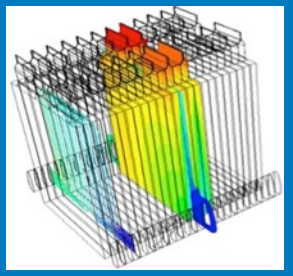
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Developing a Natural Gas-Powered Bus Rapid Transit Service



A Case Study on Leadership: Roaring Fork Transportation Authority

Green Truck Summit
Indianapolis, Indiana

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National Renewable Energy Laboratory

Photo by Dennis Schroeder, NREL 17613

NREL at a Glance

- Only U.S. National Laboratory dedicated to renewable energy and energy efficiency research
- Established in 1979 as Solar Energy Research Institute
- About 2,400 employees with world-class facilities
- Owned by the Department of Energy, operated by the Alliance for Sustainable Energy

U.S. DOE Clean Cities Program

Clean Cities Mission

To advance the energy, economic, and environmental security of the United States by supporting local decisions to reduce petroleum use in transportation.

- **Federal program established in 1992 to support local initiatives to reduce petroleum consumption**
- **Nearly 100 coalitions throughout the United States**
- **660,000 AFVs using alternative fuels**
- **Case studies and other information available at:**

www.afdc.energy.gov

Roaring Fork Transportation Authority (RFTA) - Overview

RFTA at a Glance:

- 2nd Largest public transit system in Colorado serving 4.9 million passengers in 2014
- Created in 1983 as a Regional Transportation Authority
- Maintains pedestrian and rail corridors along the Rio Grande Railroad line
- 2012 White House Champions of Change Transportation Innovator
- Operating the 1st Rural BRT System in the United States

RFTA operates along a 70-mile corridor in Colorados Western Slope serving Aspen, Snowmass Village, Pitkin County, Basalt, a portion of Eagle County, Carbondale, Glenwood Springs and New Castle

RFTA– BRT Service

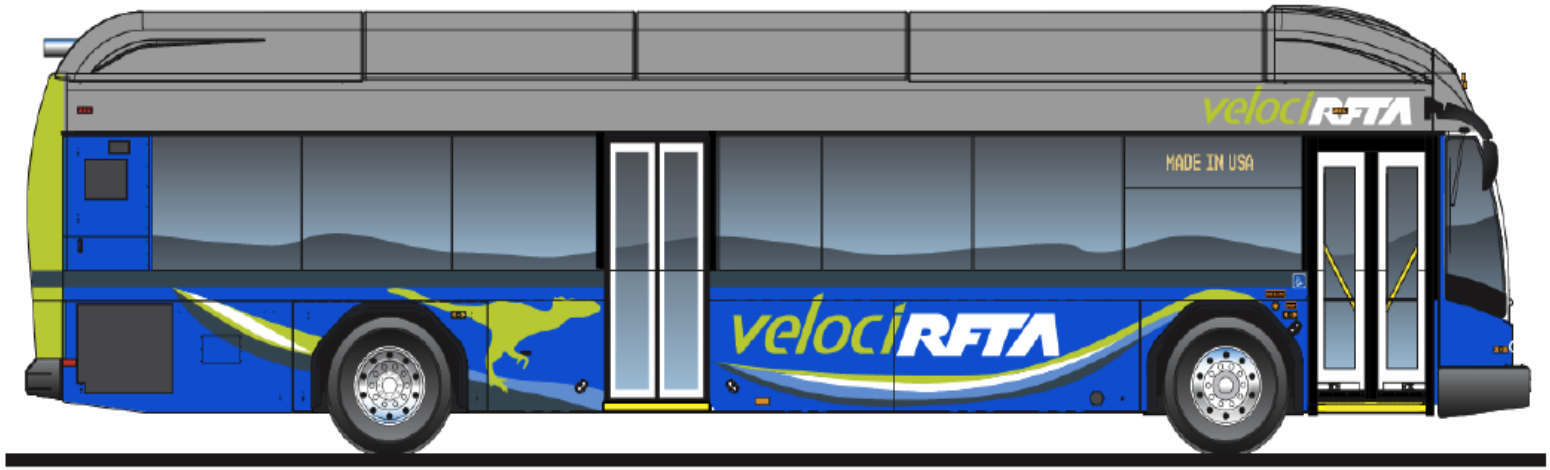
- BRT selected among other options to address growing demand
- $46 million capital investment
- 13 year process to plan, design, and construct facilities and operations for BRT service
- 13 stations in nine locations
- One-hour ride from Glenwood to Aspen (~40 miles) 10-12 minutes between buses during rush hours, 15-30 minutes off-peak
- 18 new low-floor compressed natural gas (CNG) buses equipped with free wi-fi

Making the Decision to Use CNG - Timeline

RFTA had been planning the BRT service for 11 years prior to deciding to use CNG

Aug 2011	• Initial Discussion on CNG as Potential Fuel for RFTAs BRT
Sept 2011	• CNG Solutions Summit Held
Dec 2011	• Facilities Upgrade and Fueling Infrastructure RFPs developed
Dec 2011	• Conditional notice intent given to Gillig
Mar 2012	• RFTA Board votes to move forward with CNG
Aug 2012	• Construction on facility and fueling facilities commence
Nov 2012	• Construction on facility and fueling facilities completed
Jan 2013	• Initial CNG buses received by RFTA
Jan 2013	• 4 CNG buses enter service for Winter X Games
Sept 2013	• VelociRFTA BRT service commences

Making the Decision to Use CNG – Rationale



Rationale for CNG

- Domestic fuel source
- Increasing supply
- Less price volatility
- Fuel diversity
- Lower lifecycle costs of fleet operation

Considerations

- Engine Performance
- Bus Performance
- Operational Concerns
- Warranty
- Project Schedule
- Gas Quality
- Mechanic Training
- Facility Modification
- Fueling Indoors

Making the Decision to Use CNG – Concerns

Federal Transit Administration Concerns

- Project delays resulting from additional work to fuel on CNG
- Environmental permitting issues and impacts
- Additional long-term operating costs from CNG
- Demonstration that all issues related to fueling with CNG have been identified and there is a plan to address them

RFTA Concerns

- Staffing for additional work
- Design, engineering, procurement, and construction of additional facilities
- Ability to modify bus purchase
- Training

Community Concerns

- Environmental impact
- Dialogue around natural gas extraction in the region
- Cost and schedule
- Technology familiarity

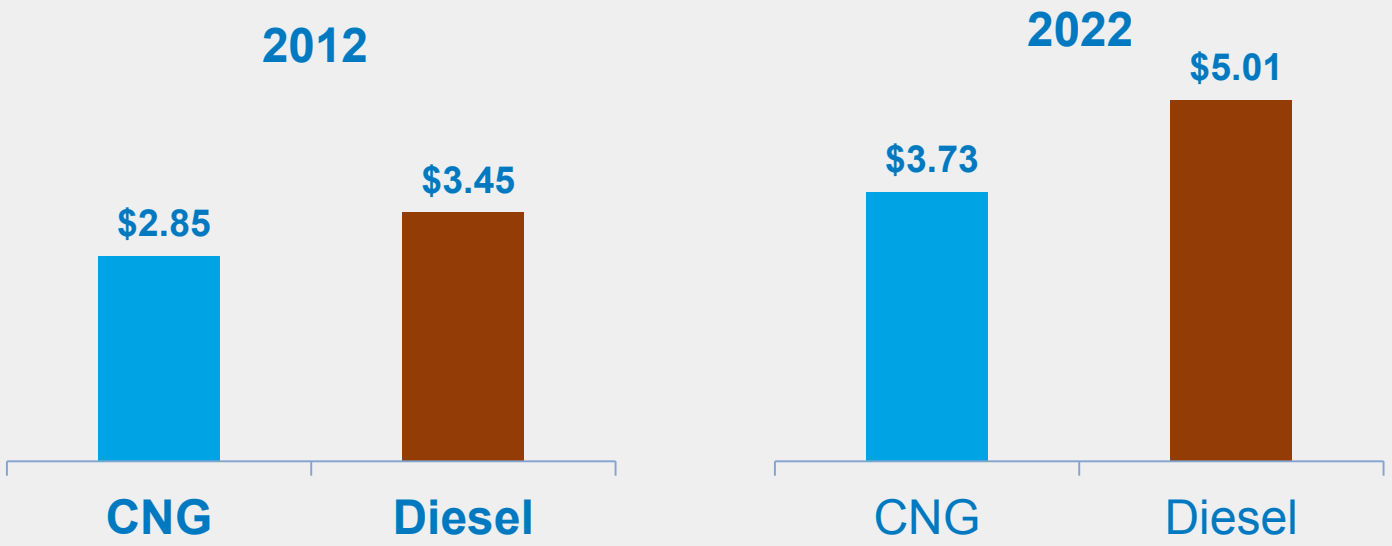
Making the Decision to Use CNG – Business Case

Operating on CNG is expected to save RFTA $250K-$300K per year

- Savings to come through fuel costs; actual savings in 2014 were $104K
- Additional expenses for buses, facility modifications, and fueling infrastructure

CNG provides a hedge against diesel prices

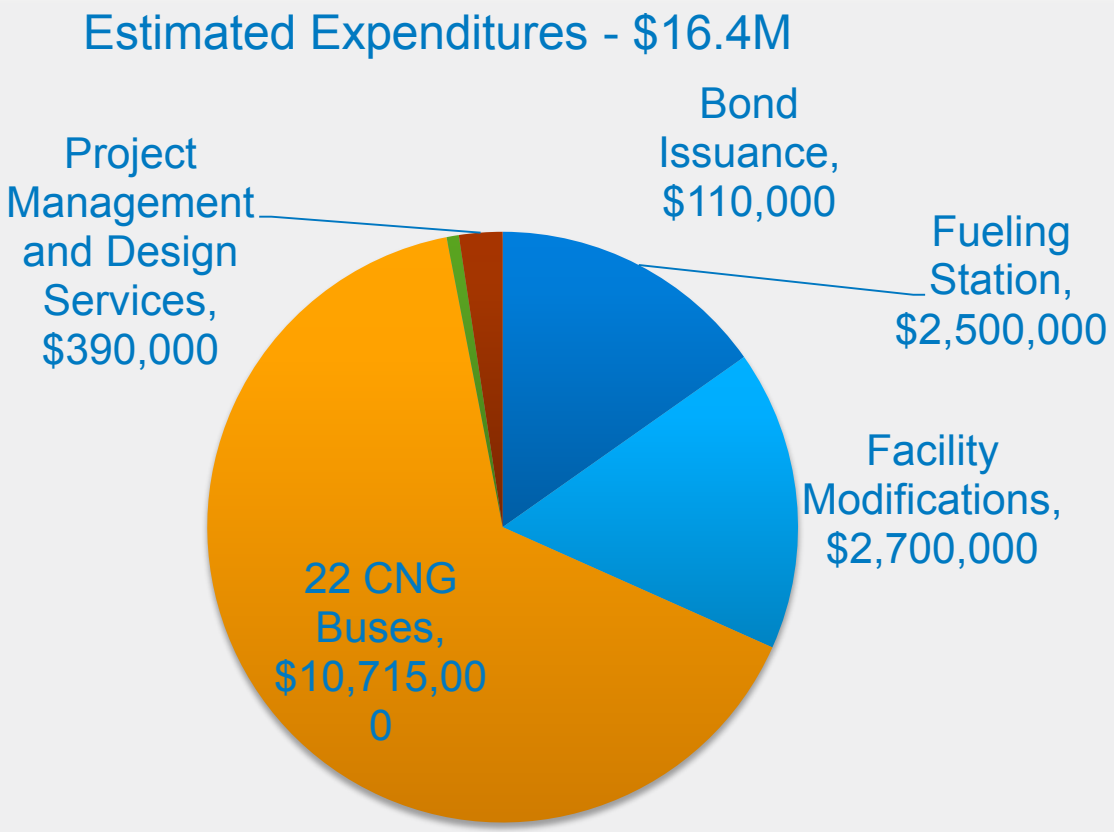
RFTA Projected Fuel Prices in 2012 and 2022 (DGE)



Making the Decision to Use CNG – Financing

3 Primary Revenue Sources to Cover Expenses

- Federal Transit Administration Grant ($9.4M)
- Qualified Energy Conservation Bonds Issued by State of Colorado ($6.65M)
  - Bond issued against fuel cost savings
- Grant from Encana ($365K)



Making the Decision to Use CNG – Due Diligence

CNG Fueling Facility Field Trip

- City of Fort Collins
- Denver International Airport

Aspen Strategy Center Solutions Summit

- Convened industry and technical experts to determine viability of CNG

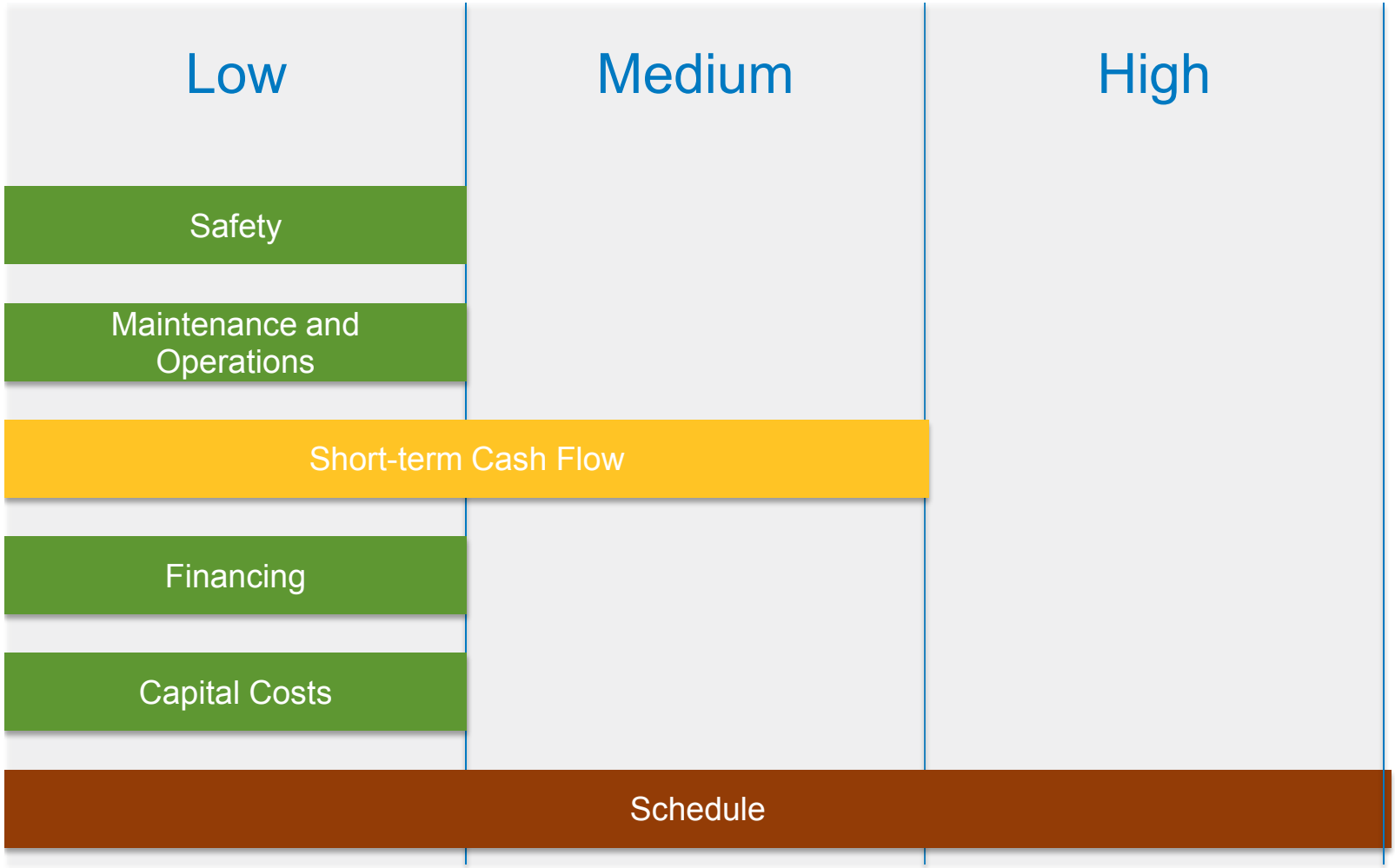
CNG Engine Reliability Issues at altitude

- Contacted Utah Transit Authority (UTA) and Santa Fe Transit regarding CNG bus operation at 6,000+ feet of elevation
- Conversations with with Cummins to discuss CNG ISL-G engine
- Contacted other transit operators using Gillig CNG Buses

RFTA hired SGM to manage the implementation of CNG

Making the Decision to Use CNG – Project Risks

Primary Risks Were Cash Flow and Schedule After Decision to Fuel With CNG



Making the Decision to Use CNG – Public Dialogue

Part of a Larger Conversation

- RFTA discussion served as a proxy for a local and statewide discussion on hydraulic fracturing and extraction in the region
- RFTA service territory located near Thompson Divide, which has been the subject of numerous legal challenges regarding energy leases

Aspen City Council Review

- Concerns raised over the use of natural gas and the consideration of alternative technologies such as diesel hybrids
- RFTA presented information that demonstrated benefits, challenges, and uncertainties of CNG

Vehicle Selection and Specifications

Initial bus order called for 22 CNG buses to be purchased

- 18 dedicated to BRT service

40-foot Gillig Low-Floor Buses

- Cummins ISL-G engine
- 155 Diesel gallon equivalents

Fueling Infrastructure - Considerations

Questions around Fueling Procedures and Operation

- Fueling profile
- Natural gas pressure/quality/volume available
- Electrical service and rates
- Fueling station equipment
- Fast fill v. time fill
- Redundancy
- Efficiency
- Fueling rate
- Defueling

RFTA Fueling and Maintenance – Fueling Indoors

Fueling Indoors Provided Operational Efficiencies

- Wanted similar process for CNG and diesel buses
- It gets cold in Glenwood...
- Only 1 or 2 other CNG indoor fueling facilities in the country supporting transit

Considerations

- Deflagration venting
- Dedicated HVAC
- Class 1, Div 2
  - Electrical
  - HVAC equipment
  - Fire separations
- Methane detection & controls
- Emergency Response
- Building Official & Fire Marshall

Maintenance Infrastructure

RFTA Glenwood Maintenance Facility Safety Modifications

- Deflagration venting
- HVAC
- Electrical
- Ventilation
- Methane detection & controls
- Overhead doors

MW Golden Constructors Hired as Contractor to Oversee Facility Modifications

Fueling Infrastructure – Codes and Standards

Fueling Indoors Required Additional Consideration of Codes and Standards and Additional Coordination with the Fire Marshall

- 2009 IBC – International Building Code
- 2009 IFC – International Fire Code
- 2009 IMC – International Mechanical Code
- 2009 IFGC – International Fuel and Gas Code
- 2009 IEC – International Energy Conservation Code
- 2009 IPC – International Plumbing Code
- NFPA 30A - Code for Motor Fuel Dispensing Facilities and Repair Garages
- NFPA 52 – Standard for CNG
- NFPA 55 – Compressed Gases and Cryogenic Fluids Code
- NFPA 70 – National Electric Code
- NFPA 88B – Standard for Repair Garages
- ANSI B31.3 Chemical Plant and Petroleum Refinery Piping
- ASME Section VIII – Boiler and Pressure Vessel Code
- NEMA – National Electrical Manufacturers Association
- OSHA – Occupational Safety and Health Administration
- SAE J616 – Recommended Practice for CNG Vehicle Fuel

Fueling Infrastructure - Specifications

RFTA selected Trillium as its CNG Fueling Station vendor

4-stage compression for CNG

- 275 DGEs of CNG storage
- 1200 amp electric service
- Up to 40 psi gas service from utility
- 400 kW emergency diesel generator
- Additional compression for redundancy and expansion

Fast-fill with two dispensers

- Indoor single dispenser
- Outdoor dual-nozzle dispenser

Ability to defuel into on-site storage

Remote monitoring of fueling operations

Training and Initial Vehicle Demonstration

4 CNG Buses Were Delivered in January 2013 to Familiarize Operators with CNG Buses

- Buses provided service to 2013 X Games
- CNG buses were found to be quieter

Training Program Developed with Colorado Mountain College

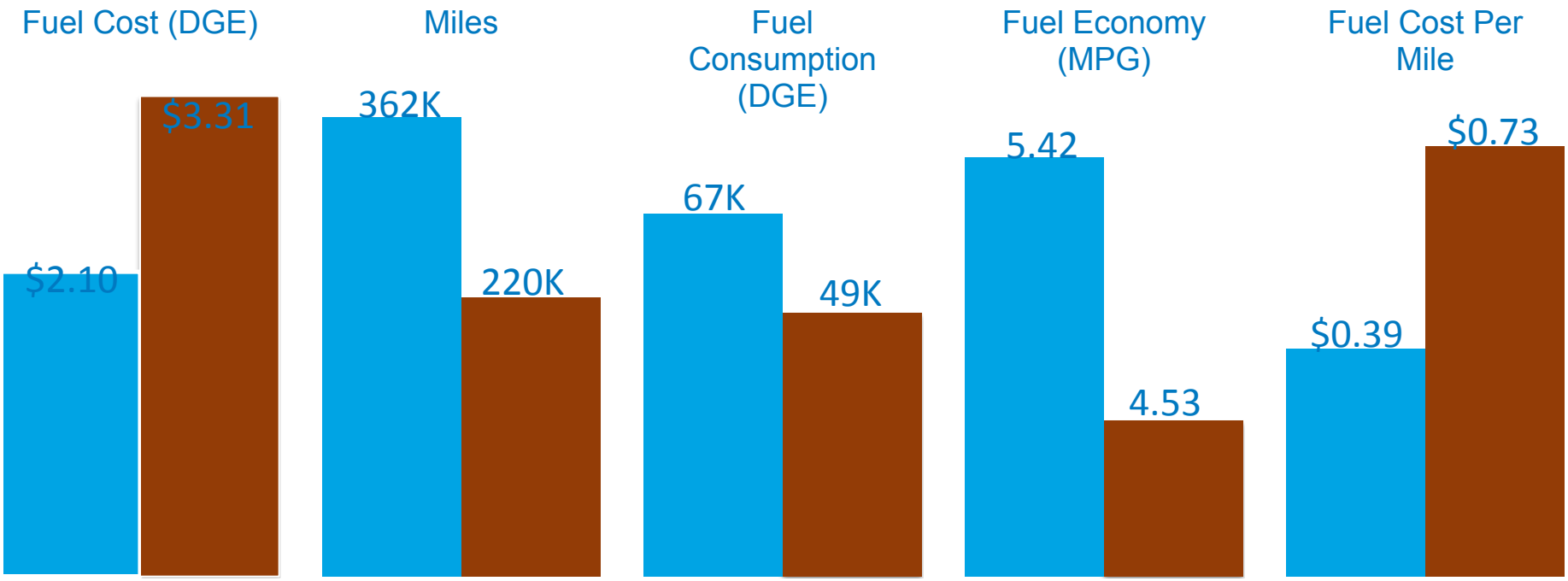
- Driver and maintenance technician training

Technician Training Limited Due to Warranty and Support from Cummins

RFTA Experience –CNG Performance and Costs

Natural Gas has Demonstrated Cost Efficiency Benefits in RFTAs Fleet*

*Data is taken from January-October 2013. It should be noted that diesel bus fleet is older and more diverse than its CNG fleet



CNG Bus Performance in Blue

Diesel Bus Performance in Red

RFTA Experience –CNG Maintenance Costs

RFTA Estimated an Increased Maintenance Cost of $40-45K per 500K Miles per Bus*

*This is based on Federal Transit Administration estimates. It should also be noted that diesel bus fleet is older and more diverse than its CNG fleet

ISL-G natural gas engine is spark ignited

- Spark plug maintenance is required

Diesel engine is compression ignited

- Additional cost and maintenance required for aftertreatment

CNG

Diesel

Routine Maintenance

$1,200 every 25,000 miles

Oil Changes

6,000 miles

*Required by Cummins as part of warranty

Routine Maintenance

$1,200 every 150K-200K miles

Oil Changes

10,000 miles

DPF Cleaning

$600/ year

RFTA Experience with CNG – Unforeseen Hurdles

Fuel contamination issues from oil carryover
- Attributed to lack of maintenance and training
- Fuel filter was not being serviced properly

Piston cracking issue being investigated
- Cummins has been responsive to concerns and has provided a RFTA with a dedicated technician

Air filter difficult to access to ensure proper seal when servicing
- Integration issue with Gillig chassis

Cummins Rocky Mountain did not have much history on ISL-G inventory to know what parts to have in stock

RFTA Experience with CNG – Lessons Learned

Get buy-in from front-line employees

Communicate early and often with local officials, particularly the fire and buildings code officials

It is important to have good working relationships with vendors

RFTA had initial concerns about durability and reliability, but they run well for the most part

- When buses go down, they are down for a while as staff and vendor familiarize itself with a new product

Difficulties in calculating diesel gallon equivalence, which is critical to validating fuel savings

- Need to convert to gasoline gallon equivalent for federal tax credit

RFTA signed a take or pay contract for operations and maintenance of its CNG station

- BRT demand has required RFTA to rotate larger, diesel coach buses into service

Thank **You**

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Learn more at
www.nrel.gov/transportation