Independent Statistics & Analysis
U.S. Energy Information Administration

World Energy Projection System Plus: Commercial Module

December 2017

This report was prepared by the U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy. By law, EIA's data, analyses, and forecasts are independent of approval by any other officer or employee of the United States Government. The views in this report therefore should not be construed as representing those of the U.S. Department of Energy or other federal agencies.

Contents

Update information 3

1. Introduction 4

  Purpose of this report 4

  Model summary 4

  Model archival citation 5

  Model contact 5

  Organization of this report 5

2. Model Purpose 6

  Model objectives 6

  Model inputs and outputs 6

    Inputs 6

    Outputs 7

  Relationship to other models 8

3. Model Rationale 10

  Theoretical approach 10

  Model projections 10

4. Model Structure 11

  Structural overview 11

  Flow diagrams 12

  Key computations 14

  Projection equations 15

    Services gross output equation 17

    Price index equation 17

    Trend index 18

    Overall projection index 18

    Exogenous Inflection Algorithm 18

    Consumption projection 19

    Adjustment factors 19

    High world oil price fuel substitution 19

    STEO calibration 20

Appendix A. Model Abstract ... 22
Model name: ... 22
Model acronym: ... 22
Model description: ... 22
Model purpose: ... 22
Most recent model update: ... 22
Part of another model: ... 22
Model interfaces: ... 22
Official model representative: ... 22
Documentation: ... 23
Archive information: ... 23
Energy system described: ... 23
Coverage: ... 23
Modeling features: ... 23
DOE input sources: ... 23
Non-DOE input sources: ... 23
Independent expert reviews: ... 23
Computing environment: ... 23
Appendix B. Input Data and Variable Descriptions ... 24
Coefficient sources: ... 26
Coefficients used for IEO2017 ... 28
Appendix C. Key to Abbreviations Used in Table 5 ... 32
Appendix D. References ... 33
Appendix E. Data Quality ... 34
Introduction ... 34
Source and quality of input data ... 34
Source of input data ... 34
Data verification ... 34

Tables

Table 1. Regional coverage of the world energy projection system plus model 6
Table 2. WEPS+ models that provide Inputs to the Commercial Model 7
Table 3. Major exogenous Commercial Model input data series 7
Table 4. Commercial Model outputs and the WEPS+ Models that use them 8
Table 5. Commercial Model projection equation coefficients 28

Figures

Figure 1. World Energy Projection System Plus (WEPS+) Model Sequence 9
Figure 2. Flowchart for the Commercial Model 12
Figure 3. Flowchart for the Comm Subroutine 13
Figure 4. Flowchart for the ClnXML Subroutine 14
Figure 5. WEPS+ Commercial Model Basic Flows 16

Update information

This edition of the WEPS+ Commercial Model reflects changes made to the model since the previous iteration of this report. These changes include:

- Replacing GDP with services gross output

1. Introduction

Purpose of this report

The Commercial Model of the World Energy Projection System Plus (WEPS+) is an energy demand modeling system of the world commercial end-use sector at a regional level. This report describes the version of the Commercial Model that was used to produce the commercial sector projections published in the *International Energy Outlook 2017* (*IEO2017*). The Commercial Model is one of 13 components of the WEPS+ system. The WEPS+ is a modular system, consisting of a number of separate energy models that communicate and work with each other through an integrated system model. The model components are each developed independently, but are designed with well-defined protocols for system communication and interactivity. The WEPS+ modeling system uses a 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 forces convergence of consumption and supply pressures to solve for an equilibrium price.

This report documents the objectives, analytical approach and development of the WEPS+ Commercial 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 U.S. 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+ Commercial Model for the *IEO2017* projects energy consumed by businesses, institutions, and service organizations. Commercial sector energy use covers a broad range of activities and services and includes energy used in schools, stores, correctional institutions, restaurants, hotels, hospitals, museums, office buildings, banks, and sports arenas. Most commercial energy use occurs in buildings or structures, supplying services such as space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings, such as for traffic lights and city water and sewer services, is also categorized as commercial energy use.

The Commercial Model projects commercial consumption for 11 energy sources in each of the 16 WEPS+ regions on an annual basis over a projection period. The model primarily uses a dynamic econometric equation for the key energy sources, basing the projection on assumptions about future growth in services gross output, commercial retail energy prices for nine fuels, and a trend factor. The dynamic equation uses a lagged dependent variable to imperfectly represent stock accumulation. The services gross output and price projections are available to the Commercial Model from the WEPS+ Global Activity Model and the supply models through the restart file, which is shared by all WEPS+ models. The trend factor is meant to represent continuing impacts on energy use not directly represented in services gross output and price, and may include a variety of behavioral, structural, and policy-induced activities. The consumption projections generated by the Commercial Model are in turn put into the restart file for use by other models.

Model archival citation

This documentation refers to the WEPS+ Commercial Model, as archived for the *International Energy Outlook 2017* (*IEO2017*).

Model contact

David Peterson
U.S. Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585
Telephone: (202) 586-5084
E-mail: David.Peterson@eia.gov

Organization of this report

Chapter 2 of this report discusses the purpose of the Commercial Model, the objectives and the analytical issues it addresses, the general types of activities and relationships it embodies, the primary input and output variables, and the relationship of the model to the other models in the WEPS+ system. Chapter 3 of the report describes the rationale behind the Commercial Model design, providing insights into further assumption 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+ Commercial Model is to generate regional annual projections of commercial sector energy use. These projections are computed annually by fuel type and region. As an integral component of the WEPS+ system, the Commercial Model provides consumption inputs to the transformation and supply models of WEPS+ and contributes to the calculation of the overall energy supply and demand balance. The consumption inputs are also used by the Greenhouse Gases Model to calculate energy-related carbon dioxide emissions.

As part of the WEPS+ system, the Commercial Model provides projections for the 16 WEPS+ 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 Non-OECD Americas

Model inputs and outputs

Inputs

The Commercial Model uses macroeconomic and commercial price projections that are imported from the WEPS+ restart file. These inputs have been previously projected by the Global Activity Model and by the transformation and supply models (Table 2).

Table 2. WEPS+ models that provide Inputs to the Commercial Model

Commercial Model Input	Source
Services gross output	Global Activity Model
Commercial motor gasoline retail price	Refinery Model
Commercial distillate retail price	Refinery Model
Commercial residual retail price	Refinery Model
Commercial kerosene retail price	Refinery Model
Commercial LPG retail price	Refinery Model
Commercial natural gas retail price	Natural Gas Model
Commercial coal retail price	Coal Model
Commercial electricity retail price	Electricity Model
Commercial district heat retail price	District Heat Model

A number of exogenous data series are also imported into the Commercial Model from the ComInput.xml file (Table 3).

Table 3. Major exogenous Commercial Model input data series

Source Input File	Model Input
ComInput.xml	GDP elasticities by fuel and region
	GDP lag coefficients by region and fuel
	Regional by-fuel price elasticities
	Regional by-fuel lag coefficients
	Regional by-fuel growth trend factors
	User adjustment factors (not currently used)
	Regional by-fuel multiplicative factors applied to services gross output and price elasticities (currently not used)
	Total liquids consumption (hard-wired into input file from Reference case run; only used in High Oil Price case)
	Increment of additional liquids that must be allocated to natural gas, coal, and electricity (only used in High Oil Price case)

Outputs

The Commercial Model projects energy consumption in the commercial or service sector by fuel and region (excluding transportation energy use). Upon completion of a model run, these values are exported into the WEPS+ restart file for use by other models (Table 4).

Table 4. Commercial Model outputs and the WEPS+ Models that use them

Commercial Model Output	Destination
Motor gasoline consumption	Petroleum Model and Refinery Model
Distillate consumption	Petroleum Model and Refinery Model
Residual fuel consumption	Petroleum Model and Refinery Model
Kerosene consumption	Petroleum Model and Refinery Model
LPG consumption	Petroleum Model and Refinery Model
Natural gas consumption	Natural Gas Model
Coal consumption	Coal Model
Electricity consumption	Electricity Model
Heat consumption	District Heat Model
Biomass consumption	(Placeholder)
Solar consumption	(Placeholder)

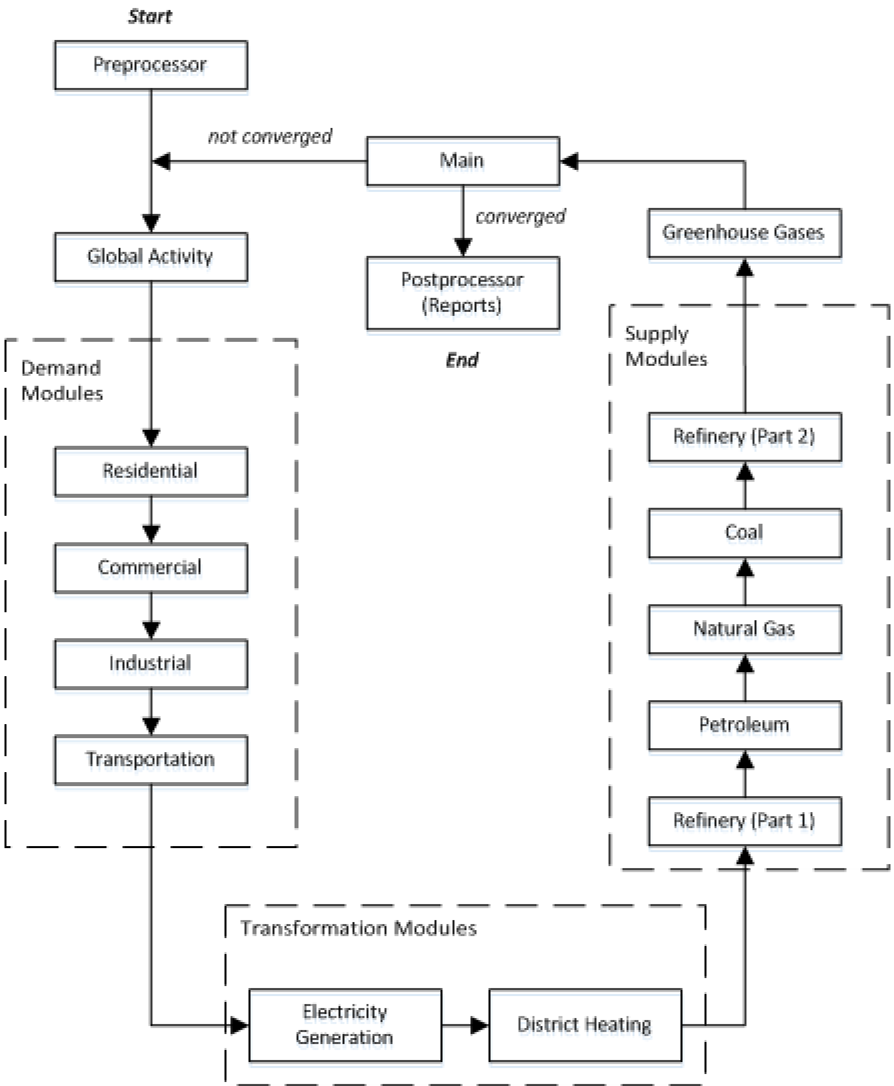
Relationship to other models

The Commercial Model is an integral component of the WEPS+ system, and depends upon other models in the system for some of its key inputs. In turn, the Commercial Model provides projections of commercial energy consumption, which are key inputs to other models in the system (Figure 1). A summary description of the models, flows, and mechanics of the WEPS+ system used for the *IEO2017* report is available in a separate *Overview* documentation.

Through the system, the Commercial Model receives services gross output projections from the Global Activity Model, and receives a variety of Commercial retail price projections from various supply and transformation models. In turn, the Commercial Model provides consumption projections through the system back to the various supply models.

Although the Commercial Model is an integral part of the WEPS+ system, it can also be easily run as a standalone, outside of the system. In standalone mode, the Commercial Model inputs macroeconomic and price projections from the WEPS+ system “restart” file as created in a previous full-system run.

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



3. Model Rationale

Theoretical approach

The Commercial Model makes projections of commercial sector energy consumption based on changes in services gross output, energy prices, and a trend factor. Commercial energy consumption is assumed to follow an overall trend while increasing with services gross output and responding inversely to price changes. Thus the model projects energy consumption by applying a trend factor and a series of exponential ratio adjustments to the most recent historical estimates. The exponents of the ratio adjustments, which are imported from other modeling systems, may be interpreted as elasticity estimates: they represent the extent to which energy consumption changes in response to changes in services gross output and price. Special adjustments are applied to simulate energy source substitution in the "High World Oil Price" case. Finally, we calibrate the projections to force consistency with EIA's short term energy projections.

Model projections

The Commercial Model makes projections of the following:

- Commercial sector energy consumption, based on the assumption that changes in consumption are related to changes in services gross output
- Commercial sector energy prices, based on an elasticity measure and the dynamics of a stock-adjustment represented by a lagged dependent variable

The projections are also based upon assumptions about autonomous trends representing behavioral, structural, and/or policy-induced activities. More specifics and the values of the elasticities and trends are presented in the model structure section below.

4. Model Structure

Structural overview

The main purpose of the Commercial Model is to estimate annual commercial sector energy consumption by region and fuel type. The Commercial energy consumption calculations are based on regional estimates of services gross output, commercial fuel prices (by type), and adjustment trend factors. Consumption is estimated for each of the 16 WEPS+ regions for 11 energy sources: motor gasoline, distillate fuel, residual fuel, kerosene, liquefied petroleum gas (LPG), natural gas, coal, electricity, heat, biomass, and solar energy.

The basic structure of the Commercial Model is illustrated in Figure 2. A call from the WEPS+ interface to the Commercial Model initiates importation of the supporting information from the restart file needed to complete the projection calculations. The Commercial Model then executes the Comm subroutine, the major component of the model, which performs all model computations. Finally, the model executes a subroutine that exports all projections to the restart file for use by other WEPS+ models.

When the Comm subroutine (Figure 3) is initiated by a call from the main Commercial Model, it initiates a call of the CInXML subroutine (Figure 4), which imports from the ComInput.xml file several exogenous data series that the model requires. ComInput.xml includes:

- The economic (services gross output) and price elasticities and lag regression coefficients associated with regions, fuels, and years. The economic elasticities indicate the extent to which commercial energy consumption changes in response to changes in services gross output.
- Multiplicative and shape and elasticity adjustment factors that are associated with each region and projection year and used if a user-specified adjustment based upon expert judgment is to be incorporated into the projection

After importing these data, the CInXML subroutine recalculates the services gross output and price elasticity factors and incorporates any shape-and-elasticity adjustment factors. The adjustment factors were not used for *IEO2017* model runs.

The Comm subroutine then begins to compute commercial sector energy consumption projections by fuel. First, it computes services gross output and commercial sector price and trend indices across the projection period by region and fuel. Next, it calculates an overall commercial sector quantity index as the product of the services gross output, price, and trend indices. If the user has specified additional adjustments, the Comm subroutine calculates an adjustment index and recalculates the overall commercial sector quantity index to incorporate the adjustment. It then calculates projections of commercial sector energy consumption by fuel, region, and year, both with and without any user-specified multiplicative factors.

When a High Oil Price case is being implemented, the Comm subroutine imports two additional data series from the ComInput.xml file: total liquids consumption by region and year from the Reference case projections, and a factor that indicates the portion of liquids that will be allocated to natural gas, coal, and electricity to represent consumer substitution away from liquids. These amounts are then calculated and allocated to the total commercial sector natural gas, coal, and electricity projections. Finally, the subroutine calculates commercial sector liquids consumption by region and benchmarks the projections to regional *Short-Term Energy Outlook* projections. The Comm subroutine generates several output files and returns them to the main Commercial Model routine.

After the Comm subroutine has executed, the WriteRestart subroutine writes the projections to the restart file for use in future iterations of WEPS+, notably in the refinery model. These output data series include projections of regional commercial energy use by fuel.

Flow diagrams

Figure 2. Flowchart for the Commercial Model

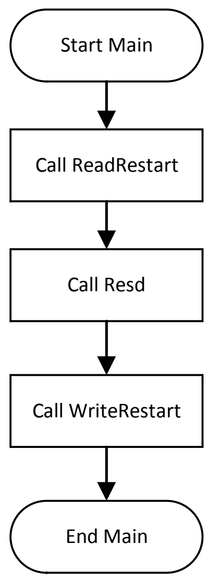


Figure 3. Flowchart for the Comm Subroutine

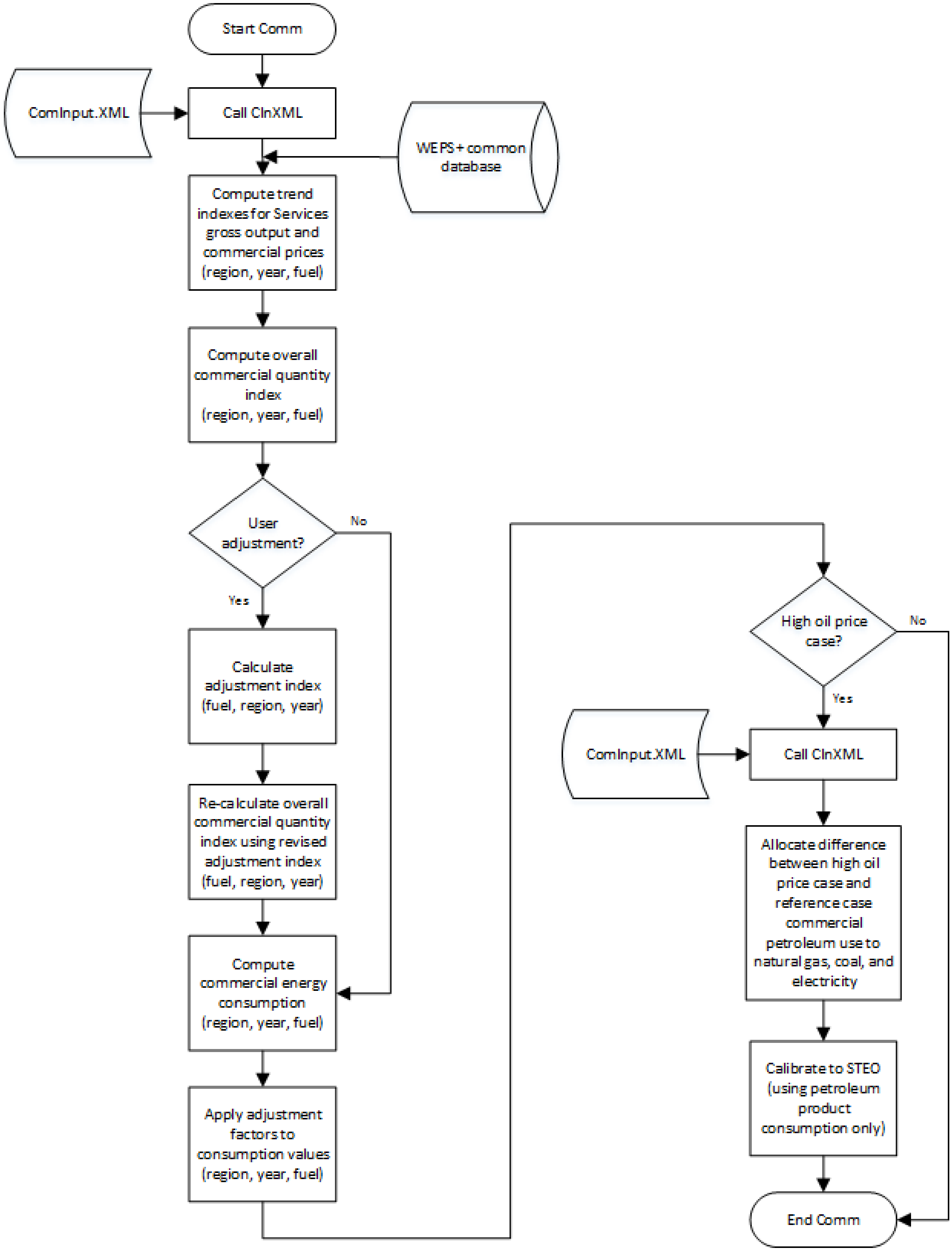
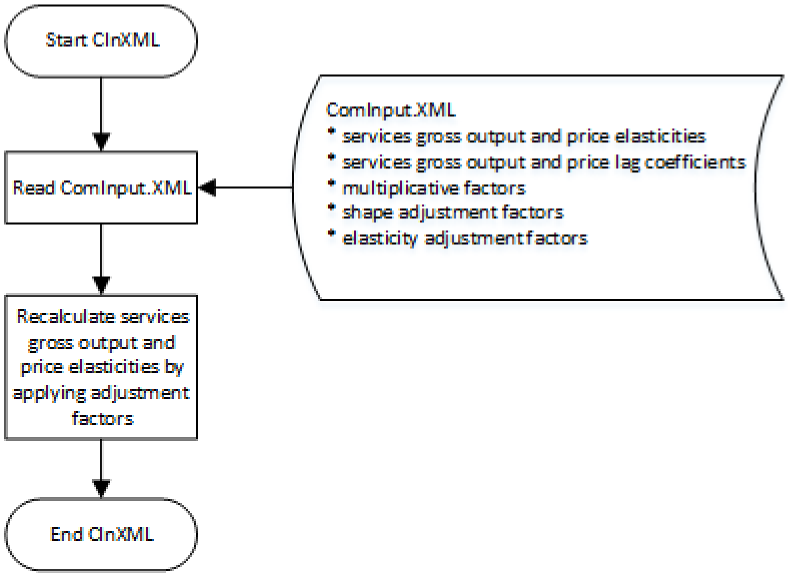


Figure 4. Flowchart for the ClnXML Subroutine



Key computations

The WEPS+ Commercial Model projects energy that is consumed by businesses, institutions, and service organizations. Most commercial energy use occurs in buildings or structures, supplying services such as space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings, such as for traffic lights and city water and sewer services, is also categorized as commercial energy use. The model projects commercial sector energy consumption for a number of energy sources in each of the 16 WEPS+ regions over the projection horizon. The Commercial Model projects energy consumption for 11 energy sources:

- Motor gasoline
- Distillate fuel
- Residual fuel
- Kerosene
- LPG
- Natural gas
- Coal
- Electricity
- District Heat (steam or hot water)
- Biomass
- Solar

The Commercial Model begins by importing the historical data from the WEPS+ shared restart file. Compiled from the International Energy Agency's *OECD* and *Non-OECD Statistics and Balances* databases, these data cover detailed energy end-use consumption in the commercial sector. The data are calibrated to be consistent with the more aggregated energy consumption data from EIA's International Statistics Database. These data are processed prior to the execution of the Commercial Model and are stored in the restart file to provide a common starting point for all WEPS+ models. The

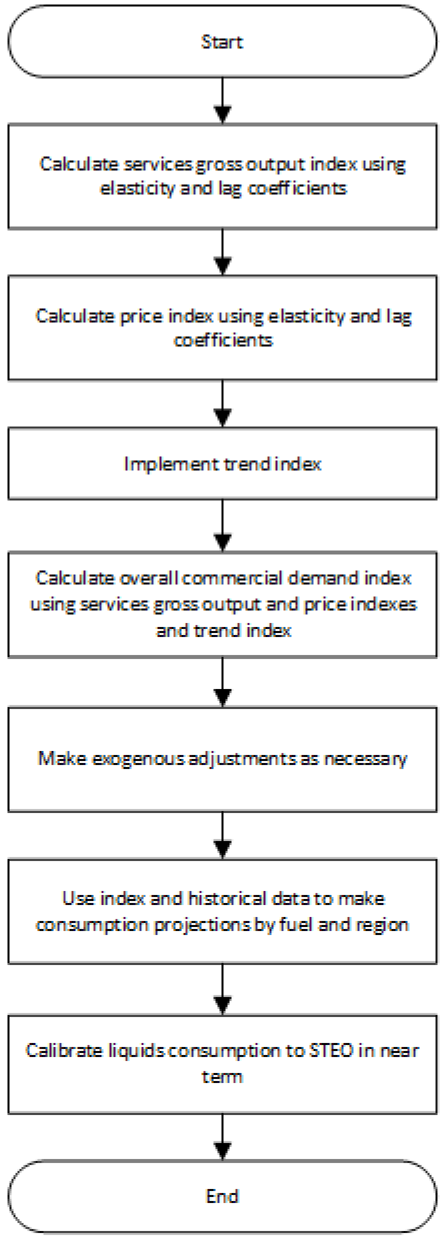
Commercial Model uses the historical data for all years up to the most recent year available for each of the 16 regions and 11 energy sources.

Macroeconomic and price projections are also imported into the Commercial Model from the restart file. These data series are projected in previous system iterations by the Global Activity Model and by various transformation and supply models (see Figure 5).

Projection equations

Figure 5 is a flowchart of the Commercial Model's major computations, which we discuss in detail here. The Commercial Model primarily uses econometric assumptions to estimate change in commercial energy consumption from the year of the most recent historical data (2015). It bases projections for the key energy sources on a services gross output projection, commercial retail energy price projections (for 11 energy sources—no prices are used for solar or biomass), and a trend factor. The dynamic equation uses a lagged dependent variable to (imperfectly) represent accumulation of commercial stock—e.g., appliances, lighting, and heating and cooling equipment. The Commercial Model obtains the services gross output projections from the WEPS+ Global Activity Model through the shared restart file. The services gross output projections are expressed in terms of purchasing power parity in real 2010 dollars. Through the restart file, the WEPS+ supply models provide by-fuel price projections to the Commercial Model. The prices are all in terms of real Figure 5 dollars per million Btu. The trend term is meant to represent continuing impacts on energy use not directly influenced by services gross output and/or price; it may account for the effects of a variety of behavioral, structural, and policy-induced activities.

Figure 5. WEPS+ Commercial Model Basic Flows



The variables used in the projection equations are all expressed in terms of indices indicating change relative to the most recent available historical value. The indexing approach allows the model to consider only changes in the services gross output and prices, not their actual levels. The effects of the three drivers of the projection—services gross output, prices, and the trend term—are each estimated separately and then multiplied together to get an overall index reflecting projected change in commercial energy consumption. The overall index is then applied to the most recent historical consumption value to compute the projection.

Services gross output equation

For each region *r* and projection year *y*, we first compute the ratio of the services gross output in year *y* to the services gross output in the most recent historical data year, *LHYr* (both adjusted to reflect purchasing power parity):

$$GDPI(r,y) = \frac{MacGO\_PPP(r,y,26)}{MacGO\_PPP(r,y=LHYr,26)},$$

where

$GDPI(r,y)$ is the index for services gross output in region r and year y;

$MacGO\_PPP(r,y,26)$ is the services gross output based on purchasing power parity in region r and year y; and

$MacGO\_PPP(r,y=LHYr,26)$ is the services gross output based on purchasing power parity in region r and year y.

The index for the services gross output-influenced part of the projection for fuel *f* and region *r* in year *y* is then given by

$$GDPIdx(f,r,y) = \exp\Big(GDPElas(f,r) * \ln\big(GDPI(r,y)\big) + GDPLag(f,r) * \ln\big(GDPIdx(f,r,y-1)\big)\Big),$$

where

$GDPElas(f,r)$ and $GDPLag(f,r)$ are exogenous coefficients (read from an input file) for the GDP and for the lag term, respectively, for fuel f in region r.

The elasticity coefficient, *GDPElas(f,r)*, reflects the extent to which commercial energy consumption increases (or decreases) with services gross output. The index *GDPIdx(f,r,y)* starts with a value of 1.0 in the last historical year of 2015.

Price index equation

The effect of prices on commercial energy consumption is estimated in similar fashion, except that the price change ratio is estimated separately for each fuel. Let

$$CPIdx(f,r,y) = \frac{RetailPrice(f,r,y)}{RetailPrice(f,r,y=LHYr)},$$

where $RetailPrice(f,r,y)$ is the retail price of fuel f in region *r* and year y.

The effect of prices on commercial energy consumption is then estimated as

$$PrcIdx(f,r,y) = \exp\Big(PrcElas(f,r) * \ln\big(CPIdx(f,r,y)\big) + PRCLag(f,r) * \ln\big(PrcIdx(f,r,y-1)\big)\Big),$$

where *PrcElas(f,r)* and *PrcLag(f,r)* are exogenous coefficients (read from an input file) for the price ratio and the lag term, respectively. The elasticity coefficient, *PrcElas(f,r)*, reflects the extent to which commercial consumption of fuel *f* in region *r* changes in response to changes in price.

There are prices for all of the fuels except for solar and biomass.

Trend index

The trend coefficient, TrendGR(f,r), which is read from an input file, represents a constant as an annual growth rate applied to consumption projections for all years. The growth rate is used to calculate the trend index term for the last model year, applying the growth rate over the period from the last historical year to the last model year. The index begins in 2015 with a value of 1.0. Once the implied value for 2050 has been calculated, the model fills in all the intervening years by linear interpolation:

$$EffIdx(f,r,y=2050) = EffIdx(f,r,y=2015) * \ TrendGR(f,r,y)^{(2050-2015)}.$$

For years from 2016 to 2049:

$$EffIdx(f,r,y) = EffIdx(f,r,y=2015) + \frac{(EffIdx(f,r,y{=}2050) - EffIdx(f,r,y{=}2015)}{(y-2015)/(2050-2015)}.$$

Overall projection index

The overall projection index for each region and fuel is calculated by multiplying by the services gross output index, price index, and efficiency index:

$$CQIdx(f,r,y) = GDPIdx(f,r,y) * PrdIdx(f,r,y) * EffIdx(f,r,y),$$

where $CQIdx$ is the overall projection index in each region, for each fuel, over the projection horizon.

Exogenous Inflection Algorithm

The model projection described thus far consists of an index based on a services gross output projection, a price projection, and a trend factor. The trend projection is computed by linear interpolation between the 2015 value and a target value for 2050. In some cases, however, linear interpolation may not be appropriate for the particular projection, because a different structural or behavioral trend is expected. For example, consumption of a specific fuel in a specific region may have grown rapidly in recent years and be expected to reach saturation, resulting in a moderation of the trend. The model allows the user to modify the projection index by adding an exogenous inflection.

To accomplish this, the user specifies the year for the midpoint of the inflection and a fraction indicating the strength of the inflection. The fraction would be a number such as 1.1, indicating that in the specified year the projection index should be 1.1 times its original value. A value of 1.0 has no effect and a value of 0.9 means the projection index in the inflection year should be 0.9 times its original value. The algorithm then will also modify all the other projection index points to smooth the series on each side of the inflection point. For example, if the inflection point is at 2020, then the values from 2016 through 2019 are smoothed based on the values for 2015 and 2020, and the values from 2021 through 2049 are smoothed based on the values for 2020 and 2050.

The smoothing algorithm uses a sine wave so that points close to the inflection point are modified more than the points nearer to the end points of the series. This approach is meant to approximate a spline smoothing technique without the computational complexity of the spline calculation.

Consumption projection

Finally, the historical starting consumption values are multiplied by the projection indices to project consumption over the projection horizon for each fuel *f*, region *r*, and year *y*:

$$CQty(f,r,y) = CQIdx(f,r,y) * HQty(f,r,y = 2015),$$

where $CQIdx$ is the overall projection index in each region, for each fuel, over the projection horizon;

$HQty$ is the historical consumption in 2015 by region and fuel; and

$CQty$ is the resulting consumption projection over the projection horizon by region and fuel.

The above equation is for all of the fuels except biomass and solar. The consumption of biomass and solar is not part of the equation primarily because there are no prices for solar and biomass, but also because these fuels account for a small percentage of commercial energy consumption. Very little solar energy is being used in commercial activities. Although a comparatively large amount of biomass is used in some regions, much of it is un-marketed and therefore not captured in EIA's historical international energy data.

Adjustment factors

In order to provide user control over the projections, the input file contains factors that users can set to adjust estimates for any fuel in any region and year. The system simply multiplies the specified consumption projection value by the user-specified factor.

High world oil price fuel substitution

The model formulation shown above, assumes no elasticity of substitution across fuels. This assumption was considered appropriate for the original Reference case, because the model was "calibrated" through user judgment for each of the individual fuels. However, because high oil prices may cause considerable substitution away from petroleum-based fuels, a simple algorithm was built into the model to recognize this fuel substitution.

In the HWOP case, a portion of the decline in petroleum consumption from the level in the Reference case is replaced by increases in consumption of other fuels. In order to determine how much petroleum consumption has declined from the Reference case, the system first reads in some data that specify the level of petroleum consumption in the Reference case. These data are supplemented with other data that provide the fractional increment of the petroleum that will be replaced by other fuels. In the input file, the fractional increment is set to be 0.5 in all regions, meaning that 50 percent of the petroleum decrease in the HWOP case will be replaced by an increase in other fuels. The model achieves the substitution over the years 2015 to 2050, and modifies the fractional increment so that it starts at 0 in 2015, gradually increases to its full value in 2020, then remains constant to 2050.

Once the model determines how much petroleum will be replaced by other fuels, it allocates consumption increases to natural gas, coal, and electricity, based on the current relative shares (expressed in Btu) of each of these fuels. For example, if 100 trillion Btu will be replaced, and the respective consumption shares of natural gas, coal, and electricity are 0.4, 0.0, and 0.6, then natural gas will increase by 40 trillion Btu, coal will be unchanged, and electricity will increase by 60 trillion Btu.

STEO calibration

EIA's *Short-Term Energy Outlook* (*STEO*) projects worldwide liquid fuels consumption in the near term. The regions in the *STEO* are more aggregate than in the WEPS+, and the consumption projections are for total petroleum with no sectoral or product differentiation. The *IEO2017* projections must be consistent with the values in the *STEO* for the projection years. Outside of the Commercial Model but within WEPS+, the Main Model reads the *STEO* data in each iteration. Based on the results from the current iteration, the Main Model allocates the total petroleum consumption to some sub-regions and to all the detailed end use sectors. The exception to this step is the electric power sector, where liquids-fired generation is not included, because electricity generation is a small liquids-consuming sector, and it is complicated due to its transformation of energy. Instead, the amount of liquids consumed in the electricity generation sector is subtracted from the total *STEO* liquids consumption. After that, the remaining amount of liquids consumption is allocated to the remaining sectors, based on the remaining share of liquids consumption. These quantities are then exported to the restart file for use by each of the WEPS+ models for calibration to *STEO*. It is worth noting that these sector allocations are performed by the Main Model for each WEPS+ iteration. Thus the allocated amounts adapt to changes in the sector-level consumption shares as the model moves towards the equilibrium solution.

The Commercial Model reads the *STEO* petroleum allocations for the commercial sector from the restart file, and then computes calibration factors for each petroleum product in each region for each of the *STEO* projection years. These factors are simply the ratios of the *STEO* commercial sector energy consumption allocation to the WEPS+ model's projection consumption in those years:

For each region *r* and year *y*,

$$STEOFac(r,y) = \frac{STEOQty(r,y)}{CQty(f = petroleum, r, y)},$$

where $STEOQty(r,y)$ is the STEO commercial consumption allocation;

$CQty(f = petroleum, r, y)$ is the model's total petroleum consumption; and

$STEOFac(r,y)$ is the STEO calibration factor.

The *STEO* calibration factors are then multiplied by the model's petroleum consumption projections, so that the model projects the *STEO* consumption levels.

$$QMGRS(r,y) = QMGRS'(r,y) * STEOFac(r,y),$$

$$QDSRS(r,y) = QDSRS'(r,y) * STEOFac(r,y),$$

$$QRSRS(r,y) = QRSRS'(r,y) * STEOFac(r,y),$$

$$QKSRS(r,y) = QKSRS'(r,y) * STEOFac(r,y),$$

$$QLGRS(r,y) = QLGRS'(r,y) * STEOFac(r,y),$$

where $QMGRS$ is the commercial motor gasoline consumption;

$QDSRS$ is the commercial distillate consumption;

$QRSRS$ is the commercial residual consumption;

$QKSRS$ is the commercial kerosene consumption; and

$QLGRS$ is the commercial LPG consumption.

Because the magnitude of *STEO* calibration adjustment for the last *STEO* year can be significant, a break in series could result if the WEPS+ consumption levels for the following years were left unadjusted. The *STEO* calibration factors are therefore applied, in mitigated form, to the projections for years immediately after the last *STEO* year, providing a smooth transition from the *STEO*-calibrated projections to the uncalibrated WEPS+ projections.

Appendix A. Model Abstract

Model name:

Commercial Model of the World Energy Projection System Plus

Model acronym:

Commercial Model

Model description:

The Commercial Model of the World Energy Projection System Plus (WEPS+) models world commercial energy demand and provides consumption projections for 11 energy sources in 16 international regions. For the *IEO2017,* the WEPS+ Commercial Model provides energy consumption projections for the commercial or services sector. The 11 energy sources covered include motor gasoline, distillate fuel, residual fuel, kerosene, liquid petroleum gas, natural gas, coal, electricity, heat, solar, and biomass.

Model purpose:

As a component of the WEPS+ integrated modeling system, the Commercial Model generates long-term projections of commercial sector energy consumption. The model also provides consumption inputs for a variety of the other WEPS+ models. The model provides a tool for analysis of international commercial sector energy use within the WEPS+ system, and can be run independently as a standalone model.

Most recent model update:

May 2017

Part of another model:

World Energy Projection System Plus (WEPS+)

Model interfaces:

The Commercial Model receives inputs from and provides output to the Global Activity Model, Refinery Model, Natural Gas Model, Coal Model, Electricity Model, and District Heat Model through the common, shared interface file of the WEPS+ restart file. In addition, the Commercial Model provides output to the Petroleum Model, again through the common, shared interface file.

Official model representative:

David Peterson
U.S. Energy Information Administration
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585
Telephone: (202) 586-5084
E-mail: David.Peterson@eia.gov

Documentation:

U.S. Energy Information Administration, U.S. Department of Energy, *World Energy Projection System Plus: Commercial Module*, DOE/EIA-M075 (2017) (Washington, DC, December 2017).

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 2017*.

Energy system described:

International commercial sector energy consumption.

Coverage:

- Geographic: Sixteen WEPS+ regions: U.S., Canada, Mexico/Chile, 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: total commercial energy consumption.
- Time Unit/Frequency: Annual.

Modeling features:

The commercial model makes projections of commercial sector energy consumption based upon changes in services gross output, energy prices, and a trend term. The model uses a dynamic simulation approach, using elasticities to model the changes over time and a lagged dependent variable to simulate dynamic adjustments.

DOE input sources:

U.S. Energy Information Administration, International Energy Statistics Database.
U.S. Energy Information Administration, *Short Term Energy Outlook* (STEO), Washington, D.C.

Non-DOE input sources:

International Energy Agency (IEA), *Energy Balances of OECD Countries*, Paris, 2016.
International Energy Agency (IEA), *Energy Balances of Non-OECD Countries*, Paris, 2016.
Oxford Economics, *Global Economic Model* (March 2017), www.oxfordeconomics.com (subscription site).

Independent expert reviews:

None.

Computing environment:

Hardware/Operating System: Basic PC with Windows.
Language/Software Used: Python, Fortran 90/95
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 ComInput.xml.

Classification: Input variable.

GDPElas(f,r):	GDP elasticity by fuel (motor gasoline, distillate, residual, kerosene, LPG, natural gas, coal, electricity, and heat; excludes renewable energy sources) and region
GDPLag(f,r):	GDP lag coefficient by region and fuel
PrcElas(f,r):	Regional by-fuel price elasticity
PrcLag(f,r):	Regional by fuel price lag coefficient
TrendGR(f,r):	Regional growth trend term by fuel
MltFac(f,r,y):	Commercial multiplicative factor by region, fuel (motor gasoline, distillate, residual fuel kerosene, LPG, natural gas, coal, electricity, heat, solar, and biomass) and projection year
AdjYr(f,r):	User adjustment term to change shape of Commercial consumption trend path by fuel and region
EGDPFac(f, r):	Regional by-fuel multiplicative factors applied to GDP elasticities (note: currently all set to 1.0)
EPrcFac(f,r):	Regional by-fuel multiplicative factors applied to price elasticities (note: currently all set to 1.0)
PetRef(r,y):	Total liquids consumption in the Reference case by region and year (note: this must physically be updated to current reference case when user intends to run a High Oil Price scenario)
PetFacA(r):	Increment of additional liquids in the High Oil Price case that must be allocated to natural gas, coal, and electricity by region

The following variables represent data input from the restart file.

Classification: Input variable from the Global Activity Model, Refinery Model, and supply models.

$MacGO\_PPP$ *(r,y,26):*	Regional services gross output expressed in purchasing power parity by year
PMGCM(r,y):	Retail price of motor gasoline for commercial sector energy use by region and year
PDSCM(r,y):	Retail price of distillate fuel for commercial sector energy use by region and year
PRSCM(r,y):	Retail price of residual fuel for commercial sector energy use by region and year
PKSCM(r,y):	Retail price of kerosene for commercial sector energy use by region and year
PLGCM(r,y):	Retail price of liquefied petroleum gas for commercial sector energy use by region and year

PNGCM(r,y): Retail price of natural gas for commercial sector energy use by region and year

PCLCM(r,y): Retail price of coal for commercial sector energy use by region and year

PELCM(r,y): Retail price of electricity for commercial sector energy use by region and year

PHTCM(r,y): Retail price of heat for commercial sector energy use by region and year

AMGSCM(r,y): Carbon price increment to the commercial sector motor gasoline price associated with the carbon allowance price by region and year (dollars per million Btu)

ADSCM(r,y): Carbon price increment to the commercial sector distillate (diesel) fuel price associated with the carbon allowance price by region and year (dollars per million Btu)

ARSCM(r,y): Carbon price increment to the commercial sector distillate (diesel) fuel price associated with the carbon allowance price by region and year (dollars per million Btu)

AKSCM(r,y): Carbon price increment to the commercial sector kerosene price associated with the carbon allowance price by region and year (dollars per million Btu)

ALGCM(r,y): Carbon price increment to the commercial sector liquefied petroleum gas price associated with the carbon allowance price by region and year (dollars per million Btu)

ANGCM(r,y): Carbon price increment to the commercial sector natural gas price associated with the carbon allowance price by region and year (dollars per million Btu)

ACLCM(r,y): Carbon price increment to the commercial sector coal price associated with the carbon allowance price by region and year (dollars per million Btu)

AELCM(r,y): Carbon price increment to the commercial sector electricity price associated with the carbon allowance price by region and year (dollars per million Btu)

AHTCM(r,y): Carbon price increment to the commercial sector heat price associated with the carbon allowance price by region and year (dollars per million Btu)

QHMGCM(r,y): Historical motor gasoline consumption in the commercial sector by region and year

QHDSCM(r,y): Historical distillate fuel consumption in the commercial sector by region and year

QHKSCM(r,y): Historical kerosene consumption in the commercial sector by region and year

Convergence complete

QHRSCM(r,y): Historical residual fuel consumption in the commercial sector by region and year

QHLGCM(r,y): Historical liquefied petroleum gas consumption in the commercial sector by region and year

QHSPCM(r,y): Historical sequestered petroleum fuel consumption in the commercial sector by region and year

QHNGCM(r,y): Historical natural gas consumption in the commercial sector by region and year

QHCLCM(r,y): Historical coal consumption in the commercial sector by region and year

QHELCM(r,y): Historical electricity consumption in the commercial sector by region and year

QHHTCM(r,y): Historical heat consumption in the commercial sector by region and year

QHBMCM(r,y): Historical biomass consumption in the commercial sector by region and year

QHSLCM(r,y): Historical solar energy consumption in the commercial sector by region and year

STEOPTCM(r,y): Projections of liquids for the commercial sector based upon EIA's *Short-Term Energy Outlook* by region and year

The following variables are calculated in the subroutine Comm.

Classification: Computed variable.

XPrc(f,r,y): By-fuel regional price adjusted according to carbon price

CQIdx(f,r,y): Commercial sector overall index combining services gross output, price, and trend by fuel, region, and year

GDPIdx(f,r,y): services gross output index by fuel, region, and year

PrcIdx(f,r,y): Price index by fuel, region, and year

EffIdx (f,r,y): Trend term growth index by fuel, region, and year

AdjIdx(f,r,y): Adjustment index to apply a user adjustment term to the consumption curves to effect a trend change (not currently used in the model)

QMGCM(r,y): Consumption of commercial sector motor gasoline by region and year

QDSCM(r,y): Consumption of commercial sector distillate fuel by region and year

QRSCM(r,y): Consumption of commercial sector residual fuel by region and year

QKSCM(r,y): Consumption of commercial sector kerosene by region and year

QLGCM(r,y): Consumption of commercial sector liquefied petroleum gas by region and year

QNGCM(r,y): Consumption of commercial sector natural gas by region and year

QCLCM(r,y): Consumption of commercial sector coal by region and year

QELCM(r,y): Consumption of commercial sector electricity by region and year

QHTCM(r,y): Consumption of commercial sector district heat by region and year

QBMCM(r,y): Consumption of commercial sector biomass by region and year

QSLCM(r,y): Consumption of commercial sector solar energy by region and year

Coefficient sources:

The elasticity and the lag coefficients used in the Commercial Model were largely developed from the behavior of the U.S. National Energy Modeling System (NEMS) Commercial Module and adapted to the

WEPS+ international regions. These elasticities were computed in an Excel spreadsheet through an analysis of the relationship between a previous *Annual Energy Outlook* Reference case, the corresponding High and Low Economic Growth cases, and the corresponding High and Low Oil Price cases. For example, services gross output elasticities were calculated for each year, by sector and fuel, by first examining the difference in energy demand, relative to the difference in GDP, between the Reference case and the high GDP case. This comparison process was repeated using the Reference case and the low Economic Growth (i.e., low GDP) case.

The estimated services gross output elasticities varied across scenarios. In general, the average of the High and Low Economic Growth cases was used in the WEPS+. In some cases, modifications based on analyst judgment were applied to ensure reasonability.

The price elasticities were calculated in essentially the same manner, using the results of NEMS runs for high and low world oil prices. In these runs, prices for the non-petroleum fuels also changed, and the changes were used for sensitivity analysis. When the price elasticity coefficients were used and placed into WEPS+, the level of the services gross output elasticities were increased by a factor of 1.25 for many of the developing or rapidly changing regions, including Mexico/Chile, South Korea, and all of the non-OECD regions.

The Commercial Model coefficients were used in a calibration process to provide a projection for each energy source based on the previous Commercial Model projections for the *IEO*. This was accomplished by calculating a target growth pattern resulting in growth similar to that in previous *IEO* reports, but accounting for subsequent services gross output and price changes. This step is an attempt to capture the extent of future efficiency or usage trends that have been established through accumulated expert judgment and built into previous projections. This final calibration, based on the trends incorporated in previous projections and on expert judgment, provides some consistency with previous projections, but is ultimately validated during the run process with newer and more current information or understanding.

The GDP index incorporates an additional exogenous factor that represents growth in capital formation relative to GDP growth. The data for these additional factors came from the World Bank (http://data.worldbank.org/indicator/all), specifically the indicators, “GDP (current US$)” and “Gross capital formation (% of GDP)”.

For all OECD countries and regions except Mexico/Chile, the additional OECD factor was applied to electricity consumption only, as those countries were assumed to be primarily focused on modernizing energy delivery for electricity. For non-OECD regions and for Mexico/Chile, the additional non-OECD factors were applied to all fuels, based on the assumption that capital formation would be going to delivery systems for all fuels.

The OECD factor is 10.0 and the non-OECD factor is 5.6. The higher OECD factor represents a higher focus on capital formation as a percentage of economic activity.

Coefficients used for IEO2017

(Table 5)**Error! Reference source not found.** provides the coefficients that were used in the projection equations for the *IEO2017*. These are largely determined in the process described above, but in several cases, various coefficients (typically the trend factor) were changed based on analyst judgment.

Table 5. Commercial Model projection equation coefficients

		GDPElas	GDPLag	PrcElas	PrcLag	TrendGR
USA	MG	0.194	0.000	-0.183	0.000	0.0000
USA	DS	-0.011	0.000	-0.183	0.000	0.0000
USA	RS	0.061	0.000	-0.183	0.000	0.0000
USA	KS	0.786	0.000	-0.183	0.000	0.0000
USA	LG	0.118	0.000	-0.183	0.000	0.0000
USA	NG	0.091	0.000	-0.346	0.000	0.0000
USA	CL	-0.004	0.000	-0.100	0.500	0.0000
USA	EL	0.138	0.000	-0.456	0.000	0.0000
USA	HT	0.037	0.865	-0.074	0.305	0.0000
CAN	MG	0.194	0.000	-0.183	0.000	0.0000
CAN	DS	-0.011	0.000	-0.183	0.000	0.0000
CAN	RS	0.061	0.000	-0.183	0.000	0.0000
CAN	KS	0.061	0.000	-0.183	0.000	0.0000
CAN	LG	0.118	0.000	-0.183	0.000	0.0000
CAN	NG	0.091	0.000	-0.346	0.000	0.0000
CAN	CL	-0.004	0.000	-0.100	0.500	0.0000
CAN	EL	1.382	0.000	-0.456	0.000	0.0000
CAN	HT	0.037	0.865	-0.074	0.305	0.0000
MEX	MG	1.954	0.000	-0.183	0.000	0.0000
MEX	DS	-0.115	0.000	-0.183	0.000	0.0000
MEX	RS	0.610	0.000	-0.183	0.000	0.0000
MEX	KS	0.610	0.000	-0.183	0.000	0.0000
MEX	LG	1.186	0.000	-0.183	0.000	0.0000
MEX	NG	0.911	0.000	-0.346	0.000	0.0000
MEX	CL	-0.038	0.000	-0.100	0.500	0.0000
MEX	EL	1.382	0.000	-0.456	0.000	0.0000
MEX	HT	0.046	0.865	-0.074	0.305	0.0000
EUR	MG	0.194	0.000	-0.183	0.000	0.0000
EUR	DS	-0.011	0.000	-0.183	0.000	0.0000
EUR	RS	0.061	0.000	-0.183	0.000	0.0000
EUR	KS	0.061	0.000	-0.183	0.000	0.0000
EUR	LG	0.118	0.000	-0.183	0.000	0.0000
EUR	NG	0.091	0.000	-0.346	0.000	0.0000

Table 5. Commercial Model projection equation coefficients (cont.)

		GDPElas	GDPLag	PrcElas	PrcLag	TrendGR
EUR	CL	-0.004	0.000	-0.100	0.500	0.0000
EUR	EL	1.382	0.000	-0.456	0.000	0.0000
EUR	HT	0.037	0.865	-0.074	0.305	0.0000
JPN	MG	0.194	0.000	-0.183	0.000	0.0000
JPN	DS	-0.011	0.000	-0.183	0.000	0.0000
JPN	RS	0.061	0.000	-0.183	0.000	0.0000
JPN	KS	0.061	0.000	-0.183	0.000	0.0000
JPN	LG	0.118	0.000	-0.183	0.000	0.0000
JPN	NG	0.091	0.000	-0.346	0.000	0.0000
JPN	CL	-0.004	0.000	-0.100	0.500	0.0000
JPN	EL	1.382	0.000	-0.456	0.000	0.0000
JPN	HT	0.037	0.865	-0.074	0.305	0.0000
ANZ	MG	0.194	0.000	-0.183	0.000	0.0000
ANZ	DS	-0.011	0.000	-0.183	0.000	0.0000
ANZ	RS	0.061	0.000	-0.183	0.000	0.0000
ANZ	KS	0.061	0.000	-0.183	0.000	0.0000
ANZ	LG	0.118	0.000	-0.183	0.000	0.0000
ANZ	NG	0.091	0.000	-0.346	0.000	0.0000
ANZ	CL	-0.004	0.000	-0.100	0.500	0.0000
ANZ	EL	1.382	0.000	-0.456	0.000	0.0000
ANZ	HT	0.037	0.865	-0.074	0.305	0.0000
SKO	MG	0.194	0.000	-0.183	0.000	0.0000
SKO	DS	-0.011	0.000	-0.183	0.000	0.0000
SKO	RS	0.061	0.000	-0.183	0.000	0.0000
SKO	KS	0.061	0.000	-0.183	0.000	0.0000
SKO	LG	0.118	0.000	-0.183	0.000	0.0000
SKO	NG	0.091	0.000	-0.346	0.000	0.0000
SKO	CL	-0.004	0.000	-0.100	0.500	0.0000
SKO	EL	1.382	0.000	-0.456	0.000	0.0000
SKO	HT	0.037	0.865	-0.074	0.305	0.0000
RUS	MG	1.082	0.000	-0.183	0.000	0.0000
RUS	DS	-0.064	0.000	-0.183	0.000	0.0000
RUS	RS	0.338	0.000	-0.183	0.000	0.0000
RUS	KS	0.338	0.000	-0.183	0.000	0.0000
RUS	LG	0.657	0.000	-0.183	0.000	0.0000
RUS	NG	0.504	0.000	-0.346	0.000	0.0000
RUS	CL	-0.021	0.000	-0.100	0.500	0.0000

Table 5. Commercial Model projection equation coefficients (cont.)

		GDPElas	GDPLag	PrcElas	PrcLag	TrendGR
RUS	EL	0.765	0.000	-0.456	0.000	0.0000
RUS	HT	0.046	0.865	-0.074	0.305	0.0000
URA	MG	1.082	0.000	-0.183	0.000	0.0000
URA	DS	-0.064	0.000	-0.183	0.000	0.0000
URA	RS	0.338	0.000	-0.183	0.000	0.0000
URA	KS	0.338	0.000	-0.183	0.000	0.0000
URA	LG	0.657	0.000	-0.183	0.000	0.0000
URA	NG	0.504	0.000	-0.346	0.000	0.0000
URA	CL	-0.021	0.000	-0.100	0.500	0.0000
URA	EL	0.765	0.000	-0.456	0.000	0.0000
URA	HT	0.046	0.865	-0.074	0.305	0.0000
CHI	MG	1.082	0.000	-0.183	0.000	0.0000
CHI	DS	-0.064	0.000	-0.183	0.000	0.0000
CHI	RS	0.338	0.000	-0.183	0.000	0.0000
CHI	KS	0.338	0.000	-0.183	0.000	0.0000
CHI	LG	0.657	0.000	-0.183	0.000	0.0000
CHI	NG	0.504	0.000	-0.346	0.000	0.0000
CHI	CL	-0.021	0.000	-0.100	0.500	0.0000
CHI	EL	0.765	0.000	-0.456	0.000	0.0000
CHI	HT	0.046	0.865	-0.074	0.305	0.0000
IND	MG	1.082	0.000	-0.183	0.000	0.0000
IND	DS	-0.064	0.000	-0.183	0.000	0.0000
IND	RS	0.338	0.000	-0.183	0.000	0.0000
IND	KS	0.338	0.000	-0.183	0.000	0.0000
IND	LG	0.657	0.000	-0.183	0.000	0.0000
IND	NG	0.504	0.000	-0.346	0.000	0.0000
IND	CL	0.504	0.000	-0.100	0.500	0.0000
IND	EL	0.765	0.000	-0.456	0.000	0.0000
IND	HT	0.046	0.865	-0.074	0.305	0.0000
OAS	MG	1.082	0.000	-0.183	0.000	0.0000
OAS	DS	-0.064	0.000	-0.183	0.000	0.0000
OAS	RS	0.338	0.000	-0.183	0.000	0.0000
OAS	KS	0.338	0.000	-0.183	0.000	0.0000
OAS	LG	0.657	0.000	-0.183	0.000	0.0000
OAS	NG	0.504	0.000	-0.346	0.000	0.0000
OAS	CL	-0.021	0.000	-0.100	0.500	0.0000
OAS	EL	0.765	0.000	-0.456	0.000	0.0000

Table 5. Commercial Model projection equation coefficients (cont.)

		GDPElas	GDPLag	PrcElas	PrcLag	TrendGR
OAS	HT	0.046	0.865	-0.074	0.305	0.0000
MID	MG	1.082	0.000	-0.183	0.000	0.0000
MID	DS	-0.064	0.000	-0.183	0.000	0.0000
MID	RS	0.338	0.000	-0.183	0.000	0.0000
MID	KS	0.338	0.000	-0.183	0.000	0.0000
MID	LG	0.657	0.000	-0.183	0.000	0.0000
MID	NG	0.504	0.000	-0.346	0.000	0.0000
MID	CL	-0.021	0.000	-0.100	0.500	0.0000
MID	EL	0.765	0.000	-0.456	0.000	0.0000
MID	HT	0.046	0.865	-0.074	0.305	0.0000
AFR	MG	1.082	0.000	-0.183	0.000	0.0000
AFR	DS	-0.064	0.000	-0.183	0.000	0.0000
AFR	RS	0.338	0.000	-0.183	0.000	0.0000
AFR	KS	0.338	0.000	-0.183	0.000	0.0000
AFR	LG	0.657	0.000	-0.183	0.000	0.0000
AFR	NG	0.504	0.000	-0.346	0.000	0.0000
AFR	CL	0.504	0.000	-0.100	0.500	0.0000
AFR	EL	0.765	0.000	-0.456	0.000	0.0000
AFR	HT	0.046	0.865	-0.074	0.305	0.0000
BRZ	MG	1.082	0.000	-0.183	0.000	0.0000
BRZ	DS	-0.064	0.000	-0.183	0.000	0.0000
BRZ	RS	0.338	0.000	-0.183	0.000	0.0000
BRZ	KS	0.338	0.000	-0.183	0.000	0.0000
BRZ	LG	0.657	0.000	-0.183	0.000	0.0000
BRZ	NG	0.504	0.000	-0.346	0.000	0.0000
BRZ	CL	-0.021	0.000	-0.100	0.500	0.0000
BRZ	EL	0.765	0.000	-0.456	0.000	0.0000
BRZ	HT	0.046	0.865	-0.074	0.305	0.0000
CSA	MG	1.082	0.000	-0.183	0.000	0.0000
CSA	DS	-0.064	0.000	-0.183	0.000	0.0000
CSA	RS	0.338	0.000	-0.183	0.000	0.0000
CSA	KS	0.338	0.000	-0.183	0.000	0.0000
CSA	LG	0.657	0.000	-0.183	0.000	0.0000
CSA	NG	0.504	0.000	-0.346	0.000	0.0000
CSA	CL	-0.021	0.000	-0.100	0.500	0.0000
CSA	EL	0.765	0.000	-0.456	0.000	0.0000
CSA	HT	0.046	0.865	-0.074	0.305	0.0000

Appendix C. Key to Abbreviations Used in Table 5

USA:	United States
CAN:	Canada
MEX:	Mexico/Chile
EUR:	OECD Europe
JAN:	Japan
ANZ:	Australia/New Zealand
SKO:	South Korea
RUS:	Russia
URA:	Other non-OECD Europe and Eurasia
CHI:	China
IND:	India
OAS:	Other non-OECD Asia
MID:	Middle East
AFR:	Africa
BRZ:	Brazil
CSA:	Central and South America
MG:	Motor gasoline
DS:	Distillate
KS:	Residual fuel
RS:	Kerosene
LG:	Liquefied petroleum gas
NG:	Natural gas
CL:	Coal
EL:	Electricity
HT:	Heat

Appendix D. 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. C. Dahl, *International Energy Markets: Understanding Pricing, Policies, and Profits* (PennWell Books, March 2004).

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

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

6. Energy Information Administration, *Commercial Sector Demand Module of the National Energy Modeling System: Model Documentation 2010*, DOE/EIA-0066(2016) (Washington, DC, May 25, 2016).

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

8. International Energy Agency, *Energy Prices and Taxes* (Paris, France, quarterly: various issues).

9. International Energy Agency, *Energy Technology Perspectives: Strategies and Scenarios to 2050*, (Paris, France 2008).

10. International Energy Agency, *World Energy Outlook 2015 Edition* (Paris, France, November 2015).

Appendix E. Data Quality

Introduction

The WEPS+ Commercial Model develops projections of world commercial sector energy use by fuel (motor gasoline, distillate fuel, residual fuel, kerosene, liquid petroleum gas, natural gas, coal, electricity, heat, solar, and biomass) for 16 regions of the world. These projections are based on the data elements detailed in Appendix B of this report. In Chapter 4: Model Structure, the documentation details transformations, estimation methodologies, and resulting inputs required to implement the model algorithms. 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

Source of input data

- *STEO* – Short-term liquid fuel consumption data are provided by region from EIA's *Short-Term Energy Outlook.*
- *International Energy Statistics Database* –EIA provides historical data on international energy consumption by fuel type.
- *International Energy Agency* – The subscription site www.iea.org provides historical energy consumption data for the OECD and non-OECD balances, along with statistics by end-use sector, product, and country. These data are benchmarked to the historical aggregate energy consumption data provided in EIA's international statistical data base.
- *NEMS* –The assumptions about price and economic elasticities are drawn largely from assumptions underlying the National Energy Modeling System (NEMS) for the United States. Expert judgment has, in some cases, been used to alter NEMS assumptions based on additional information about specific international regions in the WEPS+ system.

Data 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. commercial sector fuel consumption, retail prices, and elasticities, based on previous values, responses, and regional and technical knowledge
- Consistency checks
- Technical edits to detect and correct errors and extreme variability