Hybrid 101

An Introduction to the Hybrid School Bus

Keith Kladder – Marketing Manager

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Hybrid Buses

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Why are we discussing HEV?

- Consumers and companies have become more sensitive to economic and environmental issues. This is now being recognized throughout the world.

- Hybrid propulsion is making an impression in the automotive market and the transit bus industry. It has the potential to do the same for school bus operators.

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Why school buses?

- There are about 400,000 school buses in operation in America today
- On average, each vehicle in this huge fleet covers about 12,500 miles per year and burns about 1,925 gallons of fuel at 6.5 miles per gallon
- That adds up to over 1 billion gallons per year
- If the fuel economy could be improved by 20% to 70%, the savings in terms of fuel cost and reduced emissions would be significant
- As we will discuss, the duty cycle is near-optimum for a hybrid

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Hybrid School Bus Project – Advanced Energy

Advanced Energy is non-profit whose mission is to create economic and environmental benefit through innovatiove and market based approaches to energy issues.

- During 2003 – 2006, developed customer consortia that would develop a specification and work to obtain funding for purchase.
- The consortia, led by AE, brought in school bus mfrers for technical feasibility and consulting
- Found agencies to provide supplemental funding for the consortia
- Developed a national specification, later modified for indiividual state specification.
- Issued and awarded an RFP to manufacture buses
- Developed a low-cost national monitoring and evaluation program
- Developing more detailed monitoring with universities and labs

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DELIVERED

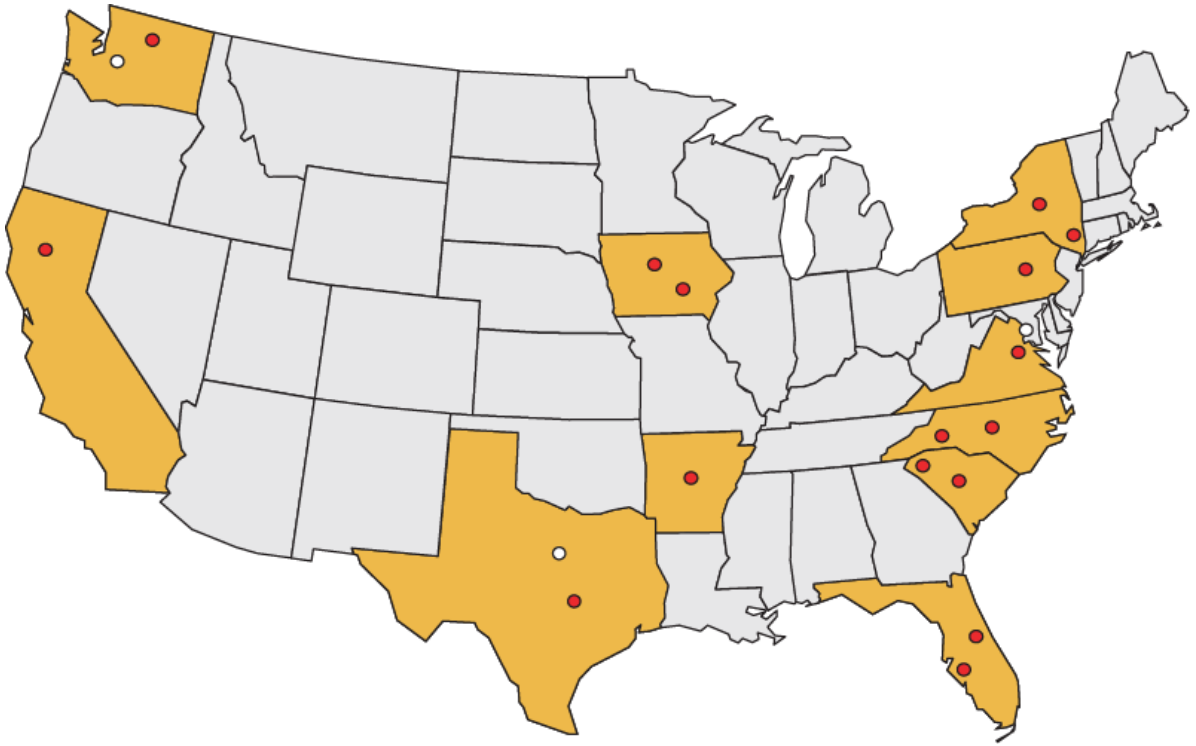
- Florida (2)
- Pennsylvania (1)
- No. Carolina (2)
- Arkansas (1)
- Washington (1)
- California (1)
- So. Carolina (2)
- Texas (1)
- Iowa (2)
- NY (1)
- Canada (1)

PENDING

- New York (2)

Dealer Orders

- MWT (1)
- McCandless (1)
- Wolfington (1)



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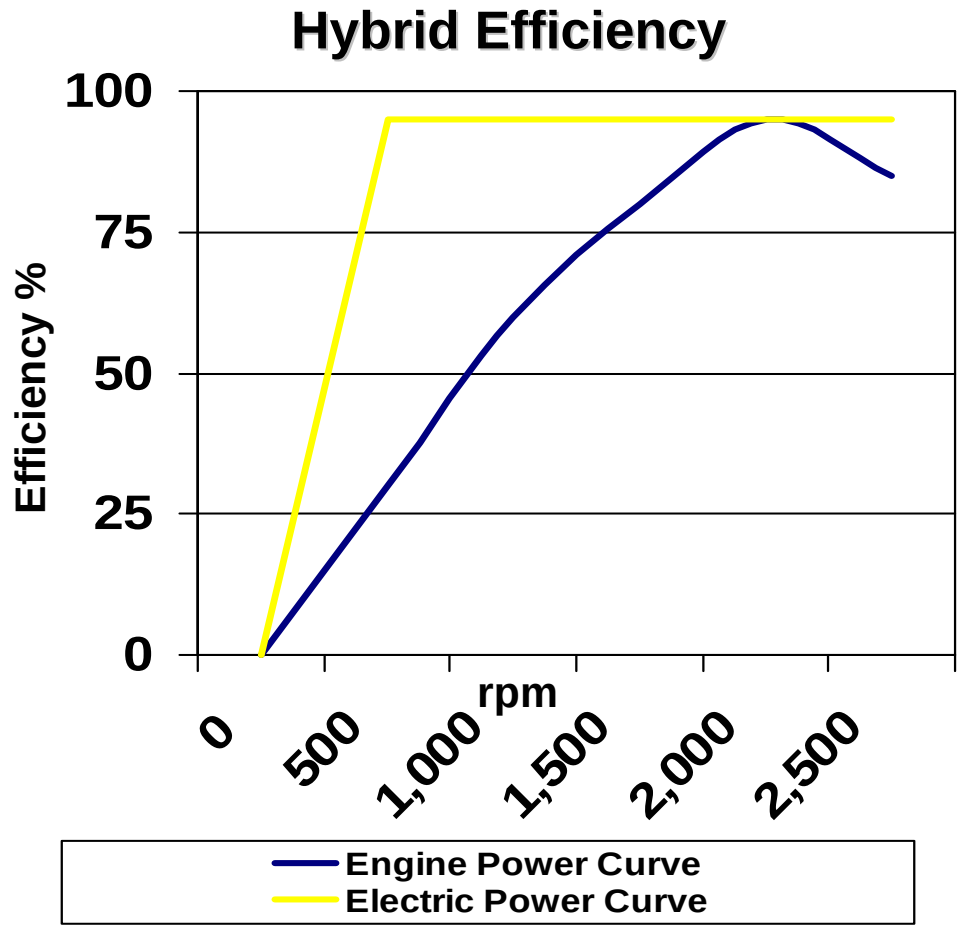
How Hybrids Work:

- Hybrids improve fuel economy and reduce emissions by using batteries and electric motors to augment the vehicle's internal combustion engine to improve efficiency.
- Batteries can be charged using the vehicle's engine, from the power grid, or a combination of the two.
- Hybridization offers 4 areas of opportunity for improvement:
  - Energy is recovered during deceleration (regeneration)
  - Intelligently blending the power output from the electric motor and IC engine can maximize the efficiency of the engine
  - Energy stored overnight from the grid can be depleted through the day, reducing the contribution of the IC engine
  - Comparable performance can be achieved with a smaller engine
- All of these can contribute to improved fuel economy and reduced emissions

Hybrid Buses



Efficiency gain is area between the lines

Duty cycle of bus is primarily in low-efficiency area of internal combustion engine

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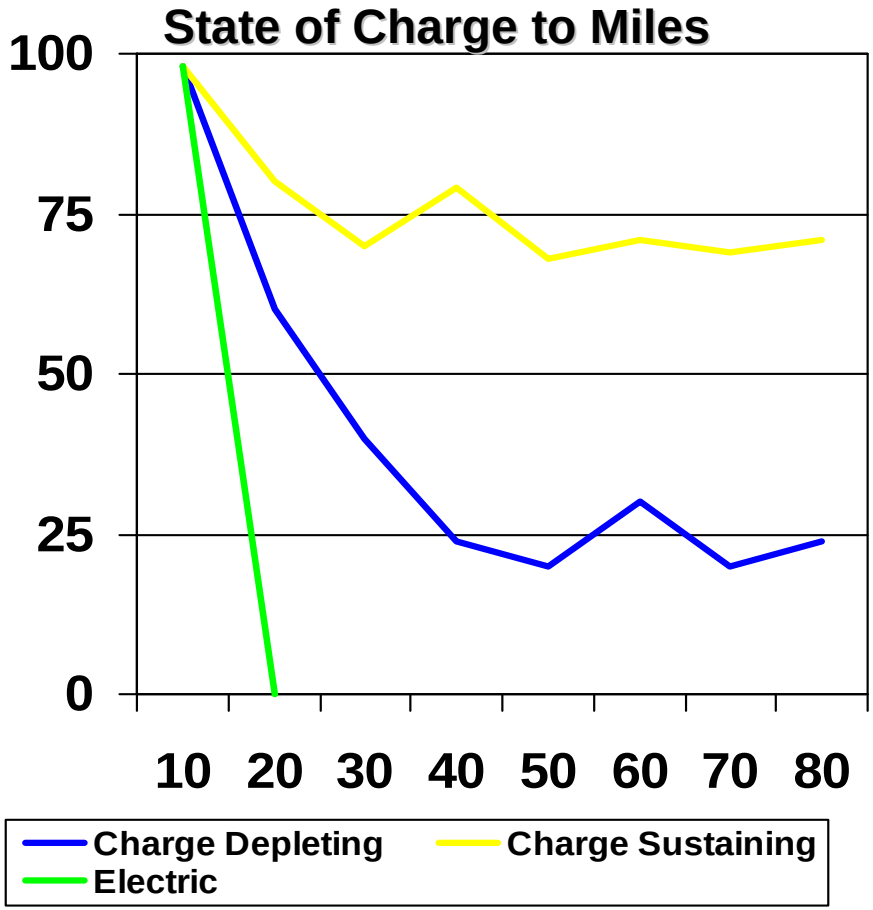
- **Charge-sustaining hybrids maintain the state of charge of the batteries in a narrow range throughout the operating period.**
  - Nickel metal hydride (NiMh) batteries
  - The fuel economy improvement is in the range of 20% to 50%, depending on drive cycle

- **Charge-depleting (plug-in) hybrids aggressively draw down energy stored in the battery over the first 44 miles of route, and must be recharged overnight**.
  - Lithium-ion (Li-Ion) batteries
  - Fuel economy improvement up to 70%

Hybrid Buses



Modes of Operation

- Charge Depleting (plug-in)
- Charge Sustaining
- Pure electric

Difference between the lines generates the savings from system to system.

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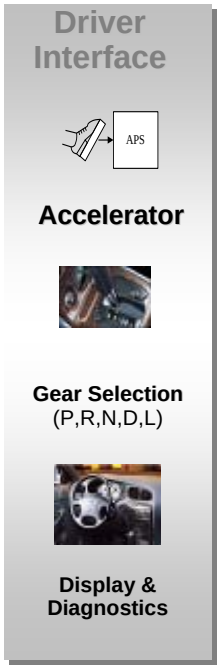
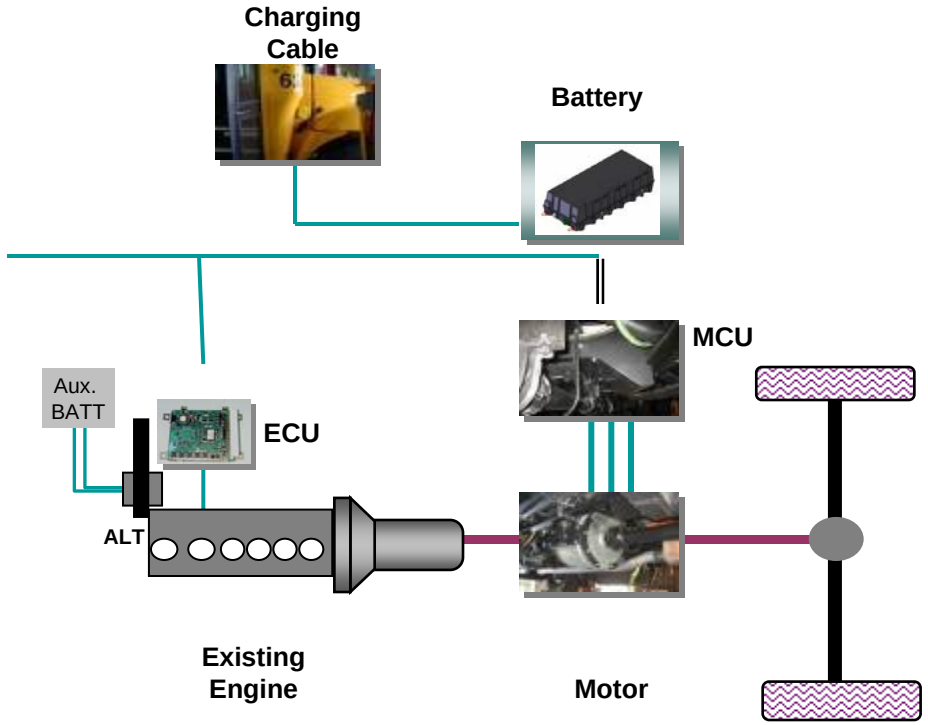
Anticipated Benefits

- Plugging in is optional (2 types of systems)
- 50% to 70% increase in fuel economy for the first 44 miles
- 20% to 40% increase for remainder
- 90% reduction in particulate matter
- 60% reduction in NOx
- Increased engine, transmission and brake life
- Diesel cost: ~ $3/gallon
- Electricity cost: ~ 60¢/gallon equivalent

Hybrid Buses

The post-transmission parallel hybrid is ideal for vehicles that make frequent stops, such as buses. The Enova hybrid system is non-invasive and does not require additional certifications to the existing engine.





Supplier – Enova Systems

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Hybrid Buses

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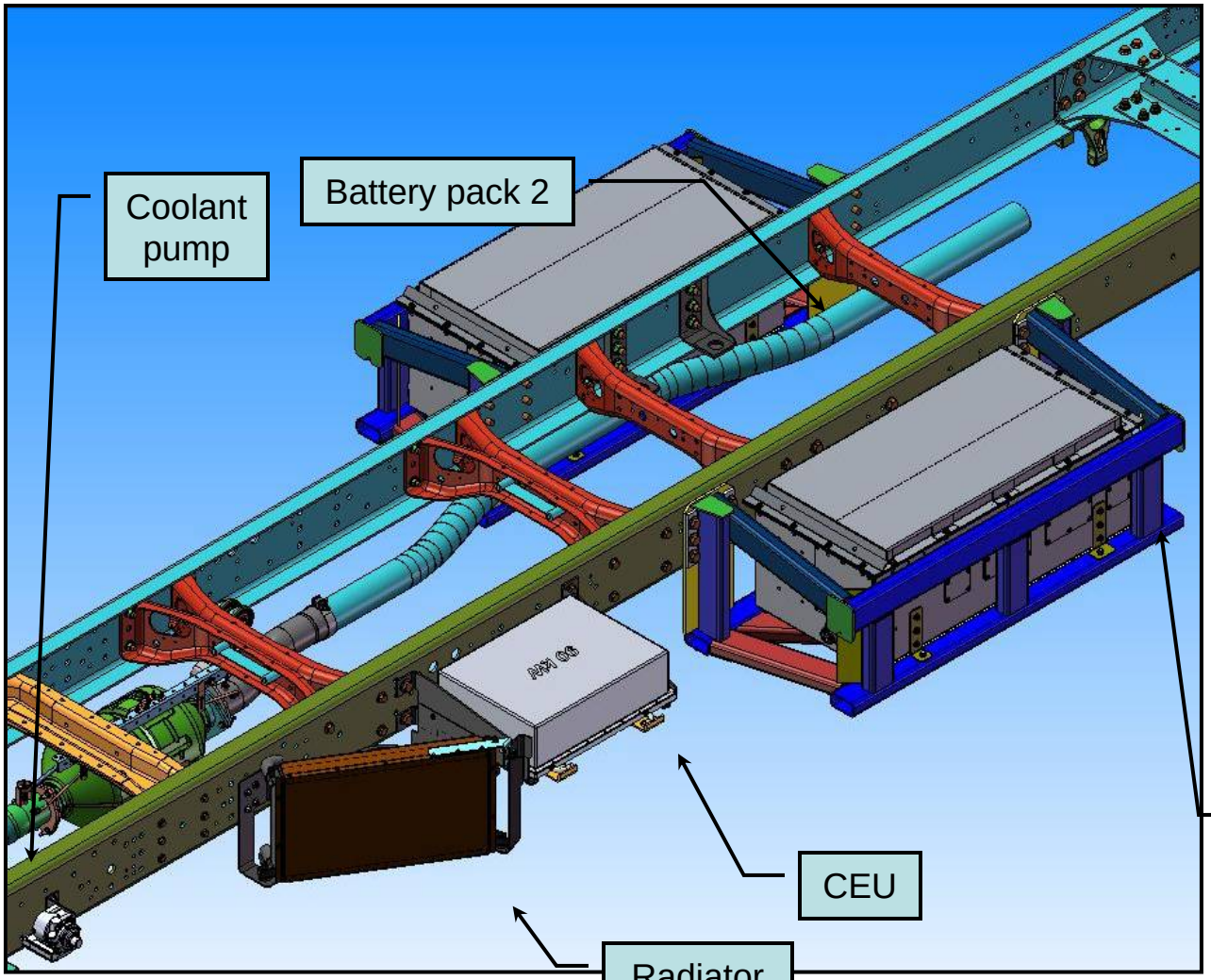
IC/Enova System(s):

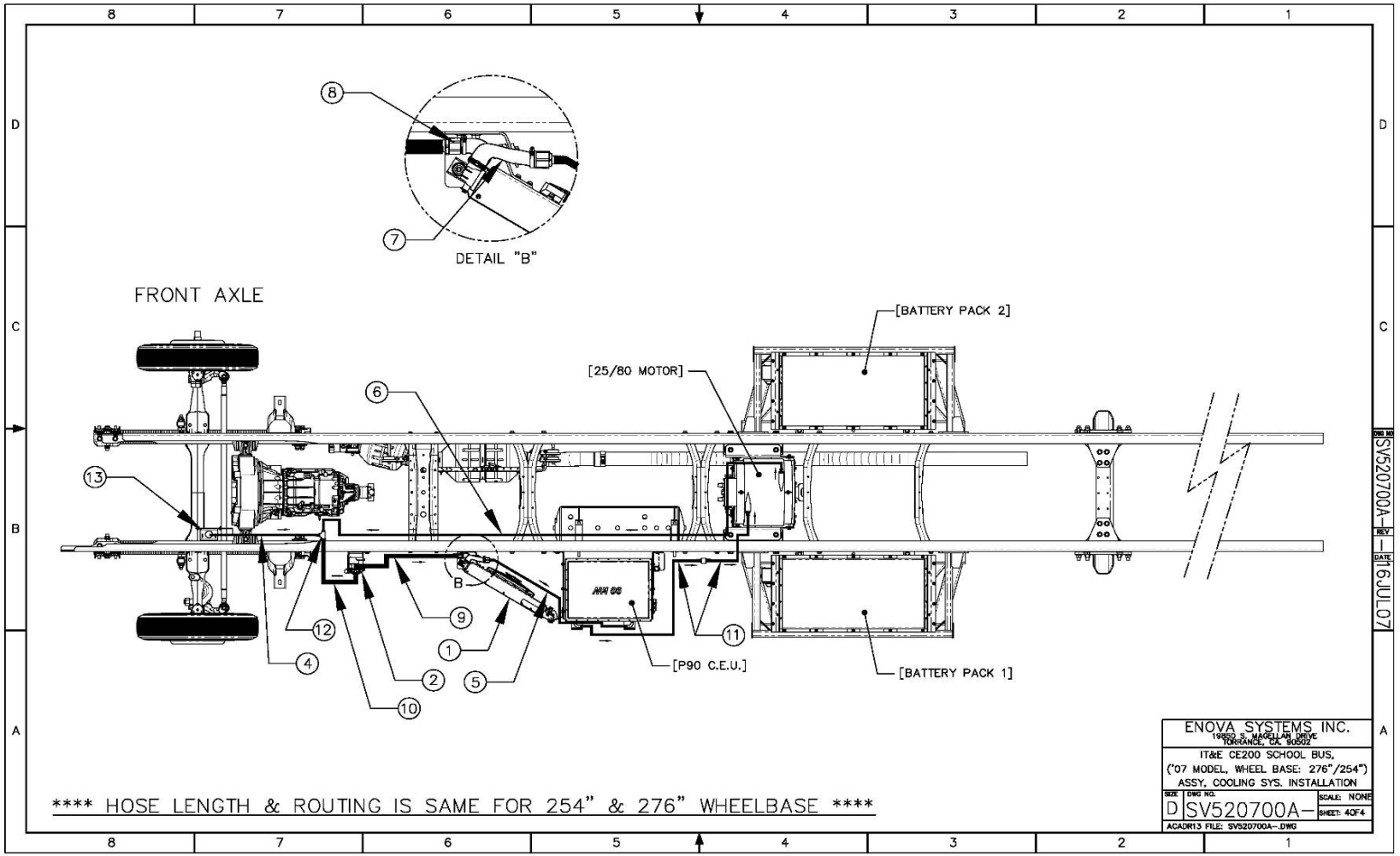
- Parallel hybrid system with isolated cooling module
  - Charge depleting (Plug-in) with lithium-ion batteries
    - 10AHJ
  - Charge sustaining with nickel metal hydride batteries
    - 10AHH

Charge Depleting Layout

10AHJ



Charge Depleting Schematic



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Enova System

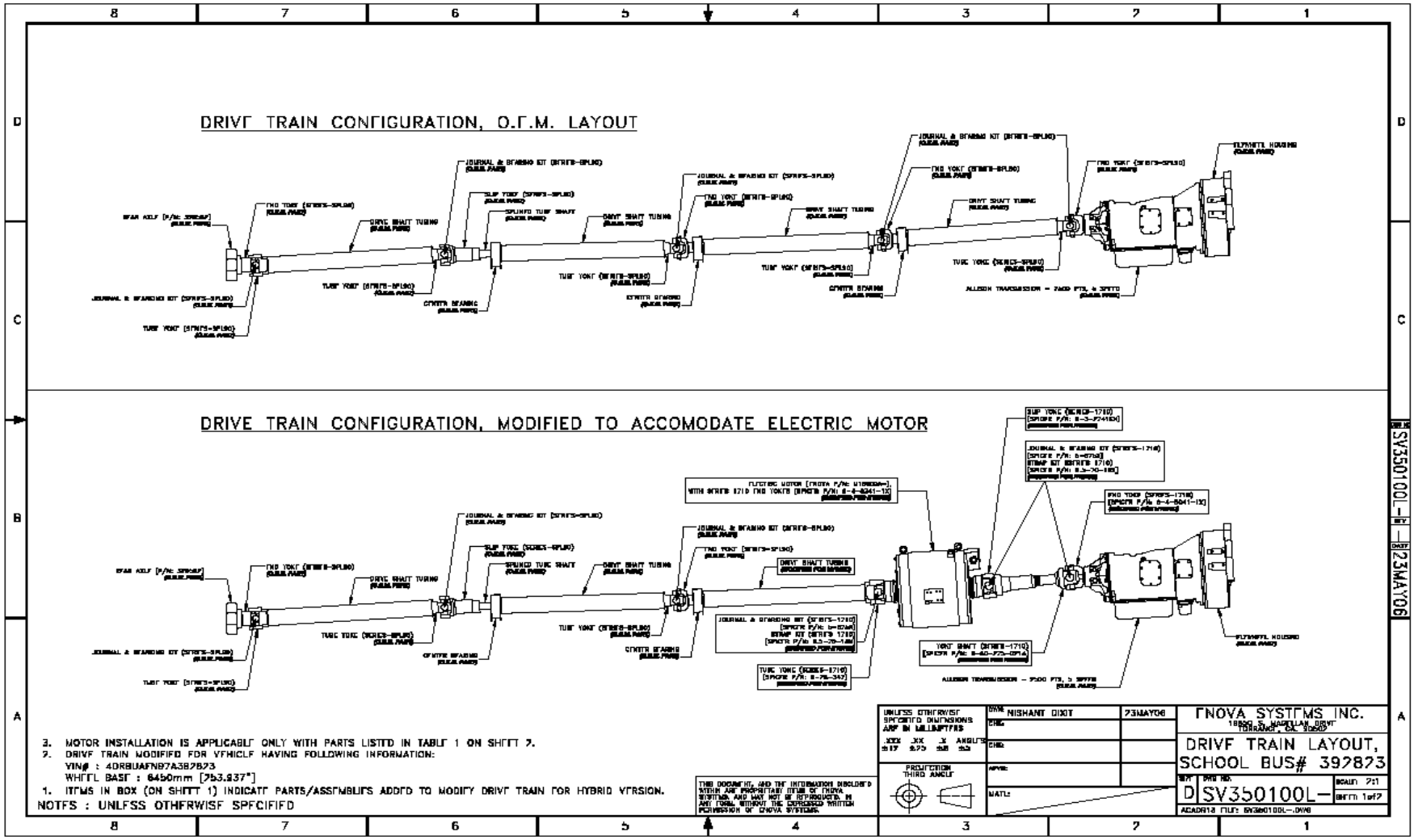
- 3 phase 25/80 kW induction motor – 68,000 gvw capable
- Electronic Control Unit – converts HV DC to AC
  - Battery technology tolerant (Battery Control Unit)
  - Engine tolerant
    - MaxxForce 7
- Lithium-ion battery pack of 28 12v batteries for 336v total
- Isolated HEV cooling system uses 2 pumps and Extended Life Coolant – same as the engine

Hybrid System

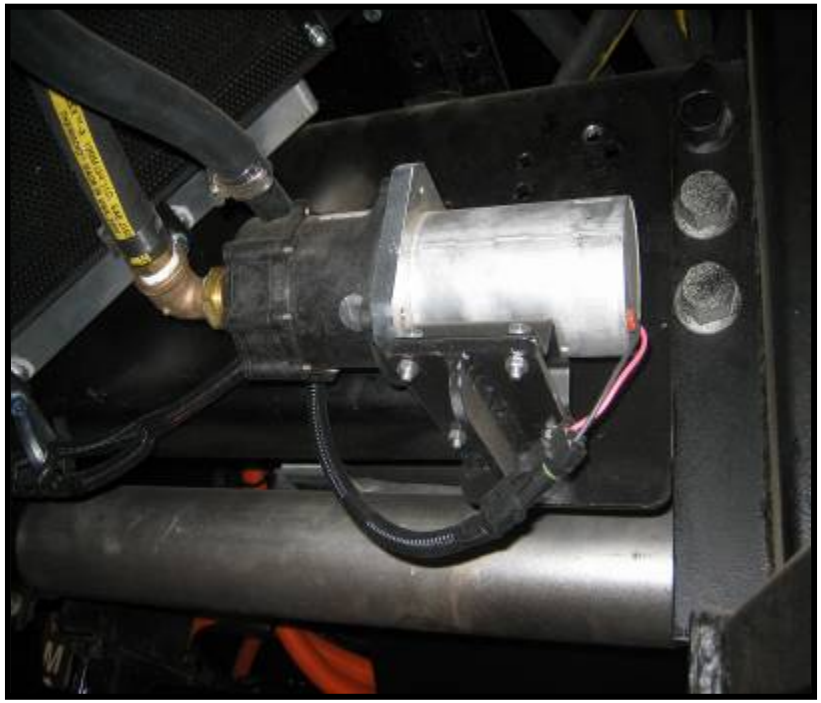
25/80 kW Motor Installation

Hybrid Driveline

(Same for both systems)



Hybrid System

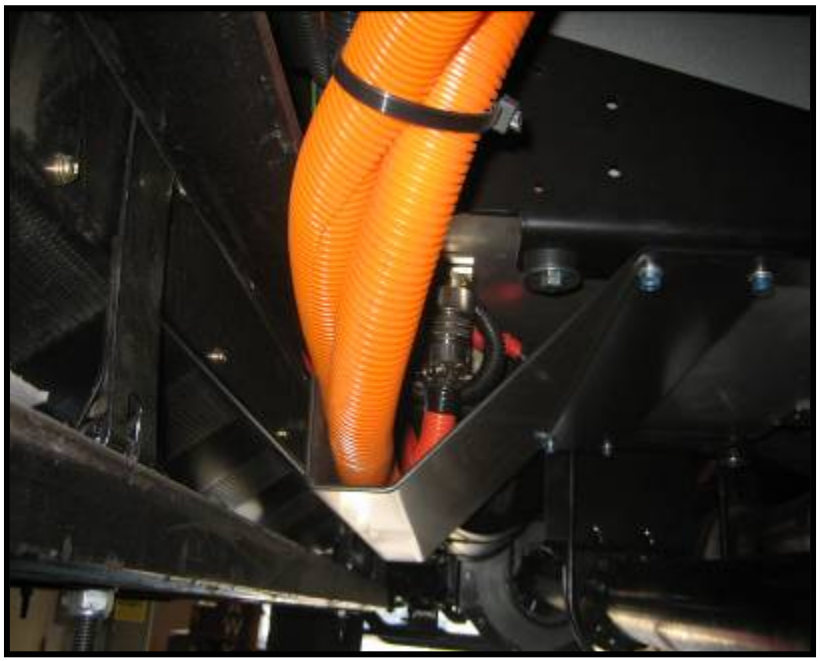


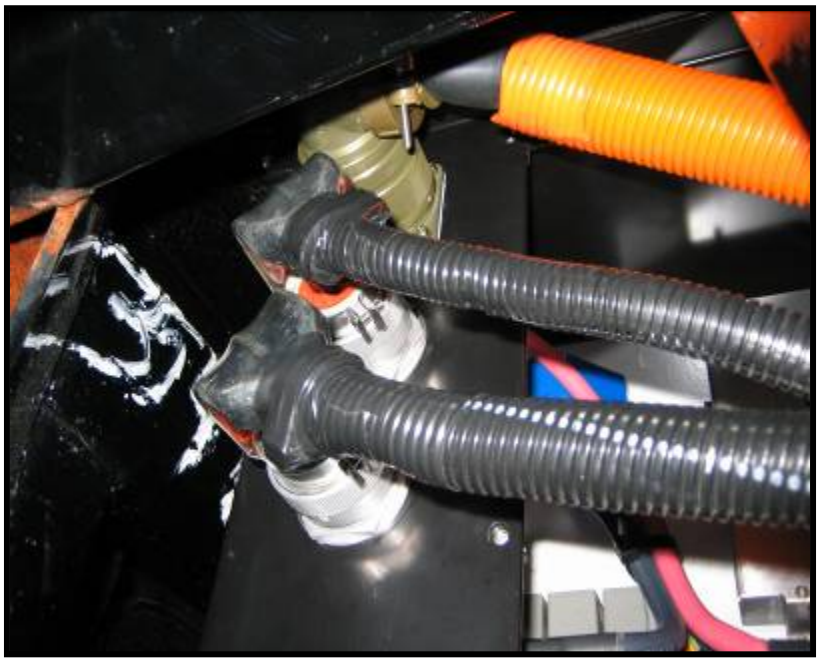
Pump

Radiator

Cooling System

Hybrid System





High Voltage Orange Cabling

Wiring Harnesses

Hybrid System

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Multiple Safety Systems

- High voltage fuse
- All HV battery packs utilize normally open switches
- Ground fault/all fault monitoring system
- Manual HV cutoff switch

Safety Infrastructure

- Orange HV cabling
- Frame-isolated cabling
- Caged battery pack
- Hybrid system status lights
- Hybrid system on/off switch
- Electrolyte absorbed into battery plates

Battery Pack, Cage and HV Switch

Hybrid System

What does the driver feel or do?

- Switch the system on via dash switch. Switch will illuminate and indicator lights will cycle.
  - Will feel stronger (assisted) acceleration off-idle.
    - Vehicle has been utilized in low mountains
  - Will feel regenerative braking occur when he foot lifts from accelerator.
- Post-transmission design provides fail-safe operation.
  - Can switch system off and operate normally.
  - System will switch off automatically if fault detected.

Dashboard Warning Lights
Mounted in LH switch area

Hybrid System

Maintenance

- **Charge-depleting system is a Plug-in Hybrid Electric Vehicle (PHEV)**
  - **Replenish batteries at night (off-peak)**
  - **220V, 30 amp, single phase, 3 prong**
    - **4 hours approx.**
    - **Can be recharged from 110v**
      - **8 hours approx.**
- **Check coolant – reservoir on engine side of cowl.**

Specifications

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Model	PB105, PC105		Applications:	
Wheelbase	254", 276"			School Transportation
Systems	10AHJ, 10AHH			Comm'l. Private Shuttle
Engine	V8 (all hp)			Commercial Public Transit Scheduled Rou
Brakes	Air *			
Fuel Tank	btr		Verification required on:	
Front Axle	10k, 12k			Luggage compartments
Rear Axle	19.8k, 21k, 23k			Sanders
Battery	Grp. 31 only			Tire Carriers
Exhaust	Rear exit only			A/C
Fire Extinguisher	C Rating			and other skirt mounted features
* Hydraulic under development				

Hybrid as a solution

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Why the focus on advanced technology?

- **Hybrids address societal concerns of Government**
  - **Reducing consumption of fuel (Dept. of Energy)**
  - **Reducing harmful emission outputs (EPA)**

Hybrid as a solution

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"To injure no man, but to bless all mankind"

BOSTON – MONDAY APRIL 2, 2007

THE CHRISTIAN SCIENCE MONITOR

DOG DAY AFTERNOONS
Meet NYC's favorite street vendor
BACKSTORY, 20

NEXT STOP

It's a plug-in hybrid – and it's a school bus

By MARK CLAYTON

CONTEST WINNER:

csmonitor.com

12 Monday, April 2, 2007 THE CHRISTIAN SCIENCE MONITOR

usa

Bus: Next stop, plug-in hybrids

Continued from page 1

School District officials last month became proud owners of the nation's first two plug-in hybrid school buses. Students are catching the spirit of their new ride, too. Emily Mulrine, a district student, helped name her middle school's new plug-in hybrid bus "Limpio," the Spanish word for clean.

Such plug-in hybrid buses use both a diesel engine and an electric motor – plugging into a power socket at night to charge batteries. Environmentalists and energy-security hawks love the idea.

"Buses are a great way to use off-the-shelf technology that can reduce pollution and energy use," says Roland Hwang, senior policy analyst at the Natural Resources Defense Council. "This move creates greater pressure on the automakers to produce similar technology."

Indeed, while big automakers tout plans to build plug-in hybrid cars a few years from now, Navistar International Corp.'s school bus division, IC Corp., is already rolling out plug-in hybrid buses. This week, another one will be delivered in Pennsylvania.

To some, it's nothing less than a role reversal in innovation.

"The school-bus industry is usually 10 to 12 years behind," says Bill Schroyer, director of fleet management for the Florida Department of Education. "It was a surprise to see them do this and jump ahead. From the plug-in standpoint, we're ahead of the auto industry."

It's a big deal to the school-bus industry as well.

"There is a huge shift going on – a seismic shift in mind-set and in technology for us and for schools," says Randall Ray, manager of bus platform marketing for the Warrenville, Ill., manufacturer. "Plug-in hybrid buses are a very viable system, and we have high expectations for it."

Other efforts to clean up school buses have emerged over the years. Some districts still employ a handful of all-electric or compressed natural-gas buses. Maintenance costs were high for CNG, and range was a problem for electric, analysts say.

Fuel prices and concerns about global warming could increase receptivity to plug-in hybrids. But all agree the cost needs to come way down first.

"There's definitely a lot of interest," says Ryan Gray, senior editor at School Transportation News, a trade publication based in Los Angeles. "Fuel savings holds a lot of weight for people."

Each of the first 19 buses costs over $200,000 – more than double the cost of a regular model. At that price, they won't pay for themselves over their lives, even with superior fuel savings. It's a chicken-and-egg problem because until about 1,000 buses roll off assembly lines, the cost of production will keep prices high.

Even after manufacturing efficiencies and competition bring the price down, plug-in hybrid school buses may still cost $40,000 more than a regular bus. But at that point, they will pay for themselves in just a few years with lower maintenance and fuel costs, analysts say.

Ordinary yellow "type c" school buses get about 6 to 8 miles to the gallon. But the new plug-in hybrid models, rated at more than 12 m.p.g., could cut fuel consumption about in half in many districts. That could mean a big fuel savings for tight budgets.

If the nation could double its fleet miles, school savings could be significant. About 475,000 buses transport 25 million kids each day. Traveling more than 4 billion miles, those buses burn about 550 million gallons of fuel annually, Mr. Gray says.

"If we could cut our fuel use in half, boy, we've done something good," says Mr. Schroyer of the Florida Department of Education. "It's that much less pollution, that much less cost."

Electricity isn't free, of course – and using it pollutes, especially in regions where coal-fired power plants predominate. Still, the price and emissions per mile powered by electricity are much less when compared with those of diesel fuel.

"It's definitely worth it to try this," says Ben Matthews, director of school support for the North Carolina Department of Public Instruction, which is buying two buses. "What we're buying is a prototype of the school bus of the future."

For Fritchard, the crusade isn't over. He's used up a small grant as seed money to help fund buses now being delivered. Now he's wishing the federal government would toss a few of its millions spent on energy research into deployment of plug-in buses.

"It's still very difficult to get people to fund this effort and buy into the idea," he says. "But in the long run, it's going to work."

NEW WHEELS: Navistar, the nation's biggest school-bus maker, has designed a vehicle that runs on electricity as well as diesel.

USA TODAY

Hybrid as a solution

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How and why can hybrids address these issues:

- **School**
  - **Teach environmentalism and want to lead by example.**
    - **Fuel usage reduction**
    - **Emission reductions**
  - **Positive face to the community**
  - **Operational budget savings**

- **Commercial**
  - **Non-attainment areas need active actions**
  - **Community demand for cleaner/more efficient vehicles**

- **Buses operate in a duty cycle that is most advantageous to hybrid usage.**
  - **No changes required to infrastructure**

Hybrid Buses

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Funding review: Think global, act local

- **Look at benefits for organizations and work with those agencies to secure funding**
- **To date, primary funding sources have been :**
  - **State Air Agencies**
  - **Power companies (Demand Side Management or Energy Efficiency)**
  - **State EPA Departments**
- **Federal opportunities are available online: www.grants.gov**
    - U.S. Environmental Protection Agency [Clean School Bus]
    - U.S. Department of Energy
- **Visit hybridschoolbus.org to download content and register for e-news updates.**
- **Review benefits with school management and/or school board, use online content for support.**
- **Contact local politicians. Seek for support and how school might secure funding.**

Hybrid Buses

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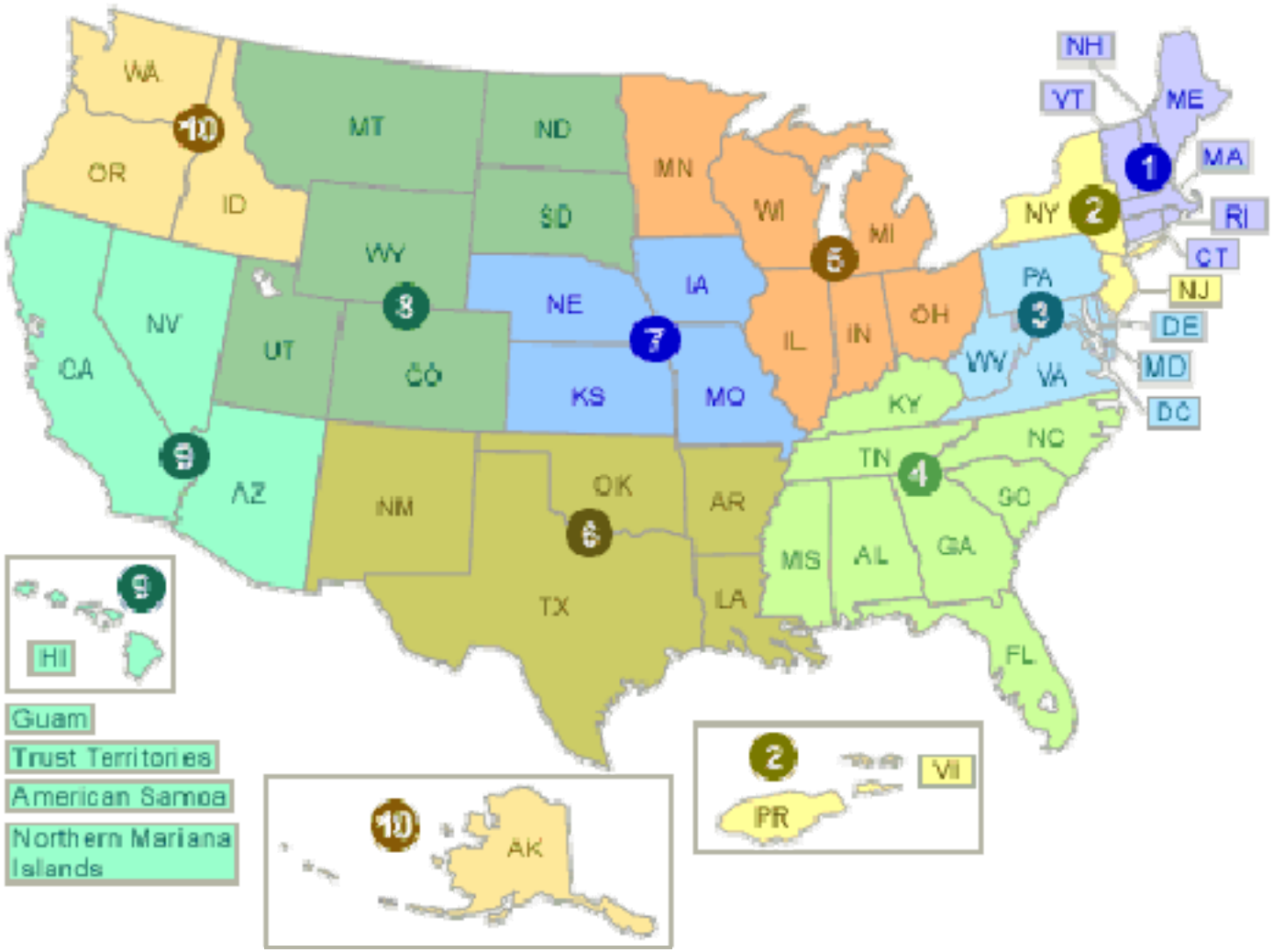
Clean School Bus USA

www.epa.gov/cleanschoolbus/funding.htm

- **Regions 1 & 2, grant requests due July 31**
- **Region 4, grant requests due Aug. 3**
- **Regions 9 & 10, grant requests due Sept. 24**
- **Regions 6 & 7, grant requests due Sept. 21**
- **Region 8 – no announcement yet for 2007**
- **Region 3, closed June 26**
- **Region 5, closed June 22**

Generally about 6-8 weeks from announcement to closing

EPA Regions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Hybrid Buses

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Summary

- **Hybrid vehicles address societal concerns and provide operational benefits**
  - **Reducing consumption of fuel**
  - **Reducing output of harmful emission**
  - **Emphasizing the “green” nature of school buses**

- **Plug-in hybrid school buses are in use now and are available**

Take action

- **Add a hybrid into your customer’s mix**

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Questions and Answers

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