Can we fix global warming?

What The Science Says:
The argument that solving the global warming problem by reducing human greenhouse gas emissions is "too hard" generally stems from the belief that (i) our technology is not sufficiently advanced to achieve significant emissions reductions, and/or (ii) that doing so would cripple the global economy. However, studies have determined that current technology is sufficient to reduce greenhouse gas emissions the necessary amount, and that we can do so without significant impact on the economy.

Climate Myth: It's too hard
"The fact is that there is no one in the world who can explain how we could cut our emissions by four fifths without shutting down virtually all our existing economy. What carries this even further into the higher realms of lunacy is that such a Quixotic gesture would do nothing to halt the world's fast-rising CO2 emissions, already up 40 per cent since 1990. There is no way for us to prevent the world's CO2 emissions from doubling by 2100" (Christopher Booker)

Technology

Pacala and Socolow (2004) (PS04) investigated our capability to reduce greenhouse gas (GHG) emissions by examining the various technologies available to reduce GHG emissions. Every technology they examined "has passed beyond the laboratory bench and demonstration project; many are already implemented somewhere at full industrial scale." PS04 examined what would be required to stabilize atmospheric carbon dioxide concentrations at 500 parts per million (ppm), which would require that GHG emissions be held near the present level of 7 billion tons of carbon per year (GtC/year) for the next 50 years.

PS04 used the concept of a "stabilization wedge", in which "a wedge represents an activity that reduces emissions to the atmosphere that starts at zero today and increases linearly until it accounts for 1 GtC/year of reduced carbon emissions in 50 years." Implementing seven such wedges would achieve sufficient GHG emissions reductions to stabilize atmospheric carbon dioxide at 500 ppm by 2050, and emissions would have to decrease linearly during the second half of the 21st century. PS04 identifies 15 current options which could be scaled up to produce at least one wedge, and note that their list is not exhaustive.

1. **Improved fuel economy:** One wedge would be achieved if, instead of averaging 30 miles per gallon (mpg) on conventional fuel, cars in 2054 averaged 60 mpg, with fuel type and distance traveled unchanged. Given recent advances in hybrid and electric vehicle technology, this is a very plausible wedge.

2. **Reduced reliance on cars:** One wedge would be achieved if the average fuel economy of the 2 billion 2054 cars were 30 mpg, but the annual distance traveled were 5000 miles instead of 10,000 miles.

3. **More efficient buildings:** One wedge is the difference between pursuing and not pursuing known and established approaches to energy-efficient space heating and cooling, water heating, lighting, and refrigeration in residential and commercial buildings.

4. **Improved power plant efficiency:** One wedge would be created if twice today's quantity of coal-based electricity in 2054 were produced at 60% instead of 40% efficiency.

5. **Substituting natural gas for coal:** One wedge would be achieved by displacing 1400 gigawatts (GW) of baseload coal power with baseload gas by 2054. Given recent natural gas price decreases, this is another very plausible wedge.

6. **Storage of carbon captured in power plants:** One wedge would be provided by the installation of carbon capture and storage (CCS) at 800 GW of baseload coal plants by 2054 or 1600 GW of baseload natural gas plants.

7. **Storage of carbon captured in hydrogen plants:** The hydrogen resulting from precombustion capture of CO_2 can be sent offsite to displace the consumption of conventional fuels rather than being consumed onsite to produce electricity. One wedge would require the installation of CCS, by 2054, at coal plants producing 250 million tons of hydrogen per year (MtH2/year), or at natural gas plants producing 500 MtH2/year.

8. **Storage of carbon captured in synthetic fuels plants:** Large-scale production of synthetic fuels from carbon is a possibility. One wedge would be the difference between capturing and venting the CO_2 from coal synthetic fuels plants producing 30 million barrels of synthetic fuels per day.

9. **Nuclear power:** One wedge of nuclear electricity would displace 700 GW of efficient baseload coal capacity in 2054. This would require 700 GW of nuclear power with the same 90% capacity factor assumed for the coal plants, or about twice the nuclear capacity currently deployed.

   Wind power: One wedge of wind electricity would require the deployment of 2000 GW of nominal peak capacity (GWp) that displaces coal electricity in 2054 (or 2 million 1-MWp wind turbines). This would require approximately 10 times the current (as of 2010) deployment of wind power by mid-century. Note that global wind power deployment increased from approximately 40 GW in 2004 to 158 GW in 2009.

10. **Solar photovoltaic power:** One wedge from photovoltaic (PV) electricity would require 2000 GWp of installed capacity that displaces coal electricity in 2054. This would require approximately 100 times the current (as of 2010) deployment of solar PV power by mid-century. Note that global solar PV power deployment increased from approximately 3 GW in 2004 to 20 GW in 2009.

11. **Renewable hydrogen:** Renewable electricity can produce carbon-free hydrogen for vehicle fuel by the electrolysis of water. The hydrogen produced by 4 million 1-MWp windmills in 2054, if used in high-efficiency fuel-cell cars, would achieve a wedge of displaced gasoline or diesel fuel. However, use of renewable energy to power electric vehicles is more efficient than powering hydrogen vehicles with hydrogen produced through electrolysis from renewable power.

12. **Biofuels:** One wedge of biofuel would be achieved by the production of about 34 million barrels per day of ethanol in 2054 that could displace gasoline, provided the ethanol itself were fossil-carbon free. This ethanol production rate would be about 50 times larger than today's global production rate, almost all of which can be attributed to Brazilian sugarcane and United States corn. The potential exists for increased biofuels production to compromise agriculturaly production, unless the biofuels are created from a non-food crop or other source such as algae oil.

13. **Forest management:** At least one wedge would be available from reduced tropical deforestation and the management of temperate and tropical forests. At least one half-wedge would be created if the current rate of clear-cutting of primary tropical forest were reduced to zero over 50 years instead of being halved. A second half-wedge would be created by reforesting or afforesting approximately 250 million hectares in the tropics or 400 million hectares in the temperate zone (current areas of tropical and temperate forests are 1500 and 700 million hectares, respectively). A third half-wedge would be created by establishing approximately 300 million hectares of plantations on non-forested land.

14. **Agricultural soils management:** When forest or natural grassland is converted to cropland, up to one-half of the soil carbon is lost, primarily because annual tilling

increases the rate of decomposition by aerating undecomposed organic matter. One-half to one wedge could be stored by extending conservation tillage to all cropland, accompanied by a verification program that enforces the adoption of soil conservation practices that work as advertised.

PS04 concludes "None of the options is a pipe dream or an unproven idea....Every one of these options is already implemented at an industrial scale and could be scaled up further over 50 years to provide at least one wedge." While the study has identified 15 possible wedges, PS04 argues that only seven would be necessary to stabilize atmospheric CO_2 at 500 ppm by mid-century. The list in the study is also not exhaustive, for example omitting concentrated solar thermal power and other renewable energy technologies besides wind and solar PV.

However, Dr. Joseph Romm (Acting Assistant Secretary of Energy for Energy Efficiency and Renewable Energy during the Clinton Administration) argues that at least 14 wedges would be necessary to stabilize atmospheric CO_2 at 450 ppm. Romm proposes what he believes to be the most plausible way to achieve 16 wedges:

- 1 wedge of vehicle efficiency — all cars 60 mpg, with no increase in miles traveled per vehicle.
- 1 of wind for power — one million large (2 MWp) wind turbines
- 1 of wind for vehicles –another 2000 GW wind. Most cars must be plug-in hybrids or pure electric vehicles.
- 3 of concentrated solar thermal power — ~5000 GW peak.
- 3 of efficiency — one each for buildings, industry, and cogeneration/heat-recovery for a total of 15 to 20 million GW-hrs.
- 1 of coal with carbon capture and storage — 800 GW of coal with CCS
- 1 of nuclear power — 700 GW plus 10 Yucca mountains for storage
- 1 of solar PV — 2000 GW peak [or less PV and some geothermal, tidal, and ocean thermal]
- 1 of cellulosic biofuels — using one-sixth of the world's cropland [or less land if yields significantly increase or algae-to-biofuels proves commercial at large scale].
- 2 of forestry — End all tropical deforestation. Plant new trees over an area the size of the continental U.S.
- 1 of soils — Apply no-till farming to all existing croplands.

The bottom line is that while achieving the necessary GHG emissions reductions and stabilization wedges will be difficult, it is possible. And there are many solutions and combinations of wedges to choose from.

Economics

Working Group III of the IPCC Fourth Assessment Report focused on climate change mitigation, and a substantial portion of the report focused on the economic impacts of mitigation efforts. The key finding of the report is as follows.

"Both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global GHG emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels (high agreement, much evidence)."

The report found that stabilizing between 445 and 535 ppm CO_2-equivalent (350–440 ppm CO_2) will slow the average annual global GDP growth rate by less than 0.12%. Additionally, this slowed GDP growth rate is in comparison to the unrealistic business-as-usual (BAU) scenario where climate change has no impact on the economy. By 2030, the IPCC found that global GDP would decrease by a total of no more than 3% compared to the unrealistic BAU scenario, depending on the magnitude of the emissions reductions.

The report also found that health benefits from reduced air pollution as a result of actions to reduce GHG emissions can be substantial and may offset a substantial fraction of mitigation costs. Some other key findings:

"Energy efficiency options for new and existing buildings could considerably reduce CO_2

emissions with net economic benefit."

"Forest-related mitigation activities can considerably reduce emissions from sources and increase CO_2 removals by sinks at low costs"

"Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes. Such policies could include economic instruments, government funding and regulation"

In short, there are numerous opportunities to reduce GHG emissions at low cost, some of which result in a net economic gain. Overall, emissions can be reduced at a cost which will not cripple the global economy. Moreover, these emissions reductions would have a significant positive economic impact by slowing global warming.

We have the necessary technology. The net costs to implement them will not be crippling. The question remains - do we have the will to put forth the effort and initial investment to solve the problem?

Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a college textbook on climate change and the book Climate Change Denial: Heads in the Sand. Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.