Bringing Novel Research into the Classroom: Carbon Sequestration as a New Opportunity for Science Education

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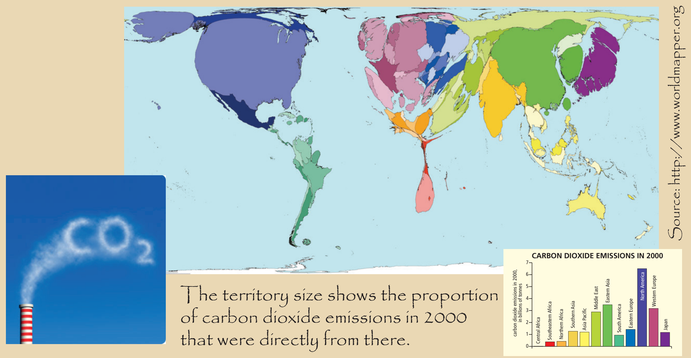
Carbon Dioxide and the Greenhouse Effect: A Problem and a Challenge

The greenhouse effect is a natural process by which thermal radiation from the sun is absorbed by atmospheric greenhouse gases (such as carbon dioxide, CO_2) and is re-radiated in all directions. This process warms our planet, allowing all life forms to inhabit it.



The territory size shows the proportion of carbon dioxide emissions in 2000 that were directly from there.

Source: http://www.worldmapper.org

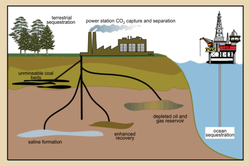
Carbon sequestration technology is an emerging area of research that is rarely presented in the current middle and high school curriculum. This poster complements a concurrent lecture at HASTI (Kevin Ellett and Cristian Medina) and presents three objectives:

(1) to introduce the topic of geologic carbon sequestration as a promising area of research for the mitigation of global warming;

(2) to show how this technology draws from different science disciplines (e.g. earth science, physics, chemistry, and mathematics) and thus offers new opportunities for science education;

(3) to present skills that students can learn by studying this technology, such as the use and display of quantitative data and the use of online resources to perform literature searches.

Possible Solutions



*Carbon sequestration is "The process of removing carbon from the atmosphere and depositing it in a reservoir.' When carried out deliberately, this may also be referred to as carbon dioxide removal, which is a form of geoengineering. The term **Carbon Sequestration** carbon sequestration may also be used to refer to the process of carbon capture and storage (CCS), where CO_2 is removed from flue gases, such as on power stations, before being stored in underground reservoirs. Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming.

*Source: Wikipedia

*Energy efficiency is the goal of efforts to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs.

Energy Efficiency

*Source: Wikipedia

Alternative energy refers to any source of usable energy intended to replace fuel sources without the undesired consequences of the replaced fuels. In a general sense in contemporary society, alternative energy is that which is produced without the undesirable consequences of the burning of fossil fuels, such as high carbon dioxide emissions, which are considered to be the major contributing factor of global warming according to the Intergovernmental Panel on Climate Change.....

Renewable Energy

*Source: Wikipedia

Science education is the field concerned with sharing science content and process with individuals not traditionally considered part of the scientific community. The target individuals may be children, college students, or adults within the general public. The field of science education comprises science content, some social science, and some teaching pedagogy. The standards for science education provide expectations for the development of understanding for students through the entire course of their K-12 education. The traditional subjects included in the standards are physical, life, earth, and space sciences.

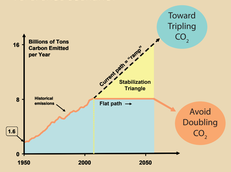
Science Education

*Source: Wikipedia

Have you heard of Stabilization Wedges?*

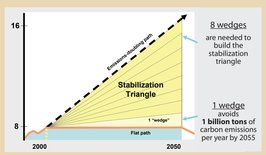
*Source of text and figures in this section: http://cmi.princeton.edu/wedges/

The "stabilization wedges" concept is a simple tool for conveying the emissions cuts that can be made to avoid dramatic climate change. We consider two futures - **allowing emissions to double versus keeping emissions at current levels for the next 50 years**. The emissions-doubling path (black dashed line) falls in the middle of the field of most estimates of future carbon emissions. The slope approximately extends the climb for the past 50 years, during which the world's economy grew much faster than its carbon emissions. Emissions could be higher or lower in 50 years, but this path is a reasonable reference scenario.



The emissions-doubling path is predicted to lead to significant global warming by the end of this century. In contrast, we can prevent a doubling of CO_2 if we can keep emissions flat for the next 50 years, then work to reduce emissions in the second half of the century **(orange line)**. This path is predicted to keep atmospheric carbon under 1200 billion tons, which corresponds to about 570 parts per million (ppm), allowing us to skirt the worst predicted consequences of climate change.

Keeping emissions flat will require cutting projected carbon output by about 8 billion tons per year by 2055, keeping a total of ~200 billion tons of carbon from entering the atmosphere **(see yellow triangle)**. This carbon savings is what we call the **"stabilization triangle."**



This page contains descriptions of 15 strategies already available that could be scaled up over the next 50 years to reduce global carbon emissions by 1 billion tons per year, or one wedge.

Stabilization Wedges – 15 Ways to Cut Carbon

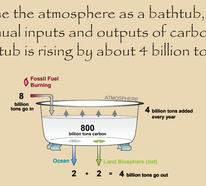
= Electricity Production, = Heating and Direct Fuel Use, = Transportation, = Biostorage

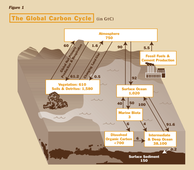
Strategy	Sector	Description	1 wedge could come from...	Cost	Challenges
1. Efficiency – Transport		Increase automobile fuel efficiency (2 billion cars projected in 2056)	... doubling the efficiency of all world's cars from 30 to 60 mpg	$	Car size & power
2. Conservation - Transport		Reduce miles traveled by passenger and/or freight vehicles	... cutting miles traveled by all passenger vehicles in half	$	Increased public transport, urban design
3. Efficiency - Buildings		Increase insulation, furnace and lighting efficiency	... using best available technology in all new and existing buildings	$	House size, consumer demand for appliances
4. Efficiency – Electricity		Increase efficiency of power generation	... raising plant efficiency from 40% to 60%	$	Increased plant costs
5. CCS Electricity		CO_2 from fossil fuel power plants captured, then stored underground (700 large coal plants or 1400 natural gas plants)	... injecting a volume of CO_2 every year equal to the volume of oil extracted	$$	Possibility of CO_2 leakage
6. CCS Hydrogen		Hydrogen fuel from fossil sources with CCS displaces hydrocarbon fuels	... producing hydrogen at 10 times the current rate	$$$	New infrastructure needed, hydrogen safety issues
7. CCS Synfuels		Capture and store CO_2 emitted during synfuels production from coal	... using CCS at 180 large synfuels plants	$$	Emissions still only break even with gasoline
8. Fuel Switching – Electricity		Replacing coal-burning electric plants with natural gas plants (1400 1 GW coal plants)	... using an amount of natural gas equal to that used for all purposes today	$	Natural gas availability
9. Nuclear Electricity		Displace coal-burning electric plants with nuclear plants (2 x current capacity)	... ~3 times the effort France put into expanding nuclear power in the 1980's, sustained for 50 years	$$	Weapons proliferation, nuclear waste, local opposition
10. Wind Electricity		Wind displaces coal-based electricity (30 x current capacity)	... using area equal to ~3% of U.S. land area for wind farms	$$	Not In My Back Yard (NIMBY)
11. Solar Electricity		Solar PV displaces coal-based electricity (700 x current capacity)	... using the equivalent of a 100 x 200 km PV array	$$$	PV cell materials
12. Wind Hydrogen		Produce hydrogen with wind electricity	... powering half the world's cars predicted for 2050 with hydrogen	$$$	NIMBY, Hydrogen infrastructure, safety
13. Biofuels		Biomass fuels from plantations replace petroleum fuels	... scaling up world ethanol production by a factor of 30	$$	Biodiversity, competing land use
14. Forest Storage		Carbon stored in new forests	... halting deforestation in 50 years	$	Biodiversity, competing land use
15. Soil Storage		Farming techiques increase carbon retention or storage in soils	... practicing carbon management on all the world's agricultural soils	$	Reversed if land is deep-plowed later

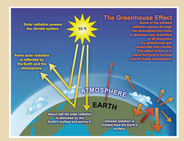
Opportunities in the Classroom

- Understand Carbon Cycle and Greenhouse Effect

If we imagine the atmosphere as a bathtub, with current annual inputs and outputs of carbon, the level in the tub is rising by about 4 billion tons per year.





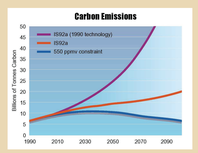


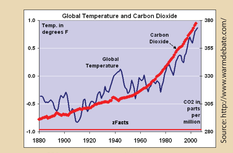
- Read Critically (blogs, webpages, etc)

Source: http://www.warmdebate.com/

Source: http://www.globalwarming.org/

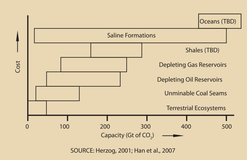
- Interpret Graphs and Tables, Understand Physical and Chemical Processes, as well as dealing with Conversion of Units



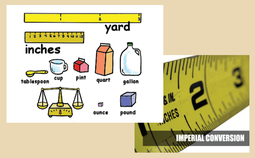


Source: http://www.warmdebate.com/

CO2 emissions against global temperature



SOURCE: Herzog, 2001; Han et al., 2007

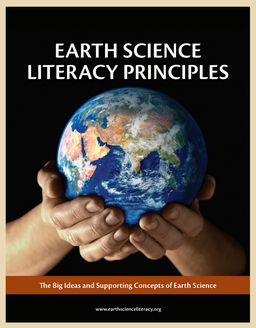


- Relevance of Carbon Capture and Storage (CCS) helps promote Science Literacy and the 'Big Ideas'

What is Earth Science Literacy?

Earth Science Literacy is an understanding of Earth's influence on you and of your influence on Earth. Earth Science Literacy Principles are defined by the scientists who carry out active research in many areas of Earth science and explain the complexities of how our planet works.

For more information about Earth Science Literacy, please visit www.earthscienceliteracy.org



- Excellent opportunity for Integrated Units, including:
  - Social Studies (economics, sociology, government)
  - English (speech and communication, composition)

Useful Links:
Department of Energy: http://www.energy.gov/
National Energy Technology Lab (DOE/NETL): http://www.netl.doe.gov/
Intergovernmental Panel on Climate Change (IPCC): http://www.ipcc.ch/