

EPA's Climate CHange Emission Calculator Kit (Climate CHECK): A Climate Change Education and Greenhouse Gas Emission Inventory Kit for High Schools

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ABSTRACT

In an effort to provide a climate-change-based educational resource for high school students, EPA's Office of Atmospheric Programs has recently released the Climate CHange Emission Calculator Kit (Climate CHECK). Climate CHECK is an Excel-based kit that educates high school students about climate change drivers and science by equipping them with the tools needed to understand, estimate, and mitigate their high school's greenhouse gas (GHG) emissions.

Climate CHECK is a technically precise emission inventory tool that is both educational and appealing to high school students. The kit combines standard emission inventory approaches with innovative content and structure that were developed according to stakeholder interviews with high school students, educators, and facilities staff. Climate CHECK consists of three sections that provide: (1) background information on GHGs, the greenhouse effect, and climate change; (2) calculators students can use to estimate and inventory their high school's GHG emissions; and (3) resources and planning devices that students can use to develop an action plan for reducing emissions.

Climate CHECK's emission inventory section helps students calculate GHG emissions from emission sources using their school's activity data (e.g., kilowatts of electricity purchased, tons of waste disposed). However, Climate CHECK differs from other emission inventory tools because it allows students to walk through calculations using appendices, a conversion-factor sheet, example calculations, and interactive explanations of selected terminology and concepts. This process helps students develop an understanding of emission sources so that they are equipped and empowered to reduce their school's GHG emissions.

To support the three sections, and the educators and students using them, Climate CHECK also provides information on how the kit meets national education standards, a quick inventory sheet for schools that are unable to produce a full inventory, a printable action plan sheet, and a feature that lets students send the results of their inventory to their school district for compiling and school-district-wide action.

INTRODUCTION

Climate CHECK was produced under EPA's Climate Science and Impacts Branch, located under the Office of Atmospheric Programs, and is an Excel-based educational kit for high school students and teachers who are interested in learning about climate change.

The climate change initiative established under EPA's Climate Science and Impacts Branch includes public education about climate change. Under this initiative, EPA produced educational materials including the "Climate Change, Wildlife, and Wildlands Toolkit" (EPA 2001) for elementary and middle school students, and the "Global Warming Wheelcard Classroom Activity Kit," (EPA 2002) for middle school students. Also under this initiative, EPA and the National Park Service (NPS) have jointly launched a program known as the Climate Friendly Parks (CFP) Program, which relays climate change education to the public via the national parks (NPS 2007). An element of the CFP Program includes the Climate Leadership in Parks (CLIP) Tool, which is an Excel-based tool that helps park staff produce an emission inventory, plan actions to reduce their emissions, and develop materials to relay GHG and climate change information to their visitors. After working with several national parks to implement the CLIP Tool, EPA and NPS recognized the educational benefits associated with having a target population (in this case, park staff) develop a GHG emission inventory. EPA decided to build on the existing Excel-based emission inventory tool to teach high school students about climate change; this led to the release of Climate CHECK.

This paper describes Climate CHECK's development process, structure and content, and additional features. Particular emphasis is placed on features that were developed in response to the three main design elements (i.e., climate change science, climate change drivers, and climate change mitigation).

CLIMATE CHECK DEVELOPMENT PROCESS

As Figure 1 depicts, the first step in producing Climate CHECK involved stakeholder interviews with high school students, educators, and facilities staff. These interviews were conducted during the spring of 2005 at high schools located in Baltimore and Montgomery County, Maryland, and Arlington County, Virginia. The outcome of these interviews solidified Climate CHECK's design elements, which are listed below

- Climate CHECK should educate students about climate change and climate change science,
- Climate CHECK should allow students to estimate their high schools emissions as a means to educate them about climate change drivers (i.e., GHG emissions and GHG emission sources), and
- Climate CHECK should encourage students to mitigate their high schools GHG emissions; mitigation actions should be reflected in an Action Plan.

In addition to these primary design elements, stakeholders also provided suggestions for additional features that would improve Climate CHECK's usefulness, both to students and to educators. These included information on how Climate CHECK meets national education standards, guidance on how to use to Climate CHECK, functionality to quickly approximate a school's emission without performing a full inventory, a glossary, and links to online resources.

Figure 1. Climate CHECK development timeline

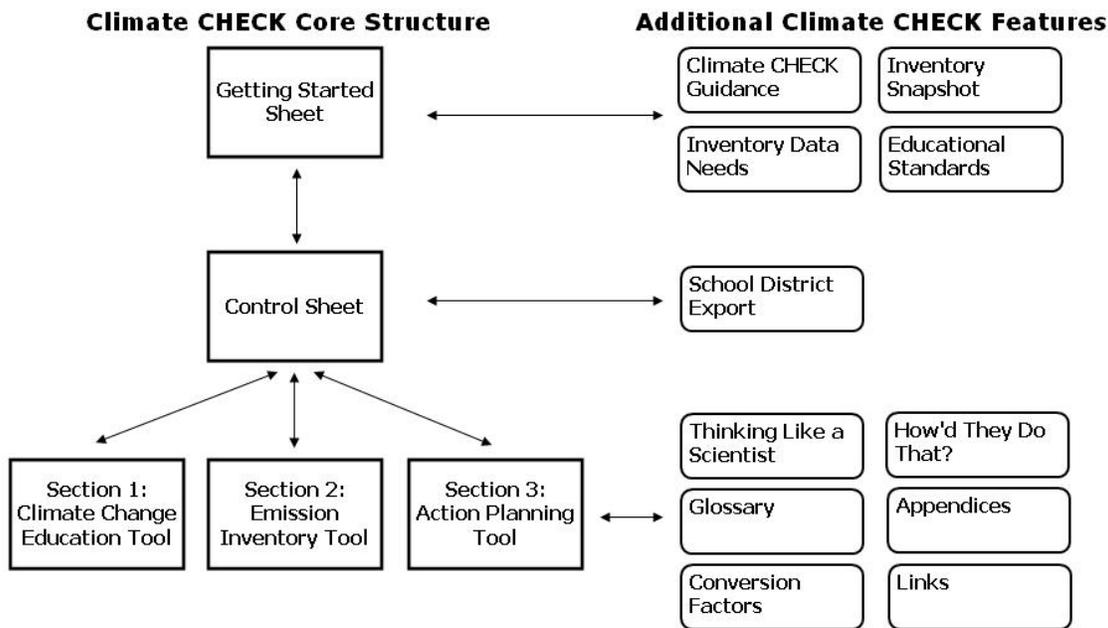


Development of Climate CHECK began during the summer of 2005 based on the three design elements established during the stakeholder process. Development, which included several contractor and EPA interim reviews, was completed in early 2006, and was followed by a stakeholder review. Comments received during the stakeholder review influenced the final Climate CHECK development stage, which was completed during the summer of 2006. Lastly, EPA submitted Climate CHECK for federal approval and posted the kit to EPA's "Climate Change: What You Can Do" website.

CLIMATE CHECK STRUCTURE AND CONTENT

In accordance with design elements established through planning and stakeholder interviews, the design team decided upon a kit consisting of three tools, which define the kit's three primary sections. Section 1 features the "Climate Change Education Tool," Section 2 features the "Emission Inventory Tool," and Section 3 features the "Action Planning Tool" (Figure 2). The user accesses these three tools via a main interface, or "Control Sheet," using built-in navigation. Prior to reaching the Control Sheet, the user is greeted by the "Getting Started Sheet," which provides an introduction to the kit. Together these three components, the Getting Started Sheet, the Control Sheet, and the three sections (education, emission inventory, and action planning) make up the core structure of Climate CHECK. This core structure is supported by additional features that help students complete aspects of the tools and better understand climate change topics, as well as inform educators of the structure and capabilities of the kit.

Figure 2. Climate CHECK structural diagram. Arrows indicate navigational structure.



Section 1: Climate Change Education Tool

The Climate Change Education Tool consists of three interactive background-information sheets that focus on the greenhouse effect, climate change science, and climate change impacts. Combined, these sheets provide an overview of climate change information from the drivers to the impacts in a format that supports classroom discussion and interactive learning.

Each background information sheet presents informational text (e.g., GHGs, the carbon cycle) that support the main topic of the sheet (e.g., the greenhouse effect) in a question-and-answer format. After the informational text, Climate CHECK asks the user questions about the information they have just read in multiple choice or true-or-false format. After the user answers the question, Climate CHECK provides the correct answer along with a description of the correct response. Key terms provided in the background sheets and throughout Climate CHECK are bolded and linked to a glossary.

Section 2: Emission Inventory Tool

The Emission Inventory Tool consists of seven source sheets and a summary sheet that allow students to estimate and summarize their school's emissions by source. Students are able to estimate carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and hydroflouorocarbon (HFC) emissions from stationary combustion (e.g., boilers, heaters, generators), purchased electricity and steam, mobile sources, (commuting and school-owned vehicles), landfilled solid waste, wastewater treatment, refrigeration and air conditioning, and land management (fertilizer application, non-road equipment, and forestry).

Emission estimates are based on methods established by the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 1997), *Good Practice*

Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000), the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002* (EPA 2004), and Volume VIII of the *Emission Inventory Improvement Program* (EPA 2003). Accordingly, methods range from simple mass-balanced based equations to complex models, such as the first order decay (FOD) model – a model designed to estimate landfill CH₄ emissions using decay rates, methane generation rates, and disposal rates.

To complete emission estimates, students follow the standard activity-based approach, wherein they multiply activity data by an emission factor to produce the emission estimate. A printable “Inventory Data Needs” Sheet, accessed through the Getting Started Sheet, lists all the activity data students will need to complete an emission inventory for their high school. Students are asked to collect activity data from the appropriate individuals (e.g., custodial staff, facilities manager) or estimate activity data using calculations provided by the tool. In so doing, students not only acquire the activity data needed to produce emission estimates, but also establish contacts that may later assist in the action-planning process.

After collecting activity data, students estimate emissions using calculators contained on a series of seven source sheets. The calculators provided for each source walk students through the process of estimating emissions. Students populate the calculator with activity data as well as information contained in source-specific appendices and a conversion factors sheet. Figure 3 presents an example from the Stationary Combustion Source Sheet, wherein students populate the cells in the table with a device name and type, the device’s fuel type and fuel consumed, and the carbon content and oxidation factor for the fuel selected. Students acquire information on carbon contents and oxidation factors from appendices accessed via the navigation button entitled “Appendix” located in the sheet’s header. As students enter data into the table, the calculator, located in the center of the sheet, populates automatically. The calculator presents a detailed breakdown of the calculation used in the emission estimate and provides the final estimate after clicking the “calculate” button. By using the calculate button, educators can encourage students to walk through the calculation before revealing the emission estimate.

Figure 3. Example calculator from Stationary Combustion Source Sheet

Stationary Combustion

Appendix
Glossary
Conversions

Key Words:

- Fossil Fuel
- Carbon Content
- Oxidation Factor
- Incomplete Combustion
- Global Warming Potential
- Carbon Dioxide Equivalent
- Boiler

Table 1: Fuel Consumption in Stationary Sources (e.g., boilers, furnaces, etc.)

Device Name	Device Type	Fuel Type	Quantity of Fuel Used		Carbon Content		Oxidation Factor (%)
			Value	Units	Value	Unit	
Basement Boiler	Boiler	Fuel Oil	5,000	Liters	0.85	kg C/liter	99.0%

To calculate CO₂ emissions, follow the steps below.

Step 1) Calculate Total Carbon

Device Name	Fuel Consumed	X	Carbon Content	=	Carbon in Fuel (kg)
Basement Boiler	5,000 Liters of Fuel Oil	x	0.85 kg C/liter	=	4,250

Step 2) Calculate Amount of Carbon Oxidized into CO₂

Device Name	Carbon in Fuel (kg)	X	Oxidation Factor (%)	=	Oxidized Carbon (kg of C)
Basement Boiler	4,250	x	99.0%	=	4,208

Total oxidized carbon from stationary combustion at your school is: **4,208 kg of C**

Oxidizing this carbon produces: **15,428 kg of CO₂**

Why does carbon dioxide seem heavier than carbon?

Thinking like a scientist...

CH₄ and N₂O Emissions

Each source sheet contains multiple calculators to accommodate different sub-sources (e.g., commuting and school-owned vehicles) as well as different methodologies for estimating emissions, or activity data, for a source. As an example, students attempting to estimate emissions from landfilled solid waste have the choice of directly entering the amount of landfilled waste, estimating the amount of landfilled waste using dumpster sizes and collection rates, or estimating the amount of landfilled waste using the school population and average waste disposal rates. For the latter two possibilities, information (e.g., dumpster sizes, average disposal rates) is provided to assist students with the estimation process.

At the bottom of each source sheet, emission results are summarized by gas and by sub-source. The emission results are presented in actual values as well as equivalents that are more tangible to students (e.g., acres of deforestation, tons of coal burned). Results are also summarized and presented in charts and tables for all sources in an emission summary page that follows the source sheets and is accessed via navigation before returning to the Control Sheet.

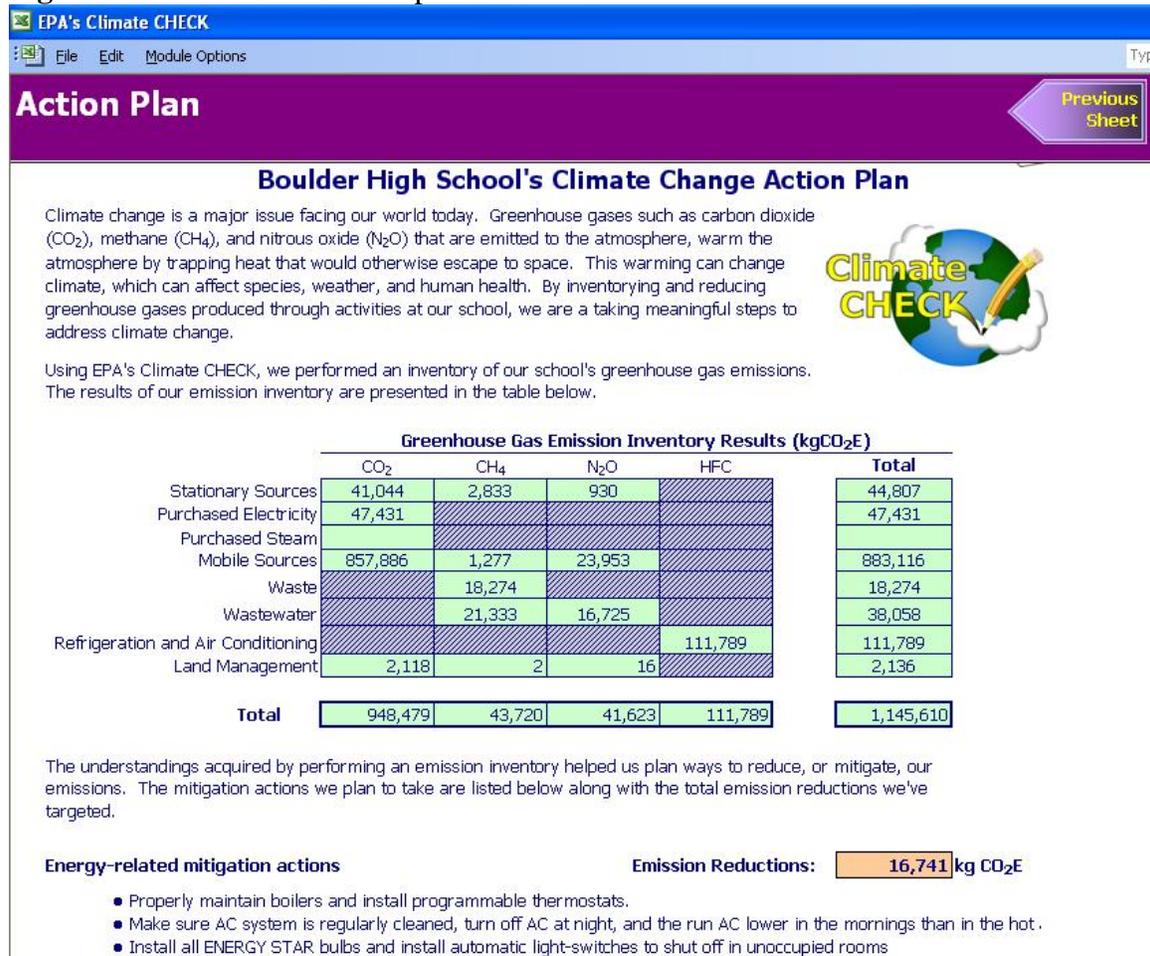
Section 3: Action Planning Tool

The Action Planning Tool consists of four mitigation sheets and a summary Action Plan that help students plan and coordinate emission reduction efforts at their high school. Those sources included in the emission inventory are grouped into planning sectors (e.g., Energy, Transportation, Waste). Information and links are provided to help students identify creative ways to reduce their school's GHG emissions.

Within each planning sheet, suggestions on ways to reduce emissions by source and sub-source (e.g., commuter vehicles, school vehicles) are provided along with the emissions estimated in Section 2. Once students have decided upon actions to reduce their high school's emissions, they can enter the action into a mitigation action cell provided under each source or sub-source and apply a percent reduction to the associated emission estimate. Mitigation actions, total emissions, and the total potential emission reduction are presented at the bottom of each mitigation sheet.

Planning results from all the mitigation sheets are summarized in a printable Action Plan that provides narrative on climate change, the results of the emission inventory, a listing of the mitigation actions the students have planned, and a summary of the potential emission reductions associated with the mitigation actions (Figure 4). The Action Plan can be printed and signed by the students, and is intended to serve as a visible reminder of the actions the students have agreed to take to reduce their school's climate change impact.

Figure 4. Climate CHECK sample Action Plan



ADDITIONAL CLIMATE CHECK FEATURES

Climate CHECK's three primary sections are supported by features that assist educators with applying the kit to their curriculum, assist school districts with running district-wide climate change programs, and assist students with linking various climate change topics.

Educational Standards

Stakeholders consistently requested that Climate CHECK not only provide the tools to educate their students about climate change, but also provide description of how those tools meet national educational standards. Expectations continue to rise for teachers to both meet performance standards and supply interesting educational materials with limited time and with limited resources. As a result, stakeholders felt that a key design feature should be to demonstrate how Climate CHECK meets educational standards so that educators can easily include Climate CHECK in their curriculum. To provide this description, the designers referenced the National Science Content Standards (NAP 2006), which identifies eight categories for growth in scientific knowledge and ability among high school students. The Educational Standards and Material Development Sheet in Climate CHECK provides examples for how Climate CHECK meets standards in each of these categories.

Climate CHECK Guidance and Inventory Snapshot

Because Climate CHECK contains or provides references to many activities and resources, educators may choose to use the tool in different ways. The "Climate CHECK Guidance" Sheet describes Climate CHECK's structure and also suggests possible options for using the kit, depending upon the amount of time available and the setting in which the kit will be used. The sheet offers guidance for using the kit as a single lesson, as a unit over a few days or weeks, or as a semester- or year-long project. To support educators who have limited time available for Climate CHECK, the tool includes an "Inventory Snapshot" Sheet, wherein educators or students can quickly approximate their school's GHG emissions using simple methods to develop activity data and emissions.

School District Compiler

After completing an emission inventory, students can export the results of their emission inventory to the school district where, using Climate CHECK, school district staff can compile emission results for all schools in their district. As climate change mitigation efforts grow, school districts may choose to lead programs to reduce GHG emissions. Accordingly, the design team sought to allow for viewing of emission inventory efforts made by individual schools at the school-district-level.

Linking GHG Emission Sources, Actions to Reduce Emissions, and Climate Change

Students interviewed during the stakeholder process possessed knowledge of the three major climate change topic areas covered by Climate CHECK (i.e., climate change science, climate change drivers, and climate change mitigation actions), but they had difficulty connecting the topics to each other. As an example, when students were asked what activities in their school generated GHG emissions the response was often, "using electricity." However, students had difficulty specifically describing how the use of electricity would result in GHG emissions or, in some cases, how electricity was

produced. Additionally, the stakeholder meetings revealed that students know the actions needed to reduce emissions (e.g., shut off the lights), but often do not understand why taking that action will reduce emissions and mitigate climate change.

To address the perceived difficulty in linking climate change topics, the design team incorporated several additional features to serve as a foundation for understanding major climate change topics. These features include step-by-step emission calculation tools, the “How’d They Do That?” Sheet, and the “Thinking Like a Scientist” Sheet.

The step-by-step emission calculation tools ensure that students understand that the fuels and other products humans are consuming, wastes humans are producing, and lands humans are managing contain carbon, nitrogen, and other elements that undergo a chemical change to produce GHGs. The calculations walk students through emission inventory concepts, such as global warming potentials (GWPs) (IPCC 2001), to help students better understand and appreciate the science behind the emission inventory process. In so doing, the calculators ensure that students understand the processes by which elements such as carbon and nitrogen transition from daily-use products to atmospheric GHGs.

The How’d They Do That? Sheet supports the step-by-step calculations by describing emission calculations that are too complex to walk students through. A call-out button located next to complex emission estimates on the source sheets navigates the user to a sheet that describes the methods behind the estimate. Students who are engaged by the complex emission estimate can complete an example calculation provided on the sheet. Examples of complex emission estimates described on the How’d They Do That? Sheet include CH₄ and N₂O emissions from stationary and mobile combustion, CO₂ emissions from steam purchases, and CH₄ emissions from landfilled solid waste.

The Thinking Like a Scientist Sheet provides text and activities that clarify common points of confusion related to climate change, and expand upon the specific activities that produce GHG emissions. A call-out button located below calculations on the source sheet presents a question related to the calculation, such as, “Why would electricity seem to get lost between the power plant and my school,” “How do cars control their emissions,” and “How does a wastewater treatment plant produce N₂O?” Students can follow the call-out buttons link to a sheet inside the kit that provides the answer to this question often in an interactive format (Figure 5).

Collectively, these three features, along with a glossary and links to online resources, are designed to help students draw connections between the sources that are producing emissions, the activities they can take to reduce emissions, and the effect emissions have on climate.

Figure 5. Climate CHECK example “Thinking Like a Scientist” Sheet.

Thinking Like a Scientist...

Carbon (C) vs. Carbon Dioxide (CO₂)

In 2003, U.S. emissions of CO₂ equaled 5,842 million metric tons. These CO₂ emissions occurred when carbon contained in fossil fuels, wood, and other carbon-based materials oxidized (underwent a chemical reaction with oxygen) usually because the fossil fuel, wood, or carbon-based material was combusted. During the oxidation process, each carbon atom picked up two oxygen atoms to become CO₂. This same process happens at your school when fuels containing carbon such as natural gas, propane, or gasoline are combusted in stationary sources (e.g., boilers, heaters, generators) or mobile sources (e.g., cars, trucks, tractors).

Carbon dioxide must have more mass than carbon because it contains two additional oxygen atoms, but how much more?

Using a periodic table of the elements in your classroom, on the web, or in this kit, enter the atomic mass of a carbon atom and an oxygen atom in the yellow cells below.

Periodic Table

	Atomic mass of a carbon atom:	<input type="text" value="12"/>	(mean relative)	Correct!
	Atomic mass of an oxygen atom:	<input type="text" value="16"/>	(mean relative)	Correct!

The mass of a molecule of CO₂ is equal to:

The mass of **one** carbon atom: plus the mass of **two** oxygen atoms: + =

The mass of a molecule of CO₂ is: + =

The percent of carbon in CO₂ is equal to the mass of carbon: mass of a carbon atom Correct!

...divided by the mass of CO₂: mass of a CO₂ molecule Correct!

percent of carbon in carbon dioxide

Carbon has 27.27 percent as much mass as carbon dioxide.

CONCLUSIONS

Climate CHECK fuses two areas of EPA’s climate change product development, emission inventory tools and educational materials, to produce a kit that educates students, estimates emissions, and mitigates GHG emissions. Since the release of Climate CHECK in December of 2006, EPA has received continual educator and student feedback regarding the kit’s usefulness as well as suggestions for improvement. Future efforts will entail broader release of Climate CHECK through existing newsletters, workshops, and conferences; user support and kit updates; and perhaps the creation of similar tools for museums, science foundations, and other institutions.

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Climate CHECK is available on EPA’s “Climate Change: What You Can Do, at School” website:

<http://www.epa.gov/climatechange/wycd/school.html>

KEY WORDS

Greenhouse Gas Emission Inventory

Emission Inventory Tools

National Science Content Standards

Climate Change Education

Microsoft Excel Applications