Independent Statistics & Analysis
U.S. Energy Information Administration

Hydrocarbon Gas Liquids Supply and Demand

Short-Term Energy Outlook Model

November 2015

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1. Overview

The U.S. Energy Information Administration's *Short-Term Energy Outlook* (*STEO*) produces monthly projections of energy supply, demand, trade, and prices over a 13-24 month period. Every January, the forecast horizon is extended through December of the following year. The *STEO* model is an integrated system of econometric regression equations and identities that link the various components of the U.S. energy industry together in order to develop consistent forecasts. The regression equations are estimated and the *STEO* model is solved using the Eviews 8 econometric software package from IHS Global Inc. Diagnostics for the regression equations are given in Appendix C.[1] The model consists of various modules specific to each form of energy resource. All modules provide projections for the United States, and some modules provide more detailed forecasts for different regions of the country.

The hydrocarbon gas liquids (HGL) module of the *Short-Term Energy Outlook* (*STEO*) model provides supply, demand, and inventory forecasts for four types of HGL:

1. ethane – including ethylene
2. butanes – including normal butane and isobutane and their olefins, butylene and isobutylene
3. propane – including refinery grade propylene
4. natural gasoline - equivalent to pentanes plus

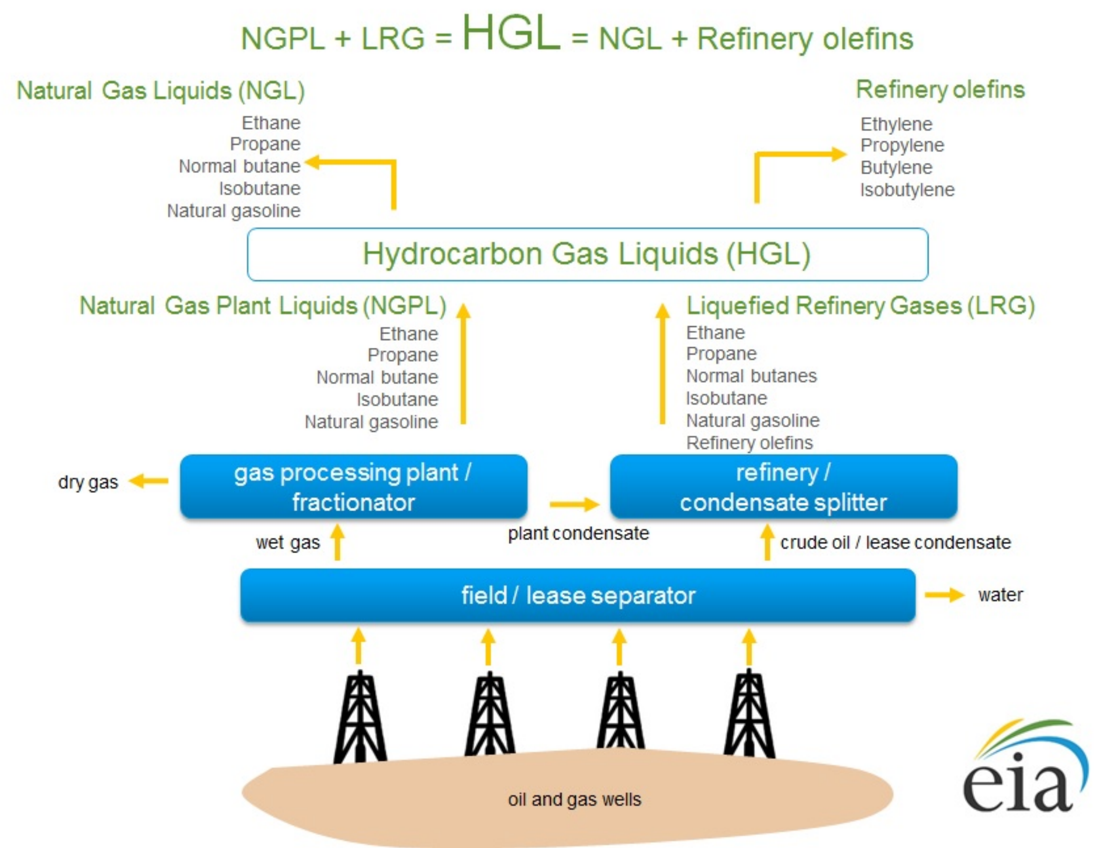
HGL are produced by natural gas processing plants, fractionation facilities, refineries, and condensate splitters (Figure 1). The HGL model provides forecasts of natural gas plant production, refinery production, net imports (exports), refinery inputs, stock build (draw), and consumption (product supplied) for each type of HGL.

HGL produced at natural gas plants and fractionators increased by about 65% between 2008 and 2014, because it is a co-product of rapidly expanding shale gas production (Figure 2). In recent years, relatively low natural gas prices and high crude oil prices have encouraged shale gas developers to concentrate on wetter gas plays, which have a higher concentration of HGL.

From a demand-side perspective, HGL is both fuel and feedstock in various markets (petrochemicals, residential heating/cooking, agriculture, and motor fuel blending). Ethane (and its olefin ethylene) and propane (and its olefin propylene) are primarily consumed in petrochemical facilities such as ethylene crackers. Natural gasoline and normal butanes are primarily consumed by the transportation sector as a denaturant for ethanol and blendstock for gasoline. Learn more about the HGL market in *Hydrocarbon Gas Liquids: Recent Market Trends and Issues*.

[1] Because of autocorrelation in the time series data used in the regression analyses, some of the p-values given in Appendix C may be understated. Prior information about energy market dynamic, however, indicates that the explanatory variables that have been retained in the models are important drivers of the corresponding dependent variables.

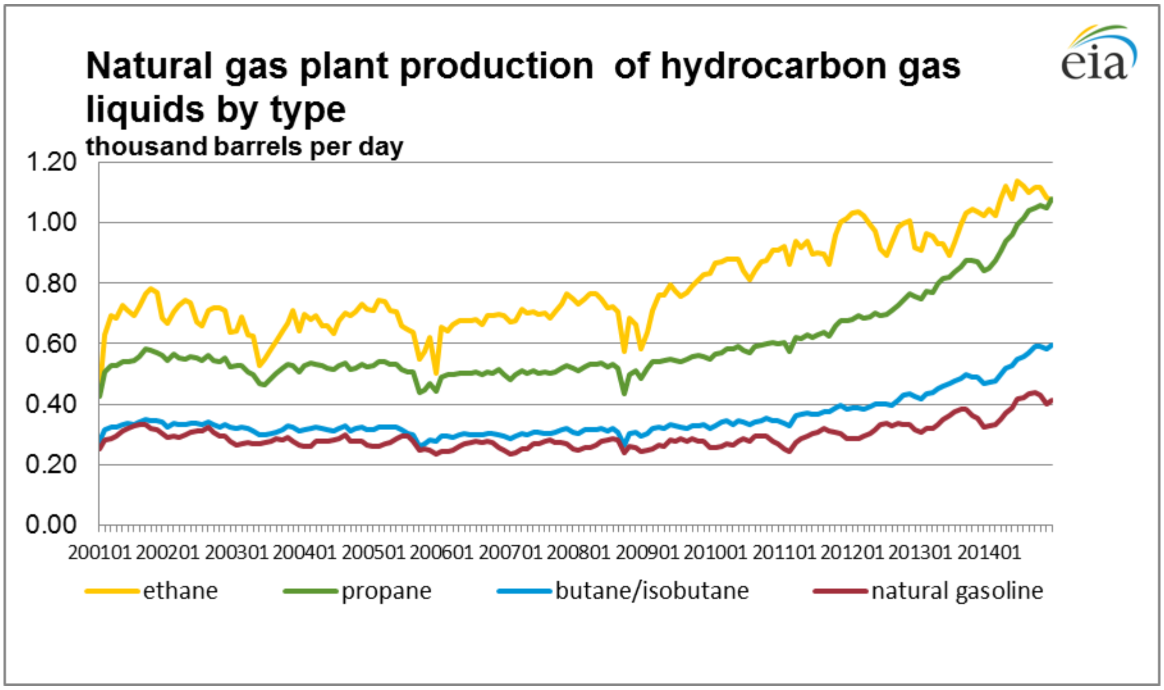
Figure 1. Hydrocarbon gas liquids (HGL) taxonomy, simplified



The HGL module, which is documented in this report, contains 44 equations, of which 21 are estimated regression equations. Some input variables to the HGL module are exogenous, coming from other modules in the *STEO* model (e.g., crude oil and natural gas prices) or forecasts produced by other organizations (e.g., weather forecasts from the National Oceanic and Atmospheric Administration).

Ongoing structural changes in the HGL market present a challenge for accurately forecasting with regression equations (see Forecast Evaluations section). However, the model is closely monitored by analysts who can utilize add factors to follow changing trends that would likely be missed by a typical model relying on historical data.

Figure 2. Hydrocarbon gas liquids production accelerated after 2008



Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*

2. Data Sources

The sources for monthly U.S. refinery inputs and outputs are

- EIA *Weekly Petroleum Status Report* (WPSR) for estimated monthly-from-weekly volumes for the 2 most recent months
- EIA *Petroleum Supply Monthly* (PSM) for preliminary monthly data;
- EIA *Petroleum Supply Annual* (PSA) for revised final monthly data

The *STEO* model uses macroeconomic variables such as population, gross domestic product (GDP), income, employment, and industrial production as explanatory variables in the generation of the forecast. The macroeconomic forecasts are generated by models developed by IHS/Global Insight Inc. (GI). GI updates its national macroeconomic forecasts monthly using its model of the U.S. economy. EIA re-runs the GI model to produce macroeconomic forecasts that are consistent with the *STEO* energy price forecasts.

The number of households that use propane as their primary space heating fuel comes from the Census Bureau's annual American Community Survey. Forecasts are developed based on simple linear trends of the number of households using natural gas in each Census region as a share of all households in that region times the forecast of total households in that region from the GI macroeconomic model.

Heating degree day history and projections are obtained from the National Oceanic and Atmospheric Administration (NOAA). NOAA also publishes forecasts of population-weighted regional heating degree days up to 14 months out. Where the *STEO* forecast horizon goes beyond the NOAA forecast period, “normal” heating degree days may be used. EIA derives U.S. population-weighted degree days using current-year rather than base-year (typically the most recent decennial census) populations to weight State degree days to capture the effect of population migration on space cooling and heating demand (see *Short-Term Energy Outlook Supplement: Change in STEO Regional and U.S. Degree Day Calculations*).

3. Variable Naming Convention

Table 1 shows the variable names for each HGL forecast element. Together the supply and demand elements for each of these HGL series comprise the Supply and Disposition for the Natural Gas Plant Liquids and Liquefied Refinery Gases section of the *Petroleum Supply Monthly*.

Table 1. Hydrocarbon gas liquids (HGL) variable names

Product	Natural gas plant production	Refinery production	Net imports (exports)	Consumption (product supplied)	Refinery inputs	Stock build (draw)	Stock levels
Ethane/ethylene	etfppus	etropus	etnipus	ettcpus	na	etpsbld	etpspus
Propane/propylene	prfppus	prropus	prnipus	prtcpus	na		prpspus
						prpsp1bld	prpsp1
						prpsp2bld	prpsp2
						prpsp3bld	prpsp3
						prpsp4bld	prpsp4
						prpsp5bld	prpsp5
Normal butane/butylene	c4fppus	c4ropus	c4nipus	c4tcpus	c4ripus	c4psbld	c4pspus
Natural gasoline	ppfpus	ppprpus*	ppnipus	pptcus	pprius	pppsbld	pppspus
Total HGL	nlprpus	na	na	nltcpus	na	na	na

Note: * Ppprpus is natural gasoline used as ethanol denaturant and reported in the Petroleum Supply Monthly as (negative) Renewable Fuels and oxygenate Plant Net Production.

Source: EIA Short-Term Energy Outlook model.

Over 2,000 variables are used in the *STEO* model for estimation, simulation, and report writing. Most of these variables follow a similar naming convention. Table 2 shows an example of this convention using total crude oil refinery inputs:

Table 2. Variable naming convention

Variable name: CORIPUSX

Characters	CO	RI	P	US	X
Positions	1 and 2	3 and 4	5	6 and 7	8 +
Identity	Type of energy: crude oil	Energy activity or end-use sector: refinery inputs	Type of data: physical units	Geographic area of special equation factor: United States	Data treatment: temporary value

Some examples of the identifiers used in this naming convention are:

Type of hydrocarbon gas liquids categories:

C4= butane (normal butane/butylene and isobutane/isobutylene)

ET= ethane (and ethylene)
PP = natural gasoline (pentanes plus)
PR = propane (and refinery grade propylene)
NL = total hydrocarbon gas liquids

Energy activity or end-use sector:
FP = natural gas plant production
HD = heating degree days
HN = heating degree days normal (20-year average, 1991 - 2010)
NI = net imports
PR = production
PS = end-of-month stocks
RI = Refinery input
RO = Refinery output
TC = total consumption

Type of data:
P = data in physical units (e.g., barrels or barrels per day)
X = share or ratio expressed as a fraction
U = price per physical unit, excluding taxes

Geographic identification or special equation factor:
US = United States
P1=PADD 1 (East Coast)
P2=PADD 2 (Midwest)
P3=PADD 3 (Gulf Coast)
P4=PADD 4 (Rocky Mountain)
P5=PADD 5 (West Coast)

Data treatment:
SA = seasonally adjusted series from Census X-11 method
SF = seasonal factors derived from Census X-11 method

Many equations include monthly dummy variables to capture the normal seasonality in the data series. For example, JAN equals 1 for every January in the time series and is equal to 0 in every other month.

Dummy variables for specific months may also be included in regression equations where the observed data may be outliers because of infrequent and unpredictable events such as hurricanes, survey error, or other factors. Generally, dummy variables are introduced when the absolute value of the estimated regression error is more than 2 times the standard error of the regression (the standard error of the regression is a summary measure based on the estimated variance of the residuals). No attempt was made to identify the market or survey factors that may have contributed to the identified outliers.

Dummy variables for specific months are generally designated Dyymm, where yy = the last two digits of the year and mm = the number of the month (from "01" for January to "12" for December). Thus, a monthly dummy variable for March 2002 would be D0203 (i.e., D0203 = 1 if March 2002, = 0 otherwise).

Dummy variables for specific years are designated Dyy, where yy = the last two digits of the year. Thus, a dummy variable for all months of 2002 would be D02 (i.e., D02= 1 if January 2002 through December 2002, 0 otherwise). A dummy variable might also be included in an equation to show a structural shift in the relationship between two time periods. Generally, these type of shifts are modeled using dummy variables designated DxxON, where xx = the last two digits of the year at the beginning of the shift period. For example, D03ON = 1 for January 2003 and all months after that date, and D03ON = 0 for all months prior to 2003.

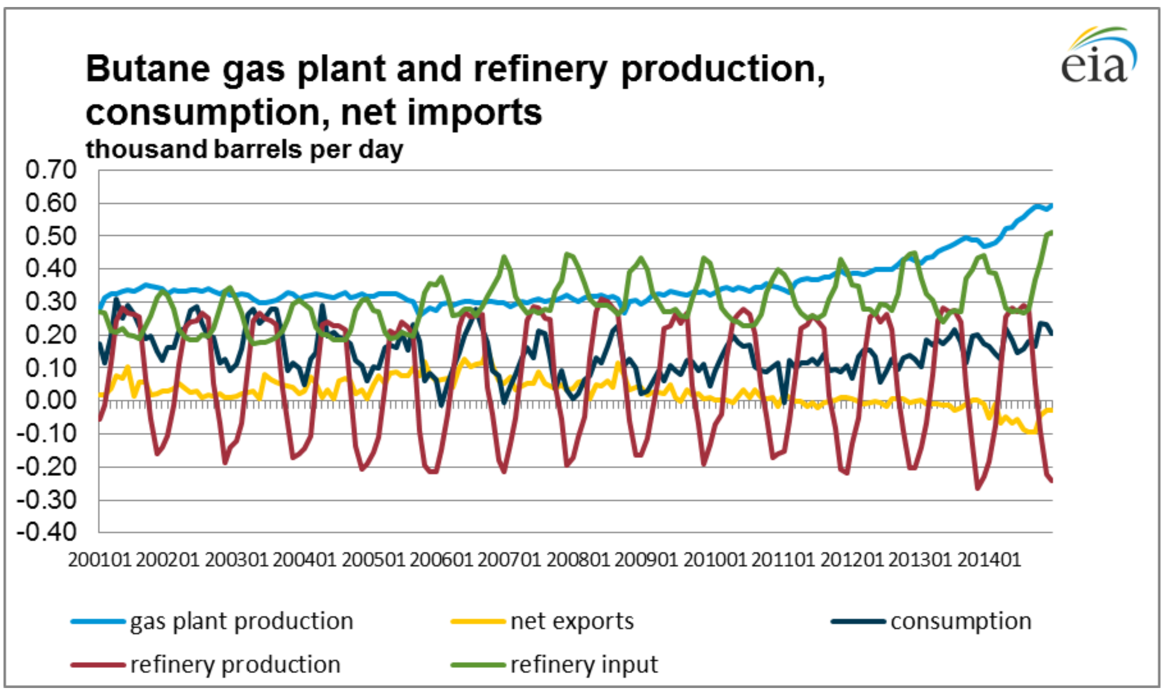
A trend function, @TREND(*base date*) is used in conjunction with DxxON dummy variable to represent a time trend that increases by one for each observation in the time series . The trend equals 0 for each observation up to and including *basedate* and increases by 1 for each month thereafter.

4. Butane (C4) – supply and disposition

Normal butane is primarily used by refiners and blenders as a gasoline blendstock. Isobutane is used primarily as a feedstock in refinery alkylation units to produce alkylate, which is used to boost octane and control volatility in motor gasoline. Refinery inputs and production of butanes are highly seasonal because of the seasonality in gasoline consumption and gasoline vapor pressure specifications. Normal butane increases the vapor pressure of motor gasoline when blended. Consequently, because finished motor gasoline has a higher allowable vapor pressure during the winter months than the summer months, refinery inputs of butane are highest during the winter (Figure 3). Similarly, refinery production of butanes is highest during the summer months when the butane content of gasoline is reduced. In the winter months when more butane is blended into gasoline than is produced as a finished product, net refinery production is negative.

Normal butane and isobutane, as well as their olefins butylene and isobutylene, are modeled as "butane" in the HGL model. The HGL model contains five estimated regression equations and two identities related to the supply and disposition of butane (C4). The estimated regression equations are for natural gas plant production, refinery production, refinery inputs, stock build (draw), and consumption (product supplied). Total U.S. stocks and net exports are calculated as identities, with net exports serving as the balancing item for supply and demand.

Figure 3. Butane supply and disposition, 2001-2014



Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*

A. Natural Gas Plant Production

Natural gas production is the key driver of natural gas plant production of butanes and other HGL (equation 1). However, as the relationship between natural gas and crude oil prices changed, producers went after wetter natural gas, which contains more liquids. The regression equation also uses the difference between the Henry Hub natural gas price and the refiner average acquisition cost of crude oil (in $/million Btu) as a proxy for the relative price of natural gas to natural gas plant liquids. The estimated regression coefficient is negative as expected; as the price of natural gas rises relative to the price of crude oil, natural gas plant production of butane decreases.

The regression equation includes trend variables to capture rapid growth in the market from January 2010 through December 2012. As natural gas production began increasing in 2006, the infrastructure for recovering butanes from wet (marketed) natural gas lagged. The annual average ratio of natural gas plant butane production-to-marketed natural gas fell from an average of 0.59% from 2001 through 2005, to a low of 0.53% in 2008. Over the next few years, the butane-to-marketed natural gas production increased back to an average of 0.59% in 2012. The recovery of butanes then advanced more quickly, averaging 0.66% in 2013 and 0.72% in 2014.

C4FPPUS = a0 + a1 * NGMPPUS (1)
+a2 * (NGHHUUS - (RACPUUS/5.8))
+ a3 * [D10ON * @TREND(2009:12) - D12ON*@TREND(2011:12)]
+ monthly dummy variables

where

C4FPPUS = natural gas plant production of butane and isobutane, million barrels per day
NGMPPUS = natural gas marketed production, billion cubic feet per day
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
RACPUUS = refiner average acquisition cost of crude oil, $/barrel
[D10ON * @TREND (2009:12) – D12ON * @TREND (2011:12)]= a trend that begins with 0 in January 2010 and increases by one for each month through December 2011

B. Refinery Net Inputs and Net Production

Refinery net inputs of butane primarily represent the purchase of butanes produced by natural gas processing plants and are modeled as a function of refinery gasoline production and the refinery yield of gasoline from crude oil inputs (equation 2). As gasoline production rises, refineries and blenders blend as much butane as gasoline vapor pressure limits will allow. The estimated regression coefficient is positive and indicates that a 1,000 b/d increase in refinery gasoline production increases refinery net inputs of butanes by 27 b/d (2.7%).

The estimated coefficient on the gasoline yield is negative but not statistically significant. The gasoline yield from a barrel of crude oil can increase when refineries process lighter crude oil or run their cat crackers at higher severities, which generally increases the amount of butane produced and blended within the refinery thereby reducing refinery inputs of butanes.

C4RIPUS = a0 + a1 * MGROPUS + a2 * MGYLD + monthly dummy variables (2)

where

C4RIPUS = refinery net inputs of butane and isobutane, million barrels per day
NGMPPUS = natural gas marketed production, billion cubic feet per day
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
RACPUUS = refiner average acquisition cost of crude oil, $/barrel(bbl)
MGYLD = refinery yield of gasoline, fraction

Refinery net production of butanes primarily represents the balance of the production and blending of butanes within a refinery. During the winter months net production is negative and during the summer months net production is positive. In 2013, for example, refinery net production ranged from a high of +286,000 b/d in May to a low of -251,000 in November, averaging +57,000 b/d for the year. Refinery net production is modeled as a simple time series model of seasonality (equation 3).

C4ROPUS = a0 + monthly dummy variables (3)

where

C4ROPUS = refinery net production of butanes and butylenes, million barrels per day

C. Consumption (product supplied)

Beyond refinery blending, butanes are also used as petrochemical feedstocks. Butane consumption is modelled as a function of the industrial production index for chemical manufacturing, in order to capture the demand for butane at petrochemical plants (equation 4). The estimated coefficient is positive as expected. The regression equation also includes a dummy variable after 2012 to capture a shift in consumption.

C4TCPUS = a0 + a1 * ZO325IUS+ a2*d13ON + monthly dummy variables (4)

where

C4TCPUS = consumption of butane, isobutane, butylene, and isobutylene, million barrels per day
ZO325IUS = industrial production index for chemical manufacturing
D13ON = a dummy variable beginning in January 2013 to capture a shift in consumption

D. Stock Build and Stock Levels

End-of-month butane inventories are calculated by adding the forecast stock build (draw) to the end-of-month inventory in the previous month (equation 5). Butane inventories are highly seasonal, typically peaking in the August and September before being drawn down to a minimum in February. The regression equation for butanes stock change includes the deviation from normal heating degree days during November-March (equation 6). The estimated regression coefficient is negative as expected (colder-than-normal weather reduces stock builds or increases stock draws) but is not statistically significant. The regression equation also includes the difference between the beginning-of-month stocks from the previous 4-year average.

$$C4PSPUS = C4PSPUS(-1) + C4PSBLD \quad (5)$$

and

$$C4PSBLD = a0 + a1 * ((ZWHDPUS - ZWHNPUS)/ZSAJQUS) * (NOV + DEC + JAN + FEB + MAR) + a2 * (C4PSPUS(-1) - C4PSPUS\_AVE) + \text{monthly dummy variables} \quad (6)$$

where

C4PSUS = end-of-month stocks of butanes and butylenes, million barrels
C4PSBLD = monthly stock change, million barrels
ZSAJQUS = number of days in a month
ZWHDPUS = U.S. heating degree days
ZWHNPUS = U.S. heating degree days normal (20-year average, 1991 - 2010)
C4TCPUS(-1) = prior end-of-month stocks, million barrels
C4PSPUS_AVE= prior 4-year average, [C4PSPUS (-13) + C4PSPUS (-25) + C4PSPUS (-37)+ C4PSPUS (-49)]/4, million barrels

E. Net Imports/Exports

Net imports (exports) of butane are calculated as an identity that balances supply-side elements with demand-side elements (equation 7).

$$C4NIPUS = C4TCPUS + ((C4PSPUS - C4PSPUS(-1)) / ZSAJQUS) + C4RIPUS - C4ROPUS - C4FPPUS \quad (7)$$

where

C4NIPUS = net imports (gross imports- gross exports), million barrels per day
C4TCPUS = consumption, million barrels per day
C4PSUS = end-of-month stocks, million barrels
C4PSPUS (-1) = prior end-of-month stocks, million barrels
ZSAJQUS = number of days in a month
C4RIPUS = refinery input of butanes and butylenes, million barrels per day
C4ROPUS = refinery output of butanes and butylenes, million barrels per day
C4FPPUS = natural gas plant production of butane and isobutene, million barrels per day

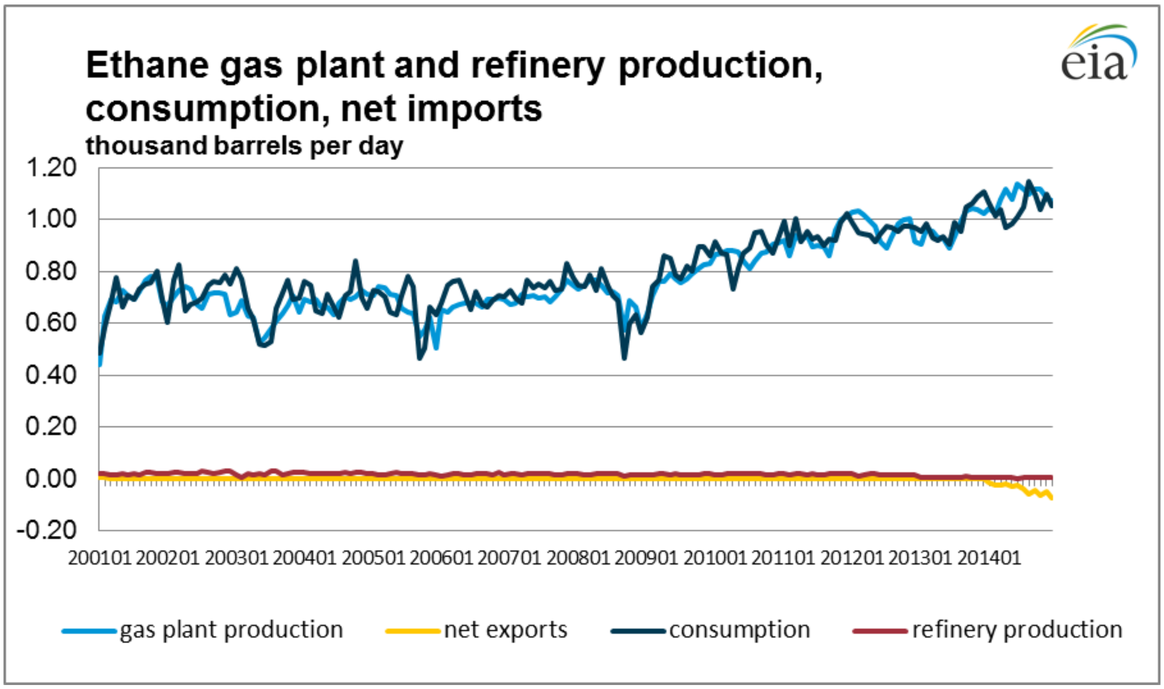
5. Ethane – supply and disposition

The HGL model contains four estimated regression equations and two identities related to the supply and disposition of ethane. The estimated regression equations are for ethane consumption (product supplied), stock build, refinery output, and net exports. Total U.S. stocks and natural gas plant production of ethane are calculated as identities.

Unlike the sets of equations for butane, propane, and natural gasoline, which use net exports as their balancing items, the set of ethane equations uses natural gas plant production to balance supply with consumption. This is because the available supply of ethane that can be extracted from natural gas has been exceeding demand for ethane, which has made it more economic for producers to "reject", or leave some ethane in the natural gas. Ethane production is expected to expand as new infrastructure allows it to be recovered and delivered to markets.

Ethane is principally used as a petrochemical plant feedstock to produce ethylene, a key building block for plastics. The abundance of this relatively inexpensive feedstock has spurred investment in ethylene cracking plants and the infrastructure to bring it to domestic and foreign markets. In December 2013, ethane was exported for the first time in 25 years (Figure 4), through a new pipeline to Canada, which was closely followed by the opening of a second pipeline to Canada.

Figure 4. Ethane supply and disposition, 2001-2014



Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*

A. Natural Gas Plant Production

The total volume of ethane produced at natural gas plants has risen along with shale gas production, increasing from 0.7 million b/d in 2007 to almost 1.1 million b/d in 2014. However, ethane production as a share of total natural gas plant HGL production fell from a high annual average of 41.9% in 2010 to 36.2% in 2014. Faced with an over-supply of ethane, producers can choose to “reject” or leave some ethane in the dry natural gas instead of separating and selling it as a separate product. The abundance of inexpensive ethane has spurred investment in petrochemical facilities that will use ethane as feedstock, as well as export facilities and related infrastructure. The STEO model assumes that ethane production will adjust to changes in domestic and foreign demand. Natural gas plant production of ethane is calculated as consumption and stock build minus refinery production and net imports (equation 8).

ETFPPUS = ETTCPUS + ((ETPSPUS - ETPSPUS(-1)) / ZSAJQUS) - ETROPUS - ETNIPUS (8)

where

ETFPSUS = natural gas plant production of ethane, million barrels per day
ETTCSUS = consumption of ethane, million barrels per day
ETPSPUS = end-of-month stock level, million barrels
ETPSPUS (-1) = prior end-of-month stock level, million barrels
ZSAJQUS = number of days in a month
ETROPUS = refinery production of ethane, million barrels per day
ETNIUS = net imports of ethane, million barrels per day

B. Refinery Production

Refineries produce less than 1% of ethane and ethylene, with most ethane produced at gas processing plants and most ethylene produced at petrochemical plants. Refinery production of ethane and ethylene is expected to follow crude oil refinery inputs. Refinery ethane and ethylene production declined by over 60% in 2013 (from 18,000 b/d in 2012 to 7,000 b/d in 2013) after a new ethylene producing petrochemical plant began operation at the end of 2012. The regression model includes a trend variable beginning in 2013 to represent this shift in production economics.

ETROPUS = a0 + a1 * CORIPUS + a2 *d130N + monthly dummy variables (9)

where

ETROPUS = ethane and ethylene refinery output, million barrels per day
CORIPUS = crude oil refinery input, million barrels per day

C. Consumption (product supplied)

Ethane consumption is modelled as a function of industrial production, the spot price of natural gas relative to the spot price of crude oil, and the deviation of heating degree days from normal, and monthly dummy variables (equation 10). Ethane is used almost exclusively by petrochemical plants that convert it into ethylene, a building block for products including plastics, PVC pipes, and detergents. The industrial production index for chemical manufacturing is included in the regression equation to capture the demand for ethane consumption by ethylene producing petrochemical plants. The estimated coefficient is positive as expected, but not statistically significant.

The expectation of continued low ethane prices and increasing demand for ethylene intermediate product exports led petrochemical companies to invest in additional ethylene capacity, most of which will come online in 2017. Estimates of ethylene cracking capacity are exogenous to the model. The ethane consumption forecast is add factored to account for the estimated contribution of the new capacity to ethane consumption.

Some ethylene plants have the flexibility to switch between using ethane and other feedstocks, like propane and butane depending which is more profitable. In the absence of an ethane price series, the STEO model uses the ratio of the Henry Hub natural gas spot price to the West Texas Intermediate crude spot price as a proxy for the relative economics of ethane prices, which tend to follow natural gas prices, whereas propane and butane prices more closely follow trends in crude oil prices (equation 10). The estimated coefficient is negative as expected, indicating that an increase in the price of natural gas relative to crude oil reduces ethane consumption.

Ethylene plants with the ability to switch feedstocks may use more ethane feedstock during periods of colder-than-normal weather because prices of propane, a heating fuel and competing feedstock, are highest during these times. The estimated coefficient for the deviation of heating degree days from normal is positive as expected.

The regression equation also includes a dummy variable that covers the period September 2013 through December 2014 to reflect a long term outage at the Williams Geismer ethylene plant, which came back online in early 2015.

$$
\begin{aligned}
ETTCPUS = {} & a0 + a1 * ZO325IUS \\
& + a2 * (NGHHUUS/(WTIPUUS/5.8) \\
& + a3 * (ZWHDPUS-ZWHNPUS)/ZSAJQUS \\
& + a4 * (D14 + D1309 + d1310 + d1311 + d1312) \\
& + \text{monthly dummy variables}
\end{aligned} \tag{10}
$$

where

ETTCPUS = ethane consumption, million barrels per day
ZO325IUS= chemical manufacturing production index
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
WTIPUUS= West Texas Intermediate oil price, $/barrel
ZSAJQUS = number of days in a month

ZWHDPUS = U.S. heating degree days
ZWHNPUS = U.S. heating degree days normal (20-year average, 1991 - 2010)

D. Stock Build and Stock Levels

The change in ethane stocks is modelled as the deviation in the end-of-month stocks from the prior month from the previous 4-year average stock level for that month and deviation in heating degree days from normal (equation 11).

A smaller stock build or larger stock draw is expected when the previous month's inventory level was above the four-year average and the opposite is expected when the previous month's inventory level was below average. The coefficient for the deviation from average inventory is negative as expected. Ethane stocks are also expected to build when winter temperatures, as measured in heating degree days, are lower (warmer than normal), and draw when heating degree days are higher (colder than normal because of the substitution affect with propane. The coefficient for the heating degree day deviation variable is negative as expected.

ETPSBLD = a0 + a2 * (ETPSPUS(-1) – ETPSPUS_AVE) (11)
+ a3 * (ZWHDPUS-ZWHNPUS)/ZSAJQUS)
+ monthly dummy variables

where

ETSBLD = monthly stock change, million barrels
ETPSPUS = end-of-month stocks, million barrels
ETPSPUS(-1) = prior end-of-month stocks, million barrels
ETPSPUS_AVE = prior 4-year average, [ETPSPUS (-13) + ETPSPUS (-25) + ETPSPUS (-37) + ETPSPUS (-49)]/4, million barrels
ZSAJQUS = number of days in a month
ZWHDPUS = U.S. heating degree days
ZWHNPUS = U.S. heating degree days normal (20-year average, 1991 - 2010)

Total ethane inventories are calculated as the previous end-of-month level plus the expected stock build (equation 11).

ETPSPUS = ETPSPUS(-1) + ETPSBLD (12)

E. Net Imports/Exports

The abundance of inexpensive ethane in the United States makes the feedstock attractive to foreign petrochemical plants. However, until recently, the lack of infrastructure prevented it from reaching foreign markets. Assuming margins for producing ethylene from ethane remain higher than margins for competing feedstocks, ethane exports are expected to expand as more ethane pipelines and export terminals come online. The STEO model uses the spread between natural gas and the refiners acquisition cost of crude oil as a proxy for cracking margins of ethane, priced near natural gas, to competing feedstocks, priced near the refiner's average acquisition cost of crude oil (equation 13). The coefficient on the price spread is positive as expected but not statistically significant. The STEO model also includes a lagged dependent variable and a trend variable that begins in 2014, when two new pipelines began exporting ethane to Canada. New export capacity from pipelines and terminals that are expected to come online in the future are accommodated by applying add factors to the forecast.

ETNIPUS = a0 + a1 * (NGHHUUS - (RACPUUS/5.8)) (13)
+ a2 * ETNIPUS(-1)
+ a3*[D14ON*@TREND (2013:12)]
+ monthly dummy variables

where

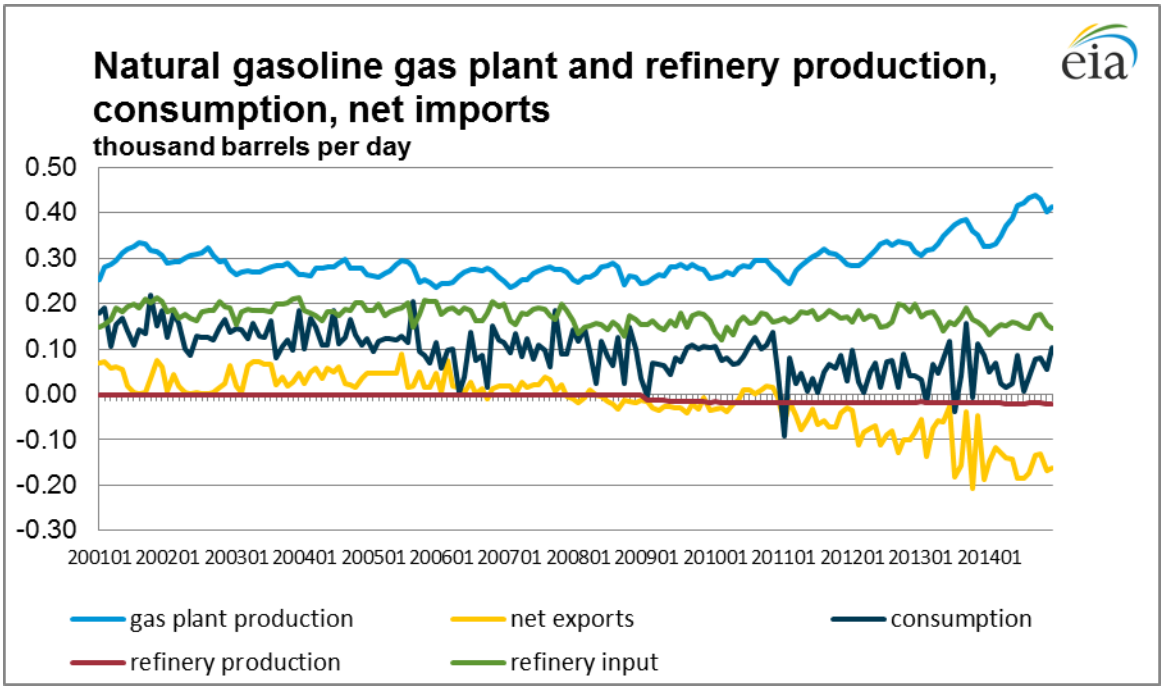
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
RACPUUS = refiner average acquisition cost of crude oil, $/barrel
ETNIPUS (-1) = ethane net imports in the previous month, million barrels per day
D14ON*@TREND (2013:12)= a trend that reflects a change in the market beginning in January 2014 when the U.S. became a net exporters

6. Natural Gasoline (pentanes plus) – supply and disposition

The HGL model contains 4 estimated regression equations and three identities related to the supply and disposition of natural gasoline, which is also known as *pentanes plus* or *C5+*. The estimated regression equations are for natural gasoline product supplied, stock build, refinery input, and natural gas plant production. Total U.S. stocks, net exports, and gasoline blending of natural gasoline are calculated as identities.

While natural gasoline production at natural gas plants and exports have expanded in recent years, refinery inputs and production have remained fairly constant (Figure 5).

Figure 5. Natural gasoline supply and disposition, 2001-2014



Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*

Natural gasoline (pentanes plus) is extracted from natural gas and can be blended directly into gasoline (reported in the *PSM* as "refinery and blender net input") or may be blended into fuel ethanol as a denaturant (reported in the *PSM* as "renewable fuel and oxygenate plant net production"). Natural gasoline blended into ethanol as a denaturant is reported in the *Petroleum Supply Monthly (PSM)* as a negative value for renewable fuel and oxygenate net production. Consequently, the total volume of natural gasoline blended into gasoline is calculated as refinery and blender net input (PPRIPUS) minus renewable fuel and oxygenate plant net production (PPPRPUS). Refineries also blend comparable products directly into gasoline as *blendstock* or marketed as *light naphtha*.

A. Natural Gas Plant Production

Natural gas plant production of natural gasoline is modeled as a function of natural gas marketed production and a trend that captures rapid changes in the market between January 2010 and December 2011 (equation 14). Production of natural gasoline was relatively flat until 2011, when natural gas producers began focusing more on developing wet shale gas plays. The rate of production increased again in 2012 as new infrastructure came online (Figure 5).

PPFPPUS = a0 + a1 * NGMPPUS + a2 *[NGHHUUS-(RACPUUS/5.8)] + (14)
a3 * (D10ON * @TREND (2009:12) - D12ON * @TREND(2011:12)) + monthly dummy variables

where

PPFPPUS = natural gas plant production of natural gasoline (pentanes plus), million barrels per day
NGMPPUS = natural gas marketed production, billion cubic feet per day
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
RACPUUS = refiner average acquisition cost of crude oil, $/barrel
[D10ON * @TREND (2009:12) – D12ON * @TREND (2011:12)]= a trend that begins with 0 in January 2010 and increases by one for each month through December 2011

B. Fuel Ethanol Denaturant

Natural gasoline blended into fuel ethanol is estimated as a fixed fraction (0.02) of ethanol production at renewable and oxygenates plants (equation 15).

PPPRPUS = - 0.02 * EOPRPUS (15)

where

PPPRPUS = natural gasoline (pentanes plus) into gasoline as denaturant, million barrels per day
EOPRPUS = ethanol production, million barrels per day

C. Refinery Inputs

Natural gasoline blended into gasoline has remained fairly steady, averaging about 170,000 barrels per day over the last 30 years. The total volume of natural gasoline blended into gasoline is calculated as refinery and blender net input (PPRIPUS) minus renewable fuel and oxygenate plant net production (PPPRPUS). The volume of natural gasoline used for blending is estimated as a function of the gasoline production and monthly dummy variables and a lagged dependent variable (equation 16).

PPRIPUS - PPPRPUS = a0 + a1 * MGROPUS (16)
+a2* (PPRIPUS(-1)-PPPRPUS(-1)) + monthly dummy variables

where

PPRIPUS = refinery and blender inputs of natural gasoline (pentanes plus), million barrels

per day
MGROPUS = refinery production of motor gasoline, million barrels per day
PPPRPUS = natural gasoline (pentanes plus) used as ethanol denaturant, million barrels per day

D. Consumption (product supplied)

Beyond what is used for gasoline blending and gasoline denaturant, natural gasoline may be marketed in the United States as light naptha. Natural gasoline consumed for this purpose is modeled as a simple lag dependent function (equation 17).

PPTCPUS = a0 +a1* PPTCPUS(-1) + monthly dummy variables (17)

where
PPTCPUS = natural gasoline consumption, million barrels per day
PPTCPUS (-1)= prior month natural gasoline consumption, million barrels per day

E. Stock Build and Stock Levels

The change in natural gasoline stocks is modelled as a function of the deviation between the end-of-month stocks for the prior month and the previous 4-year average stock level for that month (equation 18). The estimated coefficient is negative as expected. A smaller stock build or larger stock draw is expected when the previous month's inventory level was above the four-year average and the opposite is expected when the previous month's inventory level was below average. The model also includes monthly dummy variables to account for seasonal variations.

PPPSBLD = a0 +a1 * (PPPSPUS(-1) – PPPSPUS_AVE) + monthly dummy variables (18)

where
PPPSBLD = monthly stock change, million barrels
PPPSPUS = end-of-month stocks, million barrels
PPPSPUS(-1) = prior end-of-month stocks, million barrels
PPPSPUS_AVE= prior 4-year average, [PPPSPUS (-13) + PPPSPUS (-25)+ PPPSPUS (-37)+ PPPSPUS (-49)]/4, million barrels

Natural gasoline inventories are calculated as the previous end-of-month level plus the expected stock build (equation 19).

PPPSPUS = PPPSPUS(-1) + PPPSBLD (19)

F. Net Imports/Exports

The United States became a net exporter of natural gasoline in 2008. Almost half of the natural gasoline produced is exported to western Canada as diluent for heavy crude oil, enabling its movement in pipelines to the United States. Net imports (exports) are modeled as the balancing item of natural gasoline supply and disposition, and calculated as a function of consumption, stock build, and refinery inputs minus gas plant production and ethanol denaturant (equation 20).

$$PPNIPUS = PPTCPUS + ((PPPSPUS - PPPSPUS(-1)) / ZSAJQUS) + PPRIPUS - PPFRPUS - PPPPPUS \quad (20)$$

where

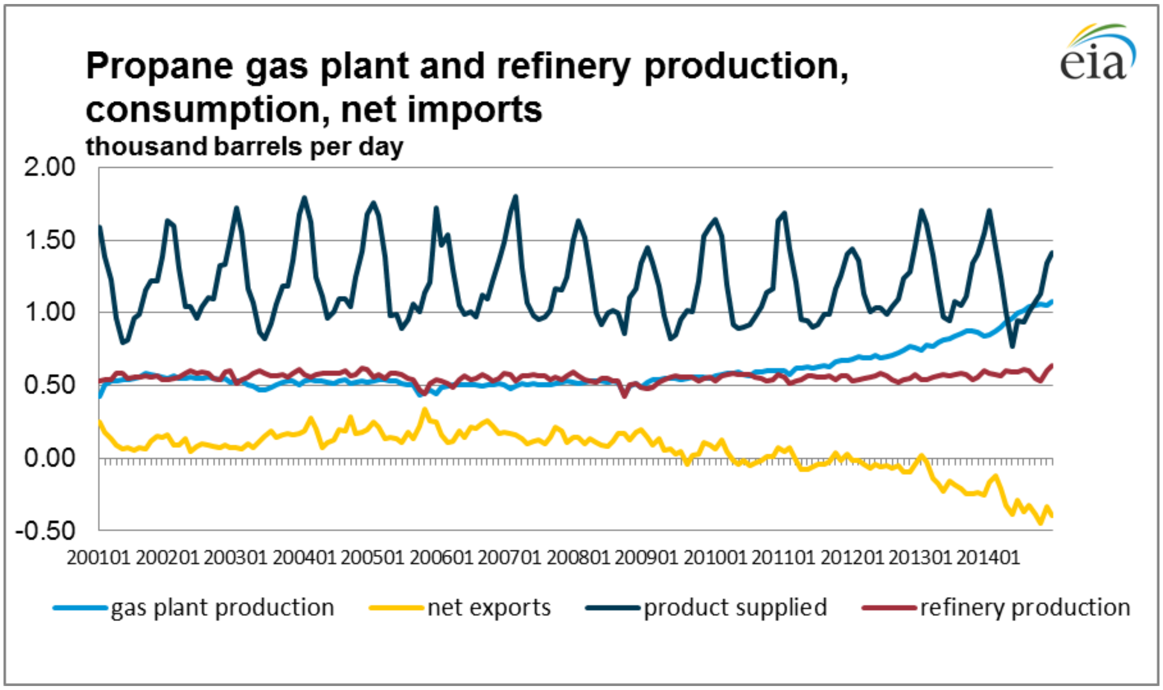
PPTCPUS = natural gasoline consumption, million barrels per day
(PPPSPUS - PPPSPUS(-1)) = monthly change in inventories, million barrels
ZSAJQUS = number of days in a month
PPRIPUS = refinery inputs of natural gasoline (pentanes plus), million barrels
PPFPPUS = natural gas plant production of natural gasoline (pentanes plus), million barrels per day
PPPPPUS = natural gasoline (pentanes plus) used as ethanol denaturant, million barrels per day

7. Propane – supply and disposition

The HGL model contains 4 estimated regression equations and seven identities related to the supply and disposition of propane. The estimated regression equations are for propane consumption (product supplied), refinery production, natural gas plant production, and stock build in each PADD region. Stock levels in each PADD region and the United States, and net imports of propane are calculated as identities.

Propane produced from natural gas has been the fastest-growing component of overall U.S. propane supply, growing from 500,000 bbl/day in 2007 to about 960,000 bbl/day in 2014 (Figure 6). Over the same period, propane (and propylene) produced at refineries has been relatively flat, growing from 560,000 bbl/day in 2007 to about 580,000 bbl/day in 2014.

Figure 6. Propane supply and disposition, 2001-2014



Source: U.S. Energy Information Administration, *Petroleum Supply Monthly*

Propane is consumed in homes and businesses for water heating, cooking, and space heating, especially in regions where natural gas supply is limited or unavailable. Propane consumption has a strong seasonal component because of its use as a space heating fuel in the winter and for drying crops such as corn in the fall.

The petrochemical industry is another important but less seasonal consumer of propane. Petrochemical plants use propane as a feedstock to produce ethylene and propylene. Ethylene manufacturers are sensitive to feedstock prices and may switch from one feedstock to another to reduce costs. Total propane consumption was 125,000 barrels per day (bbl/d) lower on average in 2014, as compared to 2013, mainly because ethylene plants switched away from propane in favor of other feedstocks. Several petrochemical companies plan to open propylene producing (PDH) plants along the Gulf Coast in 2015-16 to take advantage of relatively low propane prices and high global demand for propylene and its derivatives.

Propane prices became more competitive in the export market as production grew more quickly than domestic consumption. The United States switched from being a net importer of propane in 2010 to a net exporter in 2011. Net exports expanded from 14,000 bbl/day in 2011 to 316,000 bbl/day in 2014.

A. Natural Gas Plant Production

Natural gas plant production of propane is modeled as a function of natural gas marketed production and gas plant economics, and trend variables that captures rapid changes in the market between January 2010 and December 2011 (equation 21). The estimated coefficient for natural gas marketed production is positive as expected.

The spread between the Henry Hub spot price of natural gas and the refiners acquisition cost of crude oil is used to model economics at the gas plant. The coefficient is negative as expected; as the price of natural gas rises relative to the price of crude oil, natural gas plant production of propane decreases. Propane production grew more rapidly in 2010 after gas producers became more focused on developing wet shale gas plays and again in 2012 as gas plant processing capacity expanded.

PRFPPUS = a0 + a1*NGMPPUS + a2*(NGHHUUS-(RACPUUS/5.8))
+ a3*(D10ON*@TREND(2009:12)-D12ON*@TREND(2011:12)) (21)

where

PRFPPUS = natural gas plant production of propane, million barrels per day
NGMPPUS = natural gas marketed production, billion cubic feet per day
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
RACPUUS = refiner average acquisition cost of crude oil, $/barrel
[D10ON * @TREND (2009:12) – D12ON * @TREND (2011:12)]= a trend that begins with 0 in January 2010 and increases by one for each month through December 2011

B. Refinery Production

Propane and propylene are the key HGL outputs from U.S. refineries. Although refineries produce various HGL streams, most streams are used internally to produce other higher-value products. Refinery production of propane and propylene depends on a number of factors, including the composition of crude oil and the configuration of refinery process units, which is set to maximize profits from the production of gasoline, diesel, jet fuel, and other high-value products.

Refineries produce most propylene via fluid catalytic cracking, as a byproduct mixed with other compounds, including propane. Propylene is the primary feedstock for alkylation and polymerization, which in turn produce certain blendstocks for motor gasoline blenders.

In response to changing demand, U.S. refineries have shifted their product slate to produce more diesel fuel and less motor gasoline, on a percentage basis. This shift has resulted in less refinery propane production.

In the STEO model, refinery production of propane is a function of inputs of unfinished oils, the gasoline yield as a share of crude oil inputs, and a lagged dependent variable (equation 22). All three coefficients are positive as expected.

PRROPUS = a0 + a1 * UORIPUSX + a2 * (MGYLD*CORIPUS) + a3 * PRROPUS(-1)
+ monthly dummy variables (22)

where

PRROPUS = refinery production of propane and propylene , million barrels per day
UORIPUSX= refinery inputs of unfinished oils, million barrels per day
MGYLD = refinery yield of gasoline, fraction
CORIPUS= refinery inputs of crude oil, million barrels per day
PRROPUS (-1)= prior refinery production of propane and propylene , million barrels per day

C. Consumption (product supplied)

In the United States, propane is mainly used as a heating fuel and petrochemical feedstock. The STEO model calculates propane consumption as a function of the number of propane heated households times a seasonal factor, the spread between Henry Hub natural gas prices and West Texas Intermediate crude oil prices, growth in the chemical industry, the deviation in propane weighted heating degree days from normal, and the difference between the previous months consumption and consumption thirteen months ago (equation 23).

The number of homes using propane for space heating has been gradually declining in the United States. The estimated coefficient for the number of propane consuming homes, which is seasonally adjusted, is positive as expected. A decline in the number of households using propane as their main heating fuel reduces propane consumption. The estimated coefficient on the number of propane heated households is positive as expected.

Propane consumption is also a function of the weather, because colder than normal temperatures result in higher propane consumption for space heating. The coefficient on the propane weighted heating degree day deviation from normal is positive as expected.

Propane is also used by the petrochemical industry for the production of ethylene and propylene. The STEO model includes the industrial production index for chemical manufacturing to capture the growth in demand for propane as a petrochemical feedstock. The estimated coefficient is positive as expected. A shortage for propylene led petrochemical companies to invest in several new propylene producing plants, which are expected to begin operation in the next several years. Estimates of propane dehydrogenation (PDH) capacity are exogenous to the model. Add factors are used to account for the estimated contribution of the new capacity to propane consumption.

When the price of natural gas rises relative to crude oil prices, some ethylene producing petrochemical plants may switch from using propane as a feedstock to using naptha. This is because propane prices are affected by movements in both natural gas and crude oil, while naptha prices are strongly tied to crude oil. In the absence of propane and naptha price series, the STEO model uses the ratio of the Henry Hub natural gas spot price to the West Texas Intermediate crude spot price as a proxy for the relative economics of propane to naptha. The coefficient is negative as expected. As natural gas prices (and propane) increase relative to crude oil, propane consumed at petrochemical plants declines.

The regression equation also includes a coefficient for the difference between the previous month's consumption and consumption 13 months ago. Propane consumption in the current month is positively correlated with this difference.

PRTCPUS = a0 + a1 * QHLP_US * PRTCPUS_SF + a2*(ZWHDP_PRRC-ZWHNP_PRRC)/ZSAJQUS
+ a3*ZO3251IUS +a4 * NGHHUUS/(WTIPUUS/5.8) + a5 *(PRTCPUS(-1)-PRTCPUS(-13))
+ monthly dummy variables (23)

where

PRTCPUS= consumption of propane, million barrels per day
QHLP_US = number of U.S. households heating primarily with propane
PRTCPUS_SF = seasonal factor
ZO3251IUS= basic chemicals industry production index
ZSAJQUS = number of days in a month
ZWHDP_PRRC = U.S. propane-weighted heating degree days
ZWHNP_ PRRC = U.S. propane-weighted heating degree days normal
NGHHUUS = natural gas spot price at Henry Hub, $/million British thermal units (Btu)
WTIPUUS = West Texas Intermediate crude oil price, $/barrel
PRTCPUS(-1)= prior month consumption, million barrels per day
PRTCPUS(-13)= consumption 13 months ago, million barrels per day

D. Stock Build and Stock Levels

Propane stocks build in the summer and are drawn down in the winter to meet heating needs. Stocks are drawn down to a lesser extent in the fall when propane is used to dry crops such as corn.

Propane inventories include refinery propylene (about 6%) and are modeled at the PADD level based on the previous end-of-month stock level and the forecasted stock build (draw) (equation 24). U.S. inventories are calculated as the sum of the regional inventories (equation 25).

PRPSPx = PRPSPx(-1) + PRPSPxBLD (24)

and

PRPSPUS = PRPSP1 + PRPSP2 + PRPSP3 + PRPSP4 +PRPSP5 (25)

where

PRPSPP*x* = total propane and refinery grade propylene end-of-month inventory in PADD *x*, million barrels

PRPSPP*x* (-1) = prior month total propane and refinery grade propylene end-of-month inventory in PADD *x*, million barrels

PRPSP*x*BLD = total propane and refinery grade propylene inventory change (end of current month – end of previous month) in PADD *x* (*x* in {1,…,5}), million barrels

Total propane inventory change by PADD is estimated as a function of weather deviations from normal and the current inventory deviation from the prior 4-year average (equation 26). Heating degree day (HDD) deviations from normal are at the census division level, and PADD-level HDD deviations from normal are estimated by weighting census division HDD by the number of households that use propane as their primary space heating fuel in each census division:

QHLP_P1 * (ZWHD_P1 - ZWHN_P1) = (QHLP_NEC*(ZWHD_NEC-ZWHN_NEC)
+ QHLP_MAC*(ZWHD_MAC-ZWHN_MAC) + QHLP_SAC*(ZWHD_SAC-ZWHN_SAC))/
(QHLP _NEC+ QHLP _MAC+ QHLP _SAC)
QHLP_P2 * (ZWHD_P2 - ZWHN_P2) = (QHLP_ENC*(ZWHD_ENC-ZWHN_ENC)
+ QHLP _WNC*(ZWHD_WNC-ZWHN_WNC)) /(QHLP _ENC+ QHLP _WNC)
QHLP_P3 * (ZWHD_P3 - ZWHN_P3) = (QHLP _ESC*(ZWHD_ESC-ZWHN_ESC)
+ QHLP _WSC*(ZWHD_WSC-ZWHN_WSC)) /(QHLP_ESC+QHLP_WSC)
QHLP_P4 * (ZWHD_P4 - ZWHN_P4) = ZWHD_MTN - ZWHN_MTN
QHLP_P5 * (ZWHD_P5 - ZWHN_P5) = ZWHD_PAC - ZWHN_PAC

where

QHLP_Px= the number of households that use propane as their primary space heating fuel in PADDx

ZWHD_Px = total heating degree days in PADDx

ZWHNPx = normal (20-year average, 1991 - 2010)heating degree days in PADDx

(ZWHD_Px – ZWHNPx) = heating degree day deviations from normal (20-year average, 1991 - 2010) in PADDx

QHLP_xxx = number of households that use propane as their primary space heating fuel in census division xxx

ZWHD_xxx = total heating degree days in census division xxx

ZWHN_xxx = normal (20-year average, 1991 - 2010)heating degree days in census division xxx

(ZWHD_xxx – ZWHN_xxx) = heating degree day deviations from normal (20-year average, 1991 - 2010) in census division xxx

The regression equation for PADD *x* takes the form

$$PRPSPxBLD = a_0 + a_1 * QHLP\_Px * (ZWHD\_Px - ZWHN\_Px) / ZSAJQUS + a_2 * (PRPSPPx(-1) - PRPSPPx\_AVE) + \text{monthly dummy variables}) \quad (26)$$

where

PRPSP*x*BLD = total propane and refinery grade propylene inventory change (end of current month – end of previous month) in PADD *x*, million barrels

ZSAJQUS = number of days in a month

QHLP_Px * (ZWHD_Px - ZWHN_Px)/ZSAJQUS = daily heating degree day deviations from normal weighted by the number of households that use propane as their primary space heating fuel in PADDx

PRPSP*x* (-1) = prior month propane and refinery grade propylene stock in PADD region *x*, million barrels

PRPSPPx_AVE= prior 4-year average stock in PADD region x, ((PRPSPPx(-13)+PRPSPPx(-25) +PRPSPPx(-37) + PRPSPPx(-49))/4)), million barrels

The beginning-of-month (end of prior month) PADD inventory as a deviation from the prior four-year average for that month is included as an explanatory variable. Higher-than-historical average beginning inventory levels are expected to be correlated with smaller stock builds or larger stock draws. The four-year average generally provided the best model fit compared with shorter and longer averages. The estimated coefficients for all PADDs were negative as expected. Because of structural changes in the rapidly expanding market hub, the coefficient for the deviation from prior four-year average was not statistically significant for PADD 3.

E. Net Imports/Exports

The United States became a net exporter of propane in 2011. Between 2011 and 2014, net exports of propane increased from 42,000 b/d to 334,000. U.S. exports of propane are destined to Canada, Japan, and Latin American countries. Propane exports are expected to continue to rise as propane production growth continues to outpace domestic demand. In the past few years, a number of projects building/expanding export facilities more than tripled waterborne export capacity, with three more projects expected to be completed by the end of 2016.

Net imports (exports) of propane are calculated as a function of consumption, stock build, and refinery inputs minus gas plant production (equation 27).

$$PRNIPUS = PRTCPUS + ((PRPSPUS - PRPSPUS(-1)) / ZSAJQUS) - PRROPUS - PRFPPUS \quad (27)$$

where

PRNIPUS = net imports (gross imports- gross exports), million barrels per day

PRTCPUS = consumption, million barrels per day

PRPSPUS = end-of-month stocks, million barrels
PRPSPUS (-1) = prior end-of-month stocks, million barrels
ZSAJQUS = number of days in a month
PRROPUS = propane and propylene refinery output, million barrels per day
PRFPPUS = natural gas plant production of propane, million barrels per day

8. Hydrocarbon Gas Liquids – supply and disposition

Total HGL for every activity is calculated as the sum of butane, ethane, natural gasoline, and propane.

A. Natural Gas Plant Production

The total gas plant production of HGLs is calculated as the sum of gas plant production of the four products (equation 28).

$$NLPRPUS = C4FPPUS + ETFPPUS + PPFPPUS + PRFPPUS \quad (28)$$

where

NLPRPUS = total HGL gas plant production, million barrels per day
C4FPPUS = butane gas plant production, million barrels per day
ETFPPUS = ethane gas plant production, million barrels per day
PPFPPUS = natural gasoline gas plant production, million barrels per day
PRFPPUS = propane gas plant production, million barrels per day

B. Refinery Inputs and Production

The refinery inputs of HGL is calculated as the sum of refinery inputs of two products (equation 29).

$$NLRIPUS = C4RIPUS + PPRIPUS \quad (29)$$

where

NLRIPUS = total HGL refinery production, million barrels per day
C4RIPUS = butane refinery production, million barrels per day
PPRIPUS = natural gasoline refinery production, million barrels per day

The total refinery production of HGL is calculated as the sum of refinery production of the three products (equation 30).

$$NLROPUS = C4ROPUS + ETROPUS + PRROPUS \quad (30)$$

where

NLROPUS = total HGL refinery production, million barrels per day
C4ROPUS = butane refinery production, million barrels per day
ETROPUS = ethane refinery production, million barrels per day
PRROPUS = propane refinery production, million barrels per day

C. Consumption (product supplied)

The total consumption of HGL is calculated as the sum of consumption of the four products (equation 31).

$$NLTCPUS = C4TCPUS + ETTCPUS + PPTCPUS + PRTCPUS \tag{31}$$

where

NLTCPUS = total HGL consumption
C4TCPUS = butane consumption
ETTCPUS = ethane consumption
PPTCPUS = natural gasoline consumption
PRTCPUS = propane consumption

D. Stock Build and Stock Levels

The total U.S. HGL inventories (stocks) are calculated as the sum of inventories of the four products (equation 32).

$$NLPSPUS = C4PSPUS + PTPSPUS + PPPSPUS + PRPSPUS \tag{32}$$

where

NLPSPUS = total HGL inventories
C4PSPUS = butane inventories
PTPSPUS = ethane inventories
PPPSPUS = natural gasoline inventories
PRPSPUS = propane inventories

E. Net Imports/Exports

The net HGL imports are calculated as the sum of net imports of the four products (equation 33).

$$NLNIPUS = C4NIPUS + ETNIPUS + PPNIPUS + PRNIPUS \tag{33}$$

where

NLNIPUS = total HGL net imports
C4NIPUS = butane net imports
ETNIPUS = ethane net imports
PPNIPUS = natural gasoline net imports
PRNIPUS = propane net imports

10. Forecast Evaluations

In order to evaluate the reliability of the forecasts, we generated out-of-sample forecasts and calculated forecast errors. Each equation was estimated through December 2012. Dynamic forecasts were then generated for the period January 2013 through December 2014 using each regression equation. The forecasts are then compared with actual outcomes.

Dynamic forecasts of each equation use the actual values of the exogenous variables on the right-hand side of the regression equations (e.g., weather and prices) but simulated values of the lagged dependent variable. Consequently, the calculated forecast error is not the same as a calculated regression error, which uses the actual value for the lagged dependent variable.

Summary forecast error statistics are reported for each regression equation. The root mean squared Error (RMSE) and the mean absolute error (MAE) depend on the scale of the dependent variable. These are generally used as relative measures to compare forecasts for the same series using different models; the smaller the error, the better the forecasting ability of that model.

The mean absolute percentage error (MAPE) and the Theil inequality coefficient are invariant to scale. The smaller the values, the better the model fit. The Theil inequality coefficient always lies between zero and one, where zero indicates a perfect fit. The Theil inequality coefficient is broken out into bias, variance, and covariance proportions, which sum to 1. The bias proportion indicates how far the mean of the forecast is from the mean of the actual series signaling systematic error. The variance proportion indicates how far the variation of the forecast is from the variation of the actual series. This will be high if the actual data fluctuates significantly but the forecast fails to track these variations from the mean. The covariance proportion measures the remaining unsystematic forecasting errors. For a "good" forecast the bias and variance proportions should be small with most of the forecast error concentrated in the covariance proportion.

The forecast errors and related statistics highlight the difficulty of accurately modelling a market undergoing rapid structural changes. This is why the models are closely monitored by analysts who can utilize add factors to follow changing trends that would likely be missed by a typical model relying on historical data.

For the purpose of this analysis, the forecast errors for each of the HGL products are grouped together by activity (natural gas plant production, consumption, etc.) because the errors in the forecasts associated with each activity can often be explained by the same structural market changes.

A. Natural gas plant production

Table 3 and Figure 7 provide comparisons of the out-of-sample dynamic forecasts and actual natural gas plant production for each of the four HGL products for the period January 2013 through December 2014. The natural gas plant production forecasts of propane, butanes, and natural gasoline are based on regression equations. A forecast for gas plant production of ethane is calculated as an identity that balances the out-of-sample forecasts of the individual supply and demand elements. The forecast of total gas plant production of HGL is the sum of the 4 individual product forecasts. In general, the production forecasts were lower than actual because the regression equations could not fully capture ongoing structural changes in the market and rapid expansion of natural gas plant production capacity. The combined forecasts for gas plant production of total HGL were 126,000 b/d (5%) below actual in 2013 and 227,000 b/d (8%) below in 2014 (Table 3). The consistent below-actual forecasts also show up as large bias proportions in the Theill inequality coefficients (Table 4).

Unlike the other HGL streams, gas plant production of ethane is not modeled as a regression equation. Because of the continued oversupply of ethane and rejection of ethane back into dry natural gas, gas plant production of ethane is modeled as an equation that balances supply and demand. Producers are expected to adjust production to meet any changes in consumption, inventories, or net exports. The resulting forecast is 1% below actual ethane gas plant production for the first year, widening to 7% below actual in the second year. These forecast errors are the net result of errors in the regression equations for ethane consumption (Table 5), refinery production (Table 7), stock change (Table 9), and net exports (Table 11).

Table 3. Actual and out-of-sample natural gas plant production forecasts, annual averages (million barrels per day)

	2013		2014	
	Actual	**Forecast**	**Actual**	**Forecast**
Natural Gas Plant Liquids Production				
Ethane (ETFPPUS) *	0.970	0.964	1.091	1.012
Propane (PRFPPUS)	0.823	0.769	0.985	0.914
Butanes (C4FPPUS)	0.465	0.414	0.545	0.474
Natural gasoline (PPFPPUS)	0.347	0.334	0.394	0.388
Total HGL (NLPRPUS)	**2.606**	**2.480**	**3.015**	**2.788**

* Derived from balance: production = consumption + stock build - refinery production - net imports

Figure 7. HGL natural gas plant production out-of-sample forecasts versus actuals, January 2013 - December 2014

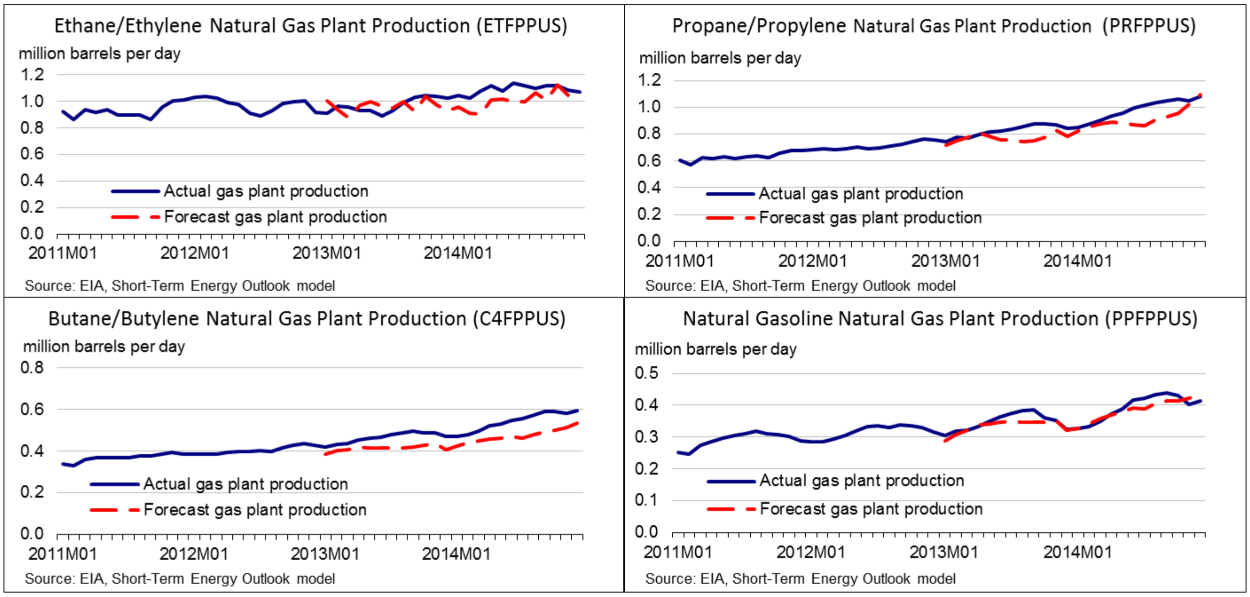


Table 4. HGL natural gas plant production out-of-sample simulation error statistics

	Ethane	Propane	Butanes	Natural gasoline
Root Mean Squared Error	NA	0.079	0.064	0.019
Mean Absolute Error	NA	0.065	0.061	0.016
Mean Absolute Percentage Error	NA	6.97	11.9	4.11
Theill Inequality Coefficient	NA	0.045	0.067	0.026
Bias Proportion	NA	0.620	0.902	0.269
Variance Proportion	NA	0.013	0.052	0.014
Covariance Proportion	NA	0.367	0.045	0.717

B. Consumption

Table 5 and Figure 8 provide a comparison of the out-of-sample dynamic forecasts and actual consumption for each HGL consumption regression equation for the period January 2013 through December 2014. A forecast for total HGL consumption is calculated as the sum of the 4 individual product forecasts. The forecasts for total HGL consumption were 108,000 b/d (4%) below actual in 2013 and 41,000 b/d (2%) below actual in 2014. The largest forecast errors were for propane. One of the largest under-predictions of propane consumption occurred in the Fall of 2013 (Figure 8), which may be the result of unusually high propane demand for a large and wet corn crop that year.

The natural gasoline consumption forecast had the largest mean absolute percent error (Table 6), primarily because of its small volumes and high volatility. The bias proportion of the Thiel inequality coefficient were highest for propane and butane (Table 6). Historical values for consumption can be negative because they are imputed from product supplied data, which is based on supply and disposition data reported in surveys.

Table 5. Actual and out-of-sample consumption forecasts, annual averages (million barrels per day)

	2013		2014	
	Actual	**Forecast**	**Actual**	**Forecast**
Consumption				
Ethane (ETTCPUS)	0.990	0.994	1.048	1.037
Propane (PRTCPUS)	1.275	1.202	1.167	1.149
Butanes (C4TCPUS)	0.174	0.144	0.181	0.174
Natural gasoline (PPTCPUS)	0.056	0.047	0.052	0.047
Total HGL (NLTCPUS)	**2.495**	**2.387**	**2.448**	**2.407**

Figure 8. HGL consumption out-of-sample forecasts versus actuals, January 2013 - December 2014

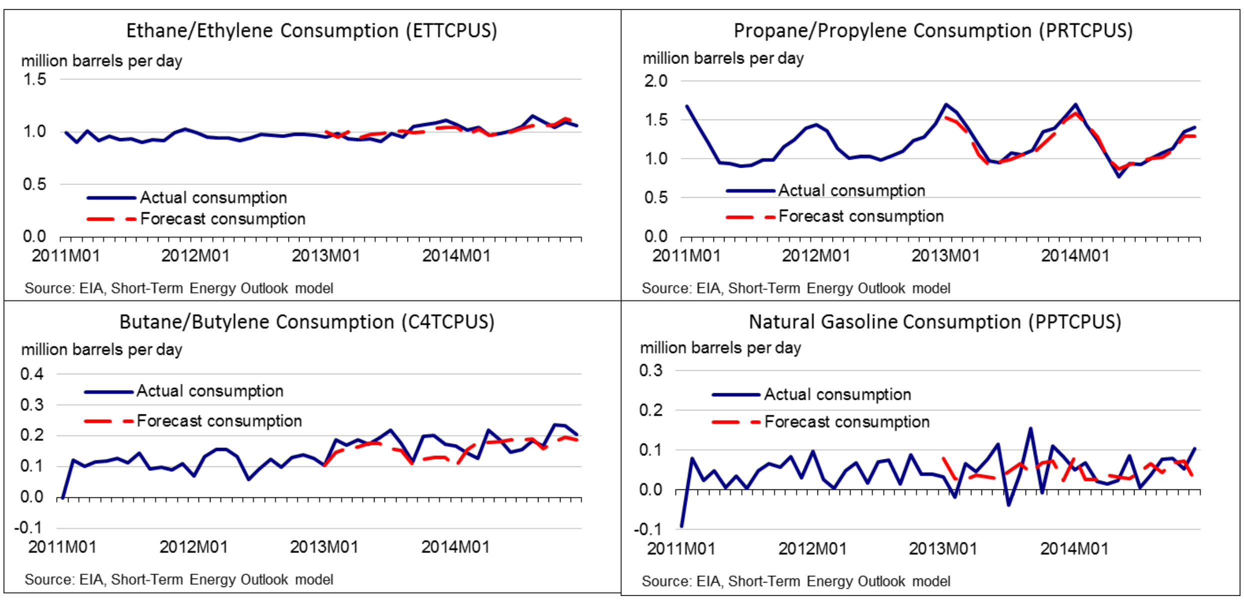


Table 6. HGL consumption out-of-sample simulation error statistics

	Ethane	Propane	Butanes	Natural gasoline
Root Mean Squared Error	0.045	0.079	0.038	0.052
Mean Absolute Error	0.039	0.064	0.031	0.044
Mean Absolute Percentage Error	3.78	5.03	16.9	138
Theil Inequality Coefficient	0.022	0.032	0.111	0.043
Bias Proportion	0.006	0.331	0.246	0.021
Variance Proportion	0.222	0.262	0.020	0.234
Covariance Proportion	0.772	0.407	0.735	0.745

C. Refinery Inputs

Table 7 and Figure 9 show the monthly actual and forecasted values for refinery inputs of butane and natural gasoline. Ethane and propane are not input into refineries. The butane and natural gasoline equations over-predicted total HGL refinery inputs by 15,000 b/d (3%) in 2013 and by 25,000 b/d (5%) in 2014. The largest forecast errors were for natural gasoline, which contributed to the large Thiel inequality coefficient bias proportion (Table 8).

Table 7. Actual and out-of-sample refinery inputs forecasts, annual averages (million barrels per day)

	2013		2014	
	Actual	Forecast	Actual	Forecast
Refinery Inputs				
Butane (C4RIPUS)	0.331	0.332	0.358	0.342
Natural gasoline (PPRIPUS)	0.165	0.179	0.154	0.194
Total HGL (NLRIPUS)	**0.496**	**0.511**	**0.511**	**0.536**

Figure 9. HGL net refinery inputs out-of-sample forecasts versus actuals, January 2013 - December 2014

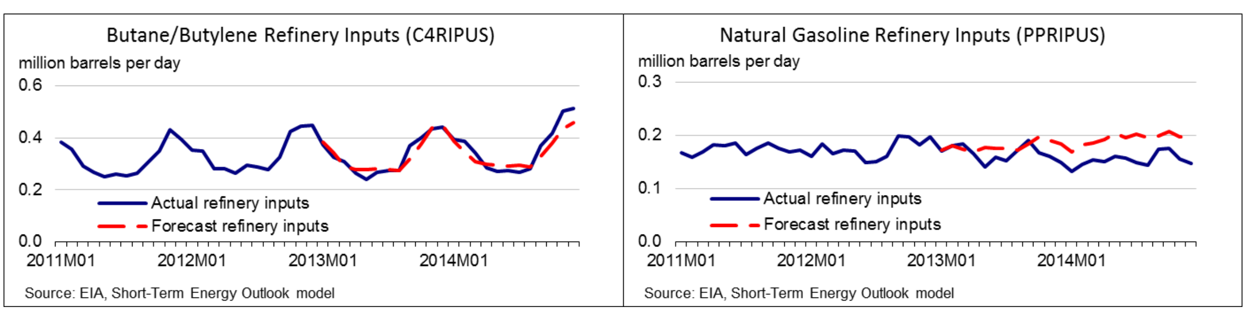


Table 8. HGL refinery inputs out-of-sample simulation error statistics

	Ethane	Propane	Butanes	Natural gasoline
Root Mean Squared Error	NA	NA	0.026	0.033
Mean Absolute Error	NA	NA	0.020	0.028
Mean Absolute Percentage Error	NA	NA	5.80	18.5
Theil Inequality Coefficient	NA	NA	0.037	0.094
Bias Proportion	NA	NA	0.093	0.671
Variance Proportion	NA	NA	0.232	0.006
Covariance Proportion	NA	NA	0.675	0.323

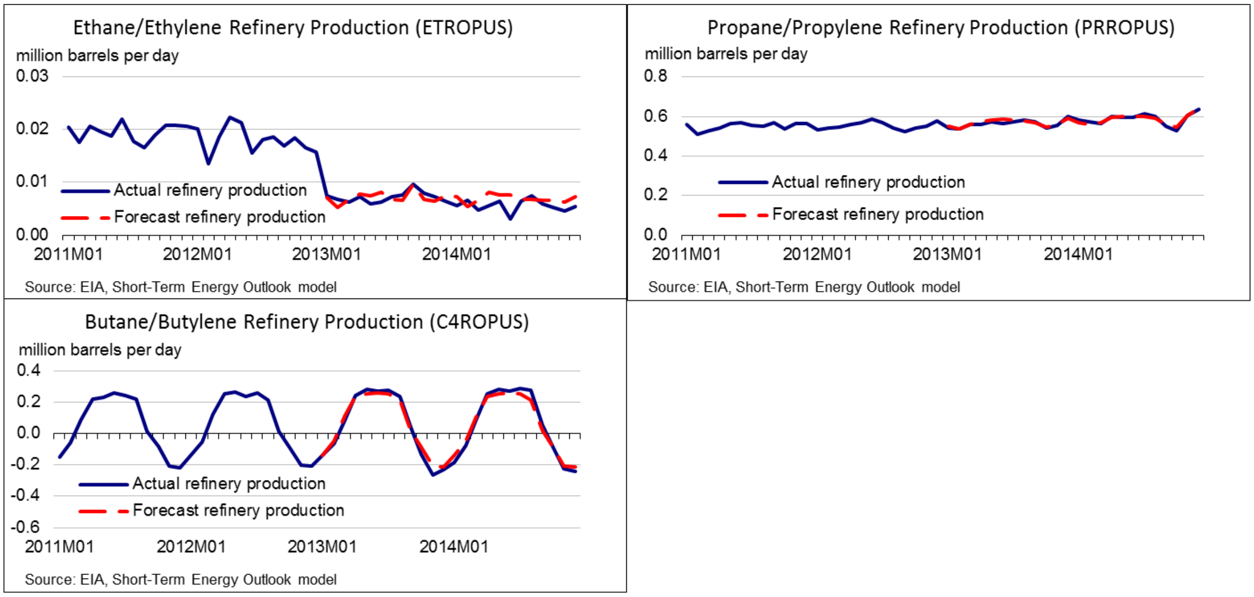
D. Refinery Production

Table 9 and Figure 10 show the monthly actual and forecasted values for refinery production of ethane, propane, and butanes. The forecast for total HGL refinery production was 9,000 b/d (1%) above actual in 2013 and 5,000 b/d (1%) below actual in 2014.

Table 9. Actual and out-of-sample refinery production forecasts, annual averages (million barrels per day)

	2013		2014	
	Actual	Forecast	Actual	Forecast
Refinery production				
Ethane (ETROPUS)	0.007	0.007	0.007	0.007
Propane (PRROPUS)	0.564	0.568	0.587	0.586
Butanes (C4ROPUS)	0.051	0.056	0.060	0.056
Total HGL (NLROPUS)	**0.623**	**0.632**	**0.655**	**0.650**

Figure 10. HGL refinery production out-of-sample forecast versus actual, January 2013 - December 2014



The mean average percentage errors are relatively large for ethane, which has relatively little refinery production, and for butanes, where the model under-predicted seasonal highs and lows (Table 10). The propane forecast had a very low mean absolute percentage error and very low bias and variance proportions for the Theil inequality coefficient.

Table 10. HGL refinery production out-of-sample simulation error statistics

	Ethane	Propane	Butanes	Natural gasoline
Root Mean Squared Error	0.002	0.009	0.029	NA
Mean Absolute Error	0.001	0.007	0.025	NA
Mean Absolute Percentage Error	24.4	1.30	17.6	NA
Theil Inequality Coefficient	0.115	0.008	0.073	NA
Bias Proportion	0.176	0.018	0.001	NA
Variance Proportion	0.072	0.083	0.567	NA
Covariance Proportion	0.752	0.898	0.432	NA

E. Inventories

Table 11 and Figures 11 and 12 show the monthly actual and forecasted values for inventories of each HGL product. The forecast inventory levels were calculated using the model-generated forecasts of monthly stock changes. Stock change forecasts for butanes, ethane, and natural gasoline are based on national level regression equations, while the total U.S. stock change for propane is modeled as the sum of forecasts of 5 Petroleum Administration Defense District (PADD)-level equations.

Table 11. Actual and out-of-sample HGL end-of-month inventory forecasts, averages of monthly inventory levels (million barrels)

	2013		2014	
	Actual	Forecast	Actual	Forecast
Inventories				
Ethane (ETPSPUS)	34.2	32.3	35.6	21.9
Propane (PRPSPUS)	53.7	61.7	57.9	52.2
PADD 1 (PRPSPP1)	3.3	4.2	4.3	3.8
PADD 2 (PRPSPP2)	16.5	19.5	19.5	16.5
PADD 3 (PRPSPP3)	31.9	36.0	31.6	30.0
PADD 4 (PRPSPP4)	0.5	0.3	1.0	0.3
PADD 5 (PRPSPP5)	1.4	1.6	1.6	1.6
Butanes (C4PSPUS)	47.2	44.9	48.0	44.8
Natural gasoline (PPPSPUS)	16.2	12.1	17.5	10.9
Total HGL (NLPSPUS)	**204.9**	**212.7**	**217.0**	**182.0**

The ethane and natural gasoline inventory change equations resulted in inventory level forecasts that were below actual (e.g., smaller-than-actual stock builds or larger-than-actual stock draws) in both 2013 and 2014. Ethane and natural gasoline inventories increased significantly over the last few years, while the regression equations biased the stock levels downwards through a regression to the longer-term mean. The butane inventory equation tended to under-predict the late summer inventory peaks. The propane inventory equation over-predicted stock levels in 2013 and under-predicted levels in 2014.

Figure 11. HGL inventories out-of-sample forecasts versus actuals, January 2013 - December 2014

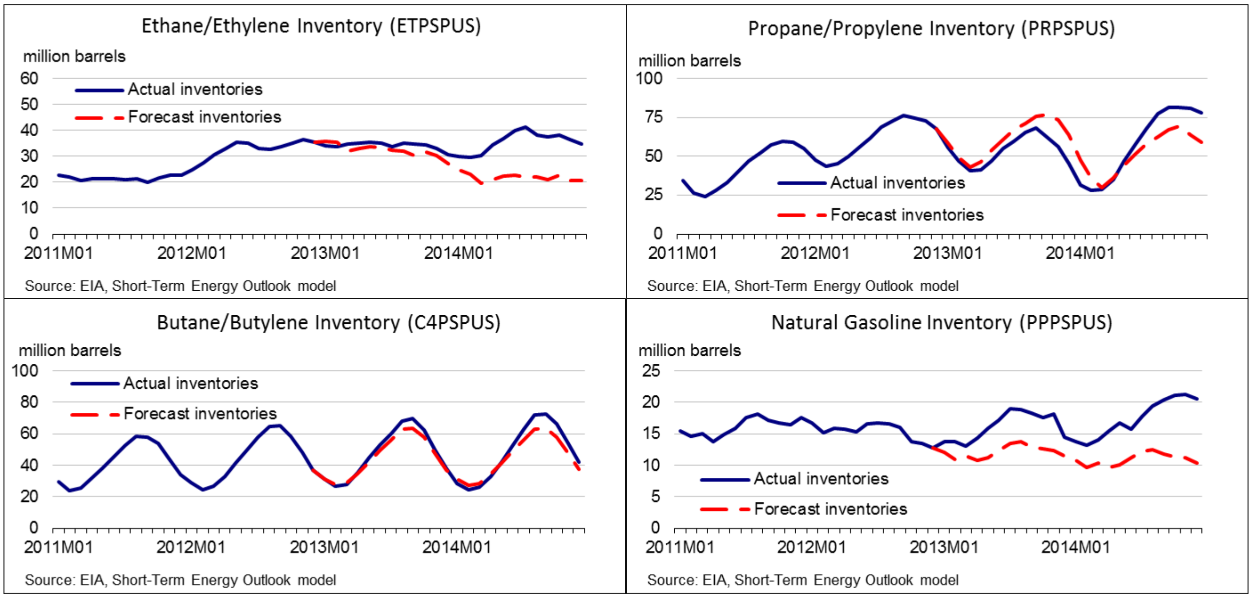
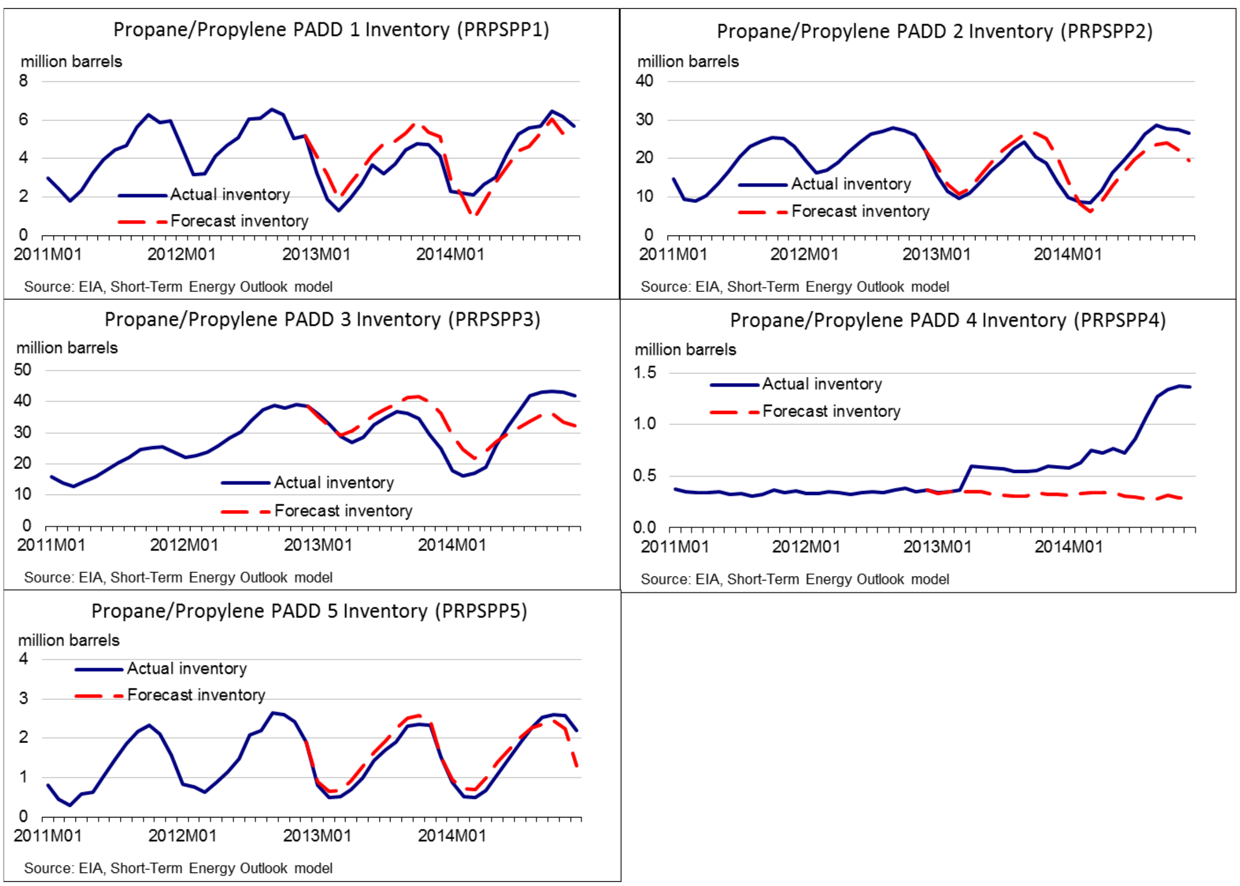


Table 12. Butane, ethane, and natural gasoline stock build (draw) out-of-sample simulation error statistics

	Ethane	Butane	Natural Gasoline
Root Mean Squared Error	2.032	1.744	1.274
Mean Absolute Error	1.620	1.404	1.040
Mean Absolute Percentage Error	231	25.3	187
Theil Inequality Coefficient	0.589	0.117	0.628
Bias Proportion	0.156	0.022	0.137
Variance Proportion	0.000	0.715	0.152
Covariance Proportion	0.843	0.263	0.711

Figure 12. Propane inventories, PADD-level out-of-sample forecasts versus actuals, January 2013 - December 2014



The out-of-sample forecasts for the PADD 1, 2, and 3 propane inventories fell below actual in 2013 and above actual in 2014. One contributor to the forecast error was the expansion of the Targa export terminal in Houston, which occurred in the Fall of 2013, before the associated fractionation capacity was available. As a result, contracted export shipments were partially met from inventories. Propane exports in the fourth quarter of 2013 average 200,000 b/d higher than exports in the same period the year before. Additionally, some PADD 3 supplies were drawn to PADD 2 in late 2013 because of the unexpected increase in propane demand for crop drying in 2013. In early 2014, low propane inventories and high prices led many petrochemical users to switch from propane to less expensive feedstocks, contributing to an unusually large stock build in the first half of the year.

From 2010 through March 2014, PADD 4 propane inventories averaged a relatively stable 350,000 barrels, then jumped to an average of 575,000 barrels over the last 9 months of 2013, and then to 960,000 barrels in 2014. The PADD 4 propane inventory change equation did not capture this structural shift in the Rocky Mountain region propane market.

Table 13. Propane stock build (draw) out-of-sample simulation error statistics

	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5
Root Mean Squared Error	0.468	1.774	2.230	0.202	0.148
Mean Absolute Error	0.361	0.309	1.726	0.158	0.102
Mean Absolute Percentage Error	135	133	97.1	571	69.8
Theil Inequality Coefficient	0.293	0.286	0.372	0.859	0.177
Bias Proportion	0.010	0.029	0.009	0.611	0.064
Variance Proportion	0.030	0.001	0.272	0.005	0.019
Covariance Proportion	0.960	0.970	0.719	0.384	0.917

The large mean absolute errors of the inventory change equations reflect monthly stock changes that may average close to 0, causing small forecast errors to result in large percentage forecast errors (Tables 12 and 13). The bias proportions of the Thiel inequality coefficients were generally low except for propane in PADD 4.

F. Net Imports

Net imports of butane, natural gasoline, and propane are calculated as identities that balance each of their supply and disposition elements. Ethane is the only HGL for which net imports are modeled as a regression equation (Table 14).

Two new ethane pipelines to Canada allowed the United States to begin exporting ethane for the first time in late 2013/early 2014. The regression equation for ethane net imports is based on history and cannot accurately predict changes resulting from structural changes like new infrastructure (Figure 25). Analysts may use add factors to adjust for expected changes in the market resulting from new pipeline/export infrastructure.

Table 14. Actual and out-of-sample ethane net imports forecasts, annual averages (million barrels per day)

	2013		2014	
	Actual	Forecast	Actual	Forecast
Ethane (ETNIPUS)	0.000	0.000	-0.038	0.000
Propane (PRNIPUS) *	-0.175	-0.148	-0.315	-0.364
Butanes (C4NIPUS) *	-0.009	0.005	-0.056	-0.014
Natural gasoline (PPNIPUS) *	-0.103	-0.095	-0.152	-0.134
Total HGL (NLNIPUS)	**-0.287**	**-0.238**	**-0.560**	**-0.512**

* Except for ethane, net exports are derived from balance: net imports = consumption + stock build - refinery production - natural gas plant production

Figure 13. HGL net imports out-of-sample forecasts versus actuals, January 2013 - December 2014

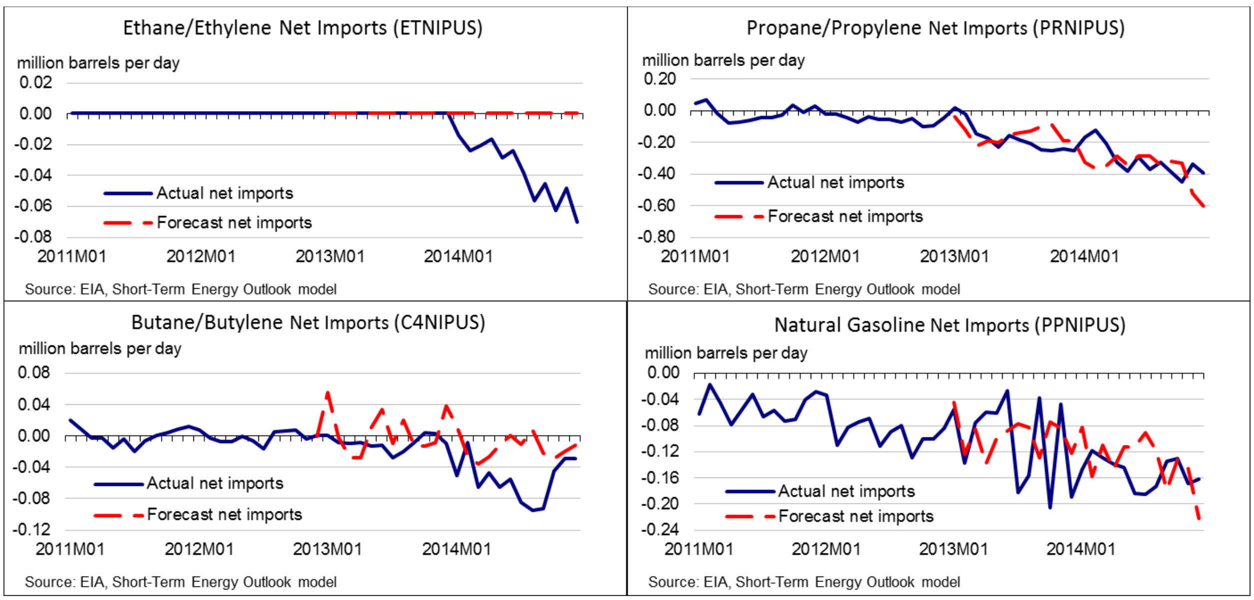


Table 15. Net imports out-of-sample simulation error statistics

	Ethane
Root Mean Squared Error	0.030
Mean Absolute Error	0.019
Mean Absolute Percentage Error	59.3
Theil Inequality Coefficient	0.996
Bias Proportion	0.405
Variance Proportion	0.592
Covariance Proportion	0.002

Appendix A. Variable Definitions, Units, and Sources

Table A1. Variable Definitions, Units, and Sources

Variable Name	Units	Definition	Sources History	Sources Forecast
APR	Integer	= 1 if April, 0 otherwise	-	-
AUG	Integer	= 1 if August, 0 otherwise	-	-
CODIPUS	MMBD	Total inputs to crude oil atmospheric distillation	PSM	STEO
CORIPUS	MMBD	Crude oil refinery inputs	PSM	STEO
C4FPPUS	MMBD	Butane natural gas plant production	PSM	STEO
C4NIPUS	MMBD	Butane net imports	PSM	STEO
C4NIPUS	MMBD	Butane net imports (exports)	PSM	STEO
C4PSBLD	MMBD	Butane stock build (draw)	PSM	STEO
C4PSPUS	MMBBL	Butane end-of-month inventories	PSM	STEO
C4RIPUS	MMBD	Butane refinery inputs	PSM	STEO
C4ROPUS	MMBD	Butane refinery production	PSM	STEO
DEC	Integer	= 1 if December, 0 otherwise	-	-
ENC	Region	East North Central Census Division	-	-
ESC	Region	East South Central Census Division	-	-
ETFPPUS	MMBD	Ethane natural gas plant production	PSM	STEO
ETNIPUS	MMBD	Ethane net imports (exports)	PSM	STEO
ETPSBLD	MMBD	Ethane stock build (draw)	PSM	STEO
PPPSPUS	MMBBL	Ethane end-of-month inventories	PSM	STEO
ETROPUS	MMBD	Ethane refinery production	PSM	STEO
ETTCPUS	MMBD	Ethane consumption	PSM	STEO
FEB	Integer	= 1 if February, 0 otherwise	-	-
JAN	Integer	= 1 if January, 0 otherwise	-	-
EORIPUS	MMBD	Fuel ethanol refinery inputs	PSM	STEO
EOTCPUS	MMBD	Fuel ethanol blending into motor gasoline	PSM	STEO
JUL	Integer	= 1 if July, 0 otherwise	-	-
JUN	Integer	= 1 if June, 0 otherwise	-	-
LGRIPUS	MMBD	Liquefied petroleum gas refinery input	PSM	STEO
LGROPUS	MMBD	Liquefied petroleum gas refinery output	PSM	STEO
LGROPUS_SF	MMBD	Liquefied petroleum gas initial refinery output seasonally factored	STEO	STEO
LGYLD	P	Liquefied petroleum gas yield	PSM	STEO
MAC	Region	Middle Atlantic Census Division	-	-
MAR	Integer	= 1 if March, 0 otherwise	-	-
MAY	Integer	= 1 if May, 0 otherwise	-	-
MGROPUS	MMBD	Motor gasoline refinery production	PSM	STEO

MGYLD	P	Motor gasoline yield	PSM	STEO
MTN	Region	Mountain Census Division	-	-
NEC	Region	New England Census Division	-	-
NGHHUUS	$/MMBtu	Henry Hub natural gas wellhead price	NGM	STEO
NGMPPUS	BCFD	Natural gas marketed (wet) gas production	NGM	STEO
NLPRPUS	MMBD	Hydrocarbon gas liquids natural gas plant production	PSM	STEO
NLNIPUS	MMBD	Hydrocarbon gas liquids net imports (exports)	PSM	STEO
NLPSBLD	MMBD	Hydrocarbon gas liquids stock build (draw)	PSM	STEO
NLPSPUS	MMBBL	Hydrocarbon gas liquids end-of-month inventories	PSM	STEO
NLROPUS	MMBD	Hydrocarbon gas liquids refinery inputs	PSM	STEO
NLROPUS	MMBD	Hydrocarbon gas liquids refinery production	PSM	STEO
NLTCPUS	MMBD	Hydrocarbon gas liquids consumption	PSM	STEO
NOV	Integer	= 1 if November, 0 otherwise	-	-
OCT	Integer	= 1 if October, 0 otherwise	-	-
PAC	Region	Pacific Census Division	-	-
PPPSBLD	MMBD	Natural gasoline stock build (draw)	PSM	STEO
PPPSPUS	MMBBL	Natural gasoline end-of-month inventories	PSM	STEO
PPRIPUS	MMBD	Natural gasoline refinery inputs	PSM	STEO
PPPRPUS	MMBD	Natural gasoline used as ethanol denaturant	PSM	STEO
PPTCPUS	MMBD	Natural gasoline consumption	PSM	STEO
PRFPPUS	MMBD	Propane gas plant production	PSM	STEO
PRNIPUS	MMBD	Propane net imports (exports)	PSM	STEO
PRPS1BLD	MMBD	Propane/refinery grade propylene PADD 1 stock build (draw)	PSM	STEO
PRPS2BLD	MMBD	Propane/refinery grade propylene PADD 2 stock build (draw)	PSM	STEO
PRPS3BLD	MMBD	Propane/refinery grade propylene PADD 3 stock build (draw)	PSM	STEO
PRPS4BLD	MMBD	Propane/refinery grade propylene PADD 4 stock build (draw)	PSM	STEO
PRPS5BLD	MMBD	Propane/refinery grade propylene PADD 5 stock build (draw)	PSM	STEO
PRPSPP1	MMBBL	Propane/refinery grade propylene PADD 1 end-of-month inventories	PSM	STEO
PRPSPP2	MMBBL	Propane/refinery grade propylene PADD 2 end-of-month inventories	PSM	STEO
PRPSPP3	MMBBL	Propane/refinery grade propylene PADD 3 end-of-month inventories	PSM	STEO
PRPSPP4	MMBBL	Propane/refinery grade propylene PADD 4 end-of-month inventories	PSM	STEO
PRPSPP5	MMBBL	Propane/refinery grade propylene PADD 5 end-of-month inventories	PSM	STEO
PRPSPUS	MMBBL	Propane/refinery grade propylene U.S. end-of-month inventories	PSM	STEO
PRROPUS	MMBD	Propane/propylene refinery production	PSM	STEO
PRTCPUS	MMBD	Propane/refinery grade propylene consumption	PSM	STEO
QHLP_US	Millions	U.S. households with propane heat	ACS	STEO
RACPUUS	$BBL	Refiner acquisition cost of crude oil (composite)	PMM	STEO

SAC	Region	South Atlantic Census Division	-	-
SEP	Integer	= 1 if September, 0 otherwise	-	-
TIME	Integer	Counts the number of months from January 1975 – Present	-	-
UORIPUSX	MMBD	Refinery inputs of unfinished oils	PSM	STEO
WNC	Region	West North Central Census Division	-	-
WSC	Region	West South Central Census Division	-	-
WTIPUUS	$BBL	Cost of West Texas Intermediate crude oil	PMM	STEO
ZO325IUS	2007=100	Chemical Manufacturing Industrial Production Index	FRB	FRB
ZO326IUS	2007=100	Plastics & Rubber Industrial Production Index	FRB	FRB
ZSAJQUS	Integer	Number of days in a month	-	-
ZWHD_US	HDD	Heating degree days, United States	NOAA	NOAA

Table A2. Units key

CPG	Cents per gallon
DPB	$/barrel
HDD	Heating degree days
Index	Index value
Integer	Number = 0 or 1
MMBD	Million barrels per day
P	Fraction or percentage

Table A3. Sources key

GI	IHS-Global Insight
NOAA	National Oceanic and Atmospheric Organization
PMM	EIA *Petroleum Marketing Monthly*
PSM	EIA *Petroleum Supply Monthly*
STEO	Short-Term Energy Outlook Model

Appendix B. Eviews Model Program File

```
' ----------------------------------------------------------------------------------------------------------
'--------- Ethane
' ----------------------------------------------------------------------------------------------------------

:EQ_ETTCPUS
@ADD ETTCPUS  ETTCPUS_A

:EQ_ETPSBLD
@ADD ETPSBLD  ETPSBLD_A
@INNOV ETPSBLD  1.302661

@IDENTITY PPPSPUS  = PPPSPUS(-1)  + ETPSBLD

:EQ_ETROPUS
@ADD ETROPUS  ETROPUS_A
@INNOV ETROPUS  0.0018852

:EQ_ETNIPUS
@ADD ETNIPUS  ETNIPUS_A

@IDENTITY ETROPUS  = ETTCPUS  + ((PPPSPUS  - PPPSPUS(-1))  / ZSAJQUS)  - ETROPUS  - ETNIPUS

' ----------------------------------------------------------------------------------------------------------
'--------- Propane
' ----------------------------------------------------------------------------------------------------------

:EQ_PRMBUUS
@ADD PRMBUUS  PRMBUUS_A
@INNOV PRMBUUS  0.0731407

:EQ_PRROPUS
@ADD PRROPUS  PRROPUS_A
@INNOV PRROPUS  0.0079662

:EQ_PRTCPUS
@ADD PRTCPUS  PRTCPUS_A

:EQ_PRROPUS
@ADD PRROPUS  PRROPUS_A
@INNOV PRROPUS  0.0109835

:EQ_PRPSP1BLD
@ADD PRPSP1BLD  PRPSP1BLD_A

:EQ_PRPSP2BLD
@ADD PRPSP2BLD  PRPSP2BLD_A

:EQ_PRPSP3BLD
@ADD PRPSP3BLD  PRPSP3BLD_A

:EQ_PRPSP4BLD
@ADD PRPSP4BLD  PRPSP4BLD_A

:EQ_PRPSP5BLD
@ADD PRPSP5BLD  PRPSP5BLD_A

@IDENTITY prpspp1  = prpspp1(-1)  + prpsp1bld
```

```
@IDENTITY prpspp2  = prpspp2(-1)  + prpsp2bld

@IDENTITY prpspp3  = prpspp3(-1)  + prpsp3bld

@IDENTITY prpspp4  = prpspp4(-1)  + prpsp4bld

@IDENTITY prpspp5  = prpspp5(-1)  + prpsp5bld

@IDENTITY prpspus  = prpspp1  + prpspp2  + prpspp3  + prpspp4  + prpspp5

@IDENTITY PRNIPUS  = PRTCPUS  + ((PRPSPUS  - PRPSPUS(-1))  / ZSAJQUS)  - PRROPUS  - PRROPUS

' -----------------------------------------------------------------------------------------------------
'--------- C4 (normal and isobutane/butylene)
' -----------------------------------------------------------------------------------------------------

:EQ_C4TCPUS
@ADD C4TCPUS  C4TCPUS_A

:EQ_C4ROPUS
@ADD C4ROPUS  C4ROPUS_A
@INNOV C4ROPUS  0.0055564

:EQ_C4PSBLD
@ADD C4PSBLD  C4PSBLD_A

@IDENTITY C4PSPUS  = C4PSPUS(-1)  + C4PSBLD

:EQ_C4RIPUS
@ADD C4RIPUS  C4RIPUS_A
@INNOV C4RIPUS  0.0274924

:EQ_C4ROPUS
@ADD C4ROPUS  C4ROPUS_A
@INNOV C4ROPUS  0.0236494

@IDENTITY C4NIPUS  = C4TCPUS  + ((C4PSPUS  - C4PSPUS(-1))  / ZSAJQUS)  + C4RIPUS  - C4ROPUS  -
C4ROPUS

' -----------------------------------------------------------------------------------------------------
'---------  LPG = ethane + propane + C4 (normal butanbe + isobutane)
' -----------------------------------------------------------------------------------------------------

@IDENTITY LGROPUS  = ETROPUS  + PRROPUS  + C4ROPUS

@IDENTITY LGTCPUS  = ETTCPUS  + PRTCPUS  + C4TCPUS

@IDENTITY LXTCPUS  = PRTCPUS  + C4TCPUS

@IDENTITY LGRIPUS  = C4RIPUS

@IDENTITY LGROPUS  = ETROPUS  + PRROPUS  + C4ROPUS

@IDENTITY LGPSPUS  = PPPSPUS  + PRPSPUS  + C4PSPUS

@IDENTITY LGNIPUS  = LGTCPUS  + ((LGPSPUS  - LGPSPUS(-1))  / ZSAJQUS)  + LGRIPUS  - LGROPUS  -
LGROPUS
```

```
' -----------------------------------------------------------------------------------------------------------
'---------  Pentanes Plus
' -----------------------------------------------------------------------------------------------------------

:EQ_PPROPUS
@ADD PPROPUS  PPROPUS_A

@IDENTITY PPPRPUS  =  - 0.02  * EOPRPUS

:EQ_PPTCPUS
@ADD PPTCPUS  PPTCPUS_A

:EQ_PPRIPUS
@ADD PPRIPUS  PPRIPUS_A

:EQ_PPPSBLD
@ADD PPPSBLD  PPPSBLD_A

@IDENTITY PPPSPUS  = PPPSPUS(-1)  + PPPSBLD

@IDENTITY PPNIPUS  = PPTCPUS  + ((PPPSPUS  - PPPSPUS(-1))  / ZSAJQUS)  + PPRIPUS  - PPROPUS  -
PPPRPUS

' -----------------------------------------------------------------------------------------------------------
'---------  Total HGLs  - reported in compare file
' -----------------------------------------------------------------------------------------------------------

@IDENTITY NLPRPUS  = ETROPUS  + PRROPUS  + C4ROPUS  + PPROPUS

'--- Note:  There is no NL aggregate for renewable plant net production, PPPRPUS

@IDENTITY NLROPUS  = ETROPUS  + PRROPUS  + C4ROPUS

@IDENTITY NLTCPUS  = ETTCPUS  + PRTCPUS  + C4TCPUS  + PPTCPUS

@IDENTITY NLNIPUS  = ETNIPUS  + PRNIPUS  + C4NIPUS  + PPNIPUS

@IDENTITY NLRIPUS  = PRRIPUS  + C4RIPUS  + PPRIPUS

@IDENTITY NLPSPUS  = PPPSPUS  + PRPSPUS  + C4PSPUS  + PPPSPUS
```

Appendix C. Regression Results

Because of autocorrelation in the time series data used in the regression analyses, some of the p-values given in Appendix C may be understated. Prior information about energy market dynamic, however, indicates that the explanatory variables that have been retained in the models are important drivers of the corresponding dependent variables.

Table C1. C4FPPUS, Butane gas plant production, regression results

Dependent Variable: C4FPPUS
Method: Least Squares
Date: 09/10/15 Time: 11:33
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.897831	0.050420	-17.80694	0.0000
NGMPPUS	0.019994	0.000779	25.65321	0.0000
NGHHUUS-(RACPUUS/5.8)	-0.001786	0.001148	-1.555060	0.1278
D10ON*@TREND(2009:12)-D12ON*@TREND(2011:12)	-0.004003	0.000681	-5.881796	0.0000
D1001	0.035646	0.010684	3.336515	0.0018
D1101+D1102	0.037213	0.007635	4.873878	0.0000
D11+D12	-0.034378	0.003580	-9.602446	0.0000
D1211+D1212	0.037384	0.007320	5.107042	0.0000
D1312	0.035857	0.010289	3.485049	0.0012
JAN	0.006374	0.006931	0.919626	0.3633
FEB	0.024493	0.006583	3.720523	0.0006
MAR	0.027693	0.006549	4.228538	0.0001
APR	0.028952	0.006655	4.350310	0.0001
MAY	0.031753	0.006386	4.971929	0.0000
JUN	0.044053	0.006311	6.980797	0.0000
JUL	0.024367	0.006261	3.891812	0.0004
AUG	0.025272	0.006254	4.041075	0.0002
SEP	0.034551	0.006264	5.515565	0.0000
OCT	0.024777	0.006196	3.998724	0.0003
NOV	0.008501	0.005899	1.441045	0.1574

R-squared	0.991408	Mean dependent var	0.424795
Adjusted R-squared	0.987327	S.D. dependent var	0.077336
S.E. of regression	0.008706	Akaike info criterion	-6.388377
Sum squared resid	0.003032	Schwarz criterion	-5.690262
Log likelihood	211.6513	Hannan-Quinn criter.	-6.115306
F-statistic	242.9214	Durbin-Watson stat	1.559104
Prob(F-statistic)	0.000000		

Table C2. C4ROPUS, Butane net refinery production, regression results

Dependent Variable: C4ROPUS
Method: Least Squares
Date: 09/15/15 Time: 09:30
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.140215	0.009255	-15.14971	0.0000
FEB	0.082512	0.011707	7.048038	0.0000
MAR	0.244454	0.011707	20.88083	0.0000
APR	0.383995	0.011707	32.80020	0.0000
MAY	0.406196	0.011707	34.69653	0.0000
JUN	0.403268	0.011707	34.44650	0.0000
JUL	0.407499	0.011707	34.80790	0.0000
AUG	0.360674	0.012244	29.45826	0.0000
SEP	0.173988	0.011707	14.86178	0.0000
OCT	0.053463	0.013089	4.084571	0.0002
NOV	-0.070307	0.013089	-5.371510	0.0000
DEC	-0.083631	0.012244	-6.830630	0.0000
D1001	0.070280	0.018511	3.796737	0.0005
D1010	0.044495	0.018511	2.403765	0.0210
D1011	0.038789	0.018511	2.095508	0.0425
D1012	0.062717	0.017923	3.499294	0.0012
D1310	-0.045151	0.018511	-2.439204	0.0193
D1311	-0.052645	0.018511	-2.844055	0.0070
D1401	-0.043752	0.018511	-2.363644	0.0230
D1408	0.057927	0.017923	3.232050	0.0025

R-squared	0.995112	Mean dependent var	0.058839
Adjusted R-squared	0.992790	S.D. dependent var	0.188787
S.E. of regression	0.016031	Akaike info criterion	-5.167433
Sum squared resid	0.010279	Schwarz criterion	-4.469318
Log likelihood	175.0230	Hannan-Quinn criter.	-4.894362
F-statistic	428.5626	Durbin-Watson stat	1.190879
Prob(F-statistic)	0.000000		

Table C3. C4RIPUS, Butane net refinery inputs, regression results

Dependent Variable: C4RIPUS
Method: Least Squares
Date: 09/15/15 Time: 11:18
Sample: 2006M01 2014M12
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.310352	0.098526	3.149950	0.0023
MGROPUS	0.026865	0.006449	4.166124	0.0001
MGYLD	-0.294171	0.180900	-1.626154	0.1078
FEB	-0.048904	0.007249	-6.746326	0.0000
MAR	-0.089040	0.007064	-12.60468	0.0000
APR	-0.114424	0.007186	-15.92235	0.0000
MAY	-0.121487	0.007790	-15.59466	0.0000
JUN	-0.122368	0.007939	-15.41411	0.0000
JUL	-0.127043	0.007744	-16.40600	0.0000
AUG	-0.126034	0.007657	-16.45999	0.0000
SEP	-0.077017	0.007581	-10.15921	0.0000
OCT	-0.024848	0.007784	-3.192053	0.0020
NOV	0.029786	0.007576	3.931685	0.0002
DEC	0.041223	0.007993	5.157347	0.0000
D09ON*@TREND(2008:12)-D12ON*@TREND(2011:12)	-0.000450	0.000159	-2.827656	0.0059
D10	-0.046228	0.005007	-9.232108	0.0000
D1001	0.037510	0.016549	2.266564	0.0261
D1112	-0.041902	0.015732	-2.663499	0.0093
D1210	0.057545	0.015668	3.672705	0.0004
D1305	-0.034248	0.015445	-2.217382	0.0294
D1309	0.053973	0.015615	3.456402	0.0009
D1402	0.043877	0.015527	2.825902	0.0059
D1409	0.043261	0.015980	2.707212	0.0083
D1410	0.039376	0.015744	2.500993	0.0144
D1411	0.070617	0.015661	4.509005	0.0000
D1412	0.058685	0.015992	3.669771	0.0004

R-squared	0.964995	Mean dependent var	0.325492
Adjusted R-squared	0.954322	S.D. dependent var	0.067520
S.E. of regression	0.014431	Akaike info criterion	-5.432868
Sum squared resid	0.017076	Schwarz criterion	-4.787170
Log likelihood	319.3749	Hannan-Quinn criter.	-5.171061
F-statistic	90.42024	Durbin-Watson stat	1.603172
Prob(F-statistic)	0.000000		

Table C4. C4TCPUS, Butane consumption, regression results

Dependent Variable: C4TCPUS
Method: Least Squares
Date: 09/22/15 Time: 10:01
Sample: 2009M01 2014M12
Included observations: 72
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.563966	0.190911	-2.954082	0.0049
ZO325IUS	0.006167	0.001904	3.239359	0.0022
D1003+D1004+D1005+D1006	0.046635	0.008398	5.553277	0.0000
D0912	-0.063476	0.006671	-9.515468	0.0000
D0909	0.047308	0.010367	4.563464	0.0000
D0904	-0.055571	0.011317	-4.910329	0.0000
D1101	-0.064503	0.011184	-5.767559	0.0000
D1111	-0.042773	0.012047	-3.550488	0.0009
D1206	-0.046214	0.010665	-4.333062	0.0001
D1401	0.054682	0.012520	4.367588	0.0001
D1403	-0.053526	0.011752	-4.554751	0.0000
D1407	-0.045169	0.016810	-2.687041	0.0099
D1410	0.045706	0.015473	2.953941	0.0049
D13ON	0.073877	0.006708	11.01341	0.0000
FEB	0.056165	0.015301	3.670556	0.0006
MAR	0.060931	0.016198	3.761554	0.0005
APR	0.081574	0.014874	5.484320	0.0000
MAY	0.067681	0.012310	5.497983	0.0000
JUN	0.056337	0.015754	3.575997	0.0008
JUL	0.071273	0.018754	3.800342	0.0004
AUG	0.066581	0.013697	4.860846	0.0000
SEP	0.028561	0.013652	2.092166	0.0419
OCT	0.055644	0.017268	3.222483	0.0023
NOV	0.073607	0.015894	4.631053	0.0000
DEC	0.058056	0.012362	4.696479	0.0000

R-squared	0.872063	Mean dependent var	0.132167
Adjusted R-squared	0.806733	S.D. dependent var	0.048822
S.E. of regression	0.021463	Akaike info criterion	-4.577020
Sum squared resid	0.021652	Schwarz criterion	-3.786511
Log likelihood	189.7727	Hannan-Quinn criter.	-4.262316
F-statistic	13.34863	Durbin-Watson stat	1.747232
Prob(F-statistic)	0.000000		

Table C5. C4PSBLD, Butane stock build/draw, regression results

Dependent Variable: C4PSBLD
Method: Least Squares
Date: 09/16/15 Time: 14:46
Sample: 2005M01 2014M12
Included observations: 120

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-9.482590	0.410846	-23.08063	0.0000
((ZWHDPUS-ZWHNPUS)/ZSAJQUS)*(NOV+DEC+JAN+FEB+MAR)	-0.068206	0.071451	-0.954585	0.3421
C4PSPUS(-1)-((C4PSPUS(-13)+C4PSPUS(-25)+C4PSPUS(-37)+C4PSPUS(-49))/4)	-0.115407	0.044827	-2.574472	0.0115
D0509	-5.662188	1.263988	-4.479622	0.0000
D0610	3.381881	1.248129	2.709561	0.0079
D0707	-2.859989	1.250279	-2.287481	0.0243
D1305	2.476357	1.247030	1.985805	0.0498
D1401	-3.750755	1.274210	-2.943592	0.0040
D1407	4.100580	1.249421	3.281983	0.0014
JAN	3.999896	0.548319	7.294829	0.0000
FEB	6.515385	0.540629	12.05149	0.0000
MAR	11.29279	0.537103	21.02537	0.0000
APR	15.93421	0.536459	29.70256	0.0000
MAY	17.35917	0.546717	31.75164	0.0000
JUN	16.99809	0.527464	32.22606	0.0000
JUL	16.52072	0.559009	29.55360	0.0000
AUG	16.83211	0.529073	31.81437	0.0000
SEP	10.50942	0.543010	19.35403	0.0000
OCT	4.486196	0.547938	8.187410	0.0000
NOV	-0.087161	0.528514	-0.164917	0.8693

R-squared	0.974628	Mean dependent var	0.118575
Adjusted R-squared	0.969808	S.D. dependent var	6.777581
S.E. of regression	1.177669	Akaike info criterion	3.315963
Sum squared resid	138.6904	Schwarz criterion	3.780545
Log likelihood	-178.9578	Hannan-Quinn criter.	3.504632
F-statistic	202.1787	Durbin-Watson stat	1.416750
Prob(F-statistic)	0.000000		

Table C6. ETROPUS, Ethane refinery production, regression results

Dependent Variable: ETROPUS
Method: Least Squares
Date: 09/15/15 Time: 09:46
Sample: 2007M01 2014M12
Included observations: 96

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.006241	0.006489	0.961701	0.3392
CORIPUS	0.000961	0.000451	2.133258	0.0361
FEB	-0.001492	0.000947	-1.575997	0.1191
MAR	-0.000794	0.000908	-0.875048	0.3843
APR	-0.000396	0.000920	-0.430671	0.6679
MAY	-0.000587	0.000952	-0.616583	0.5393
JUN	-0.000158	0.001057	-0.149858	0.8813
JUL	-0.001319	0.001030	-1.281442	0.2039
AUG	-0.001424	0.000994	-1.432822	0.1560
SEP	-0.002891	0.000955	-3.027396	0.0034
OCT	-0.001886	0.000910	-2.073121	0.0415
NOV	-0.001135	0.000932	-1.218246	0.2269
DEC	-0.000691	0.000973	-0.710295	0.4797
D1202	-0.005247	0.001960	-2.677033	0.0091
D1206	-0.005613	0.001972	-2.846276	0.0057
D1212	-0.004608	0.001955	-2.357480	0.0209
D1309	0.005141	0.001979	2.598383	0.0112
D1406	-0.004433	0.001998	-2.219140	0.0294
D13ON	-0.013787	0.000580	-23.75916	0.0000

R-squared	0.924349	Mean dependent var	0.015970
Adjusted R-squared	0.906665	S.D. dependent var	0.005942
S.E. of regression	0.001815	Akaike info criterion	-9.609943
Sum squared resid	0.000254	Schwarz criterion	-9.102415
Log likelihood	480.2772	Hannan-Quinn criter.	-9.404792
F-statistic	52.26856	Durbin-Watson stat	1.346050
Prob(F-statistic)	0.000000		

Table C7. ETTCPUS, Ethane consumption, regression results

Dependent Variable: ETTCPUS
Method: Least Squares
Date: 10/08/15 Time: 10:52
Sample: 2011M01 2014M12
Included observations: 48

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.501572	0.167085	3.001893	0.0068
ZO325IUS	0.005660	0.001715	3.299800	0.0034
NGHHUUS/(WTIPUUS/5.8)	-0.421500	0.061531	-6.850229	0.0000
(ZWHDPUS-ZWHNPUS)/ZSAJQUS	0.009505	0.001726	5.508126	0.0000
D1102	-0.034348	0.014906	-2.304299	0.0315
D1103	0.056225	0.014295	3.933200	0.0008
D1105	0.053277	0.015140	3.518829	0.0020
D1108	-0.037430	0.015555	-2.406360	0.0254
D1110	-0.052777	0.014547	-3.628159	0.0016
D1302	0.039405	0.014919	2.641230	0.0153
D1304	0.041707	0.015011	2.778477	0.0113
D1305	0.045480	0.015051	3.021656	0.0065
D1307	0.034161	0.014066	2.428701	0.0242
D1409	0.055440	0.014449	3.836972	0.0010
D1408	0.091405	0.016280	5.614599	0.0000
D14+D1312+D1311+D1310+D1309	0.102481	0.005567	18.40823	0.0000
FEB	-0.038050	0.010336	-3.681383	0.0014
MAR	-0.038622	0.009182	-4.206319	0.0004
APR	-0.076936	0.009222	-8.342807	0.0000
MAY	-0.065596	0.010923	-6.005297	0.0000
JUN	-0.046621	0.008575	-5.436638	0.0000
JUL	-0.019102	0.009096	-2.099960	0.0480
AUG	-0.019549	0.010971	-1.781880	0.0892
SEP	-0.030401	0.009230	-3.293835	0.0035
OCT	-0.004534	0.009580	-0.473310	0.6409
NOV	0.008336	0.008468	0.984376	0.3361
DEC	0.035559	0.009193	3.868194	0.0009

R-squared	0.983602	Mean dependent var	0.986353
Adjusted R-squared	0.963301	S.D. dependent var	0.061624
S.E. of regression	0.011805	Akaike info criterion	-5.742219
Sum squared resid	0.002927	Schwarz criterion	-4.689669
Log likelihood	164.8133	Hannan-Quinn criter.	-5.344459
F-statistic	48.44919	Durbin-Watson stat	1.929459
Prob(F-statistic)	0.000000		

Table C8. ETTPSBLD, Ethane stock build, regression results

Dependent Variable: ETPSBLD
Method: Least Squares
Date: 09/15/15 Time: 15:28
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.434598	0.485839	-2.952828	0.0055
ETPSPUS(-1)-((ETPSPUS(-13)+ETPSPUS(-25)+ETPSPUS(-37)+ETPSPUS(-49))/4)	-0.063451	0.028757	-2.206428	0.0338
(ZWHDPUS-ZWHNPUS)/ZSAJQUS	-0.491846	0.077875	-6.315864	0.0000
D1004	2.730352	0.992820	2.750096	0.0093
D1008	-2.866738	0.998250	-2.871764	0.0068
D1012	3.560832	1.046107	3.403888	0.0016
D1209	2.695540	0.971426	2.774828	0.0087
D1210	1.514664	0.983942	1.539383	0.1325
D1211	1.853086	0.985425	1.880494	0.0682
D1303	2.971482	1.057617	2.809602	0.0080
D1408	-3.005991	1.016149	-2.958219	0.0054
D1403+D1404	2.894368	0.743161	3.894674	0.0004
D1406+D1407	3.110777	0.682114	4.560497	0.0001
JAN	1.577473	0.610942	2.582036	0.0140
FEB	2.841937	0.626803	4.534023	0.0001
MAR	1.346109	0.647081	2.080279	0.0447
APR	3.013585	0.638828	4.717369	0.0000
MAY	3.111951	0.583980	5.328865	0.0000
JUN	1.655852	0.603387	2.744264	0.0094
JUL	0.341339	0.604134	0.565005	0.5756
AUG	2.171016	0.667895	3.250536	0.0025
SEP	0.699617	0.616858	1.134162	0.2642
OCT	1.918899	0.615196	3.119166	0.0036
NOV	2.251407	0.645502	3.487840	0.0013

R-squared	0.842245	Mean dependent var	0.231550
Adjusted R-squared	0.741456	S.D. dependent var	1.695533
S.E. of regression	0.862131	Akaike info criterion	2.830355
Sum squared resid	26.75770	Schwarz criterion	3.668093
Log likelihood	-60.91065	Hannan-Quinn criter.	3.158040
F-statistic	8.356582	Durbin-Watson stat	1.379884
Prob(F-statistic)	0.000000		

Table C9. ETNIPUS, Ethane net imports, regression results

Dependent Variable: ETNIPUS
Method: Least Squares
Date: 09/16/15 Time: 11:33
Sample: 2005M01 2014M12
Included observations: 120

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	8.33E-05	0.000856	0.097384	0.9226
NGHHUUS-(RACPUUS/5.8)	4.18E-05	4.63E-05	0.904116	0.3680
ETNIPUS(-1)	-0.277249	0.102487	-2.705208	0.0080
D14ON*@TREND(2013:12)	-0.006920	0.000510	-13.57847	0.0000
FEB	-0.000670	0.001115	-0.600768	0.5493
MAR	0.000126	0.001121	0.112228	0.9109
APR	0.001276	0.001116	1.143488	0.2554
MAY	0.000922	0.001115	0.826513	0.4104
JUN	0.001718	0.001115	1.540437	0.1265
JUL	0.001075	0.001119	0.960233	0.3391
AUG	-0.000424	0.001118	-0.379352	0.7052
SEP	0.000828	0.001131	0.731835	0.4659
OCT	5.36E-05	0.001116	0.048010	0.9618
NOV	0.001664	0.001126	1.478722	0.1422
DEC	0.000532	0.001118	0.475632	0.6353

R-squared	0.966471	Mean dependent var	-0.003396
Adjusted R-squared	0.962000	S.D. dependent var	0.012749
S.E. of regression	0.002485	Akaike info criterion	-9.040449
Sum squared resid	0.000649	Schwarz criterion	-8.692013
Log likelihood	557.4270	Hannan-Quinn criter.	-8.898948
F-statistic	216.1859	Durbin-Watson stat	1.742287
Prob(F-statistic)	0.000000		

Table C10. PPFPPUS, Natural gasoline natural gas plant production, regression results

Dependent Variable: PPFPPUS
Method: Least Squares
Date: 09/10/15 Time: 10:25
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.449101	0.040518	-11.08393	0.0000
NGMPPUS	0.011576	0.000635	18.23342	0.0000
NGHHUUS-(RACPUUS/5.8)	-0.001019	0.000936	-1.088101	0.2826
D10ON*@TREND(2009:12)-D12ON*@TREND(2011:12)	-0.002291	0.000556	-4.122511	0.0002
D1001	0.026370	0.008770	3.006752	0.0044
D11+D12	-0.014931	0.002753	-5.423683	0.0000
JAN	-0.006109	0.005039	-1.212307	0.2320
FEB	0.005879	0.004834	1.216105	0.2306
MAR	0.009355	0.005068	1.845785	0.0718
APR	0.015688	0.005183	3.026971	0.0042
MAY	0.027689	0.004912	5.636767	0.0000
JUN	0.046845	0.004764	9.832844	0.0000
JUL	0.037348	0.004800	7.780138	0.0000
AUG	0.041435	0.004801	8.631248	0.0000
SEP	0.043359	0.004796	9.041439	0.0000
OCT	0.026828	0.004759	5.636808	0.0000
NOV	0.008874	0.004695	1.889938	0.0655

R-squared	0.983723	Mean dependent var	0.325169
Adjusted R-squared	0.977666	S.D. dependent var	0.049173
S.E. of regression	0.007349	Akaike info criterion	-6.755042
Sum squared resid	0.002322	Schwarz criterion	-6.161645
Log likelihood	219.6513	Hannan-Quinn criter.	-6.522932
F-statistic	162.4187	Durbin-Watson stat	1.168277
Prob(F-statistic)	0.000000		

Table C11. PPRIPUS-PPPRPUS, Natural gasoline blended into motor gasoline, regression results

Dependent Variable: PPRIPUS-PPPRPUS
Method: Least Squares
Date: 09/15/15 Time: 11:58
Sample: 2008M01 2014M12
Included observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.025327	0.036172	-0.700203	0.4863
MGROPUS	0.009884	0.004293	2.302420	0.0245
D1002	-0.031614	0.013522	-2.338020	0.0225
D1209	0.026547	0.013477	1.969764	0.0531
D1212	0.031364	0.013628	2.301506	0.0246
D1305	-0.029634	0.013519	-2.192046	0.0320
D1310	-0.025302	0.013631	-1.856290	0.0679
FEB	0.018705	0.007079	2.642244	0.0103
MAR	0.011491	0.006820	1.684957	0.0968
APR	0.006158	0.006909	0.891351	0.3760
MAY	0.014051	0.007383	1.903111	0.0615
JUN	0.004624	0.007265	0.636490	0.5267
JUL	0.005365	0.007289	0.736059	0.4643
AUG	0.005950	0.007247	0.821003	0.4146
SEP	0.021874	0.007152	3.058571	0.0032
OCT	0.019467	0.007234	2.691091	0.0090
NOV	0.003860	0.007123	0.541918	0.5897
DEC	0.001732	0.007558	0.229192	0.8194
PPRIPUS(-1)-PPPRPUS(-1)	0.589070	0.083433	7.060406	0.0000

R-squared	0.661460	Mean dependent var	0.177469
Adjusted R-squared	0.567711	S.D. dependent var	0.018963
S.E. of regression	0.012468	Akaike info criterion	-5.735341
Sum squared resid	0.010104	Schwarz criterion	-5.185513
Log likelihood	259.8843	Hannan-Quinn criter.	-5.514315
F-statistic	7.055611	Durbin-Watson stat	2.160044
Prob(F-statistic)	0.000000		

Table C12. PPTCPUS, Natural gasoline consumption, regression results

Dependent Variable: PPTCPUS
Method: Least Squares
Date: 09/10/15 Time: 12:50
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.078405	0.018263	4.293053	0.0001
D10	0.057446	0.012576	4.567929	0.0000
D1101	-0.154762	0.037706	-4.104382	0.0002
FEB	-0.030437	0.022758	-1.337465	0.1878
MAR	-0.034908	0.022653	-1.540992	0.1303
APR	-0.031746	0.022746	-1.395681	0.1697
MAY	-0.025930	0.022670	-1.143793	0.2588
JUN	-0.006089	0.022628	-0.269111	0.7891
JUL	-0.037361	0.022577	-1.654805	0.1049
AUG	-0.014092	0.022921	-0.614812	0.5418
SEP	0.014342	0.022572	0.635414	0.5284
OCT	0.002486	0.022713	0.109437	0.9133
NOV	0.016995	0.022571	0.752961	0.4554
DEC	-0.000496	0.022755	-0.021788	0.9827
PPTCPUS(-1)	-0.324828	0.125745	-2.583221	0.0131

R-squared	0.549236	Mean dependent var	0.056652
Adjusted R-squared	0.408999	S.D. dependent var	0.043747
S.E. of regression	0.033632	Akaike info criterion	-3.734388
Sum squared resid	0.050899	Schwarz criterion	-3.210801
Log likelihood	127.0316	Hannan-Quinn criter.	-3.529584
F-statistic	3.916468	Durbin-Watson stat	2.119361
Prob(F-statistic)	0.000238		

Table C13. PPPSBLD, Natural gasoline stock build, regression results

Dependent Variable: PPPSBLD
Method: Least Squares
Date: 09/16/15 Time: 09:07
Sample: 2011M01 2014M12
Included observations: 48

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.166408	0.586411	-0.283774	0.7786
PPPSPUS(-1)-((PPPSPUS(-13)+PPPSPUS(-25)+PPPSPUS(-37)+PPPSPUS(-49))/4)	-0.164584	0.069059	-2.383229	0.0239
D1101	2.904976	0.884289	3.285100	0.0027
D1112	2.019516	0.936425	2.156624	0.0395
D1210	-1.968442	0.948823	-2.074616	0.0470
D1312	-2.694912	0.938305	-2.872108	0.0075
D1409	1.631770	0.880600	1.853021	0.0741
D1410	1.520008	0.936913	1.622357	0.1155
JAN	0.330990	0.701896	0.471565	0.6408
FEB	-0.268838	0.669319	-0.401660	0.6909
MAR	0.720780	0.671036	1.074129	0.2916
APR	0.765570	0.669054	1.144257	0.2619
MAY	1.355623	0.669561	2.024644	0.0522
JUN	1.120785	0.667309	1.679560	0.1038
JUL	1.879768	0.668562	2.811658	0.0087
AUG	1.100672	0.662657	1.661000	0.1075
SEP	-0.005820	0.696292	-0.008359	0.9934
OCT	0.156441	0.762663	0.205125	0.8389
NOV	0.708857	0.660453	1.073288	0.2920

R-squared	0.751304	Mean dependent var	0.168708
Adjusted R-squared	0.596940	S.D. dependent var	1.201222
S.E. of regression	0.762620	Akaike info criterion	2.583647
Sum squared resid	16.86608	Schwarz criterion	3.324331
Log likelihood	-43.00753	Hannan-Quinn criter.	2.863553
F-statistic	4.867114	Durbin-Watson stat	2.086065
Prob(F-statistic)	0.000083		

Table C14. PRFPPUS, Propane natural gas plant production, regression results

Dependent Variable: PRFPPUS
Method: Least Squares
Date: 09/10/15 Time: 09:12
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.657032	0.114954	-14.41477	0.0000
NGMPPUS	0.036517	0.001811	20.16442	0.0000
NGHHUUS-(RACPUUS/5.8)	-0.001427	0.002784	-0.512588	0.6109
D10ON*@TREND(2009:12)-D12ON*@TREND(2011:12)	-0.005495	0.001608	-3.417504	0.0014
D1001	0.067805	0.025675	2.640852	0.0115
D11+D12-(D1101+D1102)	-0.069283	0.008338	-8.309665	0.0000
FEB	0.032563	0.014435	2.255764	0.0292
MAR	0.034725	0.014855	2.337549	0.0241
APR	0.032947	0.015089	2.183538	0.0345
MAY	0.037622	0.014694	2.560287	0.0141
JUN	0.052682	0.014509	3.630969	0.0007
JUL	0.019864	0.014691	1.352141	0.1834
AUG	0.024048	0.014728	1.632820	0.1098
SEP	0.031263	0.014664	2.131992	0.0388
OCT	0.017182	0.014833	1.158356	0.2531
NOV	0.004270	0.014965	0.285308	0.7768
DEC	0.007971	0.015037	0.530102	0.5988

R-squared	0.985318	Mean dependent var	0.746999
Adjusted R-squared	0.979855	S.D. dependent var	0.150741
S.E. of regression	0.021395	Akaike info criterion	-4.617798
Sum squared resid	0.019683	Schwarz criterion	-4.024400
Log likelihood	155.5339	Hannan-Quinn criter.	-4.385687
F-statistic	180.3641	Durbin-Watson stat	1.306179
Prob(F-statistic)	0.000000		

Table C15. PRROPUS, Propane and propylene refinery production, regression results

Dependent Variable: PRROPUS
Method: Least Squares
Date: 09/15/15 Time: 09:59
Sample: 2009M01 2014M12
Included observations: 72

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.195467	0.039562	-4.940766	0.0000
UORIPUSX	0.038351	0.008743	4.386347	0.0001
MGYLD*CORIPUS	0.067272	0.005701	11.80083	0.0000
D1002	0.026958	0.007929	3.399735	0.0013
D1009	0.007412	0.008354	0.887171	0.3792
D1102	-0.017006	0.008387	-2.027611	0.0479
D1209	-0.018443	0.008308	-2.219743	0.0310
D1211	-0.017958	0.007793	-2.304304	0.0254
D1306	-0.017418	0.007801	-2.232967	0.0301
D1409	-0.028734	0.008670	-3.314119	0.0017
FEB	0.006870	0.004789	1.434385	0.1577
MAR	0.010645	0.004501	2.365349	0.0219
APR	0.004904	0.004975	0.985596	0.3291
MAY	-0.012633	0.006221	-2.030738	0.0476
JUN	-0.023015	0.007260	-3.170250	0.0026
JUL	-0.031525	0.007107	-4.435579	0.0001
AUG	-0.028242	0.006200	-4.555139	0.0000
SEP	-0.013025	0.006439	-2.022936	0.0484
OCT	-0.011420	0.004230	-2.699946	0.0094
NOV	0.007051	0.005731	1.230381	0.2243
DEC	0.004919	0.005924	0.830268	0.4103
PRROPUS(-1)	0.413601	0.051151	8.085938	0.0000

R-squared	0.950573	Mean dependent var	0.558720
Adjusted R-squared	0.929813	S.D. dependent var	0.026727
S.E. of regression	0.007081	Akaike info criterion	-6.816410
Sum squared resid	0.002507	Schwarz criterion	-6.120762
Log likelihood	267.3908	Hannan-Quinn criter.	-6.539470
F-statistic	45.78988	Durbin-Watson stat	1.968101
Prob(F-statistic)	0.000000		

Table C16. PRTCPUS, Propane consumption, regression results

Dependent Variable: PRTCPUS
Method: Least Squares
Date: 09/22/15 Time: 10:05
Sample: 2008M01 2014M12
Included observations: 84

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.441333	0.234463	1.882317	0.0647
QHLP_US*PRTCPUS_SF	0.098704	0.032224	3.063086	0.0033
(ZWHD_PRRC-ZWHN_PRRC)/ZSAJQUS	0.025864	0.002886	8.961991	0.0000
ZO325IUS	0.004648	0.001379	3.371635	0.0013
NGHHUUS/(WTIPUUS/5.8)	-0.376236	0.054260	-6.933976	0.0000
D0806	0.123795	0.051945	2.383190	0.0204
D0809	-0.125707	0.049296	-2.550036	0.0134
D0911	0.281344	0.051265	5.487990	0.0000
D1011	-0.123013	0.049881	-2.466136	0.0166
D1205	0.129168	0.049820	2.592690	0.0120
D1301	0.147176	0.049636	2.965118	0.0044
D1310	0.164331	0.048926	3.358769	0.0014
D1405	-0.091036	0.050114	-1.816580	0.0744
JAN	-0.011678	0.036489	-0.320037	0.7501
FEB	-0.066658	0.024751	-2.693186	0.0092
MAR	-0.158150	0.039408	-4.013136	0.0002
APR	-0.281071	0.072055	-3.900813	0.0002
MAY	-0.338184	0.083879	-4.031793	0.0002
JUN	-0.337694	0.076861	-4.393551	0.0000
JUL	-0.307579	0.074809	-4.111509	0.0001
AUG	-0.298690	0.067108	-4.450899	0.0000
SEP	-0.269433	0.063698	-4.229864	0.0001
OCT	-0.213910	0.046201	-4.630027	0.0000
NOV	-0.146081	0.037733	-3.871442	0.0003
PRTCPUS(-1)-PRTCPUS(-13)	0.125419	0.040813	3.073028	0.0032

R-squared	0.976154	Mean dependent var	1.178523
Adjusted R-squared	0.966454	S.D. dependent var	0.244712
S.E. of regression	0.044820	Akaike info criterion	-3.130359
Sum squared resid	0.118522	Schwarz criterion	-2.406902
Log likelihood	156.4751	Hannan-Quinn criter.	-2.839536
F-statistic	100.6352	Durbin-Watson stat	1.579658
Prob(F-statistic)	0.000000		

Table C17. PRPSP1BLD, Propane stock build in PADD1, regression results

Dependent Variable: PRPSP1BLD
Method: Least Squares
Date: 09/16/15 Time: 09:38
Sample: 2009M01 2014M12
Included observations: 72

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.402134	0.147533	-2.725724	0.0087
(QHLP_NEC*(ZWHD_NEC-ZWHN_NEC)/ZSAJQUS+QHLP_MAC*(ZWHD_MAC-ZWHN_MAC)/ZSAJQUS+QHLP_SAC*(ZWHD_SAC-ZWHD_SAC)/ZSAJQUS)/(QHLP_NEC+QHLP_MAC+QHLP_SAC)	-0.163913	0.048278	-3.395156	0.0013
PRPSPP1(-1)-((PRPSPP1(-13)+PRPSPP1(-25)+PRPSPP1(-37)+PRPSPP1(-49))/4)	-0.236468	0.054836	-4.312236	0.0001
D0903	1.120198	0.400491	2.797062	0.0072
D0906	-1.176858	0.398034	-2.956676	0.0046
D1004	-0.989204	0.400202	-2.471763	0.0167
D1307	-1.307627	0.395212	-3.308672	0.0017
D1402+D1403	0.857842	0.324097	2.646867	0.0107
JAN	-1.084059	0.211723	-5.120171	0.0000
FEB	-0.357971	0.217741	-1.644018	0.1061
MAR	-0.177460	0.231695	-0.765920	0.4471
APR	0.975111	0.219361	4.445233	0.0000
MAY	0.921844	0.210835	4.372340	0.0001
JUN	1.098641	0.220086	4.991865	0.0000
JUL	1.091970	0.217520	5.020081	0.0000
AUG	0.618609	0.207496	2.981302	0.0043
SEP	0.899390	0.207476	4.334920	0.0001
OCT	0.801661	0.207461	3.864154	0.0003
NOV	0.383223	0.209591	1.828429	0.0731

R-squared	0.837878	Mean dependent var	0.031181
Adjusted R-squared	0.782818	S.D. dependent var	0.769894
S.E. of regression	0.358793	Akaike info criterion	1.009259
Sum squared resid	6.822800	Schwarz criterion	1.610046
Log likelihood	-17.33331	Hannan-Quinn criter.	1.248434
F-statistic	15.21745	Durbin-Watson stat	1.755398
Prob(F-statistic)	0.000000		

Table C18. PRPSP2BLD, Propane stock build in PADD2, regression results

Dependent Variable: PRPSP2BLD
Method: Least Squares
Date: 09/16/15 Time: 14:38
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.258936	0.284408	-14.97475	0.0000
(QHLP_ENC*(ZWHD_ENC-ZWHN_ENC)/ZSAJQUS+QHLP_WNC*(ZWHD_WNC-ZWHN_WNC)/ZSAJQUS)/(QHLP_ENC+QHLP_WNC)	-0.208069	0.027003	-7.705417	0.0000
PRPSPP2(-1)-((PRPSPP2(-13)+PRPSPP2(-25)+PRPSPP2(-37)+PRPSPP2(-49))/4)	-0.093278	0.026762	-3.485502	0.0012
D14	1.344494	0.224371	5.992267	0.0000
D1301	-2.137326	0.644549	-3.316004	0.0019
D1310	-4.433497	0.660016	-6.717254	0.0000
D1402	2.866734	0.694965	4.125005	0.0002
D1410	-2.098107	0.697568	-3.007744	0.0045
D1412	1.810823	0.688911	2.628531	0.0121
JAN	-0.369260	0.406473	-0.908449	0.3691
FEB	0.417124	0.403778	1.033054	0.3078
MAR	3.432664	0.385821	8.897036	0.0000
APR	6.227147	0.385067	16.17159	0.0000
MAY	7.158945	0.387722	18.46411	0.0000
JUN	6.853746	0.385117	17.79651	0.0000
JUL	6.703855	0.385146	17.40603	0.0000
AUG	6.331351	0.386322	16.38880	0.0000
SEP	5.553142	0.384787	14.43174	0.0000
OCT	4.329915	0.435391	9.944894	0.0000
NOV	3.625605	0.383883	9.444557	0.0000

R-squared	0.976078	Mean dependent var	0.122650
Adjusted R-squared	0.964715	S.D. dependent var	3.026344
S.E. of regression	0.568479	Akaike info criterion	1.969496
Sum squared resid	12.92672	Schwarz criterion	2.667611
Log likelihood	-39.08488	Hannan-Quinn criter.	2.242567
F-statistic	85.89956	Durbin-Watson stat	1.806327
Prob(F-statistic)	0.000000		

Table C19. PRPSP3BLD, Propane stock build in PADD3, regression results

Dependent Variable: PRPSP3BLD
Method: Least Squares
Date: 09/17/15 Time: 10:27
Sample: 2010M01 2014M12
Included observations: 60

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.105196	0.623280	-4.982022	0.0000
(QHLP_ESC*(ZWHD_ESC-ZWHN_ESC)/ZSAJQUS+QHLP_WSC*(ZWHD_WSC-ZWHD_WSC)/ZSAJQUS)/(QHLP_ESC+QHLP_WSC)	-0.800057	0.141353	-5.659992	0.0000
PRPSPP3(-1)-((PRPSPP3(-13)+PRPSPP3(-25)+PRPSPP3(-37)+PRPSPP3(-49))/4)	-0.029211	0.027799	-1.050804	0.2990
D14	1.953681	0.455289	4.291081	0.0001
JAN	-1.796652	0.882684	-2.035443	0.0477
FEB	1.146931	0.875307	1.310319	0.1967
MAR	2.367703	0.865710	2.734983	0.0089
APR	3.765321	0.862234	4.366936	0.0001
MAY	5.553648	0.863075	6.434724	0.0000
JUN	6.259117	0.864535	7.239869	0.0000
JUL	5.935913	0.864870	6.863356	0.0000
AUG	5.400267	0.865315	6.240809	0.0000
SEP	3.927197	0.865823	4.535796	0.0000
OCT	2.245471	0.865876	2.593294	0.0128
NOV	2.568914	0.881404	2.914571	0.0055

R-squared	0.848202	Mean dependent var	0.292717
Adjusted R-squared	0.800976	S.D. dependent var	3.055471
S.E. of regression	1.363110	Akaike info criterion	3.669733
Sum squared resid	83.61313	Schwarz criterion	4.193319
Log likelihood	-95.09199	Hannan-Quinn criter.	3.874536
F-statistic	17.96046	Durbin-Watson stat	1.238576
Prob(F-statistic)	0.000000		

Table C20. PRPSP4BLD, Propane stock build in PADD4, regression results

Dependent Variable: PRPSP4BLD
Method: Least Squares
Date: 09/16/15 Time: 13:44
Sample: 2006M01 2014M12
Included observations: 108

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.008887	0.009828	-0.904220	0.3684
(ZWHD_MTN-ZWHN_MTN)/ZSAJQUS	-0.004946	0.001697	-2.914635	0.0045
PRPSPP4(-1)-((PRPSPP4(-13)+PRPSPP4(-25)+PRPSPP4(-37)+PRPSPP4(-49))/4)	0.009720	0.013285	0.731634	0.4664
D0602	-0.140290	0.029279	-4.791508	0.0000
D0912	-0.075647	0.030168	-2.507529	0.0140
D1003	-0.080335	0.029645	-2.709854	0.0081
D1304	0.236213	0.029362	8.044846	0.0000
D1403	0.108081	0.029795	3.627499	0.0005
D1407	0.128736	0.029653	4.341473	0.0000
D1408	0.201698	0.030095	6.702114	0.0000
D1409	0.188473	0.030933	6.092979	0.0000
JAN	-0.023641	0.013458	-1.756686	0.0825
FEB	0.038740	0.013890	2.789085	0.0065
MAR	0.012913	0.014343	0.900273	0.3705
APR	0.008093	0.013795	0.586666	0.5590
MAY	0.036833	0.013414	2.745918	0.0073
JUN	0.007511	0.013441	0.558828	0.5777
JUL	0.008504	0.013876	0.612864	0.5416
AUG	0.011274	0.013888	0.811776	0.4192
SEP	0.015897	0.013911	1.142774	0.2563
OCT	0.039779	0.013406	2.967181	0.0039
NOV	0.005105	0.013657	0.373828	0.7095

R-squared	0.778123	Mean dependent var	0.007722
Adjusted R-squared	0.723944	S.D. dependent var	0.052494
S.E. of regression	0.027581	Akaike info criterion	-4.163777
Sum squared resid	0.065420	Schwarz criterion	-3.617417
Log likelihood	246.8439	Hannan-Quinn criter.	-3.942248
F-statistic	14.36203	Durbin-Watson stat	2.218256
Prob(F-statistic)	0.000000		

Table C21. PRPSP5BLD, Propane stock build in PADD5, regression results

Dependent Variable: PRPSP5BLD
Method: Least Squares
Date: 09/16/15 Time: 10:33
Sample: 2009M01 2014M12
Included observations: 72

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.768721	0.041079	-18.71303	0.0000
ZWHD_PAC-ZWHN_PAC	-0.001085	0.000204	-5.313232	0.0000
PRPSPP5(-1)-((PRPSPP5(-13)+PRPSPP5(-25)+PRPSPP5(-37)+PRPSPP5(-49))/4)	-0.438611	0.051628	-8.495595	0.0000
D10	-0.094950	0.026363	-3.601576	0.0007
D1105	-0.161970	0.078246	-2.070002	0.0436
D1112	0.285168	0.079723	3.576976	0.0008
D12	0.074725	0.027927	2.675765	0.0101
D1207	0.303212	0.078965	3.839834	0.0003
D1209	0.186356	0.078771	2.365781	0.0219
D1212	0.380601	0.082682	4.603194	0.0000
D1412	0.502822	0.082672	6.082113	0.0000
JAN	0.043375	0.049704	0.872659	0.3870
FEB	0.546588	0.048768	11.20802	0.0000
MAR	0.704754	0.048494	14.53273	0.0000
APR	1.012370	0.048478	20.88307	0.0000
MAY	1.134542	0.050828	22.32118	0.0000
JUN	1.206577	0.049304	24.47197	0.0000
JUL	1.192744	0.051125	23.33016	0.0000
AUG	1.108105	0.049634	22.32569	0.0000
SEP	1.067185	0.051376	20.77207	0.0000
OCT	0.894314	0.049091	18.21744	0.0000
NOV	0.691844	0.048588	14.23886	0.0000

R-squared	0.978534	Mean dependent var	0.004736
Adjusted R-squared	0.969518	S.D. dependent var	0.390187
S.E. of regression	0.068123	Akaike info criterion	-2.288543
Sum squared resid	0.232035	Schwarz criterion	-1.592896
Log likelihood	104.3876	Hannan-Quinn criter.	-2.011604
F-statistic	108.5365	Durbin-Watson stat	1.857044
Prob(F-statistic)	0.000000		