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MICROGRID EMPOWERING RESILIENCY, EFFICIENCY AND SUSTAINIBILITY

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SUMMARY

There's never been a need for greater urgency when it comes to reducing greenhouse gas (GHG) emissions. As planetary temperature continues to rise due to the heat-trapping nature of these emissions, more people and infrastructure are at risk, costing our economy billions - if not trillions of dollars in damage every year.

Thankfully, over the past decade, sustainability has gone mainstream in the world business community practices. As the world is progressing towards new ways of generating, distributing, consuming, and saving energy, the end goal is Electricity for zero: zero waste, zero emissions and zero carbon.

Even in Canada, as the facility owners embrace this energy transformation journey towards energy sustainability, they are also facing climate change induced energy instability and budgetary pressures.

There have been lot of advances in the power distribution, communication, and digital intelligence. Proven technologies exist today that can fully digitize the electrical distribution infrastructure of large and critical buildings and facilities. These are helping improve safety for people and assets, increase power reliability and business continuity, optimize operational and energy efficiency, achieve sustainability goals, and meet regulatory compliance. One of the solutions is microgrid technology, which is increasingly being used to further enhance uptime, while reducing energy spend and minimizing a facility's carbon footprint. The newest of these solutions integrate advanced energy analytics to manage energy assets more intelligently, from gensets and Combined Heat & Power (CHP), to renewables and loads.

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ENERGY LANDSCAPE IS UNDERGOING A MASSIVE TRANSFORMATION

Canada's Energy Regulator populates Canada's Energy Future (EF) series which explores possible energy futures in Canada. All previous forecasts towards a lower emission energy, has either been met or exceeded the expectation and hence benchmark of emission free of Energy Supply and Demand Projections to 2050 has been improving with each revision [1].

Apart from current and evolving policies, transformation of Canada's electrical system will play a major role in a net-zero world. The total energy use intensity would be declining with more energy efficient systems and measures, but in a more electrified scenario the electricity demand will grow 47% from 2021 to 2050. This increased energy need will be majorly met using non-emitting energy sources and phasing out high carbon intensity sources like coal and oil. Wind and solar will account for 59% of new capacity additions through 2050 whereas electricity storage will reach 15% of total installed capacity in 2050.

There are some key drivers in these energy landscape transformations and these catalysts together will decide how Canada produces, distributes, and consumes electricity.

- **Carbon Pricing**: To meet the targets, Canada may drive up the carbon pricing which will lead to phasing out coal and promote carbon capture in existing natural gas power generation.
- **Higher Demand**: Specific climate actions and technology development will continue to drive electrification and higher electricity demand will drive up quick to deploy solar, wind and storage further.
- **Limited Transmission**: Inter- Intra provincial transmission may be expensive which will drive more low carbon decentralized electricity generation and distribution.
- **New emerging technologies**: With interests in hydrogen, biomass power generation or new technologies like carbon capture, the scenario of hydrogen or biomass-fired electricity generation and carbon capture is very bright.

EMISSION REDUCTION TARGETS RELEASED BY GOVERNMENT OF CANADA

Canada has committed to reducing its GHG emissions by 40 to 45% below 2005 levels by 2030 and achieving net-zero GHG emissions by 2050. Earlier this year Government of Canada released the 2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy.[2] The plan lays down achievable segment wise goals and budget allocation to achieve the above target. The 2030 emission reduction plan [3] allocated new investments of $ 9.1 Billion and phased goals to reduce GHG emissions and grow economy and following are the highlights in clean energy sector:

E-mobility: To accelerate the transition to e-mobility, more than $2.9 B investment has been allocated for charging infrastructure, rebates on zero-emission vehicles (ZEVs) and build medium – heavy duty clean transportation projects. The plan ambitiously lays down a target that 100% of new passenger vehicles sold in Canada will be zero emission by 2035 in a phased approach.

Buildings: Today in Canada buildings account for approximately $1/6^{th}$ of the overall GHG emissions. An investment of $1B will be made to develop a 'net-zero by 2050 buildings plan' which will accelerate the adoption of greener building codes, energy retrofits at building and communities. e.g., Natural Resources Canada calls for proposals in Fall 2022 facilitating financial assistance to implement ISO 50001 in commercial and institutional buildings. We see great momentum in individual cities as well e.g., Toronto Green Standard v.3 which lays down four tiers of new construction targets that will be incrementally increased over time to eventually require all new construction projects to achieve near-zero emissions by 2030. The last tier target by 2030 is to electrify all building energy needs and reduce energy use intensity (EUI) by 11 times of current existing building needs.[4]

Industries: To enable the industries, transition towards cleaner energy and still be competitive, the plan lays down investments to create higher incentives for clean energy technologies. One of the key areas is to invest $194 million to expand the Industrial Energy Management System to support ISO 50001 certification, energy managers, cohort-based training, audits, and energy efficiency-focused retrofits for key small-to-moderate projects. e.g., Natural Resources Canada called for proposals facilitating financial assistance for energy management projects in March 2022.

Electrical Grid: The plan aims to move Canada's electricity grid to zero-emissions by 2035 keeping reliable and affordable power for all. $850 million investment has been allocated for clean energy projects like wind, solar, storage with provinces, territories, and indigenous partners.

Communities: Actual groundwork on emission reduction must happen at community level, hence the plan lays down an additional investment of $2.2 billion to the Low Carbon Economy Fund to support green projects from government, schools, non-profits, and indigenous communities. e.g., earlier in 2020, approximately $100 million from the Low Carbon Economy Leadership Fund was aimed growing clean economy in Alberta. This aimed 3100 jobs creation in clean tech innovation, energy efficiency, industrial transformation and research supporting elimination of 10 million tons of GHG emissions by 2030.[5]

CLIMATE RISK INTO BUSINESS STRATEGY AND ACTIVELY IDENTIFY OPPORTUNITIES TO DRIVE CHANGE

To lead in the climate crisis means factoring climate risk into Net-Zero strategy and actively identify opportunities to drive change. Although many of climate change impacts are already felt today, its severity will increase dramatically over the coming years without immediate and substantial emissions reductions. To meet the goal of limiting the global temperature rise to below 1.5ºC compared to pre-industrial levels, a very rapid transition to a clean electrified world is needed.

The traditional energy balance equation of central generating entity and distributed consuming entities has evolved to a concept of "Prosumer" who generates as well consumes energy locally. Consumers have evolved into "Prosumers" where in they have the autonomy to manage the energy by controlling self-production, storage, and consumption from the grid.

Today, businesses want to maximize their energy independence and minimize their carbon footprint. Canada is having greater focus on clean energy and striving to have 90 percent of Canada's electricity coming from non-emitting sources by 2030. Digitization and Distributed Energy Resources (DERs) are the two key enables of decarbonization. The most significant and untapped cost reduction opportunities are expected to come from unlocking demand-side flexibility and similar opportunities with behind-the-meter assets. Renewable generation like photo-voltaic (PV) and wind are becoming cheaper day by day. Efficient process system controls have made CHP and biofuels financially more lucrative. New emerging technologies of hydrogen fuel cells and mechanical energy storage are ensuring reliable energy generation and storage for the prosumers. Prosumers also manage their energy consumption smartly. HVAC is the currently the largest consumer of the building energy whereas EV charging infrastructure will exponentially increase building load in near future. Smart controllable building or facility automation combined with microgrids, and energy storage will ensure prosumers remain smart consumers.

Electricity is proven to be 3-5 times more efficient than other energy source and it is also the best vector for decarbonization. The world is becoming more electric, and electricity will be the backbone of the entire energy systems. It's expected that renewables will contribute 6 times more in the generation mix by 2040. As energy plays such a vital role in the climate crisis, we need to upgrade each stage of the energy value chain i.e., from generation (with cleaner energy production) to distribution (with more microgrids closer to points of consumption and more access to energy), to prosumer usage (with metering and smart technology to empower users with visibility and efficiency).

Lastly the technology boom has opened new revenue streams in the effort to balance the capacities with the grid. Demand Response programs, Virtual Power Plants, AI driven Microgrids will help prosumers further reduce the cost of energy.

IMPACT OF DIESEL USE IN CANADIAN REMOTE COMMUNITIES

Diesel currently is being used for power as well as meeting the remote community thermal needs. Based on the national average, diesel still makes 79% of the overall power mix, where only 19% comes from renewable sources like solar, wind, hydro, and CHP, pre-dominantly driven by the hydro grid connected communities. For community thermal needs, diesel and other fossil fuel makes up 79% of the needs, whereas wood ad biomass as renewable generation sources make up the 21%.

Reliance on diesel for electrical and thermal needs in remote communities have many detrimental effects, impacting communities economically, environmentally, and socially.

Economic: Diesel reliance for power has many long and short-term economic impacts on the community. Based on the US Energy Information administration, its projected that diesel prices will steadily rise to almost 80% of its current rate by 2040. This coupled with any geopolitical events like the current crisis in Ukraine will lead to more fluctuation. This brings a huge uncertainty and very high energy prices for the communities. Moreover, the communities which are not connected by road, air transport of the fuel makes its twice as expensive as compared to road or barges. High maintenance costs coupled with existing capacity limitations can deter new business or existing businesses to expand, further limiting opportunities for economic growth.

Environmental: As a fossil fuel, diesel combustion for electricity generation leads to GHG emission and localized air pollution. This is particularly problematic in communities where diesel generators are in the middle of the community since people must live close to where the emissions are produced. Moreover, additional emissions are also generated from the carriers when fuel is transported. Fuel logistics to the remote communities is always a challenge. There are always risks and many recorded instances of transportation and local storage fuel spills, which contaminates the soil and water table.

Social: Capacity limit is becoming a major growth hindrance in local communities. When the community load hits the nameplate capacity of the diesel generation, they are prevented from connecting any new loads for any expansion. This capping of expansion trend limits development of new tourism, infrastructure development or any upgrades to existing commercial assets.

A healthy population defines a socially healthy community. As mentioned earlier, the noise and air pollution from generator use can have adverse health impacts on the community residents, which further induce adverse social impacts. e.g., The polycyclic aromatic hydrocarbon are group toxic compounds associated with diesel spills which is proven to cause cancer with prolonged exposure.

DEPLOY ANALYTICS POWERED INFRASTRUCTURE.

There is an urgency amongst all global business to disrupt or be disrupted in terms of digital transformation. 56% of CEOs say digital improvements have led to increased revenue and digitally mature companies are 23% more profitable than their less mature peers.[6] The advantages can be similarly translated to the energy infrastructure which is powered using digitization and data analytics.

Microgrids have become far more common in recent years and have gained a significant amount of prominence, such that their nature and purpose are much more widely understood. A microgrid is a localized energy system that interacts with the utility grid, encompassing one or more electric power generators and the necessary energy management controls to provide secure electricity to consumers. In contrast to large utility grids, microgrids locate all energy assets – from generation to loads –in proximity, to serve multiple buildings or even be contained within a single facility.

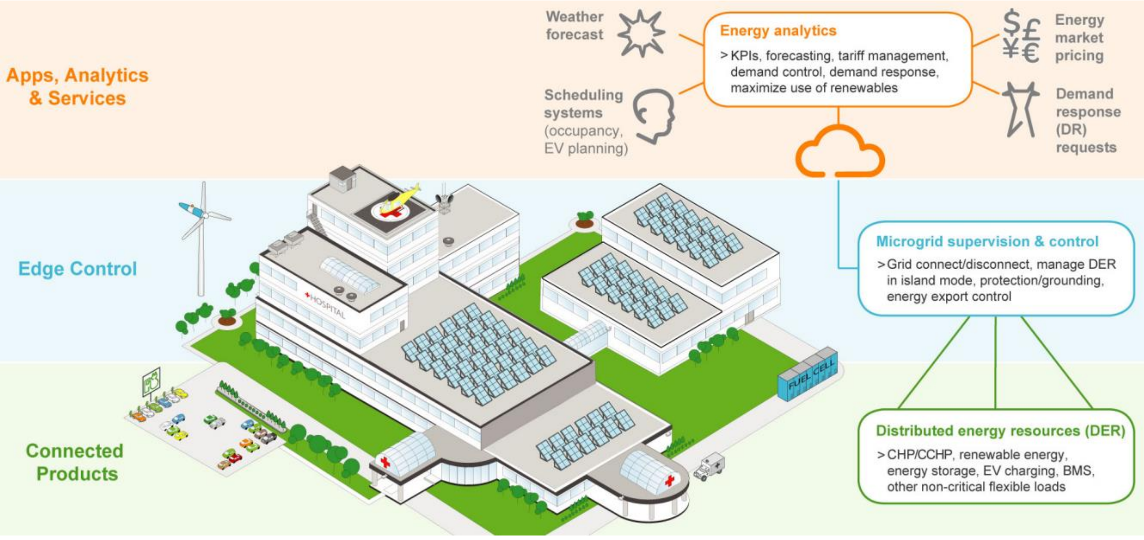

Figure 1: Microgrid architecture - control layers work in tight coordination to maximise resilience, cost savings, and use of renewable energy

Connected products are at the lowest level of control hierarchy, which constitutes of all the power distribution and Distributed Energy Resources (DERs) at site.

The power distribution includes connected switchgears, protection relays and meters whereas DERs include local generation like PV, generator sets, CHP, and manageable loads like HVAC and EV chargers.

At the **Edge control level,** the microgrid system supervises all DERs and uses intelligent, predefined algorithms to take the appropriate actions as required:

- **Manage grid connection**: The system must be able to disconnect from the grid, support critical loads, and reconnect after an event.
- **Manage DERs during island mode**: The system ensures the amount of energy production is balanced against consumption. If necessary, the system will shed non-critical loads to ensure production can meet consumption requirements.
- **Ensure microgrid safety**: The microgrid system manages facility-wide electrical network protection, in grid-connected and island mode, for every combination of DERs. This is done to ensure that circuit breaker coordination is maintained, and, in turn, impact is minimized if an electrical fault occurs anywhere in the facility.
- **Manage DERs in grid-connected mode**: The controller can be programmed to maximize the use of renewables when possible. Excess energy can be saved to an energy storage system or sold back to the grid. The microgrid system manages the level of authorized energy export to the utility grid. This can be in response to a utility signal, third party signal, or predefined threshold.

The top layer includes **applications, analytics, and supporting services** that augment the microgrid solution. Often hosted in the cloud, advanced energy analytics help optimize when and how to produce, consume, and store energy to minimize costs and maximize sustainability. The most advanced microgrid solutions provide analytic intelligence that integrates external data:

- Weather prediction
- Availability of solar and wind
- Energy market pricing, including pricing for grid electricity as well as other fuel sources such as natural gas, hydrogen, and diesel
- Facility occupancy forecast and activity schedules (e.g., HVAC or electric vehicle charging)

The **energy management analytics layer** is most often provided as a cloud-hosted service. Integration of the microgrid analytics control layer with the facility BMS system will enable coordinated optimization of sources and loads. In this way, the microgrid becomes an integral part of a complete intelligent building, allowing it to leverage smart BMS consumption functions – e.g., heating, cooling, automation of blinds for control of daylighting and passive solar, etc. The analytic layer tracks and visualizes all relevant key performance indicators listed above. Using advanced modelling, the application predicts facility demand based on weather forecasts and historical energy usage. It then determines the best times and means to generate, use, store, or sell energy.

MICROGRIDS BENEFITS ARE 3-FOLD: FINANCIAL, SUSTAINABILITY AND SYSTEM RESILIENCE.

As mentioned above the top control level of advanced energy analytics helps minimize the cost and in combination with edge control level enhances resilience and maximize use of renewables or sustainability.

Enhancing Resilience: The microgrid system requires exceptional speed and performance. Fast switching response helps ensure the stability of the facility's power by balancing load demand with available generation from DER assets.

In the event of a main grid interruption – possibly due to storm damage or a grid overload issue – the microgrid will automatically island from the grid to protect the quality of power in the facility and continuously serve all critical loads. If not active already, generation assets need to have the ability to start up immediately and independently from the grid, operating without a grid signal. And, of course, the system should be designed such that there must be enough generation capacity to support all critical loads.

The most advanced microgrid solutions also provide proactive protection capabilities. In response to weather data and alerts, a microgrid system can 'look ahead' to approaching conditions and prepare to island from the grid prior to the arrival of a major storm, giving enough time for facility personnel to take precautionary measures. Disconnection from the grid does not, necessarily, need to be in response to a complete utility grid outage. If there is instability on the main grid, islanding can help protect sensitive equipment against harmful effects of poor power quality. e.g., a local lightning storm can cause massive voltage transients that can be passed through as disturbances through the facility's power distribution network.

Cost saving and sustainability opportunities: Beyond helping a facility improve resilience against the possibility of a grid blackout or power instability, a microgrid can help optimize energy costs and maximize the use of renewable energy. With sophisticated tools and methods, the energy flexibility and functional value of DERs can be fully monetized. The analytic layer works together with the microgrid control layer, using predefined algorithms and control schemes to optimize the use of renewable energy while achieving the most economical energy spend as mentioned below:

- **Avoid demand penalties**: If the facility energy billing from the local power utility includes penalties for incurring excessive demand peaks, the microgrid system can be used to dynamically manage demand. If the system forecasts that the total facility demand is trending upward and may exceed the penalty threshold the microgrid controller can reduce energy consumption from the grid in one of two ways:
    1. Consume more energy from onsite resources. This can include renewable resources, stored energy, or CHP.
    2. Temporarily turn off non-critical load(s), e.g., controlling EV charging stations or hot water boilers for laundry.

  In Ontario Consumers who pay market prices or have signed a retail contract for electricity will see a line for Global Adjustment (GA)[7] on their electricity bill. A microgrid can also be leveraged to reduce global adjustment charges by integrating external predictions of top 5 peaks and curtail the power draw from utility during those times.
- **Tariff management:** If the facility is in a region with an open energy market experiencing significant price fluctuations, or is subject to some form of variable tariff structures (e.g., time-of-use), the microgrid system can respond to pricing signals to optimize the facility's energy consumption profile in number of ways:
    1. Determine when it makes economic sense to consume each energy resource (or combination), comparing grid pricing versus CHP, renewable, etc.
    2. Shift some load to 'off-peak' periods. This could include programming the BMS to pre-cool some areas of the facility depending on forecasted solar heating, without affecting comfort.
    3. Store energy during periods of low grid energy pricing. Consume the stored energy during periods of high grid pricing. Energy to store can come from the grid when prices are low, or from onsite renewable sources.
- **Participate in Demand Response Programs:** If the facility is in a region where the grid operator is offering 'smart grid' programs such as demand response, participation can result in significant economic benefits.

  The microgrid and its flexible DERs can be used to participate in Demand Response programs by providing a choice of using local generation or load management to comply with a curtailment request. This is where energy storage offers a great advantage. Stored energy can be consumed to respond to load curtailment requests to effectively consume less energy from the grid. In some cases, the grid operator may ask for increased consumption. In those cases, batteries can be charged from the grid.
- **Optimize self-consumption of renewables**: Optimizing sustainability will include reducing energy-related GHG by self-consuming low-carbon, low-cost energy when it's available. The microgrid system controls energy storage and onsite solar or wind generation to maximize consumption from renewable sources.

HOW CAN YOU ENSURE A MICROGRID PROJECT IS DESIGNED WITH THE BEST OUTCOMES?

Microgrid implementation and project challenges vary according to technical requirements as well as economic and business drivers, but on a broader level they can be developed using a common approach. A microgrid project implementation lifecycle has these following key milestones:

Preliminary Sizing: In real life, microgrid opportunities and projects will always differ in their business model or commercial context, in their actual environment, and in their technical content and scope of work. This step generally requires a microgrid sizing software tool that enables the following:

- Selecting cost criteria: CAPEX, OPEX, net present cost, return on investment, LCOE, CO_2 emissions, renewable penetration rate or a combination of these.
- Defining the technical perimeter to cover (assess the list of available components and level of details in the entity's existing computer models)
- Build model using existing database and typical physical /commercial parameters.
- Modelling different control strategies and evaluating their benefits

Design engineering: Once one or several economically viable scenarios have been determined in the preliminary sizing phase, some project-specific engineering studies and design steps are required. These will both specify equipment details and guarantee the correct behaviour of the microgrid while in operation.

- Identify and describe the operating philosophy with all the operating modes of the microgrid.
- Perform load flow calculations in all possible operating configurations, to mitigate risks, identify incompatible configurations and finalize system settings.
- Perform Short-circuit current calculations in different microgrid operating configurations, to correctly size the power systems equipment and protection settings.
- Perform protection and coordination study to ensure personnel safety and equipment protection, as well as to coordinate the protection tripping sequences and curves.
- Perform dynamic stability studies to evaluate, predict and monitor the dynamic behaviour of the microgrid's power system with regards to transient events like loss of power, motor starting, load shedding etc.
- Develop one lines and specify equipments based on the above studies.
- Adapt the agreed operating philosophy, into a detailed sequence of operation or control narrative to be configured into the microgrid control system.
- Perform detailed engineering to validate the energy model developed in preliminary design. Most energy control solutions include multiple tuning parameters, and simulation can be used to identify the optimal setting based on potential uncertainties and specific events.
- Develop a robust testing, validation and commissioning specification to ensure that in any actual situation the controller provides the expected behaviour and decision.

Transitioning from design to operation: Upon completion of design and commissioning of a microgrid, the success is heavily dependent on how the system is operated. So, it's very important to have proper operator training, to learn about the behaviour of the microgrid in various conditions and following certain events of faults or grid configuration change. It also important to operate the facility initially as a normal state so that the energy management algorithm learns the steady state generation and load patterns as early as possible to make more accurate forecasting and reach steady state operation sooner.

CONCLUSION

We are witnessing a major energy transition and Canada's climate action and net zero plans are a signal to fight against climate change. Canada's emissions reduction intermediate targets of 2030 will put us on a path to achieve net-zero emissions by 2050. Major technical advances over the past decade have enabled the emergence of microgrids. Substantial progress in DERs like PV, energy storage along with operational IOT environment are providing new control and optimization capabilities, thereby paving way for resiliency, reliability, and sustainability in facilities and communities.

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