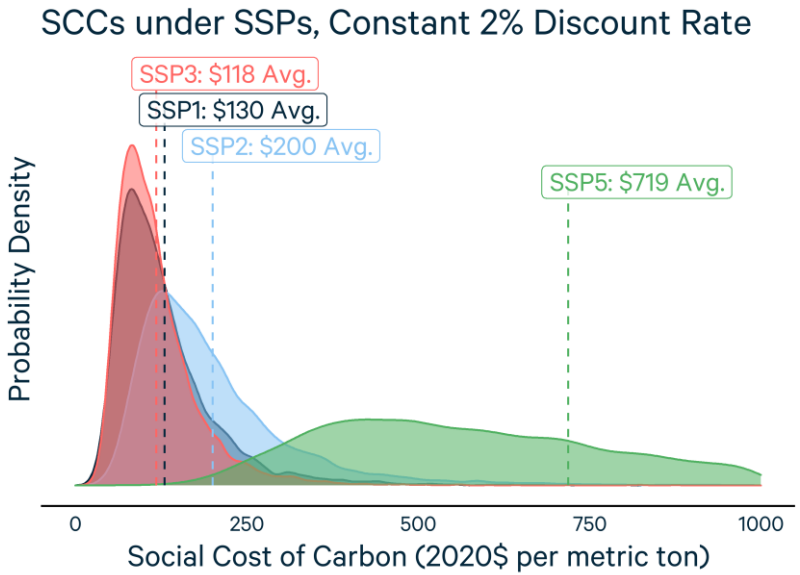

Rennert et al. (2021), BPEA

Conclusions

- Socioeconomic uncertainty has a substantial impact on the SCC
  - Conceptually and practically important to consider the full distribution of future possible paths for population, GDP per capita, and emissions
- RFF-SPs provide probabilistic projections that meet all NASEM recommendations
  - For some, but not all, variables, the SSPs span a comparable range of uncertainty to the RFF-SPs, but should not be considered equally likely
  - No single SSP reflects central expectations across all variables
- Stochastic, growth-linked discounting is critical for SCC estimation, especially amidst a full representation of socioeconomic uncertainty
- Illustrative SCC results that implement NASEM recommendations for 3 out of 4 modules (socioeconomic, climate, discounting) show a considerable increase
- Implementation of final module (damages) rapidly nearing completion on timeframe relevant for IWG consideration

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Thank you!

Social Cost of Carbon Initiative

rff.org/SCC