

CHAPTER 2

METHOD AND KEY ASSUMPTIONS

Ralph Torrie
Torrie Smith Associates

Overview

The primary objective of the quantitative analysis done as part of this study is to identify a collection of measures that would reduce North Carolina's GHG emissions to 93% of their 1990 levels by the year 2010. There are three essential steps to performing such an analysis: base year inventory, business as usual forecast, and emission reduction analysis.

Base Year Inventory

With 1990 as the base year, the first step in the analysis is to count the GHG emissions in North Carolina in 1990. The base year inventory is the essential starting point of any systematic strategic plan for emission reduction because it identifies both the level and pattern of emissions and therefore provides an initial indication of where emission reductions will have to take place if the target is to be met.

In fact, the main reason for doing an emissions inventory at the State level is to support an emission reduction strategy. If we were only interested in counting total GHG emissions, it would be sufficient to know a few key numbers, such as total energy consumption by fuel in the State. But we need an inventory that has enough disaggregation that we can begin to see where the opportunities for emission reduction lie, and we need an inventory with enough detail that we can use it to forecast future emissions according to projections of key driving forces (e.g. population, number of households, economic activity, vehicle-miles-traveled, etc.). The inventory must therefore not only reveal the total level of emissions in the State, but it must be broken down in ways (e.g. by fuel, by economic sector, or by source) that help to identify emission reduction opportunities. At the same time, it is important in a study like this that the inventory exercise not become so detailed that it takes the focus off the primary objective, which is to identify and analyze emission reduction measures. This is why we have left some of the smaller terms out of the exercise (e.g. PFC's, HFC's, SF6).

The Base Year Inventory is also where the boundaries of the analysis are defined. For example, in this study we exclude jet fuel consumption from the State emissions inventory and emission reduction strategy.

Method and Key Assumptions

The GHG emissions inventory developed in this study is based on the inventory done for the State of North Carolina by Appalachian State University (1996), with some revisions and updates that are explained more fully in Chapter 3. In the interests of making the results of this analysis comparable with other standard references on North Carolina's energy use, we have used the historical energy consumption figures by sector and fuel in the U.S. Energy Information Administration (1999) database as the basis for the inventory of energy-related GHG emissions. This is the same database that is used in the *North Carolina Energy Outlook, 1998* published by Standard & Poor's DRI (1999).

Business-As-Usual Forecast

The second basic step in the method used in this study is to forecast GHG emissions in the year 2010, under what we call "business-as-usual" conditions, or conditions under which no special effort is made to reduce GHG emissions. This is important for several reasons. First, it defines the challenge represented by the 7% target. As we will show in more detail below, under business-as-usual conditions, North Carolina GHG emissions are projected to be 49% higher in 2010 than they were in 1990. This means that to meet the 7% target, emissions in 2010 must be brought down 38% below what they are forecast to be under business-as-usual conditions.

Secondly the forecast reveals how much of the emissions in the target year (2010 in this study) will consist of new activity, as opposed to activity already in place in the base year. This is especially important in sectors, such as residential and commercial buildings, where there are very different opportunities and costs associated with reducing energy in new structures, as opposed to retrofitting of older buildings that were already existing in the base year.

Another important function of the forecast is that it provides the baseline against which emission reduction measures can be quantified. Without a clear and fairly disaggregated forecast of emissions in each sector, measures could get included that are already included in the forecast. For example, if improvements in the energy efficiency of commercial lighting systems are to be included in the strategies for meeting the reduction target, it is important that the contribution of the lighting technology in question be measured relative to what is expected to already be happening under business-as-usual conditions, and not relative to base year practice. The analyst must understand the level of energy efficiency improvement that is already embedded in the forecast so that additional improvements can be measured from that reference point and not from where energy efficiency stood in the base year.

The forecast also reveals the predicted dynamics of GHG emissions in a way that the snapshot provided by the base year inventory does not. Not all GHG emissions are projected to grow at the same rate, and the forecast reveals if there are fast growing sources that merit greater priority in the emission reduction strategy than would be suggested by the base year inventory.

Method and Key Assumptions

Growth in GHG emissions cannot be forecast directly; it is necessary to forecast emissions by relating emissions to some other driving force that can be forecast and that is routinely forecast, such as population, number of households, economic growth, energy demand, livestock population, etc. In this study we have endeavored to produce a business-as-usual forecast of GHG emissions in year 2010 that accepts current conventional wisdom on these key factors. For example, in forecasting energy related GHG emissions, we have accepted the population, household and fuel and electricity forecasts contained in the *North Carolina Energy Outlook, 1998* released earlier this year (Standard & Poor's DRI 1999). We adopt these standard forecasts so that we can focus the study on the technical and economic potential for reducing GHG emissions, given a conventional and optimistic outlook for demographic and economic growth in North Carolina.

Emission Reduction Strategies

The final and most important basic step in the method used here is the identification, quantification and analysis of measures for reducing emissions below their forecast level in 2010, with the ultimate goal of identifying sufficient measures to close the gap between the business-as-usual forecast and the target. In the case of North Carolina, an emissions level of 93% of 1990 levels is 135.0 megatons of eCO₂ and the business as usual forecast for 2010 is 216.1 megatons of eCO₂, so emission reduction (and carbon sink) measures equaling 81.1 megatons are required to close the gap between the forecast and the target.

As noted in the discussion above about the business-as-usual forecast, to avoid double counting, it is important that measures included in the emission reduction strategy are defined relative to forecast practices in the target year. The specific methods used to do this in this study varied from sector-to-sector and are described in the sector chapters. In general, the sector analysts developed spreadsheet models to assist them in developing their base year inventories and business-as-usual forecasts. These spreadsheets broke down energy use into a simple formula that included activity variables (e.g. number of households in the residential sector), energy use variables (e.g. energy use per household for space heating, water heating, appliances, etc, in the residential sector) and fuel share variables (e.g. share of space heating provided by natural gas, fuel oil, electricity, propane, etc.). These spreadsheets supplemented the *Greenhouse Gas Emissions Software* used as the primary analytical framework for this study, as described more fully below.

Sector variations are described in the sector chapters, but the basic approach to quantifying emission reduction measures in this study was an engineering based, "bottom up" method that computes the total impact of a measure by multiplying its effect in a single application by its potential when applied across an entire sector. All measures were entered in to the *Greenhouse Gas Emissions Software*, which also holds the base year inventory and business-as-usual forecast, thus allowing tracking of progress toward meeting the 7% target.

Method and Key Assumptions

While the outline of this method is simple enough in principle, the application can be complex, depending on the level of disaggregation and the precision required. Fortunately, about 90% of GHG emissions in North Carolina consist of CO₂ emissions from fossil fuel combustion, and there are very detailed databases and a large body of analytical experience in energy analysis that can be directly applied to GHG emissions analysis. Burning fossil fuel results in CO₂ emissions and, for any particular fossil fuel, the emissions per unit of fuel burned are well known and very nearly constant. This means that if we know how much of each fossil fuel is burned, we also know how much CO₂ is being emitted. If we know how much fossil fuel is saved by a particular measure or strategy, we also know how much GHG emissions have been reduced by the measure. So when it comes to the energy-related GHG emissions (which are 90% of GHG emissions in North Carolina), the three step method outlined above translates to a three step method for taking an inventory of energy use by fuel, projecting future energy use by fuel, and identifying measures for either reducing fossil fuel use or switching from a fuel that emits more CO₂ per unit of energy to one that emits less (e.g. from coal to natural gas).

About 10% of North Carolina's GHG emissions are from non-energy sources, with the two principal sources being agricultural operations (CH₄, N₂O) and sanitary landfills and sewage treatment operations (CH₄). For these sources, emissions must be estimated based on assumptions about the quantities of gases given off by various types of operations, and the results tend to be less precise than for CO₂ emissions from fossil fuel combustion.

Further details are provided below about the method used for the energy and non-energy GHG emissions analysis in this study, but first the concept of the Global Warming Potential needs to be introduced.

Global Warming Potential and “Equivalent CO₂”

Throughout this report, reference is made to “equivalent CO₂” or “eCO₂” as a unit. The effect of a particular GHG emission in contributing to global warming will depend on how much of it is emitted, how long it remains in the atmosphere, and how effective it is at causing radiative forcing (the physical phenomenon in the upper atmosphere that leads to global warming). To facilitate comparison of the relative impacts of different GHGs, climate scientists use a concept called the *Global Warming Potential*, which expresses the “radiative forcing” impact of different GHGs, relative to CO₂¹. In this report, the global warming impacts of different GHGs are compared using the 100-year Global Warming Potential values (the standard used in the U.S. national GHG inventory) -- 21 for CH₄ and 310 for N₂O. In other words, one ton of CH₄ emissions has the same global warming impact as 21 ton

¹ The *Global Warming Potential* of a GHG is technically defined as the cumulative radiative forcing between the present and some chosen future time “horizon” caused by a unit mass of gas emitted now, expressed relative to CO₂. The future global warming commitment of a GHG over the reference time horizon is the appropriate GWP multiplied by the amount of gas emitted.

Method and Key Assumptions

of CO₂, and a ton of N₂O has the same effect as 310 ton of CO₂. However, although both CH₄ and N₂O are more potent GHGs than CO₂, CO₂ emissions and atmospheric concentrations are so much higher than the other GHGs that it is by far the most important GHG. The Global Warming Potential concept oversimplifies the complexities of atmospheric chemistry and the role of various trace gases such as CFC's, HCFC's and HFC's in determining the net radiative forcing of climate, but it does provide a convenient way of approximating the relative importance of the different anthropogenic GHGs.

Methods and Assumptions for Energy Related Emissions Analysis

We adopted an end use sector approach to the analysis of the energy-related GHG emissions. The generic method described above was applied to each of the four major energy consuming sectors – industrial, residential, commercial, and transportation. As noted above, some 90% of North Carolina's GHG emissions are due to fossil fuel combustion and the method used in this study for analyzing these emissions adopts the standard emission coefficient approach. In this approach, total emissions are calculated by multiplying total fuel consumption by the appropriate emission factor for each fuel and adding up the total. Because the emission factors are well known and essentially constant for each fuel, once energy use by fuel is known, the associated CO₂ emissions can be easily calculated. Therefore, to develop an inventory of CO₂ emissions from fossil fuel combustion, we start with the State energy supply and demand statistics. In particular we chose 1990 as the base year for the inventory and we developed our base year emissions inventory from standard U.S. Energy Information Administration data sources on the consumption of fuels in North Carolina.

In mathematical terms:

$$\text{Energy-Related CO}_2 \text{ Emissions} = \sum_{\text{all fuels}} \langle \text{Total Fuel Use} \rangle \times \langle \text{Emission Coefficient} \rangle$$

A relatively small number of energy forms account for nearly all the CO₂ emissions. These include electricity, natural gas, light fuel oil, motor gasoline, diesel fuel and propane. For each of these fuels, CO₂ emissions were computed using the emission coefficients used in the 1605(b) reporting process by the Department of Energy². These coefficients represent the CO₂ emissions that take place at the point of end use, except for electricity, in which case they represent a prorating of the total CO₂ emitted by the power plants on the State grid across total electricity production.

For each of the four end use sectors, models of energy use by fuel were tuned to the actual energy use by fuel in 1990, as indicated in the Energy Information Administration (USEIA) database. This completed the first step of the analysis, which is to produce an inventory of emissions with sufficient disaggregation to support the identification and analysis of emission reduction opportunities.

² See "Voluntary Reporting of Greenhouse Gases -- Instructions", Form EIA-1605 (1996), Energy Information Administration, US Department of Energy, 1996.

Method and Key Assumptions

To complete the second step -- the business-as-usual forecast -- the sector models were “tuned” to the fuel and electricity projections in the *North Carolina Energy Outlook, 1998* (Standard & Poor’s DRI 1999) for the year 2010. For example, given the forecast of population and households and the final consumption of fuels and electricity by households forecast in the *North Carolina Energy Outlook, 1998*, it was necessary to adjust the energy use per household in our residential model until the model reproduced the total fuel and electricity consumption numbers in the State Outlook. This exercise defines the base from which emission reduction measures can be defined and it also ensures that this study is directly comparable to the *North Carolina Energy Outlook, 1998*. The business-as-usual forecast of GHG emissions in this study represents the level of emissions (at least for the 90% of emissions that are energy related) that would accompany the fuel and electricity forecast in the *North Carolina Energy Outlook, 1998*.

Finally, each of the sector analysts proceeded to identify energy saving, fuel switching and other measures that could be used to reduce emissions from the business-as-usual forecast for the sector. While the overall target is to identify strategies for reducing emissions to 93% of their 1990 levels, there was no requirement to achieve this result in every sector. The forecasts in the *North Carolina Energy Outlook, 1998* define different potentials for each sector; the information on technologies varies for each sector; and the sector authors took somewhat different approaches to measures identification and quantification. As a result the percent reductions achieved in each sector (relative to the business-as-usual forecast) vary over a wide range.

A Special Note on Electricity

Although electricity does not emit GHG emissions when it is used, CO₂ is emitted in great quantities when electricity is generated at power stations fueled by coal or oil or natural gas. For each of the energy end use sector analyses included in this study, power plant emissions were pro-rated over end use kilowatt-hours of electricity use in North Carolina to produce an emissions coefficient for electricity. This approach is required so that the end use sector analyses can be comprehensive in their evaluation of fuel switching options. It is well known that there exist large opportunities for moderating the demand for electricity at the point of end use through the application of modern, efficient technologies, and these options are best evaluated as part of the sector end use analyses.

Briefly, the method used to compute the electricity coefficient was as follows. CO₂ emissions from electricity production were computed based on data from the U.S. Energy Information Administration’s *State Energy Data Report* (USEIA 1999). The *State Energy Data Report* provides state-by-state estimates of energy inputs at electric utilities by fuel, in natural units and trillion Btu. In order to determine total emissions from electricity production from North Carolina generating stations, the amount of coal, natural gas, and petroleum utilized are multiplied by their respective CO₂ emission coefficients. Hydroelectric, nuclear, and biomass generation are all assumed to be zero GHG emitters. Once total CO₂ generation from electricity production in North Carolina has been computed, it is divided by the total end use consumption of electricity in the State. Electricity imports into North Carolina are assumed

Method and Key Assumptions

to have the U.S. average CO₂ coefficient for electricity, and this adjustment for imports is significant in North Carolina. In 1990, a simple division of emissions from power plants in North Carolina by total electricity in North Carolina yields an average kilowatt-hour emission coefficient of 0.152 tons per million Btu. Applying the correction for imported power in 1990 increases the coefficient to 0.188 tons per million Btu, which is the value used for the base year emissions inventory in this study. Applying the same method to 1996 yields an emissions coefficient of 0.202 tons per million Btu. In the absence of any better alternative for predicting where the coefficient might be in 2010 under business-as-usual conditions, the 1996 coefficient of 0.202 tons per million Btu was used for computing emissions from electricity in the 2010 forecast and in computing the emission reduction impact of electricity saving measures in year 2010. As Table 2-1 illustrates, electricity is by far the most GHG intensive form of energy being used in North Carolina.

Table 2-1: Carbon Dioxide Emissions of Fuels and Electricity in North Carolina

End Use Fuel or Electricity	Tons of CO₂ per million Btu
Direct use of natural gas	.059
Direct use of gasoline	.079
Direct use of coal	.103
Direct use of propane	.064
Electricity (average end use kW.hour in 1990)	.188
Electricity (average end use kW.hour in 2010)	.185
Heating Oil and Petroleum Fuels	.081

The end use coefficient for electricity has the disadvantage of not being useful for analyzing the impact on GHG emissions that the utility industry itself can have by making changes in the way that they make and deliver electricity. For this reason, we have also included the Utility sector in our method. In the utility sector analysis, changes in the mix of generation sources (e.g. substitute natural gas for coal generation) and the efficiency of electricity generation are evaluated in terms of their ability to further reduce the total emissions from electricity. To avoid double counting emission reductions, the impact of electricity-saving measures in the sector analyses is first computed, assuming the business-as-usual emission coefficient for electricity in 2010 (i.e. 0.202 tons per million Btu). Then in the utility analysis, we examine ways in which fuel switching and efficiency improvements in the electricity generation industry itself could reduce the average emissions per kilowatt-hour, thus reducing emissions from the demand for electricity that remains after the sector-based demand side measures have been implemented.

Methods and Assumptions for Non-Energy Related Emissions Analysis

About 10% of North Carolina's GHG emissions come from a variety of non-energy sources, with the two most important ones being Agriculture and Waste. Estimating emissions from these sources is less precise and relies on more assumptions and less hard data than is the case for CO₂ emissions from fossil fuel combustion.

Method and Key Assumptions

The specifics of the methods used for these two sectors are described in the sector chapters. In general, emissions from the North Carolina GHG inventory were used for the base year emissions, and simple models were constructed that allowed the growth of those emissions to be tied to growth in population, or agricultural output, or livestock population, or some other appropriate variable for the specific emission source under consideration. Demographic and economic growth rates consistent with the ones in the *North Carolina Energy Outlook, 1998* were used to ensure that the energy and non-energy components of the business-as-usual forecast were mutually consistent.

The Greenhouse Gas Emissions Software

A secondary objective of this study was to adapt an innovative software tool that was first developed for the International Council for Local Environmental Initiatives (ICLEI) to assist local governments in developing strategies for GHG emission reduction at the local level. The software, developed by Torrie Smith Associates, was designed to make the task of GHG emission analysis, including both inventories and emission reduction measure assessment, more accessible to non-energy experts, and to provide a comprehensive framework for supporting the development of GHG reduction strategies.

The software provides a user-friendly point-and-click interface for entering information and displaying results of both emissions inventories and measures quantification. (See Figures 2-1, 2-2, and 2-3.) It embodies a sector approach, and supports analysis of all the GHGs considered internally as critical, although emphasis is on CO₂ from energy use and CH₄ emissions from landfilled waste. The software comes equipped with default values for emission coefficients and other factors that allow the analyst to concentrate on researching the necessary input information. A variety of generic types of emission reduction measures are supported with standardized algorithms that facilitate “what if” analysis of various measures. In addition to being an emissions inventory framework, the software supports the “business-as-usual” forecast and the setting of reduction targets, and provides the user with reports showing the gap between the forecast and the sum total impact of emission reduction measures that have been entered.

In addition to quantifying GHG emissions and emission reductions, it provides estimates of the reduction in criteria pollutants from GHG reduction measures, estimates of simple financial paybacks, and a variety of other outputs in pre-formatted reports. The Greenhouse Gas Emissions Software is not intended to replace more sophisticated specialized models for detailed building energy analysis or electricity DSM analysis, but rather it is intended to provide a place where emission inventories and emission reduction strategies can be kept in a single, easy-to-use framework to facilitate target-oriented strategic planning. An underlying objective in developing the software has been to bring a certain degree of standardization to the approach being taken by local governments in developing emission reduction strategies in the hope that such standardization would facilitate the sharing of information and experience, and make the maintenance of this type of specialized software tool more feasible.

Method and Key Assumptions

A version of the software was adapted for this study and was successfully used by the study team to hold the inventory, forecast and dozens of emission reduction measures, of which about 75 were included in the final scenario. A number of recommendations are being developed for how the Torrie Smith software could be adapted for permanent use as a tool for aiding state governments in forming their GHG emission reduction plans.

Figure 2-1: Greenhouse Gas Emissions Software Screen, Example 1

The screenshot shows the CCP-Canada Greenhouse Gas Emissions Software interface. The main window is titled "CCP-Canada Greenhouse Gas Emissions Software" and has a menu bar with "File", "Record", "Report", "Settings", "Assistants", and "Help". Below the menu bar are tabs for "Community Analysis", "Community Measures", "Corporate Analysis", and "Corporate Measures". The "Residential" tab is selected, showing a "Notes Regarding Residential Sector Data" field and a table of energy sources. The table has columns for "Energy Source", "Fuel Units", and "Total Residential". The "Indicator Inputs" section shows "Population" at 450,000 and "Households" at 150,000. At the bottom, the "Forecast Builder" section shows "Energy (GJ)" at 15,343,661 and "Equivalent CO₂ (tonnes)" at 680,910. Red callout boxes highlight specific features: "Quick emissions inventory organized by key sectors, including carbon dioxide from fuels and electricity, methane from waste, and other GHG gases." (pointing to the Residential tab), "Over 40,000 words of illustrated Hypertext Help files" (pointing to the Help icon), "Automatic energy unit selection and conversions" (pointing to the Fuel Oil dropdown menu), and "Greenhouse gas emissions automatically computed and displayed." (pointing to the Equivalent CO₂ value).

Quick emissions inventory organized by key sectors, including carbon dioxide from fuels and electricity, methane from waste, and other GHG gases.

Over 40,000 words of illustrated Hypertext Help files

Automatic energy unit selection and conversions

Greenhouse gas emissions automatically computed and displayed.

Energy Source	Fuel Units	Total Residential
Electricity	(million kWh)	1,475
Natural Gas	(million cubic m)	259
District Energy	(GJ)	0
Fuel Oil	(litres)	3,100,000
Propane	(litres)	2,500,000
Wood	(cords)	0

Energy (GJ): 15,343,661 Equivalent CO₂ (tonnes): 680,910

Figure 2-2: Greenhouse Gas Emissions Software Screen, Example 2

Method and Key Assumptions

Generic emission reduction measures are defined, which the user customizes with local data...


Car or Van Pooling

This Measure Type is available in both the [Transportation sector](#) of the [Community Measures](#) module and the [Vehicle Fleet sector](#) of the [Corporate Measures](#) module. It utilizes the [Transportation Measures Calculator](#) for computing emission reductions. As with all measures, open a new [record](#) by clicking on the [Insert](#) button on the [Record Navigator bar](#).


Follow these FIVE steps to complete measure quantification:

Step 1. Select the measure type [Car/Van Pooling](#) from the measure type list.

Step 2. Fill in the [Measure Description](#) window.

Step 3. Click on the [Calculator](#) button  to open the [Transportation Calculator](#). More details are given below on how to fill out the Calculator screen for this measure.

Note: In the [Transportation Calculator](#), all fuel units are in litres and fuel efficiency is in L/100 km. If your input data is in some other unit, use the [Energy Unit Converter](#) to convert your data into litres.

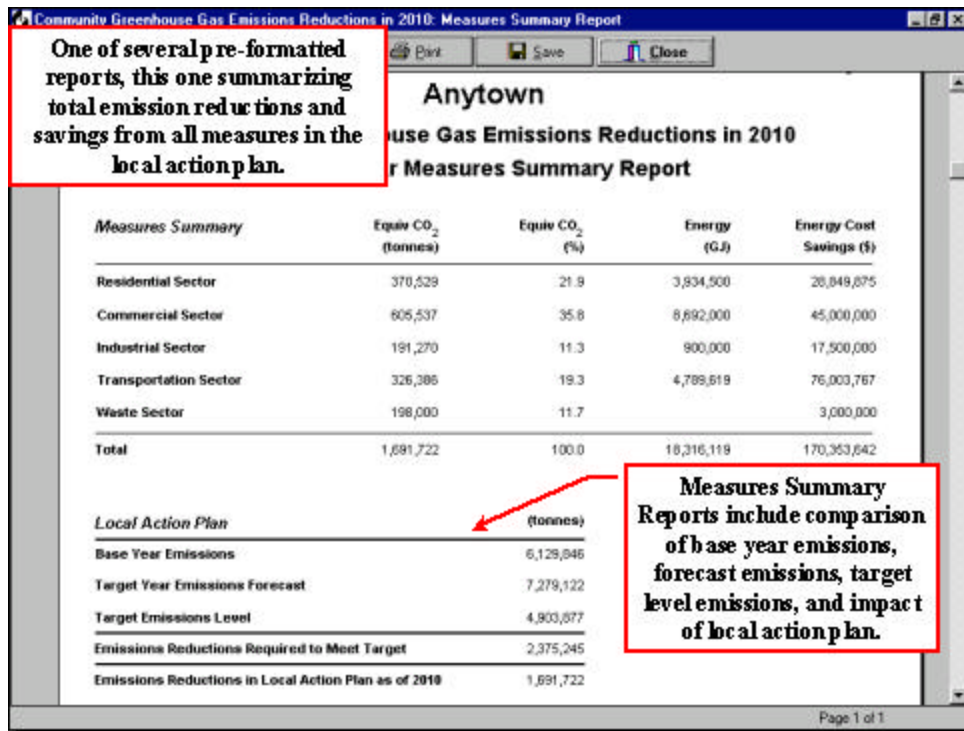
Step 4. When finished entering inputs in the [Transportation Calculator](#), click on the [Apply](#) button  and the software will calculate the emission reductions from the measure and return you to

Energy Production	(kJ)	Equivalent CO ₂ Production	(tonnes)	Savings	(t)
	13,471		918		213,767

Multiple assistants and step-by-step guides in the Help files make quantification of emission reduction measures easy...

Method and Key Assumptions

Figure 2-3: Greenhouse Gas Emissions Software Screen, Example 3



References

Appalachian State University, Department of Geography and Planning. 1996. *The North Carolina Greenhouse Gas Emissions Inventory for 1990*. Vol. 1 and 2. Appalachian State University, Boone, NC.

Standard & Poor's DRI. 1999. *North Carolina Energy Outlook, 1998*. Lexington, MA.

United States Energy Information Administration (USEIA). 1999. *State Energy Data Report, 1996*. Office of Energy Markets and End Use. United States Department of Energy, Washington, D.C.