"We need a better understanding of how the alchemy of music depends on texture." see page 160

endogenous and policy-driven intensity improvements. Given recent trends, it is hard to see how, without a massive increase in investment, the requisite number of relevant technologies will be mature and available when we need them.

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Future scenarios for emissions need continual adjustment

SIR — Pielke *et al.* show that the 2000 *Special Report on Emissions Scenarios* (*SRES*) reflects unrealistic progress on both the supply and demand sides of the energy sector. These unduly optimistic baselines cause serious underestimation of the costs of policy-induced mitigation required to achieve a given stabilization level.

This is well known among experts but perhaps not to the public, which may explain why some politicians overstate the impact of their (plans for) climate policy, and why others argue incorrectly that 'available' off-the-shelf technologies can reduce emissions at very little or no cost.

The numbers presented by Pielke *et al.* are revealing, but they divert attention from a more serious problem underlying the *SRES* approach to calculating mitigation costs: a failure to incorporate the dynamic nature of the decision problem into climate-policy analysis. Until we can keep adjusting the analysis by continually incorporating uncertainty, correction and learning, we shall continue to offer policy-makers an incomplete guide to decision-making.

The focus of policy analysis should not be on what to do over the next 100 years, but on what to do today in the face of many important long-term uncertainties. The minute details of any particular scenario for 2100 are then not that important. This can be achieved through an iterative risk-management approach in which uncertain long-term goals are used to develop short-term emission targets. As new information arises, emission scenarios, long-term goals and short-term targets are adjusted as necessary. Analyses would be conducted periodically (every 5–10 years), making it easier to distinguish autonomous trends from policy-induced developments — a major concern of Pielke and colleagues. If actual emissions are carefully monitored and analysed, the true efficacy and costs of past policies would be revealed and estimates of the impact of future policy interventions would be less uncertain.

Such an approach would incorporate recent actions by developed and developing countries. In an 'act then learn' framework, climate policy is altered in response to how businesses change their behaviour in reaction to existing climate policies and in anticipation of future ones. This differs from *SRES*-like analyses, which ignore the dynamic nature of the decision process and opportunities for mid-course corrections as they compare scenarios without policy with global, century-long plans.

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Climate policies will stimulate technology development

SIR — Roger Pielke and his colleagues argue that the IPCC "seriously" underestimates the scale of the technological changes required to stabilize greenhouse-gas concentrations, and hence conveyed an inappropriate message to policy-makers on policies required for mitigation. We believe that this argument is based on a flawed analysis.

The authors repeat a 'thought experiment' done by the IPCC, to find out what would happen over the next century if technology were frozen at present levels. In that case, the emission reductions required to reach any of the assessed greenhouse-gas stabilization levels would far exceed those computed by any of the mitigation scenarios reviewed in the IPCC fourth assessment report (AR4).

It is most unlikely, however, that technology will be frozen. Over the past 30 years, the decrease in energy intensity has been 1.1% a year — well above the 0.6% a year assumed in 75% of the energy scenarios assessed by the IPCC.

Developments in China since 2000 do raise concerns that the rate of decrease in energy and carbon intensity could slow down, or even be reversed. However, similar short-term slow-downs in technical progress have occurred in the past, only for periods of more rapid development to compensate for them. India, for example, does not show the decreasing trend in energy efficiency seen in China.

The increase in fossil-resource prices triggered by high economic growth will lead to an increase in energy efficiency. Admittedly, a possible increase in carbon intensity caused by a renaissance of coal is a worst-case scenario for any climate policy. But the impact of increasing fossil-fuel prices on technological change and on mitigation costs, or policies, cannot be analysed in any meaningful way for policy-makers by assuming a 'frozen technology' scenario.

The IPCC's main policy conclusions stand: present technologies can stop the rise in global emissions. But they will depend on governments' policies to ensure that the technologies reach the market in time. A carbon price on emissions will promote investment in lower-carbon technologies, and climate policies will stimulate technological development to bring emissions and mitigation costs down further.

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IPCC's climate-policy assumptions were justified

SIR — Pielke *et al.* suggest that the IPCC underestimates the challenge of global warming. I find their analysis misleading.

They criticize the IPCC for implicitly assuming that the challenge of reducing future emissions will mostly be met without climate policies. But the IPCC's *Special Report on Emissions Scenarios* makes clear that, although the scenarios don't technically have climate policies, they can and do have energy-efficiency and decarbonization policies, which amount to the same thing (see IPCC reference emission scenario B1, which includes aggressive policies to help limit total global warming to about 2 °C). So advances towards reducing emissions are indeed policy-driven.

The authors also caution the IPCC against assuming that spontaneous advances in technological innovation will be instrumental in cutting future emissions. They claim that the IPCC is actually diverting attention away from policies that could stimulate technological innovation, pointing out that enormous advances in energy technology will be needed to stabilize atmospheric carbon dioxide to acceptable concentrations. This claim is unjustifiable: in fact, the IPCC report makes clear that we have the necessary technologies, or soon will, and focuses on creating the conditions for rapid technological deployment.

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