# Idle Reduction Assessment for the New York State Department of Transportation Region 4 Fleet

## **Final Report**

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## Abstract

Energetics Incorporated conducted a study to evaluate the operational, economic, and environmental impacts of advanced technologies to reduce idling in the New York State Department of Transportation (NYSDOT) Region 4 fleet without compromising functionality. The fleet actively addresses fleet efficiency and reducing petroleum consumption by using more efficient light-emitting diode hazard warning signs and encourages personnel to turn off vehicles when stationary. However, with a fleet of 328 on-road vehicles and a duty to serve the more than one million customers in seven western New York counties, NYSDOT Region 4 wanted to ensure they were reducing idling at every opportunity. Onboard data collection modules gathered details on the route, engine, vehicle and driver operational characteristics from ¾-ton pickups, 6-passenger pickups, stake rack trucks, and small dump trucks. Monitored parameters included engine speed, vehicle speed, fuel rate, global positioning system data, and a variety of vehicle state and environmental conditions as available. The diversity of vehicle functions during cold-and warm-weather seasons contributed to significantly different operational characteristics throughout the year. Energetics Incorporated used the collected data to develop vehicle profiles from which an implementation plan of idling reduction solutions was developed. Overall, the results showed that the vehicle's use is extremely varied throughout the fleet and there is not a "silver bullet" approach that will work for the entire fleet. However, many vehicles in the fleet showed favorable estimated savings and are good candidates for idle reduction technology.

## Keywords

Idle Reduction, NYSDOT, Start-stop, Work Truck, Duty Cycle

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# Acronyms and Abbreviations

APU	Auxiliary power unit
BTU	British thermal unit
CAN	Controller Area Network
ECU	Engine Control Unit
EO	Executive order
ESM	Engine Start Module
°F	Degrees Fahrenheit
GHG	Greenhouse gas
GPS	Global positioning system
HVAC	Heating, Ventilation, and Air Conditioning
kW	KiloWatts
LED	Light-emitting diode
mpg	Miles per gallon
MSRP	Manufacturer Suggested Retail Price
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
SAE	Society of Automotive Engineers
V	Volts
VAC	Volts Alternating Current
W	Watt

## 1 Executive Summary

The objective of the study is to recommend idle reduction solutions that meet the requirements of New York State Department of Transportation (NYSDOT) vehicle functions and personnel. Energetics Incorporated collected and analyzed a small sample set of data on real-world NYSDOT Region 4 fleet operations to determine idle reduction opportunities. An investigation of commercially available idle reduction technologies provided system cost, characteristics, and intended operation information. A benefit analysis of potential idle reduction solutions quantified the expected operational, economic, and environmental impacts.

Idle reduction technologies include idle-stop systems, auxiliary power units (APUs), and auxiliary heating/cooling systems. Idle-stop systems (sometimes referred to as automatic stop-start systems) manage and minimize engine run time based on critical vehicle parameters. APUs are vehicle-mounted systems (battery-based for NYSDOT work trucks) that provide power for extended periods of stationary operation so the vehicle's primary engine can be shut down. Heating and cooling systems maintain interior conditions for extended periods in extreme weather (using onboard battery power or the vehicle's fuel at a more efficient rate).

To record detailed vehicle data, onboard data logging systems were installed on selected vehicles to capture daily operational data (including engine parameters and global positioning system information) on a per-minute basis. Overall, valuable data was retrieved from six ¾-ton pickup trucks, six 6-passenger trucks, four stake rack trucks, and eight small dump trucks throughout the NYSDOT Region 4 Fleet (a small, but representative sample of the fleet). Energetics Incorporated developed a model to calculate the benefits of the various idle reduction technologies selected for NYSDOT vehicles using data logging data, technology manufacturer information, ambient weather data, and information from discussions with NYSDOT staff. Based on a down-selection of available technologies, idle-stop systems with and without simple heating circulators were evaluated in detail for each vehicle group.

High variability was found in the amount of idling experienced by various NYSDOT Region 4 vehicles; within the same vehicle type and even the same function. The implementation of idle reduction technology should be an individual vehicle decision and not as a blanket strategy for the entire fleet. However, some vehicle types consume significant fuel due to idling and would be a starting point for implementing this technology. Closely monitoring all vehicles by using a tracking system would provide a clear picture on which vehicles could benefit more from idle reduction systems. It may also identify poor driver behavior that is causing longer than necessary idling. The summary of results in Table 1 is for NYSDOT Region 4 vehicles estimated to have a payback within 10 years.

	Percent of Vehicle Class Resulting in a 10 Year or less Payback	Total Annual Fuel Savings (gallons)	Total Annual Cost Savings	Total Annual CO <sub>2</sub> Emission Reduction (pounds)*		
¾-ton Pickup	32%	213	\$631	4,166		
6-Passenger	53%	434	\$1,289	8,504		
Stake Rack	42%	271	\$806	5,484		
Small Dump	33%	484	\$1,437	9,772		

Table 1: Estimated Benefits on Vehicles Experiencing a Payback within 10 years

\*Assumes 19.6 and 20.2 pounds of CO<sub>2</sub> emissions per gallon gasoline and diesel respectively

NYSDOT <sup>3</sup>/-ton pickups, Ford F-250s or Chevrolet 2500s, are used by supervisors to check on site work or winter road conditions. These trucks can be outfitted with toolboxes, fueling capabilities (for off-site equipment), light

trailers, or variable message signs. Energetics collected useful data from four <sup>3</sup>/<sub>4</sub>-ton pickups at two different NYSDOT Region divisions. 4 Combined, data from 169 days of operations were analyzed during which the trucks were driven over 15,000 cumulative miles. Statistics from these trucks are shown in Table 2.



Table 2: Three-Quarter Ton Pickup Operation Data

		Daily Data							
	Mean	Max	Min	Standard Deviation	Total				
Fuel Use (gallons)	6.6	20.1	0.8	3.4	1,110				
Mileage (miles)	89.0	288.0	8.0	47.6	15,029				
Fuel Economy (mpg)	13.6	17.8	4.4	2.6	N/A				
Operating Time (hours)	3.4	14.5	0.4	2.1	576				
Idle Time (hours)*	0.7	11.6	0.0	1.4	125				
Idle Fuel Use (gallons)*	0.4	6.6	0.0	0.8	69				
Idle Fuel Rate (gallons/hour)	0.4	1.7	0.0	0.3	N/A				

\*Includes only stationary periods that exceed 2 minutes

The majority of idling periods last fewer than twenty minutes, as shown in Figure 1. The majority of vehicle use occurs during winter months, with a noticeable increase in December. Most of the their idling events are seen between the hours of 9 AM and 7 PM. Idling events lasting less than 2 minutes comprised only 9% of the total idling.

Figure 1: Three-Quarter Ton Pickup Idling Event Durations

An idle reduction system with a controller to

manage the vehicle run time based on interior temperature and battery voltage is the best fit for this application. This technology, at approximately \$2,000 per truck, was estimated to reduce the amount of idling by 60%. The overall estimated payback period for NYSDOT Region 4 vehicles providing fuel data is shown in Figure 2.

											Gallo	ns Per	Year									
		50	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
_	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
_	19	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.0	18.0	17.0	16.2
	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.4	18.0	16.8	15.8	14.8	14.0	13.3	12.6
	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.7	17.9	16.4	15.1	14.1	13.1	12.3	11.6	10.9	10.4	9.8
	16	20+	20+	20+	20+	20 <b>X</b>	20+	20+	20 <b>X</b>	19.2	17.0	15.3	13.9	12.8	11.8	11.0	10.2	9.6	9.0	8.5	8.1	7.7
	15	20+	20+	26+	20+	20	20÷	19.9	17.1	15.0	13.3	12.0	10.9	10.0	9.2	8.5	8.0	7.5	7.0	6.6	6.3	6.0
	14	20+	20+ >	<mark>∢ ≹0</mark> +	20+	<b>X</b> 0+	18.7	15.6	13.3	11.7	10.4	9.3	8.5	7.8	7.2	6.7	6.2	5.8	5.5	5.2	4.9	4.7
	13	20+	20+	20+	20+	18.2	14.6	12.1	10.4	9.1	8.1×	7.3	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.0	3.8	3.6
	12	20+	_w×	20+	18.9	14.2	11.4	9X	8.1	7.1	6.3	5.7	5.2	4.7	4.4	4.1	3.8	3.5	3.3	3.2	3.0	2.8
	11	20+	20+	20+	14.8	11.1	8.9	7. <b>X</b>	<b>%</b> 3	5.5	4.9	4.4	4.0	3.7	3.4	3.2	3.0	2.8	2.6	2.5	2.3	2.2
<u>ଟ୍</u> ରୁ _	10	20+	20+	17.3	11.5	8.6	6.9	5.8	4.9	4.3	3.8	3.5	3.1	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7
Σ_	9	20+	20+	13.5	9.0	6.7	5.4	4.5	3.9	3.4	3.0	2.7	2.5	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3
<u> </u>	8	20+	20+	10.5	7.0	5.3	4.2	3.5	3.0	2.6	2.3	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.1
Za_	7	20+	16.4	8.2	5.5	4.1	3.3	2.7	2.3	2.0	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1.0	<b>×</b> 1.0	0.9	0.9	0.8
₹_	6	20+	12.8	6.4	4.3	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6
_	5	20+	10.0	5.0	3.3	2.5	2.0	1.7	1.4	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5
_	4	20+	7.8	3.9	2.6	1.9	1.6	1.3	1.1	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
_	3	20+	6.1	3.0	2.0	1.5	1.2	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3
_	2	20+	4.7	2.4	1.6	1.2	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2
_	1	18.5	3.7	1.8	1.2	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
	0	14.4	2.9	1.4	1.0	0.7	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1

Figure 2: Estimated Payback Periods for <sup>3</sup>/<sub>4</sub>-Ton Pickup Trucks (Individually Marked with a Red "X")

#### NYSDOT 6-passenger pickups are Ford F-

350s or Chevrolet 3500 four-door crew-cab trucks used to transport personnel, tow light trailers, re-fuel equipment at the job site, or perform snow and ice patrol. Daily data from six 6-passenger trucks monitored for over 98 days and almost 8,000 miles of operations are shown in Table 3. Because of cold weather snow patrol duties, these vehicles may be used throughout the daytime and nighttime hours.



Figure 3: 6-Passenger Idling Event Durations

	Table	3:	6-passer	iger Oi	peration	Data
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		Daily Data								
	Mean	Max	Min	Standard Deviation	Total					
Fuel Use (gallons)	7.5	24.1	0.6	4.4	731					
Mileage (miles)	82.0	297.0	6.2	56.5	7,997					
Fuel Economy (mpg)	10.6	14.4	3.4	2.3	N/A					
Operating Time (hours)	4.8	16.6	0.3	3.1	467					
Idle Time (hours)*	2.1	12.2	0.1	2.0	203					
Idle Fuel Use (gallons)*	1.2	7.0	0.03	1.1	112					
Idle Fuel Rate (gallons/hour)	0.6	3.8	0.4	0.2	N/A					

\*Includes only stationary periods that exceed 2 minutes

The idle event durations for the 6-passenger pickups vary widely, as shown in Figure 3 and there is a significant amount of long-duration idling. The majority of vehicle idling occurs between 11 AM and 7 PM, with very low levels throughout the nighttime hours. There is a relatively signification increase in overall vehicle utilization through the winter months, most notably December and January.

An idle reduction system with a coolant circulator to

provide heat and an idle-stop controller was selected to provide needed amenities and reduce idling by approximately 76%. Based on a fuel price of \$2.97 per gallon and a system cost of \$2,525, the calculated payback period distribution is shown on Figure 4. Very similar payback periods were also estimated without cab heating abilities (estimated system cost of \$2,000 and an idle reduction potential of 59.6%).

										Gal	llons P	er Yeo	ur 👘									
		50	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	19	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.2	18.2	17.3
	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.0	17.7	16.6	15.6	14.8	14.0	13.3
	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	18.6	17.1	15.8	14.6	13.7	12.8	12.0	11.4	10.8	10.2
	16	20+	20+	20+	20+	20+	20+	20+	20+	19.7	17.5	15.8	14.3	13.1	12.1	11.3	10.5	9.9	9.3	8.8	8.3	7.9
	15	20+	20+	20+	20+ <mark>×</mark>	20+	205	20+	17.3	15.2	13.5	12.1	11.0	10.1	9.3	8.7	8.1	7.6	7.1	6.7	6.4	6.1
	14	20+	20+	20+	20+	20+	18.7	15.6	13.4	11.7	10.4	9.3	8.5	7.8	7.2	6.7	6.2	5.8	5.5	5.2	4.9	4.7
_	13	20 5	20+	20+	20+	18.0	14.4	12.0	10.3	9.0	8.0	7.2	6.5	6.0	5.5	5.1	4.8	4.5	4.2	4.0	3.8	3.6
<u>ଟ</u> ୍ଲ _	12	20+	20+	20+	18,5	13.9	11.1	× 9.2	7.9	6.9	6.🗙	5.5	5.0	4.6	4.3	4.0	3.7	3.5	3.3	3.1	2.9	2.8
٤_	11	20+	×20+	×20+	14.2	10.7	8.5	<b>∡</b> 1	6.1	5.3	4.7	4.3	3.9	3.6	3.3	3.0	2.8	2.7	2.5	2.4	2.2	2.1
- 3ge	10	20+	20+	16.4	11.86	8.2	6.6	5.5	4.7	4.1	3🗶	3.3	3.0	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6
ĕ.	9	20+	20+	12.7	8.4	6.3	5.1	4.2	3.6	3.2	2.8	2.5	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3
₹_	8	20+	19.5	9.7	6.5	4.9	3.9	3.2	2.8	2.4	2.2	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	1.0
_	7	20+	15.0	7.5	5.0	3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.8	0.8
_	6	20+	11.6	5.8	3.9 1	2.9	2.3	1.9	1.7	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6
_	5	20+	8.9	4.4	3.0	2.2	1.8	1.5	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4
_	4	20+	6.8	3.4	2.3	1.7	1.4	1.1	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3
_	3	20+	5.3	2.6	1.8	1.3	1.1	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
_	2	20+	4.1	2.0	1.4	1.0	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
_	1	15.6	3.1	1.6	1.0	0.8	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
_	0	12.0	2.4	1.2	0.8	0.6	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1

Figure 4: Estimated Payback Periods for 6-Passenger Trucks (Individually Marked with a Red "X")

NYSDOT stake rack trucks are Ford F-650s, Ford F-350s, or International 4300 chassis. Truck bed accessories for

these include sign truck tools and posts, herbicide units, bridge crew equipment, signs and cones for work zones, and stripe crew paint and beads. The overall average daily data on four stake rack trucks over 100 days of operation is shown in Table 4. The vehicles were used for almost 10,000 miles.



Table 4: Stake Rack Truck Operational Data

		Daily Data						
	Mean	Max	Min	Standard Deviation	Total			
Fuel Use (gallons)	13.5	132.8	1.6	17.3	1,348			
Mileage (miles)	100.0	460.0	8.0	69.6	9,968			
Fuel Economy (mpg)	9.0	17.6	3.1	2.5	N/A			
Operating Time (hours)	4.2	22.7	0.6	3.1	422			
Idle Time (hours)*	1.1	5.3	0.1	1.1	103			
Idle Fuel Use (gallons)*	0.7	2.9	0.01	0.7	67			
Idle Fuel Rate (gallons/hour)	0.6	1.7	0.2	0.3	N/A			

\*Includes only stationary periods that exceed 2 minutes

As shown in Figure 5, the monitored operation of the NYSDOT Region 4 stake rack truck showed that most idling periods were less than 40 minutes. Longer duration idle events (>40 min) taking place at the base location *more* than at the worksite shows potential for definitive improvement. Stake rack trucks see relatively consistent use throughout the year. The majority of the idling occurs during midday and is limited very early or late in the day.

Figure 5: Stake Rack Truck Idling Event Durations

The idle reduction system recommended for stake rack trucks would use a controller to manage the vehicle run time based on interior temperature and battery voltage. A number of fleet vehicles would see a quick return on investment from this technology as shown in Figure 6.

											Gallo	ns Per	rear									
		0	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	19	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	16	20+	20+	20+	20+	20+	20+	20+	20+	×20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	15	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.8	18.8
	14	20+	20+	20+	20+	20+	20+	20+	20+	×20+	20+	20+	20+	20+	20+	20+	19.5	18.3	17.2	16.3	15.4	14.6
	13	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.0	17.6	16.3	15.2	14.3	13.4	12.7	12.0	11.4
6	12	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.8	17.8	16.2	14.9	13.7	12.7	11.9	11.1	10.5	9.9	9.4	8.9
\$_	11	20+	20+	20+	20+	20+	20+	20+	×19.9	17.4	15.4	13.9	12.6	11.6	10.7	9.9	9.3	8.7	8.2	7.7	7.3	7.0
age_	10	20+	20+	20+	20+	20+	20+	18.1	15.5	13.6	12.0	10.8	9.9	9.0	8.3	7.7	7.2	6.8	6.4	6.0	5.7	5.4
ja _	9	20+	20+	20+	20+	20+	16.9	14.1 <mark>x</mark>	12.1	10.6	9.4	8.5	7.7	7.0	6.5	6.0	5.6	5.3	5.0	4.7	4.5	4.2
¥ _	8	20+	20+	20+	20+	16.5	13.2	11.0	9.4	8.2	73	6.6	6.0	5.5	5.1	47	4.4	4.1	3.9	3.7	3.5	3.3
_	7	20+	20+	20+	17.2	12.9	10.3	8.6	7.4	6.4	57	<b>×</b> 5.1	4.7	4.3	4.🎸	3.7	3.4	3.2	3.0	2.9	2.7	2.6
_	6	20+	20+	20+	13.4	10.0	8.0	6.7 <b>X</b>	5.7	×5,0×	4.5	4.0	3.6	<b>₩</b> 3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0
_	5	20+	20+	15.7	10.4	7.8	6.3	5.2	4.5	×3.9×	3.5	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.6
_	4	20+	20+	12.2	8.1	6.1	4.9	4.1	3,5	3.1	2.7	2.4	2.2	2.0	1.9	1.7	1.6	1.5	1.4	1.4	1.3	1.2
_	3	20+	19.0	9.5	6.3	4.8	3.8	3.2	2.7	2.4×	34	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	1.0
_	2	20+	14.9	7.4	5.0	3.7	3.0	2.5	2.1	7.9	1.7	1.5	1.4	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7
_	1	20+	11.6	5.8	3.9	2.9	2.3	1.9	1.7	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6
	0	20+	9.0	4.5	3.0	2.3	1.8	1.5	1.3	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5

Figure 6: Estimated Payback Periods for Stake Rack Trucks (Individually Marked with a Red "X")

NYSDOT small dump trucks are Ford F-650s or International 4300 chassis and have a variety of uses depending on seasonal requirements. During cold weather periods, the trucks are used for snow and ice patrol and may be

outfitted with small salt spreaders reversible plows. Warm and weather activities include setting for work zones, up hauling, patching, and pulling light equipment trailers. Table 5 shows the average daily data for small dump trucks; data from nine trucks was collected for over 11,500 miles of monitoring during 128 days.



		Dail	y Data		
	Mean	Max	Min	Standard Deviation	Total
Fuel Use (gallons)	12.0	132.8	0.6	16.4	1,532
Mileage (miles)	91.0	460.0	5.5	73.8	11,627
Fuel Economy (mpg)	9.4	16.1	2.8	3.5	N/A
Operating Time (hours)	4.7	22.7	0.3	3.2	606
Idle Time (hours)*	1.2	5.6	0.1	0.9	149
Idle Fuel Use (gallons)*	0.8	3.3	0.03	0.7	102
Idle Fuel Rate (gallons/hour)	0.9	7.4	0.2	0.9	N/A

\*Includes only stationary periods that exceed 2 minutes



Figure 7: Small Dump Truck Idling Event Durations

As shown in Figure 7, most idling events are shorter than 20 minutes, with almost half less than 10 minutes. Idling in traffic is extremely limited and makes up only 5% of the total idling. Small dump trucks are mostly used in the daytime with limited use during nighttime. There is an increase in overall use during winter months due to snow and ice duties.

The idle reduction technology selected as the best fit for this application would include a vehicle controller to manage vehicle shut-down and start-up. It would optimize run time based on the interior temperature and battery voltage. The overall payback period for small dump trucks is shown in Figure 8.

									Ga	lons P	er Yeai	ŗ.							
_		250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500
_	16	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	18.5	17.2	16.1	15.1	14.2	13.4
_	15	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.3	17.5	16.1	14.8	13.8	12.8	12.0	11.3	10.7
	14	20+	20+	20+	20+	20+	20+	20+	19.3	17.1	15.4	14.0	12.8	11.9	11.0	10.3	9.6	9.1	8.6
	13	20+	20+	20+	20+	20+	20+	17.6	15.4	13.7	12.3	11.2	10.3	9.5	8.8	8.2	7.7	7.3	6.8
	12	20+	20+	20+	20+	19.7	16.4	14.1	12.3	11.0	9.9	9.0	8.2	7.6	7.0	6.6	6.2	5.8	5.5
94W	11	20+	20+	20+	19.7	15.8	13.2	11.3	9.9	8.8	7.9	7.2	6.6	6.1	5.6	5.3	4.9	4.6	4.4
age	10	20+	20+	28+	15.8	<mark>≯</mark> 2.6	10.5 <mark>&gt;</mark>	9.0	7.9	7.0	6.3	5.7	5.3	4.9	4.5	4.2	3.9	3.7	3.5
lven	9	20+	20+	16.8	12.6	10.1	8.4	7.2	6.3	5.6	5.1	4.6	4.2	×3.9	3.6	3.4	3.2	3.0	2.8
<b>~</b> –	8	20+	20+	13.5	× 10.1 ;	<mark>∢</mark> 8.1	6.7	5.8	81	4.5	4.0	3.🗙	3.4	3.1	2.9	2.7	2.5	2.4	2.2
	7	×20¥	16.2	10.8	8.1	6.5	5.4	4.6	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8
	6	20+	12.9	8.6	6.5 <mark>×</mark>	5.2	4.3	3.7	3.2	2.9	2.6	2.4	2.2	2.0	1.8	1.7	1.6	1.5	1.4
_	5	20+	10.3	6.9	5.2	4.1	3.4	3.0	2.6	2.3	2.1	1.9	1.7	1.6	1.5	<b>1</b> 4	1.3	1.2	1.1
_	4	16.5	8.3	5.5	4.1	×3.3	2.8	2.4 <mark>×</mark>	2.1	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1.0	1.0	0.9

Figure 8: Estimated Payback Periods for Small Dump Trucks (Individually Marked with a Red "X")

## 2 Introduction

### 2.1 Background

A State Department of Transportation is responsible for maintaining a safe, efficient, balanced, and sustainable transportation system. To do so, it has many types of on-road vehicles and off-road equipment, which are operated by various personnel. The New York State Department of Transportation (NYSDOT) is also governed by Executive Orders (EO) to improve overall fleet efficiency and to reduce petroleum consumption and greenhouse gas (GHG) emissions. Governor Andrew Cuomo has approved the continuation of former Governor Paterson's EO4 in which state agencies must consider "green" alternatives for their new procurements and take steps to implement sustainable initiatives. Another active EO establishes a goal of reducing GHG emissions by 80 percent across all economic sectors in New York State. There are many opportunities to address this issue in transportation, which is responsible for nearly 40 percent of statewide GHG emissions. NYSDOT has adopted a mission to integrate sustainability into its decisions and practices in planning, designing, constructing, maintaining and operating New York State's transportation system. This includes protecting and preserving the environment by limiting transportation emissions, while minimizing the consumption of fuel resources.

One of NYSDOT's key strategies to achieving their sustainability goal is to evaluate the costs and benefits (societal, environmental, and economic) of transportation investments over lifetimes as well as fiscal cycles. Unnecessary idling is one practice that all fleets should address because it consumes fuel and results in GHG emissions while producing little or no value towards the mission. There are numerous proven practices and commercially available technologies to reduce idling, but "uptake has been stymied by a multitude of barriers and central among those barriers is a lack of data about the true performance gains offered by these technologies [Rondini, Schaller, and Swim 2014]." Argonne National Laboratory has conducted numerous research projects, papers, and presentations on idling reduction that outline the emissions from unnecessary idling, costs of fuel wasted, pros and cons of various types of idling reduction equipment, and applicable laws governing idling [Gaines and Levinson 2011][Gaines 2012]. They also developed the Idling Reduction Savings Calculator to compute fuel savings for Class 1-8 vehicles (accounting for the amount of fuel used by the idling reduction equipment) [Gaines 2014]. Information from these previous studies along with a Compendium of Idling Reduction Equipment Manufacturers, which has been compiled by Energetics and is pending publication, contributed to the suggested best idle reduction systems for NYSDOT Region 4 vehicles. The key to this study is that it extends work done in a laboratory and on paper into the field, by gathering real-world operational profiles for trucks and calculating potential savings from that data.

#### 2.2 Purpose

NYSDOT Region 4 has eliminated some idling by using more efficient light-emitting diode (LED) hazard warning signs that eliminate the need for stationary trucks to remain running. They also encourage personnel to turn off vehicles when not in use. Recognizing that more unnecessary idling is likely occurring, NYSDOT brought in Energetics Incorporated to evaluate the operational, economic, and environmental impacts of using advanced

technologies to reduce idling in the fleet without compromising functionality. The New York State Energy Research and Development Authority (NYSERDA) and NYSDOT funded the study.

The objective of the study is to recommended idle reduction solutions that are tailored to meet the requirements of personnel at all levels (e.g., drivers, fleet managers, executives) and fit within available financial resources. Energetics collected and analyzed information on NYSDOT Region 4 fleet operations to determine idle reduction opportunities. An investigation of commercially available idle reduction technologies gave Energetics information on costs, characteristics, and intended operation in order to model their anticipated behavior when used in NYSDOT Region 4 vehicle duty cycles. A benefit analysis of potential idle reduction solutions quantified the expected operational, economic, and environmental impacts. Results from this NYSDOT Region 4 study will be disseminated to other NYSDOT Regional offices to share best practices and solutions that could potentially be replicated throughout the entire NYSDOT fleet of over 3,000 vehicles.

#### 2.3 NYSDOT Region 4

NYSDOT Region 4, shown in Figure 9, includes seven western New York counties: Genesee, Livingston, Monroe,

Ontario, Orleans, Wyoming, and Wayne. NYSDOT personnel serve more than one million customers in this region. The seven counties cover an area of 4,072 square miles, or about 8% of the entire State. NYSDOT Region 4 has about 1,697 centerline miles of highway and 4,626 lane miles of highway, which is 9% of the mileage within the entire state. New York State owns and maintains 18% of this region's highway system. Out of a total of 1,701 bridges in the region, NYSDOT inspects, owns, and maintains 733.



Figure 9: NYSDOT Regions [New York State 2014]

NYSDOT Region 4 operations support various transportation needs of the population and freight centers found in this region. The largest city in Region 4, Rochester, is the third largest city in the State. The region also has three more cities, 107 towns, and 57 villages. The primary mass transportation provider in Region 4 is the Rochester/Genesee Regional Transportation Authority. With its subsidiaries, the Transportation Authority serves approximately 500,000 people over approximately one hundred square miles and provides commuter express services to four counties. The Greater Rochester International Airport serves as the center for commercial airline activity and general aviation, while three Class 1 railroads, ten shortline railroads, and Amtrak passenger service provide rail service. Region 4 also has major watercourses that include the Erie Canal, Lake Ontario, and the Genesee River. The overall service area for Region 4 operations is shown in Figure 10.



Figure 10: Region 4 Service Area

To support its duties and functions, NYSDOT Region 4 has a fleet of 328 on-road vehicles and numerous other pieces of off-road equipment. NYSDOT Region 4 staff identified four vehicle types that should be examined for idle reduction solutions due to the large number of vehicles within these groups and their typical duties, which may lead to excessive idling. The study types include <sup>3</sup>/<sub>4</sub>-ton pickups, 6-passenger trucks, stake rack trucks, and small dump trucks. Annual average operational data from 2013 for each of these vehicle types is shown in Table 6.

Classification	Count	Utilization (miles)	Fuel Use (gallons)	Average MPG
Pickup, ¾-ton	28	16,263	1,125	14.5
6-passenger	21	14,499	1,232	11.8
Stake Rack	31	7,741	867	8.9
Small Dump	52	8,893	930	9.6

Table 6: 2013 Operational Averages for Four NYSDOT Region 4 Vehicle Types

## 3 Idle Reduction Technology

Throughout the workday, there are some vehicle functions that require operators to leave a vehicle running while it is stationary. The engine may be required to power onboard systems, provide exportable power, provide engine heat in extreme cold, or maintain cabin temperature in extreme hot or cold weather. However, some stationary operation can be due to operator habits, forgetfulness, excessive pre-heating, and other unnecessary engine operation that does not provide any benefit and is not required for the vehicle's intended operation. Idle reduction technologies are designed to provide required amenities at a lower fuel consumption rate without the use of the engine, to automatically shut down the engine when not needed, or a combination of the two. Idle-stop systems, auxiliary power units, and auxiliary heating systems are examples of applicable idle reduction technologies for NYSDOT Region 4 vehicles. These systems can also be combined to create an integrated system optimized for a specific application.

### 3.1 Idle-Stop Systems

Idle-stop systems (sometimes referred to as automatic stop-start systems) shut down an internal combustion engine after a set period of time as long as critical vehicle parameters are at acceptable thresholds. If a predetermined situation occurs (e.g. low engine fluid temperature or low battery voltage) while the idle-stop system is engaged, the system will restart the vehicle in order to bring the engine parameters back within set thresholds. No operator behavior modifications are required if the system is tied into the vehicle control module and automatically engages as soon as the vehicle is stationary and out of gear. The controller will automatically monitor all parameters it is set up to collect and minimize engine run time. The controller can be programmed to operate heating, air conditioning, onboard energy storage, and exported power systems. In most systems, the vehicle automatically restarts when the operator depresses the brake pedal to shift out of park, thus providing seamless operation. Idle-stop systems are available from GRIP Idle Management System, Havis, InterMotive, Vanner, and ZeroRPM.

The **GRIP** (Governor to Reduce Idle and Pollution) Idle Management System automatically controls vehicle shutdown and start-up. While the engine is off it can also operate a variety of onboard accessories to provide required amenities.

The GRIP system minimizes vehicle idling without driver intervention through the use of the vehicle's Controller Area Network (CAN). The system retrieves real time data from the vehicle's engine control unit (ECU) on engine state, transmission position, ambient conditions, and engine temperature while monitoring GRIP accessories to provide intelligent control logic. The retail price of the GRIP system varies depending on included accessories, but typically ranges from \$2,500 to \$3,000 including installation (unit cost estimated at \$2,000). The basic GRIP system contains the system controller, interface screen, hood pin, and temperature sensor. Optional accessories include; anti-theft, solenoid, auxiliary battery, external coolant heater, alarm, current sensor, and heater remote start. Pictures of the installed system and the included components are shown in Figure 11.<sup>1</sup>

<sup>&</sup>lt;sup>1</sup> Pictures and permission provided by GRIP Idle Management System.



Figure 11: GRIP Idle Management System

**Havis** offers a simple idle reduction solution, called IdleRight 2, which monitors the vehicle's battery voltage and provides a restart signal when it falls below a set voltage. This system will not automatically shut down or start up

the vehicle's engine and thus relies on the operator to do that. This product only acts as the controller and is designed to be used with aftermarket remote car starter systems and security bypasses to complete the task of restarting the vehicle. The module, shown in Figure  $12^2$ , only acts as a voltage monitor and does not provide the ability to control additional accessories while the vehicle is off. However, this system is an extremely low cost solution that may provide significant savings in the right application. At a manufacturer suggested retail price (MSRP) of \$150, plus the cost of a remote car starter (~\$300 installed), the IdleRight 2 is one of the least expensive idle reduction technology options.



Figure 12: Havis IdleRight 2 Solution

**InterMotive** offers an automatic engine stop-start system to reduce idling in a variety of applications and vehicle types. This system monitors battery voltage and interior temperature (with an optional sensor) and manages the vehicle's engine run time to meet the operational requirements. The InterMotive system components are shown in Figure 13.<sup>3</sup> To intelligently manage the run time



Figure 13: InterMotive EcoStar Idle Reduction System

of the vehicle, the system requires the battery voltage to be above 11.8V, transmission in park, brake released, and hood closed to shut down the engine. To restart the engine, the module must see that the hood is closed, the transmission is in park, the engine was initially stopped by the module, and the key is in the run position.

<sup>&</sup>lt;sup>2</sup> Havis. IdleRight 2 - Vehicle Fuel Management System Control Module - New Generation. Accessed August 11, 2014 from <u>www.havis.com/products/IDLRT2\_UNV\_CNTRLMDL-42277-924.html</u>

<sup>&</sup>lt;sup>3</sup> InterMotive. Instructions Overview. Accessed August 11, 2014 from <u>www.intermotive.net/instructions.html</u>



Figure 14: Vanner IdleWatch® System

Vanner offers their IdleWatch® system, which minimizes vehicle idling by shutting down the engine when not required (after fully recharging the battery), and restarting it when the battery discharges below a predetermined level. The controller can be programed to automatically manage the startup and shutdown of the vehicle or configured so that it notifies the driver (with a horn or buzzer) to start or shutdown the vehicle. It is applicable for any 12 or 24 volt system and any make or model vehicle. The IdleWatch® system can also control mobile volts of alternating current (VAC) power and fast idle settings can be programed specific to each vehicle. This system helps extends the life of the battery because it never allows the battery to be heavily discharged.

The potential configuration and layout of this system for work truck applications is shown in Figure 14.<sup>4</sup> This specific configuration includes an inverter and additional batteries that are not included with the basic IdleWatch® system. The basic IdleWatch® system, including the control module, voltage/current sensors, wiring harness, isolation solenoid, and remote control, costs approximately 1,000 - 1,200 (does not include auxiliary batteries or inverter).

**ZeroRPM** provides an integrated idle mitigation system that utilizes a GRIP controller (shown in Figure 15)<sup>5</sup>, priced around \$2,000, to intelligently manage the vehicle's idle time. It also has a variety of additional accessories to provide amenities and electrical energy for extended engine-off periods. These accessories include power modules, energy modules, auxiliary power units (APUs), solar panels, and a variety of heating solutions. ZeroRPM also offers an engine off air-conditioning



Figure 15: ZeroRPM Grip Controller

system that utilizes the vehicle's factory-equipped heating, ventilation, and air-conditioning (HVAC) system through the use of an all-electric compressor. A number of configurations are available for idle reduction optimization while meeting the operator's requirements, including various auxiliary energy levels, auxiliary heat levels, engine-off VAC capabilities, and grid connectivity capabilities.

<sup>&</sup>lt;sup>4</sup> Vanner. Work Truck. Accessed August 27, 2014 from <u>http://www.vanner.com/markets/work-truck/</u>

<sup>&</sup>lt;sup>5</sup> Pictures and permission provided by ZeroRPM.

**Idle-stop** technologies are a simple and non-invasive solution to reduce idling, but may not provide as much savings as more extensive idle reduction systems. Idle-stop systems have raised concerns about increased emissions and energy use from regularly restarting the engine. While starting the engine does use slightly more energy and can emit more pollution, fuel use and carbon dioxide emissions are greater for passenger cars that idle for 10+ seconds instead of shutting down and restarting [Gaines, Rask, and Keller 2013]. Idle stop technology is quite inexpensive and offers convenient packaging for most applications. A summary of idle-stop system specifications is shown in Table 7.

	Unit Cost	Installation	Packaging
Havis IdleRight	\$150 + starter	6 man hours	Under dash (<1 pound)
InterMotive EcoStar	\$800	6 man hours	N/A
Vanner IdleWatch	\$1,000-\$1,200	6 man hours	2"x6"x8" (<2 pounds)
GRIP/ZeroRPM Controller	\$2,000	7 man hours	N/A

Table 7: Idle-Stop System Information

#### 3.2 Auxiliary Power Units

Auxiliary power units (APUs) are vehicle-mounted systems that provide power for extended periods of stationary operation so the vehicle's primary engine can be shut down. These systems can be configured with a fuel operated genset or electrical energy storage. The idling duration and power requirements of NYSDOT Region 4 vehicles do not require the use of a fuel operated genset, which is typically for long-haul trucks. A battery system is a better solution for this application and is the basis for the remainder of this APU technology summary.

A battery-based APU typically requires an idle stop controller to manage the charging and discharging of the onboard energy storage module. If the energy storage is depleted, the controller will automatically restart the engine, charging the batteries from the existing alternator. Some systems come with an auxiliary charging port that allows the batteries to be charged overnight from the grid while the truck is parked at its base. While this still consumes energy, the electrical grid in most states, and particularly New York, is less polluting than combusting petroleum in a vehicle because electrical generation uses nuclear, natural gas, and renewable sources of energy. Battery-based APUs are available in various energy capacities that could be optimized for the intended operation of each vehicle.

Battery-based APU accessories can provide heating and cooling of the cab for short periods. Heating systems are available in a variety of different configurations depending on the desired British thermal unit (BTU) load and duration. Short term cab heating can be accomplished with a simple auxiliary coolant pump that circulates coolant through the hot engine after shutdown. Electric cab heaters powered directly from onboard energy storage are also available. Some systems are offered with electric air-conditioning compressor pumps that allow the vehicle's original air-conditioner system to operate without the engine running. A battery-based APU appropriate for NYSDOT Region 4 trucks may occupy a space approximately 36" x 24" x 12" and add 400 pounds, which are disadvantages for using this type of system. Energy Xtreme and ZeroRPM offer battery-based APU systems for applications similar to NYSDOT Region 4 operations.

**Energy Xtreme's** work truck idle reduction system provides complete smart power management to operate a vehicle's full electrical load without utilizing the engine, including lights, radios, computers, and auxiliary power. The system receives and stores excess electrical energy from the vehicle's alternator during normal driving that is used once the vehicle is stationary. An Energy Xtreme battery-based APU unit, shown in Figure 16<sup>6</sup>, can provide



Figure 16: Energy Extreme Independence Package

1,000 to 8,000 Watt-hours of auxiliary energy. This variation in system sizes allows solutions to be configured for a wide range of vehicle types and is applicable for NYSDOT vehicles ranging from pickups to small dumps where electrical energy may be required while stationary. Lightduty trucks would typically only require a small energy storage module (2 kilowatts [kW]) and is estimated to cost \$4,295. Larger vehicles may need VAC exportable power, requiring a larger system which can cost \$7,995 to \$15,995 depending on power requirements.

**ZeroRPM** provides several battery-based APU solutions for trucks ranging from class 1 to class 8. The systems (as shown in Figure 17)<sup>7</sup> are intelligently controlled though the GRIP controller described previously. ZeroRPM's battery-based APUs are a comprehensive idle mitigation system. Individual quotes for specific components or features are not available because they must be implemented as an entire system. However, various battery energy capacities are offered by ZeroRPM with different incremental costs to fit each application.



Figure 17: ZeroRPM Energy Module

#### 3.3 Heaters

Heating systems to maintain interior conditions for extended periods in cold weather can be integrated into an overall idle reduction solution or installed as separate units. Integrated heating systems are typically electric-based and circulate the engine's coolant to provide heat to the cab and engine simultaneously. After the engine is shut down, this may provide heating for up to an hour (depending on engine type and ambient temperature). Electric heaters can be powered from the vehicle's battery for a short period of time or longer with an onboard energy storage module. Individual fuel fired heaters can be installed just to provide supplemental heat. These produce heat more rapidly than an idling engine and have  $1/20^{th}$  the emissions because fuel fired heaters use much less fuel than the vehicle's engine. Fuel fired air heaters only warm the cab, but are fairly compact at around 12" x 6" x 6" and weigh only 15 to 20 pounds. Fuel fired coolant heaters keep the engine warm in cold weather and can be incorporated into the vehicle's heating system to provide supplemental cab heat. The coolant heaters that can

<sup>&</sup>lt;sup>6</sup> Pictures and permission provided by Energy Xtreme.

<sup>&</sup>lt;sup>7</sup> Pictures and permission provided by ZeroRPM.

provide cab heating are larger than the air heaters (24" x 12" x 10") and heavier (40 to 100 pounds), but completely eliminate the need for a vehicle to idle in cold weather since they keep both the engine and cab warm. Manufacturers that offer applicable fuel operated heaters of varying output to accommodate different operational and heating requirements for this work truck application include Autotherm, Espar, Idle Free Systems, Proheat, Webasto, and ZeroRPM. Most NYSDOT Region 4 vehicles are already outfitted with block heaters which warm up the engine's oil or block directly to make the engine easier to start in extreme cold conditions. However, block heaters do not create enough heat to provide cabin heating and are not typically considered an idle reduction technology.

Autotherm's solution for vehicle heating during shutdown periods, called the No-Idle Cab Heating System (shown

in Figure 18)<sup>8</sup>, relies on the heat energy stored in the engine coolant to maintain warm temperatures inside the cab. This system consists of an auxiliary pump located in-line with the vehicle's original heater coolant loop and continues to circulate the coolant once the key is switched off. The vehicle's fans are also powered up to evenly heat the entire interior and provide defrosting capabilities. The duration of cab heating after shutting down the engine is typically one



Figure 18: Autotherm No-Idle Cab Heating System

to four hours depending on coolant capacity, engine size, and ambient factors. The controller for this heating system automatically activates when the key is switched off. To protect the engine, it stops working once the coolant temperature drops to 95°F or the battery voltage drops below a predetermined threshold. This systems are listed at \$595 for the deluxe version (allows low power accessory operation during active heating) and \$525 for the standard version. It is estimated that installation will take approximately 3 hours.

**Espar** is a well-established idle reduction heating system manufacturer that offers a variety of solutions for vehicles ranging from pickups, highway trucks, and off-road equipment. These systems, shown in Figure 19<sup>9</sup>, are available with a variety of programmable timers, thermostats, and controllers to allow optimized preheating and worksite idle reduction.



Figure 19: Espar Heating Solutions

<sup>&</sup>lt;sup>8</sup> Autotherm. Deluxe No-Idle Cab Heating System. Accessed September 2, 2014 from <u>www.autothermusa.com/shop-deluxe-cab-heating.html</u>

<sup>&</sup>lt;sup>9</sup> Pictures and permission provided by Espar.

Their systems act as miniature furnaces that heat the cab or engine coolant using the fuel stored onboard the vehicle. This provides a much more efficient method for pre-heating and maintaining the engine and interior temperatures than idling the primary engine. Espar's E-Works AIRTRONIC systems are air heaters range from 7,500 to 18,800 BTU and are available with intelligent controllers for precise compartment air heating. Espar's E-Works HYDRONIC heaters heat the vehicle's coolant, which can then heat the cab interior and engine, and are available in 17,000 to 42,000 BTU sizes. Espar products applicable for NYSDOT Region 4 vehicles are included in Table 8.

Model	Heater Type	Output	Fuel	Cost
D2	Air Heater	2 kW	Diesel	\$2,199
B1LC	Air Heater	2 kW	Gasoline	\$2,423
B5WS	Coolant Heater	5 kW	Gasoline	\$2,559
D5WS	Coolant Heater	5 kW	Diesel	\$2,559
M12	Coolant Heater	12 kW	Diesel	\$4,220

Table 8: Espar Heater Options

The **Idle Free** Work Truck No Idle Heat system combines a coolant heater with an engine start module (ESM) to provide engine heat, interior heat, and accessory electrical power. The ESM replaces the vehicle's original starter battery with an ultracapacitor that is charged from the alternator and allows the other onboard batteries to be switched to deep cycle battery technology. This allows longer, key-off run times. This system utilizes the existing factory wiring so operators can use the vehicle's controls to operate electrical components and cab heat settings. To heat the engine coolant, and in turn the vehicle interior, a fuel fired coolant heater is used (as shown in Figure 20<sup>10</sup>). The use of the No Idle Heat system provides up to 8 hours of heat and



Figure 20: Idle Free Coolant Heater

powers the vehicle's interior and exterior lights along with electrical accessories. The installed cost of this system for a large diesel truck is approximately \$4,000. However, this price will vary depending on volume purchased and installation availability.

**Proheat** offers both air heater and coolant heater solutions for a wide range of vehicle applications to reduce idling times in cold weather applications. The air heater solution, shown in Figure 21<sup>11</sup>, provides two to four kW of heat and automatic, quiet operation with a built-in control display for programing and status information. The air heater uses approximately 0.03 gallons of fuel per hour and provides cab heating much more efficiently than idling the vehicle's motor. Proheat's coolant heater solution, the X45 shown in Figure 21<sup>11</sup>, provides up to 13 kW of heating power and is fully programmable to allow cab and engine preheating, facilitating easy starting with minimal idle warm up time in cold weather. The X45 consumes approximately 0.1 gallons of fuel per hour. By preheating the engine, significantly reduced engine wear is experienced due to lack of cold starts and decreased oil viscosity during

<sup>&</sup>lt;sup>10</sup> Pictures and permission provided by Idle Free.

<sup>&</sup>lt;sup>11</sup> Pictures and permission provided by Proheat.

extremely low ambient temperatures. The estimated costs are approximately \$950 for the air heater and \$2,400 for the X45 coolant heater system.



Figure 21: Proheat X45 Coolant Heater (left) and Proheat Air Heater (right)

**Webasto** manufactures a variety of air and coolant heaters for work truck and commercial vehicle fleets. Their coolant heaters allow the vehicle's engine to be raised to near operating temperature before being started, reducing engine wear and tear. This also allows cabin conditioning so that the vehicle can be started and driven immediately, even in extremely cold conditions, which improves the overall fuel consumption rate. These heaters are available in output ranges of 2.2 to 35 kW and, because they use the vehicle's fuel, can heat the engine coolant for extended periods of time. The air heaters offered by Webasto provide only cab heating but are less expensive and simple to install. These are ideal for maintaining operator comfort in harsh climates when engine heating is of a lesser concern (e.g. with gasoline engines). These heaters are often combined with idle-stop controllers to provide optimized and convenient operation. Both heater types are shown in Figure 22.<sup>12</sup> The cost of these heaters can vary and a specific quote should be received from a dealer before purchasing. However, the coolant heater (Thermo Top C) is estimated to cost \$1,500 for the gasoline version and \$1,700 for the diesel version. The air heaters (Air Top 2000 ST) are estimated to cost approximately \$1,500 for the gasoline version and \$1,800 for the diesel version.



Figure 22: Webasto Air Heaters (Air Top 2000 ST) Left and Coolant Heater (Thermo Top C) Right

**ZeroRPM** doesn't specifically manufacture heating systems but integrates a heater into its comprehensive idle reduction solution. Available heater options include coolant circulators, electric air heaters, fuel fired air heaters, and fuel fired coolant heaters. These heater options are controlled with the rest of the system using the GRIP controller to effectively manage use.

<sup>&</sup>lt;sup>12</sup> Pictures and permission provided by Webasto.

## 4 Approach

Data acquisition was used to gather actual real-world vehicle information so the results are specific to NYSDOT Region 4 operations. However, this means the statistical repeatability is not as high as laboratory data, because it is gathered in the field under widely varying conditions. Many of these vehicles are used on an "as needed" basis and may not see similar operations, routes, loads, or uses on a daily basis. Vehicle parameters (e.g. fuel flow, load, idle time, and vehicle speed) are also influenced by driver behavior, ambient conditions, vehicle condition, and location specific differences. However, this real-world data acquisition approach can approximate the level of idling taking place in the NYSDOT Region 4 fleet and give insight to potential idle reduction technology benefits.

For a high-level view of NYSDOT Region 4 vehicle operations, Energetics analyzed annual mileage and fuel usage data on all vehicles. However, to provide a more in-depth evaluation of the day-to-day vehicle operations and idling

activity, vehicle duty cycles, including engine data, vehicle dynamics data, and location data, were needed. To record this data, onboard data logging systems were installed on selected vehicles to capture daily operational data on a per-minute basis. These data loggers, shown in Figure 23, plugged into the vehicle's diagnostic port and recorded engine parameters as well as global positioning system (GPS) information.



Figure 23: HEM Onboard Data Loggers

Many of the larger medium-duty NYSDOT trucks (stake rack and small dump) utilize Society of Automotive Engineers (SAE) J1939 onboard vehicle network protocol [SAE International Standard 2013] which provides more data channels and information than OBD-II for the lighter-duty <sup>3</sup>/<sub>4</sub>-ton and 6-passenger pickups which utilize SAE J1962 hardware interface [SAE International Standard 2012] and SAE J1850 signaling protocol [SAE International Standard 2006]. The devices were moved between multiple vehicles during a ten month period to gather many operational profiles throughout the fleet during different environmental conditions. Specific data parameters monitored from most vehicles (some engine control modules do not broadcast all of these) included:

- vehicle speed,
- engine speed,
- percent load,
- air flow rate,
- fuel flow rate,
- time,
- ambient temperature,
- coolant temperature,
- latitude,
- longitude,
- altitude,
- and velocity.

Idle time was not a parameter available directly from the vehicle, nor was the transmission position, so idle time was calculated using vehicle speed and engine speed to determine when the vehicle was stationary while the engine was running. Stationary periods less than two minutes in duration likely occur in stop-and-go traffic and during "creep" mode, when the truck is driving slowing along the shoulder of the road or some other, low speed operation. This type of idling cannot be easily eliminated, but was found to be quite limited for most vehicles. Stationary durations longer than two minutes are events when the vehicle is assumed to be parked. Energetics used GPS coordinates to determine when the vehicle was parked at its NYSDOT Region 4 division base location. Some idling can be

expected while the truck is at its base location due to warm-up, cool down, and preparing for its functions. The remainder of the idling takes place during the workday at various locations along the road and at worksites. This portion of idling provides the largest potential for reduction using technology.

The time of year impacts duty cycles, as many vehicles are used for snow removal in the winter and other uses in warmer weather. The most beneficial idle reduction technology, if applicable, was determined by evaluating the specific vehicle type's idling behavior. Parameters evaluated include total idle time, idle location, percent of total fuel use for idling vs. average miles per gallon (mpg), and idle event duration. These factors were compared to each vehicle type's overall annual fuel use and mileage data (calculated from NYSDOT Region 4 records) to determine the idle reduction potential.

#### 4.1 Performance Modeling

Performance data for various idle reduction technologies in real-world applications is extremely limited, and most is from technology manufacturers. Therefore, Energetics developed a model for the potential idle time reduction for the various idle reduction technologies selected for the NYSDOT Region 4 vehicles using data logging data, technology manufacturer information, ambient weather data, and information from discussions with NYSDOT staff. The purpose of NYSDOT Region 4 vehicle idling, excluding driver forgetfulness, is typically to keep the battery charged (since it provides electrical power for vehicle accessories, off-board accessories, lights, etc...) or to maintain comfortable conditions inside the vehicle for occupants (heating, ventilation, or air conditioning). Idle reduction controllers monitor the voltage of the electrical system and minimize the engine run time while maintaining battery charge and interior temperatures. Because of the NYSDOT duty cycles found through monitoring the vehicles, low-cost idle reduction systems (idle management controllers with and without minimal cab heating systems) were evaluated in depth for this study. APUs, fuel fired heaters, and battery air conditioning systems have high upfront costs that are not economically justified based on the amount of idling recorded.

*Electric Load* - NYSDOT Region 4 vehicles use electrical power for onboard accessories while stationary. However, the vehicle's alternator is able to produce significantly more electrical energy than is constantly being consumed by the accessories (typical accessories and their current draw is shown in Figure 24) and the onboard battery can store energy for a limited duration of engine off time. Thus, an idle





management controller can eliminate short duration stationary idling events resulting from electrical power draw. Longer events may still require restarting the engine to charge the batteries after they have been discharged to a predefined level. For the NYSDOT Region 4 vehicles examined in this study, Table 9 lists the electrical assumptions used in this model. The vehicle amperage draw is assumed to be required to run vehicle's equipment including running lights, dash lights, and radio. Six passenger pickups, stake rack trucks, and small dump truck also typically use flashers. Accessory draw is based on assumed power for auxiliary lighting and communication equipment while

stationary. The estimated recharge time accounts for operating the equipment while recharging as well as power required to run the engine (20 amps for gasoline engines, 10 amps for diesel engines).

Vehicle Type	Battery AH	Min SOC	Vehicle Draw (A)	Accessory Draw (A)	Discharge Time (hrs)	Alternator Output (A)	Recharge Time (hrs)
<sup>3</sup> / <sub>4</sub> -Ton Pickup Truck	72	70%	17	20	1.36	125	0.32
6-Passenger Truck	78	70%	25	40	0.84	100	0.94
Stake Rack Truck	96	70%	25	40	1.03	105	0.96
Small Dump Truck	96	70%	25	40	1.03	105	0.96

Table 9: Idle Reduction Electrical Requirements

The electrical requirements for each NYSDOT Region 4 vehicle were used to calculate a theoretical maximum percentage of idle time that can be eliminated (shown in Figure 25) based on the total duration of the idling events. Within these limits, the idle management controller will maintain the health of the battery system such that it provides all required electrical energy and can restart the vehicle. Six passenger, stake rack, and small dump trucks were assumed to have similar electrical requirements resulting in similar idle reduction potential. After one hour of managed idling, the idle management controller



Figure 25: Maximum Percent Idle Reduction Due to Electrical Requirements

has shut off the engine while the battery discharged to 70% SOC and then brought the battery SOC back to 100% by restarting the engine, reaching the limit of idle reduction potential for that vehicle as this cycle repeats itself.



*Cab Conditioning Requirements* -In cold and hot weather, a stationary vehicle's engine may run to maintain cab comfort. Average ambient conditions for Rochester (shown in Figure 26) were used to approximate the maximum required heating and cooling engine run time percentages needed to maintain cab comfort.

Due to insulating capacity of the vehicle cab and the heat within the engine after it is driven, the vehicle does not require constant idling to maintain the interior temperature in winter. The overall maximum percent idle reduction possible while meeting the vehicle's thermal requirements is shown in Figure 27. For this model, it was assumed that at an average daily temperature of 60°F, no idling would be needed for heating or cooling. In addition, at 0°F, it

was assumed that the engine must constantly idle to provide heat if the vehicle did not have an auxiliary heating system. With the addition of a coolant circulator (to heat the cab), it is assumed that the engine could be shut down longer between startups due to the thermal energy stored in the engine. On average, there is a smaller percentage of idle reduction potential for longer idle durations where some engine run time will be required to maintain temperature, whereas with some shorter duration idling events the engine might only restart towards the end of the stationary period. This is reflected by the various curves on the plot. The presence of a heater does not impact the idle reduction potential during hot weather that requires cooling, but the idle reduction potential will still be influenced by the duration of the idling event. This model was used for all NYSDOT Region 4 vehicle types, but many factors can influence the thermal loads on a vehicle's cab (e.g. number of occupants, solar gain, door seal, and glass area) and these results could vary. This model was applied to average daily temperatures for Rochester, New York<sup>13</sup> to obtain the average maximum thermal idle reduction per month for each vehicle.



Figure 27: Maximum Percent Idle Reduction Due to Thermal Requirements

The lesser of the two theoretical maximums for the electric and thermal idle reduction potentials were applied to the real-world usage data collected from the NYSDOT Region 4 vehicles. Also factored into the overall percent idle reduction for each vehicle was the proportion of short and long duration idle events, along with the average vehicle use throughout the year. Table 10 shows the results from this modeling that was used to evaluate the economic viability of the various technologies for each vehicle type.

Table 10: Overall Idle Re	eduction Potentia
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	Idle Reduction Potential without Heater	Idle Reduction Potential with Heater
¾ Ton Pickup	59.5%	76.9%
Six Passenger	59.6%	76.0%
Stake Rack	60.1%	73.5%
Small Dump	62.4%	77.5%

<sup>&</sup>lt;sup>13</sup> Historic data retrieved from www.wunderground.com/weather-forecast/US/NY/Rochester.html

## 5 Three-Quarter Ton Pickups

NYSDOT <sup>3</sup>/<sub>4</sub>-ton pickups, Ford F-250s or Chevrolet 2500s, are typically driven by supervisors to check on site work. These trucks are usually outfitted with tool boxes and occasionally haul light trailers or variable message signs. Some may be outfitted with fueling capabilities for offsite equipment. NYSDOT <sup>3</sup>/<sub>4</sub>-ton pickups, shown in Figure 28,

are widely used in winter to check road conditions. Supervisors visit multiple work sites on a daily basis and often travel extensively throughout their respective areas. However, daily fuel consumption of the <sup>3</sup>/<sub>4</sub>-ton pickups is quite low due to their relatively high fuel economy.



Figure 28: NYSDOT <sup>3</sup>/<sub>4</sub>-ton Pickup

### 5.1 Duty-Cycle

Energetics collected useful data from four <sup>3</sup>/<sub>4</sub>-ton pickups at two different NYSDOT Region 4 divisions (two additional <sup>3</sup>/<sub>4</sub>-ton pickups were monitored, but did not provide useful data). Combined, data from 169 days of operations were analyzed during which the trucks were driven over 15,000 cumulative miles. Daily statistics from the truck operating days are shown in Table 11.

		Daily	/ Data		
	Mean	Maximum	Minimum	Standard Deviation	Total
Fuel Use (gallons)	6.6	20.1	0.8	3.4	1,110
Mileage (miles)	89.0	288.0	8.0	47.6	15,029
Fuel Economy (mpg)	13.6	17.8	4.4	2.6	N/A
Operating Time (hours)	3.4	14.5	0.4	2.1	576
Idle Time (hours)*	0.7	11.6	0.0	1.4	125
Idle Fuel Use (gallons)*	0.4	6.6	0.0	0.8	69
Idle Fuel Rate (gallons/hour)	0.4	1.7	0.0	0.3	N/A

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\*Includes only stationary periods that exceed 2 minutes

Operational summaries for the monitored individual <sup>3</sup>/<sub>4</sub>-ton pickups are included in the Appendix. Differences between specific vehicles in this group are quite pronounced, even within the same division. Overall, truck #085068 (Canandaigua Division) and truck #115394 (Monroe East Division) show the highest variability of MPG and percent idle from day to day, ranging from 4 to 18 MPG and 0 to 70% idle fuel consumption (for averaged daily values). The other vehicles, #115300 and #115299 (Monroe East Division), vary less from day to day and have slightly higher average MPG (13-17 mpg) and lower percent idle (0-12%).

Energetics used GPS coordinates to determine when the vehicle was parked at its NYSDOT Region 4 division base location. Some idling can be expected while the truck is at its base location due to warm-up, cool down, and preparing for its functions, but this should not be extensive. Traffic idling events make up a significant portion of the total idling for this type of vehicle. This is likely due to significant city driving and low speed moving at worksites. Idling also takes place throughout the workday at various locations along the road and at worksites.

the idling provides the largest potential for reduction using anti-idling technology. Figure 29 depicts the portions of each type of idling recorded during the monitoring period.

Energetics analyzed the idling event durations to gain insight into the type of idling most likely occurring and which idle reduction technologies would be most suitable. For the <sup>3</sup>/<sub>4</sub>-ton pickups, the majority of idling periods last fewer than twenty minutes, as shown in Figure 30. The few



long-duration idling events at the base location were likely due to driver behavior and vehicle preheating. Offsite, shorter idling events are likely from short stops at worksites when the driver leaves the vehicle running out of habit or to maintain cabin temperatures.





Energetics also analyzed the time of day when idling occurs to provide further insight into the driver's activity when the vehicle is idling. NYSDOT Region 4 <sup>3</sup>/<sub>4</sub>-ton pickups idle most during the late morning and afternoon hours as shown in Figure 31. This data includes idling events at the base location and worksites but not stop-and-go idling.







### 5.2 Idle Reduction Potential

To correlate the detailed data from the four vehicles that were data logged with the rest of the NYSDOT Region 4 <sup>3</sup>/<sub>4</sub>-ton pickup fleet, Energetics plotted fuel economy versus the percentage of fuel consumed due to idling for each day the monitored vehicles were used. While there may be other factors impacting fuel economy other than idling time, such as driving style (aggressiveness), speed, payload, tire pressure, vehicle model, and vehicle age, Figure 33 shows some correlation between overall average MPG and idle percentage. This correlation was used to estimate idle time for all <sup>3</sup>/<sub>4</sub>-ton pickups in the fleet based on their annual fuel and mileage.





The <sup>3</sup>/<sub>4</sub>-ton pickups experience minimal idling at their base and most idling events are quite short (<20 minutes). Much of that idling is likely to maintain comfortable temperatures inside the truck during snow patrol, site visits, and other operations. However, a costly idle reduction control system could not provide enough savings to payback the initial investment because these smaller pickups do not consume a lot of fuel during idling. A more basic idle reduction system with a controller to manage the vehicle run time, while monitoring the interior temperature and battery voltage, has the best potential for economic savings. The cost of this system is estimated at \$2,000 per truck. The overall estimated payback period of this technology based on annual fuel use (gallons) and average MPG for all NYSDOT Region 4 <sup>3</sup>/<sub>4</sub>-ton pickups is shown in Figure 34. The analysis uses a fuel price of \$2.97 per gallon<sup>14</sup> and an overall idle reduction of 59.5% (based on the model developed by Energetics that was described earlier in this report). For NYSDOT Region 4 <sup>3</sup>/<sub>4</sub>-ton pickup trucks reporting reasonable fuel economy values, the vehicle fueling and usage data is overlaid on the graphic (small red X). Some vehicles are not shown on this graphic as they do not fall within the displayed data (extremely low fuel use or high efficiency). From the annual data provided by the NYSDOT, it is estimated that 7% of the <sup>3</sup>/<sub>4</sub> ton pickup trucks would see a return on investment within 5 years from using idle-stop technology and 32% in 10 years. The overall average payback for vehicles with applicable data provided is 22.1 years. Similar payback periods were also found with the addition of a simple coolant circulator to the system to provide limited cab heating (estimated system cost of \$2,525 and idle reduction of 77%). The final chosen system must be determined by the specific truck and its required duties.

Gallons Per Year

		50	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
_	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	19	20+	20+	20+	20+	20+	20+	×20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.0	18.0	17.0	16.2
	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.4	18.0	16.8	15.8	14.8	14.0	13.3	12.6
_	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.7	17.9	16.4	15.1	14.1	13.1	12.3	11.6	10.9	10.4	9.8
_	16	20+	20+	20+	20+	20🌺	20+	20+	20 <b>X</b>	19.2	17.0	15.3	13.9	12.8	11.8	11.0	10.2	9.6	9.0	8.5	8.1	7.7
_	15	20+	20+	26+	20+	20 <mark>x</mark>	20 <sup>+</sup>	19.9	17.1	15.0	13.3	12.0	10.9	10.0	9.2	8.5	8.0	7.5	7.0	6.6	6.3	6.0
_	14	20+	20+ >	<b>ς 20</b> +	20+	<b>X</b> 0+	18.7	15.6	13.3	11.7	10.4	9.3	8.5	7.8	7.2	6.7	6.2	5.8	5.5	5.2	4.9	4.7
_	13	20+	20+	20+	20+	×18.2	14.6	12.1	10.4	9.1	8.1×	7.3	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.0	3.8	3.6
_	12	20+	20 <sup>×</sup>	20+	18.9	14.2	11.4	98	8.1	7.1	6.3	5.7	5.2	4.7	4.4	4.1	3.8	3.5	3.3	3.2	3.0	2.8
	11	20+	20+	20+	14.8	11.1	8.9	7.🏹	<b>%</b> 3	5.5	4.9	4.4	4.0	3.7	3.4	3.2	3.0	2.8	2.6	2.5	2.3	2.2
g 2 –	10	20+	20+	17.3	11.5	8.6	6.9	5.8	4.9	4.3	3.8	3.5	3.1	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7
ž-	9	20+	20+	13.5	9.0	6.7	5.4	4.5	3.9	3.4	3.0	2.7	2.5	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3
ğ_	8	20+	20+	10.5	7.0	5.3	4.2	3.5	3.0	2.6	2.3	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.1
ē _	7	20+	16.4	8.2	5.5	4.1	3.3	2.7	2.3	2.0	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1.0	<b>×</b> 1.0	0.9	0.9	0.8
₹_	6	20+	12.8	6.4	4.3	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6
_	5	20+	10.0	5.0	3.3	2.5	2.0	1.7	1.4	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5
_	4	20+	7.8	3.9	2.6	1.9	1.6	1.3	1.1	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
_	3	20+	6.1	3.0	2.0	1.5	1.2	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3
_	2	20+	4.7	2.4	1.6	1.2	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2
_	1	18.5	3.7	1.8	1.2	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
	0	14.4	2.9	1.4	1.0	0.7	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1

Figure 34: 3/4-ton Estimated Payback Period Based on Gallons per Year vs Average MPG

<sup>&</sup>lt;sup>14</sup> Average fuel price, for both diesel and gasoline, for 2014 (individual prices not available), retrieved December 22, 2014 from <u>https://www.dot.ny.gov/main/business-center/contractors/construction-division/fuel-asphalt-steel-price-adjustments</u>

## 6 6-passenger Pickups

NYSDOT 6-passenger pickups are Ford F-350s or Chevrolet 3500 four-door crew-cab trucks primarily used to transport personnel. Some trucks are also set up for work zone activities and may tow light trailers. Most units include tool boxes and some are also outfitted with fuel tanks to refuel equipment at the job site. During cold weather, 6-passenger pickups are used for snow and ice patrol. A NYSDOT 6-passenger pickup is shown in Figure 35.



Figure 35: NYSDOT 6-passenger Pickup

### 6.1 Duty-Cycle

The daily data from six 6-passenger trucks monitored for over 98 days and almost 8,000 miles of operations are shown in Table 12. Some data had to be eliminated due to loss of date/time information (total of 34 miles worth of data) and daily travel less than 5 miles (8 total days, where the vehicle did not appear to leave the NYSDOT facility due to vehicle maintenance or other reasons).

	Daily Data								
	Mean	Maximum	Minimum	Standard Deviation	Total				
Fuel Use (gallons)	7.5	24.1	0.6	4.4	731				
Mileage (miles)	82.0	297.0	6.2	56.5	7,997				
Fuel Economy (mpg)	10.6	14.4	3.4	2.3	N/A				
Operating Time (hours)	4.8	16.6	0.3	3.1	467				
Idle Time (hours)*	2.1	12.2	0.1	2.0	203				
Idle Fuel Use (gallons)*	1.2	7.0	0.03	1.1	112				
Idle Fuel Rate (gallons/hour)	0.6	3.8	0.4	0.2	N/A				
<b>4</b> 1 1 1 1 1 1 1									

Table 12: 6-passenger Pickup Data

\*Includes only stationary periods that exceed 2 minutes

Operational summaries for the monitored individual 6-passenger pickups are included in the Appendix. Depending on the division operating the vehicle, 6-passenger trucks are used for a variety of duties throughout the workday. Trucks operated by the highway departments showed a much wider range of when the vehicles were used, with some use throughout all hours of the day (likely due to snow patrol). Bridge crew trucks saw a more conventional workday profile with most activity between 9AM and 8PM. Highway department trucks had a much higher percentage of idling at their base location. Idling by the bridge crew trucks was almost exclusively at the worksite, which favors an idle reduction system that could provide more amenities. A simple auto shutdown system could provide some savings for highway department trucks. However, these vehicles would likely also benefit from additional idle reduction abilities as these vehicles are typically used extensively by multiple personnel in the field as a mobile office and break location. Figure 36 depicts the portions of each type of idling recorded during the monitoring period. The majority of the NYSDOT 6-passenger pickup idling occurs at worksite locations. Base location and stop-and-go idling in traffic were small portions of the total idling time. The unknown location idling is due to lack of GPS data and could be from trucks running indoors (steel buildings shield GPS signal) or from worksite locations without clear GPS signal availability (parked under a bridge, heavily wooded area, near large buildings, etc.).





The idle event durations for the 6-passenger pickups vary widely, as shown in Figure 37, and there is a significant amount of long-duration idling. The long idle durations are likely because these vehicles are often used by personnel for comfort during breaks at work sites. The majority of this idling could be for cab conditioning or potentially just due to driver behavior. Longer events at the home base are not necessary and could be significantly reduced with idle reduction technology.



#### Figure 37: 6-passenger Pickup Idling Durations (minutes)

Because of cold weather snow patrol duties, these vehicles may be used throughout the daytime and nighttime hours. The significant amount of idling shown in Figure 38 between 9AM and 7PM is bolstered somewhat by the bridge crew trucks which operate almost exclusively within this timeframe.



Figure 38: 6-passenger Pickup Idling throughout the Day

The average monthly fuel consumption for the NYSDOT Region 4 of 6-passenger fleet pickups is shown in Figure 39. Usage is relatively consistent throughout the year, is however, there slightly more fuel use in December and January than the other months due to snow patrol functions.



Figure 39: 6-Passenger Average Monthly Fuel Use and MPG

### 6.2 Idle Reduction Potential

Average Monthly Fuel Use (gallons)

6-passenger pickups typically do not haul many additional accessories and their loaded weight is usually quite consistent. This is likely the reason a very close correlation was found between fuel efficiency and the percentage of total fuel that was consumed due to idling for the NYSDOT Region 4 vehicles that were monitored. This data, as shown in Figure 40, allows for a reasonable estimate of idling for all 6-passenger pickups in the entire NYSDOT Region 4 fleet using annual fuel and mileage data.

![](_page_35_Figure_0.jpeg)

Figure 40: Correlation between 6-passenger Pickup Efficiency and the Percentage of Fuel Consumption Due to Idling

Relatively high daily idle fuel consumption was found for 6-passenger pickups, which is an opportunity for idle reduction technology to provide benefits. However, high variation in usage levels and overall fuel consumption was also found throughout the fleet. Because of this, each specific application should be carefully evaluated before idle reduction technology is installed to ensure a return on investment. The key function of 6-passenger pickups as personnel transport mostly requires cab conditioning, but there may be some limited, high power electrical load requirements for the worksite at times as well. The idle reduction system with a coolant circulator to provide heat and an idle stop controller was selected to provide these amenities. With this system, some engine operation may be required for extended cab heating during the coldest weather or for cooling during extreme hot weather. However, these vehicles are equipped with gasoline engines, which tend to heat up faster than diesel engines and use less fuel during idling. Even though these vehicles are used relatively consistent throughout the summer months, idle reduction technology that incorporates engine-off air conditioning technology was not deemed viable due to its high cost. The usage and resulting idle times vary largely throughout the fleet for this type of vehicle meaning the amount of fuel savings depends heavily on the specific vehicle's duty cycle and idling level. Based on a fuel price of \$2.97 per gallon<sup>14</sup> and a system cost of \$2,525, the calculated payback period distribution is shown in Figure 41 (payback values above 20 years were just noted as "20+"). Similar payback periods were also calculated without cab heating abilities (estimated system cost of \$2,000 and idle reduction of 59.6%). The final system to be used will be determined by the specific truck and its required duties. Overall, 20% of the six passenger fleet was estimated to see an economic payback within 5 years, 53% within 10 years, and the fleet wide average payback period is 18.4 years.
										Gal	lons P	er Yec	ir 👘									
		50	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	19	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.2	18.2	17.3
	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.0	17.7	16.6	15.6	14.8	14.0	13.3
	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	18.6	17.1	15.8	14.6	13.7	12.8	12.0	11.4	10.8	10.2
_	16	20+	20+	20+	20+	20+	20+	20+	20+	19.7	17.5	15.8	14.3	13.1	12.1	11.3	10.5	9.9	9.3	8.8	8.3	7.9
_	15	20+	20+	20+	20+🗙	20+	20%	20+	17.3	15.2	13.5	12.1	11.0	10.1	9.3	8.7	8.1	7.6	7.1	6.7	6.4	6.1
_	14	20+	20+	20+	20+	20+	18.7	15.6	13.4	11.7	10.4	9.3	8.5	7.8	7.2	6.7	6.2	5.8	5.5	5.2	4.9	4.7
_	13	20+	20+	20+	20+	18.0	14.4	12.0	10.3	9.0	8.0	7.2	6.5	6.0	5.5	5.1	4.8	4.5	4.2	4.0	3.8	3.6
g	12	20+	20+	20+	18,5	13.9	11.1	× 9.2	7.9	6.9	6.2	5.5	5.0	4.6	4.3	4.0	3.7	3.5	3.3	3.1	2.9	2.8
٤.	11	20+	×20+	×20+	14.2	10.7	8.5	<b>∡</b> 1	6.1	5.3	4.7	4.3	3.9	3.6	3.3	3.0	2.8	2.7	2.5	2.4	2.2	2.1
- <u>3</u> 6	10	20+	20+	16.4	11.04	8.2	6.6	5.5	4.7	4.1	3🗶	3.3	3.0	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.7	1.6
μa _	9	20+	20+	12.7	8.4	6.3	5.1	4.2	3.6	3.2	2.8	2.5	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3
₹_	8	20+	19.5	9.7	6.5	4.9	3.9	3.2	2.8	2.4	2.2	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	1.0
_	7	20+	15.0	7.5	5.0	3.8	3.0	2.5	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.8	0.8
_	6	20+	11.6	5.8	3.9 1	2.9	2.3	1.9	1.7	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6
_	5	20+	8.9	4.4	3.0	2.2	1.8	1.5	1.3	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.4
_	4	20+	6.8	3.4	2.3	1.7	1.4	1.1	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3
_	3	20+	5.3	2.6	1.8	1.3	1.1	0.9	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
_	2	20+	4.1	2.0	1.4	1.0	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
_	1	15.6	3.1	1.6	1.0	0.8	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
_	0	12.0	2.4	1.2	0.8	0.6	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1

Figure 41: Potential Payback Distribution for 6-passenger Pickups

#### 7 Stake Rack Trucks

NYSDOT stake rack trucks are Ford F-650s, Ford F-350s, or International 4300 chassis. Truck bed accessories for these include sign truck tools and posts, herbicide units, bridge crew equipment, signs and cones for work zones, and

stripe crew paint and beads. Stake rack trucks may have extended idling periods while hauling attenuators during summer roadwork projects. These trucks can be used for snow and ice patrol if other vehicles are not available, and serve other functions during cold weather as well. As with other NYSDOT vehicles, stake rack trucks are also used for personnel moving to and from worksites. A NYSDOT stake rack truck is shown in Figure 42.



Figure 42: NYSDOT Stake Rack Truck

#### 7.1 Duty Cycle

The overall average daily data for four stake rack truck over 100 days of operation during the period of monitoring is shown in Table 13, when the vehicles were used for almost 10,000 miles.

		Daily Data									
	Mean	Maximum	Minimum	Standard Deviation	Total						
Fuel Use (gallons)	13.5	132.8	1.6	17.3	1,348						
Mileage (miles)	100.0	460.0	8.0	69.6	9,968						
Fuel Economy (mpg)	9.0	17.6	3.1	2.5	N/A						
Operating Time (hours)	4.2	22.7	0.6	3.1	422						
Idle Time (hours)*	1.1	5.3	0.1	1.1	103						
Idle Fuel Use (gallons)*	0.7	2.9	0.1	0.7	67						
Idle Fuel Rate (gallons/hour)	0.6	1.7	0.2	0.3	N/A						

Table 13: Stake Rack Truck Data

\*Includes only stationary periods that exceed 2 minutes

Operational summaries for the monitored individual stake rack trucks are included in the Appendix. Stake rack trucks are operated for a variety of purposes throughout the NYSDOT fleet and specific operational trends are not clearly defined. Truck #085397 and #115918 had idle durations over 60 minutes with several in excess of 90 minutes. The purpose of these events is not entirely clear but may be due to extended on-site operations and operator behavior at base locations.

NYSDOT stake rack trucks are used for many different functions and may idle for a variety of purposes. As shown in Figure 43, approximately the same amount of idling occurred at the worksite and the truck's base location. Relatively high traffic idling shown suggests that this vehicle type spends a considerable amount of time creeping along at low speeds (typical of highway work when towing an attenuator). The



unknown location idling is a result of GPS signal interference.

As shown in Figure 44, the operation of the NYSDOT Region 4 monitored stake rack truck showed that the highest number of idling events were less than 20 minutes in duration. However, there were many idling event durations of all different lengths which indicates the use of power equipment or driver amenities as opposed to short stops where the driver forgets to shut off the truck. The fact that longer duration idle events (>40 min) take place at the base location *more* than at the worksite shows potential for definitive improvement. It is likely caused by driver behavior and not necessary for improved performance of the crew. However, the majority of these extended idle events at the base location were experienced by a single truck (#085397 from Canandaigua) and may not be a typical occurrence.





NYSDOT Region 4 stake rack trucks typically operate between 5 AM and 6 PM. The highest levels of idling activity, as shown in Figure 45, is between 9 AM and 5 PM, which is likely after the vehicle has reached its destination and runs to provide power, heat, or other amenities. As expected from their typical job requirements, there is limited idling during the nighttime hours. There is also a notable spike in idling at 9 AM which is likely due to trucks being started for pre-warming during colder periods.



Figure 45: Stake Rack Truck Idling Throughout the Day

Stake rack trucks see consistent use throughout the year for the entire fleet. Overall average monthly fuel consumption (gallons) values for the stake rack trucks operated in NYSDOT Region 4 are shown in Figure 46. The highest monthly fuel use is in April. The lack of increased use in the winter months is due to limited use for snow patrol as compared to other vehicles. Increased use in April may be due to springtime cleanup where these trucks are used heavily for a variety of applications.



#### 7.2 Idle Reduction Potential

The stake rack truck operational data for the monitored vehicles reveals a slight trend between fuel economy and the percentage of fuel consumed through idling, as shown in Figure 47. Events for individual vehicles tend to be grouped within different fuel economy ranges and differ from one another. This is partially due to a mix of vehicles used, ranging from light duty pickups (Ford F-350) to medium duty chassis (Ford F-650 and International 4300). This range in vehicle and engine size can have an impact on overall fuel consumption and the idle fuel rate.



Figure 47: Correlation between Stake Rack Truck Efficiency and the Percentage of Fuel Consumption Due to Idling

Stake rack trucks had some longer duration idle events, but many were less than 30 minutes during which time the cab would remain comfortable in most conditions. Idling at the base is likely not required and may be significantly reduced through more driver training. The idle reduction system recommended for stake rack trucks would be to add a controller to manage vehicle run time. While this system couldn't provide cab heat (which should not be as great of a requirement since they are not more heavily used in the winter) or cooling without the engine on, it could optimize the engine run time to provide the needed amenities without using unnecessary fuel. Due to the relatively high fuel consumption rates of stake rack trucks, there are a number of trucks in the fleet that would see a quick return on investment for such an idle reduction system (see Figure 48). This data assumes a fuel cost of \$2.97 per gallon<sup>14</sup> and a total idle fuel offset of 60% due to the idle reduction technology. Approximately 29% of the stake rake truck fleet is estimated to see a payback within 5 years and 52% within 10 years.

											Gallo	ns Per	Year									
		0	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
_	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
_	19	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
_	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
_	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
_	16	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
_	15	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.8	18.8
_	14	20+	20+	20+	20+	20+	20+	20+	20+	×20+	20+	20+	20+	20+	20+	20+	19.5	18.3	17.2	16.3	15.4	14.6
	13	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.0	17.6	16.3	15.2	14.3	13.4	12.7	12.0	11.4
ဗ ျ	12	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.8	17.8	16.2	14.9	13.7	12.7	11.9	11.1	10.5	9.9	9.4	8.9
Š.	11	20+	20+	20+	20+	20+	20+	20+	19.9	17.4	15.4	13.9	12.6	11.6	10.7	9.9	9.3	8.7	8.2	7.7	7.3	7.0
ge	10	20+	20+	20+	20+	20+	20+	18.1	15.5	13.6	12.0	10.8	9.9	9.0	8.3	7.7	7.2	6.8	6.4	6.0	5.7	5.4
ero	9	20+	20+	20+	20+	20+	16.9	14.1 <mark>x</mark>	12.1	10.6	9.4	8.5	7.7	7.0	6.5	6.0	5.6	5.3	5.0	4.7	4.5	4.2
¥.	8	20+	20+	20+	20+	16.5	13.2	11.0	9.4	8.2	7,3	6.6	6.0	5.5	5.1	47	4.4	4.1	3.9	3.7	3.5	3.3
	7	20+	20+	20+	17.2	12.9	10.3	8.6	7.4	6.4	57	<b>×</b> 5.1	4.7	4.3	4.8	3.7	3.4	3.2	3.0	2.9	2.7	2.6
	6	20+	20+	20+	13.4	10.0	8.0	6.7 <mark>×</mark>	5.7	× 5.0 ×	4.5	4.0	3.6	<b>8</b> 3	3.1	2.9	2.7	2.5	2.4	2.2	2.1	2.0
_	5	20+	20+	15.7	10.4	7.8	6.3	5.2	4.5	×3.9×	3.5	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.6	1.6
_	4	20+	20+	12.2	8.1	6.1	4.9	4.1	3,5	3.1	2.7	2.4	2.2	2.0	1.9	1.7	1.6	1.5	1.4	1.4	1.3	1.2
	3	20+	19.0	9.5	6.3	4.8	3.8	3.2	2.7	2.4×	34	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.0	1.0
_	2	20+	14.9	7.4	5.0	3.7	3.0	2.5	2.1	<b>1</b> .9	1.7	1.5	1.4	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8	0.7
	1	20+	11.6	5.8	3.9	2.9	2.3	1.9	1.7	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6
	0	20+	9.0	4.5	3.0	2.3	1.8	1.5	1.3	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5

Figure 48: Potential Payback Distribution for Stake Rack Trucks

## 8 Small Dump Trucks

NYSDOT small dump trucks are Ford F-650s or International 4300 chassis (shown in Figure 49) and have a variety

of uses depending on seasonal requirements. During cold weather periods, the trucks are used for snow and ice patrol and may be outfitted with small salt spreaders and reversible plows. Warm weather activities include set up for work zones, hauling, patching, and pulling light equipment trailers. These trucks are often used for pulling attenuators as well, which can result in extended idling while road maintenance occurs. Small dump trucks are also widely used throughout the year for personnel movement between work locations.



Figure 49: NYSDOT Small Dump Truck

#### 8.1 Duty Cycle

Table 14 shows the average daily data for small dump trucks; data from nine trucks was collected for over 11,500 miles of monitoring during 128 days.

		Daily Data									
	Mean	Maximum	Minimum	Standard Deviation	Total						
Fuel Use (gallons)	12.0	132.8	0.6	16.4	1,532						
Mileage (miles)	91.0	460.0	5.5	73.8	11,627						
Fuel Economy (mpg)	9.4	16.1	2.8	3.5	N/A						
Operating Time (hours)	4.7	22.7	0.3	3.2	606						
Idle Time (hours)*	1.2	5.6	0.1	0.9	149						
Idle Fuel Use (gallons)*	0.8	3.3	0.03	0.7	102						
Idle Fuel Rate (gallons/hour)	0.9	7.4	0.2	0.9	N/A						

Table 14: Small Dump Truck Data

\*Includes only stationary periods that exceed 2 minutes

Operational summaries for the monitored individual small dump trucks are included in the Appendix. Operational duty cycles vary significantly from vehicle to vehicle and even day to day for each vehicle within this category. Highway department vehicles see varied use at all hours during winter months due to snow patrol, light snow plowing, and other road maintenance duties. Vehicles operated by bridge crews see more consistent duty cycles as their daily duties are more predictable and uniform.

As shown in Figure 50, the majority of idling takes place away from its base and a significant portion occurs while sitting in traffic or during other stopand-go operations. Overall GPS coverage was very good for small dump trucks during the data logging periods and only 5% of the idling data recorded did not have accurate location data. Relatively low base station idling indicates that most operators were mindful of vehicle idle times, even during the cold periods throughout the data logging period.





Small dump truck operators stated that no significant electrical power is required during winter months, so heating for passenger comfort is believed to be the primary reason for idling. Summertime operations include powering other electrical and lighting accessories that may require the engine to run while the vehicle is stationary. As shown in Figure 51, most idling events are shorter than 20 minutes, with almost half less than 10 minutes. With short idling times, applicable idle reduction technologies would not require extensive heating or energy storage capabilities.



Figure 51: Small Dump Truck Idle Durations (minutes)

Because small dump trucks are not typically used for emergency snow removal, nighttime operation is quite limited. Idling throughout the day is not concentrated at one particular time, as shown in Figure 52. A spike appears near 8 and 9 AM, which is likely due to warm-up in the morning, but truck idling was found to be fairly consistent through 8 PM. However, the most idling occurs between 1 and 3 PM, presumably due to crews taking lunch breaks and staying in the trucks to remain comfortable.



Figure 52: Small Dump Truck Idling Throughout the Day

The overall average monthly fuel consumption for NYSDOT Region 4 small dump trucks is shown in Figure 53. Overall, the average monthly fuel consumption is quite consistent throughout the year, but there is significant variation from truck to truck. However, a defined spike is visible in December due to snow patrol and winter road maintenance duties. This vehicle group is one of the highest fuel consumers throughout the fleet with an average fuel consumption of over 100 gallons every month of the year. Fuel consumption by the small dump trucks is similar to the average values reported for 6-passenger trucks.



Figure 53: Small Dump Average Monthly Fuel Use and MPG

#### 8.2 Idle Reduction Potential

Small dump truck operations show a general, but not strong, correlation between fuel economy and the percentage of total fuel consumed due to idling, as shown in Figure 54 for the monitored vehicles. Small dump trucks are often carrying varying loads which likely has a greater impact on fuel economy than idling, This correlation was used to estimate the amount of idling for all small dump trucks in the NYSDOT Region 4 fleet based on annual fuel and mileage data. Because of the wide variation in vehicle efficiency it is strongly suggested that each application be individually evaluated before outfitted with idle reduction technology.



Figure 54: Correlation between Small Dump Truck Efficiency and Percentage of Fuel Consumption Due to Idling

High fuel consumption rates and short idling events provide an opportunity for a simple idle reduction system to make a large impact since most vehicle auxiliary systems can continue to operate for a limited time without the need for extensive energy storage or heating/cooling technologies. The recommendation for this application would be a vehicle controller to manage vehicle shut-down and start-up and optimize run time based on set interior temperature and battery voltage. Because of the extremely varied duty cycle seen by these vehicles and the various daily duties that may be required, the potential fuel savings will vary widely depending on vehicle use. Assuming a system cost of \$2,000 and a fuel price of \$2.97 a gallon<sup>14</sup>, 16% of small dump trucks provide a payback period on the installation of idle reduction technology within 5 years and 37% within 10 years. The overall payback period for specific fuel consumption and MPG for NYSDOT Region 4 small dump trucks is shown in Figure 55.

											Galloi	ns Per	Year									
		50	250	500	750	1,000	1,250	1,500	1,750	2,000	2,250	2,500	2,750	3,000	3,250	3,500	3,750	4,000	4,250	4,500	4,750	5,000
	20	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	19	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+
	18	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.1	18.1
_	17	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.3	18.1	17.1	16.1	15.3	14.5
_	16	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	19.3	17.8	16.6	15.5	14.5	13.6	12.9	12.2	11.6
_	15	20+	20+	20+	20+	20+	20+	20+	20+	20+	20+	18.6	16.9	15.5	14.3	13.3	12.4	11.6	10.9	10.3	9.8	9.3
_	14	20+	20+	20+	20+	20+	20+	20+	20+	18.6	16.5	14.8	13.5	12.4	11.4	10.6	9.9	9.3	8.7	8.2	7.8	7.4
	13	20+	20+	20+	20+	20+	20+	19.8	17.0	14.8	13.2	11.9	10.8	9.9	9.1	8.5	7.9	7.4	7.0	6.6	6.3	5.9
8.	12	20+	20+	20+	20+	20+	19.0	15.8	13.6	11.9	10.6	9.5	8.6	7.9	7.3	6.8	6.3	5.9	5.6	5.3	5.0	4.8
Ξ.	11	20+	20+	20+	20+	19.0	15.2	12.7	10.9	9.5	8.4	7.6	6.9	6.3	5.8	5.4	5.1	4.8	4.5	4.2	4.0	3.8
- 3g	10	20+	20+	20+	20 tx	15.2	12.2	10.1	₹ 8.7	7.6	6.8	6.1	5.5	5.1	4.7	4.3	4.1	3.8	3.6	3.4	3.2	3.0
ā.	9	20	×20+	20+	16.2	12.2	9.7	8.1	6.9	6.1	5.4	4.9	4.4	4.11	3.7	3.5	3.2	3.0	2.9	2.7	2.6	2.4
₹.	8	20+	20+×	19.5	13.0	9.7	×7.8	6.5	5.6	<b>4</b> 9	4.3	3.9	3.5	3.2	3.0	2.8	2.6	2.4	2.3	2.2	2.0	1.9
_	7	20+	207	15.6	10.4	7.8	62	5.2	4.4	3.9	3.5	3.1	2.8	2.6	2.4	2.2	2.1	1.9	1.8	1.7	1.6	1.6
_	6	20+	20+	12.5	8.3	6.2X	5.0	<b>(</b> 4.2	3.6	3.1	2.8	2.5	2.3	2.1	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2
_	5	20+	19.9	10.0	6.6	5.0	4.0	3.3	2.8	2.5	2.2	2.0	1.8	1.7	1.5	1.4	×1.3	1.2	1.2	1.1	1.0	1.0
_	4	20+	15.9	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6	1.4	1.3	1.2	1.1	1.1	1.0	0.9	0.9	0.8	0.8
_	3	20+	12.8	6.4	4.3	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9	0.8	0.8	0.7	0.7	0.6
_	2	20+	10.2	5.1	3.4	2.6	2.0	1.7	1.5	1.3	1.1	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5
_	1	20+	8.2	4.1	2.7	2.0	1.6	1.4	1.2	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4
	0	20+	6.5	3.3	2.2	1.6	1.3	1.1	0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3

Figure 55: Potential Payback Distribution for Small Dump Trucks

#### 9 Conclusions

Through this study, Energetics determined that there are opportunities for NYSDOT Region 4 to reduce fuel use. Some vehicles appear to show a quick return on investment from installing idle reduction technology. However, the overall fuel consumption due to idling is not extensive enough to justify the cost of an extensive idle reduction solution that includes fuel fire heating or cooling capabilities. An idle-stop system would be effective at reducing idling caused by the operator forgetting to shut down the vehicle when stationary. The presence of a controller actively monitoring the battery voltage should alleviate operator concerns about draining the battery such that the vehicle would not restart. The controller selected for this application should have the capability to fully manage the vehicle's run time depending on interior temperature, battery voltage, and be user configurable. The merit of including a simple coolant circulating heating system was also evaluated for each vehicle type as this option is relatively inexpensive (~\$500).

The results showed significant variations in how individual NYSDOT Region 4 vehicles are used and the amount of idle time experienced. For the vehicle types evaluated in this study, the average payback for all trucks is not favorable enough to install idle reduction systems on every vehicle, but there are individual vehicles in those groups that would have very beneficial returns on investment by using such technology. This indicates that it may be possible for these vehicles to reduce their idling without compromising job functions since other trucks are successfully accomplishing that. Ongoing real-time monitoring and analysis of vehicle performance is necessary to help either enforce the idle reduction policy or incentivize drivers to be more fuel efficient through bonuses for achieving higher miles per gallon of fuel used. Long-term monitoring may also provide a clearer picture of which vehicles need certain auxiliary vehicle functions that requires engines running to perform their job. These vehicles would then be identified as prime candidates for idle reduction technology that can provide that amenity without idling the engine.

Because of the variability in each of the vehicle types, it is difficult to select one vehicle type as the ideal candidate for idle reduction technology. The decision to install this technology must be made on a per vehicle basis and cannot be a blanket strategy for the fleet as a whole. The annual average savings for individual vehicles outfitted with the idle reduction technologies described above is shown in Table 15.

	Percent of Vehicle Class Resulting in a 10 Year or less Payback	Total Annual Fuel Savings (gallons)	Total Annual Cost Savings	Total Annual CO <sub>2</sub> Emission Reduction (pounds)*
¾-ton Pickup	32%	213	\$631	4,166
6-Passenger	53%	434	\$1,289	8,504
Stake Rack	42%	271	\$806	5,484
Small Dump	33%	484	\$1,437	9,772

Table 15: Estimated Benefits on Vehicles Experiencing a Payback within 10 years

\*Assumes 19.6 and 20.2 pounds of CO<sub>2</sub> emissions per gallon gasoline and diesel respectively

A major concern with a fleet wide deployment of idle reduction equipment is that many vehicles sit unused for large portions of the year or are only used for a very limited purpose. These vehicles just simply do not use enough fuel to offset the cost of this equipment, regardless of the overall idle percent fuel consumption. Other vehicles are currently being operated quite efficiently without the use of idle reduction technology, due to driver behavior or required duties, and the addition of onboard technology would have little to no impact on the limited idle periods. While this does not create potential savings, it does prove that other vehicles that are currently less efficient, have the potential to improve significantly while still fulfilling the requirements of the vehicle class. An overall histogram showing the payback periods throughout the fleet for the various vehicle types are shown in Figure 56.



Figure 56: Fleetwide Payback Period Distribution

Actively monitoring all NYSDOT vehicles with telematics would provide a much clearer picture on what vehicles are not following the idle reduction policies. Driver incentives to reduce idling could also be implemented and likely result in significant savings without installing idle reduction systems. This strategy has been used by many private fleets, and municipalities are starting to install telematics on their vehicles to more closely track usage. Vehicle tracking and monitoring will cause complaints from drivers (especially those that know they are not operating the vehicles as they should), so such a strategy would need strong support from upper management and be implemented in a way that highlights its benefits for the drivers.

It is recommended that NYSDOT test idle reduction systems on select vehicles that see very high use and are currently experiencing low fuel economy results based on fueling records for the past few years. Many idle reduction system manufacturers included in this study were willing to provide a system or two for free or at a steep discount for NYSDOT to trial. Longer-term monitoring of the same type of vehicles in the same functions during a side-by-side trial of various idle reduction technologies (and some vehicles with none at all), would provide some real-world results on how well the systems function for NYSDOT personnel and how effective they are at reducing idling.

#### 10 References Cited

- Gaines, L. 2012. "Idling Reduction for Medium-Duty Fleets." Argonne National Laboratory, presented at Green Fleets Conference, Schaumberg, IL, USA, October 2-3, <u>www.transportation.anl.gov/pdfs/EE/894.PDF</u>.
- Gaines, L. 2014. "Idling Reduction Savings Calculator." Argonne National Laboratory, www.transportation.anl.gov/pdfs/idling\_worksheet.pdf.
- Gaines, L. and Levinson, T. 2011. "Idling; Cruising the Fuel Inefficiency Expressway." Argonne National Laboratory, <u>www.transportation.anl.gov/pdfs/EE/700.PDF</u>.
- Gaines, L., Rask, E., and Keller, G. 2013. "Which is Greener Idle, or Stop and Restart? Comparing Fuel Use and Emissions for Short Passenger--Car Stops." Transportation Research Board Annual Meeting Paper #13-4606, <u>http://docs.trb.org/prp/13-4606.pdf</u>.
- Rondini, D., Schaller, D., and Swim, R. 2014. "Confidence Report on Idle-Reduction Solutions." North American Council for Freight Efficiency, <u>www.carbonwarroom.com/sites/default/files/reports/Idle-</u> <u>Reduction\_Confidence\_Report.pdf</u>.
- New York State. 2014. "Department of Transportation." Accessed April 7. https://www.dot.ny.gov/regional-offices.
- SAE International Standard. 2006. "Class B Data Communications Network Interface." SAE Standard J1850.
- SAE International Standard. 2012. "Diagnostic Connector Equivalent to ISO/DIS 15031-3:December 14, 2001." SAE Standard J1962.
- SAE International Standard. 2013. "Serial Control and Communications Heavy Duty Vehicle Network." SAE Standard J1939.
- Oak Ridge National Laboratory. 2013. "ORNL Operations Best Practice Guide: Idle Reduction" Accessed December 16, 2014 from <u>http://www.bnl.gov/earthday/docs/ORNL-Idle-Reduction-Guide.pdf</u>

# Appendix: NYSDOT Region 4 Vehicle Operational Summaries

#### Pickup Truck - Ford F-250 #115299 (Monroe East)



# Pickup Truck - Ford F-250 #115299 (Monroe East)



12/2/2013 to 2/20/2014



Throttle Position

#### Pickup Truck - Ford F-250 #085068 (Canandaigua)



20

10

0 0.0 0 С

2.0

Idle Time per Day (hrs)

3.0

4.0

С

1.0

Vehicle Idling Locations (color represents idle fuel consumption)

## Pickup Truck - Ford F-250 #085068 (Canandaigua)





#### Pickup Truck - Ford F-250 #135338 (Pittsford Bridge Crew)



# Pickup Truck - Ford F-250 #135338 (Pittsford Bridge Crew)





## Pickup Truck - Ford F-250 #115394 (Monroe East)



Idle Time per Day (hrs)

# Pickup Truck - Ford F-250 #115394 (Monroe East)





## Pickup Truck - Ford F-250 #115303 (Canandaigua)



## Pickup Truck - Ford F-250 #115303 (Canandaigua)





#### Pickup Truck - Ford F-250 #115300 (Monroe East)



**Vehicle Idling Locations** 

Idle Time per Day (hrs)

1.5

# Pickup Truck - Ford F-250 #115300 (Monroe East)



12/2/2013 to 2/20/2014





#### Six Passenger - Chevrolet 3500 #105102 (Pittsford Bridge Crew)



# Six Passenger - Chevrolet 3500 #105102 (Pittsford Bridge Crew)





#### Six Passenger - Ford F-350 #085110 (Monroe East)



# Six Passenger - Ford F-350 #085110 (Monroe East)





#### Six Passenger - Ford F-350 #085109 (Monroe West)



# Six Passenger - Ford F-350 #085109 (Monroe West)



6/4/2014 to 7/3/2014





#### Six Passenger - Chevrolet 2500 #115615 (Canandaigua)



# Six Passenger - Chevrolet 2500 #115615 (Canandaigua)





#### Six Passenger - Chevrolet 3500 #115612 (Pittsford Bridge Crew)



# Six Passenger - Chevrolet 3500 #115612 (Pittsford Bridge Crew)





# Stake Rack - Ford F-650 # 085397 (Canandaigua)


### Stake Rack - Ford F-650 # 085397 (Canandaigua)

Datalogging Period -





#### Stake Rack - Ford F-350 #115918 (Monroe West)



Vehicle Idling Locations

2.0 3.0 Idle Time per Day (hrs)

0.0

1.0

4.0

### Stake Rack - Ford F-350 #115918 (Monroe West)





### Stake Rack - Ford F-350 #115916 (Canandaigua)



### Stake Rack - Ford F-350 #115916 (Canandaigua)





#### Small Dump - Ford F-650 #095157 (Monroe West)



### Small Dump - Ford F-650 #095157 (Monroe West)

**Datalogging Period -**





#### **Small Dump -** Ford F-650 # 095129 (Canandaigua)



### Small Dump - Ford F-650 # 095129 (Canandaigua)

**Datalogging Period -**





### Small Dump - Ford F-650 #085356 (Monroe West)



# Small Dump - Ford F-650 #085356 (Monroe West)

**Datalogging Period -**





### Small Dump - Ford F-650 # 085355 (Canandaigua)



## Small Dump - Ford F-650 # 085355 (Canandaigua)

Datalogging Period -





#### Small Dump - Ford F-650 #125225 (Pittsford Bridge Crew)





**Datalogging Period -**





### Small Dump - International 4300 #125222 (Monroe East)



### Small Dump - International 4300 #125222 (Monroe East)

Datalogging Period -





### Small Dump - International 4300 #125218 (Monroe East)





Datalogging Period -





### Small Dump - International 4300 #125217 (Monroe West)



### Small Dump - International 4300 #125217 (Monroe West)

Datalogging Period -





#### Small Dump - Ford F-350 #115915 (Pittsford Bridge Crew)



### Small Dump - Ford F-350 #115915 (Pittsford Bridge Crew)





#### Large Dump - Mack Plow Truck #135060 (Monroe East)









### Plow Truck - Mack Truck # 135054 (Canandaigua)



#### **Plow Truck -**

#### **Datalogging Period -**



