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The World Energy Projection System Plus (WEPS+): Greenhouse Gases Model

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1. Introduction

Purpose of This Report

The Greenhouse Gases (GHG) Model of the World Energy Projection System Plus (WEPS+) is a computer-based model that computes energy-related carbon dioxide emissions by fossil fuel energy source and to allow the user to implement various carbon policy cases (specifically carbon tax and carbon cap policies). This report describes the version of the GHG Model that was used in production of the world projections published in the *International Energy Outlook 2011* (*IEO2011*). The GHG Model is one of 13 components of the WEPS+ modeling system. The WEPS+ is a modular system, consisting of separate energy models that are joined together through the overall system model in order to communicate and work with each other. These models are each developed independently, but are designed with well-defined protocols for system communication and interactivity. The WEPS+ modeling system uses a common and shared database (the "restart" file) that allows all the models to communicate with each other when they are run in sequence over a number of iterations. The overall WEPS+ system uses an iterative solution technique that allows for convergence of consumption and price to a simultaneous equilibrium solution.

This report documents the objectives, analytical approach and development of the WEPS+ GHG Model. It also catalogues and describes critical assumptions and computational methodology, and model source code. This document serves three purposes. First, it is a reference document providing a detailed description for model analysts, users, and the public. Second, it meets the legal requirement of the Energy Information Administration (EIA) to provide adequate documentation in support of its models (*Public Law 93-275, section 57.b.1*). Third, it facilitates continuity in model development by providing documentation from which energy analysts can undertake and analyze their own model enhancements, data updates, and parameter refinements for future projects.

Model Summary

The Greenhouse Gases (GHG) Model has two primary functions. First, the mode is used to calculate the energy-related carbon dioxide emissions by fuel. This is accomplished by importing all consumption by end use sector and fuel from the demand and transformation models via the restart file and applying the appropriate carbon dioxide emissions factors. A distinction between fuel used as feedstocks and "sequestered" fuels that are consumed in a carbon capture and storage (CCS) technology.

The second primary function of the GHG Model is to enable the endogenous implementation of carbon policies, such as a carbon tax or a carbon emissions cap. The model can implement a carbon tax by adding an additional price for each energy source based upon the relative carbon content. The model can also implement a carbon cap by iteratively making successively better estimates of the allowance price, which in turn causes the demand models to reduce their demand to achieve the overall emissions cap levels. The GHG Model allows the user to implement

carbon taxes at a worldwide level, at a regional level, or at a combined regional and end-use sector level. Finally, the model allows the user to implement a carbon cap at a worldwide or regional level.

Model Archival Citation

This documentation refers to the WEPS+ Greenhouse Gases Model, as archived for the *International Energy Outlook 2011* (*IEO2011*).

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Organization of This Report

Chapter 2 of this report discusses the purpose of the Greenhouse Gases Model; its objectives and analytical issues; its general activities and relationships; its primary input and output variables, and its relationship to the other models in the WEPS+ system. Chapter 3 of the report describes the rationale behind the GHG Model's design, providing further insight into assumptions utilized in the model. Chapter 4 describes the model structure in more detail, including flowcharts, variables, and equations.

2. Model Purpose

Model Objectives

The GHG model projects energy-related carbon dioxide emissions by applying factors associated with the carbon content of a fuel type to the energy consumed. The model accounts for energy used as feedstocks, energy that is sequestered (e.g., asphalt), and energy consumption for which the carbon dioxide is captured and sequestered (i.e., using carbon capture and storage). The model also can be used to implement a user-designated carbon emissions tax, calculating an allowance price for each fuel based upon its carbon content. Alternatively, the model can implement a user-designated carbon emissions limit (cap) using an algorithm to iteratively determine the carbon allowance price that reaches the cap. The carbon policies options were not used in the *IEO2011* projections.

As part of the WEPS+ system, the GHG Model produces carbon dioxide emissions and the impact of any carbon policy on each of 16 WEPS+ world regions (Table 1). These regions consist of countries and country groupings within the broad divide of the Organization of Economic Cooperation and Development (OECD) membership.

Table 1. Regional Coverage of the World Energy Projection System Plus Model

OECD Regions	Non-OECD Regions
United States	Russia
Canada	Other Non-OECD Europe and Eurasia
Mexico/Chile	China
OECD Europe	India
Japan	Other Non-OECD Asia
Australia/New Zealand	Middle East
South Korea	Africa
	Brazil
	Other Central and South America

Model Inputs and Outputs

Inputs

Table 2. WEPS+ Models that Provide Inputs to the Greenhouse Gases Model

Residential Model Input	Source
Residential energy consumption by fuel and region	Residential Model
Commercial energy consumption by fuel and region	Commercial Model
Industrial energy consumption by fuel and region	World Industrial Model
Transportation energy consumption by fuel and region	International Transportation Model
Electricity consumption by fuel and region	World Electricity Model
District heat consumption by fuel and region	District Heat Model

The Greenhouse Gases Model also relies on exogenous data sources that are input from the CtlItr.txt, EMEUConOut.txt, and GHGInput-2010_07_25.xml files (Table 3).

Table 3. Greenhouse Gases Model Exogenous Input Data Series

Source Input File	Greenhouse Gases Model Input
Ctlltr.txt	Maximum iterations allowed
	Current model iteration number
	Switch specification of whether model run is the final model run
EMEUConOut.txt	Historical EIA energy consumption by region and energy source in quadrillion Btu
	Historical EIA energy consumption by region and energy source in standard physical units
	Historical energy-related carbon dioxide emissions by fossil fuel in million metric tons
GHGInput-2010_07_25.xml	Carbon dioxide emissions and combustion factors by fuel
	Carbon allowance prices assessed by end use sector and region
	Switch specification of whether model scenario uses a carbon cap
	Carbon dioxide emissions limits under a carbon cap scenario
	Escape price; the maximum price allowed under a carbon cap scenario
	Reference case emissions projections used in a carbon cap scenario
	World tax intercept used to calculate allowance prices with a linear approximation (not used in *IEO2011*)
	World tax slope used to calculate allowance prices with a linear approximation (not used in *IEO2011*)

Outputs

Upon completion of a Greenhouse Gases Model run, results are exported into the WEPS+ restart file for use by other models (Table 4).

Table 4. Greenhouse Gases Model Output and the WEPS+ Models that Use Them

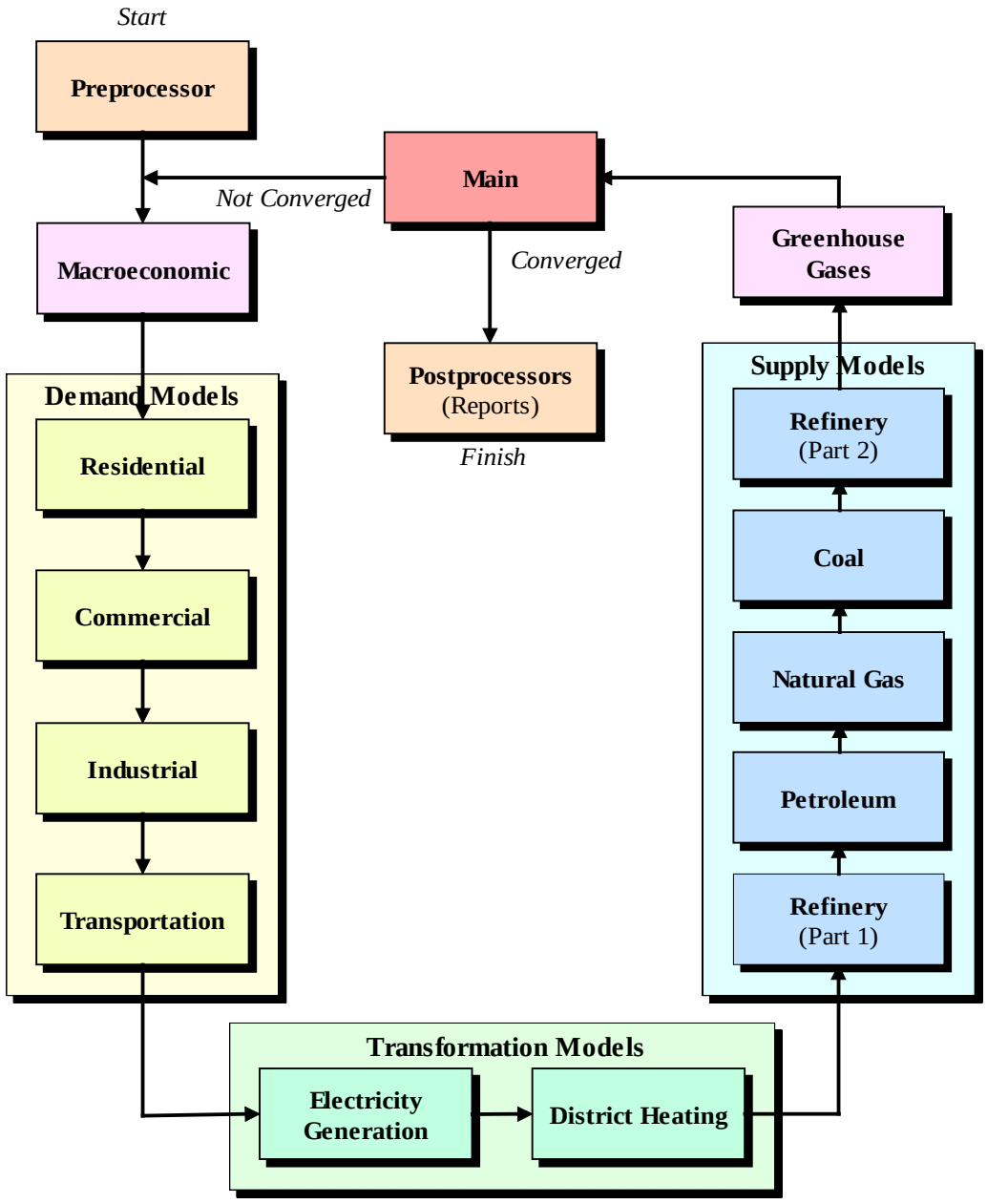
Greenhouse Gases Model Output	Destination
Carbon allowance prices for retail prices	Residential Model
	Commercial Model
	World Industrial Model

	International Transportation Model
	World Electricity Model
	District Heat Model
Carbon allowance prices for wholesale prices	Refinery Model
	Natural Gas Model
	Coal Model
	World Electricity Model
	District Heat Model

Relationship to Other Models

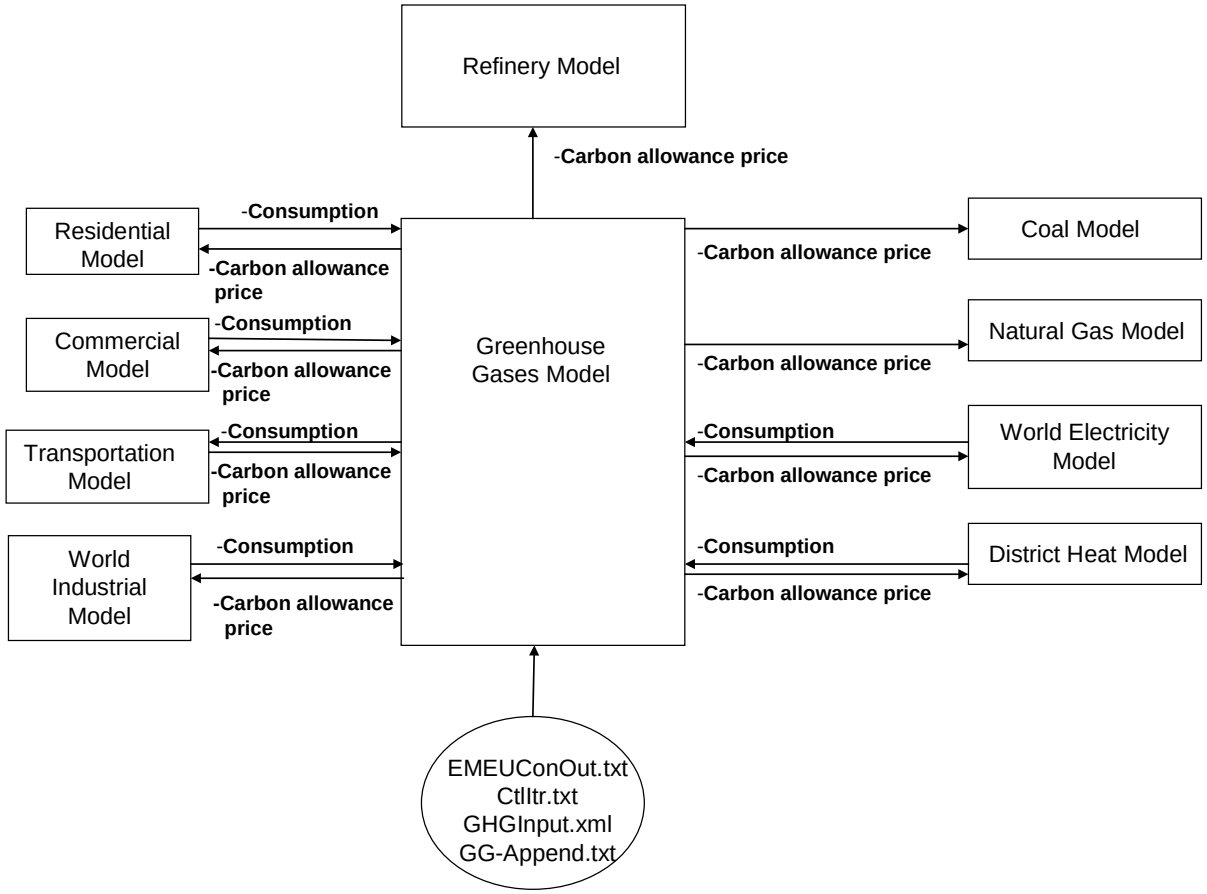
The Greenhouse Gases Model is an important component of the WEPS+ system. It is used to calculate energy-related carbon dioxide emissions by fuel and provide necessary carbon allowance prices for use in carbon tax and carbon cap scenarios. Thus, when a carbon scenario is executed, the Greenhouse Gases Model provides key inputs to the other WEPS+ components (Figure 1). A summary description of the models, flows, and mechanics of the WEPS+ system used for the *IEO2011* report is available in a separate *Overview* documentation.

Figure 1. World Energy Projection System Plus (WEPS+) Model Sequence



The Greenhouse Gases Model exogenously receives projections of energy consumption by fuel, end use sector, and region and then uses this information to calculate energy-related carbon dioxide emissions (Figure 2). If a carbon policy scenario is executed, the model supplies carbon allowance prices to the demand, transformation, and supply models.

Figure 2. The Greenhouse Gases Model Relationship to Other WEPS+ Models



3. Model Rationale

Theoretical Approach

The Greenhouse Gases Model projects energy-related carbon dioxide emissions. Carbon emissions are projected by applying a factor that measures the carbon content of a specific source of energy to the quantity consumed. The model accounts for energy that is used as feedstock, energy that is "sequestered" (for example, asphalt), and energy for which carbon dioxide emissions are captured and sequestered using a carbon capture and storage technology. The model can also be used to impose a user-specified carbon tax where a carbon allowance price is calculated for each fuel-type based upon its carbon content. In addition, the model can be used to impose a user-specified carbon limit (cap), using an algorithm to iteratively calculate the carbon allowance price needed to achieve that cap.

Model Assumptions

The Greenhouse Gases Model makes projections of:

- Energy-related carbon dioxide emissions, based upon an accounting framework that assumes carbon content and combustion factors are universally the same as the ones employed in the United States

- Carbon allowance prices, where taxes and carbon cap limits in a carbon policy scenario, are completely based upon user assumptions and they are used to calculate the appropriate carbon allowance prices

Within the context of a regional/sectoral carbon policy scenario, there is no capability, at this point, for energy trade or offsets. As a result, the carbon scenarios assume that all energy switching or reductions in energy consumption to achieve the specifications of the scenario are done without a trade mechanism.

4. Model Structure

Structural Overview

The main purpose of the Greenhouse Gases Model is to project energy-related carbon dioxide emissions by energy source. The model may also be used to implement carbon policy scenarios using a carbon tax or a carbon cap.

The basic structure of the GHG Model is illustrated in Figure 3.A call from the WEPS+ interface to the GHG Model opens the restart file and initiates the ReadCtlItr subroutine, which imports data from prior model iterations. ReadCtlItr imports data from the CurItr.txt file identifying the maximum number of iterations allowed, the current iteration number, and indicator of whether the final iteration has occurred

The Carbon subroutine is initiated once the ReadCtlItr has completed (Figure 4). In this subroutine, energy-related carbon dioxide emissions are computed and the resulting projections are calibrated to actual historical carbon dioxide emissions from the Energy Information Administration. Carbon begins by importing the historical energy consumption and carbon dioxide emissions from the EMEUConOut.txt file. Carbon dioxide emissions factors and combustion factors are the imported from the GHGInput.xml file.

Once the data imports have been completed, the Carbon subroutine calculates the ultimate carbon factor as the product of the emissions factor and the combustion factor. These factors are then applied to the by-product and sector energy consumption projections generated in the demand and transformation models to determine total carbon dioxide by region. The subroutine then is used to calibrate historical calculated emissions to the actual historical emission by adjusting the emissions factors to recreate the actual historical values. These new emissions factors are then applied to the energy consumption projections through 2035.

Once the Carbon subroutine has completed, the CarbRead subroutine is executed (Figure 5). The CarbRead scenario is used to determine whether a carbon policy scenario is to be implemented and, if it is, calculate the allowance price associated with the carbon tax according to energy type, end use sector, and/or region. The subroutine begins with the import of the carbon scenario type indicator from the GHGInput.xml file. There are 6 carbon scenario options available:

- No carbon scenario (CarbType = 0)
- World tax (CarbType = 1)
- Regional tax (CarbType = 2)
- Regional end use sector tax (CarbType = 3)
- World carbon emissions cap (CarbType = 4)

- Regional carbon emissions cap (CarbType = 5)

In each of the scenarios, excluding a "no carbon scenario," the user specifications for taxes or caps must be imported from the GHGInput.xml file. If a tax scenario is being implemented, the Carbon subroutine is then used to compute carbon allowance prices (both retail and wholesale) based on the taxation scheme. If, on the other hand, a world carbon emissions cap scenario is being implemented, a call is made to the CalcCap subroutine (Figure 6).

In the CalcCap subroutine, the world carbon allowance prices and the original total world Reference-case-generated carbon dioxide emissions (the so-called "original" emissions) are imported from the GG-Append.txt file. The file has a list of results from each previous model iteration, and the import routine is constructed to import only the latest prior iteration. Once the imports have concluded, the model is used to identify the iteration number and then assigns or calculates a world carbon price based on the system iteration number. After the new carbon allowance prices have been calculated, the resulting prices and emissions are exported to the GG-Append.txt file, the subroutine ends and the CarbRead subroutine continues.

The alternative to the CalcCap subroutine is one for regional carbon caps, the CalcCap5 subroutine (Figure 7). It is constructed exactly the same as the CalcCap subroutine, but CalcCap5 specifies caps at the regional level. As a result, regional prices and emissions are imported from GG-Append.txt and regional carbon allowance prices are calculated and exported to GG-Append.txt before control is returned to the CarbRead subroutine.

Once the CalcCap or CalcCap5 subroutines have completed, the CarbRead subroutine ends and control is returned to the main GHG model. Finally, the WriteRestart subroutine is executed. To provide the carbon allowance price projections (if any) to the restart file for use in future iterations of WEPS+.

Flow Diagrams

Figure 3. Flowchart for the Greenhouse Gases Model

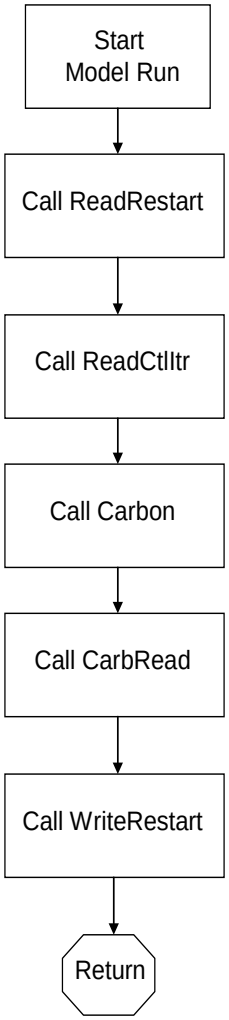


Figure 4. Flowchart for the Carbon Subroutine

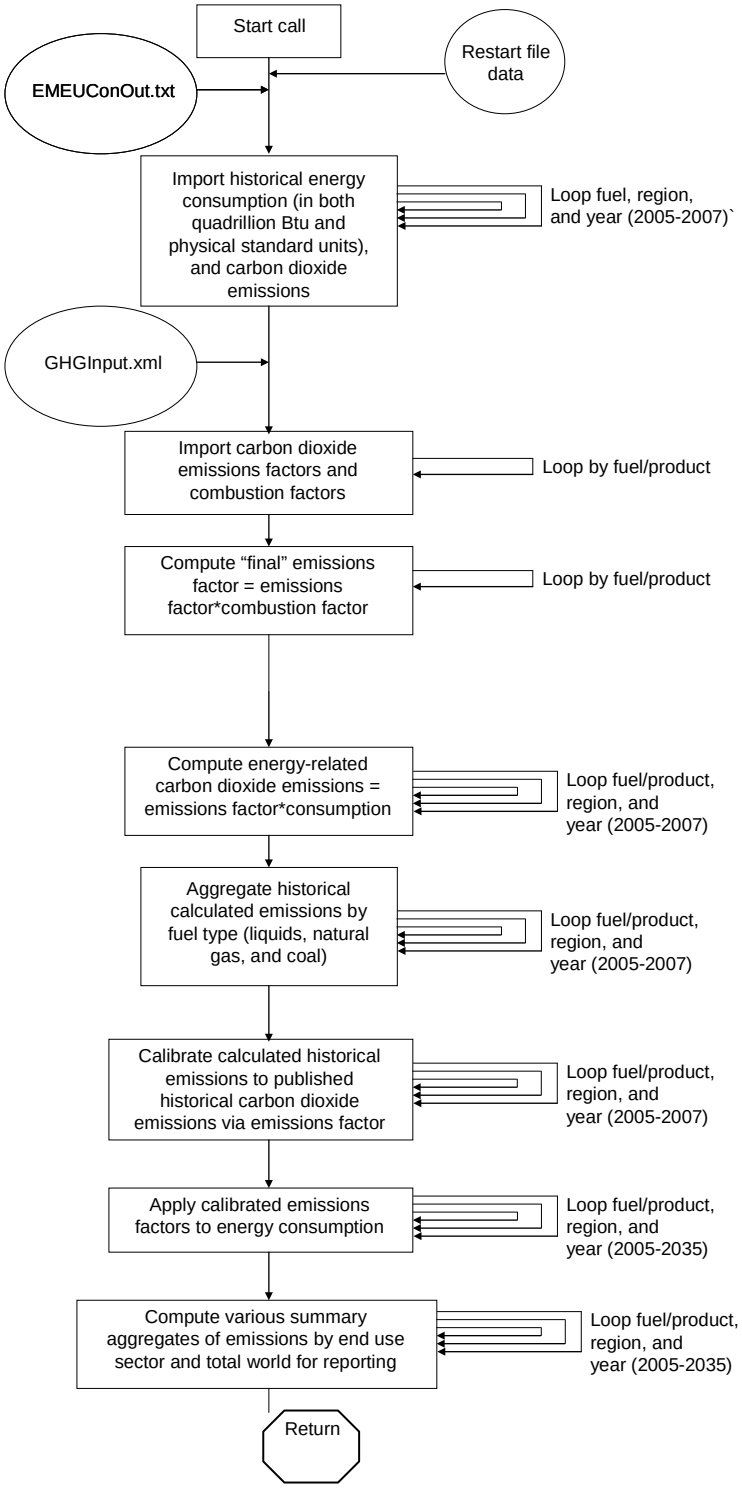
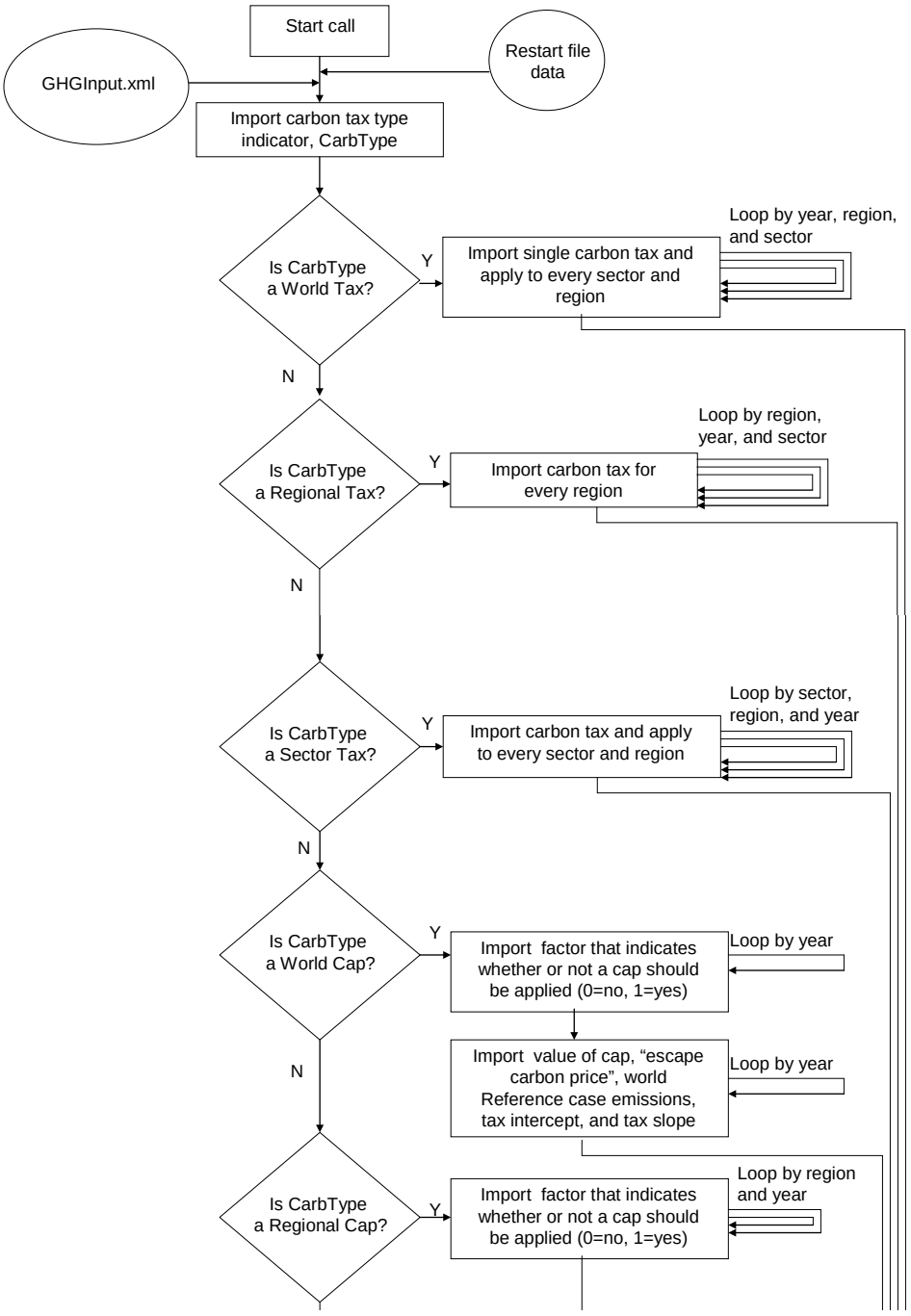


Figure 5. Flowchart for the CarbRead Subroutine



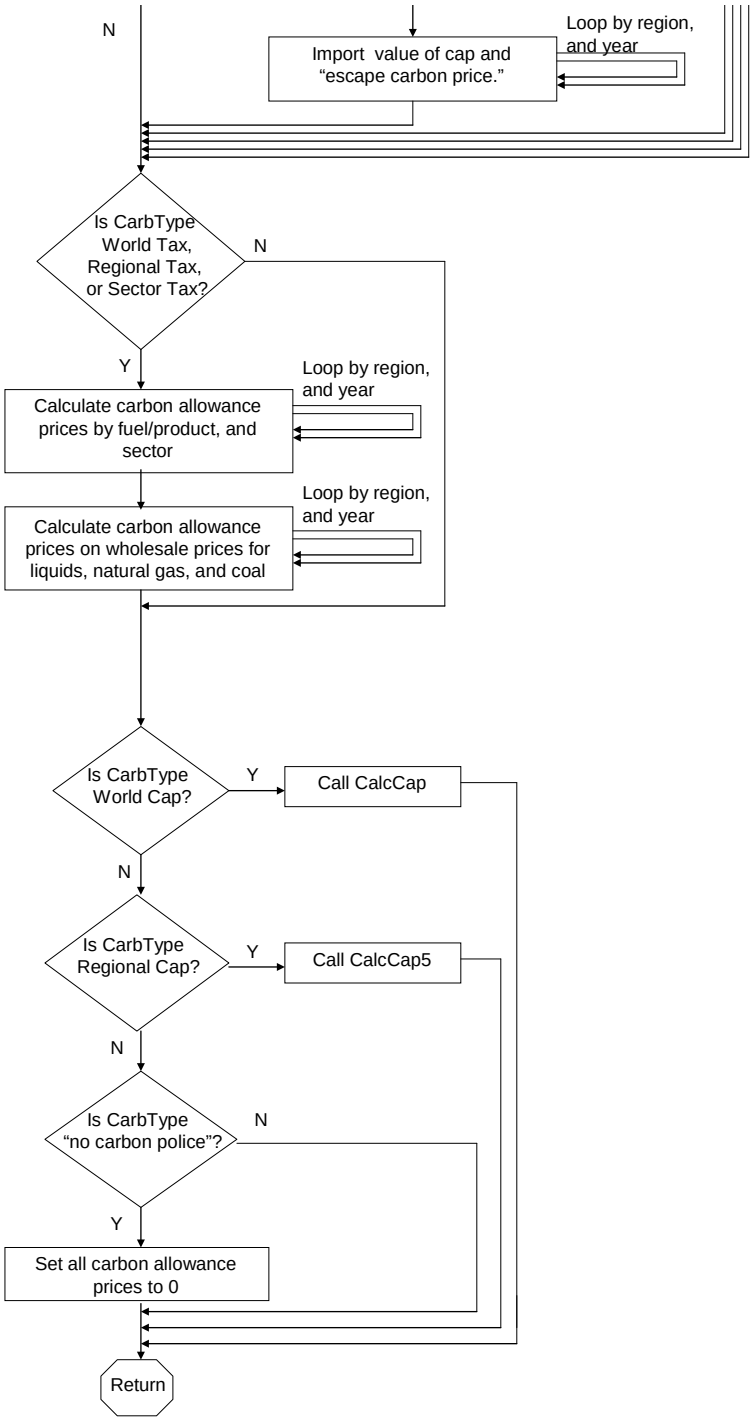
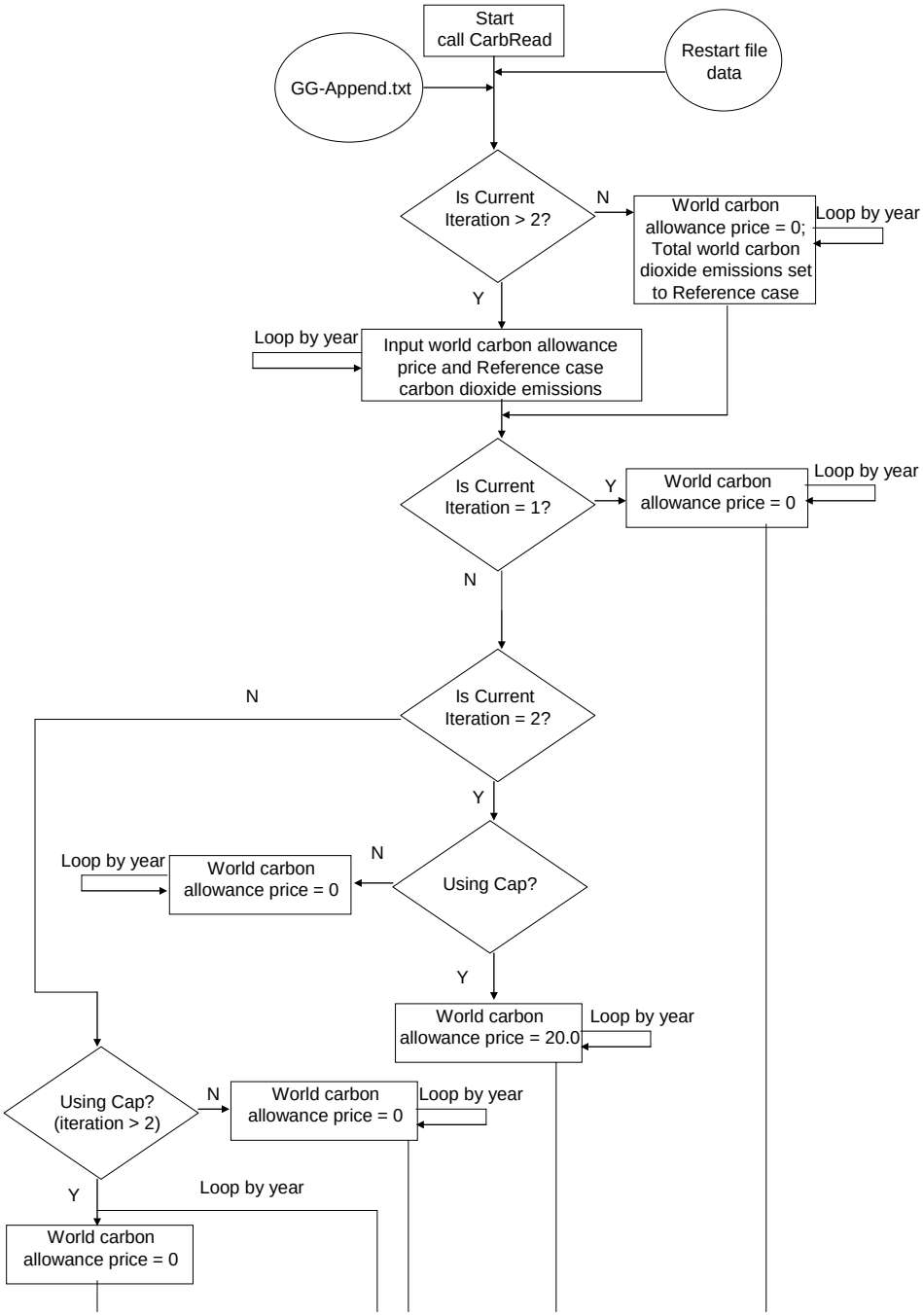

N
Import value of cap and "escape carbon price."
Loop by region, and year
Is CarbType World Tax, Regional Tax, or Sector Tax?
N
Y
Calculate carbon allowance prices by fuel/product, and sector
Loop by region, and year
Calculate carbon allowance prices on wholesale prices for liquids, natural gas, and coal
Loop by region, and year
Is CarbType World Cap?
Y
Call CalcCap
N
Is CarbType Regional Cap?
Y
Call CalcCap5
N
Is CarbType "no carbon police"?
N
Y
Set all carbon allowance prices to 0
Return

Figure 6. Flowchart for the CalcCap Subroutine



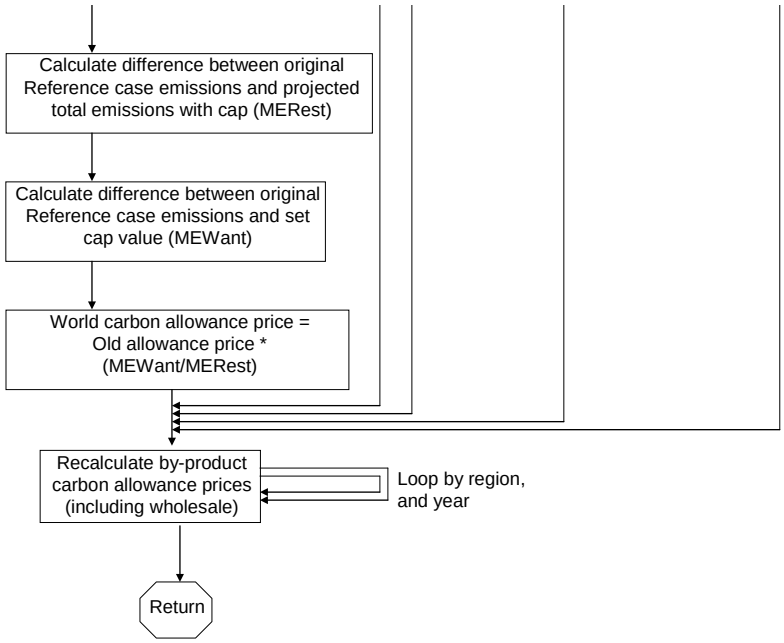
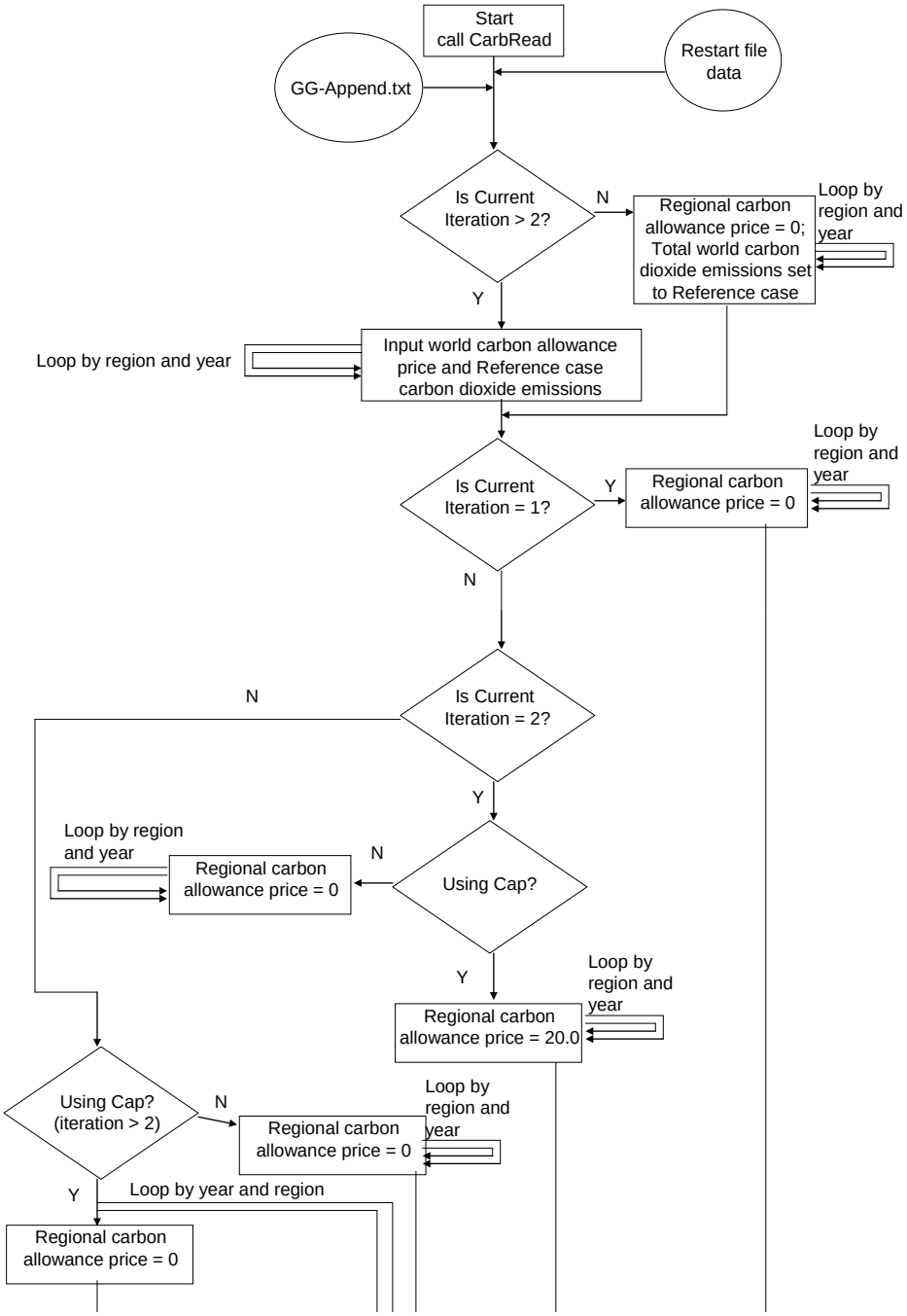
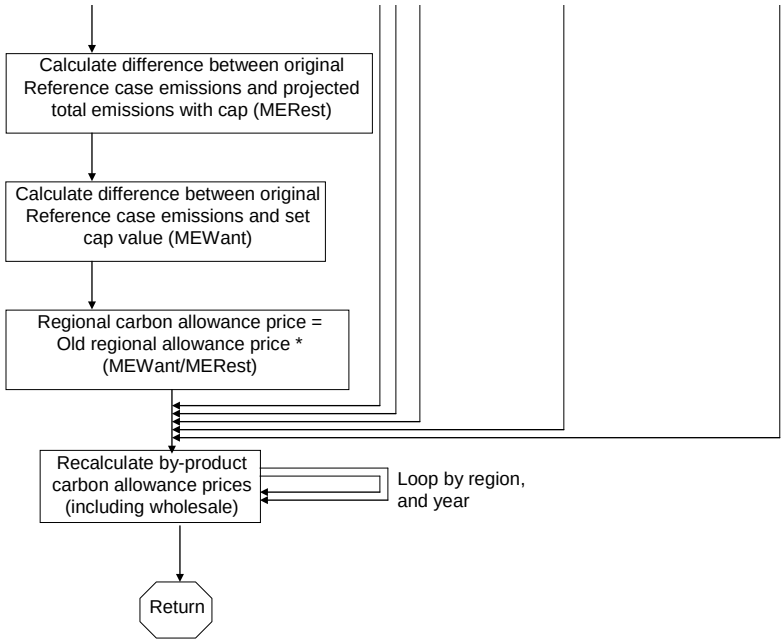

Calculate difference between original Reference case emissions and projected total emissions with cap (MERest)
Calculate difference between original Reference case emissions and set cap value (MEWant)
World carbon allowance price = Old allowance price * (MEWant/MERest)
Recalculate by-product carbon allowance prices (including wholesale)
Loop by region, and year
Return

Figure 7. Flowchart for the CalcCap5 Subroutine




Calculate difference between original Reference case emissions and projected total emissions with cap (MERest)
Calculate difference between original Reference case emissions and set cap value (MEWant)
Regional carbon allowance price = Old regional allowance price * (MEWant/MERest)
Recalculate by-product carbon allowance prices (including wholesale)
Loop by region, and year
Return

Key Computations

Energy-Related Carbon Dioxide Emissions Projections

The primary function of the GHG Model is to calculate energy-related carbon dioxide emissions using a detailed set of emissions factors imported from an exogenous input file. The emission factors are the same factors used in the Energy Information Administration's *Annual Energy Outlook 2011*. The emissions factors for each fuel type include a basic emissions factor based on the carbon content of the fuel, as well as a combustion factor that indicates the amount of fuel that is combusted. The combustion factor is intended to account for any non-emitting, non-fuel uses of the fuels. The product of the two is the emissions factor that is applied to the consumption numbers to estimate carbon dioxide emissions. The factors are expressed in million metric tons per quadrillion Btu. The projections of energy consumption within the WEPS+ model are expressed in trillion Btu and, as a result, the product of the emissions factors and the consumption must be divided by 1,000 to achieve carbon dioxide emissions in million metric tons:

$$Emissions(s, f, r, y) = \frac{Con(s, f, r, y) * EFac(f)}{1{,}000}$$

Where: *Emissions* is million metric tons of carbon dioxide emissions by sector (*s*), fuel (*f*), region (*r*), and year (*y*)

Con is the consumption in trillion Btu by sector, fuel, region, and year

EFac is the final emissions factor by fuel

In some instances, the calculation of carbon dioxide emissions varies slightly. These instances include consumption of "sequestered" petroleum (like asphalt), fuel used as feedstock, and fuel use where carbon capture and storage is employed. In the case of "sequestered" petroleum, the fact that the fuel is not combusted is accounted for by adopting a low or zero value for the combustion factor.

In the case of fuel used as feedstock, the quantity of the fuel that is feedstock use is omitted from the calculation of carbon dioxide emissions. This includes industrial liquefied petroleum gas feedstocks, other petroleum feedstocks, natural gas feedstocks, and coking coal.

The GHG Model also allows for carbon capture and storage (CCS) technologies to be implemented in the electric power sector. The electric power sector calculates the quantity of petroleum, natural gas, and coal consumed as a fuel and the quantity for which carbon dioxide emissions have been captured and stored (based upon the penetration of the technology and the effectiveness of the CCS). This information is provided to the GHG Model through the restart file and the quantity is not used in the emissions calculation. This feature was not used in the *International Energy Outlook 2011*.

The model calculates carbon dioxide emissions by fuel and region for the last available historical year (2008 for *IEO2011*). The calculated values are then compared to actual historical values

available from the Energy Information Administration's International Energy Statistics Database. Because there may be small variations between the two sets of historical values, the emissions factors are then calibrated to ensure the resulting carbon dioxide emissions computed by the model are the same as the actual published historical values. The recalibrated emissions factors are used to calculate energy-related carbon dioxide emissions over the projection period, from 2009 to 2035.

Carbon Prices

In addition to calculating the energy-related carbon dioxide emissions projections, the Greenhouse Gases Model has the capability of adding a carbon allowance price or carbon tax to the retail and wholesale fuel prices that can be used in a carbon tax policy scenario. A complete set of retail price variables by energy product, end use sector, and region is imported into the GHG Model from the restart file. Carbon price variables are calculated at the same level of product, sector, and regional detail. Whenever any of the WEPS+ models uses a price, the price is always calculated as the retail price plus the carbon price. In the absence of a carbon policy scenario, all allowance prices are set equal to zero. The Greenhouse Gases Model allocates the carbon allowance price to each of the fossil fuels based upon the carbon content of that fuel. The carbon content is given by the emissions factors discussed above.

The carbon allowance price in each year is a user-specified assumption and is imported into the GHG Model from the GHG-Input.xml file. The carbon price is specified by end-use sector, region, and projection year (from 2010 through 2035). Four end-use sector categories are represented: buildings (consisting of residential and commercial sectors, along with district heating), industrial, transportation, and electric power. The user may specify three different types of carbon price scenario: 1) worldwide carbon price per year; 2) regional carbon prices per year; and 3) by-end-use-sector and by-region carbon price per year. No carbon price scenarios were included in the *IEO2011*.

Carbon Cap

Another carbon policy option included in the GHG Model is the ability to implement a carbon dioxide emissions ceiling or a "carbon cap" for each year in the projection period. There are two ways in which the carbon cap may be implemented: 1) as a single world-wide cap on carbon emissions or 2) a separate cap for each region. The current version of the model does not include options for trading energy or offsets between regions, so when a regional carbon cap is established, the region is solved independent of the rest of the regions of the world. The user specifies the cap level in each year of the projection period in the GHG-Input.xml file.

To project energy consumption in the context of a carbon cap, a carbon price is estimated in each year to limit the amount of carbon dioxide in that projection year to the level specified by the cap. As the modeling system iterates, the carbon price is adjusted based upon the results of the previous system iteration. In the first iteration, the carbon price for each year is set to zero. Various algorithms were tested to improve the initial carbon price, but through testing it turns out the initial price estimate was not critical. In the second iteration, the carbon allowance price is set to $20 per million Btu.

In subsequent iterations, the carbon allowance price is estimated in a way that will move the amount of emissions closer to the specified cap. In order to do this, the effect of the previous carbon price on carbon dioxide emissions must be computed and a new carbon allowance price is estimated that is expected to get closer to the established cap. For example, if the previous carbon allowance price effected an emissions change that was below the cap, then a smaller allowance price is needed—one whose change is directly related to the difference between carbon dioxide emissions from the previous iteration and the current iteration. The new carbon allowance price is calculated for each year and is used in the model iterations that follow, until the cap is achieved given a certain tolerance limit.

Appendix A. Model Abstract

Model Name:

Greenhouse Gases Model of the World Energy Projection System Plus

Model Acronym:

GHG

Model Description:

The Greenhouse Gases Model of the World Energy Projection System Plus (WEPS+) is a computer-based model that is used to project energy-related carbon dioxide emissions and to implement carbon policy scenarios in the form of carbon taxes or carbon caps.

Model Purpose:

As a component of the World Energy Projection System Plus (WEPS+) integrated modeling system, the Greenhouse Gases Model generates long-term projections of energy-related carbon dioxide emissions based on the projections of regional energy consumption by fuel and product. The model also provides carbon allowance prices to the other WEPS+ models for the purpose of assessing carbon taxes on energy consumption worldwide. The model provides a tool for analysis of international greenhouse gases emissions policies within the WEPS+ system, and can be run independently as a standalone model.

Most Recent Model Update:

December 2009.

Part of Another Model:

World Energy Projection System Plus (WEPS+).

Model Interfaces:

The Greenhouse Gases Model uses the outputs generated by a complete iterative cycle of the WEPS+ system. It imports energy consumption produced by the demand and transformation models, as well as retail and wholesale prices. The Greenhouse Gases Model also imports historical energy consumption and carbon dioxide emissions from the Energy Information Administration's *International Energy Statistics Database* from 1980 through 2007 so that the model results may be calibrated to EIA historical data series.

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Documentation:

Energy Information Administration, U.S. Department of Energy, *Greenhouse Gases Model of the World Energy Projection System Plus: Model Documentation 2011*, DOE/EIA-M081(2011) (Washington, DC, August 2011).

Archive Information:

The model is archived as part of the World Energy Projection System Plus archive of the runs used to generate the *International Energy Outlook 2011*.

Energy System Described:

International energy-related carbon dioxide emissions.

Coverage:

- Geographic: Sixteen WEPS+ regions: U.S., Canada, Mexico, OECD Europe, Japan, Australia/New Zealand, South Korea, Russia, other non-OECD Europe and Eurasia, China, India, other non-OECD Asia, Middle East, Africa, Brazil, and other Central and South America.

- Mode: energy-related carbon dioxide emissions.

- Time Unit/Frequency: Annual, 2009 through 2035.

Modeling Features:

The WEPS+ Greenhouse Gases Model is used to project energy-related carbon dioxide emissions and calculate carbon allowance prices if a carbon scenario is implemented. The model is essentially an accounting model that applies carbon factors to energy consumption quantities to produce carbon dioxide emissions estimates.

DOE Input Sources:

Energy Information Administration, *International Energy Statistics Database*, web site www.eia.gov/emeu/international (as of November 30, 2009).

Energy Information Administration, *Assumptions to the Annual Energy Outlook 2011*, DOE/EIA-0554(2011), Introduction Section: "Table 1.2 Carbon Dioxide Emissions Factors," Washington, DC; April 2011.

Non-DOE Input Sources:

International Energy Agency (IEA), *Energy Balances of OECD Countries*, Paris, 2010.

International Energy Agency (IEA), *Energy Balances of Non-OECD Countries*, Paris, 2010.

Independent Expert Reviews:

None

Computing Environment:

Hardware/Operating System: Basic PC with Windows XP (or other Windows OS).

Language/Software Used: Fortran 90/95 (Currently using Compaq Visual Fortran), not required at runtime.

Run Time/Storage: Standalone model with one iteration runs in about 3-4 seconds, CPU memory is minimal, inputs/executable/outputs require less than 20MB storage.

Special Features: None.

Appendix B. Input Data and Variable Descriptions

The following variables represent data input from the file CtlItr.txt.

Classification: Input variable.

MaxItr:	The maximum number of model iterations allowed (specified by the user)
CurItr:	The current iteration the model is executing
RptItr:	Switch that identifies whether the current iteration is the final iteration (0=no, 1=yes)

The following variables represent data input from the file EMEUConOut.txt.

Classification: Input variable.

EBtu(f,r,y):	Historical energy consumption by fuel (liquids, natural gas, coal, nuclear, hydroelectricity, and geothermal and other renewable energy sources), region, and year (years 1980 through 2008) in quadrillion Btu
EPsu(f,r,y):	Historical energy consumption by fuel (liquids, natural gas, coal, nuclear, hydroelectricity, and geothermal and other renewable energy sources), region, and year (years 1980 through 2008) in physical standard units
EEms(f,r,y):	Energy-related carbon dioxide emissions for each fuel (liquids, natural gas, and coal), region, and year (years 2005 through 2008)

The following variables represent data input from the file GHGInput-2010_07_25.xml.

Classification: Input variable.

EFMGA(x):	Carbon dioxide emissions factor for motor gasoline (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFLGF(x):	Carbon dioxide emissions factor for liquefied petroleum gas used as a fuel (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFLGS(x):	Carbon dioxide emissions factor for liquefied petroleum gas used as a feedstock (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors

EFJFA(x):	Carbon dioxide emissions factor for jet fuel (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFDSA(x):	Carbon dioxide emissions factor for distillate fuel oil (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFRSA(x):	Carbon dioxide emissions factor for residual fuel oil (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFASA(x):	Carbon dioxide emissions factor for asphalt (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFLUA(x):	Carbon dioxide emissions factor for lubricants (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFPFA(x):	Carbon dioxide emissions factor for petrochemical feedstocks (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFKSA(x):	Carbon dioxide emissions factor for kerosene (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFPCA(x):	Carbon dioxide emissions factor for petroleum coke (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFSGA(x):	Carbon dioxide emissions factor for still gas (x=1 is the emissions factor, x=2 is the emissions combustion factor) in all end-use sectors
EFOPI(x):	Carbon dioxide emissions factor for other petroleum fuels in the industrial sector (x=1 is the emissions factor, x=2 is the emissions combustion factor)
EFCLR(x):	Carbon dioxide emissions factor for coal in the residential sector (x=1 is the emissions factor, x=2 is the emissions combustion factor)
EFCLC(x):	Carbon dioxide emissions factor for coal in the commercial sector (x=1 is the emissions factor, x=2 is the emissions combustion factor)

EFCLM(x):	Carbon dioxide emissions factor for coking coal (x=1 is the emissions factor, x=2 is the emissions combustion factor)
EFCLI(x):	Carbon dioxide emissions factor for coal in the industrial sector (x=1 is the emissions factor, x=2 is the emissions combustion factor)
EFCLU(x):	Carbon dioxide emissions factor for coal in the electric power sector (x=1 is the emissions factor, x=2 is the emissions combustion factor)
EFNGF(x):	Carbon dioxide emissions factor for natural gas used as a fuel (x=1 is the emissions factor, x=2 is the emissions combustion factor)
EFNGS(x):	Carbon dioxide emissions factor for natural gas used as a feedstock (x=1 is the emissions factor, x=2 is the emissions combustion factor)
CTax(s,r,y):	Carbon allowance price assessed by sector (building – including district heat=1, industrial=2, transportation=3, and electric power=4), region, and year (years 2010 through 2035)
UseCap(r,y):	Factor that specifies whether a carbon limit (cap) should be implemented (0=no, 1=yes) by region and year (years 2010 through 2035)
CapVal(r,y):	Specifies carbon dioxide emissions limit by region and year (years 2010 through 2035)
EscPrc(r,y):	Escape price (maximum carbon allowance price in a carbon cap scenario) by region and year (years 2010 through 2035)
RefEms(1,y):	Total world Reference case carbon dioxide emissions by year (years 2010 through 2035)
TaxInt(1,y):	Total world tax intercept used to calculate allowance prices with linear approximation by year (years 2010 through 2035); not used in WEPS+ (2011) edition of the model
TaxSlp(1,y):	Total world tax slope used to calculate allowance prices with linear approximation by year (years 2010 through 2035); not used in WEPS+ (2011) edition of the model

The following variables represent data input from the Restart file.

Classification: Input variable from the demand and transformation models.

QDSRS(r,y):	Distillate fuel consumption in the residential sector by region and year (years 2005 through 2035)
QKSRS(r,y):	Kerosene consumption in the residential sector by region and year (years 2005 through 2035)
QLGRS(r,y):	Liquefied petroleum gas consumption in the residential sector by region and year (years 2005 through 2035)
QNGRS(r,y):	Natural gas consumption in the residential sector by region and year (years 2005 through 2035)
QCLRS(r,y):	Coal consumption in the residential sector by region and year (years 2005 through 2035)
QELRS(r,y):	Electricity consumption in the residential sector by region and year (years 2005 through 2035)
QHTRS(r,y):	District heat consumption in the residential sector by region and year (years 2005 through 2035)
QBMRS(r,y):	Biomass consumption in the residential sector by region and year (years 2005 through 2035)
QSLRS(r,y):	Solar consumption in the residential sector by region and year (years 2005 through 2035)
QMGCM(r,y):	Motor gasoline consumption in the commercial sector by region and year (years 2005 through 2035)
QDSCM(r,y):	Distillate fuel consumption in the commercial sector by region and year (years 2005 through 2035)
QRSCM(r,y):	Residual fuel consumption in the commercial sector by region and year (years 2005 through 2035)
QKSCM(r,y):	Kerosene consumption in the commercial sector by region and year (years 2005 through 2035)
QLGCM(r,y):	Liquefied petroleum gas consumption in the commercial sector by region and year (years 2005 through 2035)
QNGCM(r,y):	Natural gas consumption in the commercial sector by region and year (years 2005 through 2035)

QCLCM(r,y):	Coal consumption in the commercial sector by region and year (years 2005 through 2035)
QELCM(r,y):	Electricity consumption in the commercial sector by region and year (years 2005 through 2035)
QHTCM(r,y):	District heat consumption in the commercial sector by region and year (years 2005 through 2035)
QBMCM(r,y):	Biomass consumption in the commercial sector by region and year (years 2005 through 2035)
QSLCM(r,y):	Solar consumption in the commercial sector by region and year (years 2005 through 2035)
QMGIN(r,y):	Motor gasoline consumption in the industrial sector by region and year (years 2005 through 2035)
QDSIN(r,y):	Distillate fuel consumption in the industrial sector by region and year (years 2005 through 2035)
QRSIN(r,y):	Residual fuel consumption in the industrial sector by region and year (years 2005 through 2035)
QKSIN(r,y):	Kerosene consumption in the industrial sector by region and year (years 2005 through 2035)
QLGFDIN(r,y):	Liquefied petroleum gas used as feedstock in the industrial sector by region and year (years 2005 through 2035)
LGIN(r,y):	Liquefied petroleum gas consumption in the industrial sector by region and year (years 2005 through 2035)
QPCIN(r,y):	Petroleum coke consumption in the industrial sector by region and year (years 2005 through 2035)
QSPIN(r,y):	Sequestered petroleum consumption in the industrial sector by region and year (years 2005 through 2035)
QOPFDIN(r,y):	Other petroleum used as feedstock in the industrial sector by region and year (years 2005 through 2035)
QOPIN(r,y):	Other petroleum consumption in the industrial sector by region and year (years 2005 through 2035)
QCDIN(r,y):	Crude oil consumption in the industrial sector by region and year (years 2005 through 2035)

QNGIN(r,y):	Natural gas consumption in the industrial sector by region and year (years 2005 through 2035)
QNGFDIN(r,y):	Natural gas used as feedstock in the industrial sector by region and year (years 2005 through 2035)
QCLIN(r,y):	Coal consumption in the industrial sector by region and year (years 2005 through 2035)
QCLCCIN(r,y):	Coking coal consumption in the industrial sector by region and year (years 2005 through 2035)
QELIN(r,y):	Electricity consumption in the industrial sector by region and year (years 2005 through 2035)
QHTIN(r,y):	District heat consumption in the industrial sector by region and year (years 2005 through 2035)
QWSIN(r,y):	Waste consumption in the industrial sector by region and year (years 2005 through 2035)
QBMIN(r,y):	Biomass consumption in the industrial sector by region and year (years 2005 through 2035)
QGTIN(r,y):	Geothermal consumption in the industrial sector by region and year (years 2005 through 2035)
QSLIN(r,y):	Solar consumption in the industrial sector by region and year (years 2005 through 2035)
QMGTR(r,y):	Motor gasoline consumption in the transportation sector by region and year (years 2005 through 2035)
QDSTR(r,y):	Distillate fuel consumption in the transportation sector by region and year (years 2005 through 2035)
QRSTR(r,y):	Residual fuel consumption in the transportation sector by region and year (years 2005 through 2035)
QLGTR(r,y):	Liquefied petroleum gas consumption in the transportation sector by region and year (years 2005 through 2035)
QJFTR(r,y):	Jet fuel consumption in the transportation sector by region and year (years 2005 through 2035)
QSPTR(r,y):	Sequestered petroleum consumption in the transportation sector by region and year (years 2005 through 2035)

QOPTR(r,y):	Other petroleum consumption in the transportation sector by region and year (years 2005 through 2035)
QCDTR(r,y):	Crude oil consumption in the transportation sector by region and year (years 2005 through 2035)
QNGTR(r,y):	Natural gas consumption in the transportation sector by region and year (years 2005 through 2035)
QCLTR(r,y):	Coal consumption in the transportation sector by region and year (years 2005 through 2035)
QELTR(r,y):	Electricity consumption in the transportation sector by region and year (years 2005 through 2035)
QETTR(r,y):	Ethanol consumption in the transportation sector by region and year (years 2005 through 2035)
QOBTR(r,y):	Other biofuels consumption in the transportation sector by region and year (years 2005 through 2035)
QHYTR(r,y):	Hydrogen consumption in the transportation sector by region and year (years 2005 through 2035)
QDSPG(r,y):	Distillate fuel consumption in the electric power sector by region and year (years 2005 through 2035)
CCSDSPG(r,y):	Amount of distillate fuel captured and stored in the electric power sector by region and year (years 2005 through 2035)
QRSPG(r,y):	Residual fuel consumption in the electric power sector by region and year (years 2005 through 2035)
CCSRSPG(r,y):	Amount of residual fuel captured and stored in the electric power sector by region and year (years 2005 through 2035)
QNGPG(r,y):	Natural gas consumption in the electric power sector by region and year (years 2005 through 2035)
CCSNGPG(r,y):	Amount of natural gas captured and stored in the electric power sector by region and year (years 2005 through 2035)
QCLPG(r,y):	Coal consumption in the electric power sector by region and year (years 2005 through 2035)
CCSCLPG(r,y):	Amount of coal captured and stored in the electric power sector by region and year (years 2005 through 2035)

QWSPG(r,y):	Waste consumption in the electric power sector by region and year (years 2005 through 2035)
QBMPG(r,y):	Biomass consumption in the electric power sector by region and year (years 2005 through 2035)
QHEPG(r,y):	Hydroelectricity consumption in the electric power sector by region and year (years 2005 through 2035)
QGTPG(r,y):	Geothermal consumption in the electric power sector by region and year (years 2005 through 2035)
QSLPG(r,y):	Solar consumption in the electric power sector by region and year (years 2005 through 2035)
QWNPG(r,y):	Wind consumption in the electric power sector by region and year (years 2005 through 2035)
QORPG(r,y):	Other renewables consumption in the electric power sector by region and year (years 2005 through 2035)
QNUPG(r,y):	Nuclear power consumption in the electric power sector by region and year (years 2005 through 2035)
QDSDH(r,y):	Distillate fuel consumption for district heat by region and year (years 2005 through 2035)
QRSDH(r,y):	Residual fuel consumption for district heat by region and year (years 2005 through 2035)
QCDDH(r,y):	Crude oil consumption for district heat by region and year (years 2005 through 2035)
QNGDH(r,y):	Natural gas consumption for district heat by region and year (years 2005 through 2035)
QCLDH(r,y):	Coal consumption for district heat by region and year (years 2005 through 2035)
QWSDH(r,y):	Waste consumption for district heat by region and year (years 2005 through 2035)
QBMDH(r,y):	Biomass consumption for district heat by region and year (years 2005 through 2035)
QGTDH(r,y):	Geothermal consumption for district heat by region and year (years 2005 through 2035)

The following variables represent data input from (and output to) the file GG-Append.txt.

Classification: Input variable.

ECOrig(r,y):	Reference case ("original") projections of energy-related carbon dioxide emissions by region and year (years 2010 through 2035)
CurCO2(r,y):	Projections of energy-related carbon dioxide emissions by iteration by region and year (years 2010 through 2035)
AllPrc(r,y):	Carbon allowance price projections by region and year (years 2010 through 2035)

The following variables represent data calculated in the subroutine Carbon.

Classification: Computed variable.

EFMGA(3):	Carbon dioxide emissions factor for motor gasoline (product of the carbon content factor and carbon combustion factors)
EFLGF(3):	Carbon dioxide emissions factor for liquefied petroleum gas fuel use (product of the carbon content factor and carbon combustion factors)
EFLGS(3):	Carbon dioxide emissions factor for liquefied petroleum gas used as a feedstock (product of the carbon content factor and carbon combustion factors)
EFJFA(3):	Carbon dioxide emissions factor for jet fuel use (product of the carbon content factor and carbon combustion factors)
EFDSA(3):	Carbon dioxide emissions factor for distillate fuel use (product of the carbon content factor and carbon combustion factors)
EFRSA(3):	Carbon dioxide emissions factor for residual fuel use (product of the carbon content factor and carbon combustion factors)
EFASA(3):	Carbon dioxide emissions factor for asphalt (product of the carbon content factor and carbon combustion factors)
EFLUA(3):	Carbon dioxide emissions factor for lubricants (product of the carbon content factor and carbon combustion factors)
EFPFA(3):	Carbon dioxide emissions factor for petroleum feedstocks (product of the carbon content factor and carbon combustion factors)

EFKSA(3):	Carbon dioxide emissions factor for kerosene (product of the carbon content factor and carbon combustion factors)
EFPCA(3):	Carbon dioxide emissions factor for petroleum coke (product of the carbon content factor and carbon combustion factors)
EFSGA(3):	Carbon dioxide emissions factor for still gas (product of the carbon content factor and carbon combustion factors)
EFOPI(3):	Carbon dioxide emissions factor for other petroleum in the industrial sector (product of the carbon content factor and carbon combustion factors)
EFCLR(3):	Carbon dioxide emissions factor for residential sector coal (product of the carbon content factor and carbon combustion factors)
EFCLC(3):	Carbon dioxide emissions factor for commercial sector coal (product of the carbon content factor and carbon combustion factors)
EFCLM(3):	Carbon dioxide emissions factor for coking coal (product of the carbon content factor and carbon combustion factors)
EFCLI(3):	Carbon dioxide emissions factor for industrial sector coal (product of the carbon content factor and carbon combustion factors)
EFCLU(3):	Carbon dioxide emissions factor for electric power sector coal (product of the carbon content factor and carbon combustion factors)
EFNGF(3):	Carbon dioxide emissions factor for natural gas fuel use (product of the carbon content factor and carbon combustion factors)
EFNGS(3):	Carbon dioxide emissions factor for natural gas used as feedstocks (product of the carbon content factor and carbon combustion factors)
ECDSRS(r,y):	Energy-related carbon dioxide emissions from distillate fuel use in the residential sector by region and year (years 2005 through 2035)
ECKSRS(r,y):	Energy-related carbon dioxide emissions from kerosene use in the residential sector by region and year (years 2005 through 2035)
ECLGRS(r,y):	Energy-related carbon dioxide emissions from liquefied petroleum gas use in the residential sector by region and year (years 2005 through 2035)

ECNGRS(r,y):	Energy-related carbon dioxide emissions from natural gas use in the residential sector by region and year (years 2005 through 2035)
ECCLRS(r,y):	Energy-related carbon dioxide emissions from coal use in the residential sector by region and year (years 2005 through 2035)
ECELRS(r,y):	Energy-related carbon dioxide emissions from electricity use in the residential sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECHTRS(r,y):	Energy-related carbon dioxide emissions from district heat generation in the residential sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECBMRS(r,y):	Energy-related carbon dioxide emissions from biomass use in the residential sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECSLRS(r,y):	Energy-related carbon dioxide emissions from solar energy use in the residential sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECMGCM(r,y):	Energy-related carbon dioxide emissions from motor gasoline use in the commercial sector by region and year (years 2005 through 2035)
ECDSCM(r,y):	Energy-related carbon dioxide emissions from distillate fuel use in the commercial sector by region and year (years 2005 through 2035)
ECRSCM(r,y):	Energy-related carbon dioxide emissions from residual fuel use in the commercial sector by region and year (years 2005 through 2035)
ECKSCM(r,y):	Energy-related carbon dioxide emissions from kerosene use in the commercial sector by region and year (years 2005 through 2035)
ECLGCM(r,y):	Energy-related carbon dioxide emissions from liquefied petroleum gas use in the commercial sector by region and year (years 2005 through 2035)
ECNGCM(r,y):	Energy-related carbon dioxide emissions from natural gas use in the commercial sector by region and year (years 2005 through 2035)
ECCLCM(r,y):	Energy-related carbon dioxide emissions from coal use in the commercial sector by region and year (years 2005 through 2035)

ECELCM(r,y):	Energy-related carbon dioxide emissions from electricity use in the commercial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECHTCM(r,y):	Energy-related carbon dioxide emissions from district heat generation in the commercial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECBMCM(r,y):	Energy-related carbon dioxide emissions from biomass use in the commercial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECSLCM(r,y):	Energy-related carbon dioxide emissions from solar energy use in the commercial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECMGIN(r,y):	Energy-related carbon dioxide emissions from motor gasoline use in the industrial sector by region and year (years 2005 through 2035)
ECDSIN(r,y):	Energy-related carbon dioxide emissions from distillate fuel use in the industrial sector by region and year (years 2005 through 2035)
ECRSIN(r,y):	Energy-related carbon dioxide emissions from residual fuel use in the industrial sector by region and year (years 2005 through 2035)
ECKSIN(r,y):	Energy-related carbon dioxide emissions from kerosene use in the industrial sector by region and year (years 2005 through 2035)
ECLGIN(r,y):	Energy-related carbon dioxide emissions from liquefied petroleum gas use in the industrial sector by region and year (years 2005 through 2035)
ECPCIN(r,y):	Energy-related carbon dioxide emissions from petroleum coke use in the industrial sector by region and year (years 2005 through 2035)
ECSPIN(r,y):	Energy-related carbon dioxide emissions from sequestered petroleum use in the industrial sector by region and year (years 2005 through 2035)
ECOPIN(r,y):	Energy-related carbon dioxide emissions from other petroleum use in the industrial sector by region and year (years 2005 through 2035)
ECNGIN(r,y):	Energy-related carbon dioxide emissions from natural gas use in the industrial sector by region and year (years 2005 through 2035)

ECCLIN(r,y):	Energy-related carbon dioxide emissions from coking coke use in the industrial sector by region and year (years 2005 through 2035)
ECELIN(r,y):	Energy-related carbon dioxide emissions from electricity use in the industrial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECHTIN(r,y):	Energy-related carbon dioxide emissions from district heat generation in the industrial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECWSIN(r,y):	Energy-related carbon dioxide emissions from waste use in the industrial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECBMIN(r,y):	Energy-related carbon dioxide emissions from biomass use in the industrial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECGTIN(r,y):	Energy-related carbon dioxide emissions from geothermal use in the industrial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECSLIN(r,y):	Energy-related carbon dioxide emissions from solar energy use in the industrial sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECMGTR(r,y):	Energy-related carbon dioxide emissions from motor gasoline use in the transportation sector by region and year (years 2005 through 2035)
ECDSTR(r,y):	Energy-related carbon dioxide emissions from distillate (diesel) fuel use in the transportation sector by region and year (years 2005 through 2035)
ECRSTR(r,y):	Energy-related carbon dioxide emissions from residual fuel use in the transportation sector by region and year (years 2005 through 2035)
ECLGTR(r,y):	Energy-related carbon dioxide emissions from liquefied petroleum gas use in the transportation sector by region and year (years 2005 through 2035)
ECJFTR(r,y):	Energy-related carbon dioxide emissions from jet fuel use in the transportation sector by region and year (years 2005 through 2035)
ECSPTR(r,y):	Energy-related carbon dioxide emissions from sequestered petroleum (lubricants) use in the transportation sector by region and year (years 2005 through 2035)

ECOPTR(r,y):	Energy-related carbon dioxide emissions from other petroleum use in the transportation sector by region and year (years 2005 through 2035)
ECCDTR(r,y):	Energy-related carbon dioxide emissions from crude oil use in the transportation sector by region and year (years 2005 through 2035)
ECNGTR(r,y):	Energy-related carbon dioxide emissions from natural gas use in the transportation sector by region and year (years 2005 through 2035)
ECCLTR(r,y):	Energy-related carbon dioxide emissions from coal use in the transportation sector by region and year (years 2005 through 2035)
ECELTR(r,y):	Energy-related carbon dioxide emissions from electricity use in the transportation sector by region and year (years 2005 through 2035)
ECETTR(r,y):	Energy-related carbon dioxide emissions from ethanol use in the transportation sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECOBTR(r,y):	Energy-related carbon dioxide emissions from other biofuels use in the transportation sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECHYTR(r,y):	Energy-related carbon dioxide emissions from hydrogen fuel use in the transportation sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECDSPG(r,y):	Energy-related carbon dioxide emissions from distillate fuel use in the electric power sector by region and year (years 2005 through 2035)
ECRSPG(r,y):	Energy-related carbon dioxide emissions from residual fuel use in the electric power sector by region and year (years 2005 through 2035)
ECCDPG(r,y):	Energy-related carbon dioxide emissions from crude oil use in the electric power sector by region and year (years 2005 through 2035)
ECNGPG(r,y):	Energy-related carbon dioxide emissions from natural gas use in the electric power sector by region and year (years 2005 through 2035)
ECCLPG(r,y):	Energy-related carbon dioxide emissions from coal use in the electric power sector by region and year (years 2005 through 2035)

ECWSPG(r,y):	Energy-related carbon dioxide emissions from waste use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECBMPG(r,y):	Energy-related carbon dioxide emissions from biomass use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECHEPG(r,y):	Energy-related carbon dioxide emissions from hydroelectricity use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECGTPG(r,y):	Energy-related carbon dioxide emissions from geothermal fuel use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECSLPG(r,y):	Energy-related carbon dioxide emissions from solar energy use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECWNPG(r,y):	Energy-related carbon dioxide emissions from wind energy use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECORPG(r,y):	Energy-related carbon dioxide emissions from other renewable energy use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECNUPG(r,y):	Energy-related carbon dioxide emissions from nuclear power use in the electric power sector by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*
ECDSDH(r,y):	Energy-related carbon dioxide emissions from distillate fuel use for district heat by region and year (years 2005 through 2035)
ECRSDH(r,y):	Energy-related carbon dioxide emissions from residual fuel use for district heat by region and year (years 2005 through 2035)
ECCDDH(r,y):	Energy-related carbon dioxide emissions from crude oil use for district heat by region and year (years 2005 through 2035)

ECNGDH(r,y): Energy-related carbon dioxide emissions from natural gas use for district heat by region and year (years 2005 through 2035)

ECCLDH(r,y): Energy-related carbon dioxide emissions from coal use for district heat by region and year (years 2005 through 2035)

ECWSDH(r,y): Energy-related carbon dioxide emissions from distillate fuel use for district heat by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*

ECBMDH(r,y): Energy-related carbon dioxide emissions from biomass use for district heat by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*

ECGTDH(r,y): Energy-related carbon dioxide emissions from geothermal fuel use for district heat by region and year (years 2005 through 2035); these values are 0.0 in the *IEO2011*

The following variables represent data calculated in the subroutine CarbRead.

Classification: Computed variable.

APTWD(r,y): Carbon price increment to wholesale oil price according to the carbon allowance price by region and year (dollars per million Btu)

ANGWD(r,y): Carbon price increment to wholesale natural gas price according to the carbon allowance price by region and year (dollars per million Btu)

ACLWD(r,y): Carbon price increment to wholesale coal price according to the carbon allowance price by region and year (dollars per million Btu)

ADSRS(r,y): Carbon price increment to retail distillate price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu)

AKSRS(r,y): Carbon price increment to retail kerosene price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu)

ALGRS(r,y): Carbon price increment to retail liquefied petroleum gas price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu)

ANGRS(r,y): Carbon price increment to retail natural gas price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu)

ACLRS(r,y):	Carbon price increment to retail coal price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu)
AELRS(r,y):	Carbon price increment to retail electricity price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AHTRS(r,y):	Carbon price increment to retail electricity price in the residential sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AMGCM(r,y):	Carbon price increment to retail motor gasoline price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
ADSCM(r,y):	Carbon price increment to retail distillate fuel price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
ARSCM(r,y):	Carbon price increment to retail residual fuel oil price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
AKSCM(r,y):	Carbon price increment to retail kerosene price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
ALGCM(r,y):	Carbon price increment to retail liquefied petroleum gas price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
ANGCM(r,y):	Carbon price increment to retail natural gas price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
ACLCM(r,y):	Carbon price increment to retail coal price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu)
AELCM(r,y):	Carbon price increment to retail electricity price in the commercial sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AHTCM(r,y):	Carbon price increment to retail electricity price in the commercial sector according to the carbon allowance price

	by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AMGIN(r,y):	Carbon price increment to retail motor gasoline price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
ADSIN(r,y):	Carbon price increment to retail distillate fuel price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
ARSIN(r,y):	Carbon price increment to retail residual fuel oil price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
AKSIN(r,y):	Carbon price increment to retail kerosene price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
ALGIN(r,y):	Carbon price increment to retail liquefied petroleum gas price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
AOPIN(r,y):	Carbon price increment to retail price for 'other' petroleum in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
ANGIN(r,y):	Carbon price increment to retail natural gas price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
ACLIN(r,y):	Carbon price increment to retail coal price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu)
AELIN(r,y):	Carbon price increment to retail electricity price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AHTIN(r,y):	Carbon price increment to retail electricity price in the industrial sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AMGTR(r,y):	Carbon price increment to retail motor gasoline price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)

ADSTR(r,y):	Carbon price increment to retail distillate fuel price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
ARSTR(r,y):	Carbon price increment to retail residual fuel oil price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
ALGTR(r,y):	Carbon price increment to retail liquefied petroleum gas price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
AJFTR(r,y):	Carbon price increment to retail jet fuel price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
AOPTR(r,y):	Carbon price increment to retail price for 'other' petroleum in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
ANGTR(r,y):	Carbon price increment to retail natural gas price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
ACLTR(r,y):	Carbon price increment to retail coal price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu)
AELTR(r,y):	Carbon price increment to retail electricity price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AETTR(r,y):	Carbon price increment to retail ethanol price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AOBTR(r,y):	Carbon price increment to retail price of other biofuels in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
AHYTR(r,y):	Carbon price increment to retail hydrogen fuel price in the transportation sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*

ADSPG(r,y):	Carbon price increment to retail distillate fuel price in the electric power sector according to the carbon allowance price by region and year (dollars per million Btu)
ARSPG(r,y):	Carbon price increment to retail residual fuel oil price in the electric power sector according to the carbon allowance price by region and year (dollars per million Btu)
ANGPG(r,y):	Carbon price increment to retail natural gas price in the electric power sector according to the carbon allowance price by region and year (dollars per million Btu)
ACLPG(r,y):	Carbon price increment to retail coal price in the electric power sector according to the carbon allowance price by region and year (dollars per million Btu)
ANUTR(r,y):	Carbon price increment to retail nuclear power generation price in the electric power sector according to the carbon allowance price by region and year (dollars per million Btu); these values are 0.0 in the *IEO2011*
ADSDH(r,y):	Carbon price increment to retail distillate fuel price for district heat generation according to the carbon allowance price by region and year (dollars per million Btu)
ARSDH(r,y):	Carbon price increment to retail residual fuel oil price for district heat generation according to the carbon allowance price by region and year (dollars per million Btu)
ANGDH(r,y):	Carbon price increment to retail natural gas price for district heat generation according to the carbon allowance price by region and year (dollars per million Btu)
ACLDH(r,y):	Carbon price increment to retail coal price for district heat generation according to the carbon allowance price by region and year (dollars per million Btu)
APrcEqu(r,y,x):	Carbon allowance price increment to fuel price by region, year, and price product number (73 products)

The following variables represent data calculated in the subroutine CalcCap (All prices calculated in CarbRead are also calculated in CalcCap)

Classification: Computed variable.

AllPrc(r=1,y):	World carbon allowance price (2009 dollars per million Btu) by year, world region = 1

The following variables represent data calculated in the subroutine CalcCap5 (All prices calculated in CarbRead are also calculated in CalcCap5)

Classification: Computed variable.

AllPrc(r,y):	Carbon allowance price (dollars per million Btu) by region and year

Appendix C. References

1. Walter Nicholson, *Microeconomic Theory: Basic Principles and Extensions* (Harcourt College Publishers, Fort Worth: Texas, 1972).

2. Franklin J. Stermole and John M. Stermole, *Economic Evaluation and Investment Decision Methods: Eleventh Edition* (Investment Evaluations Corporation, Lockwood, CO, 2006).

3. Alpha C. Chiang, *Fundamental Methods of Mathematical Economics* (McGraw-Hill Book Company, NY: NY, 1967).

4. Wayne L. Winston, *Operations Research: Applications and Algorithms* (Brooks/Cole—Thomson Learning, Belmont, CA, 2004).

5. International Energy Agency, *Energy Statistics and Balances of OECD Countries*, web site www.iea.org (subscription site).

6. International Energy Agency, *Energy Statistics and Balances of Non-OECD Countries*, web site www.iea.org (subscription site).

7. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2011*, DOE/EIA-0554(2011), Introduction Section: "Table 1.2 Carbon Dioxide Emissions Factors," Washington, DC; April 2011.

8. Energy Information Administration, *Emissions of Greenhouse Gases in the United States*, DOE/EIA-0573, Washington, DC; March 2011.

Appendix D. Data Quality

Introduction

The WEPS+ Greenhouse Gases Model is used to compute energy-related carbon dioxide emissions by fossil fuel energy source and to allow the user to implement various carbon policy cases (specifically carbon tax and carbon cap policies). These computations use the data elements as detailed in Appendix B of this report. The documentation details transformations, estimation methodologies, and resulting inputs required to implement the model algorithms in Chapter 4: Model Structure. The quality of the principal sources of input data is discussed in Appendix D. Information regarding the quality of parameter estimates and user inputs is provided where available.

Source and Quality of Input Data

Sources of Input Data

- *International Statistics Database* – The Energy Information Administration provides historical data on international energy consumption by fuel type from 1980 through 2008. These data are used as the historical basis for all regional projections that appear in the *IEO2011*. While the numbers are continuously updated, WEPS+ used a "snapshot" of the database as it existed on April 1, 2011 as the source of its international data.

- *International Energy Agency* – The by-end-use-sector, by-product historical data are available from the OECD and non-OECD balances and statistics databases by country on the subscription site www.iea.org. These data are benchmarked to the historical aggregate energy consumption data provided in the Energy Information Administration's international statistical data base.

- *Annual Energy Outlook 2011* – The by-product carbon dioxide emissions and combustion factors used to calculate carbon dioxide emissions are taken from the assumptions used for the *Annual Energy Outlook.*

Data Quality Verification

As a part of the input and editing procedure, an extensive program of edits and verifications was used, including:

- Consistency checks

- Technical edits to detect and correct errors, extreme variability