Assumptions of Spontaneous Decarbonization in the IPCC AR5 Baseline Scenarios

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Abstract

Projections of future climate change depend upon future anthropogenic greenhouse gas emissions. In preparation for its Fifth Assessment Report, the Intergovernmental Panel on Climate Change implemented a new approach to generating emissions scenarios, called 'Representative Concentration Pathways' (RCPs), which replace the scenarios in the 'Special Report on Emissions Scenarios' (SRES). The RCPs are designed to provide a range of emissions consistent with a particular radiative imbalance, but projected climate policy actions are heavily influenced by the choice of 'reference' or baseline scenario, often derived from the SRES. Here we show that 'built in' to the RCP reference cases are some of the same implicit and aggressive assumptions regarding rates of the decarbonization of economic activity found in the SRES [1]. Rates of 'automatic' reduction in energy and carbon intensities in the RCPs in the absence of policy are broadly inconsistent with observations from 2000-2008. The 'stabilization' pathways

used to drive physical climate models are more aggressive still, with reductions in carbon and energy intensities substantially larger than observed. The fact that much of the required improvement in energy and carbon intensities are built into the RCP reference scenarios has profound implications for our ability to evaluate climate stabilization goals.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) assesses the science, impacts and mitigation of climate change in periodic "Assessment Reports", of which the most recent is the Fourth Assessment Report, or AR4 [2]. The reports of the IPCC are unique in that they are formally approved by participating governments, and thus have an authoritative status in international policymaking. To project future climate change, emissions scenarios describing future technological and demographic changes are required: until recently, the state of the art in emissions scenarios was the set of projections described in the 2000 'Special Report on Emissions Scenarios', or SRES [3]. The SRES scenarios are divided into four major 'families' which differ in future rates of population and economic growth, as well as energy usage. Generally speaking, the A scenarios (particularly A1B) provide projections closer to 'business as usual'. The past 10 years have, however, seen emissions surpass the A1B scenarios for greenhouse gas (GHG) emissions. During the past decade in aggregate, demographic and economic trends appear relatively well represented in the SRES [4], which indicates that the underestimates result from assumptions regarding energy use and CO_2 emissions [1,5].

The IPCC has altered its approach to scenario construction for the forthcoming Fifth Assessment Report (AR5; [6]). The new ‘Representative Concentration Pathways’ (RCPs) specify a radiative imbalance at which the atmosphere will stabilize, rather than the greenhouse gas concentrations themselves: that imbalance is consistent with a range of social, technological and economic pathways. Four RCPs were adopted for AR5, constructed with four different integrated assessment models: these were selected from the peer-reviewed literature to span a range of potential climate outcomes. The RCPs are referred to by the radiative imbalance (in watts per meter squared) at the top of the atmosphere in 2100: thus we have the RCP 2.6 [7,8], RCP 4.5 [9], RCP 6.0 [10], and the RCP 8.5 [11].

The RCPs are properly regarded as “stabilization scenarios”, which combine climate policy projections with a simplified climate system model to provide an optimal emissions pathway. However, built into each RCP is a “baseline scenario”, which is a projection of future emissions in the absence of climate policy: this is the ‘starting point’ for evaluating projected policy actions, including their costs, and is thus the relevant scenario for evaluation of assumptions of spontaneous decarbonization.

Here we show that significant technological advances are built into the baseline RCP plans, just as was the case for the SRES scenarios. This analysis discusses the spontaneous technological advances – and commensurate decarbonization – built into the RCPs, following the analysis of [1].

3. Assumed Decarbonization of Economic Activity via Reductions in Carbon and Energy Intensities in the RCP Reference Scenarios

The widespread adoption of less carbon-intensive energy technologies is fundamental to all stabilization scenarios with positive rates of economic growth [12,13,14]. This is generally referred to as the decarbonization of the economy [1]: the rate at which the carbon emission per unit of gross domestic product decreases with time. The decarbonization rate is the product of two quantities from the Kaya Identity: carbon intensity (CI) and energy intensity (EI) as a function of time. (The other two quantities are per capita wealth and population). CI measures the carbon emission required per unit of energy consumed, while EI reflects the energy consumed per unit of GDP. Reductions in both CI and EI are required to achieve the necessary levels of decarbonization described in the RCPs.

Pielke et al. (2008)[1] look into the projected decarbonization rates generated from AR4 data. Using a 'frozen technology' baseline, they show that the decarbonization in the AR4 simulations relies on 'automatic' efficiency improvements built into the baseline scenarios (i.e., those without climate policy) which are inconsistent with advances in energy efficiency to date. In fact, those built-in improvements account for the vast majority of CO_2 emissions reductions to 2100 (see Figure 3). Are the same assumptions built into AR5?

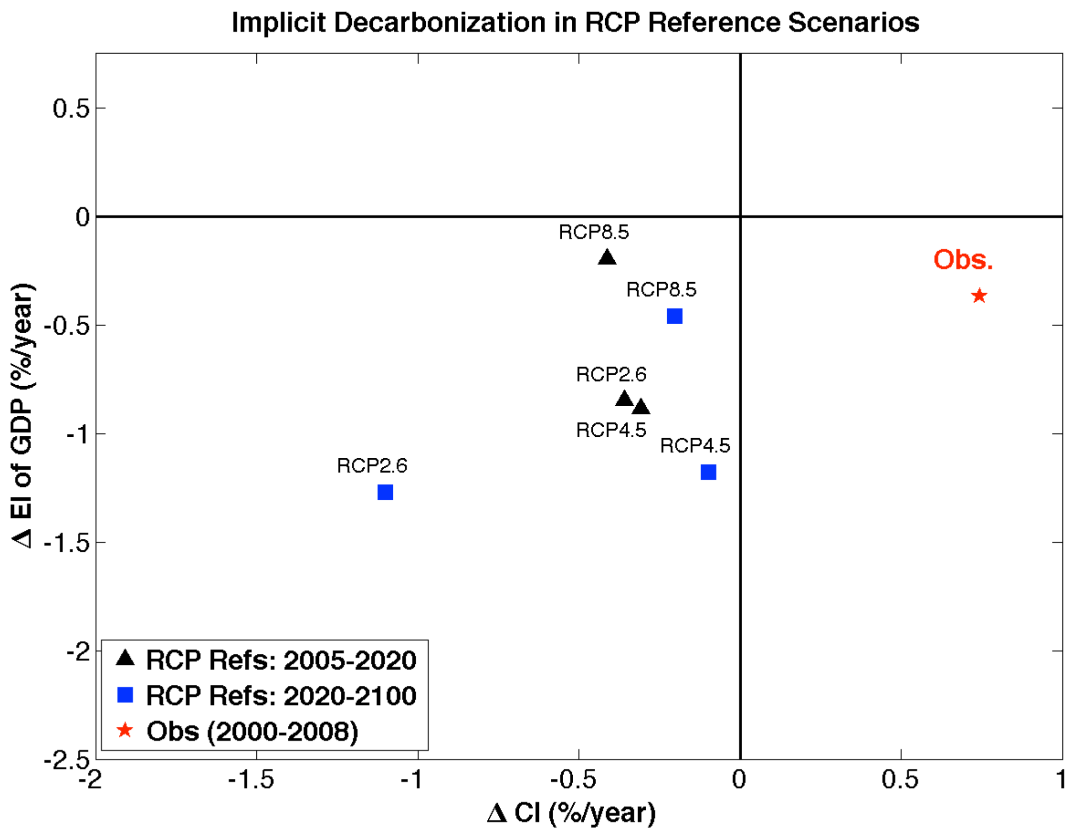

Figure 1: Rates of decarbonization in three of the RCP baseline scenarios for which data is available as compared with the observed rate. This figure is modeled after Figure 2 from [1]. Observations are from the World Bank database for 2000-2008.

The RCP reference scenarios are used here to evaluate the CI/EI reductions in the absence of climate policy. RCP2.6 [7,8] is the most stringent pathway, and the reference scenario used is a modified version of the SRES B2 [15,16,17]. RCP 4.5 provides the lower intermediate pathway, with a reference scenario (the 'GCAM Reference') developed independently by the GCAM group[9]. The same is true for RCP6.0, where the baseline was developed by the AIM group[10] using International Energy Association (IEA) data. Unfortunately no reference data is publicly available for RCP6.0, but the CI/EI reductions should fall within the range encompassed by the other RCPs based on a description of the baseline scenario in [18]. Finally, the highest forcing pathway, RCP 8.5 [11,19] used baseline emission scenarios derived from the SRES A2 family (the IIASA A2r simulation).

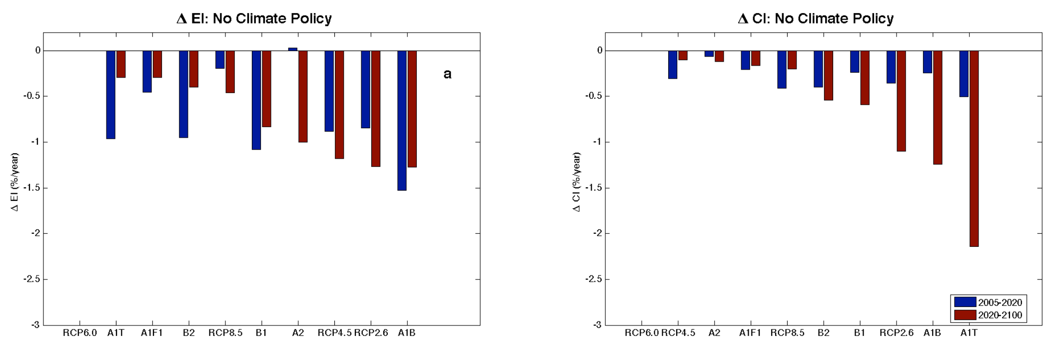

Figure 2: Mean reductions in a) EI and b) CI, averaged over the periods 2005-2020 and 2020-2100. Both SRES and RCP reference scenarios are shown for comparison.

CI and EI values for the RCP reference cases are shown in Figure 1. CI and EI are averaged over 2005-2020 (black triangles) to provide an estimate of short-term changes, and 2020-2100 (blue squares) to give a sense of the sustained improvements over the course of the 21st century necessary to achieve stabilization targets. All of the RCP references show reductions in CI of -0.2%/year or more: but over the 2000-2008 period, CI has in fact increased. For EI, recent observations fall just above the range covered by the RCPs. However, current CI/EI reductions are insufficient to meet even the least stringent RCP climate stabilization goals.

Next we compare the RCP references with the SRES. Figure 2 shows EI and CI averaged over 2005-2020 and 2020-2100 for both the SRES and RCPs. Notable pairings in Figure 2 are SRES B2/RCP 2.6 and SRES A2/RCP8.5, which allow for comparisons between CI/EI reductions *in the absence of climate policy* between the RCPs and the SRES baselines from which they were derived. The RCP 8.5 reference assumes a larger CI reduction than SRES A2 in both the short and long-term projections; in EI the RCP reference is less ambitious than SRES. In the RCP 2.6 reference the comparison is even more striking: both CI and EI show larger sustained (2020-2100) reductions than the SRES B2. Thus in both cases where direct comparisons are possible between the SRES and RCP references, the RCP shows even larger 'built-in' rates of decarbonization than its predecessor.

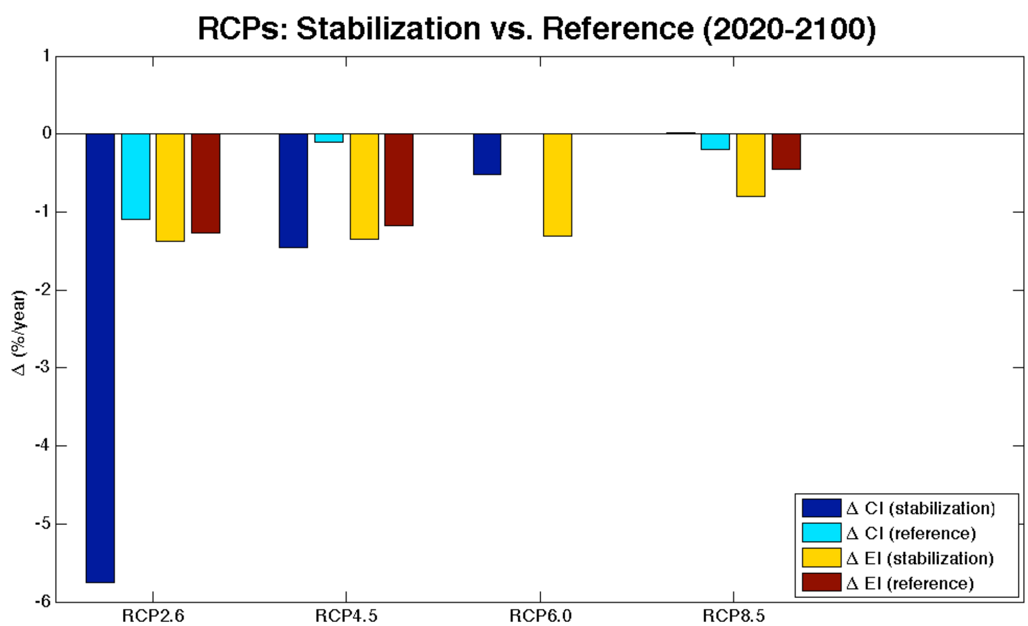

Figure 3: Rates of decarbonization in the RCP reference and stabilization scenarios. The reference scenarios for RCP 6.0 are unavailable and thus not shown.

Finally, the stabilization pathways are considered (Figure 3). Data used in Figure 3 comes from GCAM, and consists of the official RCP4.5 scenario along with the GCAM 'replicates' of the other three pathways. As one would expect, given that the RCP references are themselves ambitious compared with current economic development, the mitigation pathways are even more so. The difference between the stabilization and reference scenarios in Figure 3 represents the action of climate policies: in RCP8.5, 4.5 and 2.6 there is little difference between the EI reductions during 2020-2100. In other words, the majority of the EI reductions in the RCPs can be considered to happen 'automatically'. The situation is different for CI, where RCP2.6 and 4.5 show marked shifts between the reference and stabilization scenarios. Thus less CI reductions are built into the RCP stabilization scenarios.

4. Conclusions

The RCPs developed for the IPCC Fifth Assessment Report are designed to provide independence from socioeconomic scenarios, but share many of the same 'baseline' assumptions as did the SRES scenarios of AR4. A comparison of the carbon and energy intensity reductions in the RCP baseline scenarios for 2005-2020 and 2020-2100 shows that assumptions of spontaneous decarbonization rate in the reference scenarios are similar to the results from the SRES. In fact, for the RCPs (2.6 and 8.5) where the reference scenarios are derived from SRES families, CI and EI reductions are even larger over the 2020-2100 period. This implies that the IPCC continues to use very aggressive assumptions of spontaneous technological advancement and deployment as the basis for evaluating mitigation efforts.

Both authors contributed to the work presented in this paper. S.S. obtained all data and conducted the analysis, and S. S. and R.P. wrote the manuscript.

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