




Geography of Existing and Potential Alternative Fuel Markets in the United States

Caley Johnson and Dylan Hettinger

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Technical Report
NREL/TP-5400-60891
November 2014

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All judgments in the final weighting of market factors, resulting maps, and analytical interpretations are the responsibility of the authors and not of the experts acknowledged above.

List of Acronyms

AFDC	Alternative Fuels Data Center
AFV	alternative fuel vehicle
B20	20% biodiesel in 80% petroleum diesel
CNG	compressed natural gas
DOE	U.S. Department of Energy
E85	blends containing 51% to 83% ethanol, depending on geography and season
FFV	flexible fuel vehicle
HEV	hybrid electric vehicle
MV	market value
NREL	National Renewable Energy Laboratory
OPIS	Oil Price Information Service
PEV	plug-in electric vehicle
PV	photovoltaic

Executive Summary

When deploying alternative fuels, it is paramount to match the right fuel with the right location, in accordance with local market conditions. We used six market indicators to evaluate the existing and potential regional market strength for each of the five most commonly deployed alternative fuels: electricity (used by plug-in electric vehicles), biodiesel (blends of B20 and higher), E85 ethanol, compressed natural gas (CNG), and propane. Each market indicator was mapped, combined with the others, and evaluated and adjusted by industry experts. This process revealed the weight the market indicators should be given, with the proximity of fueling stations being the most important indicator, followed by alternative fuel vehicle density, gasoline prices, state incentives, nearby resources, and finally, environmental benefit.

Though markets vary among states, no state received “weak” potential for all five fuels, indicating that all states have an opportunity to use at least one alternative fuel. California, Illinois, Indiana, Pennsylvania, and Washington appear to have the best potential markets for alternative fuels in general, with each sporting strong markets for four of the fuels. Wyoming showed the least potential, with weak markets for all alternative fuels except for CNG, for which it has a patchy market. Of all the fuels, CNG is promising in the greatest number of states—largely because freight traffic provides potential demand for many far-reaching corridor markets and because the sources of CNG are so widespread geographically.

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Introduction

It has become a common mantra in the alternative fuel deployment world that there will be no single "silver bullet" to reduce consumption of conventional fuels. Rather, a combination of all viable fuels and vehicle technologies is necessary to improve U.S. energy security and reduce environmental impacts. But in any given location, some fuels may be better than others in terms of economic viability, ease of deployment, and environmental benefits. This report maps indicators of existing and potential fuel supply and demand to provide insight into the regional applicability of various alternative transportation fuels. Because no alternative fuel markets are close to saturation, significant market activity in a particular geographic area also indicates strong potential for future growth. The process by which the fuel markets are mapped reveals the relative prioritization of market indicators, enabling policymakers, entrepreneurs, investors, fleets, and analysts in a particular geographic area to pursue the most appropriate or promising fuel. This prioritization scheme also highlights the market components most in need of improvement for those hoping to prime a specific market in a given area. Finally, the report gives a fuel-based summary of the state markets for use by national-level policymakers, investors, and entrepreneurs.

This type of analysis has been commonly deployed for the incipient hydrogen market (Agnolucci and McDowall 2013), but little such work has been performed for fuels with greater market penetration. Analysis of these fuel markets has the potential of higher fidelity and usefulness, because there is more data to inform the analysis.

Fuel markets considered by this study include electricity (for use by plug-in electric vehicles [PEVs]), biodiesel (blends of B20 and higher), propane, compressed natural gas (CNG), and E85 (blends containing 51% to 83% ethanol, depending on geography and season). Our analysis does not include hydrogen, as our focus is on markets that are more developed. Nor does it include liquefied natural gas, which is strategically deployed by large fleets and not considered a promising fuel for non-fleet vehicles.

Methodology

Our project employed the following general steps in order to identify market potential for alternative fuels in various geographic areas of the United States:

1. Gather market indicators—data that have been shown (or are assumed by market experts) to have a positive association with existing or potential supply or demand of alternative fuels.
2. Convert all indicators to a percentile value (attributed to 10X10 km squares) to ensure equal baselines when weighting and comparing indicators.
3. Apply a generalized prioritization scheme and weighting of those parameters, and combine to calculate a single market-strength value for each fuel in a specified geographic area.
4. Poll market experts to ensure that the calculated scores match the known, general pattern of existing markets and deployment patterns of each fuel.

5. Adjust parameter weights so that the most active market areas better match the expectations of industry experts.
6. Study locations in which the order of prioritization of a given fuel was changed from the generalized prioritization scheme, as such cases have the highest potential to reveal market insights.
7. For each fuel, categorize states (in categories ranging from weak to strongest) based on each state's overall market potential and the geographical distribution pattern of market potential within the state.

General Market Indicators

Each fuel has market indicators that are either proven through previous analysis or assumed to be reasonable by industry experts. Proven indicators have a positive association with the potential or existing supply or demand of alternative fuels. Assumed indicators have been included to help test the actual influence of known market indicators.

The six market indicators used in this analysis are described below.

1. Existing Fueling Stations

The availability of fueling infrastructure is a primary indicator of a strong market for a given fuel. If fueling stations are operating in a given area, we can safely assume there are vehicles that can use the fuel and a population that is willing to use it. We assigned a five-mile circle of influence to each station (public and private) listed in the Alternative Fuels Data Center (AFDC) stations database (AFDC 2013b). This limit reflects the relative unwillingness of drivers to travel out of their way to refuel. Daley et al. (forthcoming) found that only 14% of surveyed federal fleet drivers were willing to drive five or more miles to refuel with an alternative fuel when they had readier access to a conventional fuel compatible with their vehicles. Notably, stations selling only low-level blends of ethanol (lower than E51) or biodiesel (lower than B20) are not tracked by the AFDC. Consequently, this study does not include such stations in the analysis.

2. Vehicle Density

The density of light-duty alternative fuel vehicles (AFVs) using a given fuel is another strong indicator of existing and/or potential demand. We calculated vehicle density for each fuel by dividing the number of vehicles in each U.S. ZIP code by the area of that ZIP code. Density is more telling than the absolute number of vehicles, because ZIP codes vary greatly by geographic size—a given ZIP code may have a large total number of vehicles simply because it is physically large. Vehicle density better describes the number of AFVs that could *conveniently* refuel at a given location rather than the total number that could *possibly* refuel.

We used diesel vehicles as a proxy for biodiesel vehicles because vehicle registrations do not differentiate between vehicles that can use B20 and vehicles that cannot. Furthermore, a majority of diesel vehicle models can use B20 (National Biodiesel Board 2012).

We included an additional factor in the vehicle density calculations for three of the five fuel types. Biodiesel market analysis also accounts for freight ton-miles (and weighs it higher than diesel light-duty vehicles) because the majority of freight is transported by diesel (I.C.F. Consulting 2005). Number of freight ton-miles is, therefore, a key indicator of diesel demand.

This demand for diesel translates to potential B20 demand, because, as previously noted, a majority of heavy-duty diesel engine models are able to use B20 (National Biodiesel Board 2012). The CNG market analysis also considers freight ton-miles, because CNG is being used in an increasing number of long-haul applications (Baker 2013).

In the electric vehicle market analysis, we used density data from the more mature hybrid electric vehicle (HEV) market to supplement the plug-in electric vehicle (PEV) density data, as HEV ownership has proven to be a prime indicator of potential PEV purchasers (Tal et al. 2013). Given the incipiency of the PEV market at the time the data were gathered, we assigned a higher weighting to HEV density than to PEV density.

Vehicle counts used in this report are light-duty vehicle registrations aggregated from local motor vehicle departments by R.L. Polk & Co. CNG and propane vehicles are underreported in this dataset, as they are often the products of after-market conversions or classified as dual-fueled vehicles. These nuances are not reflected in the vehicle identification number, which the data collection process relies on. We adjusted the study strategy for this shortcoming, as discussed in the results section.

3. Gasoline and Diesel Prices

When other factors are equal, higher gasoline and diesel prices improve the economic case for using alternative fuels (Johnson and Melendez 2007; Johnson 2010). Therefore, we took into consideration gasoline or diesel prices (depending on which competes with the alternative fuel in question) when showing which regions of the nation are favorable for alternative fuel deployment. Figure 1 maps the average gasoline price (in percentiles to facilitate comparison) throughout the United States, as recorded by the Oil Price Information Service (OPIS 2010). We used 2010 average fuel prices because it was a year of relative price stability and few events that would have regional influence on prices. The diesel map exhibits similar trends. In general, these fuel prices are lowest along the Gulf Coast and increase in the North and West. Hawaii has the most expensive gasoline, followed by Alaska, California, Washington, Nevada, Oregon, New York, Idaho, and Connecticut. Gasoline price is highly dependent on state boundaries because the state fuel tax is one of the most regionally variable components of the price.

4. State Incentives

State incentives range from tax credits for installing fueling infrastructure to allowing AFVs to drive in high occupancy vehicle lanes. By definition, these incentives encourage the use of targeted fuels and technologies. We gave them less weight than we gave to resource proximity because of the wide range of type, structure, and monetary value of incentives. State incentives are tracked by the Laws and Incentives section of the AFDC (AFDC 2013a). The keepers of the AFDC are currently assessing the efficacy of various categories of laws and incentives, but there work is not done yet so all laws and incentives are given an equal weighting.

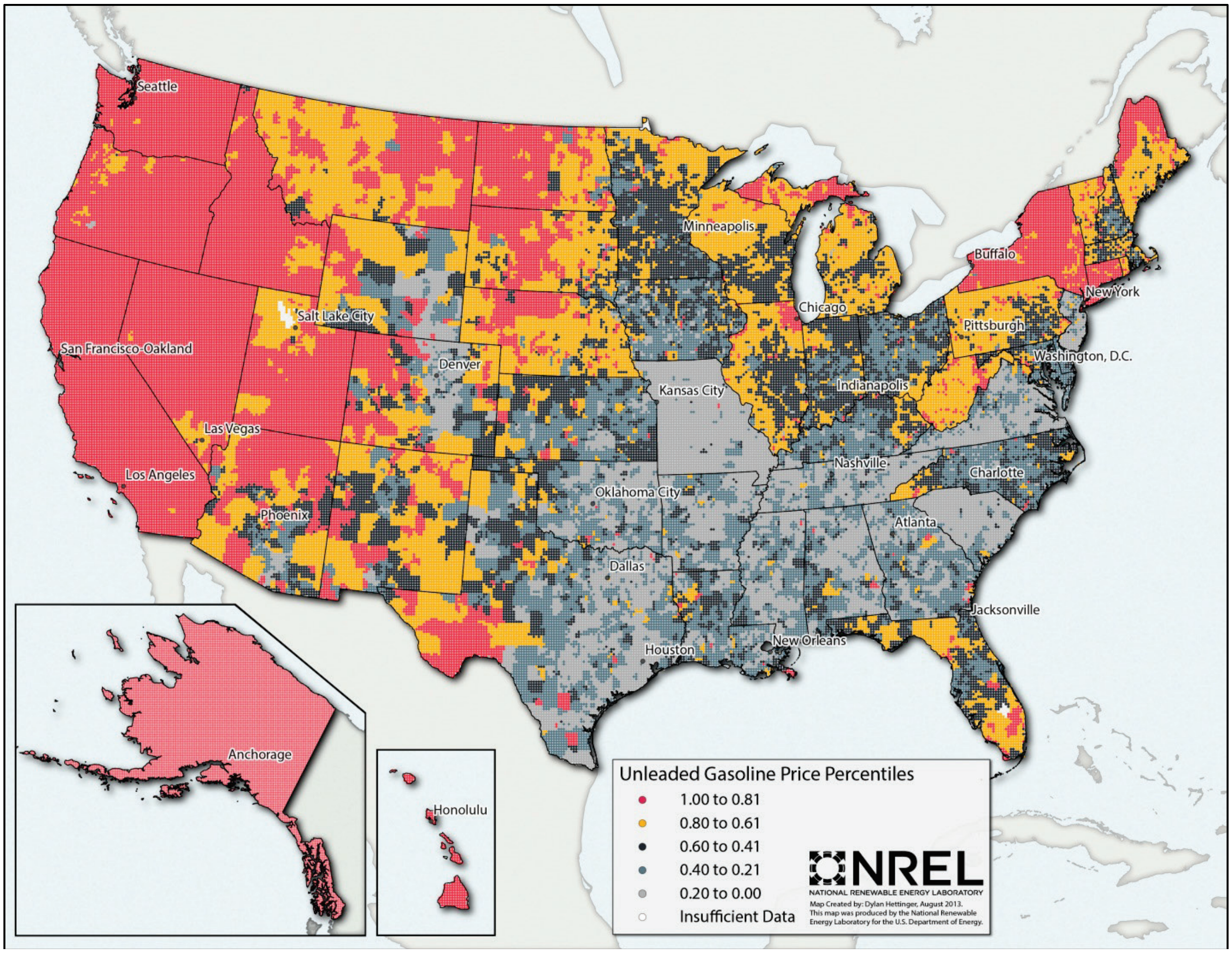

Figure 1. Gasoline price percentiles by ZIP code. Data source: OPIS 2010.

5. Resource Proximity

Proximity to biodiesel and ethanol refineries is used as an indicator of supply. In general, we assumed that locations closer to refineries have lower fuel transportation costs and, therefore, lower fuel prices. This is particularly important for fuels such as ethanol and biodiesel, which are transported by truck and rail rather than pipelines (Wu 2008). Furthermore, communities near biofuel refineries have been shown to be supportive of biofuel consumption because they expect job creation, new markets for farm products, and greater energy security (Selfa 2010). We assigned a radius of influence of 100 miles to reflect the general limit at which ethanol can be trucked cost-effectively (Johnson and Melendez 2007). We did not account for rail lines in the distance calculations, because, while they can reduce transportation costs, they do not offer the community benefits that biorefineries do.

Natural gas processing plants, as reported and mapped by the U.S. Energy Information Administration (2013), serve as the “resources” for CNG. Both natural gas processing plants and petroleum refineries serve as the resources for propane, because propane is produced in approximately equal parts in both facilities (National Propane Gas Association 2013). These resources are assumed to have local influence in a manner similar to biorefineries and are, therefore, also mapped with a circle of influence. However, breaks at radii of 50, 100, and 150 miles are used to reflect a diminishing influence as distance from the plant increases.

Given that access to electricity is nearly ubiquitous in the continental Unites States, resource proximity does not vary regionally in any meaningful way for the purposes of this study. However, proximity to photovoltaic (PV) panels does serve as a good indicator of demand for electricity for use by PEVs, because ownership of PEVs is highly correlated with PV panel ownership, as demonstrated in a survey of PEV-owning California households by Tal et al. (2013). The study found that 42% of PEV owners surveyed had PV panels, a significantly higher ownership rate than the statewide average of less than 1%.

6. Environmental Benefit

Environmental benefit is one of the most commonly cited reasons for using alternative fuels. For some alternative fuels, the degree of benefit is dependent on geographic location. This regional variability is most pronounced for electricity, where the degree of benefit ultimately depends on the fuels used to generate the electricity in a given region. In this report, we used carbon intensity of electricity generation as an indicator of the environmental benefit of PEVs. We derived carbon intensity by interpolating carbon dioxide emissions factors at electricity generating facilities for each location (Ventyx 2008).

The environmental benefits of the other alternative fuels we examine here are relatively consistent across geographic locations and, therefore, were not considered in this study.

Indicators Not Included

The market strength of each alternative fuel is determined by numerous factors with varying degrees of influence. This report focuses on a limited number of indicators that we considered to be the most telling and for which there are robust data available. It is worth noting some indicators we did not consider and our reasoning for excluding them.

Household income: While household income is a reasonable indicator of the ability to purchase AFVs, we opted to use the more direct indicator of AFV registrations. In the incipient PEV market, two other indicators (HEV ownership and PV ownership) serve as more direct indicators of willingness to pay a premium than does income alone (Tal et al. 2013). Furthermore, gas prices directly impact payback periods for AFVs and are, therefore, considered more important than income.

Population density: We do not directly take this factor into account because it is represented by both vehicle density and existing infrastructure, which requires a minimum population density to support.

Commuting distance: This factor has two distinct and opposing effects on a commuter's likelihood of purchasing an AFV. A shorter commute can increase the appeal of AFVs by reducing the impact of range anxiety, whereby commuters feel uncomfortable driving an AFV distances close to its maximum range. However, longer commute distances make AFVs a better investment with a shorter payback period (O'Keefe et al. 2011). These two effects mitigate each other, and commuting distance, therefore, is not taken into account.

Average regional temperature: We received recommendations to consider using this factor as an indicator because PEVs operate more efficiently in warm temperatures than in cold ones. However, repeated exposure to high ambient temperatures reduces battery life (Smith et al. 2012). Currently, no data yet exist to definitively characterize the impacts of local climatic factors on PEV deployment, so we omitted this factor from consideration in the electricity market.

Temperatures do not have significant effects on any of the other alternative fuels examined in this study. Flex-fuel vehicles (FFVs) do experience drivability impacts in cold weather when using fuel with a very high percentage of ethanol; however, fuel suppliers reduce the percentage of ethanol in E85 during cold months to prevent such problems.

PEV hot spots: PEV hot spots are locations in which public and private PEV-promotional programs are focusing their efforts. They have been treated as indicators in past market assessments (Johnson et al. 2011), but enough time has passed since their initiation that the market effects of these programs should be captured by indicators we have already considered here, including charging station availability, PEV densities, and pro-PEV incentives. Any location that is a PEV hot spot that does not exhibit strong station availability or PEV densities could potentially be considered a poor market because previous efforts have not been successful there. Alternatively, it is possible that the program has not been executed effectively and thus has not achieved its intended effects in the PEV market.

Education campaigns: As with PEV hot spots, educational campaigns for propane have been proposed as indicators for increased demand (Taylor 2013). However, it is quite difficult to accurately specify geographic boundaries for such campaigns. Furthermore, there is significant variability in scale and scope among campaigns, thus precluding us from assigning a single weight to characterize their effects in the market.

Heavy-duty vehicle density: No datasets exist that fairly represent a broad spectrum of heavy-duty AFVs and adequately tether them to a given location. Some fuel-specific industry organizations track and publish data on various subsets of the heavy-duty vehicle population, but other subsets are completely unrepresented. Attempts to use heavy-duty vehicle registration data are hampered by the fact that most registrations are tied to corporate headquarters rather than to garage or delivery locations.

Proportion of households with more than one vehicle: This factor has served as an indicator of areas in which the population is likely to purchase limited-range AFVs (such as CNG vehicles and PEVs) in some studies (see, e.g., Melendez and Milbrandt 2007). This assumption is logical because a multi-car household can still make necessary long-distance trips by utilizing its conventional vehicle. However, we consider AFV registrations to be a more direct indicator of AFV-purchasing populations than the prevalence of second vehicles.

Voting preferences: This factor has also been used as an indicator of alternative fuel markets in past studies (see, e.g., Melendez and Milbrandt 2007), under the assumption that populations that vote pro-environment and pro-energy independence are also likely to purchase AFVs. Our study uses two indicators that are more directly tied to propensity to purchase a PEV. First is the number of enacted laws and incentives in an area, which reflects the electorate's political support for such policies. The second indicator is the number of AFVs that have actually been purchased.

Generalized Prioritization and Weighting System

Each market indicator has its own magnitude of impact on the alternative fuel market. Therefore, each indicator must be weighted accordingly. We derived a weight for each indicator through a series of reviews for each fuel (the details for this process are provided in the results and discussion section below). However, a generalized prioritization was necessary to develop a consistent starting point. Table 1 lists the criteria and order of the general prioritization scheme from left to right. It also notes whether data is available to map.

Table 1. Screening Criteria for Market Potential, Weighting, and Data Availability

Fuel	Existing Fueling Stations	Freight or HEVs	Vehicle Density	Gasoline or Diesel Prices	State Incentives	Resource Proximity	Environmental Benefit
Criterion Weight	Heavy						Light
Electricity	X	X	X	X	X	X	X
Biodiesel	X	X	X	X	X	X	Consistent
Ethanol	X	—	X	X	X	X	Consistent
Natural Gas	X	X	X	X	X	X	Consistent
Propane	X	—	X	X	X	X	Consistent

X denotes that applicable data is available to map, and it is suitable to inform decisions.
— denotes that no applicable data is available.
"Consistent" indicates that the data do not depend on location.

Existing infrastructure is weighted the most heavily because we assume it to be indicative of a variety of factors conducive to retailing a fuel within a given region. For most fuels, this is a prerequisite to having any alternative fuel market at all. This data is available, complete, and relevant to all fuels.

Freight and HEVs is one of two indicators representing potential demand for AFVs and, therefore, demand for alternative fuel. For the biodiesel market analysis, freight is weighted more heavily than diesel vehicle density because it represents a more concentrated source of demand along major highways. Furthermore, this indicator allows us to account for the demand of heavy-duty vehicles. HEV density is weighted more heavily than PEV density because the PEV market was in its infancy when the dataset was developed. There is also strong evidence showing that early adopters of HEVs become the early adopters of PEVs (Tal et al. 2013).

Vehicle density is prioritized over the remaining indicators because it is not only a driver of healthy alternative fuel markets, but also a result of healthy markets; the remaining indicators are only considered causes of healthy markets. There are, however, caveats to the relative applicability for each fuel type, which we detail in the results section.

Gasoline or diesel prices are weighted more heavily than state incentives because they are more influential on alternative fuel fleet and station business plans than state incentives are (Johnson and Melendez 2007; Johnson 2010). These prices are also weighted more heavily than resource proximity because the primary driver by which a nearby resource improves the alternative fuel market is through price reduction, but an equal rise in gasoline prices can achieve the same relative price advantage. Gasoline and diesel prices are readily available and relevant to all alternative fuel markets. However, they are most relevant for CNG and electricity markets because, as Figure 2 shows, the prices of these two fuels correlate least with the price of gasoline. Therefore, in the face of high gasoline prices, these fuels afford greater fuel savings.

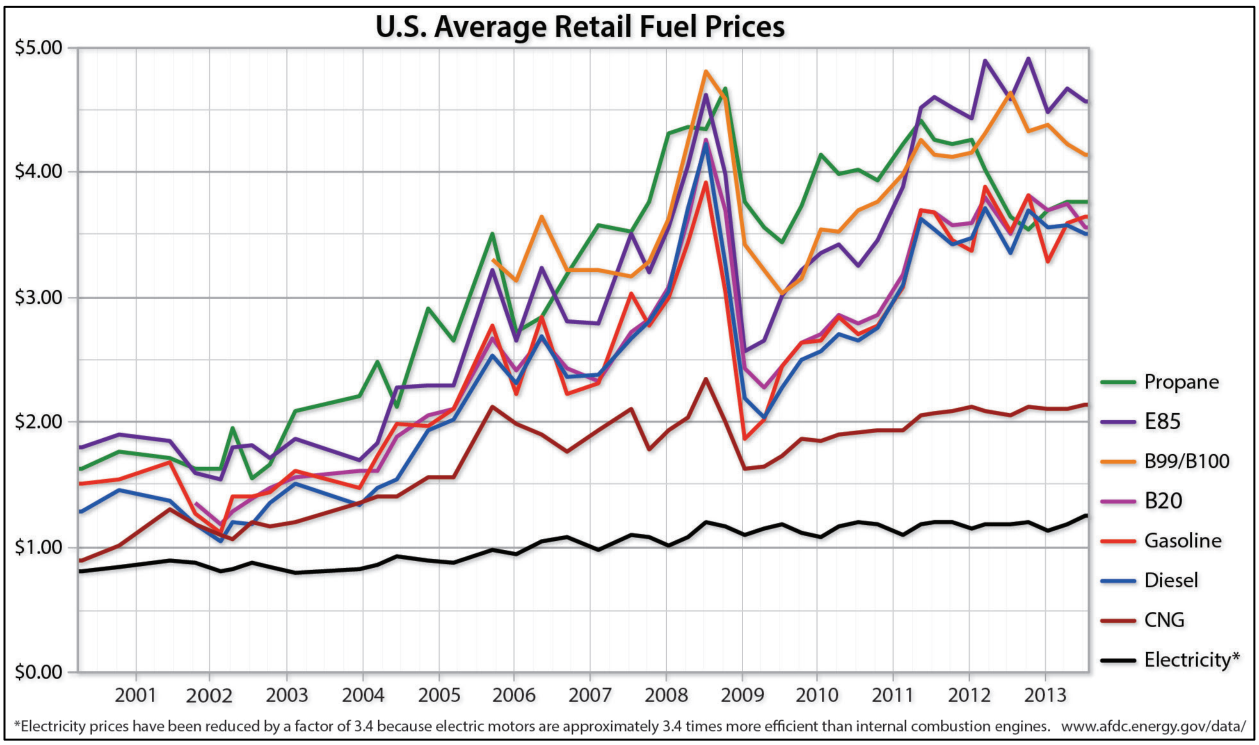

Figure 2. Average retail fuel prices for gasoline, diesel, and alternative fuels.

Electricity and CNG markets are the least tied to gasoline and diesel prices. Note that propane prices appear inflated due to retailers that sell for higher-value usage such as campers.

State incentives are weighted more heavily than resource proximity for two reasons: Incentives can change the economics of using an alternative fuel to overcome additional transportation costs of long-distance imports. Secondly, state incentives signify a population's acceptance of and support for a fuel.

Resource proximity is viewed as more influential than environmental benefit because, despite consumer intentions and stated preferences, economics typically trump environmental concerns in transportation choices (Hensher 2010). These economics are heavily impacted by transportation costs, so the proximity of a resource creates downward pressure on fuel prices.

Environmental benefit is rated as the weakest indicator we consider. The environmental benefit afforded by most fuels does not vary from one region to the next, which renders this factor irrelevant for those fuels, for the purposes of this study. The exception is electricity, whose climate change impacts vary widely among regions. This is discussed in greater depth in the Results section.

Results and Discussion

In this study, we mapped the factors listed above for each fuel and combined them using weightings determined in collaboration with market experts. We calculated final "score" values by determining the relevant parameter value at each location across the United States (using a 10-km grid and excluding Alaska, where the data were insufficient). For each metric, the values at each location were then converted to percentiles, ignoring unknown and 0 values, in order to create unit-free values that are readily combined. These percentiles were combined using the final parameter weightings shown in Table 2.

In this section, we provide a composite map for each fuel and discuss general patterns and primary drivers of these patterns. The composite maps display market intensities from 0 to 1, reflecting the cumulative weighted percentiles. They have different thresholds for various colors, as shown in the legends, reflecting the fact that market strength is comparable within fuels but less directly so between fuels. Portions of the map assessments are broken down by state, in which cases the analysis is aided by the state mean market strength, as shown in Appendix A. We go on to highlight unexpectedly strong and weak areas for each fuel type. This process is intended to guide policymakers, investors, and entrepreneurs in evaluating alternative fuel markets within a given region and help assess market health in smaller areas (not identifiable on the map) and in future times as market conditions change.

Finally, this section addresses how the factor weightings for each fuel deviate from the general weighting system listed above. By discussing which factors are the most important indicators of market health, this section will also enable policymakers to better target their efforts and funds as they seek to prime markets for a given fuel.

Table 2. Weighting of Screening Criteria for Various Fuels

Fuel	Existing Infrastructure	Freight or HEVs	Vehicle Density	Gasoline/ Diesel Prices	State Incentives	Resource Proximity	Environmental Benefit
Electricity	19%	20%	16%	14%	10%	9%	12%
Biodiesel	24%	20%	16%	15%	13%	12%	—
Ethanol	30%	—	21%	10%	16%	23%	—
Natural Gas	34%	12%	11%	20%	15%	8%	—
Propane	32%	—	16%	19%	17%	16%	—
Average	28%	—	18%	16%	14%	14%	—

Electricity

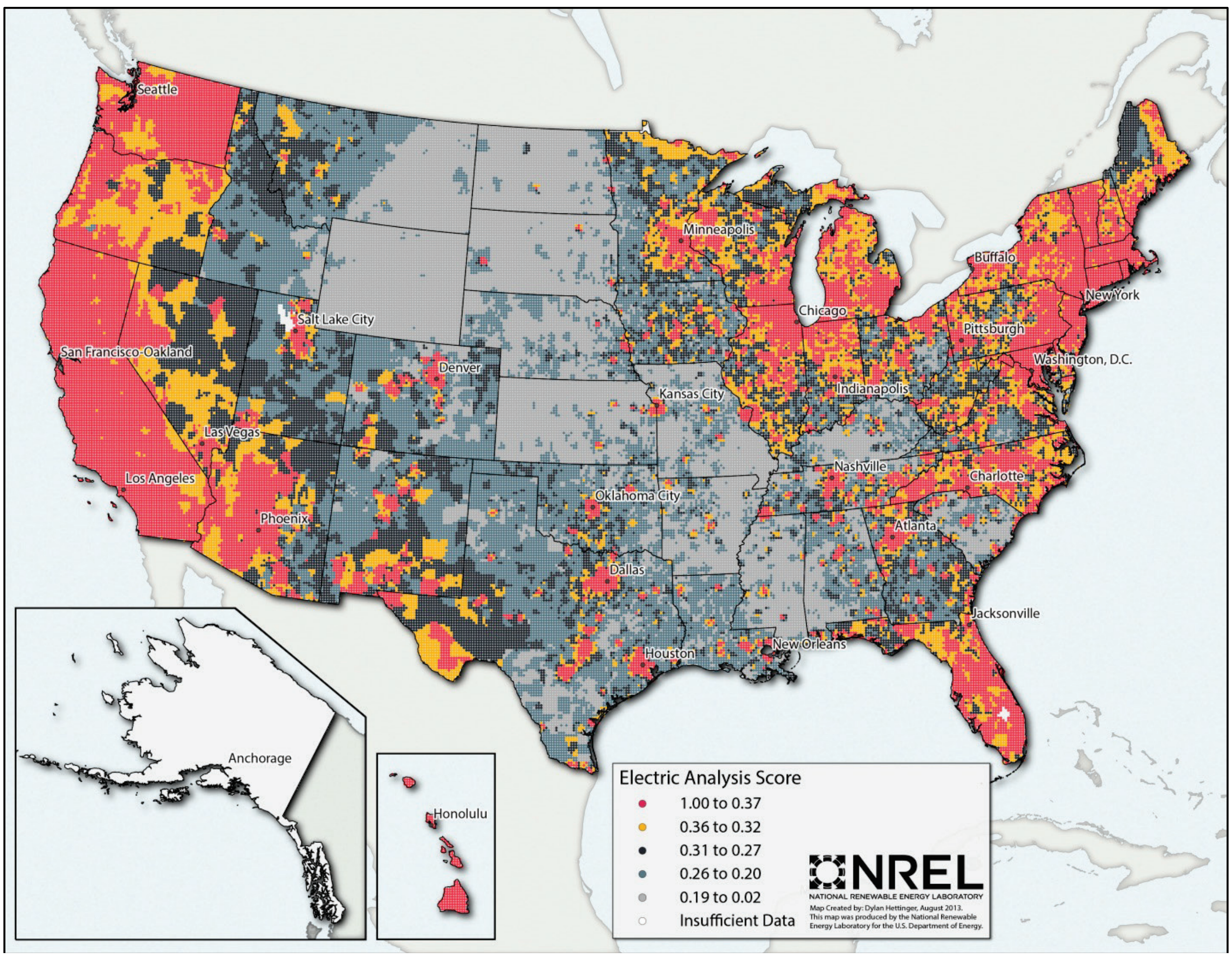

Figure 3. Map of the most active vehicle electricity markets

Our analysis indicates that the electricity markets for PEVs are strongest in Hawaii, along the West Coast, and in the Northeast, followed by isolated urban areas throughout the nation and linked urban areas in the Great Lakes region, Florida, North Carolina, Arizona, and Nevada.

Geographic areas with unexpected market strength include the western half of Arizona and southern portion of Nevada. This is driven by the high prevalence of PV installations, low-carbon-intensity electricity, and high number of PEV incentives in this area. Western Texas is another surprise, with market potential largely due to the state's high proportion of low-carbon wind power (which makes PEVs environmentally attractive) and higher gasoline prices (which make them economically attractive). North Carolina's PEV market potential is strong largely because of a high number of PEV incentives and a high PEV density. Eastern California and Washington are attractive despite their relatively low population density, largely because of high PEV density. Numerous statewide incentives also help, as does eastern Washington's clean electricity. Experts feel that the low population density of northern Michigan makes it an unlikely location for good PEV market, yet the clean electricity, high HEV density, and strong state incentives point to stronger-than-expected market potential.

Changes in factor prioritization included a reduction in the weighting of existing infrastructure. We deemed this factor less influential than originally proposed because 75% to 80% of charging events occur at home via residential charging equipment (EV Project 2013). We increased the weight assigned to environmental benefit because PEVs are appealing to early adopters motivated more by environmental concerns and energy independence benefits than by economics (Ungar and Fell 2010).

Biodiesel

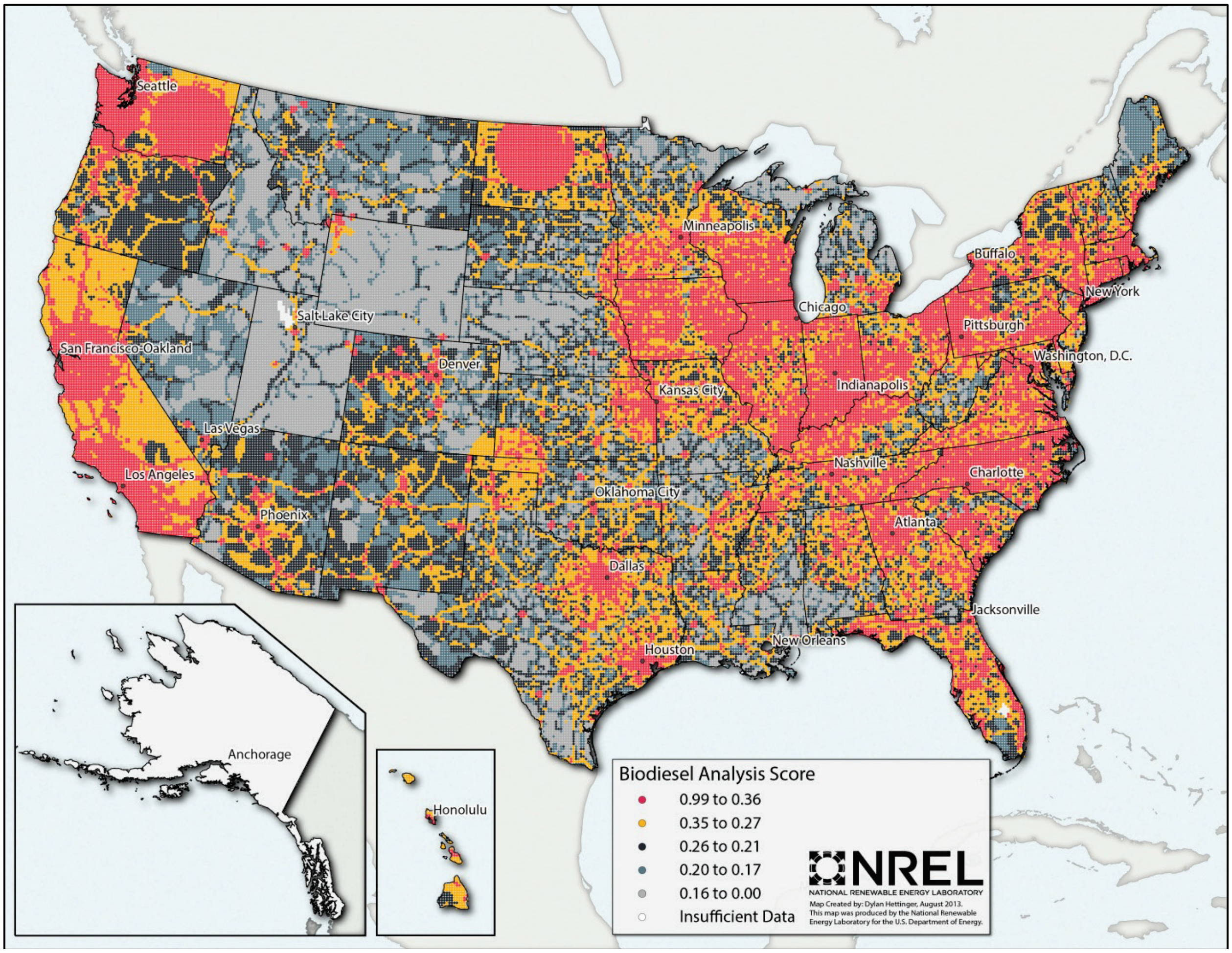

Figure 4. Map of the most active vehicle biodiesel markets

Markets for biodiesel appear primed throughout the Midwest, centered on the Chicago area. This is where the majority of biodiesel production occurs, providing both reduced shipping costs and a pro-biodiesel population. Urban areas and linking highways from Atlanta to Boston also show strong market potential because of high freight traffic and diesel registrations throughout the greater region. Memphis, Houston, Dallas, Denver, and Phoenix appear as islands of promising market potential due to high diesel prices and well-connected corridors of high freight tonnage. Wyoming, Utah, and Idaho have the weakest biodiesel markets despite the activity in Yellowstone National Park and Salt Lake City and the existence of interstate highways connecting Idaho Falls to Boise.

Geographic areas with unexpected market strength include North Dakota, the Oklahoma panhandle, and southwestern Oregon, where biodiesel refineries and a high number of state incentives push market ratings into high categories. Despite low population densities, these areas should be of interest to strategists.

North Carolina has many pro-biodiesel incentives and a disproportionate number of B20 refueling stations: 18% of the nation's total, with only 3% of the U.S. population (AFDC 2013b).

The stations are well dispersed throughout the state. Pennsylvania shows great promise due to high gasoline prices, freight tonnage, diesel vehicle registrations, and a number of biodiesel refineries. Hawaii is surprisingly strong as well: it has very high gasoline prices, many state incentives, a high density of diesel registrations, and seven B20 stations. However, the lack of biodiesel supply is currently overriding these indicators of high demand. Appalachia has surprisingly poor biodiesel market potential, considering it is surrounded by relatively strong biodiesel markets.

We did not observe any need for changes in factor prioritization for biodiesel.

Ethanol

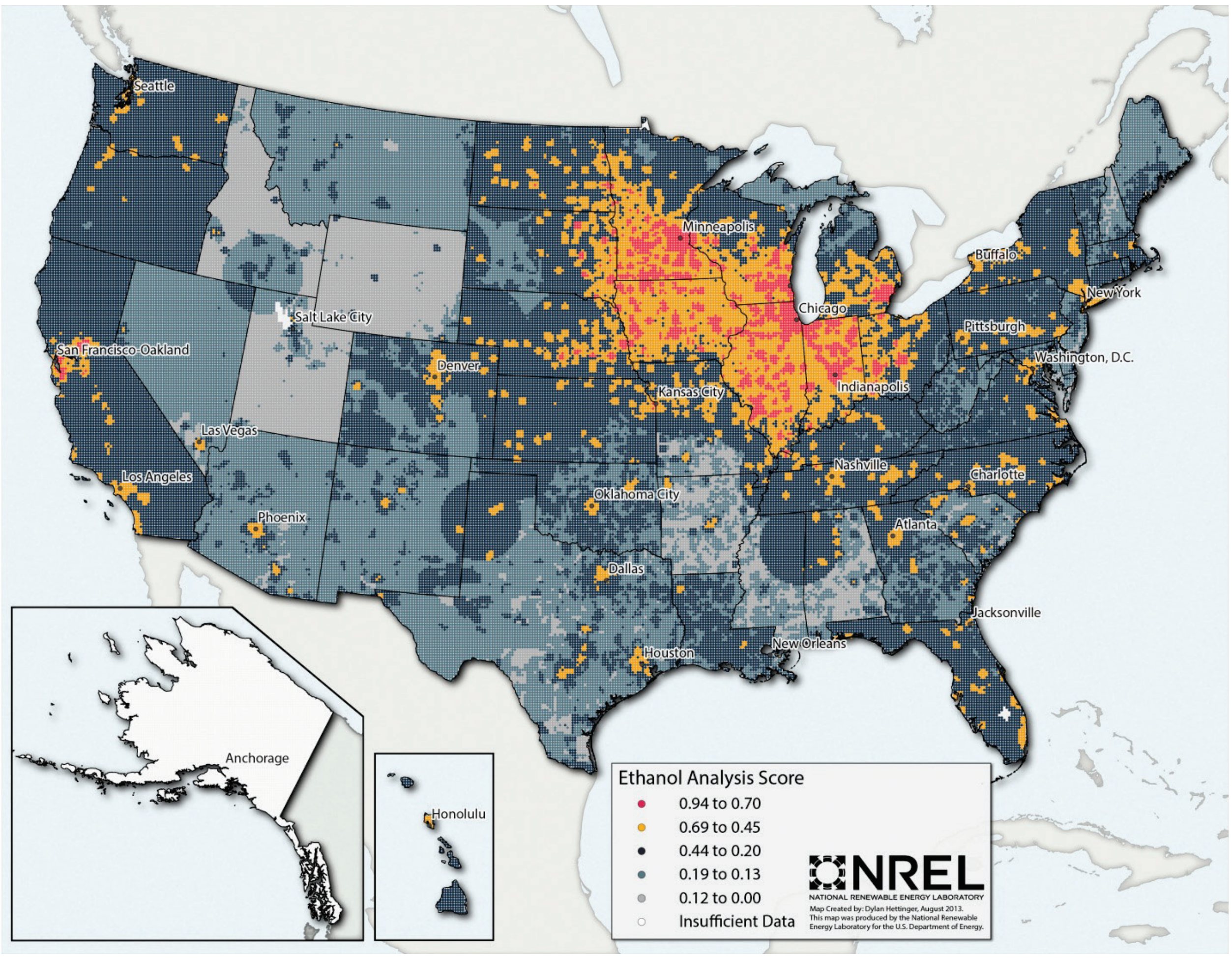

Figure 5. Map of the most active vehicle ethanol markets

Ethanol markets are most robust in the Midwest. Outside the Midwest, the urban areas surrounding the San Francisco Bay (including Sacramento), Los Angeles, Denver, New York City, Rochester-Buffalo, Houston, Miami, and Dallas have large markets (listed in order of the size of the geographic area that received scores in the highest quintile). The weakest ethanol markets are found in the region comprising Wyoming, Utah, Idaho, Nevada, and Montana. These states have very few pro-ethanol incentives, low FFV density, few fueling stations, and only one ethanol refinery.

Experts were surprised that markets in Kansas and Missouri were not as strong as some of the areas to their northeast. This is likely because Missouri has some of the cheapest gasoline prices in the country, few ethanol incentives, and no local sources in the southwest portion of the state. The ethanol market in southern Kansas is hampered by inexpensive gasoline, a shortage of E85 stations, and no local fuel sources in the southeast portion of the state. Louisiana appeared better than expected, largely because of a refinery within the state, a fair number of ethanol incentives, and high FFV density. The addition of a relatively small number of E85 stations would result in strong scores for Louisiana's ethanol market.

Following the initial analysis, we made several changes to the prioritization of ethanol market indicators. Gasoline price is less important for spurring adoption of FFVs than for other AFVs. The majority of FFVs on U.S. roads are owned by individual consumers, who tend to prioritize performance and design over lifecycle cost much more than fleets (Consumer Reports 2013; National Association of Fleet Administrators 2012). Furthermore, retailers seem to peg the price of E85 to that of gasoline (as shown in Figure 2), meaning high gasoline costs do not necessarily translate to substantial fuel savings when using E85. Therefore, the current pricing strategy of E85 is not providing as much incentive to use E85 as other fuels that have their price based on the feedstock and production cost of the fuel. Nearby resources were weighted more heavily than all other factors, excepting existing E85 fueling infrastructure. More so for ethanol than for other fuels (and better documented than for biodiesel), there are strong social, economic, and cultural ties to the feedstock and fuel production plants. Ethanol plants are located near corn-based economies, where farmers feel the positive effects that corn-based ethanol production has on corn prices and where a great deal of farm work requires light-duty trucks, which are disproportionately FFVs (Clean Cities 2013).

Compressed Natural Gas

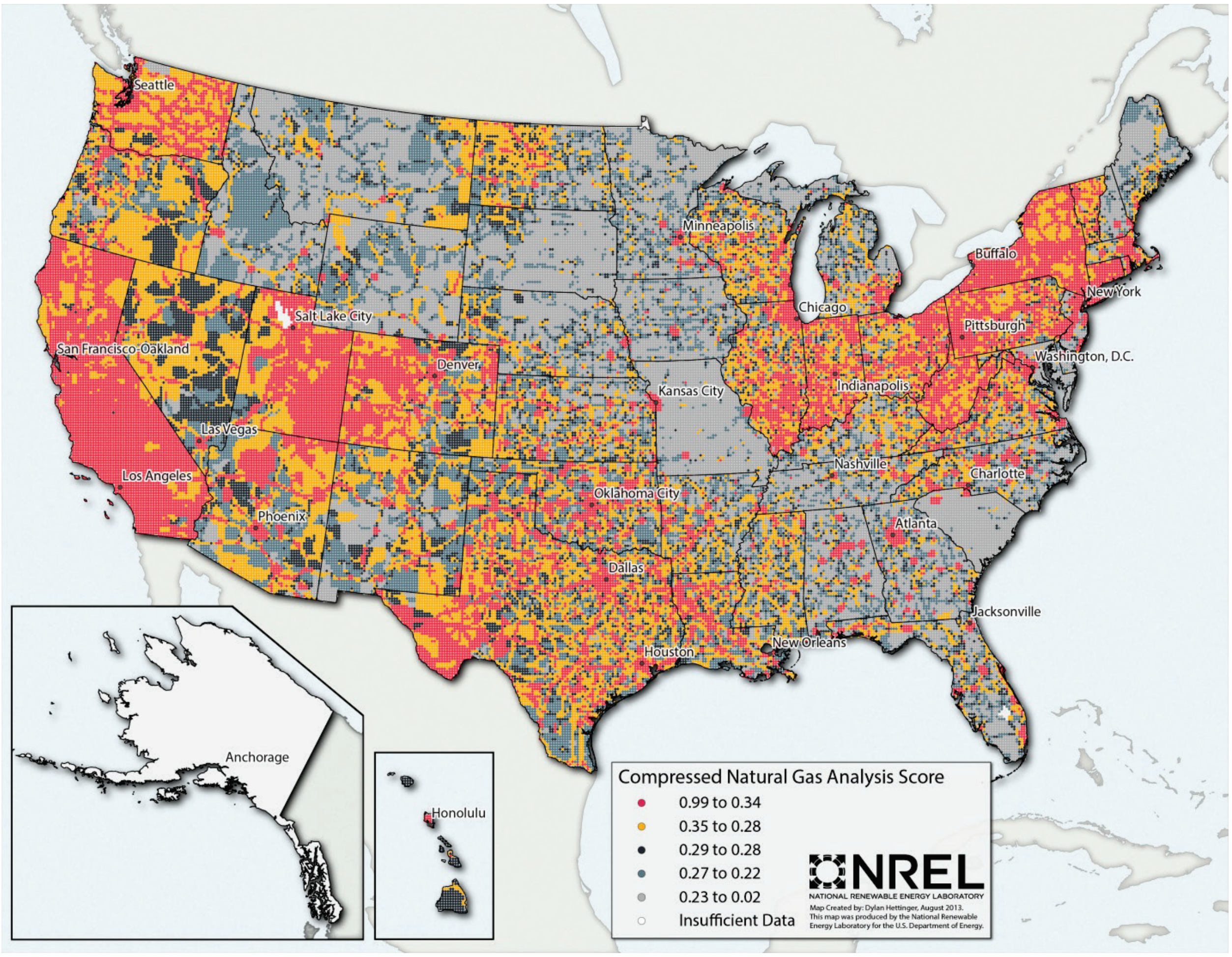

Figure 6. Map of the most active vehicle CNG markets

Connecticut, New York, Rhode Island, California, Pennsylvania, Utah, Massachusetts, West Virginia, Ohio, and Washington have the strongest markets for CNG vehicles. Many of these states are bolstered by the natural gas processing plants over the Marcellus shale play. Oklahoma's CNG market is stronger than it appears on the map: The state has large numbers of CNG vehicles and fueling stations, but these factors tend to be concentrated in small geographic areas. As a result, the state as a whole is pulled into a lower score category by low gasoline prices. This is reflected in a large difference between the state average market value and the state median market value (see Appendix A). Oklahoma's strong spots are some of the most highly rated in the nation.

A swath of relatively poor CNG markets stretch from Florida to Idaho, including the states of Alabama, Georgia, South Carolina, Tennessee, Missouri, Iowa, Nebraska, Minnesota, South Dakota, Wyoming, and Montana. Notable exceptions within these states are Atlanta, Birmingham, Kansas City, and the area of North Dakota over the Bakken shale play (where multiple natural gas processing plants exist). These cities are an exception due to CNG stations and vehicle densities, despite low gasoline prices and few state incentives.

It surprised market experts to see that sparsely populated areas in eastern Washington, southeastern California, southwestern Colorado, and southeast Utah rated high on the CNG market map. The markets in these areas were bolstered by numerous natural gas processing plants despite having a low density of CNG vehicles. Weighting the CNG station and CNG vehicle density portions of this map more heavily resulted in lower scores for these regions but distorted other portions of the map; so these adjustments were not made. Policymakers, investors, and entrepreneurs in these sparsely populated regions should be cautious when interpreting this map. However, they should consider the potential for emerging markets in municipalities and along heavily traveled transportation corridors within these regions, given their high gasoline prices, state incentives, and proximity to natural gas processing plants.

Changes in factor prioritization included a heavier weighting for CNG fueling stations than we assigned for stations offering any other fuel. This allowed us to better reflect population density (which is generally a prerequisite for fueling stations) in the CNG market map in response to multiple experts pointing out errant areas in the fifth quintile that were in areas of too low population to truly have a strong market. We chose to increase the weight for fueling stations rather than for vehicle density because the CNG vehicle density data only included dedicated CNG vehicles, and not dual-fueled vehicles. Therefore, an increased weighting of vehicle densities would have exaggerated market activity in locations with a high proportion of dedicated vehicles while under-representing market activity in locations with a high proportion of dual-fuel vehicles. As such, we reduced the weight assigned to vehicle densities. We reduced the weight assigned to freight because CNG use by long-haul trucks is still an incipient market, albeit a quickly developing one (Baker 2013). We reduced the weighting of resource proximity because natural gas is less expensively transported than other alternative fuels, generally over a vast and efficient pipeline network (Stilwell 2013).

Propane

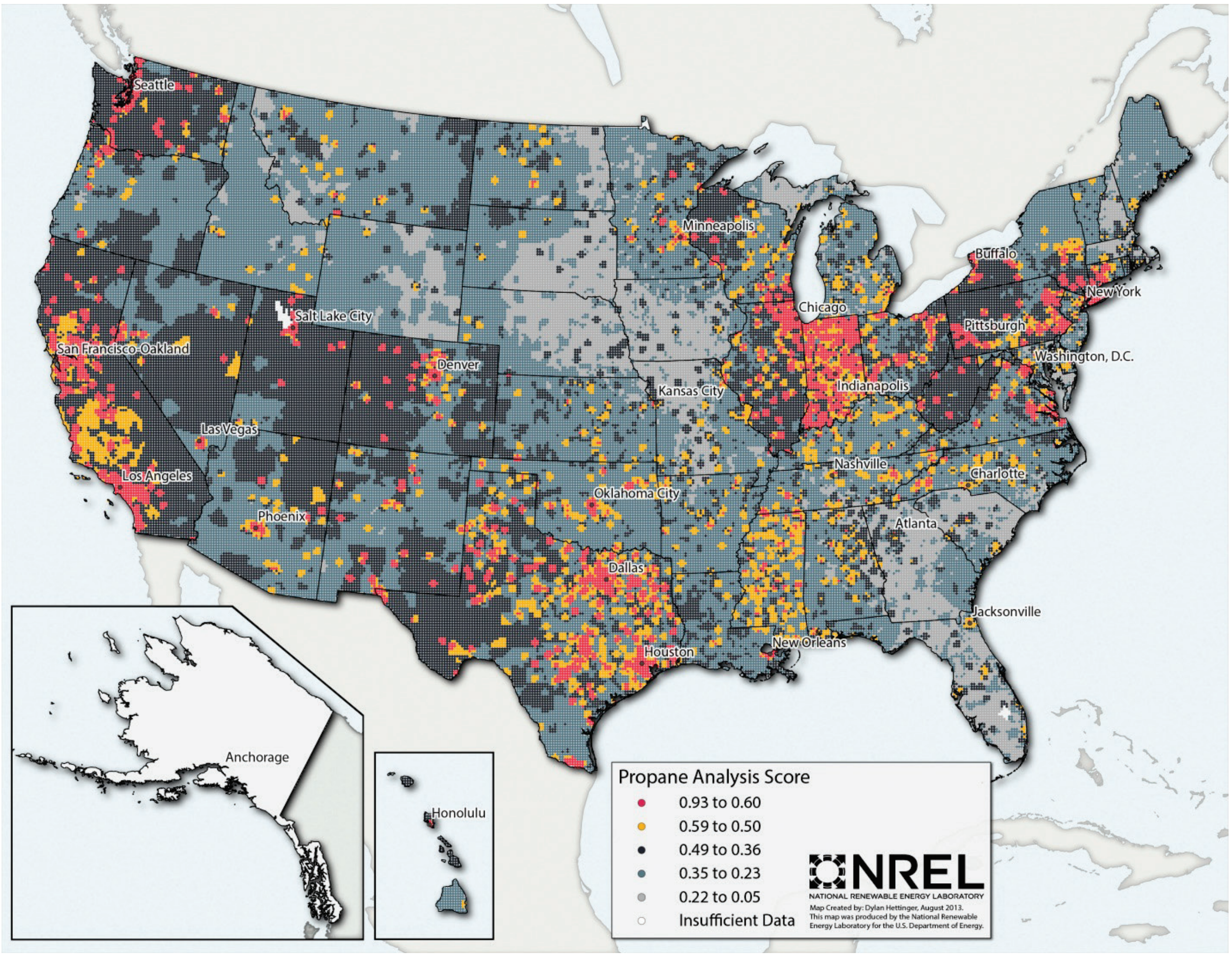

Figure 7. Map of the most active vehicle propane markets

Our analysis revealed the propane market to be quite fragmented, with a high frequency of strong markets in Indiana, Connecticut, California, Illinois, Washington, Pennsylvania, Texas, West Virginia, Ohio, and Mississippi. The only areas in which locations of high activity conglomerate into a large, consistent market are in Indiana, Connecticut, California, and Texas. The markets in South Carolina, Georgia, Iowa, Nebraska, South Dakota, and Wyoming are particularly weak.

Lack of reliable vehicle density data makes our propane market analysis the least reliable of all the fuels we consider in this study. Heavy-duty propane vehicles substantially bolster demand for the fuel, but they are not captured in vehicle registration data, so we were unable to include them in the map. In particular, propane market experts noted that Georgia and South Carolina have strong propane markets, as propane-powered Blue Bird and Thomas Built buses are manufactured in this area. However, this factor is not captured in our map because there is no geospatial database of heavy-duty propane vehicles. In another example, Omaha, Nebraska, is home to a large fleet of propane-powered school buses, but this is not reflected in the map either.

We reduced the weighting of vehicle density to match the weighting of resource proximity as the lowest-weighted parameters in order to account for the incomplete vehicle registration dataset (only dedicated OEM-manufactured light-duty vehicles are captured).

State-Based Categorizations

The majority of incentives and laws facilitating the deployment of alternative fuels in the United States are enacted at the state level (AFDC 2013a). As such, state policymakers require reliable quantitative and qualitative information about potential and existing market strength for these fuels in their respective states, which is exactly what we aim to provide in this report. In Table 3 we describe the market potential in each state for each alternative fuel analyzed in this report, using categories ranging from Strongest to Weak. To arrive at these categorizations, we compared each state's mean and median market strength scores and the size of the area in that state that received scores in the two highest score quintiles (orange and red zones in the preceding maps), as explained in greater detail below and shown in Appendix A. In addition to these quantitative geographic information system boundaries, the authors' interpretations of the maps above also influenced the ratings.

The market-strength categories are as follows:

- Strongest Market Potential: The majority of the state has high levels of potential supply of and demand for the alternative fuel, indicated by high mean and median market strength scores.
- Healthy Market Potential: The state has a mean market strength score below that of states with Strongest market potential and above that of most states with Patchy market potential. The mean and median market strength scores for states with healthy markets are usually relatively close together, indicating a fairly uniform market across the state. For comparison, in states with Patchy market potential, the mean is usually larger than the median.
- Patchy Market Potential: The state has isolated patches and corridors of strong market potential. The patches are usually in urban areas with high densities of vehicles and fueling stations. The corridors are along major highways with high volumes of freight traffic. Only biodiesel and CNG have such markets along corridors. Patchy markets tend to have mean market strength scores between those of Healthy and Weak markets. What differentiates them from Weak markets is a large area (in real terms, not as a percent of the state's area) receiving scores within the two highest quintiles for a given fuel and a mean market score that is much higher than the median score. This latter factor is an indicator that the market potential for a particular fuel is not uniform throughout the state, and that certain areas within the state show strong potential, while the majority of the state is relatively weak.
- Weak Market Potential: The state has little or no potential supply of or demand for a given alternative fuel, indicated by the state's low mean and median market strength scores.
- NA: The state has insufficient data available to determine market potential.

Table 3. Market Categorization by State and Fuel

State	Electricity	Biodiesel	Ethanol	CNG	Propane
Alabama	Patchy	Patchy	Weak	Patchy	Patchy
Alaska	NA	NA	NA	NA	NA
Arizona	Healthy	Patchy	Weak	Healthy	Patchy
Arkansas	Weak	Patchy	Weak	Healthy	Patchy
California	Strongest	Strongest	Healthy	Strongest	Strongest
Colorado	Patchy	Patchy	Patchy	Strongest	Healthy
Connecticut	Strongest	Strongest	Weak	Strongest	Strongest
Delaware	Strongest	Healthy	Weak	Weak	Healthy
Florida	Strongest	Healthy	Healthy	Patchy	Weak
Georgia	Patchy	Healthy	Patchy	Patchy	Weak
Hawaii	Strongest	Healthy	Weak	Healthy	Patchy
Idaho	Weak	Weak	Weak	Patchy	Weak
Illinois	Healthy	Strongest	Strongest	Strongest	Strongest
Indiana	Healthy	Strongest	Strongest	Strongest	Strongest
Iowa	Patchy	Strongest	Strongest	Weak	Weak
Kansas	Weak	Patchy	Strongest	Healthy	Patchy
Kentucky	Weak	Healthy	Healthy	Patchy	Patchy
Louisiana	Patchy	Patchy	Weak	Healthy	Patchy
Maine	Healthy	Weak	Weak	Weak	Weak
Maryland	Strongest	Healthy	Patchy	Weak	Patchy
Massachusetts	Strongest	Strongest	Patchy	Strongest	Patchy
Michigan	Strongest	Patchy	Healthy	Patchy	Patchy
Minnesota	Patchy	Patchy	Strongest	Weak	Patchy
Mississippi	Weak	Patchy	Weak	Healthy	Healthy
Missouri	Weak	Patchy	Healthy	Weak	Weak
Montana	Patchy	Weak	Weak	Weak	Patchy
Nebraska	Weak	Weak	Strongest	Patchy	Weak
Nevada	Healthy	Weak	Weak	Healthy	Patchy
New Hampshire	Strongest	Patchy	Weak	Weak	Weak
New Jersey	Strongest	Healthy	Weak	Strongest	Patchy
New Mexico	Patchy	Patchy	Weak	Patchy	Patchy
New York	Strongest	Healthy	Strongest	Strongest	Patchy
North Carolina	Strongest	Strongest	Healthy	Patchy	Patchy
North Dakota	Weak	Healthy	Strongest	Patchy	Weak
Ohio	Healthy	Strongest	Strongest	Strongest	Healthy
Oklahoma	Patchy	Patchy	Patchy	Healthy	Patchy
Oregon	Strongest	Patchy	Patchy	Healthy	Patchy
Pennsylvania	Strongest	Strongest	Healthy	Strongest	Strongest
Rhode Island	Strongest	Strongest	Weak	Strongest	Healthy
South Carolina	Patchy	Healthy	Patchy	Weak	Weak
South Dakota	Weak	Patchy	Strongest	Weak	Weak
Tennessee	Patchy	Strongest	Strongest	Patchy	Patchy

State	Electricity	Biodiesel	Ethanol	CNG	Propane
Texas	Patchy	Patchy	Patchy	Healthy	Strongest
Utah	Patchy	Weak	Weak	Strongest	Healthy
Vermont	Strongest	Healthy	Weak	Strongest	Patchy
Virginia	Healthy	Strongest	Patchy	Healthy	Patchy
Washington	Strongest	Strongest	Healthy	Strongest	Strongest
West Virginia	Healthy	Patchy	Weak	Strongest	Strongest
Wisconsin	Healthy	Healthy	Strongest	Healthy	Healthy
Wyoming	Weak	Weak	Weak	Patchy	Weak

As Table 3 shows, some locations have promising markets for numerous fuels, while others are promising for fewer fuels. No state, though, has a Weak rating for all five fuels, indicating that all of them have opportunities to pursue successful deployment of at least one alternative fuel in a portion of the state.

California, Illinois, Indiana, Pennsylvania, and Washington appear to have the greatest market potential for alternative fuels in general. Each was rated Strongest for four fuels and Healthy for one fuel. Ohio follows closely, with three Strongest markets and two Healthy markets. Connecticut also shows much promise, with Strongest ratings for four fuels and a Weak rating for the remaining one. Next come New York and Rhode Island, each with three Strongest markets and one Healthy market.

On the opposite end of the spectrum, Wyoming and Idaho exhibit Weak market potential for all alternative fuels except CNG, for which they have only Patchy market potential. Alabama and New Mexico do not have any Strongest or Healthy markets, but they each have Patchy markets for four fuels. Maine has four Weak markets, but it has a Healthy market for PEVs.

Policymakers, investors, and entrepreneurs may also gain important insights by examining the proportion of states that have strong market potential for a given fuel. In Figure 8, we show the breakdown of market strength among all states for each alternative fuel. This is not meant to represent the relative potential for each fuel in the United States as a whole, because the state markets do not take size (in square miles, vehicles, or potential fuel sales) into account. For example, a physically large state with Patchy market potential for electricity could feasibly support vigorous deployment of PEVs and charging infrastructure in certain dense urban areas linked by charging corridors. Figure 8 shows CNG to be promising in the largest number of states, largely because freight traffic serves as a potential source of demand for many far-reaching corridor markets and because the sources of CNG are so widespread.

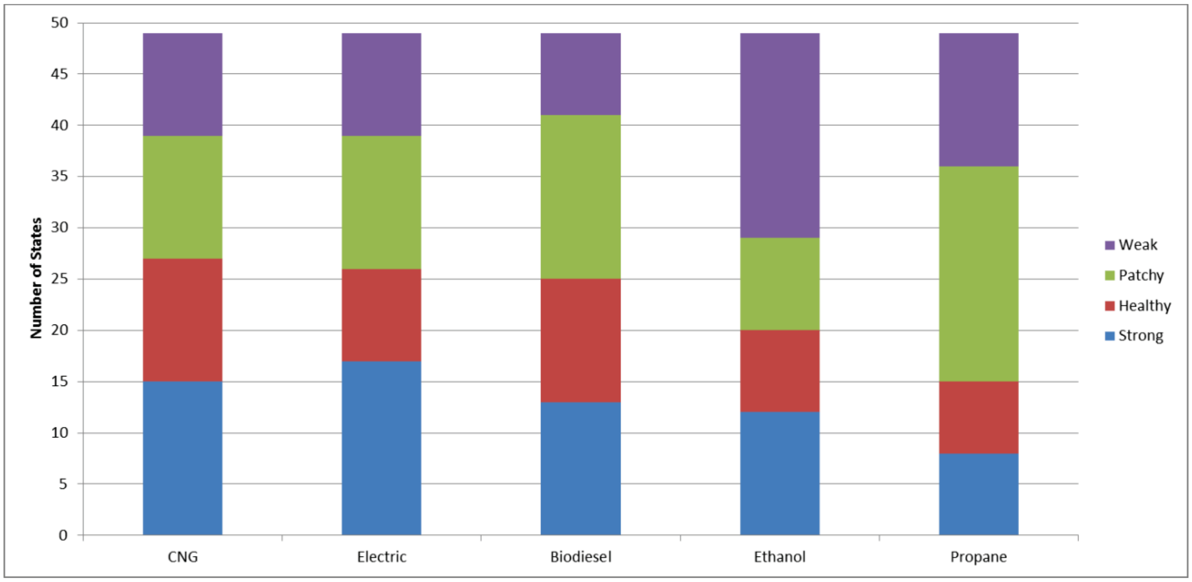

Figure 8. Number of states with alternative fuel markets, by fuel and market strength

Conclusion

Taken together, the results of this study may serve as a roadmap of sorts in the strategic deployment of alternative fuels in support of environmental, economic, and energy security goals. By identifying locations that have the greatest potential for success, we offer the opportunity for more targeted approaches to policymaking, public and private investments, business development, and mitigation of environmental impacts. By summarizing the market potential for a given fuel at the state level, we have flagged which fuels could offer the greatest market penetration for a given input of resources.

The analyses we conducted in this study included all relevant, reliable data sets available at the time. Unfortunately, data pertaining to the operational locations and fuel types of heavy-duty vehicles were sorely lacking and represent a lacuna in our current understanding of alternative fuel markets. Heavy-duty vehicles are a large source of fuel demand, and insights into this segment of the transportation market stand to further inform policymaking and investment decisions. Notably, numerous organizations and initiatives in the public and private sectors are now undertaking efforts to better characterize this market segment. The DOE's Clean Cities program works with large private-sector fleets through the National Clean Fleets Partnership to support and measure the efforts of member fleets to reduce petroleum use, including through the deployment of alternative fuels. The Propane Education and Research Council and DOE's Federal Fleets program are beginning to document garage locations for heavy-duty vehicles that use alternative fuels. Future studies should work to obtain data from these and similar initiatives to determine the heavy-duty segment's contributions to market potential.

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Appendix A. State-Based Market Categorization Data

This appendix provides the data we used to categorize potential market strength for each fuel in each state except Alaska. Each of the tables below uses the following metrics:

1. Mean market value (MV) is the state average of the values assigned to each 10-km square, as mapped in Figures 3 through 7. We derived each of the component values through the percentile and weighting system described in the Methodology section of this report. This is the primary value used to categorize states into strongest, healthy, and weak markets, with additional metrics used to determine which states had patchy markets.
2. Median MV is the state median of the values assigned to each 10-km square, as mapped in Figures 3 through 7.
3. The difference between the Mean MV and the Median MV is shown as "Mean–Median." This is useful when differentiating between patchy and healthy markets. States with a large difference between mean and median market values are less uniform and therefore more likely to have patchy market potential.
4. The final metric in each row is the total area (in square kilometers) within a state that received scores in either of the top two quintiles, indicated in red or orange on the maps of Figures 3 through 7. This metric is useful when discerning patchy from weak markets. We reasoned that, for a market to be categorized as "patchy," the isolated areas receiving high scores had to meet a certain minimum size threshold. In other words, if a patch falls below the minimum size, it does not represent sufficient market activity or potential to be very meaningful in the contexts of state policy or private-sector investment.
5. Notes include explanations for our categorizations of states for which little reliable data exists. The analyses we applied to these states relied more heavily upon our subjective judgment.

Table A-1 State Electric Vehicle Market Categorization Data

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
HI	Strongest	0.627	0.616	0.011	16,700	
CT	Strongest	0.621	0.635	-0.014	12,600	
MA	Strongest	0.537	0.529	0.008	20,600	
CA	Strongest	0.522	0.485	0.037	407,900	
NJ	Strongest	0.508	0.518	-0.010	18,600	
RI	Strongest	0.487	0.487	0.000	2,700	
MD	Strongest	0.479	0.464	0.015	23,000	
VT	Strongest	0.458	0.447	0.011	24,600	
WA	Strongest	0.442	0.413	0.029	174,000	
DE	Strongest	0.440	0.404	0.036	4,600	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
NY	Strongest	0.434	0.398	0.036	115,700	
FL	Strongest	0.425	0.385	0.040	120,800	
NC	Strongest	0.400	0.377	0.023	106,000	
NH	Strongest	0.389	0.375	0.014	20,600	
PA	Strongest	0.387	0.360	0.027	83,000	
OR	Strongest	0.386	0.354	0.032	211,400	
MI	Strongest	0.383	0.363	0.020	115,400	
IL	Healthy	0.374	0.346	0.028	94,300	
AZ	Healthy	0.364	0.347	0.017	175,100	
WI	Healthy	0.358	0.343	0.015	92,800	
IN	Healthy	0.355	0.345	0.010	58,100	
ME	Healthy	0.347	0.331	0.016	47,800	
VA	Healthy	0.343	0.319	0.024	53,900	
NV	Healthy	0.338	0.321	0.017	148,200	
WV	Healthy	0.326	0.313	0.013	28,700	
OH	Healthy	0.320	0.298	0.022	43,400	
GA	Patchy	0.305	0.282	0.023	43,100	Break point between healthy and patchy set at 1/3 area of the state being in top two quintiles.
MN	Patchy	0.301	0.293	0.008	73,400	
UT	Patchy	0.296	0.274	0.022	36,600	
TN	Patchy	0.294	0.270	0.024	34,900	
NM	Patchy	0.289	0.281	0.008	77,900	
IA	Patchy	0.276	0.268	0.008	27,500	
TX	Patchy	0.270	0.254	0.016	118,900	
CO	Patchy	0.258	0.245	0.013	29,700	
ID	Weak	0.250	0.246	0.004	9,900	Too uniform and patch area too small to be categorized as patchy
OK	Patchy	0.250	0.244	0.006	14,900	
LA	Patchy	0.244	0.230	0.014	12,300	
SC	Patchy	0.232	0.210	0.022	13,600	
AL	Patchy	0.230	0.219	0.011	13,900	
MT	Patchy	0.228	0.239	-0.011	16,200	
KY	Weak	0.210	0.199	0.011	6,500	
NE	Weak	0.200	0.196	0.004	2,800	
MO	Weak	0.193	0.183	0.010	9,700	
AR	Weak	0.189	0.180	0.009	5,300	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
MS	Weak	0.185	0.175	0.010	5,000	
ND	Weak	0.173	0.169	0.004	1,000	
SD	Weak	0.172	0.167	0.005	2,200	
KS	Weak	0.170	0.159	0.011	4,300	
WY	Weak	0.124	0.127	-0.003	-	

Table A-2. State Biodiesel Market Categorization Data

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
NC	Strongest	0.511	0.545	-0.034	115,400	
RI	Strongest	0.462	0.407	0.055	2,600	
WA	Strongest	0.445	0.427	0.018	164,200	
IN	Strongest	0.439	0.432	0.007	91,400	
CT	Strongest	0.418	0.418	0.000	12,400	
MA	Strongest	0.406	0.389	0.017	17,900	
IL	Strongest	0.405	0.397	0.008	133,700	
IA	Strongest	0.402	0.403	-0.001	139,700	
CA	Strongest	0.398	0.361	0.037	393,900	
OH	Strongest	0.393	0.373	0.020	91,300	
PA	Strongest	0.389	0.388	0.001	99,000	
TN	Strongest	0.389	0.357	0.032	88,700	
VA	Strongest	0.386	0.375	0.011	99,200	
WI	Healthy	0.373	0.380	-0.007	122,400	
MD	Healthy	0.371	0.347	0.024	21,000	
SC	Healthy	0.370	0.332	0.038	56,800	
DE	Healthy	0.368	0.350	0.018	4,400	
KY	Healthy	0.359	0.354	0.005	84,500	
NY	Healthy	0.358	0.348	0.010	95,800	
GA	Healthy	0.355	0.339	0.016	116,300	
ND	Healthy	0.350	0.329	0.021	137,700	
FL	Healthy	0.341	0.331	0.010	106,000	
NJ	Healthy	0.338	0.314	0.024	13,800	
HI	Healthy	0.328	0.311	0.017	13,100	
VT	Healthy	0.302	0.295	0.007	16,500	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
NH	Patchy	0.296	0.276	0.020	12,500	Break point between healthy and patchy at 50% of state's area of top two quintiles
OR	Patchy	0.283	0.257	0.026	92,300	
KS	Patchy	0.279	0.264	0.015	101,000	
MO	Patchy	0.276	0.271	0.005	91,400	
AL	Patchy	0.273	0.260	0.013	62,200	
WV	Patchy	0.268	0.257	0.011	28,500	Connects to strong PA market
MN	Patchy	0.265	0.249	0.016	92,600	
TX	Patchy	0.262	0.252	0.010	282,400	
AZ	Patchy	0.258	0.242	0.016	83,600	
LA	Patchy	0.257	0.247	0.010	48,500	
OK	Patchy	0.256	0.251	0.005	73,100	
AR	Patchy	0.254	0.249	0.005	52,700	
NM	Patchy	0.245	0.236	0.009	75,500	
CO	Patchy	0.241	0.227	0.014	70,000	
ME	Weak	0.239	0.207	0.032	21,300	Small area overrides high Mean–Median value
SD	Patchy	0.233	0.221	0.012	44,900	
MI	Patchy	0.232	0.211	0.021	41,000	Non-uniform and large area of good markets
MS	Patchy	0.224	0.222	0.002	33,600	Connects to corridors in AR and LA
MT	Weak	0.204	0.194	0.010	35,900	
NV	Weak	0.201	0.192	0.009	20,900	
NE	Weak	0.190	0.174	0.016	27,700	
ID	Weak	0.182	0.164	0.018	18,000	
UT	Weak	0.150	0.141	0.009	7,800	
WY	Weak	0.118	0.101	0.017	8,600	

Table A-3. State Ethanol Market Categorization Data

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
IL	Strongest	0.627	0.585	0.042	136,500	
IN	Strongest	0.605	0.579	0.026	82,500	
IA	Strongest	0.594	0.606	-0.012	134,200	
WI	Strongest	0.483	0.463	0.020	76,500	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
MN	Strongest	0.479	0.481	-0.002	117,800	
OH	Strongest	0.444	0.428	0.016	41,800	
NE	Strongest	0.381	0.371	0.010	42,600	
NY	Strongest	0.374	0.372	0.002	22,800	
SD	Strongest	0.352	0.334	0.018	42,200	
TN	Strongest	0.352	0.337	0.015	17,100	
ND	Strongest	0.351	0.312	0.039	32,000	
KS	Strongest	0.346	0.354	-0.008	20,300	
MI	Healthy	0.336	0.282	0.054	40,500	Cutoff here due to low median
PA	Healthy	0.330	0.323	0.007	12,900	
KY	Healthy	0.328	0.311	0.017	12,800	
CA	Healthy	0.325	0.285	0.040	30,600	
NC	Healthy	0.317	0.292	0.025	14,300	
WA	Healthy	0.309	0.284	0.025	10,300	
MO	Healthy	0.307	0.290	0.017	35,100	
FL	Healthy	0.300	0.275	0.025	14,600	
HI	Weak	0.296	0.266	0.030	1,100	Too small of area for top two quintiles to be patchy
VA	Patchy	0.273	0.255	0.018	7,500	Break between healthy and patchy at 10% area
CT	Weak	0.268	0.263	0.005	100	Too uniform and too small of area for patchy
GA	Patchy	0.253	0.220	0.033	8,300	
MA	Patchy	0.252	0.239	0.013	1,100	
CO	Patchy	0.250	0.212	0.038	16,600	
RI	Weak	0.250	0.225	0.025	0	No area in top two quintiles
SC	Patchy	0.250	0.188	0.062	5,700	
MD	Patchy	0.242	0.201	0.041	3,100	
OR	Patchy	0.241	0.222	0.019	4,600	
OK	Patchy	0.239	0.215	0.024	5,400	
LA	Weak	0.232	0.231	0.001	1,400	Too uniform to be patchy
VT	Weak	0.226	0.224	0.002	0	
WV	Weak	0.226	0.212	0.014	500	
DE	Weak	0.223	0.196	0.027	100	
NJ	Weak	0.210	0.181	0.029	300	
MS	Weak	0.205	0.166	0.039	100	
TX	Patchy	0.205	0.183	0.022	15,300	Large Mean–Median and large area of top two quintiles
NM	Weak	0.202	0.188	0.014	2,700	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
AL	Weak	0.201	0.152	0.049	4,700	
ME	Weak	0.189	0.171	0.018	0	
AZ	Weak	0.188	0.180	0.008	4,600	
MT	Weak	0.170	0.165	0.005	100	
AR	Weak	0.162	0.141	0.021	3,400	
NH	Weak	0.162	0.163	-0.001	0	
NV	Weak	0.157	0.150	0.007	1,800	
ID	Weak	0.137	0.113	0.024	300	
UT	Weak	0.118	0.109	0.009	200	
WY	Weak	0.095	0.093	0.002	100	

Table A-4. State CNG Market Categorization Data

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
CT	Strongest	0.482	0.414	0.068	12,500	
NY	Strongest	0.455	0.402	0.053	123,400	
RI	Strongest	0.452	0.503	-0.051	2,100	
CA	Strongest	0.446	0.397	0.049	404,200	
PA	Strongest	0.388	0.363	0.025	98,700	
UT	Strongest	0.386	0.362	0.024	192,300	
MA	Strongest	0.369	0.315	0.054	12,300	
WV	Strongest	0.366	0.372	-0.006	58,900	
OH	Strongest	0.365	0.346	0.019	81,400	
WA	Strongest	0.365	0.345	0.020	159,600	
IN	Strongest	0.361	0.350	0.011	77,000	
NJ	Strongest	0.361	0.314	0.047	10,200	
CO	Strongest	0.347	0.338	0.009	193,600	
IL	Strongest	0.347	0.334	0.013	103,000	
VT	Strongest	0.346	0.340	0.006	18,600	
OK	Healthy	0.340	0.294	0.046	83,600	Boundary largely due to low median, relative to mean
TX	Healthy	0.327	0.316	0.011	408,500	
LA	Healthy	0.326	0.309	0.017	65,000	
VA	Healthy	0.324	0.307	0.017	59,400	
WI	Healthy	0.316	0.300	0.016	72,500	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
AZ	Healthy	0.312	0.302	0.010	151,600	
OR	Healthy	0.307	0.300	0.007	125,800	
NV	Healthy	0.305	0.293	0.012	125,200	
HI	Healthy	0.298	0.282	0.016	3,000	
MS	Healthy	0.286	0.281	0.005	46,400	
AR	Healthy	0.283	0.273	0.010	46,000	
KS	Healthy	0.282	0.279	0.003	74,000	Too uniform to be patchy
NC	Patchy	0.280	0.259	0.021	32,900	
KY	Patchy	0.278	0.276	0.002	35,200	Connects to patches all around it
DE	Weak	0.276	0.248	0.028	1,100	Area too small to be patchy
NM	Patchy	0.276	0.271	0.005	97,200	
ND	Patchy	0.274	0.277	-0.003	59,400	
FL	Patchy	0.266	0.254	0.012	34,800	
MI	Patchy	0.261	0.248	0.013	32,300	
GA	Patchy	0.255	0.238	0.017	26,900	
TN	Patchy	0.252	0.239	0.013	20,600	
ID	Patchy	0.244	0.239	0.005	19,400	
AL	Patchy	0.243	0.229	0.014	19,600	
ME	Weak	0.243	0.232	0.011	9,300	Area too small to be patchy
NE	Patchy	0.242	0.244	-0.002	31,700	
NH	Weak	0.239	0.220	0.019	3,300	Mean and median too close to be patchy
MD	Weak	0.237	0.197	0.040	5,900	
WY	Patchy	0.237	0.227	0.010	32,500	Patchy due to large area of Area of Top Two Quintiles (square km)
MT	Weak	0.234	0.231	0.003	52,800	
MN	Weak	0.227	0.222	0.005	16,300	
IA	Weak	0.223	0.222	0.001	8,800	
SD	Weak	0.197	0.199	-0.002	5,900	
MO	Weak	0.181	0.170	0.011	7,900	
SC	Weak	0.134	0.125	0.009	3,000	

Table A-5. State Propane Market Categorization Data

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
IN	Strongest	0.586	0.616	-0.030	89,100	
CT	Strongest	0.506	0.490	0.016	10,100	
CA	Strongest	0.497	0.465	0.032	394,900	
IL	Strongest	0.465	0.408	0.057	125,400	
WA	Strongest	0.461	0.441	0.020	157,400	
PA	Strongest	0.452	0.400	0.052	101,900	
TX	Strongest	0.448	0.394	0.054	473,900	
WV	Strongest	0.447	0.430	0.017	59,600	
OH	Healthy	0.435	0.386	0.049	77,700	Break at a large drop in mean, median, and % Area of Top Two Quintiles (square km)
MS	Healthy	0.434	0.494	-0.060	70,800	
DE	Healthy	0.433	0.371	0.062	3,100	
UT	Healthy	0.424	0.421	0.003	187,900	
RI	Healthy	0.418	0.449	-0.031	2,200	
CO	Healthy	0.415	0.401	0.014	210,600	
WI	Healthy	0.407	0.384	0.023	90,300	
VA	Patchy	0.405	0.357	0.048	51,400	Patchy because of large Mean–Median value
NV	Patchy	0.402	0.392	0.010	208,300	
NY	Patchy	0.401	0.362	0.039	65,100	
OK	Patchy	0.379	0.335	0.044	46,700	
HI	Patchy	0.375	0.333	0.042	6,700	
LA	Patchy	0.374	0.349	0.025	47,400	
AZ	Patchy	0.370	0.355	0.015	143,300	
NM	Patchy	0.367	0.355	0.012	144,300	
KY	Patchy	0.363	0.318	0.045	36,600	
NJ	Patchy	0.361	0.309	0.052	7,700	
TN	Patchy	0.358	0.310	0.048	38,000	
NC	Patchy	0.356	0.324	0.032	44,800	
OR	Patchy	0.355	0.343	0.012	96,100	
VT	Patchy	0.353	0.343	0.010	4,200	
AR	Patchy	0.346	0.314	0.032	34,300	
AL	Patchy	0.344	0.299	0.045	49,000	
KS	Patchy	0.337	0.320	0.017	59,600	
MN	Patchy	0.332	0.323	0.009	52,200	
MD	Patchy	0.331	0.269	0.062	9,200	

State	Category	Mean MV	Median MV	Mean–Median	Area of Top Two Quintiles (square km)	Notes
MT	Patchy	0.319	0.314	0.005	83,400	
MI	Patchy	0.315	0.276	0.039	39,400	Patchy because of large area in top two quintiles
MA	Patchy	0.314	0.260	0.054	8,000	Patchy because high Mean–Median value and close to CT and NY patches
ND	Weak	0.312	0.322	-0.010	35,800	
MO	Weak	0.289	0.251	0.038	41,400	
ME	Weak	0.287	0.276	0.011	5,200	
ID	Weak	0.282	0.274	0.008	12,300	
FL	Weak	0.265	0.229	0.036	25,700	
NH	Weak	0.263	0.219	0.044	5,700	
WY	Weak	0.262	0.251	0.011	13,200	
SD	Weak	0.249	0.236	0.013	18,900	
NE	Weak	0.246	0.236	0.010	15,000	
IA	Weak	0.242	0.214	0.028	16,500	
GA	Weak	0.241	0.219	0.022	20,000	
SC	Weak	0.232	0.191	0.041	13,100	