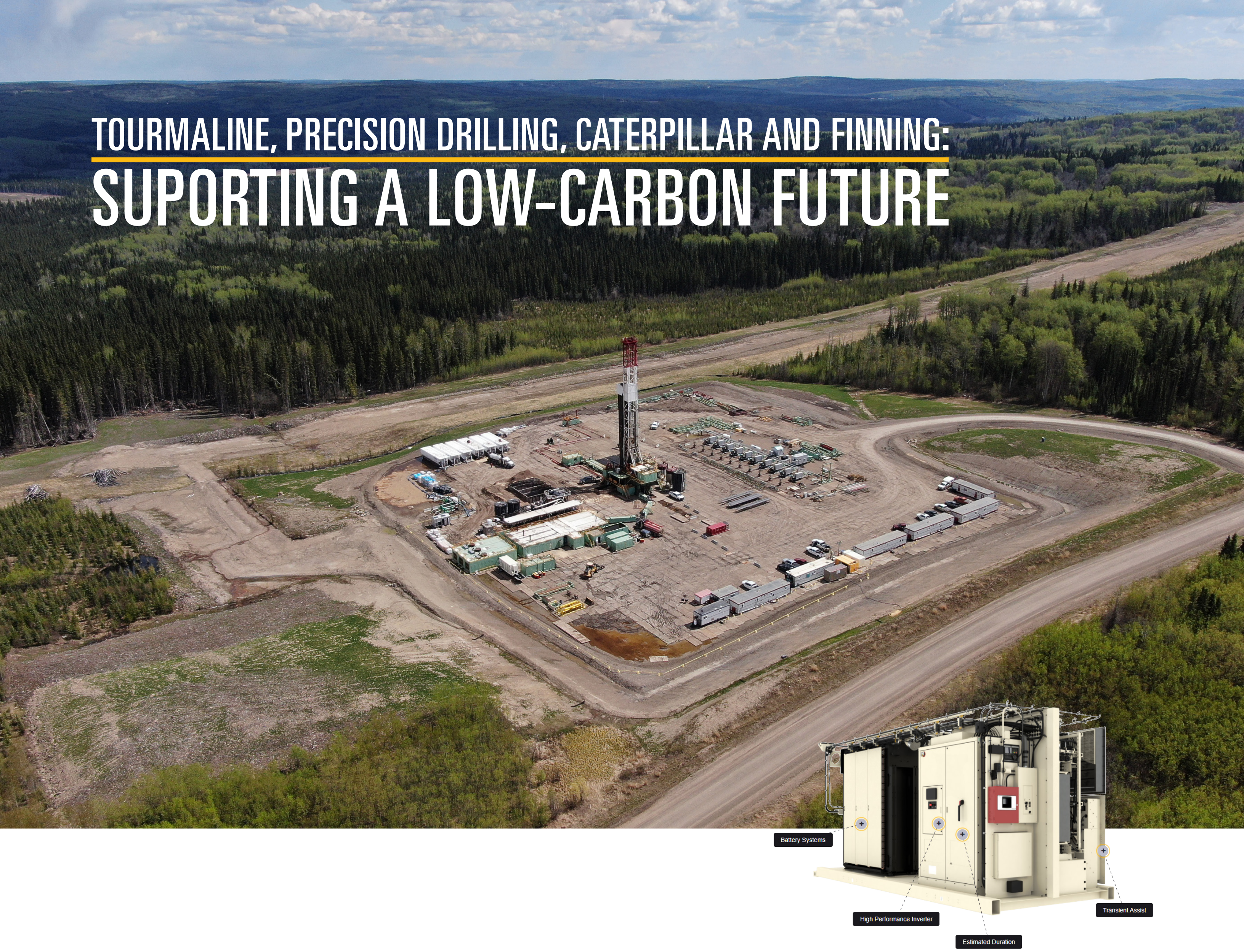
TOURMALINE, PRECISION DRILLING, CATERPILLAR AND FINNING:
SUPORTING A LOW-CARBON FUTURE



1. EXECUTIVE SUMMARY

Although many rigs in Canada are powered by a duel-fuel system, they still use a lot of diesel. Working collaboratively, Tourmaline Oil Corp. (Tourmaline), Precision Drilling Corporation (Precision), Caterpillar Inc.® (Caterpillar), and Finning Cat® (Finning) upgraded two rigs with a hybrid energy storage solution that uses natural gas gensets and a battery to validate the environmental and economic benefits. Case results led to a 95% reduction of diesel consumption, a 30% reduction in engine run hours, and a 40% reduction in CO_2e emissions. The project proved that this upgrade not only provided greenhouse gas reductions, but also lowered the total cost of ownership. End users are happy with the results and are now making this their new standard.

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2. INTRODUCTION

Tourmaline, in collaboration with Precision, Caterpillar and Finning has been has been working to develop a mobile natural gas generator and energy storage system (ESS) for drilling rig power supply using Caterpillar's Hybrid Energy Storage. This project involved upgrading two rigs' existing diesel engines to Dynamic Gas Blending® (DGB) engines, built 100% natural gas engines, and demonstrating the hybrid system. Our goals were to prove the system reduces greenhouse gas (GHG) emissions and the cost of power generation by substituting raw natural gas for diesel fuel.

2.1 PROJECT OUTLINE

This project involved upgrading two rigs' existing diesel engines to Dynamic Gas Blending engines, which were built as 100% natural gas engines. These were used to demonstrate the hybrid system. In addition, we focused on upgrading fuel capability to be bi-fuel, upgrading genset controls to the Electronic Modular Control Panel (EMCP) 4.4, and installing Caterpillar's Smart Engine Management System (Smart EMS). A Smart EMS is used to automatically start and stop generators in conjunction with the ESS to match the power demand of the rig without wasting power. It functions in synchronization with the active rig, allowing it to operate like a plug-and-play unit. The rig can operate with existing diesel engines if the gas supply is interrupted.

The hybrid system uses three lean burn, 100% natural gas engines that efficiently combust the natural gas. It includes a 1 megawatt (MW) ESS, Caterpillar's Power Grid Stabilization (PGS) 1260HD, to store power that would otherwise be wasted.

The system was connected to and operated on the two existing rigs with target performance results of:

- <5% utilization of backup diesel
- >30% reduction of engine run hours
- >40% carbon dioxide equivalent (CO_2e) emission reduction by diesel displacement

2.2 INDUSTRY BACKGROUND

Historically, Canada's drilling rig fleet was built with 100% diesel-fueled generator engines to supply power to the rig. Over recent years, a large portion of the Canadian fleet has been retrofitted with dual-fuel conversion kits that allow for the blending of natural gas and diesel for engine fuel combustion. On average, these kits consume 40% natural gas and 60% diesel to power the rig. This has helped reduce the use of a higher-carbon-intensive fuel (diesel) but still causes major drawbacks. Incomplete combustion with fuel blending results in wasted fuel and added GHG emissions, and power generation runs inefficiently by supplying more power than is typically consumed during normal drilling operations.

Power generation for a rig is not like typical power generation for houses, hospitals, or other industrial applications. The loads of a drilling rig are significant and are mostly consumed by four electric motors:

- Drawworks, the electric winch that lifts and lowers the drill pipe
- Top Drive, the electric motor that rotates the drill pipe
- Two Mud Pumps, the electric drive piston pumps that circulate drilling fluid

These four motors are turned on and off during every connection, so the power load peaks and valleys are extreme. A connection occurs when the rig crew needs to add a length of pipe to the entire drill string to continue drilling. Unknown downhole conditions make the loads variable and unpredictable.

Poor hole conditions cause increases in drag and torque, and variable pump pressure spikes. Variations during on-bottom drilling also cause huge variations in load. Changes in the formation from sand to shale can result in large pressure and torque spikes. These large, unpredictable swings in power load are what power generation companies refer to as a transient load. The large transient load makes drilling rig power generation extremely difficult and often wasteful.

At the beginning of this project, there were no drilling rigs in Canada that used 100% dedicated natural gas engines to generate electricity for their equipment. This is because a lean burn natural gas generator set cannot support the transient load demands of a drilling rig. Furthermore, dual-fuel engines do not consume natural gas during transient demand periods; engines run on 100% diesel to handle the transient load.

The technology developed in this project is a mobile plug-and-play, 100% natural gas power generation system, equipped with Caterpillar's 1 MW ESS that is used to store power that would otherwise be wasted. The system uses a Smart EMS to automatically start and stop natural gas generators in conjunction with the ESS to match the power demand of the rig without wasting power. Excess generated electricity is stored in batteries rather than discharged and wasted, as is the case with current contemporary drilling rigs. Cat's DGB kits that have been installed have the ability of achieving 70% substitution. In contrast, the aftermarket kits struggle to achieve 50% substitution. The mobile package model was designed to be integrated with an existing stationary dual-fuel system and can be switched back to diesel supply if gas supply is interrupted.

3. PROJECT DESIGN

3.1 SITE LAYOUT

Three natural gas generators and the 1 MW battery system were housed in separate storage containers and integrated into a conventional rig layout (*Figure 1*).

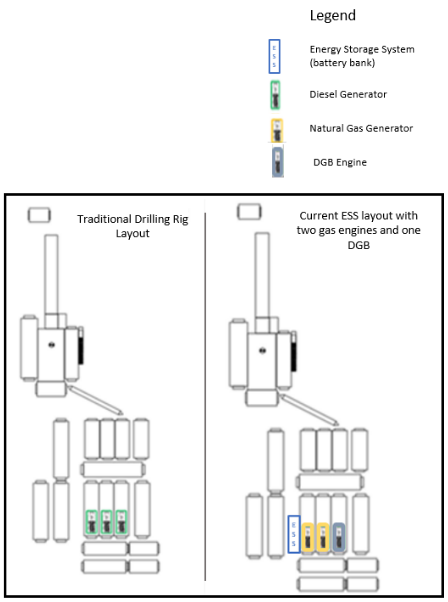

Figure 1*: Conventional Technology vs. Mobile Natural Gas Power Generation System*

This system has a diesel backup solution in case the natural gas supply is interrupted. The DGB engines can be run in diesel-only mode. However, the natural gas generators and the diesel (DGB) generators are not integrated into one system such that the diesel generators start automatically if gas supply is interrupted. Further work beyond the scope of this project will include getting all six engines (diesel and natural gas) to work together automatically.

Each generator was housed in a sound-attenuated building, with lighting, electrical, controls, and engine radiators to ensure they are always functioning in an optimal environment (*Figure 2*). The buildings were built on rugged skids so they can be winched onto a standard rig moving truck for transportation. The ESS was housed in a separate climate-controlled shipping container (*Figure 3*).

Figure 2*: Inside of the Natural Gas Generator Building*

The system accepts an inlet feed of 0 to 882 normal metered cubed per hour (Nm^3/h) of fuel gas combined with 0 to 14.7 Nm^3/h of air. It can accept any fuel with a calculated methane number more than 70% and it will not accept hydrogen sulfide (H_2S). The inlet pressure and temperature at the system manifold for full load conditions is designed at 276 kilopascals (kPa) and 58 °C with a tolerance of ±5%.

A natural gas pipeline was installed to the pad and gas was pipelined to the location for the drilling and completion phases. The raw gas was then conditioned with a small treatment skid to drop out the liquids and reduce the pressure, making it engine-ready for the drilling rig. Once the pad wells were ready to be brought on production, they were tied into the same pipeline and the flow was changed to go back to the gathering line (i.e., to the nearest facility). Raw gas from gathering lines can have variable composition as it comes from numerous locations. This can cause the fuel supply to be of poor quality and not meet specifications to be engine-ready. For example, the gas could contain H_2S. If this happens, a dedicated fuel gas line can be run with processed gas to location and only require a pressure drop skid.

***Figure 3**: ESS Container and Trailer.*

The mobile ESS can also be installed on 100% diesel rigs. These batteries can be moved site to site as rigs go up and down thanks to the brain power of Cat's 4.4 control panels utilizing dual ecms. Inside the drive house, Tourmaline installed the Smart EMS control system, saving another 15% fuel as unneeded engines auto start and shut down depending on load. It is worthwhile to note that an optional digital control panel can be installed in the driller's chair or wall space so the operator knows operational outputs and engines online at all times.

3.2 BATTERY/SYSTEM CAPABILITIES

Electric loads on a drilling rig can fluctuate by more than 2 MW in seconds. The ESS was sized to provide sufficient response to meet this demand and the requirements that fall outside the generators' capabilities. It can deliver 1 MW continuously and is also able to deliver 1.26 MW of power for up to five minutes.

The ESS container was mounted on a flat deck trailer for ease of transport. Between rig moves the heating, ventilation, and air conditioning (HVAC) runs off the internal batteries. If the unit is to be stored for long periods of time, it can be plugged in to maintain the HVAC and tend the batteries.

The natural gas generators are specifically designed to read the load demand directly from the rig and react by talking to the controller (Microgrid Master Controller) and adjusting the fuel consumption. The controller was developed to communicate with the software on the drilling rig, decipher the power requirements, and assign the appropriate tasks to the natural gas generators or ESS (*Figure 4*). Transient load capabilities were also developed on the controller to selectively choose the ESS over bringing on additional generators when quick power supply is required. Having a controller capable of optimizing a transient load will ensure the generators use the minimal amount of fuel needed as opposed to sharing the load equally. The ESS can instantly respond to the transient load and provides immediate power within a narrow frequency range. Keeping a tight frequency range is key to ensuring the rig's circuit breakers do not trip and cause a blackout. The ESS has been measured at +/- 1 hertz (Hz) when responding to a demand spike, which is superior to a conventional diesel generator at +/- 3 Hz (Caterpillar Inc.).

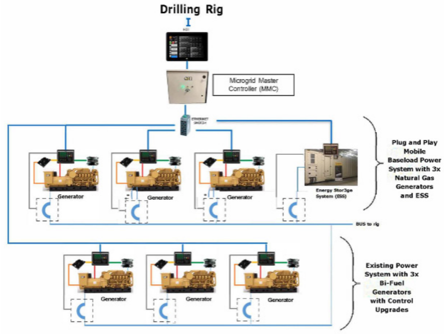

***Figure 4**: Process Flow of Plug-and-Play System Integrated with Current Drilling Rig. (Graph supplied by Tourmaline.)*

3.3 PERFORMANCE EXPECTATIONS

The outputs of the system include 0 to 4 MW of electricity or 1 MW per natural gas generator set along with 1 MW of stored power through the ESS. The exhaust is between 0 to 15.6 Nm^3 per kilowatt hour (kWh) with mass compositions typical of natural gas engines. *Figure 5* summarizes the inputs and outputs of the system.

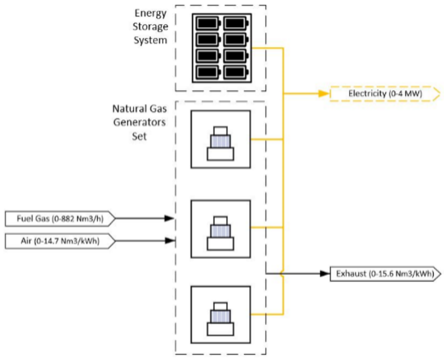

***Figure 5**: Process Flow Diagram. (Graph supplied by Tourmaline.)*

The mass energy balance of combustion is well understood, but this new process emphasizes the energy capture and storage of excess electricity that is produced above the demand curve. Quantification of this storage relative to the wasted energy from traditional rig power generation systems is represented in *Figures 6* and *7*.

These graphs were created to represent a typical rig power demand for various operational instances; they are not to be taken as actual generator output data. *Figure 8* describes the comparison of the project system to current practice based on operating stages.

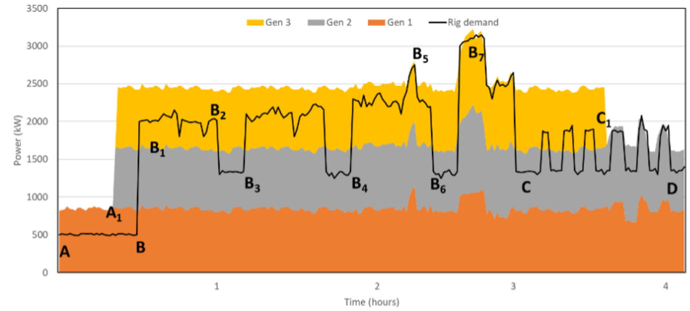

Figure 6: *Rig Power Demand and Supply Curve for a Traditional 3 Generator System. (Graph supplied by Tourmaline.)*

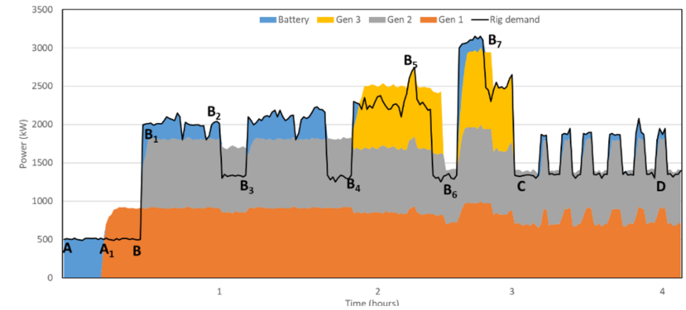

Figure 7: *Rig Power Demand and Supply Curve for the Mobile ESS and Natural Gas Generator System. (Graph supplied by Tourmaline.)*

		POINTS ON DIAGRAM	RIG OPERATIONS	CURRENT SYSTEM "CONVENTIONAL RIG"	PROJECT SYSTEM "MOBILE NATURAL GAS POWER UNIT"
A–B	**HOTEL POWER** "Hotel Power"—the rig is not drilling. Power is used for lights, controls, and heating.	A–A1	The rig is between operations and getting ready to drill—only hotel power is being used.	One generator running for hotel power. About half the power is wasted. Gen 1 is on idle with low natural gas substitution.	Rig is running on battery. No fuel is being consumed.
		A1		Driller expects to begin drilling: starts Gen 2 and Gen 3.	Battery becomes depleted, Gen 1 starts automatically.
		A1–B		All three generators are on low idle waiting to start drilling. Large energy waste to the environment, and low natural gas substitution at low idle.	One natural gas generator is running to charge the battery and power the rig (if the battery charges, the generator will shut down).
B–C	**DRILLING** During drilling operations, the rig is under high power load. Drill fluid pumps are circulating at high rates and pressures, and the top drive is rotating the drill pipe. After drilling a section of drillpipe, the pumps are shut off, the pipe rotation is stopped, and a "connection" is made. Drilling loads are very erratic with large variations.	B–B1	The rig turns on pumps and starts pipe rotation. The power required ramps up extremely quickly.	The transient load is not an issue as the generators are at idle and producing more load than required.	The system responds automatically by starting natural gas Gen 2. Gen 2 is slow to ramp to full power and the battery compensates for the transient load.
		B1–B2	The rig is drilling on bottom. There is variation in the rock and power load, but the load is relatively low in this section.	The power load is low. The generators remain on idle. Extra power is wasted and the natural gas substitution is low at low idle.	The power load is low. Two natural gas generators are running at optimum fuel economy rpm. The battery is making up the remaining load.
		B2–B3	The rig has finished drilling and needs to add a section of drill pipe (make a "connection"). Pumps are turned off and pipe rotation is stopped to connect a new section of pipe.	With the pumps off and the pipe rotation stopped, the generators are extremely wasteful, but the driller knows the connection will only take a few minutes so he keeps all the generators running.	The system notices the drop in load, but has been consuming battery power during the drillilng phase. It provides extra power to charge the battery to prepare for the nect drilling phase.
		B3–B4	The rig drills another section of drill pipe and makes a second connection. It drills similar to the last phase.	All three generators are still on low idle wasting the excess power. The driller could shut down a generator during connections, but that is not practical to do manually.	The system drills and completes this connection much like before, but the battery is being depleted and the connections are too fast for it to fully charge. It keeps the two generators at high idle to charge the battery during the connection.
		B4–B6	The rig drills another section of drill pipe and makes a third connection. This section requires a higher pump rate at B5 increasing the load.	All three generators are mostly on low idle wasting the excess power. The pump increase at 85 causes the generators to temporarily idle up to compensate for the load.	This section is slightly harder drilling and the battery does not have capasity, so natural gas Gen 3 is started. Since the power spike B5 was gradual, the generators were able to ramp up to power the spike. Gen 3 keeps running to top up the battery for part of the connection, then shuts off.
		B6–C	Another connection is made, but while going to bottom, the hole becomes unstable. The drill pipe torque increases and the pump pressure spikes, adding significant load (B7).	All three generators must ramp up quickly to respond to the hole conditions. These engines are not quick to respond at transiend load, so the driller notices a delay in power response. The bi-fuel engines at high rpm are burning an optimum 70% natural gas and 30% diesel.	After the connection, the system responds to the load spike by starting gen 3. Gen 1 and Gen 2 ramp up. The battery compensates for the transient power while the engines ramp to high rpm. The battery provides the remaining load gap. All three engines stay at high rpm after the load drops to top up the battery.
C–D	**TRIPPING** "Tripping" is the action of pulling the drill pipe in or out of the hole. This is done to change bits or at the end of a hole section.	C–D	Tripping the pipe is a series of continuous connections. The pumps are off and the top drive is off. There is a spike of load while the pipe is pulled out of the hole. Tight sections in the hole cause additional spikes of load. (The diagram shows a six-connection trip)	The driller trips out the first three sections of pipe and at C1 remembers that he has all three generators running. He chooses to shut one off (some drillers may choose to leave it running for higher performance). The bi-fuel engines do not consume natural gas during trips; the load spikes are too frequent, so the engines need to run on 100% diesel to handle the transient load.	During tripping, the system runs two natural gas generators. The transient power spikes are compensated for with the battery bank. Once tripping at shallow depths with lower loads, the system will automatically compensate and shut down the second generator. Near-surface trips may be performed on 100% battery power.

Figure 8: *Detailed Description of Operating Stages. (Graph supplied by Tourmaline.)*

4. PROJECT RESULTS

All objectives were met, and diesel consumption was decreased by an average of 3,750 litres per day (L/day).

4.1 OBJECTIVE FULFILLED

The group was able to meet the project objectives by successfully:

- Understanding the relationship between the power demand and the size of the unit during drilling.
- Validating the reliability and efficiency of the plug-and-play mobility of the unit during field operations. Ongoing work is still being done to improve reliability and efficiency.
- Understanding the volume of diesel reduction and backup usage.
- Understanding the reduction in trucking.
- Understanding the reduction in methane slip.
- Validating the potential economic benefits from developing this technology.

During the project, Tourmaline was more concerned about maintaining power reliability than focusing on efficiency, at the expense of using more fuel. As further progress is made, Tourmaline will focus on system efficiency once reliability can be sustained. The project achieved emission reductions of nearly 40% after including life cycle emissions, trucking, and methane slip on top of the standard exhaust emissions.

4.2 DIESEL CONSUMPTION REDUCTION

Originally, Tourmaline assumed a baseline rig would consume an average of 6,150 L of diesel per day. However, over the past two to three years, Tourmaline has placed greater focus on reducing diesel consumption. For example, field personnel now turn off un-needed, or idling, engines, and use a Smart EMS. Simply by changing their attitude toward diesel use, Tourmaline saw reductions occur in the field without any physical technology changes to equipment. Given this new outlook, new baseline projections would be around 4,500 L daily diesel consumption.

Comparing the Baseline Rig and Project Rig #2 for the same six-month period, the average reduction in diesel consumed was 3,824 L/day and the increase in gas consumed was 3.25 thousand cubic metres per day (m^3/day). Using emission factors outlined at the beginning of the project, this represents a 21% reduction in GHG emissions. Data from Dec. 2021 to Apr. 2022 was still showing higher-than-expected diesel and natural gas consumption, as represented by data points in Figure 19. Diesel would still be used when fuel gas liquid buildup would shut down the scrubber, forcing the rig crew to switch back to the dual-fuel generators.
Gas consumption was higher than expected since the battery was still not peak shaving as designed, which meant more gas engines running. This is why there was still a high total fuel being used after the hybrid system was installed on either rig. Analyzing the data for engine run hours during June and July 2022 indicates that the reduction in engine run hours is now meeting the 30% target outlined at the beginning of the project, proving that the battery is starting to operate as expected.

4.3 EMISSIONS REDUCTION

To measure emission reductions most accurately, the Baseline Rig and Project Rig #2 were compared over the same period (Dec. 19, 2021, to June 30, 2022). Numerous variables contribute to drilling rig emissions, including well design, drilling days, formations encountered, and ambient temperature. An effective way to minimize differences in these variables is to compare rigs that are drilling the same type of well, targeting the same zone, at the same time. To that end, both rigs were drilling Montney wells in the Gundy/Aitken/Nig Creek area during this time. Project Rig #2 had 186 total drilling days and the Baseline Rig had 167 total drilling days.

Four emission categories were quantified as part of the comparison:

- Exhaust emissions, based on recorded diesel and natural gas consumption. Standard natural gas and diesel emission factors used at the beginning of the project were used again for these calculations (Government of Alberta, 2019).
    - Natural gas: 1.939 CO_2e kg/m^3
    - Diesel: 2.804 CO_2e kg/m^3
- Life cycle upstream emissions, based on the amount of natural gas and diesel consumed. The diesel life cycle emission factor was pulled from GHGenius (Squared Consultants Inc.) while a Tourmaline-specific natural gas life cycle emission factor was used from a third-party study conducted in 2021.
    - Natural gas: 2.46 CO_2e kg/GJ
    - Diesel: 21.53 CO_2e kg/GJ[3]
- Trucking emissions for hauling diesel to a drilling location. A standard diesel emission factor and a trucking fuel efficiency value were used in these calculations (Government of Canada, 2019).
    - Diesel: 2.804 CO_2e kg/m^3
    - Fuel efficiency: 39.5L/100km
- Methane slip emissions, based on third-party engine exhaust emissions testing and analysis conducted on Baseline Rig and Project Rig #2. Flow rate and gas sampling were conducted to determine the amount of methane in the exhaust stream.

Using all the data for the project period, the reduction in emissions from the baseline to project level rig was 10.66 tCO_2e/day.

In Figure 9, the overall GHG emissions between the bi-fuel engines and natural gas engines are displayed both as an average and at different loads. As methane is a

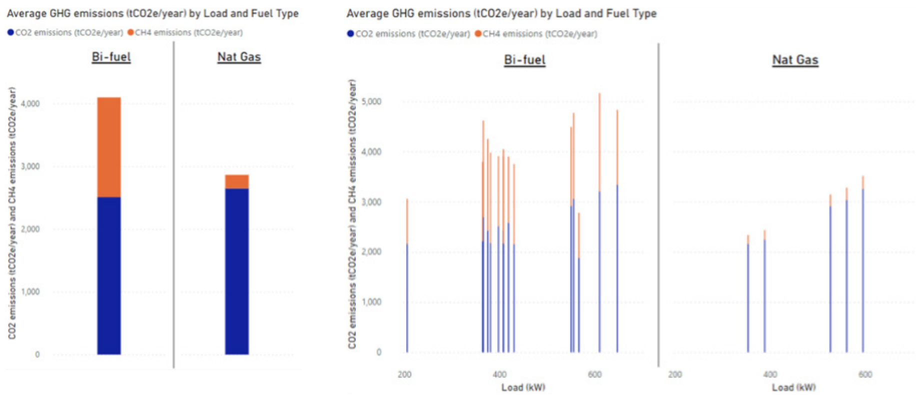

***Figure 9**: Methane Percentage in Exhaust for Bi-fuel and Natural Gas Engines (Baseline and Project #2 Rigs) (Graph supplied by Tourmaline.)*

GHG with 25x the global warming potential of CO_2, reducing methane has a significant impact on overall CO_2 equivalent emissions. When both combustion emissions and methane slip emissions are considered, there is an average ~30% decrease in GHG emissions by switching to the fully natural gas engines from bi-fuel engines.

From December 19, 2021, to June 30, 2022, Project Rig #2 was consuming an average of 6.37 e^3m^3 of natural gas and 787 L of diesel per day. The Baseline Rig was 3.12 e^3m^3 of natural gas and 4,611 L of diesel per day. It is expected that the gas consumption on Project Rig #2 could be reduced 1-2 e^3m^3 further after the ESS is more efficiently shaving off any peak load spikes. However, the real results from this period were used to forecast the emission reduction potential in Alberta and Canada for commercialization of this technology.

5. PROJECT IMPACT

5.1 COMMERCIALIZATION

The oil and gas industry is already seeing more market adoption of this technology. Caterpillar's hybrid drilling solution has been successfully deployed on multiple drill rigs in North America, with over 50,000 hours of operation to date. Precision has experienced an increasing market uptake of drilling with packages that include a hybrid power generation system.

This technology is an iteration of the plug-and-play system and can nearly eliminate diesel usage. The two key operating conditions for success are fuel gas conditions and ESS reliability. Fuel gas containing excessive liquid content will trigger high-liquid-level alarms on the inlet fuel gas scrubber and eliminate the gas supply to two of the three generators. Diesel would be available to supply the third generator, but overall power for the rig would be limited until the fuel gas system is back online. If the battery is operating as designed, the two natural gas generators would run to supply enough power for normal drilling operations, and any power requirement exceeding the two-generator capacity would be supplied by the battery. All diesel use would be eliminated if the system operated consistently in this manner.

It is possible based on the success of this project that the industry will see an increasing share of the total addressable market shift to a natural gas hybrid power system. It is projected that ~20% of the serviceable active rigs will be upgraded over the next five years. Further commercialization of this technology will lead to incremental jobs, both temporary and permanent to Tourmaline, Precision, Caterpillar, Finning, third-party vendors, and any other end-users or distributors competing in the space of this technology.

5.2 ALBERTA EMISSIONS PROJECTIONS

By decreasing the emissions produced to drill a well, this project is demonstrating a continuous improvement in the environmental footprint for Alberta's natural gas sector. This will reinforce Alberta's image as an global leader in low-emission-intensity oil and gas production. Specifically, this project is reducing the amount of fuel required to generate power (electricity) for a drilling rig and substituting all diesel fuel with natural gas—a cleaner-burning fuel that further reduces GHG emissions.

Current rig count data was used for the Alberta GHG reduction projection. The potential emission reduction focuses on natural gas and battery hybrid systems. Bi-fuel and battery hybrid systems are removed from the projections below.

There are currently 462 rigs in the Canadian fleet, 344 of which are in Alberta (JWN Energy, 2022). The utilization rate of active rigs is 44% for Alberta and 46% for Canada. Today, it's estimated that about 70% of the marketable rigs are AC powered and could be equipped with a natural gas hybrid power generation package. By 2030, it's projected that 95% of the marketable rigs will be AC powered, with only a few DC rigs remaining in the fleet. Of the available AC powered rigs, it is expected 25% of those to install a natural gas power generation package by 2030, reaching 30% by 2040. It is expected that a larger portion of the fleet will remain running on a bi-fuel engine type, eventually being equipped with a battery for further reduction in fuel consumption. With these projections, the cumulative emission reduction potential in Alberta is 0.74 megatonnes (Mt) CO_2e by 2030 and 4.65 Mt CO_2e by 2050.

Figure 10 shows the annual CO_2e emission reduction potential for Alberta and Canada. *Figure 11* shows the cumulative emission reduction potential for Alberta and Canada.

Drilling and completions activities are typically large consumers of diesel fuel and present a great opportunity for using hybrid power generation systems. This completed project will help industry understand the environmental and economic benefits of using gas for power generation and could help pave the way for technology adoption into completion activities such as hydraulic fracking and service rigs.

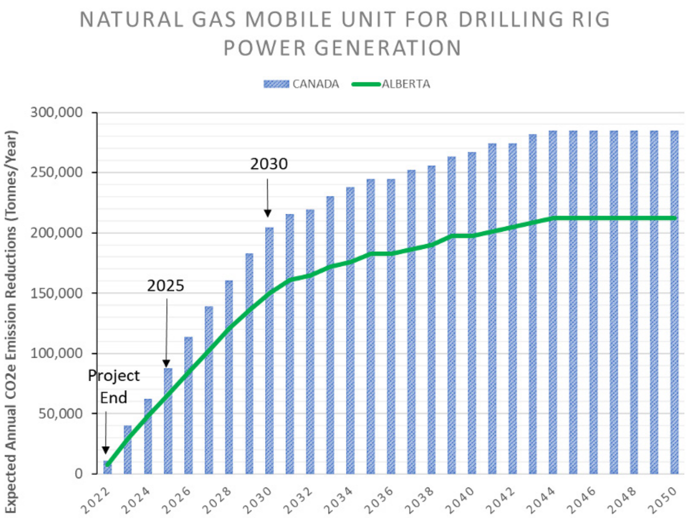

Figure 10: *Annual CO_2e Emission Reduction Potential for Alberta and Canada (Graph supplied by Tourmaline.)*

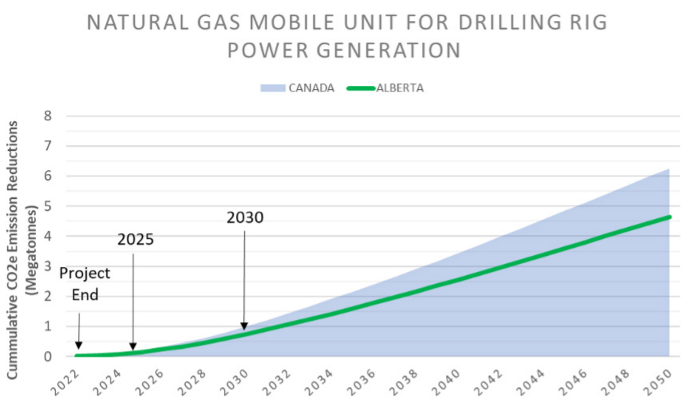

Figure 11: *Cumulative CO2e Emission Reduction Potential for Alberta and Canada (Graph supplied by Tourmaline.)*

5.3 OTHER ENVIRONMENTAL IMPACTS

The technology offers several benefits that are beyond GHG emissions reduction. The combustion of natural gas compared to other fossil fuels produces negligible amounts of sulfur, mercury, and particulate matter (Union of Concerned Scientists, 2014). The result is less fine particulate matter and nitrogen oxides injected into the air through the exhaust, thus improving overall air quality related to oil and gas drilling operations.

Adopting this technology will also provide a safety benefit. With all fuel requirements being supplied at the rig site by existing pipelines, projects like this are minimizing fuel trucking and associated highway traffic. This improves Alberta's environmental footprint, economy, and community relations.

The oil and gas industry suffers from an image problem in Canada. The industry needs to continue demonstrating that it is constantly improving how it does business with clear priorities set on reducing environmental impacts. The benefits achieved through this project illustrate that Canada is the ethical choice for hydrocarbon production and a global leader of low-emitting production.

6. CONCLUSION

The package was successfully integrated into both upgraded rigs for approximately one year. After the integration was complete and the hybrid system was up and running as designed, Tourmaline's original performance targets were met:

- less than 5% utilization of backup diesel
- 30% reduction of engine run hours
- 39% CO_2e emission reduction by diesel displacement, trucking reduction, and reduction of life cycle emissions and methane slip

Fuel consumption reduction was determined to be ~4,300 L/day. Interruptions in fuel gas supply were mitigated by improved controls and better positioning of gas conditioning equipment around the rig. This testing period was focused on maintaining rig reliability over battery efficiency; improving efficiency will be addressed moving forward.

After quantifying all emission sources as part of this project analysis, we determined that this package was reducing emissions by 10.66 tCO_2e/day (~3,650 tCO_2e/year, assuming 343 rig operating days). The main project cost savings comes from having produced raw gas available on each drilling location versus hauling in diesel.

The emission reduction potential from the project indicates that a reduction of 10.66 tCO_2e/drilling rig operating day can be met, with further reductions being realized after the system is tweaked. Considering the factors for commercialization into the Canadian drilling rig fleet, the cumulative emission reduction potential is 0.99 $MtCO_2e$ by 2030 and 6.25 $MtCO_2e$ by 2050.

In summary, the Natural Gas Mobile Unit for Power Generation project was a success.

7. PARTNERS

About Tourmaline

Tourmaline is a Canadian senior crude oil and natural gas exploration and production company focused on long-term growth through an aggressive exploration, development, production and acquisition program in the Western Canadian Sedimentary Basin.

About Precision Drilling

Precision is a leading provider of safe and environmentally responsible High Performance, High Value services to the energy industry, offering customers access to an extensive fleet of Super Series drilling rigs. Precision has commercialized an industry-leading digital technology portfolio known as Alpha™ that utilizes advanced automation software and analytics to generate efficient, predictable, and repeatable results for energy customers. Our drilling services are enhanced by our EverGreen™ suite of environmental solutions, which bolsters our commitment to reducing the environmental impact of our operations. Additionally, Precision offers well service rigs, camps and rental equipment all backed by a comprehensive mix of technical support services and skilled, experienced personnel.

About Caterpillar

With 2021 sales and revenues of $51.0 billion, Caterpillar Inc. is the world's leading manufacturer of construction and mining equipment, off-highway diesel and natural gas engines, industrial gas turbines, and diesel-electric locomotives. For nearly 100 years, we've been helping customers build a better, more sustainable world and are committed and contributing to a reduced-carbon future. Our innovative products and services, backed by our global dealer network, provide exceptional value that helps customers succeed. Caterpillar does business on every continent, principally operating through three primary segments—Construction Industries, Resource Industries and Energy & Transportation—and providing financing and related services through our Financial Products segment. For more information, visit caterpillar.com.
To connect with us on social media, visit **caterpillar.com/social-media**.

About Finning

Finning is the world's largest Caterpillar dealer, delivering unrivalled service to customers for 90 years. Headquartered in Surrey, British Columbia, we provide Caterpillar equipment, parts, services, and performance solutions in Western Canada, Chile, Argentina, Bolivia, the United Kingdom, and Ireland.

Our Power Systems team is a strong link in the chain that binds drilling companies, gas producers, engineers, and operators together to offer the best value over the life of the gas field. Our experienced staff of engineers and technicians understand the importance of reliable gas production and are committed to providing engine systems, including energy storage systems, that deliver maximum uptime and reduce environmental footprint.

We believe Caterpillar is the engine of choice for the energy sector. This is based on years of service on the job and the world's best product support as well as engines that meet stringent EPA regulations, burn less fuel, and have a longer working life.

We continually work to minimize our impact on the environment through the reduction of GHG emissions from the products and services we use and sell, to the enhancement of our waste and wastewater management at our facilities and the mitigation of potential spill risks to land and water. Sustainability is an integral part of our strategy and operations. For more information, visit **finning.com**.

8. ABBREVIATIONS

BHA Bottom Hole Assembly

CNG Compressed Natural Gas

DGB Dynamic Gas Blending®

DLE Diesel Litre Equivalent

EMCP Electronic Modular Control Panel

ESD Emergency Shutdown

ESS Energy Storage System

GHG Greenhouse Gas

HMI Human-machine Interface

HVAC Heating, Ventilation, and Air Conditioning

LNG Liquified Natural Gas

MMC Microgrid Master Controller

PT Potential Transformer

SEMS Smart Engine Management System

TAM Total Addressable Market

TRL Technology Readiness Level

9. REFERENCES

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