# Progress Energy Bucket Truck Monitoring


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## BACKGROUND

Plug-in hybrid bucket trucks have seen increased interest in recent times due to the recent spike in fuel prices and increasing environmental concerns. Bucket trucks are a natural fit for hybrid technology as they tend to idle for hours at a time after driving short distances. Advantages of these systems include potential fuel savings and reductions in emissions, noise, engine wear and maintenance. Disadvantages that must be overcome include battery capacity, added vehicle weight and cost.

Progress Energy Carolinas was awarded a Clean Fuels Alternative Technology (CFAT) grant in 2008 which assisted with the purchase of a plug-in hybrid bucket truck manufactured by Dueco, Inc. As part of the grant requirements, Progress Energy requested that Advanced Energy establish a test plan and monitor and report fuel economy findings as well other benefits for this vehicle. This project consists of two parts. The first part, presented in this report, compares the fuel usage between the plug-in hybrid bucket truck and a conventional diesel bucket truck as measured during controlled tests and a short in-use monitoring period. The second part of the project consists of long-term monitoring of both the plug-in and a conventional bucket truck to compare fuel economy on real road conditions. The long-term monitoring data will be collected at 6-month intervals and will continue for a total of three years.

## INTRODUCTION

A pre-production Dueco plug-in hybrid bucket truck was delivered to Progress Energy in December 2008. Due to a series of technical issues with the hybrid truck, Advanced Energy was not able to gain access to the truck for testing and monitoring until May 2009. Advanced Energy compared two 55-foot material handler bucket trucks for the purpose of this test – the Dueco hybrid and a standard diesel truck. Both trucks are based upon an International 4000 series chassis with a DT466 engine and Allison transmission. Figure 1 shows the trucks used in testing.

**Figure 1. Dueco Plug-in Hybrid (left) and Standard Diesel (right) Bucket Trucks**

The findings from the controlled and in-use field testing show that the hybrid truck can save approximately $20,000 in a 10 year time frame with today's conservative fuel prices. Due to the $50,000 - $80,000 price premium over conventional diesel bucket trucks, the Dueco hybrid is not financially viable based upon fuel savings alone without grant assistance. However, there are other benefits to owning a hybrid bucket truck that should be considered, and fuel prices are likely to go up while purchase prices are likely to decrease with greater production.

## CONTROLLED TESTING

To allow for an accurate comparison between the Dueco hybrid truck and a comparable standard truck, Advanced Energy created a test plan for controlled testing (shown in Appendix A). The test plan established a typical bucket truck duty cycle based on data previously collected from a conventional truck. The duty cycle included runnning the trucks through a series of operational parameters, including a drive cycle, boom movement and idling in power take-off (PTO) mode. Each duty cycle took approximately one hour to complete, with three cycles performed concurrently for each truck. At the start and end of the testing, each truck was filled with diesel fuel. The change in fuel was measured after completion of all test cycles.

A Kvaser Memorator data logger was installed on each truck to collect vehicle speed, fuel burn rate and engine revolutions per minute (RPM). From this data, Advanced Energy could determine when the truck was in electric power take off (e-PTO) mode powering the hydraulic systems and could also calculate fuel consumed when the engine was running. Due to technical issues with the standard truck's on-board diagnostic system, Memorator data was not able to be collected for the standard truck. Instead, Advanced Energy used data collected from records of each fuel station stop to keep a log of miles travelled and fuel used for the standard truck.

Results from the controlled tests are shown in the table below.

**Table 1. Controlled Test Results**

| | Standard International Truck | Dueco Plug-in Hybrid Truck |
|---|---|---|
| Test Time | 3 hours 31 minutes | 3 hours 31 minutes |
| Miles Driven | 32 miles | 32 miles |
| Fuel Consumption | 6.0 gallons | 4.8 gallons |
| Fuel Economy | 5.3 mpg | 6.7 mpg |
| Initial Battery State of Charge | n/a | 95% |
| Final Battery State of Charge | n/a | 70% |
| Estimated kWh Usage | n/a | 10.9 kWh |

As shown in Table 1, the hybrid truck saved 1.2 gallons of fuel over all controlled tests when compared to the standard truck. This correlates to an approximate 27% increase in fuel economy over the standard truck. To account for the electrical energy used by the hybrid truck during testing, Table 1 also shows the hybrid battery state of charge (SOC) at the beginning and ending of the tests. This number comes directly from the display readout on the Dueco hybrid truck. The kilowatt-hour (kWh) usage is the estimated amount of electricity required from the electric grid to charge the truck based upon the state of charge and a typical 80% charging efficiency.

## IN-USE FIELD MONITORING

In addition to the controlled testing, Advanced Energy also collected data over a short in-use monitoring period when the truck was in the field under normal operations. As with the controlled tests, a Kvaser Memorator data logger was installed on the hybrid truck to collect vehicle speed, fuel burn rate and RPM. Advanced Energy also collected records of each fuel station stop to keep a log of miles travelled and fuel used. In-use monitoring took place for 18 consecutive days. During this time, the hybrid truck was in use for only eight days. For the purpose of this report, the eight days that the truck was in service in the field will represent average truck usage.

To determine yearly fuel and cost savings associated with diesel engine idling that a hybrid truck offsets, Advanced Energy data analysts first extracted portions of the data collected when the truck was idling (for instance, at stop lights) to determine idle fuel consumption. Fuel consumption of between 0.65 and 1.7 gallons per hour were

observed at idle, depending on the operation of the truck. For this report, Advanced Energy chose to use the average of these values (1.2 gallons per hour) to represent diesel fuel consumption while idling. During the eight day in-use period, the hybrid truck was observed to be in e-PTO mode for 21.4 hours. This offsets 21.4 hours that the truck would normally have been idling, resulting in savings of approximately 25.7 gallons of diesel fuel over eight days, or 3.2 gallons per day. Assuming the hybrid truck operates 250 days per year and a diesel fuel price of $2.50 per gallon, this results in an approximate fuel savings of 800 gallons per year at a value of $2000 saved per year. Multiplying this over an assumed 10-year life cycle of the hybrid truck yields a life savings of approximately $20,000.

The truck must be plugged in when not in use, generally at night, to recharge. Based upon the data gathered from the in-use monitoring, it is estimated that 117 kWh of energy from the electric grid were required to recharge the truck over the eight day period. This equates to approximately 15 kWh required per day to charge the hybrid truck.

**Emissions Benefit**

Potential emission reductions are a key advantage to the use of hybrid electric bucket trucks. The hybrid truck allows for turning off the diesel engine while the boom and bucket are in use, thus eliminating those associated emissions. Advanced Energy analysts estimated potential emission reductions associated with the use of a hybrid truck based on data collected during the long-term monitoring of the Progress Energy truck. The long-term monitoring data showed that the trucks idle for approximately three hours per day. Assuming that the trucks operate 250 days per year, this results in approximately 750 hours of idle time per year. Table 2 lists the emission factors for idling diesel trucks that were used for calculating emission reductions, as well as the estimated emission reductions associated with the use of a hybrid truck.

**Table 2. Idling Emission Rates for Heavy-Duty Diesel Trucks**

| Name | Emission rate (grams/hr)* | Estimated Emission Reductions | |
|---|---|---|---|
| | | grams/yr | metric tons/yr |
| Nitrogen Oxides (NOx) | 135 | 101,250 | 0.101 |
| Particulate Matter (PM) | 3.68 | 2,760 | 0.003 |
| Volatile Organic Compounds (VOCs) | 6.9 | 5,175 | 0.005 |
| Carbon Monoxide (CO) | 56.7 | 42,525 | 0.043 |
| Carbon Dioxide (CO2) | 6000 | 4,500,000 | 4.500 |

* Source: Jones, Stephen. "Evaluating Truck Idle Reduction Technology for Rest Areas in North Carolina." North Carolina State University, 2007.

As shown in Table 2, there are air quality benefits associated with operating hybrid bucket trucks over regular bucket trucks. Though the truck has to plug in to recharge, this typically occurs overnight when the power is considered off-peak and generated from baseload power plants, which are generally the most efficient.

**Other Benefits**

The hybrid truck has several other benefits in addition to fuel savings. Perhaps one of the biggest benefits is noise reduction. A standard truck continuously produces at least 75 dB of noise 10 feet away from the truck. The hybrid truck was observed to emit 73 dB when the electric pump is running, though this pump only runs for a minute or two at a time. The rest of time that the hybrid system is in use, it is nearly silent except for the electrical hum of some of the electronics. As a normal conversation is only 60dB, standard trucks make communicating nearby difficult. This is also especially valuable in neighborhoods where work may have to take place early in the morning or late at night.

Another benefit is the potential for reduced maintenance. As the hybrid system has regenerative braking, it helps to slow the truck when coming to a stop, reducing wear on the brakes. In addition, the reduced idle time with a hybrid

truck may increase intervals for maintenance like oil changes and air filter replacements. However, while regular maintenance for the hybrid system is minimal, there is still a potential for unexpected maintenance problems to occur.

## OPERATOR SURVEY

Advanced Energy conducted an interview with David Blair and Adam Elliott, service line technicians of Progress Energy's West Raleigh Garage, to obtain information on the operators' perspective of the hybrid truck. The operators, first and foremost, need an operating truck. They were pleased that, should everything fail on the hybrid system, the truck can still function as a standard truck until it can be serviced. Overall, the operators said they were happy with how well the truck drove and with the launch assist and regenerative braking features. They also noted the benefit of bucket to ground communications that are improved with the engine off in e-PTO mode. This was the main benefit of the hybrid truck, in their opinion.

However, both operators expressed a fear of damaging one of the most expensive bucket trucks in the fleet, due to its greater weight and low mounted battery packs. The reduced ground clearance causes them some concern in off-road conditions, so they are required to avoid using the hybrid truck in jobs where terrain could be a problem.

## CONCLUSION

The hybrid truck was shown to save diesel fuel, reduce noise and reduce emissions. However, due to the cost premium for the hybrid truck, it does not yet appear to be financially viable based on fuel savings and today's diesel fuel prices. Yet, when considering the need for reduced maintenance, reduced emissions output, reduced noise, and greater operator comfort, hybrid trucks still have a high value. As fuel prices rise and the cost of these trucks decreases, they will become more economically viable.

## Appendix A

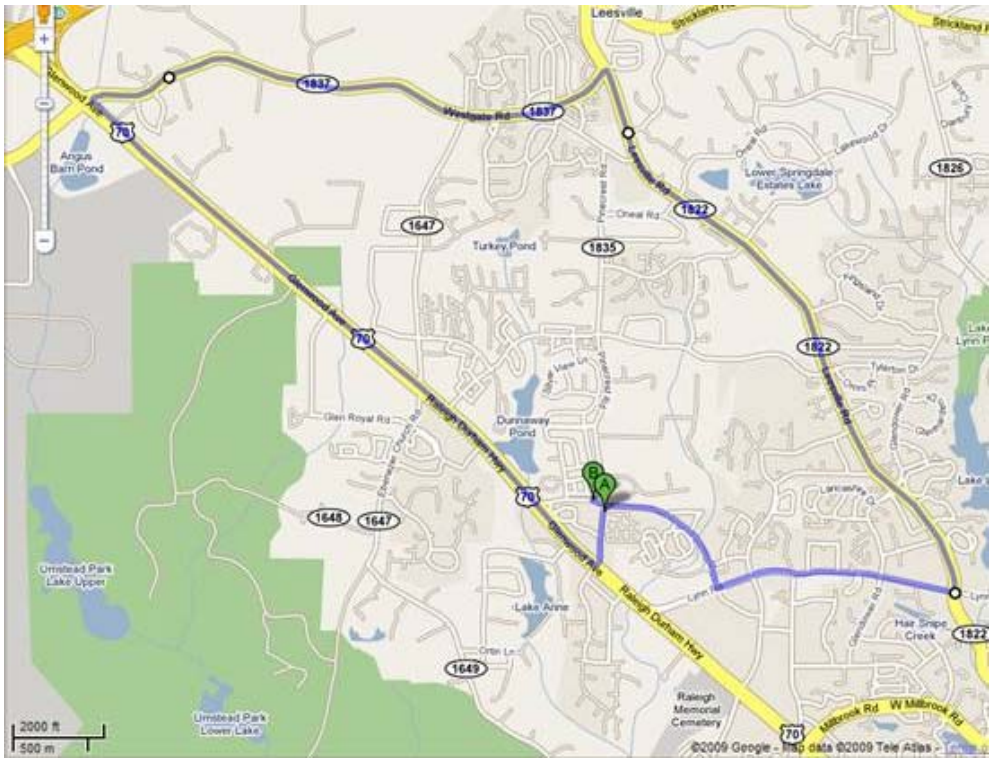
### TEST CYCLE

### Drive (Approximately 20 minutes)

The Drive cycle shown below is to represent an average drive to a location using 45 and 55 mph roads and highways.

### Test route 1 (9.8 miles):

- Turn right out of Progress Energy West Raleigh Garage onto Pinecrest Rd. (45 mph)
- Turn right onto Glenwood Ave/US 70 W (55 mph)
- Exit Glenwood Ave at Aviation Pkwy/Westgate Rd exit
- Turn right onto Westgate Rd (45 mph)
- Turn right at Leesville Rd. Continue to follow Leesville Rd. (45 mph)
- Turn right at Lynn Rd. (45 mph)
- Turn right at Grove Barton Rd. (35 mph)
- Take 2nd exit of traffic circle to stay on Grove Barton Rd.
- Go through stop sign at Pinecrest Rd. onto Toscana Dr. (35 mph)
- Return to Progress Energy parking lot pole location for boom usage portion of the test



**Boom Usage (Approximately 10 minutes)**

- Engage PTO. (For hybrid truck engage e-PTO)
- Set feet.
- Raise bucket 25-35ft up to the top of a stationary object such as a telephone/power pole that can act as a reference point. Maneuver within arms reach of this point. Sit for one minute. Lower bucket. Repeat this procedure (raise bucket, maneuver, sit for one minute, lower) two more times for a total of three repetitions.
- Lower bucket, raise feet, disengage PTO.

**Idle (Approximately 30 minutes)**

- Idle for 30 minutes with PTO disengaged.

This cycle is to be run three times for a total approximate run time of three hours in order to get an average daily duty cycle.