ClearFlame TCO and Emissions Study

ClearFlame ENGINE TECHNOLOGIES

Two challenges face the over-the-road, heavy-duty truck market: reducing operating costs and meeting demands – both from consumers and regulators – to reduce emissions. Transitioning to more sustainable fuels and technologies could be a potential solution, but fleets have faced several challenges adopting them: practical challenges such as cost, range, and technological development, and many of these fuels and their infrastructure are not yet widely available.

ClearFlame is changing that. Its technology enables diesel engines to run on 100% plant-based fuels like ethanol, and it, as this study shows, could represent a rapid emissions reduction solution while reducing operating costs for fleets.

This independent study, conducted by Gladstein, Neandross & Associates (GNA), shows how ClearFlame's technology, combined with its ethanol supply model, could help fleets quickly and cost-effectively overcome the barriers to adopting this readily available, renewable, decarbonized fuel.

By comparing ClearFlame's total cost of ownership (TCO) and emissions performance expectations compared to alternatives – compressed natural gas (CNG), battery electric (BEV), and fuel cell vehicles (FCV) – this study also shows how ClearFlame can help fleet owners and operators lower total costs while meeting sustainability goals sooner than any available alternative.

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Key Takeaways

- ClearFlame's technology has the lowest TCO of any current technologies, including diesel, natural gas, electric, and hydrogen.
- ClearFlame provides a 42% greenhouse gas reduction compared to diesel, as well as 23% less carbon than battery electric vehicles based on the national average grid mix.
- While most of the discussion around sustainable fuels today focuses on compressed natural gas, battery-electric, and hydrogen fuel cell vehicles, ClearFlame's technology and fuel supply model could play a valuable role in sustainable transportation.
- ClearFlame can provide a quick and cost-effective path to substantial reductions of greenhouse gas (GHG) and tailpipe emissions compared to other sustainable fuels and technologies, all while utilizing familiar technology and existing infrastructure.

ClearFlame was allowed to comment on the study protocol and was provided with a report of the results. The study results were not impacted apart from suggestions for clarification.

Executive Summary

Fleets are facing continually increasing pressure to transition their equipment to more sustainable fuels and technologies. While most of the discussion around sustainable fuels today focuses on compressed natural gas (CNG), battery-electric (BEV), and hydrogen fuel cell vehicles (FCV), alcohol fuels have the potential to play a valuable role in sustainable transportation.

ClearFlame Engine Technologies (ClearFlame) has developed engine technology and an ethanol fuel supply model that could address the historic barriers to the adoption of ethanol fuels in the heavy-duty market. An analysis of the expected emissions performance and total cost of ownership for the ClearFlame business model versus diesel, CNG, BEV, and FCV options in the over-the-road heavy-duty truck market presented in this paper indicates that:

- The TCO of ClearFlame-based trucks could be, on average, $0.08 per mile lower than diesel trucks in over-the-road applications.
- ClearFlame's cost per mile in this application is expected to be substantially lower than BEV and FCV platforms, primarily due to the high purchase costs of these platforms.
- ClearFlame's technology has the potential to significantly reduce well-to-wheels GHGs and tailpipe emissions relative to traditional diesel fuel.
- GHG reductions from the ClearFlame system could actually outstrip BEVs based on the national average grid mix and referenced fuel economies.
- While both BEV and FCV platforms have the potential to provide zero tailpipe emissions, these technologies are not yet commercially available for long-haul trucking, and fueling/charging infrastructure remains a significant barrier. Additionally, the cost per mile for these technologies in long-haul trucking is currently high, making technologies like ClearFlame important options to immediately provide cost-effective GHG and tailpipe emissions reductions.

Introduction

Fleets are facing continually increasing pressure to transition their equipment to more sustainable fuels and technologies. These pressures include federal, state, and local emissions requirements focused on criteria pollutant and air toxics as well as greenhouse gas (GHG) reduction targets set by customers and shareholders. While most of the discussion around sustainable fuels today focuses on compressed natural gas (CNG), battery electric (BEV), and fuel cell vehicles (FCV), alcohol fuels have the potential to play a valuable role in sustainable transportation. Historically, alcohol fuels like ethanol – primary seen as a gasoline blending ingredient (e.g., E85) – have been limited to spark-ignited engine applications. In heavy-duty on-road trucking applications, spark-ignited engines demonstrate lower thermodynamic efficiency and typically lower torque, resulting in performance tradeoffs and higher fuel consumption rates. When these tradeoffs are combined with retail ethanol prices that are traditionally higher than diesel fuel on an energy-equivalent basis, previous ethanol-based heavy-duty engine applications have struggled to find a compelling value proposition.

Challenging these assumptions, ClearFlame Engine Technologies (ClearFlame) has developed engine technology and an ethanol fuel supply model that could address the historic barriers to the adoption of ethanol fuels in the heavy-duty market. This whitepaper analyzes the expected emissions performance and total cost of ownership (TCO) for the ClearFlame business model versus diesel, CNG, BEV, and FCV options in the over-the-road (OTR) heavy-duty truck market.

Diesel Engine Technology

Diesel engines achieve their high fuel efficiency and torque, relative to spark-ignited engines, because fuel is combusted as it enters the combustion chamber. Diesel fuel combusts as it enters the high pressure/temperature combustion chamber and mixes with the combustion air and is referred to as mixing-controlled compression ignition (MCCI) combustion. This rapid heat release when the piston is near the top of its compression stroke allows the subsequent expansion stroke to extract maximum energy from the fuel.

While this process maximizes efficiency, it also produces high in-cylinder temperatures that aid in the formation of oxides of nitrogen (NOx) that must be controlled through additional measures. Typically, these control mechanisms are exhaust gas recirculation (EGR) and Selective Catalytic Reduction (SCR). Additionally, diesel fuel is a complex hydrocarbon chain that has a high propensity for soot, or particulate matter (PM), formation from partially combusted carbon chains in the engine exhaust. Control measures that reduce NOx tend to increase PM emissions, and vice versa. For example, EGR recirculates exhaust gases into the cylinder to displace oxygen and reduce the peak cylinder temperatures that promote NOx formation. However, lower cylinder temperatures reduce the speed of combustion, typically resulting in more of the complex diesel hydrocarbon chains being only partially combusted before being exhausted from the engine.

These tradeoffs necessitate that modern diesel engines be equipped with diesel particulate filters (DPF) in addition to EGR and SCR systems so that the engines can meet current emissions standards that simultaneously require very low NOx and PM emissions.

ClearFlame's Engine Technology

ClearFlame has developed a technology that allows a heavy-duty engine to continue to operate using MCCI-based combustion when fueled on a wider range of fuels, including ethanol. Because this technology allows the engine to continue to operate on an MCCI diesel-like cycle, the engine maintains the high thermal efficiency and torque of traditional diesel engines.

Ethanol is composed of much shorter hydrocarbon chains (two-carbon atoms vs diesel's twelve-carbon atoms) that reduce or eliminate soot formation under typical engine conditions. This is the same mechanism that allows natural gas engines to reduce in-cylinder soot formation due to the single-carbon molecular composition of methane. Additionally, the inherently lower soot forming propensity of ethanol compared to diesel fuel would allow ClearFlame to minimize engine-out NOx emissions and reduce the burden on the existing SCR system. ClearFlame als has the potential to operate the engine at stoichiometric conditions, enabling the use of three-way catalyst (TWC) aftertreatment systems to control NOx emissions. TWC systems are the same aftertreatment technology used in light-duty gasoline vehicles and in heavy-duty CNG vehicles. TWC systems are lighter and less expensive than SCR systems, and do not require the use of diesel emission fluid (DEF), resulting in lower capital, operating, and maintenance costs for the aftertreatment system. While replacing the SCR with a TWCC remains a long-term goal of the company, their initial products will continue to utilize SCR technology.

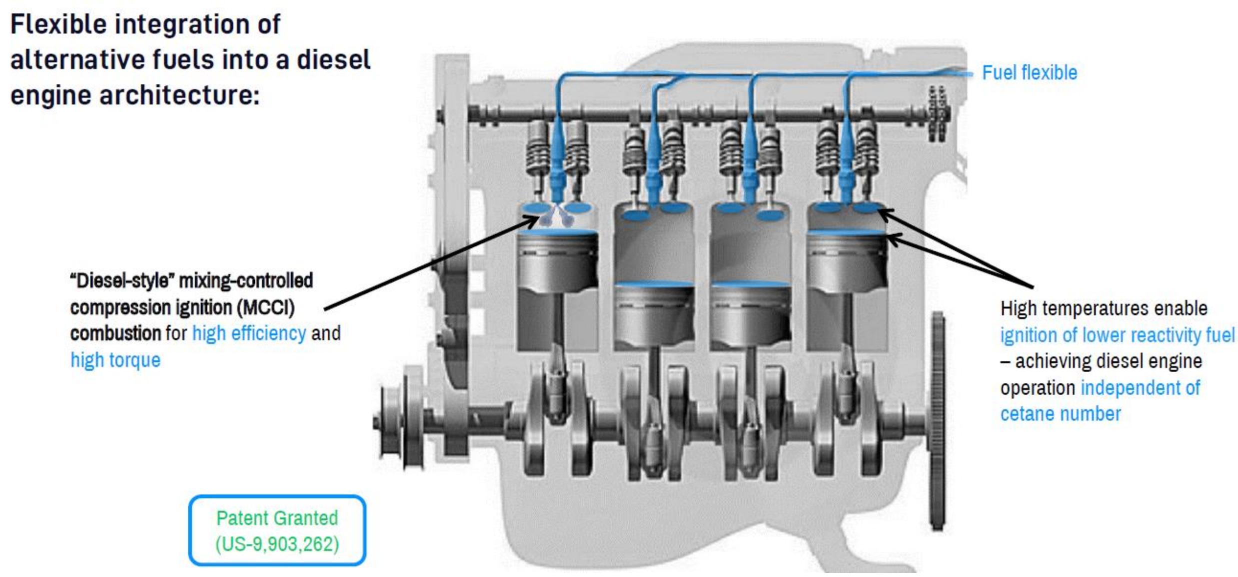

Figure 1. ClearFlame-based engine technology uses MCCI to maintain diesel engine cycle efficiency and torque

Retrofit and New Engine Options

The ClearFlame system is currently being demonstrated on the Cummins X15 diesel platform through a retrofit strategy that entails the modification of some EGR and intake air components (Figure 2), as well as fuel injectors and other fuel system components. While this means the system cannot dynamically switch between diesel and ethanol in operation, it does allow the ClearFlame system to leverage existing diesel engine platforms as either a retrofit of an existing in-use vehicle or as an upfit of a new diesel vehicle on the factory production line.

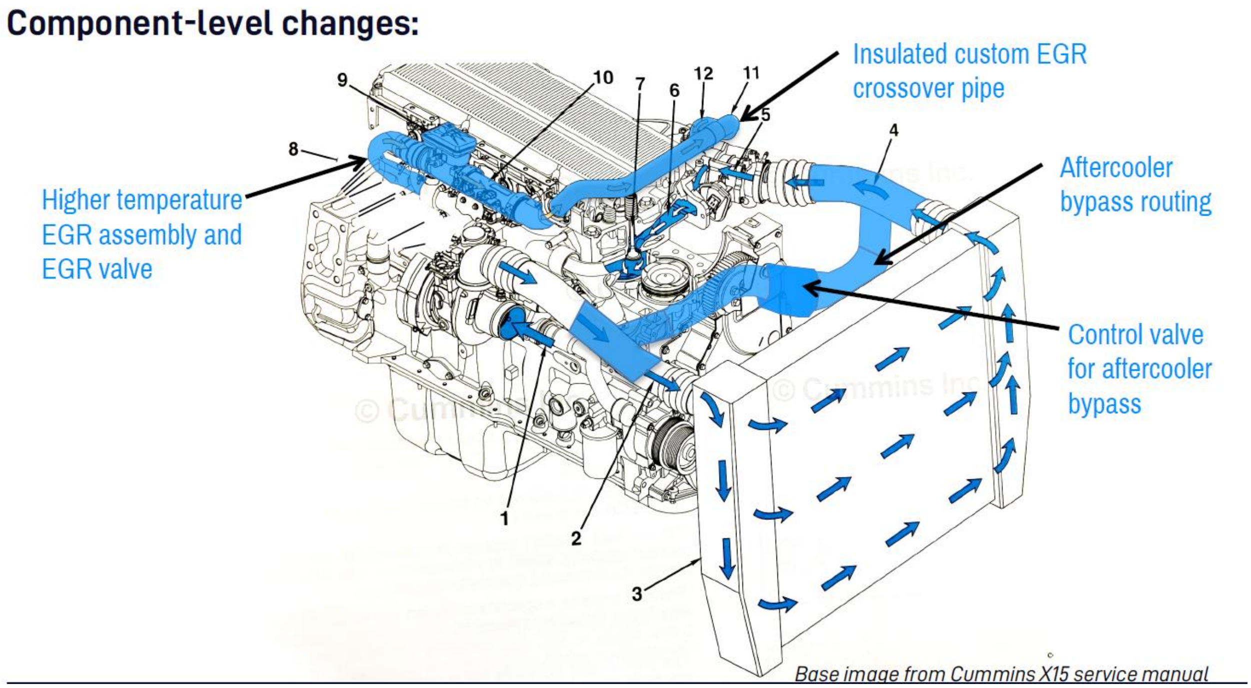

Figure 2. EGR and air flow component modifications

ClearFlame Fuel Supply Model

Ethanol is one of the most commonly used transportation fuels, blended into gasoline in many areas of the US at levels of up to 15 percent by volume. Additionally, blends of ethanol in gasoline of up to 85 percent by volume (E85), are used in some light-duty vehicles. These vehicles, known as flexible fuel vehicles, can run on any mix of gasoline and ethanol up to E85 and include many popular makes and models of light duty cars and trucks. As of 2018, IHS Markit estimated that there were more than 21 million FFVs in the US,[1] however, the Renewable Fuels Association reports that the number of new vehicle models available for sale in the US that are FFVs have declined to just 11 models.[2] Further, the existing base of FFVs in the US predominantly uses regular gasoline rather than preferentially purchasing E85.[3] While

[1] https://afdc.energy.gov/vehicles/flexible_fuel.html

[2] https://ethanolrfa.org/media-and-news/category/news-releases/article/2021/12/rfa-analyses-of-2022-automobile-models-more-e15-approvals-but-fewer-ffvs

[3] FFVs represent about 8 percent of light-duty on-road vehicles, while E85 consumption equates to only 0.2 percent of on-road gasoline consumption.

there are several factors contributing to this decline, the lack of compelling fuel savings is likely a central issue that has limited E85 use in the US.

As of October 2021, the Alternative Fuels Data Center reported the national average price of E85 at $2.73 per gallon versus gasoline at $3.25 per gallon.[4] However, E85 contains approximately 23 percent less energy per gallon than gasoline. When converted to an energy equivalent basis, E85 is priced approximately ten percent more than gasoline ($3.55 per gasoline-gallon equivalent).

This price gap can grow when E85 is compared to diesel fuel. E85 contains approximately 32 percent less energy than a gallon of diesel fuel. For the same October 2021 time period discussed above, the national average diesel price was $3.48 per gallon. On a diesel-gallon equivalent price basis of $4.01, E85 represents a 15 percent cost increase. Further, because E85 is used in spark-ignited engines that are less fuel efficient than diesel engines, the price penalty for E85 versus diesel increases. While the exact fuel efficiency penalty of spark-ignited engines versus diesel engines varies, the penalty is often in the 5 to 15 percent range, potentially increasing the fuel cost disadvantage of E85 to 30 percent relative to diesel fuel.

ClearFlame seeks to address this fuel price gap in two ways. First, because ClearFlame's technology maintains the diesel-like efficiency of the engine, there is no additional fuel cost associated with the reduced efficiency of traditional spark-ignited ethanol engines. Second, ClearFlame is working with partners to ensure that the value of important environmental credits are passed on to the fleet.

Ethanol used in transportation applications is eligible to generate credits under the Renewable Fuel Standard (RFS). These credits, known as RINs, can carry significant value. In the first two months of 2022, a standard ethanol RIN[5] had an average value of $1.13 per ethanol gallon.[6] Note that this is for neat ethanol (E100). When adjusted to a diesel-equivalent price, the value of the RIN is $1.86 per diesel-gallon equivalent. Ethanol in transportation will always be denatured to prevent human consumption, typically by adding two percent natural gasoline or other denaturant. This E98 blend would generate a RIN value of $1.83 per diesel gallon equivalent. A review of E98 rack fuel pricing and an evaluation of implied E98 fuel costs based on national average E85 prices indicates that the current cost for E98 is approximately $2.49/gallon, or $4.11 per diesel-equivalent gallon.[7]

Without the value of the RIN, E98 would represent a cost penalty of 18 percent versus diesel, for the ClearFlame system. However, when E98 is sold at the rack, the price typically includes transferring the right to claim the RIN to the fuel purchaser. If the value of the RIN could be applied to the fuel, it would reduce the effective cost of the E98 to $2.28 per diesel gallon equivalent, or a 35 percent cost reduction compared to diesel fuel. Unfortunately, fleets are

[4] https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_october_2021.pdf

[5] Assumed to be a D-6 RIN for "conventional biofuel."

[6] https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information

[7] OPIS End of Day Ethanol Price Assessments for January and February 2022.

rarely equipped to properly claim, detach, and sell RINs from fuel they purchase. Hence, the value of the RINs would typically be lost if a fleet were to purchase E98 from the fuel rack.

ClearFlame has developed partnerships with fuel providers that will allow ClearFlame to provide fuel supply contracts to fleets that pass through most or all of the value of the RIN credit to the fleet. By handling the administrative and credit brokering components of the RIN process for fleets, ClearFlame seeks to provide E98 at a significant discount to diesel on an energy-equivalent basis.

Total Cost of Ownership Analysis

To assess the potential comparative costs of ClearFlame's technology to diesel, CNG, BEV, and FCV platforms, a TCO model was developed. The model evaluates these platforms in a Class 8 over-the-road application. This market is assumed to be well suited to the ClearFlame technology as vehicle range, weight, fuel costs, fuel availability, and fueling time are key concerns in this application.

The TCO model evaluates the following cost components for each technology:

- Vehicle Purchase Cost
- Federal Excise Tax
- State Sales Tax
- Vehicle Maintenance
- Vehicle Insurance
- Fuel Costs
- Depreciation Tax Benefits
- Incentives (RFS and Low Carbon Fuel Standard)
- Residual Value

The net cash flow over the useful life of the truck (8 years) is used to calculate the average cost per mile (CPM) for each of the technologies. The average annual mileage for this analysis is 101,000 miles, based on the US EPA MOVES model default value for Class 8 long-haul semi-tractors. Regional CPM estimates were developed using projections of fuel prices for each technology at the Petroleum Administration Defense District (PADD) level (Figure 3).

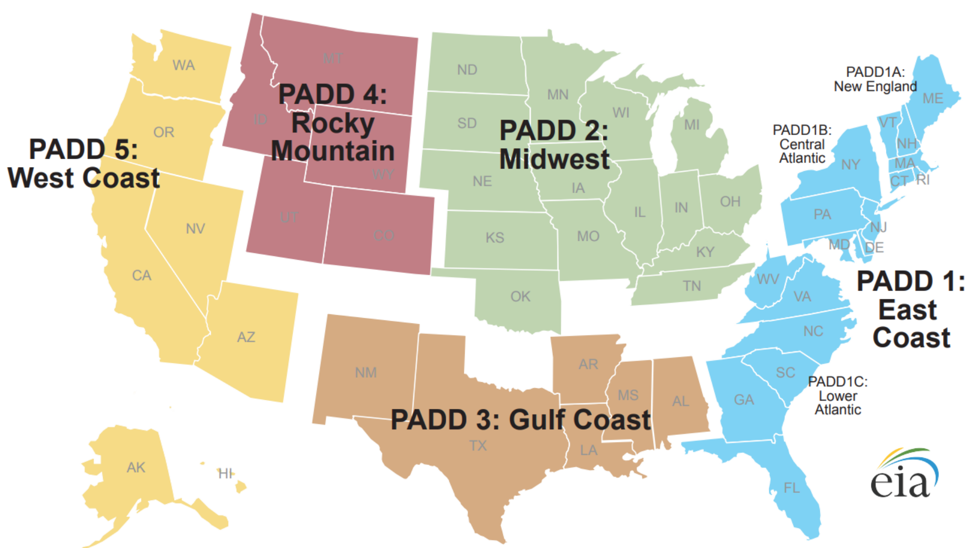

Figure 3. PADD Regions (US Energy Information Administration)

Vehicle Purchase Prices

Table 1 summarizes the vehicle purchase price assumptions used in the TCO analysis. BEV and FCV pricing are consistent with assumptions a recent TCO study for zero-emission vehicles conducted by NREL. [8] The ClearFlame sale price is based on an incremental system cost of $15,000 for a new truck with the system integrated at the factory. Retrofit of an existing truck would be approximately $25,000 more than a factory-integrated system, per ClearFlame's estimates. Federal Excise Tax (FET) applies to the sale price of Class 8 trucks of the kind that would be used in OTR applications, adding 12 percent to the sale price. Sales tax is also considered on a state-by-state basis, using statewide average rates.[9]

Table 1. Vehicle Purchase Price Assumptions

Technology	Diesel	ClearFlame	CNG	BEV	FCV
Fuel	Diesel	E98	CNG	Electricity	Hydrogen
Sale Price	$135,000	$150,000	$190,000	$550,000	$312,500
FET (12%)	$16,200	$18,000	$22,800	$66,000	$37,500
Sales Tax	Varies by State				

Fuel Prices

Fuel prices used in this analysis are intended to reflect retail fuel prices, inclusive of fueling infrastructure costs. The ClearFlame approach is certainly applicable to depot-based fueling, however, for the OTR application considered in this analysis it is likely that trucks would rely on retail or cardlock fueling stations. Consequently, fueling infrastructure costs are not explicitly modeled but are assumed to be accounted for in the retail fuel prices. Table 2 summarizes the fuel price assumptions for the 2022 calendar year.

Prices for CNG, Diesel, E85, and Gasoline are based on Alternative Fuels Data Center prices as of October 2021. While more current diesel and gasoline prices are available, the market is currently experiencing fuel price shocks related to international conflicts and it was determined that using these currently high prices relative to the October 2021 prices for other fuels would potentially overstate the relative cost of diesel and gasoline. The cost of E98 was estimated using E85 and gasoline prices to determine the cost of ethanol in the E85 blend.[10]

Electricity and hydrogen retail prices are necessarily speculative. Currently, no retail heavy-duty truck charging stations (truck stop-like facilities) exist. Electricity prices were based on current network pricing for DC fast charging at Electrify America locations. Similarly, only two semi-public heavy-duty hydrogen fueling stations exist in the US. These are located in Southern California and have received extensive subsidies for construction, making fueling prices at these

[8] Hunter C. et al, "Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks", September 2021. National Renewable Energy Laboratory. NREL/TP-5400-71796. https://www.nrel.gov/docs/fy21osti/71796.pdf. Figure 27 prices adjusted to remove the 5% flat tax assumption used by the authors.

[9] State & Local Sales Tax Rates, as of January 1, 2022. www.taxfoundation.org/2022-sales-taxes

[10] E85 sold in the US is typically about 68 percent ethanol by volume.

stations likely unrepresentative of future hydrogen pricing. This TCO analysis uses hydrogen pricing assumed in a recent NREL study of on-road heavy-duty vehicle costs.[11]

Table 2. Retail Fuel Price Assumptions

Region	Diesel ($/gal)	E85 ($/gal)	CNG ($/DGE)	Gasoline ($/gal)	Implied E98 ($/gal)	Elect. ($/kWh)	Hydrogen ($/kg)	DEF ($/gal)
PADD 1A - New England	3.41	3.55	3.15	3.23	3.70	0.31	$10.00	3.89
PADD 1B - Central Atlantic	3.27	2.68	2.74	3.16	2.45	0.31	$10.00	3.89
PADD 1C - Lower Atlantic	3.34	2.68	2.34	3.08	2.49	0.31	$10.00	3.89
PADD 2 - Midwest	3.38	2.69	2.5	3.08	2.51	0.31	$10.00	3.89
PADD 3 - Gulf Coast	3.09	2.52	2.52	2.82	2.38	0.31	$10.00	3.89
PADD 4 - Rocky Mountain	3.54	3.05	2.51	3.54	2.82	0.31	$10.00	3.89
PADD 5 - West Coast	4.38	3.35	2.88	4.34	2.88	0.31	$10.00	3.89
NATIONAL AVERAGE	3.48	2.73	2.63	3.25	2.49	0.31	$10.00	3.89

Operating and Maintenance Costs

Annual maintenance costs for the baseline diesel truck were derived from the American Truck Research Institute's annual Analysis of the Operational Costs of Trucking report for 2021. Specifically, maintenance costs for full truck load operations were used for this analysis. Diesel maintenance costs were $0.148/mile. CNG and ClearFlame maintenance costs are assumed to be equal to diesel costs. BEV and FCV costs are much more speculative and rely on NREL's assumptions of 35 percent reductions for BEVs and no maintenance cost reduction for FCVs versus diesel.

Table 3. Maintenance Cost Assumptions ($/mile)

Diesel	ClearFlame	CNG	BEV	FCV
$0.148	$0.148	$0.148	$0.10	$0.15

Costs associated with Wages, Benefits, Permits, and Tires account for an additional $0.833 per mile. Insurance costs are estimated assuming truck-related costs at 3 percent of the market value of the truck. Liability and other insurance costs are not calculated and assumed to be independent of the truck technology used.

Residual values for the baseline diesel truck assume a 25 percent residual at the end of the 8 year useful life. All other technologies are assumed to have the same residual value as the diesel vehicle, regardless of their higher initial purchase price.

[11] Hunter C. et al, "Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks", September 2021. National Renewable Energy Laboratory. NREL/TP-5400-71796. https://www.nrel.gov/docs/fy21osti/71796.pdf

Environmental Credit Values

As previously discussed, the value of RIN credits is an important component of the ClearFlame value proposition. RINs are applicable throughout the US. For purposes of this analysis, RINs were assumed to have a value of $1.13 per RIN and the full value of the RIN is passed through to the fleet. In California and Oregon, the use of low carbon fuels can also generate credits under each state's Low Carbon Fuel Standard (LCFS) program. However, because the fuel prices used in this analysis represent retail prices, it is assumed that LCFS credits would not be available to the fleet in these regions.

TCO Modeling Results

The results of the TCO analysis for diesel and ClearFlame-based trucks are shown in Figure 4 and Figure 5. Results are strongly influenced by the PADD region a state belongs to as this impacts fuel price assumptions. As shown, the ClearFlame-based truck provides a lower CPM than diesel in most states. Figure 6 shows the net difference between the ClearFlame and diesel truck CPMs in each state. On average, the ClearFlame truck results in a $0.06 per mile lower operating cost. Table 4 summarizes the CPM averaged across all states and the average cost differential between each technology and the ClearFlame CPM. As shown, CNG and diesel exhibit a similar CPM in this application (assuming using retail fueling stations). This is largely associated with the significant fuel economy penalty assumed for the CNG truck (approximately 20% lower fuel economy than diesel) in this analysis. Both BEV and FCV platforms show substantially higher costs per mile than the other three technologies. This is primarily due to the high purchase costs of these platforms at this time.

Table 4. Average Cost per Mile Results ($/mile)

	Diesel	ClearFlame	CNG	BEV	FCV
Average of all states	$1.53	$1.47	$1.54	$2.46	$2.12
Avg Differential vs Diesel	$0.00	-$0.06	+$0.01	+$0.93	+$0.58

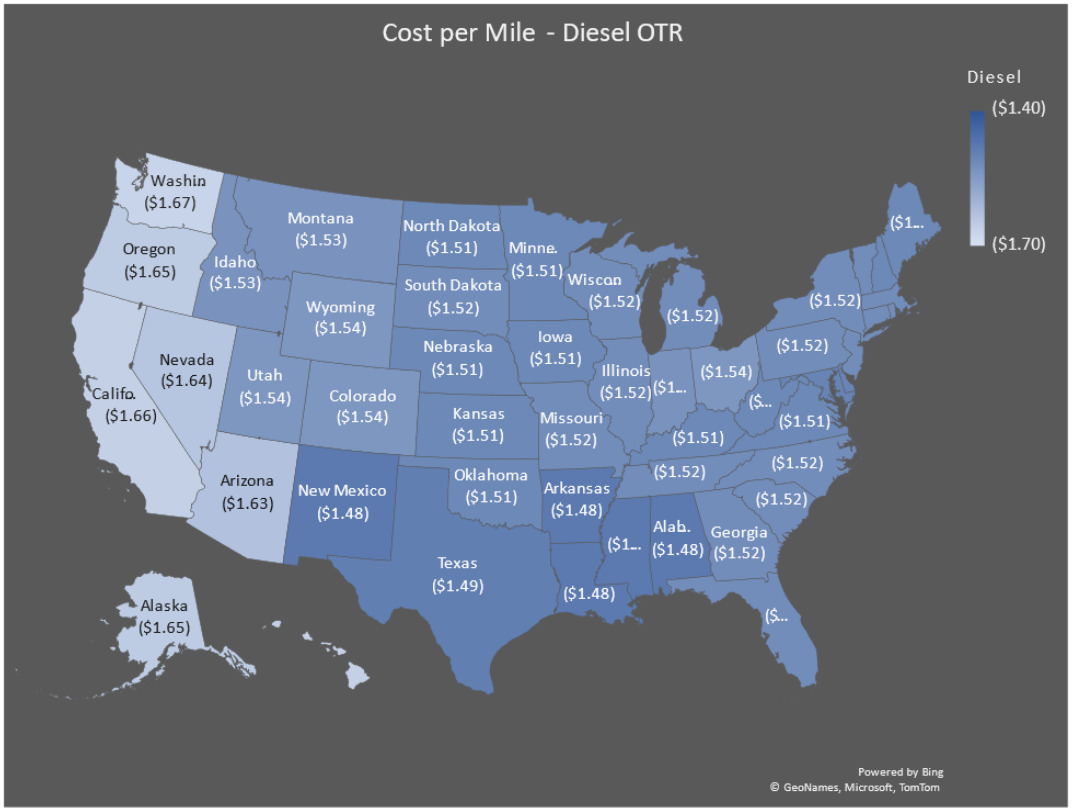

Figure 4. Cost per Mile - Diesel Over-the-Road Truck

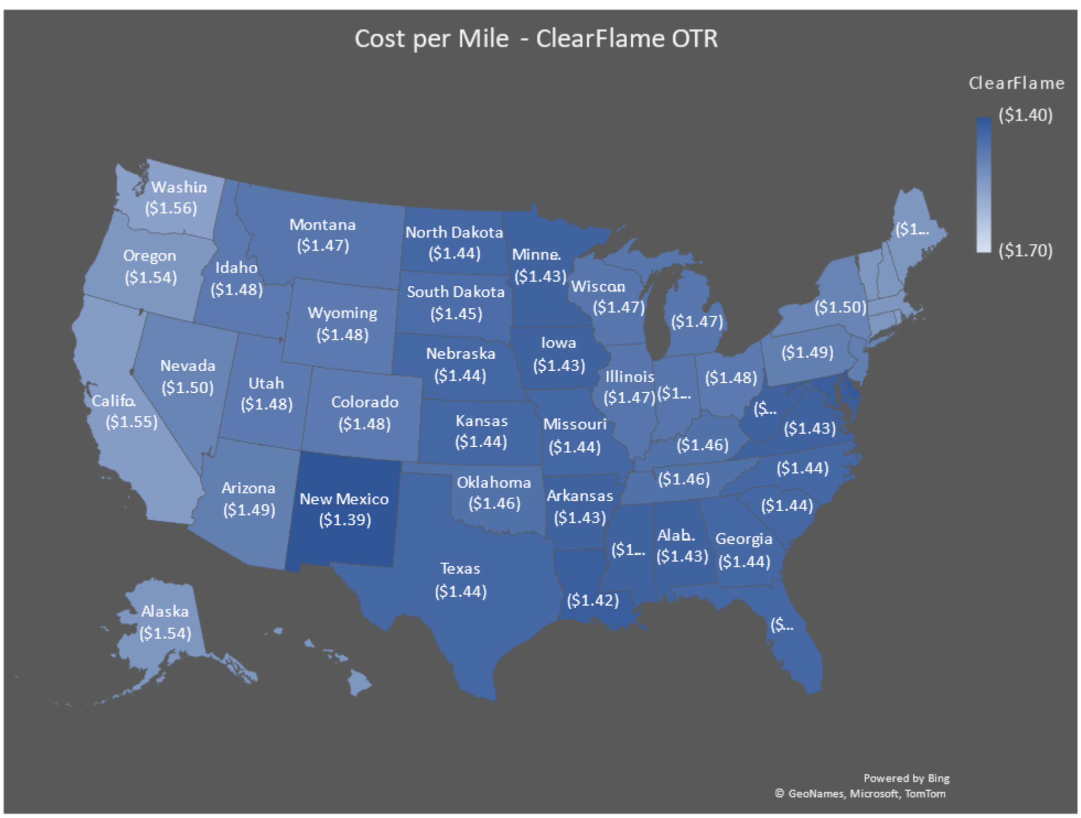

Figure 5. Cost per Mile - ClearFlame Over-the-Road Truck

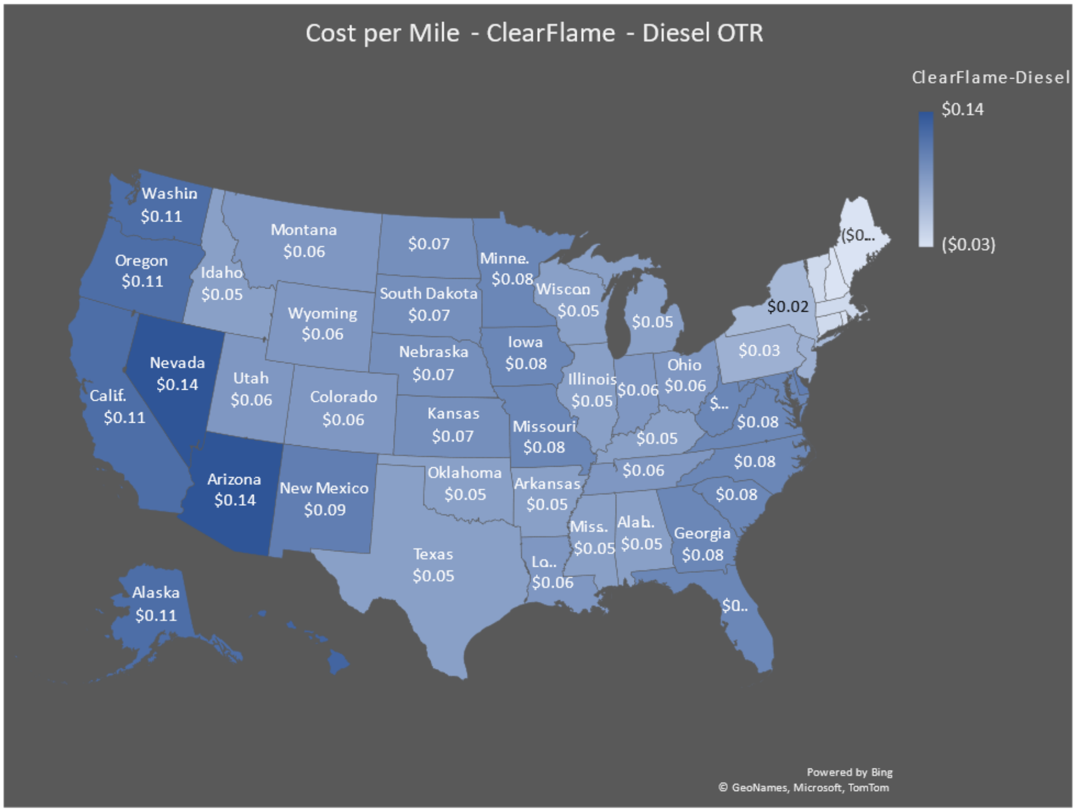

Figure 6. Cost per Mile - Diesel versus ClearFlame

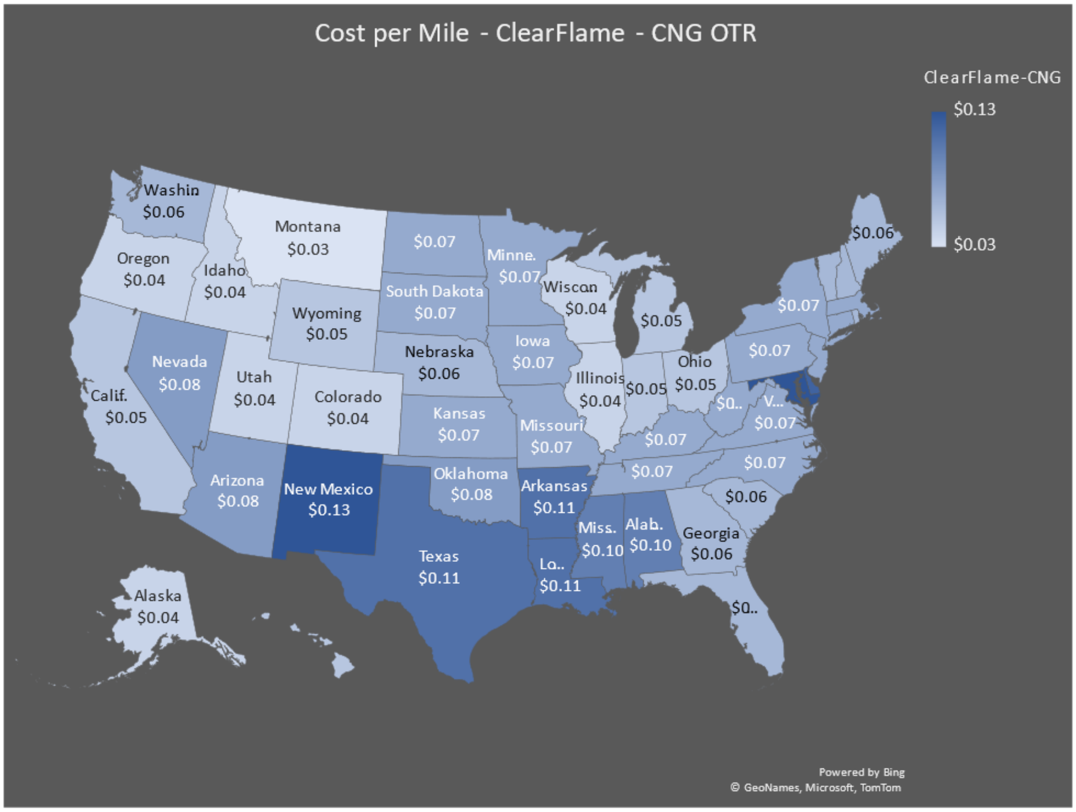

Figure 7. Cost per Mile - CNG versus ClearFlame

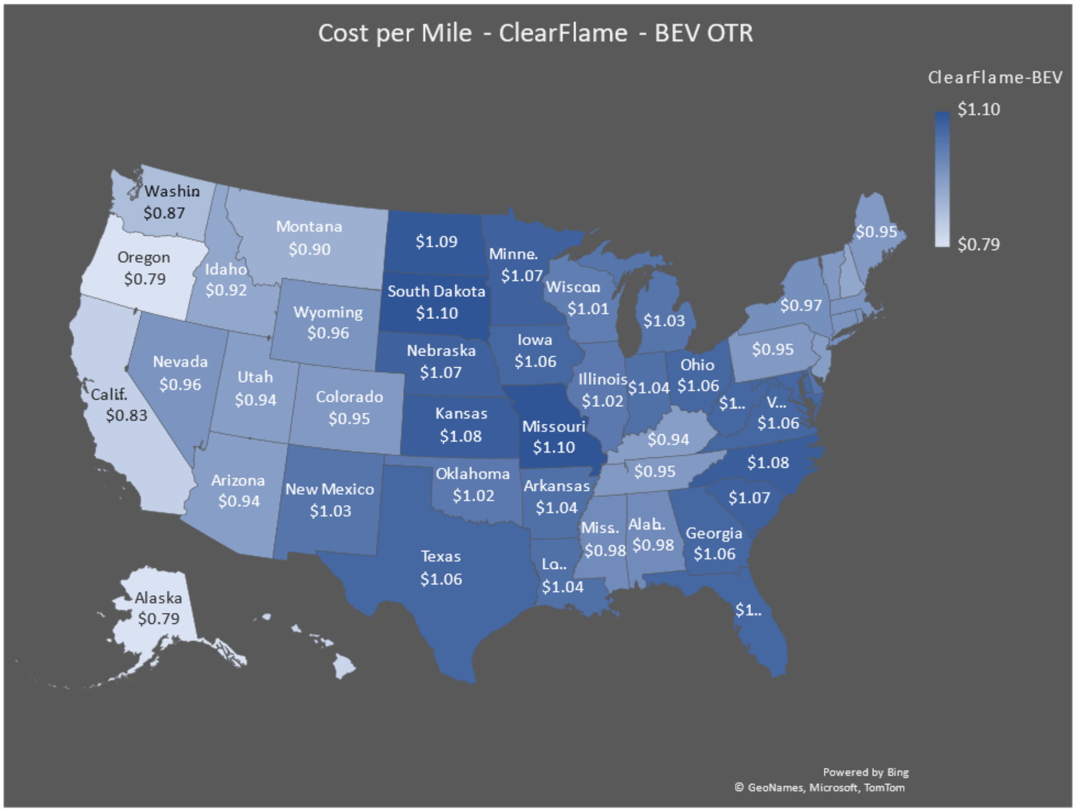

Figure 8. Cost per Mile - BEV versus ClearFlame

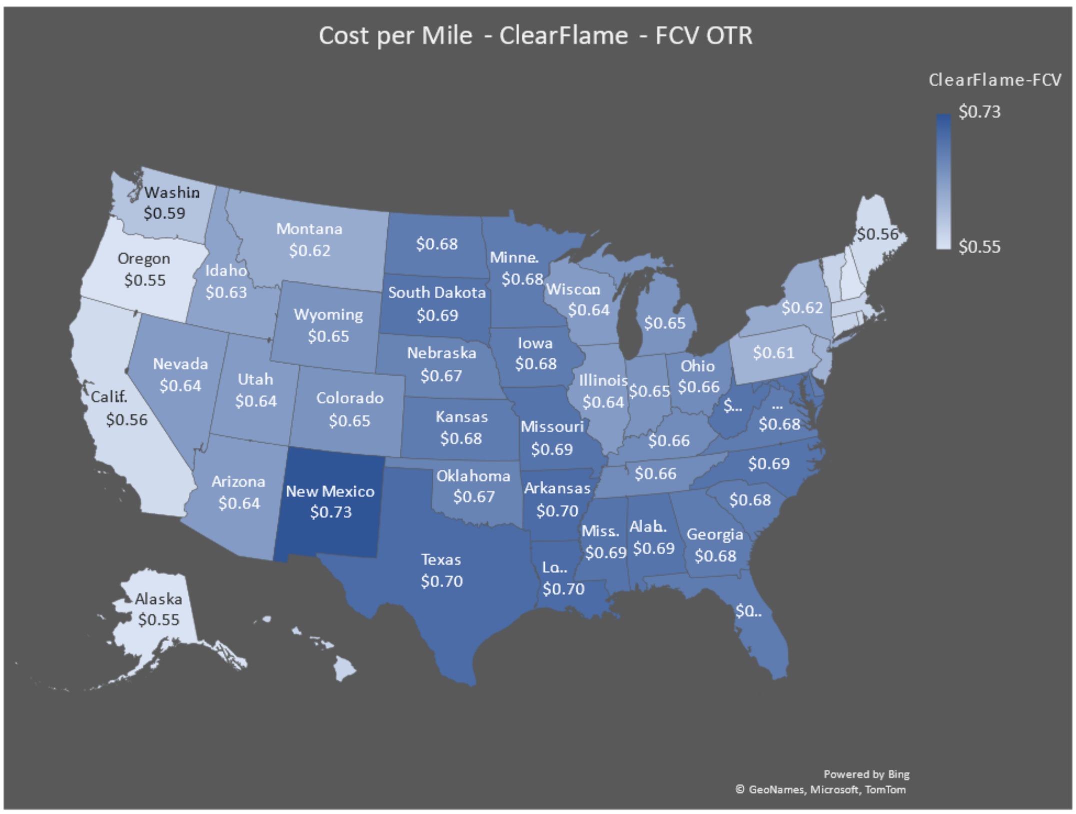

Figure 9. Cost per Mile - FCV versus ClearFlame

Emissions Analysis

To assess the potential emissions performance of ClearFlame's technology to diesel, CNG, BEV, and FCV platforms, an emissions model was developed. The model assumptions are linked to the assumptions used in the TCO analysis. Specifically, fuel economy and annual mileage assumptions are linked to the TCO model and, when coupled emissions factors for each fuel and technology, drive the majority of the emissions results.

The emissions model estimates emissions rates for the following pollutants:

- Well-to-tank GHGs
- Tank-to-wheels GHGs
- Well-to-wheels GHGs
- Tailpipe NOx
- Tailpipe PM2.5
- Tailpipe DPM
- Tailpipe SOx
- Tailpipe NMHC

PM2.5: Particulate matter with a characteristic diameter of 2.5 microns or less, DPM: Diesel fuel-derived particulate matter, SOx: Oxides of sulfur, NMHC: Non-methane hydrocarbons

The model also considers both traditional and renewable fuel types. Table 5 summarizes the fuel feedstock/pathway assumptions for all states other than California and Oregon. In these two states, the statewide averages or default fuel pathways as reported in the states' LCFS program reporting are used to establish the traditional and renewable fuel pathways and associated carbon intensities.

Table 5. Fuel Feedstock Assumptions

Platform	Traditional Fuel	Renewable Fuel
Diesel	Ultralow Sulfur Diesel	Renewable Diesel (Soy)
ClearFlame	Average E98 (Corn)	E98 from Corn Stover
Low NOx CNG	Fossil Natural Gas	Renewable Natural Gas (Landfill Gas)
BEV	Grid-average	PV/Wind Generation
FCV	Reformation of Fossil Natural Gas	Electrolysis using PV/Wind

Emissions Factors and Assumptions

Tailpipe pollutant emissions are calculated using default state level emissions factors from the US EPA's MOVES 3.0 model. This model is the approved and required emissions model for reporting of transportation emissions inventories in State Implementation Plans and for Transportation Conformity analyses. Emissions factors and annual mileage from the MOVES model were extracted for calendar year 2022 for Class 8 Combination Long-haul Diesel Trucks on a state-by-state basis.

The MOVES emissions factors were calculated using the Emissions Inventory mode of the model to report total annual emissions. These emissions were then divided by the total annual mileage to calculate an average per-mile emissions rate. Because the MOVES model assumes a certain amount of work done over specific drive cycles in its emissions calculations, the per-mile emissions rates are subsequently scaled using the ratio of the MOVES fuel economy to the baseline diesel fuel economy in the TCO model. Emissions factors for non-diesel platforms were then estimated by applying multipliers (summarized in Table 6) based on engine/technology certification values and fuel studies to the baseline diesel vehicle emissions rates. While the current ClearFlame technology is achieving NOx parity with modern diesel engines, ClearFlame is developing the system to comply with California's 2027 Low NOx standards. The emissions analysis evaluates both the current ClearFlame system and a Low NOx version of the ClearFlame technology.

Table 6. Emission Factor Multipliers by Technology and Fuel

Platform	Fuel	NOx	PM2.5	SOx	NMHC
Diesel[12]	Renewable Diesel	0.87	0.71	0.05	1
ClearFlame	E98	1	0.01	0.05	1
ClearFlame Low NOx	E98	0.05	0.01	0.05	1
Low NOx CNG[13]	CNG	0.05	1	0.71	1
BEV	Electricity	0	0	0	0
FCV	Hydrogen	0	0	0	0

Fuel economy assumptions for each technology are based on the previously mentioned NREL study[14] and reported in Table 7 on a mile per diesel-gallon equivalent basis. The ClearFlame technology is assumed to have no fuel economy penalty relative to diesel, based on chassis dynamometer testing by ClearFlame.

Table 7. Fuel Economy Assumptions

Platform	Fuel Economy (mpDGE)
Diesel	8.4
ClearFlame	8.4
ClearFlame Low NOx	8.4
Low NOx CNG	6.6
BEV	15.2
FCV	12.0

Fuel Cycle Carbon Intensities

GHG emissions are reported on a well-to-wheels basis using carbon intensity (CI) values in grams CO2-equivalent per megajoule, or gCO2e/MJ. For most states, these CI values are taken from Argonne National Laboratories GREET 1 2021 fuel cycle model. Both California and Oregon have developed their own state-specific versions of GREET, known as CA-GREET and OR-GREET, respectively. These models are used in each state's LCFS program to determine the CI of transportation fuels in the state. While many of the CIs are similar between the Argonne,

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[12] GNA assessment of renewable diesel emissions studies for neat RD in SCR-equipped diesel on-road engines.

[13] Argonne National Laboratories, AFLEET 2019

[14] Hunter C. et al, "Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks", September 2021. National Renewable Energy Laboratory. NREL/TP-5400-71796. https://www.nrel.gov/docs/fy21osti/71796.pdf

California, and Oregon models, some fuels have significant differences. For example, California and Oregon's electricity grid mixes have significantly lower CIs than the national average. Further, California has been very successful in promoting the use of carbon-negative natural gas sources like anaerobic digestion of food waste and animal manure. This has resulted in a CI for the average mix of renewable natural gas in California that is below zero. Because of these regional differences in the two states with LCFS-style programs, the emissions model uses CIs from these two state programs when evaluating emissions in these states. Table 8 summarizes the well-to-wheels CI assumptions for each fuel.

Table 8. Well-to-Wheels Carbon Intensity Assumptions by Fuel and State

State	Fuel	CI	Notes
CA	Diesel	100.45	CA-GREET 3.0 using ULSD lookup table CI for total GHG emissions
CA	CNG	79.21	CA-GREET 3.0 using CNG lookup table CI for total GHG emissions
CA	Low NOx CNG	79.21	CA-GREET 3.0 using CNG lookup table CI for total GHG emissions
CA	RNG	-35.31	Q4 2020 - Q3 2021 Average reported in the CA LCFS program.
CA	Low NOx RNG	-35.31	Q4 2020 - Q3 2021 Average reported in the CA LCFS program.
CA	ClearFlame E98 - Average	60.48	Q4 2020 - Q3 2021 Average reported in the CA LCFS program. Blended with 2% CARBOB
CA	ClearFlame E98 - Stover/Fiber	28.82	Average of approved domestic corn stover/fiber/kernal fiber pathways, CA LCFS program
CA	Biodiesel (B5)	96.77	2021 Default CI for Biodiesel with "unknown source"
CA	Renewable Diesel	36.47	Q4 2020 - Q3 2021 Average reported in the CA LCFS program.
CA	Renewable Electricity	0	Assumes 100% Zero-CI Sources (PV, Wind, Geothermal, etc)
CA	Electricity	75.93	California grid average, per CARB for 2021
CA	Renewable Hydrogen	10.51	California LCFS Lookup Value for Hydrogen from Zero-CI sources
CA	Hydrogen	117.67	CA-GREET 3.0 using Compressed Hydrogen from SMR of North American Natural Gas lookup table CI for total GHG emissions
OR	Diesel	98.67	OR-GREET 3.0 for Soy-based B5 (OR mandate for B5 diesel in effect)
OR	CNG	79.93	Oregon default - North American NG delivered via pipeline; compressed in OR
OR	Low NOx CNG	79.93	Oregon default - North American NG delivered via pipeline; compressed in OR
OR	RNG	54.90	2020 Average reported in the OR LCFS program
OR	Low NOx RNG	54.90	2020 Average reported in the OR LCFS program
OR	ClearFlame E98 - Average	54.37	Q4 2020 - Q3 2021 Average reported in the OR LCFS program. Blended with 2% gasoline
OR	ClearFlame E98 - Stover/Fiber	30.88	Average of approved domestic corn fiber pathways, CA LCFS program

State	Fuel	CI	Notes
OR	Biodiesel (B5)	98.74	Oregon default - B5 from Soybean oil
OR	Renewable Diesel	45.66	Q4 2020 - Q3 2021 Average reported in the OR CFS program.
OR	Renewable Electricity	0	Assumes 100% Zero-CI Sources (PV, Wind, Geothermal, etc)
OR	Electricity	97.54	Oregon grid average, per Or DEQ for 2020
OR	Renewable Hydrogen	10.51	California LCFS Lookup Value for Hydrogen from Zero-CI sources
OR	Hydrogen	124.70	OR-GREET 3.0 using Compressed Hydrogen from SMR of North American Natural Gas CI for total GHG emissions
Other	Diesel	90.47	GREET 1 2021 defaults for CY2022 Scenario Year - Long Haul Class 8 truck
Other	CNG	73.74	GREET 1 2021 defaults for CY2022 Scenario Year - LDV (nearly identical to HS TS values)
Other	Low NOx CNG	73.74	GREET 1 2021 defaults for CY2022 Scenario Year - LDV (nearly identical to HS TS values)
Other	RNG	11.71	GREET 1 2021 defaults for CY2022 Scenario Year - LDV on LFG
Other	Low NOx RNG	11.71	GREET 1 2021 defaults for CY2022 Scenario Year - LDV on LFG
Other	ClearFlame E98 - Average	52.28	GREET 1 2021 defaults for CY2022 Scenario Year - LDV on E98 Avg Denatured Ethanol at Bulk Terminals
Other	ClearFlame E98 - Stover/Fiber	15.29	GREET 1 2021 defaults for CY2022 Scenario Year - LDV on E98 from Corn Stover
Other	Biodiesel (B5)	87.48	GREET 1 2021 defaults for CY2022 Scenario Year - Long Haul Class 8 truck, B5 from Soy
Other	Renewable Diesel	32.63	GREET 1 2021 defaults for CY2022 Scenario Year - Long Haul Class 8 truck, RDII 100% Soy
Other	Renewable Electricity	0	Assumes 100% Zero-CI Sources (PV, Wind, Geothermal, etc)
Other	Electricity	122.15	GREET 1 2021 defaults for CY2022 Scenario Year - Long Haul Class 8 truck, US Mix
Other	Renewable Hydrogen	17.08	GREET 1 2021 defaults for CY2022 Scenario Year - H2 from PV Electrolysis, H2 transported by tube trailer to station
Other	Hydrogen	92.46	GREET 1 2020 defaults for CY2020 Scenario Year - H2 from SMR of NA NG, H2 transported by tube trailer to station

Use and Availability of Low Carbon Fuels

Gasoline and diesel fuel are the dominant transportation fuels in the US, collectively representing approximately 150 billion DGE of consumption in 2021 for on-road vehicles.[15]

[15] Finished motor gasoline production calculated from US EIA "Petroleum & Other Liquids – Product Supplied" (https://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm). On-road ULSD consumption estimated from US EIA Annual Energy Outlook 2022 "Transportation Sector Energy Use by Fuel Type Within a Mode" (https://www.eia.gov/outlooks/aeo/data/browser/#/?id=46-AEO2022&cases=ref2022&sourcekey=0)

While no renewable transportation fuel is currently produced and consumed in these volumes, the current consumption of renewable transportation fuels provides an indicator of their availability in the transportation market.

Fuel ethanol is the third most used on-road transportation fuel, representing 8.4 billion DGE (13.9 billion ethanol gallons) in 2021 or 79 percent of the 17.5 billion gallons of fuel ethanol production capacity in the US.[16]

Renewable diesel production is rising rapidly, with several new investments from major refiners. However, RD production was limited to approximately 1 billion gallons in 2021,[17] with the vast majority of RD supply consumed in California where LCFS program credits allow RD producers to offer RD at price parity with traditional diesel fuel.

Natural gas consumption as a vehicle fuel reached an estimated 350 million DGE in 2021.[18] Roughly half of this consumption occurred in California and 98 percent of natural gas consumption in California was RNG.[19]

Electricity for on-road transportation is seeing significant market growth in the light-duty sector and early growth the in the medium and heavy-duty sectors, particularly in transit bus applications. However, current transportation use of electricity equated to 179 million DGE in 2021.[20] The higher efficiency of electric vehicles is not accounted for in this figure. When adjusting for efficiency, electricity consumption in the transportation sector is estimated to equate to 360 to 540 million DGE.[21] The fraction of electricity dispensed for EV charging that is renewable depends in local grid mixes and the extent to which on-site renewable generation and renewable energy credits are used to claim renewable electricity use. Utility scale generation in the US averaged 20.1 percent renewable content in 2021, suggesting a reasonable minimum renewable fraction for EV charging during the year.[22]

Hydrogen for on-road transportation is still nascent, primarily used in light-duty transportation in California. Hydrogen consumption in California in 2021 is estimated at approximately 1.5 million DGE based on data from the California LCFS program.[23] While the LCFS program does not report renewable hydrogen volumes separately from fossil based hydrogen, most existing hydrogen stations in California are required to dispense a minimum of 40 percent renewable hydrogen, with some stations dispensing up to 100 percent renewable hydrogen.

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[16] US EIA, "U.S. Fuel Ethanol Plant Production Capacity" as of January 1, 2021.

[17] US EIA "Petroleum & Other Liquids – Product Supplied" (https://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm)

[18] US EIA Annual Energy Outlook 2022 "Transportation Sector Energy Use by Fuel Type Within a Mode" (https://www.eia.gov/outlooks/aeo/data/browser/#/?id=46-AEO2022&cases=ref2022&sourcekey=0)

[19] California Air Resources Board, Quarterly LCFS summary data.

[20] US EIA Annual Energy Outlook 2022 "Transportation Sector Energy Use by Fuel Type Within a Mode" (https://www.eia.gov/outlooks/aeo/data/browser/#/?id=46-AEO2022&cases=ref2022&sourcekey=0)

[21] Assumes in-use EV efficiency is 2 to 3 times that of gasoline and diesel vehicles.

[22] US EIA, "U.S. utility-scale electricity generation by source, amount, and share of total in 2021." (https://www.eia.gov/tools/faqs/faq.php?id=427&t=3)

[23] California Air Resources Board, Quarterly LCFS summary data.

It must be noted that natural gas, electricity, and hydrogen are all produced and consumed in non-transportation applications at much greater scales than suggested by their transportation consumption. However, their availability as a *renewable transportation fuel* is constrained by their infrastructure requirements, the availability of their renewable feedstocks, and their use in non-transportation sectors.

Emissions Modeling Results

The results of the emissions analysis are summarized in Table 9, Table 10, and Table 11, below. The emissions analysis indicates that the ClearFlame technology has the potential to significantly reduce well-to-wheels GHGs and tailpipe PM2.5, DPM, and SOX relative to traditional diesel fuel. GHG reductions from the ClearFlame system could actually outstrip BEVs based on the national average grid mix and referenced fuel economies. When using ethanol from a cellulosic source like corn stover or corn fiber, GHG emissions reductions rise to 69 to 83 percent depending on the region. While both BEV and FCV platforms have the potential to provide zero tailpipe emissions, these technologies are not yet commercially available for long-haul trucking and fueling/charging infrastructure remains a significant barrier. Additionally, the cost per mile for these technologies in long haul trucking is currently high, making technologies like ClearFlame and CNG trucks (using RNG) the only options to immediately provide cost-effective GHG and tailpipe emissions reductions.

Table 9. Emissions Reductions vs Traditional Diesel (National Average excluding CA and OR)

Platform	ClearFlame	ClearFlame Low NOx	Low NOx CNG	BEV	FCV
Fuel	**E98 - Average**	**E98 - Average**	**Fossil CNG**	**Grid Average**	**Fossil H2**
WTW GHGs	42%	42%	-4%	25%	28%
Tailpipe NOx	0%	95%	95%	100%	100%
Tailpipe PM2.5	99%	99%	0%	100%	100%
Tailpipe DPM	100%	100%	100%	100%	100%
Tailpipe SOx	95%	95%	29%	100%	100%

Platform	Diesel	ClearFlame	ClearFlame Low NOx	Low NOx CNG	BEV	FCV
Fuel	**RD**	**E98 - Stover/Fiber**	**E98 - Stover/Fiber**	**RNG**	**PV/ Wind**	**H2 from PV/Wind**
WTW GHGs	64%	83%	83%	84%	100%	87%
Tailpipe NOx	13%	0%	95%	95%	100%	100%
Tailpipe PM2.5	29%	99%	99%	0%	100%	100%
Tailpipe DPM	29%	100%	100%	100%	100%	100%
Tailpipe SOx	95%	95%	95%	29%	100%	100%

Table 10. Emissions Reductions vs Traditional Diesel (CA)

Platform	ClearFlame	ClearFlame Low NOx	Low NOx CNG	BEV	FCV
Fuel	**E98 - Average**	**E98 - Average**	**Fossil CNG**	**Grid Average**	**Fossil H2**
WTW GHGs	40%	40%	0%	58%	18%
Tailpipe NOx	0%	95%	95%	100%	100%
Tailpipe PM2.5	99%	99%	0%	100%	100%
Tailpipe DPM	100%	100%	100%	100%	100%
Tailpipe SOx	95%	95%	29%	100%	100%

Platform	Diesel	ClearFlame	ClearFlame Low NOx	Low NOx CNG	BEV	FCV
Fuel	**RD**	**E98 - Stover/Fiber**	**E98 - Stover/Fiber**	**RNG**	**PV/ Wind**	**H2 from PV/Wind**
WTW GHGs	64%	71%	71%	145%	100%	93%
Tailpipe NOx	13%	0%	95%	95%	100%	100%
Tailpipe PM2.5	29%	99%	99%	0%	100%	100%
Tailpipe DPM	29%	100%	100%	100%	100%	100%
Tailpipe SOx	95%	95%	95%	29%	100%	100%

Table 11. Emissions Reductions vs Traditional Diesel (OR)

Platform	ClearFlame	ClearFlame Low NOx	Low NOx CNG	BEV	FCV
Fuel	**E98 - Average**	**E98 - Average**	**Fossil CNG**	**Grid Average**	**Fossil H2**
WTW GHGs	45%	45%	-3%	45%	12%
Tailpipe NOx	0%	95%	95%	100%	100%
Tailpipe PM2.5	99%	99%	0%	100%	100%
Tailpipe DPM	100%	100%	100%	100%	100%
Tailpipe SOx	95%	95%	29%	100%	100%

Platform	Diesel	ClearFlame	ClearFlame Low NOx	Low NOx CNG	BEV	FCV
Fuel	**RD**	**E98 - Stover/Fiber**	**E98 - Stover/Fiber**	**RNG**	**PV/ Wind**	**H2 from PV/Wind**
WTW GHGs	54%	69%	69%	29%	100%	93%
Tailpipe NOx	13%	0%	95%	95%	100%	100%
Tailpipe PM2.5	29%	99%	99%	0%	100%	100%
Tailpipe DPM	29%	100%	100%	100%	100%	100%
Tailpipe SOx	95%	95%	95%	29%	100%	100%

Conclusion

As fleets look to address continually increasing pressure to transition their equipment to more sustainable fuels and technologies, practical challenges including cost, range, and fuel availability of alternative fuel platforms have slowed adoption, particularly in the long-haul over-the-road truck market. While most of the discussion around sustainable fuels today focuses on CNG, BEV, and FCV technologies, alcohol fuels have the potential to play a valuable role in sustainable transportation.

ClearFlame Engine Technologies (ClearFlame) has developed engine technology and an ethanol fuel supply model that could address the historic barriers to the adoption of ethanol fuels in the heavy-duty market. An analysis of the expected emissions performance and total cost of ownership for the ClearFlame business model versus diesel, CNG, BEV, and FCV options in the over-the-road heavy-duty truck market presented in this paper indicates that:

- The TCO of ClearFlame-based trucks could be, on average, $0.08 per mile lower than diesel trucks in over-the-road applications.
- ClearFlame's cost per mile in this application is expected to be substantially lower than BEV and FCV platforms, primarily due to the high purchase costs of these platforms at this time.
- ClearFlame's partnerships and approach to passing through most or all of the RIN value of ethanol is critical to realizing the net TCO benefits modeled in this paper.
- ClearFlame's technology has the potential to significantly reduce well-to-wheels GHGs and tailpipe PM2.5, DPM, and SOX relative to traditional diesel fuel.
- GHG reductions from the ClearFlame system could actually outstrip BEVs based on the national average grid mix and referenced fuel economies. When using ethanol from a cellulosic source like corn stover or corn fiber, GHG emissions reductions rise to 69 to 83 percent depending on the region.
- While both BEV and FCV platforms have the potential to provide zero tailpipe emissions, these technologies are not yet commercially available for long-haul trucking and fueling/charging infrastructure remains a significant barrier. Additionally, the cost per mile for these technologies in long haul trucking is currently high, making technologies like ClearFlame important options to immediately provide cost-effective GHG and tailpipe emissions reductions.

Appendix

Estimated Cost Per Mile by State and Technology

State	Diesel	ClearFlame	CNG	BEV	FCV
Alabama	($1.48)	($1.43)	($1.53)	($2.41)	($2.12)
Alaska	($1.65)	($1.54)	($1.58)	($2.33)	($2.09)
Arizona	($1.63)	($1.49)	($1.57)	($2.43)	($2.13)
Arkansas	($1.48)	($1.43)	($1.54)	($2.47)	($2.13)
California	($1.66)	($1.55)	($1.60)	($2.38)	($2.11)
Colorado	($1.54)	($1.48)	($1.52)	($2.43)	($2.13)
Connecticut	($1.52)	($1.54)	($1.61)	($2.50)	($2.11)
Delaware	($1.50)	($1.41)	($1.53)	($2.44)	($2.09)
D.C.	($1.50)	($1.42)	($1.55)	($2.48)	($2.11)
Florida	($1.52)	($1.44)	($1.50)	($2.50)	($2.12)
Georgia	($1.52)	($1.44)	($1.50)	($2.50)	($2.12)
Hawaii	($1.66)	($1.54)	($1.59)	($2.36)	($2.11)
Idaho	($1.53)	($1.48)	($1.52)	($2.40)	($2.11)
Illinois	($1.52)	($1.47)	($1.51)	($2.49)	($2.11)
Indiana	($1.53)	($1.47)	($1.52)	($2.51)	($2.12)
Iowa	($1.51)	($1.43)	($1.50)	($2.49)	($2.11)
Kansas	($1.51)	($1.44)	($1.51)	($2.52)	($2.12)
Kentucky	($1.51)	($1.46)	($1.53)	($2.40)	($2.12)
Louisiana	($1.48)	($1.42)	($1.53)	($2.46)	($2.12)
Maine	($1.51)	($1.54)	($1.60)	($2.49)	($2.10)
Maryland	($1.50)	($1.42)	($1.55)	($2.48)	($2.11)
Massachusetts	($1.52)	($1.54)	($1.61)	($2.50)	($2.11)
Michigan	($1.52)	($1.47)	($1.52)	($2.50)	($2.12)
Minnesota	($1.51)	($1.43)	($1.50)	($2.50)	($2.11)
Mississippi	($1.48)	($1.43)	($1.53)	($2.41)	($2.12)
Missouri	($1.52)	($1.44)	($1.51)	($2.54)	($2.13)
Montana	($1.53)	($1.47)	($1.50)	($2.37)	($2.09)
Nebraska	($1.51)	($1.44)	($1.50)	($2.51)	($2.11)
Nevada	($1.64)	($1.50)	($1.58)	($2.46)	($2.14)
New Hampshire	($1.51)	($1.54)	($1.60)	($2.46)	($2.09)
New Jersey	($1.52)	($1.49)	($1.56)	($2.43)	($2.10)
New Mexico	($1.48)	($1.39)	($1.52)	($2.42)	($2.12)
New York	($1.52)	($1.50)	($1.57)	($2.47)	($2.12)
North Carolina	($1.52)	($1.44)	($1.51)	($2.52)	($2.13)
North Dakota	($1.51)	($1.44)	($1.51)	($2.53)	($2.12)
Ohio	($1.54)	($1.48)	($1.53)	($2.54)	($2.14)
Oklahoma	($1.51)	($1.46)	($1.54)	($2.48)	($2.13)
Oregon	($1.65)	($1.54)	($1.58)	($2.33)	($2.09)

State	Diesel	ClearFlame	CNG	BEV	FCV
Pennsylvania	($1.52)	($1.49)	($1.56)	($2.44)	($2.10)
Rhode Island	($1.52)	($1.55)	($1.61)	($2.51)	($2.11)
South Carolina	($1.52)	($1.44)	($1.50)	($2.51)	($2.12)
South Dakota	($1.52)	($1.45)	($1.52)	($2.55)	($2.14)
Tennessee	($1.52)	($1.46)	($1.53)	($2.41)	($2.12)
Texas	($1.49)	($1.44)	($1.55)	($2.50)	($2.14)
Utah	($1.54)	($1.48)	($1.52)	($2.42)	($2.12)
Vermont	($1.52)	($1.54)	($1.60)	($2.49)	($2.11)
Virginia	($1.51)	($1.43)	($1.50)	($2.49)	($2.11)
Washington	($1.67)	($1.56)	($1.62)	($2.43)	($2.15)
West Virginia	($1.51)	($1.43)	($1.50)	($2.49)	($2.12)
Wisconsin	($1.52)	($1.47)	($1.51)	($2.48)	($2.11)
Wyoming	($1.54)	($1.48)	($1.53)	($2.44)	($2.13)
Average	**($1.53)**	**($1.47)**	**($1.54)**	**($2.46)**	**($2.12)**

Estimated Cost Per Mile Difference between ClearFlame and other Technologies

State	ClearFlame-Diesel	ClearFlame-CNG	ClearFlame-BEV	ClearFlame-FCV
Alabama	$0.05	$0.10	$0.98	$0.69
Alaska	$0.11	$0.04	$0.79	$0.55
Arizona	$0.14	$0.08	$0.94	$0.64
Arkansas	$0.05	$0.11	$1.04	$0.70
California	$0.11	$0.05	$0.83	$0.56
Colorado	$0.06	$0.04	$0.95	$0.65
Connecticut	($0.02)	$0.07	$0.96	$0.57
Delaware	$0.09	$0.12	$1.03	$0.68
D.C.	$0.08	$0.13	$1.06	$0.69
Florida	$0.08	$0.06	$1.06	$0.68
Georgia	$0.08	$0.06	$1.06	$0.68
Hawaii	$0.12	$0.05	$0.82	$0.57
Idaho	$0.05	$0.04	$0.92	$0.63
Illinois	$0.05	$0.04	$1.02	$0.64
Indiana	$0.06	$0.05	$1.04	$0.65
Iowa	$0.08	$0.07	$1.06	$0.68
Kansas	$0.07	$0.07	$1.08	$0.68
Kentucky	$0.05	$0.07	$0.94	$0.66
Louisiana	$0.06	$0.11	$1.04	$0.70
Maine	($0.03)	$0.06	$0.95	$0.56
Maryland	$0.08	$0.13	$1.06	$0.69
Massachusetts	($0.02)	$0.07	$0.96	$0.57
Michigan	$0.05	$0.05	$1.03	$0.65
Minnesota	$0.08	$0.07	$1.07	$0.68
Mississippi	$0.05	$0.10	$0.98	$0.69
Missouri	$0.08	$0.07	$1.10	$0.69
Montana	$0.06	$0.03	$0.90	$0.62
Nebraska	$0.07	$0.06	$1.07	$0.67
Nevada	$0.14	$0.08	$0.96	$0.64
New Hampshire	($0.03)	$0.06	$0.92	$0.55
New Jersey	$0.03	$0.07	$0.94	$0.61
New Mexico	$0.09	$0.13	$1.03	$0.73
New York	$0.02	$0.07	$0.97	$0.62
North Carolina	$0.08	$0.07	$1.08	$0.69
North Dakota	$0.07	$0.07	$1.09	$0.68
Ohio	$0.06	$0.05	$1.06	$0.66
Oklahoma	$0.05	$0.08	$1.02	$0.67
Oregon	$0.11	$0.04	$0.79	$0.55
Pennsylvania	$0.03	$0.07	$0.95	$0.61
Rhode Island	($0.03)	$0.06	$0.96	$0.56

State	ClearFlame-Diesel	ClearFlame-CNG	ClearFlame-BEV	ClearFlame-FCV
South Carolina	$0.08	$0.06	$1.07	$0.68
South Dakota	$0.07	$0.07	$1.10	$0.69
Tennessee	$0.06	$0.07	$0.95	$0.66
Texas	$0.05	$0.11	$1.06	$0.70
Utah	$0.06	$0.04	$0.94	$0.64
Vermont	($0.02)	$0.06	$0.95	$0.57
Virginia	$0.08	$0.07	$1.06	$0.68
Washington	$0.11	$0.06	$0.87	$0.59
West Virginia	$0.08	$0.07	$1.06	$0.69
Wisconsin	$0.05	$0.04	$1.01	$0.64
Wyoming	$0.06	$0.05	$0.96	$0.65
Average	**$0.06**	**$0.07**	**$0.99**	**$0.64**