

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

November 2010

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1. Introduction

Purpose of This Report

The Macroeconomic Model of the World Energy Projection System Plus (WEPS+) is a computer-based model that describes the world's macro economy, providing the outlook for gross domestic product (in terms of both purchasing power parity and market exchange rates), and population on a regional basis, as well as gross output by industry. This report describes the version of the Macroeconomic Model that was used to produce the macroeconomic projections published in the *International Energy Outlook 2010 (IEO2010)*. The Macroeconomic Model is one of 13 components of the WEPS+ modeling system, but it can also be run as a separate, individual model. The WEPS+ is a modular system, consisting of a number 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+ Macroeconomic Model. It also catalogues and describes critical assumptions, computational methodology, parameter estimation techniques, 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 WEPS+ Macroeconomic Model for the *IEO2010* provides macroeconomic projections for use by the other models in the WEPS+ system. The four primary projections that it currently provides are:

- Gross domestic product (GDP) by region, expressed in purchasing power parity (PPP)
- GDP by region, expressed in market exchange rates (MER)
- Population by region
- Gross output

The estimates of GDP and population are generally exogenous to WEPS+. They are based upon macroeconomic projections provided by IHS Global Insight, but are adjusted to account for differences in oil price path assumptions and different regional expectations for future economic growth potential. The WEPS+ Macroeconomic Model has the capability of using regional GDP elasticities, relative to world oil prices, to change the GDP assumptions relative to the *IEO2010* Reference case to provide macroeconomic feedback.

The Macroeconomic Model also provides projections of gross output (GO) for 53 economic sectors, including manufacturing, non-manufacturing, and commercial sectors. These projections are currently being used by the WEPS+ World Industrial Model to inform projections of manufacturing and non-manufacturing energy use. The macroeconomic projections are derived for each of the 16 WEPS+ regions, and are exported into the restart file to be available to all the other models.

Model Archival Citation

This documentation refers to the WEPS+ Macroeconomic Model, as archived for the *International Energy Outlook 2010 (IEO2010)*.

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Organization of This Report

Chapter 2 of this report discusses the purpose of the Macroeconomic 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 Macroeconomic 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 primary objective of the WEPS+ Macroeconomic Model is to generate projections of macroeconomic activity by region, and in the case of gross output, by economic sector or industry. Regional projections are computed annually for the period of 2008 through 2035. As an integral component of the WEPS+ system, the Macroeconomic Model provides WEPS+ demand models and the World Electricity Model with GDP inputs, which are the key drivers for calculating world energy consumption in these models. In addition, population estimates are provided to the Transportation Model. Finally, gross output is a key driver for calculating world energy consumption in the World Industrial Model, and is provided to this model by the Macroeconomic Model for 53 economic sectors by region.

As part of the WEPS+ system, the Macroeconomic Model provides projections for the 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	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

The Macroeconomic Model relies primarily on exogenous data sources that are input from the MacInput.xml and GORpt.txt data files (Table 2).

Table 2 Exogenous Macroeconomic Model Input Data Series

Source Input File	Macroeconomic Model Input
MacInput.xml	Gross domestic product by region in 2005 dollars and expressed in purchasing power parity terms
	Gross domestic product by region in 2005 dollars and expressed in market exchange rate terms
	Population by region (millions)
	India
	The world oil price that corresponds to the assumed GDP
	Regional GDP elasticities relative to the world oil prices
	Switch that indicates whether or not elasticities are to be implemented
	Price deflators
	GDP deflators
	Consumer price index for energy
GORept.txt	Gross output for 53 sectors (2005 dollars)

Outputs

Upon completion of a Macroeconomic Model run, results are exported into the WEPS+ restart file for use by other models (Table 3).

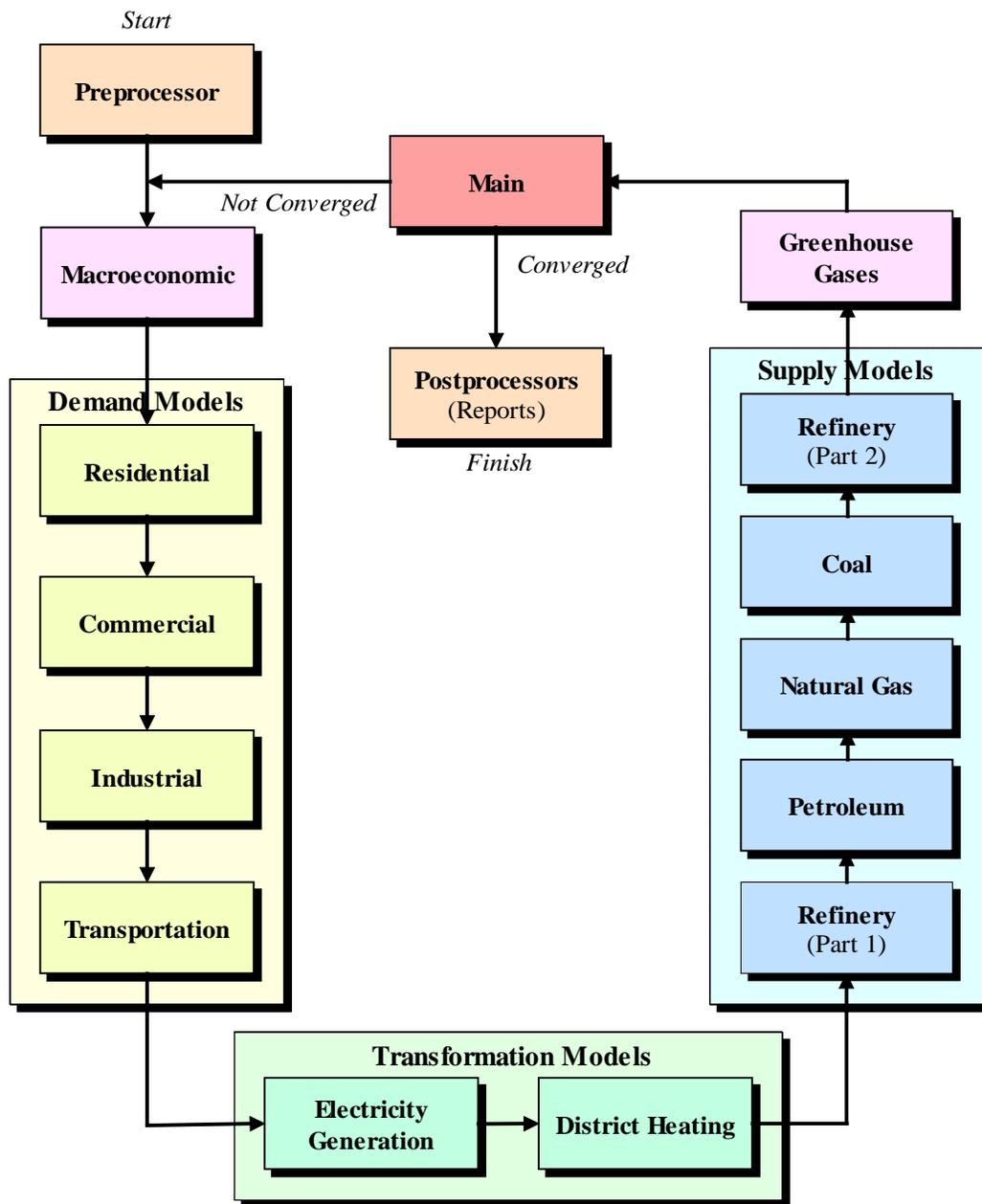
Table 3 Macroeconomic Model Output and the WEPS+ Models that Use Them

Macroeconomic Model Output	Destination
Gross domestic product (PPP)	Residential Model
	Commercial Model
	World Industrial Model
	International Transportation Model
	World Electricity Model
Population	International Transportation Model
Gross output	World Industrial Model

Relationship to Other Models

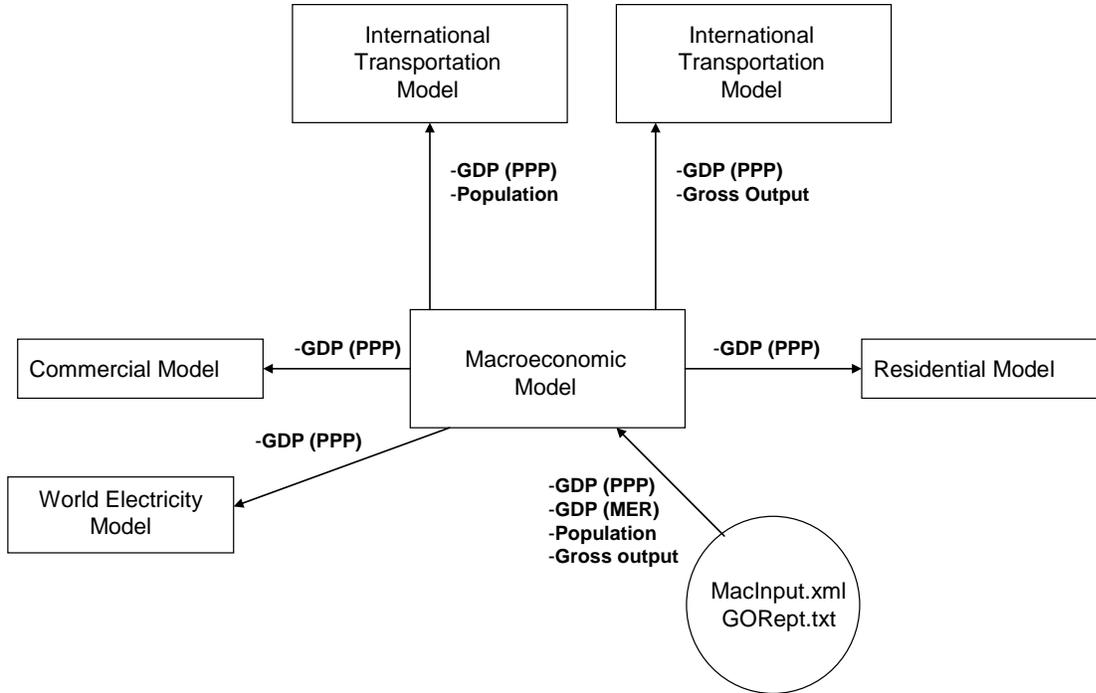
The Macroeconomic Model is an important component of the WEPS+ system. It provides largely exogenous projections of GDP, population, and gross output, which other models in the system depend upon as key inputs (Figure 1). A summary description of the models, flows, and mechanics of the WEPS+ system used for the *IEO2010* report is available in a separate *Overview* documentation.

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



The Macroeconomic Model exogenously receives assumptions and projections of gross domestic product, population, and gross output for 53 economic sectors, and then provides these estimates (with some adjustments) to the WEPS+ demand models and the World Electricity Model (Figure 2).

Figure 2 The Macroeconomic Model Relationship to Other WEPS+ Models



3. Model Rationale

Theoretical Approach

The Macroeconomic Model imports GDP and population data, and then exports them to the restart file. The model also imports detailed gross output projections by region and industry to 2015, and extends these series to 2035 using the 2010-2015 growth rate. In addition, the resulting gross output projections are calibrated so that the overall relationship of gross output to GDP is maintained as it was in 2015. To provide macroeconomic feedback, the model has the capability of applying elasticities relative to changes in world oil price; however, this feature was not used in the *IEO2010*.

Model Assumptions

The WEPS+ Macroeconomic Model provides macroeconomic projections for use by the other models in the WEPS+ system. The four projection series that it currently provides are:

- Gross Domestic Product (GDP) by region, expressed in purchasing power parity (PPP)
- GDP by region, expressed in market exchange rates (MER)
- Population by region
- Gross output by region and economic sector

The Macroeconomic Model provides projections of gross output for a variety of economic sectors, including manufacturing, non-manufacturing, and commercial sectors. These values are currently being used by the Industrial Model to drive its projections of manufacturing and non-manufacturing energy use. The initial projections of gross output are exogenous to the Macroeconomic Model, and are generated by the *World Industrial Service* from IHS Global Insight. These projections of gross output extend to the year 2015, and cover many more industries than are required by WEPS+.

The original gross output projections are aggregated into 53 industries in a pre-processor, and are made available to the Macroeconomic Model in an input file. The projections to 2015 are imported from the GOREpt.txt input file; the Macroeconomic Model extends them to 2035 using the more recent trends from 2010 to 2015, by industry. The values are then calibrated in a nesting structure so that they are consistent with the overall total gross output in each region and down through each subcategory. The overall total gross output projections are also calibrated to be consistent with the regional projections of GDP over the projection horizon. The resulting GDP, population, and gross output projections of the Macroeconomic Model are then exported to the WEPS+ restart file for use by the other models.

4. Model Structure

Structural Overview

The main purpose of the Macroeconomic Model is to import exogenous estimates of historical and projected GDP (both in terms of purchasing power parity and market exchange rates), as well as population on a regional basis and projected gross output by economic sector and region. The model makes any required adjustments to the GDP, basing them upon changing world oil price assumptions (though this feature was not used in preparation of the *IEO2010*). In addition, the model extends projections of gross output from 2015 to 2035 and calibrates them with GDP projections for consistency.

The basic structure of the Macroeconomic Model is illustrated in Figure 3. **Flowchart for the Macroeconomic Model**

A call from the WEPS+ interface to the Macroeconomic Model opens the restart file and initiates the CalcGDP subroutine. The CalcGDP subroutine, the major component of the model, performs most model computations before the execution of the subroutine that exports all projections to the restart file for use by other WEPS+ models.

The CalcGDP subroutine (Figure 4) is initiated by a call from the main Macroeconomic Model. The model requires four exogenous data series. The CalcGDP subroutine begins by initiating a call of the XMLInput subroutine (Figure 5) to import data from the MacInput.xml data file. The MacInput.xml includes historical and projected GDP data, by region, in terms of both purchasing power parity and market exchange rate, and historical and projected population. The file also contains several other elements: the world oil price path upon which the GDP projections are based; GDP elasticities relative to the world oil price, by region; a factor that indicates whether the user wishes to adjust GDP to reflect a new world oil price path; and U.S. price and GDP deflators and the consumer price index (CPI) by year. The subroutine sets regional deflators and CPI to the U.S. values.

After the XMLInput subroutine has executed, the CalcGDP subroutine checks to see if the user has specified that GDP estimates be adjusted to reflect a new world oil price path. If so, the GDP estimates are recomputed using the price and GDP elasticities imported in XMLInput. Next, the CalcGDP subroutine initiates a call of the GetGO subroutine (Figure 6) to import data from the GORpt.txt file. The GORpt.txt file includes regional gross output for 53 economic sectors (or industries) for the years 2001 to 2015. After the data are imported, gross output by region and industry is calibrated to any adjustments that have been made to GDP because of a new world oil price. Next, the average annual growth rate between 2010 and 2015 is calculated for every region and industry. These growth rates are used to generate projections of gross output from 2016 through 2035 by region and industry. Finally, the extended gross output projections are adjusted to reflect the regional GDP growth rates between 2016 and 2035. Once GetGO has completed, the CalcGDP subroutine also ends, and the main Macroeconomic Model exports the data series to the restart file.

Flow Diagrams

Figure 3. Flowchart for the Macroeconomic Model

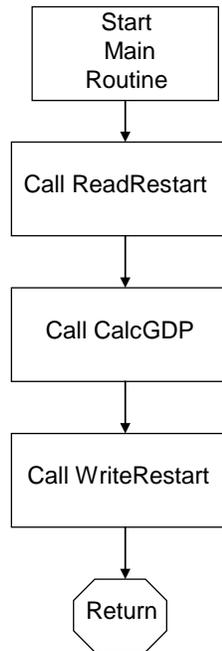


Figure 4. Flowchart for the CalcGDP Subroutine

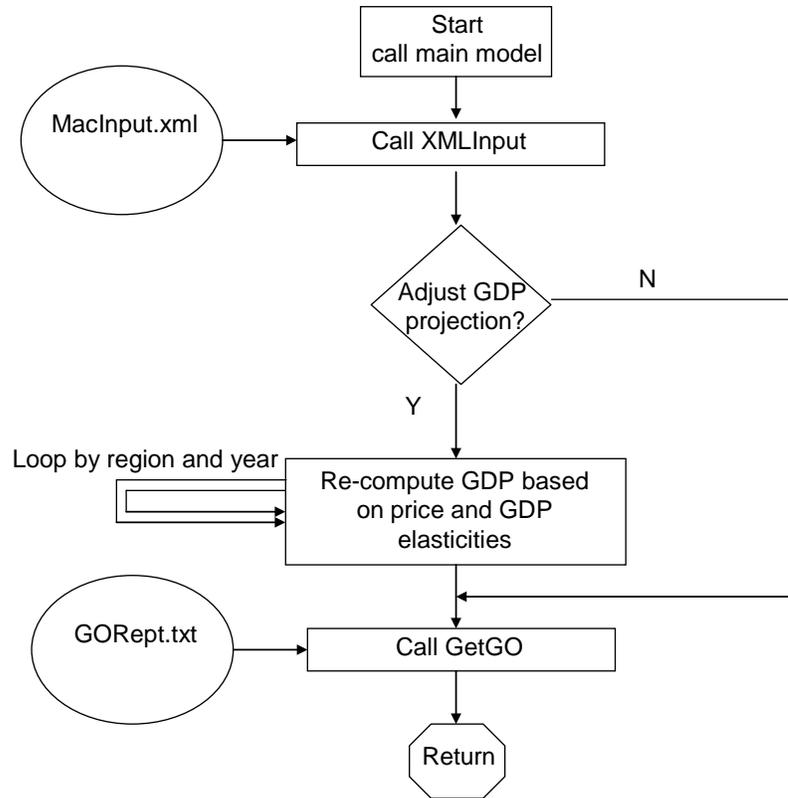


Figure 5. Flowchart for the XMLInput Subroutine

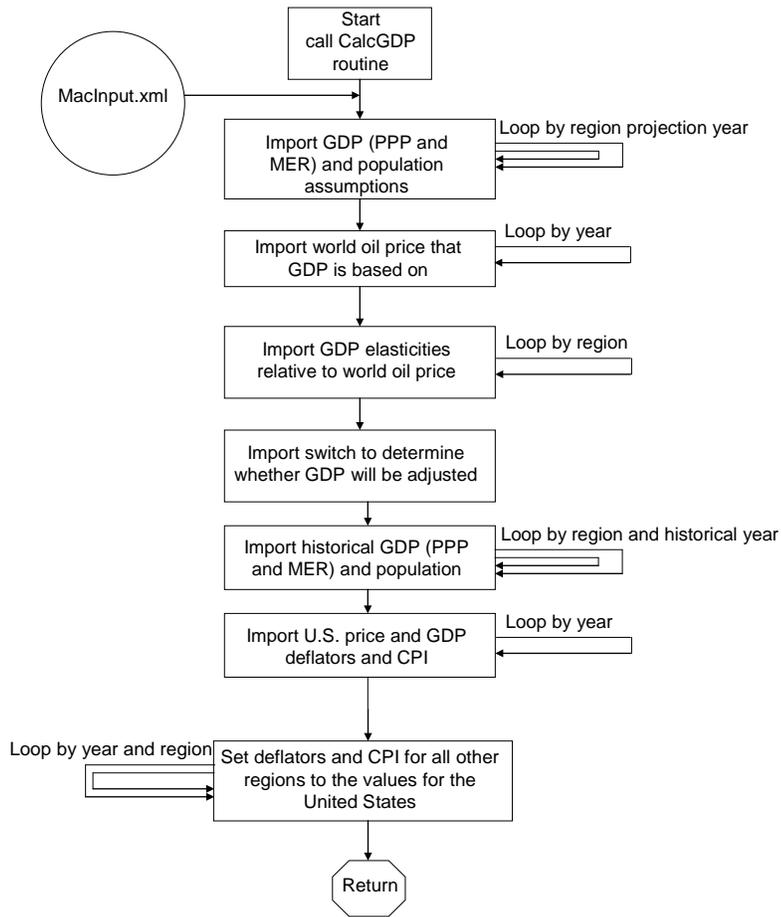
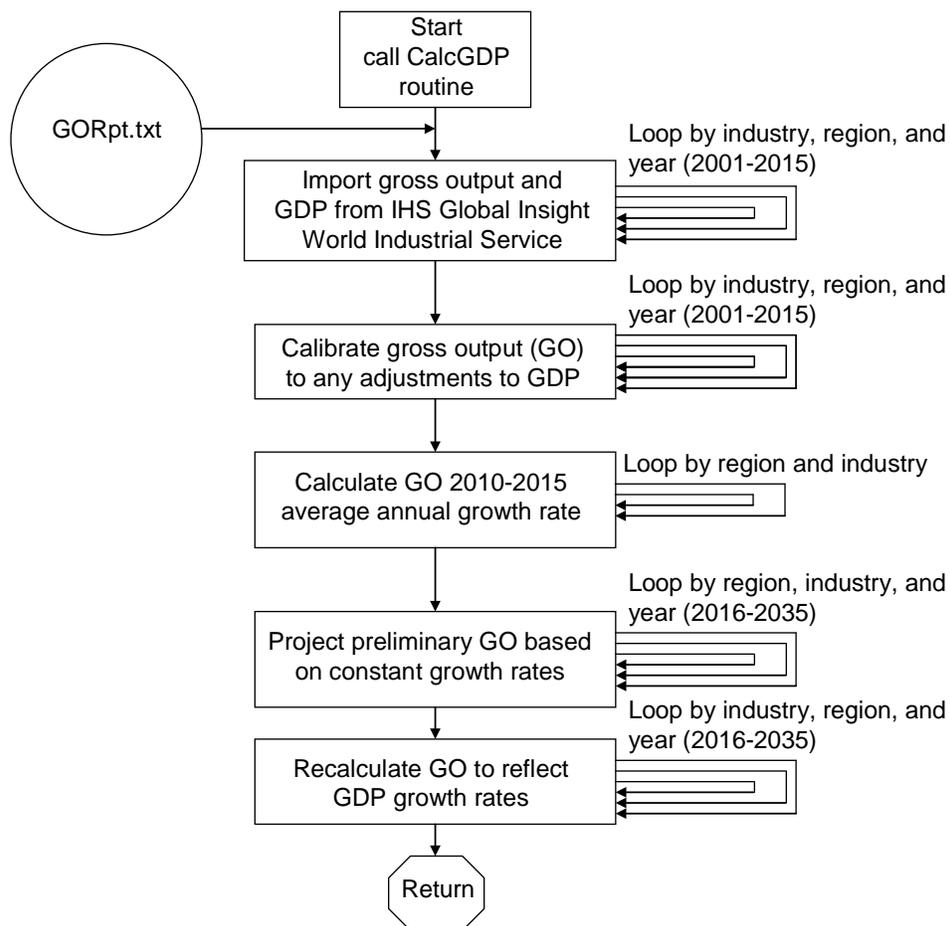


Figure 6. Flowchart for the GetGO Subroutine



Key Computations

Gross Domestic Product Adjustments

GDP assumptions are exogenous to the WEPS+ modeling system. Typically, the Macroeconomic Model imports the GDP series from an input file and then exports it to the restart file for use by the demand models and the World Electricity Model. The WEPS+ Macroeconomic Model, however, also allows the user to adjust GDP assumptions to account for changes in the world oil price, relative to the NEMS Reference case, by region. The basic elasticity relationship that is used for each region r and each year y is given by:

$$WOPElas(r, y) = \frac{\ln\left(\frac{New_GDP_PPP(r, y)}{Base_GDP_PPP(r, y)}\right)}{\ln\left(\frac{New_WOP(r, y)}{Base_WOP(r, y)}\right)}$$

Where for each region r and year y ,

$New_GDP_PPP(r, y)$ = new value for the GDP after the price change

$Base_GDP_PPP(r, y)$ = original base starting value for the GDP

$New_WOP(r, y)$ = new value for the world oil price

$Base_WOP(r, y)$ = original base starting value for the world oil price

$WOPElas(r, y)$ = elasticity of GDP to world oil price

Given a new world oil price, $New_WOP(r, y)$, the equation above may be used to solve for the corresponding GDP, $New_GDP_PPP(r, y)$:

$$New_GDP_PPP(r, y) = Base_GDP_PPP(r, y) * \exp(WOPElas * \ln\left(\frac{New_WOP(r, y)}{Base_WOP(r, y)}\right))$$

This relationship was not used in producing the *IEO2010*.

Gross Output Projections

The WEPS+ Macroeconomic Model also provides projections of gross output (GO) for 53 economic sectors and subsectors for use in the World Industrial Model. The WEPS+ uses an initial set of GO projections from the IHS Global Insight *World Industry Service*. The *World Industry Service* provides projections for 135 economic sectors, which are aggregated to the 53 sectors and subsectors maintained by the Macroeconomic Model. The sectors include industrial manufacturing and non-manufacturing sectors, along with a variety of commercial sectors (Table 4).

Table 4. Economic Sector Aggregations from the IHS Global Insight *World Industry Service*

Sector	ISIC ¹	Sector/Subsector	Sector	ISIC	Sector/Subsector
1	A_B	Agriculture	28	DM	Machinery and Equipment
2	C	Mining	29	DN	Electrical – Computers
3	CA	Energy Mining	30	DO	Electrical – Other
4	CB	Non-Energy Mining	31	DP	Motor Vehicles and Prods.
5	D	Total Manufacturing	32	DQ	Transport Equipment, nonMV
6	DA	Food and Beverages	33	DR	Furniture, Jewelry, etc.
7	DB	Tobacco Products	34	DS	Recycling
8	DC	Textiles and Apparel	35	E	Utilities
9	DD	Wood Products, non-Furn.	36	F	Construction
10	DE	Paper and Pulp	37	G	Wholesale and Retail Trade
11	DF	Printing and Publishing	38	GA	Wholesale Trade
12	DG	Refinery and Other Trans.	39	GB	Retail Trade, Motor Veh.
13	DH	Total Chemicals	40	GC	Retail Trade, non-MV
14	DHA	Basic Industrial Chemicals	41	H	Hotels and Restaurants
15	DHB	Fertilizers	42	I	Transport and Telecommun.
16	DHC	Synthetic Resins	43	IA	Transportation Services
17	DHD	Specialty – Ex. Pharms	44	IB	Post and Telecommun.
18	DHE	Pharms, Drugs, and Meds.	45	J	Financial Intermediation
19	DHF	Synthetic Fibers	46	K	Real Estate, Business Serv
20	DI	Rubber and Plastics Prods	47	KA	Real Estate
21	DJ	Total Mineral-Based Prods	48	KB	Business Services
22	DJA	Mineral-Based Products	49	L	Public Admin. And Defense
23	DJB	Cement, Concrete, Lime	50	M	Education
24	DK	Total Basic Metals	51	N	Health and Social Services
25	DKA	Iron and Steel	52	O	Social and Personal Services
26	DKB	Non-Ferrous Metals	53	P	Private Household Services
27	DL	Fabricated Metal Products			

From the *World Industrial Service*, the Macroeconomic Model's GetGO subroutine (illustrated in Figure 6) imports gross output and GDP projections to 2015 for the industries specified in

¹ ISIC = International Standard of Industrial Classification code.

Table 4. Although the imported GDP values are generally similar to the GDP projections used for the WEPS+ scenarios, they are estimated independently by IHS Global Insight and may differ somewhat from the WEPS+ projections. All of the imported gross output values are therefore adjusted to ensure consistency between the WEPS+ GDP and gross output projections. The adjustment factor for each region r and year y is a simple ratio of the two GDP estimates:

$$AdjFactor(r, y) = \frac{ModelGDP(r, y)}{InputGDP(r, y)}$$

Then for each industry i :

$$InGO(i, r, y) = InGO'(i, r, y) * AdjFactor(r, y)$$

Where, for each industry i in region r and year y ,

$ModelGDP(r, y)$ = GDP projection from WEPS+

$InputGDP(r, y)$ = GDP projection from the *World Industry Service*

$AdjFactor(r, y)$ = the adjustment factor to correct for differences in the GDP projections

$InGO'(i, r, y)$ = gross output projection from the *World Industry Service*

$InGO(i, r, y)$ = adjusted WEP+ gross output projection

Next, the gross output projections are extended to 2035 by industry, based on an assumed constant growth rate within each industry i from 2010 to 2015:

$$GrowthRate(i, r) = \left(\frac{InGO(i, r, y = 2015)}{InGO(i, r, y = 2010)} \right)^{\frac{1}{5}}$$

For each year after 2015, a preliminary gross output measure is computed for each industry and region. (These preliminary measures are used only for industry allocation purposes, as discussed below.)

$$TempGO(i, r, y) = InGO(i, r, y - 1) * GrowthRate(i, r)$$

Where $InGO(i, r, y)$ = gross output from the *World Industry Service*

$GrowthRate(i, r)$ = assumed constant gross output growth rate for 2010 to 2015

$TempGO(i, r, y)$ = preliminary projection of gross output for year y .

This computation results in a set of gross output projections that are not necessarily consistent with the WEPS+ GDP projections. Each of the gross outputs may have very different growth rates, and there is no reason to assume that they are all independent. Therefore, the next step is to calibrate the growth in the estimated gross output projections to the growth in GDP. This is done in a manner that ensures consistency in aggregation among all the sectors and subsectors.

The gross outputs of all of the higher level sectors are calculated as sums of the gross outputs of their subsectors. For example, the gross output for “Mining” is calculated as the sum of the gross output for “Energy Mining” and “Non-Energy Mining.” These calculations start with the most detailed sectoral categories and proceed up the aggregation tree to the most general sectors.

$$TotalGO(r,y) = \sum_i TempGO(i,r,y).$$

The second step is to calculate the annual growth rates for the WEPS+ GDP projections and to apply these growth rates to the total (all sectors) gross output. That is, total gross output is assumed to increase at the same rate as GDP over the projection period.

$$TotalGO(r,y) = TotalGO(r,y - 1) * \left(\frac{ModelGDP(r,y)}{ModelGDP(r,y - 1)} \right)$$

Next, the total gross output is allocated to the sectors and subsectors according to the shares from the preliminary projections ($TempGO(i,r,y)$, described above):

$$FinalGO(i,r,y) = \frac{TempGO(i,r,y)}{TotalGO(r,y)}$$

For example, if “Total Manufacturing” represented 40 percent of the original temporary total gross output projection, then 40 percent of the readjusted total gross output will be put into “Total Manufacturing.” Once all of the gross output values have been determined, the values are exported to the restart file for use by the World Industrial Model.

Appendix A. Model Abstract

Model Name:

Macroeconomic Model of the World Energy Projection System Plus

Model Acronym:

None

Model Description:

The Macroeconomic Model of the World Energy Projection System Plus (WEPS+) is a computer-based model that describes the world's macro economy. Specifically, it provides the outlook for gross domestic product (in terms of both purchasing power parity and market exchange rates), and population on a regional basis, as well as gross output by industry in each of the 16 WEPS regions over the projection period to 2035.

Model Purpose:

The primary objective of the WEPS+ Macroeconomic Model is to generate projections of macroeconomic activity by region, and in the case of gross output, by economic sector or industry. Regional projections are computed annually for the period of 2008 through 2035. As an integral component of the WEPS+ system, the Macroeconomic Model provides GDP and population inputs – key drivers for calculating world energy consumption – to the WEPS+ demand models and the World Electricity Model. In addition, gross output is a key driver for calculating world energy consumption in the World Industrial Model, and is provided to this model by the Macroeconomic Model for 53 economic sectors by region.

Most Recent Model Update:

December 2009.

Part of Another Model:

World Energy Projection System Plus (WEPS+).

Model Interfaces:

The Macroeconomic Model provides outputs to the WEPS+ demand models, the World Electricity Model, and the World Industrial Model, through the common, shared interface file of the WEPS+.

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Documentation:

Energy Information Administration, U.S. Department of Energy, *Macroeconomic Model of the World Energy Projection System Plus: Model Documentation 2010*, DOE/EIA-M076(2010) (Washington, DC, July 2010).

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 2010*.

Energy System Described:

International gross domestic product, gross output, and population.

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: GDP, gross output, and population.
- Time Unit/Frequency: Annual, 2008 through 2035.

Modeling Features:

The Macroeconomic Model provides macroeconomic projection for use by the other models in the WEPS+ system. The model has the capability – albeit one that is not generally used – of using elasticities relative to world oil price to change the GDP relative to the Reference case in order to provide macroeconomic feedback. The model also projects gross output using existing gross output projections through 2015 from the IHS Global Insight *World Industry Service*. The model uses an algorithm to extend those projections to 2035 for 53 economic sectors, and also to calibrate the results to the GDP assumptions for any given WEPS+ scenario.

DOE Input Sources:

None.

Non-DOE Input Sources:

IHS Global Insight, *World Overview, Third Quarter 2009* (Lexington, MA, November 2009).
IHS Global Insight, *World Industry Service Forecast Tables: Sector Gross Sales by Regions and Countries* (Lexington, MA, Revised August 24, 2009).

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 MacInput-JH121009.xml.

Classification: Input variable.

<i>TmpPPP(r,y):</i>	GDP expressed in purchasing power parity by region and year (years 2005 through 2035)
<i>TmpPop(r,y):</i>	Population by region and year (years 2005 through 2035)
<i>TmpMER(r,y):</i>	GDP expressed in market exchange rates by region and year (years 2005 through 2035)
<i>MEWOP(y):</i>	World oil price upon which imported GDP is based by year (years 2005 through 2035); <i>Note: in the Key Computations section of this report, this variable is called Base_WOP(r,y)</i>
<i>MEVal(r):</i>	Regional GDP elasticities relative to the world oil price; <i>Note: in the Key Computations section of this report, this variable is called WOPElas</i>
<i>MESw:</i>	Factor indicating whether GDP elasticities should be used to re-estimate the GDP assumptions relative to the world oil price (0 = no, 1 = yes)
<i>HistPPP(r,y):</i>	Historical GDP expressed in purchasing power parity by region and year (years 1980 through 2007)
<i>HistPop(r,y):</i>	Historical population by region and year (years 1980 through 2007)
<i>HistMER(r,y):</i>	Historical GDP expressed in market exchange rates by region and year (years 1980 through 2007)
<i>TmpHDef(2,r,y):</i>	Implicit U.S. price deflator from EIA, <i>Annual Energy Review 2008</i> (2000=1.0) assigned to every region
<i>TmpFDef(1,r,y):</i>	U.S. GDP deflator from EIA, <i>Annual Energy Outlook 2009</i> (2000=1.0) assigned to every region
<i>TmpFDef(2,r,y):</i>	U.S. consumer price index (CPI) from EIA, <i>Annual Energy Outlook 2009</i> (1984=1.0), assigned to every region

The following variables represent data input from the file GORpt-JH082409c.txt.

Classification: Input variable.

<i>RLLAB(r):</i>	Regional label (“United States”, “Canada”, “Mexico”, etc.)
<i>ILLAB(i):</i>	Industry label by economic sector (55 labels; 1= GDP, 2= total gross output, the remaining 53 are listed in Table 4)

InGO(i, r,y): Gross output by economic sector (53 industrial sectors, plus GDP=1 and total gross output=2), region, and year (years 2001 to 2015); *Note: in the Key Computations section of this report, this variable is, depending on context, called InputGDP(r,y), TempGO(i,r,y), TotGO(i,r,y), and FinalGO(i,r,y)*

The following variables represent data input from the Restart file.

Classification: Input variable from the Petroleum Model.

WTPPrC(y): World oil price associated with run scenario; *Note: in the Key Computations section of this report, this variable is called New_WOP(r,y)*

The following variables represent data calculated in the subroutine CalcGDP.

Classification: Computed variable.

GDP_PPP(r,y): GDP in purchasing power parity by region and year (includes any adjustment made when factor indicates elasticities relating GDP to a new world oil price must be used); *Note: in the Key Computations section of this report, this variable is called, depending on context, New_GPD_PPP(r,y) or ModelGDP(r,y)*

GDP_MER(r,y): GDP in market exchange rates by region and year (includes any adjustment made when factor indicates elasticities relating GDP to a new world oil price must be used)

Pop(r,y): Population by region and year

MacGDPD (r,y): GDP deflators by region and year

MacPrCD(r,y): Price deflators by region and year

The following variables represent data calculated in the subroutine GetGO.

Classification: Computed variable.

InGO(i, r,y): Gross output by economic sector (53 industrial sectors, plus GDP=1 and total gross output=2), region, and year (years 2015 to 2035);

MacGO(r,y,i): Gross output by region, year, and economic sector for export to restart file (years 2001 to 2035).

Appendix C. References

1. IHS Global Insight, *World Industry Service Forecast Tables: Sector Gross Sales by Regions and Countries* (Revised August 24, 2009).
2. IHS Global Insight, *World Overview, Third Quarter 2009* (Lexington, MA, November 2009).
3. International Monetary Fund, *World Economic Outlook October 2009* (Washington, DC, October 2009).
4. Franklin J. Stermole and John M. Stermole, *Economic Evaluation and Investment Decision Methods: Eleventh Edition* (Investment Evaluations Corporation, Lockwood, CO, 2006).
5. Energy Information Administration, *Model Documentation Report: Macroeconomic Activity Module (MAM) of the National Energy Modeling System 2009*, DOE/EIA-0066(2009) (Washington, DC, January 2009).
6. International Energy Agency, *Energy Prices and Taxes* (Paris, France, quarterly: various issues).
7. United Nations, *World Economic Situation and Prospects 2010* (New York, NY, 2010).

Appendix D. Data Quality

Introduction

The WEPS+ Macroeconomic Model incorporates exogenous projections of world GDP (in purchasing power parity and market exchange rate terms), population, and gross output by economic sector for 16 regions of the world. These projections are based upon 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

- *IHS Global Insight: GDP and Population* – Historical and projected gross domestic product (GDP) and population are initially provided by IHS Global Insight. GDP projections are provided both in terms of purchasing power parity and market exchange rates, annually from 1980 (in most regions) through 2035. The GDP projections are adjusted for use in the WEPS+ Macroeconomic Model through expert judgment. Such adjustments are made for the Reference case in certain regions, including the United States, where GDP projections from IHS Global Insight are overwritten by those provided in the *Annual Energy Outlook*. GDP adjustments are also made to reflect the impact of world oil prices on GDP. This latter feature was not used in the *IEO2010* projections.
- *IHS Global Insight: World Industry Service* – The World Industry Service provides the Macroeconomic Model with historical and projected gross output for 53 economic sectors by region. The gross output projections are available only from 2000 to 2015, so the Macroeconomic Model must extend the projections to 2035 and calibrate the results with the regional GDP projections
- *NEMS* – Many of the assumptions about price and economic elasticities are based in large part on those included in the National Energy Modeling System for the United States. For some specific regions represented in the WEPS+, expert judgment on regional economic conditions was used to adjust the assumptions.

Data Quality Verification

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

- Checks on world and U.S. macroeconomic indicators—including GDP, price elasticities, and GDP elasticities—to ensure consistency with previous values, and regional and technical knowledge

- Technical edits to detect and correct errors, extreme variability