

The Transit Bus Niche Market For Alternative Fuels:

Module 2:
Basics of Alternative Fuels in Transit Bus Applications

Clean Cities Coordinator Toolkit

Prepared by
TIAX LLC, Irvine Office

December 2003

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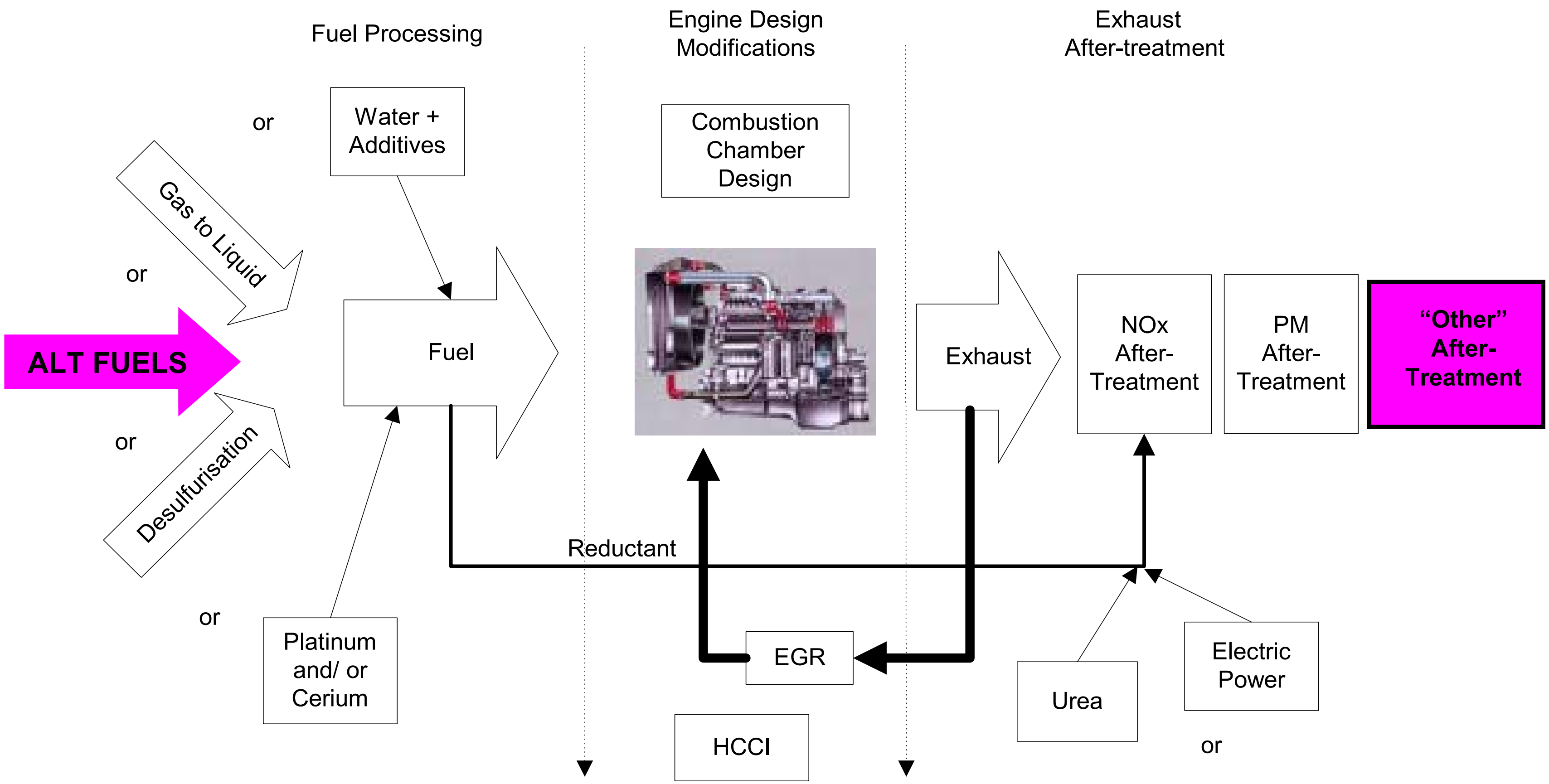
TIAX LLC
One Park Plaza, 6th Floor
Irvine, California 92614
949-833-7131 /
leonard.jon@tiaxllc.com

Emission Reduction Approaches for Heavy-Duty Vehicles

- Strategies to reduce NOx, PM and toxics are implemented at 3 basic levels:



- To date, using alternative fuels <u>(w/ minimal after-treatment)</u> has been very effective.

- Advanced AF technology and after-treatment will provide even greater benefits.

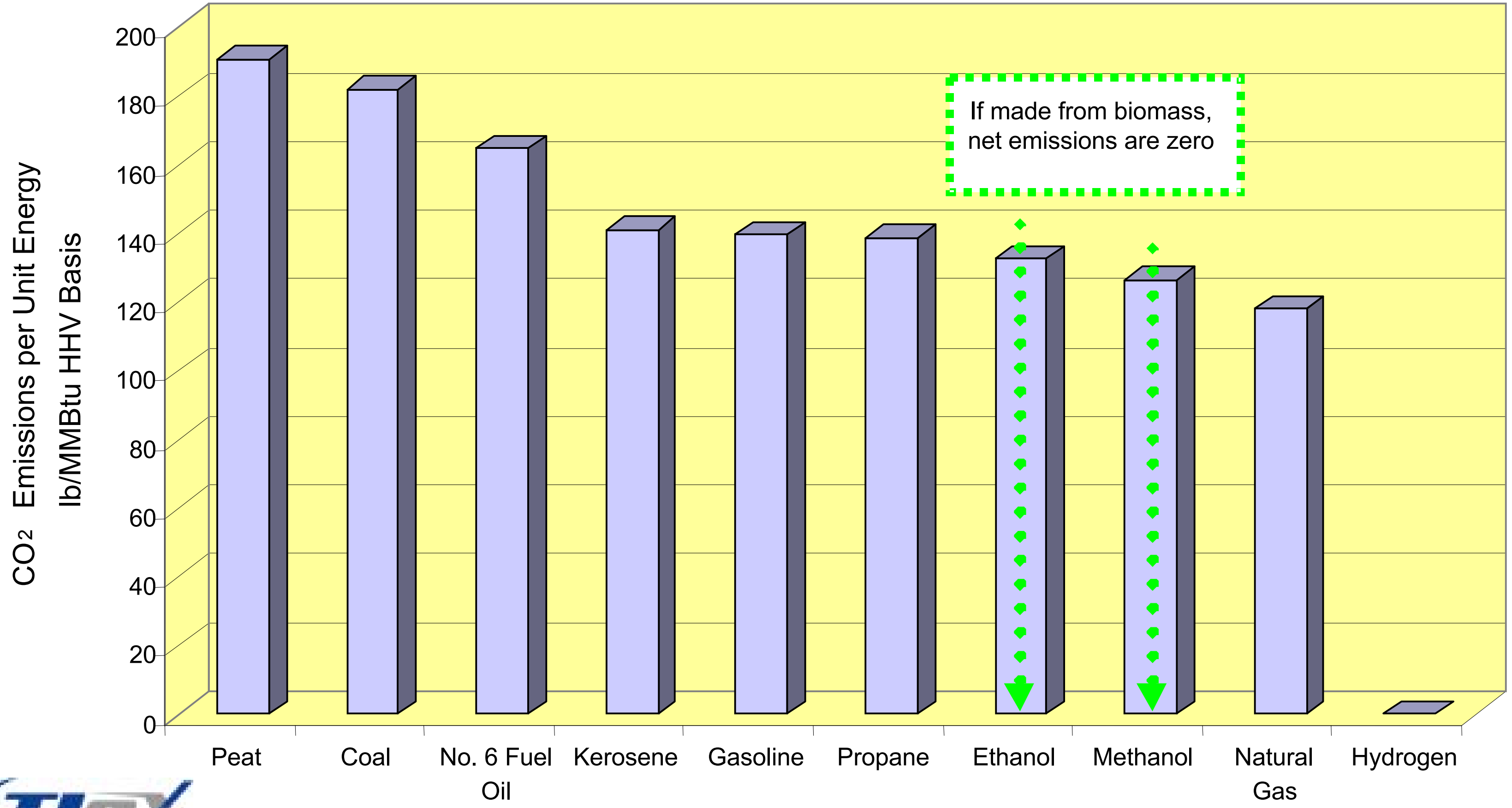
Advantages of Alternative Fuels:

- Non-petroleum energy supply
  - Lessens dependency on foreign sources of oil and refined products
  - Insulates economy from fuel price volatility
- Chemically simple, with high hydrogen-to-carbon ratios
  - Methane CH_4
  - Ethanol C_2H_5OH
  - Propane C_3H_8
  - Hydrogen H_2

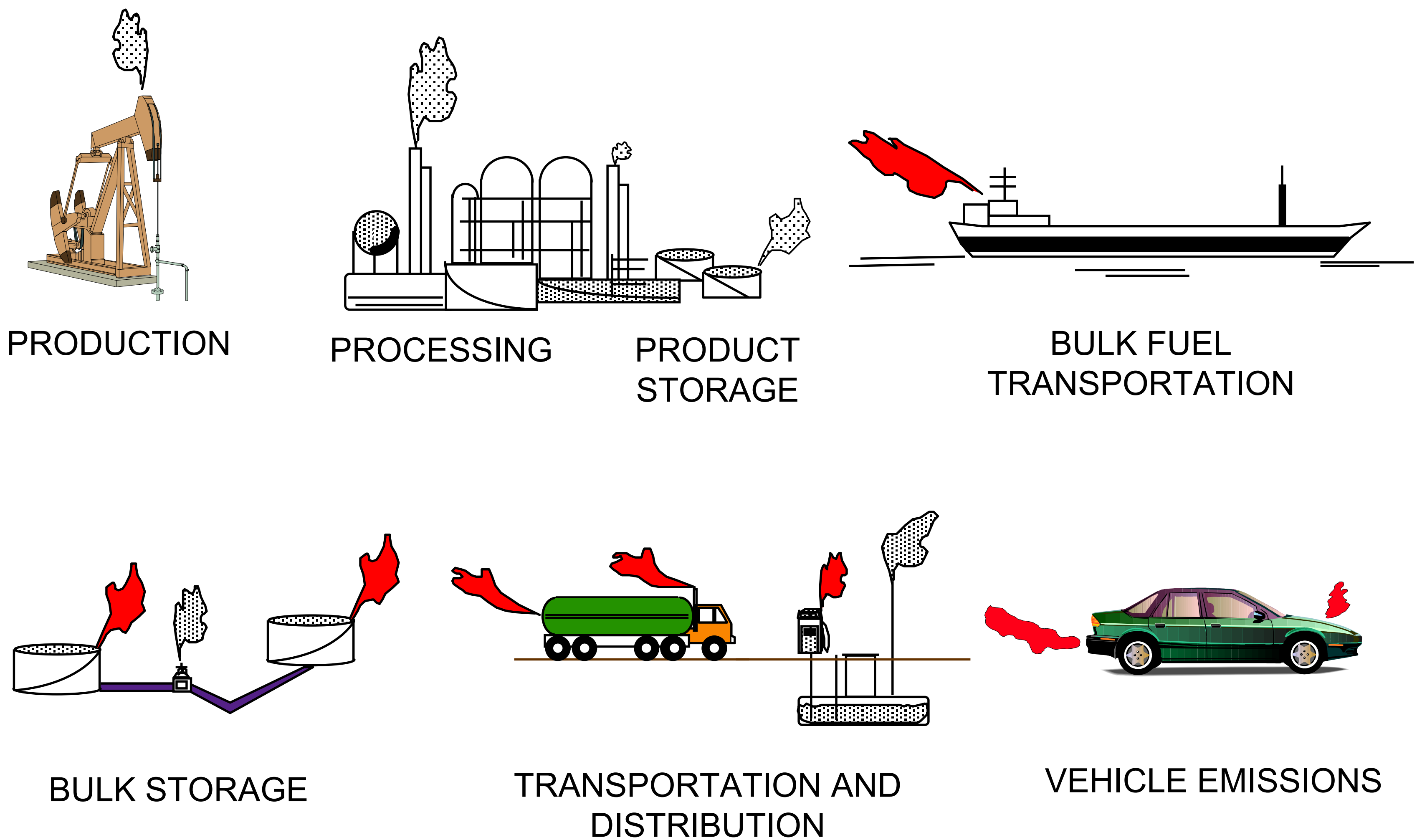
  } – Gasoline (isooctane) C_8H_{18}
  – Diesel (cetane) $C_{16}H_{34}$
- This chemical simplicity (along with other combustion characteristics) helps to simultaneously reduce NOx and PM in heavy-duty engines
- **Result:** today's alternative fuel (e.g., natural gas, LPG) heavy-duty engines already achieve low NOx and PM levels with minimal after-treatment
- **Larger Picture:** alternative fuels also provide lower "life-cycle" emissions of ozone precursors, particulate matter, and global warming gases
- **Bonus:** lower "life-cycle" costs can occur in high-fuel-use applications (transit)

Alternative Fuels Can Reduce Global Warming Emissions

- Alternative fuels have lower carbon content relative to heating value and result in lower CO_2 emissions
- Need to account for upstream and vehicle energy use in comparing CO_2 emissions



Well-to-Wheels Fuel Cycle Emission Events



Why are transit buses a very good niche application for alternative fuels?

- **Motivating Factors:**
  - **Location:** transit buses are often operated in CAA "non-attainment" urban environments, and serve as symbols for the need to eliminate "dirty diesels"
  - **Public sector:** transit agencies are quasi-government entities under intense pressure to **lead** towards clean air and environmental justice
- **Application:** high fuel use and centralized fueling allow volume purchasing of fuels at lower cost and leveraging of infrastructure investments
- **OEM support:** numerous low-emission alternative engines and chassis are commercially available for the application
- **Other key success factors:**
  - Legislation promoting or mandating the use of alternative fuels in application
  - Availability of incentives for capital investments (vehicles, infrastructure)
  - Strong community support

<u>The Upshot</u> - transit fleets are **among the most viable alternative fuel applications** because they frequently offer many (or all) of these elements . . .

. . . but often the most important ingredients are ***the desire to achieve success***, and ***determination*** to make it happen.

Clean Alternative Fuel Buses Are Part of the Transit Industry's Key Goals

APTA AMERICAN PUBLIC TRANSPORTATION ASSOCIATION

APTA Strategic Goal #4:

"Improve the perception of the value and benefits of public transportation"

Desired Outcome:

"Strengthen the link between public transportation and critical key issues, i.e., economic development, **clean air**, congestion mitigation, safety, and good business practices, etc."

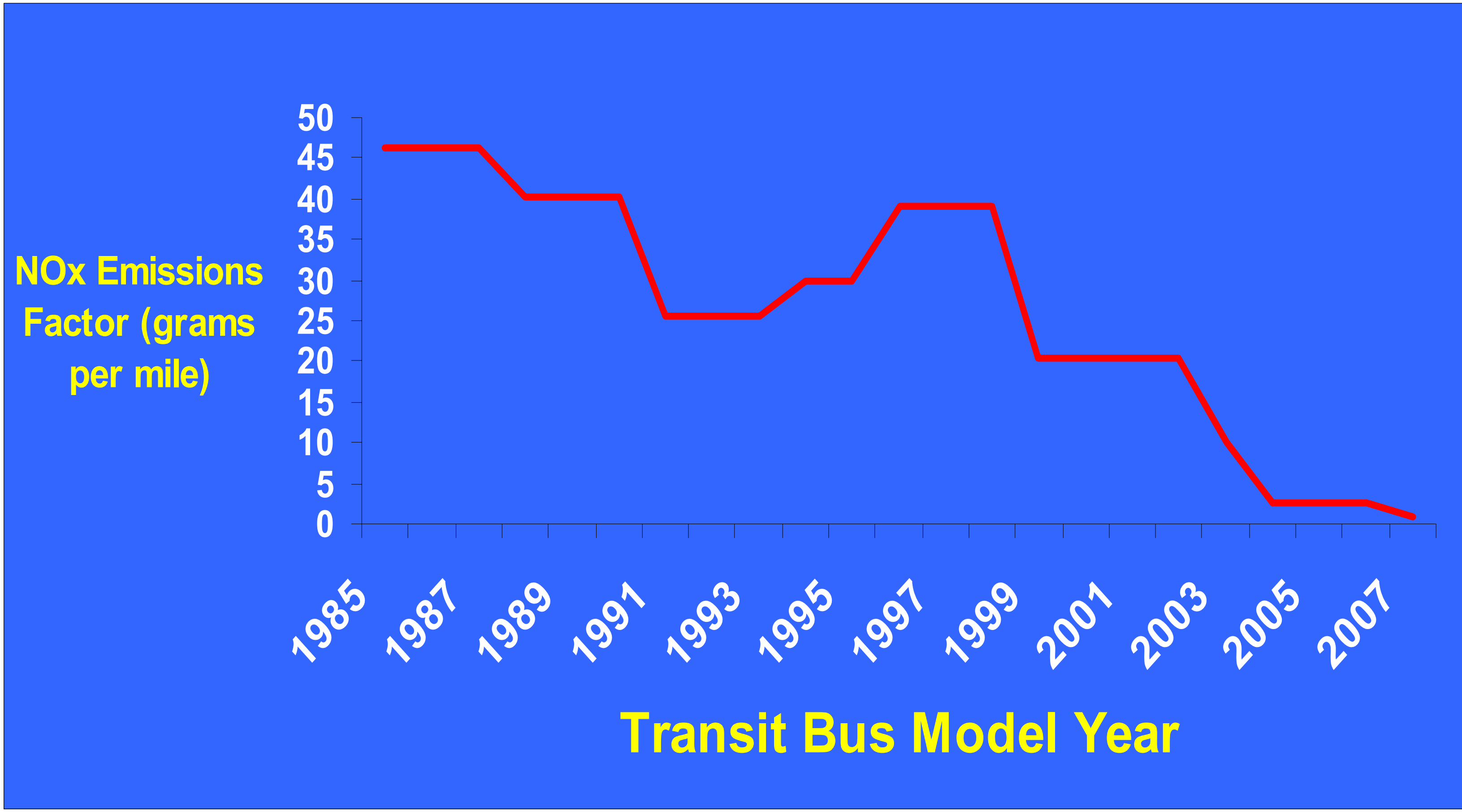
Source: American Public Transportation Association (APTA), Strategic Plan 2000-2004, October 1999

How Much Longer Will Air Quality Be A Major Driver for Alternative Fuels?

- California's South Coast AQMD has been strongly challenged on the legality of its Rule 1192 transit bus fleet rule (and other fleet rules)
- California's statewide transit bus fleet rule and other potential AQMD fleet rules (e.g., Sacramento) may hinge on the Supreme Court's decision, expected in Q1 2004
- As long as emission benefits are clear, public funding may be available to support incremental capital costs (vehicles, infrastructure) for AFVs
- But, as progressively cleaner diesel technologies are deployed to meet the 2007 / 2010 standards, justification for such funding is likely to diminish
- Now more than ever, the **petroleum-displacement benefits** of using alternative fuels in transit must be recognized and emphasized, if not **monetized**

Arizona and California have implemented legislation requiring alternative fuel use in urban transit buses

NOx Emissions Factors for Urban Transit Buses (EMFAC 2002)



- A Pre-1987 urban transit bus emitted about 46 grams of NOx per mile
- By 2007 time frame, newly purchased urban buses will emit only 1 gram of NOx per mile

Source: California Air Resources Board

Snapshots of Mainstream Alternative Fuel Options for Transit in 2003

Sacramento Regional Transit CNG Bus

	CNG for HDVs
Lower Heating Value	100,000 Btu/therm* of CNG
Diesel Gallon Equivalent	1.4 CNG therm/ Diesel gallon
Vehicle Technology	Dedicated and Dual Fuel
Vehicle Providers	Engines: Detroit Diesel, Deere, Westport/Cummins Chassis: All major chassis manufacturers
Infrastructure Needed	Yes, high pressure storage tank and fuel dispensers
Fuel Price	$1.01 to $1.11/CNG therm
Vehicle Incremental Price	$30,000 to $60,000

*A therm is equivalent to about 0.8 gasoline gallon equivalents (GGE)

An LNG fueling station with a single above-ground LNG tank.

An OCTA LNG Bus seen from the engine compartment

	LNG for HDVs
Lower Heating Value	~75,000 Btu/gallon LNG
Diesel Gallon Equivalent	1.7 LNG gallon/Diesel gallon
Vehicle Technology	Dedicated and Dual Fuel
Vehicle Providers	Engines: Detroit Diesel, Mack, Westport/Cummins Chassis: Most major chassis manufacturers
Infrastructure Needed	Yes, Cryogenic storage tank and fuel dispensers
Fuel Price	$0.63 to $0.95/LNG gallon
Vehicle Incremental Price	$30,000 to $60,000

- Mostly used in 30 foot or smaller buses and paratransit vehicles
- Largest user of propane buses for transit is San Antonio VIA Metro Transit
- Also used in some hybrid-electric buses with Capstone Microturbines

Champion Solo 30 foot low floor transit bus

	Propane (LPG)
Lower Heating Value	84,900 Btu/gallon LPG
Gasoline Gallon Equivalent	1.51 gallons LPG/diesel gallon
Vehicle Technology	Bi-fuel, SI engines with low pressure on-board storage trucks
Bus Providers	Chance, Champion, others
Infrastructure Needed	Yes, propane tanks and dispensing systems (tank infrastructure widely used)
Fuel Price	$1.09 to $1.76/gallon
Vehicle Incremental Price	$15,000 to $40,000

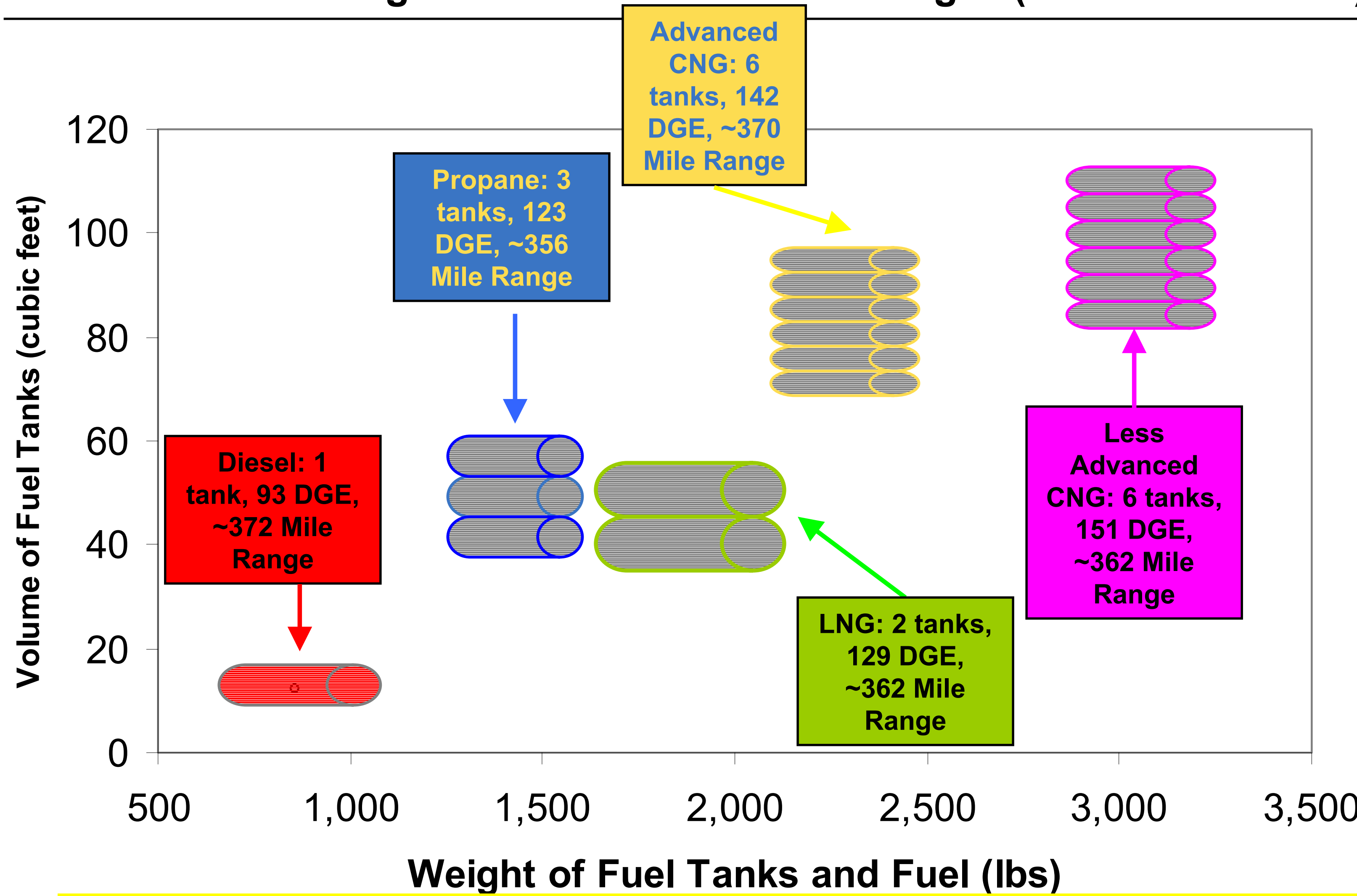
City of Seattle Biodiesel Bus

	20% Biodiesel Blend (B20)
Lower Heating Value	131,900 Btu/gallon B20
Diesel Gallon Equivalent	1.01 B20 gallon/ Diesel gallon
Vehicle Technology	Dedicated and Blends
Vehicle Providers	Engine: All major diesel engine manufacturer Chassis: All major chassis manufacturers
Infrastructure Needed	No, segregated fuel tanks
Fuel Price	$1.57 to $1.84/ B20 gallon
Vehicle Incremental Price	None

Twin Challenges: Reduced Engine Efficiency and Limited Energy Density

- Dedicated alternative fuel engines (CNG, LNG, LPG) use spark ignition, which provides **lower thermal efficiency** than compression ignition (diesel engines)
- For transit buses with dedicated AF engines, this translates to a significant **fuel economy reduction** (roughly, 25% per Btu of fuel used)
- To carry as much energy as a diesel bus, alternative fuel buses (e.g., NG and LPG) require **larger and heavier on-board fuel storage systems**
- The net effect: NG and LPG buses provide **significantly reduced range**
  - A typical 40 ft diesel bus gets a range of about 400 miles
  - NG and LPG buses cannot match this without compromising bus payload (carrying fewer people)
- Still, the range of AF buses is **fully adequate for most transit routes & uses**
- Initially, some transit districts requiring longer range reported issues with out-of-fuel road calls, and had to restrict AF buses to shorter routes
- However, **fuel tank technology has improved** -- more “BTUs” of alternative fuel can now be stored on board at lower weight and volume
- Also, transit agencies have **learned to maximize range** (additional tanks, improved shift points, etc.)

On-Board Fuel Storage Needed for 350+ Mile Range* (40 ft. Transit Bus)



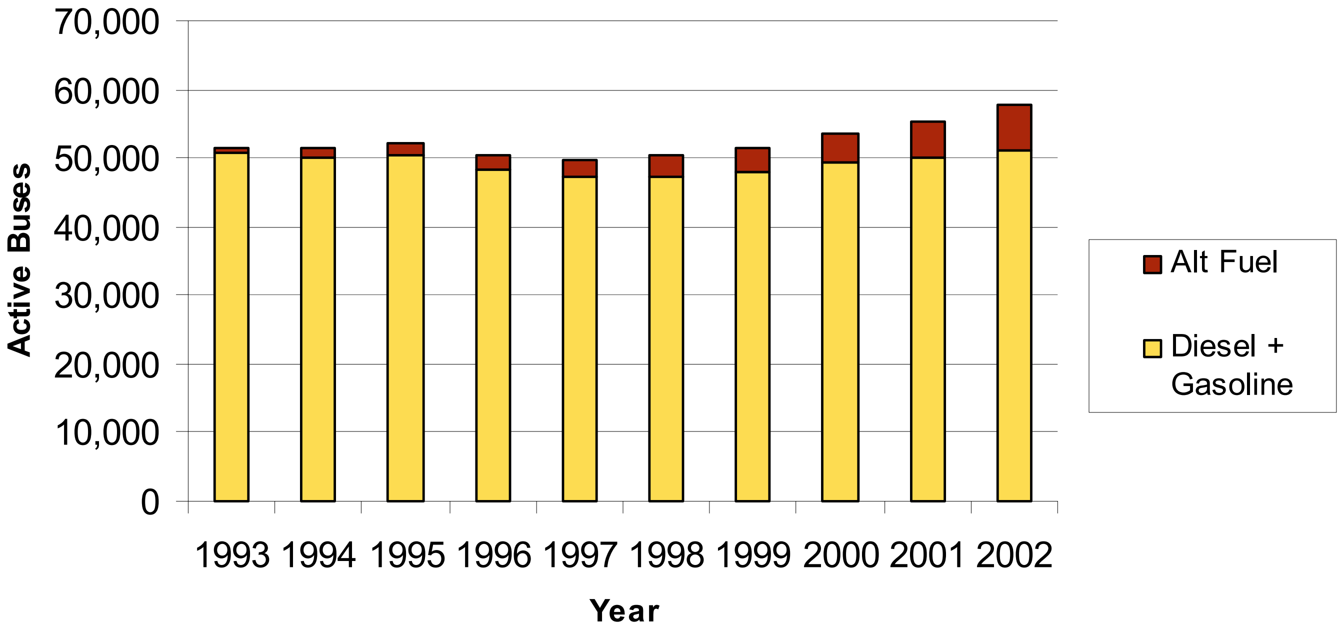
***Important Note: most transit bus routes don't require a 300+ mile range!!!!**

Based on manufacturers' tanks specifications and actual experience reported by various user districts. Assumes 4 miles per DGE as baseline FE, but reduced efficiencies for 1) spark ignition of CNG, LNG, and LPG, and 2) excess weight over diesel fuel storage system.

Snapshot of Alternative Fuels in Transit, 2003

The use of alternative fuel buses has been gradually increasing

- The number of active transit buses in the U.S. has ranged from 50,000 to about 57,000 over the last decade
- The American Public Transit Association's annual surveys have documented a growing alternative fuel bus population
- In 2002, AFVs made up nearly 12% of buses in surveyed fleets (representing 2/3 of active buses). Thus, more than 88% were diesel and gasoline fueled.



2002 APTA Survey Result Summary

APTA 2003 Data: Conventional (ICE) diesel buses continue to dominate the in-use fleet (~87%), but dedicated CNG and LNG collectively account for 12%

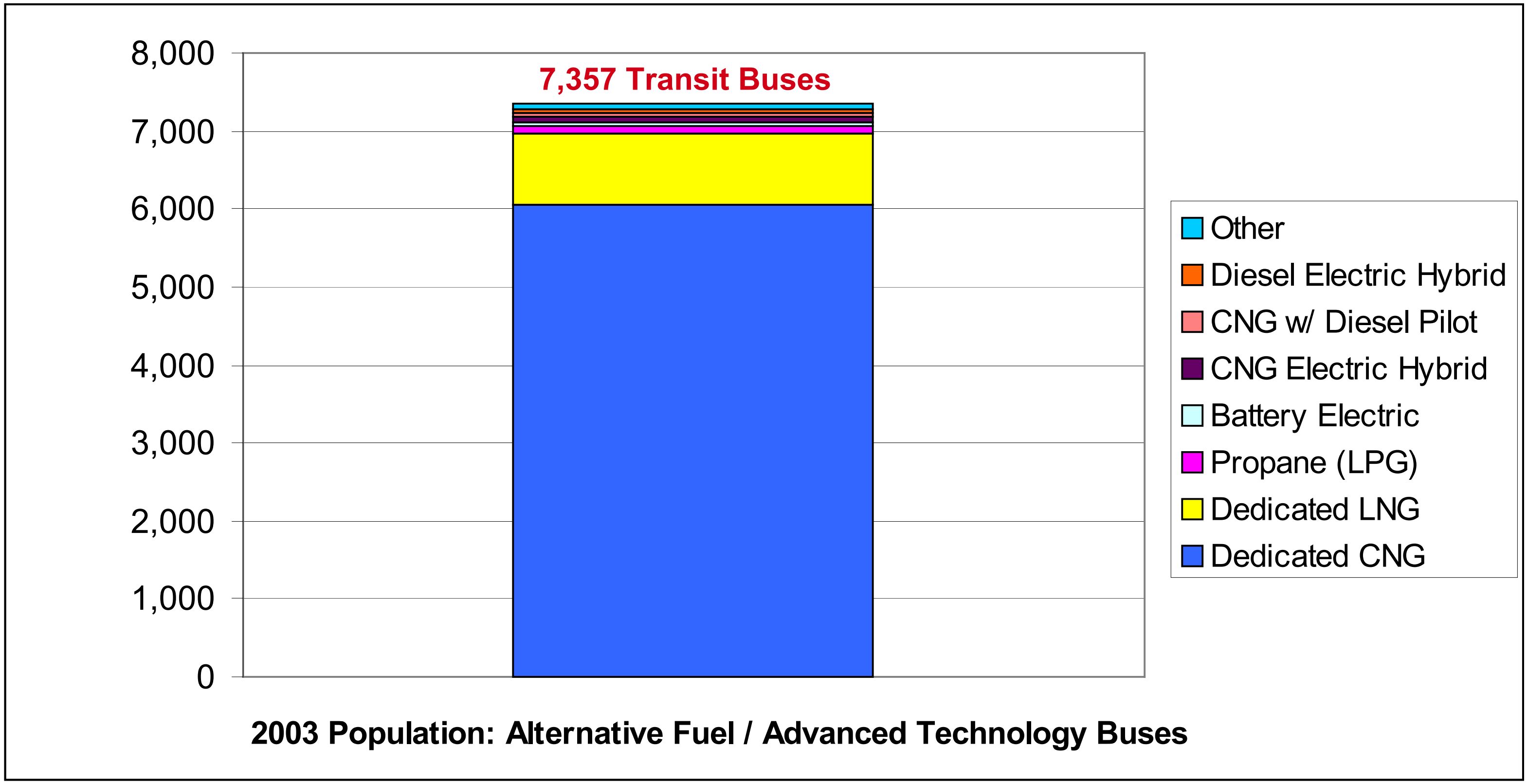
Propulsion Fuel / Technology	APTA 2003 Survey for In-Use Transit Buses	% of U.S. Fleet
Diesel ICE	49,755	86.59%
Dedicated CNG	6,052	10.53%
Dedicated LNG	910	1.58%
Gasoline ICE	241	0.42%
Jet Fuel	108	0.19%
Propane (LPG)	90	0.16%
Battery Electric	70	0.12%
CNG Electric Hybrid	59	0.10%
CNG w/ Diesel Pilot	57	0.10%
Diesel Electric Hybrid	50	0.09%
Gas Turbine Electric	20	0.03%
LNG w/ Diesel Pilot	18	0.03%
Methanol ICE	11	0.02%
Bi-Fuel CNG / Gasoline	8	0.01%
Propane Microturbine Hybrid	6	0.01%
Biodiesel (B20 or B100)	4	0.01%
Hythane (CNG & Hydrogen)	2	0.00%
TOTAL	57,461	100.00%

Soure: Table 14 of APTA 2003 Database

*Represents data for approximately 67% of all U.S. Transit Buses

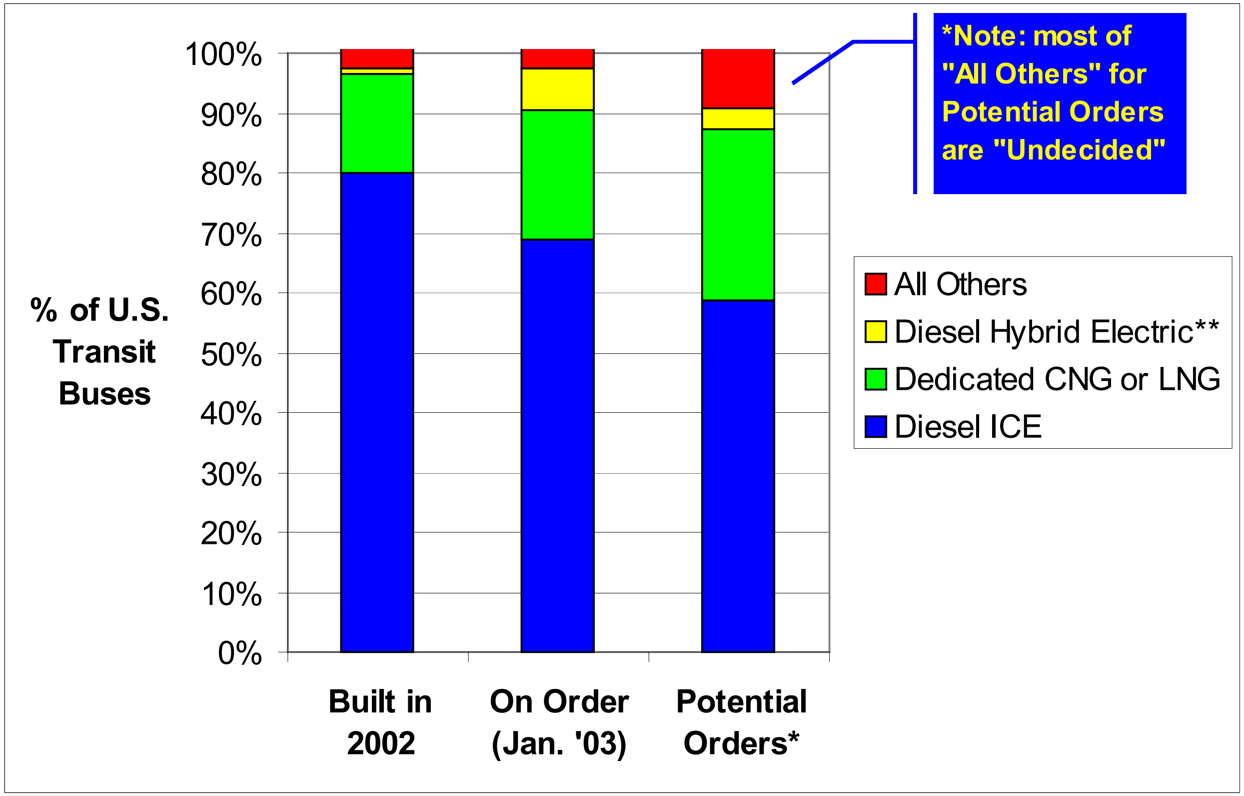
Approximately 7,400 transit buses are now powered by alternative fuels and/or advanced technologies

- APTA's 2003 survey for U.S. transit: dedicated CNG and LNG buses account for 82% and 12%, respectively, of these alternative fuel buses



Source: 2003 APTA Survey, Table 14

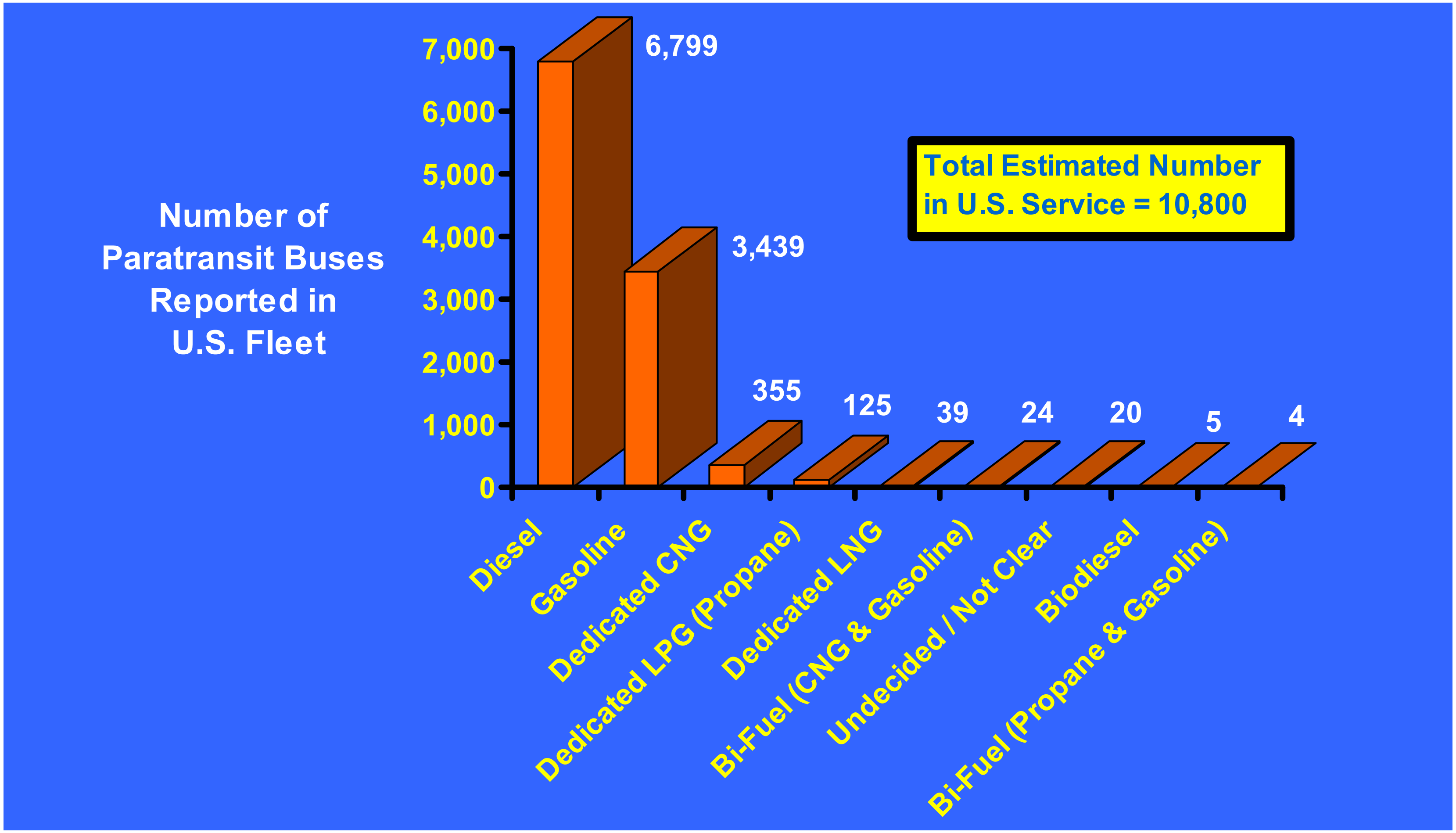
Transit: What Are the Key Current and Expected Short-Term Trends?



- Overall market share for conventional diesel buses (ICEs, including “green” types) is declining
- Natural gas buses are increasing in number (still mostly CNG)
- Diesel electric hybrid buses will increase with ‘03 orders, and likely will increase beyond then (i.e., “undecided” portion of All Others)

Source: APTA 2003 Survey, Table 60. Represents survey of about 67%of transit districts, but includes high % of orders. Potential Order data are tentative and may not come to fruition.

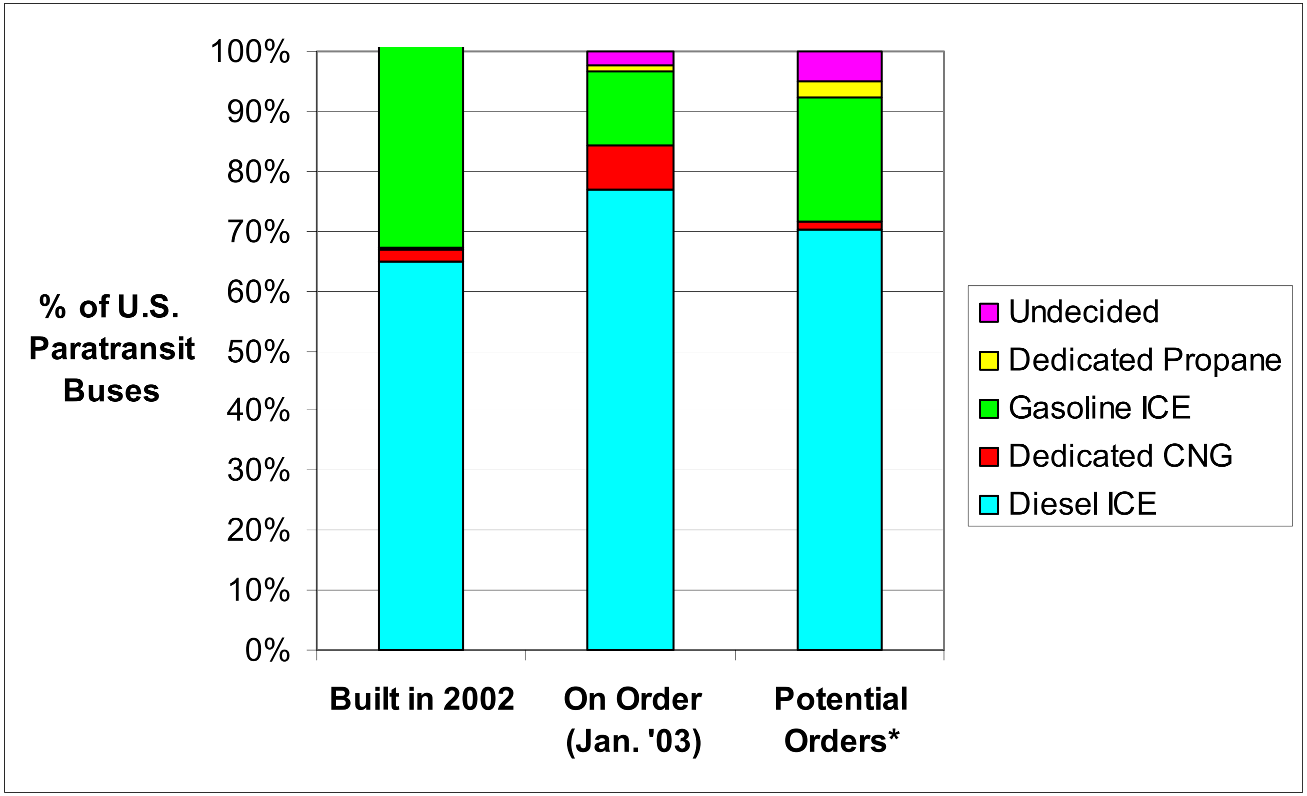
In-Use Paratransit Buses by Fuel Type



Source: APTA 2003 Survey Data (Table 14). Represents an estimated 22% of actual U.S. fleet.

- Diesel and gasoline make up 63% and 32%, respectively
- Dedicated alternative fuel engines (CNG, LNG, LPG) make up less than 5%

Paratransit: What Are the Key Current and Expected Short-Term Trends?



- Market share for conventional diesel (including "green" types) is stable, while market share for conventional gasoline appears to be slightly declining
- Dedicated CNG vehicles increased in '03, but "potential orders" are hazy
- Potential for increased use of dedicated propane looks promising
- "Undecided" makes up 5% of "potential orders" (= OPPORTUNITY?)

Source: APTA 2003 Survey, Table 67. Represents only 22% of paratransit operators, but includes high % of major cities. Potential Order data are tentative and may not come to fruition.

Overview of Cost Issues Related to Alternative Fuel Use in Transit Applications

(See Module 9a and 9b for Detailed Comparative Economics)

Incremental Costs of Alternative Fuel Buses

- Alternative fuel buses are more expensive than diesel buses for several reasons
  - Produced in smaller volume (which almost always translates into higher cost)
  - Costlier on-board fuel storage: Diesel<LPG<Natural Gas (LNG and CNG)
  - Specialized components (e.g., fire suppression, spark plugs and coils)
- Incremental costs vary with bus specifications and order size -- $35,000 to $50,000 is typical for a full-size transit bus (13% to 18% higher than diesel)
- Transit operators portion can vary
  - The Federal Transit Administration subsidizes up to 83 percent of the cost of a new alternative-fuel transit bus
  - Local air district funding is available to many transit agencies that buy clean-fuel buses
  - Some states offer additional incentive funding
- Result: transit agencies may pay NO INCREMENTAL capital cost for alternative fuel buses

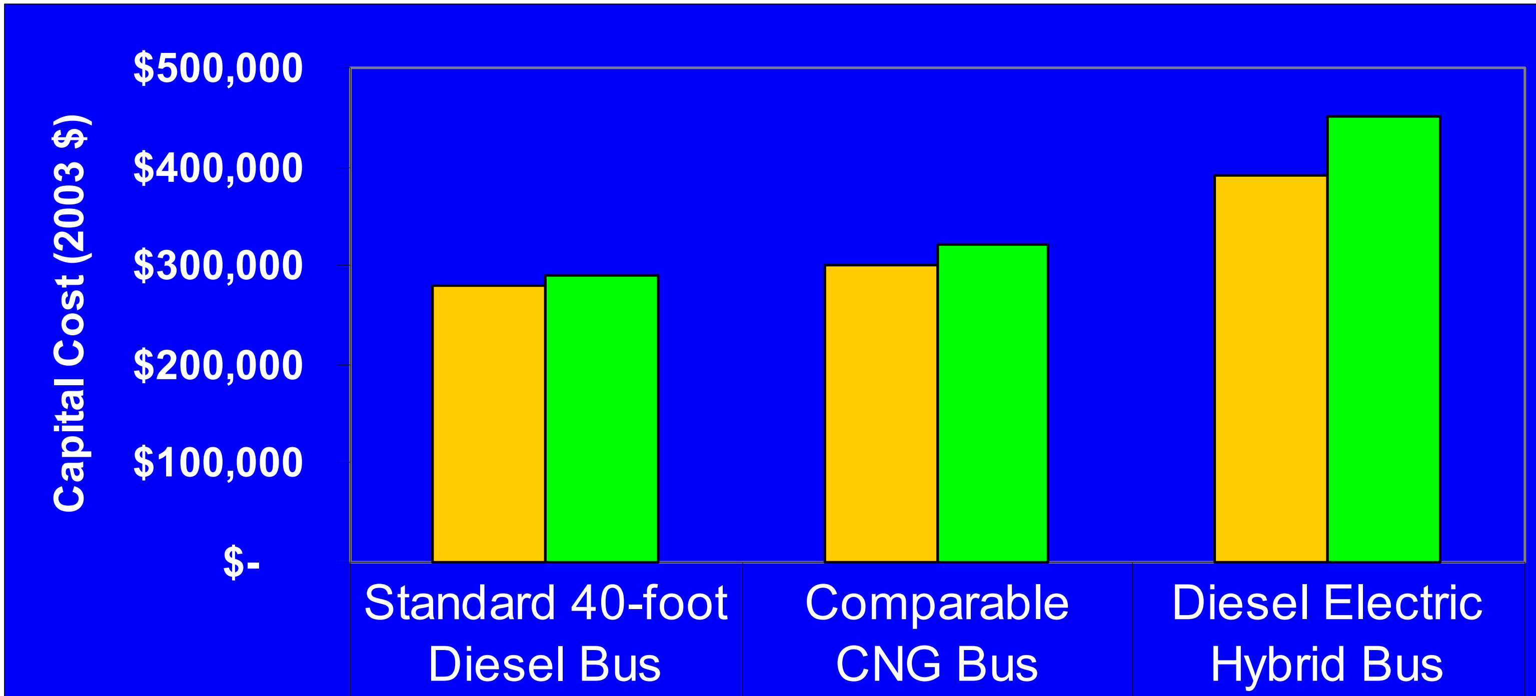
Transit Bus Pricing: Many Variations Specific to Bus Type and Agency

- Many factors dictate the price for transit bus procurements, e.g.,:
  - Bus size, type, fuel, technology, features (e.g., floor type), and options
  - Number purchased, and “piggybacked” procurements
- Generally, bus types produced and sold in the highest quantities are sold for the lowest price (40 ft. conventional diesel ICE buses)
- Low-volume / highly customized buses (e.g., NJ Transit and King County hybrids) are the most expensive

Bus Size / Type	Fuel / Technology	Floor Height Type	Total Quantity Purchased (U.S.)	District Placing Largest Order (Number Ordered)	Average Cost
40 ft. Transit	Diesel Hybrid	High Floor	3	New Jersey Transit (3)	$ 1,034,000
60 ft. Articulated	Diesel Hybrid	Low Floor	1	King County DOT (1)	$ 963,328
60 ft. Articulated	Diesel ICE	High Floor	149	Minneapolis Metro Transit (25)	$ 467,398
60 ft. Articulated	Diesel ICE	Low Floor	380	Chicago Transit Authority (380)	$ 438,084
40 ft. Transit	Diesel Hybrid	Low Floor	145	NY City Transit (125)	$ 401,804
40 ft. Transit	CNG ICE	Low Floor	612	NY City Transit (255)	$ 314,700
40 ft. Transit	CNG ICE	High Floor	179	Foothill Transit, CA (66)	$ 314,207
40 ft. Transit	LNG ICE	High Floor	45	Dallas Area Rapid Transit (45)	$ 313,774
40 ft. Transit	LNG ICE	Low Floor	7	City of Tempe Trans Div (4)	$ 296,927
40 ft. Transit	Diesel ICE	High Floor	599	Maryland Transit Authority (100)	$ 287,726
40 ft. Transit	Diesel ICE	Low Floor	2166	Chicago Transit Authority (125)	$ 281,196

But, as a general rule, NG buses and hybrids cost ~10% and 45% more, respectively

40 foot Bus Cost Comparison: Today's Diesel, CNG, and Hybrid-Electric



	Standard 40-foot Diesel Bus	Comparable CNG Bus	Diesel Electric Hybrid Bus
Low	$280,000	$300,000	$390,000
High	$290,000	$320,000	$450,000

Source: Leslie Eudy, National Renewable Energy Laboratory, and Mathew Gifford, Battelle, draft white paper entitled "Challenges and Recent Experiences with Electric Propulsion Transit Buses in the United States," June 2003.

What about operating costs associated with alternative fuel buses?

- **Generally Includes:** fuel price (with delivery, compression, etc.) facility maintenance, replacement parts, bus maintenance, training and other costs
- **However:** accounting procedures vary - different agencies report significantly different operating costs, based partly on size and location of their operations
- **Maintenance:**
  - Most bus equipment is common to all transit buses and not fuel specific (frame, doors, seats, wheels, brakes, transmission, equipment for the disabled, etc.), so costs to maintain and operate are relatively similar
  - Some maintenance costs can be lower for alt fuels, because the engines burn cleaner and can have longer intervals between rebuilds
  - But, alt fuel engines also have unique, relatively expensive parts (low sales volume) that must be replaced
  - NG buses are heavier than diesel (extra weight of tanks), but brake wear is not always worse than diesel buses (depends on bus loading)
- **Training:** can be a very significant operating cost
  - Fueling procedures and safety
  - Maintenance for computer-controlled engines and new technologies
  - But, this applies to new diesel technologies also (e.g., hybrids, PM traps)

Transit Agencies Have Options on Fueling Stations and Fuel Purchase

- Many transit agencies using CNG or LNG have begun contracting for on-site fueling services with third-party fuel providers
  - Companies build facilities and maintain them for a monthly fee that is added to the delivered cost of the fuel
  - In some cases, the bus operator owns the fueling station at end of contract
- Such arrangements have the potential to save the transit agency money -- if they can use very high volumes of fuel (20,000 DGE per month and up)
- Trillium USA (www.trilliumusa) and Clean Energy (www.cleanenergy.com) are two leading providers of “turn-key” natural gas stations for transit applications
- However, not all transit operators want to share management of their operations, or can use such high volumes of fuel
- One alternative: purchase / operate station and sell fuel to other fleets
- Also, joint use of a refueling facility (station sharing) by several public and private fleets can reduce costs
- DOE and NREL have pursued this station sharing concept through outreach by its Tiger Teams
- Coordinators can play an important role in facilitating station sharing

Operating Costs: Good Comparative Data Are Beginning to Emerge

- Some "apples-to-apples" comparisons of CNG and diesel engine maintenance and repair costs are beginning to emerge
- Natural gas buses have not been on the road long enough in large numbers to provide an ideal comparison
- Early adopters were subject to a fairly steep learning curve, but significant improvements have occurred
- Early buses were under warranty -- agencies were not responsible for many of the high repair costs
- Many in-use CNG buses are now out of warranty, but are only now reaching the point where normal engine overhauls are needed
- It is not clear how far CNG buses can go before an overhaul – therefore the size of this benefit is not known
- Generally, incentive funding is not available to subsidize any increased operating costs
- **Fuel costs are a major issue to transit districts**
  - Alternative fuels have been cheaper than diesel in many cases
  - But, price volatility for all transportation fuels has become commonplace

Diesel Prices for On-Highway Applications Have Been Especially Volatile

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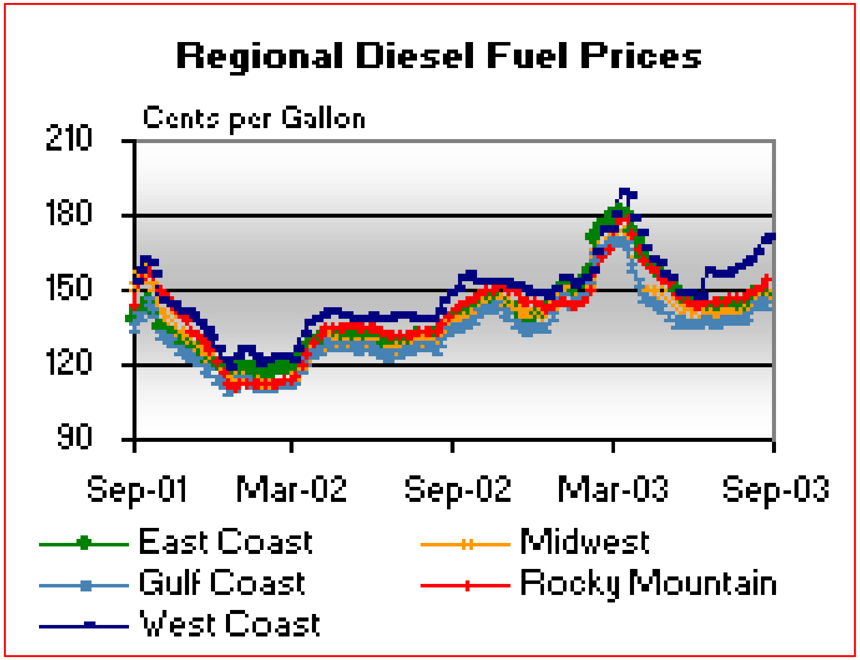
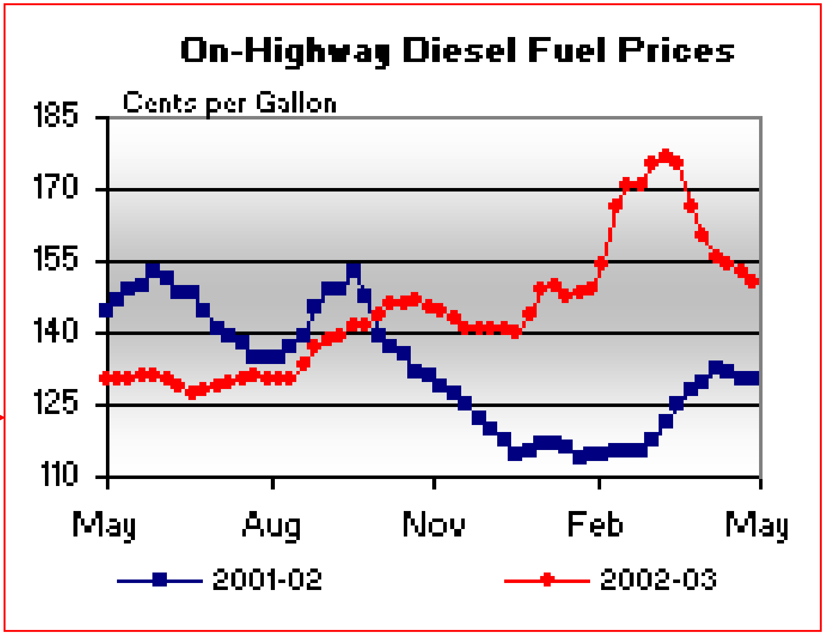
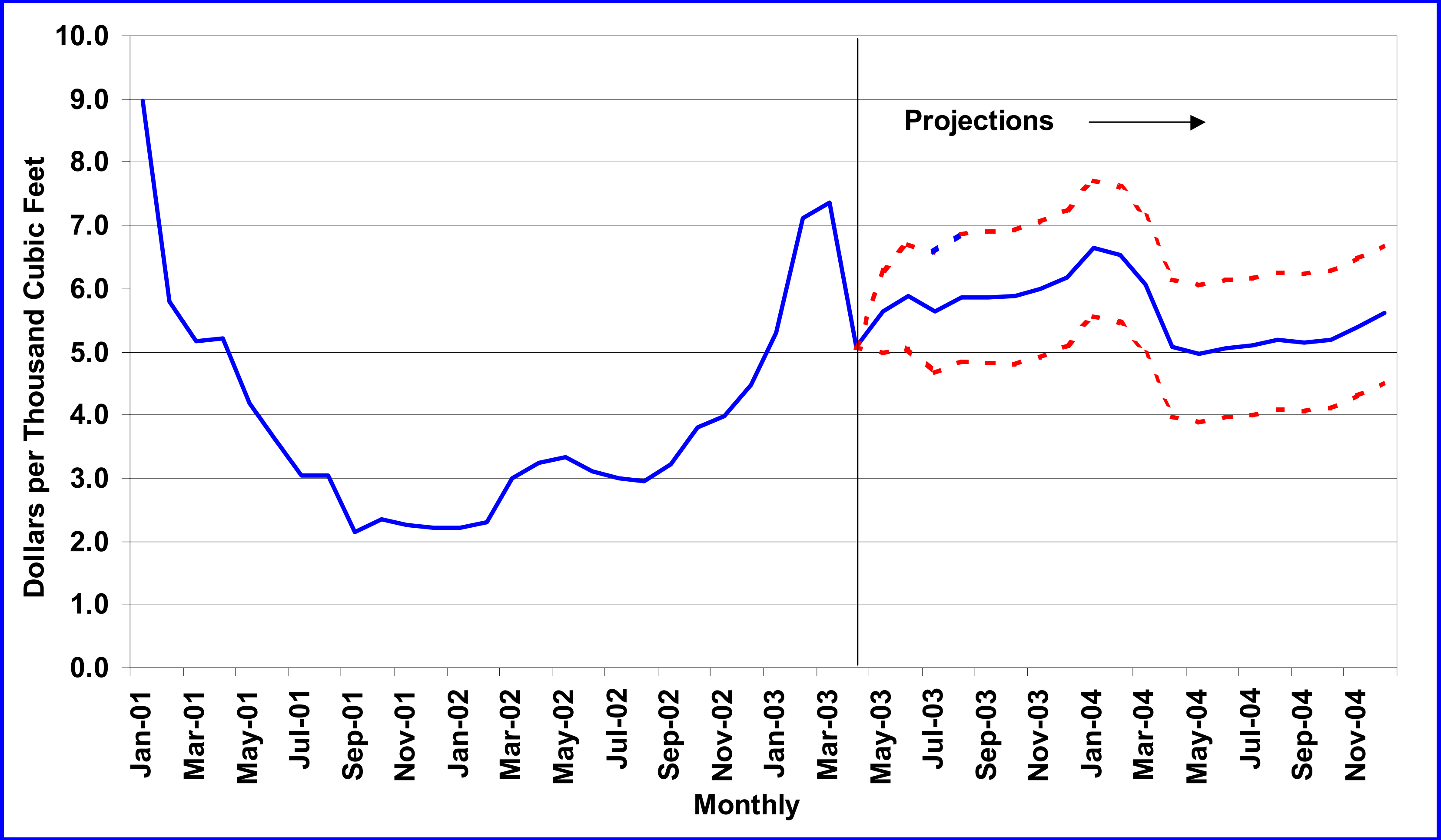


Diesel price trends by region since Sept. 2001

Diesel price volatility: Last two similar 12-month periods



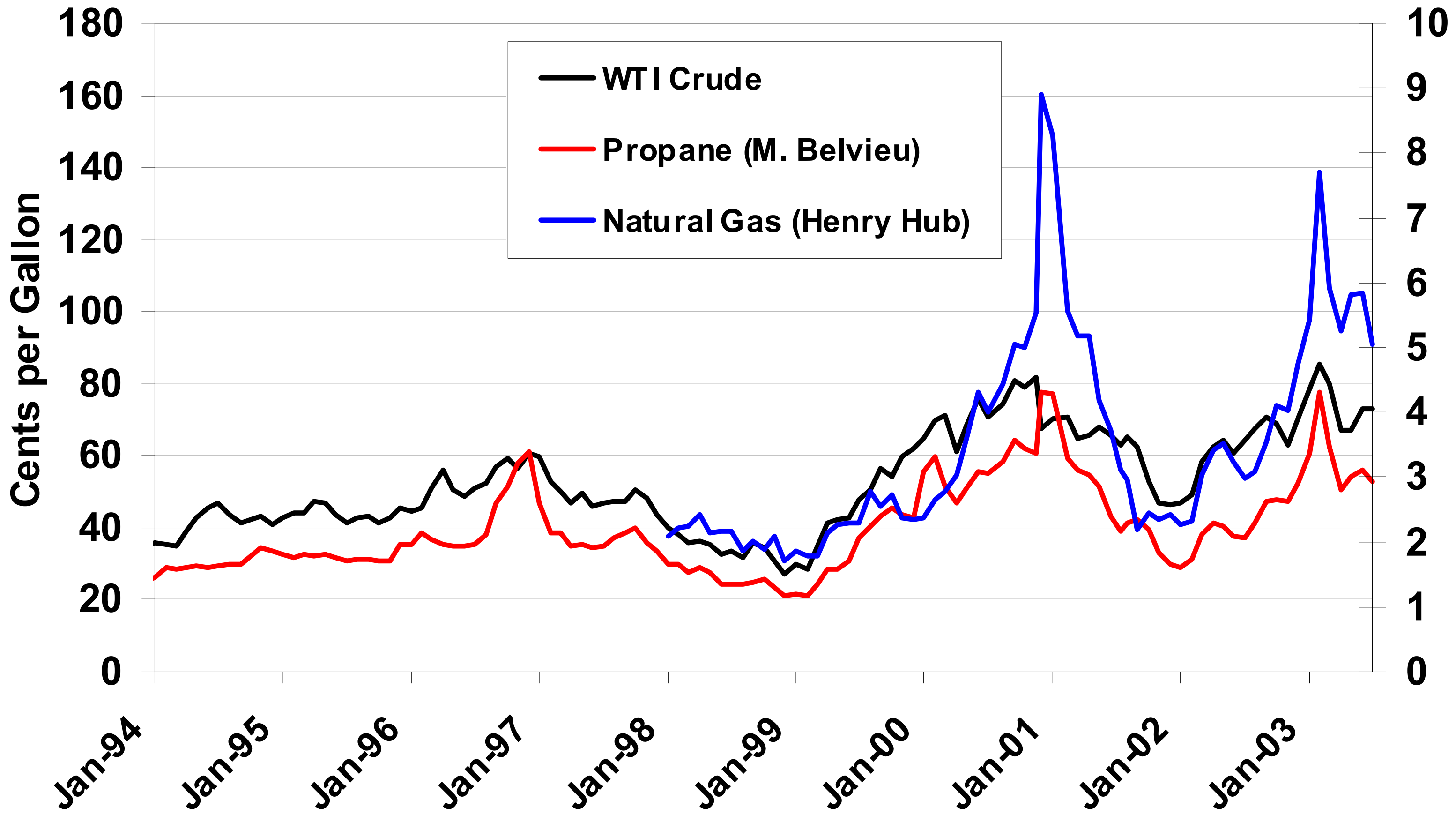
Natural gas spot prices have also been very volatile . . .
. . . but are expected to decline from Q1 2003 Levels



Source: Power Point presentation by William Trappman, EIA, June 17, 2003
Data from 1) Natural Gas Week (history); 2) Short-Term Energy Outlook,June 2003 (projections).

Propane Prices Generally Follow Crude Oil and Natural Gas Prices (EIA)

Spot Prices



Source: DRI Platt's Spot Prices

Note: EIA did not define "Gallon" in this chart. Use this chart only to compare pricing trends.

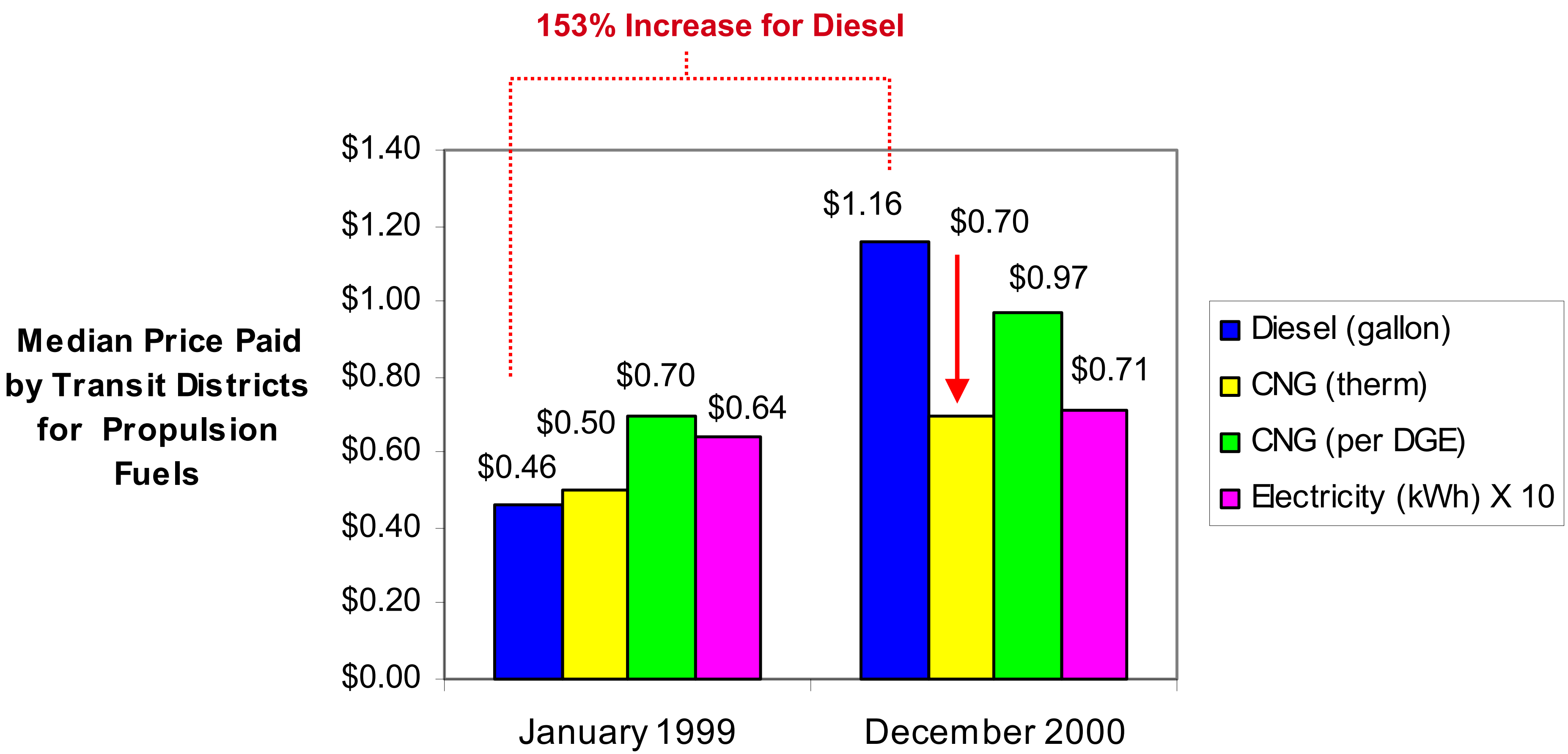
APTA's Fuel Price Survey <u>for Transit Districts</u> (Jan. '99 to Dec. '00)

APTA conducted a "Survey of the Effects of Increased Energy Prices on Public Transportation in the United States and Canada" during December 2000

Respondents to that survey reported the following:

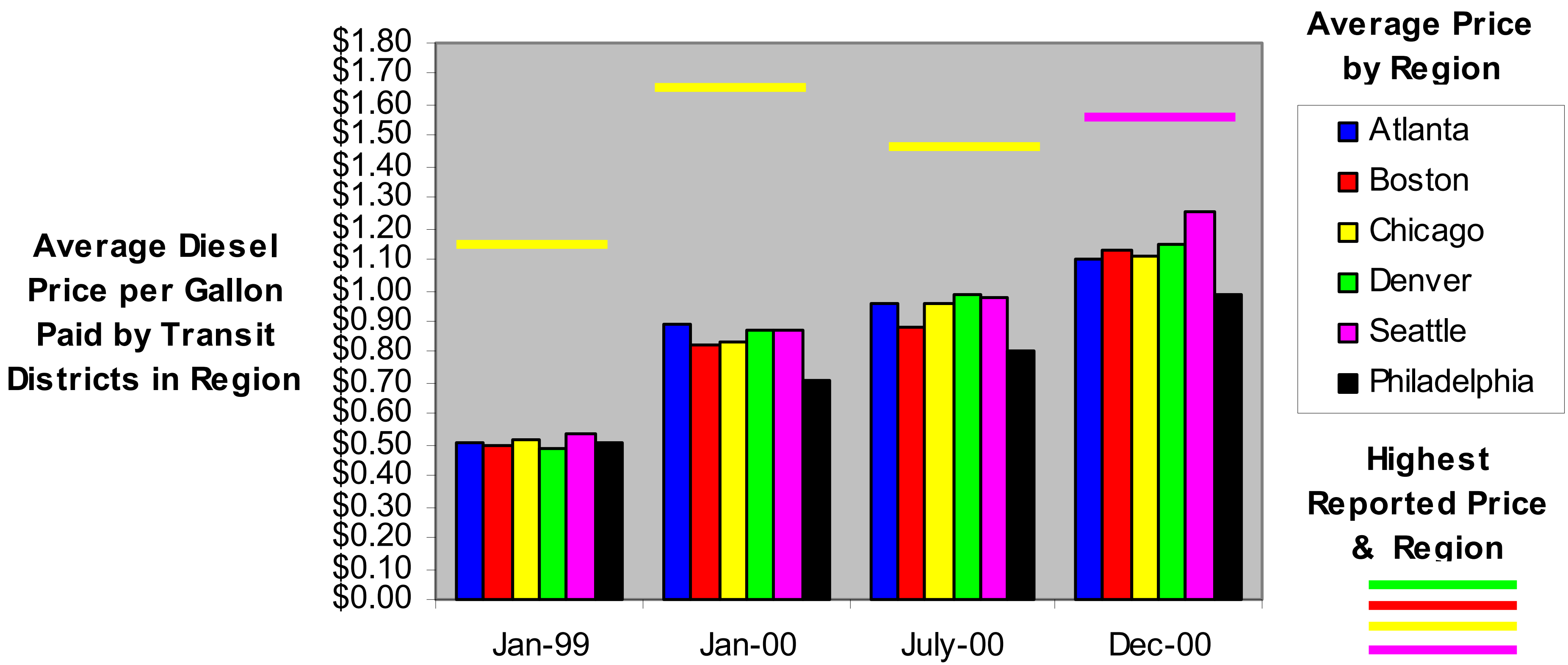
- The median price paid for diesel fuel increased 153 percent, from $0.4583 per gallon to $1.1581 per gallon.
- The median price paid for compressed natural gas increased 38 percent, from $0.5033 per therm to $0.6989 per therm.
- The median price paid for electricity (for propulsion power) increased 10 percent, from $0.0644 per kilowatt hour to $0.0710 per kilowatt hour.
- Long-term fuel contracts:
  - 38% of respondents had long-term fuel contracts, 56% did not, and 6% did not respond to the question
  - Existence (or absence) had no strong effect on energy price variations during the dates the survey was conducted (NOTE: long-term contracts have merits beyond this issue)
- More than 75% of responding transit agencies indicated they would need to take actions as a response to increased fuel costs
- The most frequent responses to rising prices (in order of frequency) were:1) Reduce other operating costs, 2) Transfer funds from reserves, and 3) Increase fares

Median Price Increases Paid by Transit Districts for Propulsion Fuels (Diesel, CNG and Electricity) From Early 1999 to Late 2000



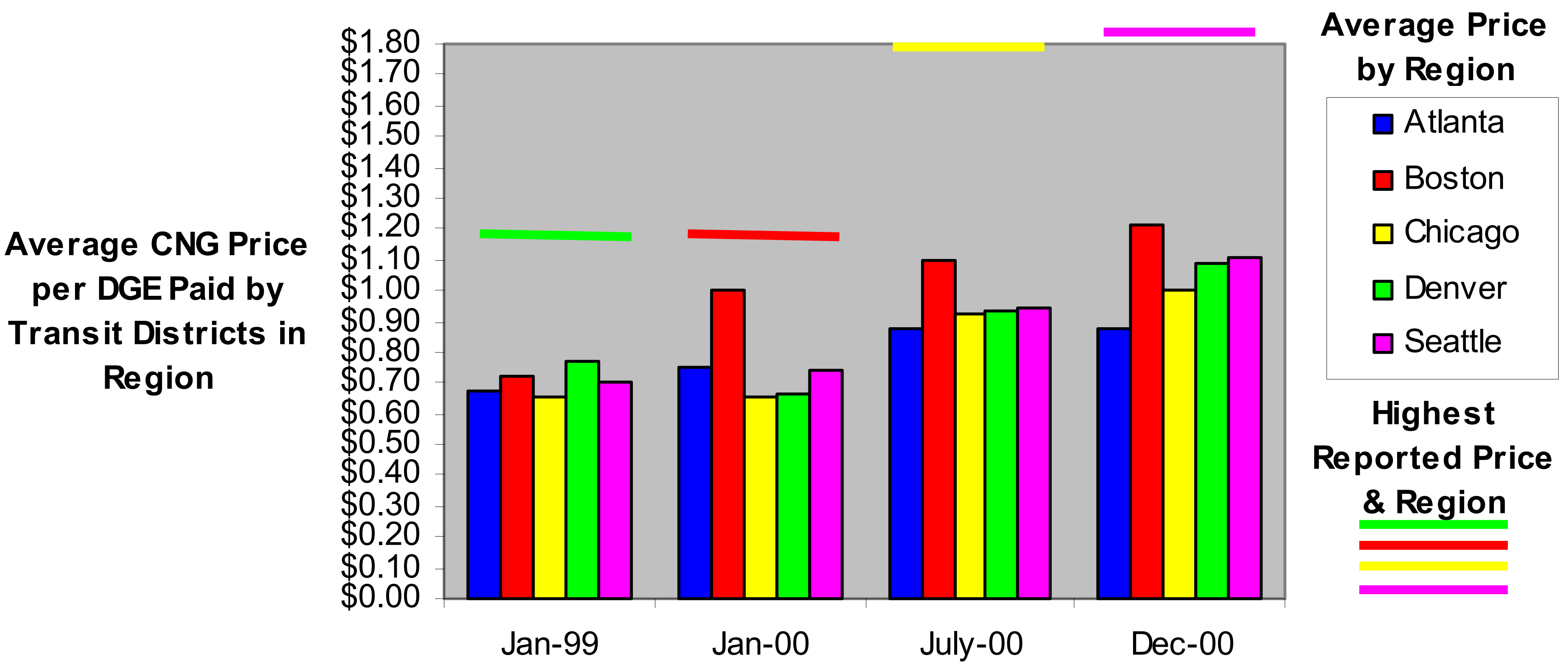
Source: APTA, "Survey of the Effects of Increased Energy Prices on Public Transportation in the United States and Canada," online at (http://www.apta.com/research/info)

Average and Peak Diesel Prices (per Gallon) for Transit Districts by DOE Region



Source: APTA, "Survey of the Effects of Increased Energy Prices on Public Transportation in the United States and Canada," online at (http://www.apta.com/research/info)

Average and Peak CNG Prices (per DGE) for Transit Districts by DOE Region



Source: APTA, "Survey of the Effects of Increased Energy Prices on Public Transportation in the United States and Canada," online at (http://www.apta.com/research/info)

DOE / APTA Workshop: Transit Agencies Can "Pay Less for Natural Gas"

- DOE's Natural Gas Vehicle Technology Forum provides ongoing assistance to NGV user fleets, including a special "Transit User's Group" (TUG)
- DOE joined with APTA to host a "Natural Gas Purchasing Workshop" in November 2003
  - Part of APTA's 2003 Bus Equipment and Maintenance Workshop
- Designed to help transit agencies learn about:
  - Current status of natural gas supply
  - How to take advantage of the "dynamic" energy market
  - Fuel supply options of transit agencies using natural gas (CNG or LNG)
  - Utility ratemaking and contract negotiations
  - Case studies of transit fleets that have negotiated "good deals"
- Additional information on the workshop at: **http://www.ott.doe.gov/ngvtf/pdfs/ng_purchasing_workshop_flyer.pdf**
- Similar workshops in other areas of the country may follow
- Clean cities coordinators can get access to proceedings and presentations by contacting NREL's Richard Parish (303-275-4453)

Operational Costs for Diesel Technologies Will Increase

- **New components** may be needed for all diesel buses, as progressively more stringent NOx and PM standards are phased in
  - New fuel management systems
  - Aftertreatment devices such as particulate traps and catalysts
  - Careful **INTEGRATION** of engine strategies (EGR, etc.), cleaner fuels, and aftertreatment devices
- These devices and technologies will **increase the maintenance costs** of diesel engines
- This trend is already being seen in field trials of DPFs (e.g., NYC Transit)
- These increases may tend to close any gap between the maintenance costs of diesel engines and alternative-fuel engines
- Natural gas engines already approach 2007 NOx levels (with averaging) -- and therefore **may not require extensive redesign and improvements by manufacturers** (at least until the 2010 time frame)
- **Diesel fuel price increases (transition to ULSD)** will add to diesel bus operational costs

Summary Outlook: Life-Cycle Costs for Alternative Fuel Transit Buses

- Costs for natural gas buses are best documented, due to numbers deployed
- Initially, CNG and LNG bus fleets are likely to have higher maintenance costs
- Availability of more reliable NG engines, and operation of diesel engines meeting future lower emission standards, will tend to decrease this difference
- Together, these changes should close the gap, and result in equivalent to slightly higher maintenance costs for NG transit buses
- Special fuel-purchasing deals are available for transit - **VOLUME** is the key
- Fuel costs per mile, including NG compression or liquefaction, can be lower for NG fleets (except in times of extreme NG price spikes)
- The increased price of ULSD needed for future diesel engines, or fuel costs associated with the possible use of SCR systems (e.g., urea) should accentuate this difference
- Total operating costs of new NG fleets in the future are estimated to be only slightly higher than new diesel fleets
- The capital costs for NG fleets -- initial bus purchase price and the refueling and facility modification costs -- will continue to be higher than diesel fleets
- Incentive funds exist to help offset these costs, and will be needed in the future