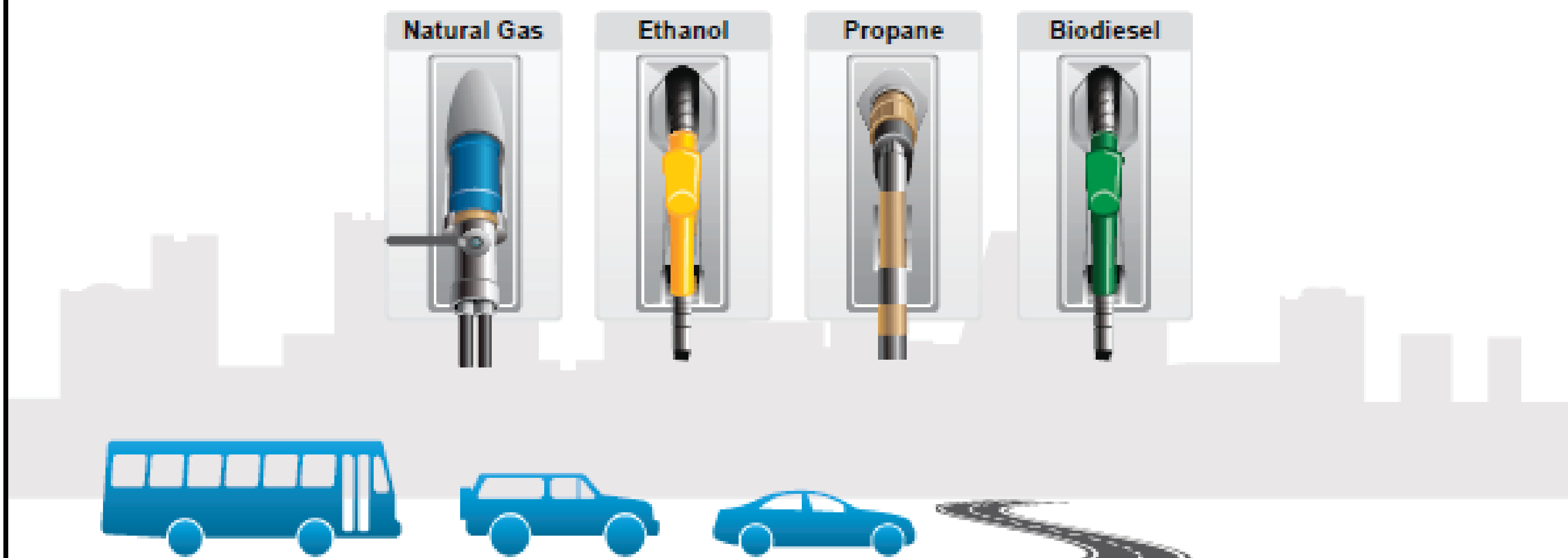
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

June 2016



CLEAN CITIES Alternative Fuel Price Report

SPECIAL REPORT ON PRICE VARIABILITY

Clean Cities
U.S. Department of Energy

Introduction

This special report on historical price variability is provided as a supplement to the quarterly Clean Cities Alternative Fuel Price Report. This report examines how variable alternative fuel and conventional fuel prices have been over time. The report uses statistical methods for analyzing such data sets and extracting the appropriate variability metrics. The intention of this report is to help illustrate numerically how transportation fuel prices vary over time, and which fuels exhibit lower (more favorable) variability. Lower variability can help fleets justify the business case for adoption of a particular fuel, and insulate the fleet from price spikes in transportation fuels. Clean Cities intends this to be a periodic report, potentially published once or twice per year depending on interest level.

Overview of Methodology

This special report analysis uses the average prices for transportation fuels collected as part of the quarterly Clean Cities Alternative Fuel Price Report, dating back to the start of its current methodology in September 2005, and continuing through the April 2016 report. This data set includes nearly 10 years of prices for gasoline, diesel, natural gas, ethanol (E85), propane, and biodiesel (B20). To ensure a statistically significant sample for each fuel, the national-level average prices were used. Regional-level prices are also collected, but some of these data sets are too small for accurate analysis at this geographic level.

The price data sets are known in the statistical world as “time series data sets,” which are simply data that change over time. Analyzing the statistical variability of time series data is more complex than simply taking a standard deviation of each fuel’s time series data set and comparing these standard deviations to get relative variability. This is because data sets like these transportation fuel prices have several components that add up to the overall time series path, as described below.

- There is a **general trend** over time for the transportation fuel prices that represents how the fuel price is broadly changing (is it going up, going down, staying the same, or some combination of these), as driven by long-term considerations (for example, hydraulic fracturing technology for natural gas that lowered natural gas prices over time).
- There is a **seasonality trend** over time that represents how the transportation fuel prices are changing as a result of the changes in weather (does the fuel get more expensive in the winter months because of its other uses, or does it get more expensive in the summer because of transportation demand).
- The **remainder variability** over time represents the often unpredictable short term price fluctuations resulting from external factors like hurricanes, political unrest, and the like, as well as other factors not associated with seasonality and broader trendlines.

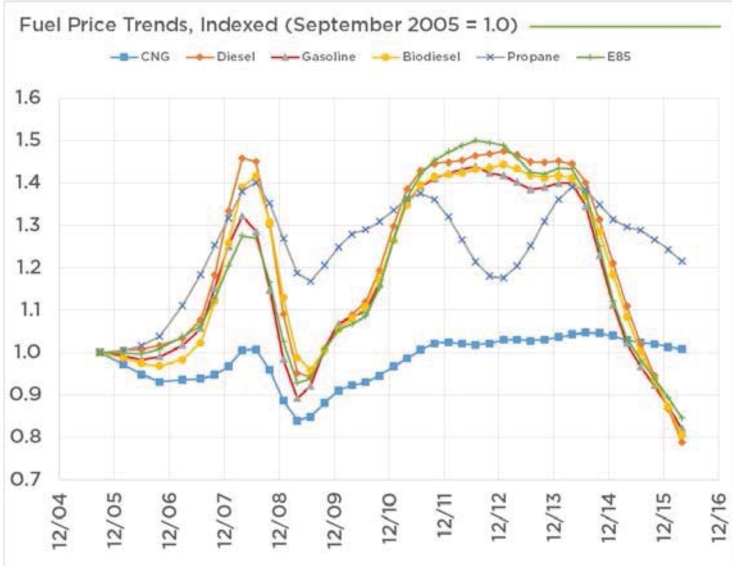
The combination of all these trends produces prices as a function of time that can appear to be completely random at first glance. Extracting these separate trends and comparing them is difficult with simple statistics, but more complex statistical methods can isolate these separate price components and illustrate their magnitudes. This report uses seasonal and trend decomposition using Locally Estimated Scatterplot Smoothing (LOESS). This methodology assumes that seasonality is a value added on top of the trend and remainder, and the trend is isolated by taking a moving average of the difference between the data and the seasonality. Several references are provided at the end of this document to explain the statistical methods used in more detail.

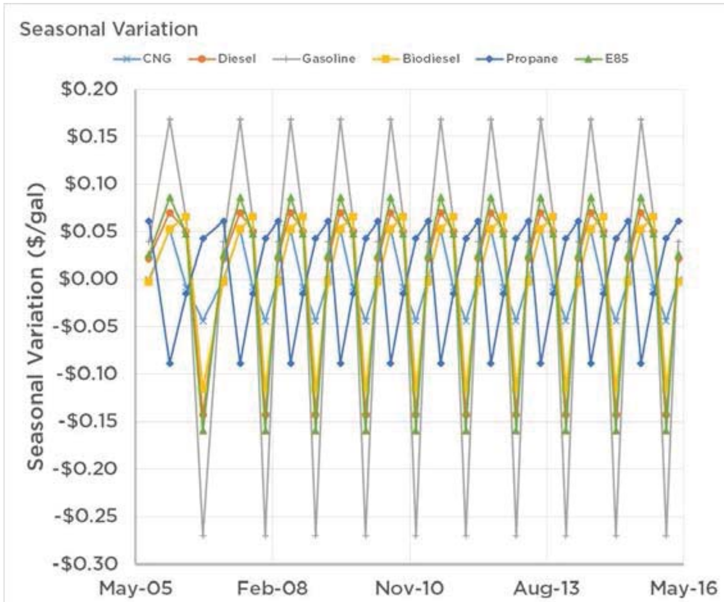
This report will review the components of the fuel price trend for each fuel: the trends over time (do the fuel prices for alternative fuel and competing conventional fuels track each other); the remainder variability (how much do the fuel prices vary around the general trend, or how “noisy” is the fuel price); and the correlation between each alternative fuel and its corresponding conventional fuel (do these fuel prices seem to be tied to each other, or are they completely independent).

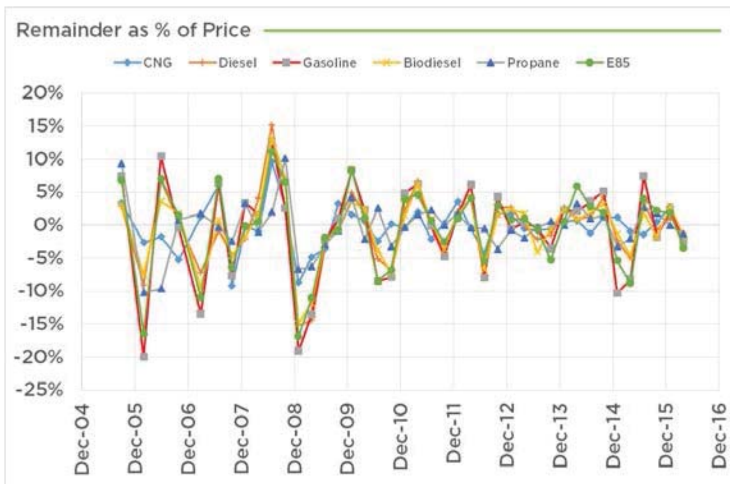
High-Level Results

The graphs on this page present the three components of the fuel price for all the fuels analyzed: the top graph is the fuel price trend (normalized to September 2005), the middle graph is the seasonal variation, and the bottom is the remainder (not trend or seasonal) variation. Several high-level conclusions can be drawn from these graphs.

1. The trends for gasoline, diesel, biodiesel, and E85 are very similar over time, showing price rises in the 2007-2008 timeframe and the 2012-2014 timeframe. Biodiesel and E85 appear to be tightly coupled to their corresponding conventional fuels.
2. The trends for propane and CNG are different from the other fuels in this list. Propane shows a trend similar to gasoline and diesel through 2008, and then a very different trend. CNG shows a relatively stable price over time.
3. Seasonal variations add or subtract very little to the fuel price over time (less than 1 cent per gallon, on average). All the fuels, with the exception of propane, have similar seasonal trends, but at different magnitudes.
4. Based on a root sum of squares (RSS) [1] analysis of the remainder variability, CNG and propane have the lowest overall variability, and gasoline the highest.
5. The remainder variability is lower between 2009 and 2016 than in the 2005-2009 timeframe, possibly due to the stabilization of the data collection processes between 2005 and 2009.
6. There do not appear to be any fuel-specific trends in the remainder variability.







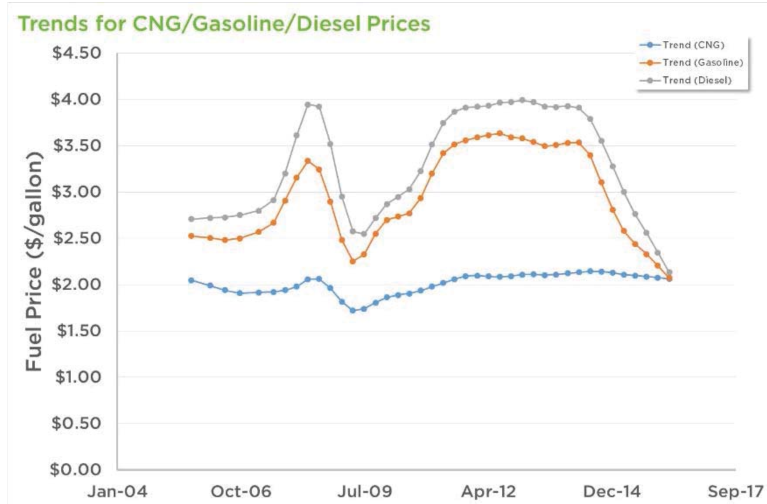
[1] Root sum of squares, or RSS, is a statistical method to estimate the variation of some quantity around a typical behavior: here, it estimates the changes in remainder around the general trend in fuel prices. Lower RSS numbers represent lower variations.

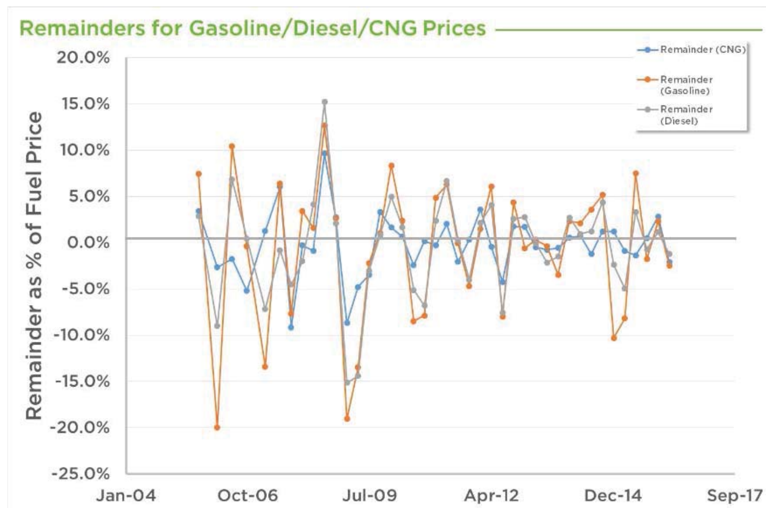
Natural Gas (Relative to Gasoline and Diesel)

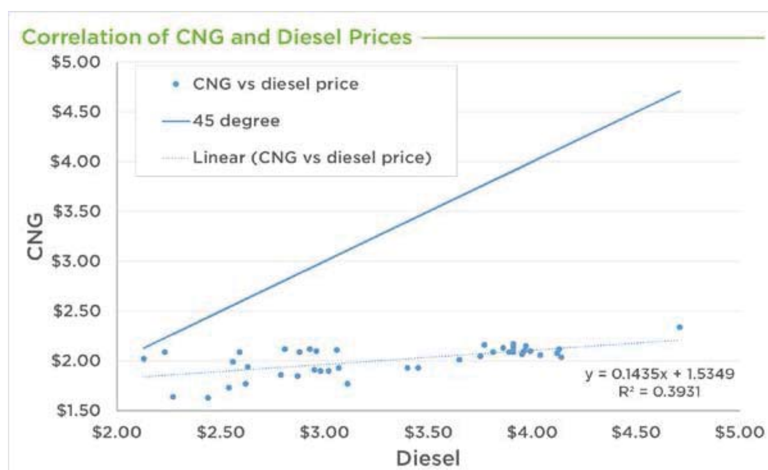
The top graph illustrates the general trends of natural gas prices over time, relative to conventional gasoline and diesel prices. As this graph shows, the general trend for natural gas has been relatively consistent over the 2005-2016 timeframe at a price in the $2 per gasoline gallon equivalent range, while gasoline and diesel fuel prices have risen and fallen more dramatically, and following similar trends.

The price remainders (the price data minus the seasonality and trends) are shown in the middle graph, normalized as a percent of the fuel price. The CNG price remainders are generally lower than those for gasoline and diesel, implying a lower price variability for CNG. The root sum of squares (RSS) of the price remainder as a percent of fuel price is 22% for CNG, 48% for gasoline, and 35% for diesel.

The lower graph illustrates the level of coupling between CNG prices and gasoline/diesel prices, to show how closely tied the prices of these two fuels are to each other. If CNG and gasoline/diesel prices were directly tied to each other, the CNG price line would directly follow the 45 degree line on the graph (that is, each increase or decrease in CNG price would directly follow a similar increase or decrease in gasoline or diesel price). As the graph shows, the CNG price does not follow the 45 degree line, so CNG prices for transportation are relatively independent of diesel prices. (The trend is similar for gasoline, but is not shown here.)





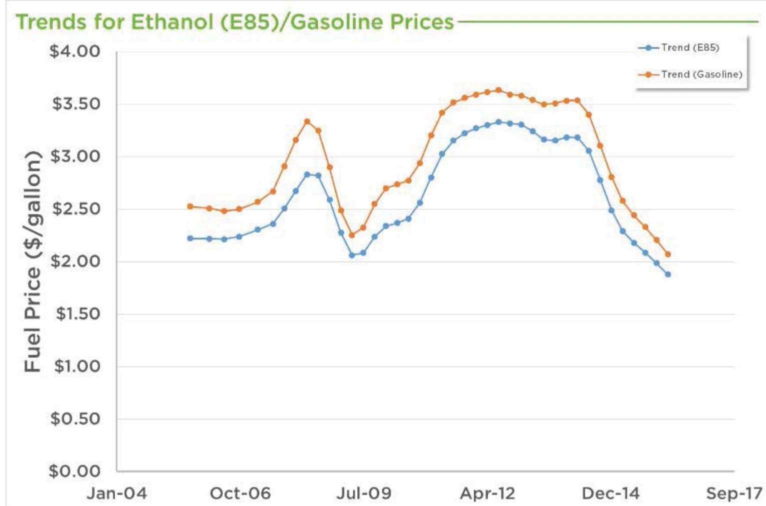


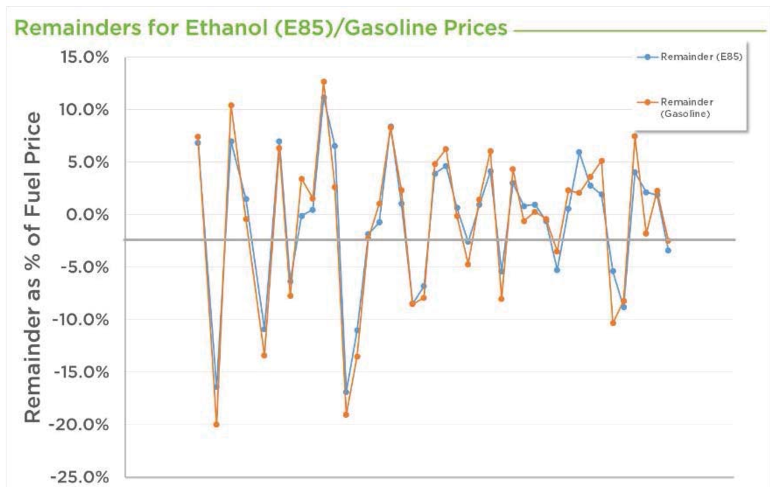
Ethanol (E85)

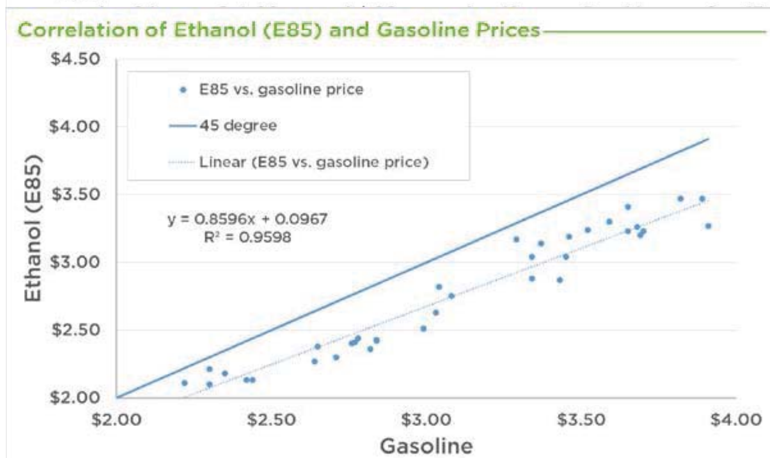
The top graph illustrates the general trends of ethanol (E85) prices over time, relative to conventional gasoline prices. As this graph shows, E85 price trends closely follow those of gasoline, as could be expected given the close relationship between ethanol and gasoline (ethanol is used for a large portion of the current gasoline stock in a 10 percent blend, so prices for ethanol might be expected to track closely with gasoline).

The price remainders (the price data minus the seasonality and trends) are shown in the middle graph, normalized as a percent of the fuel price. The E85 price remainders are close to those for gasoline, implying similar price variability for E85 and gasoline. The root sum of squares (RSS) of the price remainder as a percent of fuel price is 41% for E85 and 48% for gasoline.

The lower graph illustrates the level of coupling between E85 prices and gasoline prices, to show how closely tied the prices of these two fuels are to each other. If E85 and gasoline prices were directly tied to each other, the E85 price line would directly follow the 45 degree line on the graph (that is, each increase or decrease in E85 price would directly follow a similar increase or decrease in gasoline price). As the graph shows, the E85 price generally follows the 45 degree line at a slight offset, so E85 prices for transportation are closely tied to gasoline prices. The reason for the offset is difficult to determine strictly from this data set, but may be attributable to tax credits applied on a per gallon basis for ethanol.





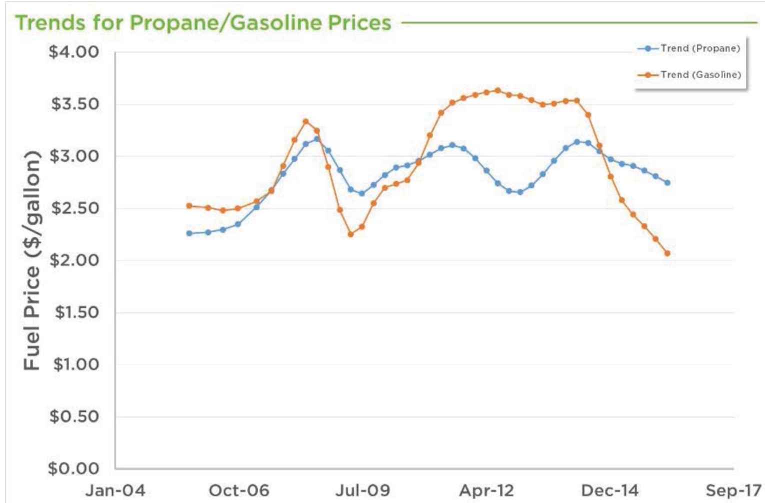


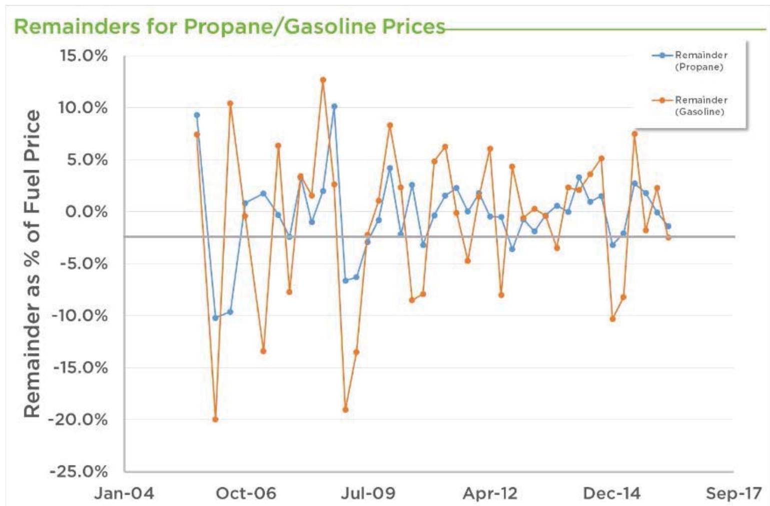
Propane

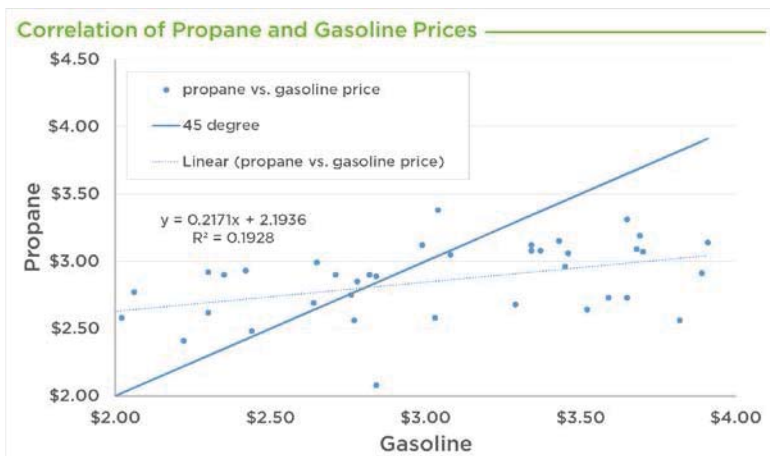
The top graph illustrates the general trends of propane prices over time, relative to conventional gasoline prices. As this graph shows, propane price trends do not follow those of gasoline. Propane exhibits a much different behavior than gasoline, particularly during the 2012-2014 period when gasoline prices were high. During the economic recession in 2008-2009, propane and gasoline prices followed similar trends.

The price remainders (the price data minus the seasonality and trends) are shown in the middle graph, normalized as a percent of the fuel price. The propane price remainders are lower than those for gasoline, implying a lower price variability for propane. The root sum of squares (RSS) of the price remainder as a percent of fuel price is 25% for propane and 48% for gasoline.

The lower graph illustrates the level of coupling between propane prices and gasoline prices, to show how closely tied the prices of these two fuels are to each other. If propane and gasoline prices were directly tied to each other, the propane price line would directly follow the 45 degree line on the graph (that is, each increase or decrease in propane price would directly follow a similar increase or decrease in gasoline price). As the graph shows, the propane price does not follow the 45 degree line, so propane prices for transportation are relatively independent of gasoline prices.





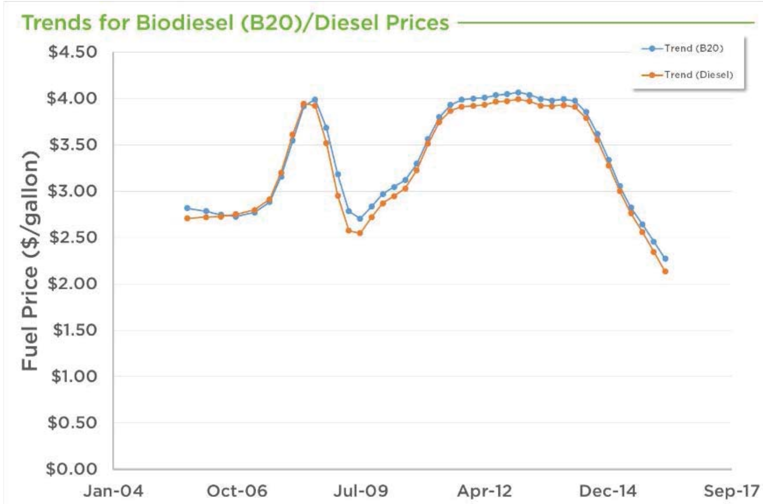


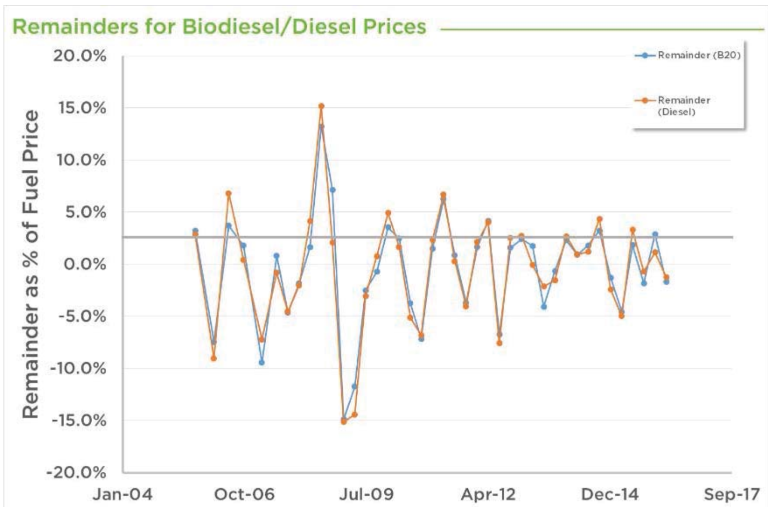
Biodiesel (B20)

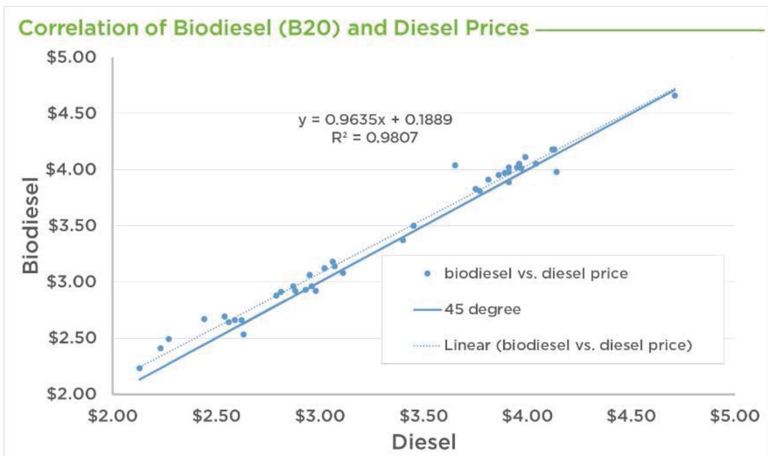
The top graph illustrates the general trends of biodiesel (B20) prices over time, relative to conventional diesel prices. As this graph shows, B20 price trends follow conventional diesel price trends almost exactly. This would be expected, as a B20 blend is 80 percent diesel fuel, and B20 can be used interchangeably with conventional fuel so its price will likely follow conventional diesel and be close to the diesel price.

The price remainders (the price data minus the seasonality and trends) are shown in the middle graph, normalized as a percent of the fuel price. The B20 price remainders are very close to those for diesel, implying very similar price variability for B20 and diesel. The root sum of squares (RSS) of the price remainder as a percent of fuel price is 33% for B20 and 35% for diesel.

The lower graph illustrates the level of coupling between B20 prices and diesel prices, to show how closely tied the prices of these two fuels are to each other. If B20 and diesel prices were directly tied to each other, the diesel price line would directly follow the 45 degree line on the graph (that is, each increase or decrease in B20 price would directly follow a similar increase or decrease in diesel price). As the graph shows, the B20 price closely follows the 45 degree line, so B20 prices for transportation are tied very closely to diesel prices.







References

Below are several online references that explain seasonal and trend decomposition in more detail.

https://www.otexts.org/fpp/6/5

http://robjhyndman.com/uwafiles/5-Cross-validation.pdf

http://www.wessa.net/download/stl.pdf

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