SCHOOL BUS FUEL SYSTEMS AND OPERATING COSTS

Never before has there been more choice or debate on school bus power systems. Gas, propane, diesel and electric options all have advantages and disadvantages. It's important to evaluate them on the latest technologies rather than old rationales.

Diesel powered buses, which are the most common buses are used as the baseline from which other platforms operating and capital costs are measured. The rise in propane and gasoline power system popularity is largely a result of customer frustration with first- and second-generation diesel emissions systems that reduced reliability and increased maintenance costs. Does this still hold true?

There are currently 4 fuel choices. Each have very different up-front capital and operating costs which, when combined, give the total cost of ownership (TCO). Below is a list of each power system based on fuel type.

DIESEL

Diesel power systems have evolved immensely in recent years. The *third*-generation emissions systems of medium duty diesel power have been on the North American market for about 18months and shows vast improvements in reliability, cleanliness, and fuel economy over first- and second-generation diesel emission systems.

Detroit DD5 Diesel

- Currently the most modern diesel 3RD generation emissions platform
- Lowest fuel consumption of any fossil fuel platform
- Double to 2.25 times the fuel economy of gasoline and propane engines depending on city vs highway application
- Designed from the ground up to meet todays and *upcoming* emissions standards
- Extensive durability testing and operating in Europe for **6 years** already
- For a modest cost the emissions warranty can be extended to 7 years
- Much lower emissions, Regens and DEF consumption than earlier diesel designs
- Simpler, more robust Turbo Charger for longer life than Cummins Variable Turbo Vane designs
- Self-Cleaning EGR. Exclusive variable cam phasing to reduce after treatment
- *Annual* engine oil change intervals
- *Designed* to operate in Vocational (Urban) applications
- *Tested* B10 Engine Life up to 600,000km
- Virtual Tech gives live online engine diagnostics while on route
- Lowest C02 production of any platform except electric
- Extremely clean with lowest overall emissions and much less C02. See attached chart
- Low volatility fuel in a spill due to collision

- Mid-level cost to purchase plus lowest fuel consumption and advanced design to reduce maintenance put it at the **low** end of the TCO

Cummins Diesel

- Second generation emissions design
- Low fuel consumption but still about 7 to 10% higher than the Detroit DD5
- Historic engine that was *adapted* to meet current emissions requirements
- Higher maintenance required on the emissions system due to a lack of ground up design
- Variable Vane Turbo Charger that is higher maintenance with typically about half the life of the engine
- EGR prone to plugging
- Usually 2 engine oil services per year
- Common parts
- Operates better on rural than urban routes as the Cummins emissions system design has its challenges in urban applications
- Has good range
- Medium capital cost
- Overall TCO somewhat higher due to emissions and turbo maintenance on an old design

Max Force Navistar V8 Diesel

- Out of production but still common in many fleets
- Highest fuel consumption of any diesel and very poor reliability with high emissions
- First generation emissions system using poor design that unfortunately gave the once reliable diesel engine platform a poor reputation
- Low purchase cost at the time and sold in volume based on price
- *Very high* TCO because of engine failures
- A good example of how *not* to build a diesel engine

PROPANE

There are currently 2 engine choices available on the market. Propane fuel systems are a simple, reliable engine platform. They are clean running but do have a significant increase in CO2 output due to increased fuel consumption. Cost analysis on operating propane buses is often based on the assumption that propane will always be available at a massive discount to make up for the doubling of fuel consumption per km. It's also assumed that propane engines will last as long as well-designed diesel, which historically is not the case. Statistics bear out that in industrial high-hour applications, propane engines last about half the life of a diesel engine. Long term life in school bus application is yet unproven.

When considering fuel costs, future developments may affect TCO. 4 export terminals planned for the BC coast and 2 large industrial complexes completing in Alberta in the next few years will greatly increase demand for propane and likely reduce the current surplus resulting in rising prices for the fuel [1]. Anticipated future increases in fuel costs, coupled with very high fuel consumption, higher initial capital

cost to purchase and unproven long-term durability can easily ***erase*** anticipated savings of propane power systems.

- Highest fuel consumption
- Higher capital cost up to $12,000 more to purchase than a diesel school bus
- Double the fuel consumption of diesel and about 15% higher than gasoline
- Short range and increased fueling time
- Expensive in tank fuel pumps are typically replaced two to three times over the life of the bus
- Requires expensive equipment to evacuate fuel tanks or they have to be flared off to service the in-tank fuel pumps
- Higher volatility of the fuel can be a significant safety hazard in the shop and on the road.
- More affordable engine platform to replace than diesel
- Three to four engine oil services per year
- Historically propane can be the cheapest fuel per litre but this is uncertain going forward as industrial demand looks to increase sharply in the next 5 years reducing the surplus.
- Propane has limited range of travel; availability of fueling stations during extended travel is a concern

PSI HD 8.8 L

- Uses a GM big block and proven HD Allison transmissions
- Low rev high torque design
- Used by Thomas Built Buses and Freightliner as well as IC Bus

FORD ROUSH 6.8L

- **High Rev** engine with smaller displacement
- Uses Ford Transmissions
- Borrowed from Fords HD pickup truck platforms
- Used by Blue Bird Bus

GASOLINE

In decades past, gasoline was the only choice in school buses. When reliable, affordable diesels came to market, the gasoline school bus quickly disappeared due to the significant savings in fuel, about half the consumption. Gas has made a comeback largely as a response to reliability issues in early generation diesel emissions systems. More recently, there has been some misrepresentation on the actual fuel economy of today's gasoline buses. While slightly better than years ago, they still use almost double the fuel of a modern diesel, which greatly increases TCO.

- Available in PSI 8.8L GM or Ford 6.8l Ford Roush
- Lowest cost to purchase
- Same base engine as propane engine
- Usually about $5,000 less to purchase than either diesel platform
- Simple and reliable
- Three to four engine oil services per year

- Higher C02 output from high fuel consumption
- Shorter range requiring more fueling stops
- Almost ***double*** the fuel consumption than diesel
- Low maintenance costs
- Common fuel available everywhere
- Higher volatility fuel that can compromise safety
- Higher TCO largely from very high fuel consumption and fuel cost that on average is 90% of the diesel fuel cost per litre
- Over 300,000km life of the bus it can easily burn an extra $65,000 more in fuel than diesel engine or about 2/3 the initial capital cost of the bus in extra fuel
- The best application for this platform is in remote areas on short runs
- New emissions requirements will likely drive up the capital cost to purchase this bus in coming years
- Engine life normally not as long as a well-designed diesel

ELECTRIC

Electric vehicles in general are getting a lot of interest; advancements in school bus power systems are reflective of this. Electric school buses work well but require massive subsidies to purchase. They also require expensive infrastructure, such as charging stations. The TCO is generally unattainable for most school board budgets that are already stretched thin. This emerging technology holds promise, given time, but could be ten years before it is cost effective without large subsidies. Usually still needs fossil fuels burned to generate the required volumes of electricity to charge.

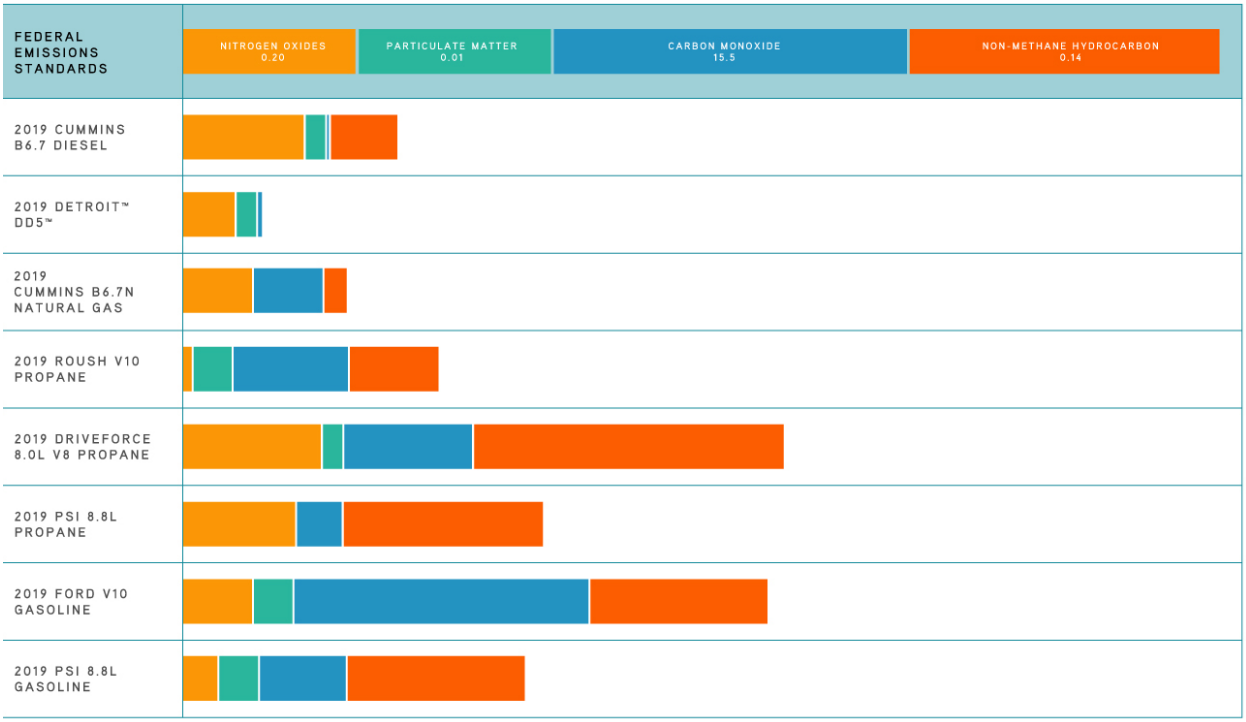
- Currently **extremely** high cost to purchase: at least 3 times the cost of a propane, diesel or gasoline bus
- $100,000 batteries usually last **half** the life of the bus
- Very reliable and low maintenance and fuel costs
- Quite clean
- Alberta climate necessitates a large *diesel* fired coolant heating system to keep the interior and batteries at optimum temperature during the winter months
- Highest TCO because of purchase price, battery replacement and infrastructure costs
- Currently an **evolving** technology that is well out of reach for most customers to afford without subsidies
- **Expensive** infrastructure at a central location to charge buses in 3 to 6 hours
- Shortest range
- Not recommended outside urban applications

GETTING INFORMED

In the end, customer preferences play a large roll in fuel choices. Rather than considering true operating costs, some may pick a higher TCO power system because it's what they are familiar with, or they anticipate propane and gasoline *may* provide fuel or maintenance savings over earlier design diesel

emissions systems. An abundance of misinformation has been published promoting propane and gasoline over diesel as the greenest and lowest TCO. In fact, the long-term durability of propane and gasoline platforms is unproven in school buses. Much of this data compares propane to **older** diesels with first- and second-generation emissions systems that had lower fuel economy and higher maintenance. This is ***not* true** with the latest generation diesel.

The latest third generation of diesels is similar to the evolution from a propeller to jet aircraft. Progress brings advancements in *efficiency, cleanliness and reliability* thus reducing the TCO to operate. Currently in the school bus industry, only **Detroit Diesel** has made a large investment to develop the needed improvements to build the cleanest, longest life and most efficient power system on the market. Detroit Diesel has *designed dependability* back into diesel. Increased reliability, and cleaner greener need not require **twice** the fuel burn of propane and gasoline and resulting CO2 as some would suggest. The **Detroit DD5 engine** is showing how to lower fleets TCO by **affordably** and **reliably** operating an ***efficient*** super clean fleet.



[1] April 2020 Financier Worldwide - RIPET is the first of four propane export terminals proposed for Canada's west coast. Pembina Pipeline Corporation (Pembina) is currently building the Prince Rupert Export Terminal on Watson Island in British Columbia, with exports expected to begin in the second half of 2020. In February 2020, Pembina announced plans to expand the Watson Island facility to have greater export capacity. The expanded terminal is expected to be in service mid-2023. The other two terminals, a second terminal on Ridley Island proposed by Royal Vopak, and Pacific Traverse Energy's terminal at Kitimat, British Columbia, may come online in 2022. As the west coast of Canada is the closest location for LPG terminals to Asia, and given the construction of LPG terminals there, there is an opportunity for western Canadian propane producers to diversify their market access to Asia, a premium market for propane. Heartland Petrochemical Complex at Hardisty is a propane processing facility that converts propane

into polypropylene comes online in 2021. Canada Kuwait Petrochemical Corp propane process facility in Sturgeon County is scheduled to come online in mid 2023.

ADDITIONAL READING

Correcting Diesel Myths:

https://thomasbuiltbuses.com/powertrains/diesel

DD5 Highlights:

https://www.youtube.com/watch?v=qFgBMMlQMfM

For more information, contact:

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