Energy Management

FALL EDITION

PLANT ENGINEERING eBOOK | WAGO | YOKOGAWA Co-innovating tomorrow™

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How energy harvesting can boost predictive maintenance for sustainable industrial growth

Energy harvesting is revolutionizing industrial operations by transforming ambient energy, such as heat, into electrical power

The push for sustainability is reshaping global industries, compelling them to embrace innovative technologies that optimize operations and minimize environmental impacts. Among these technologies, energy harvesting stands out prominently. This method converts ambient energy, such as heat, into usable electrical power and is proving particularly critical in applications like wireless sensors for remote monitoring and predictive maintenance.

By revolutionizing how industries manage power consumption, energy harvesting is playing a key role in enhancing both operational efficiency and environmental sustainability.

The role of energy harvesting in industrial applications

Energy harvesting technologies, especially those converting thermal energy into electrical power, offer robust solutions for powering devices in locations where traditional power sources are impractical. Industrial sensors, which are crucial in monitoring operational parameters in remote or hazardous environments, traditionally depend on batteries.

However, batteries are costly, require frequent replacement and pose significant environmental burdens from manufacturing, transportation and disposal processes.

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Thermoelectric generators (TEGs), operating on the Seebeck effect — the direct conversion of temperature differences into electricity — exemplify effective energy harvesting devices. These devices are ideal for industrial settings where heat is routinely produced as a byproduct. For instance, sensors mounted on factory machinery can use the machine's heat output to generate power through TEGs, ensuring continuous operation without the need for external power sources.

Enhancing predictive maintenance and remote monitoring

Energy harvesting significantly boosts the effectiveness of predictive maintenance and remote monitoring across various industries by providing a dependable and continuous power source for sensors. This continuous power supply is crucial as it allows sensors to consistently monitor and transmit data regarding the health of equipment, which is essential for timely maintenance and preventing potential failures.

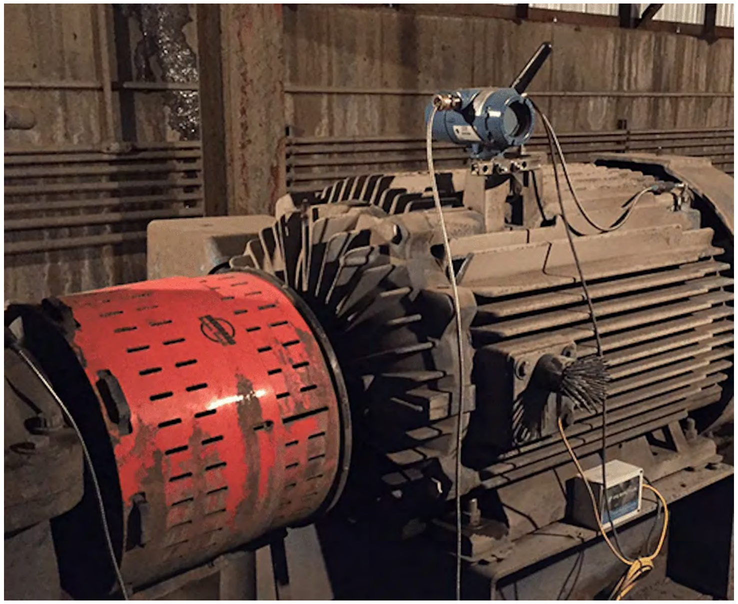

Figure 1: This close-up shows an energy harvester attached to industrial piping, harnessing thermal energy to power a local sensor, crucial for predictive maintenance. Courtesy: Grace Technologies

The integration of energy harvesting technologies enables deeper and more complex sensor networks. With sensors that do not rely on traditional power sources, industries can place them in more remote or less accessible areas of machinery or infrastructure. This broader deployment

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Figure 2: Energy harvesting device mounted on industrial machinery to capture heat energy from operation, ensuring continuous power supply for sensor networks. Courtesy: Grace Technologies

allows for the collection of more comprehensive data, which can be used to create a detailed picture of equipment health and operational conditions.

The data collected from these sensors can feed into sophisticated predictive analytics and machine learning algorithms. These technologies can analyze patterns and predict potential failures with greater accuracy than ever before.

For instance, sensors on a turbine could detect subtle changes in vibration patterns that precede a mechanical failure, allowing maintenance teams to address the issue before the turbine experiences a catastrophic breakdown.

Sustainability benefits of energy harvesting

Adopting energy harvesting technologies can substantially reduce environmental waste associated with conventional battery use. These technologies minimize the hazardous waste and carbon emissions produced during the battery lifecycle by eliminating the need for batteries altogether. Additionally, using ambient energy as a power source significantly lowers a facility's overall energy consumption, supporting global sustainability goals aimed at reducing carbon emissions and environmental degradation.

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Energy harvesting's potential to lessen environmental impacts is well recognized. Renewable energy sources like solar and wind, which are often used in energy harvesting, are generally considered more environmentally friendly than traditional fossil-fuel-based resources. They typically result in lower air and water pollution and do not produce harmful carbon dioxide emissions that contribute to climate change.

Despite these benefits, it's essential to consider that all energy sources, including renewables, have some impact on the environment. These impacts can vary greatly depending on the technology and scale of the implementation but are generally less detrimental than those associated with nonrenewable energy sources.

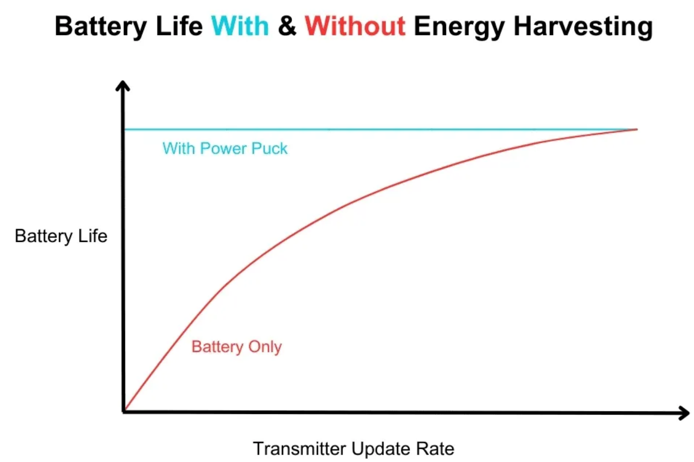

Figure 3: Graph illustrating the extended battery life of sensors equipped with energy harvesting devices compared to those powered by batteries alone, demonstrating significant efficiency gains. Courtesy: Grace Technologies

Practical applications of energy harvesting

Energy harvesting technologies are making significant strides across various sectors. In the oil and gas sector, energy harvesting technologies are increasingly used to enhance operational efficiency and safety. These industries, characterized by remote and harsh environments, benefit significantly from deploying TEGs. These devices are particularly valuable in capturing waste heat from high-temperature processes

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such as flaring, refining or gas compression to generate electricity. This not only recycles energy that would otherwise be lost but also powers sensors and monitoring equipment crucial for maintaining system integrity and detecting early signs of equipment failure.

In the manufacturing sector, TEGs are employed to capture waste heat from industrial processes, converting it into electrical energy. This technology is particularly useful in environments with significant temperature gradients, where it can enhance energy efficiency by using the heat produced by machinery or industrial processes.

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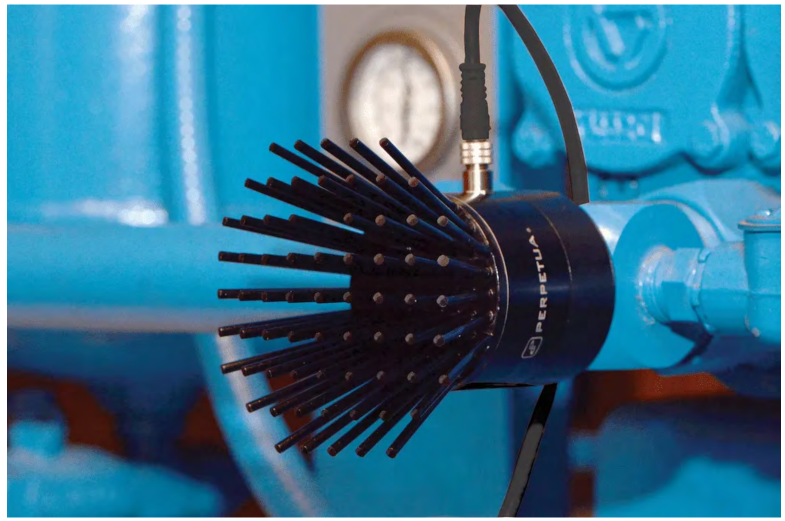
The future of energy harvesting

The future of energy harvesting appears bright as digital transformation continues to influence various industries. Advances in materials science and improvements in thermoelectric efficiency are expected to expand the practical applications of these technologies, making them more effective across a variety of operational conditions. Additionally, the potential for integration with other renewable energy sources, such as solar or kinetic energy, suggests the development of hybrid systems that provide even greater reliability and flexibility.

Figure 4: This thermoelectric generator is used to convert waste heat from oil and gas operations into electrical power, optimizing energy use and reducing environmental impact. Courtesy: Grace Technologies



The integration of energy harvesting with the internet of things and artificial intelligence technologies promises to further revolutionize industrial maintenance and monitoring. Smart sensors that cannot only collect but also analyze data in real time will dramatically improve the ability of industries to predict and preempt equipment failures. This advanced integration represents a significant move toward fully automated, self-sustaining industrial systems that are efficient and environmentally responsible.

Long-term economic and environmental impact

The long-term benefits of integrating energy harvesting into industrial applications extend beyond immediate operational improvements. Economically, the reduced need

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for maintenance and the extended life span of equipment can significantly lower overall costs. Environmentally, decreasing reliance on nonrenewable power sources and reducing waste production contribute substantially to a smaller carbon footprint, aiding industries in meeting stringent environmental regulations and fulfilling public expectations for sustainable operations.

Energy harvesting is reshaping the landscape of industrial innovation, sustainability and operational efficiency. As industries strive to reduce their environmental footprints while enhancing data-driven decision-making, technologies that use ambient energy sources, such as heat, are becoming increasingly essential. With ongoing advancements, energy harvesting is set to revolutionize industrial power management, establishing a new standard for sustainable industrial practices.

Nick Schiltz

Nick Schiltz *is a copywriter for Grace Technologies located in Davenport, Iowa. The company specializes in electrical safety products and predictive maintenance solutions. During his five years at Grace, Schiltz has published more than 250 blog posts ranging in topics from electrical safety best practices to the future impact of the industrial Internet of Things (IIoT) in the industrial space.*

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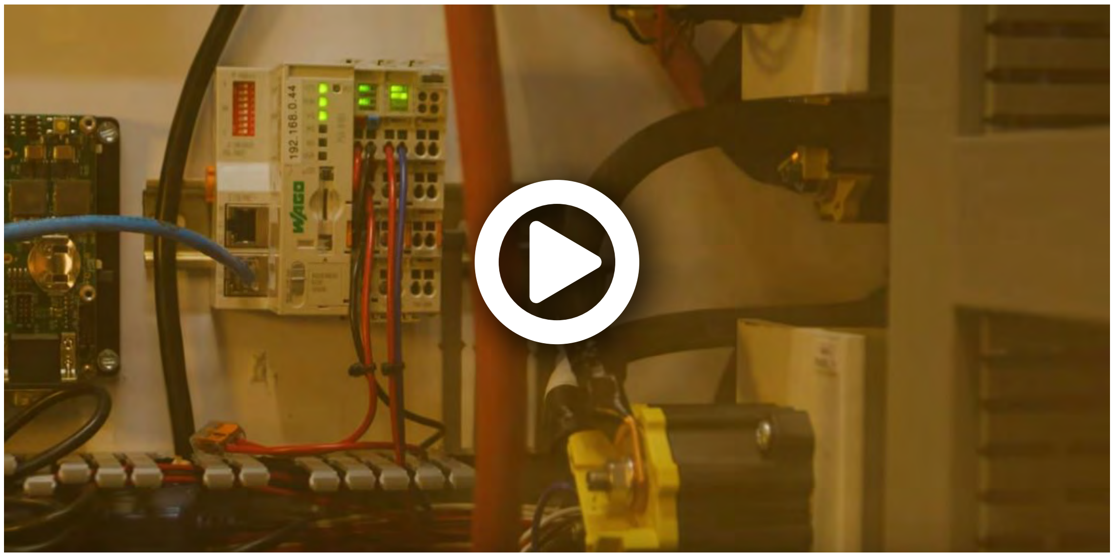

The Peak Energy Moment

Transitioning from carbonaceous fuels to #renewableenergy requires commitment. For example, at the Headwaters Center in Winter Park, USA, Ageto ensured that all of the energy consumed there could also be generated and stored on site. An important detail here: As the interface manager, WAGO Technik builds the bridge between Ageto's Modbus TCP/IP microgrid controller and the CAN-based battery storage system — a nice project by our American colleagues that deserves a thumbs up from us.

Thirteen ways to meet energy-efficiency goals in buildings

Based on engineering focus, here are several ways to achieve energy efficiency and sustainability goals

To meet sustainability and energy-efficiency goals in commercial buildings, mechanical, electrical, plumbing (MEP) and fire protection engineers play a pivotal role. The coming year presents another opportunity for professionals to elevate their practices, incorporating innovative technologies and methodologies to enhance energy and resource efficiency.

The convergence of these engineering disciplines can yield significant gains in optimizing building performance and reducing environmental impact. Manufacturers are meeting and exceeding efficiency goals, making it less difficult to provide the right system to building clients.

Mechanical engineers:

1. **Variable refrigerant flow (VRF) systems:** Consider implementing VRF systems, which offer precise control over heating and cooling, resulting in energy savings of up to 30% compared to traditional heating, ventilation and air conditioning (HVAC) systems.

2. **Energy recovery ventilation (ERV):** Integrate ERV systems to recover and reuse energy from exhaust air, improving indoor air quality while minimizing the energy required for conditioning fresh air.

3. **High-efficiency boilers and chillers:** Specify boilers and chillers with high-efficiency ratings, ensuring optimal performance and minimizing energy consumption in heating and cooling processes.

4. **Building automation systems (BAS):** Implement advanced BAS to enable real-time monitoring and control of HVAC systems, allowing for proactive adjustments based on occupancy, weather conditions and other variables.

Electrical engineers:

1. **LED lighting systems:** Transition to energy-efficient LED lighting systems, which consume significantly less power than traditional lighting technologies, while offering superior performance and longer lifespan.

2. **Power factor correction:** Integrate power factor correction devices to enhance electrical system efficiency by reducing reactive power, resulting in reduced energy losses and improved overall power quality.

3. **Smart grid integration:** Explore opportunities for smart grid integration to optimize electricity consumption, leveraging real-time data to adjust loads and minimize peak demand.

4. **Renewable energy integration:** Evaluate the feasibility of integrating renewable energy sources, such as solar panels or wind turbines, into the building's electrical system to offset conventional energy consumption.

Plumbing engineers:

1. **Water-efficient fixtures:** Specify water-efficient fixtures and appliances, such as low-flow toilets and sensor-activated faucets, to minimize water consumption and contribute to overall building sustainability.

2. **Greywater systems:** Explore the implementation of greywater systems, which recycle nonpotable water for applications like irrigation, reducing the demand on the municipal water supply.

3. **Rainwater harvesting:** Integrate rainwater harvesting systems to collect and store rainwater for nonpotable uses, reducing reliance on traditional water sources for landscaping and other nondrinking purposes.

Fire protection engineers:

1. **Water mist systems:** Consider water mist fire suppression systems, which use significantly less water compared to traditional sprinkler systems while maintaining effective fire suppression capabilities.

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2. **Occupancy-based design:** Employ occupancy-based fire protection design strategies to optimize system efficiency, focusing resources on areas with higher occupancy and potential fire risk.

The collaborative efforts of MEP and fire protection engineers hold the key to achieving greater energy and resource efficiency in commercial buildings. By embracing cutting-edge technologies and adopting a holistic approach to building design, these professionals can contribute substantially to the global imperative of sustainable development. The new year presents an exciting opportunity for these engineers to spearhead transformative change in the way commercial buildings are designed, ensuring a more sustainable and resilient future.

Amara Rozgus

Amara Rozgus *is the Editor-in-Chief/Content Strategy Leader.*

The key to 50% energy savings in compressed air systems revealed

Learn three control types for compressors — load-on-load control, inlet modulation with unloading and variable speed drive control — and understand the energy savings achieved by improving part-load capacity control

This summary highlights the importance of various controls in optimizing compressed air systems. The discussion includes insights on coordinating compressors based on size, efficiency and reliability, and introduces the concept of a pressure flow controller for optimizing air storage and stabilizing pressure, resulting in increased production and reduced energy consumption. Watch the educational webcast "Energy efficiency: Focus on compressed air systems" and then read this transcript for additional details. This has been edited for length and clarity.

Compressed air controller experts:

- Tom Taranto, Principal Engineer and Owner, Data Power Services LLC, Baldwinsville, New York

- Eric Bessey, President, TTed Solutions, Beaverton, Oregon

Tom Taranto: Now, we're comparing here three different control types in Figure 4. The red dotted line is the load-on-load control. The top line is inlet modulation with unloading when it gets to 40% of full capacity. The bottom line is the best available part-load capacity control of a variable speed drive compressor. What we want to talk about here is: What is the difference between turning a compressor off or improving compressor efficiency?

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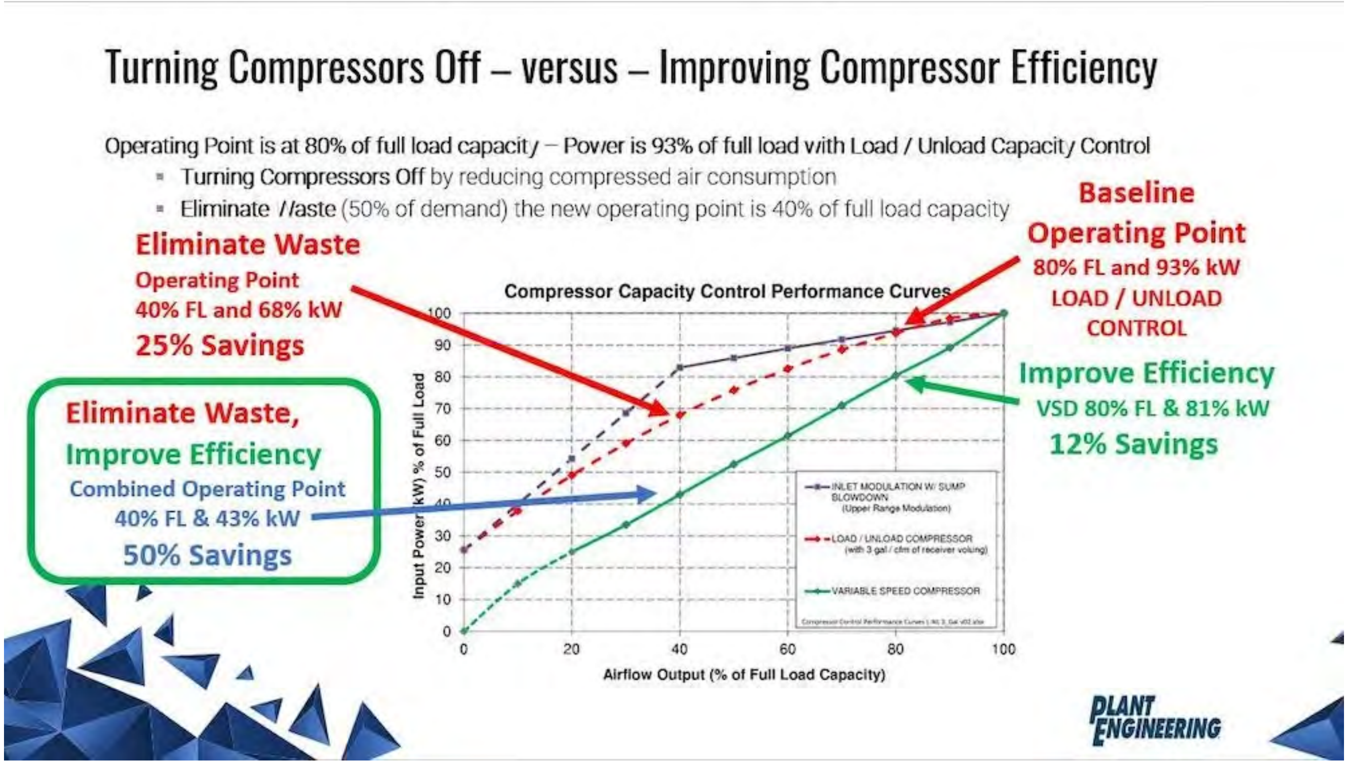

Well, if we look at an operating point of 80% of full-load capacity, we see that with both modulation and load-on-load control, we're still pulling about 92% of full-load power. Whereas if we go to variable speed drive control at 80% capacity, we're probably pulling 81% or 81.5% of full-load power. That's a 12% savings by simply improving the type of part-load capacity control that we're using.

Let's consider what happens if we fix leaks, eliminate artificial demand and we eliminate waste of air in the system. What does that do for us? Well, if we eliminate 20% of waste in the system, now remember, we talked about the pie chart and we think about half the year is wasted. If we simply go from 80% capacity on this compressor down to 40% capacity, look at what happens?

With the load-on-load control, we're down below 70% of full-load power and that is 25% savings. How do we get such a great savings? Well, when you compress air, 85% of the energy that the compressor uses goes to overcome the heat of compression. The single biggest energy gain you can make in a compressed air system is avoiding the compression of a cubic foot of air.

When we eliminate that waste, now we're at 25% savings versus 12% savings by improving the efficiency. I'm going to eliminate waste, avoid the compression of all the air I possibly can and I'm going to use a good, efficient part-load capacity control and I'm going to get 50% savings.

This is where you get to something that we talk about the synergistic effects of measures that you implement in a compressed air system. It is the sum of the two parts here is 37%, but because of the synergy between reducing the amount of air we're compressing and improving the capacity control, we've netted a 50% savings by combining the synergy of both of those measures together. That's what we're looking to do.

Eric Bessey: We probably don't want compressors to run all the time. There are low loads, weekends, holidays where we only need a little bit of air. The traditional method was to set the compressors up into what's called a cascade range.

You can see that on the far left of Figure 5, if I need very little air, I can get by with one compressor, but the pressure is going to be higher. Then as I take air out of the system, the pressure drops. We'll pick up No. 2 at about 95 psi, we'll pick up compressor three at 90 and then finally, No. 4 at 85 psi. Now we have what's called the minimum production requirement of 85, so I certainly can't drop below that.

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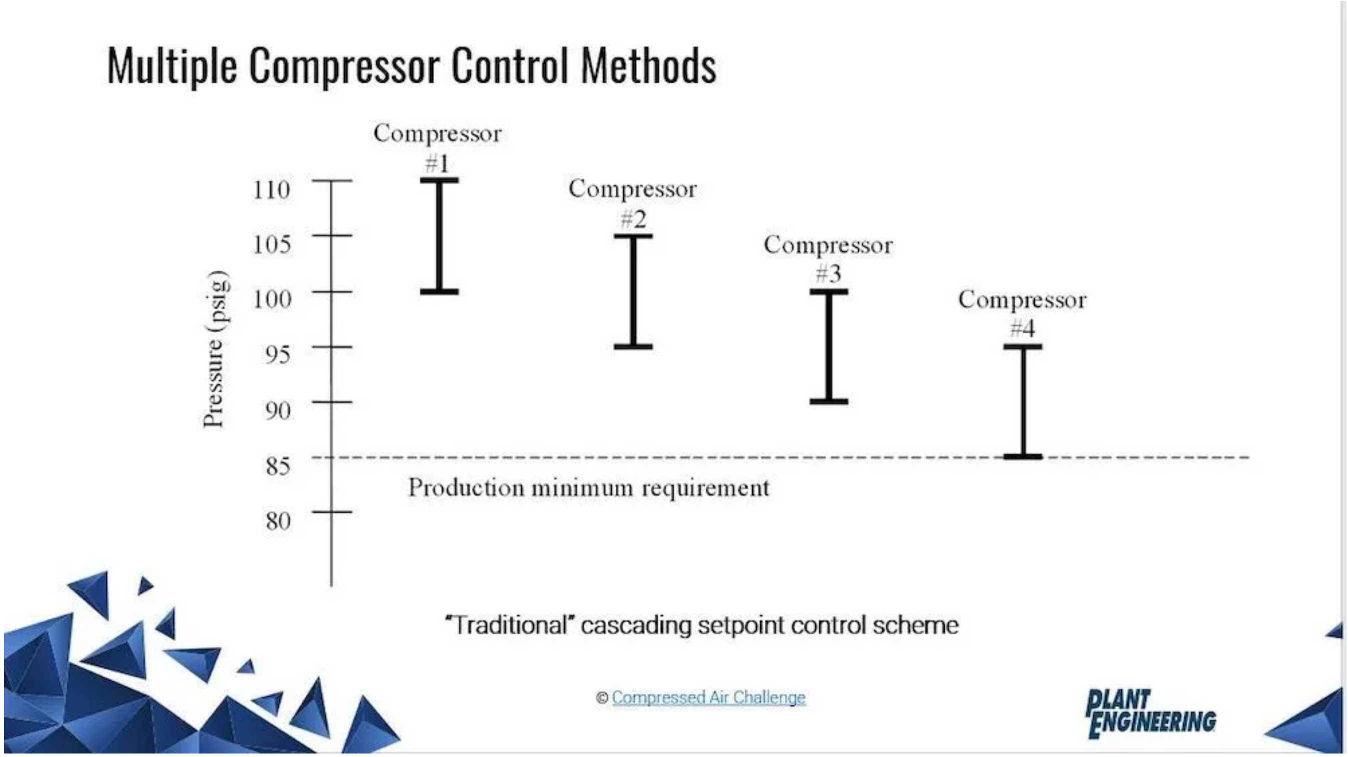

But you can see that this presents a couple of different problems about energy and waste and that is problems with traditional control. That is we can end up turning on more compressors that we need. Those compressors that are running, are going to operate in part load according to that performance curve. You might have two or three compressors that are operating very inefficiently.

Maybe they're operating at part load, they're throttling maybe or other various wasteful forms. One thing that should be considered, is multiple compressor control systems. We get into the concept of let's have a maestro orchestrate all our compresses together. Let's perhaps consider operating fully loaded, a lot of compressors and maybe we only provide a trim or part-load machine with one or two compressors.

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Compressors are most efficient operating at full load, if they must operate at all. Of course, if you can shut them off, that's good too.

Tom Taranto: You might not think of storage affecting being able to turn compressors off. But you got to remember that when we turn a compressor off, it's because the air demand has gone down to a point where that compressor's capacity is no longer needed. Rather than have the machine run unloaded or share the load with other compressors, we have devised a good, solid control strategy that says, "Hey, we could turn the compressor off."

You have to think about turning it back on. When that air demand jumps up, when you go from third shift to first shift and everybody starts running, you get that rapid increase in the air demand. It takes time for an air compressor to start up and to go through its permissions and open the valve and pressurize the internals of the compressor. Then it might be 10 seconds or 15 seconds later, before the first cubic foot of air passes the discharge check valve into the system.

What do you do during that time? Well, the system must utilize storage. The amount of storage, the equation for it is show below, is dependent upon two things. What's the volume of the receiver tank? How much is the storage pressure above the target pressure that I need to have for my system? Those two factors will determine for a given air demand, so many cubic feet per minute of air, how fast the air pressure decays.

You'll notice if you have a small tank, this tank is half the size of the other one, it means the pressure's going to go down twice as fast. This is where you need to design your storage to support the permissive startup time of the compressor.

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Eric Bessey: Storage allows for that preparation time. It's like a big bank of money and it can feed the system until you get the compressor running. How do we do this? How do we coordinate all these operations with system storage, various control types? We know that we have some compressors that are inefficient, some are very well-suited for part load. What we can do is begin to prioritize which compressors we want to operate in terms of their size, their ability, their efficiencies.

Reliability is a big consideration. Some compressors might run only once a month because you know they're going to break.

Many plants have programmable logic controller (PLCs) of various brands, or it can be a dedicated computer board. In a case that would be considered a little more of a black box, so to speak, but not to give them a bad name. What we'd like to do really is baseload. Baseloads of centrifugal compressors when you must, they throttle fairly efficiency in their upper range.

But once they get down to that blow-off mode, it's just a waste. If I have multiple centrifugal compressors and one of them is blowing off and the other ones are not, there are some strategies to minimize the blow off. One of them is called load sharing.

Control inputs can be matched to production schedules, operating machinery. We simply configured the controller to turn the compressor on in advance. These were large centrifugal compressors with lots of storage, but we got them up and running and we were ready to go.

Assume you have four compressors of varying types, of variable speed, fixed speed,

another fixed speed and a rotary. With master control systems, you can implement and integrate all kinds of sensors, dewpoint sensors, pressure flow. Then in the modern age of industrial internet of things, we can grab that stuff and we can save it to the cloud. Then from the cloud, it can be available for other locations or at a corporate level.

Tom Taranto: The pressure flow controller is a device that serves to separate the supply side and the demand side. Now, we talked about artificial demand and it's the increased compressed air consumption caused by operating the system at higher pressure than necessary. But by the same token, if you remember when we talked about the air receiver, we said there's two factors.

Bigger receiver holds more air and a receiver at higher pressure holds more air. If we want to optimize the use of the receiver, we'd like to have the receiver at a sufficiently high pressure to create the amount of storage that we need. At the same time, if we don't do anything to separate the demand side, we start shoving that higher pressure out to the demand side and everything out there starts consuming more air.

What does the pressure flow controller do? Well, the pressure flow controller allows you to build high pressure in storage, to get the maximum amount of air in the size of the receiver tank you have. While it controls that pressure down to the optimum target for the demand side, the lowest optimum pressure that production demands require. At the same time, it stabilizes that pressure.

It takes all the swings here of the compressors starting and stopping and the pressure goes up and it unloads and goes down. All those pressure variations that are occurring on the supply side don't propagate to the demand side when you install a pressure

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flow controller. Many production requirements do better with stable, consistent pressure and at the same time we eliminate artificial demand.

There are two cost benefits of a pressure flow controller.

- One is you might have an increase in production because you don't have as much interruption due to unstable pressure.

- At the same time, by eliminating artificial demand, you're compressing less air while still supporting the same amount of production and you get the two economic benefits.

Pressure flow controllers may be a relatively new term and a new device for some, as artificial demand might be a new term. But you apply these things together, it can have a very good impact on plant productivity, reliability, the air system and at the same time reducing energy now.

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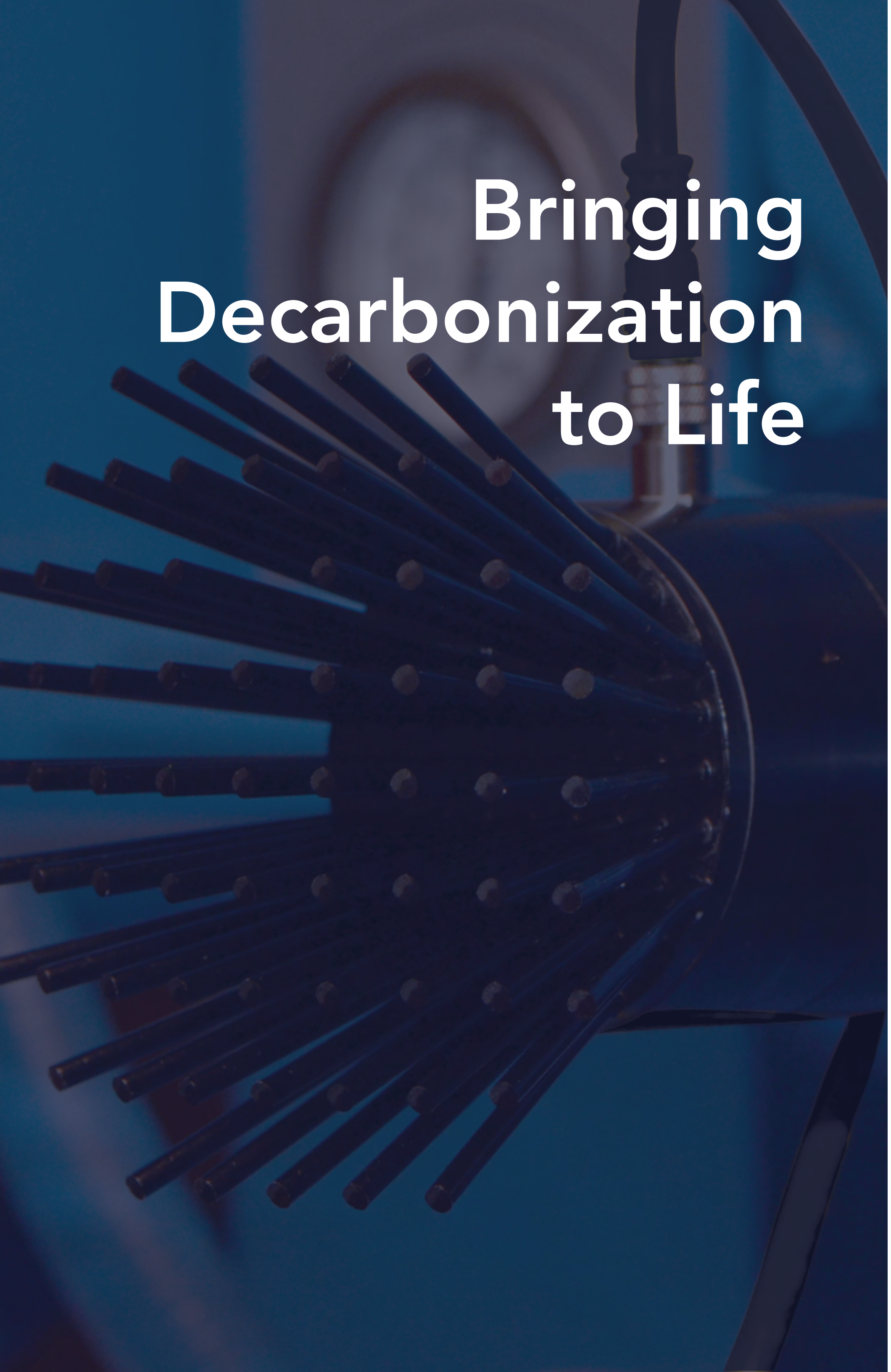
OpreX Asset Health Insights

OpreX Asset Health Insights is a cloud-based asset monitoring service that collects, refines, and aggregates Operational Technology (OT) data from distributed assets. The service connects any asset with sensors from anywhere helping organizations manage large, asset-intensive operations to increase efficiency and reduce downtime.

Bringing Decarbonization to Life



Pablo Jimenez-Asenjo, Federico Neira and Nicolas Visuara, KBC, alongside Rafael Rebouças de Araujo, Joana Variani and Juan Carlos Moreno, Acelen, explore how real-time emissions monitoring drives decarbonization.

The Brazilian refining industry is a significant contributor to the world economy. Not only is it a crucial player in meeting energy, raw material, and chemical needs, but it also has a promising future. According to the US International Trade Association, Brazil will be responsible for producing around 50% of the world's offshore oil in 2040, about 5.2 million bpd.[i] As a prominent energy producer, Brazil's government has worked to increase domestic oil production. In addition, discoveries of pre-salt oil deposits have propelled Brazil into the top 10 of global liquid fuels producers, as reported by the US Energy Information Administration (EIA).[ii]

However, the process of refining raw petroleum into marketable fuels and chemicals is energy intensive, resulting in carbon dioxide (CO_2) emissions. Statista reports that Brazil's refining industry generated about 0.49 gigatonnes (Gt) of CO_2 in 2021.[iii] The Carbon Emission Accounts and Datasets-Global Refinery Emission Inventory (CEADs-GREI) estimates that oil refineries worldwide could generate up to 16.5 Gt from 2020 to 2030.[iv]

Refineries are an indispensable link in the energy supply chain. They also have the power to contribute towards decarbonization. To achieve this, refineries can implement various mitigation strategies. They can upgrade heavy oil-processing technologies, improve refinery efficiency, use alternative power sources, and integrate energy initiatives with other local manufacturing plants to create an industrial cluster strategy. These solutions have the potential to reduce global cumulative refinery and petrochemical emissions by 10% from 2020 to 2030, according to the CEADs-GREI research.5 To reach these goals, accurate reporting of greenhouse gas (GHG) emissions is paramount. This helps refineries identify areas where they can reduce their emissions and improve their environmental performance. Accurate reporting can also lead to higher credit ratings for disclosing refineries.

Therefore, implementing a GHG emissions management software solution is crucial. This advanced technology measures the composition and concentration of the main emissions from multiple sources throughout the plant and across all its assets – from key stacks, or even a select few. Besides calculating emissions, it also tracks energy production, energy consumption, and process efficiencies. By tracking their performance in real time, refineries can take prompt action.

Case study: Acelen, Brazil

The Acelen Mataripe refinery in Brazil is a key player in the country's energy sector and has made energy transition one of its top priorities. With a production capacity of 300 000 bpd of oil, Acelen is committed to decreasing GHG emissions from its operations. This effort is crucial considering Brazil's pledge to reduce GHGs by 50% in 2030 com-

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pared to 2005, per Enerdata.[v]

Therefore, refineries such as Acelen play a crucial role in global sustainability, but how can they ensure their operations do not harm the environment? The answer lies in embracing advanced technologies that continuously monitor GHG emissions and other pollutants. Carbon monoxide (CO), nitric oxide (NO), particulate matter (PM), sulfur dioxide (SO_2), and volatile organic compounds (VOC) are some of the contaminants that refiners need to monitor.

Using a model-based approach

Acelen is taking strides to improve its emissions data accuracy and reporting by implementing an energy and emissions management system that uses a model-based approach. Automating data collection leads to more reliable results while minimizing human error.

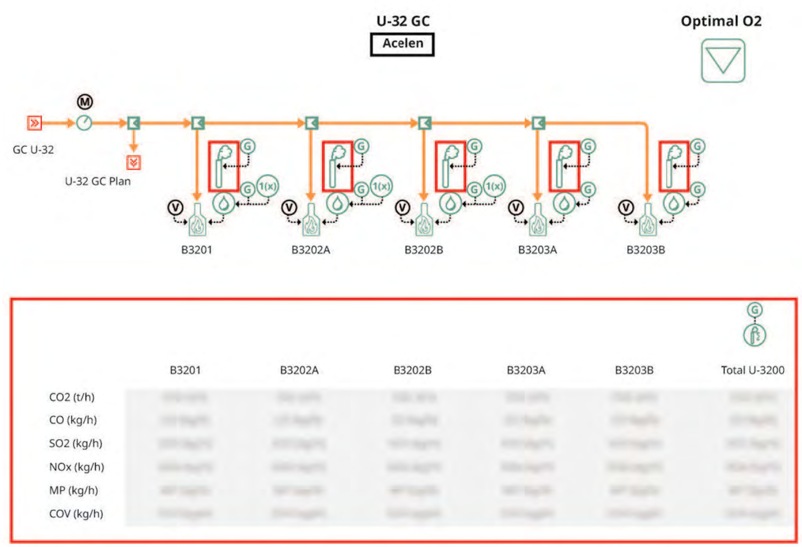

Figure 1. VM-GEM emissions management software represents emissions data in a single pane of glass.

The GHG emissions management software calculates GHGs and other emission pollutants, such as CO, NO, PM, and VOCs, as shown in Figure 1. Engineers can quickly scan this data from a single pane of glass to identify patterns and/or anomalies and make informed decisions.

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To ensure accuracy in emissions calculations, the emissions module uses production accounting technology. In addition, a GHG factor is commonly used. This factor considers the characteristics of the fuel, combustion conditions, and other relevant factors, such as combustor type, as shown in Table 1. By multiplying the emissions factor by the corresponding activity data, the emissions can be calculated.

Table 1. Emissions correlations

Emissions component	Correlation
CO	(1.3452/1000) x (volume flowrate)
NO_x	(0.00495/1000) x (volume flowrate)
NO_x	(0.004/1000) x (volume flowrate)
PM	(0.1217/1000) x (volume flowrate)
VOC	(0.0881/1000) x (volume flowrate)

It should be noted that measuring emissions depends on specific emission and regulatory requirements. The following is a general explanation of how emissions are calculated:

A mass balance approach is often used to determine emissions, such as CO_2 and SO_2. This involves gauging the plant's inputs and outputs to determine the corresponding emissions based on chemical reactions and stoichiometry.

Correlation models provided by governmental organizations, such as the US Environmental Protection Agency (EPA), are used to calculate emissions including CO, PM, and VOCs. These models establish a relationship between certain process parameters and the corresponding emissions.

Calculating fuel gas composition

At the core of every refinery lies the process of crude production. Refining crude oil

involves a complex system that involves the use of furnaces and considers each energy vector, including fuels and power, that produce Scope 1 and 2 emissions. For refiners, accurately calculating these emissions is essential, not only to comply with regulations and achieve environment, social and corporate governance (ESG) goals, but also to maintain their reputation as responsible corporate citizens and avoid costly fines. By doing so, refiners can enhance transparency and trust with stakeholders, while also identifying opportunities to reduce costs and improve efficiency within their value chain.

Furnaces module

Furnaces play a pivotal role in the refining process as they help transform crude oil into a range of products. However, burning fuels in these furnaces can trigger the release of GHGs and other emissions, demanding effective monitoring to control emissions.

The Acelen refinery employs GHG emissions management software to track all relevant emissions. These sources include all of the process furnaces, fired boilers, gas turbines, flares, and a detailed model of the fuel gas system. By incorporating the details of the fuel gas system, the model calculates the composition of the fuel gas in real time. This data, combined with measurements of fuel volume flow or mass flow for each source, provides the ability to calculate emissions for each specific emissions component. Further details are provided in Figure 2, which illustrates the furnace module.

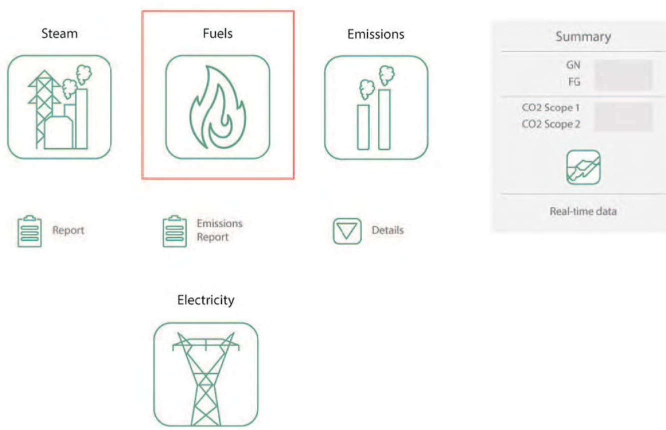

Figure 2. VM-GEM emissions management software dashboard depicts flow gas and Scope 1 and 2 emissions output from the furnaces module.


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Fuels module

The emissions management solution encompasses multiple fuel sources, whether they are internally produced or imported. It involves tracking and recording data related to various energy sources, which for Acelen includes natural gas, propane, hydrogen, and power. This comprehensive approach is facilitated by a single platform that allows for efficient monitoring and management of emissions.

Within the fuels module, as shown in Figure 3, there are interconnected blocks that link to the burners. This configuration enables the calculation of emissions for each emission source. By accurately measuring and assessing emissions at these specific points, refiners gain insights into the environmental impact associated with their fuel use and can take appropriate measures to reduce emissions as necessary.

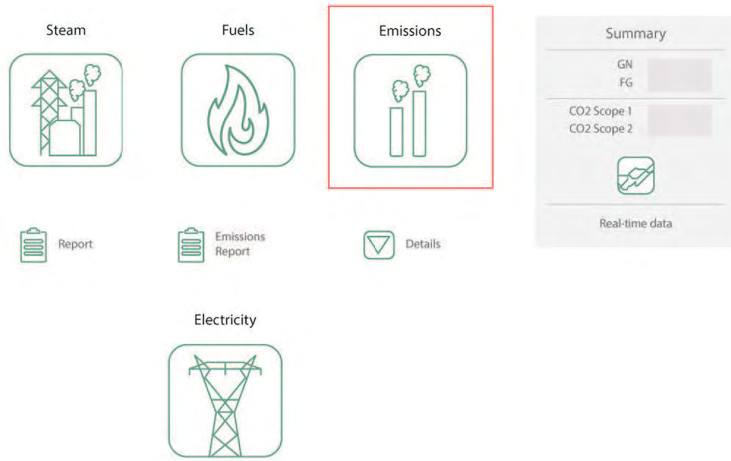

Figure 3. VM-GEM emissions management software dashboard depicts flow gas and Scope 1 and 2 emissions output from the fuels module.

Visualising KPIs

Acelen employs a system that encompasses multiple modules as depicted in Figures 2 and 3. These modules include the emissions and fuel model networks. Each allows for frequent monitoring of key variables related to energy, such as fuel usage and related emissions. Figure 4 shows that key performance indicators (KPIs) related to emissions are continuously monitored and flagged in real-time, and can be inspected using the software's drill-down feature.

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Reporting emissions

The standard protocols for producing quarterly or annual emissions reports can be tedious and time-consuming. As a result, most refineries opt to submit their emissions reports annually, some on a quarterly basis, and even fewer on a monthly basis. Generally, ESG corporate functions prepare these reports using averages, yet the information is not shared or derived from operations. This approach creates a disconnect between the two, making it difficult to take corrective action in case of deviations from targeted emissions.

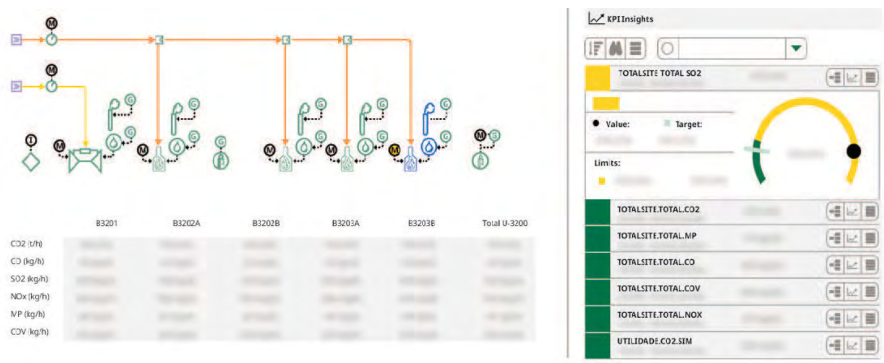

Figure 4. VM-GEM emissions management software continuously tracks and alarms emissions-related KPIs in real time.

To bridge this communications gap, Acelen is taking a different approach that uses an emissions reporting module to streamline its reporting process. By pulling data from various sources, including mass balance calculations, correlations models, and GHG factors, refiners can generate comprehensive, real-time reports. This unified reporting system provides a holistic view of the refiner's emissions profile, enabling engineers to identify areas for improvement, track progress, and take corrective actions swiftly to comply with regulatory bodies.

Furthermore, this software operates in an auditable environment, ensuring compliance with strict emissions standards. The availability of auditable reports is important in

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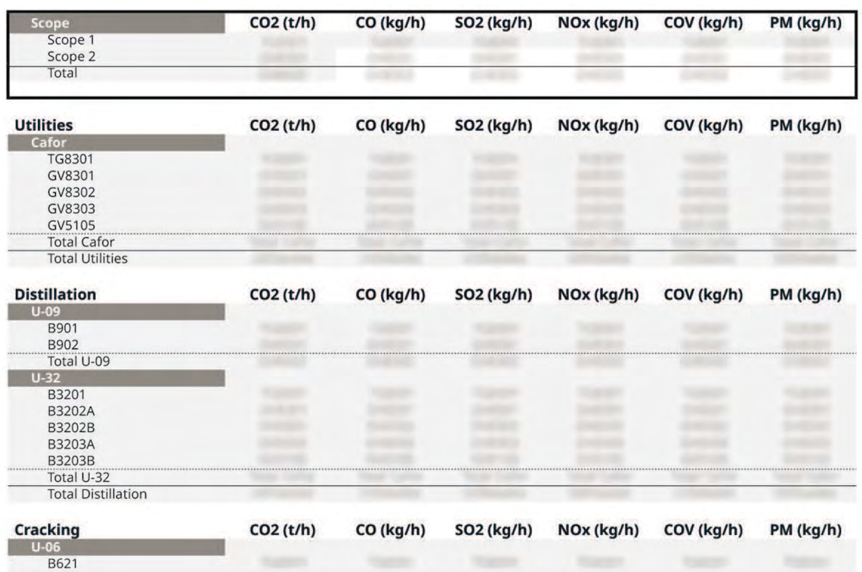
terms of transparency and accountability. With full life cycle tracking, the data's reliability and consistency ensure legal compliance.

Making decarbonization a reality

Currently, optimizing emissions is not typically included in real-time operational variables. However, with the escalating cost of carbon and the growing influence of carbon tax credits on daily trading activities, refiners will soon be more motivated to reduce their emissions on a daily basis. As a result, refiners will likely shift from annual, quarterly, and monthly targets to daily emission goals.

The ability to report emissions more frequently can be achieved through automatic, unattended energy real-time execution. This technology has a proven track record in the refining industry and is the foundation of online optimization.

Figure 5. VM-GEM emissions management software provides comprehensive energy and emissions reporting campus-wide.



Acelen intends to use GHG emissions management technology to monitor and automatically report Scope 1 and 2 emissions data from plant operations in real time using digital data sources. Based on the energy usage and emissions patterns shown in Figure 5, refiners

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can optimise their operations and reduce emissions by making data-driven decisions. By meeting emissions reduction targets, Acelen anticipates that all aspects of its ESG practices are in line with the UN Sustainable Development Goals.

As Brazil introduces its latest carbon pricing system, the GHG emissions management technology will prove to be a critical tool for Acelen in meeting the country's emissions reduction targets. This two-system initiative consists of an energy trading system (ETS) and offsetting system. Together, these systems aim to establish a carbon market and incentivise emissions reductions.

Acelen, like many refineries, uses ongoing performance monitoring and analysis to optimise operations, reduce emissions, and improve the accuracy of emissions reporting. For instance, Acelen reported reductions including a 6% decrease in electricity consumption, a 268 000 t reduction in CO_2 emissions, and a 41% reduction in sulfur emissions. These reductions were a result of Acelen's teams prioritising energy efficiency initiatives, ranging from the recovery of important systems and equipment, improving work processes, and optimising operations. Overall, the use of GHG emissions management technology has helped the refiner to measure the impact of these actions in emissions, highlight bad actors, and consequently meet their corporate responsibility goals while bringing decarbonization to life.

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Motors and drives: How to optimize industrial energy use, part 1: The importance of motors

In an October 30, 2023, webcast "Motors and drives: How to optimize industrial energy use," Michael Lyda from Advanced Energy specifies and analyzes how to optimize energy use for motors and drives and other factors to consider.

Over their operating lives, most ac induction motors exhibit common problems, from transients to voltage imbalances and single phasing.

Therefore, being familiar with general troubleshooting techniques is important. To start, it's vital to understand the operating parameters and forces acting against a motor; to perform tests and make observations based on those parameters; and to remove system components to isolate a problem.

Proper size and power source connection must be verified. Regular measurement procedures, starting with nominal voltage, current and frequency can be the starting point for long-running optimal motor and drive operation.

In an October 30, 2023, webcast, Michael Lyda from Advanced Energy analyzed how to optimize energy use for motors and drives and other factors to consider.

The transcript of this presentation has been provided with minor edits and adaptions for clarity.

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Michael Lyda: Why are electric motors important? We estimate here motor-driven systems account for approximately 50% of all the electricity generated in the world. Likely we have a lot of facilities folks on the call today, so motor-driven loads like compressors, pumps, fans, things like that, account for a lot of the energy usage and also the energy bills at the facility. So if you have an effective motor management system, a database, taking surveys of the motors regularly and then also being able to take advantage of energy-saving opportunities by adding variable frequency drives (VFDs) can certainly help you reduce that energy usage.

Or maybe if you don't reduce energy usage, you get more output for the same energy usage and that can save you a lot of money and get you basically more widgets out the door for the same energy is going to improve your efficiency in the plant.

The other thing that we want to look at today and think something that interests us here at Advanced Energy is what motors are available in the market and as a plant, or as plant personnel, being able to understand what motors may be available in the market and then also what regulations cover those products. That's going to be able to help you long-term with making your purchasing decisions and then pursuing motors that may run longer or be more reliable and then also run at a higher level of efficiency over their life.

Our content today is going to be mainly in two pieces. We have the electric motor regulations piece. We'll do a brief history of electric motor regulations, primarily focused on the United States. We do have a slide on the European Union. If you have questions after the presentation on the region that you're in, just give me a call or shoot me an email. We don't know all the regions, but certainly we could help navigate you to the

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right place if you are looking for the regulations that cover your specific country or region.

We'll go over some recent changes on the regulations. And then the meat of the material today is going to be around VFDs drives. So we'll cover basics, we'll look at applications, we'll do energy-savings potential, and we have a nice example that we'll review. And then also we'll talk about application issues when you add VFDs drives, as well.

Focusing on the United States for now, the governing body for appliance standards in the United States is the Department of Energy, so US DOE. US DOE passed rules back in the early to mid-1990s. Electric motors are an appliance. They consider motors an appliance.

I guess a good place to start is what is an electric motor? An electric motor is a device that converts electrical input power into mechanical output power. These were not regulated products, and when I say regulated, I mean regulated to efficiency levels. These are not regulated products. Back in the '60s, '70s, '80s, early to mid '90s, that's when regulation started going into effect and motors started having efficiency requirements. Motor manufacturers didn't really change. They were selling products into the United States. The thing that changed is they now had to do efficiency testing and meet the compliance rules passed by the Department of Energy through the Energy Policy Act.

The most basic rule for a motor manufacturer when they're needing to get in compliance in the United States, they may sell 10, 15 different basic models of motor. Maybe they sell 200 basic models of motor. We have clients who sell over 1,000 different basic models. A basic model is a motor, it's a horsepower rating, a speed, a voltage. So if

you had to test all of those basic models in order to be compliant, it could be thousands and thousands of motor tests. So what the Department of Energy allowed back then, and they still allow today, is pick five of those basic models and then test five samples of each of those models.

Then there are requirements about what the average efficiency of those five tests needs to be. And then the motor manufacturer will have a model which is, well, I'm using model a lot, but a model which is called an alternative efficiency determination method (AEDM).

It's a statistical model that represents the population of their electric motors. So the requirements about which five models that you pick to validate your AEDM, and then they will be across the size range and the highest volume sellers, different frame types, on frame transitions, things like that. Once the motor manufacturer has tested those five, then they can apply for compliance in the United States. So that's kind of the history of things.

Over the years, there have been new motors added to the regulations. Efficiency levels have crept up. At the beginning we were at IE1 level of efficiency. That's a European term. And then we went to IE2, or Energy Efficient was the US term. Now we're at IE3 level of efficiency, or in the United States it's called NEMA Premium. NEMA is a trade association that represents the electrical equipment manufacturers, in this case, electric motor manufacturers.

So on down through a couple of the changes that are listed on the slides, you had the small motor rule, started in 2010 and went into effect 2015. That added one quarter

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horsepower up to three horsepower small motors, two-digit frame size, only open drip proof motors, not fan cooled. Then you had an expanded expansion of scope. So more products were added back in 2014 into effect of 2016, including brake motors, vertical hollow shaft and a few others. And then we had the newest rule that came out back in 2022, new test procedure that went into effect April of 2023. This is the summary of the newest rule that you would need to be concerned about. Total Enclosed Air Over Motors, TEAO motors were added during that time to the regulations.

Induction motors previously were covered up to 500 HP. Now between 500 and 750 are included. Previously not covered were synchronous motors. Synchronous motors are motors that don't operate on the principle of induction, so they don't have a slip in order to get to their target torque. The thing is, synchronous motors, a few types, switch reluctance motors, permanent magnet motors, synchronous reluctance motors are a few types of synchronous motors, those motors haven't been regulated in the past. And one of the reasons why is those motors are required to have some type of controller in order to operate.

So now, the Department of Energy has taken a new turn and is adding synchronous motors and motors with a controller. The test standards that have been applicable for many, many years that just cover, like IAAA112, IAAA114, which focus on just induction motors aren't necessarily applicable to things like synchronous motors.

There's some new IEC test standards that apply for synchronous motors, IEC 61800-9-2 is one of the standards. And then also for the next category, inverter-driven motors, this is motors that require an inverter to operate, as well, IEC 60434-2-3 is the test standard.

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And then of course my favorite acronym from the United States Department of Energy, the SNEM category, small-non-small-electric-motor electric motors.

The reason why it has this real convoluted name is because, like I mentioned in the small motor rule, you had a third horsepower to three horsepower, three-phase motors and then single-phase motors, but only open drip proof frames. This new category of SNEMS is meant to cover any small electric motors that weren't previously covered by the small motor rule. That's why you get this crazy small-non-small-electric-motor electric motor name.

A few other categories I wanted to go over. Motor manufacturers who choose self-certification path and are utilizing an AEDM as I discussed, they must have a third-party nationally-recognized certification program certify the efficiency of their motors. Advanced Energy is one of those. If this is something that you need help with, feel free to reach out to review our website or reach out to me. Also, motors can be tested for enforcement at any voltage on the nameplate. So this is a big one. A lot of motor manufacturers do put "Rated from 208 to 230 and 460" on the nameplate, things like that.

If the motor is going to be enforcement tested to efficiency levels, the Department of Energy can now choose which voltage to do the enforcement testing at on the nameplate. We did receive just, I don't know, a month, maybe four to six weeks ago, we received a recent notification from the Department of Energy regarding the test procedure updates. So DOE will delay enforcement activities for manufacturers making voluntary representations of those additional categories that were mentioned on the previous slide.

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I'm just going to read these quickly. The size category motors between 500 and 750 HP, that enforcement commencement date, rather than being October 14th, 2023, now it will be 2024, so manufacturers will have up to 12 months to get those in order for their voluntary representation. And that voluntary representation means they're placing efficiency levels on the nameplate and then also submitting data on those efficiencies to the Department of Energy. Air over electric motors, manufacturers will have a two-year delay, so October 14th, 2025. Inverter-only and synchronous motors, there will be a three-year delay, so October 14th, 2026. And then the last group, the expanded scope electric motors, also the same three-year delay to October 14th, 2026.

And then we did include a slide on European Union, European Commission updates for ecodesign requirements. And I will admit I'm less familiar with this then in the DOE realm, but if there are more deeper questions around these additions, feel free to reach out to me, shoot me an email or something after the presentation or sometime this week. One that definitely stands out is motors rated between 100 to 250 HP, or in kilowatts that's 75 to 200 kw. New motors sold after July 2023 are required to be rated for IE4 efficiency level. That's one band higher than IE3 or NEMA Premium as efficiency's mostly referred to in the United States.

And then there were some others. These things were written in 2019, 2020 and then released in 2021. So the addition of 60 hertz motors, kW range extended up to 1,000 kW, voltage range extended up, VFDs or VFDs drives were added to the scope of the requirements. And then also single-phase motors are now required to meet IE2 level of efficiency from the EU.

Video: Energy efficiency solutions for plant managers

Energy efficiency is top-of-mind for plant managers, and Eder Matias with SEW Eurodrive discusses the challenges and solutions. In this conversation, he also touches on robots, which offer flexibility for customers.

During Modex 2024 in Atlanta, Eder Matias, Director of Sales for controls and automation at SEW Eurodrive, had a conversation with editor Amara Rozgus. He discussed his takeaways from the show, including energy efficiency solutions for plant managers and the flexibility offered by robots.

Plant Engineering

How hydrogen fuel cells, grid upgrades are revamping EV charging

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Restructuring aging utility grids that were primarily built to distribute energy and EV adoption is a major challenge, but hydrogen fuel cells can help.

In April 2024, global energy, technology, and utility provider Hitachi Energy announced a US$1.5 billion investment program to ramp up global transformer production by 2027. IDTechEx's research into electrical grids indicates that transformers are a critical component and potential supply bottleneck for large-scale grid upgrades. These upgrades are essential as society shifts from a transportation sector fuelled by petrochemicals transported in tankers to a sector powered by electricity carried by wires. In their market report, "Off-Grid Charging For Electric Vehicles 2024-2034: Technologies, Benchmarking, Players and Forecasts," IDTechEx explores the challenges utility grids face amid vehicle electrification.

Restructuring aging utility grids that were primarily built to distribute energy from centralized coal power plants into systems that can cope with increasing renewable energy generation and electric vehicle adoption is a major challenge that industry and policy are beginning to take steps to tackle. The investment from Hitachi Energy involves a new factory in Finland, which should reduce lengthy wait times (currently over two years in the US) for transformers, which are essential in stepping down the high voltage long-distance transmission lines to useable voltages for end customers.

However, some locations and situations will likely always exist beyond the reach of the grid and thus mains electricity. Temporary locations such as construction sites, festivals, or the most rural industrial locations may never be economically or technically viable

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for expensive grid upgrades. Instead, they will have to resort to distributed generation for power. The incumbent technology is diesel generators, which are increasingly viewed as polluting and may soon be banned from inner city construction sites due to air and noise pollution regulations. Additionally, charging 'green' electric construction vehicles from a carbon-intensive diesel generator does not make environmental sense. IDTechEx has researched several proposed options for green on-site power generation, and one technology stands out as a likely candidate for construction and temporary power generation: the hydrogen fuel cell generator.

Repurposing the fuel cell for distributed generation

Fuel cell technology is not new, and their use was pioneered in early space programs. There has been consistent interest in FCEVs (fuel cell electric vehicles) as a faster refueling and greater range alternative to BEVs (battery electric vehicles). However, sales figures suggest that BEVs are significantly outperforming FCEVs, and IDTechEx expects fully battery electric to emerge as the dominant net-zero drivetrain. However, there is growing momentum in the fuel cell generator space, which repurposes fuel cell generator technology and utilizes this to generate electricity from hydrogen. Fuel cell generators take in H2, combine it with oxygen from the air, and produce electricity and water with no carbon emissions and much-reduced noise compared with a diesel generator.

Compared with solar/wind integrated systems, which require an on-site battery, fuel cell generators can use stored energy in the form of on-site compressed hydrogen. Large power outputs can be generated by scaling up the fuel cell stack, which can then charge increasingly large electric construction vehicles or a large number of conventional vehicles. These generators offer the promise of clean, non-intermittent, and scalable power. IDTechEx research has observed these being used in electric construc-

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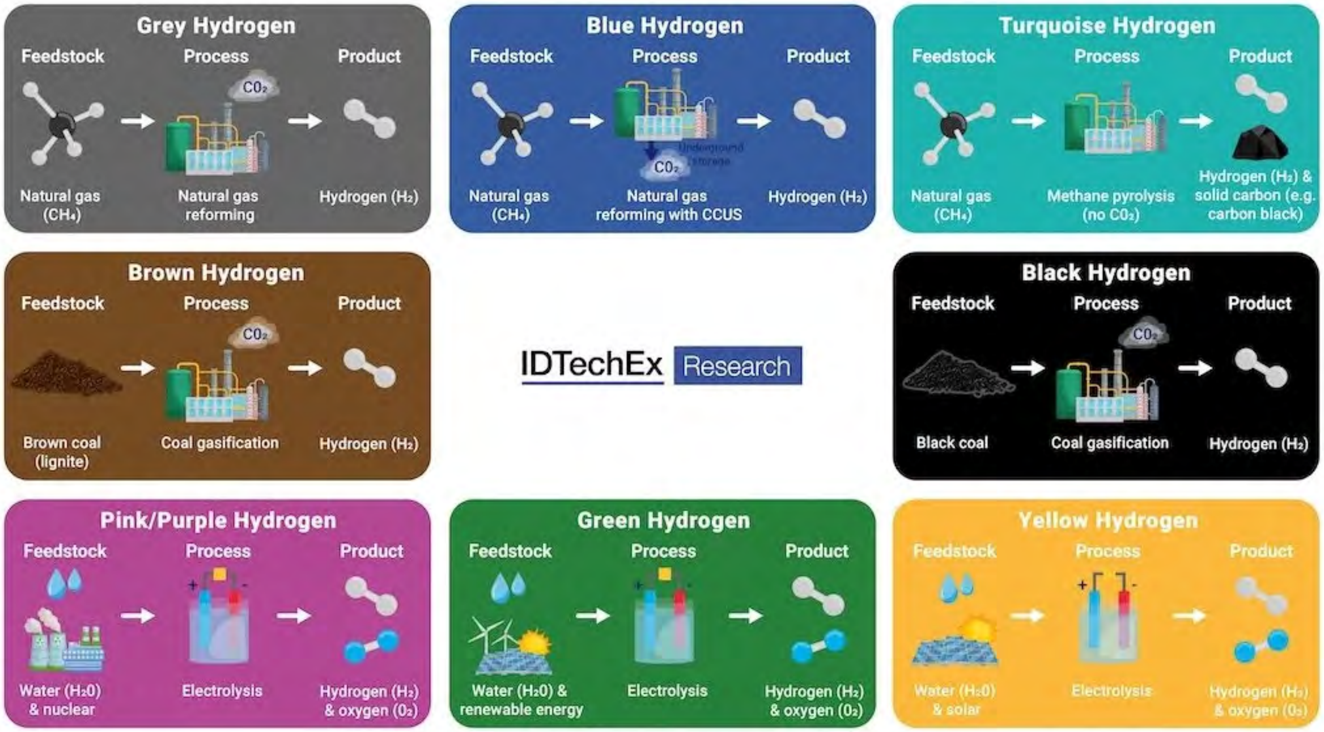

The colors of hydrogen refer to the method of production. Only green and yellow hydrogen are truly renewable. Courtesy: IDTechEx

tion sites, festivals, remote multi-day electric vehicle races, and even public highway fast charging. Hitachi Energy is one of the latest companies to invest in hydrogen fuel cell generators, an industry that IDTechEx predicts will generate over US$14 billion by 2034.

The challenge is affordable and green hydrogen

The promise of carbon-free on-site electricity is attractive; however, the entire supply chain must be considered for an accurate assessment of emissions and for hydrogen, which involves the method or "color" of H2.

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If grey or black hydrogen is utilized, hydrogen generators simply displace the emissions from the point of use to the source of hydrogen production and represent no serious overall reductions in emissions. If, on the other hand, green, renewable hydrogen is used, then the overall emissions are drastically reduced. The question then is – will operators use green or grey hydrogen? This depends on the cost and availability. Currently, green hydrogen is significantly more expensive, in part due to the overall energy inefficiency inherent in its production (around 3kWh input renewable energy creates 1kWh equivalent of H2). As the end users are often commercial operators, OPEX considerations are likely to take priority, and if the price of green hydrogen remains too high, then it seems unlikely they will pay a significant premium.

Availability is another challenge, as current green H2 production remains small and regionally focused. IDTechEx research has found certain hydrogen fuel cell generator companies have had to make their own green hydrogen to supply their customers, as no one else can produce the quantities required. The IDTechEx report, "Off-Grid Charging For Electric Vehicles 2024-2034: Technologies, Benchmarking, Players and Forecasts", assesses these challenges quantitatively and provides market intelligence about the growing market for fuel cell generators, as well as the context of utility grid challenges. The report also explores quantities of green hydrogen required to fuel the electric construction industry, which IDTechEx pinpoints as one of the key applications of fuel cell generators. Forecasts are broken down by generator size and region, resulting in a high level of granularity informing readers on this market.

Mika Takahashi

Mika Takahashi, *technology analyst at IDTechEx.*

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