NON-CONFIDENTIAL REPORT

CROSSFIELD ENERGY CENTRE HYBRID ELECTRIC GAS TURBINE

Disclaimer:

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Table of Contents

1.0 EXECUTIVE SUMMARY

ENMAX has integrated a new 10 MW/4.3 MWh lithium-ion battery from GE Renewables with one of the existing natural gas fuelled turbines at it's Crossfield Energy Centre. The Hybrid Electric Gas Turbine (EGT) allows Crossfield Unit 3 (CRS3) to provide spinning reserves, up to its maximum capability (48 MW), without burning any natural gas, eliminating greenhouse gas (GHG) emissions until the reserves are called due to a power system contingency.

Traditionally, gas turbines providing spinning reserve must operate at lower, inefficient outputs to ensure reserve capacity is available on demand. With the EGT, the gas turbine can be offline and when reserves are called due to a system contingency (called a "directive"), the battery immediately provides the demanded energy, which allows time for the gas turbine to start and ramp up to meet the directive.

With this approach, it is anticipated that CRS3 will run approximately 80 per cent less. GHG modelling has shown that the implementation of this project is expected to reduce historical GHG emissions between 47,743 and 96,807 tonnes per year, depending on dispatch levels.

ENMAX is leading the way, implementing this technology for the first time in Canada. Development of Canadas first hybrid EGT will serve as a model for lowering emissions from existing fossil fueled power plants while helping train the workforce of tomorrow in designing, operating and maintaining these novel low carbon technologies.

2.0 PROJECT DESCRIPTION

This project upgraded one of the LM6000 turbines at the Crossfield Energy Centre to a hybrid EGT through the integration of a 10 MW, 4.3 MWh battery energy storage system. Integrating a battery "behind the meter" allows the battery and turbine to perform like a single, consolidated, resource on the Alberta Interconnected Electric System (AIES).

The integration of the battery storage system allows for the Crossfield Unit 3 (CRS3) generating resource to be grid connected without the need for the turbine to be running and producing power. With the need to run the turbine removed, this allows the CRS3 generating resource to offer power into the Alberta Ancillary Services (AS) spinning reserve market without the need to burn fuel. No other fossil-fueled power plant in the country is able to offer spinning reserve without producing greenhouse gas (GHG). This project, the first of its kind in Canada, has enabled the natural gas fueled CRS3 generating resource to provide GHG-free spinning reserve until a power system contingency event occurs and a directive is issued.

The AESO uses Spinning Reserves to provide standby power to the grid during unplanned events such as large generators being disconnected from the grid abruptly. For a generating asset to provide Spinning Reserves, the asset must be frequency responsive, meaning the asset must add or remove power to the grid automatically during frequency excursions outside of the nominal frequency of 60Hz, and must be able to provide full power output within 10 minutes of receiving a directive.

When a power system contingency directive is called, the battery instantly responds providing up to 10 MW of power to the Alberta Interconnected Electric System (AIES). While the battery ramps, the gas turbine is started and begins ramping to its dispatched level within a 10-minute window, satisfying the spinning reserve directive.

How do you make a gas turbine a hybrid?

The EGT is comprised of 2 main components: (1) The Gas Turbine, and (2) The Battery Energy Storage System (BESS):

<u>(1) Gas Turbine with a Hybrid Control System:</u>

Picture of BESS in front of CRS3 Turbine Stacks

The CF6 family of GE Aviation's aircraft engines is modified and packaged by GE Power for industrial use as the LM6000 in power generation or mechanical drive applications. Introduced in 1961, there have been more than 1,100 LM6000's in operation around the world, adapted to dynamically demanding applications using a broad range of liquid and gaseous fuels. Combustor configurations include steam or water injection for emissions control, or a Dry Low Emissions (DLE) option which is what is installed at the Crossfield Energy Centre. Wet compression power augmentation is also offered through spray intercooling (SPRINT™).

The Hybrid EGT Control System (HCS) is a fully integrated control solution which enables a hybrid performance profile from a system containing a Li-ion Battery and an aeroderivative gas turbine. The primary purpose of the HCS is to ensure that the EGT delivers the commanded net-output on a blended basis from the battery storage and gas turbine at the most optimal ratio given both internal and external system requirements.

(2) BESS:

The BESS is further comprised of 5 key sub-components:

The Control Enclosure:


Picture of control cabinets inside the Control Enclosure Building


Picture of Control Enclosure Building (Centre) during construction.

The Control Enclosure is the "brain" of the BESS. The control house contains a SCADA rack comprised of various networking devices, patch panels, media converters, the SCADA server and various power supplies, a protection panel, a number of power distribution panels, a UPS and the RCU or UCSC Plant controller for the BESS.

High Power Storage Units (HPSU) with 10MW of Samsung Li-Ion Batteries:


Picture of battery racks inside the HPSU


Picture of one of the HPSU's

The HPSU's are what contain the battery energy storage component of the EGT. There are two HPSU's and each HPSU contains half of the battery energy storage respectively. Each HPSU's is comprised of on-board battery management systems (BCU) to regulate charge/discharge and balancing of all individual battery cells.

Inverters:

Picture of four inverters (there are 8 total)

There are 8 total inverters in the BESS. Each inverter converts DC power from the batteries to AC power to the grid. The DC input voltages range from 630 VDC up to 820 VDC depending on the state of charge (SOC) of the batteries, but the AC connection must always be maintained at 480 V at 60 Hz to remain synchronized to the grid. Internal to the inverter cabinet, each cabinet contains metering/protection equipment to ensure they are performing in the range they are required to, DC and AC breakers, and controls and circuit boards to dispatch the inverter as required and fire the Insulated Gate Bipolar Transistors (IGBT's).

Transformers:

Picture of 4 of the transformers (there are 8 total)

The transformers in the BESS serve to step up the voltage from the inverters at 480VAC to 13,800VAC and isolate triple harmonics from the inverters with the delta-wye configuration. By stepping up the voltage, less current runs through the cables/wires which ultimately reduces losses and sizing requirements for cabling and increases efficiency. Each transformer has gauges to indicate, alarm or trip to ensure the transformer is protected if a fault occurs.

<u>Medium Voltage Switchgear (MVSG):</u>

Picture of MVSG

The medium voltage switchgear (MVSG) is a power distribution and switching centre. Its role is to distribute power, meter, protect and isolate components within the BESS. The medium voltage switchgear is comprised of breakers to isolate faults and de-energize different components when required for routine maintenance and inspections. It also contains current and voltage transformers, to provide signals to meters and relays to indicate real time measurements of power, current and voltage and ensure equipment is being operated within ratings. Other components within the switchgear include surge arresters to protect against overvoltage's, and a control power transformer to feed local heaters and lights.

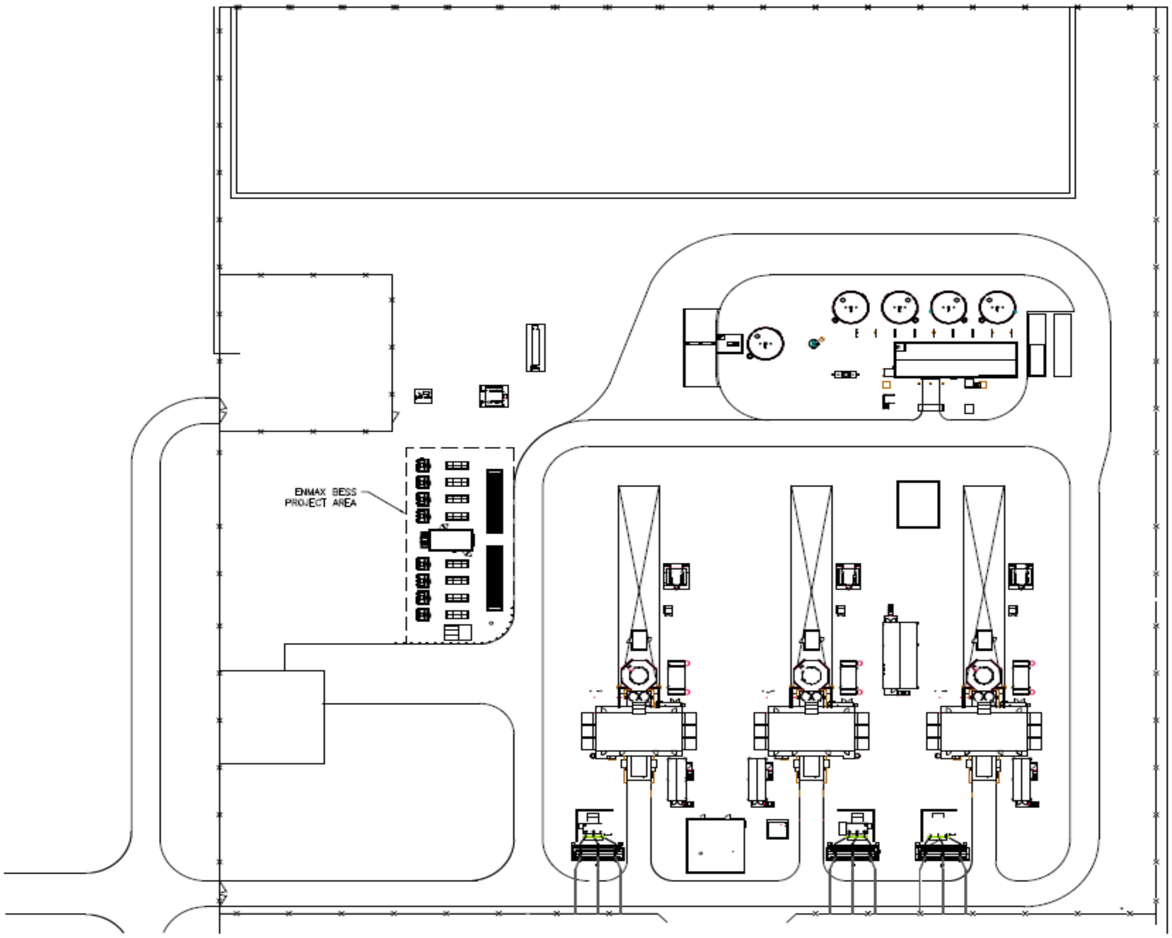
EGT Layout:

Picture of integrated BESS Components

Aerial picture of Crossfield showing BESS with Turbines

The EGT was completed by integrating all the individual BESS parts together with the Gas Turbine. The BESS interconnects with CRS3 via a 13.8kV isolated bus duct system in between the generator circuit breaker and the low voltage bushings of the generator step up transformer. The interconnection point is connected to 750MCM three phase underground cable connections that distribute power to/from the MVSG. The upgraded Hybrid control system seamlessly integrates the BESS and the Turbine, managing energy between the battery and turbine. The layout of the EGT at Crossfield Energy Centre is shown below. The EGT was constructed within the existing Crossfield Energy Centre site

Figure 2.7: BESS General Arrangement



BESS General Arrangement Drawing. BESS integrated within existing site boundary.

Project Objectives:
The project objectives and the status of each objective are listed in the table below:

Table 2.1: Project Objectives & Status

	OBJECTIVE	STATUS
1	Provide spinning reserves up to the maximum capability of the unit with zero greenhouse gas emissions	Met
2	Demonstrate ENMAX's continuing commitment to the Alberta Climate Leadership plan.	Met
3	Demonstrate ENMAX's vision of being Canada's leader in the electricity industry through the integration of a novel GHG reduction technology, the first of its kind in Canada.	Met
4	Collaborate with regulators on the evolution of market constructs to facilitate the deployment of future grid-scale energy storage.	Met & On-going
5	Share project and operating lessons learned via participation in industry forums.	Met & On-going

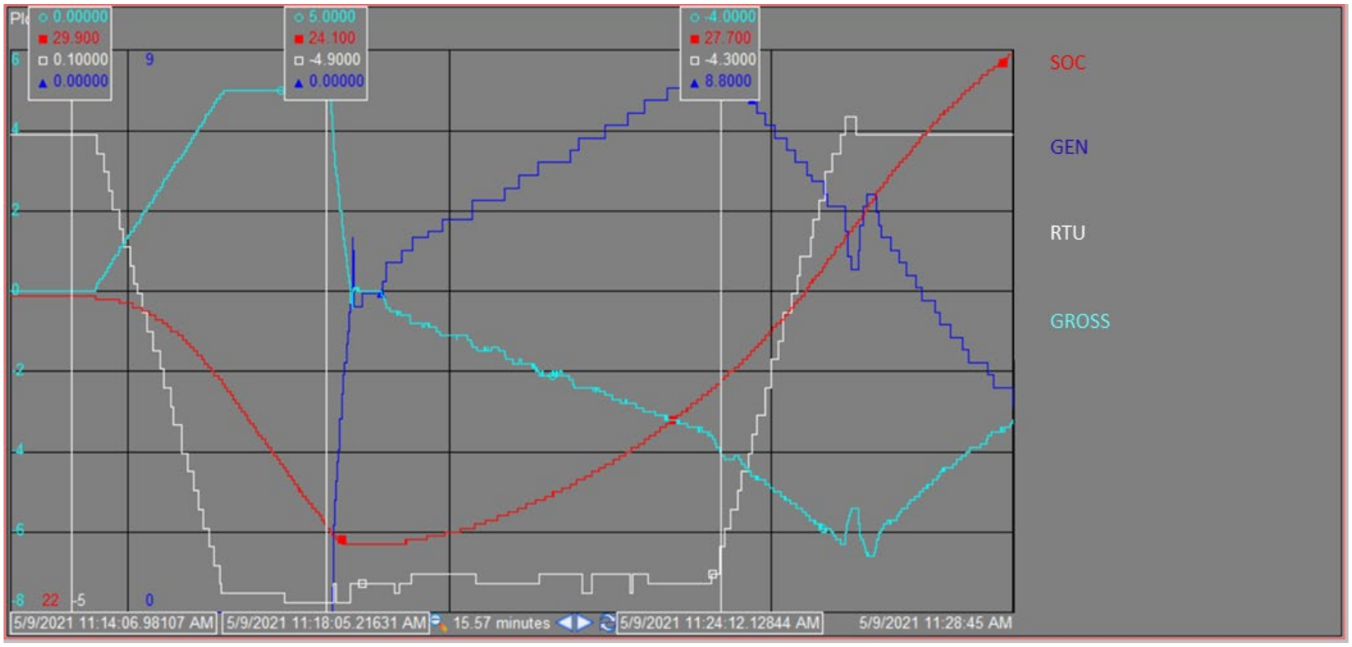
Project Milestones:
The planned project milestones and the corresponding completion dates of each milestone are provided below. Like many projects executed in 2020/2021 this project experienced several delays as a result of the global manufacturing shutdown and labour force interruptions associated with the COVID-19 pandemic. Particularly, the timelines associated with the delivery of major equipment were significantly delayed which impacted GE's ability to meet the planned schedule. As such, certain construction activities were re-sequenced to allow construction to proceed while accommodating late delivery of the equipment. These delays ultimately impacted the ability of the project to achieve the planned milestone dates. Accordingly, ERA and ENMAX undertook to execute an amending agreement to revise the milestone dates and associated tasks to align with the revised project schedule.

Table 2.2: Project Milestones:

Milestone	Planned Date	Amended Date	Actual Date	Variance Explanation	Current Status
1: Procurement	Aug 12, 2019	N/A	Aug 12, 2019	N/A	Complete
2: Detailed Design & Fabrication	April 13, 2020	Sept 1, 2020	Sept 1, 2020	Amended Date Met	Complete
3: Construction	Aug 3, 2020	Dec 1, 2020	Dec 15, 2020	Minor Change from Dec 1 to Dec 15 to accommodate submission of vendor invoices for the period.	Complete
4: Commissioning and Close-Out	Dec 21, 2020	April 16, 2020	July 15, 2021	Minor change due to impact of Ferro-Resonance issue.	Complete

The project reached substantial completion on May 7, 2021. Interestingly, only two days post commercial operation, the Alberta Power system experienced a system contingency and the EGT was called to provide spinning reserve power. The EGT operated exactly as designed. The results of this event are depicted in the figure below:

Figure 2.9: May 9 System Contingency Event



The figure above shows the first directive received while offering Spinning Reserve on May 9, 2021. The directive was for 5MW. In the figure above, at time 11:14:06 the hybrid net output to the grid, (tag "RTU") starts at 0.1 MW, meaning ENMAX was importing 0.1 MW from the grid to support auxiliary loads of the BESS. At this same point in time, the BESS State of Charge (SOC) starts at 29.9%, and both the turbine and BESS are not outputting any power with both measurements at 0 MW.

The next measurement point shown in the figure is at 11:18:05, where the net output to the grid is now at –4.9 MW showing the directive is being met by only the BESS at that time and the BESS power measurement is at 5MW (tag "GROSS"). Shortly after, notice the generator synchronizes to the grid and the blue line starts to increase indicating the generator is ramping up to continue to meet the demand and later charge up the battery. In this scenario, the generator synchronizes when power continues to be demanded from the Hybrid unit, and the BESS SOC is lower than 25%.

By time 11:24:12, the power demand of the Hybrid Unit has already been sent to 0, so the Hybrid unit starts to ramp down from –4.3 MW towards 0 MW. Notice at this point, the generator is running above 5 MW (8.8 MW) to allow for the BESS to charge at –4 MW. As the trend continues moving into the shutdown sequence, the generator will continue to output power until the BESS SOC returns to 40%, and at that point as long as all other criteria are met, the generator breaker opens, and the BESS returns to 0 MW power output ending the directive.

3.0 PROJECT OUTCOMES & LEARNINGS

The Hybrid Electric Gas turbine EGT technology was co-developed by General Electric, Inc (GE) and Wellhead Power Solutions, LLC (WPS) based on background intellectual property for the Hybrid Energy System and Method developed and owned by WPS and licensed to GE as part of a Joint Development Agreement with WPS for use on the GE LM6000 in North America on an unlimited basis.

The GE Battery Energy Storage System (BESS) was developed by GE utilizing independently developed IP, in the form of trade secrets, software copyrights, etc., related to system control, state of charge management, safety and other features combined with fully-licensed IP (where applicable) from the selected battery cell/module manufacturer and other system components.

The GE LM6000 Aeroderivative Gas Turbine contains intellectual property, in the form of patents, trade secrets, etc., from the parent GE Aviation flight engine, the CF6-80C2, and IP developed in the derivation of that platform to the energy space. Modifications involving intellectual property, in the form of trade secrets, to the LM6000 gas turbine or gas turbine package to enable implementation of the EGT are exclusively developed and owned by GE.

As such, the project objectives were not to develop the technology, but instead lead the way in implementing this technology for the first time in Canada. As this technology is proprietary to GE, GE was sole sourced and contracted to provide a full EPC solution. However, as one of the objectives of this project was to train the workforce of tomorrow, ENMAX stipulated that GE must use local contractors and sub-contractors to complete the construction. As such, GE tendered the work locally and Iconic Power Systems, an Alberta based company, was awarded the construction scope. Through the course of construction Iconic employed 11 full time and 19 part time staff, as well as engaged various local sub-contractors to complete the work. In addition, with the exception of the major equipment, the materials (cabling, wiring, conduit, screw piles, etc.) utilized for the project were all sourced locally.

Constructing the EGT:

Aerial picture of fully constructed BESS

Aerial picture of fully constructed BESS with Turbines

The EGT was constructed over a six-month period between June 2020 and Dec 2020. The Major equipment (HPSU's, Control Enclosure, Inverters, Transformers, and Switchgear) were factory fabricated offsite. On-site work was comprised of civil and structural preparations for the major equipment, electrical interconnections, as well as the turbine control system upgrades.

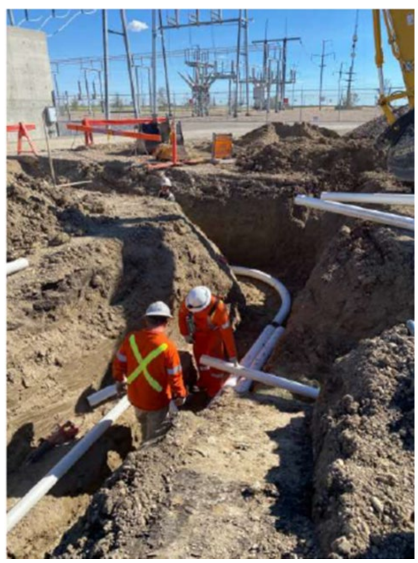
Civil & Structural Construction Highlights:

Excavation of BESS Area

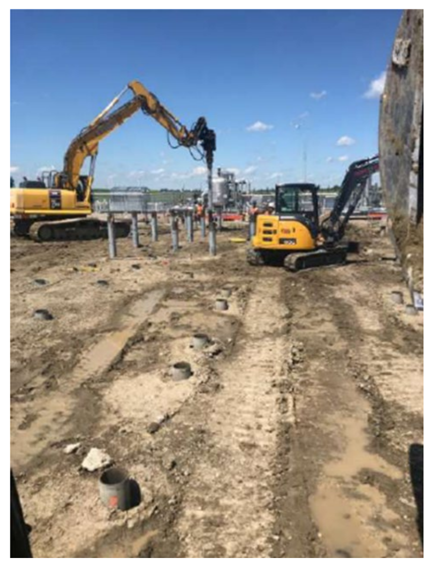
Underground Conduits

Screw piles for equipment

Trenches from MVSG to CRS GSU



Trenches from MVSG to CRS GSU



Installation of Screw Piles

The layout was developed based on existing site conditions as well as to provide future expansion opportunities. As BESS technology continues to improve, there are options of integrating the battery containers, inverters, and transformers all on the same skids or increasing inverter sizing to allow for less major equipment. However, for this installation, the solution used was one which was a proven solution implemented at other sites previously in California.

- Interconnection of all DC and AC power within the BESS is connected by underground cabling in individual 1”- 4”conduits buried between 650mm to 2m and protected by warning tape and treated fir plank. The BESS area was excavated, and the underground conduits installed.

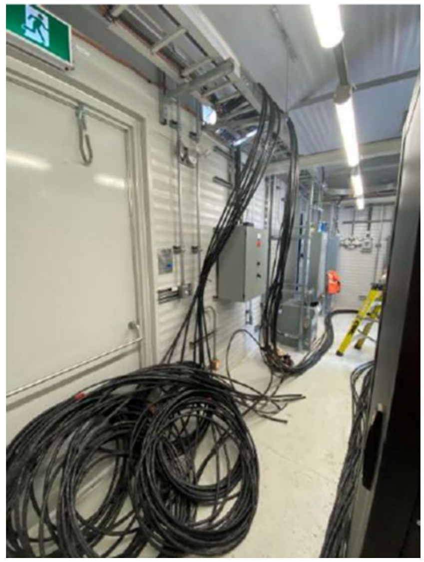
- Trenches were excavated and underground conduit installed from BESS MVSG to CRS3 as well as to the adjacent Altalink Substation control building.

- 180 screw piles were installed to support the equipment. Grillages were mounted between the screw piles to support the placement of the equipment.

- New grounding rods for the BESS were installed and all primary equipment was connected to by copper ground wire. The BESS grounds were interconnected with ENMAX's existing plant ground grid.

Electrical Construction Highlights:


Cable Delivery


Cable pulled inside Control Enclosure


Cables pulled into inverter via conduit


Power Cables


Cable tray from HPSU


Battery Modules being loaded into HPSU

- It is estimated that over 26 km of cabling (power and electrical) was installed as part of this project, to interconnect the AC and DC components of the BESS, as well as the BESS to CRS3.

- A 10-day plant outage occurred to upgrade the bus duct and tie in the 750MCM cables to the 52-M3 breaker within the BESS Switchgear. At the end of the outage the 13.8kV connection from the BESS Switchgear to the GSU was successfully energized.

- ENMAX proposed the location in which the BESS would connect to the existing CRS3 medium voltage electrical system. 750 MCM cables were installed connecting the BESS Switchgear to the

GSU. These wires carry 13.8 kV power from the BESS to the low side of the GSU before exiting the plant to the grid. Terminating these cables required careful preparation and attention to detail.

- Two power meters were installed and tested. These meters measure BESS output, and hybrid output. These meters are critical for power measurement in the control system and overall operating scheme.

- A protection relay was installed in the Control Enclosure to protect the medium voltage equipment. The original design specified 5 different protection relays to perform specific protective functions, however, ENMAX proposed the same functionality could be implemented by only using one protection relay which resulted in large cost savings and is more reliable.

- Two separate three phase runs of 1C, 250MCM-500MCM cables (collection lines) were installed upstream of the 13.8kV switchgear. The collector lines are interconnected with the BESS ISO Transformers.

- The batteries were shipped loose and loaded into racks within the HPSU. All battery racks were wired together and then wired to their respective BCU.

- Cable trays were installed between to guide the battery strings and communication cables from the HPSU's to their respective underground conduit.

Instrumentation & Control Construction Highlights:

Interior of control cabinets within the BESS Control Enclosure

- The Turbine control system was upgraded. This included installing both new hardware (CPU's & Fuel Valve drivers) and upgraded software to account for the new hybrid functionality. GE provided the updated software, and design and layouts for the new CPU's, and provided the software user logic updates to the Turbine Control System.

- The Hybrid Control System (HCS) was installed. This controller is the master controller that receives power demand setpoint from the grid and coordinate and blend power delivery from the BESS and the gas turbine. It responds deliberately to provide the fastest possible delivery of power to the grid while monitoring and controlling the health of the system such as state of charge of the battery (by charging the battery using power from the gas turbine), ramp rate limits of gas turbine etc.

- The SCADA equipment was installed for the HCS/BESS control system. This includes HMI (Human Machine Interface) stations for both the BESS system and the HCS hybrid system.

- ENMAX used an innovative approach to implement Phasor Measurement Unit (PMU) streaming to the AESO. PMU data streaming was enabled in two protection relays and a Phasor Data Concentrator (PDC) was installed to report real time data to the AESO and historize locally as well.

- A complex fiber/ethernet network was installed between various locations (BESS, gas turbine, main electrical building, and substation) to establish communication between the HCS, BESS and gas turbine control system. For this installation, the HMI interface was built into the existing Crossfield Ovation DCS (Distributed Control System) to make for seamless integration with existing screens for the operators.

<u>Mechanical Construction Highlights:</u>

Inverter being offloaded

Transformer being offloaded

HPSU being offloaded

- A bottle test PT was added to CRS3 gas train to ensure there would be no gas retained between shut off valves during fast start mode.

- The BESS components were transported to site and offloaded and attached to the grillage.

Commissioning of the EGT

Through commissioning the first Hybrid EGT in Canada, key insights and knowledge have been developed by ENMAX engineering, maintenance, and operations personnel. Commissioning was broken out into testing and proving out three main systems. These systems included the Battery Energy Storage System (BESS), the Hybrid Electric Gas Turbine, and protection/safety systems.

The first step was to prove the protection and safety systems worked effectively to ensure - prior to moving into energization and running the Hybrid EGT - adequate protection existed in case of equipment failure or malfunction. Safety systems in this project include, but are not limited to, fire safety systems for the BESS Containers, electrical protection for monitoring and isolating faults, battery management systems for battery protection and gas turbine controls to protect the engine. All tests were performed to simulate various events and ensure the associated shutdowns isolated the proper equipment, fire monitoring/suppression equipment activated, and alarms were generated.

BESS commissioning consisted of first proving communication between the BESS controller and controller inverters, the battery and building management systems. Once communication was proven, all high voltage equipment went through integrity testing (VLF, Insulation Resistance, etc.) and test results were verified, prior to being safely energized. Finally, Samsung performed necessary diagnostic and function testing on the batteries, prior to proceeding into battery charging and discharging. Once each BESU wing was fully tested by GE and Samsung, performance testing the batteries for power capability and energy capacity was completed.

Finally, the full Hybrid EGT system was commissioned. This consisted of many sequential steps. First, proving all offline tests to ensure all equipment could be operated safely and per design. This included things like the Hybrid HMI screen, toggling between AUTO and MANUAL on the BESS controller, the GT Controller and then the Hybrid Controller and testing all alarms and trips would take appropriate action. Once the offline tests were completed, witnessed and signed off, run tests began with the BESS but this time operated through the Hybrid Controller. Next, the Hybrid system was run through various tests, initially proving the system was stable at low loads and the GT could synchronize to the grid at a more expedited rate per design, and the Hybrid Controller could effectively and responsively control the BESS and gas turbine in a coordinated fashion. Lastly, the Hybrid System was tested for frequency droop response, various MW dispatch setpoints from minimum stable load to full load, and voltage response.

An important test conducted during commissioning was the frequency droop test, where an over-frequency excursion of 0.32Hz when the Hybrid system was running at 30MW was simulated. Normally the gas turbine would be forced to respond quickly, ramping power output for the droop event, however, in this scenario with the hybrid system, the battery begins to charge rapidly, and then the gas turbine ramps back more slowly while the battery charging eases off putting less wear and tear on the gas turbine. Given the battery takes on the quick transient response, the gas turbine just follows load/droop requirements at a more controlled ramp rate. The BESS system went through performance tests to ensure the actual performance of the system met the design ratings. Three different performance tests were completed. The first test was the capacity test to show the MWh capacity. This test was performed by charging the BESS to 100% SOC, then setting the BESS to 4.3MW discharge and analyzing how long it took for the BESS SOC to get to 0% while maintaining the 4.3MW power output. In this test, GE and ENMAX proved the BESS capacity was slightly greater than designed, 4.3MWh(AC).

The second performance test completed was the battery peak power discharge test. This test was designed to prove that the batteries and inverters could perform as designed. The test was completed by setting the BESS to peak output (9.9MW) for 2 minutes. One thing that was noted during this test was that although the discharge setpoint was set to 9.9MW (rated capability of the system), the system was only capable of outputting approximately 9.5MW. This is due to the fact there are auxiliary loads connected off the BESS switchgear, which reduce power output to the grid at the BESS meter given the load is subtracted off the battery output prior to reaching the meter. This and a combination of other factors such as losses in the system, and general battery constraints only allowed 9.5MW at the BESS meter.

The last performance test completed was the battery peak power charging test. In this test, the system was set to –9.9MW for two minutes to ensure the batteries were capable of charging at their highest rating. Note, for the charging test, it is easier to meet the 9.9MW rating, given the auxiliary loads add extra load onto the meter, which would not actually be getting absorbed by the batteries, similar to the statement above for discharging but it works in favour of this test rather than against it. All performance tests were passed and met the criteria set out in the performance agreement.

Project Challenges & Lessons Learned:

Upon energization of the BESS switchgear an unforeseen technical issue occurred where a voltage transformer on B phase failed after the switchgear was energized. The voltage transformer purpose is solely for protection and metering of the BESS switchgear. It was determined the cause of this failure was due to a phenomenon called ferro-resonance (non-linear resonance). This phenomenon is explained by parallel inductance and stray capacitive properties in the power circuit which essentially serve to defeat the inductive properties of the voltage transformer. As a result, the voltage transformer ends up acting like a pure resistor and will eventually overheat/degrade due to experiencing high voltages and currents. Immediately upon failure, commissioning was put on hold and a third-party power systems specialist was engaged to study the incident.

This issue, although not new to the power system industry, is rare in that it requires a very specific RLC circuit to observe ferro resonance as well as utilizing an ungrounded neutral system. It was not foreseen in the design stage due to its uncommonness. As a result, two engineering fixes were installed to mitigate the ferro-resonance. Extra burden was added to the PT circuit in the form of resistors for dampening, and a neutral grounding transformer package was installed to add a high resistance path to ground rather than using the existing capacitive system (ungrounded).

Like many projects executed in 2020/2021 this project experienced several delays as a result of the global manufacturing shutdown and labour force interruptions associated with the COVID-19 pandemic. The timelines associated with the delivery of the major equipment for this project were delayed which impacted GE’s ability to meet their original schedule. GE and ENMAX worked collaboratively to develop a revised project schedule in order to mitigate the magnitude of the delays. As such, certain construction activities were re-sequenced to allow construction to proceed while accommodating the late delivery of equipment.

As an example, at onset of the project it was intended that the battery cells from Samsung would arrive at site following the delivery of the battery enclosures and then the battery cells would subsequently be installed shortly thereafter. However, due to supply chain logistic challenges, the batteries arrived in Calgary six months prior to the delivery of the battery enclosures. This created a major challenge as the battery cells have a limited de-energized shelf life and also need to be stored in a temperature-controlled environment. As such, a specialized warehouse in Alberta was sourced whereby the batteries could be safely stored and balanced until such time that they were required at site.

To allow construction activities to proceed safely, ENMAX immediately implemented COVID-19 site protocols for all workers. Daily screenings were conducted on all workers accessing the site and any exceptions noted during the screening process were referred to a private nurse for further assessment prior to those individuals being allowed to enter the site. To limit potential contacts, the site staff were treated as a cohort, whereby they were dedicated to this project and not working across multiple sites. In order to prevent potential spread, in the event any staff member developed symptoms, all site work was stopped until such time a negative test result was obtained by that individual. Additional office trailers were added to site equipped with plexiglass screen between desks to allow workers to spread out while completing paperwork and while eating lunch. In addition, any sub-contractors working on the project were kept separate from the primary project team to further limit outside exposure.

At the onset of the project it was planned that certain subject matter experts from outside of Canada would be on site to support construction and commissioning as well as to perform certain specialized tasks. However, based on the evolving provincial and federal restrictions, this was often not possible. As such, GE and ENMAX worked together to complete many tasks virtually whereby the subject matter expert guided a local resource through the completion of the task, and/or whenever possible Canadian subject matter experts were substituted for non-Canadian. This process, while unanticipated and significantly less efficient than planned, also had unintended positive impacts as it provided an opportunity for local resources to learn and perform more of the detailed tasks related to the inner workings of the EGT. In a project lessons learned with GE, it was discussed that this process may become standard as it was proven achievable on this project.

Overall, the project was delayed seven months from its planned completion date, however despite the major challenges it faced, ENMAX remained committed to completing this industry leading project.

Advancing Industry Knowledge:

ISO rule 205.5, Spinning Reserve Technical Requirements and Performance Standards defines the technical requirements for a market participant wanting to offer spinning reserve within the Alberta ancillary services market. The rule contains three key sections relevant for this project:

1. A generating resource must be capable of providing a minimum of 10 MW of power,
2. within 10 minutes of dispatch,
3. for a period of up to 60 minutes while always connected and frequency responsive.

Through this project ENMAX has work collaboratively with the AESO to demonstrate that an EGT can meet or exceed all of the technical requirements as defined within ISO rule 205.5 as well has obtained formal approval for battery-based assets to provide spinning reserve in Alberta, paving the way for future market participants to seamlessly deploy this technology.

Achievement of Planned Project Success Metrics:

The following table identifies the achievements of the project relative to the planned success metrics developed at the on-site of the project:

Table 3.1: Project Success Metrics:

Success Metric	Project Target	Achievement Progress
Capital Cost	Deliver project for a capital cost of $14,568,780	Achieved. Project was completed on budget. This is a remarkable achievement given the impacts of the COVID-19 pandemic.
Schedule	Deliver project and achieve final completion by Dec 21, 2020	The project was completed in July 2021. The project schedule impacted by the COVID-19 pandemic. Despite the materiality and duration of the pandemic, of the project was completed only seven months later than planned.
Performance	Battery provides minimum of 4MWh of storage capacity and 9MW's of output.	Achieved. The battery exceeds both values.
Reliability	Battery has an availability of >90%	The battery has been operation since May 7, 2021 and has well exceeded 90% availability since that time.
Ancillary Services Capacity	Achieve spinning reserve capability of >=43MW	Achieved. The EGT is capable of providing up to 48MW of spinning reserve.
Ancillary Service Participation Hours	Percentage of Hours spinning reserve offered into market >=75%	Achievement will be reviewed following 1 full year of operation.

4.0 GREENHOUSE GAS BENEFITS

Please note that this section provides preliminary estimates of the GHG impacts of the project at a facility level. A third-party GHG verification will be completed following the first full year of commercial operations.

For the purpose of this analysis reductions in GHG have been quantified by "direct" and "indirect" reductions, defined as follows:

Direct Reductions: are the reductions associated with the actual volume of spinning reserve provided by the EGT vs. had the same volume been provided by the gas turbine.

Indirect Reductions: are the reductions that will result from displacing market participants utilizing fossil fuels with higher marginal costs and higher GHG emissions.

Direct Emission Reductions

The direct GHG reductions of the project have been derived based on the actual spinning reserve volumes that the EGT has provided year to date (YTD).

2021 pro-rated annual emissions savings = 47,743 CO_2e tonnes

If the hybrid were to supply its full capacity for a full year, the direct GHG reductions would be much higher. **The maximum annual emissions savings = 96,807 CO_2e tonnes per year**

Indirect Emission Reductions

The indirect GHG reductions of the project will result from displacing market participants utilizing fossil fuels with higher marginal costs and higher GHG emissions. Quantification of indirect GHG emissions reductions considers several factors (coal to gas conversion, carbon tax, fuel cost, facility retirement). In the first year of operation, coal fired facilities production will be replaced by combined cycle production. Displacing a higher GHG emitter will result in lower GHG emissions in Alberta. Indirect emission reductions are calculated as the difference between increased gas-fired generation emissions and decreased coal-fired generation emissions in the energy market.

The indirect GHG reductions of the project have been derived based on the actual spinning reserve volumes that the hybrid has provided year to date (YTD).

2021 Pro-Rated Indirect Emission Savings = 33,546 CO_2e tonnes per year

If the hybrid were to supply its full capacity of 48 MW for a full year, the indirect GHG reductions would be much higher. **The Maximum Indirect Emissions Savings = 274,153 CO_2e tonnes per year**

Total Lifetime Reductions

During the lifetime of the project, the direct GHG reductions will be 938,247 to 1,902,456 CO_2e tonnes and indirect GHG reductions of 281,601 to 2,210,744 CO_2e tonnes. The magnitude of which will depend on market conditions and adoption of the EGT into the spinning reserve market.

5.0 ECONOMIC & ENVIRONMENTAL IMPACTS

The electricity market will require spinning reserve. The project provides an opportunity for supplying direct and indirect emission free spinning reserve. Additionally, smog and acid rain pollutants (CO, NO2, PM, SO2) will be reduced. The project is built on existing developed land and will have negligible increased environment footprint.

As ENMAX gains more operational experience with the EGT at Crossfield, further opportunities will be explored to deploy the technology across ENMAX's fleet. If market opportunities were present, ENMAX has the opportunity to commercially deploy a Hybrid EGT technology on the two remaining gas turbines at the Crossfield Energy Centre. The design of this project has already taken into account considerations for deployment on these two additional units. ENMAX's Cavalier Energy Centre has two additional LM6000 units which have the potential to be hybridized. Lastly, ENMAX's generation fleet consists of 1444 MW of gas fired generation. These other facilities could also be hybridized if economic conditions were right, providing additional greenhouse gas reduction possibilities. For our renewable assets, grid scale batteries could be deployed as a means of firming the intermittent nature of wind generation.

6.0 SCIENTIFIC ACHIEVEMENTS

While the scope of this project was not intended to develop brand new technology, but more so to lead the way in the adoption of any early technology and help test and refine the technology for future adoption by others, ENMAX has been leading discussion on this technology and project within the Canadian utility industry. Recently, ENMAX was interviewed for an article in the Western Energy Institute Magazine. Additionally, ENMAX presented its findings from this project at a recent CEATI industry conference. CEATI it is a utility focused organization that includes interest groups and working groups who develop training, projects of common interest and exchange information. It has membership across North America and throughout the world. Finally, members from the ENMAX, GE, and Wellhead project teams participated in a Reddit "Ask Me Anything" (AMA) session hosted on the subreddit r/futurology, which has over 15 million members globally.

ENMAX and GE continue to work together collaboratively to improve the performance of the EGT product and make enhancements for future releases and generations of the technology. ENMAX shares its EGT operational data with GE to allow GE to analyze and improve the technology based on actual field level results. By doing so, ENMAX is actively supporting improvements to the technology such that other industry participants can deploy a more refined project in the future.

7.0 OVERALL CONCLUSIONS

Alberta has always been known for its innovative and entrepreneurial spirit and the Crossfield Hybrid Electric Gas Turbine is another example of that. The development of Canada's first Hybrid EGT will serve as a model for lowering emissions from existing fossil fueled power plants. Battery energy storage systems are going to play an increasingly important role in the future of the electricity industry and this EGT is just the beginning. What we have learned here and what we continue to learn about this technology will provide a model for other utilities in Alberta and across Canada to follow – both in terms of incorporating a battery to make their operations more efficient and in training the workforce of the future.

8.0 NEXT STEPS

With commissioning of the Crossfield Hybrid EGT complete, our focus now shifts to maximizing the environmental and economic benefits of this project. Economic benefits for ENMAX are closely coupled with achieving greater environmental benefits. Specifically, the more spinning reserve volume ENMAX is able to achieve the less the turbine will run and therefore the greater the environmental benefits. Cross functional teams within ENMAX continue to collaborate on the development of innovative strategies to enhance the value of this resource to the Alberta Interconnected Electric System.

GE and ENMAX continue to work closely together on optimizing and understanding operations of the EGT, specifically in the Alberta market. GE receives periodic updates from the EGT which is used to not only trouble shoot operation issues but is also used to help ENMAX improve performance but also help GE fine tune the offering for future deployments.

In our ERA submissions for this project four years ago we talked about how this project could provide a platform for the introduction of a Fast Frequency Response Ancillary Service Market similar to other global jurisdictions. Recently AESO has announced a procurement offering for a Fast Frequency Response pilot project. Leveraging the learnings from the Hybrid EGT project, ENMAX continues to collaborate with the Alberta Electric System Operator not only in this regard but also to update the regulatory framework within the province. Through a combination of these efforts our goal is for market participants to develop future projects like the Crossfield Hybrid EGT without the need for external funding.

"When the world thinks about new and better ways to produce energy, we want them to think about Alberta." That 2018 quote from a provincial politician inspired some of the early work on the Crossfield Hybrid. Three years later, ENMAX has completed a bold step towards achieving that vision. Moving forward, ENMAX is committed to speaking on the results of this project, further demonstrating Alberta's leadership in the development of low carbon technologies.

9.0 COMMUNICATION PLAN

The following is a summary of the key communications undertaken during the project.

Media

Since we were unable to have an in-person launch and media event due to COVID-19, we held a virtual launch in the form of a stylized email that went to media, industry peers and key stakeholders. It included a link to the news release, embedded videos of the battery and remarks from Wayne O'Connor, President and CEO; Mayor Nenshi, Steve MacDonald, CEO ERA; Prakash Chandra, CEO GE Renewables; and Minister Jason Kenney. These remarks and videos are also available on our News and Events page on enmax.com. In addition, ENMAX published the news release on our website and social channels the morning of June 10. Our proactive media efforts resulted in two broadcast interviews with Lonnie Enns, President, ENMAX Energy, two online articles and one magazine feature.

News Release – ENMAX Energy introduces Canada's first Hybrid Electric Gas Turbine

CTV (online)
Clean electricity turbine a Canadian first
June 14, 2021

Global News (online)
Electric-gas turbine hybrid begins powering Calgary
June 10, 2021

BNN Bloomberg (broadcast)
New clean electricity turbine in Calgary sees better results than anticipated: ENMAX Energy's Enns

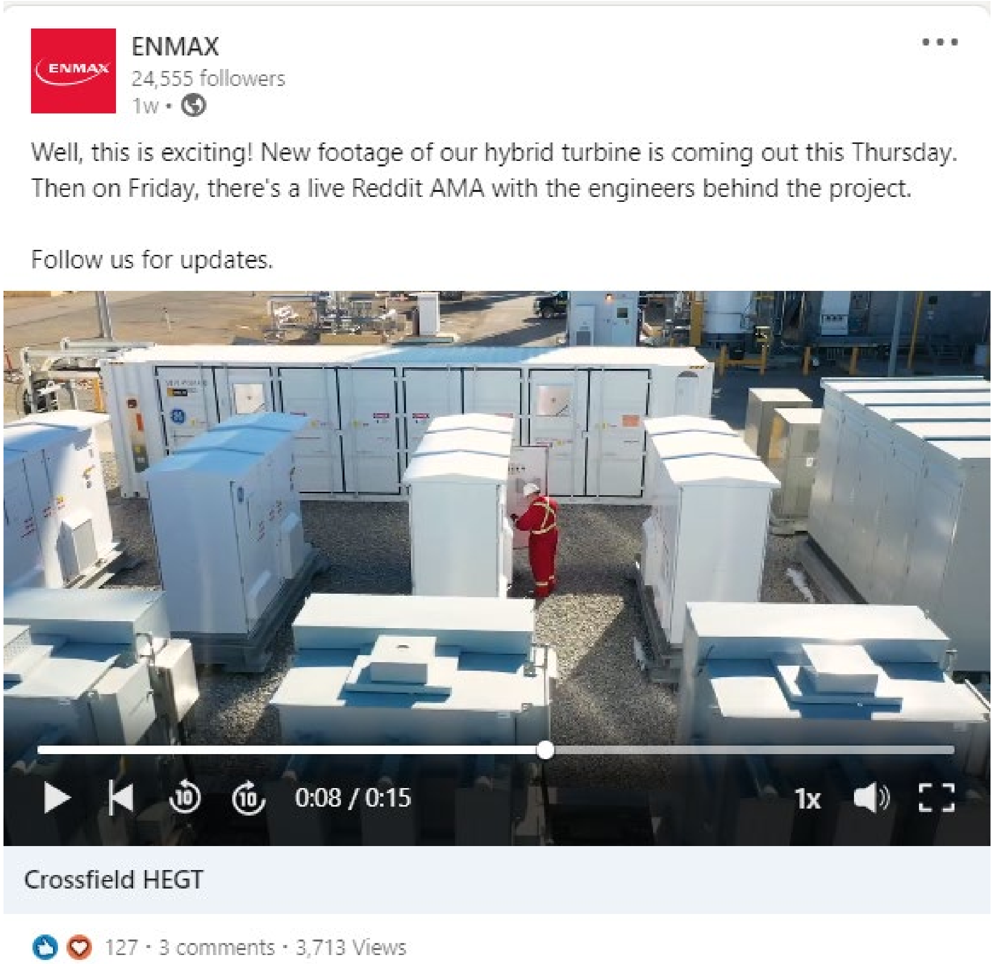
Energi Media (broadcast)
Batteries combined with gas turbine reduce ENMAX peaker plant GHG emissions by 80%
https://www.youtube.com/watch?v=T5QODiEJtBs
June 10

Social media

On June 10 and in the days leading up to it, we posted about the project seven times on LinkedIn, 14 times on Twitter, twice on Facebook and once on Instagram. Each message was adapted to suit the audience and the channel based on what we've learned over the years.

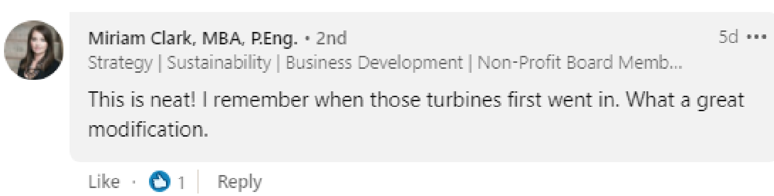
LinkedIn

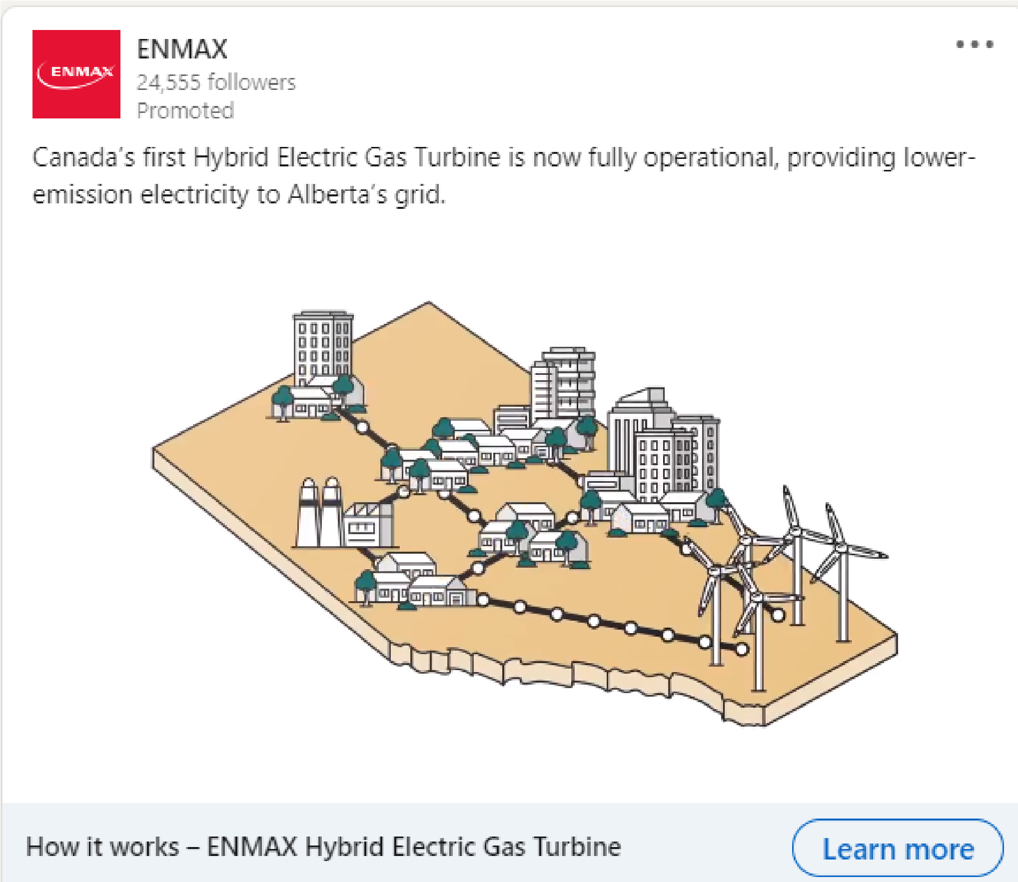
LinkedIn was our primary channel as we anticipated that the broader technical audience here would be the most receptive to messaging about the Hybrid Electric Gas Turbine (HEGT).



A new animation video was posted on June 4 and unsurprisingly, it was the LinkedIn post that produced the most engagements. A second video on June 10 featured Lonnie speaking to the significance of the project and once again, LinkedIn came out on top for organic performance.

Perhaps the best part about posting to LinkedIn is that the comments are almost always professional and positive.



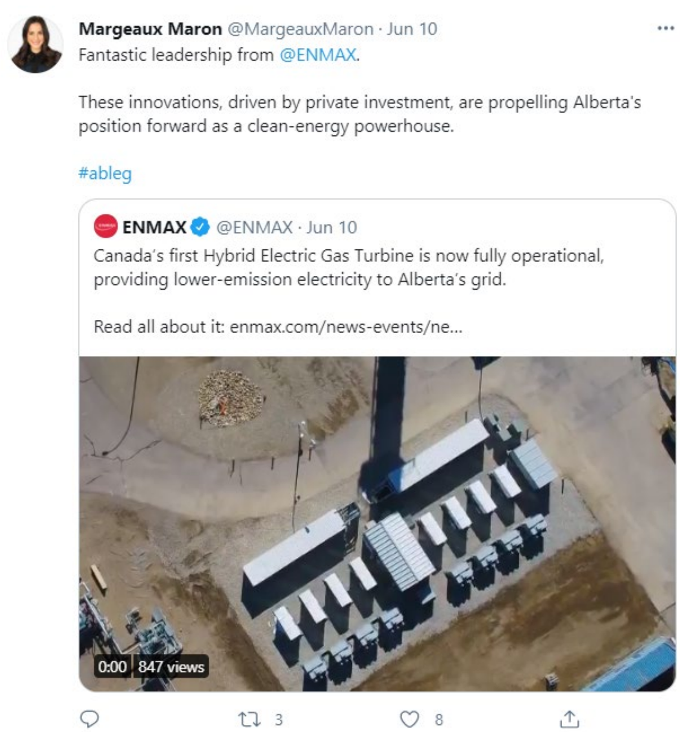


Twitter

While a tweet can be fleeting, if the right person sees it and shares it, it can significantly amplify the engagements. This was the case with one of our tweets on July 10 which was retweeted by provincial government officials as well as Calgary Economic Development, both with large followings.

We also shared the video remarks from Mayor Nenshi, Minister Nixon, ERA and GE and directly tagged the relevant handles.

Global and CTV tweeted their news articles which further increased impressions.



Facebook

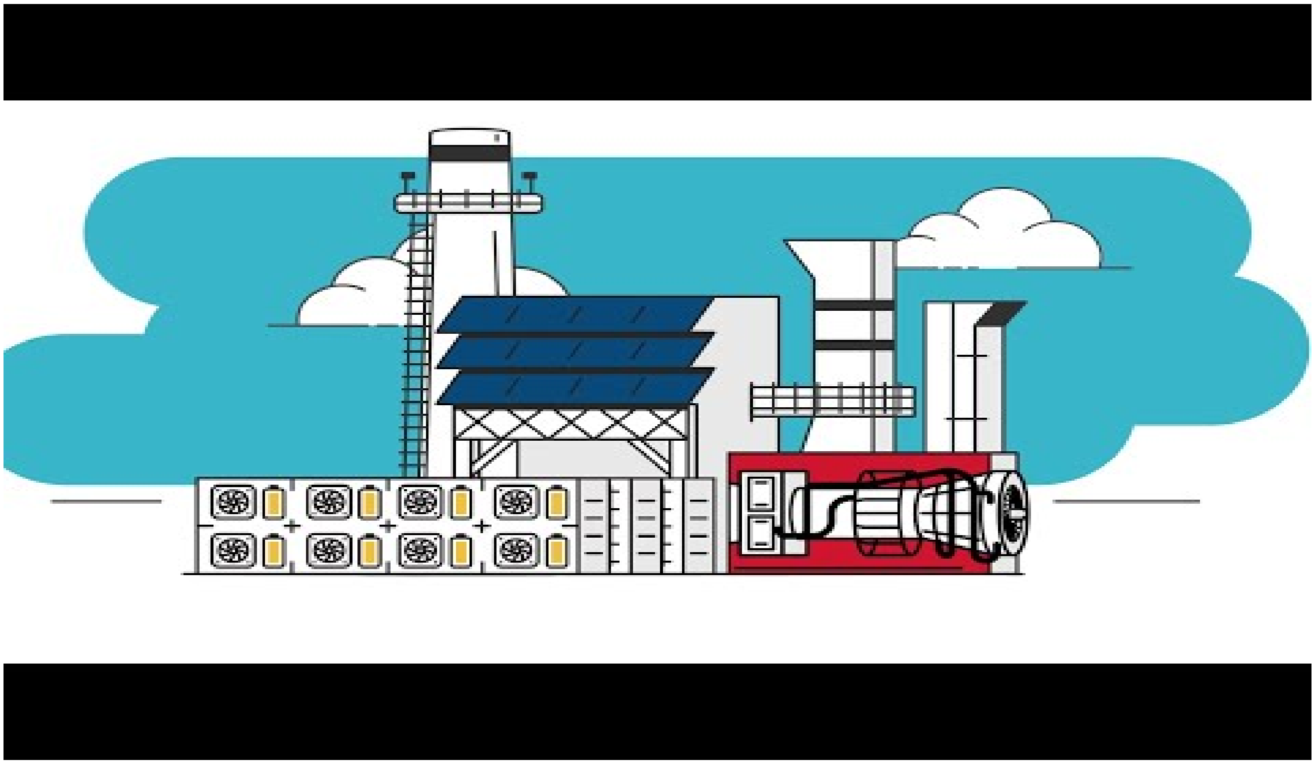
Knowing that organic posts don't produce high engagements, we added a boost to this Facebook post so that a broader audience interested in electricity, battery storage, etc. would be able to see it.

Videos

As part of our communications and media launch, we developed two videos to help explain turn this complex technology into engaging content for a variety of audiences:

Learn more about the project: Canada's First Hybrid Electric Gas Turbine

How it Works: How it works – ENMAX Hybrid Electric Gas Turbine



While the project was underway, we also shared a video internally and on our social channels featuring team members who had the opportunity to work on the project:

What's it like working on Canada's first Hybrid Electric Gas Turbine?