In FUND, a given year’s increase in the temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year’s level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity, a relationship first noted by Hansen et al. (1985) based on the heat uptake of the deep ocean.

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OCEAN ACIDIFICATION.

None of the most widely adopted IAMs for estimating the SCC (DICE, FUND, and PAGE) address the multiple damages due to ocean acidification. As defined by Shinryokan (2011): “Ocean acidification refers to a reduction in the pH of the ocean over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide from the atmosphere.” In terms of market damages, ocean acidification impacts fisheries via its effects on marine ecosystems and organisms, particularly shellfish and crustaceans. In addition to fisheries, ocean acidification will impact ecosystems, biodiversity, and tourism via its effect on coral and also human settlements. While the economic effects of acidification are likely substantial, few economic values of the damages are available because scientists only recently recognized the threat of ocean acidification to marine life (Guinotte and Fabry, 2009) and fisheries, for the most part, are excluded from IAMs; see previous sub-section.

Though fisheries are expected to suffer significant economic damage as a result of ocean acidification, there are few studies of the economic costs of these impacts. Since 2009, economists have completed several impact studies that attempt to more accurately quantify the economic costs of climate change to fisheries. Two such

studies, Cooley and Doney (2009) and Narita et al., (2012), estimate these monetary effects with a focus on mollusk production; recent scientific literature finds that acidified ecosystems significantly reduce mollusk populations. Cooley and Doney (2009) conduct a case study of the effect of ocean acidification on U.S. fisheries revenues, with a focus on mollusks. If there were a reduction of 10 percent to 25 percent in the U.S. mollusk harvest from the 2007 level, $75 million to $187 million of direct revenue would be lost each subsequent year; these values correspond to a net present value loss (that is, the sum of annual losses over all futures years in terms of its current dollar value) of $1.7 billion to $10 billion through 2060. Similarly, using a partial-equilibrium model to assess the welfare loss to society from a decline in shellfish supply, Narita et al., (2012) find that the costs of ocean acidification could exceed $100 billion. Because mollusks represent a small fraction of total fisheries, the cumulative economic impact of ocean acidification on fisheries will likely be significantly larger. In addition to fisheries, ocean acidification will impact tourism associated with the ocean, particularly coral reefs. Coral reefs are expected to be among the worst-affected ecosystems. A study by Brander et al., (2009) considers the economic damages associated with coral reefs and estimates valuation per area. They expect losses in this sector to be at least $50 billion annually by 2050. It should be noted that the overall effects of climate change on tourism are also excluded, but the magnitude and direction of these effects is uncertain (Tol, 2009; Bigano et al., 2007) and potentially negative (Berrittella et al., 2006)