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Scientific Analysis of
the Climate Protection Act of 2013

Workshop in Applied Earth Systems Management
S. 332: Climate Protection Act of 2013
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Executive Summary

Passage of Senate Bill 332, the Climate Protection Act of 2013, is necessary to establish the United States as a key player in the global effort to curb carbon pollution and mitigate the impacts of a warming planet. The bill seeks to reduce United States carbon emissions through the use of a carbon tax, which would concurrently fund the research and development of sustainable technology as well as accompanying efforts to adapt industry and labor in a steady transition to a low carbon economy.

Several renewable energy technology solutions currently exist in the market including solar, wind, and carbon capture and storage. These technologies are readily available and some quickly scalable, however, if the U.S. wishes to adopt them, it will first need to make necessary improvements to infrastructure as well as abate its reliance on carbon-based fuels and goods.

Due to the global scale and complexity of the climate change problem, it may be difficult to clearly assess the efficacy of national U.S. carbon reductions in a quantifiable manner. However, the scientific evidence of climate change and the need to act is undeniable. This report will summarize the legislative background of the Climate Protection Act of 2013. It will then provide a thorough analysis of the science associated with carbon pollution’s causation of climate change, examine United States’ primary sources of carbon pollution and recommend subsequent policy and technology solutions. Finally, it will explore the scientific uncertainties of measuring the bill’s success. Ultimately, the Climate Protection Act is a significant legislative step towards diminishing the United States’ status as a top carbon polluter and proposing pathways to improved adaptation and infrastructure resiliency through the use of renewable energy.
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I Introduction

The Climate Protection Act of 2013 was introduced into the Senate on February 14, 2013 and proposes that the U.S. carry out activities to return greenhouse gas emissions to 2005 levels by reducing total carbon emissions by 80% by 2050. It will amend the Clean Air Act, establishing a carbon pollution fee on producers of carbon emissions including manufacturers, producers and importers in two categories: carbon polluting substances and carbon pollution-intensive goods. These two categories cover the majority of possible direct and indirect sources of carbon dioxide emissions. Funds collected will be used for climate change programs (adaptation and infrastructure resiliency), a Residential Environmental Rebate Program, and the creation of a Pollution Reduction Trust Fund. The second purpose of this proposed bill is to provide financial assistance for projects to reduce greenhouse gas emissions through the establishment of a Sustainable Technologies Finance Program. The third and final part of this legislation amends the Safe Drinking Water Act to require disclosure of chemicals used in hydraulic fracturing. This analysis will thoroughly examine Senate Bill 332's potential effectiveness and limitations in the context of its scientific implications.

[Note: This report will focus only on the carbon-related sections of S. 332. It will not address the proposed amendments to the Safe Drinking Water Act.]
II Overview of the Bill

Background
The Climate Protection Act will amend the Clean Air Act, enacted in 1970. The Clean Air Act\(^1\) was designed to control air pollution on a national level by authorizing the development of national ambient air quality standards through comprehensive federal and state regulations to limit emissions. The Environmental Protection Agency (EPA) was created in 1970 as the chief government office dedicated to protecting human health and the environment through the implementation of minimum standards for air and water quality. The Clean Air Act was significantly amended for the first time in 1990, in order to curb three major threats: acid rain, urban air pollution, and toxic air emissions.

Climate Protection Act of 2013: Section-by-Section Summary

Title I - Carbon Pollution Fee

Carbon Pollution Fee (Section 101):
This section amends Title I of the Clean Air Act, adding at the end, a Part E – Carbon Pollution Fee, and new sections.

Definitions (new Section 195):
Five important terms are defined. The terms defined include: carbon polluting substances, carbon pollution-intensive goods, first calendar year, substantially equivalent measure, 12th calendar year. [Note: Carbon polluting substances and carbon pollution-intensive goods will be defined in the next section.]

Imposition of Fee (new Section 196):
The EPA Administrator shall impose a fee on any manufacturer, producer or importer of a carbon polluting substance. The amount of the fee shall be assessed per ton of carbon dioxide content (or methane) of the carbon polluting substance.

Carbon Equivalence Fee (new Section 197):
A fee, called the carbon equivalency fee, will be imposed on imported carbon pollution-intensive goods. This fee will be equivalent to the cost that domestic producers of comparable goods incur, and take into consideration the amount of emissions released during manufacturing and transporting of the goods from the country of origin. There will be a process to petition for adjustment of the fee amount.

Use of funds will focus on the environment and transportation. Each applicable fiscal year, the Secretary of the Treasury shall transfer 50 percent of collected funds to the Administrator, and 50 percent to the Secretary of Transportation.

- The Administrator, in consultation with the Secretary of Agriculture, the Secretary of the Interior, and the Secretary of State, shall use the funds to support State and local programs that assist communities in climate change adaptation; critical infrastructure resiliency; and protecting environmental quality and wildlife; and to meet international climate change adaptation commitments made by the U.S.
- The Secretary of Transportation shall use the funds received to support State and local programs that assist communities in improving the resiliency of critical infrastructure and for projects where the primary purpose of the facilities is the reduction of vehicular traffic.

Report to Congress (new Section 198):
Within 5 years of enactment of this part, the Administrator shall submit to Congress a report that includes recommendations, including a schedule for establishing the amount of the fee (once the original schedule has expired), future investments to reduce greenhouse gas emissions, and resources for climate change adaptation.
Residential Environmental Rebate Program (Section 102): The Administrator will receive an amount equal to $3/5 of the amount received from the carbon pollution fees to provide a monthly residential environmental rebate to legal residents of the U.S.

Pollution Reduction Trust Fund (Section 103): In the Treasury of the U.S., a trust fund to be known as the “Pollution Reduction Trust Fund” will be established using the remaining revenues from the carbon pollution fees, and it will implement carbon pollution reduction programs.

The funds will be appropriated into 4 areas for each of the first 10 calendar years after enactment of this Act:

- $7,500,000,000 to the Environmental Protection Agency to mitigate the economic impacts of the fee for energy-intensive and trade-exposed industries
- $5,000,000,000 to the Secretary of Energy to carry out the Weatherization Assistance Program for Low-Income Persons
- $1,000,000,000 to the Secretary of Labor to support transition for individuals employed by the fossil fuel industry seeking to transition to clean energy jobs
- $2,000,000,000 to the Advanced Research Projects Agency-Energy.

Title II – Sustainable Technologies Finance Program (Section 201): The “Sustainable Technologies Finance Program” will be established and provide loans, credit instruments, loan guarantees, and other financial assistance for eligible projects. A project shall be eligible if the project reduces greenhouse gas emissions and uses a technology for energy efficiency, alternative energy, electric vehicle infrastructure, energy storage, or public transportation. Priority will be given to projects that provide the largest greenhouse gas emissions reductions per Federal dollar invested. During each of the first ten years of the program, the Secretary of the Treasury will transfer $5,000,000,000 to the Administrator to cover program costs.
Budgetary Effects (Section 202):
This section refers to maintaining compliance with the Statutory Pay-As-You-Go Act of 2010.

Reports to Congress (Section 302):
[This section relates to the Safe Drinking Water Act and therefore will not be addressed.]

Sense of Congress Relating to Reduction in Greenhouse Gas Emissions (Section 303):
This final section states the goal of the Act, which is that the U.S. shall carry out activities to ensure that, by January 1, 2015, the total quantity of greenhouse gas emissions released by in the U.S. is reduced by not less than 80 percent, as compared to the total quantity of greenhouse gas emissions released during calendar year 2005.
At current emissions rates, scientists have predicted a minimum of a 2° Celsius global temperature rise by the end of the 21st century due to excessive greenhouse gas levels in the Earth’s atmosphere. The most prevalent of these gases is carbon dioxide, or CO₂, more colloquially known in this act as carbon. Carbon and other greenhouse gases are considered pollutants to the atmosphere because they disrupt the natural chemistry of our environment and lead to changes in our climate.²

What is Carbon and Where Does it Come From?

Background: The Carbon Cycle

Carbon dioxide, like other greenhouse gases, such as nitrous dioxide and methane, exists naturally in our environment. It is a gaseous form of the element carbon, which is the building block of all life on Earth. Our environment includes natural reservoirs and sources of carbon, as well as mechanisms to transfer carbon between these reservoirs and producers³ such as the biological processes of animal respiration and plant respiration (photosynthesis).

![Figure 1: The Carbon Cycle](image)

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The primary source of excess carbon in the atmosphere is the human combustion of fossil fuels. Fossil fuel is made from the fossilized remains of dead plants. The reserves of fossil fuel in our Earth are a non-renewable resource because they take millions of years to form. The reserve of fossil fuel in Earth’s crust represent stores of carbon that are released through combustion: “The burning of fossil fuels produces around 21.3 billion tons of carbon dioxide (CO₂) per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year.”

**Definition of Carbon Polluting Substance**

According to the Climate Protection Act of 2013, a carbon polluting substance is:

- “Coal (including lignite and peat), petroleum and any petroleum product, or natural gas” that produces greenhouse gas emissions when combusted for energy.
- Any “carbon pollution intensive good,” such as “iron, steel, a steel mill product (including pipe and tube), aluminum, cement, glass…pulp, paper, a chemical or industrial ceramic.”
- Or any other manufactured product that “generates, in the course of the manufacture of the product, direct and indirect greenhouse gas emissions that are comparable... to emissions generated in the manufacture or production of a product identified [above].”

**How does a carbon polluting substance pollute?**

This act focuses on carbon polluting substances that emit carbon pollution during the process of combustion. Although the substances that would be taxed in this act are not carbon pollutants in their raw form, when they are combusted, they release carbon dioxide into the atmosphere. At the rate that the U.S. currently uses these substances, this rate of pollution is detrimental to our environment. Following are examples of chemical reactions for the two most common carbon pollutants:
Coal:
\[
C + O_2 \rightarrow CO_2 + \text{energy}
\]

Gasoline:
\[
2\text{C}_8\text{H}_{18} + 25O_2 \rightarrow 16\text{CO}_2 + 18\text{H}_2\text{O} + \text{energy}
\]

Although both of these chemical reactions start with different substances, they end with two common results: carbon dioxide and energy.\(^5\)

**How does a *carbon pollution intensive good* pollute?**

The Climate Protection Act defines a Carbon Pollution Intensive Good as:

- Iron, steel or a steel mill product, aluminum, cement, glass, industrial ceramic.
- These substances can add to pollution in their production because they require massive amounts of *energy*, which can be sourced through the combustion of a carbon polluting substance.
- Pulp and paper also require large amounts of energy to produce. However they contribute to carbon pollution more specifically through their fiber supply, which can require large amounts of deforestation. Instead of directly producing carbon, pulp and paper eliminate potential carbon reservoirs that could act to absorb excess carbon in the atmosphere.

**Why Excess Carbon Dioxide is a Problem**

*Interference with Earth’s radiation budget*: Incoming shortwave radiation from the sun is absorbed by Earth’s surface and re-emitted back out into space in the form of longwave radiation. Excess carbon present in our atmosphere creates a greenhouse effect and traps some of this longwave radiation in the form of heat. The trapped heat in the atmosphere produces a global warming effect, which leads to climate disturbances.\(^6\) Global mean surface temperatures have risen by 0.74°C ± 0.18°C when estimated by a linear trend over the last 100 years (1906–2005). The rate of warming over the last 50 years is almost double that over the last 100 years. During the first 50

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years of the last century, the rate of warming was $0.07^\circ C \pm 0.02^\circ C$ per decade. During the second half the past century, this rate increased to $0.13^\circ C \pm 0.03^\circ C$ per decade.²

Figure 2: Greenhouse Effects

Acidification of the oceans: The oceans absorb carbon from the atmosphere. Since there is more atmospheric carbon than the cycle can naturally absorb, the carbon reacts with the water to form an acid.⁹ via the following chemical reaction:

$$\text{CO}_2 \text{aq} + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$$

According to the National Oceanic and Atmospheric Association oceans have absorbed 50% of the carbon emitted from the burning of fossil fuels. This acidification is detrimental to some marine life, such as coral reefs. Coral reefs host the majority of plankton in the ocean from which the majority of marine life feeds.⁶

The Impacts of Climate Change

Global mean sea level rise: Sustained global warming greater than 1.5-2.5° Celsius is a threshold beyond which there is likely to be at least partial deglaciation of the Greenland ice sheet, and possibly of the West Antarctic ice sheet. This would cause sea level rise of 4-6 meters in the coming centuries.¹⁰ From 1961 to 2003, the average rate of sea level rise was $1.8 \pm 0.5$ mm/yr. For the 20th century, the average rate was

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1.7 ± 0.5 mm/yr. There is high confidence that the rate of sea level rise has increased between the mid-19th and the mid-20th centuries.\textsuperscript{11} NASA scientists have tracked the correlated sea rise since 1900:

![Figure 3: Sea Level Change Since 1900\textsuperscript{12}]

**Mass loss of glaciers and ice caps:** The degree of glacial retreat and ice cap deterioration is estimated to be 0.50 ± 0.18 mm/year in sea level equivalent (SLE) between 1961 and 2004, and 0.77 ± 0.22 mm/year SLE between 1991 and 2004. The maximum extent of seasonally frozen ground has decreased by about 7\% in the NH from 1901 to 2002, with a decrease in spring of up to 15\%.\textsuperscript{13}

**Hydrological cycle disturbances:** The global water cycle will be affected and lead to higher risks of drought and flood. The number of additional people at risk of clean water scarcity is projected to increase substantially with increasing temperature from


\textsuperscript{12} “Features of Global Warming” NASA. Web. 15 June 2013.

0.4-1.1 billion for 1.1-1.5°C Celsius warming above pre-industrial levels to 1.1-3.2 billion for 3-4°C Celsius warming\textsuperscript{14}.

**Changing weather patterns (Climate Change):** A warmer climate means a change in climate. As the air heats up, more evaporation occurs from the ocean into the atmosphere, leading to higher rates of precipitation. Warm air could also be responsible for the increase in hurricanes and more severe major storm events as “Both the increased warming of the upper troposphere relative to the surface and the increased vertical wind shear are contributing factors for hurricane development and intensification”\textsuperscript{15}

![Figure 4: Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauges (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values](image)


\textsuperscript{15} “Global Warming and Hurricanes.” *NOAA Geophysical Fluid Dynamics Laboratory*. Web. 15 June 2013.
Loss of ecosystems and species: A 2-3º Celsius increase in global mean temperature would increase the risk of extinction for 20-30% of species and have widespread adverse effects on biodiversity and ecosystems. There are additional impacts on animal migration and hibernation habits, as well as elongation of the grow season for many plants, leading to failing crops.

Public health effects on human populations: Increased global temperatures can cause significant threats to public health and safety which include: food shortages due to droughts and floods, higher frequency of deadly heat waves, reduced access to freshwater, poor air quality and spread of disease.

Global Context of U.S. Carbon Pollution

We know that a large amount of carbon pollution is taking place, but who is responsible? In 2011, CO₂ accounted for about 84% of all U.S. greenhouse gas emissions from human activities.

Since CO₂ is the greenhouse gas most emitted by the U.S., it is important to understand the context of U.S. CO₂ emissions when compared to the rest of the world. Leading climate change scientists have advised that global CO₂ emissions should not be allowed to exceed 350 ppm. At 275 ppm, the amount of carbon dioxide plays an important role in supporting life on Earth – without some retention of greenhouse gases to capture the sun’s heat in the atmosphere, the Earth would be too cold to inhabit. However, the amount of carbon in the air has risen

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steadily since the beginning of the 18th century and the Industrial Revolution. Over the past century and a half, carbon levels have increased from 275 ppm to 390 ppm. On May 9th, 2013, a global carbon level of 400 ppm was measured at the Mauna Loa Observatory in Hawaii. This is the highest amount recorded in the past 800,000 years.19

When compared to the rest of the world, the U.S. is a major contributor to climate change. At 300 million of the world’s 7 billion people, or 4.2 percent, it accounted for 19% of the world’s 2008 carbon emissions in the amount of 1.55 billion metric tons of carbon. It ranked second after China, who accounted for 23% of global 2008 CO2 emissions. China has 1.3 billion people, or 19% of the world’s population. 21 This means that

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although China has five times the population as the U.S., the amount of U.S. carbon pollution is roughly equal to that of China.
IV The Proposed Policy Solutions

Carbon Pollution and Equivalency Fees

For the first calendar year of the bill in effect, the fee will be of $20 per ton of carbon (equivalent), increasing by 5.6% for the following 10 years. The intent of a $20 carbon pollution fee per ton of carbon is to assign a cost to carbon that polluters must pay for their ability to pollute. By adding the true cost of carbon into a carbon-intensive product, we would expect a subsequent market correction to occur. Year over year fee increases will actively serve to diminish industry’s reliance on carbon fuels.

The purpose of the carbon equivalency fee is to assign the same cost of carbon to imported goods, which equalizes the effects of the carbon tax across both foreign imports and domestically produced goods. The revenues from these two taxes also provide the necessary funds to achieve the objectives of the other programs set forth in the bill.

Residential Environmental Rebate Program

The Residential Environmental Rebate Program is intended to protect low- to middle-income families from unintended consequences of the tax. Allocating 3/5 of the revenues received from carbon fees to the Residential Environmental Rebate Program ensures that the increasing costs of carbon-based goods associated with a carbon tax do not pose inordinately severe impacts on the average American household.

Pollution Reduction Trust Fund

The Pollution Reduction Trust Fund will assist with the technology and labor transition of the economy. It allocates a generous portion of the fund ($7.5 billion) to minimize the effects of the carbon fee on energy-intensive and trade-exposed industries. An additional $1 billion will be used by the Secretaries of Energy and Labor to carry out a Weatherization Assistance Program for Low-Income Persons and
capacity building activities focused on individuals employed in the fossil fuel industry seeking transitions to clean energy jobs, respectively. $2 billion will be designated for the Advanced Research Projects Agency-Energy. With the distribution of these funds, the bill includes mechanisms to soften the impacts of a carbon fee on industries that are currently dependent on carbon-based fuels and also prepares the labor force for a shift to renewable energy sectors.

**Sustainable Technologies Finance Program**

The bill will also create the Sustainable Technologies Finance Program, to be administered by the EPA. The Administrator shall provide loans and credit incentives, including public-private partnerships, to promote projects in the United States that curb greenhouse gases emissions. The range of this program is broad within the realm of clean energy and shall include the following types of investments: energy efficiency; combined heat and power; solar energy (including geothermal, wind, thermal and photovoltaic technologies); biomass and biofuel from non-crop sources; ocean, tidal and hydropower energy; electric vehicle infrastructure; energy store and advanced batteries; and public transportation methods with clean sources of energy. The EPA will have U.S. $5 billion each year to concede in the form of loans and grants to carry out projects within these parameters. Priority will be given for projects with the highest potential of reducing greenhouse gases emissions. In addressing domestic and imported carbon polluting substances as well as carbon pollution-intensive goods, the bill aims to tax most of the significant sources of emissions responsible for climate change. While the tax addresses the problem by raising the cost of carbon, its proceeds and the Sustainable Technologies Finance Program address the other half of the solution: renewable energy. Since energy demand will not be significantly lowered by this legislation, the focus is instead on clean replacement technologies.
The Potential of Regulation to Change Polluting Behavior

This bill does not propose an outright ban on the use of carbon above a given range of use. A quick glance at the U.S. economy would be enough to prove this to be an impossible solution. Rather, it differs from a cap and trade system, for example, by simply instating a fee with no cap, and allowing the fee to provide an incentive for reductions. If price signals mean anything at all, a carbon tax will cause a slow shift towards different sources of clean energy, driven by an increase in the cost of carbon and resulting in a change in consumer and polluter behavior. Increasing the cost of carbon by $20 per ton will have disparate impacts throughout the American economy; each industry sector will respond to the increasing cost differently according to the amount of carbon “used” in various products. A good baseline of carbon consumption can be established for transportation logistics, but when it comes to manufacturing, greatly varying outcomes may be observed. The tax incentivizes less carbon intensive practices and the research and development of new technologies; industries can interpret the tax in this way, by becoming more efficient and sustainable.

Costs and Benefits

The bill will certainly stimulate research and development of clean energy sources. Even with limited funding, $5 billion per year is more than enough to spur scientific innovation and allow a more competitive market for consumers in terms of which type of energy they will choose to serve their needs in the long run. Solar energy is currently the renewable technology that would benefit the most from technological investments. The highest photovoltaic cell efficiency currently on the market only reaches 19.7%\textsuperscript{22}, with significant room for growth. Higher efficiency would allow more the generation of more energy per area, potentially increasing solar roofs around the country.

A potential immediate negative impact of the tax is an increase in prices for goods that Americans depend on daily, such as electricity to heat their homes and gasoline to fuel their cars. Increasing $20 per ton of a resource so commonly used in

\begin{footnote}
\textsuperscript{22} “Solar Frontier Reaches 19.7% Conversion Efficiency…” Solarserver.com. 1 January 2013. Web. 13 August 2013
\end{footnote}
the economy will cause an increase in prices, both for producers and consumers. It is still not clear what the magnitude of this impact will be, especially taking into account the Residential Rebate Program and financial incentives for clean energy producers.

With legislation that seeks to shift behavior, rather than impose strict regulations, outcomes can prove uncertain. This is true for the Climate Protection Act of 2013. There is a risk that rather than seeing a transition to alternative fuel sources, fossil fuels producers will simply pass along the cost of the tax to consumers in the form of increased pricing and no significant change in emissions would occur. The bill states that $\frac{3}{5}$ of the collected funds will be dispersed to U.S. citizens to mitigate the impacts of increasing energy costs. It is unclear whether consumer habits will change if prices are not effectively increased after the rebate. However, the rebate is not extended to large energy-consuming entities like corporations and universities, presenting a strong potential for behavior changes in this side of the economy.

Another aspect of the bill to consider is the fact that it only looks to the future. The existing atmospheric carbon level is already enough to lead us to very unstable climate conditions, and the Climate Protection Act of 2013 focuses only on reducing upcoming emissions.

On the other hand, the potential benefits of this bill reach beyond the borders of the United States. It could provide a model for other nations to emulate and the opportunity to reassert American environmental leadership. Even if other nations do not follow America’s lead, it would behoove the U.S. to transition to renewable energy, as fossil fuels are finite and will only increase in price. This legislation has the potential to inspire technological advances in alternative energy, energy efficiency, energy storage, and low or zero-emission transportation. Though industry may be resistant to change, enacting this legislation could generate change that benefits both industry and the public.
V Science and Technology Solutions and Their Uncertainties

This Act uses the tax and money from other sources to support programs and renewable energy technologies that would help to reduce the carbon emissions and current atmospheric carbon dioxide concentration. The sections below will examine two renewable energy options as well as carbon capture and storage.

Wind Energy

Wind energy is used to make electricity that is typically generated by wind turbines. Incoming wind turns the blades of a wind turbine, which converts the kinetic energy of the wind into mechanical energy. The spinning blades of the turbine are connected to a rotor, which is connected to a main shaft. The main shaft spins a generator to create AC electricity. The tower of a wind turbine is often made of steel or concrete, and built to be 100 feet (30 m) or taller to take advantage of better winds. The turbine usually operates in a range of winds from 8-55 mph and can be used to produce electricity for a single building or for distribution in an electric grid.

Solar Energy

Solar energy is also mostly used to produce electricity and is typically divided into two categories of energy absorption: photovoltaic (PV) and solar thermal, which is also referred to as concentrating solar power (CSP).

Photovoltaic Energy

The basic principle behind PV cells is that sunlight is converted directly into electricity. Incoming radiation contains photons of solar energy that shine on the surface of PV cells and are either reflected, absorbed, or pass right through the cells. When enough photons are absorbed by the semiconductor material on the panel’s surface, electrons are dislodged and light is converted to electricity.

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Solar Thermal

Solar thermal or CSP energy uses mirrors or lenses to convert sunlight into electricity in an indirect way. Using the reflective surfaces, incoming light is concentrated onto receivers that convert solar energy to heat. Typically, this heat elevates the temperature of a special kind of working fluid, which is used to power a steam turbine that is connected to an electricity generator.\(^{26}\)

The Emission Advantage of Wind and Solar Energy

\[Table 1: \text{Carbon Emission Reduction Advantage (based on 2010 production)}\]

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Electric Power Production(^{27}) (GWh)</th>
<th>Life-cycle Greenhouse Gas Emission(^{28}) (g CO(_2)/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil Fuels</td>
<td>2,872,049</td>
<td>450~1000</td>
</tr>
<tr>
<td>Solar</td>
<td>1,212</td>
<td>22 (CSP); 46 (PV)</td>
</tr>
<tr>
<td>Wind</td>
<td>94,652</td>
<td>12</td>
</tr>
</tbody>
</table>

From the table above we can see that when producing the same amount of power, wind and solar energy have very low carbon emission outputs, but also that overall energy production from these renewable sources is still far outweighed by fossil fuel energy production. Note that the large range of life-cycle emissions for fossil fuels is due to the different fuel sources (natural gas, petroleum, coal).

Carbon Capture & Storage

Carbon capture and storage, or carbon capture and sequestration (CCS), is a set of technologies that can greatly reduce CO\(_2\) emissions from new and existing coal and


gas-fired power plants and large industrial sources. CCS is a three-step process that includes:

1) Capture of CO₂ from power plants or industrial processes
2) Transport of the captured and compressed CO₂ (usually in pipelines).
3) Underground injection and geologic sequestration (also referred to as storage) of the CO₂ into deep underground rock formations. These formations are often a mile or more beneath the surface and consist of porous rock that holds the CO₂. Overlying these formations are impermeable, non-porous layers of rock that trap the CO₂ and prevent it from migrating upward.²⁹

In addition to reducing carbon emissions at the source (e.g. coal-fired power plants), CCS technologies can also remove CO₂ from the atmosphere. An example of this technology is the synthetic tree, designed by scientist Klaus Lackner in collaboration with Columbia University’s Earth Institute, which could trap CO₂ in the air and collect it more efficiently than real trees.³⁰

The Uncertainties of Technology

There are also some uncertainties related to the supported technologies. First, renewable energy, especially wind and solar energy, are still far away from mass use due to their low production and high costs at present. In 2011, wind and solar energy only account for about 3% of U.S. electricity production.³¹ For mass production and use, we need innovation in these fields and increased political support.

The supported technologies still have some negative environmental impacts as well. For example, carbon storage risks CO₂ leaking from the deep underground, the manufacturing of photovoltaic cells produces toxins, and wind turbines cause disturbances to local eco-systems. With uncertainties and impacts such as those mentioned above, it remains to be seen what role the carbon-reducing technologies will play in the future of carbon emissions and global warming.

VI  Scientific and Environmental Measures of the Program’s Success

The legislation states the sense of Congress as the reduction of total greenhouse gas emissions (GHG) by 80% of 2005 levels by 2050. According to the U.S. Energy Information Administration, GHG emissions in 2005 were 7.1 billion metric tons of CO$_2$ equivalent.\footnote{“Emissions of Greenhouse Gases in the United States 2009.” U.S. Energy Information Administration, Mar. 2011. Web. 12 Aug. 2013.} Reducing this level by 80% means that emission levels in 2050 should be 1.4 billion metric tons of CO$_2$ equivalent. The majority of these emissions are CO$_2$.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure8.png}
\caption{Total U.S. greenhouse gas emissions from 1990-2009. Emission in 2005 were 7.1 billion metric tons of carbon dioxide equivalent, and the target goal by 2050 is an emission level of 1.4 billion metric tons of carbon dioxide equivalent. Data used comes from the U.S. Energy Information Administration.}
\end{figure}

Other objectives in the bill include addressing climate disruptions, enhancing the use of clean energy, and promoting increased resilience in U.S. infrastructure. These objectives are not given as explicit numerical goals in the legislation, but there are scientific and environmental indicators that may signal success:

**Reduced climate disruptions:** Climate disruptions include increased temperature, sea level rise, and snow cover. With significant global reductions of GHG emissions, the
rates of change of these indicators are expected to decrease. Several factors complicate
the use of temperature change, decreased sea level rise and increased snow cover
measurements as valid indicators of success. It is unknown how the environment will
respond to emission reductions due to the fact that the removal of CO$_2$ from the
atmosphere is a slow process. The National Oceanic and Atmospheric Administration
(NOAA) predicts atmospheric concentrations will continue to increase for some time
before they eventually decrease.\textsuperscript{34} Also, the impact of U.S. reductions will be difficult
to assess due to increasing CO$_2$ emissions from other rapidly developing nations like
China and India. More detailed analysis about this subject will be discussed later.

**Increasing use of clean energy:** As of 2011, clean energy accounted for 13\% percent of
the U.S. energy mix.\textsuperscript{35} In the absence of the Climate Protection Act, the U.S. Energy
Information Administration projects this number to be 16\% by 2040. With effective
implementation of the bill, this percentage should be well above 16\% by 2050.

\textbf{Figure 9:} Electricity generation by fuel from 1990-2040 in trillion kilowatt hours (kWh) per year.\textsuperscript{36}

\begin{footnotesize}
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Increasing resilience of U.S. infrastructure: Measurement of this goal will use economic indicators, and thus will not be discussed in this analysis.

**Desired Outcomes**

Implementation of the legislation involves inputs, or work carried out to achieve the desired outcomes. Inputs of the Climate Protection Act of 2013 may include: staff time dedicated to the collection of the carbon tax, clean energy research and development, financing of energy efficiency and renewable energy technologies, infrastructure development, and investments in low-emission transportation.

Inputs yield outputs such as the closing of high-emission facilities like coal-fired power plants, higher efficiency solar cells, utility-scale batteries with increased storage capacity, and more ubiquitous distribution of electric vehicle charging stations.

Transportation accounts for 28% of U.S. CO$_2$ emissions. In a study conducted by J.I. Arar, it was determined that transportation emissions could be reduced by 36% if electric vehicle uptake is increased by 10% each year between 2011 and 2020. This reduction would be even more dramatic if the energy mix powering the grid were to include more low-emission fuel sources.

Another promising potential output is the development of grid-scale liquid metal batteries, which could hasten the transition to renewable energy that requires storage. Liquid metal batteries have a greater energy and power density than existing energy storage technologies like compressed air and hydro pumping—a battery the size of a 40-foot shipping container can store enough energy to provide power for the daily needs of 200 average American homes. With increased investment in research and development, the liquid metal battery may be ready for market at pricing that is cost-competitive with the traditional storage technologies.

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The importance of an output is measured by its effectiveness in contributing to the solution to the problem. In other words, do outputs create the desired outcomes? Will the closure of coal-fired power plants lead to lower global temperatures? Will the increased use of renewable energy lead to a healthier and safer U.S. population?

**Measurement Techniques**

Assessing the success of the program will require the measurement of CO\(_2\) emissions. Three sources of emissions account for over 80% of CO\(_2\) emissions in the U.S.: electricity generation (33%), transportation (28%), and industry (20%)\(^4\).

**Electricity Generation**

The Emissions & Generation Resource Integrated Database (eGRID) is a database that provides information for virtually every power plant in the United States.\(^2\) eGrid gathers and integrates emission data sources from the Environmental Protection Agency (EPA), Energy Information Administration (EIA) and North American Electric Reliability Corporation (NERC).\(^3\) Emissions data is either reported or estimated, so there is some degree of uncertainty in these numbers.\(^4\)

**Transportation**

The EPA publishes the Inventory of U.S. Greenhouse Gas Emissions and Sinks, which provides emission information for personal as well as commercial transportation involving the combustion of fossil fuels. Several government agencies assist the EPA with these calculations, including the Department of Transportation, and the Bureau of Transportation Statistics.\(^5\)

**Industry**

Reporting of CO\(_2\) emissions for all carbon-intensive industries must be mandated under the legislation. A number of methods for calculating emissions for

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\(^{4}\) Pechan, E.H. “The Emissions &Generation Resource Integrated Database

industry exist, but many only account for a portion of emissions. Researchers at Carnegie Mellon University have developed a tool that provides “Tier 3” calculations, which is a comprehensive calculation of emissions including emissions released through the supply chain of goods and services.\textsuperscript{46}

Aside from emission measurements, CO\textsubscript{2} is also measured in terms of concentration in the atmosphere. Scientists are able to model how increased emissions will affect global CO\textsubscript{2} concentrations; with higher emissions, higher concentrations are expected.\textsuperscript{47} NOAA monitors CO\textsubscript{2} concentrations at the Mauna Loa observatory in Hawaii.\textsuperscript{48}

**Challenges in Measuring Success**

While the legislation states the goal of an 80\% reduction in CO\textsubscript{2} emissions as compared to 2005 levels by 2050, the intention is to slow global warming. Measuring the impact of the bill will be challenging, as the U.S. accounts for only around 20\% of emissions that contribute to global warming.\textsuperscript{49} This percentage will shrink as nations like China and India continue to increase their emissions. Between 1990 and 2011, the U.S. increased emissions by about 6-7\%. China’s emissions

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increased 280% during this same period of time\textsuperscript{30}. If these trends continue, decreases in U.S. CO\textsubscript{2} emissions will be overshadowed by increased emissions from other nations.

By introducing a carbon tax, this bill is looking at long-term solutions to facilitate a shift from fossil fuel markets to low carbon markets. However, long-term solutions often stimulate resistance as they imply behavioral change and the tolerance of sacrifices in the short- and mid-term until the implemented changes come to fruition. Scientific evidence of increased man-made environmental problems have intensified over the last decades making a shift away from fossil fuel markets necessary to help minimize negative impact on the ecosystem and humans. Only three months after this bill was introduced to the Senate, an atmospheric carbon level of 400 ppm, a level deemed unhealthy by scientists, was measured at the NOAA Mauna Loa Observatory in Hawaii on 9th May 2013. This is not only the highest amount recorded in the past 800,000 years, but the 125 ppm increase in only 150 years represents irrefutable evidence of human’s impact on nature and the need to act fast.\footnote{Monroe, Robert. “Carbon Dioxide at Mauna Loa Observatory reaches new milestone: Tops 400 ppm.” \textit{Scripps Institution of Oceanography}, 10 May 2013. Web. 12 Aug. 2013.}

Implementation of long term solutions, such as investments in renewable energy and increased energy efficiency as discussed in this report are required when trying to reduce carbon emissions and prevent further environmental damage.
Works Cited


“Global Warming and Hurricanes.” NOAA Geophysical Fluid Dynamics Laboratory. Web. 15 June 2013.


