Steamboat Springs Transit
Transit Alternative Fuel Systems Analysis

May 13, 2014

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APPENDIX

1. Alternative Fuel Research and Interview

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We also with to thank Steve Andrews, retired energy consultant, for providing peer review of the 'Projected Energy Price Analysis' section of this report; and John Gonzalez, Senior Engineer - Advanced Vehicle Deployment at the National Renewable Energy Laboratory (NREL), who provided peer review of the entire report.

Cover Photo by Scott Franz, Steamboat Today

Executive Summary

As defined by Steamboat Springs Transit (SST), the intent of this project is to "perform an analysis and feasibility study of alternate clean fuel systems and options for transit vehicles in Steamboat Springs, Colorado." Specifically "This project will assess clean fuel transit systems in a mountain environment and research, evaluate, analyze and present findings regarding the cost, performance, carbon footprint, vehicle and infrastructure implementation needs, and feasibility for implementing various clean fuel alternatives in Steamboat Springs." In addition, this report also includes an analysis of projected long-term energy prices.

Summary of SST and Alternative Fuels

SST provides local and regional service with a fleet of 24 buses in a rural resort community with a cold climate, high altitude (6,732') and varying terrain. It has evaluated nearly all alternative fuels in the past and currently runs 4 diesel/electric buses and uses a 5% biodiesel blend in all of its buses. The Steamboat Springs community generally supports alternative fuels, particularly if they reduce air and noise pollution and don't negatively affect service levels.

According to the American Public Transit Association (APTA), the percentage of public transit buses in service in the U.S. powered by alternative fuels increased from 2% in 1992 to 36% in 2011, which is at least 10 times as many alternatively fueled buses as alternatively fueled cars. The breakdown by fuel source is as follows:

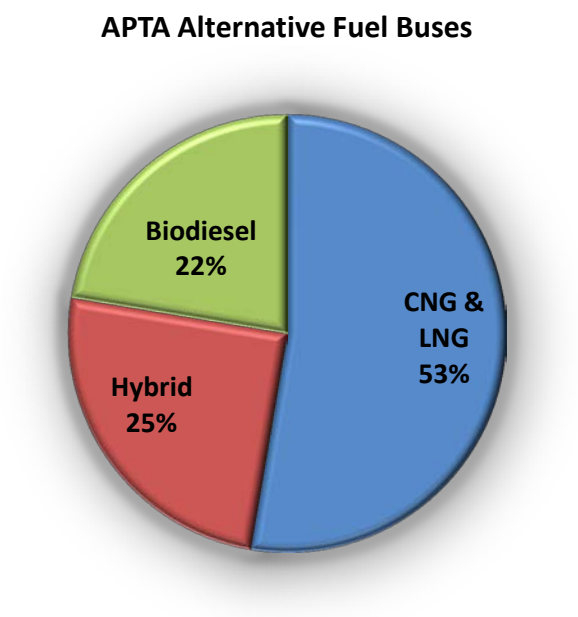


Figure 1: APTA Alternatives Fuel Buses

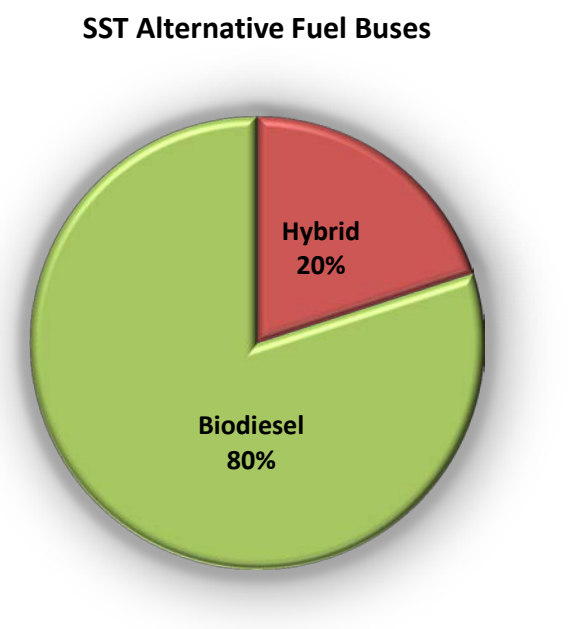


Figure 2: SST Alternative Fuel Buses

Summary of Analysis

The alternative fuel technologies considered in this study include diesel, diesel-electric hybrid, compressed natural gas (CNG), and battery-electric. Diesel is considered the baseline to which the other technologies were compared. Because SST has extensive experience with diesel and several years' experience with hybrids, research centered around reviewing historical SST data on diesel and hybrids, and researching other transit-specific information for CNG and battery-electric buses. While there are certainly other alternative technologies available, no others were considered viable for SST and therefore worthy of inclusion of this analysis.

The methodology of this analysis was as follows:

1. SST Data Review: Review bus performance data for SST fleet.
2. Literature Review: Perform a review of recently published or otherwise relevant information regarding the performance of CNG and battery-electric buses.
3. Transit Agency Representative Interviews: Inquire about bus performance and lifecycle costs.
4. Vendor Interviews: Inquire about bus performance and lifecycle costs.
5. Web research: Research applicable case studies, vehicle performance information or other pertinent information.
6. Energy Price Analysis: Research historical trend data for diesel, electricity and natural gas prices via the Energy Information Administration (EIA) website and from SST-specific data and utility information; research projected price information via industry trade websites and for SST-specific natural gas and electricity suppliers.
7. Lifecycle Cost Modeling: Develop a custom excel-based model to analyze the different variables associated with the baseline alternative fuel technologies included in this analysis.
8. Peer Review: Conduct third party peer review for both alternative fuel analysis and energy price analysis.
    - Alternative Fuel Analysis peer review provided by John E. Gonzales, Senior Engineer, Advanced Vehicle Deployment, National Renewable Energy Laboratory (NREL).
    - Energy Price Analysis peer review provided by Steve Andrews, retired energy consultant and freelance writer.

Summary of Key Findings

- SST recently purchased (3) new hybrid buses with (3) more to be purchased in the near future. Six diesel buses are currently being refurbished. The next significant bus purchase is not planned until 2019.
- Due to significant budget constraints and the potential to receive grants for capital purchases, reducing operating expenses, especially fuel expenses, is a high priority.
- Because of the high volatility of diesel, the business as usual approach is highly susceptible to large price swings that, due to historically fixed operating expenses, could result in additional service reductions. Diversifying fuel sources will provide more stability in overall fuel costs.

- SST has explored and accepted the viability of Proterra battery-electric buses and therefore this option is more viable than if this due diligence had not been done. According to transit agency representatives interviewed, these buses are operating well.
- The Roaring Fork Transportation Authority's (RFTA) experience with CNG has been very positive to date and because of the very similar climate and operating conditions, demonstrates that CNG is a viable alternative for SST.
- Perhaps the most significant variables in determining lifecycle costs will be: 1) the future cost of energy; 2) the availability of grants to offset the cost premium of buses and/or infrastructure; and 3) the number of alternative fuel buses purchased.

Summary of Alternatives

Alternative	Advantages	Disadvantages
Diesel	Lowest cost bus; lowest lifecycle cost (under current conditions); familiarity with the technology	Susceptible to volatile and increasing cost of diesel; air pollution associated with diesel; noisiest alternative
Hybrid-electric	12% lower annual fuel costs; reduced noise; familiarity with the technology	Higher cost of buses; susceptible to volatile and increasing cost of diesel; more maintenance than diesel, potential battery replacement needs
Compressed Natural Gas (CNG)	Second lowest annual fuel costs; low projected price volatility; lowest lifecycle cost when most of fleet is replaced and infrastructure costs can be significantly offset with grants	Highest capital expenses - constructing a fueling station and upgrading the maintenance facility; higher cost of buses; unfamiliarity with the technology
Battery-electric	By far lowest annual fuel costs; lowest projected price volatility; lowest maintenance cost, lowest lifecycle cost when bus cost premium can be significantly offset with grants	By far highest bus cost; battery replacement needs; route scheduling challenges due to recharging; unfamiliarity with the technology

Table 1: Summary of Alternative Fuels Analyzed in this Report

Summary of Recommendations

Successfully managing a public transit operation is both technically and financially challenging. It's a continuous balancing act of providing reliable service at a reasonable cost with significant variables, not least of which is the cost of fuel. While the primary drivers for evaluating alternative fuels may be environmental stewardship, fuel diversity and/or sourcing local fuels, it is imperative that the entire fleet operate reliably, on schedule and within budget. For this reason several factors were considered with respect to performance, capital costs and operating costs. The Lifecycle Cost Model was created so that the different costs and the variables affecting these costs could be compared over the life of the bus. It is important to point out that as these variables change, so do lifecycle costs. All this is to say that the alternative with the lowest lifecycle cost and best score may and likely will change as conditions change.

For this reason, there isn't one 'winner', but rather specific recommendations on how to pursue each alternative depending on conditions, including present conditions. These recommendations are based on SST's stated priorities as well as SGM's research and analysis. Until conditions warrant re-evaluation, SGM recommends the following:

1. Continue current plan to acquire grant funding for hybrid bus purchase.
2. Begin budgeting higher than anticipated for fuel expenses. Reserve any surplus funds in a 'fuel volatility fund' to better prepare for large price swings in the future.
3. Regularly re-evaluate potential funding sources to offset the bus premiums and infrastructure costs for both battery-electric and CNG, including the State's recently announced CMAQ program.
4. Continue to assess potential partnership with other fleet owners and/or fueling station owners about the possibility of a CNG fueling partnership.
5. Monitor the 'Lifecycle Cost Model Variables' discussed on page 40 and re-run scenarios as appropriate in order to determine whether conditions have changed enough to alter the present course of action.
6. Evaluate electrification of accessories during refurbishment of existing buses or for new bus purchases.
7. Explore a dedicated funding source for SST operations.

Regardless of which alternative fuel SST wishes to pursue, the following next steps are recommended before any investment is made because they are likely to change over time:

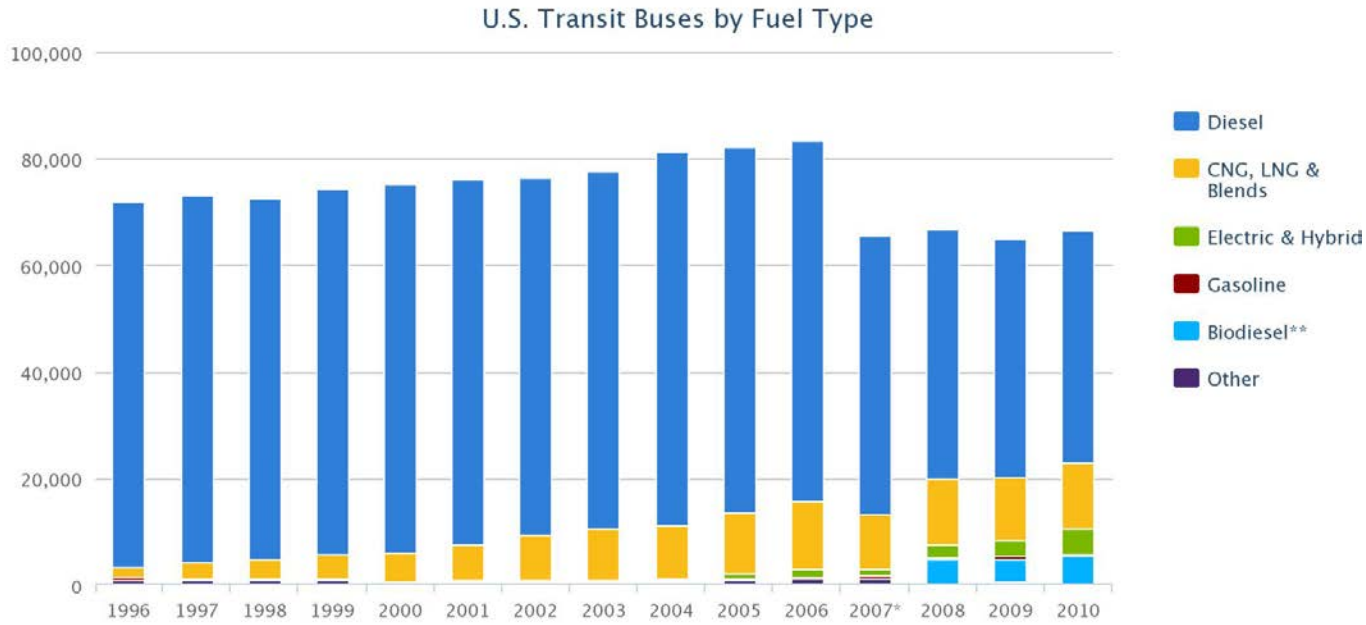
1. Confirm the assumptions for the scenario for which you wish to plan.
2. Confirm lifecycle cost estimates for the scenario.
3. Confirm the priority and weighting factor for each of the primary decision drivers.
4. Achieve consensus within SST as to which technology you wish to purse and how aggressively you would like to pursue it.
5. Pursue technology-specific next steps as outlined in conclusion of this report.

Project Background

As defined by Steamboat Springs Transit (SST), the intent of this project is to "perform an analysis and feasibility study of alternate clean fuel systems and options for transit vehicles in Steamboat Springs, Colorado." Specifically "This project will assess clean fuel transit systems in a mountain environment and research, evaluate, analyze and present findings regarding the cost, performance, carbon footprint, vehicle and infrastructure implementation needs, and feasibility for implementing various clean fuel alternatives in Steamboat Springs." In addition, this report also includes an analysis of projected long-term energy prices.

The alternative fuels considered in this study include:

- Clean diesel
- Diesel/Electric hybrid
- Compressed natural gas (CNG)
- Battery-electric



Source: American Public Transportation Association Fact Book Derived from Table 16 and 27 in Appendix A of Edition 2012.
Notes: * Data not continuous between 2006 and 2007 due to new data sources and improved accuracy.

** Biodiesel was counted in the "other" category until 2008. Current numbers do not indicate methodology for defining what blend qualifies a bus as biodiesel and discretion is advised in the use of these numbers beyond basic trend analyses.

Figure 3: This chart shows the number of transit buses in use in the United States, broken down by fuel type, from 1996 to 2010. In all years shown, diesel buses represent the largest portion of total buses, with natural gas buses a distant second. The share of alternative fuel buses has risen from 8% of the buses in 2000 to 34% in 2010. Over the same decade, natural gas buses have risen from 7% to 19% of all buses. This increase is largely due to the favorable economics and clean air benefits of natural gas in transit bus applications.

SST Background Information

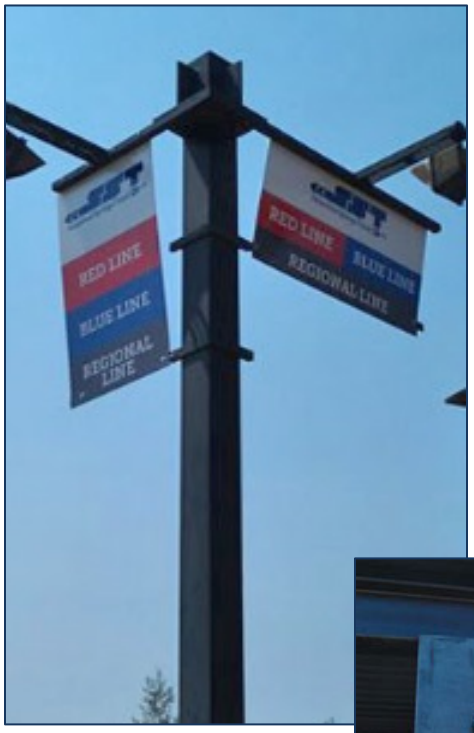
This report is based on SST data provided by staff, personal and phone interviews of SST and other comparable transit agencies and the analysis of this information. The summary of findings from SST's data and interview information is summarized as follows:

- SST provides local and regional service in a rural resort community with a cold climate, high altitude (6,732') and varying terrain. It operates 365 days a year, roughly 19 hours per day and carried over one million riders in 2012. The vast majority of riders are considered to be 'choice riders' in that they have a choice whether they ride or not. The City has operated the service since 1981 and has an experienced staff with considerable longevity among management staff.
- SST's existing fleet consists of 2 gasoline/electric hybrid staff vehicles, 1 gasoline paratransit van, 16 diesel buses and 4 diesel/electric hybrid buses.
- It has 5 facilities including two park and ride lots, the Gondola Transit Center, a regional storage facility in Craig and the main Transit Operations Center. The Transit Operations Center has recently been upgraded with some energy efficient technologies, is large enough to store all buses overnight and provides indoor fueling. Mechanics would like more space.
- It appears that the Steamboat Springs community generally prefers 'clean fuel' technology as long as it does not compromise the availability of service (i.e. the Yellow Line). Cleaner emissions ("zero visible smoke") vehicles are a particularly high priority for the community. The City Council has provided direction to continue to pursue alternative fuel vehicles.

- SST's staff has evaluated propane, CNG, biodiesel, smaller gasoline, clean diesel, diesel/electric and all-electric vehicles in the past. It currently uses a 5% biodiesel blend in all of its buses which has proven to reduce costs and maintenance. It also currently runs 6 diesel/electric buses. SST staff reports that they appear to have lower lifecycle costs than diesel buses when used for local service. These buses also are preferred by community members because they are quieter than diesel buses and are preferred by drivers due to better breaking and acceleration.
- SST was close to purchasing 5 battery-electric buses and 3 charging stations in 2010 with TIGER grant funding; however the City ultimately decided it did not want to provide additional revenue to Yampa Valley Electric Association.
- SST is currently replacing (6) 1990's era diesel buses with diesel/electric hybrid buses. SST has received 3 buses and has grants for 3 additional buses. SST is currently refurbishing all (6) of its 35' 2000's era diesel buses as a cost-saving measure versus replacing the buses. In 3-5 years, SST will look to replace the paratransit van and the 4 regional clean diesel buses are expected to remain in service until at least 2023. No fleet expansion is planned for at this time.
- SST staff would like to standardize vehicles because multiple vehicle types require more parts storage and more training for an already undersized mechanics staff. They also desire a

consistency of driving experience for bus drivers. Switching from long to short buses causes mishaps, especially with seasonal winter drivers.

- Due to the City's location, down-time for buses that require servicing in Denver is significant and therefore can compromise operations. Therefore beta-testing new technology is not desirable.
- SST currently recycles its waste oil as heating fuel in the Transit Operations Center.
- SST's annual expense budget has remained "relatively flat" at or around $3M for several years while costs, such as the price of fuel, parts, labor, etc. continue to rise. Service reductions have occurred in the past as a result. There is no dedicated funding for SST and all funds are appropriated annually. This is particularly challenging when budget decisions are made in October with service modifications needing to be adjusted by November. Therefore staff is motivated to implement strategies that result in lower operating costs, including fuel efficient technologies. Staff is also concerned that grant funding for vehicle replacement is not as reliable as it once was.



Alternative Fuels / Propulsion Technologies Summary

Literature Review Sources

Please refer to the Appendix for a complete list of reviewed literature. The following is a summarized list of studies and/or reports referenced for this report:

- RTD: Comparative Study of Diesel, CNG, and Hybrid Technologies – April 2011
- NREL: Compressed Natural Gas (CNG) Transit Bus Experience Survey - April 2010
  http://www.afdc.energy.gov/pdfs/48814.pdf
- RMI: Examining the Case for Natural Gas in Transportation Part 1; Fleets and Natural Gas: A Good Match? Part 2 – July 2012
  http://blog.rmi.org/blog_Examining+the+Case+for+Natural+Gas
- CEO: Experience with Compressed Natural Gas in Colorado Vehicle Fleets - Case Study Analysis – 8/12
  http://www.colorado.gov/cs/Satellite?c=Document_C&childpagename=GovEnergyOffice%2FDocument_C%2FCBONAddLinkView&cid=1251629763829&pagename=CBONWrapper
- TTI: Cap Metro CNG Implementation Study – November 2011
  http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2011-7.pdf
- MJB&A: Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses: Efficiency & Environmental Performance – November 2013; authored by MJB&A
  http://mjbradley.com/sites/default/files/CNG%20Diesel%20Hybrid%20Comparison%20FINAL%2005nov13.pdf

Comparable Transit Agencies

Please refer to the Appendix for a complete list of notes, contacts and contact information.

Transit Agency	Nickname	Location	CD	DH	CNG	Elec
Utah Transit Authority	UTA	Salt Lake City, UT	Y		Y	
Roaring Fork Transportation Authority	RFTA	Glenwood – Aspen, CO	Y	Y	Y	
Regional Transportation District	RTD	Metro Denver, CO	Y	Y	Y	
Transfort	n/a	Ft. Collins, CO	Y		Y	
Denver International Airport	DIA	Denver, CO			Y	
Central New York Regional Transit Authority	Centro	Syracuse NY, CO	Y		Y	
Capital Metro	Metro	Austin, TX	Y		Y	
Western Reserve Transit Authority	WRTA	Youngstown, OH	Y		Y	
Valley Metro	n/a	Phoenix, AZ	Y		Y	
Greater Cleveland Regional Transit	RTA	Greater Cleveland, OH	Y		Y	
Metro Regional Transit Authority	Metro	Akron, OH	Y		Y	
Blue Water Area Transit	BWAT	Port Huron, MI	Y		Y	
Golden Empire Transit District	GET bus	Bakersfield, CA	Y		Y	
Star Metro	StarMetro	Tallahassee, FL	Y			Y
Clemson Area Transit	CAT	Clemson, SC	Y			Y
Foothill Transit	Foothill	Pasadena, CA	Y		Y	Y

Legend:
D = diesel; DH = diesel hybrid; CNG = compressed natural gas; Elec = Battery electric

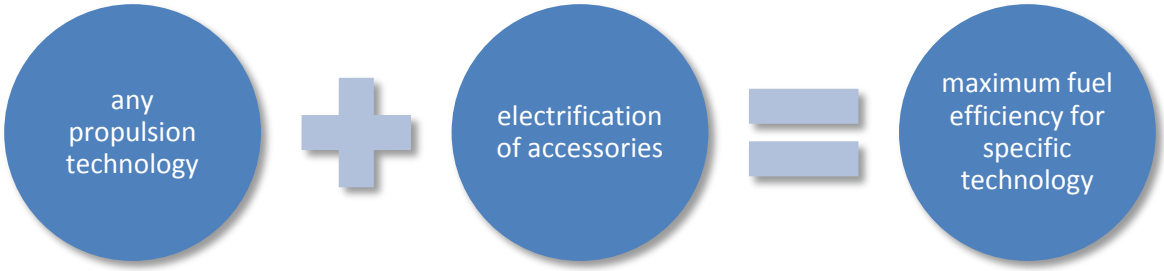
Table 2: Comparable Transit Agencies Referenced in Report

Electrification of Accessories

Because electrification has the potential to be added to any bus (diesel, hybrid, CNG, battery-electric, etc.), it is included for informational purposes but not included in any analysis.

Electrification of Accessories

All buses can increase fuel efficiency beyond the specific propulsion technology through electrification of accessories. These accessories can be directly driven by electrical power, enabling them to be decoupled from operation of the prime mover (e.g., the diesel engine, turbine, fuel cell, or electric propulsion motor). Benefits could include the ability to shut down the prime mover when not required for propulsion ("no-idle" or "engine-off" capability), while continuing to operate accessories, such as air conditioning or power steering. Such technology will also enable bus accessories to be better matched to their actual average and instantaneous power demands rather than being sized for extreme conditions thus increasing fuel efficiency by as much as 25%. These technologies may include, but are not limited to direct-drive (beltless) electrically-powered accessories; integrated starter/alternators; DC/DC converters; auxiliary power units; electric power steering; electric air compressors; electric power brakes; and electric air conditioners, heaters, and defrosters.



Diesel

The term 'clean diesel' refers to ultra-low sulfur diesel (ULSD) which as the name implies has substantially less sulfur and therefore is less polluting than conventional diesel. As of 2006, almost all of the petroleum-based diesel fuel available in North America is of a ULSD type. The downside is that ULSD requires more refining and therefore costs more than conventional diesel. The upside is that ULSD opened the door for advancements in new diesel engine control systems and the significant reduction of emissions. *Note that clean diesel is the baseline for comparison for all other fuels in this analysis.*

SST's fleet currently has 16 diesel buses and there are no immediate plans to purchase more.

Engines

Advanced new technologies such as electronic controls, common rail fuel injection, variable injection timing, improved combustion chamber configuration and turbocharging have made diesel engines cleaner, quieter and more powerful than past vehicles. Exhaust emissions control systems are increasingly used to meet new emissions standards. Those systems include or combine processes such as exhaust gas recirculation, diesel oxidation catalysts, diesel particulate filters, and selective catalytic

reduction to reduce emissions but these new engine components have increased maintenance requirements.

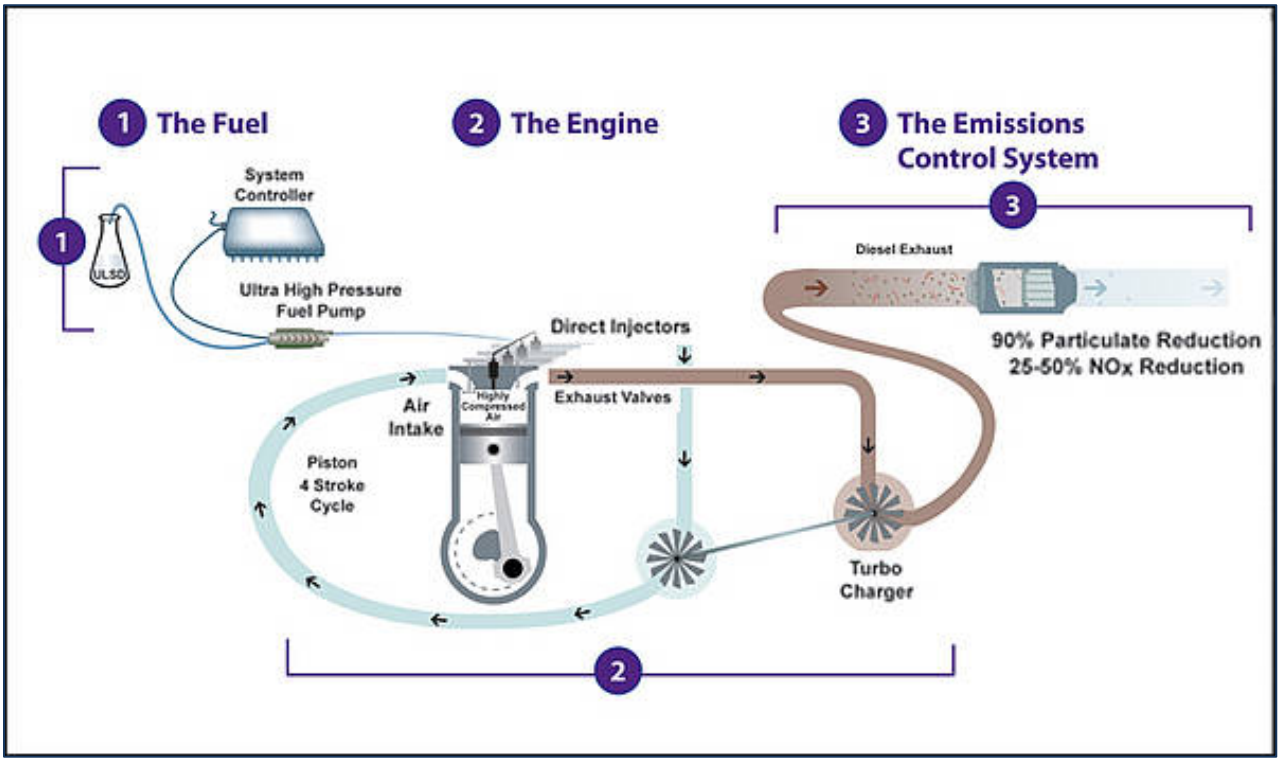


Figure 4: Clean diesel diagram from http://images.huffingtonpost.com/2008-08-13-CleanDieselSystemchart.jpg

Fueling

Because diesel is the baseline, there is no difference in fueling procedures or fueling infrastructure. SST also blends 5% biodiesel into all of its diesel vehicles. Currently for SST, biodiesel is not only less expensive than ULSD but it also increases component durability because it increases the lubricity of the fuel whereas sulfur was the main lubricating component before. As the name implies, there is far less sulfur in the fuel now and therefore the biodiesel blends helps compensate for the lost lubricity.

Specialty Equipment

Because clean diesel is the baseline, there is no specialty equipment. The technology that differentiates clean diesel from other bus technologies is included in the 'Engines' section above.

Available Vehicle Types

Clean diesel vehicles are widely available in buses, pick-up trucks and some passenger vehicles.

Alternative	Advantages	Disadvantages
Diesel	Lowest cost bus; lowest lifecycle cost (under current conditions); familiarity with the technology	Susceptible to volatile and increasing cost of diesel; air pollution associated with diesel; noisiest alternative

Table 3: Advantages and Disadvantages of Diesel

Diesel / Electric Hybrid

Hybrid-electric bus technology is similar to that used in hybrid cars and trucks except buses are typically fueled by diesel instead of gasoline. The fuel efficiency of hybrid vehicles is achieved by absorbing energy in a battery during braking and by allowing the engine to operate more often at its peak efficiency. There are options for both parallel and series drive train designs and most employ similar technology including regenerative braking, electric motors, and battery storage. In order to reap the full fuel efficiency benefits from these buses requires optimizing the hybrid system for the specific transit bus routes, taking into consideration the terrain the bus travels or whether the bus frequently travels at freeway speeds or stays on city streets. Most hybrid transit buses are currently being manufactured by two companies; General Motors (GM) Allison transmission and British Aerospace Engineering (BAE) Systems.

SST initially evaluated hybrid technology in 2004 but decided that the costs outweighed the benefits at that time. The technology was reevaluated a few years later and SST subsequently added one hybrid bus to its fleet in 2008. It now has 6 hybrid buses, 3 with Allison transmissions and 3 BAE buses. Grant funding has been awarded for an additional 3 hybrid buses.

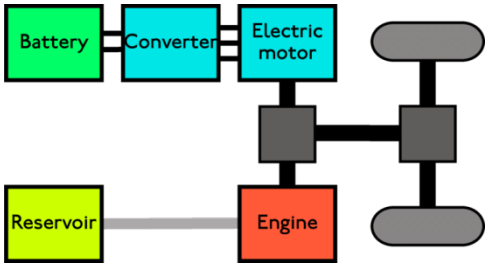


Figure 5: Parallel drive diagram

While many different studies report different emissions reductions of hybrid buses, for this report we reference the NREL study: King County Metro Transit Hybrid Articulated Buses: Final Evaluation Report; National Renewable Energy Laboratory; Chandler and Walkowicz 2006; NREL/TP-540-40585 which reported the following results:

Summary of NREL percentage decreases for hybrid versus diesel buses					
Cycle	**CO**	**NO_x**	**HC**	**PM**	**CO_2**
Manhattan	NS	-38.7	NS	-92.6	-43.8
OCTA	-32	-28.6	NS	-50.8	-34.5
CBD	-48	-26.6	-75.2	-97.1	34.8
KCM	-59.5	-17.8	-56.3	NS	-24.1

Table 4: NREL Emissions Summary

Engines

Typical diesel electric hybrids are powered by both a diesel ICE (internal combustion engine) and an electric motor although the ICE is typically smaller than on conventional diesel buses. The diesel engine powers the vehicle and generates electricity for the electric motor. The electric motor derives its power from an alternator or generator that is coupled with an energy storage device, such as a set of batteries or ultracapacitors.

SST prefers Gillig hybrid buses with the hybrid drive system supplied by BAE which uses the latest series drive technology which BAE claims is more efficient than the traditional parallel systems.

Fueling

Diesel hybrid buses are fueled with the same blend of ULSD and 5% biodiesel as its clean diesel buses.

Specialty Equipment

Hybrid buses do not require any additional fueling or maintenance infrastructure. Hybrids do have additional batteries which are recommended for replacement approximately every 5-7 years at a cost of approximately $30,000 - $55,000 each. It should be noted however that to our knowledge battery replacement is not required until failure and to date it is the exception rather than the rule that batteries fail. For lifecycle costing purposes, replacement is assumed. They also require laptops to troubleshoot software glitches but this is becoming commonplace for all bus types.

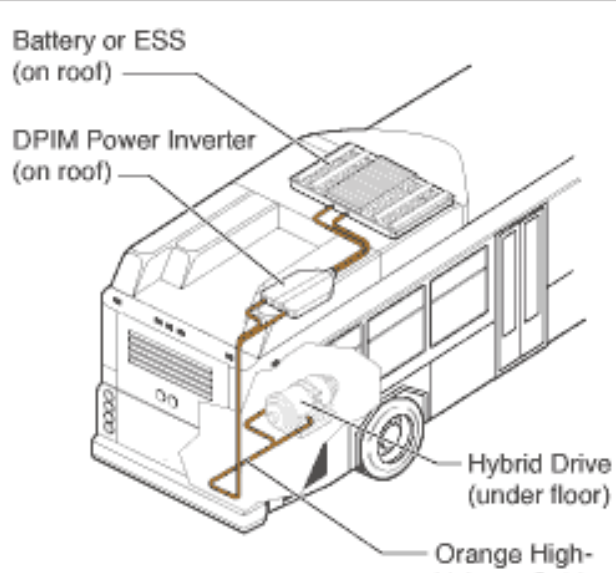


Figure 6: Gillig Hybrid Diagram

Available Vehicle Types

There are several hybrid-electric vehicle types available; including other transit buses. However because there is no infrastructure needed for hybrid vehicles, there would not be any economies of scale to adding other types of hybrid-electric vehicles to the City's fleet. Currently SST has 6 hybrid buses, 3 with Allison transmissions and 3 BAE buses. The majority of hybrid transit buses are currently being manufactured by two companies; General Motors (GM) Allison transmission and British Aerospace Engineering Systems (BAE).

To review a list of other hybrid-electric vehicles available, visit the DOE's Alternative Fuels Data Center website. Vehicle types include:

- sedans/wagons
- sport utility vehicles
- vans
- pick-up trucks

Alternative	Advantages	Disadvantages
Hybrid-electric	12% lower annual fuel costs; reduced noise; familiarity with the technology	Higher cost of buses; susceptible to volatile and increasing cost of diesel; more maintenance than diesel, potential battery replacement needs

Table 5: Advantages and Disadvantages of Diesel Hybrid

Compressed Natural Gas (CNG)

Natural gas is a common alternative to diesel in the Transit market and is domestically produced. Today there are many transit agencies and other sectors that are using CNG in part or in full to fuel their fleet. The Roaring Fork Transportation Authority (RFTA), which is very comparable to SST in terms of market, climate, altitude, fleet size, ridership, etc., recently converted 20% of its fleet (22 buses) to CNG. For this reason this case study will be widely referenced for this analysis.

Use of natural gas (compressed natural gas, liquefied natural gas, or blends) in transit bus fleets went from 2.8% of buses in 1996 to 18.6% in 2011. According to APTA, more than 40 North American transit agencies now use CNG buses and they accounted for about one-third of the new buses on order by transit agencies.

Engines

Natural gas engine technology has improved significantly in recent years, particularly as it relates to operating at altitude. The Cummins-Westport C-Gas-Plus was released in 2001 and thousands of engines are deployed across the US and in Colorado and operating reliably. In 2007, the ISL G replaced the C-Gas-Plus versus as the leading bus engine in the natural gas engine market. This engine meets EPA 2010 emissions with a simple automotive-style 3-way catalyst, is turbocharged and spark ignited, and matches equivalent diesel performance ratings of 320 hp and 1,000 lb-ft. RFTA purchased and is currently operating the Cummins ISL-G natural gas engine with 280 hp @ 2,000 rpm and 900 lb-ft of torque @ 1,300 rpm. The most recent engine is the Cummins Westport ISX12-G.

Figure 7: RFTA CNG tanks on roof

Natural Gas engines also tend to be quieter at 75 dBa than diesel engines that operate at 83 dBa or above. Maintenance costs of CNG buses are regarded by RFTA to be slightly higher than the diesel models equipped with increasingly complex emissions controls.

For RFTA outfitting a bus for CNG engine, tanks and fuel system resulted in a $54,000+/- price premium per bus (roughly 13% extra).

Fueling

CNG involves compressors that store natural gas in vehicle storage tanks that are pressurized to 3,600psi. CNG fuel takes up more space on a vehicle than diesel fuel, so tanks are typically located on the roof of a low-floor transit bus. Compressed gas in the tanks is regulated to a lower pressure and delivered to the natural gas engine.

Figure 8: RFTA Compressor Station building

Costs to install fueling facilities for natural gas are somewhat related to the number of buses that must be fueled each day but mostly determined by the type of fueling. Fast-fill stations can fuel a bus in about the same time as diesel fueling, but they can be more expensive to construct. Time-fill stations can be less expensive to build and operate, but are designed to take several hours to fill a bus. They work well for

fleets that can sit parked all night and only require one fueling per day. A fueling station for 10 - 20 buses at SST may cost $1.2 – $1.7 million.

It's important to note that ambient air temperature affects the quantity of CNG that can be dispersed. Because of pressure limitations, it may not be possible to reach a maximized temperature compensated fill on a warm day and thus a bus would receive a lesser fill. It is difficult to get a complete full fill when fast filling because the heat of recompression does not allow for this. For this reason time-fill stations typically result in a fuller fill because the rate of fueling is slower and therefore creates less heat.

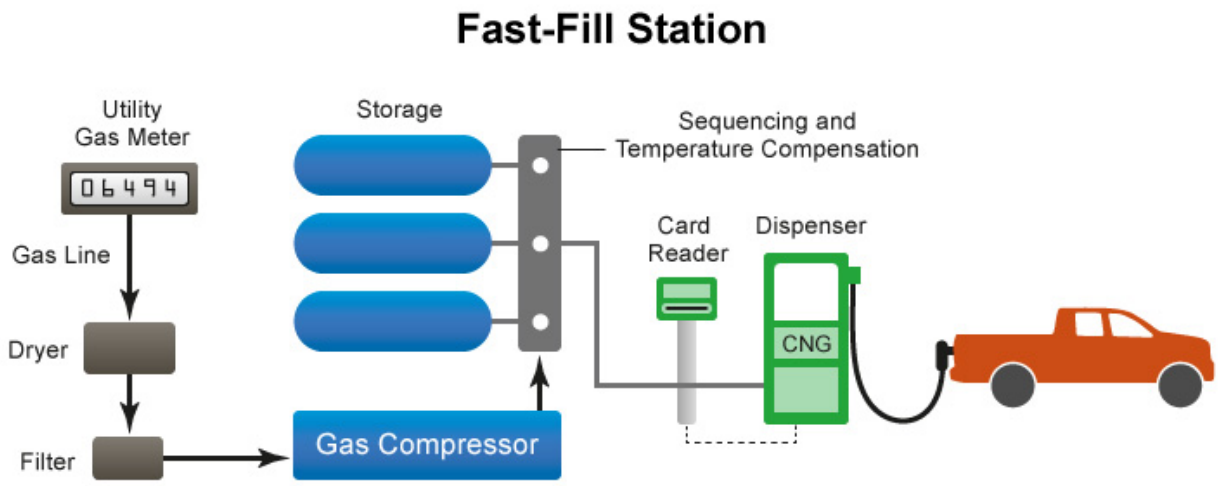


Figure 9: Example of a fast-fill compressed natural gas (CNG) station configuration courtesy DOE.

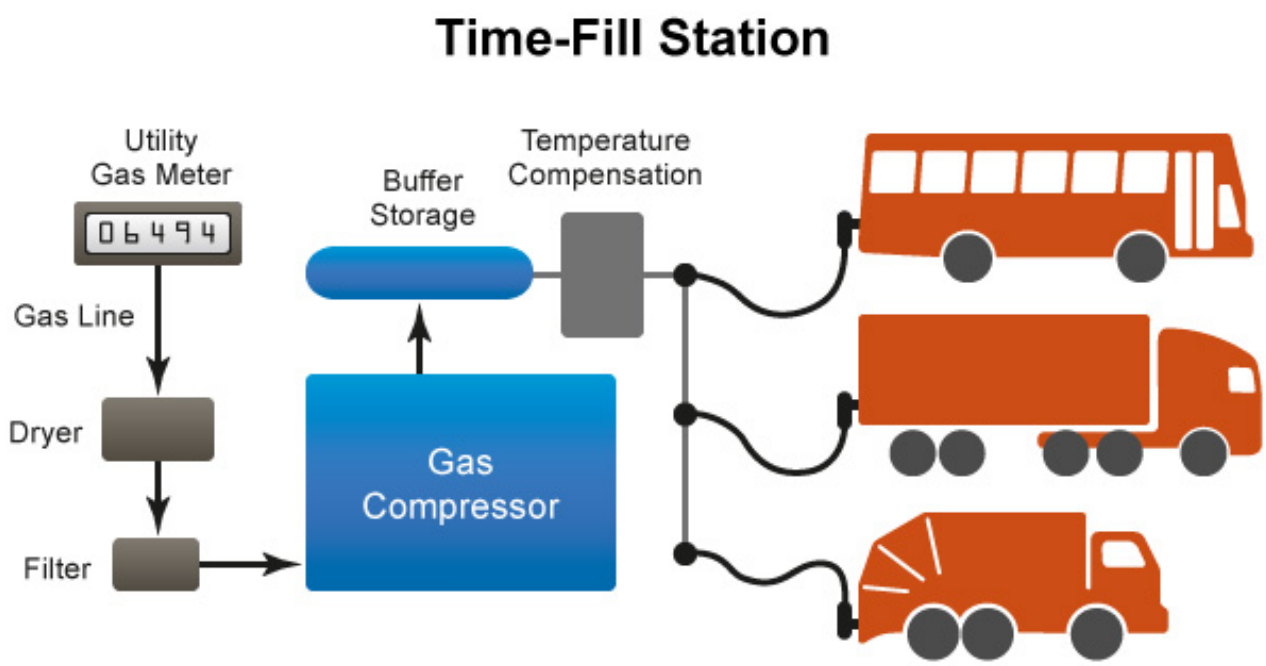


Figure 10: Example of a time-fill compressed natural gas (CNG) station configuration courtesy DOE.

Specialty Equipment

In addition to needing a natural gas compressor station and dedicated CNG dispensers, SST would need to upfit its maintenance facility in order to legally and safely service and fuel (because SST fuels indoors) CNG buses. This upfit would likely include the following facility upgrades:

- Install a methane detection and alarm system throughout the facility.
- Upgrade the ventilation system in the fueling bay and service bays for more continuous and event-based ventilation, including the sequenced operation of overhead doors as part of the ventilation strategy.
- Retrofit the fueling bay with deflagration venting and Class 1, Division 2 explosion proof motors, lighting, fans, heaters and electrical components.
- Retrofit the service bays with Class 1, Division 2 explosion proof motors, lighting, fans, heaters and electrical components where within 18" of the ceiling.
- Pressurize the office areas to resist fugitive methane entry.
- Interlock gas appliances to the methane detection system to terminate gas flow during an event.
- Install a defueling stack in the service bays.

Figure 11: RFTA Fueling Bay

It is estimated that up-fitting the SST Transit Maintenance Center would cost approximately $2,800,000.

Available Vehicle Types

There are several CNG vehicle types available including different bus manufacturers. Because CNG has gained such a significant presence in the transit industry, most if not all major bus manufacturers sell natural gas transit buses, including Gillig, Foton America Bus Co., North American Bus Industries, Orion, New Flyer, and El Dorado National. They typically are powered by a Cummins Westport engine. Smaller shuttles and other vehicles are also available from smaller manufacturers who retrofit new or retrofit existing fleets to run on natural gas.

To review a list of other CNG vehicles available, visit the DOE's Alternative Fuels Data Center website. Vehicle types include:

- sedans/wagons
- sport utility vehicles
- vans with and without cutaway chassis
- pick-up trucks*

* It should be noted that the AFDC website does not list any available CNG pick-up trucks. Currently both Ford and Ram sell OEM CNG pick-up trucks.

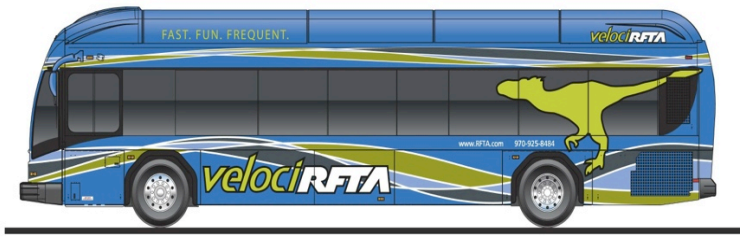
Unlike hybrid-electric and battery-electric vehicles, CNG fueling does require dedicated fueling infrastructure and therefore there are economies of scale in purchasing other CNG vehicles. In fact the lifecycle cost of purchasing CNG vehicles once CNG fueling infrastructure is in place is likely much lower than other types of vehicles. SGM research conducted on behalf of another Western Slope local government, normalized for what the City of Steamboat is currently paying for diesel and what is

estimated it would pay for CNG per DGE after the fueling infrastructure was installed, indicates that a CNG pick-up truck has about a 23% lower lifecycle cost when considering vehicle and fuel costs. Similar results would be expected for sedans and vans as well.

Alternative	Advantages	Disadvantages
Compressed Natural Gas (CNG)	Second lowest annual fuel costs; low projected price volatility; lowest lifecycle cost when most of fleet is replaced and infrastructure costs can be significantly offset with grants	Highest capital expenses - constructing a fueling station and upgrading the maintenance facility; higher cost of buses; unfamiliarity with the technology

Table 6: Advantages and Disadvantages of CNG

RFTA CNG Case Study



RFTA 2011 Information:

- 4.14 million passengers
- 3.68 million miles of service
- 250 employees during peak winter season
- 101 large transit vehicles, including 22 CNG, 13 diesel hybrids, 66 diesel
- $31.8 million budget
- Operating on a 70-mile corridor

RFTA CNG Information:

- As part of its BRT (bus rapid transit) project RFTA replaced 22 diesel buses with 22 CNG buses, representing approximately 20% of its fleet.
- The buses are Gillig Low Floor 40' CNG - BRT*Plus* powered by the Cummins ISL-G natural gas engine with 280 hp @ 2,000 rpm and 900 lb-ft of torque @ 1,300 rpm.
- To fuel, RFTA had designed and constructed a fueling station at RFTA's Glenwood Maintenance Facility (GMF).
- In order to be allowed to service CNG buses, RFTA also made safety upgrades to the GMF.
- RFTA also chose to incorporate fast-fill fueling in its *indoor* fueling bay which significantly increased its capital costs for both the fueling station and facility upgrades.
- With approximately 1 year of service from buses and fueling equipment, all running smoothly with only minor issues.

RFTA CNG performance to-date:

- CNG bus operation began in February of 2013.
- Mileage range is higher than diesel at up to 700 miles.
- Fueling time is comparable to diesel but is contingent upon ambient temperature and how full the tanks are.
- Fuel efficiency is 5.49 MPG, approximately 5% better than diesel, contrary to other agencies.
- Maintenance is more than diesel due to shorter periods between PM's (every 1,500 miles)
- Cost per diesel gallon equivalent (DGE) is $2.89 (all-in), approximately 17% less than its conventional 5% biodiesel blend.[i]

Battery-Electric

An all-electric bus is often referred to as a battery-electric bus – not to be confused with electric buses powered by overhead wiring. Battery-electric buses use a battery pack to power an electric motor as its sole source of propulsion. Typically batteries are lead acid, nickel metal hydride, or lithium ion. Rechargeable batteries offer a number of benefits, including reduced noise from the lack of an internal combustion engine (ICE), no gear changes, and fewer moving parts. The vehicles themselves generate no NOx, SOx, PM, CO2, or CO emissions; however there are emissions attributable to the vehicle if the electricity used to power the bus was generated from a fossil fuel power plant.

Electricity prices have remained remarkably stable over the decades, especially compared to the volatility of petroleum prices. Electricity is made more attractive by the fact that it is an efficient way to propel a motor vehicle. Modern traction motors are over 90% efficient compared to an average of 25% efficiency common in internal combustion engines. Electric drivetrains also offer regenerative braking which recovers energy during braking that would otherwise be wasted while also wearing out brake pads.

With the advent of batteries and chargers capable of "fast charging" battery-electric buses have become increasingly more feasible. Battery technology has improved greatly in recent years with several different competing lithium ion technologies offering long life and high performance during operation and charging.

While there are a handful of viable battery-electric bus manufacturers, in 2009 SST was close to purchasing five Proterra battery-electric buses and therefore this analysis uses Proterra data and information.

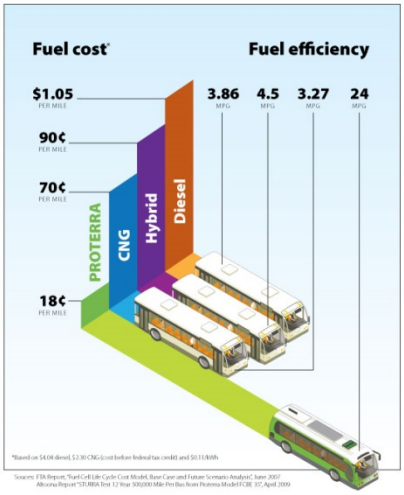


Figure 12: Proterra promotional graph

Engines

Proterra's EcoRide™ BE35 is propelled by a 220 kW (peak) permanent magnet drive motor with a two-speed EV transmission. Published results from Proterra's visit to the Altoona Bus Research and Testing Center show that the EcoRide™ BE35 achieves between 17.5 and 29 miles per gallon (diesel equivalent range).

Fueling

Proterra's FastFill™ charge system is comprised of the software and hardware to rapidly charge the TerraVolt™ Energy Storage System from 0% to 95% with >92% energy charge efficiency in as little as 6 minutes. Proterra claims that its proprietary architecture allows for lower cost and lower impact grid connections while maintaining high charge rates but a comparison with other manufacturers was not performed as part of this study. Phone interviews with current Proterra users confirmed that O&M costs were lower, but no users had needed to replace a battery as of yet.

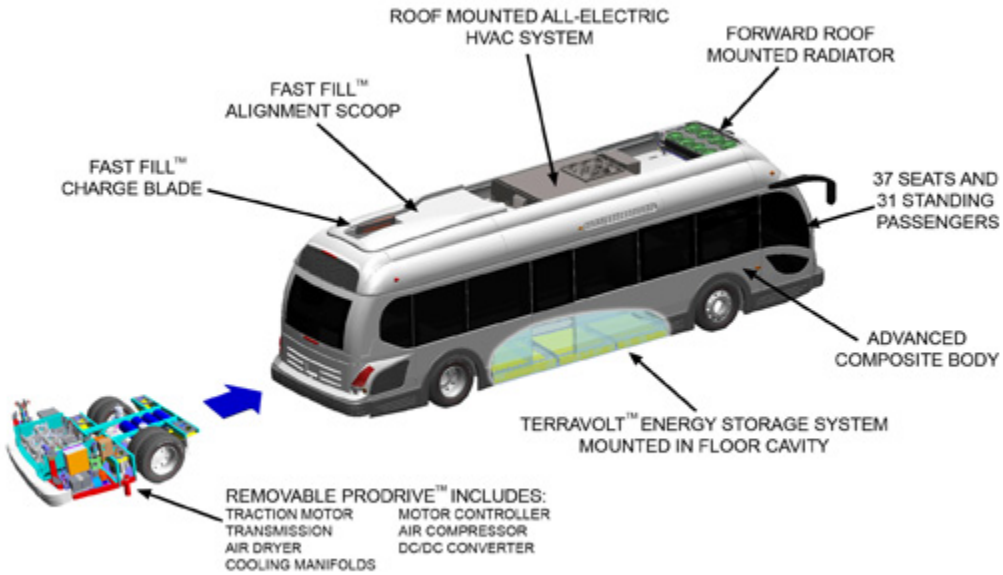


Figure 13: Proterra EcoRide diagram

Transit Agencies Running Proterra Buses as of September 2013	
Transit Agency	**Location**
Capital Metro Transit	Austin, TX
Burbank Bus	Burbank, CA
CMRTA	Columbia, SC
Pierce Transit	Fort Lewis, WA
Foothill Transit	Pomona, CA
VIA Transit	San Antonio, TX
City of Seneca & Clemson Area Transit	Seneca, SC
San Joaquin RTD	Stockton, CA
StarMetro	Tallahassee, FL
RTC of Washoe County	Reno, NV

Table 7: Current Proterra Users

Specialty Equipment

As the name implies, battery-electric buses do have additional batteries which are recommended for replacement approximately every 6 years at a cost of approximately $95,000 each according to Proterra. They also require laptops to troubleshoot software glitches but this is becoming commonplace for all bus types.

Available Vehicle Types

There are several battery-electric vehicle types available; however no other vehicles that would use the same charging infrastructure. Therefore there would not be any economies of scale to adding other types of battery-electric vehicles to the City's fleet. It should also be noted that the two leaders in battery-electric transit buses, Proterra and BYD both use proprietary charging infrastructure and therefore it's to SST's financial advantage to purchase the same make if additional buses are purchased in the future so that charging infrastructure doesn't need to be added and/or replaced.

To review a list of other battery-electric vehicles available, visit the DOE's Alternative Fuels Data Center website. Vehicle types include:

- sedans/wagons
- sport utility vehicles

Alternative	Advantages	Disadvantages
Battery-electric	By far lowest annual fuel costs; lowest projected price volatility; lowest maintenance cost, lowest lifecycle cost when bus cost premium can be significantly offset with grants	By far highest bus cost; battery replacement needs; route scheduling challenges due to recharging; unfamiliarity with the technology

Table 8: Advantages and Disadvantages of Battery-electric

Foothill Transit Case Study

Foothill Transit 2013 Information:

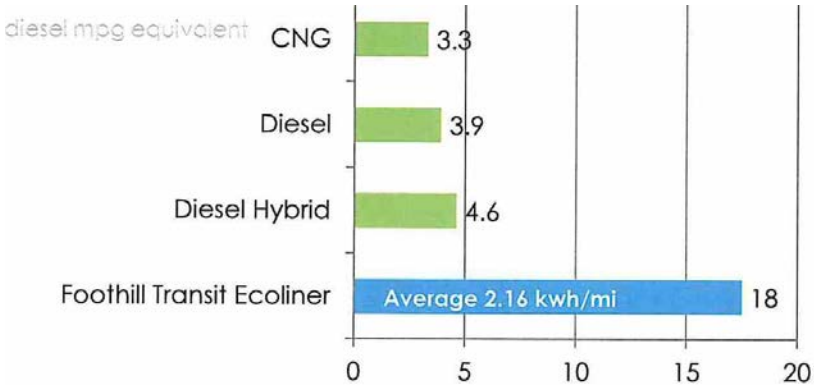
- Serves the San Gabriel and Pomona Valleys
- 13 million passengers boardings
- 34 fixed-route bus lines
- Fleet consists of 288 CNG, 17 diesel and 15 battery-electric

Foothill Transit Battery-Electric Bus Information:

- Replaced 3 buses on its Line 291 route in 2010 with Proterra EcoRides
- Currently replacing an additional 12 buses on 291
- Line 291 is a 16 mile loop with each bus traveling 140mi/day
- Route has (2) 500kW rapid charging stations with mid-route charging for both north and southbound
- Maintenance facility also has slow charging station
- Buses are Proterra EcoRides with Eaton transmissions with a range of 30 miles
- 3 original buses and 2 charging stations were paid for by $6.5M in ARRA funding
- 12 new buses are funded from $10.2M TIGER II grant

Foothill Transit Battery-Electric Bus performance to-date:

- Foothill Transit reports 90% reduction in fuel costs and noticeably less maintenance costs when compared to diesel buses
- Buses typically arrive at bus stop with charging station at 60%~ where gets recharged to 99% in 10 minutes, but this route only requires 3-4 minutes worth of charge
- Foothill Transit reports great toque and power regardless of rider capacity and is pleased with Proterra buses and Eaton transmissions
- Drivers reportedly love driving the EcoRide

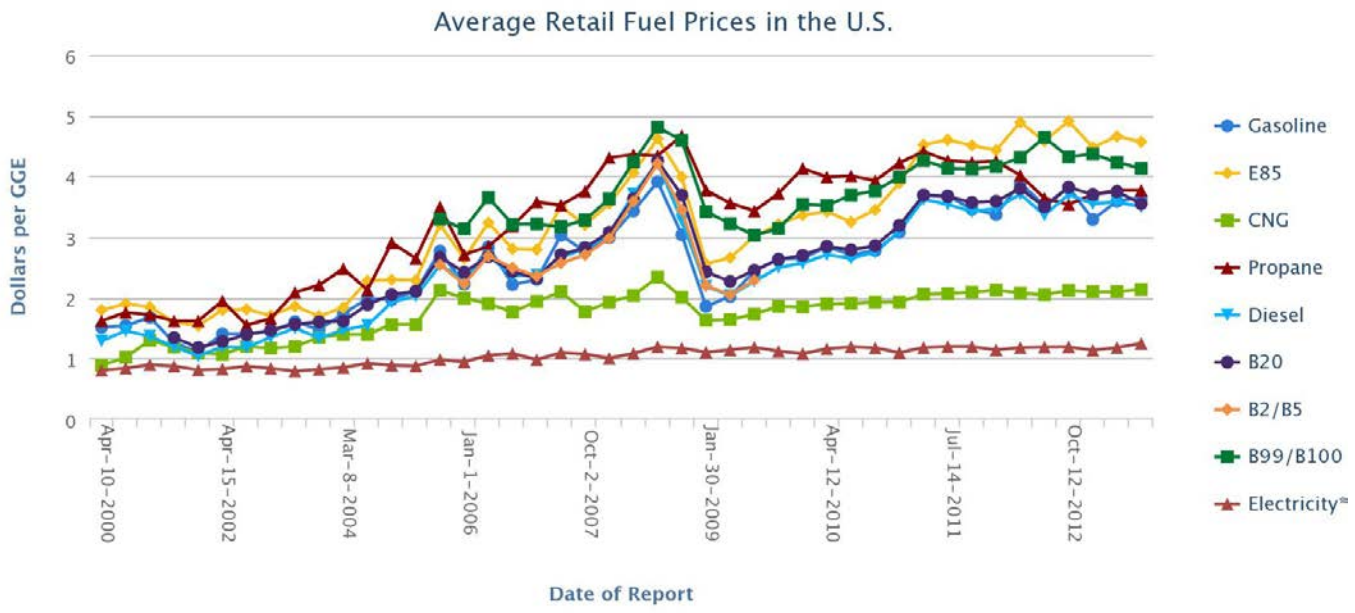


Projected Energy Price Analysis

Evaluating alternative fuel systems requires projections of future fuel costs from which to build lifecycle cost analysis. The purpose of this section is to provide those projections as well as some context on the sources on which they are based.

The Energy Information Administration (EIA) is the U.S. government's agency for projecting and reporting energy supply, consumption and price and therefore its data serve as the basis of this analysis. The EIA data that follows is largely from its July 2013 Annual Energy Outlook (AEO)[ii]. This data is also supplemented with EIA historical trend data and other industry perspectives and SST's average annual diesel price since 2010.

It should be noted that due to the inherent unpredictability of energy markets, this analysis and the resulting recommendations give more weight to historical data than industry projections.



Source: Clean Cities Alternative Fuel Price Reports
Notes: Fuel volumes are measured in gasoline-gallon equivalents (GGEs), representing a quantity of fuel with the same amount of energy contained in a gallon of gasoline. *Electric prices are reduced by a factor of 3.4 because electric motors are 3.4 times more efficient than internal combustion engines.

Figure 14: This chart shows average monthly retail fuel prices in the United States from 2000 to 2013. The price of petroleum fuels (gasoline and diesel fuel) is the primary driver of overall fuel prices. For as petroleum prices rise, so does demand for alternative fuels, thereby pushing their prices upward as well. Additionally, alternative fuels are partially tied to petroleum prices since petroleum is often used during the process of producing and delivering those alternatives. However, natural gas and electricity prices have been buffered from this driver because transportation only constitutes a tiny portion of their markets. These two fuels are tied to each other, though, because over a quarter of all electricity is produced from natural gas.

Analyzing the Forecasts

Like any forecast, the historic margin of error should be clearly understood. While the EIA is the best resource available for comprehensive energy forecasting, its forecasts have not been overly reliable. It has a reputation for overestimating production and therefore underestimating price. To be sure, the energy industry is inherently volatile which makes forecasting extremely difficult. And to its credit, the EIA publishes an annual retrospective that compares its past forecasts with actual data. Additionally, it should be noted that a number of private, propriety sources have at best spotty records on energy price forecasting; and the farther back one goes, the more the flaws in all the forecasting records become evident.

The EIA's 'AEO Retrospective Review: Evaluation of 2012 and Prior Reference Case Projections' indicates the following:

- When projecting the cost of crude oil since 1994, the EIA has underestimated the price over 80% of the time by 30% or more on average.
- When projecting the cost of natural gas since 1994, the EIA has underestimated the price over 70% of the time by 30% on average.
- When projecting the cost of electricity since 1994, the EIA has underestimated the price over 60% of the time by 10% or more on average.

"The U.S. Energy Information Administration (EIA) produces projections of energy production, consumption and prices each year in the Annual Energy Outlook *(*AEO*). Each year, EIA also produces an* AEO Retrospective Review *document, which presents a comparison between realized energy outcomes and the Reference case projections included in previous editions of the* AEO*. The purpose of the* Retrospective *is to show the relationship between past* AEO *projections and actual energy indicators, enable trend analysis, and inform discussions of potential improvements to the* AEO*."*

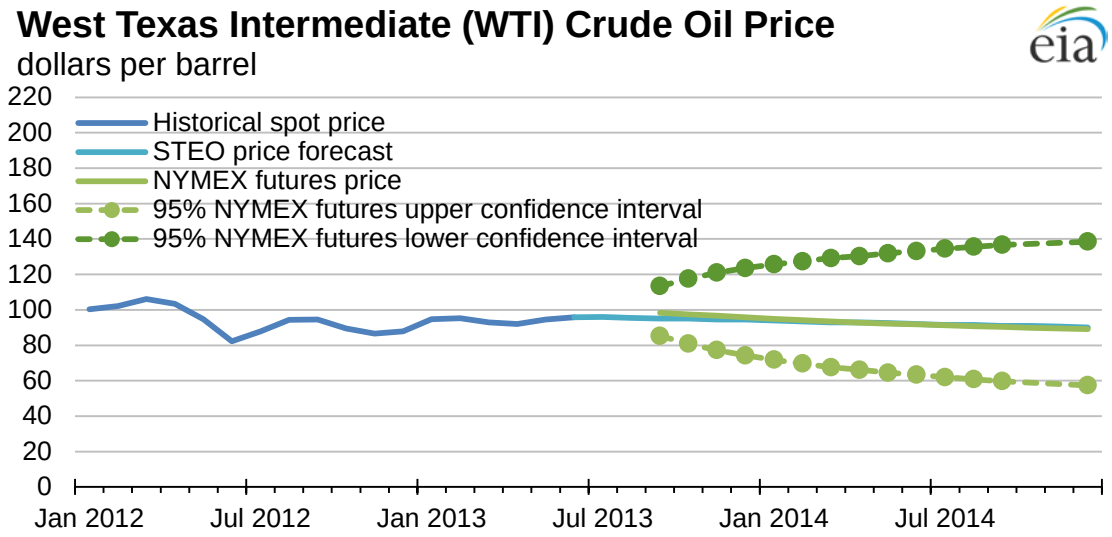
- EIA website

The energy industry is as politicized as it is technically complex. Strong forces are at play in the world of energy production and forecasting and therefore it's important to gain multiple perspectives and plot your confidence level within those perspectives before making vehicle purchases or other fuel source decisions. This is particularly important in light of recent reports of abundant domestic oil and natural gas discoveries. Often the reports state that there is ample energy supply for the foreseeable future, implying little need for concern about energy resources. Additionally, there is disagreement about the length of the time frame implied by the phrase "the foreseeable future." But often missing from the report is any reference to the myriad of forces that affect that which is typically the biggest decision factor – which is energy price.

Diesel

The price of diesel fuel has been fairly stable over the last few years, but fairly volatile over the last decade. Note that this analysis uses EIA data for 'Rocky Mountain No 2 Diesel Retail Prices' which includes Ultra Low Sulfur Diesel (ULSD) which became the standard diesel fuel in 2007. While the price of diesel has typically been very volatile, there are several factors that could contribute to greater volatility in the future. These factors include:

- the commodity cost of crude oil as impacted by many factors including the cost of refining, extraction and transporting; geopolitical developments; violence and wars in and between oil producing nations;
- global or national demand reduction;
- increased demand internationally for diesel fuel, and the impact that has on international trading and pricing of both gasoline and diesel;
- steeper than projected production declines in existing wells, especially in newer shale oil (aka "tight oil" plays;
- political factors within the U.S. as well as oil exporting countries; and
- potential pollution mitigation costs associated with carbon-intensive fuels.



Note: Confidence interval derived from options market information for the 5 trading days ending July 3, 2013. Intervals not calculated for months with sparse trading in near-the-money options contracts.
Source: Short-Term Energy Outlook, July 2013

Figure 15: above indicates relatively stable oil prices over the last 2 years but the possibility for huge price swings (+55% to -33%) in the future. Because the commodity cost of oil is such a strong driver for the delivered cost of diesel and shown in Figure 23, analyzing projected commodity costs is very useful in projecting diesel costs.

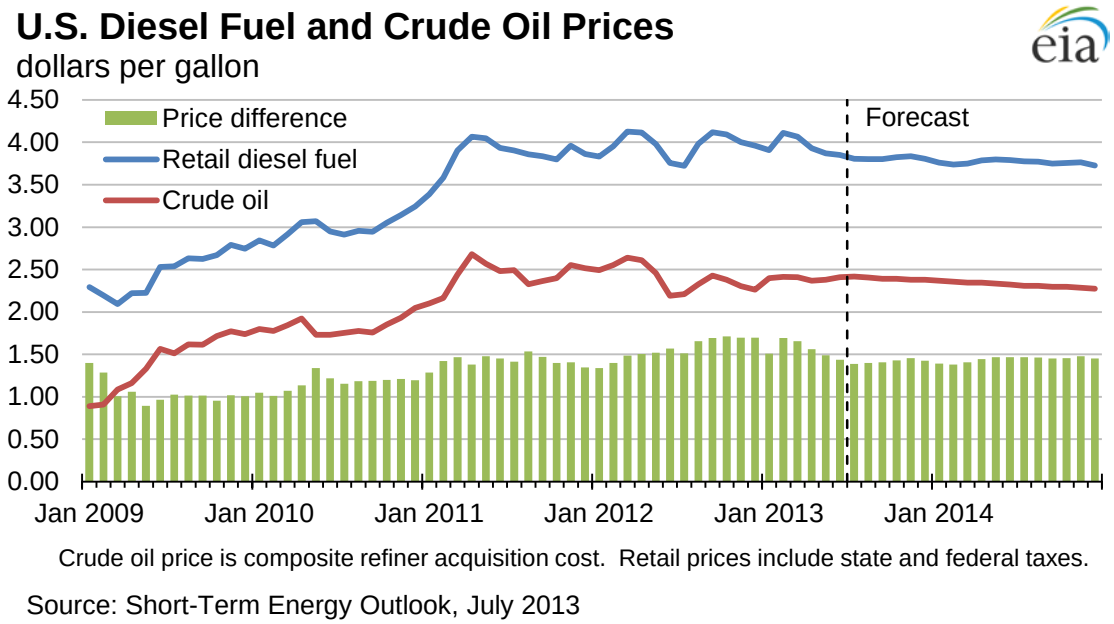


Figure 16: This graph indicates the volatility in crude oil and diesel fuel prices over the last four and a half years but assumes stable prices for the next year and a half.

In contrast to the EIA's projections, the following commentary from the July 15, 2013 *Peak Oil Review* (POR), a weekly report from the Association of the Study of Peak Oil and Gas USA offers a different perspective.

> "In its monthly report the IEA (International Energy Agency) grapples with the uncertainties of global oil supply and demand in 2014. The Agency has increased its forecast for the growth in global demand next year to 1.2 million b/d, but has not yet factored in recent IMF (International Monetary Fund) projections of lower economic growth in the months ahead. Unusually large growth in non-OPEC oil production of 1.3 million b/d underpinned by growth of 530,000 b/d in US oil production is forecast for next year."[iii]
>
> "All this says that while the next 18 months looks good for increases in US and non-OPEC production, there are geopolitical factors in several OPEC states which could easily offset the increase and drive oil prices higher."

This commentary suggests that despite widespread reports of abundant oil supplies, the chances for a significant decline in the global commodity price of oil, not to mention the refined price of its products (gasoline and diesel for example), remains problematic. The current boom in oil supplies from tight-oil/shale oil fields appear very likely to crest during the 2015-2020 time frame as shown in Figure 17. These variables that lead to volatility in the oil market are not necessarily new and are supported by EIA's *historical data* (Figure 18) showing the price of diesel increasing *13%* per year on average over the last decade and *9%* per year since 1996.[iv] Unfortunately this does not support EIA's *projection* (Figure 16) for the price of diesel to increase *1.44%* per year on average for the next 3 decades.[v] Therefore this analysis projects diesel to be the most volatile fuel source and more volatile than the EIA projects.

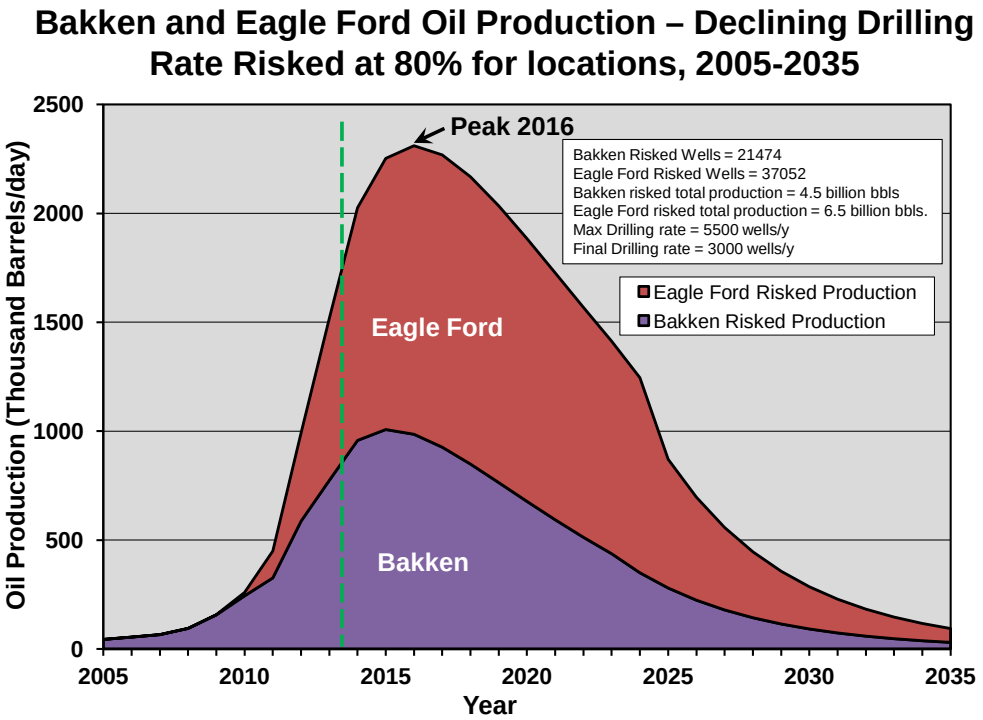
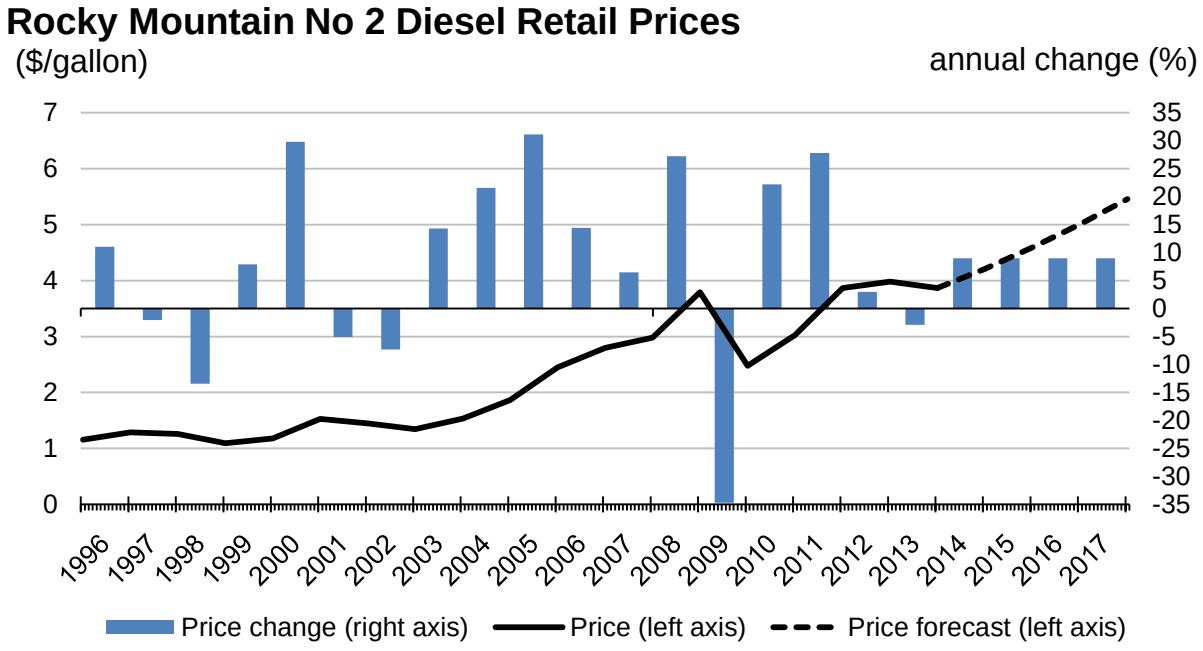


Figure 17: The graph to the left shows the projected trends by one analyst of two primary oil fields in the U.S. Note that by the end of the planning horizon for this report (12 years) production will nearly be exhausted.



Source: Short-Term Energy Outlook, July 2013

Figure 18: The graph above shows the historical trend of diesel prices and the annual change in price.

SST:

The three years of fuel cost data provided by SST is relatively consistent with national EIA data. There is no apparent reason why future costs at the local level would vary from national trends.

SST Fuel Cost Data		
Year	$/gallon	% increase
2011	$3.24	N/A
2012	$3.32	2.54%
2013	$3.46	4.17%

Table 9: SST Fuel Cost Data

Analysis Assumptions:

Diesel prices have increased 9% per year on average for the past 17 years. Most analysts agree that this trend of sustained annual increase is inevitable for the foreseeable future. Market indicators suggest that future annual increases, including the associated volatility, should be similar to historic trends. However; many analysts believe and very recent analysis would suggest that the U.S. and perhaps the global economy has reached a breaking point with respect to fuel prices.

As of the writing of this report, "oil prices have essentially remained unchanged over the last two years. At the same time, exploration and production costs have been rising at an 11 percent pace. Thus, costs have been rising faster than revenues, which is why many of the oil majors are getting hammered." (Peak Oil Review, November 2013). This increase in costs would typically indicate that the price of diesel would increase accordingly - but it hasn't for the last two years.

If historic trends continued, the present price of diesel would double before the end of this report's planning horizon of 12 years. This seems unlikely because it's economically unsustainable. How the market will adapt to this phenomenon is unknown, but we project that diesel prices will continue to increase on an annual basis, but not at the 9% per year historical average.

Based on the analysis above, this analysis assumes:

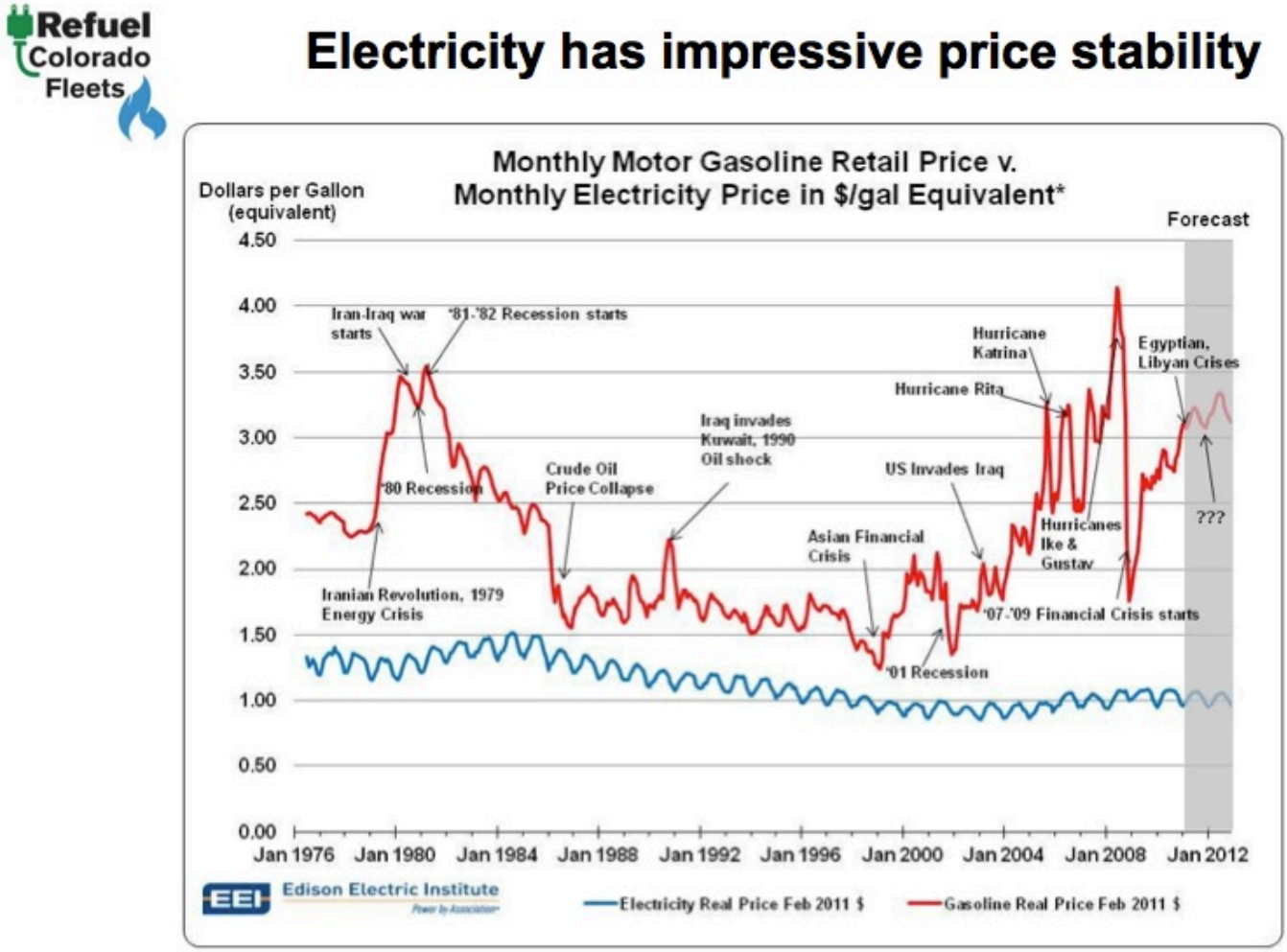
- The 2013 price of diesel ($/gallon) will increase 5.5% per year, but SST should expect historic volatility to continue, if not increase.

"The most interesting message in this year's World Energy Outlook from the International Energy Agency is also its most disturbing. Over the past decade, the oil and gas industry's upstream investments have registered an astronomical increase, but these ever higher levels of capital expenditure have yielded ever smaller increases in the global oil supply. Even these have only been made possible by record high oil prices. This should be a reality check for those now hyping a new age of global oil abundance."

Financial Times (11/26)

Electricity

Historically in Colorado and around the country, electricity has been largely generated by coal-fired power plants. In the past coal was typically purchased by utilities with 20 year contracts thus resulting in very stable electricity prices as depicted in Figure 19.



http://switchboard.nrdc.org/blogs/mbaumhefner/buck-a-gallon_gas_for_life.html

Figure 19: Fuel costs have been much more volatile than electricity costs, partly due to several external factors as noted in this graph.

While electricity rates will likely remain more stable than diesel or natural gas, there are several factors that could contribute to greater volatility in the future. These factors include:

- utility rate structure changes that could increase overall costs;
- recent legislative requirements to incorporate more renewable resources in electricity generation which could stabilize rates even further over the long term, but increase them in the short term;
- a strong incentive for new power plants to be fueled by natural gas instead of coal which is projected to be more volatile than coal;

- potential pollution mitigation costs associated with carbon-intensive electricity;
- increasing global demand and therefore increasing commodity costs of coal; and
- potential investments into upgrading antiquated distribution and transmission lines.

Figure 20: Figure 4 above indicates the relatively stable but increasing cost of electricity over the last decade.

Electricity is by no means immune to the volatility widely predicted for the oil & gas industry; however the source mix of electricity is ever changing and therefore it is becoming increasingly difficult to project its price. Coal has increasingly become a global commodity which means Americans are less buffered by larger U.S. coal reserves than we used to be. Natural gas continues to be the fuel of choice for new power plants which also increases volatility compared to coal-based electricity. Additionally, some amount of natural gas may be exported overseas within two or three years, where prices are two to four times higher than the US market price. New developments in grid-scale renewable energy, both in terms of technology and policy are also beginning to affect price. Finally the electricity distribution system (aka 'the grid') is becoming increasingly antiquated and in need of significant capital investment, and therefore carries with it a long term financial risk.

The other important consideration, similar to the wellhead price of natural gas, is that the price of fuel used to generate electricity is a much lower percentage of the overall lifecycle cost of supplying electricity to power a bus than crude oil's percentage within the cost per gallon of diesel, as depicted in Figure 23. It also appears that electric utilities have greater control over the cost of electricity than fuel suppliers have of diesel or natural gas and therefore electricity is assumed to be the most stable fuel source of the three included in this analysis.

SST Data:

Yampa Valley Electric Association Rate Information: *(Provided in McKinstry Report with updated costs)*

Large Power Service: Rate Code 10	2009	2013
Customer Charge per Month:	$105	$105
Energy Charge per kWh:	$0.08412	$0.09223
Xcel Energy ECA[1] per kWh:	varies monthly	

[1] Electric Commodity Adjustment

McKinstry's 2009 Technical Energy Audit states that the City's 2009 base rate cost for electricity plus the average Xcel Energy ECA from 2006-2009 was $0.09735/kWh. Using the same formula for the last 12 months the most current rate is approximately $0.10/kWh. In 2009 McKinstry was projecting an average annual increase of 3%. Yampa Valley's retail electric rate has increased 33% since 2004 with an annual average increase of 3.6% per year. Public Service Company's (YVEA's wholesale provider) PUC filing was not available and YVEA's Board has not yet adopted official rate increases.

Analysis Assumptions:

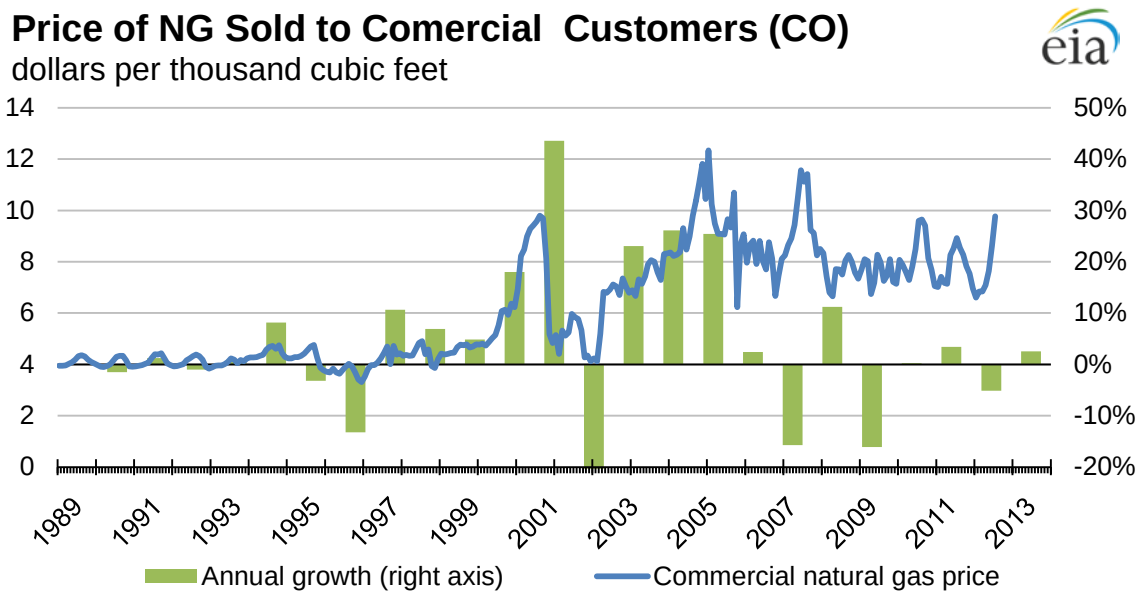
Based on the analysis above, this analysis assumes:

- The 2013 blended unit price of electricity ($/kWh) will increase 4.0% per year based on SGM projections. Although YVEA rates have historically increased only 3.6% per year, the continuing cost increases of coal, existing and new regulation and other variables will likely cause the annual increases to likely be higher.

Compressed Natural Gas (CNG)

Like diesel, natural gas has also been stable over the last few years but volatile over the last decade. Also, the unit price or $/DGE (diesel gallon equivalent) for CNG is comprised of several factors which is explained in more detail below. In addition to the price of natural gas, the CNG unit price also consists of the electricity cost to compress the natural gas and the maintenance cost to maintain the compressor station. This section however focuses on the commodity of natural gas because electricity is covered in a separate section.

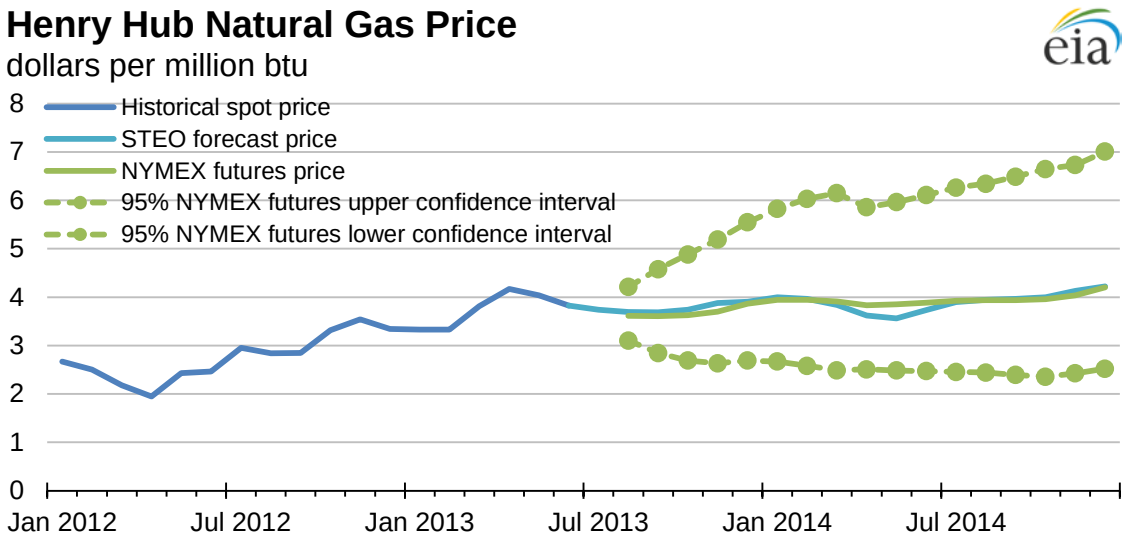
While the price of natural gas is projected to be less volatile than diesel, it is still subject to the factors inherent in the extractive industry as listed elsewhere in this report. As mentioned, some amount of natural gas may be exported overseas within two or three years, where prices are two to four times higher than the US market price. The larger the amount exported, the greater the likelihood that US prices will also increase, though there are considerable unknowns here.



Source: Short-Term Energy Outlook, July 2013

Figure 21: This graph indicates the volatility in the natural gas market particularly since 2000.

History has proven that wellhead price for natural gas can be as volatile if not more so than crude oil; however there appears to be general agreement among analysts that natural gas wellhead prices will remain relatively stable over the next few years. Beyond that is difficult to project. The other important consideration is that the delivered price of natural gas is a much lower percentage of the overall lifecycle cost per DGE of compressed natural gas than oil's percentage within the cost per gallon of diesel, as depicted in Figure 23. For this reason, the pump price of compressed natural gas fueling is less vulnerable to a volatile natural gas market than the pump price of diesel fueling is to the volatility in the crude oil market.



Note: Confidence interval derived from options market information for the 5 trading days ending July 3, 2013. Intervals not calculated for months with sparse trading in near-the-money options contracts.

Source: Short-Term Energy Outlook, July 2013

Figure 22: This graph indicates the relatively moderate increase in natural gas wellhead prices over the last year and a half but the possibility for huge price swings (+75% to -60%) in the future.

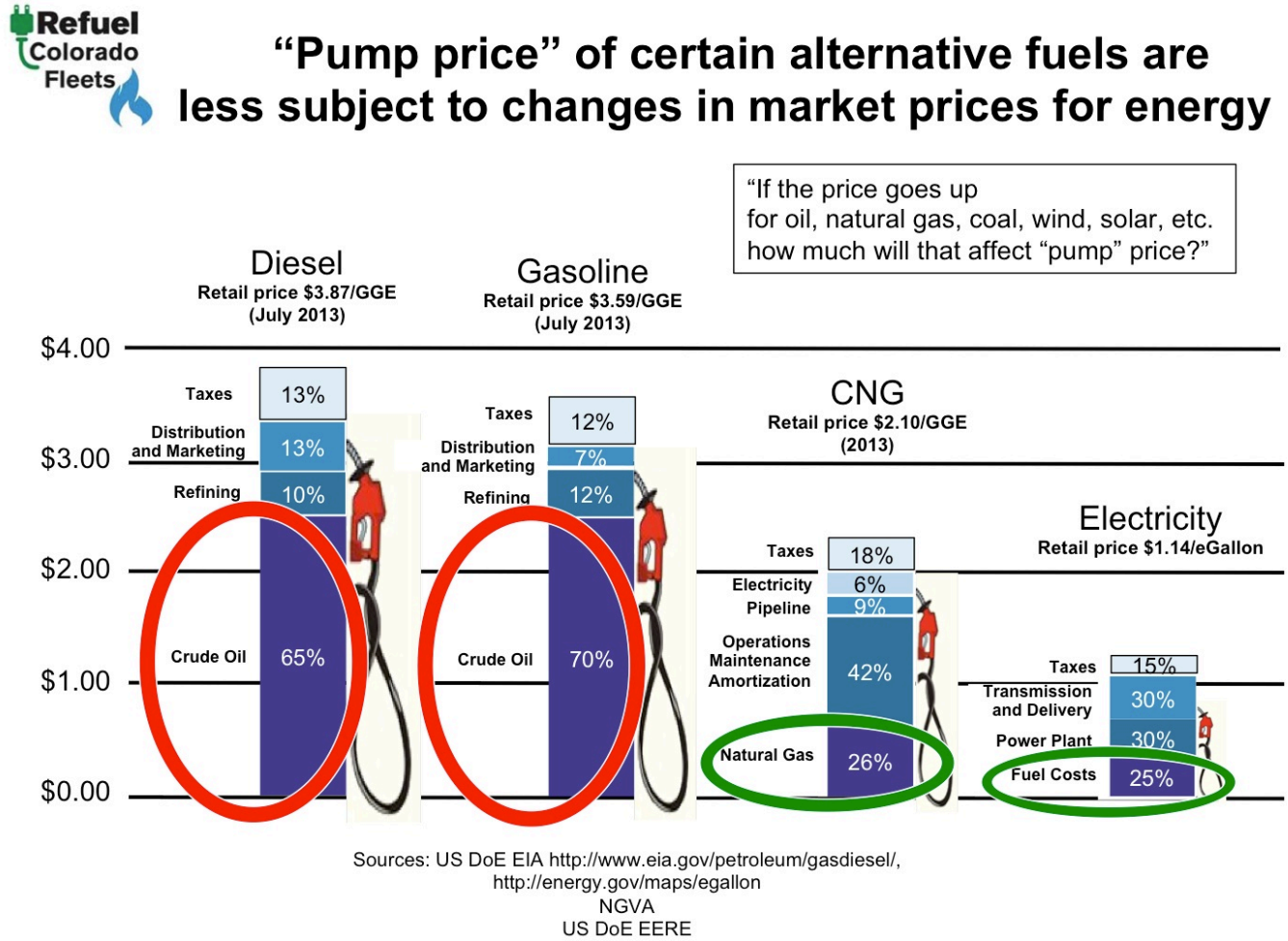


Figure 23: Percentage of Fuel Price is Affected by Commodity Price

<u>SST:</u>
<u>Atmos Energy Rate Information:</u> *(Provided in McKinstry Report)*
Commercial & Public Authority – Rate Code 05NP, 05NC

	2009	2012	2014
Facility Charge per Month:	$21.50	$24.00	$25.00
Gas DSMCA[1] per month:	$0.14	$0.12	$0.12
Gas Cost Adjustment			
PA LDC[2] Cost per CCF:	$0.12726	$0.11242	$0.09868
Upstream Cost per CCF:	$0.0990	$0.1506	$0.16436
Commodity Cost per CCF:	$0.4172	$0.4266	$0.50124
Deferred Gas Cost per CCF:	$0.0209	($0.0647)	($.01330)
Volumetric DSMCA:		$0.00055	$0.00055
Total volumetric rate:	**$0.66436**	**$0.62547**	**$0.75153**

[1] Demand Side Management Cost Adjustment
[2] Local Distribution Charge

McKinstry's 2009 Technical Energy Audit states that the City's average unit cost for delivered (fees, taxes, etc.) natural gas from 2006-2009 was $0.9553/CCF. The average cost for the last 12 months has been $1.26/CCF but includes what appear to be some anomalies. The commodity cost of natural gas represents approximately 34% of SST's gross unit cost. In 2009 McKinstry was projecting an average annual increase of 8% however Atmos's current PUC filing requests the following rate adjustments:

2013: 4.8% increase
2014: 3.3% increase
2015: 3.8% increase

Note that these requested increases are subject to change based on changing utility costs.

Analysis Assumptions:

Based on the analysis above, this analysis assumes:

- The 2013 estimated $/DGE (diesel gallon equivalent) cost of CNG including natural gas, electricity and compressor station maintenance is $1.81, based on RFTA information. It is assumed that of this $1.81, $1.08 is for delivered natural gas; $0.12 is for compression electricity; and $0.61 is for compressor station maintenance.
- The 2013 delivered price of natural gas will increase 4.5% per year based on industry projections that although Atmos is only projecting 3.6% increases in the next two years, commodity prices will slowly increase either before or soon after Atmos's planning horizon.
- The 2013 cost to compress the natural gas will increase 4.0% per year as discussed in the Electricity section.
- The 2013 cost to maintain the compressor station will increase 3.0% per year based on historical labor rate trends from 2000 to 2012 from Routt County provided by Yampa Valley Data Partners. There is no 'maintenance' rate therefore the rate used is an average of construction, manufacturing, mining and utilities.
- Based on the assumptions stated above, the 2013 estimated $/DGE cost of CNG will increase 3.85% per year.

Conclusion

Based on analysis of historical data and likely industry trends, SGM's Alternative Fuel Systems Analysis assumes that the delivered price of fuel averaged annually over the next 12 years will be as follows:

Diesel:	5.5% increase per year on average
Electricity:	4% increase per year on average
Natural Gas:	4.5% increase per year on average
CNG:	3.85% increase per year on average

Suffice it to say that forecasting energy prices is more of an art form displayed in Las Vegas than it is a science practiced at MIT. To quote the late Randy Udall discussing energy price forecasting: "Let's be humble about the future." To be humble means to accept the fact that we have much less control over the cost of fuels than we used to and therefore must adapt to greater volatility in energy markets. Therefore fuel diversity may prove to be an energy user's best friend in the coming decades.

Analysis

The purpose of this analysis is to compare lifecycle costs and other attributes of the following alternative technologies:

- Diesel (baseline)
- Electric hybrid
- Compressed natural gas (CNG)
- Battery-electric

Certainly other fuel sources are available at this time; however SGM suggested and SST agreed that this analysis should only focus on technologies that are readily viable for SST. As such this analysis also focused on the primary evaluation categories that are important to SST including:

- Vehicle and infrastructure needs;
- Tools, equipment and training needs;
- Performance in a similar climate;
- Lifecycle carbon footprint;
- Lifecycle financial analysis; and
- Implementation feasibility.

Because SST has several years of experience with both clean diesel and diesel-electric hybrids, less emphasis was put to assessing and reporting pros and cons of each. SST was also close to purchasing Proterra battery-electric buses a few years ago but ultimately chose not to at that time. Because SST is familiar with Proterra's technology, Proterra is used for the battery-electric base case.

Photo by Scott Franz, Steamboat Today

Bus Performance

Bus performance is paramount for successful implementation of any alternative fuel technology. Therefore in order to compare bus performance of the various alternatives, SST developed a list of performance categories to include in this analysis. The following table summarizes the findings.

Alternative Fuel Systems Analysis – Vehicle Performance				
Decision Driver	**Diesel**	**Diesel Hybrid**	**CNG[3]**	**Battery electric**
Fuel efficiency	5.21 MPG[1] Most suited for regional routes	5.98 MPG[2] 14.8% better; more suited for inclines and city routes	5.49 MPGE[4] 5.4% better, more suited for regional routes	22.5 MPGE[5] more suited for city routes
Distance range	~1,000 miles[6]	~600 miles for Allison; ~1,302 miles for BAE[6]	up to 700 miles for RFTA[7], depending on fueling variables	26-30 miles on 1 charge[8]
Noise	Noisiest option at 83 dBa[9]	Noticeably quieter at 70 dBa[9]	Somewhat quieter at 75 dBa[9]	Quietest option at 58 dBa[9]
Temperature	No issues	Staff reports cold temps are hard on battery life if parked outdoors	Requires coolant pre-heaters[7] if parked outdoors	No issues[10]
Altitude	No issues	No issues	No issues[7]	No issues
Load factor	Typical power loss at altitude	Typical power loss at altitude	0 torque loss to 12,000'; 0 HP loss to 8,700' (3% loss per 1000' above)	No reported issues
Road incline	Performs adequately	Performs better than diesel	RFTA mgmt. reports no issues, some drivers report power loss, could be resolved with software fix	1 user reported power loss on incline, reportedly resolved with software fix
Schedule	N/A	N/A	Construction of fueling station and facility upgrades could delay implementation	Construction of charging station(s) could delay implmt, re-charge time could impact route scheduling

Table 10 Notes:

1. Based on SST data, average of all diesel transit buses from January 2012 – April 2013
2. Based on SST data, average of all hybrid transit buses from January 2012 – April 2013
3. Assumes Gillig with Cummins ISL-G, 300 HP
4. Based on RFTA data, average of (4) 40' Gillig BRT buses from January 2013 – July 2013
5. Based on fleet-wide average MPGE from Proterra
6. Based on SST information provided.
7. Based on RFTA information provided.
8. Based on information provided by Proterra and supported by Proterra users.
9. Based on research of industry standards of buses traveling at average speeds.
10. While no Proterra buses have been consistently tested at altitudes similar to Steamboat Springs, no issues are anticipated. SST staff believes battery life may be compromised if parked outdoors.

Lifecycle Cost Analysis

The lifecycle cost analysis includes all projected costs associated with each alternative throughout a bus's expected life, except bus disposal cost / salvage value. In order to account for many different variables in the analysis, a model was created so that several different scenarios can be evaluated. The model includes the variables described and shown in the model screenshot in Table 12. The baseline costs / first-year for each alternative are also summarized below in Table 11. Note that this table is for quick comparison purposes only. The model is intended to accurately evaluate lifecycle costs.

Alternative Fuel Systems Analysis - Costs				
Decision Driver	**Diesel**	**Diesel Hybrid**	**CNG**	**Battery electric**
Bus acquisition capital	$380,000 bus cost baseline[2]	$576,631 bus cost; $205,524 (~54%) more per bus[3]	$430,000 bus cost; $50,000 (~13%) more per bus[4]	$950,000 bus cost; $570,000 (~150%) more per bus[5]
Vehicle maintenance	$15,147 / yr baseline @ $0.44/mile[6]	$19,967 / yr @ $0.58/mile; $4,820 (~32%) more per bus per year[7]	$19,967 / yr @ $0.58/mile; $4,820 (~32%) more per bus per year[8]	$12,049 / yr @ $0.35/mile; $3,098 (~21%) less per bus per year[9]
Fuel *(first year)*[1]	$22,863 / yr baseline @ $3.46/gal[10]	$19,919 / yr @ $3.46/gal ; $2,944 (~13%) less per bus per year[10]	$11,287 / yr @ $1.80/DGE; $11,576 (~51%) less per bus per year[11];	$5,474 / yr @ $0.09223/kWh; $17,389 (~76%) less per bus per year[12]
Facility capital	$0	$0	$4,381,618,000 one-time cost for fueling station and maint. Facility upgrades[13]	$600,000 one-time cost for (1) fast charging station[14]

Table 11: Alternative Fuel Systems Analysis - Costs

1. Note that this table only lists first year costs for simple comparison. The model takes into account true lifecycle costs that are affected by annual inflation such as the cost of energy, financing costs and labor rate increases.
2. Based on non-binding quote from Joe Saldana (Gillig) to Jonathan Flint (SST) on 10/9/2013.
3. Based on comparing most recent SST hybrid bus procurement with Gillig quote for diesel bus.
4. Based on non-binding quote from Joe Saldana (Gillig) to Jonathan Flint (SST) on 10/9/2013.
5. Based on Proterra's /Total Cost of Ownership Comparison' provided to SGM on 10/2/2013.
6. Based on SST diesel bus maintenance cost data from Jan 1 – Aug 31 of 2013.
7. Based on SST hybrid bus maintenance cost data from Jan 1 – Aug 31 of 2013.
8. Based on RFTA's estimate of CNG bus maintenance being very similar to hybrid bus maintenance.
9. Based on adjusting information provided by Proterra and supported by some Proterra users.
10. Based on SST's 2013 cost for diesel and MPG stated in Table 9.

11. Based on RFTA's cost per DGE including cost of natural gas, compressor station maintenance and electricity used to compress natural gas; and MPGE stated in Table 10.
12. Based on SST 2013 cost of electricity and MPGE stated in Table 10.
13. Based on cost estimate provided by MW Golden Constructors (RFTA's general contractor) to upgrade SST's Transit Center; and a general cost estimate from Trillium CNG for a time-fill station.
14. Based on information provided by Proterra for one fast charging station.

Lifecycle Cost Model Variables

A lifecycle cost model was also constructed to quickly and accurately evaluate the costs of the different propulsion technologies under different scenarios. For this model, the following variables can be easily changed to evaluate different scenarios:

- Fuel efficiency of the vehicle: New technology may increase fuel efficiency over time or new data may prove that old assumptions are incorrect.
- Unit cost of fuel: This price represents baseline costs so this shouldn't change for diesel, hybrid or electricity, but new data could change the calculated cost of CNG per DGE.
- Energy inflation factor: The baseline assumptions for these factors are listed in the 'Energy Price Analysis' section and represent perhaps the biggest unknown in this analysis. Changes in this factor will have a significant effect on model projections.
- Gross bus acquisition cost per bus: These numbers should be updated when firm bids or more accurate cost estimates are received.
- Grant funding available as a percentage of gross bus acquisition cost: These numbers should be updated when grants are identified and/or awarded.
- Financing rate and term for bus acquisition costs: These numbers should be updated as financing strategies are identified.
- Gross infrastructure costs for fueling and/or charging stations, maintenance facility upgrades, etc.: These numbers should be updated when firm bids or more accurate cost estimates are received.
- Grant funding available as a percentage of gross infrastructure cost: These numbers should be updated when grants are identified and/or awarded.
- Financing rate for infrastructure costs: These numbers should be updated as financing strategies are identified.
- Bus maintenance cost per mile: New technology may change maintenance costs over time or new data may prove that old assumptions are incorrect.
- Labor inflation rate per year for mechanics: New data may prove that old assumptions are incorrect.
- Average miles traveled per bus per year: This number should change if routes change or more accurate route mileage projections become available.
- Average lifespan of buses: This number should change if new data proves that old assumptions are incorrect, or if lifecycles wanted to be evaluated for a different timespan.
- Number of buses purchased: This number has a significant effect on lifecycle cost and should account for whether buses are replaced through attrition or whether a larger quantities of buses can be purchased in order to justify infrastructure costs.

SST Alternative Fuel Lifecycle Cost Model				
	Diesel	Hybrid	CNG	Electric
Length	35	35	35	35
MPGe	5.21	5.98	5.49	0.58
Unit price of fuel (2013)	$ 3.46	$ 3.46	$ 1.81	$ 0.09223
Fuel inflation rate (%/yr)	5.5%	5.5%	3.9%	4.0%
Lifetime average unit fuel price	$ 5.02	$ 5.02	$ 2.33	$ 0.1199
Gross bus acquisition cost	$ 380,000	$ 576,631	$ 430,000	$ 950,000
Grant funding (%)	0%	0%	0%	0%
Net bus acquisition cost	$ 380,000	$ 576,631	$ 430,000	$ 950,000
Financing	Rate:	0.0%	Term:	12
Bus cost with cost of financing	$ 380,000	$ 576,631	$ 430,000	$ 950,000
Annual bus debt service	$31,667	$48,053	$35,833	$79,167
Bus acquisition cost/mile	$ 0.92	$ 1.40	$ 1.04	$ 2.30
fueling/charging station cost	$ -	$ -	$ 1,650,000	$ 600,000
maintenance facility upgrade cost	$ -	$ -	$ 2,731,618	$ -
Gross infrastructure cost	$ -	$ -	$ 4,381,618	$ 600,000
Grant funding (%)	0%	0%	0%	0%
Net infrastructure cost	$ -	$ -	$ 4,381,618	$ 600,000
Financing terms	Rate:	0.0%	Term:	12
Infrastructure cost with cost of financing	$ -	$ -	$ 4,381,618	$ 600,000
Annual infrastructure debt service	N/A	N/A	$219,081	$30,000
Infrastructure cost/mile	N/A	N/A	3.54	$ 0.48
2013 fuel cost/mile	$ 0.66	$ 0.58	$ 0.33	$ 0.1590
Lifetime fuel costs	$ 398,080	$ 346,677	$ 175,259	$ 85,434
Lifetime average fuel cost/mile	$ 0.96	$ 0.85	$ 0.42	$ 0.2068
2013 bus maintenance cost/mile	$ 0.44	$ 0.58	$ 0.58	$ 0.35
Labor inflation rate (%/yr)	3.0%	3.0%	3.0%	3.0%
Lifetime maintenance costs	$ 220,467	$ 290,616	$ 290,616	$ 175,372
Lifetime average bus maint. cost/mile	$ 0.53	$ 0.70	$ 0.70	$ 0.42
2013 Total cost/mile	$ 2.02	$ 2.55	$ 5.49	$ 3.29
Total Lifetime cost/mile	$ 2.42	$ 2.94	$ 5.70	$ 3.42
Lifetime cost (1 bus)	$ 998,547	$ 1,213,923	$ 2,356,414	$ 1,410,806
Lifetime cost/mile (w/out infrastructure $)	$ 2.42	$ 2.94	$ 2.17	$ 2.93
Lifetime cost (1 bus w/out infrastructure $)	$ 1,123,610	$ 1,322,837	$ 895,875	$ 1,356,114
Lifetime cost x # of buses + infra. $	$ 3,370,830	$ 3,968,511	$ 6,187,625	$ 4,668,342

average annual miles	34,426
average years in service	12
lifetime miles	413,117
number of buses purchased	3
lifetime miles x number of buses	1,239,352

Table 12: SST Alternative Fuel Lifecycle Cost Model Screenshot

Preliminary scenario modeling results

It is important to note that for SST, lifecycle cost is but one category used in evaluating the best alternative. For this reason, rather than simply using the model to determine which alternative has the lowest cost given the baseline assumptions, optimal scenarios for each alternative were created based on other possible assumptions. For example, if grant funding for one alternative suddenly became available making its lifecycle costs lower than under the baseline assumptions, it could change the outcome and possibly the recommendation. This model is intended to be a tool for SST to continue to evaluate alternatives as conditions or assumptions change.

Model Baseline Assumptions and Optimal Scenarios for Each Alternative
Baseline Assumptions
SGM's fuel inflation rates.
No financing costs for buses or infrastructure.
No grant funding for buses or infrastructure.
Three buses purchased.
Labor rates increase 3% per year.
Lifecycle cost ratings (low to high): Diesel, Hybrid, Electric and CNG.
Diesel Optimal
Base case assumptions.
Hybrid Optimal
Base case assumptions except Hybrid net bus acquisition cost is ≤ $357,511 (equivalent to a 38% discount on cost.)
Electric Optimal
Base case assumptions except diesel cost increase ≥ 14.5% per year.
Base case assumptions except Electric bus acquisition cost is ≤ $536,750 (equivalent to a 43.5% discount on cost.)
CNG Optimal
Base case assumptions except diesel cost increase ≥ 9% per year and ≥ 20 buses are purchased.
Bus purchase ≥ 43 buses.
Net infrastructure costs don't exceed $1,007,772 (equivalent to a 77% discount on cost) and ≥ 10 buses are purchased.
Net infrastructure costs don't exceed $2,037,452 (equivalent to a 53.5% discount on cost) and ≥ 20 buses are purchased.

Table 13: Lifecycle Cost Model Assumptions

Primary Decision Drivers

In addition to bus performance and lifecycle cost, SST developed a comprehensive list of evaluation categories to guide the decision-making process. In the table below, a summary for each alternative within each category is listed. Based on how each alternative measured up to SST's criteria for performance, a score was assigned for each alternative. The highest possible score is 10. In addition, each category was weighted by SST based on the importance the category has in the decision-making process. Then the score for each alternative in each category was multiplied by the weighting factor of each category to come up with a weighted score for each category and a total weighted score.

Alternative Fuel Systems Analysis - Summary

Decision Driver	Diesel	Diesel Hybrid	CNG	Battery electric
Vehicle maintenance Weighting: **8**	Requires particulate filter changes and exhaust fluid maintenance	Battery maintenance and replacement req'd; SST experiences approximately 32% more maintenance	Requires periodic tank inspection, spark plug changes, valve adjustments, and fuel filter draining; approximately 32% more maintenance projected	Battery maintenance and replacement req'd (5-7 yrs), reportedly requires 'significantly' less maintenance than diesel or CNG
Score	4	3	3	5
Weighted Score	32	24	24	40
Tools & equipment Weighting: **6**	N/A	N/A	Calibration tools for methane detectors	Potential minor maintenance of charging station
Score	5	5	4	4
Weighted Score	30	30	24	24
Training Weighting: **5**	N/A	N/A	Requires CNG vehicle, fueling and facility training for staff	Requires high voltage training for staff for charging stations
Score	5	5	2	4
Weighted Score	25	25	10	20
Lifecycle cost for 3 buses Weighting: **9**	$ 2,995,642	$ 3,641,770	$ 7,069,243	$ 4,232,418
Score	5	4.4	1	3.8
Weighted Score	45	40	9	34

Price volatility Weighting: **7**	Highest risk exposure of all alternatives	Slightly less due to fuel costs per mile being ~6% less	Less volatile than diesel, more volatile than electricity; fuel is smaller % of $/gal cost	The most stable of all alternatives
Score	1	2	3	5
Weighted Score	7	14	21	35
Carbon Footprint[1,2] Weighting: **4**	0 (baseline)	15 – 20% less[3] Slightly less due to fuel use being ~6% less	0 - 10% more[3] Dependent upon GHG calculation methodology	25 – 55% less[4] Dependent on the carbon-intensity of the electricity
Score	2	3	1.5	5
Weighted Score	8	12	6	20
Implementation Weighting: **10**	N/A	Continue order of hybrid buses	Most difficult: would require new fueling station, upgraded TOC, staff and first responder training; at least 1 year from decision	More difficult: would require route planning with charging station, construction of new charging station(s), staff and first responder training
Score	4	5	1	2
Weighted Score	40	50	10	20
Total Score	**26**	**27.4**	**15.5**	**28.8**
Total Weighted Score	**187**	**195**	**104**	**193**

Table 14: Alternative Fuel Systems Analysis - Summary

1. Because there are several variables influencing the carbon footprint of SST's fleet, rather than state a specific 'lbs of CO_2/mile' for each technology, each technology is compared to diesel.
2. While tailpipe emissions were not a primary decision driver included in the original scope of this report, this topic is discussed in greater detail on the following page.
3. For diesel, hybrid and CNG, this analysis cites greenhouse gas emissions analysis from the WBJ&A report listed on page 10 of this report. The emissions from the two different types of buses listed in that report were averaged and the 'short-term' and 'long-term' global warming potential (GWP) was addressed in the ranges stated in the table.
4. For electricity, a carbon factor was used to calculate greenhouse gas emissions. The carbon factor used is (1.618 lb/kWh) and is based on an estimated Xcel Energy (YVEA wholesale provider) source mix.

Additional Decision Driver: Emissions

On the following page is an excerpt from the Executive Summary of the report *Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses: Efficiency & Environmental Performance*, by M.J. Bradley & Associates. This report was released in November of 2013 and summarizes the research and analysis on efficiency, air quality and climate change impacts of transit buses, based on data collected by the Altoona Bus Research & Testing Center under the Federal Transit Administration's new model bus testing program. This excerpt is included in this report because it includes relevant findings, but also because it highlights the complexities of comparing emissions of different propulsion technologies.

An example of this is comparing the 'Carbon Footprint' of each propulsion technology. As stated in the 'Climate Impacts' section of the Executive Summary excerpt below, the "upstream impact of methane emissions" is higher than has previously been estimated, largely due to recent analysis of fugitive methane emissions or 'leaks' from gas distribution pipelines. It is still highly likely that this analysis may continue to change as further research is conducted and methane collection practices evolve. Suffice it to say the MJB&A report represents the most recent and thorough analysis on the topic and therefore its conclusions are adopted as part of the SST report.

Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses:

Efficiency & Environmental Performance

MJB & A

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47 JUNCTION SQUARE DRIVE
CONCORD, MA 01742
978-405-1275
www.mjbradley.com

Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses: *Efficiency & Environmental Performance*, by M.J. Bradley & Associates

Excerpt from the Executive Summary:

EFFICIENCY & FUEL CONSUMPTION

- CNG and diesel buses have similar over-all drivetrain efficiency. Of 14 direct comparisons (diesel and CNG versions on the same bus platform) the diesel bus had higher fuel economy over ten different tests, while the CNG bus had higher fuel economy on one test and the diesel and CNG versions had virtually identical fuel economy on three tests.
- Hybrid buses consistently have higher average fuel economy than the diesel and CNG versions of the same bus platform on slow- and medium-speed test cycles (< 18 MPH); on these cycles average fuel economy of the hybrid buses was between 7% and 44% higher than the average fuel economy of the diesel version of the same bus. On higher-speed test cycles the hybrid buses generally have the same or lower average fuel economy than the diesel version of the same bus. On slow- and medium-speed duty cycles the annual fuel savings from operating new hybrid buses instead of new diesel buses could be as high as 3,100 gallons per bus. According to data reported to the National Transit Database, approximately 75% of U.S. transit agencies, and 90% of U.S. transit buses on average operate in slow- and medium-speed duty cycles (<16 MPH).

AIR QUALITY

- CNG buses consistently have lower NOx emissions and higher CO emissions than diesel and hybrid buses across all duty cycles. Annual reductions in NOx emissions from operating new CNG buses instead of new diesel buses could be as high as 82 pounds per bus. Annual increases in CO emissions from operating new CNG buses instead of new diesel buses could be as high as 1,000 pounds per bus.
- Hybrid buses generally have slightly lower NOx emissions than diesel buses, but on several tests hybrid NOx emissions were higher than from the diesel version of the same bus.
- Diesel and hybrid buses both have very low PM emissions, equivalent to only about one third or less of the allowable EPA standard. PM was not measured for the CNG buses.
- All three technologies have very low NMHC emissions, equivalent to only about one fourth or less of the allowable EPA standard.

CLIMATE IMPACTS

- Diesel and CNG buses emit very similar levels of CO_2 from their tailpipes (g/mi); while natural gas has lower carbon content than diesel fuel this advantage is eroded by generally higher fuel economy for diesels. This result is different than reported results for other heavy-duty vehicles (for example long-haul trucks) due to differences in engine technology and duty cycle. Hybrid buses generally emit lower CO_2 (g/mi) than diesel or CNG buses due to their higher fuel economy.
- Total wells-to-wheels GHG emissions (g CO_2-e/mi) are generally slightly higher from CNG buses than from diesel buses, due primarily to the “upstream” impact of methane emissions from natural gas production and processing. The increase in total annual GHG emissions from operating new CNG buses instead of new diesel buses could be as high as 13.3 tons CO_2-e per bus.
- Total wells-to-wheels GHG emissions are generally lower from hybrid buses than from diesel or CNG buses due to their higher fuel economy. The reduction in total annual GHG emissions from operating new hybrid buses instead of new CNG buses could be as high as 54.5 tons CO_2-e per bus.

Conclusions and Recommendations

Successfully managing a public transit operation is both technically and financially challenging. It's a continuous balancing act of providing reliable service at a reasonable cost with significant variables, not least of which is the cost of fuel. While the primary driver for evaluating alternative fuels may be environmental stewardship, it is imperative that the entire fleet operate reliably, on schedule and within budget. For this reason several factors were considered with respect to performance, capital costs and operating costs. The Lifecycle Cost Model was created so that the different costs and the variables affecting these costs could be compared over the life of the bus. It is important to point out that as these variables change, so do lifecycle costs. All this is to say that the alternative with the lowest lifecycle cost and best score may and likely will change as conditions change.

For this reason, there isn't one 'winner', but rather specific recommendations on how to pursue each alternative depending on conditions, including present conditions. These recommendations are based on SST's stated priorities as well as SGM's research and analysis. The following is a summary of key findings that have guided these recommendations.

Summary of Key Findings

- SST recently purchased (3) new hybrid buses with (3) more to be purchased in the near future. Six diesel buses are currently being refurbished. The next significant bus purchase is not planned until 2019.
- Due to significant budget constraints and the potential to receive grants for capital purchases, reducing operating expenses, especially fuel expenses, is a high priority.
- Because of the high volatility of diesel, the business as usual approach is highly susceptible to large price swings that, due to historically fixed operating expenses, could result in additional service reductions. Diversifying fuel sources will provide more stability in overall fuel costs.
- SST has explored and accepted the viability of Proterra battery-electric buses and therefore this option is more viable than if this due diligence had not been done. According to transit agency representatives interviewed, these buses are performing well.
- The Roaring Fork Transportation Authority's (RFTA) experience with CNG has been very positive to date and because of the very similar climate and operating conditions, demonstrates that CNG is a viable alternative for SST.
- Perhaps the most significant variables in determining lifecycle costs will be: 1) the future cost of energy; 2) the availability of grants to offset the cost premium of buses and/or infrastructure; and 3) the number of alternative fuel buses purchased.

Summary of Alternatives

Alternative	Advantages	Disadvantages
Diesel	Lowest cost bus; lowest lifecycle cost (under current conditions); familiarity with the technology	Susceptible to volatile and increasing cost of diesel; air pollution associated with diesel; noisiest alternative
Hybrid-electric	12% lower annual fuel costs; reduced noise; familiarity with the technology	Higher cost of buses; susceptible to volatile and increasing cost of diesel; more maintenance than diesel, potential battery replacement needs
Compressed Natural Gas (CNG)	Second lowest annual fuel costs; low projected price volatility; lowest lifecycle cost when most of fleet is replaced and infrastructure costs can be significantly offset with grants	Highest capital expenses - constructing a fueling station and upgrading the maintenance facility; higher cost of buses; unfamiliarity with the technology
Battery-electric	By far lowest annual fuel costs; lowest projected price volatility; lowest maintenance cost, lowest lifecycle cost when bus cost premium can be significantly offset with grants	By far highest bus cost; battery replacement needs; route scheduling challenges due to recharging; unfamiliarity with the technology

Table 15: Summary of Alternatives

Summary of Recommendations

1. Continue current plan to acquire grant funding for hybrid bus purchase.
2. Begin budgeting higher than anticipated for fuel expenses. Reserve any surplus funds in a 'fuel volatility fund' to better prepare for large price swings in the future.
3. Regularly re-evaluate potential funding sources to offset the bus premiums and infrastructure costs for both battery-electric and CNG, including the State's recently announced CMAQ program.
4. Continue to assess potential partnership with other fleet owners and/or fueling station owners about the possibility of a CNG fueling partnership.
5. Monitor the 'Lifecycle Cost Model Variables' discussed on page 40 and re-run scenarios as appropriate in order to determine whether conditions have changed enough to alter the present course of action.
6. Evaluate electrification of accessories during refurbishment of existing buses or for new bus purchases.
7. Explore a dedicated funding source for SST operations.

Regardless of which alternative fuel SST wishes to pursue, the following next steps are recommended before any investment is made because they are likely to change over time:

1. Confirm the assumptions for the scenario for which you wish to plan.
2. Confirm lifecycle cost estimates for the scenario.

3. Confirm the priority and weighting factor for each of the primary decision drivers.
4. Achieve consensus within SST as to which technology you wish to purse and how aggressively you would like to pursue it.
5. Pursue technology-specific next steps as outlined in conclusion of this report.

Implementation

If diesel is the choice:

- Make upcoming bus purchase diesel.
- Begin budgeting higher than anticipated for fuel expenses. Reserve any surplus funds in a 'fuel volatility fund' to better prepare for large price swings in the future.
- Prepare public outreach campaign to combat likely pollution and noise complaints.

If hybrid is the choice:

- Continue current plan to acquire grant funding for upcoming bus purchase.
- Begin budgeting higher than anticipated for fuel expenses. Reserve any surplus funds in a 'fuel volatility fund' to better prepare for large price swings in the future.

If CNG is the choice:

- Re-evaluate current plan to purchase 3 additional hybrid buses and refurbish diesel buses and consider larger replacement purchase with CNG buses. Get firm bids from vendors on CNG buses.
- Confirm that timeframe to take delivery of buses and completing fueling station and facility upgrade project is acceptable.
- Assess potential partnership with other fleet owners and/or fueling station owners about the possibility of a CNG fueling partnership.
- Release RFI to interested vendors for the design, construction, operation and maintenance of a CNG station. This will help solidify what options for a fueling station are really possible and what the cost would be.
- Evaluate funding sources for bus premiums and infrastructure costs. Note this recently posted grant opportunity: Colorado announces Federal Highway Administration's Congestion, Mitigation and Air Quality (CMAQ) program
- Work with a contractor to further refine the cost to upgrade the Transit Operations Center.
- Update the lifecycle cost model with current pricing for buses, fueling station and facility upgrades.
- Confirm choice to pursue CNG.
- Plan the design and implementation of fueling station and facility upgrades. Decide on the structure of the fueling station RFP and contract (ie separate design, build, operate and maintain or create a combination the four components).
- Draft separate RFPs for 1) the design and/or construction of the fueling station; and 2) Transit Operations Center facility upgrades.
- Select contractors/vendors and begin the project.
- Develop staff training and either develop or integrate CNG into existing Emergency Response Protocol.

If battery-electric is the choice:

- Carefully evaluate route(s) to confirm that on-route charging will work within schedule parameters. Perform preliminary planning and budgeting of charging station.
- Confirm that timeframe to take delivery of buses and completing charging station project is acceptable.
- Meet with Yampa Valley Electric Association to confirm rate structure for charging station.
- Re-evaluate current plan to purchase 3 additional hybrid buses and refurbish diesel buses and consider larger replacement purchase with battery-electric buses. Get firm bids from vendors on battery-electric buses and charging station.
- Evaluate funding sources for bus premiums and infrastructure costs.
- Update the lifecycle cost model with current pricing for buses and charging station.
- Confirm choice to pursue battery-electric.
- Complete planning and design of charging station.
- Draft a RFP for the construction of the charging station.
- Select contractors/vendors and begin the project.
- Develop staff training and either develop or integrate battery-electric buses into existing Emergency Response Protocol.

ENDNOTES

[i] RFTA's 'all-in' cost per DGE includes the cost of natural gas and the electricity to compress it; O&M costs which include Trillium CNG providing contract O&M services; and amortized debt service over 20 years. Note that the amortized debt cost includes the full cost of all buses; the full cost to design, construct and manage all facility improvements including a new fueling station, back-up generator and maintenance facility upgrades; the cost of bond issuance; *minus* grant revenues which covered approximately 60% of total project costs.

[ii] http://www.eia.gov/forecasts/aeo/pdf/0383(2013).pdf

[iii] http://peak-oil.org/wp-content/files/por130715.pdf (Accessed July 15, 2013)

[iv] http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm (Accessed July 12, 2013)

[v] http://www.eia.gov/forecasts/aeo/tables_ref.cfm (Accessed July 12, 2013)

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