The Center for Climate Strategies
Helping States and the Nation Tackle Climate Change

ES QUANTIFICATION MEMORANDUM

To: Arkansas Governor's Commission on Global Warming

From: The Center for Climate Strategies

Subject: Brief overview of the proposed approach for the quantification of greenhouse gas (GHG) emissions reductions associated with energy supply policy options in Arkansas

Date: June 5, 2008

This memo outlines key elements of the approach that CCS is using to quantify the GHG impacts and costs for those Energy Supply (ES) TWG policy options that are considered amenable to quantification. The TWG is encouraged to suggest modifications and additions. The list of topics addressed in the memo are:

A. Underlying Premises and Methodology
B. Outputs
C. Data Sources
D. Cost Inclusion
E. Using the Models to Test Varying Parameters

A. Underlying Premises and Methodology

There are a number of key premises upon which the analysis will be based, as briefly outlined below.

- *CCS role:* Unless a member of the TWG offers to undertake an analysis of any of the options, we assume that we (i.e., CCS) will undertake the analysis of the options. In the case where a TWG member does offer to undertake the analysis of one or more options, we will provide analytical support (e.g., review and technical feedback) as needed.
- *Transparency:* Data sources, methods, key assumptions, and key uncertainties are clearly indicated. The document of priority policy options, as well as the Excel workbooks quantifying each policy's impacts, clearly explains the assumptions that were used in the quantification process for each option.
- *Analytical approach:* We adopt the general analytical approach of cost-effectiveness and net present value, as widely applied to GHG mitigation policy options.[1] We include direct, economic costs from the perspective of the state as whole (e.g., avoided costs of electricity rather than consumer electricity prices).

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[1] See e.g. Section 2.4 of the IPCC Fourth Assessment Report, Working Group III, for more discussion of various economic analysis approaches. http://www.mnp.nl/ipcc/pages_media/AR4-chapters.html

- *Bottom-up analysis:* We adopt a bottom-up approach which is amenable to transparency and is capable of reflecting the costs (and cost savings) associated with individual policy options, in contrast to macroeconomic analysis, which aims to capture flows and interactions across all sectors of the economy. Potential macroeconomic impacts, cost or benefits that fall disproportionately on specific groups or actors, as well external costs and benefits, are noted qualitatively where studies or other information are available.

As much as possible, the analysis will proceed using simple spreadsheet modeling techniques in which assumptions are transparent and readily accessible to any TWG member for review and adjustment. In order to ensure consistent results across options, common factors and assumptions will be used for items such as:

- *Independent and Integrated Analyses:* Each option will first be analyzed individually and then addressed as part of an overall integrated analysis.
- *Fuel costs and projected escalation:* Fuel cost estimates will be based on common sources wherever possible. For example, fossil fuel price escalation will be indexed to the U.S. DOE projections as indicated in their most recent Annual Energy Outlook.
- *Consumption-based approach:* the analysis uses a consumption-based approach where emissions are calculated based on the electricity sources used to deliver electricity to Arkansas consumers, as opposed to a production-basis approach which considers the emissions from Arkansas power plants, regardless of where the electricity is used.
- *Full fuel cycle approach:* Where studies are sufficient to enable estimation, a fuel cycle analysis is applied when an activity has emissions impacts upstream (e.g., production and extraction) or downstream (e.g. waste disposal) that constitute a significant fraction of a policy option's emissions impacts.
- *Overlap with other TWGs:* Where ES options overlap with options being considered in the Residential, Commercial and Industrial (RCI) TWG, the analysis for these options will be conducted in close coordination with the assumptions and other inputs used in the ES analysis.

B. Outputs

The analysis of mitigation options produces the following results:

- *Net GHG reduction potential* in million metric tons of carbon dioxide equivalent ($MMtCO_2e$) is calculated from the 100 yr global warming potentials used by the Intergovernmental Panel on Climate Change (IPCC). The GHG reductions are calculated on an annual basis as well as cumulatively. Where significant additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, these will be indicated as appropriate. Positive numbers represent GHG reductions.
- *Net present value (NPV) cost* (or cost savings) is calculated in 2005 constant dollars, using a 5% real discount rate, for a range of periods from project launch through 2012, 2020 and 2050.[2] Positive numbers represent options with net costs; negative numbers

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[2] Capital investments with lifetimes longer than 2030 are represented in terms of levelized or amortized costs, in order to avoid "end effects".

represent options with net cost savings.

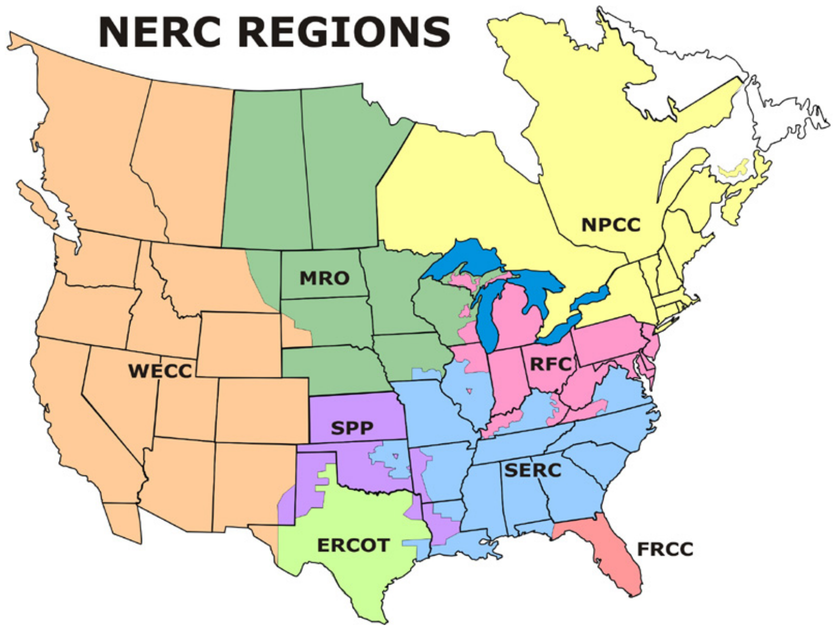
- *Costs per metric tonne of CO_2 equivalent* emissions reduced (or avoided) are given in units of dollars per metric tonne of carbon dioxide equivalent ($/tCO2e). This figure represents the NPV cost divided by the cumulative emission reductions, and it is calculated for each year as well as cumulatively.

C. Data Sources

TWG members are often in a good position to obtain and provide data sources that are specific to Arkansas, and these will be used as much as possible. The success of this approach depends on such information being provided to the CCS analysis team as early in the process as possible. Where Arkansas-specific information can not be readily obtained from the TWG, the analysis relies on published data from the US Department of Energy, National Laboratories, and other state climate change processes.

1) **Baseline Energy Consumption By Sector** *(billions of Btu)*
   Historical energy consumption in the state, by sector, is from the U.S. DOE Energy Information Administration (EIA) State Energy Data available at http://www.eia.doe.gov/emeu/states/_seds.html. To calculate future projected energy consumption, growth factors were applied to the historical 2005 data to calculate projections through 2030. The growth factors are based on a combination of two parameters. One accounts for growth within the RCI sectors, with growth factors for residential based on projected population growth (from University of Arkansas Center for Business and Economic Research Population Projections ; growth in the commercial sector based on non-manufacturing employment growth projections at http://cber.uark.edu/default.asp?show=population, and the Time Series Extrapolations, 2005-2030, from http://www.aiea.ualr.edu/research/demographic/population/default.html). Industrial growth projections were based on manufacturing employment. Employment projections were taken from the Arkansas Department of Workforce Services long-term industry employment projections (http://www.discoverarkansas.net/?PageID=156). The other factor is growth in electricity sales, which was calculated based on historical retail sales from 1990 to 2005 obtained from the EIA state electricity profile, in GWh, available from Table 8 at: http://www.eia.doe.gov/cneaf/electricity/st_profiles/arkansas.html.

2) **Baseline Power Station Electricity Generation** *(GWh)* **and Fuel Use** *(BBtu)*
   Gross generation for 2005 was obtained from the EIA database (EIA-906/920) on fuel stocks at all electric power sector generating facilities, broken down by fuel type. Data for later years was projected from the 2005 figure based on projections of growth in generation for the the Southwest Power Pool (SPP) region and the Southeastern Reliability Council (SERC) region were used. Arkansas was assumed to be partly (85%) located in the SERC region and partly (15%) located in the SPP region. The projected regional consumption and generation data are from the EIA Annual Energy Outlook (AEO) and can be accessed by downloading the “Electric Generation & Renewable Resource” file at http://www.eia.doe.gov/oiaf/aeo/supplement/index.html. On-site usage was subtracted from all generation figures.



3) **Heat Rates** *(Btu/kWh)*
Heat rates indicate how much fuel is used (Btu) to generate a given amount of electricity (kWh), and they vary greatly depending on the type of power stations and the fuel used. Heat rates are used to convert figures for electricity into figures for fuel use so the fuel use can be converted into GHG emissions using GHG emission factors. Heat rates for 2005 for each type of generation and fuel were calculated from 2005 fuel use (in BBtu) divided by 2005 generation (GWh). Projections for 2006 and beyond are based on annual combustion efficiency growth rates for the SPP and SERC regions. Combustion efficiency for a given year is calculated for each fuel type as the fuel use (in quadrillion Btu) divided by the electricity generated (in billion kWh), and the combustion efficiency growth rate applied to this value is based on the change in combustion efficiency from the previous year.

4) **Baseline GHG Emissions Associated with End-Use Consumption (by Sector)**
Historical CO_2 data by sector (and further broken down by fuel type) was calculated by two EPA State Greenhouse Gas Inventory Tool (SIT) software modules: the Fossil Fuel Combustion Module and—for emissions from industrial sources—the SIT module for industry. Methane (CH_4) and nitrous oxide (N_2O) emissions were calculated by the Stationary Combustion Module and—for emissions from industrial sources—the SIT module for industry.

Projected emissions through 2030 were based on the 2005 data with growth factors compounded from year to year as discussed above in (A) for energy consumption.

5) **Baseline GHG Emissions Associated with Electricity Generation From Different Technologies and Fuels**
The projected baseline data for each GHG was calculated for each fuel and generation type (e.g., non-lignite coal in a steam plant) as a direct product of the projected generation data (in GWh) described above in C.2 above. Metric tonnes of CO_2 are calculated from generation as:

tonnes CO2 = GWh * (Btu/kWh) * (tonnes CO2/MBtu) * (% of that fuel in the fuel mix)

where (Btu/kWh) is the heat rate and (tonnes CO2/MBtu) is the CO_2 emission factor. Similarly for CH_4 and N_2O, which are then converted to CO_2 equivalents [CO_2(e)] using global warming potentials (GWPs) of 21 for CH_4 and 310 for N_2O. The emission factor used for each GHG were the same as those used in the EPA State Greenhouse Gas Inventory Tool (SIT) software modules.

6) **Costs Associated with Electricity Generation**

The costs in the U.S. to produce electricity using different types of technologies are from the AEO 2007, and are based on an analysis of energy supply, demand, and prices in the U.S. using the EIA National Energy Modeling System. See Table 39 in the "Electricity Market Module available at: http://www.eia.doe.gov/oiaf/archive/aeo07/assumption/index.html.

7) **Energy Price Projections through 2030**

Energy prices by region are from the EIA Supplemental Tables to the Annual Energy Outlook 2007, with projections through 2030. Download "Consumption & Prices by Sector & Census Division" at: http://www.eia.doe.gov/oiaf/aeo/supplement/. Energy prices by region begin with Table 11.

D. Cost Inclusion

The analytical models being used can incorporate a wide variety of costs, depending on the availability of cost sate. Fuel costs are incorporated into all analyses where relevant. Other types of costs will be explicitly considered in the analysis if they can be readily estimated, such as:

- ❑ Capital costs levelized (amortized) where appropriate, e.g. for new energy supply facilities and associated infrastructure.
- ❑ Labor costs such as operations and maintenance.
- ❑ Fuel and material costs, e.g. for natural gas, electricity, biomass resources, water, fertilizer, material use, electricity transmission and distribution
- ❑ Other direct costs administrative and other costs (where readily estimated), such as the grid integration costs for renewable energy technologies.

Types of costs that are not incorporated include:

- ❑ External costs such as the monetized environmental or social benefits and impacts (such as the cost of damage by air pollutants on structures and crops), quality of life improvements, and health impacts and benefits such as improved road safety.
- ❑ Energy security benefits.
- ❑ Macroeconomic impacts related to reduced or increased consumer spending, and shifting of cost and benefits among different sectors of the economy.

E. Using the Models to Test Varying Parameters

Although all assumptions used in the calculations of estimated emissions reductions can be altered as needed by the TWG, all analyses include a set of assumptions specifically programmed so the impacts of modifying them can be tested. These parameters are identified in the 'Assumptions' tab of each spreadsheet by cells that are shaded in yellow and bordered in blue. The values in these cells are embedded in formulas throughout the analysis so that changes to them are instantly reflected in the results. TWG members are invited to make use of this facility to test the impacts of different assumptions.