# Process Electrification and Application of Net-zero Power Hub Solution


Paper No. PCIC energy SA22_73

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***Abstract*** - Momentum is continuing to gather at pace regarding a relative unknown piece of this puzzle – the electrification of existing and future Oil & Gas platforms and its integration with clean power sources. Greenfield assets with adoption of electrification into the design, allowing for key features such as energy storage and/or renewable sources of power can abate emissions by 2-3Mt$CO_2$ per year.

With rapid advances in technology, the pace of adoption of digital analytics by industrial clients must accelerate and hybrid power management hub helps in efficient operation of the facility.

The aim of this paper is to present process electrification concepts for Oil & Gas applications and to detail net-zero journey with hybrid generation mix and its management through applications of predictive control of onsite energy production using microgrid advisory layer. Approach to define use cases are presented.

*Index Terms* — FPSO, Process electrification, Decarbonization, GHG emissions, Net-zero power management hub.

## I. DECARBONIZING INDUSTRIAL FACILITY

### *A. Introduction – Understanding emissions*

Emissions are grouped by type or scope and must be addressed according to their classification. There are three scopes of emissions per the Greenhouse Gas Protocol (GHG Protocol).

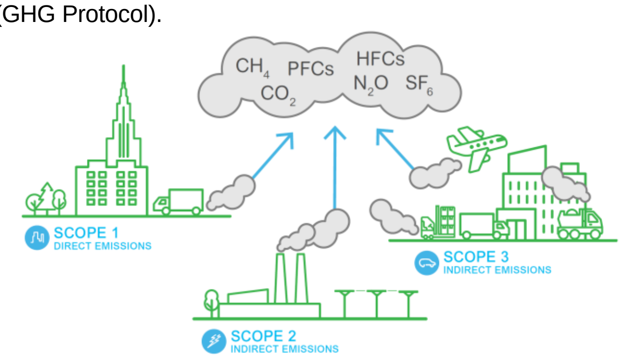



Fig. 1 Three scopes of emissions per the Greenhouse Gas Protocol (GHG Protocol)

Scope 1 emissions are those emissions an organization is directly responsible for generating. Common examples include gas or steam turbine driven large compressor or pumps and onsite sources of heat or power generation such as boilers.

Scope 2 emissions are those emissions resulting from grid-sourced generation of power. These emissions are considered outside the direct responsibility of the industrial facility (since it is the utility operator who determines the energy mix), but the company is still responsible for these emissions, as they are driven by demand.

Finally, Scope 3 emissions are all other indirect emissions. This broad category includes everything from the emissions generated through waste management to those generated in the value chain. For many cases, Scope 3 emissions not only make up the highest amount of their total emissions footprint but are also the most difficult to address.

### *B. Ways to decarbonize industrial facility*

Industrial activity is a major contributor to GHG emissions which includes oil, gas, and refining industries, The sector has several sub-segments covering entire value chain of Oil & Gas.

There is no one-size-fits-all solution to meet net-zero emissions target but rather countless opportunities for innovation. Table I identifies some of the potential opportunities for decarbonizing industrial facility.

**Table I** summarizes decarbonize approach for certain services, certainly process electrification is one of the available approaches to decarbonize industrial facility. There could be several situations where more than one approach can be adopted

TABLE I
WAYS TO DECARBONIZE INDUSTRIAL FACILITY

| Service Type | Renewables | Direct Electrification | Green Hydrogen |
|---|---|---|---|
| Heating | Solar water heaters | Heat Pumps | High-grade Heating |
| Industrial Process | Solar drying, Thermal energy storage and re-use to generate heat / steam for process requirement | Electrical application like replacement of GT/ST's with motors, Electric arc furnaces (eg. for glass industry) | Steel making process such as using at direction plant, Chemical industry |

Scope 1 & 2 emissions can be optimized through hybrid energy mix, furthermore, zero emissions at power generation can be achieved via substituting energy from fossil fuels with clean energy sources. Process electrification and net-zero power management hub help end user in managing energy mix, which in turn optimizes emissions and are detailed in later section(s).

### *C. Replacing the replaceable*

Low or zero-carbon replacement of fuels and technologies that generate Scope 1 and Scope 2 emissions is where the decarbonization journey begins. In some situations, these efforts can also result in budgetary savings and stability, and in some cases, resilience against disruption. Common actions in this stage include renewable electricity and cleantech procurement, electrification, and the exploration of alternative fuel sources.

Process electrification technologies are already available for large pump and compressor applications and full potential of GHG emission reductions can be achieved when electrical power is through a cleaner source. Shore powered platforms are also on the rise, where energy mix at shore is optimized with more renewables and is fed via sub-sea cables to platforms.

There is still a common misconception in the marketplace that the procurement of renewable energy today is costly and difficult. Today, we also have offshore floating wind solutions which can help in powering up FPSO/FLNG's.

### D. *Three-step approach*

Strategize

- ✓ Establish Scope 1 and 2 emissions
- ✓ Develop decarbonization roadmaps for Scope 1 and 2 emissions
- ✓ Identify opportunities for Energy Efficiency
- ✓ Explore for solutions in area of process electrification and green power integration (such as renewable energy)

Digitize

- ✓ Establish baseline through energy assessment and find potential ideas for energy conservation measures (ECMs)
- ✓ Identify missing points for energy assessment by adding new metering points if needed
- ✓ Track complete site's Scope 1 and 2 emissions at cloud level where energy tracking is closely monitored

Decarbonize

Directly reducing GHG emissions can be accomplished in a variety of ways without carbon offsetting, including but not limited to:

- ✓ Use renewable power for facilities
- ✓ Use renewable gas as feedstock (biomethane, green hydrogen)
- ✓ Reduce emissions from facility operations via improved equipment and facilities (i.e., electric drivers for pumps, compressors, electric boilers etc.)
- ✓ Use carbon capture, utilization, and storage (CCUS) technologies

Striking balance on commercial aspect (energy economics) is critical as energy prices can impact the viability of process electrification. For example, in an upstream LNG field, at high electricity prices it may be economical to replace grid connected power with gas direct drive or central gas turbine generation powered by project gas. However, it will not help to achieve reduction in carbon emissions. In this situation, if facility operations invest to integrate renewable energy, then overall cost dynamics can be further optimized through available digital analytics.

## II. COMPRESSOR ELECTRIFICATION

### A. *Review of Options: Replacement of Gas Turbine (GT) or Steam Turbine (ST) with Electric Motors*

Following options are possible from constructability point of view. In below scenarios, GT can be replaced with Motors:

Option-1: New motor on the existing skid in place of existing GT retaining the compressor on the existing location.

Option-2: New motor on the existing skid in place of existing GT retaining the compressor at new location.

Option-3: New motor and the new compressor at new location.

Option-3 has more advantages from Option-1&2. This is primarily due to associated costs related with adequacy checks, shut-down planning, and execution.

The present study explores the impact of process electrification in an FPSO with initial design comprising of major compressor(s) and pump(s) driven by GT's.

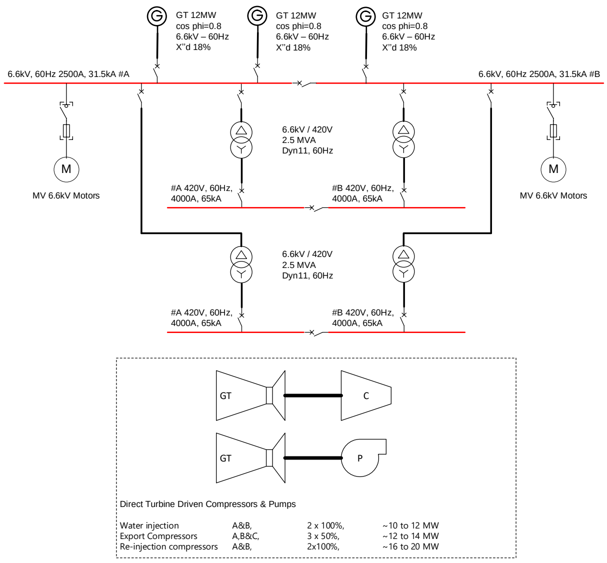



Fig. 2 Conventional design FPSO, Direct GT Driver for a Medium Size FPSO

Below presented approach was adopted for design development:

1. Load Flow Analysis
2. Design Modifications
3. Energy Management

1. Load Flow Analysis

   Load flow analysis was carried out to establish minimum power requirements needed to supply the FPSO for all operating scenarios; and variations in active and reactive power capabilities and power flows of onboard power generation were verified. The key finding of the analysis indicates that proposed system design is feasible.

   Fig. 3 summarizes possible combination of prime mover for large compressor(s) and pump(s).

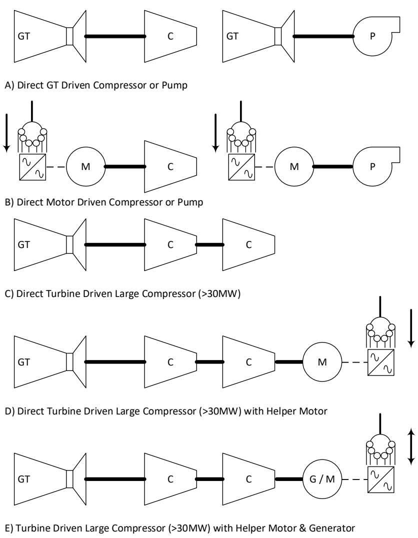



Fig. 3 Summary of possible combinations for electrifying medium to large compressors or pumps

2. Design Modifications
   Load flow analysis informed design modifications required at process and power generation systems. Following design changes were proposed for topsides power system and onboard power generation, comprised:

   - Upgrade generator sizes from 3x12MW to 4x35MW
   - Move from a 11kV main distribution to combination of 13.8kV + 6.6kV
   - Introduce fault current limiters at topsides 13.8kV MV switchboard
   - Addition of large drives for improving energy inefficiency suiting process needs

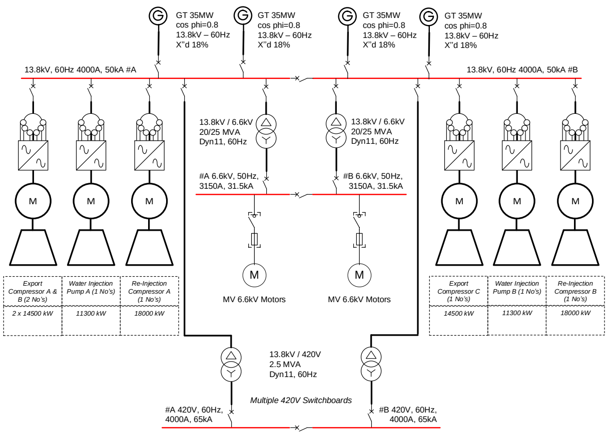



Fig. 4 All Electric design FPSO, MV VSD & Motors as Drivers for a Medium Size FPSO

3. Energy Management
   To optimize and reduce emissions further, energy mix can be diversified with integration of offshore sources (such as offshore wind) and on-board battery energy storage system (BESS).

   Ideally, an energy storage solution can fit to meet FPSO power demands during loss of one generator, thus system could reach 100% production availability, while waiting for stand-by power generators to come to live. However, the size, weight and cost of the energy storage solution remains as a challenge due to premium real estate at topsides.

**Table II** summarizes key findings with 100% electrification of typical medium size FPSO:

TABLE II
IMPACT ANALYSIS – All ELECTRIC FPSO

| **Description** | **Observation** |
|---|---|
| Direct Drive GT | 2x18MW + 5x14MW, loading ~85-90% |
| Power Plant with Direct Drive GTG | 3x12MW (N+1 operating mode), 20 MW electrical load |
| Motor Configuration for Full Electrification | 2x18.5MW + 2x11.3MW + 3x14.5MW |
| Power Plant with Full Electrification | 4x35MW (N+1 operating mode), 90 MW electrical load |
| Availability | ↑ by 8% |
| Overall Emissions | ↓ by 10% |
| Energy Efficiency | ↑ by 10% |
| Electricity Demand | ↑↑ by 3.5x |

## III. ENERGY AND $CO_{2e}$ SAVINGS CASE STUDY

The global net energy factor for Oil & Gas production continues to decline, as production moves into more complex reservoirs which means more energy is needed for flow assist & pressure support. Finally, as operation carbon footprint shift to geographically remote areas, there is a higher increase in the amount of energy used for pipeline transportation / liquefaction.

Therefore, reducing the energy expenditure is a strong contributor to reduce operation costs and environmental footprint. One successful route is process electrification, many Oil & Gas companies are tackling electrification from different angles, since process electrification increases consumption of electricity, emissions can be offset via integration of cleaner energy sources such as renewables.

In addition to energy efficiency factors and improvement solutions, process electrification can also introduce other operational improvements. These are part of the reason why process electrification generally leads to improved operational efficiency and therefore is economically attractive in itself. Some of these are:

- ✓ Improved asset availability - reduce number of unplanned stops and downtime. In several studies, asset availability improved as much as 98%.
- ✓ Improved stability – reduce the control time response to seconds. Electrical drive system that experiences a short duration power loss can usually be restarted and re-accelerated, thereby preventing a full system shutdown. Even in the case of a shutdown, the variable speed drive can supply the full torque needed to start up a fully loaded

compressor without depressurization. This is an important characteristic for most compressor applications as it both saves time and eliminates flaring of gas resulting from this blowdown.

- ✓ Reduced maintenance intensity – offer the opportunity to reduce facility staffing or remote operations/remote operations support.
- ✓ Reduced ignition points, noise, and vibration – improve working environment and safer operations.

For upstream, downstream and pipeline transportation, process electrification has evolved to become the preferred solution based on life cycle costs. Globally, there is now an extensive replacement of old direct drive GT (mainly due to high CAPEX cost) with motors (reduction of CO2e emissions, increase of efficiency and production).

Energy Efficiency is the main argument for process electrification. Large compressor(s) and pump(s) are conventionally powered by GT; and ideally, under normal operation, the actual performance of GT is in the range of 25-35% (the low end for older machines in high ambient temperatures and higher for new machines in colder parts).

Electrical Drive systems, transmission cables/overhead lines and generation systems (unless mains grid connection), are in the range of 95% efficiency and the same quantity of gas will typically give twice as much usable energy powered from a modern power plant as compared with a conventional (non-electrified) Oil & Gas facility. This is valid for a case where the gas is transported to a central power plant onshore, and the power is transmitted back to the facility to be used in a variable speed drive system.

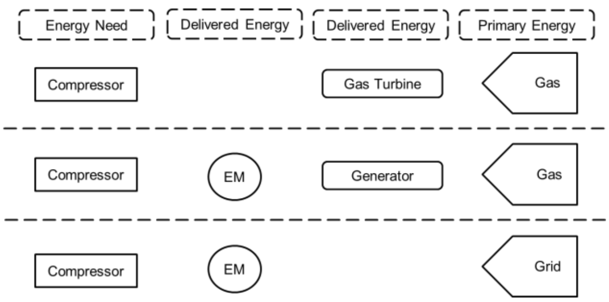



Fig. 5 Schematic illustration of the Power to Compressor scheme

Impact in GHG emissions were carried out, for the case as mentioned in above section (compressor electrification for an FPSO) where electrification was proposed to replace gas fired engines with electric motors and the use of VSDs to reduce emissions. With a compression power per NG production of 2750 HP per compressor and a total of 8 compressors installed, working 333 days per year on average, it is possible to have over 42% $CO_{2e}$ reduction.

The main reduction in GHG emissions can be seem in the $CH_4$ emissions avoided, which is 25 times more polluting than $CO_2$. For this case, we used an average emission factor for the gas fire engines emissions leak and the average carbon footprint from the USA electric system. One of the key findings is that with a greater participation of renewables in the grid higher is the $CO_{2e}$ emissions reduction without the use of electric drivers like VSD.

This supported the main aims of this paper to improve overall efficiency long term, reduce energy consumption and greenhouse gas emissions.

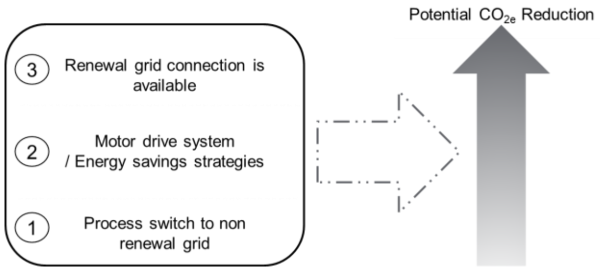



Fig. 6 Possible sourcing power to feed electrified process and its potential to reduce emissions

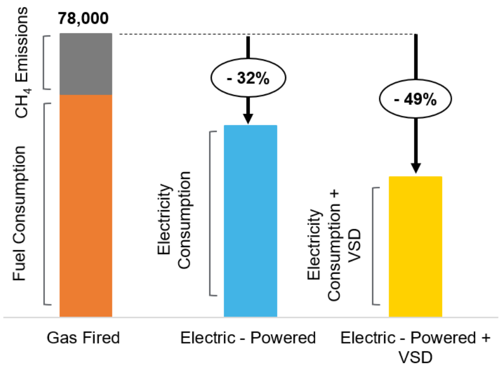



Fig. 7 Annual $CO_{2e}$ Emissions (metric tons $CO_{2e}$/year)

## IV. HYBRID POWER GENERATION MANAGEMENT – NET-ZERO POWER HUB

The electrical energy value chain consists of three major functions: generation, transmission, and distribution. Even though utility infrastructure is highly robust, outages can still occur, leading to system disruptions. For such reasons, critical process industries such as Oil & Gas are traditionally powered from onboard power generation and in some cases, utility power is made available as a back-up during onboard generation outages.

### *A. Energy Value Chain – Present*

The electrical energy value chain includes all activities necessary for the production, distribution and consumption of electrical energy. Fig. 8 indicates historical electrical energy value chain, where generations were managed centrally by utility with energy mix dominated by fossil fuels.

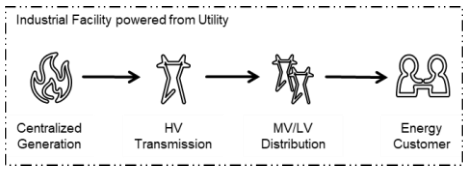



Fig. 8 Historical Electrical Energy Value Chain

However, offshore Oil & Gas has its complexity due to operations remotely located, thus, most of the facilities have onboard power generation which is predominantly by a GT based power plant. Fig. 8 is thus simplified and represented below in Fig. 9

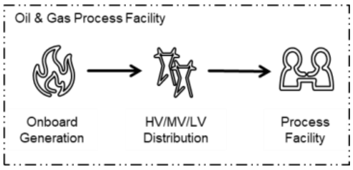



Fig. 9 Electrical Energy Value Chain for an Oil & Gas Process Facility

*B. Energy Value Chain – Future*

As industry is getting more energy intense, i.e., more and more electricity to feed their process, to reach the net-zero targets, end user(s) can eliminate or reduce $CO_2$ emission due to electricity consumption through integration of cleaner sources. This can be summarized into three cases:

Case-1: Centralized generation including clean power feeding an industrial facility and integration of distributed energy resources (DER) at energy consumer size

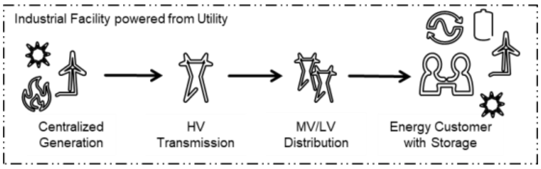



Fig. 10 Case–1 Diversified energy mix at utility and energy consumer level – typical industrial facility

Case-2: Tailored to visualize islanded Oil & Gas process facility with centralized generation including DERs to feed energy requirements for facility

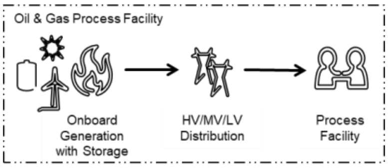



Fig. 11 Case–2 Oil & Gas process facility with diversified energy mix feeding process facility

Case-3: Tailored to visualize multiple set(s) of DERs interconnected to Oil & Gas process facility with hybrid power generation operation & control capabilities to manage energy mix along with centralized generation enabling end user to minimize GHG emissions (Scope 1 or 2).

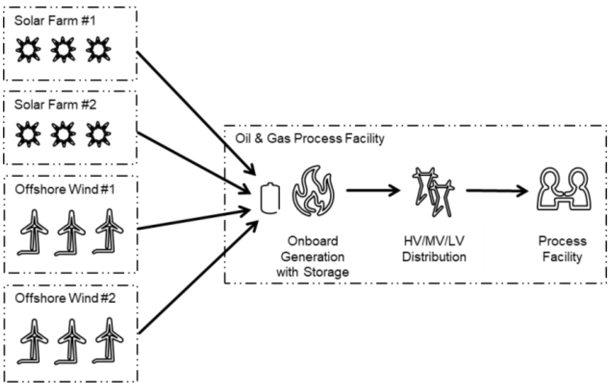



Fig. 12 Case–3 Oil & Gas process facility with diversified energy mix through offshore interconnections feeding process facility

Having centralized Hybrid Power Generation Management is the best approach to manage energy mix. It also enables end user to manage DERs, Utility import/export, grid connectivity, and traditional generation. Thus, empowering process facility operations to be fed by decarbonized energy and at the same time manage traditional generators as a backup solution.

*C. Digital Advisory Layers for managing Hybrid Power Generation*

Combination of process electrification and advisory layer can help to further optimize facility operations. Custom built objective functions can be developed based on load profile which optimizes energy costs, emissions, and revenues. These are driven by:

- ✓ Thermal energy supply costs

  Composed of dynamic time-of-use (TOU) costs and a monthly demand charge for the consumption peak. The latter is computed as the average consumption over a sliding 3-hour interval.
- ✓ Frequency reserve markets

  Computation of the reserve capacity to be committed to is not managed by the system; instead, the reserve is calculated and set as an input to the component which will then define battery control setpoints which aim to guarantee that the committed frequency reserve can be delivered.
- ✓ Diesel or LNG generator fuel costs
- ✓ Thermal energy sales revenues

  For hybrid process electrification, both thermal and/or electrical energy is consumed. System calculates the price for energy sold to the heating network dynamically.
- ✓ $CO_2$ taxes or credit benefit opportunity

  Effectively managing power sources by costing approach which includes additional $CO_2$ taxes.

Hybrid power management system is built on five main pillars as detailed below:

1. Power System
2. Power Plant Controller
3. Islanding Management System
4. Energy Management & Control System
5. Generator Management System

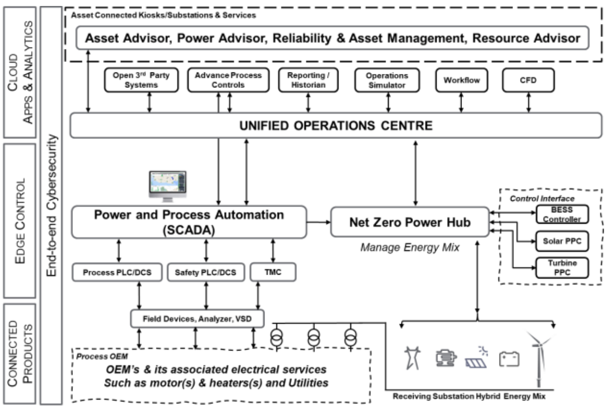



Fig. 13 Digital Architecture

1. Power System
   The Power System is key to be able to connect all the DERs; to feed the loads and to be connected to the grid. Electrical distribution is operated by Energy Management & Control System. When it comes to managing energy mix, Hybrid Power Generation would essentially operate at medium voltage level enabling operations to import/export energy at high voltage level and the communication backbone uses the IEC61850 protocol.
2. Power Plant Controller
   The Power Plant Controller (PPC) takes charge to control the energy export in respect to the local grid code. It also measures the performance compliance and drive the DERs according to the order received from the Energy Management & Control System. PPC controls the quantity of MW & MVAR exported to the grid.
3. Islanding Management System
   Due to remote nature of Oil & Gas facility, in some circumstances, they may operate while disconnected from the Grid. In this case, a microgrid advisory layers will manage all the DERs.
4. Energy Management & Control System
   Energy Management & Control System is connected to the weather forecast, load forecast, utility for the price of energy (import and export). Its role is to optimize the production of decarbonized energy and to take the decision to import/export energy according to economical equation. This application controls the other applications.
5. Generator Management System
   Traditional generators become a backup. In an ideal scenario, they can be used to feed the loads. In such situation, GTG's must be properly managed to limit $CO_2$ and $NO_X$ emissions until normal hybrid power generation comes into action to feed the facility with decarbonized energy.

   To simplify, we classify electrical power system into three configurations, viz., type I, II, or III.

   - ✓ Type I — Always Grid-connected
   - ✓ Type II — Island-able Site
   - ✓ Type III — Always Off-grid Site

   On-grid / Off-Grid / Island-able systems with NET-ZERO POWER HUB solution can help Oil & Gas facility with below use cases:

   - ✓ Simulate what-if scenarios for planned and unplanned situation(s)
   - ✓ Demand response and P&Q Power Control
   - ✓ Manage energy mix via auto-sequencing source connection / disconnection / control, thus optimizing GHG emission(s)
   - ✓ Remote energy monitoring and forecasting
   - ✓ Self-consumption and Export Management
   - ✓ Tariff Management
   - ✓ Black Start

When the local energy production is higher than the site consumption (situations where installed solar PV within facility is higher than power consumption), surplus power can be utilized to charge the battery energy storage system (BESS). Later during the day, when the clean energy production is higher than the site consumption, then the BESS will be discharged. Similar approach can be extended with Solar PV + Wind as well.

Net-zero Power Hub Solution aka Hybrid generation management systems work by collecting weather forecast information, can calculate the probability to have a storm coming in the next 3 hours. If the probability for a storm is high, then the facility operations manager can activate the off-grid preparation mode. It will then switch the optimization priority from economic to reliability. With this approach, automation layers will ensure to store and accumulate as much energy as possible

Currently, for process heating application, hybrid heaters are being developed that uses a mix of gas and electricity energy. With the help of advisory layer, we can schedule primary energy source (gas or renewable electricity) with equations working toward reduction of overall cost of energy and peak management as indicated in Fig. 14.


Fig. 14 Process heating scheduling and peak management

## V. KEY DRIVERS – UNCERTAINTIES – CHALLENGES

Field electrification is an effective way for to reduce Scope 1 emissions. As gas and / or diesel turbines used for powering large pump(s), compressor(s) and power generation, they contribute a significant percentage of emissions to Oil & Gas value chain.

By integrating renewable energy into Oil & Gas value chain, end users can reduce emissions, avoid carbon taxes and increase operational efficiency.

Even though process electrification remains as an attractive option to decarbonize Oil & Gas value chain, strong policies are required to drive this change. Key challenges and uncertainties persist and are summarized below:

Key Drivers

- ✓ Incentives for electrification technology development and its application from local government(s)
- ✓ Techno-economic analysis for different electrification technologies (as per process) with new laws on sustainability, carbon taxation

Uncertainties

- ✓ Availability of clean energy sources
- ✓ Energy cost & GHG emission potential of each possible energy mix (dilemma to use LNG due to lower cost)
- ✓ Electricity unit prices and utility readiness to meet power demands

Challenges

- ✓ Estimate and predict required demand response due to increased electrification in the Oil & Gas facility. If power is imported from utilities, then immense planning is required to establish utility infrastructure.
- ✓ Financial implications to utilities to meet power demands
- ✓ Utilities should adopt electricity rate designs that encourage process electrification
- ✓ Technology maturity of process electrification
- ✓ Skilled resources to operate after process electrification

One of the most critical needs for end user while managing Oil & Gas operation is to receive recommendations in managing energy mix.

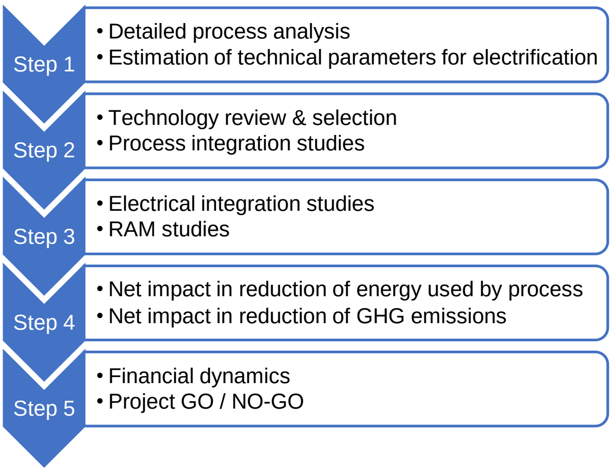
Compressor electrification use case presented indicates that energy use and emissions generated can be substantially reduced by process electrification. Our estimate is that non-electrified processes on average uses 45% more energy than an optimal powered solution.

## VI. CONCLUSIONS

Today, companies see sustainability commitments as essential to paving a resilient future; but achieving a science-based target can be easier said than done.

The three-step approach presented (in above section I.D. ), suggests the end user to begin with a clear strategy, track GHG emissions using digital apps & analytics, which enables Oil & Gas production facility to decarbonize their operation.

Strategic study of process electrification can be outlined in five major steps as mentioned below:




For majority of the cases, primary benefits of process electrification are higher production regularity, reduced fuel consumption, reduced emissions tax, reduced cost of maintenance and direct $CO_{2e}$ reduction. All these advantages can directly contribute to improved profitability and additional benefits in low manning, remote and safer operations.


## VII. ACKNOWLEDGEMENTS

The authors would like to acknowledge Guillaume BRUANDET for his valuable contribution on Net-Zero Power Hub. Guillaume leads technical solution architect community in area of energy automation at Schneider Electric.

Special thanks for Mr. Kevin HUNG for his valuable inputs on sustainability solutions. Kevin has 17+ years of experience in Energy Management solutions and is part of Power Systems Competency Center leading technical community in area of new energy landscape at Schneider Electric.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