Independent Statistics & Analysis
U.S. Energy Information Administration

World Energy Projection System Plus: Refinery Module

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1. Introduction

Purpose of this report

This report documents the objectives, analytical approach, and development of the World Energy Projection System Plus (WEPS+) Refinery Model. It catalogues and describes the model assumptions; computational methodology; parameter estimation techniques; and model source code that are used to generate projections in the reference and side cases, as well as other scenarios.

The 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 model enhancements, data updates, and parameter refinements as future projects.

Model summary

The WEPS+ Refinery Model is a calculation tool. It uses the projected light, low sulfur crude oil price (a proxy for West Texas Intermediate—WTI—crude) and other input information to model global refined product markets. The WEPS+ Refinery Model computes wholesale and retail refined product pricing in key global refining centers and the 16 International Energy Outlook 2016 (IEO2016) regions (referred to as demand regions in this document).

Model archival citation

This documentation refers to the WEPS+ Refinery Model.

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Organization of this report

Chapter 2 of this report, "Model Purpose," identifies the analytical issues of the WEPS+ Refinery Model, and addresses the general types of activities and relationships it embodies, its primary inputs and outputs, and its interactions with other WEPS+ modules. Chapter 3 describes in greater detail the rationale behind the model design, the modeling approach, and the assumptions used in the model development process, citing theoretical or empirical evidence to support those choices. Chapter 4 details the model structure, model flows, and key computations.

The Appendices to this report provide supporting documentation for the input data and parameter files. Appendix A lists and defines the input data used to generate parameter estimates and endogenous projections, along with relevant outputs. Appendix B contains a mathematical description of the computational algorithms, including the complete set of model equations and variable transformations. Appendix C is a bibliography of reference materials used in the development process. Appendix D provides the model abstract. Appendix E discusses data quality and estimation methods.

2. Model Purpose

Model objectives

Understanding the interactive effects of changes in U.S. and world energy markets has always been a key EIA focus. The Refinery Model was incorporated into WEPS+ in order to enhance the capabilities of WEPS+ to address the interaction of the global and U.S. oil markets. The main objective of the Refinery Model is to further enhance the EIA's long term price projection capabilities. The model is divided into two parts. Part 1 is a simple aggregation of liquids demands projections from the WEPS+ demand and transformation models. Part 2 is used to calculate refined product prices based on crude oil prices provided by the Petroleum Model.

Components of the WEPS+ Refinery Model accomplish the following:

- Refinery Model 1: Calculation of world crude demand delivered to refineries in order to meet the aggregated product demand in the transportation, industrial, residential, commercial, electric power, and district heat sectors. The computed world crude demands are used by the Petroleum Model.
- Refinery Model 2: Calculation of reasonable, long-term equilibrium-type refined product pricing for the three primary global refining centers: the U.S. Gulf Coast (USGC), Northwest Europe (N.W.E.), and Singapore.
- The Refinery Model uses the projected WTI price at Cushing, Oklahoma as the basis for marker crude oil prices in the USGC, Brent projected crude prices in N.W.E., and Dubai projected crude prices in Singapore.
  - The model also uses projected light to heavy product differentials and the expected marginal refining configuration in each of the three refining centers as bases for the respective refined product pricing calculations.
  - Refined product pricing guidelines for the three global refining centers have also been established to ensure that relative product pricing among the three centers is in agreement with projected global trade patterns.
- Refinery Model 2: Calculation of refined product pricing for the 16 IEO2016 regions.
- The Refinery Model uses a set of global pricing guidelines which have been established to relate pricing in the three global refining centers to pricing in the demand regions.
- The set of global pricing guidelines is based on the projected transportation linkages between the three global refining centers and each of the demand regions.
- The transportation costs used for these linkages are reasonable representations of the relative shipping costs between the refining centers and the demand regions.
- Refinery Model 2: Calculation of five crude type prices using the Alternative Crude Valuation method, which is based on the concept of indifference or parity pricing.
- In a perfect market, the price differential between two crude types should be very close to the difference between their netbacks at the refinery that sets the price (marginal refinery).
- In a Global Refining Center, refiners can select from a variety of crudes to fill out their marginal refining capacity.

- Refiners will typically pay more for light sweet crudes vs. heavy sour crudes since the light sweet crudes yield a more highly valued product slate with less hydroprocessing than do heavy sour crudes.

Model inputs and outputs

Because Refinery Model 1 is a simple aggregation of output from other WEPS+ components, the remainder of this documentation focuses on the computations performed in Refinery Model 2 and will refer to it as "Refinery Model."

Inputs

The primary inputs to the WEPS+ Refinery Model are as follows:

- For the calculation of refined product pricing for the three global refining centers, inputs include the projected WTI price; the corresponding marker crude prices in the three global centers; the marker crude product yields in the marginal refining configuration for the three centers; the heavy fuel oil to crude oil discount, which sets the light to heavy refined product differential environment; expected variable and fixed refining operating costs; a capital recovery cost factor; light product pricing deltas to a primary light product (motor gasoline); and the liquefied-petroleum-gas (LPG)-to-crude-oil discount.

- For the calculation of wholesale refined product pricing in the demand regions, inputs include the transportation cost differentials from the three global refining centers to the 16 regions.

- For the calculation of the retail refined product pricing in the demand regions, inputs include the multipliers that are used to compute retail product prices by sector based on the wholesale product prices.

The major inputs are summarized in Table 1 with additional detail in Appendix A.

Table 1. Refinery model inputs

Model Inputs	Source
To Determine Long Term, Equilibrium Pricing in the Three Global Refining Centers	
Expected WTI Market Crude price	Exogenous values from WEPS+
Expected Corresponding Marker Crude prices in the three Global Refining Centers	Determined in Refinery Model via adjustment constants derived from linear regressions.
Marker Crude yields in the appropriate Marginal Refining Configuration	Constants provided to the Refinery Model Source: Refinery2.xml
Expected Heavy Fuel Oil to Marker Crude discount for the three Global Refining Centers	Constants provided to the Refinery Model Source: Refinery2.xml
Expected LPG to Marker Crude discount for the three Global Refining Centers	Constants provided to the Refinery Model Source: Refinery2.xml
Expected Variable and Fixed Operating Costs and Capital Recovery Factor for the three Global Refining Centers	Constants provided to the Refinery Model Source: Refinery2.xml

Table 1. Refinery model inputs (cont.)

Model Inputs	Source
Light Product Pricing Delta to the Primary Light Product	Constants provided to the Refinery Model Source: Refinery2.xml
Heat content for Refined Petroleum Products	Constants provided to the Refinery Model Source: Refinery2.xml
Multipliers, by region and sector, used to compute retail prices for Refined Petroleum Products	Constants provided to the Refinery Model Source: Refinery2.xml
To Determine Long Term, Equilibrium Pricing in the demand Regions	
Transportation Cost Differentials from three Global Refining Centers to the 16 IEO Regions and between Regions	Constants provided to the Refinery Model Source: Refinery2.xml
To Determine Long Term, Equilibrium Pricing for alternative crudes in the US Gulf Coast region	
Sulfur content for five crude types considered (%)	Constants provided to the Refinery Model Source: Refinery2.xml
Liquefied Gases yields for five crude types considered (%)	Constants provided to the Refinery Model Source: Refinery2.xml
Motor Gasoline/Naphta yields for five crude types considered (%)	Constants provided to the Refinery Model Source: Refinery2.xml
Distillate yields for five crude types considered (%)	Constants provided to the Refinery Model Source: Refinery2.xml
Residual yields for five crude types considered (%)	Constants provided to the Refinery Model Source: Refinery2.xml
Incremental High Sulfur Fuel Oil discount for five crude types considered ($/% sulfur)	Constants provided to the Refinery Model Source: Refinery2.xml
Incremental sulfur Marginal Operational Cost for five crude types considered ($/% sulfur)	Constants provided to the Refinery Model Source: Refinery2.xml
Fixed Operational Cost for five crude types considered ($/BBL)	Constants provided to the Refinery Model Source: Refinery2.xml
Capital Recovery Cost for five crude types considered ($/BBL)	Constants provided to the Refinery Model Source: Refinery2.xml
Transportation Cost to US Gulf Coast Region for five crude types considered ($/BBL)	Constants provided to the Refinery Model Source: Refinery2.xml
High Sulfur Fuel Oil Demand for Medium Sulfur Heavy crude type ($/BBL)	Constants provided to the Refinery Model Source: Refinery2.xml

Outputs

The primary outputs of the WEPS+ Refinery Model are projected long-term, equilibrium-type refined product prices for the three global refining centers and the demand regions. Table 2 summarizes these outputs.

Table 2. WEPS+ Model Outputs

Model Outputs	Destination
Computed Wholesale Refined Product Prices for three Global Refining Centers	Reporting
Computed Wholesale Refined Product Prices for the 16 WEPS+ Regions	Reporting
Computed Retail Refined Product Prices for the 16 WEPS+ Regions	Demand, transformation, and supply models
Computed Prices for five crude types for US Gulf Coast region	Reporting

Relationship of the Refinery Model to the other WEPS+ Models

The Refinery Model uses information from other WEPS+ components (Figure 1). It also provides information to and receives information from other WEPS+ components. The information it uses is primarily the projected WTI crude price. The information it provides includes refined product pricing for the three global refining centers and the demand regions. The Refinery Model focus is on the international oil and refined products markets.

Through the system, the Refinery Model receives projected liquids consumption of fuel by end use, coal-to-liquids production, gas-to-liquids production, and crude oil prices from the demand, transformation, and supply models of WEPS+ (Figure 2). In turn, the Refinery Model provides retail petroleum product liquids prices, through the system, back to the demand, transformation, and supply models.

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

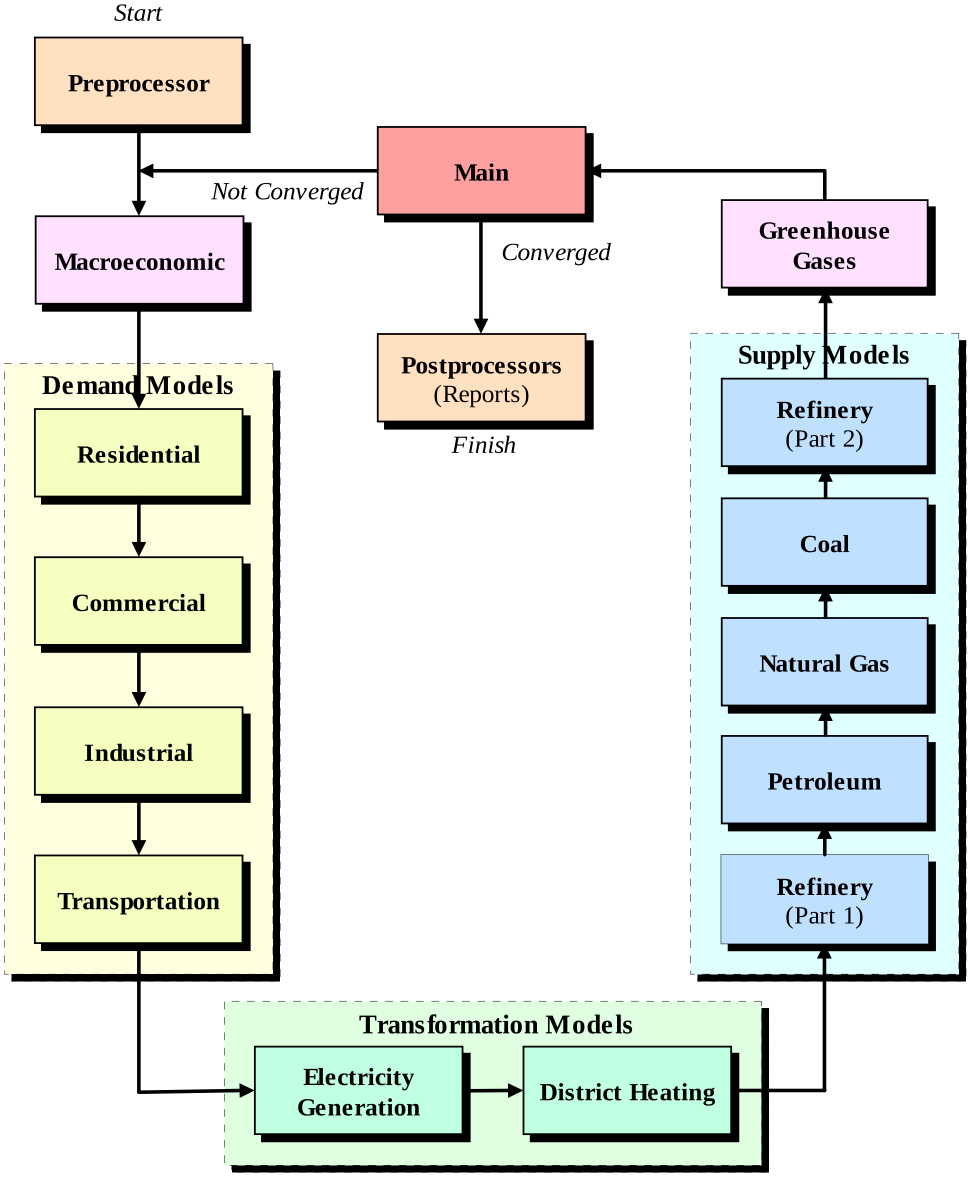
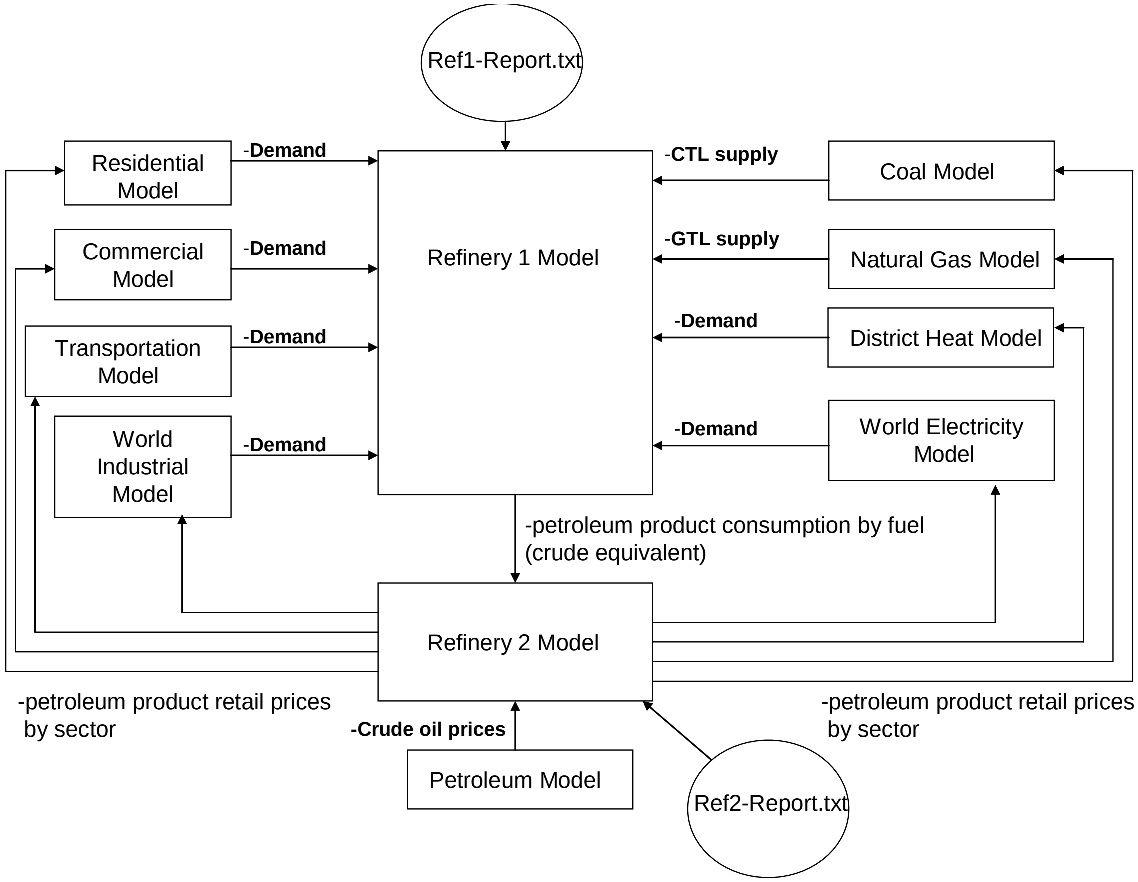


Figure 2. Relationship between the Refinery Model and Other WEPS+ Models



3. Model Rationale

Theoretical approach

The WEPS+ Refinery Model uses projected crude oil prices and other input information to model global refined product markets. The Refinery Model computes long-term, equilibrium refined product pricing in key global refining centers and the demand regions. The underlying logic and approach used in the Refinery Model acts to yield internally consistent price sets for both crude oil and refined products.

Fundamental assumptions

The WEPS+ Refinery Model uses the concept of light product price setting for a given refining center based on three fundamental pricing drivers:

- Marker Crude Oil Price
- Refining Marginal, or Price Setting, Configuration
- Light-to-Heavy Refined Product Price Differential

This light product price setting concept is widely used in the global refining and marketing industry by operating companies, industry consultants, and other market participants. The light product price setting concept uses the corresponding marker crude price as the netback value of petroleum products. These netback value of petroleum products is computed using the marker crude product yields, the heavy fuel oil to crude oil discount, liquefied-petroleum-gas (LPG)-to-crude-oil discount, and light product pricing deltas to a primary light product (motor gasoline).

For the marker crude oil price, the following crude oils are used for the three primary global refining centers:

- WTI - United States Gulf Coast (USGC)
- Brent - Northwest Europe (N.W.E.)
- Dubai - Singapore

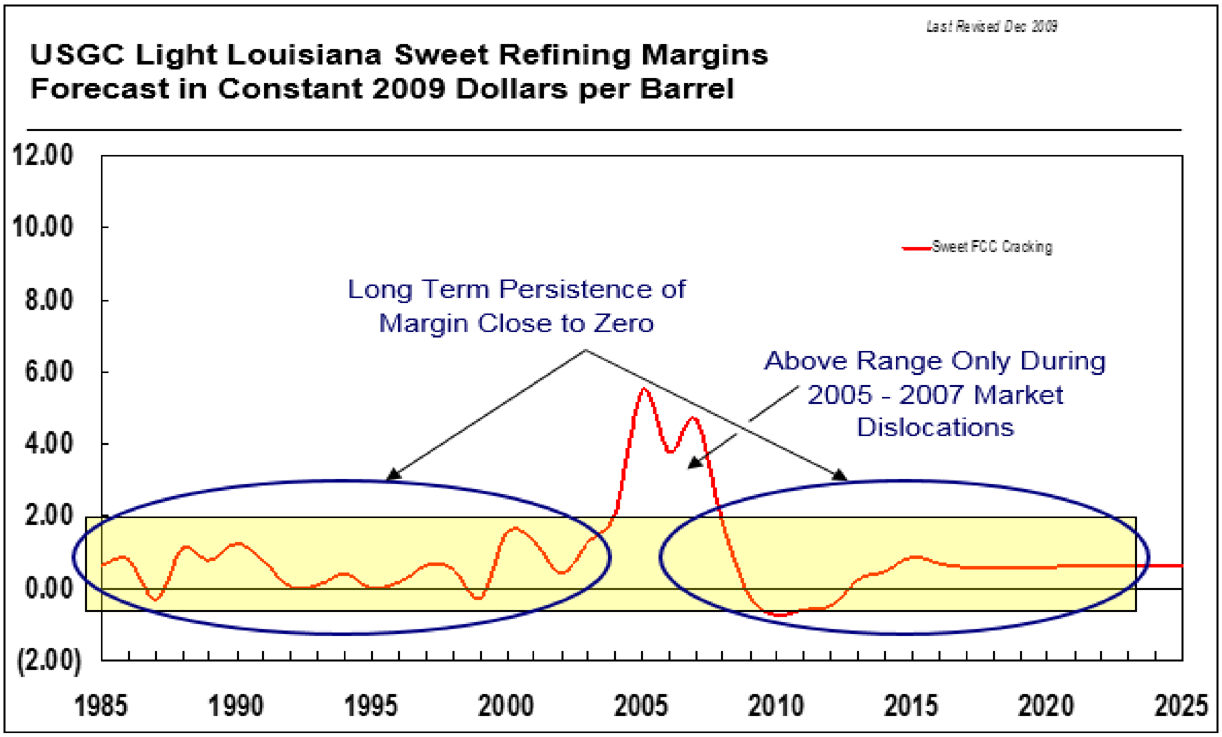
The WTI, Brent and Dubai crude oil prices are brought into the Refinery Model as input values.

For the refinery types, the following configurations are used as the appropriate respective refining price setting modes:

- Catalytic Cracking USGC, N.W.E.
- Hydroskimming Singapore

The refining margin is the difference between the wholesale value of the refined products that the refinery produces and the value of the crude oil from which they were produced. The margin differs by refining configuration. The refining configurations above were determined based on historical data and expected future marginal capacity refining modes. In addition, the marginal refining configuration for a given global refining center generally persists for an extended time period as seen in Figure 3 which shows Louisiana Light Crude (LLS) refining margins as an example. The persistence of low margins for a typical catalytic cracking refinery in the U.S. Gulf Coast supports validity of the marginal refinery approach used in the Refinery Model. These marginal configurations act to set the refined product yield patterns for the respective crude oils in the three refining centers.

Figure 3. Long Term Persistence of Marginal Refining Configuration for a Given Global Refining Center



Source: Purvin and Gertz (GPMO – Dec 09)

For the light-to-heavy refined product differential, the expected long term equilibrium price differential is projected to be relatively narrow. In other words, the differential is expected to be wide enough to support reasonable incremental refining margins, but not so wide as to reflect non-equilibrium differentials that are periodically seen in refining markets and which then promote additional bottoms upgrading refining capacity additions.

For Alternative Crude Prices, the following five crude types are considered:

1. Foreign Light Sulfur Light (FLL)
2. Foreign Medium Sulfur Heavy (FMH)
3. Foreign High Sulfur Light (FHL)
4. Foreign High Sulfur Heavy (FHH)
5. Foreign High Sulfur Very Heavy (FHV)

Key Assumptions

The key assumptions that enable use of the marginal refinery light product price setting model in the Refinery Model are as follows:

- Method adheres to basic, long-term commodity supply/demand concepts and typical refining reality, including:
  - Liquids, normally functioning spot markets for crude oil and refined products, with transportation-based links to other markets
  - Sufficient global refining capacity to meet refined product demand
  - Refiners acting in a rational, profit-maximizing manner, thereby processing crude oil up to the point of essentially zero margin operation
- Method does not attempt to predict pricing under short-term market dislocations that yield extraordinary crude oil and/or refined product imbalances and non-equilibrium pricing
- Even with the presence of short-term market dislocations, the method is still valid for long-term, equilibrium pricing projections because market participants will act to address short-term disturbances
  - A seven-year horizon is currently used to reach equilibrium-type pricing. This assumption is based on the two waves of new refining capacity additions in India, China and Middle East during this period.

4. Model Structure

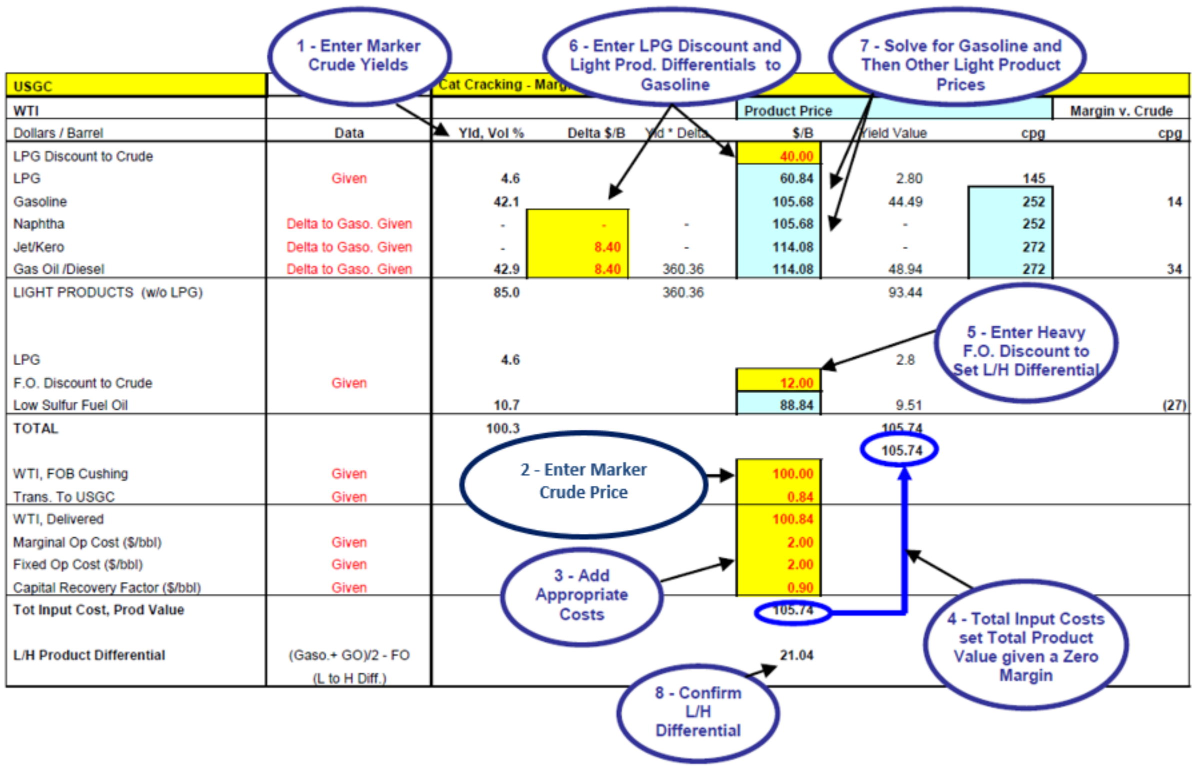
Structural overview

The main purpose of the Refinery Model is to compute long-term, equilibrium refined product pricing in key global refining centers and the demand regions. It uses the projected WTI crude oil price and other input information to model global refined product markets. The underlying logic and approach used in the Refinery Model acts to yield internally consistent price sets for both crude oil and refined products.

Refined product pricing – Three global refining centers

The Refinery Model first computes the long-term, equilibrium refined product pricing in the three Global Refining Centers: the USGC, North West Europe and Singapore. An example of the model's structure and the logic flow used to determine the refined product pricing in one of the Global Refining Centers—the U.S. Gulf Coast—is illustrated in Figure 4.

Figure 4. Example Refining Center Refined Product Determination – USGC



In Step 1, the product yields for the marker crude in the marginal refining configuration are entered in the Refinery Model. For this example, the USGC marker crude is WTI and the marginal refining configuration is catalytic cracking.

- Refinery yield, expressed as a percentage, represents the percent of petroleum products produced from input of WTI crude oil into the specific USGC refinery type.

- A catalytic cracking (cat cracking) refinery configuration is one in which the crude oil and its intermediate products are processed through the following primary refinery processes in order to produce final products:
    - Atmospheric and Vacuum Crude Distillation
    - Reforming
    - Catalytic Cracking
    - Alkylation
    - Hydrotreating
    - Final Product Blending
- In this example, the primary products are
    - Liquefied petroleum gas (LPG)
    - Gasoline and Naphtha
    - Diesel and Kerosene
    - Low Sulfur Heavy Fuel Oil

In Step 2, the marker crude price is entered. In the case of the USGC, this is the price for WTI at Cushing, Oklahoma.

In Step 3, reasonable additional costs, on a barrel of crude oil basis, are added to the marker crude price in order to arrive at the total cost, including

- Transportation cost from Cushing, Oklahoma to the USGC
- Marginal, or Variable, Operating Cost
- Fixed Operating Cost
- Long Term Capital Recovery Factor
    - The capital recovery factor represents the relatively small overall return realized by refining assets across time.
    - The factor does not reflect the return for individual investments in specific upgrading capacity that a given refiner may have made. Rather, the factor reflects the overall modest returns refiners have realized from the entirety of their investments across time.

Once the necessary data has been imported, the Refinery Model sums up the marker crude price and the refining costs to yield the total input cost to process a barrel of crude into refined products in the marginal, or price setting, configuration.

In Step 4, the Refinery Model sets the total input cost equal to the total product value. This can be done because the marginal refining configuration is, in fact, the price setting configuration.

In the price setting configuration, the total product value equals the total input cost, given a zero profit margin above the variable, fixed, and capital return factors included in the input cost.

In Step 5, the heavy fuel oil discount to crude is entered in the Refinery Model. This discount acts to define the light to heavy product differential environment.

In Step 6, the LPG discount to crude oil is entered. The relative product price differentials for Gas Oil/Diesel, Jet/Kero and Naphta to Gasoline are also entered. These are the final inputs to the Refinery Model.

In Step 7, the Refinery Model solves for the Gasoline/Naphtha price and following that, the Diesel/Kerosene price.

In Step 8, as a final confirmation step, the Refinery Model calculates the Light to Heavy Product Differential to ensure that it is in the expected range. The Light to Heavy Product Differential is projected to be relatively narrow in the long term.

The differential is expected to be wide enough to support reasonable incremental refining margins, but not so wide as to reflect non-equilibrium differentials that are periodically seen in refining markets and which then promote additional bottoms upgrading refining capacity additions. Incremental operating margin is the increase or decrease of income from continuing operations before stock-based compensation, interest expense and income-tax expense between two periods, divided by the increase or decrease in revenue over the same period.

The Refinery Model projects the refined product pricing for the other two global refining centers, Singapore and North West Europe, using a methodology similar to that used for the U.S. Gulf Coast.

Refined product pricing – 16 IEO regions

Once the Refinery Model projects the refined product pricing for the USGC, N.W.E. and Singapore, the model then calculates the long-term equilibrium product wholesale pricing for each of the demand regions. The primary inputs are the relative transportation cost differentials from the appropriate refining center(s) to a region (Figure 5).

As seen in the Figure 5 example, the refined product price in China is tied to the price in the Singapore Global Refining Center via the estimated transportation cost from Singapore to China. In addition, Japan is tied to Singapore via the projected trading patterns for that region. As a refined product exporter to China, Japan's refined product pricing is linked to Singapore pricing through its export trade to China. The transportation costs used for the demand regions are reasonable representations of the projected costs, with the primary focus on their relative values to one another across the global refined product trading network.

Figure 5. Example Refined Wholesale Product Price Determination for two of the 16 IEO Regions

The product pricing for each IEO Region is tied to one or more of the three Global Refining Centers via transportation-based pricing links

– Asia Example:

- Product Pricing in China =

  Product Pricing in Singapore +

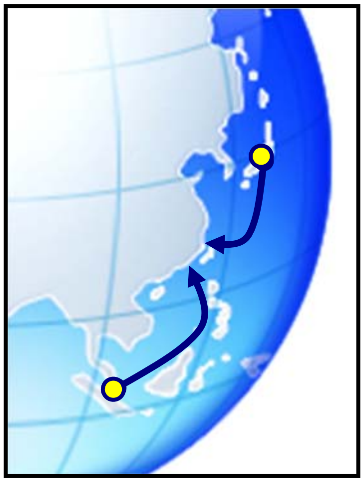
  Transportation from Singapore to China

- Product Pricing in Japan =

  Product Pricing in Singapore +

  Transportation from Singapore to China –

  Transportation from Japan to China



Key Computations and Equations

This section provides detailed solution algorithms arranged in order of execution by the Refinery Model. General forms of the fundamental equations involved in the key computations are presented, followed by discussion of the details considered by the full forms of the equations provided in Appendix B.

Refined product wholesale pricing – Three global refining centers

This section explains the algorithm the Refinery Model uses to compute refined product pricing in the three Global Refining Centers. The crude price basis for these calculations begins with the projected WTI price at Cushing, Oklahoma, in **Petroleum Administration for Defense District 2 (**PADD2). A description of the methodology used to compute the long term, equilibrium refined product prices for each of the three Global Refining Centers follows.

Let TIC be the expected Total Input Cost (in dollars per barrel) for a USGC refinery in a cat cracking marginal configuration.

$$TIC = WTI\ (FOB\ Cushing) + Transportation\ Cost\ to\ the\ USGC\ +$$

$$Marginal\ Operating\ Cost + Fixed\ Operating\ Cost + Capital\ Recovery\ Factor$$

In the price setting (marginal) configuration, the total product value equals the total input cost, given a zero profit margin above the variable, fixed, and capital return factors included in the input cost.

Let TPV be the expected Total Product Value for the USGC refinery. From the relationship noted above,

$$TPV = TIC.$$

Therefore the total product value is known, based on input data.

The total product value equals the sum of refined product yields times their respective prices, as follows:

$$TPV = (LPG\ Yield * LPG\ Price) +$$

$$(Gasoline\ Yield * Gasoline\ Price) + (Naphta\ Yield * Naphta\ Price) +$$

$$(Diesel\ Yield * Diesel\ Price) + (Kerosene\ Yield * Kerosene\ Price) +$$

$$(Low\ Sulfur\ Fuel\ Oil\ (LSFO)\ Yield * LSFO\ Price)$$

Based on input data, the LPG price and Low Sulfur Fuel Oil (LSFO) prices are estimated in terms of the WTI crude cost. The only prices left to be estimated are the gasoline and naphtha prices and the diesel and kerosene prices.

Based on historical information and the projected long term pricing relationship between gasoline and naphtha and diesel and kerosene, a reasonable price premium may be estimate for diesel and kerosene above gasoline and naphtha. Therefore, the diesel and kerosene prices can be expressed in terms of the gasoline price, as follows.

$$Diesel\ Price = Gasoline\ Price + Diesel\ Premium\ above\ Gasoline\ Price$$

$$Kerosene\ Price = Gasoline\ Price + Kerosene\ Premium\ above\ Gasoline\ Price$$

Because all of the variables are known except for the gasoline price (same as naphta price), the equation can be explicitly solved for that single variable. Once the gasoline price is computed, the diesel and kerosene prices are also computed. As a final check, the refined product light to heavy differential (LHPD) is calculated:

$$LHPD = [(Gasoline\ Price + Naphta\ Price + Diesel\ Price + Kerosene\ Price)/4] - LSFO\ Price$$

The overall result is a set of long term, equilibrium crude oil and refined product wholesale prices that are internally consistent and that are based on reasonable assumptions and projections about the projected refined products market in the USGC. The calculations are similar for the North West Europe and Singapore global refining centers.

Refined Product Wholesale and Retail Pricing – 16 WEPS+ regions

After the Refinery Model determines the refined product pricing for the USGC, N.W.E. and Singapore, the model then calculates the long-term equilibrium product pricing for each of the demand regions:

1	- USA	- United States
2	- CAN	- Canada
3	- MXC	- Mexico/Chile
4	- EUR	- OECD Europe
5	- JPN	- Japan
6	- ANZ	- Australia and New Zealand
7	- SKO	- South Korea
8	- RUS	- Russia
9	- URA	- Non-OECD Europe and Eurasia
10	- CHI	- China
11	- IND	- India
12	- OAS	- Other Asia
13	- MID	- Middle East
14	- AFR	- Africa
15	- BRZ	- Brazil
16	- CSA	- Central and South America (excluding Brazil)

The following are examples of the formulas relating regional wholesale pricing to pricing in one of the three global refining centers, in this case the USGC.

$$PP = Petroleum\ Products$$

$$P = Price$$

$$T = Transportation\ Cost$$

1	- USA	$P\ (PP, USA) = P\ (PP, USGC)$
2	- CAN	$P\ (PP, CAN) = P\ (PP, USGC) - T\ (CAN\ to\ USGC)$
3	- MXC	$P\ (PP, MXC) = P\ (PP, USGC) + T\ (USGC\ to\ MXC)$

In the example shown above for Canada, the long term, equilibrium refined product pricing is generally lower than the U.S. pricing (as represented by USGC pricing). This is because Canada is generally a refined product exporter to the United States.

Of course, on a more detailed sub-regional basis, the precise transportation linkages are more complex than those shown above.

For example, Canada is typically a refined product exporter into the U.S. Midwest and U.S. Northeast sub-regions.

However, for the demand regions, the goal was to present the overall refined product trade and resultant pricing patterns in a reasonable and straightforward manner, without adding another layer of sub-regional complexity.

For Mexico/Chile, the long term, equilibrium refined product pricing is generally higher than the U.S. pricing. This is because Mexico is generally a refined product importer from the United States.

It should also be noted that the calculated pricing is on an open market basis and does not include specific pricing adjustments within a given country.

The rest of the formulas relating regional wholesale pricing to pricing in one of the three global refining centers are enumerated below.

- EUR $P\ (PP, EUR) = P\ (PP, N.W.E.)$
- JPN $P\ (PP, JPN) = P\ (PP, SING + T\ (SING\ to\ CHI) - T\ (JPN\ to\ CHI)$
- ANZ $P\ (PP, ANZ) = P\ (PP, SING) - T\ (SING\ to\ ANZ)$
- SKO $P\ (PP, SKO) = P\ (PP, SING) + T\ (SING\ to\ CHI) - T\ (SKO\ to\ CHI)$
- RUS $P\ (PP, RUS) = P\ (PP, SING) - T\ (RUS\ to\ EUR)$
- URA $P\ (PP, URA) = P\ (PP, EUR) - T\ (RUS\ to\ EUR) + (RUS\ to\ URA)$
- CHI $P\ (PP, CHI) = P\ (PP, SING) + T\ (SING\ to\ CHI)$
- IND $P\ (PP, IND) = P\ (PP, SING) - T\ (IND\ to\ SING)$
- OAS $P\ (PP, OAS) = P\ (PP, SING) + T\ (SING\ to\ CHI)$

Middle East

- $P\ (DS, JF, KS, MID) = [(P\ (DS, JF, KS, EUR) - T\ (MID\ TO\ CHI)\ +$ $P\ (DS, JF, KS, SING) - T\ (MID\ to\ SING\ )]/2$
- $P\ (MG, MID) = P\ (MG, SING) + (MID\ to\ SING)$
- $P\ (RS, MID) = P\ (RS, SING) - T\ (MID\ to\ SING)$

Africa

- P (DS,JF,KS,AFR) = P (DS,JF,KS,MID) + T (MID to AFR)
- $P\ (MG, AFR) = P\ (MG, SING) + T\ (SING\ to\ AFR)$
- $P\ P\ (RS, AFR) =\ P\ (RS, USGC) - T\ (AFR\ to\ USGC)$

- BRZ $P\ (PP, BRZ) = P\ (PP, USGC) - T\ (BRZ\ to\ USGC)$
- CSA $P\ (PP, CSA) = AVERAGE\ (P\ (PP, USGC + T\ (USGC\ to\ CSA)\ and\ P\ (PP, USGC) - T\ (CSA\ to\ USGC)$

Wholesale prices for ethanol (ET) are computed relative to motor gasoline (MG) prices. There is a 14% percent premium to MG price for the first 10% of barrel of Ethanol. For the remaining 90% of a barrel of Ethanol, the price is computed based on the heat content relative to MG. Wholesale prices for other biofuels (OB) are computed according to the heat content of diesel (DS).

Retail prices for petroleum products in each of the demand regions, and for each sector, are computed based on the wholesale prices by applying exogenous multipliers computed based on the historical data. The following sectors are considered in the model: industrial, commercial, residential, transportation, electric power, and district heating. The complete list of petroleum products considered in each sector is available in Appendix A.

Alternative crude pricing

This section explains the algorithm the Refinery Model uses to compute prices, for every year in the forecasted period, in the USGC region for the following crude types:

1. Foreign Low Sulfur Light (FLL)
2. Foreign Medium Sulfur Heavy (FMH)
3. Foreign High Sulfur Light (FHL)
4. Foreign High Sulfur Heavy (FHH)
5. Foreign High Sulfur Very Heavy (FHV)

FLL has similar chemical characteristics as WTI therefore its price, by definition, is the price of WTI (FOB Cushing) in a catalytic cracking refinery type in USGC. Following are the formulas used to compute prices for five alternative crudes. All product prices used are for the USGC region.

$$FLL\ Total\ Input\ Cost = WTI\ (FOB\ Cushing) + Transportation\ Cost\ to\ the\ USGC + Marginal\ Operating\ Cost + Fixed\ Operating\ Cost + Capital\ Recovery\ Factor.$$

$$FMH\ Total\ Input\ Cost = (LPG\ Yield * LPG\ Price) + (Gasoline\ Yield * Gasoline\ Price) + (Naphta\ Yield * Naphta\ Price) + (Diesel\ Yield * Diesel\ Price) + (Kerosene\ Yield * Kerosene\ Price) + (High\ Sulfur\ Fuel\ Oil\ Yield * High\ Sulfur\ Fuel\ Oil\ Price),$$

where

$$High\ Sulfur\ Fuel\ Oil\ Price = Low\ Sulfur\ Fuel\ Oil\ Price - High\ Sulfur\ Fuel\ Oil\ Discount\ for\ FMH\ crude\ type.$$

$$FMH\ Price\ (USGC) = FMH\ Total\ Input\ Cost - Capital\ Recovery\ Cost - Fixed\ Op\ Cost - Marginal\ Op\ Cost.$$

$$FMH\ (FOB) = FMH\ price\ (USGC) - Transport\ Cost\ to\ USGC.$$

$$FHL\ Total\ Input\ Cost = (LPG\ Yield * LPG\ Price) + (Gasoline\ Yield * Gasoline\ Price) + (Naphta\ Yield * Naphta\ Price) + (Diesel\ Yield * Diesel\ Price) + (Kerosene\ Yield * Kerosene\ Price) + (High\ Sulfur\ Fuel\ Oil\ Yield * Sulfur\ Fuel\ Oil\ Price),$$

where

$$High\ Sulfur\ Fuel\ Oil\ Price = Low\ Sulfur\ Oil\ Price - High\ Sulfur\ Fuel\ Oil\ Discount\ of\ FHL\ crude\ type,$$

and

$$High\ Sulfur\ Fuel\ Oil\ Discount\ for\ FHL\ crude\ type = (High\ Sulfur\ Fuel\ Oil\ Discount\ for\ FMH\ crude\ type) + (FHL\ Sulfur\ Content - FMH\ \ Sulfur\ Content) * Incremental\ High\ Sulfur\ Fuel\ Oil\ Discount\ for\ FHL\ crude\ type.$$

$$FHL\ price\ (USGC) = FHL\ Total\ Input\ Cost - Capital\ Recovery\ Cost - Fixed\ Op\ Cost - Marginal\ Op\ Cost\ (FHL),$$

where

$$Marginal\ Op\ Cost\ (FHL) = (Marginal\ Op\ Cost\ (FLL)) + (Incremental\ Cost\ for\ Alt. Crude\ Sulfur\ (FHL)) * (FHL\ Sulfur\ Content - FLL\ Sulfur\ Content).$$

$$FHL\ (FOB) = FHL\ Price\ (USGC) - Transport\ Cost\ to\ USGC.$$

Prices for the other two alternative crudes, FHH and FHV, are computed in the same way as they were computed for FHL crude type.

Appendix A. Input Data and Variable Descriptions

The following variables represent data input from the restart file.

Classification: Input variables from demand, transformation, and supply models.

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

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

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

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

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

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

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

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

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

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

QHPCIN(r,y): Historical petroleum coke consumption in the industrial sector by region and year

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

QHOPIN(r,y): Historical other petroleum consumption in the industrial sector by region and year

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

QHDSTR(r,y): Historical distillate (diesel) fuel consumption in the transportation sector by region and year

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

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

QHJFTR(r,y): Historical jet fuel consumption in the transportation sector by region and year

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

QHOPTR(r,y): Historical other petroleum consumption in the transportation sector by region and year

QHETTR(r,y): Historical ethanol (E85) consumption in the transportation sector by region and year

QHOBTR(r,y): Historical biofuels (excluding ethanol) consumption in the transportation sector by region and year

QHDSPG(r,y): Historical utility consumption of distillate

QHRSPG(r,y): Historical utility consumption of residual by region and year

QHDSDH(r,y): Historical distillate fuel consumption in the district heat sector by region and year

QHRSDH(r,y): Historical residual fuel consumption in the district heat sector by region and year

QDSRS(r,y): Consumption of residential distillate fuel by region and year

QKSRS(r,y): Consumption of residential kerosene by region and year

QLGRS(r,y): Consumption of residential liquefied petroleum gas by region and year

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

QMGIN(r,y): Motor gasoline consumption in the industrial sector by region and year

QDSIN(r,y): Distillate fuel consumption in the industrial sector by region and year

QRSIN(r,y): Residual fuel consumption in the industrial sector by region and year

QKSIN(r,y): Kerosene consumption in the industrial sector by region and year

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

QPCIN(r,y): Petroleum coke consumption in the industrial sector by region and year

QSPIN(r,y): Sequestered petroleum fuel consumption in the industrial sector by region and year

QOPIN(r,y): Other petroleum consumption in the industrial sector by region and year

QMGTR(r,y): Motor gasoline consumption in the transportation sector by region and year

QDSTR(r,y): Distillate fuel consumption in the transportation sector by region and year

QRSTR(r,y): Residual fuel consumption in the transportation sector by region and year

QLGTR(r,y): Liquefied petroleum gas consumption in the transportation sector by region and year

QJFTR(r,y): Jet fuel consumption in the transportation sector by region and year

QSPTR(r,y): Sequestered petroleum fuel consumption in the transportation sector by region and year

QOPTR(r,y): Other petroleum consumption in the transportation sector by region and year

QETTR(r,y): Ethanol (E85) consumption in the transportation sector by region and year

QOBTR(r,y): Biofuels (excluding ethanol) consumption in the transportation sector by region and year

QDSPG(r,y): Distillate fuel consumption in the electric power sector by region and year

QRSPG(r,y): Residual fuel consumption in the electric power sector by region and year

QDSDH(r,y): Consumption of distillate fuel used for district heat generation by region and year

QRSDH(r,y): Consumption of residual fuel used for district heat generation by region and year

QGTLProd(r,y): Quantity of gas-to-liquids fuel produced by region and year

QGTLProd(r,y): Quantity of coal-to-liquids fuel produced by region and year

QBTLProd(r,y): Quantity of biofuels-to-liquids fuel produced by region and year

The following variables represent data input from Refinery2.xml file.

Classification: Input variable.

LMYr	Last model forecast year
LHYr	Last model historical year
ICrude_Type(ty)	Type of crude oil (1 = WTI, 2 = Brent, 3 = Dubai)
IPrice_Center(c)	Price center (1 = USGC, 2 = N.W.E., 3 = Singapore)
IRef_Type(rt)	Refining type (1 = catalytic cracking, 2 = hydroskimming)
IDifferential(d)	Type of price differential (1 = narrow, 2 = wide)
IReg(r)	Region indicator (1= United States, 2= Canada, 3 = Mexico/Chile, 4 = OECD Europe, 5 = Japan, 6 = Australia/New Zealand, 7 = South Korea, 8 = Russia, 9 = Other non-OECD Europe and Eurasia, 10 = China, 11 = India, 12 = Other non-OECD Asia, 13 = Middle East, 14 = Africa, 15 = Brazil, and 16 = Other Central and South America)
TrCost(r1,r2)	Transportation costs between each of the demand regions
RCVar(c,x,2001;pFYr)	Real pricing projections for each center (c – potential for 5, but only 3 are currently used); x is: 1-Transportation Cost, 2-Marginal Op. Cost, 3-Fixed Op. Cost, 4-Capital Recovery, 5-LG_Y, 6-MG_Y, 7-NA_Y, 8-JF_KS_Y, 9-DS_Y, 10-RS_Y (Yields), 11-LG_P (Price), 12-RS_D, 13-NA_D, 14-JF_KS_D, 15-DS_D (Discounts)—potential for 20 variables, but currently only 15 are used

rLHeatContent(20)	Heat content for 15 liquids in million Btu per barrel; there is space for 20 different products, but only 12 liquids are currently used (MG, DS, RS, KS, LG, JF, PC, SP, OP, ET OB, NA)
tr(rte)	Transportation costs by route for two miscellaneous U.S. routes: tr(1) = T(USGC to USEC); tr(2) = T(EUR to USEC); where USEC = U.S. East Coast

Classification: Computed variable.

rCenterProductPrice(15,c,y)	Wholesale crude product prices by product, center and year
rCenterProductYieldValue(15,c,y)	Yields wholesale product prices value by product, center and year
rRegionProductPrice(15,r,y)	Wholesale crude product prices by product, region and year
coeffPrSect(r,24)	Coefficients to compute retail prices by sector based on wholesale product prices in each region. First dimension is region, second dimension is as follows: 1-PDSCM, 2-PDSDH, 3-PDSIN, 4-PDSPG, 5-PDSRS, 6-PDSTR, 7-PJFTR, 8-PKSCM, 9-PKSIN, 10-PKSRS, 11-PLGCM, 12-PLGIN, 13-PLGRS, 14-PLGTR, 15-PMGCM, 16-PMGIN, 17-PMGTR, 18-POPIN, 19-POPTR, 20-PRSCM, 21-PRSDH, 22-PRSIN, 23-PRSPG, 24-PRSTR
AltCrudeRCVar(10,20,2001:2050)	Coefficients to compute alternative crude prices. First dimension is crude type as follows: 1-FLL (WTI), 2-FMH, 3-FHL, 4-FHH, 5-FHV. Second dimension is as follows: 1-sulfur content, 2-LG yield, 3-Gas/Naphta yield, 4-DS yield, 5-FO yield, 6-Incremental HSFO discount ($/%sulfur), 7-Incremental sulfur Marg. Op. Cost ($/%sulfur), 8-Incremental TAN Marg. Op. Cost,9- Fixed Op. Cost ($/bbl), 10-Capital Recovery Factor ($/bbl), 11-Transportation to USGC ($/bbl)

****Retail Crude Product Prices by region and sectors are stored in following WEPS+ variables

!Prices for Residential Sector

PDSRS(pReg,2001:pFYr)	Distillate
PKSRS(pReg,2001:pFYr)	Kerosene
PLGRS(pReg,2001:pFYr)	Liquefied petroleum gas

!Prices for Commercial Sector

PMGCM(pReg,2001:pFYr)	Motor gasoline
PDSCM(pReg,2001:pFYr)	Distillate
PRSCM(pReg,2001:pFYr)	Residual
PKSCM(pReg,2001:pFYr)	Kerosene
PLGCM(pReg,2001:pFYr)	Liquefied petroleum gas

!Prices for Industrial Sector

PMGIN(pReg,2001:pFYr)	Motor gasoline
PDSIN(pReg,2001:pFYr)	Distillate
PRSIN(pReg,2001:pFYr)	Residual
PKSIN(pReg,2001:pFYr)	Kerosene
PLGIN(pReg,2001:pFYr)	Liquefied petroleum gas
POPIN(pReg,2001:pFYr)	Other petroleum

!Prices for Transportation Sector

PMGTR(pReg,2001:pFYr)	Motor gasoline
PDSTR(pReg,2001:pFYr)	Distillate
PRSTR(pReg,2001:pFYr)	Residual
PLGTR(pReg,2001:pFYr)	Liquefied petroleum gas
PJFTR(pReg,2001:pFYr)	Jet fuel
POPTR(pReg,2001:pFYr)	Other petroleum

!Prices for Electric Power Sector

PDSPG(pReg,2001:pFYr)	Distillate
PRSPG(pReg,2001:pFYr)	Residual

!Prices for District Heating Sector

PDSDH(pReg,2001:pFYr)	Distillate
PRSDH(pReg,2001:pFYr)	Residual

****Alternative crude prices for 5 crude types are stored in the variable:

rCrudeTypePriceFOB(10,2001:2050) First dimension is the crude type as mentioned above.

Table 3 includes a list of the liquid products considered in WEPS+ Refinery Model together with their identification number and heat rate.

Table 3. Heat Rates

Refined Product	LiquidID	Million BTU per barrel
Motor Gasoline	1	5.15
Distillate	2	5.76
Residual	3	6.28
Kerosene	4	5.67
LPG	5	3.54

Table 3. Heat Rates (cont.)

Refined Product	LiquidID	Million BTU per barrel
Jet Fuel	6	5.67
Petroleum Coke	7	6.29
Sequestered Petroleum	8	5.8
Other Petroleum	9	5.8
Ethanol	10	3.56
Biodiesel	11	5.36
Naphtha	12	5.25

Appendix B. Subroutines Description

This section provides the formulas and associated mathematical descriptions that represent the detailed solution algorithms. The section is arranged by sequential submodule as executed in the WEPS+ Refinery Module.

SUBROUTINE: Refinery2_Main

Description: The Refinery2_Main subroutine is the central subroutine of the Refinery Module. This subroutine is first used to read, from FileCntl.txt file, the values for last historical data year (LHYr) and for the last year in the forecast (LMYr). Following this, by calling ReadInputData subroutine, the input data file Refinery2.xml is opened, all necessary input data is read and stored in the appropriate variables (See Appendix A) and then Refinery2.xml file is closed. Next, a sequence of subroutines is beeping called in the following order: ComputeCenterPrices, ComputeRegionPrices, CheckPriceCenterRules, ComputeRegionSectorPrices. The role of each of these subroutines is illustrated below.

SUBROUTINE: ReadInputData

Description: The ReadInputData subroutine is responsible for reading all required input data from Refinery2.xml file. After Refinery2.xml file is opened, following variables will receive their values: *ICrude_Type, IPrice_Center, IRef_Type, IDifferential, IReg, TrCost, RCVar, rLHeatContent,tr, coeffPrSect.* See Appendix A for a complete description of these variables. At the end of this process the Refinery2.xml input file is closed.

SUBROUTINE: ComputeCenterPrices

Description: The ComputeCenterPrices subroutine computes wholesale crude product prices in each of the three centers: United States Gulf Coast, Northwest Europe and Singapore. These prices are stored in *rCenterProductPrice* variable. The entire process is described in detail in **Error! Reference source not found. section** of this documentation. These prices are logged to the Ref2-Report.txt output report file.

SUBROUTINE: ComputeRegionPrices

Description: The ComputeRegionPrices subroutine computes wholesale crude product prices in each of the 16 world regions considered in WEPS+ Refinery Model. It uses the wholesale crude product prices in each of the three centers computed by the ComputeCenterPrices subroutine, the assumptions made in connection with transportation costs between regions, and expert assumptions about the flows of specific products from one region to another. These prices are stored in *rRegionProductPrice* variable. The entire process is described in detail in **Refined**

Wholesale Product Pricing – 16 *IEO2011* regions section of this documentation. These prices are logged to the Ref2-Report.txt output report file.

SUBROUTINE: CheckPriceCenterRules

Description: The CheckPriceCenterRules subroutine checks for some logical rules to hold during the process of running this Refinery Model. Specifically, 2 rules are enforced.
Rule 1. Because EUR region exports MG to U.S.A. following rule is enforced: P (MG, EUR) <= P (MG, USGC) + T (USGC to USEC) – T(EUR to USEC).
Rule 2. Because USGC region exports DS to EUR following rule is enforced:
P (DS, EUR) >= P (DS, USGC) + T (USGC to EUR). If any of these rules are not observed, a corresponding message is logged to the Ref2-Report.txt output report file.

SUBROUTINE: ComputeRegionSectorPrices

Description: The ComputeRegionSectorPrices subroutine computes retail crude product prices in each of the 16 regions by product, sector and year. These prices are computed based on wholesale crude product prices in each of the 16 regions of WEP+ Refinery Model by applying corresponding multipliers *coeffPrSect* read by ReadInputData subroutine from refinery2.xml input file. Final results are stored in variables described in Appendix A.

SUBROUTINE: ComputeAlternativaCrudePricingsubroutine

Description: The ComputeAlternativaCrudePricingsubroutine computes prices (FOB) for five alternative crudes: FLL, FMH, FHL, FHH, and FHV, based on the concept of indifference or parity pricing. In a perfect market, the price differential between two crude types should be very close to the difference between their netbacks of the marginal refinery, which sets the price.

Appendix C. References

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Appendix D. Model Abstract

Introduction

Model name:

Refinery Model

Model acronym:

RM

Description:

The WEPS+ Refinery Model is a calculation tool. It uses the projected WTI crude oil price and other input information to model global refined product markets. The WEPS+ Refinery Model computes long term, equilibrium refined product pricing in the three global refining centers (the U.S. Gulf Coast, North West Europe and Singapore) and the 16 International Energy Outlook (IEO) regions.

The underlying logic and approach used in the Refinery Model acts to yield internally consistent price sets for both crude oil and refined products.

Purpose of the model:

As a component of the WEPS+, the Refinery Model accomplishes the following:

- Calculation of reasonable, long-term equilibrium-type refined product pricing for the three primary global refining centers: the U.S. Gulf Coast (USGC), Northwest Europe (N.W.E.) and Singapore.
    - The Refinery Model uses the projected WTI price at Cushing, Oklahoma as the basis for marker crude oil prices in the USGC, N.W.E. and Singapore.
    - The RM also uses projected light to heavy product differentials and the expected marginal refining configuration in each of the three refining centers as bases for the respective refined product pricing calculations.
    - In addition, refined product pricing guidelines for the three global refining centers have been established to ensure that relative product pricing among the three centers is in agreement with projected global trade patterns.
- Calculation of refined product pricing for the International Energy Outlook regions.
- The Refinery Model uses a set of global pricing guidelines that have been established to relate pricing in the three global refining centers to pricing in the IEO' S 16 regions.
- The set of global pricing guidelines are based on the projected transportation linkages between the three global refining centers and the 16 regions.
- The transportation costs used for these linkages are reasonable representations of the relative shipping costs between the refining centers and the regions.

Most recent model update:

September 2015.

Part of another model?

WEPS+

Model interfaces:

The Refinery Model uses information from other WEPS+ components; it also provides information to other WEPS+ components. The information it uses is primarily the projected WTI crude price. The information it provides includes refined product pricing for the three global refining centers and the 16 *IEO2016* regions, and alternative crude pricing for the EIA's five import crude types.

The expected WTI price for any year in the projection period is exogenously provided to the Refinery Model through data included in the input file

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Documentation:

U.S. Energy Information Administration, U.S. Department of Energy, *Refinery Model of the World Energy Projection System Plus: Model Documentation 2016 Report*, DOE/EIA-M084(2016) (Washington, D.C., May 2016).

Archive media and installation manual(s):

The Refinery Model, as part of the WEPS+ system, has been archived for the Reference case published in the *International Energy Outlook 2016*, DOE/EIA-0484 (August 2016). The WEPS+ archive contains all of the nonproprietary modules of WEPS+ as used in the Reference case.

Energy system described:

Refined product pricing for the three global refining centers (the U.S. Gulf Coast, North West Europe and Singapore) and the 16 *International Energy Outlook 2016* (*IEO2016*) regions.

Coverage:

- Geographic: 16 *IEO2016* regions
- Time Unit/Frequency: Annual through 2040
- Products: Primary refined product pricing for 16 *IEO2016* regions

Modeling features:

- Model Structure: The WEPS+ Refinery Model is a calculation tool that uses the projected WTI crude oil price and other input information to model global refined product markets. The WEPS+ Refinery Model computes long term, equilibrium refined product pricing in the three global refining centers (the U.S. Gulf Coast, North West Europe and Singapore) and the 16 International Energy Outlook (IEO) regions.
- Modeling Technique: The Refinery Model uses the projected WTI price at Cushing, Oklahoma as the basis for marker crude oil prices in the USGC, N.W.E. and Singapore. It then uses projected light to heavy product price differentials and the expected marginal refining configuration in each of the three refining centers as bases for the respective refined product pricing calculations. A set of global pricing guidelines relate pricing in the three global refining centers to pricing in the IEO'S 16 regions.
- Special Features: The underlying logic and approach used in the Refinery Model acts to yield internally consistent price sets for both crude oil and refined products.

Model inputs:

- For calculation of refined product pricing for the three global refining centers, inputs include the projected WTI price; the corresponding marker crude price in the three centers; the marker crude product yields in the marginal refining configuration for the three centers; the heavy fuel oil to crude oil discount, which sets the light to heavy refined product differential environment; expected variable and fixed refining operating costs; a capital recovery cost factor; light product pricing deltas to a primary light product; and the LPG to crude oil discount.
- For calculation of the refined product pricing in the 16 *IEO2016* regions, inputs include the transportation cost differentials from the three global refining centers to the 16 regions.

Non-DOE input sources:

- IEA Data - Product Yields Used for computing wholesale product prices in each of the three price centers: U.S.G.C., N.W.E., and Singapore.

DOE input sources:

NEMS: crude types

Input file Refinery2.xml: all input data necessary to run the WEPS+ Refinery Module.

Computing environment:

Hardware Used: PC
Operating System: Windows
Language/Software Used: Fortran
Memory Requirement: 4,000K
Storage Requirement: 126.5 Megabytes
Estimated Run Time: 32 seconds
Special Features: None

Independent expert reviews conducted:

None

Status of Evaluation Efforts by Sponsor:

None

Appendix E. Data Quality

Introduction

The WEPS+ Refinery Model uses the projected WTI crude oil price and other input information to model global refined product markets. The WEPS+ Refinery Model computes long-term, equilibrium refined product pricing in key global refining centers and the demand regions. The underlying logic and approach used in the Refinery Model acts to yield internally consistent price sets for both crude oil and refined products.

These projections are based upon the data elements as detailed in Appendix A of this report. The input data, parameter estimates, and module variables are described in Appendix A. 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 E. Information regarding the quality of parameter estimates and user inputs is provided where available.

Source and Quality of Input Data

Source of Input Data

- *AEO2015* – Final results from this publication are used to provide the expected WTI crude oil pricing for the projected time horizon. This information, along with the projected refining center marginal configuration and refined product light to heavy product differential forms the basis for the refined product and alternative crude oil pricing projections.

IEA Data - Product Yields Used for computing wholesale product prices in each of the three price centers: U.S.G.C., N.W.E., and Singapore.

Data Quality Verification

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

- World and U.S. crude and petroleum product price checks based on previous values and projections and knowledge of the industry
- Consistency checks
- Technical edits to detect and correct errors, extreme variability