An Action Plan to Reduce U.S. Global Warming Pollution

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The United Nations Framework Convention on Climate Change (UNFCCC) establishes the objective of preventing "dangerous anthropogenic interference with the climate system." While a "non-dangerous" concentration level has not been defined under the UNFCCC and is not a purely scientific concept, the European Union has set a goal of avoiding an increase of more than 2 degrees Celsius from pre-industrial levels in order to avoid the most dangerous changes to climate. This target finds strong support in papers presented at a conference hosted by Prime Minister Tony Blair at the Hadley Center, Exeter, in February 2005.[1]

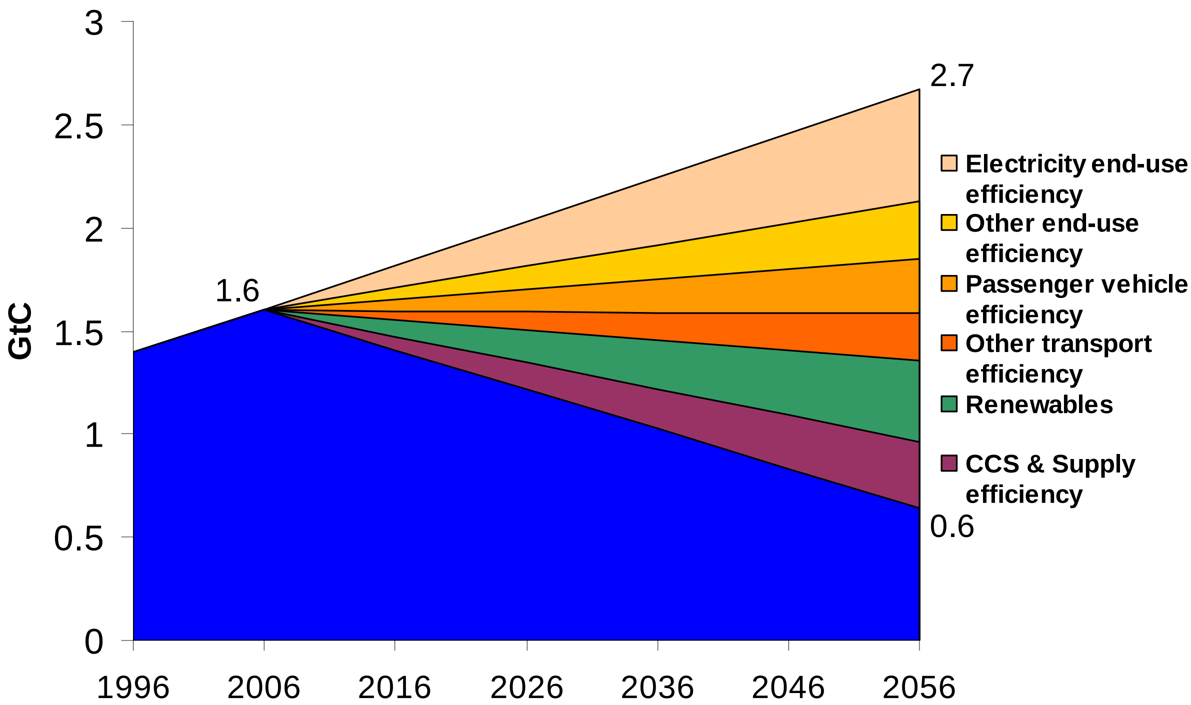
Meinshausen shows that greenhouse gas concentrations need to be stabilized below 450 ppm CO_2-equivalent in order to provide a high level of confidence that the 2 degree target will not be exceeded in this century.[2] His multi-gas scenario (S450Ce) has global energy-related CO_2 emissions equal to 480 billion metric tonnes of carbon (GtC) in the 21st Century. To obtain a U.S. CO_2 emissions budget consistent with this stabilization scenario the U.S. share of global emissions is assumed to decline from 25% to 5% linearly between 2000 and 2100. This results in a U.S. emissions budget of 84 GtC in the 21st Century.

A simplified pathway for allocating this emission budget over time can be constructed as follows: U.S. annual emissions have increased by about 5% since 2001 to 1.6 GtC in 2005, implying that the U.S. will have consumed almost 10 GtC of this budget through 2006.[3] The U.S. could stay within the remainder of its 21st Century emission budget by reducing emissions 60 percent linearly between 2006 and 2056 (consuming 56 GtC during that 50 year period) and then reducing emissions further from 0.64 GtC in 2056 to 0.2 GtC in 2100 (consuming the remaining 18 GtC).

This pathway contrasts with business as usual (BAU), in which emissions are expected to grow by 67 percent to 2.67 GtC in 2056. Required reductions from business as usual are therefore just over 2 GtC in 2056. Following Pacala and Socolow,[4] a "U.S. Wedge" can be defined as an emission reduction of 0.25 GtC 50 years from now, reflecting the fact that U.S. emissions are almost 25 percent of global emissions today. Hence, eight U.S. Wedges are needed to stay on the stabilization pathway over the next 50 years.

Kuuskraa et al. developed a spreadsheet model to examine U.S. emissions scenarios to 2050.[5] This tool facilitates accounting for the potential overlap between different measures (e.g., electricity end-use efficiency and renewable electricity supply) to develop self-consistent scenarios for the U.S. energy system. The Kuuskraa et al.'s spreadsheet model (extrapolated to

2056) is used here to construct an emissions scenario consistent with the U.S. carbon budget described above. In this scenario the largest reductions are obtained from energy efficiency improvements in electrical end uses, non-electric stationary end uses, and motor vehicles. Additional reductions come from renewable fuels and electricity and carbon capture and disposal at coal-fired power plants and other high-concentration industrial CO_2 vents. The elements of this scenario are briefly outlined below.



1. **Electric end-use efficiency, 2.2 Wedges (0.54 GtC):** Efficiency improvements in motors, lighting, refrigeration and other electrical equipment reduce total electricity consumption by 40% in 2056 compared to BAU. Resulting total electricity consumption is 4400 billion kilowatt-hours (BkWh), 20 percent greater than current consumption levels. California has demonstrated in practice that such reductions are possible. Sustained policies to promote energy efficiency through a combination of appliance standards, building code enforcement, and utility efficiency programs have stabilized per capita electricity consumption in California over the last 30 years while national per capita electricity use continued to grow such that per capital electricity consumption in California is now more than 40% lower than in the rest of the country.[6]

2. **Other end-use efficiency, 1.1 Wedges (0.28 GtC):** Improvements in building designs and industrial processes result in a 40 percent reduction in non-electric energy consumption by stationary sources compared to BAU. Overall emissions from these sources decline by 15 percent from current levels.

3. **Passenger vehicle efficiency, 1.1 Wedge (0.27 GtC):** Widespread use of hybrid vehicles, as well as improvements to conventional vehicles, raises the average fuel economy of the in-use vehicle fleet to 54 miles per, compared with 24 mpg under BAU.

4. **Other transport efficiency, 0.9 Wedges (0.23 GtC):** Heavy truck fuel economy increases to 13 mpg, compared with 7 mpg under BAU and aircraft efficiency increases to 105 seat miles per gallon (smpg), compared with 80 smpg under BAU. In addition, smart growth policies reduce total travel demand by 10 percent.

5. **Renewable energy, 1.6 Wedges (0.39 GtC):** Renewable energy (e.g. wind and biomass) accounts for 30 percent of total electricity generation by 2050, compared with less than 5 percent under BAU. This much electricity could be supplied by 500 GW of wind (e.g. 250,000 2-MW-turbines). Turbines would be spread over 20 million acres, but the land could also be used for crop production or livestock grazing. In addition, 40 percent of transportation fuel is provided by sources with zero net CO_2 emissions (e.g. cellulosic ethanol with soil carbon increases compensating for fossil carbon inputs; Fischer-Tropsch diesel from biomass with geologic carbon sequestration compensating for fossil carbon inputs; renewable electricity supplied to plug-in hybrids). This corresponds to 80 billion gallons of biofuels, which could be supplied from energy crops grown on 60 million acres of land, assuming productivity of 12 tons/acre.[7] Alternatively, this could be supplied by 40 billion gallons of biofuels plus 520 billion kWh of additional renewable electricity supplied to plug-in hybrids.[8]

6. **Carbon capture and storage, 1.3 Wedges (0.32 GtC):** Carbon capture and storage technology is applied to 160 GW of coal-fired integrated gasification combined cycle power plants, capturing 0.19 GtC in 2050. Additional carbon dioxide is captured from natural gas production facilities, large industrial sources, and ethanol plants, contributing 0.12 GtC to the 2050 emission reductions. The total volume of carbon dioxide put into storage would be 30 times the volume currently used for enhanced oil recovery and would be equivalent to 5 times the annual flow of natural gas through buffer storage facilities. In addition, increased thermal efficiency at power plants from replacing older units reduces emissions by 0.03 GtC.

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[1]. H. Schellnhuber, et al., eds. *Avoiding Dangerous Climate Change* (Cambridge University Press, New York, 2006)
[2]. M. Meinshausen "What Does a 2 C Target Mean for Greenhouse Gas Concentrations? A Brief Analysis Based on Multi-Gas Emission Pathways and Several Climate Sensitivity Uncertainty Estimates." in H. Schellnhuber, et al., eds. *Avoiding Dangerous Climate Change* (Cambridge University Press, New York, 2006)
[3]. U.S. Department of Energy, Energy Information Administration. http://www.eia.doe.gov/oiaf/1605/flash/pdf/flash.pdf
[4]. S. Pacala and R. Socolow, 2004. Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. *Science* **305**: 968.
[5]. V. Kuuskraa, P. DiPietro, S. Klara, and S. Forbes, 2004. Future U.S. Greenhouse Gas Emission Reduction Scenarios Consistent with Atmospheric Stabilization of Concentrations. GHGT-7: 506.
[6]. http://www.nrdc.org/air/energy/fcagoals.asp
[7]. N. Greene, et al., 2004. *Growing Energy: How Biofuels Can Help End America's Oil Dependence.* (NRDC, New York, 2004)
[8]. Assumes 13 kWh displace 1 gallon of gasoline in a plug-in hybrid.