

# The Transit Bus Niche Market For Alternative Fuels:

## *Module 8: Overview of Advanced Hybrid and Fuel Cell Bus Technologies*

## Clean Cities Coordinator Toolkit

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## The future is now for electric propulsion in transit bus applications . . .

**APTA definition:**

"Electric Buses (EBs) are rubber-tired transit vehicles capable of operating by electric power distributed through an overhead twin-wire power supply, or from **batteries**, or from a prime mover electrical source **(Internal Combustion Engine or Fuel Cell)**."

**Prognosis:**

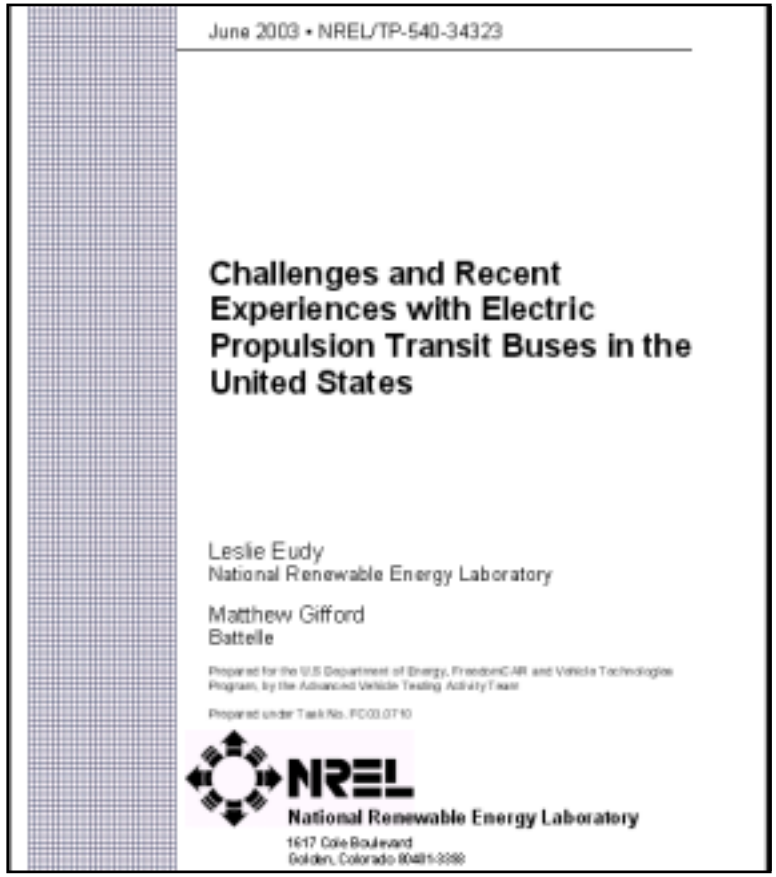
Most experts agree that electric propulsion offers clear and compelling advantages for vehicles, especially transit buses.

Emerging technologies (ultra-clean ICEs, microturbines, fuel cells) give opportunity to develop and commercialize *hybridized platforms with interchangeable prime movers* . . . the choice of which can depend on regional needs and markets.

From: http://www.apta.com/about/committees/buseq/elecbus.cfm

# DOE and NREL Have Established "Focus Groups" for Electric Propulsion

- To date, transit agencies participating have included:
  - New York City Transit (NYCT)
  - Orange County Transportation Authority (OCTA)
  - Santa Barbara Metropolitan Transit District (MTD)
  - Santa Barbara Electric Transportation Institute
  - SunLine Transit Agency
  - Dallas Area Rapid Transit
- Draft report prepared June 2003
- Excellent source of information about issues and challenges associated with battery- and hybrid-electric transit buses
- Copies available from **Leslie Eudy** at NREL, or on NREL website


June 2003 • NREL/TP-540-34323

Challenges and Recent Experiences with Electric Propulsion Transit Buses in the United States

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National Renewable Energy Laboratory

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Prepared for the U.S Department of Energy, FreedomCAR and Vehicle Technologies Program, by the Advanced Vehicle Testing Activity Team

Prepared under Task No. FC03.0710

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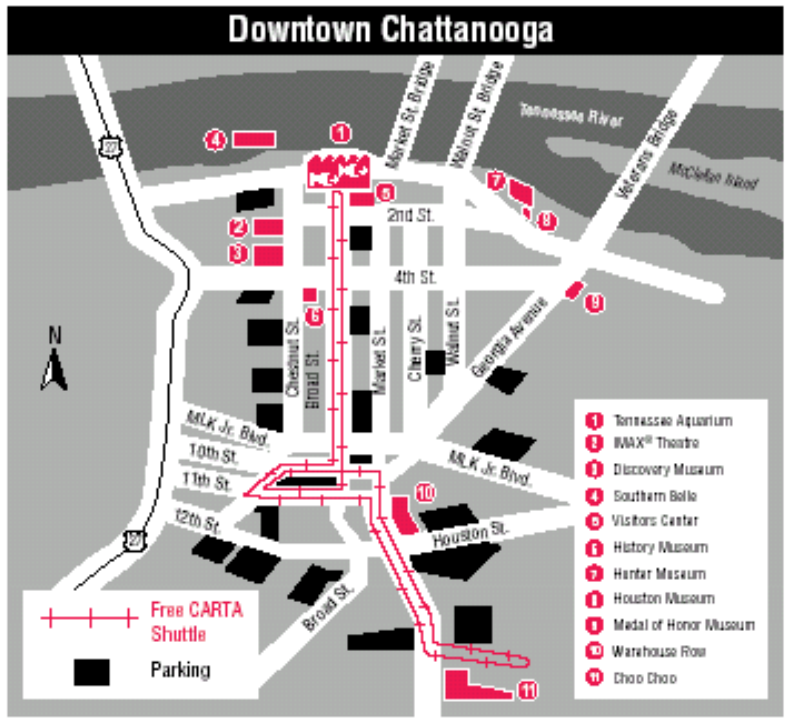
# Snapshots of Transit Agencies Using Battery- Electric Buses

## Santa Barbara MTD Was a Pioneer in Battery-Electric Buses


Santa Barbara MTD's fleet includes 24 battery-electric buses. This shows the newest technology in the fleet.

# Chattanooga Area Regional Transportation Authority (CARTA)

- Began deploying 22-ft. battery buses in 1992 to “get away from diesel”
- 18 battery-electric buses (existing or on order) are used for 2 downtown routes
- Ride is free: paid by parking fees collected from two city parking garages
- Spinoff: creation of Advanced Vehicle Systems (AVS), which now builds electric buses for customers worldwide
- In 2001, CARTA began receiving 30 and 35 ft hybrid-electric buses
  - Series hybrids: AVS built, diesel-fueled Capstone microturbines used to recharge battery packs, which provide propulsion power
  - Cost premium: 15% or more over normal diesel bus of same size




CARTA’s battery-electric buses are operated on fixed, 3.5 mile routes in downtown Chattanooga

## CARTA is testing out various electric propulsion concepts vs. diesel

### Battery Electric Buses vs. Conventional Diesel Buses:

- Mean time between failure **slightly better for electrics**, and **maintenance costs are 8 to 10 percent lower**
- 50 mile range for EVs is adequate for downtown use, but **~400-mile range diesels are needed for vast majority of passenger miles**
- **Minimal extra training** requirements for battery-electric buses

### Hybrid-Electric Buses vs. Conventional Diesel Buses:

- Relatively new technology to CARTA
- "Overly complex" to some CARTA mechanics and users
  - More training required than conventional diesel or battery electric
  - So far, hybrids have experienced high Mean Time Between Failure rate
  - Performance of diesel HEBs is expected to improve

# Snapshots of Advanced Transit Technologies: Clean-Fueled Hybrids and Fuel Cells

## Hybrid Buses with Twin Capstone 30 kW Microturbine Engines

- Certified by California Air Resources Board on diesel, natural gas and propane


LA DOT bus powered by Capstone's microturbine engine fueled by propane

- **Series hybrid**: each bus has two 30-kW microturbines, which recharge battery packs

Photos from Capstone Turbine Corp. at www.microturbine.com.


- Field trial by Los Angeles DOT in revenue service
- Proceeding to Phase 2
- Tempe reportedly interested in large procurement

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# Full View of Engine Compartment for Capstone Microturbine Bus

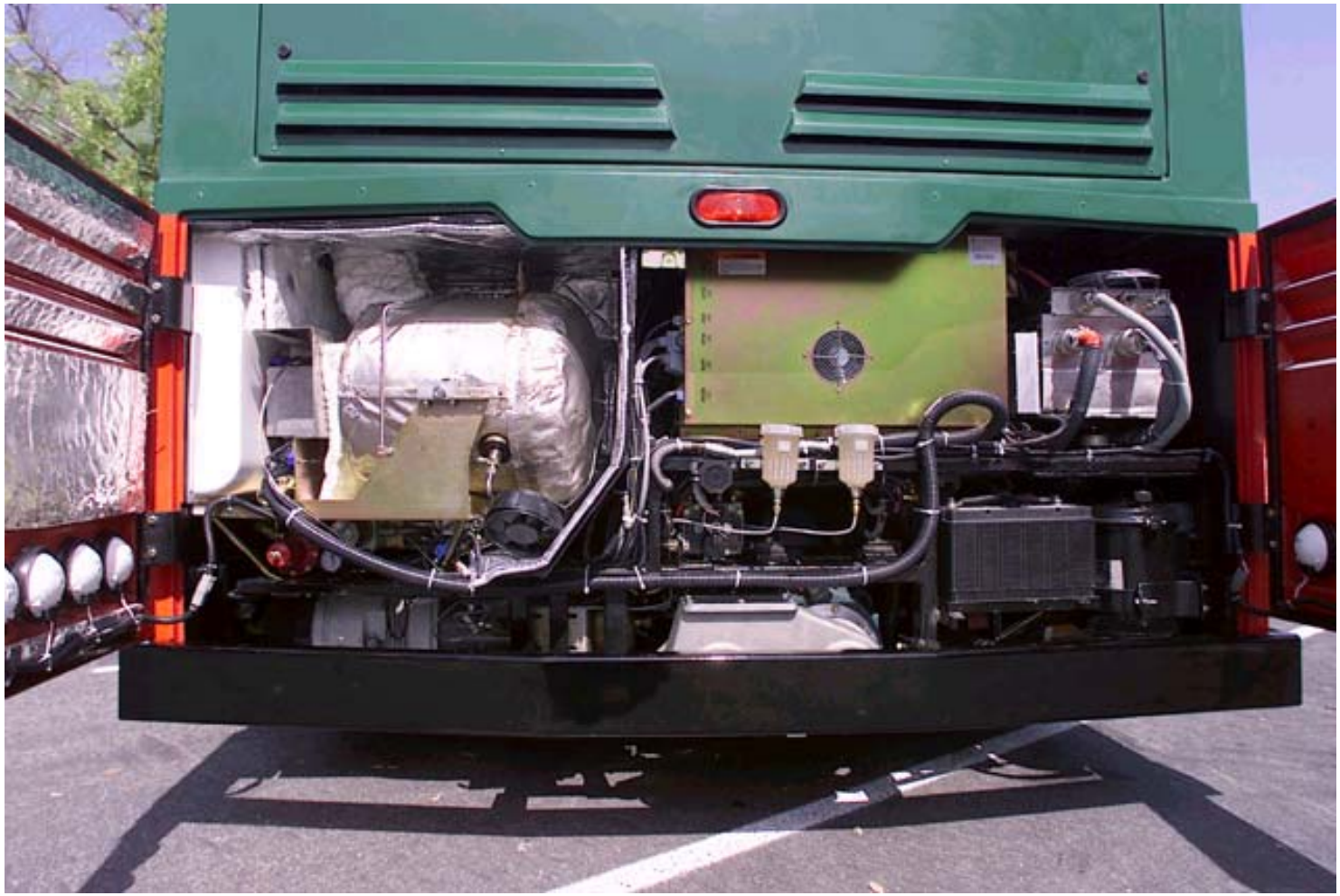


**Photo from Capstone Turbine Corp. at www.microturbine.com.**

## Advantages of Fuel Cells for Transit Bus Applications

- Fuel cells offer a number of potential benefits that make them appealing for transportation use:
- **Efficiency**: FC buses are more efficient than ICE buses
- **Near-Zero or Zero Emissions**: Depending on the source fuel
- **Greenhouse Gas Reductions**: greatly reduced CO2 emissions (depending on fuel). Hydrogen generated using renewables will have zero greenhouse gas emissions.
- **Energy Security**: Reduced dependence on petroleum and allow greater energy diversity. Natural gas, ethanol, electrolysis -- different regions could choose a hydrogen source based on the most available and economical source for that region
- **Quiet and smooth operation**: Fuel cells may offer significantly more pleasant operation for transit riders. The fuel cell itself has no moving parts, although the fuel cell system will have pumps and fans. Quieter than diesel engine. Electric motors: smoother starts and stops than a typical diesel-engine buses.

## Where are fuel cell buses being demonstrated?

- Chicago TA and Vancouver conducted early tests on Ballard fuel cell buses
- A few “direct-hydrogen” FC bus demos are now underway or planned, primarily in conjunction with the California Fuel Cell Partnership and DOE / NREL
  - SunLine Transit (Palm Springs area)
  - Bay Area: AC Transit (Oakland) and Valley Transit (San Jose)
- Georgetown University has a leading program, focusing on reforming liquid fuels
- Other worldwide ventures include Daimler Chrysler’s Citaro program, in which FC buses with Ballard technology will be demonstrated in 10 European cities
- Biggest barriers: 1) FC cost, and 2) fuel type and logistics (cost, on-board storage)



*Ballard - Xcellsis demonstration bus powered by a hydrogen-fueled proton exchange membrane fuel cell, fueling at SunLine Transit Agency’s solar hydrogen station*

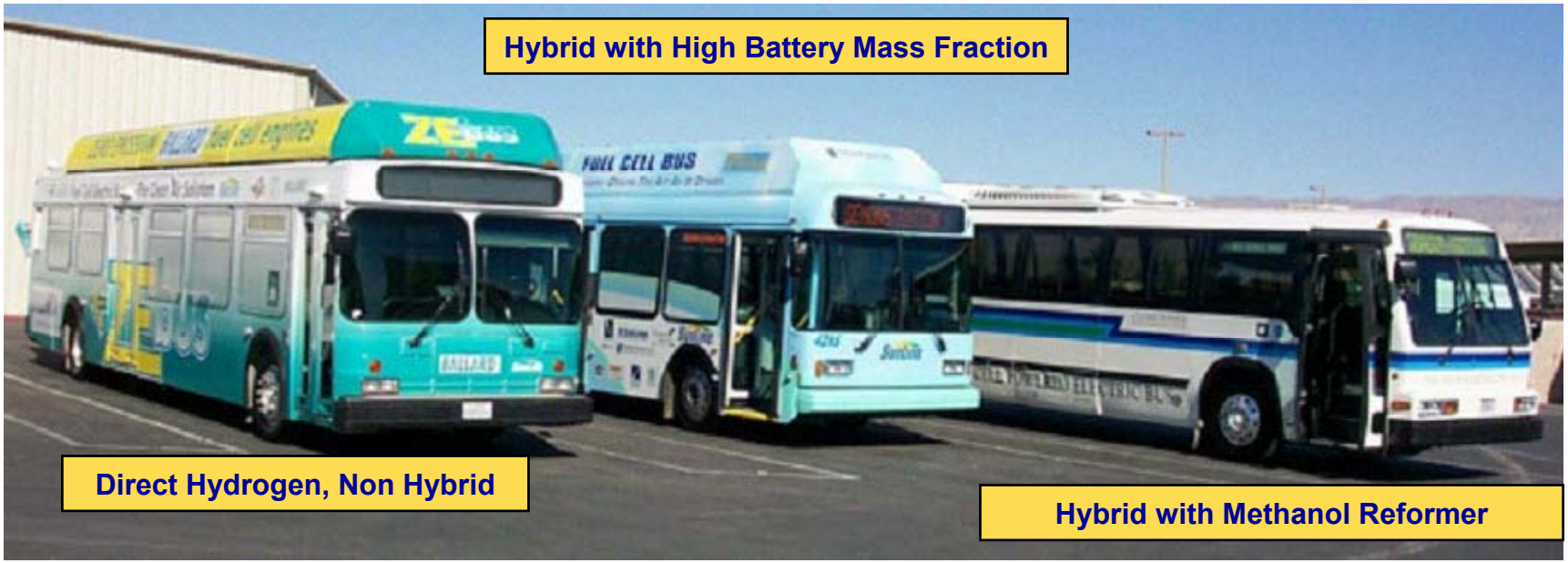
# Preliminary testing of XCELLSiS P4 Direct-H2 FC bus at Sunline Transit


Refueling using Stuart Energy's prototype hydrogen bus refueler

Non-revenue-service testing with water tanks to simulate curb weight

Photos by R. Barnitt, TIAX LLC

## Three Types of Prototype Fuel Cell Buses




- SunLine Transit Agency has demonstrated three fuel cell buses: Ballard's Zebus, ISE Research's ThunderPower bus, and Georgetown University's methanol fuel cell bus.
- Each bus and technology type has a different approach involving fueling and hybridization -- to achieve different operational characteristics

## Daimler's Citaro Program: Fuel Cell Buses in Europe

- Up to 30 Citaro fuel cell buses will be demonstrated in 10 European cities
- Barcelona received first bus in mid 2003 for use in normal revenue service
- 3 buses delivered to the City of London in December 2003
- All utilize a Ballard 205 kiloWatt fuel cell system fueled by gaseous hydrogen
- A similar program is being initiated in Australia


Source and photo: California Fuel Cell Partnership (www.fuelcellpartnership.org/PG_hirez/PG_30.jpgzz0

## SunLine Transit Sees NG Buses as a Bridge to Hydrogen Fuel Cell Buses

| Type | Current Number |
|---|---|
| CNG Buses (40-foot, 30-foot) | 46 |
| CNG Shuttle Buses | 25 |
| Hythane® Buses | 4 |
| LNG High Capacity Shuttles | 3 |
| **Total Bus Fleet** | **78** |

## Summary: Advanced Transit Bus Technologies and Fuel Cell Buses

- Wireless electric propulsion is an important step forward for the future of transit buses across America
- Depending on regional needs and operational characteristics of the user transit agency, a variety of zero-emission or near-zero emission technologies are commercially available or undergoing testing:
  - **Battery electric:** available now as a ZEB technology, for 22 foot bus applications not requiring long driving ranges (downtown shuttle routes)
  - **Hybrid electric using clean fuels and/or advanced prime movers:** available now as near-ZEB technology, in demonstration capacity
  - **Fuel cell electric:** available now as near-ZEB or ZEB technology, but strictly in an R&D capacity
- Today's alternative fuel buses and hybrid-electric buses are "bridge technologies" to these buses of the future
  - Powertrains, fuel storage, safety systems, aftertreatment for exhaust, etc.
  - Fueling infrastructure
- New codes and standards, training programs, etc. will be essential as commercialization proceeds and new deployments are made
- Resources are available to Coordinators to assist deployment (Module 11)