We create a mapping from mitigation policy to damages over time by focusing on the radiative forcing created by different mitigation policies. Radiative forcing determines the excess energy created by greenhouse gases in the atmosphere. The damage distribution associated with a given radiative forcing is interpolated, or extrapolated, relative to the radiative forcing of damage distributions estimated from three scenarios. The first scenario is based on the reference New Policies Scenario of the International Energy Agency and leads to a carbon dioxide level around 1000 ppm. The second assumes a constant mitigation leading to an eventual carbon dioxide level of 650 ppm, which requires a reduction of 58.3% relative to the first scenario emissions. The third scenario assumes a constant mitigation of 91.7%, leading to an eventual carbon dioxide level of 450 ppm.

For each of three values for the maximum GHG—450, 650, and 1000 ppm—we run a set of 4,000,000 random scenarios to generate a distribution of for each period. We order the scenarios based on , the damage to consumption in the final period. We choose states of nature with specified probabilities to represent different percentiles of this distribution. For example, if the first state of nature is the worst 1% of outcomes, then we assume the damage coefficient at time *t* for the given level of mitigation is the average damage at time *t* for the worst 1% of values for .

More generally, if the *k*th state of nature represents the simulation outcomes in the range [prob(k-1) , prob(k)], then the damage coefficient for the *k*th state of nature is the average damage in that range of scenarios in which the distribution for lies within those percentiles.

The simulations are used to calculate damages in each period for any particular state of nature and any chosen time path for mitigation actions. We do this by first calculating the radiative forcing associated with each simulation at the end of each period, and then interpolating the damage smoothly between the three different simulations with respect to the radiative forcing. Functional forms for both GHG levels and climate forcing as a function of GHG emissions are fitted to the Representative Concentration Pathway (RCP) scenarios adopted by the IPCC for its fifth assessment report (AR5) in 2014. In the IPCC report emissions, GHG concentrations, and radiative forcing are given for each of four RCP scenarios. The radiative forcing is assumed to be proportional to the integral over time of an excess GHG level raised to a power[[1]](#footnote-1). The carbon absorption itself is similarly fit to the RCP scenarios, and is assumed to be proportional to the difference between the GHG level in the atmosphere and the cumulative carbon absorption up to that point in time, raised to a power[[2]](#footnote-2).

Our task is to calculate an interpolated damage function using our three simulations where we have damage coefficients (for a given state and period) to find a smooth function that gives damages for any particular radiative forcing up to each point in time.

Maximum damages occur in the 1000 ppm maximum GHG scenario (for a given state and period) associated with no emissions mitigation. For mitigation that leads to radiative forcing less that the 1000 ppm simulation we assume that damages decrease linearly as a function of radiative forcing to the level of damages in the 650 ppm simulation, which is reached when radiative forcing equals the radiative forcing of that simulation.

When emissions mitigation increases so that radiative forcing is below that level we extend the interpolation along a quadratic curve. Damages decrease with reduced radiative forcing along a quadratic interpolation that matches the derivative and level of damages of the linear interpolation at level of the 650 ppm simulation, and has a curvature such that it reaches the level of damages in the 450 ppm simulation when radiative forcing decreases to match the level in that simulation.

If mitigation increases to the extent that radiative forcing decreases below the level of the 450 ppm simulation, then we extrapolate the damage function so that it matches the level and derivative at the 450 simulation, and exponentially decays toward zero. We create such an extrapolation of the damage function as follows: Let , where is the derivative of the quadratic damage interpolation function at 450 ppm, is the average mitigation in the 450 ppm simulation, and the level of damages is . Let the radiative forcing at that point be percent below that of the 450 ppm simulation. where is the radiative forcing in the 450 ppm simulation and is the radiative forcing given the mitigation policy. Letting =60, the extension of the damage function for is defined as: , which has the desired properties.

1. Radiative forcing in a ten year interval is given by: where GHG is the average level of carbon dioxide in the atmosphere measured in ppm. The constants were estimated from the IPCC RCP scenarios. [↑](#footnote-ref-1)
2. The carbon absorption in a ten year interval is given by: , where the sum is over absorption in previous periods. Again, the constants were estimated from the IPCC RCP scenarios. [↑](#footnote-ref-2)