

Carbon, climate and humans: Australia in the Earth System

Michael R. Raupach

CSIRO Marine and Atmospheric Research, Canberra, Australia

Abstract: Climate change and its hydrological impacts will have far-reaching consequences for Australia (along with other Mediterranean-climate regions in both hemispheres) because of mid-latitude drying trends. To address the principal driver, uncontrolled anthropogenic CO₂ emissions, a rule is proposed for allocation of a biophysically limited cumulative global emission of CO₂.

The new global ecology

Humans have transformed the environment in which evolution occurs, so that the earth now functions as a coupled biophysical-human system (Steffen *et al.* 2004; Field and Raupach 2004). The industrial revolution brought about a dramatic acceleration of this planetary transformation (Figure 1). Growth in per-capita Gross Domestic Product (GDP), a surrogate for per-capita human energy use, accelerated in the few decades 1800-1850 from negligible to its present growth rate, a doubling every 45 y. Economic growth, with its associated energy and ecological demands, is a very recent phenomenon.

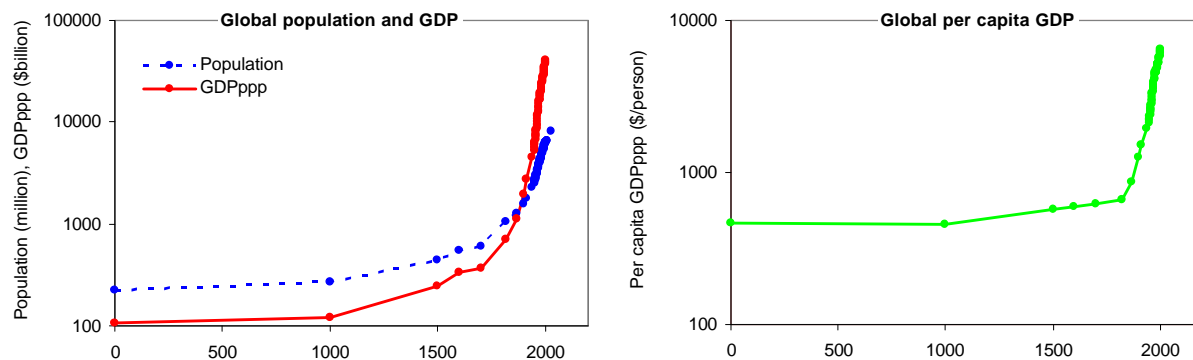


Figure 1: Changes over the past two millennia in global population, GDP (in Geary-Khamis international 1990 dollars, a unit with constant purchasing power) and per capita GDP. Source: Historical Statistics for the World Economy: 1-2003 AD, by Angus Maddison, Groningen Growth and Development Centre (<http://www.ggdc.net/maddison/>).

Climate change induced by rising concentrations of greenhouse gases (GHGs) is a direct consequence of this growth pattern and its dependence on fossil energy. The dominant contribution comes from CO₂ emissions from fossil fuels, which make up about 2/3 of all GHG emissions in terms of 100-year radiative forcing (IPCC 2007). The result is a rapid and currently uncontrolled buildup of CO₂ and other GHGs in the atmosphere, in turn provoking other positive feedbacks such as the ice-albedo feedback, climate feedbacks from cold and hot wetland releases of CO₂ and methane, terrestrial water-carbon feedbacks from increased drought, ocean circulation changes, etc.

CO₂ emissions

Figure 2 (from Raupach *et al.* 2007) shows that global fossil fuel emissions are growing faster than even fossil-fuel-intensive emissions scenarios, let alone stabilisation trajectories. Drivers include the growth of emissions with income (Figure 3) and the properties of carbon intensities (Figure 4).

Australia, with 0.32% of world population, contributed 1.43% of fossil-fuel CO₂ emissions in 2004 (104 MtC y⁻¹ or 381 MtCO₂ y⁻¹). Australia's carbon intensity of energy (fossil fuel burned per unit of energy produced) is 20% higher than the world average, and 25 to 30% higher than values for the USA, Europe and Japan (Figure 4). Australia's carbon intensity of GDP (fossil fuel burned per dollar of GDP) is

25% higher than the world average and nearly double that of Europe and Japan (Figure 4). For 1980-2004, the average growth rate of Australian emissions was about twice that for the world, twice that for the USA and Japan, and five times that for Europe. The rate of improvement (decline) in the carbon intensity of GDP for Australia is lower than in the USA and Europe.

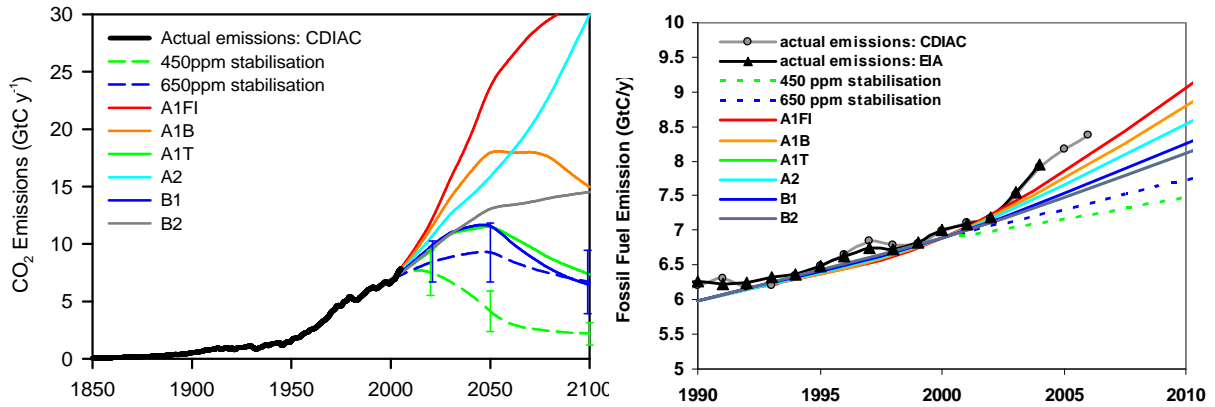
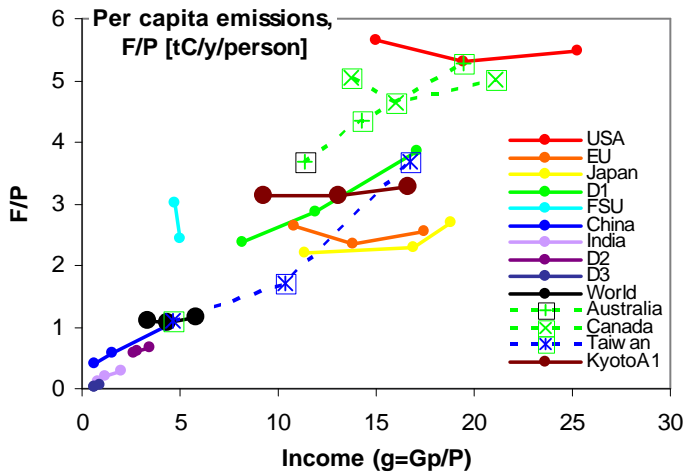
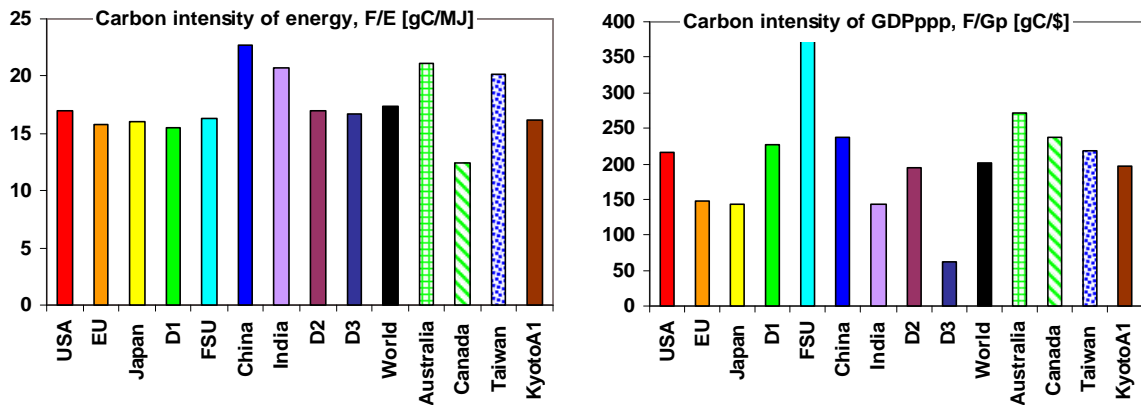


Figure 2: Observed global CO₂ emissions from fossil fuels, compared with IPCC SRES emissions scenarios and stabilisation trajectories. Data are from EIA and CDIAC, and are normalised to same mean for 1990-1999 because of small accounting differences between the two data sets. Left panel shows period 1850-2100; Right panel shows 1990-2010, including an update and revision of the CDIAC data to 2006. For details see (Raupach *et al.* 2007).



(Left) Figure 3: Per capita CO₂ emissions (F/P) plotted against per-capita income defined with GDP-PPP (G_p/P), for 9 regions spanning the world: USA, EU, Japan, other developed nations (D1), FSU, China, India, other developing nations (D2), least developed nations (D3). Also shown are the world average, three D1 nations (Australia, Canada, Taiwan) and the average for Kyoto Annex 1 nations. Points linked by lines represent values in 1980, 1992 and 2004 (left to right). Data from (Raupach *et al.* 2007).

(Below) Figure 4: Carbon intensity of energy and carbon intensity of GDP-PPP, both in 2004, for regions in Figure 3.



Global and local targets

Let us consider connections between global and local actions, using Australia as an example. Many impacts of climate change (on water resources, agriculture, terrestrial ecosystems, coral reefs, human health, coastlines, ...) will be very significant for Australia (Steffen *et al.* 2006), perhaps proportionally more than for other developed nations. Adaptation is possible and important, but there is a point beyond which a global GHG mitigation strategy is essential for Australia's long-term national interest. This is clearly apparent in the water challenge faced by southern Australia (along with other Mediterranean-climate regions in both hemispheres) arising from mid-latitude drying trends superimposed on a globally wetter and warmer future climate (IPCC 2007).

Important elements of any mitigation strategy are (1) a global GHG emissions reduction target, and (2) a concept of how the target should be shared. These elements are needed whether the main mechanism for achieving future emissions reductions is an international Kyoto-style treaty with negotiated targets, or cooperative behaviours evolving naturally from the unilateral responses of nations repeatedly playing a common climate game (Liebreich 2007).

The global emissions target: A broad, long-range target for avoiding "dangerous" climate change is necessary because of biophysical, social, technological and policy inertias in carbon-climate-human feedbacks (Field and Raupach 2004). Recent analyses (eg Schneider and Lane 2006) have emphasised that this target is a value judgement.

There has been recent widespread affirmation (eg by the UK Stern Review in 2006) of the 1995 European Union target of a 2 degC temperature rise above preindustrial levels. About 0.8 degC has already occurred and about an equal increment is committed in the future by climate-system inertia (IPCC 2007). To keep the probability of exceeding this 2 degC target to less than 50%, GHG concentrations must stabilise at 440 (± 70) ppm CO₂eq (Meinshausen 2006, Fig 28.5 and Table 28.1) or at less than about 400 ppm CO₂. At current CO₂ growth rates, 400 ppm CO₂ will be reached within a year or two of 2017, and 440 ppm CO₂eq has arguably been passed already. Hence, this target seems unrealistic.

Let us express a long-term (~100 y) target simply as a maximum allowable cap on *cumulative* total CO₂ emissions (from fossil fuels and land use) from 2000 to 2100. An illustrative cap is 500 GtC, which is consistent with stabilisation at approximately 500 to 550 ppm CO₂ (Meinshausen 2006, Fig 28.3) and a stabilisation temperature around 2.5 to 3 degC above preindustrial under a median climate sensitivity to CO₂ doubling. A lower cap would provide more allowance for the possibility of positive climate and carbon-climate feedbacks, which would imply a higher climate sensitivity.

Even a 500 GtC cap is a severe challenge. In the six years 2001-2006, 55 GtC has already been emitted. Total emissions were 9.85 GtC y⁻¹ in 2006, with a growth rate above 3% y⁻¹ (Raupach *et al.* 2007; Canadell *et al.* 2007). If this growth rate continues, a 500 GtC cap will be reached around 2035.

Sharing future emissions: By focusing on cumulative emissions, the problem of defining targets is changed from determination of flux trajectories to allocation of a stock, the non-renewable resource represented by the remaining capacity of the planet to bear CO₂ emissions from fossil fuels. How should this resource be divided among nations? This is a highly negotiable question to which it is not possible to give a simple answer, but it is possible to place the answer within simple bounds.

Cumulative emissions through the 21st century could be allocated according to (a) current shares of global annual emissions (1.43% for Australia), or (b) population (0.32% for Australia). Option (a) locks in present global inequalities in the use of fossil fuels for development and wealth creation (Figure 3), while (b) immediately removes all present inequalities. Neither is politically acceptable: developing nations require differentiation of targets and would not accept (a), and (b) is unacceptable to developed nations. Therefore let us consider a middle option, (c), in which the share of nation receives a share midway between those from options (a) and (b), determined using data for a reference year (present figures use 2004). This would provide a cumulative emission of 0.87% of 500 GtC = 4400 MtC, for Australia, which

will last about 42 years from 2000 at a constant (2004) emission rate. Stated formally, the share of globally capped 21st century cumulative emissions for nation i is $wF_i/F + (1-w)P_i/P$, where F_i and P_i are emissions and population for nation i at a reference time, F and P are global totals at that time, and w is a globally uniform weight ($0 \leq w \leq 1$). Options (a), (b) and (c) correspond to $w = 1, 0$ and $1/2$, respectively, and option (c) can be varied by choosing w other than $1/2$.

Climate change as a tragedy of the commons: Climate change is now widely seen as a "Tragedy-of-the-Commons" problem (Hardin 1968). Solutions for these problems involve the natural or engineered emergence of "adaptive governance in complex systems". Known prerequisites (Dietz *et al.* 2003) are the ability for users of the commons to (1) monitor their common resource, (2) devise rules for sharing and nurturing it, (3) induce compliance with the rules, (4) resolve rather than escalate conflicts, and (5) adapt to change. All of this relies on a store of "social capital" (Pretty 2003): the understandings, institutions and basic trust which enable users of the commons to work together. From this perspective, international negotiations are a critical step in building the global social capital needed for the sharing of emissions. This is true whether emissions reductions are sought by treaty (Kyoto-style) or by the emergence of cooperative behaviours from repeated plays of a climate game (Liebreich 2007).

Summary: This paper explores (1) placing a firm cap on global cumulative 21st century emissions, and (2) apportioning this stock according to a weighted mix of population share and emissions share in a reference year. One general advantage of a stock approach is that nations have flexibility in choosing an emissions trajectory consistent with the cumulative constraint, limited only compliance requirements.

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