

David Keith

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Citizenships: Canada, United States and United Kingdom.

Education

- B.Sc. University of Toronto, 1986: Physics.
- Ph.D. Massachusetts Institute of Technology, 1991: Experimental Physics, “An Interferometer for Atoms”, supervised by David Prichard.

Academic Employment

2011–Present: Gordon McKay Professor of Applied Physics in the School of Engineering and Applied Sciences (SEAS) and Professor of Public Policy at the Harvard Kennedy School, Harvard University.

2009–Present: President, Carbon Engineering Ltd.

2004–2011: University of Calgary, Canada Research Chair in Energy and the Environment; Director and Professor, ISEEE Energy and Environmental Systems Group; Professor, Department of Chemical and Petroleum Engineering; Adjunct Professor, Faculty of Environmental Design, 2007-present, Faculty of Physics and Astronomy, 2010-present, and Department of Economics, 2004-2008.

1999– 2011: Carnegie Mellon University, Department of Engineering and Public Policy, Adjunct Professor, 2004-2011; Assistant Professor, 1999-2003; Adjunct Assistant Professor, 1992-1999; Post-Doctoral Fellow, 1991-1992.

1993–1999: Research Scientist, Harvard University, Department of Earth and Planetary Science.

1992–1993: National NOAA Global Change Fellowship, National Center for Atmospheric Research, Climate Modeling Section.

Awards

- Time Magazine, Hero of the Environment, 2009.
- The City of Calgary Award for Environmental Achievement by an Individual, 2008.
- Canadian Geographical Society, Environmental Scientist of the Year, 2006.
- MIT Martin Deutsch Prize, MIT’s biennial prize for excellence in experimental physics, 1989.
- Canadian Association of Physicists, National University Prize Exam, First prize, 1986.

Research Foci

My research has spanned four domains: climate-related technology assessment and policy analysis, technology development, atmospheric science, and physics.

- *Climate-related technology and policy assessment*, including:
 - Methods for eliciting and analyzing quantitative expert judgments about climate science and energy technologies from climate sensitivity to solar PV.
 - Environmental impacts of energy technologies including the development of Canada’s leading effort to assess the lifecycle impacts of oil sands technologies; the first study of the climate

impact of large-scale wind power; and most recently, the development of new methods for quantifying the land use footprint of energy technologies.

- Integrated assessment of CO₂ capture and storage (CCS) including early work on its implications for public policy, its risk and costs, the potential for biomass energy with CCS, the factors that determine public perception of these technologies, and the difficulties of managing CCS risks within current regulatory frameworks. In Canada, I served on several high-profile committees that influenced governments to commit \$2B to a set of commercial CCS demonstration projects.
- Technology assessments examining, for example, viability of hydrogen as a transportation fuel and the economics of integrating large-scale wind power into electricity systems.
- Assessment of geoengineering. In 1990 I wrote one of the first comparative technology and policy assessments of geoengineering, work that grew into a more systematic look at the technology and its historical roots. Over the last few years I have organized interdisciplinary meetings on geoengineering, created an annual summer school, and have worked to develop understanding of the risks, governance and public perception of climate engineering.
- *Technology development.* I lead Carbon Engineering, an angel-funded startup company developing industrial-scale technology for direct capture of CO₂ from ambient air. Carbon Engineering will spend more than ~\$6M on process engineering and hardware development over the next three years. In addition, I have developed novel methods for engineering reservoirs to minimize risk by CO₂ leakage by accelerating the dissolution of injected CO₂ in brine and new methods of lofting particles to the upper atmosphere for geoengineering using photophoresis.
- *Atmospheric science.* Working for James Anderson at Harvard, I lead the development of a new high-accuracy infrared spectrometer that flew on the NASA ER-2 high-altitude aircraft, an engineering effort that entailed about 15 scientific and technical personnel along with NASA pilots and engineers as well as Arrhenius, a proposed small satellite mission that was a precursor to CLARREO. In addition to experimental work, I used isotopic measurements to constrain models of water vapor transport and did the first analysis of the climatic impacts of wind power.
- *Physics.* As a graduate student with David Prichard I built the first interferometer for atoms, a high-profile experiment that was named among the 10 “hottest” areas of science by ISI and covered in news stories by *Science* and *Nature*; my publications on this work have been cited over 500 times.

Service

- Lead organizer of an annual transdisciplinary summer school on geoengineering jointly managed and funded by The University of Calgary, the University of Heidelberg, and Carnegie Mellon University.
- Member, Research Advisory Board, Electric Power Research Institute.
- Member, Geoengineering Task Force, National Commission on Energy Policy.
- Member, UK Royal Society’s geoengineering study panel, 2009.
- Member, Canada’s ecoENERGY Carbon Capture and Storage Task Force, 2007. Note: I was the only academic on this seven member panel that included three CEO’s and two deputy ministers.
- Member, InterAcademy Council (IAC) study on Transitions to Sustainable Energy, 2007. Note: The IAC is the union of the world’s major science academies. I was one of 15 experts world-wide named to their first energy study.
- Member, Canada’s National Advisory Panel on Sustainable Energy Technology, “Bruneau report”, 2006. Note: I was the only Canadian academic on this ten member panel.
- Member of the US National Academy of Sciences Panel on Benefits of Sequestration R&D.
- Lead author and chair of crosscutting group on Regulation, Legal Issues and Public Perception, of the IPCC Special Report on Carbon Storage. Note: As chair of one of the three crosscutting groups my responsibility was roughly equivalent to a “Convening Lead Author”. I became the *de facto* crosscutting lead for issues related to timescales and the risk of leakage, one of the most crucial issues for policymakers.

- Principal organizer of a major international workshop on Industrial Carbon Management, Aspen Global Change Institute, July 2000. The week-long workshop brought together 33 experts on capture technologies, geological and oceanic sequestration, technology policy, and representatives of major US and European environmental organizations.
- Consulting to a consortium of clients including Environment Canada and the provinces of British Columbia, Alberta and Saskatchewan. Developing protocols for managing the risk of geological sequestration of CO₂.

Testimony

Canadian House of Commons, Standing Committee on Energy, the Environment and Natural Resources (The Current State and Future of Canada's Energy Sector [Including Alternative Energy]). Calgary, AB. December 2011.

Canadian House of Commons, Standing Committee on Natural Resources (Energy Security in Canada). Videocon. November 2010.

UK House of Commons, Science and Technology Committee. London, UK. January 2010.

US House of Representatives, Committee on Science and Technology, Subcommittee on Energy and Environment. Geoengineering II: the Scientific Basis and Engineering Challenges. "Learning to manage sunlight: Research needs for Solar Radiation Management". Washington DC, US. February 2010.

Canadian House of Commons, Standing Committee on Energy, the Environment and Natural Resources (The Current State and Future of Canada's Energy Sector [Including Alternative Energy]). Ottawa, ON. April 2010.

Canadian House of Commons, Standing Committee on Natural Resources (Oil Sands). Ottawa, ON. December 2007.

Canadian House of Commons, Standing Committee (The Environment and Sustainable Development). Ottawa, ON. May 2007.

Canadian Legislative Committee. Bill C-30. Ottawa, ON. February 2007.

Publications

See keith.seas.harvard.edu for a more complete list with PDFs.

Under review

Carr, W., C. Preston, L. Yung, D.W. Keith, B. Szerszynski, A. Mercer. Public Engagement on Solar Radiation Management and Why it Needs to Happen Now. *Climatic Change*.

Hossein Safaei, David W. Keith and Ronald J. Hugo. Compressed Air Energy Storage (CAES) with compressors distributed at heat loads to enable waste heat utilization. *Journal of Applied Energy*.

Justin McClellan, David W. Keith, and Jay Apt. Cost analysis of stratospheric albedo modification delivery systems. *Environmental Research Letters*.

Douglas G. MacMartin, David W. Keith, Ben Kravitz, and Ken Caldeira. Managing tradeoffs in geoengineering through optimal choice of non-uniform radiative forcing. *Nature Climate Change*.

Published or accepted

Geoffrey Holmes and David W. Keith. An Air-Liquid Contactor for Large-Scale Capture of CO₂ from Air. *Philosophical Transactions of the Royal Society A – Mathematical, Physical & Engineering Sciences*.

Juan B. Moreno-Cruz and David W. Keith (2012). Climate Policy under Uncertainty: A Case for Geoengineering. *Climatic Change*, DOI 10.1007/s10584-012-0487-4.

- Katharine L. Ricke, Dan Rowlands, William J. Ingram, David W. Keith and M. Granger Morgan (2011). Effectiveness of stratospheric solar radiation management as a function of climate sensitivity. *Nature Climate Change*, **2**: 92-96.
- H. Safaei Mohamadabadi, R. Hugo and D. Keith (2011). Enhancing the economics of wind-based compressed air energy storage by waste heat recovery. *ASME Energy Sustainability Conference, Washington DC*.
- David Keith (2011). Reshaping the energy landscape. *Physics Today*, **64**: 56-57.
- A M Mercer, D W Keith and J D Sharp (2011). Public understanding of Solar Radiation Management. *Environmental Research Letters*, doi: 10.1088/1748-9326/6/4/044006.
- G. Doluweera, S. Jordaan, J. Bergerson, M. Moore and D. Keith (2011). Evaluating the Role of Cogeneration for Carbon Management in Alberta. *Energy Policy*, doi:10.1016/j.enpol.2011.09.051.
- David Keith, Juan Moreno-Cruz (2011). Pitfalls of coal peak production. *Nature*, **469**: 472.
- Eduard Cubi Montanya and David W. Keith (2011). LEED, Energy Savings, and Carbon Abatement: Related but Not Synonymous. *Environmental Science and Technology*, **45**: 1757-1758.
- Juan Moreno-Cruz, Katharine Ricke and David W. Keith (2011). A simple model to account for regional inequalities in the effectiveness of solar radiation management. *Climatic Change*, doi: 10.1007/s10584-011-0103-z.
- Douglas G. MacMynowski, Ho-Jeong Shin, Ken Caldeira and David W. Keith (2011). Can we test geoengineering? *Energy and Environmental Science*, **4**: 5044-5052.
- Ghaderi, S., D. Keith, R. Lavoie and Y. Leonenko (2010). Evolution of Hydrogen Sulfide in Sour Saline Aquifers During Carbon Dioxide Sequestration. *International Journal of Greenhouse Gas Control*, **5**: 347-355.
- Sonia Yeh, Sarah M Jordaan, Adam R Brandt, Merritt Turetsky, Sabrina Spatari and David Keith (2010). Land Use Greenhouse Gas Emissions from Conventional and Unconventional Oil Production. *Environmental Science & Technology*, **44**: 8766-8772.
- Ken Caldeira and David W. Keith (2010). The Need for Climate Engineering Research. *Issues in Science and Technology*, Fall: 57-62.
- Jeffrey R. Pierce, Debra K. Weisenstein, Patricia Heckendorn, Thomas Peter and David W. Keith (2010). Efficient formation of stratospheric aerosol for climate engineering by emission of condensable vapor from aircraft. *Geophysical Research Letters*, **37**: L18805.
- Keith, D. W. (2010). Photophoretic levitation of aerosols for geoengineering. *Proceedings of the National Academy of Sciences*, **107**:16428-16431.
- Kirsten Zickfeld, M. Granger Morgan, David J. Frame and David W. Keith (2010). Expert judgments about transient climate response to alternative future trajectories of radiative forcing. *PNAS*, **107**: 12451-12456.
- Joule Bergerson and David Keith (2010). The truth about dirty oil: Is CCS the answer? *Environmental Science & Technology*, **44**: 6010-6015.
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- Rhodes, J. S. and D. W. Keith (2009). Biomass co-utilization with unconventional fossil fuels to advance energy security and climate policy. *A synthesis report Sponsored by the National Commission on Energy Policy*. Washington DC, Bipartisan Policy Center.

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- Keith, D. (2009). Why Capture CO₂ From The Atmosphere. *Science*, **325**: 1654-1655.
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- Mahmoudkhani M., Heidel K.R., Ferreira J.C., Keith D.W. and Cherry R.S. (2009). Low energy packed tower and caustic recovery for direct capture of CO₂ from air. *Energy Procedia*, **1**: 1535-1542.
- Keith, D. (2009). Dangerous Abundance. *Carbon Shift: How The Twin Crises Of Oil Depletion And Climate Change Will Define The Future*. T. Homer-Dixon and N. Garrison eds, p 26-57, Random House, Toronto.
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- Eduard Cubi, David Keith and Jim Love (2009). Performance challenges of UFAD. *American Society of Heating, Refrigerating and Air-Conditioning Engineers*, **51**.
- Hassanzadeh, H., M. Pooladi-Darvish and D. W. Keith (2009). Accelerating CO₂ Dissolution in Saline Aquifers for Geological Storage--Mechanistic and Sensitivity Studies. *Energy & Fuels*, **23**: 3328-3336.
- Hassanzadeh, H., M. Pooladi-Darvish and D. Keith (2009). The Effect of Natural Flow of Aquifers and Associated Dispersion on the Onset of Buoyancy-driven Convection in a Saturated Porous Medium. *American Institute of Chemical Engineers Journal*, **55**: 475-485.
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Outreach

- I give 10-20 invited talks per year ranging from departmental colloquia at various north american universities to public talks at major national or international events to audiences up to 500.
- I often speak to Canadian industry and environmental groups, ranging from briefings for CEOs and environmental leaders to talks at major energy industry conferences.
- I have been interviewed by public media outlets such as the BBC, CBC, NPR, various talk radio, and Canadian and US TV networks as well as by reporters from *Science* and *Nature*.