Climate Science

Climate Mitigation through Carbon Emission Cap-and-Trade / Carbon Dioxide Emissions, Carbon Footprints, and Public Policy

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Climate Mitigation through Carbon Emission Cap-and-Trade

Driving Question: *How can heat-trapping carbon dioxide emissions be reduced through a cap-and-trade or carbon tax program?*

Educational Outcomes: To describe the projected global warming for different carbon emissions scenarios. To present the choices the world community faces with the associated global temperature increases. To explain the basics of a cap-and-trade system that employs regulation and market forces and the fundamentals of a carbon tax to achieve mitigation goals.

Objectives: After completing this investigation, you should be able to:

- Describe the relationship between global greenhouse gas emissions and predicted average global temperatures during the 21st century.
- Explain the fundamentals of the cap-and-trade system for reducing global greenhouse gas emissions into the atmosphere.
- Provide an overview of the concept of a carbon tax.

Climate Mitigation through Reductions in Greenhouse Gas Emissions

There is overwhelming agreement among climate scientists that current and anticipated global climate changes are primarily the result of increased concentrations of heat-trapping greenhouse gases, mainly carbon dioxide (CO_2), in the atmosphere. It is known that these increases are the result of human activity, much of which involves the burning of fossil fuels (petroleum, coal, and natural gas) for generation of electricity and for transportation. It is of paramount importance that these emissions be reduced in order to prevent a dangerous rise in atmospheric CO_2.

National and international efforts are underway to develop and implement strategies to significantly reduce emissions of CO_2 and other greenhouse gases. Central to the efforts is the achievement of international agreement on the essential elements of a comprehensive global approach to prevent climate disaster. The goal is to acquire long-term commitments and the launching of immediate action to shape our common future and that of generations to come.

Introduction: The IPCC ***Climate Change 2007 Fourth Assessment Report (AR4)*** projects climate change and its impacts through this century in terms of global greenhouse gas (GHG) emissions and global surface warming for different emissions scenarios. These projections are summarized in **Figure 1**. Different emissions scenarios have been devised to explore their impacts on global temperature. They are grouped into four scenario families (A1, A2, B1, and B2) that explore alternative development pathways, covering a wide range of demographic, economic and

technological driving forces and resulting GHG emissions. The figure's left panel displays emission rates expected with the different scenarios. The panel to the right shows the 20th century global surface warming curve as well as 21st century global surface warming projections under different emissions scenarios.

1. In the right panel of Figure 1, the vertical axis is the global surface temperature anomaly (in Celsius degrees) compared to the average temperature during the 1980-1999 time period (i.e., the position of 0 on the temperature anomaly scale). Draw a horizontal line across the graph to represent the 0-degree temperature anomaly. The black curve represents the change in global average surface temperature from 1900 to 2000. It shows that during the 20th century, the global surface temperature increased approximately **[(*0.2*)(*0.8*)(*1.2*)]** Celsius degree(s).

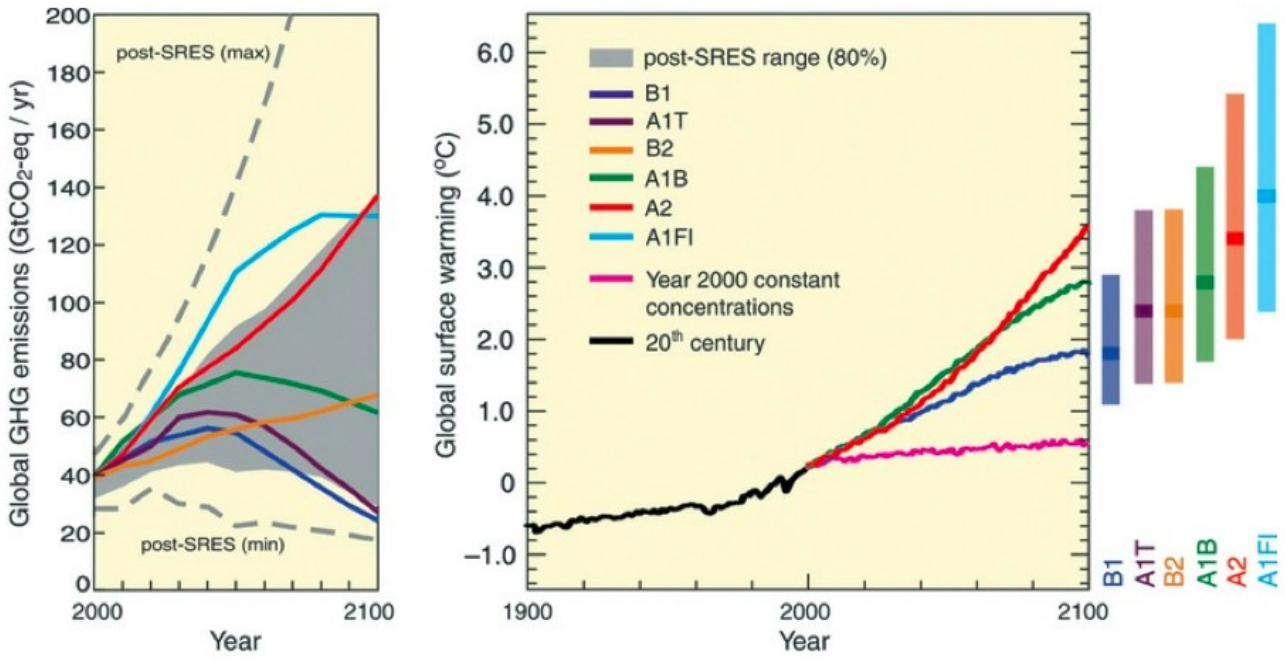

Figure 1.

Scenarios for greenhouse gas (GHG) emissions in the 21st century and projections of surface temperatures. [IPCC, Figure SPM5]

2. What would happen if the concentration of atmospheric greenhouse gases were to remain constant at their Year 2000 levels? The lowest (magenta) temperature curve extending to the Year 2100 shows that with a steady concentration of greenhouse gases, the global average surface temperature would **[(*slightly decrease*)(*remain steady*)(*slightly increase*)]** during the 21st century.

3. The blue, green, and red curves in the figure's right panel show best estimates of temperature changes in the other emissions scenarios during the 21st century. They project a 21st century average global temperature warming as much as approximately **[(*1.6*)(*2.6*)(*3.4*)]** Celsius degree(s).

Even if the global community acts ambitiously together to reduce emissions, the different IPCC scenarios show Earth's climate system is already ***committed*** to rising temperatures. A business-as-usual (doing-nothing-more) path is potentially disastrous as it is likely to result in substantially greater average global temperature increases in the future. A recent scientific study estimates as much as a 7 Celsius degree rise in temperature is possible by the end of the century. A number of strategies are needed to prevent such warming. One approach of great promise is through a system called cap-and-trade.

Climate Mitigation through Cap-and-Trade

Underlying the **cap-and-trade** approach to reducing greenhouse gas emissions is a simple idea that the marketplace can be a powerful tool for achieving environmental progress. In the program, the **cap** is a legal limit imposed on the quantity of greenhouse gases that a company, region or country can emit each year and **trade** means that companies, regions or countries that emit greenhouse gases may buy and sell the permission, or permits, to emit greenhouse gases up to the overall cap among themselves. The net effects are that as the cap declines over time the total emissions are forced to decrease and, in the trading process, overall costs of abatement are reduced.

Figure 2 is a schematic depiction of how a cap-and-trade system works after it is up and running. To start the system, government at some level sets the target, or cap, on how much pollution (e.g., CO_2) a business sector (or region or country) is allowed to emit into the atmosphere. The cap places a legal limit subject to enforcement on emissions of greenhouse gases by significant polluters. The non-governmental marketplace then is left to figure out how to achieve the target at the lowest possible cost. With commonsense rules set in place, the competitiveness and ingenuity of the marketplace reduces emissions as smoothly, efficiently, and cost-effectively as possible.

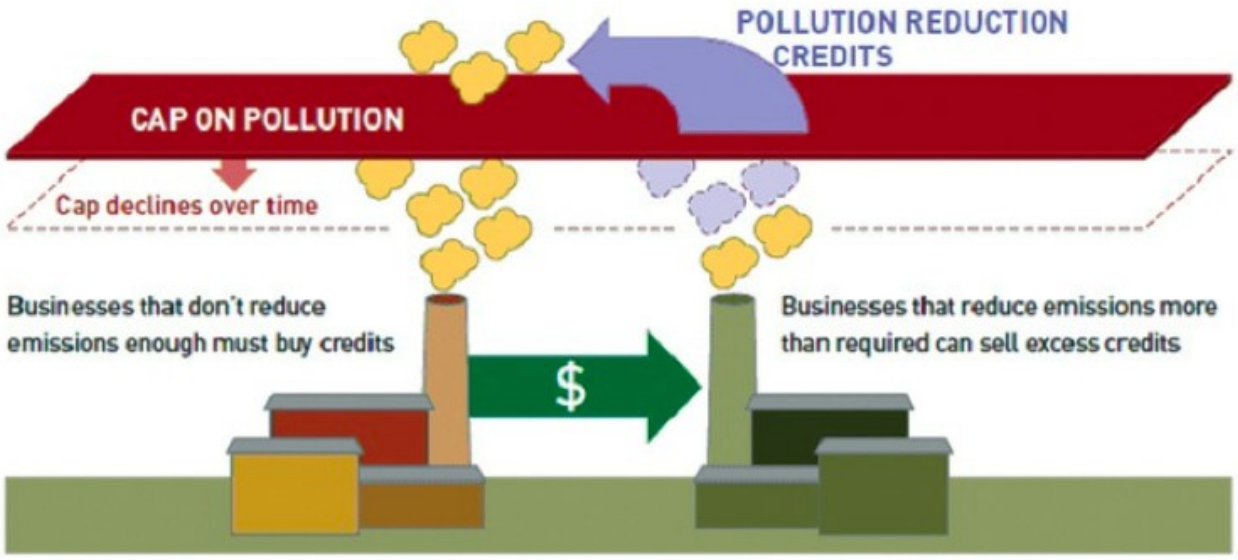

Figure 2.
How an established **cap-and-trade** system works. Cap limits emissions and trade allows trading (selling) of carbon credits. [Copyright © 2009 Environmental Defense. Used by permission.]

After an overall cap has been established, all significant polluters must collectively meet it. In cap-and-trade, businesses that can reduce emissions at relatively low cost do so. They have an incentive to reduce emissions below the amount required as they can profitably sell the differences (called credits) between their emissions and their caps to other businesses. Companies faced with high costs to cut emissions might choose to save money by buying excess pollution credits from other companies rather than paying the costs of pollution abatement.

4. In Figure 2, the company at the right was able to reduce its pollution below its cap. This put the company in the position of being able to sell its excess credits in the marketplace. In the figure, tan puffs denote pollution units and blue puffs depict credit units. It is evident from counting the arbitrary number of puffs in the figure, the company at the right had a cap of 5 pollution units, but it had reduced its pollution to the point that it had **[(*2*)(*3*)(*5*)]** credits it could sell.
5. In Figure 2, the company at the left did not or could not achieve its pollution cap of 5 pollution units (shown by the 5 tan puffs under the cap) as it was exceeding its emissions cap by **[(*2*)(*3*)(*5*)]** as shown by the tan puffs above the cap.

6. Both businesses met their legal obligations to maintain pollution concentrations below the combined cap level of ten pollution units. This was possible because the business at the left could buy **[(*2*)(*3*)(*5*)]** excess credits from the business at the right.

7. Summarizing, Figure 2 shows the flow of pollution reduction credits from companies that reduce emissions below their cap to companies that emit more than their caps in exchange for money. In the trading process, both companies **[(*earn or save money*)(*collectively meet the emissions cap*) (*both of these*)]**.

8. Figure 2 shows the cap on emissions as decreasing over time. This drives companies towards adopting clean technology infrastructure as the diminishing number of pollution reduction credits causes individual credits to become more costly (the concept of supply and demand). This gradual lowering of the cap allows time for the marketplace to find the lowest-cost alternatives to meeting the new emissions caps, minimizing the overall costs of compliance. This stepwise process of lowering the cap guarantees that emissions from these companies will **[(*decline*) (*steady out*) (*increase*)]** over time.

Cap-and-trade systems are not new. The U.S. Environmental Protection Agency (EPA) claims considerable experience developing and implementing cap-and-trade systems for other environmental problems. For an overview of EPA's cap-and-trade programs, go to: *http://www.epa.gov/captrade/index.html*. There, under Quick Links, click on "Acid Rain Program."

9. The EPA reports that perhaps its most successful cap-and-trade program has been the Acid Rain Program. Its overall goal is to achieve significant environmental and public health benefits through reductions in emissions of sulfur dioxide and **[(*nitrogen oxides*)(*ozone*)]** — the primary precursors of acid rain.

During the operation of the Acid Rain Program's cap-and-trade system, the atmospheric concentrations of those gases causing acid rain were dramatically reduced. For example the ambient air sulfur dioxide concentration in the U.S. declined 56% between 1980 and 2008.

Climate Mitigation through Carbon Tax:

A **carbon tax** (also called **carbon price**) is an environmental tax that is levied on the carbon content of fuels. The focus of the tax is the carbon dioxide emitted to the atmosphere when fossil fuels (coal, petroleum, and natural gas) are burned. Like cap-and-trade, the purpose of a carbon tax is to control access to the use of the atmosphere as a repository for emitted greenhouse gases. Both approaches (carbon tax and cap-and-trade) forces users to pay for access, and the potential for generating revenue is considerable. How the revenue would be applied has major political implications.

For a thorough review of these proposed incentives that would drive behaviors and investments towards a transition to a low-greenhouse-gas emissions economy, go to the U.S. National Academies National Research Council's 2011 publication ***America's Climate Choices*** report ***Limiting the Magnitude of Future Climate Change*** at: *http://www.nap.edu/catalog.php?record_id=12785*. The report concludes that a carbon pricing system (either cap-and-trade, taxes, or a combination of the two) is the most important step for providing needed incentives to reduce emissions.

Summary: Cap-and-trade and carbon tax systems offer market-based approaches to limiting greenhouse gas emissions. But because the operational details are vital to the success or failure of such systems, governments need to experiment and gain experience in order to build the most effective systems possible. The U.S. has already conducted successful cap- and-trade programs, providing ample evidence that cap-and-trade systems could be effective mitigation tools in reducing concentrations of heat-trapping gases in Earth's atmosphere and thereby heading off potentially disastrous climate change.

CARBON DIOXIDE EMISSIONS, CARBON FOOTPRINTS, AND PUBLIC POLICY

Driving Question: *What are some of the individual and national contributions to atmospheric carbon dioxide from energy consumption? How do our American carbon footprints compare to those of other countries? What are American perceptions concerning climate change?*

Educational Outcomes: To describe worldwide carbon dioxide emissions from energy consumption in terms of country and per capita. To compare U.S. contributions of carbon dioxide emissions with those of other countries. To investigate public perceptions concerning the resulting global warming, including those of six audiences, called the ***Six Americas***, polled via an audience segmentation analysis.

Objectives: After completing this investigation, you should be able to:

- Describe the national and per capita carbon dioxide emissions from energy consumption for a number of countries around the world.
- Explain carbon footprints while providing an overview of U.S. carbon dioxide emissions compared to other countries.
- Describe U.S. public perceptions concerning climate change according to the ***Global Warming's Six Americas Reports.***

Carbon Footprints in a Global Perspective

Observations show that warming of Earth's climate system is unequivocal. It is also the overwhelming consensus of climate scientists that global warming over the past half-century has been due to human-induced emissions of heat-trapping gases. [IPCC, USGCRP] These emissions are bringing about increases in the average global surface temperature while perturbing other components of Earth's climate system.

A measure of the amount of carbon dioxide produced by a person, activity, or nation in a given time interval has been referred to as a **carbon footprint.** Not surprisingly, carbon footprints vary considerably around the world when determined on a national or per capita (per person) basis.

Unlike most ordinary footprints, carbon footprints linger. In fact, the impacts of carbon footprints persist for a very, very long time. The carbon footprints you are creating today will be making their presence known far beyond this century.

It is well established through climate science that increasing concentrations of greenhouse gases, most notably carbon dioxide, due to human activity are largely responsible for observed and projected global climate change. While all scientifically informed persons recognize the human role in the increase in greenhouse gas concentrations in Earth's atmosphere, few have made strong connections between these increases and their own actions.
Table 1 describes the national and per capita carbon dioxide emissions from energy consumption for a selected number of countries for the most recent year of available data (2009) [Energy Information Administration, CIA World Factbook].

Table 1: Carbon Dioxide Emissions from Energy Consumption, 2009

Country	Total CO_2 emissions (Millions of Metric Tons)	Population (Millions)	Per Capita CO_2 emissions (Metric Tons)
United States	5425	307.0	17.7
Canada	541	33.4	16.2
Mexico	444	111.3	4.0
Brazil	420	199.1	2.1
France	397	63.0	6.3
Germany	766	82.4	9.3
United Kingdom	520	62.3	8.4
Russia	1572	140.0	11.2
Iran	527	75.9	6.9
Egypt	192	78.7	2.4
South Africa	450	49.0	9.2
Australia	418	21.3	19.6
China	7711	1322.6	5.8
India	1602	1160.9	1.4
Japan	1098	127.1	8.6
World	30,398	6770.2	4.5

1. According to Table 1, the two countries generating the most total CO_2 emissions from energy consumption in 2009 were China and **[(*Russia*)(*India*)(*the United States*)]**.

2. Of the countries listed in Table 1, the one generating the most CO_2 emissions on a per capita basis was **[(*China*)(*the United States*)(*Australia*)]**.

3. Of the countries listed with populations over 25 million, the one with the greatest per capita CO_2 emissions from energy consumption was **[(*China*)(*the United States*)(*Australia*)]**.

4. The United States reported a 2009 per capita CO_2 emissions rate that was **[(*0.25*)(*0.98*)(*3.05*)]** times that of China.

5. The United States reported a per capita CO_2 emissions rate that was **[(*0.07*)(*4.3*)(*12.6*)]** times that of India.

6. With 4.5% of the world population in 2009, the United States was generating about **[(*4.3%*)(*18%*)(*32%*)]** of the world's total CO_2 emissions from energy consumption.

There are numerous reasons for the broad range of CO_2 emissions by country, including levels of development, transportation needs, heating/cooling requirements, industrial demands, availability of other energy sources, and the efficiency of energy use. Faced with the requirement to reduce global CO_2 emissions, a first step is to analyze the current sources of emissions. Highly detailed data on emissions are compiled by the U.S. Department of Energy at: *http://www.eia.doe.gov/* and by the International Energy Agency at *http://iea.org/*.
An Update: The U.S. Energy Information Administration (EIA) annually updates U.S. CO_2 emissions data in August. In August 2011, it reported a 3.5% increase in U.S. energy-related CO_2 emissions during 2010. This was the largest annual percentage increase since 1988. It was attributed primarily to the rebound from the economic downturn experienced in 2008 and 2009. The U.S. Gross Domestic Product (GDP) rose 3.0% in 2010. As of August 2010, the EIA was projecting significantly slower emissions growth over the next decade, averaging 0.2% per year.
[*http://www.eia.gov/pressroom/releases/press365.cfm*]

Estimating your Carbon Footprint: To help you in approximating your personal carbon footprint, the U.S. Environmental Protection Agency (EPA) has developed calculators. Go to: *http://www.epa.gov/climatechange/emissions/individual.html*.

There, you can click on "Personal Emissions Calculator" to roughly estimate your personal or family's greenhouse gas emissions and explore the impact of taking various actions to reduce your emissions.

Climate Change and Public Policy: Advances in climate science in recent decades clearly point to the need to develop and implement climate change pubic policy at global, national, regional and local levels with strong mitigation and adaptation components. While some climate change impacts may

be positive at local and regional levels, the reality is that most consequences of inaction are very likely to be dire.

Policymaking, in general, requires recognition that a public problem exists. As stated in the course text, policymakers (e.g., elected officials, senior bureaucrats, and other public servants) are more likely to address the issue if it "is easy to understand, is the result of a crisis or catastrophe, has a relatively inexpensive solution, attracts widespread public attention, and spurs demands for action." It is suggested that, as an issue, climate change is not seen by many policy makers (or by the general public) as meeting all of these criteria.

How does the general public view climate change? This is a critical question as the formulation and implementation of a public policy ultimately depends on citizen support. Polling is a primary means for estimating public perceptions and support for public policy that adequately meets the climate change challenge we and our descendents must face in the decades and centuries ahead.

Effective engagement and communication on any public policy issue must start with the recognition that people are diverse and have different psychological, cultural, and political reasons for acting or not acting on a public policy issue. An attempt to identify and better understand how different audiences within the American public respond to the issue of global warming in their own distinct ways has made via national representative surveys conducted by the Yale Project on Climate Change and the George Mason University Center for Climate Change Communication.

The George Mason/Yale effort produced its first study, entitled ***Global Warming's Six Americas 2009: An Audience Segmentation Analysis,*** based on survey questionnaire responses by 2,129 adults in fall 2008. In-depth measures were made of the public's climate change beliefs, attitudes, risk perceptions, motivations, values, policy preferences, behaviors, and underlying barriers to actions. Six audiences, the ***Six Americas***, were distinguishable on these dimensions and exhibited very different levels of engagement with the issue of climate change.
Based on the survey, **Figure 1** shows the Proportion of the U.S. adult population in the ***Six Americas.*** Labels identifying the six population segments appear in the figure. Detailed descriptions of the segments appear in the published report available online.

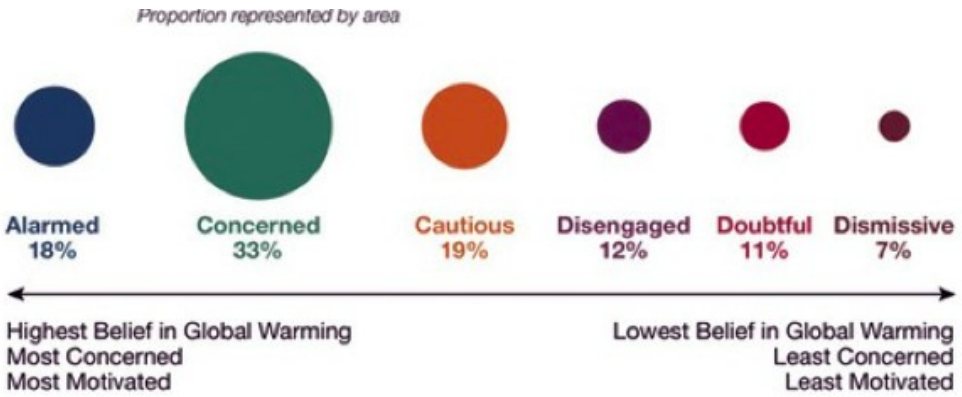

Figure 1.
Proportion of the U.S. adult population in the Six Americas. November 2008 [George Mason/Yale *Global Warming's Six Americas 2009*]

7. Figure 1 reports that the largest identified group, the "Concerned", was composed of **[(*7%*)(*11%*)(*18%*)(*33%*)]** of the adult U.S. population. Members of this group are convinced global warming is real and serious, but have not yet engaged the issue personally.

8. The "Alarmed" group is already taking action to address the issue. At the opposite end of the spectrum the "Dismissive" group is also actively engaged. The Dismissive group, composed of **[(*7%*)(*11%*)(*18%*)(*35%*)]** of the adult U.S. population, generally believes global warming is not happening, is not a threat, and strongly believes it does not warrant a national response.

The Six Americas 2009 report contains highly detailed analyses and is available at: *http://www.climatechangecommunication.org/images/files/GlobalWarmingsSixAmericas2009c.pdf*. For example, if you wish (a) to determine the level of support for a cap and trade policy, go to Figure 22 on page 19, or (b) to evaluate the political party affiliation of the members of the different Six Americas as of fall 2008, go to Figure 29 on page 25.

Update on *Global Warming's Six Americas* Study: The *Global Warming's Six America's nationally representative* survey group was re-assessed in January 2010, June 2010, and May 2011. **Figure 2** provides a summation of the May 2011 survey.

Figure 2.
Proportion of the U.S. adult population in the Six Americas. May 2011. [George Mason/Yale *Global Warming's Six Americas 2011*]

9. Compare Figures 1 and 2. While 51% of those surveyed in November 2008 were alarmed or concerned about climate change, in May 2011 **[(*27%*)(*39%*)(*51%*)]** of those surveyed were alarmed or concerned.

10. The surveys showed that **[(*18%*)(*25%*)(*51%*)]** were doubtful or dismissive about climate warming when surveyed in November 2008, and in May 2011 the total that were doubtful or dismissive of global warming was 25%.

11. The trend of the surveyed group's perceptions about global warming between November 2008 and May 2011 was towards **[(*less*)(*more*)]** concern about climate warming.

This trend was consistent with the levels of awareness of the survey respondents to the increasingly high level of scientific certainty that global climate warming is a reality. On page 7 of the May

2011 report, “Only in the Alarmed and Concerned groups were a majority aware that most scientists think global warming is occurring. Majorities in the other four groups said that either there was a lot of disagreement among scientists or that they didn’t know.

Even among the Alarmed and Concerned, however, awareness of the *strength* of scientific agreement is low: While approximately 97% of publishing climate scientists agree that climate change is occurring and that it is caused primarily by human activities, this high level of scientific agreement is recognized by only 44% of the Alarmed, 18% of the Concerned, 12% of the Cautious, and 5% or fewer of the Disengaged, Doubtful and Dismissive.”

During 12-30 March 2012, interviews were conducted with 1,008 adults (18+) as part of the ongoing Climate Change in the American Mind series to gather new information on Americans’ climate change and energy beliefs, attitudes, policy support, and behavior. Among reports issued from this survey were: *Public Support for Climate and Energy Policies in March 2012* and *Extreme Weather, Climate & Preparedness in the American Mind.* These and other reports of this joint George Mason University/Yale University project can be accessed via: *http://www.climatechangecommunication.org/reports*.

Table 2. Issue Priority of global warming for the President and Congress

	Mar 2012	Nov 2011	May 2011	Jun 2010	Jan 2010	Nov 2008
Very high	12	12	13	17	13	21
High	28	25	27	27	25	33
Medium	32	33	31	33	31	30
Low	28	30	30	23	31	17

Table 3 from page 7 of *Public Support for Climate and Energy Policies in March 2012* shows responses to different versions of the question: **Do you think global warming should be a low, medium, high, or very high priority for the President and Congress?**

12. Table 2 shows that in March 2012 **[(*40%*)(*60%*)(*72%*)]** of Americans think that global warming should be a very high, high, or medium priority for the President and Congress.

13. Table 2 also shows that between November 2008 and March 2012, **[(*fewer*)(*the same percentage of*)(*more*)]** survey respondents felt the President and Congress should place a very high, high, or medium priority on global warming issues.

According to the March 2012 survey, among registered voters, 84% of Democrats, 68% of Independents, and 52% of Republicans think global warming should be a priority. The survey also shows that 91% of Democrats, 77% of Independents, and 70% of Republicans think that overall, protecting the environment either improves economic growth and provides new jobs, or has no effect on economic growth or jobs.

Because climate change is such an important issue, there is a steady flow of surveys conducted

by major polling organizations.

Summary: The development and implementation of a U.S. climate change public policy requires ample public support and demand for action. Regardless of the high level of confidence that the climate science community has concerning global climate change, it is critically important in policymaking that the general public perceives the threat of global warming. The use of well designed polls is essential in any public policy development and implementation process, including that dealing with climate change. They provide guidance and reality checks with the public. For example, the polls reported in this investigation indicate substantial public support for action, but trends show less certainty on the part of the public even as the scientific community becomes more certain of the effects of damaging climate change in the decades ahead.

The formulation of a U.S. climate change policy and its implementation are formidable tasks. While science informs, society must determine our actions through enlightened policy making.