

The Role of Technology in Addressing Climate Change

Jae Edmonds and Gerry Stokes¹

Two recent papers published in *Science* have addressed the question of technology's role in addressing climate change. Hoffert et al.² challenged the IPCC's statement that ". . . known technological options could achieve a broad range of atmospheric CO₂ stabilization levels, such as 550 ppm, 450 ppm or below over the next 100 years or more. . . . Known technological options refer to technologies that exist in operation or pilot plant stage today. It does not include any new technologies that will require drastic technological breakthroughs. . ." they asserted that the IPCC claim demonstrates "misperceptions of technological readiness" and calls for "revolutionary changes" in mitigation technology. Pacala and Socolow³ argue that "*Humanity can solve the carbon and climate problem in the first half of this century simply by scaling up what we already know how to do.*" They are both right; and they are both wrong.

It is true that stabilization of CO₂ concentrations at a level above approximately 300 parts per million (ppm) is *technically* feasible with known technologies simply by ceasing all net anthropogenic emissions of carbon to the atmosphere.⁴ This is the strategy implemented for most ozone depleting compounds through the Montreal Protocol. But, technical feasibility is not the question that is confronting the decision makers in the public and private sectors. Of far more importance is the question, what resources did society divert from other ends, such as health care or economic development, to obtain the desired outcome. In other words, what was the economic cost? For example, it would be possible to stabilize with 1750's technology, since in 1750 the global energy system was dominated by biomass. However the societal price would be horrific, giving up the ease of electricity, transportation dominated by walking, deforestation would denude the land, and food would have to compete with fuel for land. From this perspective, the critical observation is that the role of technology in addressing greenhouse gas emissions mitigation is not to make mitigation possible, but rather to control cost, broadly construed. The better the technology, the lower the cost. That is, all other things being equal, improvements in mitigation technology reduce the cost of obtaining any particular level of environmental protection. The economic value of improving a particular technology depends on many factors—the economic performance of competing technologies, the economic performance of complementary technologies, the timing and degree of improvement, and the applicability of the technology to deliver

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² Hoffert, M. et al. 2002. Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet. *Science* 298(1):981-987.

³ Pacala, S. and R. Socolow. 2004. Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. *Science* 305:968-972.

⁴ Kheshgi, H., Smith, S.J., and Edmonds, J. 2005. "Emissions and Atmospheric CO₂ Stabilization: Long-term Limits and Paths," *Mitigation and Adaptation Strategies for Global Change, Climate Change and Environmental Policy*. 10: 213–220. [PNNL-SA-38439]

energy services across space and time. Yet, the potential payoff is denominated in 10^{12} USD⁵.

Technology Today, in 2050 and in 2100

Time also has economic value and is a critical resource in addressing climate change. Time is required to retire old technology, deploy new technology, conduct the R&D that creates new options, and to allow time for ubiquitous technology spillovers. Further, while actions are only taken in the present, they are taken in the shadows of past decisions and cast shadows of their own into the future. The time and geographic scales of the climate problem and its inherent implications for risk management lie outside of the political and institutional comfort zones of most decision makers in both the public and private sectors. The scales encompassed by the issue are daunting. A large CO₂ storage experiment today accounts for tens of millions of tons of CO₂. By 2050 billions of tons could be stored, and by the end of the century, hundreds of billions of tons could be stored in geologic repositories, in a world stabilizing CO₂ concentrations. By the end of the century, commercial biomass energy crops could be the largest managed ecosystems on the surface of the planet⁶. Literally millions of wind turbines and thousands of nuclear reactors could be deployed in that same time frame. Yet, much needs to be accomplished for that scenario to come to pass, not the least of which are the establishment of the social, political, and regulatory regimes that would facilitate the deployment of these technologies⁷.

Stabilizing the concentration of CO₂ in the atmosphere implies that annual global emissions must peak and then begin a decline that proceeds indefinitely thereafter⁸. Thus, global emissions mitigation requirements will grow throughout the century⁹. In the post-2050 period cumulative emissions mitigation may be as much as an order of magnitude larger than in the period between the present and 2050.

Pacala and Socolow are right in arguing that the foundations for the stabilization of CO₂ must be laid in the years and decades immediately ahead. If those foundations are not

⁵ Edmonds, J.A., T. Wilson, and R. Rosenzweig. 2001. *A Global Energy Technology Strategy Project Addressing Climate Change: An Initial Report on International Public-Private Collaboration*. Joint Global Change Research Institute, College Park, MD.

⁶ Edmonds, J.A., J. Clarke, J. Dooley, S.H. Kim, R. Izaurralde, N. Rosenberg, and G. Stokes. 2003. "The Potential Role of Biotechnology in Addressing the Long-term Problem of Climate Change in the Context of Global Energy and Ecosystems," *Greenhouse Gas Control Technologies*, J. Gale and Y. Kaya (eds.). Pergamon, Amsterdam. Pp. 1427-1432. [PNNL-SA-37370]

⁷ Dooley, James, J., Robert T. Dahowski, Casie L. Davidson, Marshall A. Wise, N. Gupta, S.H. Kim, and E. L. Malone. 2006. *Carbon Dioxide Capture and Geologic Storage—A Core Element of a Global Energy Technology Strategy to Address Climate Change*. Joint Global Change Research Institute (JGCRI), Battelle Memorial Institute, College Park Maryland; and Edmonds, J.A. and G.M. Stokes. 2004. "Launching a Technology Revolution," in *Climate Policy for the 21st Century: Meeting the Long-Term Challenge of Global Warming*, The Brookings Institution, Washington DC.

⁸ Wigley, T.M.L., R. Richels and J. A. Edmonds. 1996. "Economic and Environmental Choices in the Stabilization of Atmospheric CO₂ Concentrations," *Nature*. **379**(6562):240-243.

⁹ Edmonds, J.A., T. Wilson, and R. Rosenzweig. Op. site.

laid appropriately, then the “carbon shadow”¹⁰ implies commensurately more dramatic emissions mitigation in the second half of the century for any environmental goal and the attendant higher costs for the same environmental benefit. But, Hoffert et al. are also right in pointing to the need for the continued development of technology throughout the century—not because stabilization is impossible without those technology improvements, but because technology improvements will enable society to control costs. Technology creation and development is a complex process¹¹. But, the payoffs to accelerating the process are large. If for example, the rate of improvement of end-use energy intensity could be accelerated by 0.25 percent per year, the cumulative effect on fossil fuel CO₂ emissions could be to reduce annual global fossil fuel CO₂ emissions by as much as the global total¹².

¹⁰ Stokes, G.M., C.J. Bernier, A.L. Brenkert, and S.J. Smith. 2004. *Current Carbon Emissions in Context: Final Report to the National Commission on Energy Policy*. Battelle Memorial Institute, Joint Global Change Research Institute (JGCRI), College Park, MD.

¹¹ Clarke, L. and J. Weyant. 2002. “Modeling Induced Technological Change: An Overview,” In A. Grübler, N. Nakicenovic, and W. Nordhaus (Eds.), *Technological Change and the Environment*. Resources for the Future, Washington, DC.

¹² Edmonds, J. and S. Smith. 2006. The Technology of Two Degrees. *Avoiding Dangerous Climate Change*, Schellenhuber, H J., Cramer, W., Nakicenovic, N., Wigley, T. and Yohe, G (Eds). Cambridge University Press. Pp. 385-392. PNNL-SA-45609