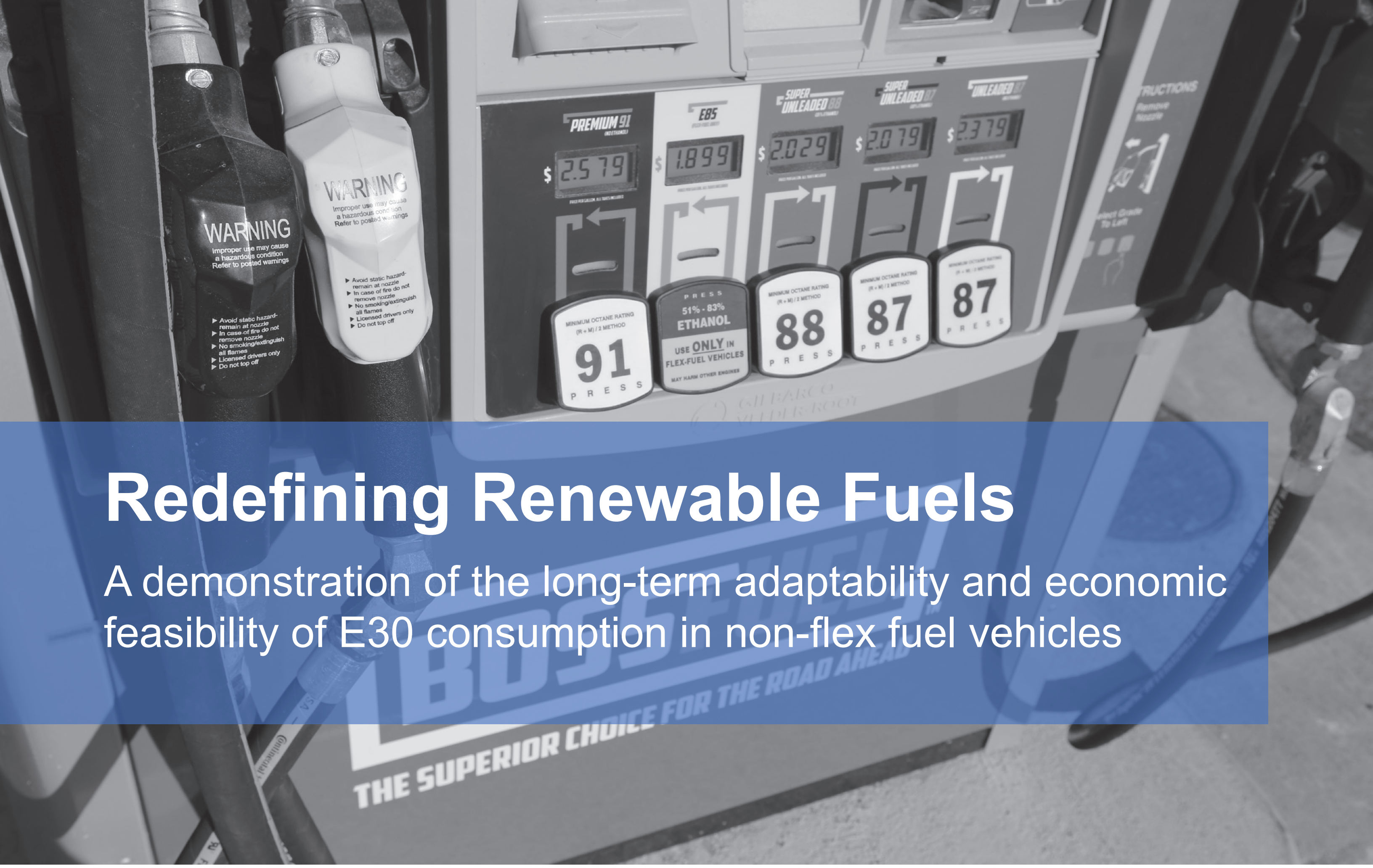

Redefining Renewable Fuels

A demonstration of the long-term adaptability and economic feasibility of E30 consumption in non-flex fuel vehicles

Department of Chemical and Biomolecular Engineering,
University of Nebraska-Lincoln

Published February 2021

Rajib Saha,
Assistant Professor
rsaha2@unl.edu

Adil Alsiyabi,
Graduate Research Assistant

Seth Stroh,
Undergraduate Researcher

University of Nebraska Lincoln

College of Engineering

Highlights

Goal

The yearlong demonstration involved 50 non-flex fuel vehicles (non-FFVs) from the State of Nebraska to determine adaptability, economic feasibility, and environmental impact of using E30. Twenty six vehicles were fueled by E15, and twenty four vehicles were fueled by E30.

Effect of using E30 on performance and fuel efficiency

- Non-FFVs were able to adjust the air-to-fuel ratio (AFR) to adapt to the higher oxygen content of E30.
- E30 had no observable negative effect on overall vehicle performance.
- The cost per mile for E15 and E30 fueled vehicles were nearly identical over the one year demonstration.
- A price difference of more than 2.5% compared to E15 would cause E30 to become the more economically viable fuel.

Impact of using E30 on state-owned vehicles

If the Nebraska Transportation Service Bureau (TSB) and State Patrol (SP) non-FFV fleets change from E15 to E30 fuel:

- Ethanol consumption would increase by 66,000 gallons per year
- CO_2 emissions would decrease by 529 tons per year.

Impact of allowing state-wide E30 consumption

If only 10% of the 1.7 million registered non-FFVs in Nebraska convert from E10 to E30:

- Ethanol consumption would increase by 18.5 million gallons per year
- CO_2 emission would decrease by 64,000 tons per year.

Introduction

In this demonstration, a total of fifty vehicles were tested on either E10/E15 or E30 to determine the effect of using 30% ethanol in non-flex fuel vehicles (non-FFVs). The vehicles were divided into a control group consuming E10/E15 and a test group consuming E30. Information regarding vehicle make/model, mileage driven, and primary location is provided in **Table 1**. It is noted that all Dodge Avengers and Ford Fusions were owned by the Nebraska Transportation Bureau (TSB). In addition, the Dodge Chargers were owned and operated by Nebraska's State Patrol (SP). Vehicles were selected by matched pairs based on model and drive route to minimize bias caused by factors other than fuel type. Each vehicle was equipped with a monitoring device to track different driving parameters in real-time throughout the duration of the demonstration (06/2019-06/2020). Furthermore, the drivers were provided with driver logs to track fuel consumption. This data was analyzed to determine the long-term adaptability of non-FFVs to E30 and to demonstrate the economic feasibility and environmental impact of using higher ethanol blends. **Table 2** provides a summary of miles driven by fuel type and fleet.

Table 1. General information regarding vehicles participating in the E30 demonstration.

Fuel Type	Make	Model	Year	Location	Starting Mileage	Final Mileage	Miles Driven
E15	Dodge	Avenger	2013	Ogallala	90766	100525	9759
E15	Dodge	Avenger	2013	Omaha	45517	50058	4541
E15	Dodge	Avenger	2013	Norfolk	93181	111198	18017
E15	Dodge	Avenger	2013	Bellevue	42832	48016	5184
E15	Dodge	Avenger	2013	Lincoln	-	-	-
E15	Dodge	Avenger	2013	Pierce	97586	109455	11869
E15	Dodge	Avenger	2013	Omaha	64443	72482	8039
E15	Dodge	Avenger	2013	Omaha	86847	111671	24824
E15	Dodge	Avenger	2013	Columbus	101927	116505	14578
E15	Dodge	Avenger	2013	Omaha	53318	65536	12218
E15	Dodge	Avenger	2013	Grand Island	67789	73975	6186
E15	Dodge	Avenger	2013	Chapman	65818	71993	6175
E15	Dodge	Avenger	2013	Omaha	91101	108903	17802
E15	Dodge	Avenger	2013	Gering	74714	87843	13129
E15	Dodge	Avenger	2013	Omaha	72213	79055	6842
E15	Dodge	Avenger	2013	Omaha	76745	87653	10908
E15	Dodge	Avenger	2013	Omaha	61271	79858	18587
E15	Dodge	Avenger	2013	Grand Island	80053	91991	11938
E15	Dodge	Avenger	2013	Seward	86669	97511	10842
E15	Ford	Fusion	2014	Gering	85642	103159	17517

E15	Ford	Fusion	2014	North Platte	85321	98439	13118
E15	Dodge	Charger	2015	Lincoln	82415	102792	20377
E15	Dodge	Charger	2015	Omaha	74625	98940	24315
E15	Dodge	Charger	2015	Seward	126820	146504	19684
E15	Dodge	Charger	2015	Omaha	82558	107592	25034
E30	Dodge	Avenger	2013	York	103293	114267	10974
E30	Dodge	Avenger	2013	Fremont	87247	97003	9756
E30	Dodge	Avenger	2013	Omaha	75023	87497	12474
E30	Dodge	Avenger	2013	Gering	88332	102711	14379
E30	Dodge	Avenger	2013	Hastings	84103	93463	9360
E30	Dodge	Avenger	2013	Norfolk	45839	53267	7428
E30	Dodge	Avenger	2013	Omaha	74893	85380	10487
E30	Dodge	Avenger	2013	York	88345	101608	13263
E30	Dodge	Avenger	2013	North Platte	57474	66900	9426
E30	Dodge	Avenger	2013	Hastings	62341	67480	5139
E30	Dodge	Avenger	2013	Grand Island	100880	112183	11303
E30	Dodge	Avenger	2013	Plattsmouth	80855	95156	14301
E30	Dodge	Avenger	2013	York	70593	89113	18520
E30	Dodge	Avenger	2013	Lincoln	72116	80318	8202
E30	Dodge	Avenger	2013	Omaha	64704	80492	15788
E30	Ford	Fusion	2014	Grand Island	61705	70503	8798
E30	Ford	Fusion	2014	Omaha	67859	78611	10752
E30	Dodge	Avenger	2013	Lincoln	75238	85529	10291
E30	Dodge	Avenger	2013	Omaha	51785	58273	6488
E30	Dodge	Charger	2015	Norfolk	88762	118952	30190
E30	Dodge	Charger	2015	Pierce	89832	118038	28206
E30	Dodge	Charger	2015	York	94295	121065	26770
E30	Dodge	Charger	2014	Aurora	135625	149770	14145
E30	Dodge	Charger	2014	Norfolk	111793	112869	1076

Table 2. Miles driven by fuel type and fleet.

Fuel Type	Miles Driven (SP)	Miles Driven (TSB)	Total Miles Driven
E15	89410	242073	331483
E30	100387	207129	307516
Total	189797	449202	638999

Non-Flex fuel vehicles adaptability to 30% ethanol blends

Changes in On-Board Diagnostic (OBD) parameters were investigated to determine the long-term adaptability of vehicles to E30 fuel. Long-term fuel trim (LTFT) and O2 sensor readings were monitored to investigate whether the vehicle's engine control module (ECM) can adapt to the increased oxygen concentration resulting from the added ethanol. The ECM controls the air/fuel ratio (AFR) by measuring the voltage generated through the oxygen sensor which indicates the proportion of oxygen in the exhaust. The distribution of these two parameters, recorded over an entire year, was compared between vehicles operating on E30 and those operating on E15. As expected, there was an average increase in the LTFT of vehicles operating on E30 (Figure 1A). However, the distribution of O2 sensor readings for the two conditions were similar (Figure 1A). This indicates that the ECM of the tested vehicles was able to account for the increased oxygen content in the fuel. Furthermore, a similar comparison was implemented on coolant temperatures from vehicles running on each fuel type (Figure 1B). As shown, the increase in ethanol concentration does not cause engine coolant temperature to change significantly. Finally, a multitude of more complex statistical data analyses were conducted to determine the effect of E30 on overall vehicle performance. Results from that analysis indicates no significant change in performance between the two fuel types.

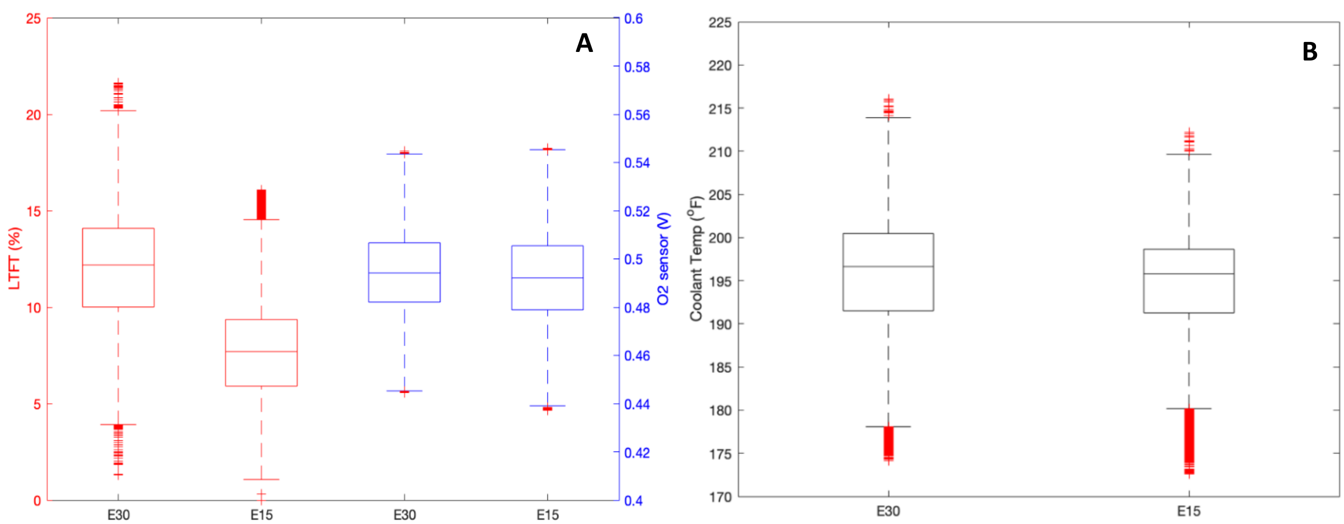

Figure 1. Distribution of different driving parameters for vehicles operating on E30 and E15. (A) Box plot of the distribution of average LTFT and O2 sensor values, and (B) Box plot of distribution of coolant temperatures.

Fuel Efficiency of 30% ethanol blends in non-flex fuel vehicles

Analysis of fuel consumption trends of both fuel blends (E15 and E30) demonstrates that fuel efficiency is not compromised by the increased ethanol content. As shown in Figure 2A, the mileage obtained per gallon was comparable throughout the year (<3% difference). Furthermore, the cost per mile for each fuel type was determined by combining calculated fuel efficiencies with rack fuel prices for both fuel types (Figure 2B). It was determined that a price difference of more than 2.5% would cause E30 to become the more economically viable fuel.

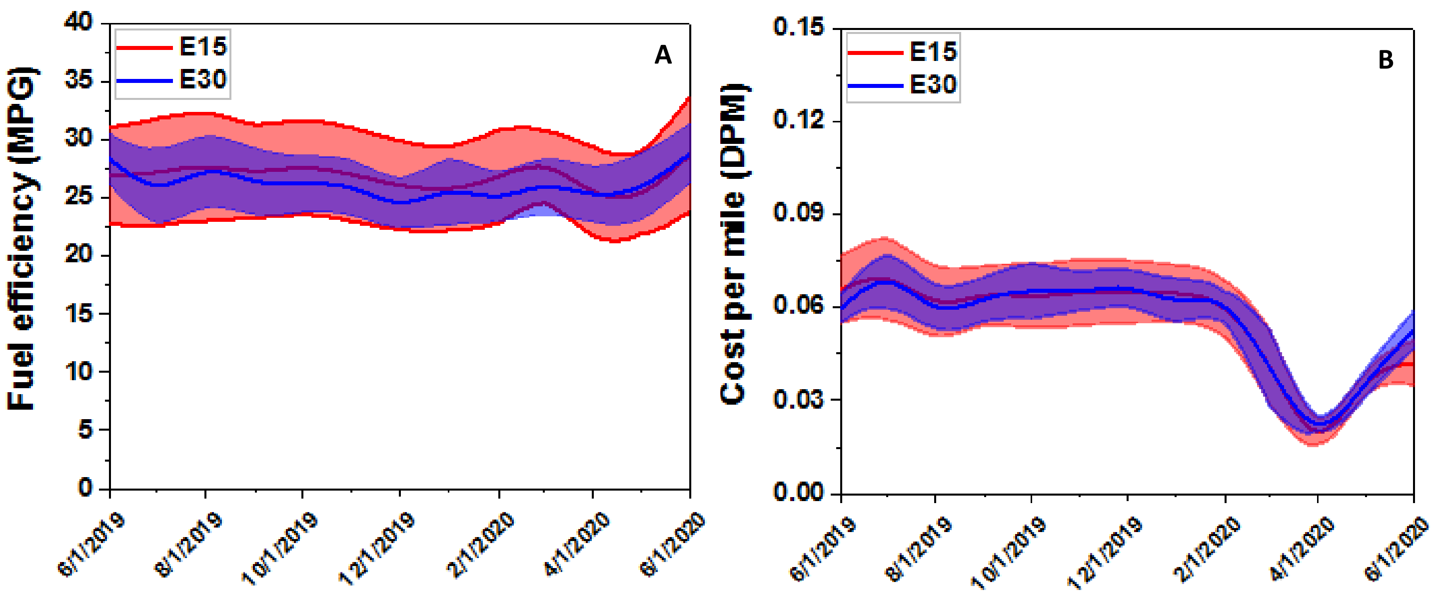

Figure 2. Comparison of the economic feasibility of using E15 and E30. (A) Time-course fuel efficiency (in miles per gallon) of the two different fuel blends. (B) Time-course cost (in USD) per mile for the two different fuel blends.

Effect of introducing E30 into state fleets on ethanol consumption

The increase in ethanol consumption brought about by switching half the vehicles in this demonstration to E30 was determined (Figure 3A). Fuel consumption trends and average miles driven by the vehicles from each fleet (TSB and SP) was used to determine the number of extra gallons of ethanol required. These values were then used to project the impact of switching all TSB and SP fleets over to E30 on increasing ethanol consumption.

A similar analysis was conducted to determine the impact of state-wide E30 use. The average vehicle travels approximately 13,000 miles per year which corresponds to an average consumption of 550 gallons of fuel. Figure 3B demonstrates the potential impact if 10% of state registered non-FFVs convert from consuming E10 to E30 each year.

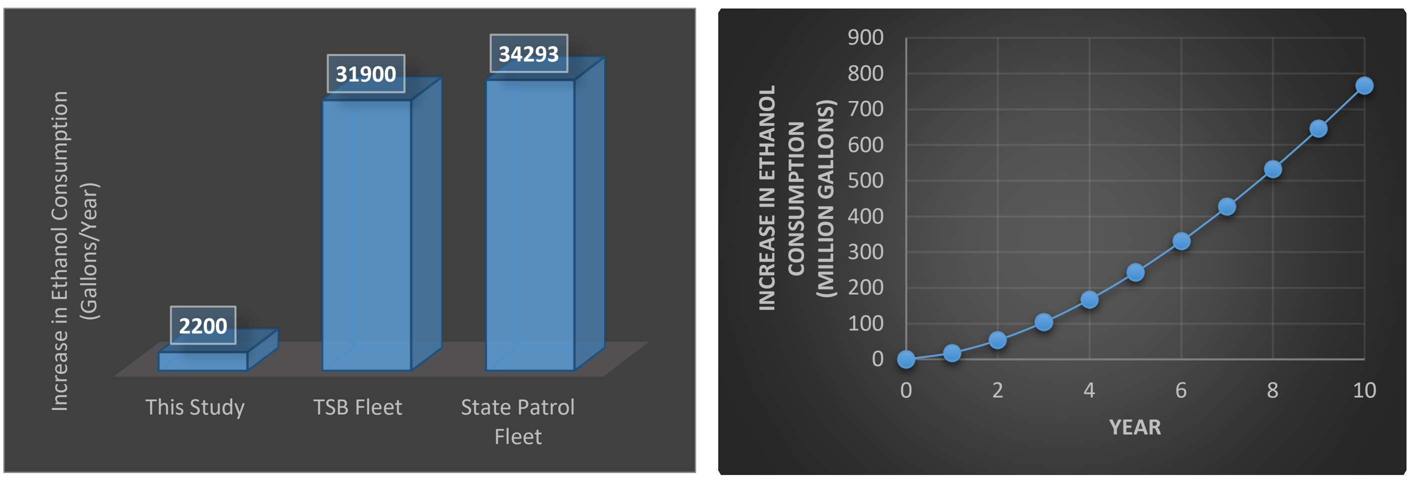

Figure 3. Impact of using E30 on ethanol consumption. (A) Increase in fuel consumption observed in this demonstration and projected out to account for entire TSB (Transportation Service Bureau) fleet or SP (State Patrol) fleet. (B) Predicted increase in ethanol consumption if 10% of NE registered vehicles switched to E30 each year.

Effect of introducing E30 into state fleets on CO_2 emissions

Consumption of 1 gallon of pure gasoline results in approximately 19.6 pounds of CO2 emitted into the atmosphere. This value is substantially less for ethanol (12.7 lbs/gal). Using these values, the yearly reduction in CO2 emissions was determined for this demonstration and projected for the case where either all TSB or SP vehicles convert to E30. As shown in Figure 4A, significant reductions in emission can be obtained when entire state fleets convert to higher ethanol blends. This is especially apparent for the State Patrol fleet (200 vehicles) due to their driving habits (~ 21,000 miles driven per year) and moderate mileage efficiency due to necessarily aggressive driving conditions.

Similarly, projections were made to predict the decrease in CO_2 emissions caused by 10% of the 1.7 million state registered (non-FF) vehicles switching from consuming E10/15 to E30 each year. As can be seen from Figure 4B, the environmental impact of such a shift is pronounced.

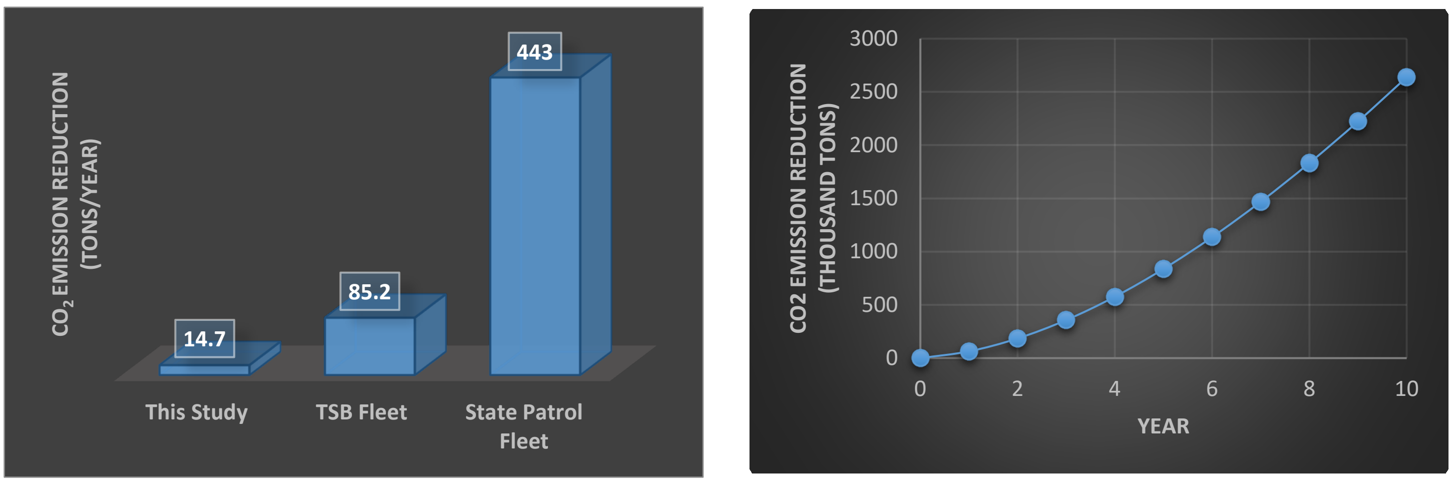

Figure 4. Impact of using E30 on CO_2 emissions. (A) Reduction in carbon dioxide emission observed in this demonstration and projected out to account for entire TSB (Transportation Service Bureau) fleet or SP (State Patrol) fleet. (B) Predicted reduction in carbon dioxide emission if 10% of NE registered vehicles switched to E30 each year.

Acknowledgments

We would like to thank Jason Frazier, State Fleet Services Manager, and Stephen Rasgorsheck, State Patrol Investigation Officer, for their help coordinating and setting up the participating vehicles at the Nebraska TSB and State Patrol, respectively.