# Executive Summary

Chesapeake Utilities Corporation (CUC) was requested to provide a cost-benefit analysis for converting NASA's Wallops facility from propane to natural gas. CUC and its subsidiaries Eastern Shore Natural Gas (ESNG) and Sharp Energy collaborated in the study. ESNG operates the high-pressure interstate gas transmission system in southern Delmarva, and would be responsible for extending its gas pipeline south from Salisbury MD into Virginia to provide service to Wallops. Sharp Energy currently provides propane to the base.

As discussed previously with personnel from NASA and LJT and Associates, ESNG has investigated the cost for extending its pipeline system to Virginia for more than a decade. It is not currently economical to build a new pipeline to serve Wallops based on the Federal Energy Regulatory Commission (FERC) process for the approval of new pipeline projects. CUC and ESNG continue to work with state and local stakeholders to develop options to incent construction of new pipeline infrastructure. Unfortunately, it is unlikely that pipeline gas will be extended to Virginia in the next five years.

CUC and other entities have investigated alternative methods for providing natural gas to Delmarva regions not served by natural gas. Two options are truck-delivered compressed natural gas (CNG) and liquefied natural gas (LNG). Truck-delivered CNG and LNG are logistically similar to propane. On-site storage tank(s) provide surge capacity; a delivery system ensures gas flows at the correct pressure and temperature; and the existing propane delivery system (piping, meters, etc.) provides connectivity across the facility. Propane, CNG, and LNG compete for market share. The total delivered energy costs depends on the cost of the commodity, and the cost to compress/liquefy, transport, store, decompress/regasify. With the decrease in propane prices in 2014, CUC concluded that propane currently has the lowest total delivered cost in southern Delmarva. CUC continues to monitor market conditions. It is possible that CNG may become an economical option in the next 1-3 years. Two key issues are the relative escalation of propane and natural gas commodity prices, and the development of a sufficiently large CNG market in the Delmarva region. While LNG could also become an economical option in the next 1-3 years, there are more challenges due to the greater distance to LNG sources, and the high capital costs for a new facility closer to Wallops.

When natural gas becomes a cost-effective option, Wallops should see several benefits:

- Greenhouse gas (GHG) reductions: At point-of-use, natural gas has 16% lower $CO_2$ emissions than propane. Since the majority of equipment at Wallops has already been converted to propane, site-based (GHG inventory scope 1) GHG reductions should approach 16%. A more comprehensive GHG criterion is a fuel's life-cycle GHG impact. Argonne National Laboratory's GREET model provides some indications for GHG impacts for pipeline natural gas, CNG, LNG, and propane. It is beyond the scope of this study to establish specific values for each energy option at Wallops. However, it is likely that using natural gas, regardless of method of delivery, will reduce total life-cycle GHG emissions by at least 10% compared to propane.

- Ability to convert current equipment: Under Wallop's previous ESPC contract, most of the larger energy users were converted to propane and connected to the facility's underground distribution system. We assume the distribution system was designed to accommodate conversion to natural gas, so most equipment (meters, regulators) can be field-modified when gas is available. Boilers and other end-use equipment can also be economically converted, typically with minor equipment modifications (orifice replacement, adjustment of burner control settings).
- Energy cost savings: Wholesale commodity prices for natural gas are currently 50% lower for natural gas compared to propane. However, the delivered cost for natural gas is currently higher than the delivered cost of propane. As noted above, the most likely option for gas service to Wallops in the 1-3 year time frame is CNG via "virtual pipeline". If propane prices escalate faster than natural gas, and a sufficiently large CNG market develops in Delmarva, CNG could be 10-20% less expensive than propane in the 1-3 year time frame. We do not anticipate that pipeline natural gas will be available to Wallops in the foreseeable future.

As part of the study, CUC was asked to work with Wallops facility personnel and provide projected fuel consumption at WFF over the next 10 years for equipment that would be transitioned to natural gas. Preliminary assessment indicates that the ESPC contractor has been effective in replacing or converting the major energy users on the facility. Consequently we do not anticipate increased energy consumption unless new loads are added to the base.

The potential to use propane today, or natural gas in the future, for vehicle fueling is another option to reduce cost and GHG emissions. Most of the current fleet operates on gasoline. Propane is a cost-effective alternative to gasoline; paybacks can be less than three years, depending on vehicle fuel consumption (miles driven and fuel efficiency). Since the base already has substantial propane infrastructure, the incremental costs for propane vehicle fueling is modest. Propane vehicles generally offer a 10% or greater GHG reduction compared to gasoline vehicles on a wells-to-wheels basis.

# Natural Gas Infrastructure Options and Cost

As part of this study CUC has summarized the factors that impact the total delivered cost of fuel options for Wallops. Wallops primarily uses propane, with only two small units firing ultra-low sulfur diesel (ULSD). Natural gas could be delivered via pipeline, or via “virtual pipeline” options such as truck-delivered compressed natural gas (CNG) or liquefied natural gas (LNG). Currently propane is the lowest-cost fuel option for Wallops. This section compares and contrasts the factors that influence the total delivered energy costs for propane, CNG, LNG, and pipeline natural gas. The two major factors are the cost of the commodity (propane, natural gas), and the cost to make it available at the facility. We address these two issues in the next sections.

**Commodity Costs**

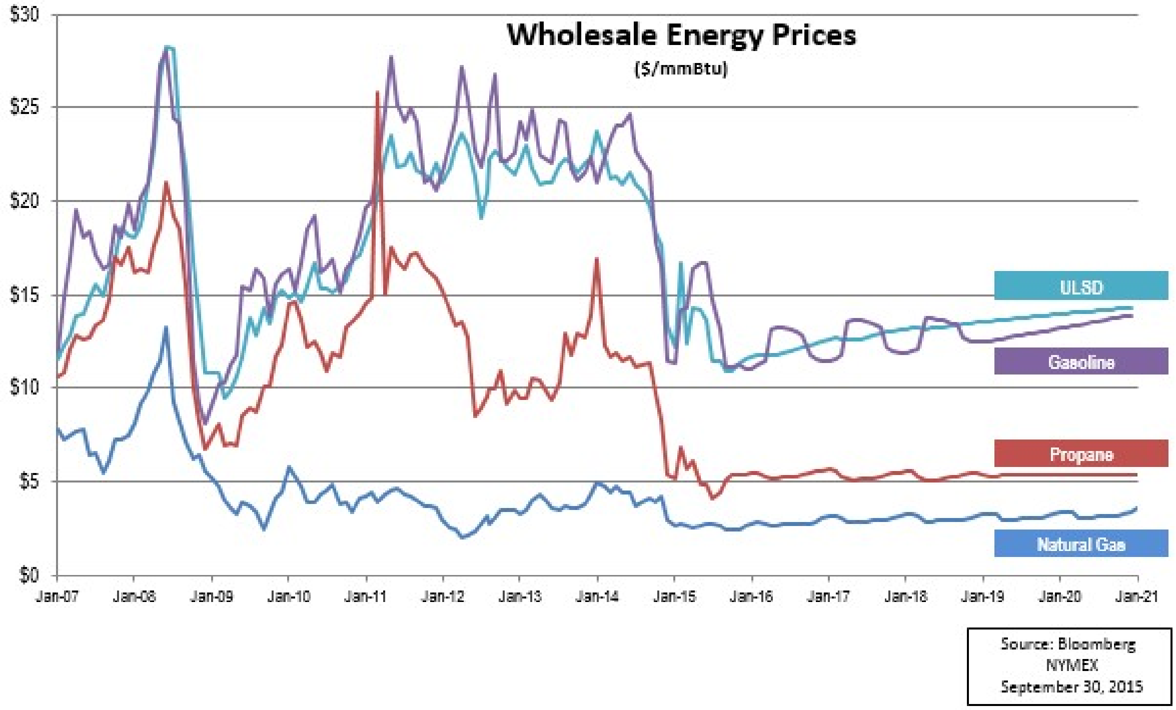
Energy commodity costs have varied significantly in the past decade, as shown in Figure 1. The price for energy commodities are tied to trading locations:

- Natural gas – Henry Hub
- Propane – Mt. Belvieu
- Gasoline and ULSD – New York harbor

In general, natural gas costs “delinked” from oil and petroleum products in 2009 due to increased domestic production. Propane prices also “delinked” from oil, gasoline, and diesel around 2011 due to increases domestic production. In less than 4 years the US has transitioned from being a LPG importer to the largest LPG exporter in the world. Historically natural gas has retained a commodity cost advantage over propane, although the discount decreased significantly in late 2014. Both natural gas and propane have significant commodity cost advantage over gasoline and ULSD.

Future energy costs are speculative. However, NYMEX energy futures markets provide insights, and can be used to create financial instruments to “lock in” projected energy prices. Based on NYMEX, it appears that natural gas and propane will experience relatively low cost and lower cost increases than gasoline and ULSD through 2020. Based on the commodity futures markets, the spread between natural gas and propane commodity costs is projected to be is expected to be in the $1-3/MM Btu in the next five years, below the historical range. An alternative view is that domestic propane prices will get linked to oil prices due to the large volume of propane exports. If this happens, propane prices could escalate at the same rate as gasoline and ULSD in Figure 1. In this case the spread between natural gas and propane could widen, which would make natural gas more competitive with propane.

**Figure 1 Wholesale Energy Commodity Prices**




## Delivered Fuel Costs

The supply chains for propane, CNG, and LNG fuels differ, but have several common characteristics:

- Cost of fuel at the aggregation point
- Cost to move from the aggregation point to Wallops by truck
- Cost to store fuel at site
- Cost to transition fuel from storage into the propane distribution grid

Table 1 shows a comparison cost and other factors for fuel options, which are discussed below for each option.

**Table 1 Fuel Considerations 1-3 year time frame**

| Consideration | Propane | CNG | LNG | Pipeline gas |
|---|---|---|---|---|
| Projected Commodity Cost ($/MM Btu) | $5-8 | $2-5 | $2-5 | $2-5 |
| Delivered Cost ($/MM Btu) | $11-14 | $12-20 | $15-25 | Not expected to be economical to build pipeline |
| Incremental Investment cost to deliver, store, and introduce fuel into distribution grid | NA | $4-6MM (compression, tube trailers, decompression skid) | $3-5MM (LNG tankers, LNG tank, vaporizer; excludes cost for LNG production) | >$70MM |
| Time to implement | NA | 12-18 months, depending on permitting and equipment | 6-12 months, depending on permitting | >3 years |
| One-way trucking distance | 35 miles | ~100 miles, assuming DE site for new facility | 200 miles (based on current sources) | NA |
| Max energy stored on site (MM Btu) | 5000 (assuming 2 X 30,000 gal tanks) | 600-1000 (assuming manifold for 2 tube trailers | 1200 (assuming 15,000 gal tank) | NA |
| Vehicle fueling | Primarily for gasoline engines | Gasoline and diesel engines | Gasoline and diesel engines | Gasoline and diesel engines |

**Propane**

Propane is competitively priced at present. Recent delivered propane costs are approximately $11-14/MM Btu, and are projected to stay at the lower end of this range for the near future. Propane is likely to remain the lowest-cost fuel on a delivered basis in the 1-3 year time frame. In addition to low cost, propane has an advantage in terms of “fuel supply security”. Propane is delivered to the base from Sharp’s terminal in Princess Ann MD, which will have approximately one million gallons of storage in 2016. The trucking distance to Wallops is about 35 miles, the shortest distance among the options. Propane is delivered in transport trailers which contain 1600-2700 MMBtu of propane. Propane is stored on-site in pressurized tanks. The propane has the lowest on-site storage cost, and hence will likely have the largest on-site storage capacity. Propane is regasified from approximately ambient temperature and regulated to a delivery pressure of the on-site system.

**CNG**

CNG is currently not available on Delmarva. However, CUC believes CNG could become an option in the near-term. There is an on-going interest in CNG in Delmarva, suggesting there could be a larger customer base to share fixed costs. Delaware has a state-sponsored grant program to support construction of new facilities. It is expected that CUC and possibly other companies will apply for grants.

CNG could become competitive with propane if a sufficiently large CNG market develops to support infrastructure investment, and the spread between natural gas and propane commodity costs increases. Should both factors emerge, CNG is estimated to cost $12-20/MM Btu. The cost would trend to the lower end if other CNG customers can be served in Delmarva. Under these circumstances, CNG could be in the range of 10-20% less expensive than propane.

The cost for CNG includes the cost of the natural gas commodity, approximately $2.2-2.5/MM Btu, and the cost to deliver it to a future (ie not yet planned) CNG compression facility in Delmarva, which is estimated at $1-2/MM Btu. A CNG tube trailer compressor facility is projected to cost $0.8-2.5M, depending on the size of the facility. Tube trailers cost approximately $250K. We estimate that Wallops would require two dedicated tube trailers to meet winter requirements, although there would be fewer deliveries in summer months. Decompression equipment is $100-250K, depending on the flow rate, need to reheat gas, and complexity of metering requirements.

CNG would most likely be produced at a new compressor station built adjacent to the ESNG pipeline infrastructure in Delaware, ideally south of Dover. Permitting and constructing CNG infrastructure would require approximately 12-18 months. We estimate the trucking distance at about 100 miles, although it could range from 50-150 miles. CNG is compressed to approximately 3500 psi and delivered via tube trailers. Currently available CNG tube trailers contain about 300 MM Btu of gas. Several manufacturers have announced higher-pressure trailers with capacity greater than 500 MM Btu. At Wallops, the tube trailers would be connected to a decompression unit that has a manifold to connect several tube trailers. Gas is depressurized, and heated if required.

CNG deliveries by “virtual pipeline” using tube trailers could be provided by Chesapeake or by an unregulated third-party service. It is also possible that Wallops could elect to purchase its own equipment. The above commodity, equipment, and construction costs are typical regardless of equipment ownership. The delivered cost for CNG would depend on the actual ownership of the equipment, the business model for the equipment owner, and the potential to attract additional customers to allocate fixed and variable costs over a larger base. If there were no other customers, CNG is not expected to be cost effective compared to propane.

**LNG**

LNG is currently not available on Delmarva. LNG is produced in specialized liquefaction facilities, which have on-site cryogenic storage tanks and truck loading facilities. Although Delmarva Power and Light has a peak-shaving LNG facility in Wilmington, this LNG is not available to the market. Currently the closest supply option is 210 miles north in Temple, PA. CUC is aware of proposals to develop or expand LNG facilities in the Philadelphia area, but the sites are also approximately 200 miles north. CUC is not aware of any programs to provide incentives for construction of new LNG facilities.

The cost for LNG includes the cost for the commodity, approximately $2.2-2.5/MM Btu, and the cost to liquefy gas to make LNG. This cost is dependent on the scale and age of the facility, but is generally in the $4-7/MM Btu range. LNG trailers contain approximately 1000 MM Btu of gas. An LNG tanker costs approximately $500K, although Wallops would not require a dedicated tanker. More likely Wallops would have a supply contract that includes delivery costs as part of the overall cost. At Wallops, the LNG trailers would pump LNG into a cryogenic tanks. The installed cost for an LNG cryogenic tank is estimated in the $400-600K range. The LNG is re-heated in a vaporizer, typically using electricity, from -160C to ambient temperature and regulated to the delivery pressure. The vaporizer has an estimated installed cost of $100K, depending on regasification rate.

Delivered LNG estimated cost is $15-25/MM Btu. The cost is sensitive to the trucking distance, and the installed cost of the cryogenic tank. Although the situation could change, LNG is not expected to be competitive with propane in the 1-3 year timeframe.

The timing to implement LNG at Wallops is likely influenced by permitting issues. It is outside the scope of this report to complete a HAZOP analysis for the use of LNG at Wallops. However, LNG installations require permitting and review by state and local officials, and generally require setbacks, so installation of a LNG storage tank and vaporizer may be more involved than propane or CNG facilities.

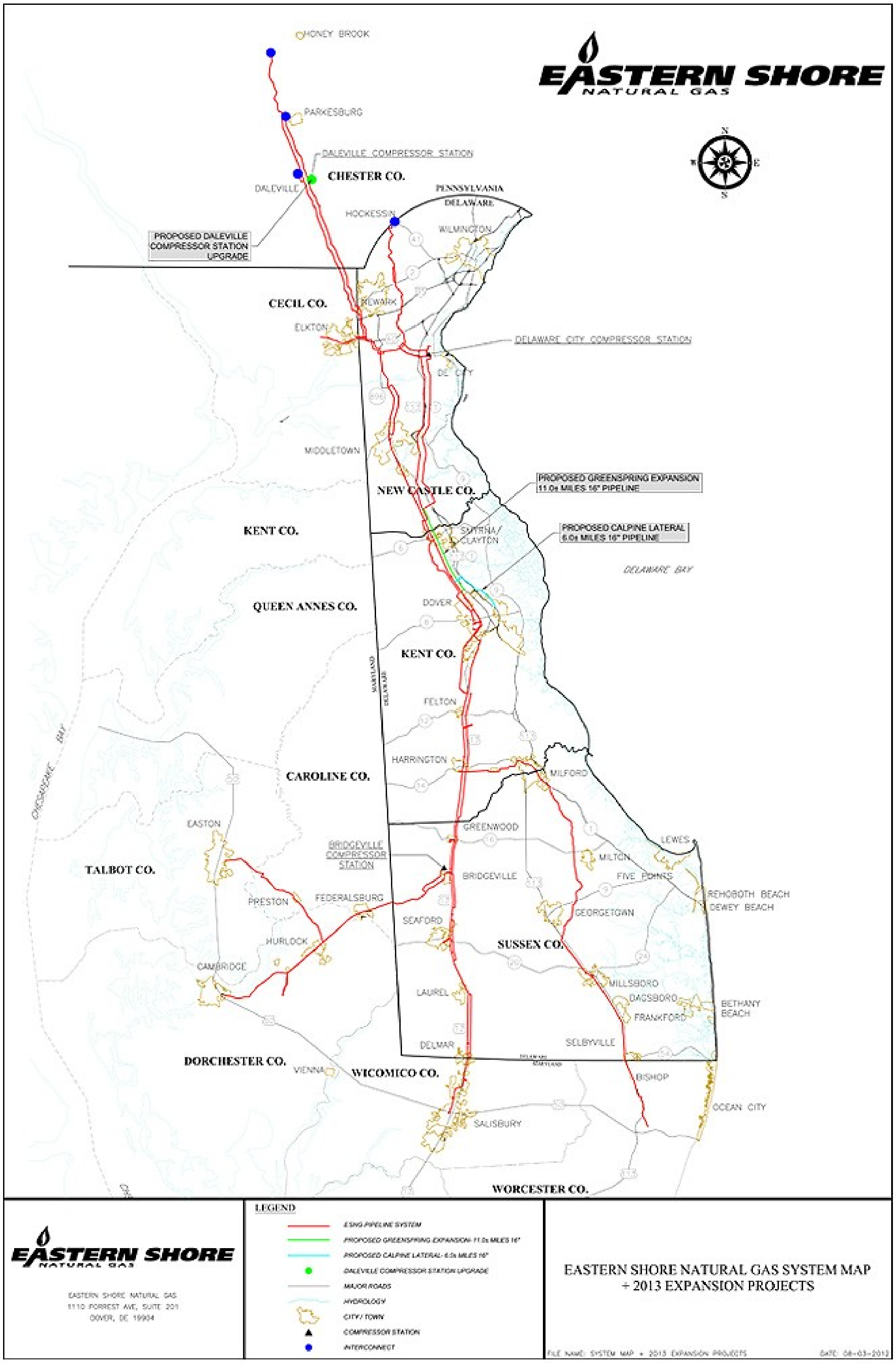
**Pipeline Natural Gas**

Pipeline gas is delivered from wells and storage fields through several interstate pipelines to the Eastern Shore Natural Gas (ESNG) transmission system at the northern end of the Delmarva Peninsula. ESNG has several compressor facilities to move gas south. High-pressure gas moves through a “gate station” to reduce it pressure, and would be distributed within the facility using the current on-site propane distribution system.

ESNG current pipeline infrastructure is shown in Figure 2. The system extends to central Salisbury MD, where it terminates at the river. ESNG has developed several scenarios for extending service into Maryland and Virginia. In general, it is more cost-effective to bypass Salisbury following the US 50 Bypass, and then use state road right-of-ways to extend gas down to Accomack VA. ESNG has estimated the cost to extend the pipeline from Salisbury to Wallops at $67 million. This cost does not include costs for upstream modifications, such as additional compression capacity (most likely near Bridgeville DE). Total costs are projected to exceed $70MM.

Wallops alone does not presently have sufficient load to justify extending pipeline infrastructure, and this situation is not likely to change even if the facility experienced a major expansion. Currently the aggregated energy demand for southern Delmarva is marginal to support a new pipeline infrastructure. CUC and ESNG are in discussion with several state and local stakeholders interested in extending natural gas service into Maryland. The key issue is aggregating sufficient demand to make pipeline service economical. The southern Delmarva area has several regions with clusters of demand. However, these are fairly distant, resulting in a relatively high cost to connect them. It is possible that gas service could be extended into Worcester and Somerset counties in the next several years, but this would likely require some form of incentives or subsidy given the current potential customer base. It is possible that Maryland may create incentives to extend gas service in to unserved areas. We are not aware of comparable programs in Virginia. Barring significant change in policy or economic development, it is unlikely that the pipeline will be extended to Wallops in the next five years.

**Figure 2 Eastern Shore Natural Gas Pipeline System**



**Cost to convert the current on-site LPG distribution and equipment system to natural gas**

The current propane distribution system, which includes the piping from the propane tank to the end-use devices in the facility, should be readily converted to natural gas service. The cost is estimated at $50K to modify meters and regulators at end-use devices. The conversion cost does not include the cost to change the control systems on the propane distribution grid.

CUC does not have sufficient information to estimate the cost to convert all of Wallop's end use equipment. However, we understand that the ESPC contractor has installed new equipment throughout the facility, with almost all the boilers now less than five years old. We received a list of 56 boilers (Appendix 2), and understand there may be additional water heaters and small HVAC units. Based on the equipment list in Appendix 2, and typical costs for converting commercial HVAC and water heating equipment from propane to natural gas, we estimate the end use conversion costs to be in the $50-200K range, depending on complexity of the burner control systems. This cost includes the changes to the burners (typically replacing the orifice and returning the fuel/air mixture) to allow them to burn natural gas instead of propane. It does not include the cost to modify the control systems or data acquisition systems on the end use devices. Many newer boilers and appliances require an orifice change, and some equipment is capable of switching fuels without modification.

**Projected Fuel Consumption**

As part of the study, CUC was asked to work with Wallops facility personnel and provide projected heating fuel consumption at WFF over the next 10 years for equipment that would be transitioned to natural gas. A large fraction of the facility's energy requirements are for space heating, which is relatively insensitive to overall level of activity. However, in discussions there appears to be potential for the facility to expand its scope, which could include additional building and conditioned space, which would increase the overall energy requirements. We were able to make a preliminary assessment of the existing propane-fired equipment. From equipment records and reports, it appears the ESPC contractor has been effective in replacing or converting the major energy users on the facility. Only two older, smaller oil-fired units were not replaced, presumably because it was not cost-effective to replace them or convert them to propane. The equipment is all less than 5 years old, suggesting that it meets high-efficiency standards for HVAC equipment. Consequently we do not foresee further equipment replacement in the next 5 to possibly 10 years, barring expansion of the facility.

Although outside the direct scope of this study, CUC considered the potential for alternative fueling for vehicles. This option would be best applied as the current fleet is replaced, versus retrofitting existing vehicles, which tend to be older models. Most of the current fleet operates on gasoline. Both propane and CNG could have potential application for vehicle conversions.

Propane is a proven cost-effective alternative for gasoline engines. Since Wallops already has significant propane storage infrastructure, the incremental costs for vehicle fueling are relatively small. Propane is also common for utility vehicles such as fork lifts, and is used for lawn care equipment. Propane vehicle dispensers are less complicated and less expensive than CNG dispensers, and range from $5-35K. Paybacks for new propane vehicles can be less than three years, depending on vehicle fuel consumption (miles driven and fuel efficiency). Propane vehicles generally offer a 10% or greater GHG reduction compared to gasoline vehicles on a wells-to-wheels basis.

Using propane can reduce operating costs substantially. Delivered fuel savings range from 30-40% versus gasoline. Propane suppliers, including Sharp, can offer fixed pricing if requested to reduce exposure to fuel price volatility. Since the US is now one of the largest propane exporting countries in the world, domestic propane supplies are relatively immune to supply interruptions seen in the oil industry. Maintenance costs are also lower with propane compared to gasoline. Propane has a higher octane rating (105) than gasoline (87), so propane-fueled vehicles experience a cleaner burn, require less frequent oil changes, demonstrate increased engine life and lower associated vehicle downtime.

Propane is a safe transportation fuel. Thousands of school buses, taxicabs, and transit agencies across the U.S. are already safely fueled by propane. Propane tanks are more puncture and pressure resistant than gasoline vehicle tanks. Propane has a lower flammability range than gasoline. Unlike gasoline, diesel, and ethanol, propane is not poisonous. Should an accidental release of propane occur, it would dissipate into the atmosphere with no harmful contaminants released into the soil or water.

We recommend that management consider specifying dedicated or dual-fuel propane vehicles as part of its replacement program.

CNG is also a potential alternative fuel. If CNG were available in the future for facility-wide energy use, a dispensing system could be installed for approximately $20-200K, depending on complexity. The lowest cost is for a time-fill dispensing system. Costs increase for a fast-fill dispenser, and site equipment such as a canopy, lights, card-readers, etc. Paybacks for CNG will likely be longer than for propane, due to the higher costs for infrastructure.

**Cost-Benefit, Timing, and Benefits for Transition to Natural Gas**

As noted above, Wallops is unlikely to be the sole or even major factor in extending natural gas service, whether by pipeline or virtual pipeline. The overall energy use at the facility, approximately 90,000 MM Btu/yr, is too small to move the market by itself. Extending pipeline service to Wallops would likely require a regional aggregated gas load more than an order of magnitude larger than Wallops' annual consumption to justify a new pipeline. CNG may become economical with a smaller market, perhaps 2-5X larger than Wallops' annual consumption.

The key issue for a cost/benefit analysis for transitioning from propane to natural gas is the price differential between the delivered costs of the fuels. As noted above, propane costs fell rapidly in 2014 due to increasing domestic production, and also in response to the drop in oil prices. If propane and natural gas continue to trade in a narrow price range, it is likely that propane will continue to be the lower-cost energy option for Wallops, since there is already a well-established propane infrastructure in Delmarva.

Based on CUC's above cost estimates, it is possible that CNG could become competitive with propane if propane/gas commodity spreads widen, and if a sufficiently large CNG market develops on Delmarva to justify the cost of new infrastructure. We estimate that the delivered propane/CNG cost savings would likely be in the range of $1-2/MM Btu in the near term (1-3 years). Since Wallops uses about 90,000 MM Btu/year, the energy savings could be in the $100-200K/year range. Based on limited information, the cost to transition the gas distribution grid and end use equipment, excluding costs to modify control systems, is estimated in the $100-200K range, suggesting that a simple payback of 1 to 2 years.

Several factors influence the timing for the transition from propane to CNG. Developing a viable CNG business will require minimum commitments from customers. While Wallops would likely not be the largest load, it would still be a major customer. It is possible that CNG vendors would request multi-year contracts and perhaps minimum volume commitments. Customers may be hesitant to commit, given the recent downward price pressures on propane. Once sufficient commitments have been made, CUC estimates that it will take 12-18 months to permit, build, and commission a CNG facility. Once CNG is available, it will likely take 1-3 months to convert Wallops to natural gas, depending on the season (shorter in summer, longer in winter) and the availability of staff to support the project.

Should it be economical to convert to natural gas, the GHG benefits will largely accrue from the inherently lower $CO_2$ emissions of methane compared to propane. While other emission species, particularly NOx, can contribute to overall GHG impact, it is likely that emissions of species other than $CO_2$ will be relatively unchanged upon switching from propane to natural gas. Equipment efficiency also impacts GHG emission rates. However, boilers properly tuned for propane and natural gas generally have very similar overall efficiencies. Consequently, we assume that the difference in GHG emissions is solely due to the difference in $CO_2$ per unitof energy between propane and natural gas.

Natural gas is a mixture of primarily methane with other components, including higher hydrocarbons. Its $CO_2$ emission is 117 lb/MM Btu, compared to propane at 139 lb/MM Btu, so fuel switching reduces GHG emissions 16% at the site compared to propane. Site-based GHG emissions are a useful metric. However, a more commonly cited criterion is based on life-cycle analysis, which includes the GHG impacts of the supply chain as well as the impact at the point of use. Argonne National Laboratory maintains the GREET model, which provides comprehensive analysis of many fuel options, including propane and CNG. Currently there is significant debate regarding the impact of fugitive methane emissions on overall natural gas GHG footprint. In addition, the supply chain for compressing and delivering CNG will be somewhat specific for Wallops, since supply logistics include a 100 to 200 mile round trip (estimated to add 1-4 lb $CO_2$/MM Btu to CNG's GHG impact). It is beyond the scope of this study to develop a more precise estimate for GHG reduction, but is it likely that switching from propane to CNG will reduce GHG emissions by at least 10%.