



Project Summary & Results

January 31, 2014



HYBRID HORSEPOWER FOR KENTUCKY SCHOOLS

Overview

156 aging diesel school buses across Kentucky were replaced with new hybrid-electric school buses with an average of 35% greater fuel efficiency. Federal and state funding of approximately \$28 million provided the incremental cost of the hybrid system to Kentucky school districts ordering new buses through the Hybrid Horsepower for Kentucky Schools project.



The purpose of the four year project was to provide real world performance data and engage and educate diverse stakeholders from industry, school systems, and the community. Bus procurement ran from 2009-2011, mileage and fuel data were tracked from 2010-2013, and education and engagement was ongoing from project implementation in mid-2009 to project completion in December 2013.

The project resulted in a large publicly available dataset tracking the monthly mileage and fuel used by each hybrid bus across a variety of topographies and urban and rural routes; multi-disciplinary hybrid-electric school bus elementary and secondary education curricula; training programs for first responders, drivers, and technicians; and real life bus and hybrid system performance experience that can be leveraged by manufacturers to improve future performance.

The Hybrid Horsepower for Kentucky Schools project was funded by the U.S. Department of Energy and the Kentucky Department of Education. It was executed in partnership with the Kentucky Clean Fuels Coalition, Eaton, ThomasBuilt Bus, International Bus, and the National Energy Education Development (NEED) project.







 <p>Grant application and project coordination</p>	 <p>Hybrid system manufacturer and technician training</p>	 <p>Bus manufacturer and technician training</p>
 <p>Bus manufacturer and technician training</p>	 <p>Classroom education</p>	 <p>Kentucky Department of Education - Fiscal agent</p>

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Background

About the Project

In 2009 the Kentucky Clean Fuels Coalition, a 501(c)3 nonprofit and U.S. Department of Energy Clean Cities partner, collaborated with the Kentucky Department of Education to apply for a \$12.98 million U.S. Department of Energy grant. The federal funding was matched with \$15.34 million in funding from the Kentucky Department of Education, for a total of approximately \$28 million over four years. The federal funding paid the incremental cost of the

hybrid system while the state funded the base cost of the buses as well as insurance and maintenance. The new hybrid-electric school buses were placed in counties across the Commonwealth participating in the Hybrid Horsepower for Kentucky Schools project.



Goals

Data Collection

A primary goal of this hybrid-electric school bus project was to provide real world data for a transportation sector that has seen little improvement in engine efficiency since the adoption of the diesel engine in the late 1970s. The hybrid-electric school buses use the Eaton hybrid system, and were expected to achieve 30-40% greater fuel efficiency. Kentucky was selected as an ideal location for large scale deployment of hybrid-electric school buses because of the wide variation in terrain, including hilly, flat, urban, and rural bus routes. The Kentucky Clean Fuels Coalition (KCFC) and the Kentucky Department of Education tracked monthly mileage and fuel data from 2011-2013, and made the data publicly available on KCFC's website.

Engagement, Education, and Training

A second key goal of the Hybrid Horsepower for Kentucky Schools project was engagement of industry, student, educator, and other community stakeholders in exposure to the hybrid-electric technology. Bus and hybrid system manufacturers and the Kentucky Department of Education partnered to provide hands-on training to school district superintendents, transportation directors, mechanics, school bus drivers, students, and teachers about the hybrid school bus technology.

Hybrid School Bus Performance Results

The program successfully placed 156 hybrid-electric school buses in thirty five districts across the Commonwealth of Kentucky, achieving an average 8.5 mpg and 35% greater fuel efficiency than the standard diesel school bus. The highest cumulative miles per gallon achieved over the length of the project was 11.7 mpg. The lowest cumulative miles per gallon was 6.8.

8.5 mpg
35% more efficient

The program has saved almost 200,000 gallons of fuel and saved school districts over \$700,000. These fuel savings are expected to continue over the fourteen year life span of the vehicles. The Hybrid Horsepower for Kentucky Schools project has logged over 4 million hybrid miles and provides a wealth of information for future hybrid-school bus deployment efforts across the nation.

Program Details

Methodology

Full bus performance data can be accessed on the Kentucky Clean Fuels Coalition's [website](#). The data were output directly from electronic control modules and submitted electronically by school districts on a monthly basis. Data was then manually keyed for entry into a master spreadsheet. Data were accepted as submitted by the school districts, but were cleaned for outliers to identify manual entry errors. Numerous manual resets of some electronic control modules resulted in inconsistent reported cumulative figures, so cumulative figures were calculated using sums of monthly reported data. Annual and project end average hybrid miles per gallon were calculated using reported miles and gallons, and not an average of all monthly reported miles per gallon.

Bus Procurement

Kentucky's unique and highly efficient master agreement procurement process enabled the hybrid-electric system to be included in procurement orders from bus manufacturers.

To announce the funding opportunity a Request for Assistance (RFA) was posted on the Kentucky Department of Education's website for each of the four procurement cycles for school districts to apply for funding. The Kentucky Commissioner of Education also included the RFAs in the e-newsletter sent to superintendents across the state. In addition, KCFC promoted the RFAs in its e-newsletter, on its website, and at conferences and workshops across the state.

School districts completed applications that were then reviewed by a Department of Education committee. Once schools were notified that funding was approved they selected ThomasBuilt or International buses, signed purchase contracts with manufacturers, and ordered the buses.

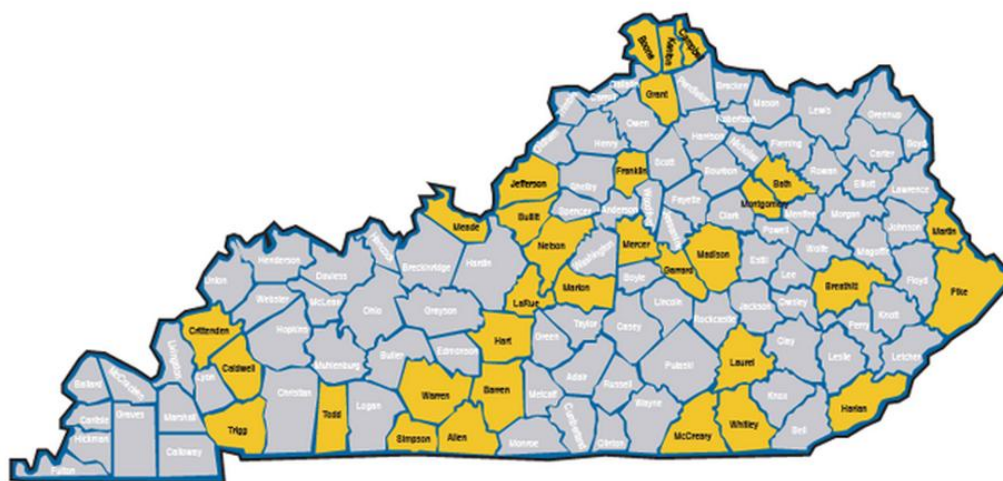
While battery replacement was not included in the funding, a five year warranty on the hybrid system was provided by Eaton.

Bus Placement

156 hybrid-electric buses were placed in 35 districts throughout Kentucky, representing various urban and rural routes and hilly and flat terrains. The map and table below detail how many hybrid-electric buses of each type, ThomasBuilt (TB) or International (IC) were placed in each participating district.

35 districts and number of hybrid buses:

<p>Allen County (1 TB) Bardstown Independent (1 IC) Barren County (2 IC) Bath County (3 IC) Boone County (2 TB) Breathitt County (12 TB) Bullitt County (5 IC) Burgin Independent (1 IC) Caldwell County (1 IC) Campbell County (1 IC) Corbin Independent (1 IC) Covington Independent (1 TB) Crittenden County (1 IC) Frankfort Independent (1 TB) Franklin County (1 TB) Garrard County (1 TB) Harlan Independent (1 IC) Hart County (1 IC)</p>	<p>Jefferson County (34 TB, 16 IC) Kenton County (5 TB) LaRue County (4 TB) Madison County (6 TB) Marion County (1 TB) Martin County (1 TB) McCreary County (1 IC) Meade County (1 TB) Mercer County (2 IC) Montgomery County (1 IC) Pike County (37 TB) Simpson County (1 TB) Todd County (1 TB) Trigg County (1 TB) Warren County (4 TB) Whitley County (1 TB) Williamstown Independent (2 TB)</p>
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Training, Education, and Engagement

Over the length of the project over forty hands-on in person training sessions were provided to hundreds of people across the state. Each of the thirty five districts receiving buses underwent training sessions provided by Eaton, the hybrid-system manufacturer. School district superintendents and transportation directors, technicians and first responders all received Eaton training. In addition, Eaton provided three additional training sessions to certify school district technicians to work on the hybrid-electric system.

The National Energy Education Development (NEED) project provided three cross-disciplinary curriculum trainings for primary and secondary school teachers.

Approximately 70 teachers across 40 districts received cross-disciplinary K-12 hybrid system curriculum training in 2012-2013, including Science, Math, English, and Social Studies.

The ongoing data collection process required continuous engagement between the Kentucky Clean Fuels Coalition, the Kentucky Department of Education, the Kentucky Department of Transportation, and school district



Training



- ❖ Provided as part of contract between manufacturers and State of Kentucky
- ❖ Technicians, drivers, first responders all trained together on site






When I heard I would be getting one of the new hybrid buses, needless to say I was a bit skeptic. Upon receiving the hybrid bus, I along with several others was in-serviced on the bus. We had a classroom session and actual driving session. At that time, that was when I decided I wanted to have the best MPG in Pike County. One of our Driver Trainers drove a hybrid for a month on a regular run to see what he could get mileage wise. The techs retrieved the information from his bus. He was at 12.5 MPG. That WAS the best up to that time. Then they read my bus information. Better than 13MPG. This bus is quiet to drive. My bus was in for service and I drove another bus. I could not wait to get my hybrid back."

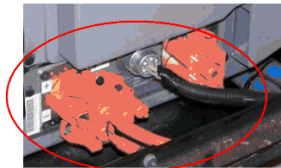
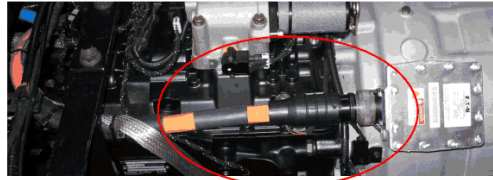
*-- Joan Hampton, 2012 Driver of the Year,
Pike County, KY.*

Transportation Directors.

Technician Training

- All 35 districts receiving hybrid buses underwent technician training by Eaton.
- 10 districts opted for extended training to certify their own technicians to service the Eaton system.

Identifying Hybrid Vehicles – High Voltage Cables



Roadranger  EATON

Transportation Training

- All superintendents from the 35 districts receiving hybrid buses were present during day of delivery trainings.

Teacher Training

- Approximately 70 teachers across 40 districts received cross-disciplinary K-12 hybrid system curriculum training in 2012-2013, including Science, Math, English, and Social Studies.
- The National Energy Education Development (NEED) project provided cross-disciplinary curriculum training for primary and secondary school teachers



I used several of the [hybrid-electric school bus] lessons, and they fit perfectly with the science standards last year. I loved and used many of the activities shared. I plan on using the hybrid data more this year.

– A 6th grade teacher in Boone County, KY

NEED Curriculum Examples



Section 2

COMPARING CONVENTIONAL AND HYBRID ELECTRIC SCHOOL BUSES

Activity 3: School Bus Comparison

★ Objective

- To compare traditional and hybrid electric school buses.

🕒 Time

- 30-45 Minutes

📋 Materials

- Student backgrounder
- Copies of the student worksheets
- Large construction paper
- Art supplies
- Glue

📅 Preparation

- Prepare one copy of the *School Bus Comparison Icons* (page 20) and one copy of the *School Bus Comparison Facts* (page 21) for each student.

☑ Procedure

1. Students can work in groups.
2. Ask students to cut out the traditional.
3. Have students cut out the hybrid.
4. Direct students to create a comparison chart.
5. Depending on the level of the students, you can direct them to use the facts, or you can direct them to use the icons.

📋 Extension

1. Have students add their own facts.
2. Have students color code the facts.

Activity 4: School Bus Routes

★ Objective

- To economically compare traditional and hybrid electric school buses.

🕒 Time

- 15 minutes

📋 Materials

- Copies of the student worksheets



School Bus Routes

❓ Question

- What is the most effective use of a hybrid electric school bus?
- Your school district has purchased a new hybrid electric school bus. Now a plan must be put in place to best utilize the bus and its fuel-saving features. As a group, determine the best bus route for the hybrid bus. Prepare three reasons to justify your plan.

📋 Materials

- Map
- School bus routes

☑ Procedure

1. Brainstorm factors that influence the fuel economy of a hybrid electric school bus. Decide which factors you believe are most critical.
2. Review the current bus routes using the schedules and a map.
3. Using your critical factors, compare bus routes and determine which is the best choice to use the hybrid electric bus.
4. Prepare a three to five-minute presentation about your plan. Include visual aides and three reasons to support your plan.

Critical Factors

Reasons for Plan

** Conclusions

1. Which factors influenced your choice of a bus route?
2. Did all groups choose the same route? If not, which factors influenced the decisions of the groups?
3. How might hidden factors like topography and individual driver behaviors impact route decisions and cost effectiveness?

First Responder Training

- Over 70 fire, police, and ambulance first responders were trained on the hybrid technology across 35 districts.



Emergency Procedure – Do's and Don'ts




- Do's
 - Always assume the vehicle is "live" when you approach a Hybrid
 - Always perform one of the three "Emergency Shutdown Procedures" and allow the vehicle to set for 5 minutes prior to working on a Hybrid
- Don'ts
 - Never work on the vehicle if you haven't performed one of the three "Emergency Shutdown Procedures" and allowed the vehicle to set for 5 minutes
 - If at all possible, never cut the orange high-voltage cables
 - If at all possible never cut into or open the Inverter, PEC, or DC/DC Converter

Roadranger  F.T.M.

Conclusion

The Hybrid Horsepower in Kentucky hybrid school bus project successfully educated key stakeholders on hybrid electric bus technology, saved school districts fuel and money, and provided real life driving data. Kentucky is now a national leader in the application of hybrid electric bus technology across school districts statewide.

Resources

 <p>KENTUCKY CLEAN FUELS COALITION</p>	<p>www.kentuckycleanfuels.org</p>
 <p>HYBRID HORSEPOWER FOR KENTUCKY SCHOOLS</p>	<p>Hybrid Horsepower for Kentucky Schools</p>
 <p>National Energy Education Development Project (NEED)</p>	<p>Primary</p> <ul style="list-style-type: none"> • Hybrid Buses <p>Elementary</p> <ul style="list-style-type: none"> • Hybrid Buses <p>Intermediate</p> <ul style="list-style-type: none"> • Exploring Hybrid Buses <p>Secondary</p> <ul style="list-style-type: none"> • Exploring Hybrid Buses