Updated Estimates of the Social Cost of Carbon and Other Greenhouse Gases

Overview of EPA "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances"

April 24, 2024

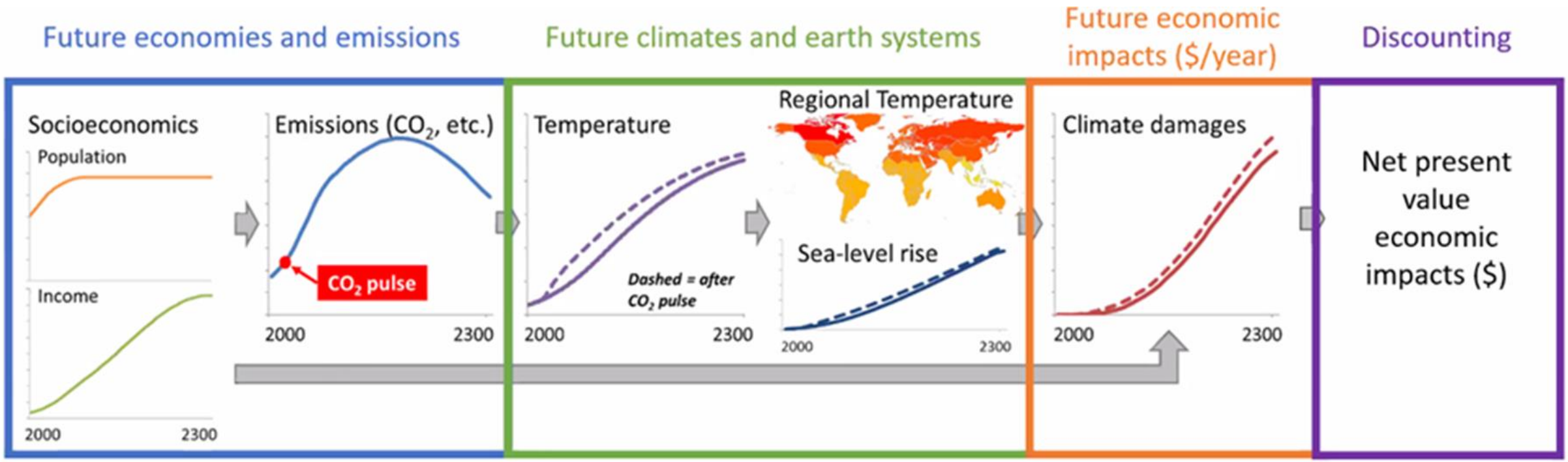
National Center for Environmental Economics

U.S. Environmental Protection Agency

What Is the Social Cost of Carbon (SC-CO_2)?

- The monetized present value of global net damages from emitting a ton of CO_2 into the atmosphere in a particular year (and conversely, the benefits from a ton decrease)
  - In principle, it is a comprehensive metric that reflects the value of *all* future climate change impacts (both negative and positive)
  - In practice, all estimates of the SC-CO_2 are a partial measure of net damages given data and modeling limitations
- SC-CO_2 provides a measure of the incremental or *marginal benefit of abatement* and is how the benefits of CO_2 reductions are valued in benefit-cost analysis (BCA).
- Estimates of the social cost of other GHGs (SC-CH_4, SC-N_2O) measure the value of changes in their emissions (collectively, "social cost of greenhouse gases" (SC-GHG))

The 4 Steps of SC-CO_2 Estimation



Source: Weyant and Rose (2024). Developed from Rose et al (2017, 2014) and used in NASEM (2017).

This 4-step procedure is done with both baseline emissions and with a small additional amount (a pulse) of CO_2 emissions in a particular year.

SC-CO_2 is the per-ton difference in present value of damages due to the pulse.

Why does U.S. Government need SC-GHG estimates?

- Rigorous benefit cost analysis (BCA) is a core tenant of the U.S. federal rulemaking process
  - It provides a consistent framework for comparing regulatory designs that have different costs and emission reductions for multiple pollutants
  - Since 1981, BCA is required for all significant U.S. Federal regulations (Executive Order (E.O.) 12866)
  - Other types of analyses (required by statute, other E.O.s, discretionary) provide insight into different dimensions of a rule's impacts (e.g., distributional analysis, EJ analysis)
- SC-GHG estimates are needed in BCA to develop an aggregated measure of affected individuals' willingness to pay for reduced climate change impacts associated with policy actions that reduce GHG emissions
- SC-GHG estimates are also useful in assessing the climate impacts of Federal actions even in absence of a full BCA (e.g., NEPA)

In 2008, the U.S. Ninth Circuit Court of Appeals remanded a fuel economy rule to DOT for failing to monetize CO_2 emissions. The court stated,
"[w]hile the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero."

U.S. Government (USG) Use of SC-GHG Estimates

- Since 2008, SC-GHG estimates have been used in 100+ Federal regulatory BCAs (primarily by EPA, DOE, DOT, and DOI)

- Increasing Federal use in non-regulatory context - e.g.,
  - National Environmental Policy Act (NEPA) analyses
  - Some use in project level BCAs (e.g., DOT discretionary grants), government procurement analysis
  - Legislative proposals

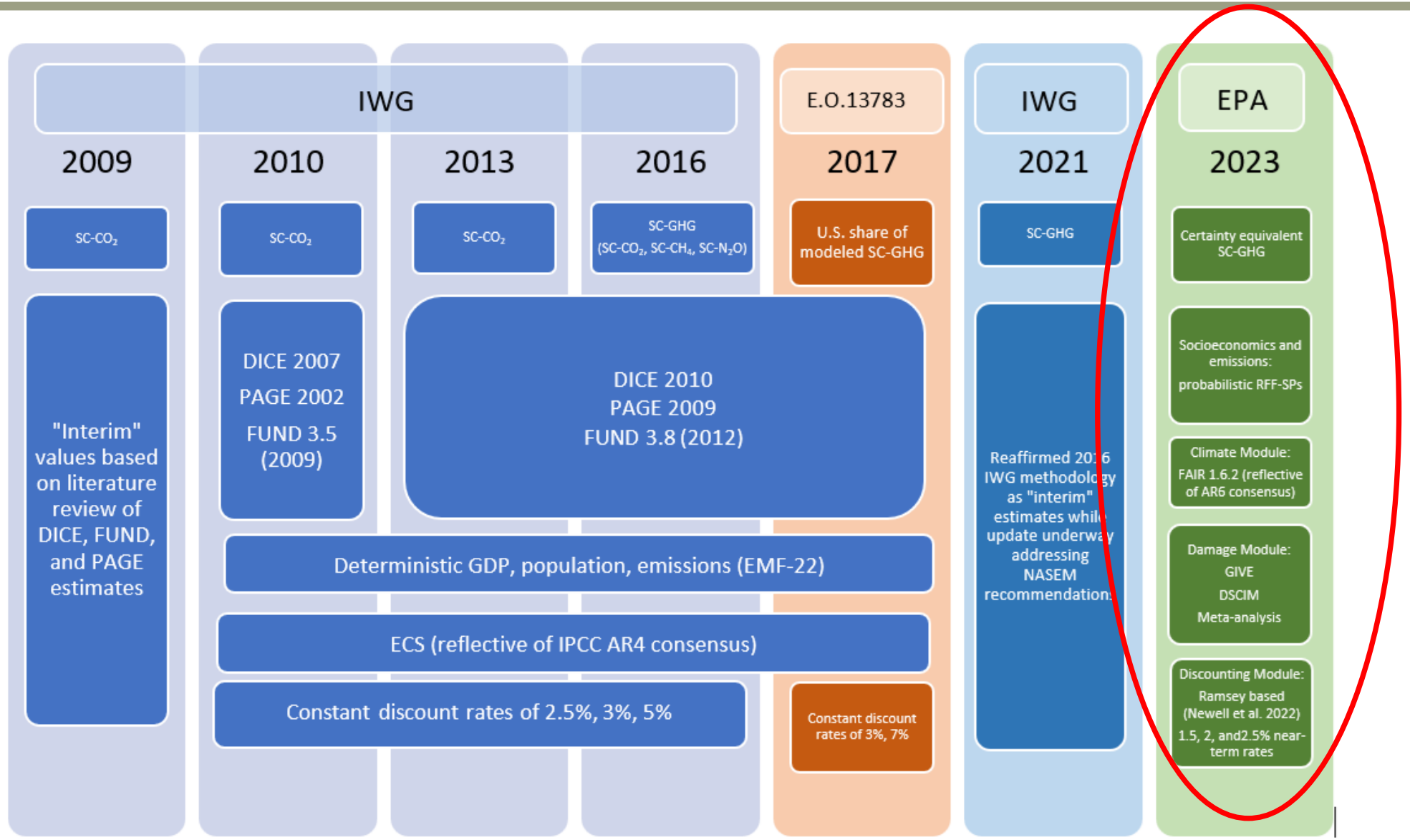
    ➢ September 2023 White House directive further encourages Federal use of SC-GHG beyond regulatory BCA

- Increasing use by non-Federal entities – e.g.,
  - By states (see www.costofcarbon.org/states), regional organizations (e.g., Northwest Power and Conservation Council), other nations (e.g., Canada)

Development of USG SC-GHG Estimates to Date

2008	• SC-CO_2 estimates used in regulatory analysis after a Circuit Court remand of a fuel economy rule to DOT for not monetizing CO_2 emissions
2009 - 2016	• **Interagency working group (IWG)** develops SC-CO_2 estimates for recommended use in Federal BCA; adds SC-CH_4 and SC-N_2O estimates in 2015-2016
2017	• **National Academies of Sciences, Engineering and Medicine (NASEM)** issues recommendations for updating estimates to ensure they continue to reflect the best available science
2017 - 2020	• **E.O. 13783** disbands the IWG, and instructs agencies to focus on "domestic" share of SC-GHG only and with 3% and 7% discount rates; all other assumptions unchanged
2021	• **E.O. 13990** reestablishes IWG and calls for a renewed focus on updating SC-GHG estimates to reflect the latest science – IWG "interim" recommendation to use SC-GHG estimates from 2016 while comprehensive update is underway
2022	• EPA releases draft updated SC-GHG estimates addressing NASEM near-term recommendations within sensitivity analysis in a proposed rulemaking
2023	• White House encourages expanded Federal use of SC-GHG beyond regulatory BCA (fulfilling another directive of E.O. 13990)
	• **EPA begins to use updated SC-GHG estimates** in primary analysis, responding to public comment and peer review

Methodology underlying USG developed SC-GHG estimates



EPA SC-GHG Update Results

- Responsive to the NASEM near-term recommendations, improved scientific basis, and greater transparency of implementation and results.

> E.g., as peer reviewers noted, the report "*…represents a huge advance in estimating the US Social Cost of Carbon (SCC). The estimates reported have successfully incorporated all of the short-term recommendations of the* [NASEM]*, and some of the longer-term recommendations...*";
> *"…provides the basis for both an improved estimate to be used…in the near term, as well as providing the core foundation for continuing refinements and improvements in the future"*

- Results are based on characterization of major uncertainties in estimating the SC-GHG and their interactions.

- Updated estimates are larger than what EPA previously used in our analyses.
  - For example, the updated central SC-CO_2 of $190 per ton of CO_2 for 2020 emissions is more than 3 times the IWG estimate of $51 per ton.

- Many categories of climate impacts are still not captured in the updated estimates.

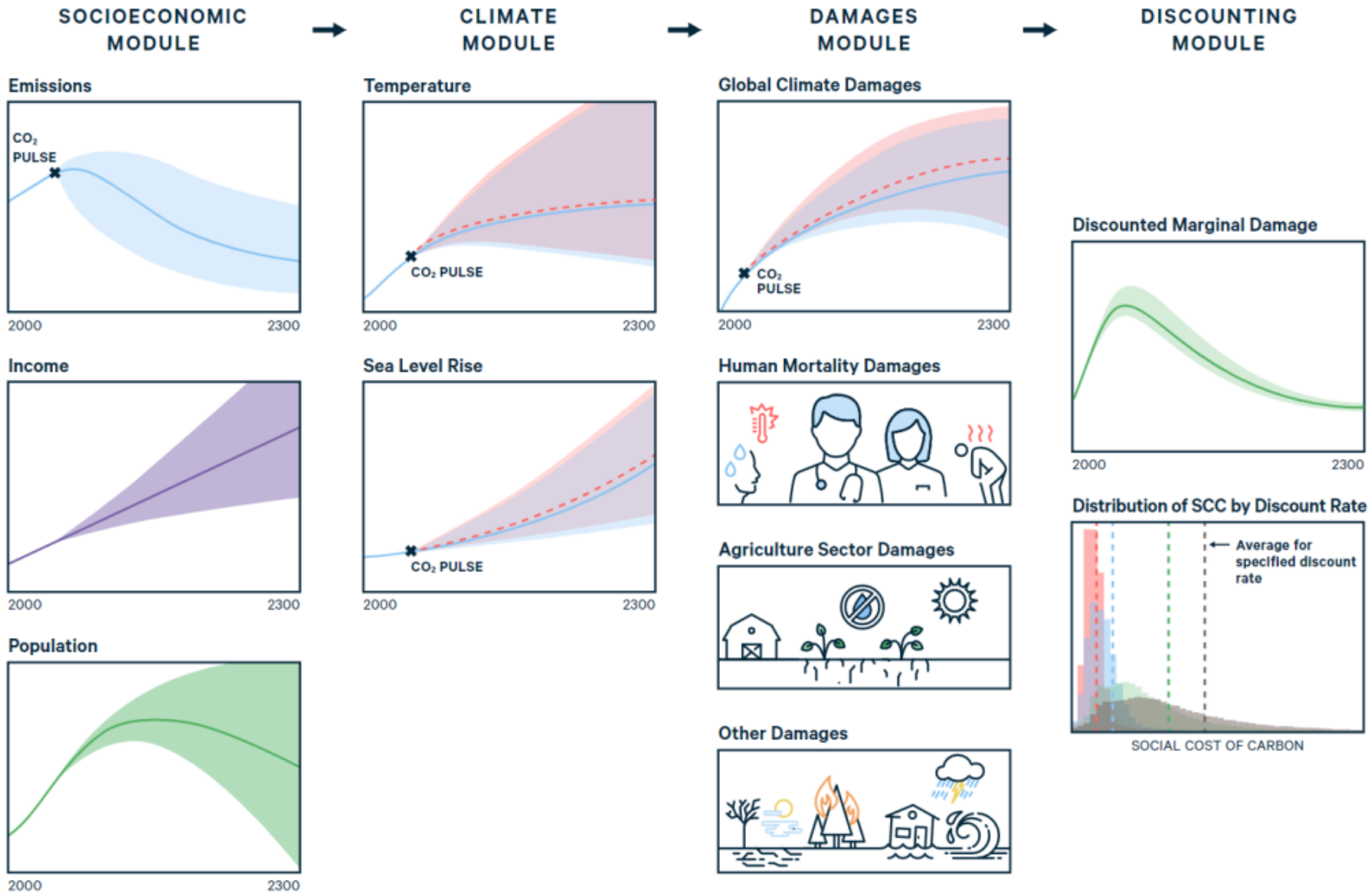
Overview of NASEM 2017 Recommendations

- "Unbundle" SC-GHG estimation into 4 modules
  - Socioeconomics, Climate, Damages, Discounting
- Conduct near term updates to each module:
  - Each module to be developed based on expertise within the relevant disciplines
  - Uncertainty at each stage to be quantified and combined to generate a distribution of SC-GHG values
- Going forward, update SC-GHG estimates every 5 years
  - 5 years balances the need to respond to evolving research with the need for a thorough and predictable process.
  - Use a three-step process: revise, solicit comment, review by independent scientific assessment panel

Overview of NASEM 2017 Recommendations

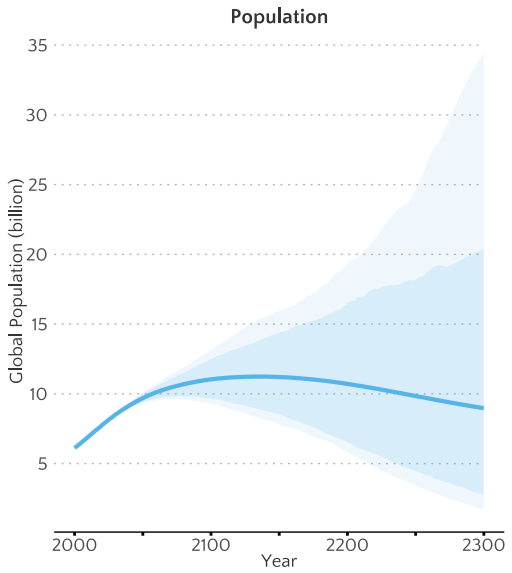
- **Statistical methods and expert elicitation** should be used to project distributions of GDP, population growth and emissions into the future
- **Link between emissions and climate** should use a simple Earth system model that satisfies well-defined diagnostic tests
- **Damage calculations** should improve and update existing damage functions, drawing on recent scientific literature
- **Future damages should be discounted** at a rate reflecting rate of economic growth underlying damage projections
  - **Ramsey discounting will achieve this and allow correlation between climate damages and the discount rate**

A Modular Framework

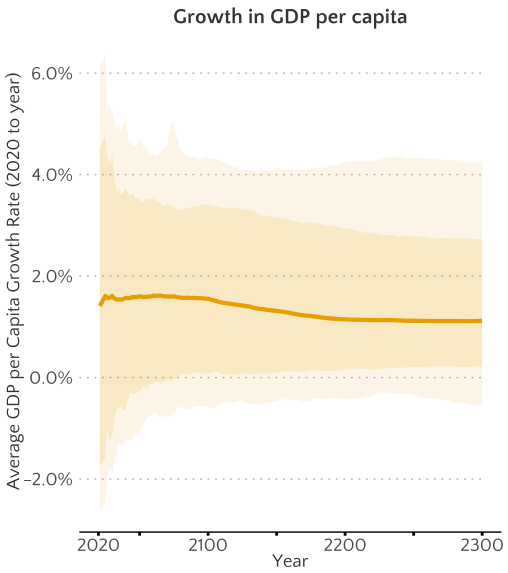


Socioeconomic Module

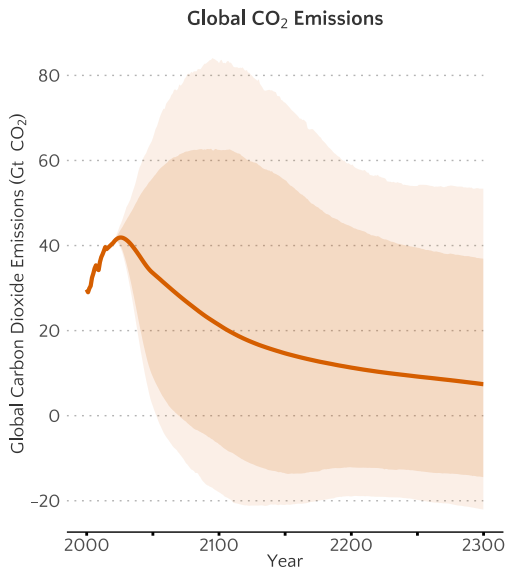
- Socioeconomic projections from the Resources for the Future Social Cost of Carbon Initiative (RFF-SPs)
- Multi-century, probabilistic projections of population, GDP per capita, and GHG emissions
- Account for future policies and interdependencies
- Use statistical and structured expert judgment methods



Extends UN probabilistic country-level population forecasts incorporating improvements from a panel of expert demographers



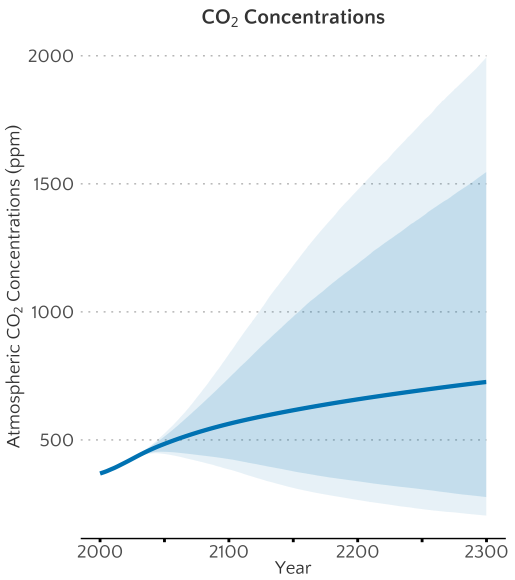
Country-level empirical economic growth projections extended in time using expert elicitation



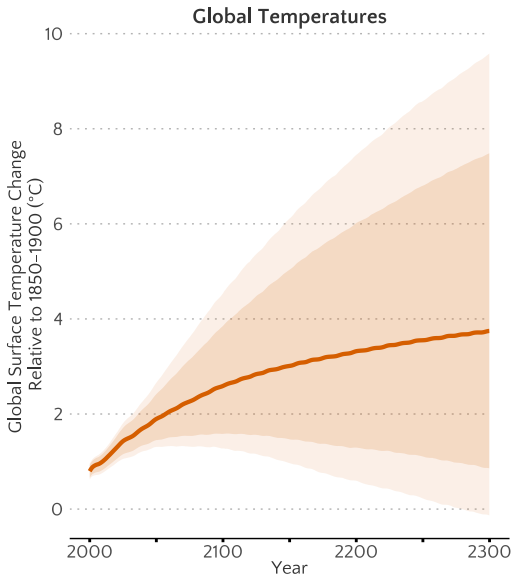
Emissions projections conditioned on future economic growth and reflection of an “Evolving Policies” case

Climate Module

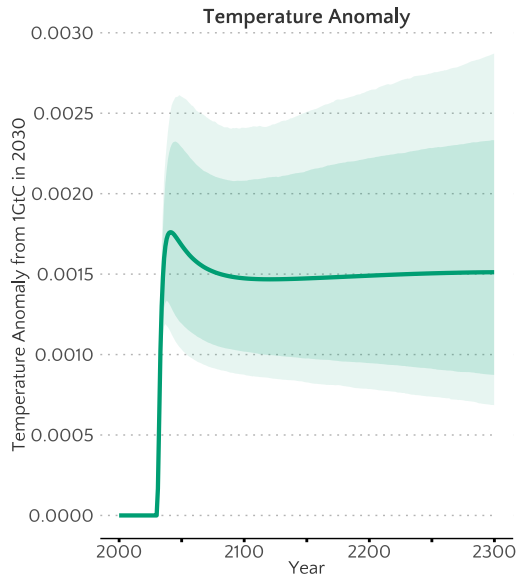
- Finite Amplitude Impulse Response (FaIR) model (v 1.6.2)
- Open source and widely used reduced complexity climate model highlighted by NASEM and used by the IPCC
- Uncertain parameters calibrated to be consistent with IPCC AR6, such as the IPCC assessed likely range of 2.5 to 4°C for the climate sensitivity



Climate projections represent uncertainty in the probabilistic RFF-SPs as well as from the climate model parameters



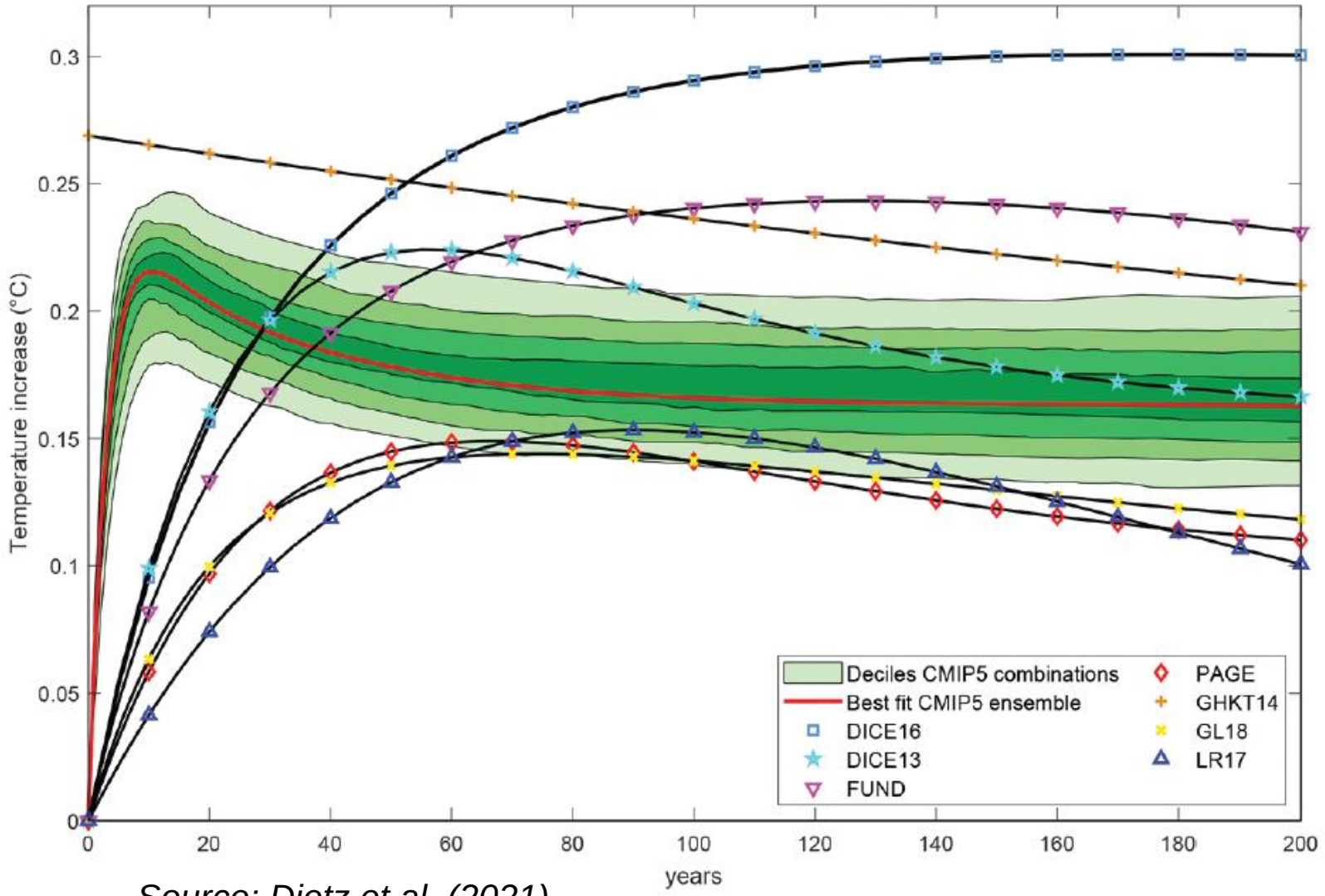
Translates GHG emissions into mean surface temperature response and represents the current understanding of the climate and GHG cycle systems and associated uncertainties within a probabilistic framework.



Climate Module

- Temperature dynamics in FaIR represent a significant scientific advancement over the climate system representation in the three IAMs used in SC-GHG estimates to date

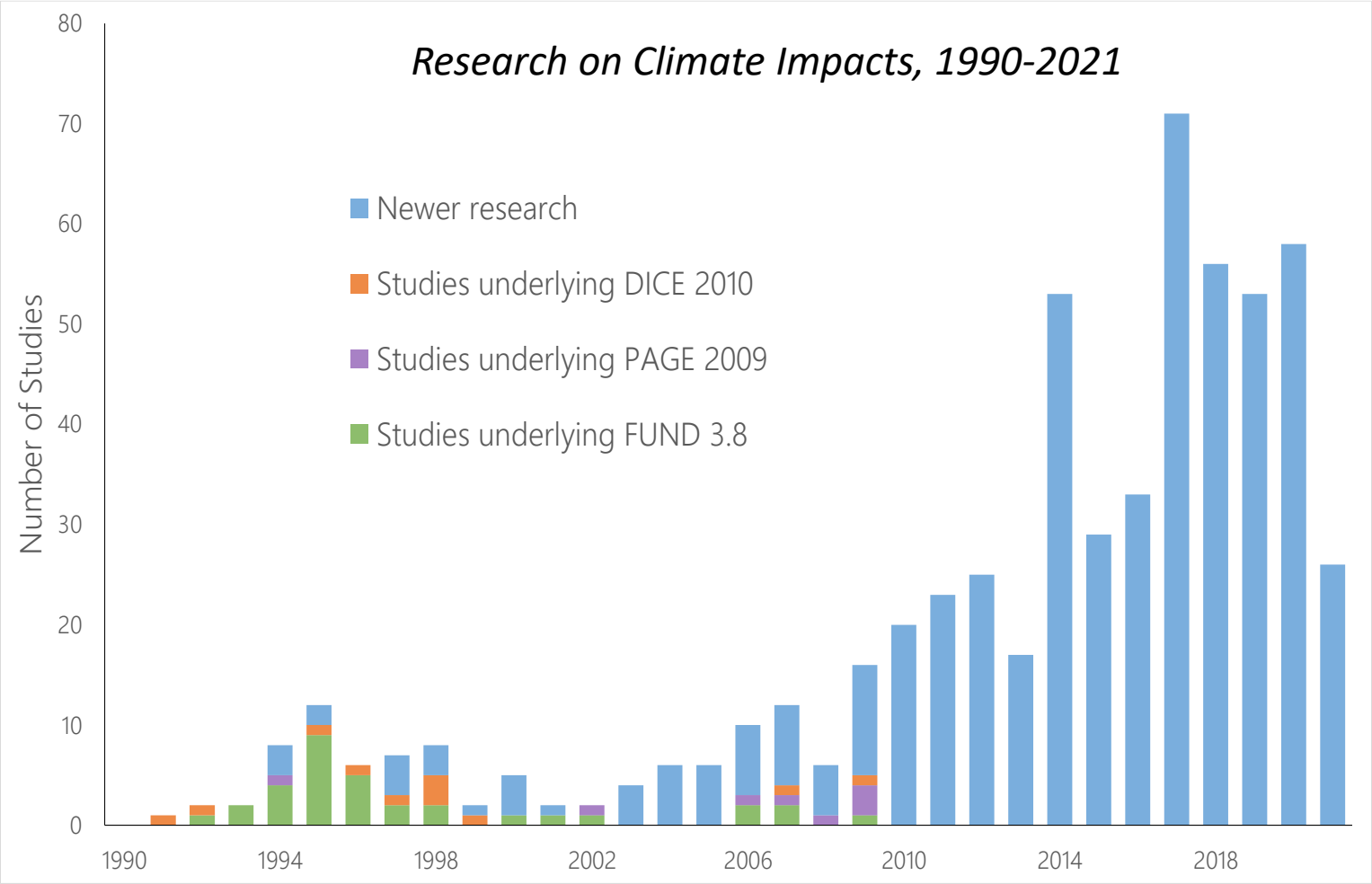
Temperature response from pulse of emissions



Source: Dietz et al. (2021)

Damages Module

- Large increase in climate impacts research since the models used by EPA to date were published
- Continues to be wide variation in methodologies and scope of studies

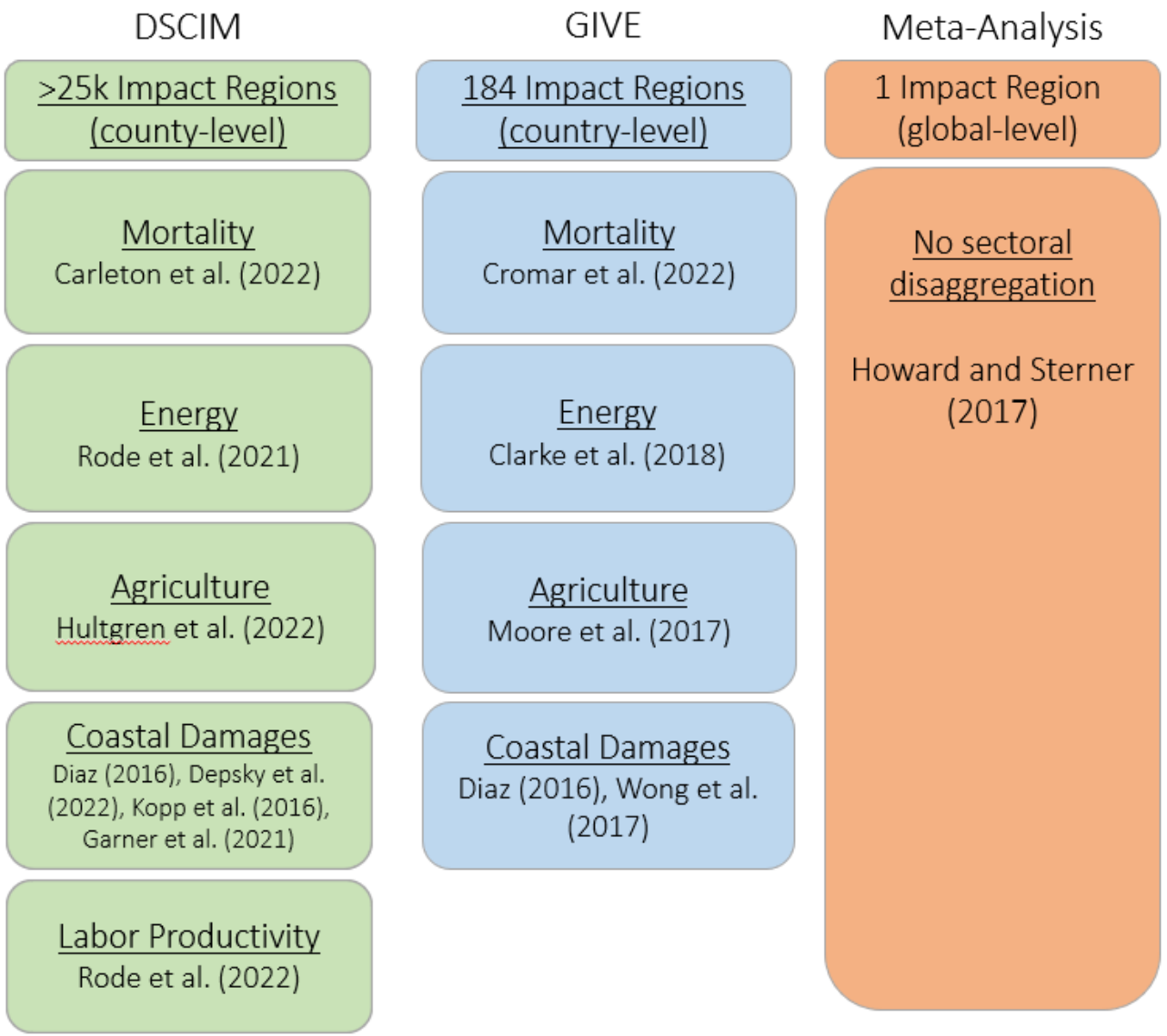


Source: Greenstone (2016), updated in 2021.

Damages Module

Use 3 separate damage functions to synthesize the literature

1. Subnational-scale, sectoral damage function (based on the Data-driven Spatial Climate Impact Model (**DSCIM**) developed by the **Climate Impact Lab**),
2. Country-scale, sectoral damage function (based on the Greenhouse Gas Impact Value Estimator (**GIVE**) model developed under **RFF's Social Cost of Carbon Initiative**), and
3. **Meta-analysis**-based damage function.



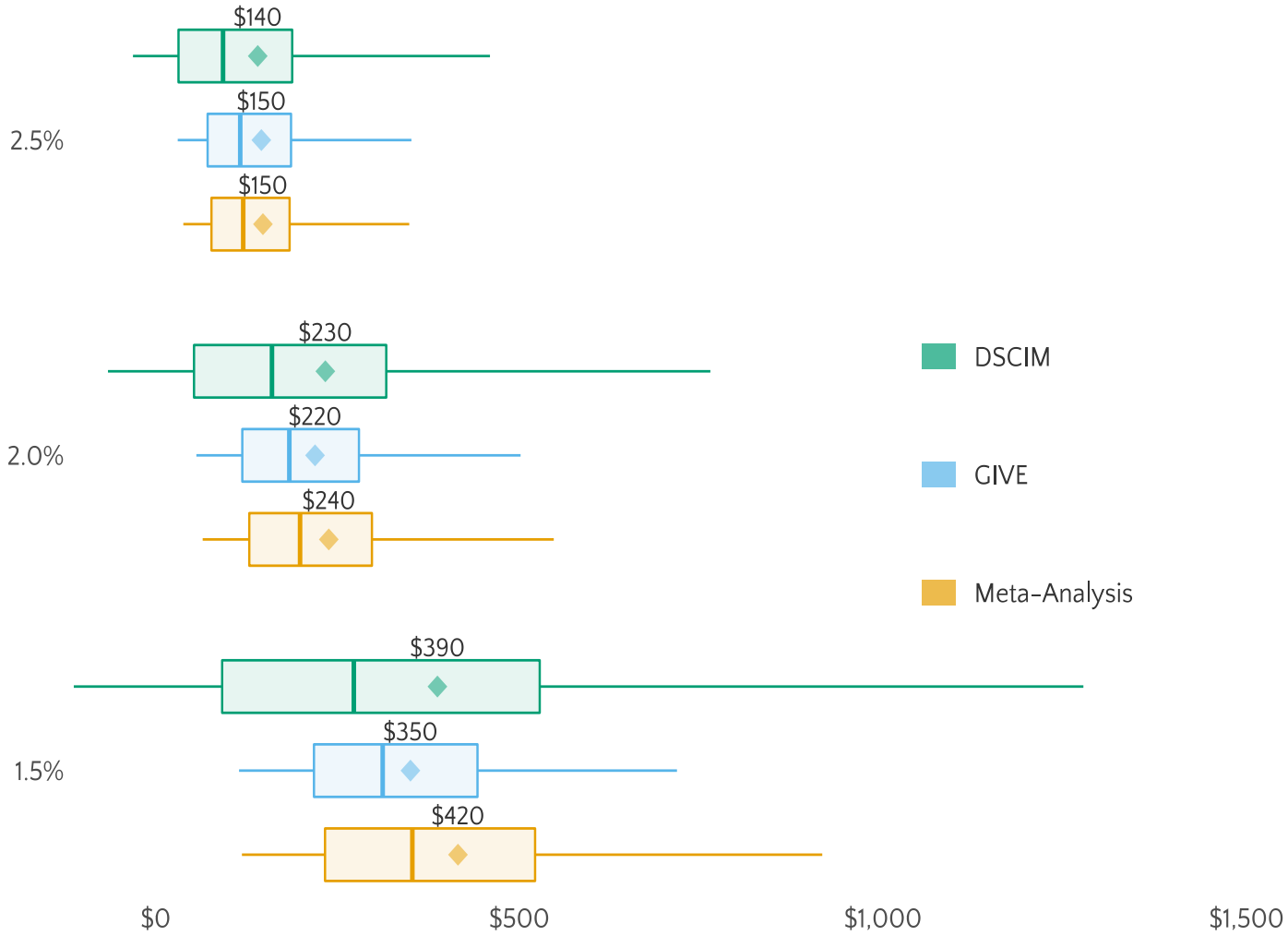
Discounting Module

- Updated SC-GHG estimates use a set of **calibrated dynamic discount rates**
  - Approach uses Ramsey discounting formula: $\boldsymbol{r_t = \rho + \eta g_t}$
  - Parameters ρ and η are calibrated to match near-term consumption interest rates and reconcile long-run interest rate behavior and economic growth uncertainty consistent with the RFF-SPs
  - Uncertainty in the starting rate is addressed by using three near-term target rates – 1.5, 2.0, and 2.5% – based on multiple lines of evidence on observed interest rate data.
- This approach is consistent with:
  - NASEM recommendations: discount rate should align with the consumption rate of interest and capture the long-term relationship between discount rates and economic growth
  - USG BCA Guidance (OMB Circular A-4, 2023): updated recommended consumption-based discount rate to 2%. Explicitly endorses Ramsey framework for long-term discounting.

Results

- Means and distributions of the SC-CO_2 from 10,000 runs for 3 damage functions with discounting approaches calibrated to 3 near-term rates

- Using the 2% near-term discount rate, the mean SC-CO_2 across the 3 damage functions is $230/ton of CO_2 in 2030.



Distribution of the Discounted Marginal Damages per Metric Ton CO_2 for 2030 Emissions, by Near-term Ramsey Discount Rate and Damage Module

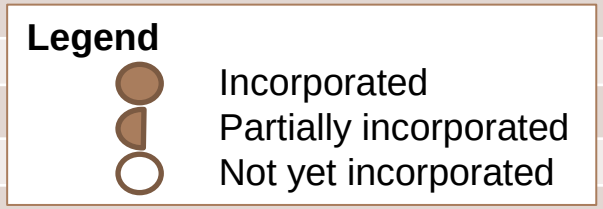
Updated SC-GHG Estimates

Emission Year	SC-GHG and Near-term Ramsey Discount Rate								
	$SC\text{-}CO_2$ *(2020 $/metric ton of CO_2)*			$SC\text{-}CH_4$ *(2020 $/metric ton of CH_4)*			$SC\text{-}N_2O$ *(2020 $/metric ton of N_2O)*		
	2.5%	2.0%	1.5%	2.5%	2.0%	1.5%	2.5%	2.0%	1.5%
2020	120	190	340	1,300	1,600	2,300	35,000	54,000	87,000
2030	140	230	380	1,900	2,400	3,200	45,000	66,000	100,000
2040	170	270	430	2,700	3,300	4,200	55,000	79,000	120,000
2050	200	310	480	3,500	4,200	5,300	66,000	93,000	140,000
2060	230	350	530	4,300	5,100	6,300	76,000	110,000	150,000
2070	260	380	570	5,000	5,900	7,200	85,000	120,000	170,000
2080	280	410	600	5,800	6,800	8,200	95,000	130,000	180,000

Source: EPA (2023).

Scope of Climate Science, Impacts, and Damages Included in the Updated SC-GHG Estimates

Climate Science			
Temperature change	◐	Non-climate mediated effects of GHG emissions	◐
Averages	●	Carbon fertilization (CO2)	●
Extremes	○	Ocean acidification (CO2)	○
Variability	○	Tropospheric ozone formation (CH4)	○
Sea level rise	◐	Stratospheric ozone destruction (N2O)	○
From average temperature change	●		
Non-linear effects (e.g., ice-sheet collapse)	◐	Methodology	◐
Precipitation	○	Explicit treatment of uncertainty	●
Averages	○	Accounting for adaptation and costs of adaptation	◐
Extremes	○	Interactions/feedbacks across sectors	○
Variability	○	Feedbacks from damages to socioeconomics and emissions	○
Humidity - wet-bulb temperature	○	Valuation of risk	◐
Large scale earth system changes (tipping elements, etc.)	◐		
Additional changes in temperature	◐		
Sea level rise	◐		
Precipitation	○		
Extreme weather events	○		
Ecosystems	○		
Other impacts	○		



Source: EPA (2023).

Scope of Climate Science, Impacts, and Damages Included in the Updated SC-GHG Estimates

Impacts and Associated Damages	
Human Health and Well-being	**Buildings, transportation, and infrastructure**
Heat and cold related mortality	Sea level rise
Mortality/morbidity from extreme weather events (e.g., storms, wildfire, flooding), and sea level rise	Intensity or frequency of coastal storms
Mortality/morbidity from climate mediated changes in the formation of criteria air pollutants (e.g., ozone, PM2.5)	Extreme weather inland (e.g., storms, wildfire, flooding)
Infectious diseases	Environmental conditions (e.g., melting permafrost, air temperature and moisture)
Other morbidity (e.g., malnutrition, allergies)	**Food production**
Displacement and migration	Agriculture/Crop production
Labor	Animal and livestock health and productivity
Labor supply (i.e., hours worked)	Fisheries and aquaculture production
Labor productivity (i.e., output per hour worked)	**Forestry-** Timber, pulp, and paper production
Energy	**Tourism, recreation, aesthetics**
Energy consumption (e.g., heating, cooling)	Visitation, locations, opportunities (e.g., recreational fishing, skiing, scuba diving, scenic views)
Energy production and provision (e.g., hydroelectric, thermal power generation)	**Ecosystem services**
Water	Availability and quality of natural capital used in production of marketable goods
Water consumption (residential, industrial, commercial)	Biodiversity and wildlife habitat (e.g., aquatic environments, breeding grounds)
Provision of safe drinking water	Other provisioning and regulating services (e.g., water filtration, wildfire and flood mitigation, medicinal resources, pest control, pollination)
Water storage and distribution	Cultural services
Land	**Crime (property, violent)**
Coastal land loss from sea level rise	**National Security**
Trade and logistics	Military base impacts
Supply chain disruption (e.g., from extreme weather)	Military mission impacts from international civil conflict
Supply chain transitions (e.g., altering trade routes)	International development, humanitarian assistance

Source: EPA (2023).

How to apply SC-GHG values to a stream of estimated emissions changes

- SC-GHG estimates represent the damages associated with each additional ton of emissions released from the perspective of the year of emission.

- Therefore, several steps are necessary when conducting a policy analysis at the present time about policies that affect GHG releases in the future.

1. Analysts should apply the gas-specific SC-GHG value corresponding to the year of estimated emissions changes.

$$Benefits_{YEAR\ t} = (SC\text{-}CO_2\ for\ YEAR\ t) * (\Delta\ in\ metric\ tons\ CO_2\ emitted_{YEAR\ t})$$

2. Analysts incorporate the results into the rest of the analysis by calculating the present value of the resulting stream of monetized climate damages (i.e., discounting back to the year of analysis).

- NCEE has created a spreadsheet to help analysts with these calculations

See: https://www.epa.gov/environmental-economics/scghg

Discounting back to the year of analysis

- The correct discount factor to use when discounting the updated SC-GHG estimates is the certainty-equivalent discount factor.
  - This is because the SC-GHG estimates are certainty-equivalent values that account for the uncertainty in future consumption per capita.
  - The certainty-equivalent discount factor incorporates the uncertainty in future consumption using the RFF-SP probabilistic growth scenarios.
  - Discounting the SC-GHG estimates using a constant discount rate equal to the near-term target rate would not capture the uncertainty in consumption per capita for that year.
- However, if the stream of future emissions being evaluated is moderate (e.g., 30 years or less), the difference between discounting from the year of emissions to the year of analysis using a constant discount rate equal to the near-term target rate, and discounting using the certainty-equivalent discount factor will be small.
- EPA has created a spreadsheet tool to assist analysts in calculating the present and annualized value of a stream of climate benefits using constant discounting

For more information

See EPA's SC-GHG website (https://www.epa.gov/environmental-economics/scghg) for more information on:

- Final Report on the Social Cost of Greenhouse Gases
- Estimation Code and Replication Files
- Public Comments on the "Report on the Social Cost of Greenhouse Gases" and EPA Responses
- External Peer Review of the "Report on the Social Cost of Greenhouse Gases"
- Spreadsheet for calculating present and annualized values using the SC-GHGs
- December 2023 Oil and Gas Final RIA (see Section 3.2)