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POWER SYSTEMS TECHNOLOGY

PST POWER SYSTEMS TECHNOLOGY

GREEN ENERGY

TRANSFORMER TECHNOLOGY MAG

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Transitioning to Green Energy
Interview with **Markus Heimbach**, Executive Vice President and the Managing Director at Hitachi Energy
Clean Energy

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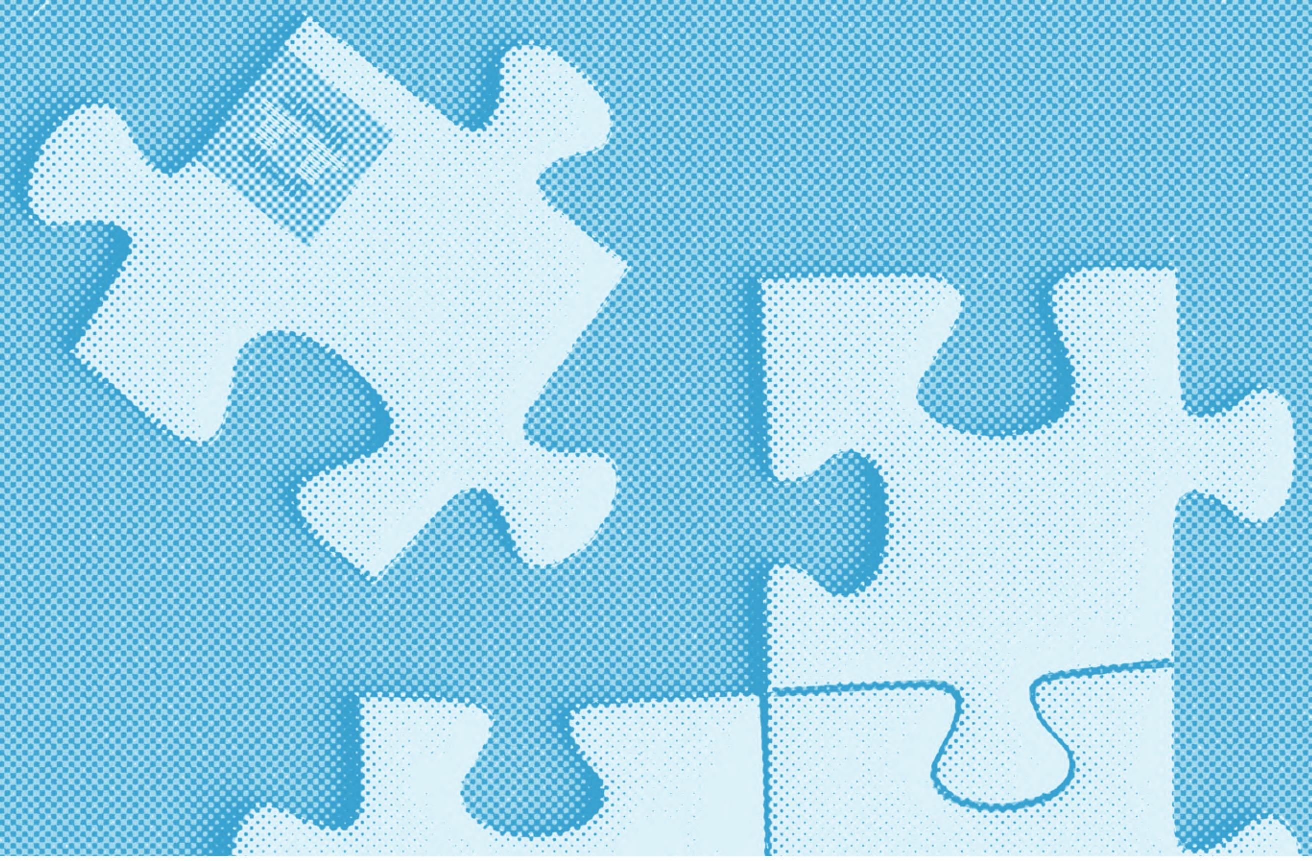

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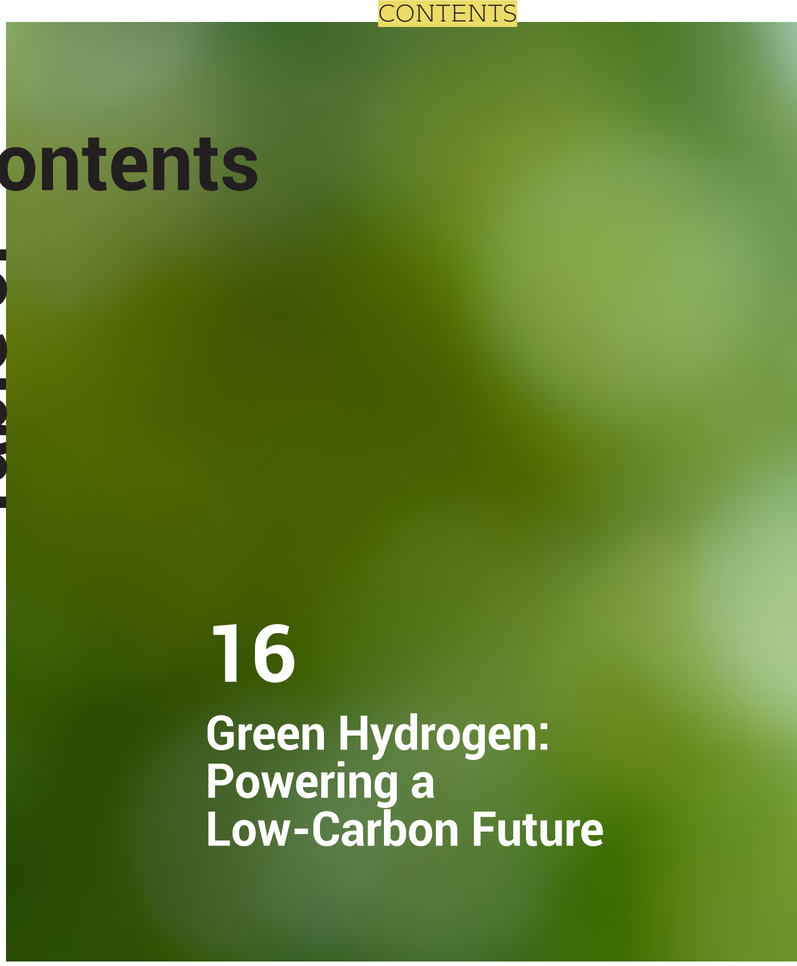

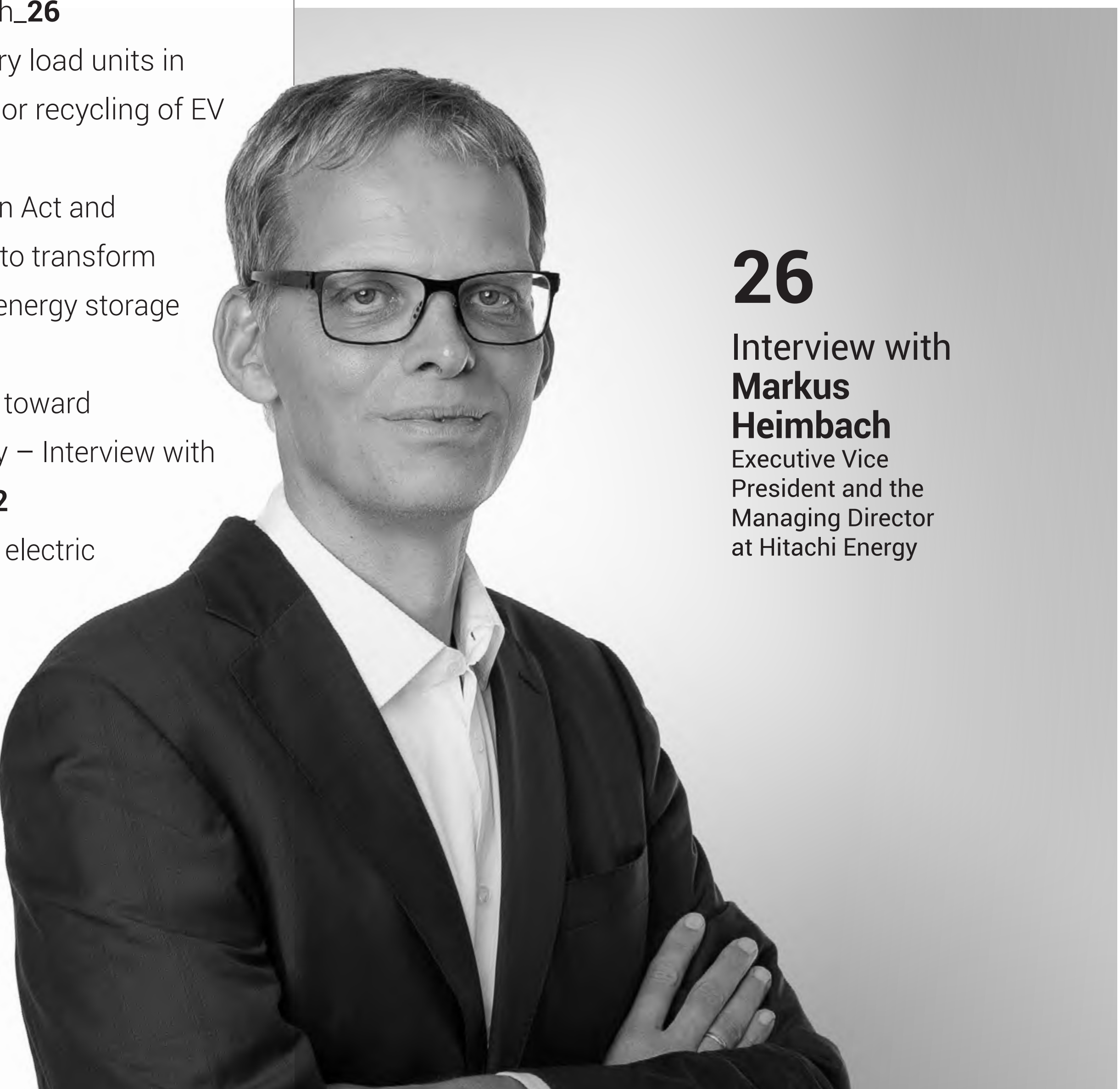

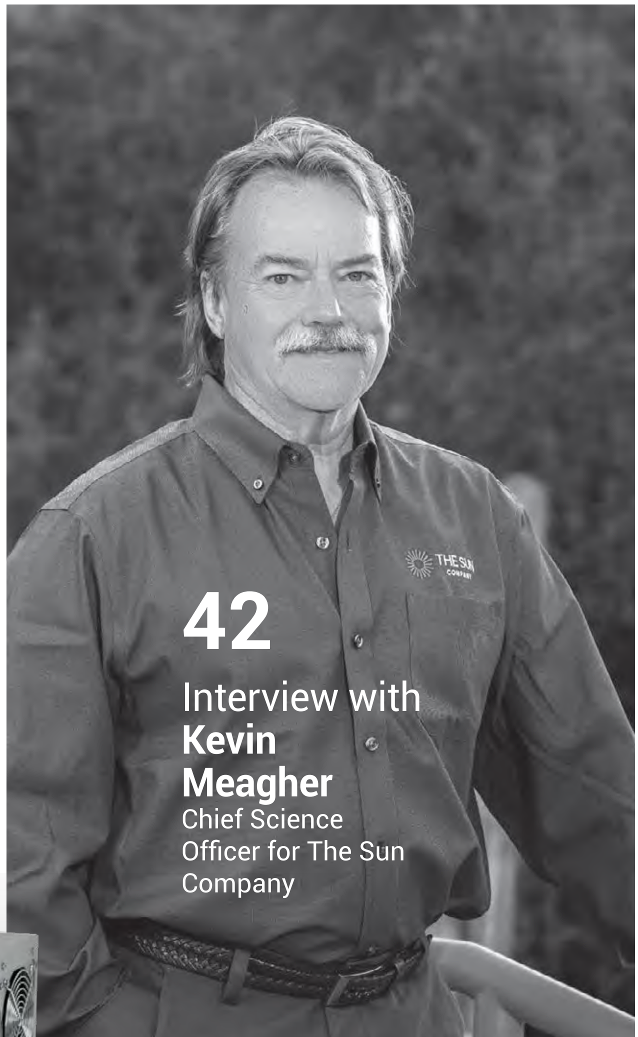


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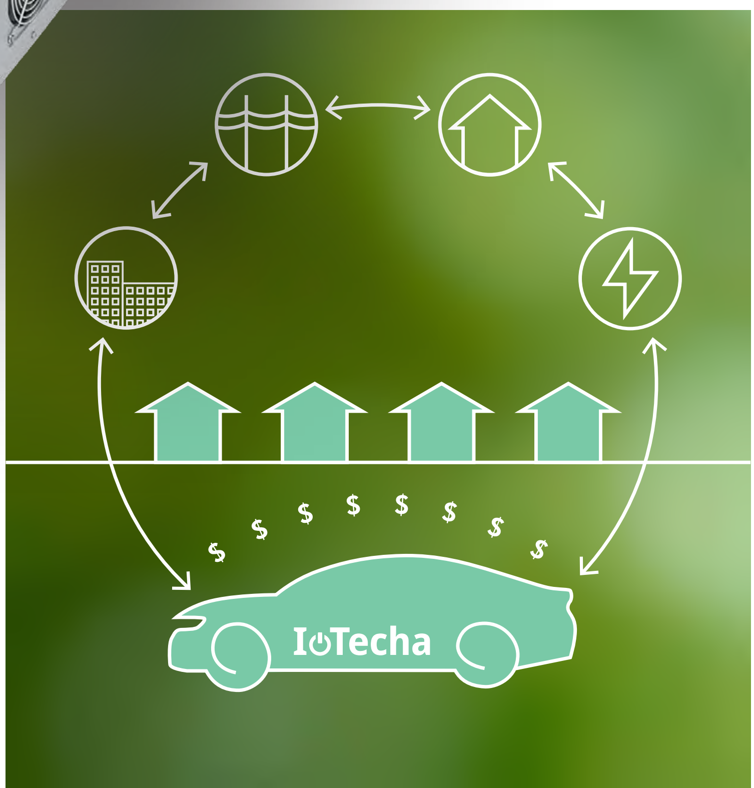
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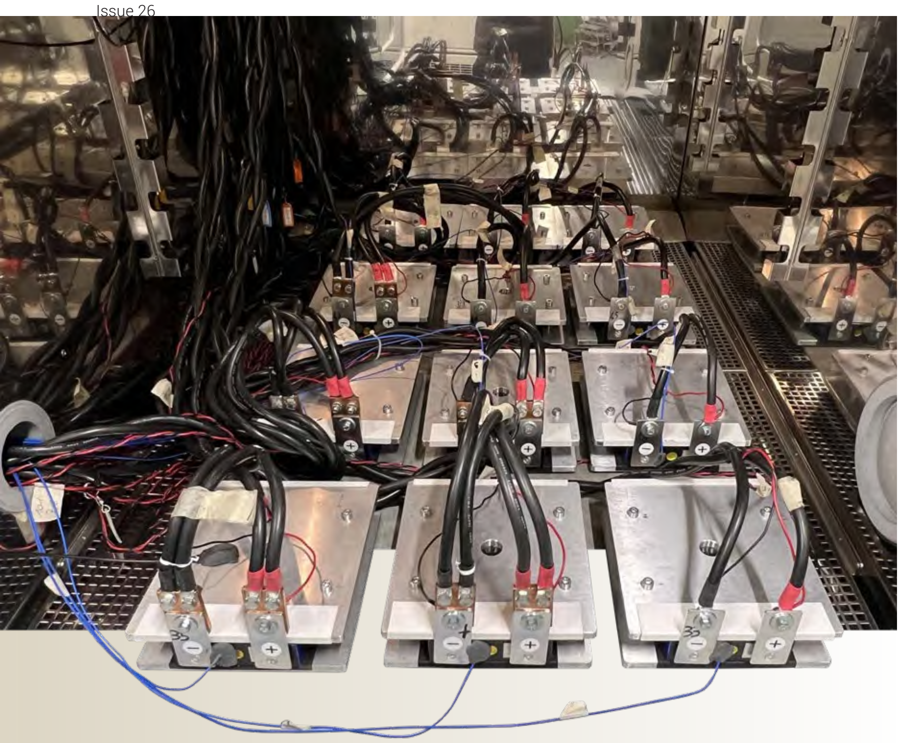


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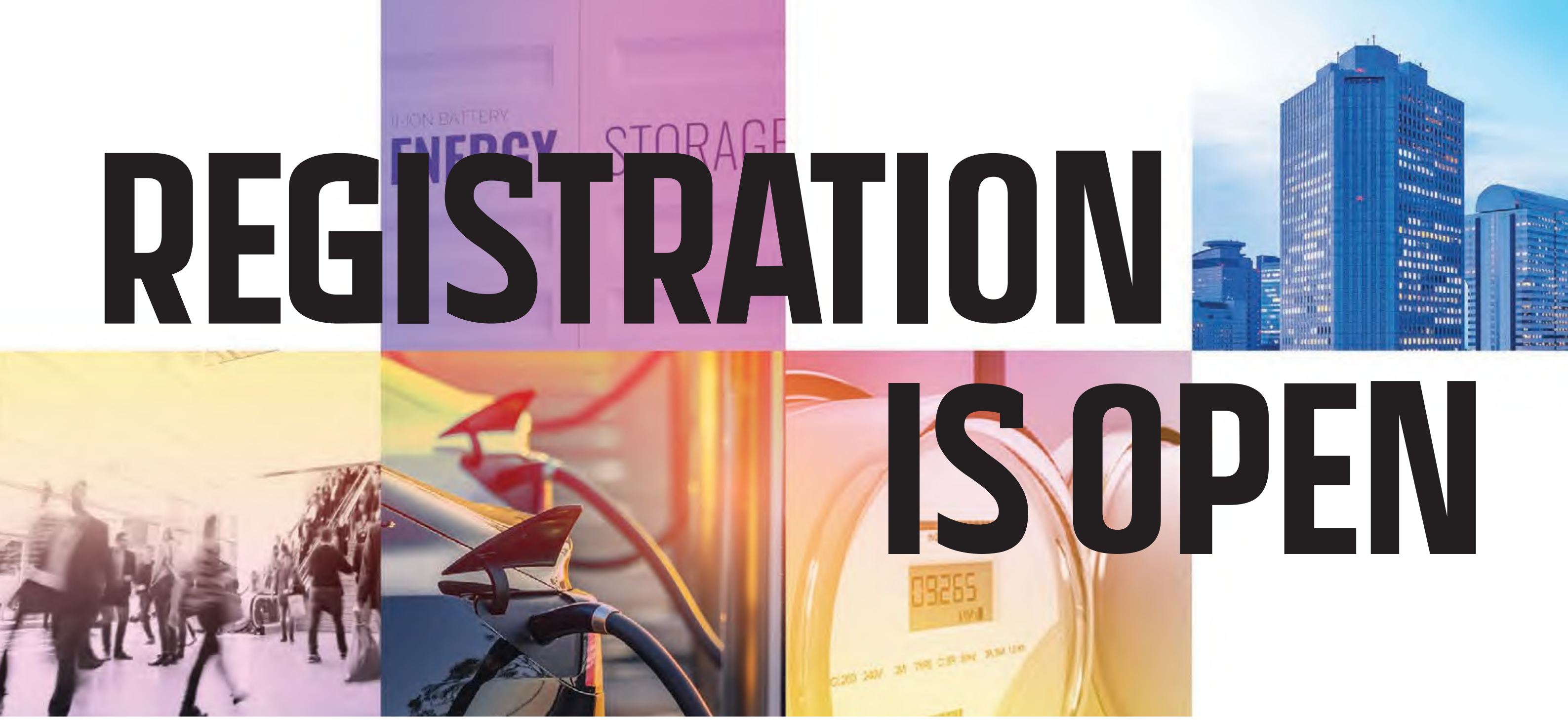

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Dear Readers,

Our focus this month is on Green Energy and the transformation taking place in the power industry globally. I mentioned recently that at the Renewable Energy, RE+ Conference, and Expo in Anaheim, California last year, we were able to interview 29 SME's and thought leaders who spoke about the innovation and developments taking place in the green energy space. We came away content rich, and some of those interviews are here in this issue. We could not do all of the interviews justice, so over the year we will be adding a new feature to our Digital Magazines to cover expanded content areas of Power Systems and Green Energy Technologies, while continuing to provide great content on Transformer Technology and Women in Power Systems.

I will make this letter shorter than most because I believe I cover a lot of what this issue is about in the article I wrote on where green and clean energy is focused. One of the great joys I have as Managing Editor is to be exposed to so many great technologies, ideas and movements within the power industry. Having just returned from the DistribuTech International Conference and Expo in San Diego, which we will cover in our March issue, I am thankful for all of the thought leaders I was able to interview, each of whom raised my own awareness of how great a change we are undergoing in the power industry.

One senior executive said it best:

"After 30 years of working in the power industry, I have never seen as much of an appetite for change as I am seeing right now. And it bodes well for society as a whole as we grapple with some very tough issues on a global scale, decarbonization, decentralization and digitalization.

Starting in March, and continuing going forward, even though each issue is "themed", we will have separate sections for Transformer focused content, Power Systems content, Green Energy content, and Women in Power Systems content. While each issue might have a very strong focus on one of these content areas, we hope to cover all of the change taking place in both technology and in how each of these areas will impact the global power industry going forward. While our geographic focus will remain the Americas and Europe, much of our content will have relevance throughout the globe.

We believe transformers are and will always be the "Heart of the Power System", but given the changes elsewhere within that system, we think this is a better way to cover the changes taking place all around us. It will also expand our community as we rebrand ourselves as APC Technologies, a better description of our brand.

In the meantime, enjoy our first foray into Green Energy Technology, with articles of importance and interviews with key thought leaders from the industry. Moving forward, I would love to hear from you, our community members, on any of the subjects we will cover as a way of serving you better. Our vision is to be the "Digital Voice of the Power Industry" and that vision becomes clearer as we make these changes going forward. We will forever have Transformer Technology as our own heart, but we are also cognizant of the fact that we have been given a platform as a trusted source for informative, enlightening and inspiring content for the power industry, and we take that role as a "trusted provider" very seriously at APC Technologies.

If you are interested in providing content for any of our targeted areas, please feel free to connect with me personally at alan.ross@apc.media.

Onward and Upward!

Alan M Ross
CRL, CMRP
Managing Editor
APC Media
Technical Director

Green Hydrogen: Powering a Low-Carbon Future

by Dr. **Ahad Esmaeilian**

Green hydrogen

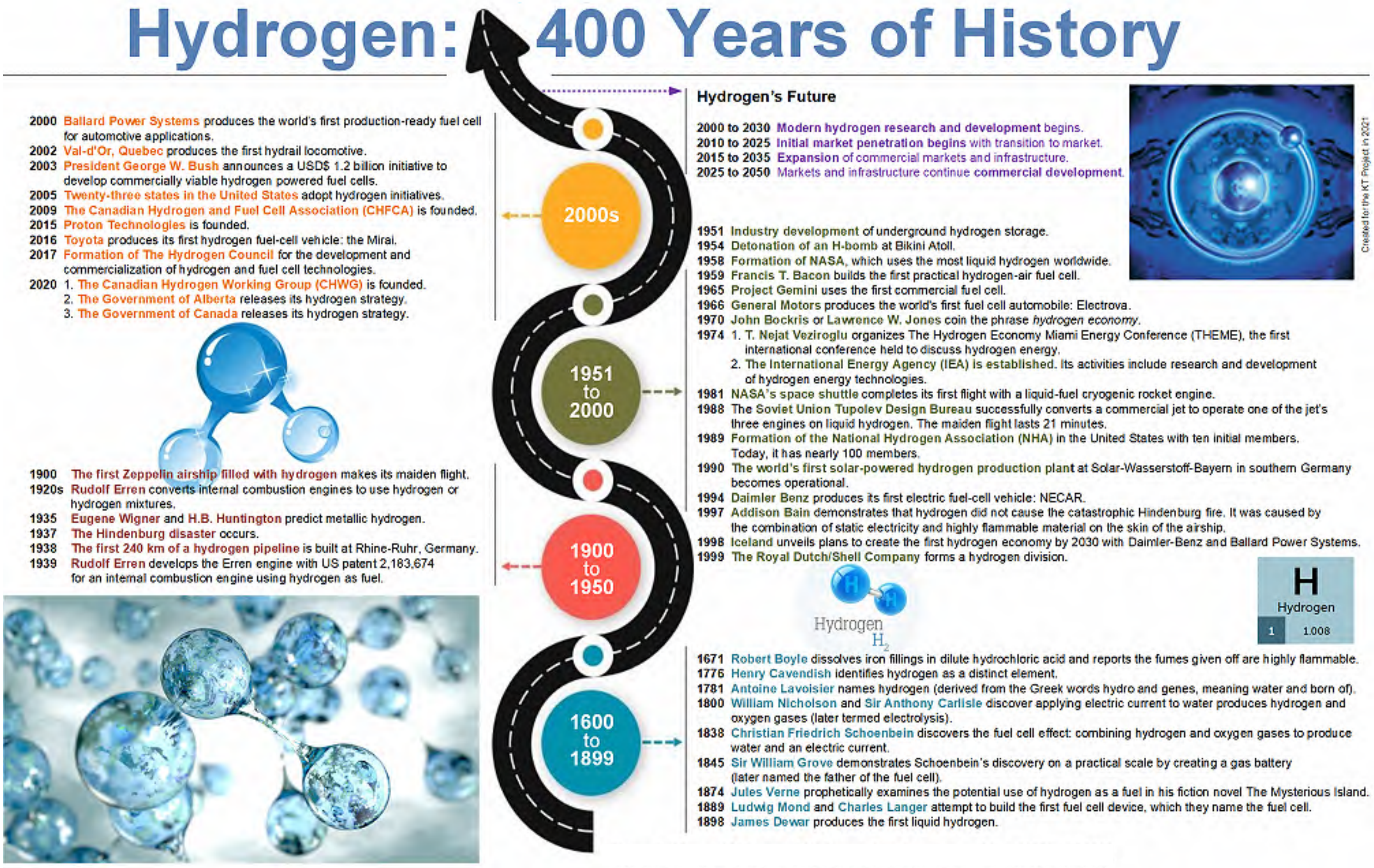
is considered a versatile and potentially transformative technology in the transition to a low-carbon energy system. Its ability to decarbonize various sectors and to store and transport renewable energy makes it a key player in the energy transition.

Dr. **Ahad Esmaeilian** is Vice President of Clean Energy at Audubon Engineering Company. He holds bachelor and master's degrees in Electrical Engineering from The University of Tehran, a master's degree in Business Administration from the Clarkson University, and a PhD in Electrical Engineering from the Texas A&M University, and has a rich experience in both electrical engineering and business. He is also a Senior Member of the IEEE and currently serves as the Chairman of the IEEE PES Grid Edge Technologies Conference & Expo.

Background

The history of hydrogen production dates to 1800s, when scientists first discovered that hydrogen could be produced from water through the process of electrolysis. However, it

wasn't until the 20th century that hydrogen began to be used as a fuel on a large scale. Initially, hydrogen was mainly produced using fossil fuels such as natural gas, leading to the emission of greenhouse gases. Green hydrogen is produced using renewable energy sources such as wind or solar power, rather than fossil fuels. In recent years, interest in green hydrogen has grown as a means of using renewable energy to produce hydrogen without emitting carbon. The production of green hydrogen involves the electrolysis of water, where an electric current is passed through water, splitting it into hydrogen and oxygen. The electricity used in this process can come from a variety of renewable sources such as solar, wind, or hydroelectric power.



Source: https://ktproject.ca/hydrogen-an-introduction-to-the-clean-energy-of-the-future/

Electrolysis Technologies

There are several different electrolysis technologies currently available, each with its own set of advantages and disadvantages. The three major electrolysis technologies are:

Alkaline electrolysis

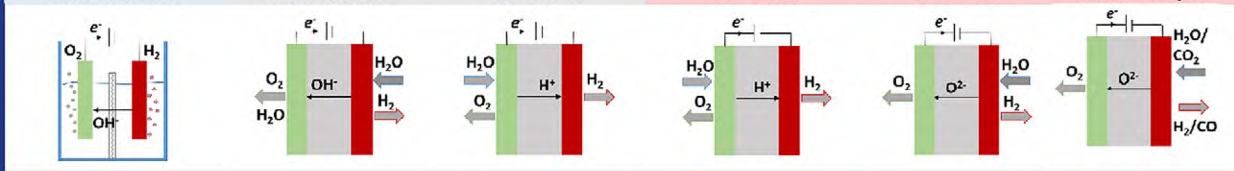
Alkaline electrolysis is one of the oldest and most mature electrolysis technologies. It uses an alkaline solution, such as potassium hydroxide (KOH), as the electrolyte. Alkaline electrolysis cells have a relatively high efficiency and are able to operate at relatively low temperatures, which makes them well suited for use in large-scale hydrogen production. The efficiency of alkaline electrolysis cells ranges from 70-80%, with an operational temperature range of 25-80°C. Moreover, alkaline electrolysis is relatively tolerant to impurities in the water, which can decrease the capital costs. However, the use of an alkaline electrolyte, such as KOH, can be corrosive, resulting in higher maintenance costs over time. Additionally, the efficiency of alkaline electrolysis decrease as the temperature increases above 80°C.

Proton exchange membrane (PEM) electrolysis.

PEM is a type of electrolysis technology that utilizes a proton-conducting polymer membrane as the electrolyte. The membrane selectively allows protons to pass through, but not electrons, resulting in high electrical efficiency of around 60-70%. PEM electrolysis cells are relatively compact and lightweight, making them well suited for small-scale and portable hydrogen production systems. Additionally, PEM electrolysis cells are able to operate at a relatively low temperature range of 20-80°C. This range of temperature and efficiency makes PEM electrolysis well suited for a wide range of applications, particularly in the transportation and power generation sectors. However, PEM electrolysis cells can be sensitive to impurities in the water, which can decrease the cell's lifespan and efficiency. Furthermore, PEM electrolysis cells require the use of a precious metal catalyst such as platinum, which increases the cost of the technology.

Solid oxide electrolyzer (SOE)

SOE is a type of electrolysis technology that utilizes a solid oxide material as the electrolyte. The electrolyte is typically composed of ceramics such as zirconia or yttria-stabilized zirconia. The solid oxide electrolyte allows for the movement of both ions and electrons, resulting in high electrical efficiency of around 60-80%. SOE cells are able to operate at high temperatures, typically 700-1000°C, which allows for high efficiency and the ability to use waste heat as a source of energy. This high operational temperature also allows SOE cells to be used in a variety of applications such as hydrogen production, power generation, and carbon capture. However, SOE cells are a relatively new technology and further research is needed to optimize their performance, decrease their costs and improve their reliability.

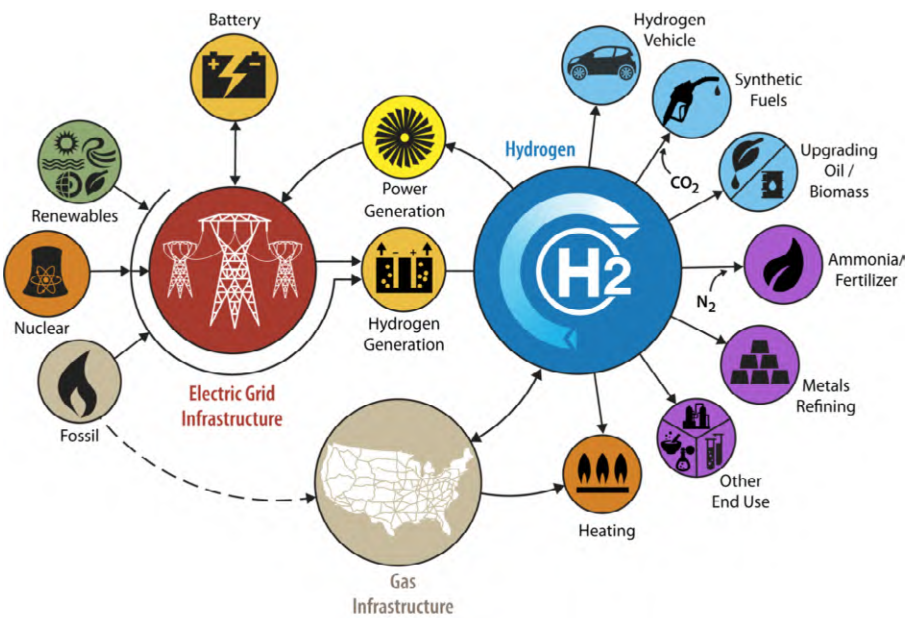


	Low Temperature Electrolysis			High Temperature Electrolysis		
	Alkaline (OH^-) electrolysis		*Proton Exchange (H^+) electrolysis*		*Oxygen ion(O^{2-}) electrolysis*	
	Liquid	*Polymer Electrolyte Membrane*		*Solid Oxide Electrolysis (SOE)*		
	Conventional	*Solid alkaline*	*H^+ - PEM*	*H^+ - SOE*	*O^{2-} - SOE*	*Co-electrolysis*
Operation principles						
Charge carrier	OH^-	OH^-	H^+	H^+	O^{2-}	O^{2-}
Temperature	20-80°C	20-200°C	20-200°C	500-1000°C	500-1000°C	750-900°C
Electrolyte	liquid	solid (polymeric)	solid (polymeric)	solid (ceramic)	solid (ceramic)	solid (ceramic)
Anodic Reaction (OER)	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$	$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$	$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$	$2H_2O \rightarrow 4H^+ + 4e^- + O_2$	$O^{2-} \rightarrow {}^1/_2 O_2 + 2e^-$	$O^{2-} \rightarrow {}^1/_2 O_2 + 2e^-$
Anodes	Ni > Co > Fe (oxides) Perovskites: $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$, $LaCoO_3$	Ni-based	IrO_2, RuO_2, $Ir_xRu_{1-x}O_2$ Supports: TiO_2, ITO, TiC	Perovskites with protonic-electronic conductivity	$La_xSr_{1-x}MnO_3$ + Y-Stabilized ZrO_2 (LSM-YSZ)	$La_xSr_{1-x}MnO_3$ + Y-Stabilized ZrO_2 (LSM-YSZ)
Cathodic Reaction (HER)	$2H_2O + 4e^- \rightarrow 4OH^- + 2H_2$	$2H_2O + 4e^- \rightarrow 4OH^- + 2H_2$	$4H^+ + 4e^- \rightarrow 2H_2$	$4H^+ + 4e^- \rightarrow 2H_2$	$H_2O + 2e^- \rightarrow H_2 + O^{2-}$	$H_2O + 2e^- \rightarrow H_2 + O^{2-}$ $CO_2 + 2e^- \rightarrow CO + O^{2-}$
Cathodes	Ni alloys	Ni, Ni-Fe, $NiFe_2O_4$	Pt/C MoS_2	Ni-cermets	Ni-YSZ Subst. $LaCrO_3$	Ni-YSZ perovskites
Efficiency	59-70%		65-82%	up to 100%	up to 100%	-
Applicability	commercial	laboratory scale	near-term commercialization	laboratory scale	demonstration	laboratory scale
Advantages	low capital cost, relatively stable, mature technology	combination of alkaline and H^+-PEM electrolysis	compact design, fast response/start-up, high-purity H_2	enhanced kinetics, thermodynamics: lower energy demands, low capital cost		+ direct production of syngas
Disadvantages	corrosive electrolyte, gas permeation, slow dynamics	low OH^- conductivity in polymeric membranes	high cost polymeric membranes; acidic: noble metals	mechanically unstable electrodes (cracking), safety issues: improper sealing		
Challenges	Improve durability/reliability; and Oxygen Evolution	Improve electrolyte	Reduce noble-metal utilization	microstructural changes in the electrodes: delamination, blocking of TPBs, passivation		C deposition, microstructural change electrodes

Source: https://www.sciencedirect.com/science/article/pii/S0360128516300260#f0010

Industry Applications

Green hydrogen has the potential to revolutionize multiple sectors across industries. From transportation to heating and cooling, and from industrial processes to power generation, green hydrogen offers a clean, efficient, and sustainable energy solution. With its versatility and scalability, green hydrogen has the potential to significantly reduce carbon emissions and contribute to a low-carbon future, making it a key enabler in the transition to a sustainable energy system. The adoption of green hydrogen across various sectors has the potential to drive economic growth, create new jobs, and provide energy security, making it a critical component in the global energy mix.



Source: https://www.energy.gov/eere/fuelcells/h2scale

Power Generation, Heating & Cooling

Green hydrogen can be used by utilities to decarbonize their natural gas distribution pipelines, and thermal power generations to provide their customers with lower carbon emission electricity, heating and cooling solutions. This can be achieved through a process known as hydrogen blending, where a small percentage of hydrogen is added to the existing natural gas pipeline, reducing the overall carbon intensity of the delivered energy. As the percentage of hydrogen in the blend increases, the carbon emissions from the natural gas pipeline will decrease. This provides a stepping-stone for utilities to transition their customers to a low-carbon

energy source, without requiring significant infrastructure changes. Additionally, green hydrogen can also be used as a standalone energy source for heating and cooling, either through direct use or through conversion to electricity through fuel cells.

This can help to significantly reduce the carbon emissions from the heating and cooling sector and contribute to a more sustainable energy system. In the power and utilities sector, green hydrogen can be used to store excess renewable energy, which can then be used to meet demand during periods of low renewable energy generation. Green hydrogen can also be used to balance the electricity grid, helping to integrate more renewable energy into the system.

Hydrogen blending into the natural gas power generation turbines or distribution pipelines faces several challenges, including:

- **Technical compatibility:** Hydrogen is a highly reactive gas, and blending it with natural gas requires ensuring that the existing natural gas pipelines, appliances, and meters are compatible with hydrogen gas.
- **Safety concerns:** Hydrogen is a flammable gas and requires special handling and storage procedures to ensure safety. This requires the development of appropriate safety protocols, risk assessments, and hydrogen leak detection systems.
- **Cost:** The production and transportation of hydrogen, as well as the retrofitting of existing natural gas infrastructure to accommodate hydrogen blending, can be expensive. The development of cost-effective hydrogen production and transportation technologies is critical to the success of hydrogen blending.
- **Hydrogen production and distribution infrastructure:** The development of a hydrogen production and distribution infrastructure is necessary to support the widespread adoption of hydrogen blending. This requires significant investment in renewable energy sources, hydrogen electrolyzers, hydrogen storage, and hydrogen transportation technologies.
- **Regulatory and policy support:** The development of appropriate regulations and policies to support hydrogen blending is necessary to ensure its safe and efficient deployment. This includes the development of standards for hydrogen blending, safety protocols, and the licensing of hydrogen production and distribution activities.

Transportation Sector

Green hydrogen has the potential to decarbonize the transportation sector that is currently reliant on fossil fuels. In the transportation sector, green hydrogen can be used to power fuel cell vehicles, which convert hydrogen into electricity to power the vehicle's electric motor. According to a study by the European Commission, hydrogen fuel cell vehicles could account for up to 14% of new car sales in Europe by 2050. The technology for light-duty fuel cell cars is currently at a mature stage and several Original Equipment Manufacturers (OEMs) such as Toyota, Honda, Hyundai, and General Motors are currently producing and selling fuel cell vehicles. The state-of-the-art technologies in light-duty fuel cell cars include the use of PEM fuel cells and high-pressure hydrogen storage systems. These technologies have enabled the development of fuel cell vehicles with a high driving range, and low emissions.

Captive fleets, such as buses, delivery vans, port and airport ground support equipment, can also rely on green hydrogen as the fuel source. These vehicles typically operate within a specific area and return to a central depot at the end of each day. This makes it feasible to build a hydrogen refueling station at the depot, providing a convenient and reliable source of fuel for the fleet.

Several OEMs such as Toyota, Daimler, Volvo, and Nikola Motors are investing in the development of hydrogen fuel cell trucks. These companies are currently testing and demonstrating prototypes of hydrogen fuel cell trucks, and some have even started to take pre-orders for commercial production. According to a study by the Hydrogen Council, a global CEO-led initiative, it is estimated that by 2030, hydrogen fuel cell trucks could account for around 14% of the global truck market, which is expected to be worth around $230 billion. The study also estimates that by 2050, hydrogen fuel cell trucks could reduce CO_2 emissions by 6 gigatons per year, which is equivalent to taking 1.5 billion cars off the road.

Green hydrogen can also be used as a marine fuel, reducing the carbon emissions of ships and helping the shipping industry to meet its emission reduction targets. According to a study by the International Transport Forum, hydrogen fuel cell ships could reduce CO_2 emissions by up to 90% in comparison to conventional ships. In the aviation sector, green hydrogen has the potential to power aircrafts, as well as to be used in the production of synthetic jet fuels. Several OEMs and startups are investing into designing and piloting vessels and airplanes that could rely on green hydrogen/ammonia as their source of fuel. According to a study by the International Civil Aviation Organization, hydrogen has the potential to reduce the aviation sector's CO_2 emissions by up to 80%.

The use of green hydrogen in the transportation sector faces several challenges, including:

- **Infrastructure:** The development of hydrogen fueling infrastructure is necessary to support the widespread adoption of green hydrogen in the transportation sector. This includes the construction of hydrogen production and fueling stations, as well as the deployment of hydrogen storage and transportation technologies.
- **Cost:** Green hydrogen production and fueling are currently more expensive than traditional fossil fuel-based transportation systems. The development of cost-effective green hydrogen production and fueling technologies, as well as economies of scale in the production and distribution of green hydrogen, is critical to making green hydrogen a viable alternative to fossil fuels in the transportation sector.
- **Fuel cell technology:** The use of green hydrogen in transportation requires the development of advanced fuel cell technologies that can effectively convert hydrogen into electrical energy to power vehicles. These technologies need to be cost-effective, durable, and reliable, and they need to meet the performance requirements of the transportation sector.
- **Regulatory and policy support:** The development of appropriate regulations and policies to support the use of green hydrogen in the

transportation sector is necessary to ensure its safe and efficient deployment. This includes the development of standards for hydrogen fueling, vehicle safety protocols, and the licensing of hydrogen production and distribution activities.

- **Public awareness and perception:** The public perception of green hydrogen as a safe and viable energy source for transportation is critical to its widespread adoption. Raising awareness about the benefits of green hydrogen, including its clean and sustainable characteristics, will be necessary to overcome any public skepticism.

Industry Feedstock

Green hydrogen can be utilized as a feedstock in the production of fertilizer, chemicals, fuels, steel, cement, glass, and microchips. The versatility and scalability of green hydrogen make it a promising solution for reducing the carbon footprint of these industries and advancing towards a more sustainable future. According to a study by the Hydrogen Council, hydrogen has the potential to reduce CO_2 emissions in the industrial sector by up to 6 Gt by 2050.

The use of green hydrogen in the production of fertilizers can help reduce the carbon footprint of this industry, which currently accounts for approximately 2% of global greenhouse gas emissions. In the fertilizer industry, hydrogen is used as a feedstock for the production of ammonia, which is the basic building block for many fertilizers. The process of producing ammonia starts with the reaction of nitrogen from the air with hydrogen to form ammonia, Haber-Bosch process, which traditionally uses natural gas as the source of hydrogen. The ammonia can then be processed further to produce various fertilizers, such as urea and ammonium nitrate. By 2030, the market size for green hydrogen in the fertilizer industry is estimated to reach $3.8 billion.

The chemical industry is one of the largest energy consumers and greenhouse gas emitters, with hydrogen being used in the production of various chemicals such as ammonia and methanol. Green hydrogen has the potential to replace the use of fossil fuels in this industry, leading to significant reductions in carbon emissions. The market size for green hydrogen in the chemicals industry is estimated to reach $17.5 billion by 2050.

In the oil and gas industry and refineries, hydrogen can be used in a variety of processes to improve efficiency, reduce emissions, and upgrade heavy crude oil into lighter products. Some specific applications include hydrotreating, hydrocracking, and hydrogenation. Hydrogen can also be used as a fuel to power operations in the industry, replacing fossil fuels and reducing emissions. The market size for green hydrogen in the oil and gas industry and refineries by 2030 is estimated to reach $18.2 billion.

The steel industry is one of the largest producers of carbon dioxide emissions, with the production of steel using significant amounts of energy and hydrogen. In the steel manufacturing process, green hydrogen can be used to replace as a reducing agent in the production of iron, removing oxygen from the ore to produce pig iron. The use of green hydrogen in this process can reduce the carbon footprint of the steel industry and make it more sustainable. The market size for green hydrogen in the steel industry is estimated to reach $7.3 billion by 2050.

The cement industry is also a significant contributor to global carbon emissions, with the production of cement consuming a large amount of energy. Green hydrogen can be used to heat the kilns used to produce cement clinker, which is then ground into cement powder. The use of green hydrogen in this process can reduce the carbon footprint of the cement industry, making it more sustainable and environmentally friendly. The market size for green hydrogen in the cement industry is estimated to reach $5.2 billion by 2030.

The production of glass requires high temperatures and energy, making it a significant contributor to carbon emissions. Green hydrogen can be used as an energy source in the melting process of glass to heat the furnaces that melt the raw materials into liquid glass. The use of green hydrogen in this process can reduce the carbon footprint of the glass industry and make it more sustainable, as it replaces traditional energy sources such as natural gas. The market size for green hydrogen in the glass industry is estimated to reach $1.9 billion by 2050.

In the microchip industry, hydrogen is used as a reducing agent in the production of silicon wafers, the basic building blocks of microchips. During the process, hydrogen reacts with silicon dioxide to form silicon and water, producing a purified silicon crystal. The use of green hydrogen in this process can help reduce the carbon footprint of the microchip industry, as it replaces traditional hydrogen made from fossil fuels. The market size for green hydrogen in the microchip industry is estimated to reach $3.6 billion by 2030.

The applications of green hydrogen as a feedstock in various industries extend beyond the few examples discussed previously. Although the challenges specific to each industry may differ, the general challenges faced by the transportation and utility sectors are also relevant to these other industries. The challenges facing the wider adoption of green hydrogen in various industries include factors such as the current high cost of production, the lack of scalable production methods, difficulties in storage and transportation due to hydrogen's low density and the need for specialized infrastructure, a shortage of technical expertise in utilizing green hydrogen, and an uncertain policy and regulatory environment. Addressing these challenges will be crucial to expanding the use of green hydrogen as a feedstock in a wider range of industries.

What is Next?

In conclusion, green hydrogen is considered a versatile and potentially transformative technology in the transition to a low-carbon energy system. Its ability to decarbonize various sectors and to store and transport renewable energy makes it a key player in the energy transition. The global green hydrogen market is expected to reach around $80 billion by 2030, and

over $2.5 trillion by 2050. Despite the potential benefits of green hydrogen, its large-scale production and use are still in their early stages. The cost of producing green hydrogen currently ranges from $3 to $6 per kilogram. This is significantly higher than the cost of hydrogen produced from natural gas, which is around $1 to $2 per kilogram. However, as the technology and economies of scale improve, the cost is expected to decrease to $1 to $2 per kilogram by 2030, making it competitive with hydrogen produced from natural gas. The additional governmental subsidies and incentives in USA and across the world will further enable the cost reduction and technology advancement.

Markus Heimbach

HITACHI
Inspire the Next

Interview with **Markus Heimbach**

Executive Vice President and the Managing Director at Hitachi Energy

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SF$_6$-free high-voltage technology needs to be reliable and scalable in order to achieve the lowest carbon footprint and accelerate the energy transition.

Photo: Hitachi Energy

Hitachi Energy

Alan Ross: Hello, I am Alan Ross, the Managing Editor of APC Media. I am thrilled to have as my guest today Markus Heimbach. Markus is the Executive Vice President and the Managing Director at Hitachi Energy for High Voltage Products. Markus, welcome. Thank you for being here today.

Markus Heimbach: Thank you very much for inviting me, Alan.

AR Today I want to talk to you about SF_6 because it is such a big topic in the industry right now and rightfully so. But before we get there, I want to ask you a little bit about your background. I know you were with ABB for 20-some-odd years prior to the Hitachi ABB transformation. So how long have you been in your current role?

MH I have been with ABB, then Hitachi ABB and then Hitachi Energy for more than 25 years in total. And I have been in my current role for roughly four years.

AR Excellent. Therefore, you've got a great background in high voltage. You've also got a great background in SF_6 gas and that's specifically what I want to talk about. People may not know but it has been a brilliant insulator for a lot of primary breakers, and a lot of products. Tell me a little bit about when SF_6 first came on the market. What was the thinking back then?

MH As you already said, Alan, SF_6 is a brilliant gas for insulation; it helps high-voltage products become more and more compact. SF_6 is not only very good when it comes to insulation, but it is also a brilliant gas when it comes to arc quenching or basically interruption, which is the primary goal of every circuit breaker. So, with these two excellent possibilities that SF_6 provides, it was a revolution in the high-voltage industry to make the whole equipment more cost-efficient, smaller, and more compact, reducing the footprint for the substations and enabling the development of a gas-insulated switchgear, which is reducing 95% of the complete footprint compared to air-insulated switchgear substation.

AR In consequence, we know it was a revolution and it was great. However, on the flip side, there's a problem with SF_6. Now, talk a little bit about that.

MH As said, we have these two brilliant properties of SF_6 the insulation and the interruption. But on the other hand, it is also one of the most potent greenhouse gases. It has a global warming potential in the range of 25,000. It stays in the atmosphere for more than 3000 years. Even though the overall contribution of SF_6 to global warming is not high percentage-wise, it's still in the range of 0.5%. And considering the use of SF_6, it is not negligible. Hence, there has been ever-increasing pressure over the last decades to phase out SF_6, with all the global warming and climate change discussions.

AR It seems like there are a lot of different companies that are taking this approach. And my concern was that we had different standards and the ultimate end user was going to be confused about how one was to replace SF_6. Could you talk a little about the standard that was developed for all the companies, including Hitachi Energy, creating alternatives for SF_6?

MH At the moment, we can say that there are mainly three global players working in that area in high-voltage products. At the very beginning, each of them had their own solution. We then all started looking at what would be best for the industry and somehow, we came together with GE and agreed on a very similar solution that has the same foundation. It's for sure different when it comes to the breaker itself, and it's different when it comes to the switchgear, but it's basically using the same solution, just as SF_6 was a similar solution for the industry until now. I do believe this is important because the customer doesn't want to deal with the complexity of every supplier and their different solutions. So, from that point of view, this was a move to enable a faster transition.

AR When you do that, look at things from the perspective of the end users, what are the things that you, the developers of the replacement technology should be thinking about? What are the things that they should consider with these major changes?

MH First and foremost, the new solution has to be as reliable as SF_6 is today. Otherwise, we cannot provide reliability to the equipment and to the overall grid. Secondly, we need to achieve a balance between a gas that is as good at interruption and insulation, but is significantly better than SF_6 when it comes to the global warming potential. And at the end of the day, we also need to have a solution that somehow fits into the concept of the existing substation.

AR So SF_6 is kind of ubiquitous. Is it and the new alternative solution interchangeable for the end user?

Photo: Hitachi Energy

MH First of all, what is in this big transition? We are not going from one gas to another gas. We are going from a gas to a gas mixture. We are using CO_2, which is the second-best when it comes to interruption. And we are using a gas which is called C_4-flouronitriles for improving the insulation performance of the CO_2, which is the main gas or the carrier gas. Then, we need the O_2 to prevent soot after switching. So that is basically the gas mixture that we and GE are using. As a result, the gas is interchangeable with the equipment from the customer to maintain the gas filling and all this equipment.

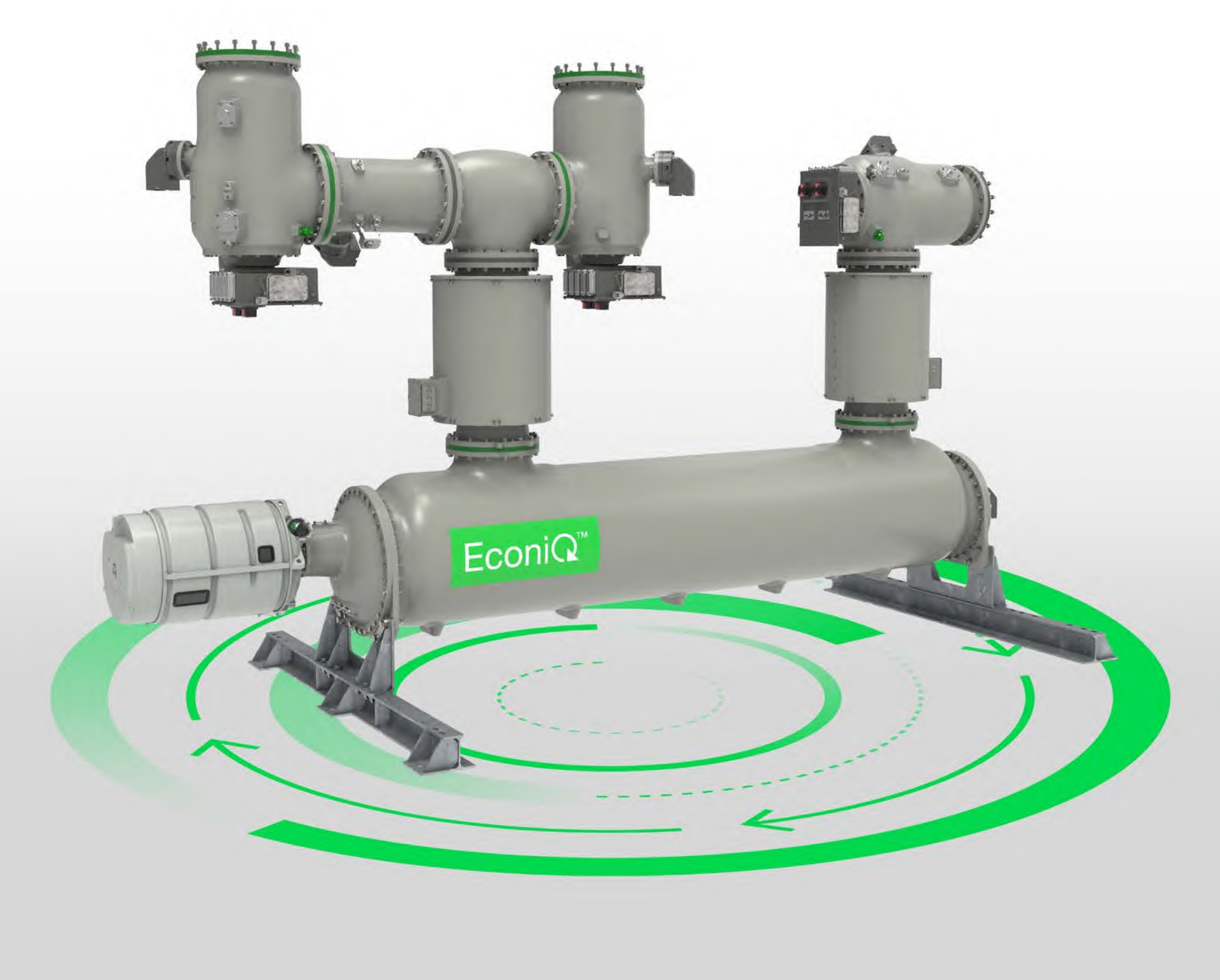
AR Okay, so that makes it a lot easier. But when we say SF_6 gas, there's one. What are we going to call this? Just new gas? What has Hitachi Energy named their solution?

MH Our solution is called EconiQ™.

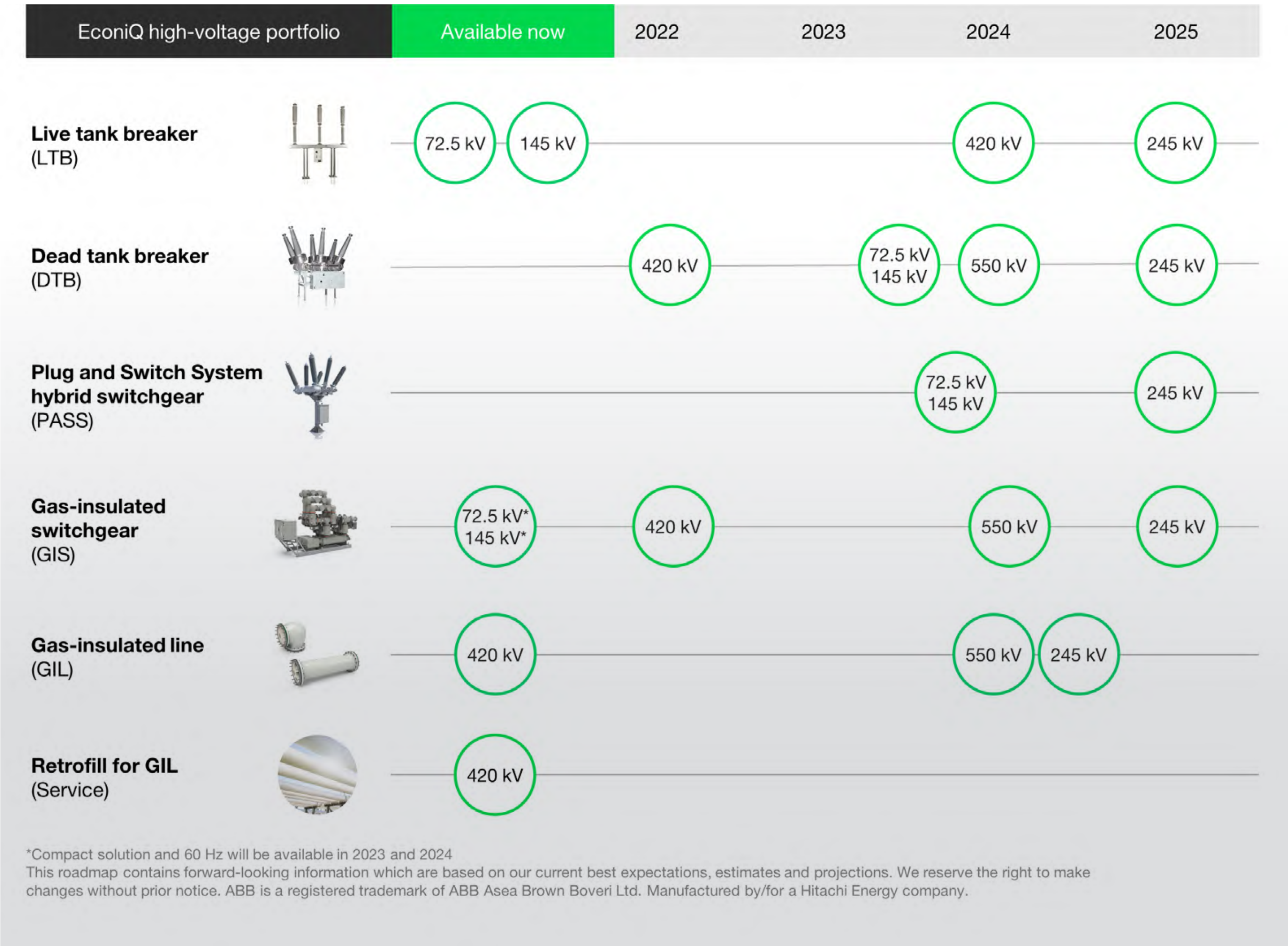
AR I really appreciate you sharing the insight because right now there is a lot going on in the high-voltage world. There's a lot going on in the utility world. And being able to have companies work together to solve a problem is the only way that we're going to move forward. There will be no one proprietary solution for the most part, right? And the fact that companies have worked together to create a solution, thinking of the end user is fantastic.

Tell me, Markus, what do you think is the normal utility timeline for changing things out?

MH It's a huge challenge and it cannot be done by just one company.



Hitachi Energy's breakthrough EconiQ™ 420-kV circuit-breaker unlocks the widest range of eco-efficient switchgear applications.



Hitachi Energy's EconiQ™ high-voltage portfolio roadmap eliminates SF_6 and accelerates the energy transition.

> SF_6 IS ALSO ONE OF THE MOST POTENT GREENHOUSE GASES. IT HAS A GLOBAL WARMING POTENTIAL IN THE RANGE OF 25,000. IT STAYS IN THE ATMOSPHERE FOR MORE THAN 3000 YEARS… AND CONSIDERING THE USE OF SF_6, IT IS NOT NEGLIGIBLE. HENCE, THERE HAS BEEN EVER-INCREASING PRESSURE OVER THE LAST DECADES TO PHASE OUT SF_6.

It is a huge challenge for us to develop a portfolio. At the end of the day, we need to have a portfolio which is matching the whole SF_6 portfolio in all voltage ranges, interruption, and current ranges, which have been deve-loped for decades. And now we have a huge pressure to phase out SF_6, mainly within this decade, at least in Europe and probably soon in the US as well. It is a huge effort to have good people who are able to develop this new solution. When it comes to the timeline, from a utility point of view, we are now undergoing the last type test for a 420 kV solution. We have already sold both prototypes and pilots to Eversource, for example, from the DTB side, the tank breaker side, into the US.

We have also sold to TenneT and to National Grid in Europe, 420 kV GIS, which will be installed somewhere between the middle of this year and the end of next year. We are now about to industrialize the solution and we can ramp up our offer so that we can provide the market according to the needs for SF_6-free switchgear as soon as possible and across voltage ranges. And our overall goal is to have the whole portfolio developed around 2025.

AR That's still a very aggressive solution time-wise. This ground-breaking and I applaud Hitachi Energy and your peers who have worked on this because sometimes these solutions get talked about, but they're not practical to implement. And you've got a practical implementation of that.

Hitachi Energy's EconiQ™ Retrofill replaces SF_6 in existing high-voltage equipment with an eco-efficient gas mixture.

Photo: Hitachi Energy

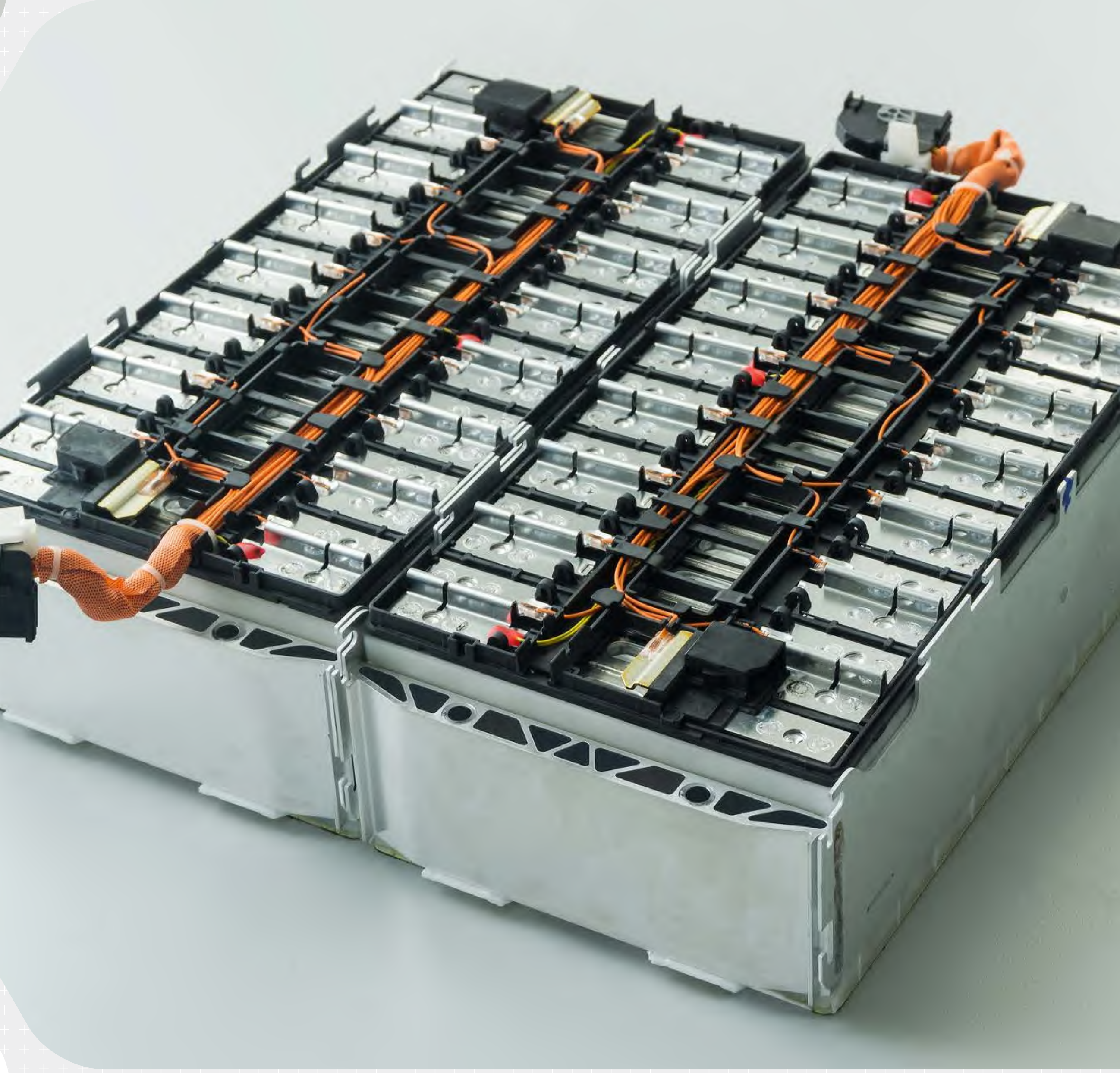
THE NEW SOLUTION HAS TO BE AS RELIABLE AS SF_6 IS TODAY... SECONDLY, WE NEED TO ACHIEVE A BALANCE BETWEEN A GAS THAT IS AS GOOD AT INTERRUPTION AND INSULATION, BUT IS SIGNIFICANTLY BETTER THAN SF_6 WHEN IT COMES TO THE GLOBAL WARMING POTENTIAL... AND AT THE END OF THE DAY, WE ALSO NEED TO HAVE A SOLUTION THAT SOMEHOW FITS INTO THE CONCEPT OF THE EXISTING SUBSTATION.

I appreciate that. Is there anything else you would like to reflect upon?

MH The huge transformation which we are doing here in Hitachi Energy being the spearhead of the industry is only possible when you have brilliant people on your team. And when you have as well, people who are not only brilliant but who work as one team. You need to have a seamless approach going forward. And what helps us here very much as it is not just the technical challenge of building up a portfolio. Also, it is something that is good for the people and for society. And this is a huge motivation that makes everybody go the extra mile to go achieve the roadmap that we have defined. And I appreciate that you are commenting on how aggressive it is.

AR One of these factors that are crucial in making this happen is the next generation of engineers. They want to make the world a better place. What you have done and what you are doing does exactly that. So, anybody who's thinking about going into this industry, will work with people that make the world a better place. Thank you for doing that, Markus. You're one of the leaders that is spearheading that, and I appreciate that very much.

MH Thank you very much. Alan. It was a pleasure to talk to you.



DV power

HOW TO USE BATTERY LOAD UNITS ? IN PROCESS OF REPAIR OR RECYCLING OF EV BATTERIES

It is becoming critical to recycle batteries to ensure environmentally friendly battery production, prevent human health risks due to inadequate disposal of certain types of batteries, as well as to secure very scarce and valuable raw material for production (nickel, cobalt, lithium, etc), which reduces the costs of new batteries.

Photo: Shutterstock, DV Power

A rapidly increasing demand for batteries, especially in automotive industry and energy storage solutions, combined with more stringent battery usage and disposal regulations, is putting pressure on battery manufacturers to optimize their waste management.

It is becoming critical to recycle batteries to ensure environmentally friendly battery production, prevent human health risks due to inadequate disposal of certain types of batteries, as well as to secure very scarce and valuable raw materials for production (nickel, cobalt, lithium, etc), which reduces the costs of new batteries. Increased electrification of the transport sector will probably require automotive industry to make close partnership with the recycling sector.

The increased presence of electric cars nowadays (e.g. in Norway and Sweden) leads to increased demands for battery workshops and recycling facilities.

Typical activities for electric cars workshops are:

- Replacement of bottom boxes on the battery base due to damage or rust,
- Replacement of one or more modules with deviations in cell voltage/capacity,
- Replacement of high-voltage contacts that were mechanically damaged (e.g. hit by some object, stone, etc.).
- Replacement of springs and contractors after an overload in an AC compressor or a PTC heating element.

The battery module which has one or more weak cells cannot be replaced with a brand new module, since the other modules are not in a new condition. It is required to work with used parts and modules with the same residual capacity as other modules in the battery pack. Hence, it is required to use battery load units (e.g. BLU-800C) and to balance and measure the capacity of the module which is intended to fit into the battery. This is done in the following way:

- Both modules (one which needs to be replaced and one which will fit instead of the malfunctioning one) are charged to 90% SOC.
- With use of battery load unit, both modules are discharged up to 30% SOC.
- Deviations in battery cell voltage are being monitored during this process and compared with the specification given in the technical data from car suppliers (Typically 10 mV to 0.50 mV results between the different cells in a battery).

The replaced module is usually very suitable for the second lift application such as a battery for solar panels, etc.

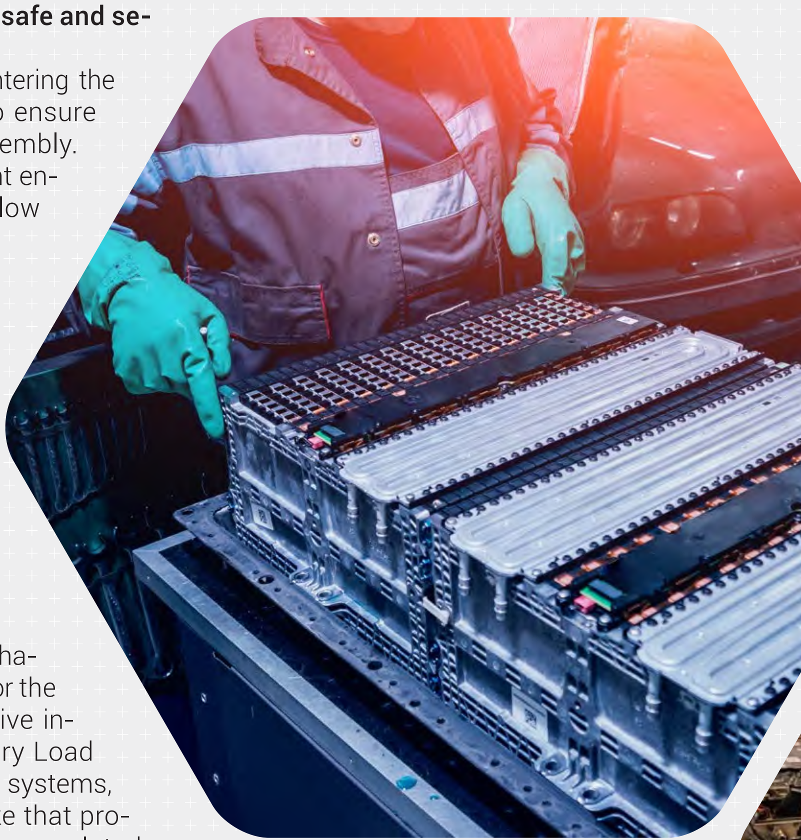
However, in some cases it is impossible to repair the battery pack, due to many modules damaged by water or some other cause. The damaged battery packs and modules needs to be prepared for the transport and recycling process in a safe and efficient way.

A few examples of damaged battery modules are presented in the following figure:

Figure 1.
Damaged battery packs

When it is decided that the battery has reached its end of life, the main question is: **How to prepare the battery for the recycling process in a safe and secure way?**

Fully discharging batteries before entering the recycling process is a crucial step to ensure safe and secure transport and disassembly. It is necessary to remove any remanent energy even from batteries with a very low State of Health (SoH).



Battery systems with nominal voltages of 400 Vdc or 800 Vdc are commonly used in newer generations of electric vehicles (e.g. Porsche Taycan, Audi e-tron GT, Lucid Air, Hyundai Ioniq 5, and the Kia EV6). There are some predictions that most of the EV industry is going to shift to 800 V by 2025, but this will depend on the decisions of the main manufacturers in the industry.

Considering the fact that we already have 400 V and 800 V systems available, for the recycling of batteries in the automotive industry it is important to have a Battery Load Unit capable of fully discharging such systems, from 800 Vdc down to 0 Vdc. To make that process more efficient, it is vital to ensure regulated current that is closely monitored during the entire discharge.

To avoid such uncontrolled temperature rise, besides monitoring the battery voltage and discharge current during the entire process, it is important to ensure temperature monitoring as well.

Due to specific battery characteristics, one deep discharge will not be enough for extracting all the remanent energy from the battery. Due to the *battery voltage rebound,* a rapid voltage increase will occur after the load is disconnected from the battery, even if the battery was previously discharged at 0 Vdc.

To prevent the *battery voltage rebound*, the Battery Load Unit should be used in combination with the Zero Voltage Discharge Module ZVD80. Besides enabling regulated (constant) current during the entire discharge process, the module drains remanent energy by short-circuiting the battery after the Battery Load Unit discharged it down to 0 Vdc.

The discharge current continues to be monitored and recorded and the battery is considered fully discharged and ready for recycling after the current drops to 0 A.

Figure 2.
Battery Load Unit BLU800C used for safe discharge of the batteries to 0 V

The most important demand in battery recycling preparation processes is

SAFETY!

Elevated demands on the battery recycling industry are challenging it to advance the processes in order to ensure shorter discharging times. This can be obtained by increasing the discharge currents, which can lead to an undesirable sharp rise of battery temperature or in extreme circumstances to temperature runaway and fire. In case of lithium batteries catching fire, toxic gases are released, life-threatening for the operating personnel.

Since the fire on lithium batteries cannot be suppressed with traditional fire extinguishers, special airtight containers with water tanks are used during the discharge process, as a safety measure. In case of fire, batteries are immediately immersed in water.

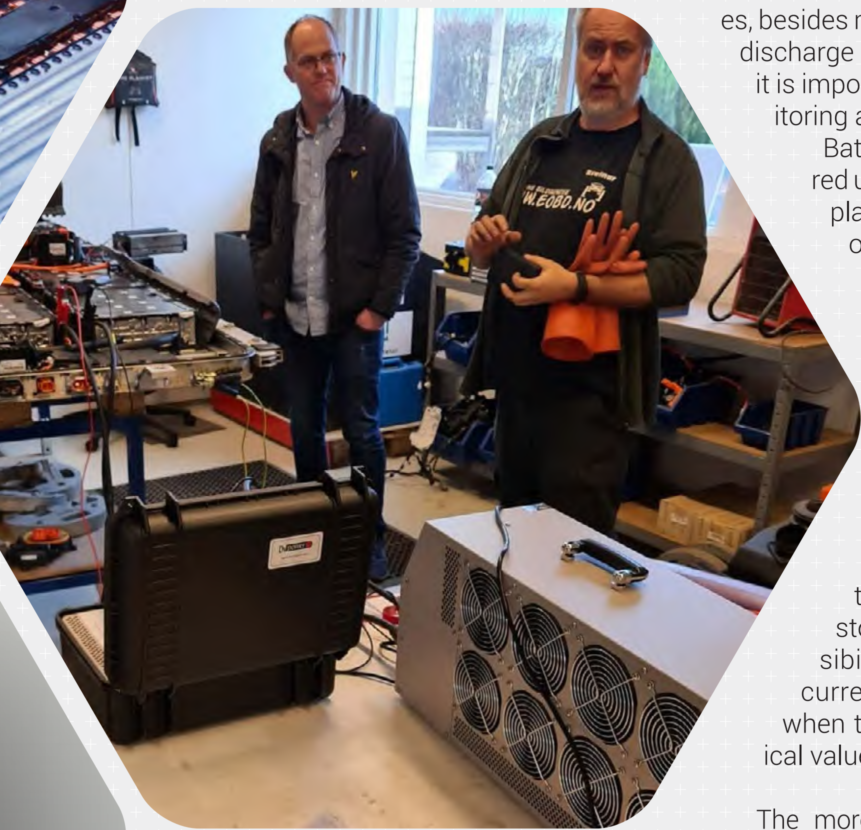


Figure 3.
Detached EV battery (left) and Battery load unit BLU360V (right)

To avoid such uncontrolled temperature rises, besides monitoring the battery voltage and discharge current during the entire process, it is important to ensure temperature monitoring as well.

Battery temperature can be monitored using several temperature sensors placed on chosen measuring points on the batteries or the thermal camera which have an alarm setting connecting to the BLU 800 remote control dry type, and the alarm indicates a dangerously high temperature over the entire battery and stops the discharge in a second. In case of a sudden temperature rise above the critical limit in any of those measuring points, the discharge process will be stopped. The operator has the possibility of decreasing the discharge current and continuing the discharge when the temperature is below the critical value.

The more advanced technical solution is to read measured parameters from the battery monitoring system (BMS) directly and control the discharge process accordingly. The BMS is usually an integral part of the batteries in electric vehicles, and it is possible to extract the necessary data important for the discharging process by using the CAN communication on BLU-C devices.

- Temperature of each individual battery cell or cell group
- Voltage of each cell or cell group
- Battery cell voltage deviation
- Isolation resistance

By monitoring the above- mentioned parameters, the operator can optimize the discharge profile for different battery types.

In case the BMS is not installed on the battery that is being discharged, or it is not available for any reason, BLU-C series can be used with its own battery supervising system, capable of monitoring battery cell voltages and temperatures, providing full control over the discharge process.

Photo: Shutterstock, DV Power

Inflation Reduction Act and Infrastructure Bill to transform US long duration energy storage market

by **Mark Higgins**

Photo: Redflow

Much has been said about the recently passed Inflation Reduction Act's impact on America's clean energy industry. The Act, combined with programs in the Build Back Better bill, is creating a massive restructuring of the energy sector in terms of project deployment scale-up, global supply chains, critical minerals, and local manufacturing.

Energy storage has long been the forgotten stepchild in the national clean energy tax code, with far fewer tax benefits than other clean energy technologies, and a lack of political support to get a standalone energy storage tax credit passed. The solar investment tax credit – under which energy storage systems paired with and charged by solar – was the primary mechanism by which an energy storage project could receive tax credits. However, this credit distorted the energy storage market by making storage paired with solar 30% less expensive than standalone storage or storage paired with anything else. On top of that, many customers couldn't monetize the tax credit, so projects that were otherwise viable never got built.

Moreover, battery manufacturing was heading the way of so many other advanced manufacturing sectors in our economy: overseas. For many reasons, the United States leads the world at innovation but hasn't been competitive at mass manufacturing. Battery manufacturing has followed the same path, with a few notable exceptions, where large scale manufacturing largely has taken place elsewhere.

But things are different now.

Mark Higgins, President, North America & Chief Commercial Officer at Redflow is a globally-recognised leader in energy storage strategy and an experienced executive with deep connections throughout North America's energy ecosystem. Mark served as chair of the US Department of Commerce's Renewable Energy & Energy Efficiency Advisory Committee, co-founded and serves as a venture partner at Resilient Earth Ventures, and is the former COO and board member of Strategen where he ran the company's global consulting business and managed the company operations. He has also held past leadership roles at PG&E, SunEdison, Fotowatio Renewable Ventures (FRV), MMA Renewable Ventures, the California Energy Storage Alliance, and the Vehicle-Grid Integration Council.

The Inflation Reduction Act's changes to the tax code, combined with grant programs in the Infrastructure Bill, stand to have a drastic impact on the competitiveness of American-made stationary energy storage – and particularly long duration storage.

With the IRA's creation of a standalone energy storage investment tax credit (ITC) previous projects that would not have been economically viable to use long duration energy storage are now much less expensive for buyers. The 30% base credit could in some cases cover well more than half the value of a project in scenarios where tax credits can be stacked. Those tax credit adders include:

- 10% when energy storage (and other renewable energy) projects can meet domestic content levels which increase from 40-55% over the next few years;
- 10% for being located on a brownfield site, a census tract in which a coal mine or coal-fired power plant was closed, or in which there was significant employment or tax revenue from extraction or processing of fossil fuels; and
- 10-20% tax credit adders for solar- or wind-attached storage projects in low income communities.

There are apprenticeship and prevailing wage requirements for most projects to qualify for the maximum tax credit levels, but all told these credits will result in projects that have significantly lower net capital costs than ever before.

Furthermore, now that energy storage no longer needs to be charged from solar PV to receive the ITC, the true flexibility of energy storage as a grid resource – and enabler of a resilient decarbonized grid – can be unlocked.

As grid planners know, storage doesn't need to be co-located with a renewable resource – and exclusively charging from that resource – to support the grid's resilience and enable it to integrate renewables. Storage Projects can now be sited on a standalone basis or paired with whatever energy source best meets the grid needs and maximizes the economic viability of the energy storage resource. The result: gigawatts of projects that didn't quite pencil before are now going to be economically viable. Energy storage will blossom throughout the grid in a wide range of configurations, locations, and with a diverse set of project objectives.

Where lithium was previously the go-to battery of choice due to cost, with proven tech and accessibility, the act will now provide space for the energy storage industry to diversify and enable the best

Storage Projects can now be sited on a standalone basis or paired with whatever energy source best meets the grid needs and maximizes the economic viability of the energy storage resource.

Photo: Redflow

technology to be chosen to suit the deployment.

The demand for lithium batteries has grown exponentially over the last 10 years, with electric vehicles dominating future demand, and resulting in supply-demand imbalances and battery shortages. Other factors driving interest in non-lithium alternatives include the immense supply chain challenges of lithium, commodity price pressures, and safety concerns. Furthermore, given supply chain constraints, a lithium battery deployed in a stationary storage application is essentially one less lithium battery available for electric vehicles – which is not a great public policy outcome.

Alternative chemistries – such as flow batteries - have always been the better choice for medium to long duration storage needs. Zinc bromine flow batteries, for example, offer a low fire risk, no degradation, an abundant supply chain, and the ability to work in a varied temperature range, and as a result they are now a serious contender for large energy storage deployments. Flow batteries are often better for stationary storage applications because of their rugged profile and the fact their performance doesn't degrade materially over their useful life.

As a proven technology class with one of the longest commercial track records outside of lithium ion, flow batteries are perfectly placed to deliver large scale megawatt energy storage cost effectively and play their part in contributing to an energy storage market that is expected to be valued in excess of US$31 billion by 2029.

Until recently, however, the market hasn't been ready, and lithium batteries had seemingly insurmountable advantages at the outset of the energy storage boom. Early use cases for energy storage were for applications like ancillary services, and to a lesser extent, energy arbitrage, which proved how useful a battery could be for grid applications. However, these early use cases for batteries were for power applications over short bursts of time – generally use cases where the vast majority of value could be captured from short duration energy storage systems.

Where lithium was previously the go-to battery of choice due to cost, with proven tech and accessibility, the act will now provide space for the energy storage industry to diversify and enable the best technology to be chosen to suit the deployment.

As a proven technology class with one of the longest commercial track records outside of lithium ion, flow batteries are perfectly placed to deliver large scale megawatt energy storage cost effectively and play their part in contributing to an energy storage market that is expected to be valued in excess of US$31 billion by 2029.

Photo: Redflow

Furthermore, companies producing lithium batteries came out of the consumer electronics space and had large, bankable balance sheets, unlike technology startups working on new battery chemistries optimized for the grid.

To this day, organized wholesale still generally aren't valuing longer duration energy storage (i.e., with a duration exceeding four hours) because market design hasn't caught up with the need for longer duration storage as renewables levels increase. Therefore, load serving entities in those markets, such as California, haven't had an incentive to procure long duration storage. However, US Department of Energy's ARPA-E research shows that the need for long duration storage increases significantly when renewables reach 60-70% of power capacity[1].

With all this being said, perspectives of the benefits of and the need for longer duration storage are finally evolving. The state of California has now started setting 8+ hour duration storage procurement goals, and utilities' integrated resource plans are increasingly showing the need for long duration storage to match supply and demand, starting in markets with significant amounts of solar PV such as the southwest and Texas. Furthermore, permitting authorities are increasingly seeing lithium batteries through the lens of fire risk, and the alternative chemistries of flow batteries are viewed as a safer chemistry. Many commercial and industrial customers of behind-the-meter storage are also scrutinizing the safety of lithium and are increasingly concerned about potential risks of siting lithium batteries close to customers, employees, and neighbors.

Thanks to recently passed legislation and the Biden Administration's priorities, DOE is now rolling out more than a half billion dollars[2] of grant funding for long duration energy storage starting with a $350 million pilot project grant program announced in November[3]. Long duration and alternative chemistry projects currently have an enormous opportunity to receive a "buy down" from the US government to help make projects competitive with short duration lithium ion projects, to prove new use cases, and to support manufacturing ramp-up of alternative chemistries. This is complemented by state grant programs, such as the California Energy Commission's up to $380 million program between now and 2024 to support long duration storage projects in the state, and by a massive infusion of loan guarantee underwriting authority at the DOE's Loan Program Office, leading to announcements of billions of dollars of investments in future long duration energy storage manufacturing facilities in the US. These programs can give long duration technologies the boost they need to both bring down their capital costs to meet or beat that of lithium, and to help overcome the structural market compensation disincentives for utilities to start buying longer-duration storage systems, even though in many markets, integrated resource planning shows a well-defined need for long duration storage as the energy transition continues to accelerate.

Of course, no one type of battery storage will tick all the boxes. A blend of battery technologies will enable the establishment of a strong and secure energy storage-based grid, and according to the Long Duration Energy Storage Council, long duration storage could provide up to 140 TWh of energy capacity by 2040, equaling approximately 10% of all electricity consumed worldwide.

While nobody can force changes to our energy infrastructure overnight, the Inflation Reduction Act has provided all the tools to accelerate decarbonization of our energy system and diversify the tools in our energy storage toolkit to include long duration storage. From tax code changes to DOE funding programs, the tailwind behind long duration energy storage should give it the jumpstart it needs to gain traction in the market, ramp up manufacturing capacity, and bring cost down to the point where it can compete on its own merits and economics. The opportunities created by the IRA have also focused the attention of buyers on long duration storage, accelerating their progression on the technology learning curve, enabling them to effectively evaluate and compare long duration technologies with their established peer technology, lithium ion. So, welcome to the next chapter in the clean energy economy – it's going to be an exciting decade for the US energy transformation, and for the maturation of long duration storage technologies and the critical role they can play in ensuring a reliable and clean 21st century grid.

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[1] https://www.ldescouncil.com/assets/pdf/journey-to-net-zero-june2022.pdf / p.11
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Kevin Meagher

Chief Science Officer
for The Sun Company

Interview with **Kevin Meagher**

THE SUN COMPANY

"The changes in the industry are this bizarre convergence of unfortunate events both from climate change and the resiliency factor that that's bringing into play, as well as the realization that distributed energy makes a lot more sense for resiliency, not just for reliability on the macro grid."

Photo: The Sun Company

Alan Ross: Hi. I'm Alan Ross, Managing Editor of APC Media. My guest is Kevin Meagher, he is the Chief Science Officer for The Sun Company. Kevin, thank you for joining us. Could you tell us how you got started in all of this and how you became the CSO of The Sun Company?

Kevin Meagher: I actually started in mission-critical applications, analytics really, in the semiconductor days. And there are industries that are very dependent on consistent, reliable power and that slowly migrated from semiconductor manufacturing to power. I've spent about 25 years at the beginning of the microgrid space working with a lot of battery technologies and battery startups for different organizations and then had an opportunity after I sold my previous company, to meet up with and join The Sun Company. And The Sun Company proclaimed a vision that is all about the democratization and rapid advancement of renewable energy everywhere.

And that company in particular has focused on what I believe is one of the really key technologies towards renewable energy, which is energy storage. We are currently developing our own flow battery, which I know you have some previous experience with, but it's a particular technology that's exceptionally well-suited to stationary applications like energy storage. And the combination of energy storage and the rapid expansion of renewable energy is just exciting. It's never been more exciting than right now to be in this industry, for sure.

AR Is it utility-scale?

KM It is utility-scale, but we're not focused on utilities. So, in fact, one of the things that we're doing is what we refer to as Independent Renewable Energy Power Plants. They're areas that are designated with the greatest possible amount of energy storage. But they do not have to be connected to the utility either because there is no adequate service in the location like the desert in California or in other places. So it is only connected to the utility when it makes sense. And I believe it makes tremendous sense. I'm one of those people who believe that microgrids will enhance the reliability and resilience of the macro grid instead of the other way around. Add to that the flow battery we are developing in collaboration with a couple of the Department of Energy national labs.

AR When the hurricane hit five years ago in Puerto Rico, I was the president of an organization called the Electric Power Reliability Alliance. We were asked by the DOE to look at the proposal to spend $5 billion to rebuild it. Our answer was that they should do storage and microgrids instead of big generation plants and sending power over the mountains.

If we had done Puerto Rico that way, the last hurricane would not have had the impact that it did again. We are coming to realize that the old system has done well for us but that it's not working anymore.

KM And it's funny because in every other advanced technology today, we always go to distributed architectures as the right solution. But it's been more difficult to do with power partly because power is a different animal. Firstly, nobody's going to get killed from having a bad cell phone but you can definitely kill people with power and start fires. So it's a lot more complicated problem. But there's no question in my mind that it's the right approach.

AR Let's talk about the idea that we're at a point, the inflection point where the whole decarbonization and renewable energy movement is happening rapidly. Battery storage has got to be a big part of that solution or else it just doesn't work at scale. So talk about the industry. From what you have seen, where we are today, and what are the current challenges that we're going to face?

KM I was fortunate enough to have been heavily involved in the DOE Sunshine Initiative and I believe that is one of the most successful Department of Energy programs that ever happened by far. And they're now doing something similar with the Grand Energy Challenge, trying to structure it the same way in a similar approach. But the changes in the industry are this bizarre convergence of unfortunate events both from climate change and the resiliency factor that that's bringing into play, as well as the realization that distributed energy makes a lot more sense for resiliency, not just for reliability on the macro grid. And there are other technologies like EVs that are really driving even more reliance on reliable energy than we've ever seen before. And then you throw in the Ukraine war and just the geopolitical problems that everybody's concerned about like supply chains, available technologies. And it doesn't just concern power people anymore but everyone.

AR One of the challenges that we most often hear about is the fact that we have built a sub-optimized grid. There is no real interoperability. How does what you do affect interoperability? How is The Sun Company becoming part of that interoperability equation?

KM Like many companies of our size, we are heavily dependent on enterprise software technology, which absolutely embraces interoperability as a primary consideration and one of the most important things to think about is the impact of cybersecurity on these mission-critical systems. So we've got the hardware components and all of the management of that from a power perspective and then the overlay of that, as we call it, our digital twin, which is this idea of designing a physical system electronically and then being able to simulate and modify that as well as operate it. I'm an IEEE guy too, so I completely understand a lot of the reliability concerns. And I think they come partly from the question of interoperability on the power side. Most people still associate interoperability with communications protocols. And the predominant communications protocol in the power industry still is the modulus. It's 20 years old, but it's the cheapest thing for a manufacturer to put on a board. So that's what they do.

The key to making this work is recognizing the fact that there is a significant amount of installed equipment that you have to work with. You don't have the luxury of replacing everything. So you have to be open architecture, if not necessarily open source, but you have to be open architecture and you have to embrace the standards like IEEE 2030 on our microgrid site. That makes all of this a requirement in order to meet that standard.

AR You're doing something at The Sun Company to change the world for the better but nobody can do it all alone. So talk a little bit about how The Sun Company specifically is addressing changing your world.

KM I have to give a shout-out to our CEO, Joley Michaelson. She's an unusual

Photo: The Sun Company

We want is to make a difference. And we're going to make a difference by delivering what we believe will be the best energy storage technology for stationary applications, as well as being able to address this democratization of power so that it's ubiquitous in its application rather than centralized.

visionary who has a passion for building an organization that has some of the best standards, objectives, and values that are well articulated and she makes sure we as a company live them. And part of that is also recognizing that to be successful, a company has to embrace all of the people that it impacts, not just the people who can afford something. So we look at what the requirements to deliver renewable generation are. And if there is an impediment to that or a dependency on something else, how do we solve that dependency? We are a unique collection of talented people that have lived through a lot of trials and tribulations over the past 15 years and have decided that we want is to make a difference. And we're going to make a difference by delivering what we believe will be the best energy storage technology for stationary applications, as well as being able to address this democratization of power so that it's ubiquitous in its application rather than centralized.

AR I'd like to talk a little about the whole idea of flow batteries. I was sold on them ten years ago and I didn't even know

Photo: The Sun Company

what they were, but I thought they sounded like something that could be a game changer because of the scale and the fact that they don't depend on lithium. Tell me a little bit about what The Sun Company does in that space.

KM The technology we use was developed at the PNNL lab and it's the highest energy density that we can get in a flow battery. We think that in order to achieve the kinds of penetration levels, we have to be able to get above 250 watts per liter. So starting to get to the low end of lithium, but not having the environmental concerns. And as you said, flow batteries are unique. With the exception of maybe annual servicing on pumps and switches, they really don't wear out. The electrolyte doesn't wear out. They don't require any special environmental conditions. And new advances have started happening a lot more in Europe now as well. A couple of months ago, there was a flow battery symposium in Brussels. The Europeans are now very focused on flow batteries. There have been huge advances in the past couple of years. Vanadium batteries were one of the early ones.

With the exception of maybe annual servicing on pumps and switches, flow batteries don't really wear out. The electrolyte doesn't wear out. They don't require any special environmental conditions.

Now the focus is on getting more energy density to get a smaller size. Because you really want to get a flow battery that will fit in a residential environment. Ultimately, that's where you want to be. I'm talking about homes, where you need high energy density, very good efficiency, and a footprint that ensures that you have extensive runtime on a 200 amp circuit.

AR That is a game changer. Are these going to be above-ground underground?

KM It's likely that the tanks will probably be below ground just because it's more stable, like the geothermal, but not necessarily so. And the power electronics will be in your garage.

AR That's excellent. The Sun Company hasn't been around for a long time. But obviously there's a pedigree with your CEO, yourself and many others. A lot of other people talk to me about the value system that makes it work.

KM I'm old enough to have been around a lot of organizations and companies that have professed a level of concern, whether

Photo: The Sun Company

they now refer to it as ESG or not, that is more for a report or more for talking points in an interview as opposed to the way they live it. And the difference with The Sun Company is that Joley leads by example. It's exactly what she says. We are always discussing not only doing things for The Sun Company but making sure we do things for our local communities as well. We ask our team members what they’re doing, how they're volunteering, what they're involved in, and how can we help in that process. As well as just some very simple things, whether it's authenticity, which is maybe the most important one, the quality of life and your life balance to the way you interact with other people around you. And it's the grit to be able to get through all that and a small set of values that really represent an extraordinary approach to problem-solving. It's getting everybody on board and everybody to believe it.

AR That is absolutely excellent. Thank you so much for being here today, Kevin.

KM Thank you so much for the opportunity, Alan, I appreciate it.

IoTecha
Accelerate Electrification

From the dawn of electric vehicles to a fully electrified world

How IoTecha and its partners are building the future of infrastructure

Electric vehicles are everywhere now, and that's no exaggeration. Gone are the days when private cars were the only type of transportation to be electrified — today, cargo trucks, buses, motorcycles, boats, planes, delivery vans, and more have joined their ranks in countries all over the world, alongside specialized infrastructure to support all manner of electric transportation.

The infrastructure that makes these vehicles work together with the energy ecosystem is perhaps even more transformative than the explosion of electrified transportation itself. But the process of developing this still-growing electric vehicle (EV) support did not happen overnight, nor did it happen on its own. So how did we get here? What makes this network tick? And what does all this mean for where we're headed?

The answers to these questions are complex and multifaceted, involving thousands of people who have been working for years to divest our world from non-renewable energy sources and all the geopolitical baggage that comes with them. A vital common thread weaving all these efforts together is the story of IoTecha — a company that is helping create a large-scale, unified EV charging system through cross-industry collaboration, where all the moving parts are interoperable with each other.

By focusing on interoperability and connectivity between vehicles, chargers, the power grid, and the energy environment at large, the people behind IoTecha helped set the stage early on for the wide-scale electrification of vehicles of all kinds. But in doing so, they also achieved something else — creating the conditions for electrification to eventually transform society itself and meet head-one climate challenges that affect all of us.

Before digging into where we are today, let's take a look at how far we've come.

As we all remember, the first hybrid EV to gain widespread popularity was the Toyota Prius. However, while the Prius was an important step toward greening the auto industry, it was still an island of increased sustainability in a sea of untapped potential. Even with the advent of the next major disruption in the EV industry years later, the all-electric Tesla Roadster which triggered a boom for EVs, the opportunities that EVs presented for the auto industry remained largely underutilized. In addition, the Roadster and other all-electric vehicles ushered in an era where a plethora of different charging methods and connectors appeared on the market, making the prospect of an interconnected global charging network that worked for everyone increasingly difficult.

To simplify charging and move the relationship between the EV driver and the energy domain forward, the way that vehicles interacted with chargers and the power grid had to change. That's where the future founders of IoTecha came in: in the late 2000s and early 2010s, they were part of an industry-wide movement to create a unified standard for EV chargers that would allow vehicles to connect with the power grid more directly and efficiently than ever before. This standard became known as ISO 15118, and having spearheaded this and other innovations, the founders of IoTecha established the company itself in 2016 to create products that accelerate the smart electrification of the auto industry at large. To meet this goal, IoTecha collaborated and continues to work with other players in the EV sector to encourage the adoption of the Combined Charging System (CCS), which implements ISO 15118, as the basis for interoperability within the industry.

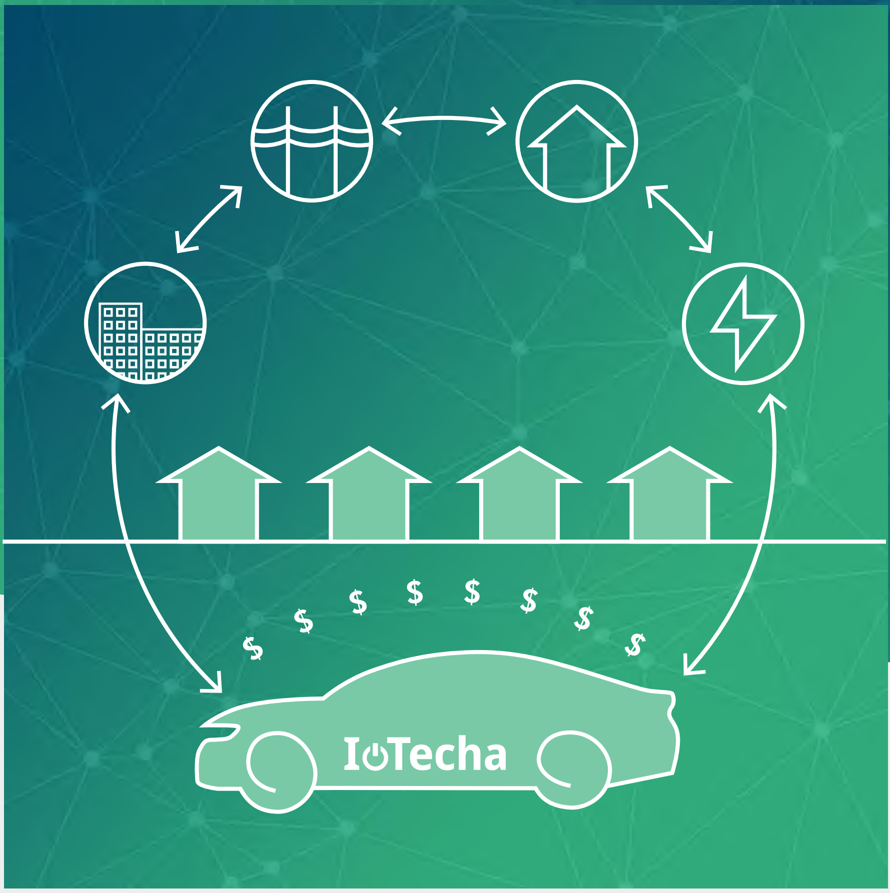
Why is this so important? As the nationwide, sustainable charging network continued to develop, IoTecha's products allowed charger manufacturers to produce intelligent chargers more easily, more rapidly, and more efficiently, while also creating improved communication between vehicles, chargers, and the energy grid itself.

Below, we can see the impact these technologies have had on the ability of a hypothetical customer, whom we'll call Nadya, to interact with the energy ecosystem around her. With opportunities for interoperability between chargers, vehicles, and grids, Nadya's vehicle can now not only be connected to the local power grid in a bi-directional fashion, but also to her home, her neighborhood, and more. Nadya and her vehicle are now able to distribute the charging load evenly through this system, save on electricity costs by selling power back to the grid, and create a more sustainable, less wasteful energy environment.

Years after realizing the potential that auto electrification holds for our society, IoTecha's products like white-label chargers, testing equipment, cloud services, and more have decreased the costs of electrification, creating the foundation for a fully integrated energy environment.

As the EV industry has continued to develop over the six years since IoTecha was founded, aided by investments in the development of a nationwide charging network, IoTecha has taken an ecosystem approach toward expanding EV infrastructure and making it more efficient,

Photo: IoTecha



more economical, and more accessible than ever. Although the industry still has a long way to go, IoTecha has been able to produce tangible dividends for businesses, individual users, and the energy domain at large, and has worked with vehicle manufacturers, EV charging network operators, and more to make that happen.

As we've already touched on, the first step in creating an EV infrastructure that works for all of us is interoperability, and several of IoTecha's products have made interoperable charging easier than ever.

IoTecha's charging solutions implement a variety of features that are crucial for sector-wide interoperability, including bi-directional power flow and Plug and Charge capability. The ISO 15118 standard makes vehicle-to-grid (V2G) communication possible, connecting vehicles with smart electric grids through the charging hardware. ISO 15118 is also used for Plug and Charge, which automates authentication and payment for charging and further simplifies the charging process. This last point is what these features are all about — making sure that charging EVs is as easy and intuitive for customers as charging smartphones.

Yet despite the benefits these solutions have given EV drivers and charging network operators, we're still missing a crucial piece of the puzzle — a mechanism through which the charging system's V2G capabilities can be customized to fit the energy environment that charging stations are part of. This is where IoT.ON, IoTecha's modular Internet of Things (IoT) platform, comes into play.

IoT.ON is a user-friendly, cloud-based tool that gives operators the ability to manage the way chargers and EVs interact with the grid through intuitive visualizations, unlocking the full potential of smart charging. With IoT.ON, charging station operators can achieve substantial savings on energy costs by implementing energy management strategies such as peak shaving, which cuts down on high electricity consumption peaks in a charging interval by intelligently distributing the load across devices in the ecosystem.

Peak shaving is only one example however, and IoT.ON has a range of customizable settings and modes through which operators can manage tens of thousands of devices distributed across a wide geographic range. Only by using a secure, scalable, and extensible platform can a standards-based charging infrastructure enable ubiquitous EV adoption across the world, and across transportation applications. In the process, by collecting data and putting it to use through artificial intelligence, IoT.ON opens up an exciting array of possibilities for the future of our built infrastructure that we can only begin to imagine today.

Below, we can see how IoT.ON enables individual actors within the energy ecosystem to distribute the charging load across various devices, buildings, and modes of transportation within the network to make charging as cheap, intelligent, and scalable as possible.

By lowering the barrier to the widespread implementation of EV charging infrastructure, IoTecha is giving individual drivers, station operators, EV fleet managers, and many

other players the ability to tailor charging systems to their specific energy needs. Each individual actor in this network can contribute in its own small way to making the emerging nationwide EV network ever more harmonious, accessible, and efficient, shepherding our communities toward a fully electrified reality.

A fully electrified future is no longer a pipe dream and could be achieved by extending the innovations that IoTecha and its partners in the auto industry have developed to a host of new domains, creating an energy-efficient, responsive, and data-powered world.

The total electrification of our society will take some time, but could ultimately result in a reality where everything, including personal devices, homes, businesses, apartment buildings, utility infrastructure, transportation networks on land, air, and sea, and entire urban areas work in concert with everything else. As we've seen from tools like IoT.ON, such an ultra-connected infrastructure would potentially yield a treasure trove of data that would then be used to inform how we live, the kinds of opportunities we create for each other, and how efficiently we manage our communities. If everything falls into place these vast datasets could lead to the development of optimized economies, smart cities, and AI-assisted politics.

This revolution in data utilization could create immense benefits for our civilization if used responsibly, but will likely also trigger new debates around privacy, government oversight, and corporate control. The key for balancing efficient data-driven organization with an equitable distribution of decision-making power, privacy rights guarantee, and protection of individual liberties will be the decentralization of managerial authority over energy and data governance to the community level, where individuals, acting in the best interest of themselves and their neighbors, will be able to be the masters of their own energy destinies — just like Nadya and Tim are within today's EV ecosystem.

The electrification of our world would bring enormous progress, giving us the tools to create dynamic communities that respond to the behaviors of the people who live with them and stave off the worst climate change scenarios — but in order to address the emergent externalities of this reality, we must approach this future with appropriate reverence and forethought. By working together over the coming decades, we can learn from our collective experiences in the auto industry to set ourselves up for success in the long term, beyond just the next product launch. This is the approach IoTecha has always taken and continues to foster with a wide swathe of players in the EV sector to create today the conditions for tomorrow's successes.

How boldly we wish to move toward a totally electrified future will be a central question that politicians, business leaders, consumers, and researchers will have to answer as the 21st century progresses. But what we can do today is make sure we overcome our differences to intelligently respond to the great hurdles our civilization faces right here, right now. Let's dream big, let's use the tools at our disposal to their full potential, and let's continue to open new opportunities to better our world — one EV charger at a time.

Photo: IoTecha

The Green Energy Revolution

by **Alan Ross** CRL, CMRP
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The power industry is currently facing a tremendous number of technology challenges as it works to adopt more green energy resources, such as wind, solar power and geothermal, into the grid. These challenges include:

Grid integration

One of the biggest challenges facing the power industry is integrating large amounts of intermittent renewable energy into the grid. Wind and solar power are dependent on weather conditions, which means that their output can fluctuate greatly. This can make it difficult to maintain a stable and reliable power supply. Given this challenge, it makes Distributed Energy Resource Management (DERM) one of the most important challenges for operators. Add to the problem will be the expansion of Microgrids which have the potential to disrupt supply and demand issues and further complicate things. More on grid integration when we discuss Transmission and Distribution issues.

Energy storage

Another major challenge is finding cost-effective ways to store the energy generated by renewable sources. Currently, the most common form of energy storage is by batteries, which can be expensive and have limited capacity. Developing more advanced forms of energy storage, such as compressed air, pumped hydro storage and flow batteries, will be crucial for the widespread adoption of renewable energy.

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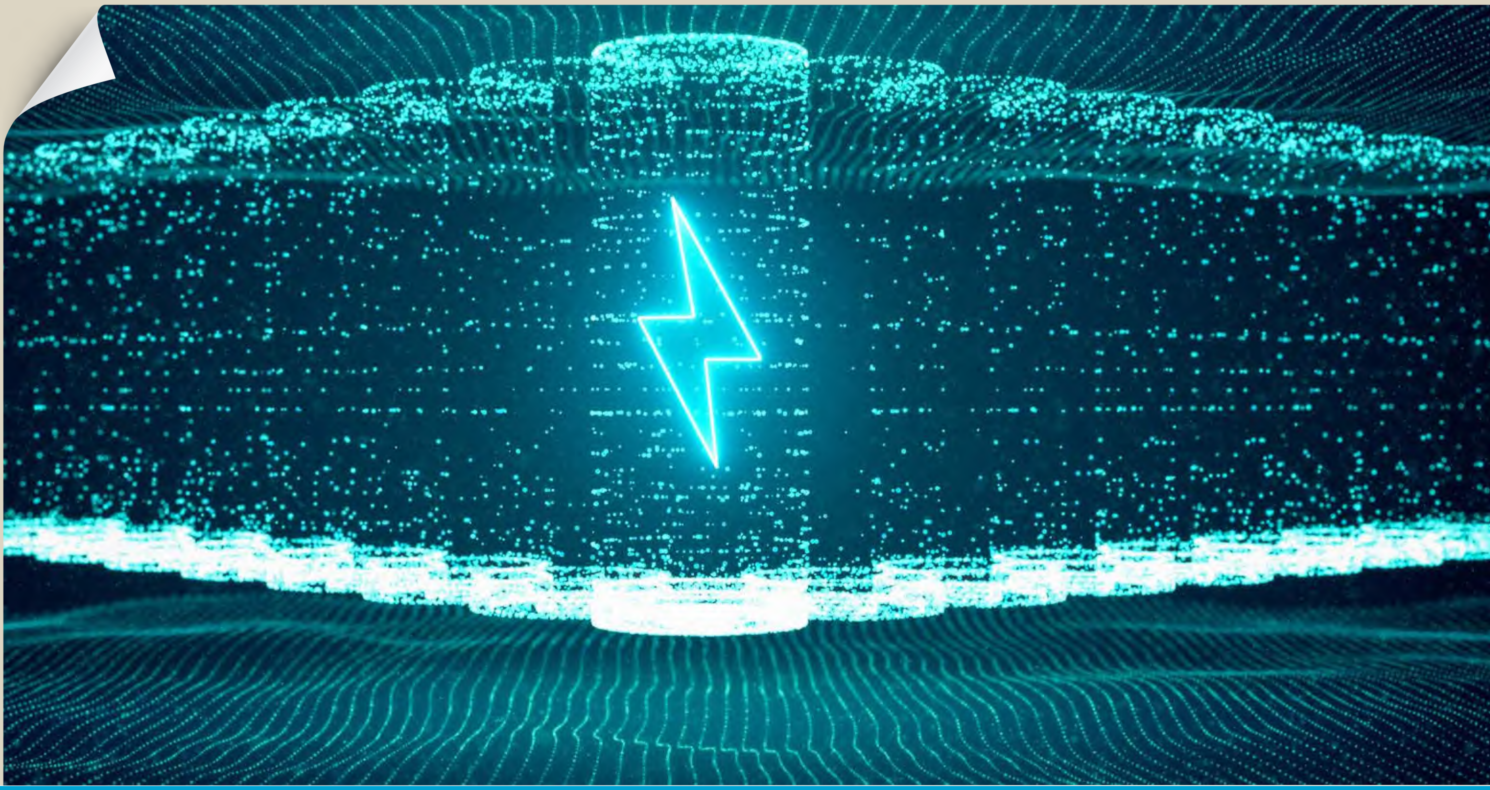
Alan Ross CRL, CMRP, is the Managing Editor of APC Media. Alan has decades of experience in the power systems industry and is one of the greatest reliability experts out there.



Flow batteries have some advantages over other types of batteries, such as lithium-ion batteries. They can store large amounts of energy, which makes them well-suited for use in renewable energy systems.

A flow battery is a type of rechargeable battery in which the energy storage components are dissolved in liquids that are stored in external tanks or reservoirs. The liquids are pumped through an electrochemical cell, where they are converted into electrical energy. This process can be reversed to charge the battery.

Flow batteries have some advantages over other types of batteries, such as lithium-ion batteries. They can store large amounts of energy, which makes them well-suited for use in renewable energy systems. They also have a relatively long lifespan, as the energy storage components can be replaced separately from the rest of the battery. Additionally, they can be quickly charged and discharged, which can be useful in applications such as grid stabilization.

However, flow batteries also have some disadvantages. They can be relatively large and bulky, which can make them difficult to install in some applications. They also tend to be more expensive than other types of batteries, which can be a barrier to widespread adoption.

There are different types of flow batteries exist, such as Vanadium Redox Flow Battery (VRFB), Zinc-Bromine Flow Battery, Iron Chromium Flow Battery, and many others. Each of them has their own advantages and limitations.

Transmission and distribution

As more renewable energy is added to the grid, there will be a greater need for transmission and distribution infrastructure to connect renewable energy sources with the main grid. Building new transmission and distribution lines can be expensive and time-consuming and may face resistance from local communities.

The integration of Distributed Energy Resources (DERs) such as solar panels, wind turbines, and energy storage systems into the transmission and distribution (T&D)

systems poses several challenges. These challenges include:

- **Grid integration:** as stated previously, integrating DERs into the T&D systems requires coordination and communication between the distributed energy resources and the central grid. This can be challenging as DERs may not be able to provide the same level of predictability and controllability as traditional power plants.
- **Grid stability:** DERs can introduce new types of disturbances and dynamics into the T&D systems, which can affect grid stability. For example, the sudden loss of many distributed solar panels during a grid blackout can cause additional stress on the grid.
- **Grid protection:** The integration of DERs into the T&D systems can require significant changes to grid protection schemes, which are designed to detect and isolate faults on the grid. This can be challenging as DERs can have different characteristics than traditional power plants.
- **Communication and control:** To effectively manage DERs, utilities need to have real-time visibility into the state of the distributed energy resources and the ability to control them remotely. This requires advanced communication and control systems, which can be complex and expensive to implement.
- **Cybersecurity:** As the integration of DERs increases the number of connected devices on the grid, it also increases the risk of cyber attacks. Ensuring the security of DERs and the communication systems that connect them to the grid is crucial to protect the integrity and reliability of the grid.
- **Regulation:** The integration of DERs also requires changes in regulations and policies, as well as coordination between utilities and regulators. In addition, DERs may not be subject to the same regulations as traditional power plants, which can create challenges in terms of interconnection, metering, and liability.

To overcome these challenges, utilities will need to invest in advanced technologies and develop new policies and regulations. Collaboration between utilities, regulators, and DER developers will be crucial to ensure the safe, secure, and efficient integration of DERs into T&D systems.

Smart grid technology

Smart grid technology is another important area of development for the power industry. Smart grids use advanced communication and control systems to improve the efficiency and reliability of the power grid. They also allow for greater integration of renewable energy sources and electric vehicles.

Smart Grid technology refers to the integration of advanced digital technologies, communication systems, and advanced metering infrastructure (AMI) into the electrical grid.

The goal of smart grid technology is to improve the efficiency, reliability, and security of the power grid while also enabling the integration of renewable energy sources and the integration of distributed energy resources (DERs).

The goal of smart grid technology is to improve the efficiency, reliability, and security of the power grid while also enabling the integration of renewable energy sources and the integration of distributed energy resources (DERs).

The key components of smart grid technology include:

- **Advanced Metering Infrastructure (AMI):** This includes the installation of smart meters at homes and businesses, which can provide real-time data on energy usage. This data can be used to improve grid operations and enable customers to better manage their energy usage.
- **Advanced Distribution Management Systems (ADMS):** These systems use real-time data and advanced analytics to improve the efficiency and reliability of the distribution grid by monitoring and controlling the flow of electricity.

- **Advanced Transmission Management Systems (ATMS):** These systems use real-time data and advanced analytics to improve the efficiency and reliability of the transmission grid by monitoring and controlling the flow of electricity across long distances.
- **Communication and Control Systems:** Smart grid technology relies on advanced communication systems to connect the various components of the grid and enable remote monitoring and control of the grid.
- **Customer Engagement:** Smart grid technology can also enable customers to better manage their energy usage through tools such as online portals, mobile apps, and in-home displays.

Smart grid technology can improve the efficiency, reliability, and security of the power grid while also enabling the integration of renewable energy sources and the integration of distributed energy resources. However, the implementation of smart grid technology also poses challenges, such as the high cost of deployment, the need for advanced communication and control systems, and the need for robust cybersecurity measures.

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Cybersecurity

The power Industry is also facing the challenge of securing the grid from cyber threats, as more and more advanced technologies are integrated into the grid and the number of connected devices increases, the risk of cyber-attacks increases.

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- **Protection of critical infrastructure:** The power grid is critical infrastructure that is essential for the functioning of society. A cyber-attack on the power grid could cause widespread power outages and have severe economic and societal consequences.
- **Vulnerabilities in communication systems:** Smart grid technology relies on advanced communication systems to connect the various components of the grid, such as advanced metering infrastructure, substations, and control centers. These systems can introduce new vulnerabilities to the grid and can be targeted by cyber attackers.
- **Interconnected systems:** The power grid is interconnected with other critical infrastructure systems, such as transportation and water systems, which can create additional vulnerabilities.
- **Increasing complexity:** As the power grid becomes more complex, with the integration of renewable energy sources and distributed energy resources, the number of potential vulnerabilities increases.
- **Financial losses:** Cyber-attacks on the power grid can cause direct financial losses to utilities and indirect losses to customers and the economy as a whole.
- **Reputation:** Cyber-attacks can also damage the reputation of utilities and can lead to loss of customer trust.

To protect the power grid from cyber-attacks, utilities must implement robust cybersecurity measures, such as network segmentation, access control, and incident response plans. It's also important for utilities to stay up to date with the latest cybersecurity threats and to continuously monitor and test their systems for vulnerabilities. Collaboration between utilities, government, and the private sector is crucial to share information and resources to help protect the grid from cyber threats.

Conclusion

The power industry is facing several technology challenges as it works to adopt more green energy resources into the grid. These challenges include grid integration, energy storage, transmission and distribution, smart grid technology, and cybersecurity. To address these challenges, the industry will need to invest in research and development, as well as work closely with government and other stakeholders to develop and implement new technologies and policies.

Roberto Jardón

Interview with Dr. **Miroslaw Wrobel** **CEO/CTO & Co-Founder** of Passero
and **Roberto Jardón** and **Regional Technical Leader** at Cargill BioIndustrial - Power Generation

Photo: Cargill , Passerro

Miroslaw Wrobel

Natural Esters: Insulation Fluids for Green and Reliable Transformers

Synthetic esters started in the 70s as the second generation. But at some point, several additional questions arose: can we make fluid based on bio-based material that also solves the fire safety issues?

Alan Ross: Hello, I am Alan Ross and this is more than an APC Media interview. It is in fact a big reveal. With us today are two extraordinary experts. One is Miroslaw Wrobel the CEO, CTO, and Co-Founder of Passerro and the other is Roberto Fernandez Jardón, the Technical Leader for Europe and Turkey at Cargill in the Insulating Liquids Division. And that's really what we're here to talk about, natural and synthetic esters. and some of the things that we found out as these gentlemen have worked together and people from Cargill and Passerro have worked together. But first of all, why do we need ester oils? When did their story start? Why did somebody have the idea to make oil out of plants and to put it in transformers?

Roberto Jardón: Well, natural esters were the first natural step, when we were thinking about the development of insulation fluids. We started in the 70s with silicon oil and some other fluids just to breach a gap in fire safety that mineral oil can't deal with. *Synthetic esters started in the 70s as the second generation. But at some point, several additional questions arose: can we make fluid based on bio-based material that also solves the fire safety issues?* In addition to that, it is biodegradable, and it comes from a renewable source. So some very smart guys that were working at Cooper Transformers at that time decided to explore if it could be made to work in the electrical field. And after several years of research, and a lot of different kinds of oils and plants, they came up with a very nice solution that added together all the properties that the transformer manufacturer was willing to have in insulation fluid and additionally having all these fire behavior that they were looking for.

AR So it could be said that safety was an important instigator, particularly fire safety. And since then, Cargill has developed a fire retardant, solution, FR3. But since those early days, we have found there are a lot of other advantages to natural esters as opposed to synthetic ones. And there is a difference between the two. We're going to get a little bit into it. Miroslaw. Let me ask you this question: What do we know about natural esters from a laboratory data standpoint?

Miroslaw Wrobel: We know much already, Alan. Esters will be a very good fluid, for instance in urban areas where we have a transformer close to people's homes, and that is for two reasons. Firstly, due to their fire-retardant properties. The flash point of natural esters is much higher than with mineral oil. Secondly, unlike crude oil derivatives, it's not toxic, and that is very important. We already know that the ester can handle the overload of the transformer much better than mineral oil. If you think about all the electrification levels we want to achieve in the future, like electric cars, and everything else that has to be electric and digital, just think about the amount of power that we will need. But changing out all the transformers in urban areas would be extremely difficult. So why not just change the oil instead?

Changing out all the transformers in urban areas would be extremely difficult. So why not just change the oil instead?

AR So, if I understand you correctly, Miroslaw, is that the data we're gathering is showing some really positive, unique values to esters. Anything else you would like to add, Roberto?

RJ Yes, I just want to add to what Miroslaw said. In addition to the higher flash point, esters are also better at handling moisture in the transformer which makes a huge difference. And that was something that was discovered while the FR3 was being developed. The initial tests were conducted in real-life transformers and distribution transformers.
They realized that the paper and the solid insulation aged much slower when immersed in natural ester than in mineral oil. We can discuss that a little. But the main idea is that we are having the same hardware installation around mineral oil and natural ester. And with natural ester, the transformer may last two to three times longer. And there are two ways of approaching this. We can have the transformer working in the same conditions, but longer, or we can explore the transformer working at higher temperatures. Both of these options are very important for handling overloads and this change in the energy consumption profile that Miroslaw was talking about.

AR Yes, absolutely. In the case of esters, we're finding that the law of

Photo: Cargill

unintended consequences was getting much more benefit, especially today. The demand for medium-sized transformers has gone crazy. Two years ago, we had a supply chain issue. Today we have a demand curve issue. The demand curve is going through the roof. So retrofitting old transformers can keep them lasting longer while you wait for a replacement.

MW We are considering the feasibility of switching isolating oil from mineral to biodegradable. There is a deep need to know how the oil is behaving and if our diagnostic and monitoring method is still fit for our purpose to gather the new information. For the last 100 years, we have been using transformers with mineral oil. The biggest question now is whether we can we apply all those standards to the ester oils, and whether we can expect the same behavior of green oil isolating systems. Mineral oil insulation has many disadvantages, but we take this into account and we try to counteract this with technical solutions like the berms under the transformers, and the constant replacement of the oil. But all of these "fixes" create costs and if the need for the transformers and the electrical power will grow as much as we think, these costs will go through the roof. Changing to ester oils will be the best way to bring these maintenance costs down.

We have over 160,000 data sets from Cargill and we go with the data in all different dimensions, and compare it with the isolating oil data. And I have to tell you, it is absolutely astonishing! The readings are almost perfect! Until now the huge nightmare of the mineral oil isolating transformer has been the acids and water inside it, degrading it and causing problems. These don't play *any* role with Cargill's FR3 and other esters. Instead of degrading, the BDV values are almost on the high because in a natural ester, the water reacts with the acids, hydrating them.

Changing to ester oils will be the best way to bring maintenance costs down.

So now you have less acid in the transformer, which means that the paper and the solid cellulose material stay stable for much longer.

You have to use something else. Another point is the different viscosity of the oil. The heat capacity is higher than with mineral oil and this means that you can *transform more energy* out of the core. Even better: You can make a smaller, more compact transformer. This means less copper and just generally fewer materials inside the transformer, which is great.

But we will probably have to have to think about different sensors to put on the ester transformer than on the mineral oil ones. DGA for mineral oil is one of the most important things to monitor. Large transformers have something like eleven DGA gases and the behavior of gases in ester-filled transformers is different. Here other factors like the flash point temperature the distribution of the temperature from the core and the viscosity are much more important. A vital aspect of the different viscosity of natural esters is, for example, the lubrication of the windings. Because if you have just paper-insulated windings and the oil is too thick to go through the windings, you will have just a dry removal of the paper inside.

RJ Exactly, that is an excellent point! Natural esters have proven to be not just reliable, but virtually maintenance-free. So what they discovered during the tests over the last years is that the higher moisture tolerance of the esters *extracts* the water from the solid insulation that is naturally generated because of the heating of the transformer. It *consumes* that water by reaction with the molecules of the natural ester. And as Miroslaw was saying, we keep the insulation dry to slow down the aging. But this consumption of water also generates free fatty acids that unlike in mineral oil, are mild and non-reactive. This means that they are *not generating a sludge*. So the very important thing to understand is that we can monitor the same things with mineral-oil-filled and ester-filled transformers, but the meaning of these parameters is different for mineral and natural.

MW Exactly! Another example is the temperature model of the transformer through which we calculate the flash point. It doesn't really work for natural esters, because the ester behavior and the heat dispersion are completely different than in mineral oil. So, you can't use those parameters.

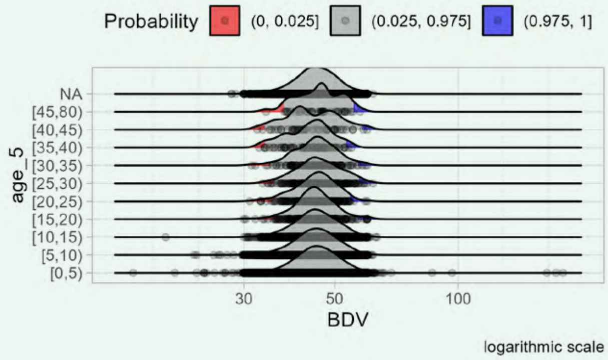
RJ That is a very good point, Miroslaw. With natural esters, especially when there is constant contact with oxygen, we can see long-term how the viscosity of the fluid may increase. Of course, it takes a lot of time, but this is a parameter that is not a routine test for mineral oil transformers but should be a routine test for natural esters because it's an important parameter. Another important thing is to differentiate the *meaning* of these occurrences for the two different insulators. We mentioned acids, which are very dangerous for mineral oils and it is something that needs to be monitored constantly. But for natural esters, it just means

We mentioned acids, which are very dangerous for mineral oils and it is something that needs to be monitored constantly. But for natural esters, it just means that they are working as they're supposed to.

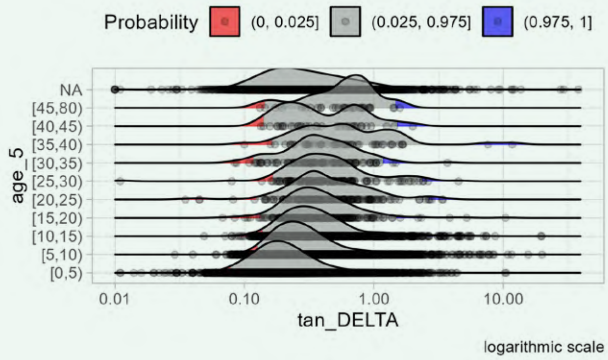
that they are working as they're supposed to. It's important to bring this knowledge to the people, to explain the *different meanings* of the tests and how they reflect not only the status of the fluid itself but the complete transformer.

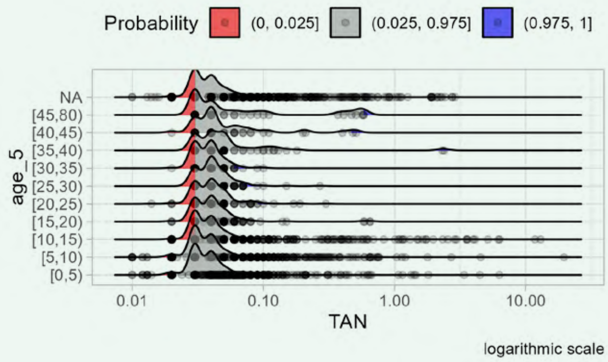
MW Oh absolutely. For instance, you can really overload an ester-filled transformer without serious consequences. If you try this with a mineral oil transformer, you can do this once or twice, and the third time you have a big explosion. You can exploit ester-filled transformers all you want and they will keep coming back for more. However, that still doesn't mean that we don't need some system to monitor the transformer, to tell them when it's enough. But the systems and the parameters used can't be the same as those used for the mineral oil.

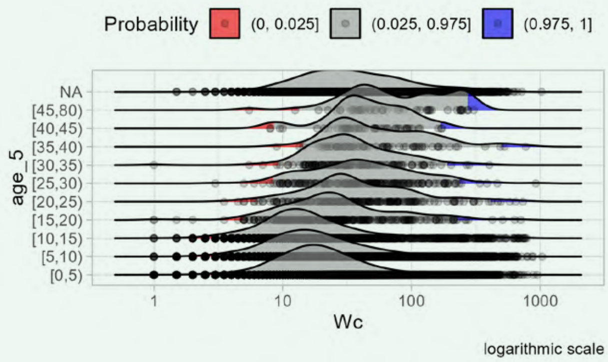
RJ And this is exactly what will enable utilities to deal with these different loads and strains on the network efficiently. And connecting with the smart meters that we talked about in the beginning, having the thermal behavior, the thermal image of the transformer, by measuring different points of the temperature inside the transformer with fiber optics can give you an idea of exactly to what extent you can exploit that transformer. For example, if you are having an ambient temperature of ten degrees and a ten MBA transformer under those circumstances, maybe can reach 12 - 13 MVAS without exceeding the temperature limits. And this gap is bigger in



To keep the numbers in the same style as in TTM Issue 24 - "Diagnostic Basics and Laboratory Data Sets", we also put the full age of the transformer with ester. However, note that the total amount of aged ester transformers in the following vintages is only [35,40) => 83, [40,45) => 61, [45,80) => 58. Another point is the compatibility of the BDV measurements. "The mineral oil is typically measured using IEC 60156 and the FR3 ester using ASTM 877. So 50kV with ASTM 877 makes about 80-90kV







natural esters than in mineral oil. So having the right material with the right monitoring can increase not only the reliability of the installation but the complete resilience of the network. That is something that we need to address urgently also in future network developments.

AR I think people are slowly realizing that transformers are the heart of the power system and how crucial they are because of it. And so what you both and your companies are working on, is quite brilliant. I'd like you to end with this question: Miroslav mentioned the operator, the owner of the transformer. Imagine you're riding an elevator together, he asks you what he should do and you have two minutes.

MW If you have a transformer, that runs with a sustainable and constant load, you don't need to do anything. If you have a transformer that deals with peak loads and peak comparison to the grid, photovoltaic, wind energy, etc. you *need to use ester* and you *need to measure parameters* like viscosity, temperature, and interfacial tension. If you have a transformer with a fault and are in a country with minus degrees Celsius like North Europe, or Canada, you have to keep an eye on the viscosity because it is not as straightforward as with mineral oil.

AR So now, Roberto, it's your two minutes.

RJ Natural ester is a natural and smart choice for transformers. First, you are having a transformer that is fire resistant, that has a fluid that is non-toxic and biodegradable. So in case of any spill or any issue, you will not cause damage to nature. You can explore your transformer at higher loads without jeopardizing the life span of the transformer. You are keeping the insulation dry, which reduced the risk of dialectic discharge or bubbling inside the transformer, reducing the risk of dialectic failures. So you are having a more reliable asset that makes your network more resilient to any change. Additionally, you are going to have the same footprint of the transformer will handle more power, meaning that you don't need to make any upgrades in the substation.

AR Brilliant! I think we made a good case for the benefits of biodegradable esters as the future of liquid insulation. Is there any other point that you think we've not covered?

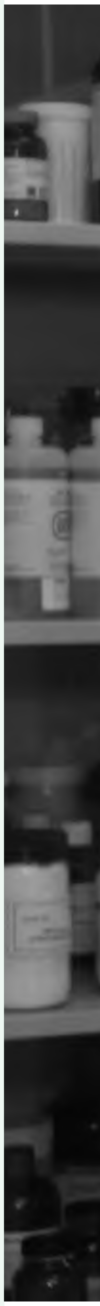
MW The most important part is just how the oil behaves in cold temperatures. If we keep an eye on that and perhaps adjust the technology a little, everything is doable and the transformer will work without problems. What some experiments with FR3 have shown is, that ester is much better if you have cooling with not laminar, but turbulent flow, because through the turbulent flow, you have more surface contact and you can take more energy out of the core. As I already mentioned before, the heat capacity of esters is much higher than that of mineral oil. So, you can make a compact transformer, but you have to make sure that you pump the oil through the transformer.

And of course, as I mentioned before, we need to adjust the monitors and what they monitor. We at Passerro are currently working on specific sensors for this. It will be something like the Trafostick we already have for mineral oil. At the moment, we can only monitor from the outside of the transformer, but we are extrapolating data from the core. We are still six to nine months away from working out the last kinks but after that we will have the sensor running just right and utilities will be able to just stick it on the transformer and let it be. And if something should go wrong, they will have the information and will be able to act. This will save lots of monitoring and maintenance time because with the increasing number of transformers, we won't be able to take care of all of them simultaneously.

At the moment, we can only monitor from the outside of the transformer, but we are extrapolating data from the core. After that we will have the sensor running just right and utilities will be able to just stick it on the transformer and let it be.

AR Roberto, what are your closing thoughts?

RJ I would like to cotton onto what Miroslaw said about the importance of this change in the shifting paradigm. We are adding a lot of harmonics in the system from E-chargers, photovoltaic or even wind farms, and even though these harmonics go through the network and reach the transformers, they have several implications. One of them is the harmonic currents, meaning that additional heating may happen on the coils, basically. And the second point is the voltage harmonics that may lead to partial discharge inside the



transformers. And this is something that we have seen in mineral oil transformers and that has been solved by retrofilling them with FR3, because the dielectric properties of FR3 regarding the partial discharge in temperature of voltage are higher than mineral oils. For this change and for this additional challenge that the transformers need to face, FR3 will still be the best solution.

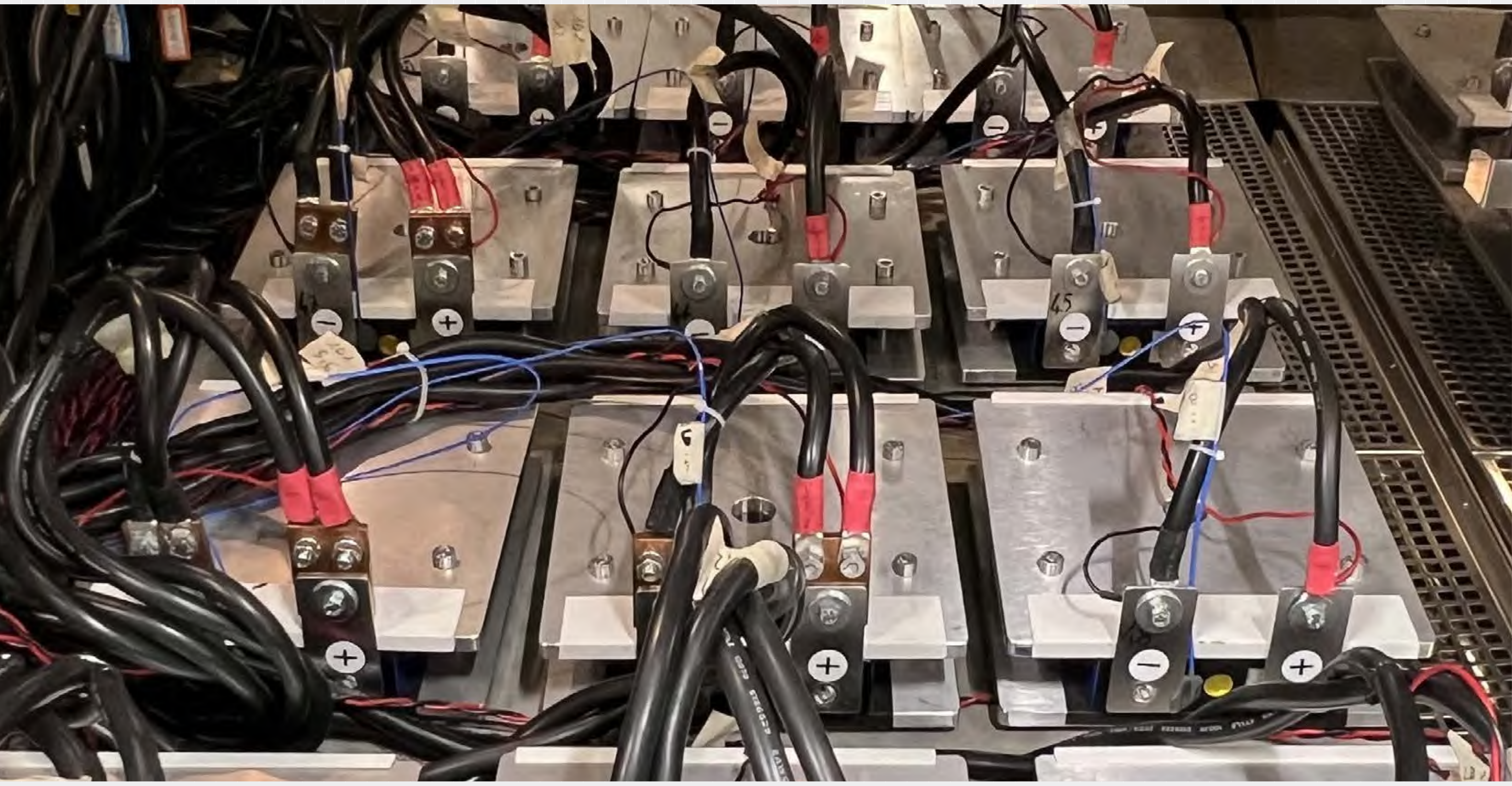
AR One of the things I walk away with from this interview is that we can't take the same parameters that we've looked at for mineral oil and apply them to FR3. We have to apply new parameters. But in every instance, we actually get a higher resiliency and a higher reliability. And those are the two big issues for power systems today. We need to take those better standards and apply them and know that we can operate our transformers much better. They can withstand all of these harmonics, all of these changes. The inverter-based system that we're moving to, power in, power out, you're going to have to have transformers that can withstand all of that, and filling them with sustainable, biodegradable esters will be the way forward. If I were buying a transformer now, I would firewire all around the coil so that I get constant data and I would fill it with Cargill's FR3, and I'd just sit back and be happy and my bosses would love me for reducing labor time and costs.

This has been a great discussion and revelation, gentlemen. Thank you so much for being here today.

RJ Thank you, Alan.

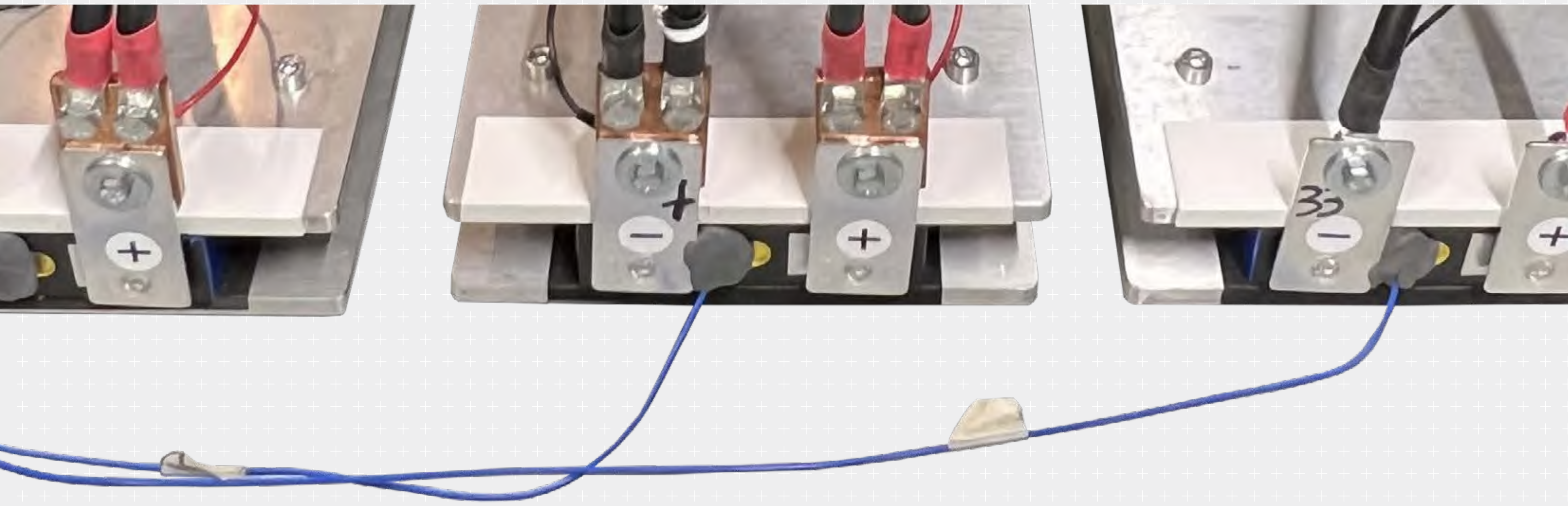
MW Thank you.

Photo: Cargill



E-MOBILITY DEVELOPMENT REQUIRES INTERDISCIPLINARY APPROACH, DEEP KNOWLEDGE AND BATTERY TESTING

HOW CESI IS CONTRIBUTING



A more sustainable approach to the use of electrical energy is widely spreading out in most sectors, ranging from stationary applications, such as energy storage systems both for domestic and for large plants, to e-vehicles, which are supposed to replace a big slice of the cars on our roads in the next years.

The use of energy in an electric vehicle must necessarily follow strategies different from those considered in combustion engine vehicles, given the different diffusion of the refueling systems which, for the electric vehicles, are the charging stations.

All current and future EV models should be tested for homologation (at both full vehicle and component levels) to ensure safety and conformity.

CESI Group designed specific laboratories to test the different E-mobility aspects.

CESI
Shaping a Better Energy Future

Test on storage solutions

Manufacturers focus on quality, safety and efficiency of the elements they produce; it is in this area that electric car battery testing and certification operates, ensuring that batteries, cells, chargers, and electrical components for use in e-mobility comply with global safety requirements and perform reliably.

Over the course of their service life, batteries, and their subsystems such as connections and cooling systems tend to deteriorate. This can result in a loss of battery performances, potentially leading up to a total failure. In addition, batteries in electric and hybrid vehicles come in a wide variety of sizes, shapes, weights, and chemical compositions. This makes it essential to carry out EV battery testing to verify durability, safety, and reliability of the components.

E-vehicles are supposed to replace a big slice of the cars on our roads in the next years.

Battery Cyclers for testing EV cells and battery modules

Photo: CESI

Electric car battery testing and certification ensure that batteries, cells, chargers, and electrical components for use in e-mobility comply with global safety requirements and perform reliably.

Whether Customers are seeking to bring new products to market or consolidating a developed technology, it is essential to be able to carry out non-destructive (pre-)testing of batteries, among which:

- Life cycle tests in conditioned environments
- Functional, climatic, and electromagnetic compatibility testing
- Performance measurements and modelling of new applications, including systems adjacent to the main energy storage system
- Failure investigation of energy storage systems.

CESI Battery Testing Laboratories lie in a context of increasing development, as batteries are more and more used, both in storage and vehicular applications. CESI tests samples of batteries with different technology, using different testing systems, thus gaining increasing experience and knowledge in this field.

The Battery laboratory is equipped with all the necessary instruments to perform battery testing, by guaranteeing a controlled environment, allowing the monitoring of the tests even remotely and providing a database in which to store the records of all the tests for later use and analysis.

Climatic chambers, **Cyclers** and **Data Acquisition Systems**, are the main tools available at their laboratories to simulate and reproduce the behavior of battery cells in the real world, where they power the vehicles and the storage plants.

Several climatic chambers, with volumes ranging from **1000 to 2000 liters**, are used to create and reproduce the environmental conditions, regulating both temperatures, from **-35°C to 180°C**, and humidity, from **10 to 98%**.

They are equipped with safety devices, to prevent and mitigate risks associated to Lithium battery operation. Climatic chambers have completely independent systems and are user configurable according to the needs.

The laboratories are also equipped with "cyclers", which impose charge and discharge currents on the batteries. These devices are built following the principle of modularity with independent channels, which can be parallelized to obtain currents even very high, up to 1200 A. The wide range of voltages makes them flexible in terms of possible applications.

Our specific laboratories investigate charging stations potential and behavior, carry out tests to assess battery lifetime, performs automotive EMC tests define semi-empirical models of battery associated to E-vehicles.

Test on charging stations

CESI is developing studies and technical/economic models to analyze how cars parked – and especially their batteries, if properly managed – could represent an invaluable "reservoir" in which to pour energy produced in excess during some hours of the day, so that they can return energy back to the electricity grid in case of necessity.

For years, CESI has been committed to the study and test of the best technologies for charging stations infrastructure. CESI/KEMA laboratories can test and verify e-vehicles power components which deal with remarkable current peaks circulating in a system of limited dimensions.

Water tightness test on charging column

Dust tightness test on charging column

Photo: CESI

When talking about E-mobility, safety requirements is extremely important;.one of the most striking and easy-to-understand examples may be the water and dust tightness tests on the charging columns. These tests are not conducted in live-circuit, as the risks of electric discharges would be hard to manage.

CESI laboratories are also equipped to evaluate how much stress the charging infrastructure is subjected to. The column is literally 'hammered in', using specific tools, to check its resistance.

Automotive EMC tests

Electromagnetic Compatibility (EMC) disturbances arising from the proximity of other electromagnetic devices could potentially interfere with the proper use and operation of the equipment for automotive. This leads to the most complex communication problems between the vehicle charging system and the station itself, for example.

In their labs, CESI uses anechoic chambers to test components and auxiliaries connected to e-mobility and their interactions. Anechoic chambers offer a controlled and reproducible environment to measure electromagnetic compatibility phenomena, such as the generation of electromagnetic fields by the devices and the effect of these fields on their operation.

Electric batteries are "a core component" of an EV, affecting the quality of the entire vehicle.

Developing of semi-empirical battery aging model

An accurate battery model can provide information about battery behavior, in conjunction with data coming from the working conditions.

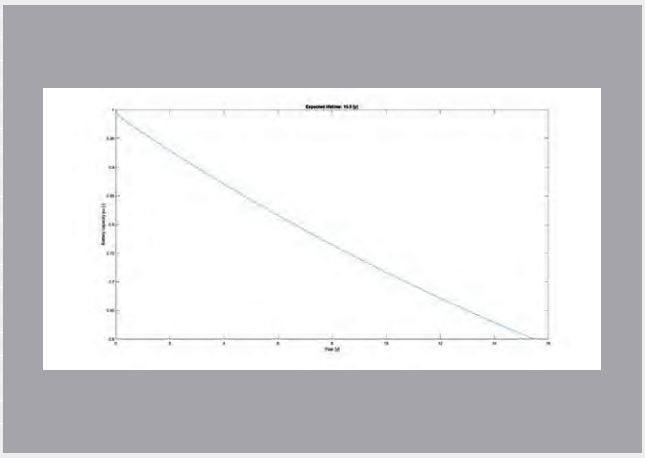
Some examples:

- Long term horizon, such as the degradation model of expected life.
- Short term horizon, such as predicting battery performances during the route of the vehicle.

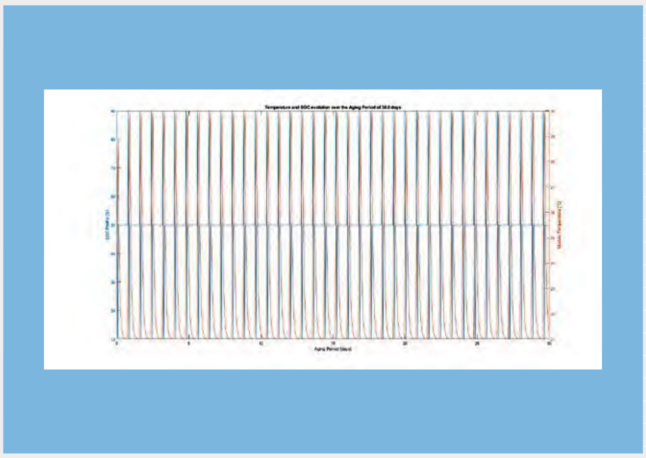
Battery cells model can be initially designed considering the physics and chemistry, using the "Analytical approach". This aprioristic knowledge suggests the proper selection of the data set for refining the model. A "Big data approach" will be used in combination with the analytical modelling when the complexity of the environment increases and interactions with exogenous factors and variables must be also considered.

Data both from the experimental tests and from the real-world flow into the model, improving it.

In the following images, you can find an example of the output of one aging model developed by CESI.



Aging model Output
Progressive capacity degradation of a battery module, depending on the operating conditions over its whole life



Aging model Output
Module temperature in relation with SOC profile

Regulations Paving Way for Widespread Installation of Smart Chargers

by **Kamil Maqsood**

- Developed countries across the globe are rapidly moving towards widespread adoption of electric vehicles.
- Regulations revolving around billing requirements, roaming, remote management and intelligent metering are themselves pushing for installation of smart chargers in some of the largest EV markets in Europe.
- With the widespread adoption of EVs, the traditional charging infrastructure will burden the grid infrastructure instead of supporting the grid.

Photo: Shutterstock

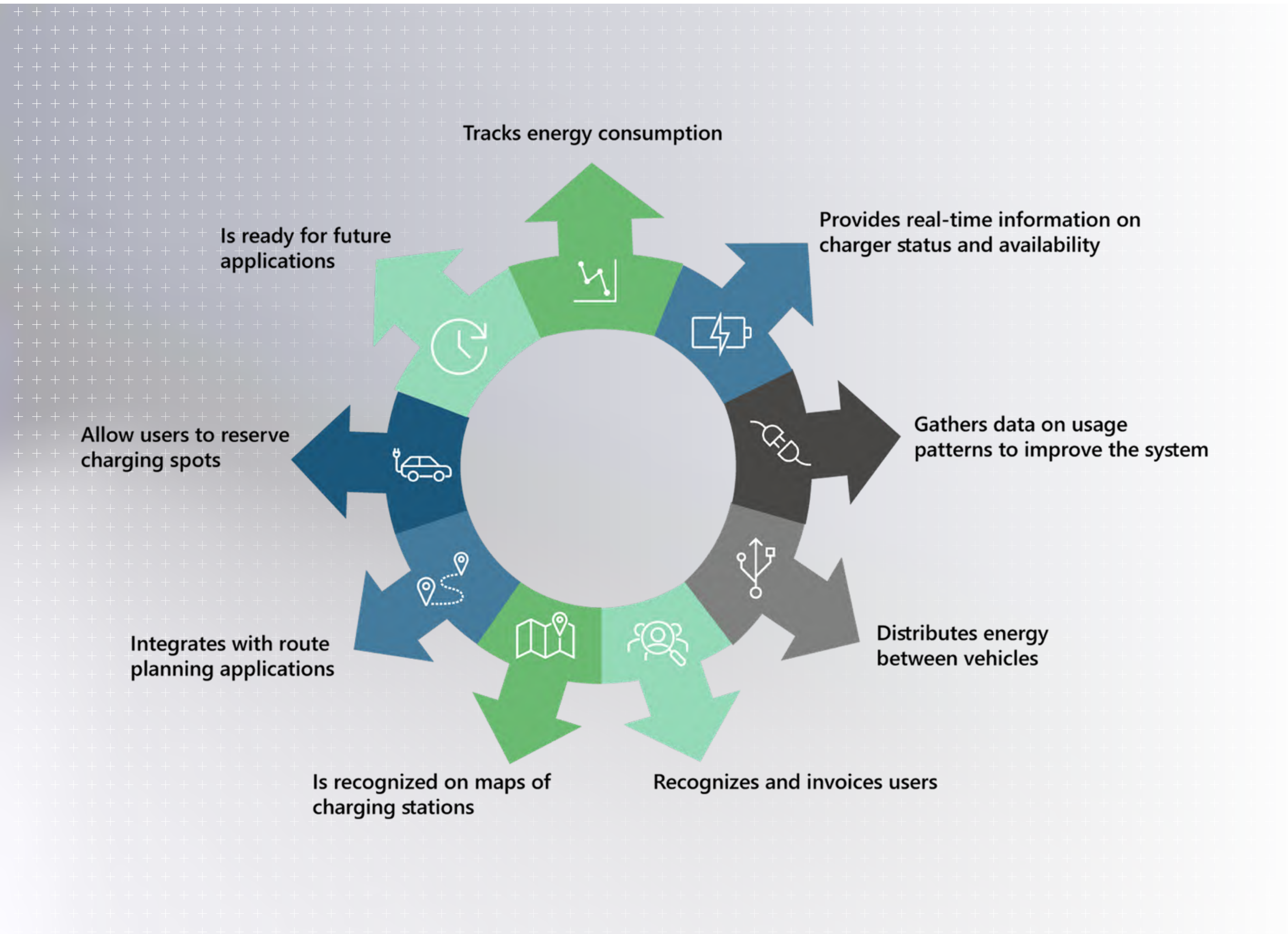


Figure 1: Smart Charging Enhances Customer Experience and Promotes Ease and Convenience
Source: PTR Inc.

Developed countries across the globe are rapidly moving towards widespread adoption of electric vehicles. This is driving the associated charging infrastructure which is necessary to sustain the adoption of EVs. It is expected that the EV and EVSE market of the future will be radically different from what it is today, so it is necessary to future proof the electric vehicle supply equipment technology keeping in mind the latest regulations and policies. This presents a challenge to present day Original Equipment Manufacturers (OEMs) of electric vehicle supply equipment who are responding by developing intelligent charging infrastructure, also referred to as smart charging infrastructure.

Contrary to traditional charging infrastructure, that is not capable of two-way communication, smart charging infrastructure includes multiple types of communication in real time:

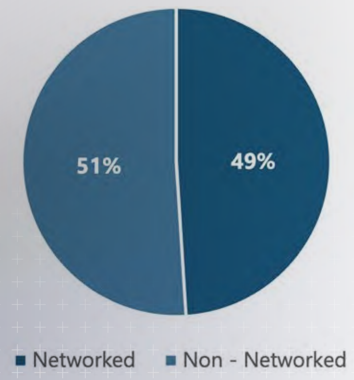
1) Communication between the car and the charger
2) Communication between the charger and the charging operator
3) Management of the charging event to support the needs of operator to alter the charging power without disrupting the charging event.

Kamil Maqsood is a Senior Technical Research Writer at PTR Inc. He has a BSc degree in electrical engineering from the University of Engineering and Technology Lahore and is currently pursuing a master's in electrical engineering from the Lahore University of Management Sciences with a focus on Power System Planning, Electricity Markets, Power System Operations, and Control and Battery Energy Storage Systems. At PTR, Kamil is responsible for the creation & editing of technical content for which he coordinates with the research team. Additionally, he has experience working with The World Bank (energy team) as STT Consultant.

Regulation on Smart Charging

Regulations revolving around billing requirements, roaming, remote management and intelligent metering are themselves pushing for installation of smart chargers in some of the largest EV markets in Europe: Germany, France and UK.

Figure 2: Share of Networked Chargers in EMEA in 2021
Source: PTR Inc.



Germany

In Germany each electric car driver should be able to charge and pay at the same time without requiring an agreement with a service provider beforehand. The regulation aims to ensure unhindered use of electric vehicles across operators, and municipalities can choose from the following payment mechanisms:

1) Cash or cashless payment (standard card-based payment system for instance credit card) in the vicinity of the charging point.

2) Web-based payment system (meaning a QR-code, app or

Figure 3: Chargers with Load Management Capability in EMEA in 2030
Source: PTR Inc.

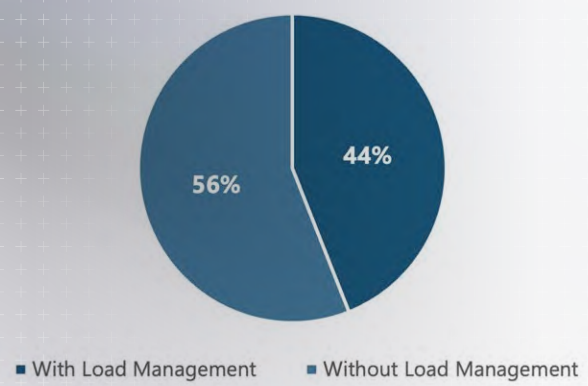


Photo: Shutterstock

website) including at least one variant of access to the web-based payment system (i.e., PayPal, credit card or others), which must be available free of charge.

3) The menu for charging should be available in at least German and English.

Similarly, regulations in Germany require chargers to have the ability to manage load as well which is a feature only available in smart chargers.

A charging infrastructure, open to the public, is operated by a charging infrastructure operator that utilizes a monitoring system that allows data exchange with each charging point. It also has the capability to monitor the status of charging points, and records the important parameters of service use, including those concerning the delivery of energy.

On the other hand, the French IRVE decree requires the use of a supervisory system that ensures

Furthermore, the charge point should be accessible remotely to the public through a data communication protocol and communication technology (Open Charge Point Protocol (OCPP) version 1.6 (equivalent or above). Additionally, the regulations in the UK require intelligent metering systems to be installed alongside recharging stations that are accessible to the public.

For three or more EV chargers, load management features are generally required in multi-unit buildings in Germany. With the installation of EV chargers, the utilization of electricity increases and to keep the network from overloading and for smooth charging of multiple electric vehicles simultaneously, many OEMs have integrated load management in their chargers.

France

Regulations in France require chargers to have the capacity to be managed remotely and to use a supervision system that supports EV roaming.

that each charging point accessible to the public can be monitored remotely. Interoperability can be achieved either through a contract or via a data exchange platform as provided in the decree.

United Kingdom

The UK has regulations that require intelligent metering, payment and data communication related features from EV chargers. For instance, charging stations in the country are required to have charging information displayed on a screen or at the time of service directly conveyed to the consumer through SMS, Web App or an email.

Looking Ahead

Traditional charging technology was a great help in the initial phases of EV charging deployment in Europe but as the region moves towards the widespread adoption of electric vehicles, smart charging infrastructure is a must. For the implementation of the latest regulations, smart charging infrastructure is a prerequisite. Secondly, with the widespread adoption of EVs, the traditional charging infrastructure will burden the grid infrastructure instead of supporting the grid (possible only through smart charging).

Diane Cherry

Interview with **Diane Cherry**

Principal consultant
at Diane Cherry Consulting

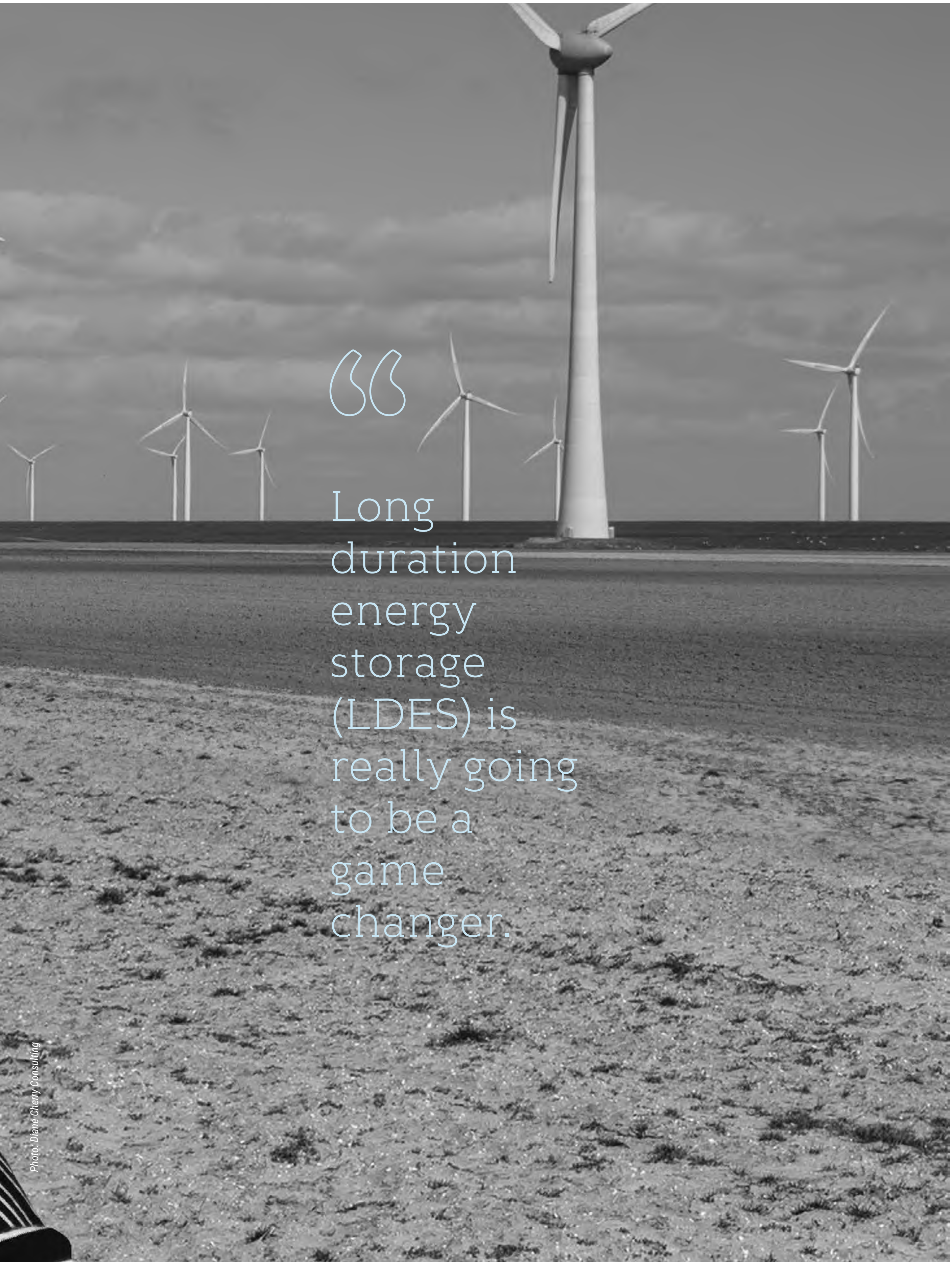


Photo: Diane Cherry Consulting

> Long duration energy storage (LDES) is really going to be a game changer.

Alan Ross: My guest today is Diane Cherry. Diane is the principal consultant at Diane Cherry Consulting, a woman-owned small business providing environmental and energy services in the areas of business development, policy and regulatory analysis, and communications. Diane, thank you for joining me today.

Diane Cherry: I'm delighted to be part of your conversation.

AR One of the things that intrigued me about you, Diane, is how involved you are in energy policy, regulation, and how they connect to green, clean energy, which is what I'd like to talk about today. But first of all, could you tell me how you became a policy consultant?

DC I've been in this field for about 25 years. My education was in economics, and after college, I worked for a non-profit research organization in Washington, DC. called *Resources for the Future (RFF).* RFF champions the application of economics to energy and environmental policy. Congress passed the Clean Air Act Amendments of 1990 while I was at RFF, and I had a chance to witness economic incentives at work in the acid rain provisions of that law. That's where my interest truly began, and it has only grown over time. I got my master's degree at Harvard, then I moved to Washington D.C. for a while, worked at EPA, and I've been in North Carolina for the last 25 years working on energy and environmental issues in the Southeastern United States. Energy is important to our lives each and every day. The work has changed immensely over the years and it always piques my interest.

AR I would like to address an issue with you: Clean and green energy have been used a lot of times interchangeably, right? What is the difference between clean and green?

DC There is a big difference and I think you're right, people do use these terms interchangeably. Clean means emissions-free, however resources might be limited or have some negative impact. Green energy, on the other hand, refers to energy that is good for the environment, with no emissions, and relies on renewable resources.

- Nuclear technology is clean but not green. Nuclear processes produce emissions-free energy but use finite resources and also produce toxic waste that has to be handled.

- Solar and wind, on the other hand, are clean and green because they're both emissions-free and utilize abundant renewable energy.

- Hydrogen as a fuel doesn't directly produce emissions so it could be considered clean. But if it's produced using fossil fuels, for example, as it is in most cases now, that's not considered green. That's why we have the distinction of green hydrogen, which is produced via processes powered by green, renewable energy and blue hydrogen which is produced using fossil fuels.

- Biomass is not clean or green, but it's often marketed as such and falls under a concept that you might have heard of - *greenwashing*. Burning wood pellets, for example, produces emissions. Wood pellets reduce some greenhouse gas emissions in the atmosphere but they don't reduce CO_2 overall.

That's why you can't really have a single key solution to alleviate climate change. You need a holistic approach, reducing emissions and other pollution across the board, utilizing renewable resources, and also taking steps to eliminate carbon and other pollutants that already exist in the environment.

Policy is a huge technology driver but it is most effective when it is a mandate as opposed to just a target or goal.

AR You've seen a lot of policy decisions. Where do you think policy positively or negatively impacts technology and vice versa?

DC Policy is a huge technology driver but it is most effective when it is a mandate as opposed to just a target or goal. Unlike a binding law, an Executive Order passed

Photo: Diane Cherry Consulting

by the President or a Governor does not have the same market push. For example, North Carolina just enacted a new law, House Bill 951: Energy Solutions for North Carolina. It requires a 70 percent carbon emissions reduction by 2030 and carbon neutrality by 2050. This is the first carbon mandate in the Southeastern United States and will serve as a market signal to clean energy developers that North Carolina wants and needs clean energy technology.

Consider a Renewable Energy Portfolio Standard as another example. The REPS, as it is called, may have a set aside or a requirement for renewable-powered electricity. It indicates a state's interest in green technologies and drives green investment and development.

North Carolina is the fourth largest in solar capacity in the country. Key favorable laws and policies over the past two decades spurred solar's success. These include generous interpretations of the federal Public Utilities Regulatory Policies Act of 1978, a now expired 35 percent renewable energy tax credit, and a renewable portfolio standard like I just mentioned.

AR Could you tell me where you see traction on green energy development? Places where you can say that's working. Some would say California is working, but there are times when it's not, like when it's been raining for weeks.

DC The American Clean Power Association, which is the association that includes energy storage, solar, wind, and transmission developers, has a new graph that shows all the renewable energy projects currently planned across the U.S. It shows where certain technologies are thriving. Offshore wind, for example, is going gangbusters in New England. We just had our first offshore wind project in Virginia, and we have two planned in North Carolina, but we don't have the cluster of projects that are in the New England area.

Energy storage is prevalent in California, which should be no surprise given that they have the most far reaching clean energy laws in the country. California must have some way to match the reliability and variability in their renewable energy generation and that is precisely what energy storage does. So if you look at the graph, you'll see a proliferation of energy storage in that state.

Virginia and North Carolina have a preponderance of utility scale solar projects. I already discussed North Carolina's history of solar support, and Virginia passed the

Photo: Diane Cherry Consulting

Virginia Clean Economy Act in 2020 which got them started. Virginia is home to technology companies such as Facebook and Google which demand that their operations be supplied by 100 percent renewable energy.

Texas deregulated their electricity system back in the 1990s, which forced power plant owners to compete based on who could offer the lowest price. As wind and solar plummeted in costs they gained an edge on older fossil fuel plants. Texas also has the strongest onshore wind in the country and some of the brightest sun. So their renewable energy success is part market structure and part geographic advantage.

As costs level out over time, there will be less geographic variability across the United States in terms of which regions specialize in what clean energy technologies. But the ACP map does indicate where things are going. The Midwest still has a ton of legacy fossil fuel

plants, so they don't quite have the proliferation of green energy like the rest of the country.

Consider a Renewable Energy Portfolio Standard as another example... It indicates a state's interest in green technologies and drives green investment and development.

AR If I were investing in the future of clean or green energy, or both, where would you suggest that I put my money?

DC Long duration energy storage (LDES) is really going to be a game changer. And by long-duration energy storage, I mean 10 hours of stored energy. Right now energy markets are focused on short term applications. Short term lithium ion batteries with a 4 to 6 hour duration have dominated the market to date, driven in part by the automotive industry trying to develop competitive batteries for electric vehicles. But that's not enough duration to allow green energy to disrupt natural gas peaker plants, which have replaced coal to provide dispatchable power at peak times.

Utilities across the country are developing their Integrated Resource Plans or IRPs, looking at the generation portfolio for the next 10 to 20 years, and they're getting rid of coal as it is completely uneconomical. As those assets are retired, then, where should we invest our energy? We ideally want an investment in green technology, but that will require LDES. Energy storage batteries require mining lithium, cobalt, or other minerals, which presents challenges. The U.S. only has one large lithium mine in Nevada, and it's less than 5 percent of the world's supply of lithium. We need to do more to ensure a supply in the U.S. So coming up with what the disruptive long-term energy storage technology can be, whether it is lithium-ion, whether it's something like sulfate, whether it's something entirely different, that's going to be, in my mind, the game changer.

The next game changer I see is green hydrogen. There are not a lot of commercial projects to date, but if three things are addressed it will be a great technology for our energy transition. First, projects need to have binding offtake agreements. Second, green hydrogen projects must have access to low cost, high load renewables. And finally, transportation and distribution infrastructure needs to be developed. Connecting supply and demand with transportation access is exceedingly difficult.

A final question that could make a huge difference is deciding what to do with baseload power. Germany is getting rid of their nuclear facilities in the aftermath of the Fukushima disaster. In the United States we're extending our nuclear facilities from the recommended 60 years to 80 years. Some at the Nuclear Regulatory Commission have even recommended extension to 100 years. But what do we have in place already? What are we going to do for baseload power? And I think that is the most interesting question in European countries as well as the United States.

AR Diane, this has been not just informative, but brilliant. Thank you so much for taking the time to discuss these important topics.

DC It was great. I enjoyed it. Thank you so much for having me, Alan.

Q&A

AN EXPERT Q&A WITH:

SALES MANAGER
TMC TRANSFORMERS

ANDREA GHIDINI

Photo: Shutterstock

Remarks about current situation and future expectations in dry type transformers market

What's the situation that characterizes the transformers market after the pandemic?

Andrea Ghidini: After the end of the covid restriction, we started to see two main factors that have characterized the market. The first was the increase in volume requested and the second was related to the increase of the cost of raw materials, together with a longer lead time.

Initially we considered this to be a reaction to the reduction in global activity due to covid, but we continued to see a significant upturn in orders and growth continued over many months that followed.

How is TMC positioned? Where is TMC investing?

AG: It all started five years ago, when TMC invested heavily in the dry transformer business. We saw continuous growth as a result, even during covid time we managed to retain all employees, which helped give TMC the platform to continue the journey and grow the business.

In order to maintain sustainable growth, we have always tried to anticipate the market, although what happened after covid was not easy to predict. Our investment continued with the purchase of new winding machines, new facilities, special tools for production and the latest software to improve design and production processes. In addition to this, TMC have and continue to invest heavily in bringing new people on board across all functions of the business. This will enable us to increase capacity in the medium and long term.

But we didn't stop there! We've expanded our global presence by opening new facilities in both the USA & Israel.

What's the most complex challenge we're facing? How will we overcome it?

AG: The most challenging aspect, first and foremost, is to secure material and to manage prices.

More recently, the signs are that the availability of material has increased, although lead times remain long. Over that past few months, we have learnt how to manage our supply chain more effectively, thus improving the management of longer lead time projects, mitigating the risk linked to cost variations.

We also encountered challenges relating to the availability of skilled people that we need to continue our growth plans. In many ways we are fortunate to be based in a region where we can find experienced people, on the other hand we have worked hard in to retain our employees by investing heavily in Human Resources.

Our investment continued with the purchase of new winding machines, new facilities, special tools for production and the latest software to improve design and production processes. In addition to this, TMC have and continue to invest heavily in bringing new people on board across all functions of the business.

The pandemic changed market variables.

TMC Transformers faced this complex background with resiliency and strength.

Which sector is seeing the most growth, both in Europe & the USA?
AG: Overall, the economy has a positive trend, with most applications requiring dry type transformers demanding more investments. The need of a green transition is creating more & more new opportunities for infrastructures that are linked to new technologies such as Hydrogen production, electrical chargers and battery storage.

Global digitalization is creating a need for new data centres and a growing demand for clean energy is driving investment in renewable energy generation, together with new and more-efficient distribution infrastructures.

How is TMC set in the green economy?
AG: Following a period of considerable investment in R&D, we are now delivering products for traditional renewables, such as wind and solar. TMC have also developed innovative solutions that support hydrogen production, improving our products continuously in order to position ourselves as a reliable supplier to our customers that supports demanding applications where dry transformers play a fundamental role. These technological advances mean that TMC's dry type transformer offer is a very credible alternative to traditional, liquid-filled assets.

When it comes to our internal approach to sustainability, we've invested in processes that enable us to reduce the CO_2 emitted by our facilities. We installed an array of solar panels on the roof of our main production site, which has a capacity to generate more than 1 GWh/year. Other initiatives include the recycling of packaging, reduction in the scrap material that we produce in many operations and the installation of more efficient tools to reduce consumption.

TMC has also composed the Carbon Footprint report that let us to quantify the greenhouse gas emissions associated with the life cycle of the products offered and communicate the results outside.

How has TMC grown?
AG: TMC's success in the market to-date has far exceeded our expectations. The positive return that we've seen, both in standard and special products, is a direct result of and driven by the competence of our people and the quality of TMC products.

The original plan was to enter the market and try to meet the needs of our customers, providing competence, flexibility, reactivity and proximity to the market. To implement this, we managed to hire a team of people with many years of industry experience in all strategic functions, including Sales, Engineering, Production and Quality.

We then reinforced other key functions, such as marketing and IT, with highly skilled people that complemented and added value to the team.

So, the human capital is the for sure the main driving factor of our growth.

The future of TMC?
AG: Our achievements to date have put TMC in a very strong position, which will help us realize our future plans. Our growth is not only linked to market expansion, but also to high penetration of the customer base. We've created a strong network of agents and distributors across the globe and the return we are having is based on solid relationships with our customers.

We are positioning our products and overall offering into new applications and solutions, differentiating in numerous areas and, therefore, operating independently from the economic cycle. TMC work tirelessly to mitigate risk and take advantage of these positive trends.

We will continue to develop our global footprint, expanding into developing regions.

NEXT TECHNOLOGY GROUP

TMC Transformers SpA - Viale dell'Industria 65, 21052 Busto Arsizio (Italy) - marketing@tmctransformers.com

Transitioning to Green Energy
How Utilities Can Leverage Thermal and Visual Monitoring

by **Richard Harada**
Marketing and Product Management teams leader
at Systems With Intelligence

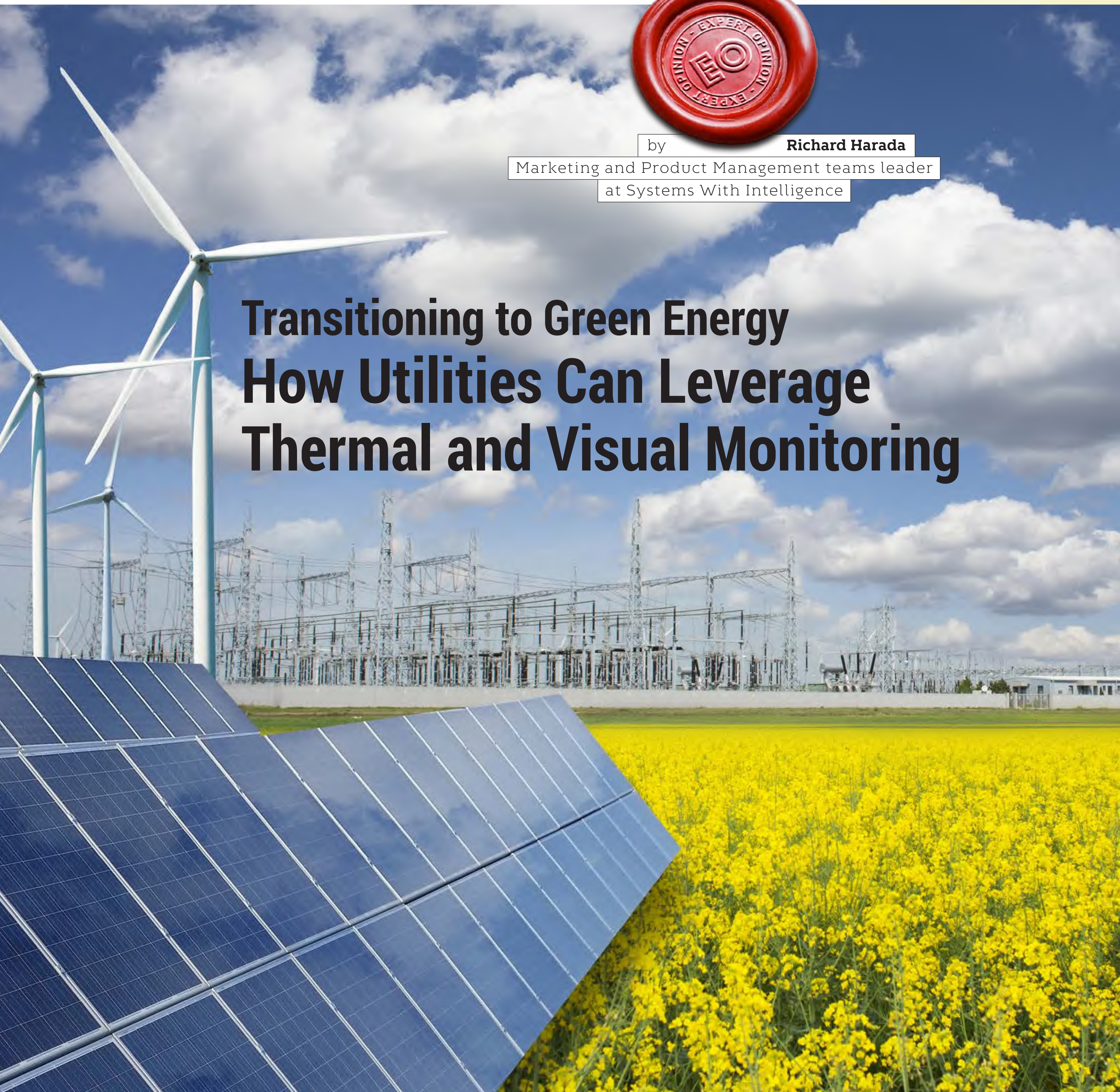
Around the world, both governments and utilities are striving to reduce the greenhouse gas (GHG) emissions of the electricity sector through renewable and sustainable generation technologies.
While these efforts have resulted in significant progress, there is still a substantial amount of work left to be done to fully decarbonize the grid while delivering affordable and reliable power to customers.
As utilities continue to transition, they will also need to adapt their maintenance programs to a more complex and varied environment. With more substations, new generation facilities, and a wide range of new technologies all spread across a wide geographic area, utilities need a cost-effective and proactive approach to maintenance and repairs.

This article will highlight some of the major green energy initiatives in Canada and the US before showing how utilities can leverage advanced thermal and visual sensors to monitor green energy infrastructure.

The Role of Green Energy Today

Green energy initiatives such as wind, solar, and hydroelectric are primarily being implemented to reduce the GHGs produced by the electricity sector.

While the volume of carbon dioxide (CO_2) and carbon dioxide equivalent (CO_2e) depends on the fuel source, the power generation sector contributes a significant portion of total emissions in both Canada and the US.



Richard Harada heads the Marketing and Product Management teams at Systems With Intelligence and he has over 20 years of experience in industrial networking communications and applications. Richard's role at Systems With Intelligence is ensuring that products are developed to solve customer needs. Richard has previous work experience at RuggedCom and Siemens Canada where he was focused on business development and product management for communications in the electric power market. Richard is an Electronic Engineering Technologist and has a Bachelor of Science degree in Computer Science from York University in Toronto.

The US has reduced carbon emissions in the power sector by 40 percent since 2005, mostly attributed to the transition away from coal in favour of natural gas.

Fossil fuels are still the primary source of electricity in the US, with natural gas and coal making up 61 percent of the total energy mix. Renewables, including wind, hydroelectric, and solar account for 19.8 percent, followed by nuclear at 18.9 percent.

Because of this heavy dependence on fossil fuels, electricity generation produces about 32 percent of the country's total CO_2 emissions, or about 1,552 million metric tons of CO_2 each year.

Canada, on the other hand, relies more heavily on renewable energy sources. Hydroelectric power contributes to 59 percent of total generation, while a further 15 percent comes from nuclear. As a result, the electricity sector in Canada only accounts for 8.33 percent of total CO_2e emissions, or 56 million metric tons of CO_2e per year.

Government Efforts to Lower Emissions

Governments in both Canada and the US are setting aggressive targets to reduce emissions.

Already, the US has reduced carbon emissions in the power sector by 40 percent since 2005, mostly attributed to the transition away from coal in favour of natural gas. Similarly, Canada has reduced electricity sector emissions by 52 percent in the same period, as provinces like Ontario retired coal-fired plants.

The Canadian Government has increased its 2030 targets to reduce total emissions by up to 45 percent from 2005 levels and has set a target to reach net-zero emissions by 2050. The US has been even more aggressive, with the Biden Administration aiming to slash utility emissions by 2030 and achieve full decarbonization by 2035.

The Role of Thermal and Visual Sensors

Advanced thermal and visual sensors provide continuous, real-time monitoring of utility infrastructure. As green energy initiatives become more prevalent, utilities can leverage these solutions to enhance reliability, reduce the cost of physical inspections, and allocate maintenance teams more effectively.

Inspecting Wind Turbines

Wind turbines pose a unique challenge when it comes to maintenance. Technicians require knowledge of both mechanical and electrical components, and they must be trained to work at heights and in cramped, tight environments. A single inspection can take a full day, require multiple technicians, and cost thousands of dollars.

With hundreds or thousands of individual panels, it can be difficult for maintenance teams to identify and pinpoint issues, especially as there is often no visual indicator of a problem.

Photo: Shutterstock, Systems With Intelligence

Instead, utilities can deploy thermal and visual sensor solutions that continuously monitor the turbine, reducing the time and budget needed for routine inspections. Crews can be dispatched in response to a known issue, allowing the utility to prioritize repairs and minimizing the time spent by teams in difficult conditions.

Monitoring Solar Farms

Like wind, solar generation facilities present their own challenges to technicians. With hundreds or thousands of individual panels, it can be difficult for maintenance teams to identify and pinpoint issues, especially as there is often no visual indicator of a problem.

Thermal sensors can be deployed to pan and tilt across multiple panels. Instead of looking for high temperatures, these sensors can detect cold spots that indicate that a panel is not working properly. Maintenance teams can quickly scan the site and detect problems for repair from a central location.

Remote Substation Monitoring

Renewable energy will require a larger number of small, more localized

Renewable energy will require a larger number of small, more localized substations. Each of these needs to be inspected, and components must be maintained, repaired, or replaced.

substations. Each of these needs to be inspected, and components must be maintained, repaired, or replaced.

Rather than adding to the already high burden on maintenance teams, utilities can deploy thermal and visual sensors to monitor the health of substation assets and automatically alert crews to a potential problem.

High Voltage Direct Current Converter Station Monitoring

High voltage direct current (HVDC) transmission lines are the most efficient ways to move power over large distances. The HVDC converter stations convert AC power to HVDC for transmission and DC power back into AC power for distribution and use by customers. Like substations, they contain high-value assets such as transformers, switches, capacitors, thermistors, and filters that all need to be inspected and maintained despite the hazardous conditions.

Thermal and visual sensors can be deployed within the site and especially within the HVDC convertor hall to continuously monitor the health of the station while reducing the time that crews spend on-site. Not only does this improve overall safety, but it also reduces the cost of inspections and frees technicians to focus on maintenance and repairs.

Transitioning to a Sustainable Power Grid

The push for sustainability is transforming the way that we generate, transmit, and use power. But it is also adding complexity for utilities. As maintenance requirements change, utilities need a cost-effective alternative to physical inspections.

Thermal and visual sensors provide a continuous, real-time view of electricity infrastructure. In addition to remote substations, these sensors can be used to monitor wind turbines, photovoltaic solar panels, HVDC converter stations, and the transmission and distribution lines that link them all together. With the right technologies and approach to maintenance, utilities can modernize existing infrastructure and invest in new capabilities that support the transition toward green energy.

High voltage direct current (HVDC) transmission lines are the most efficient ways to move power over large distances.

Photo: Systems With Intelligence

Protecting Equipment with Powder Elevates Protection and Sustainability

Photo: PPG

Regular review of paint specifications is an important task to ensure that power industry manufacturers are leveraging the best possible coatings to protect their equipment, manage costs and improve application efficiencies.

This evaluation of solutions in terms of performance requirements and paint line maintenance considerations often leads manufacturers to products that offer more durable protection, but also to advantages that put them closer to their sustainability goals.

Based on key evaluation metrics like performance, maintenance, material usage and aesthetics, powder coatings often come out on top. In fact, it is currently the world's fastest growing coating technology.

BASED ON KEY EVALUATION METRICS LIKE PERFORMANCE, MAINTENANCE, MATERIAL USAGE AND AESTHETICS, POWDER COATINGS OFTEN COME OUT ON TOP. IN FACT, IT IS CURRENTLY THE WORLD'S FASTEST GROWING COATING TECHNOLOGY.

One of the most appealing features of powder is that it offers important sustainability benefits like low volatile organic compound (VOC) content and higher first pass build rates.

Since powder coatings are generally made without solvents, they generate virtually no harmful VOC emissions, helping manufacturers stay compliant with increasingly stringent environmental regulations around the world.

Because it is an electrostatic process that applies charged particles to a grounded part, powder has excellent adherence to metal, even on hard-to-reach areas. The result is less powder needed to coat the parts, improving material utilization rates.

Finally, unlike liquid paint that is always a spray-to-waste process, powder overspray can be reclaimed and recycled, depending on the capabilities of the coater, the number of colors utilized, the absence of contaminants and financial considerations related to the quality of the powder.

While these features are appealing to manufacturers striving to reduce costs and their environmental footprint, there are valuable protective performance gains with powder coatings as well.

Powder coatings are formulated for applications that require the ultimate combination of corrosion resistance, weathering performance and operational advantages. These coatings are typically formulated with polyester resins that are favored for their excellent corrosion and chemical resistance, as well as all-around application versatility.

In fact, powder coatings, particularly, newer generations, often offer better protection in a single coat in terms of coverage, corrosion resistance and weathering than two-coat liquid systems, which reduces the overall amount of product needed, and also eliminates the need to manage and treat wastewater.

Specification & Paint Line Maintenance

The most effective way to make progress in sustainability goals is to select the right coating for metal electrical equipment using a total system approach that accounts for the following variables:

1. The composition of the metal substrate (cold-rolled steel, hot-rolled steel, stainless steel, galvanized metal, mixed-metal, etc.) while ensuring those suppliers are considering sustainability in their manufacturing processes.

2. The types of lubes and coolants used to fabricate the equipment. Manufacturers can work with their steel supplier to get a better understanding of what is used so that they are better able to control contaminants in the paint process that result in unnecessary increases in water usage or additional chemicals to clean the substrate. This affects the materials needed to pretreat the metal substrate (zinc, iron- or zirconium-based pretreatments).

3. The type of finish coat, including film build (coating thickness) and cure (baking time and temperature) requirements.

4. Optimal paint line maintenance programs limit excess water usage and chemical additives. In addition, oven temperature monitoring reduces energy demands.

Photo: PPG

Improve first-pass build rates

With the notable advantages of protective powder coatings, it's not surprising that more manufacturers than ever are switching to this coating technology. But leading powder makes are continuing to develop formulations that take these sustainability, performance and application benefits to the next level, including a new generation of high transfer efficient (HTE) powders that offer:

HIGH TRANSFER EFFICIENT (HTE) POWDERS OFFER UP TO 85% FIRST-PASS BUILD RATES THAT REDUCE LABOR, MATERIAL AND UTILITY COSTS.

- up to 85% first-pass build rates that reduce labor, material and utility costs
- improved wrapping on complex parts for fewer rejected parts and touch-ups
- better control of powder film thickness so less powder is needed for full coverage
- reduced energy needs with lower baking temperatures (320°F)
- good penetration on complex parts, shapes and recesses

Of course, there are several ways to improve first-pass application build rates, including regular equipment maintenance and refining application technique. But leveraging HTE solutions specifically formulated for excellent edge-to-edge coverage goes a long way in increasing throughput, reducing material usage and costs, while limiting waste.

Today, newer generations of powder coatings are giving manufacturers tools that not only elevate the protection of their switchgear, transformers and generators, but also support their environmental compliance and stewardship initiatives.

Maria Lamorey is a commercial strategy manager at PPG. With over 20 years of industry experience, Maria plays a leading role in PPG's commitment to delivering high-performance coatings products across a variety of general industrial applications including electrical equipment of all types.

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MONITORING & DIAGNOSTICS

Monitoring is one of the fastest growing areas in transformer management and almost every asset within the power system. With more monitors comes more data, and with more data comes the need for better data science. The March issue will be dedicated to advances and practices in this booming field.

Starting in March, and continuing going forward, even though each issue is "themed", we will have separate sections for Transformer focused content, Power Systems content, Green Energy content, and Women in Power Systems content. While each issue might have a very strong focus on one of these content areas, we hope to cover all of the change taking place in both technology and in how each of these areas will impact the global power industry going forward.

Alan Ross
Technical Director and Managing Editor, APC Media

COMING IN MARCH ISSUE

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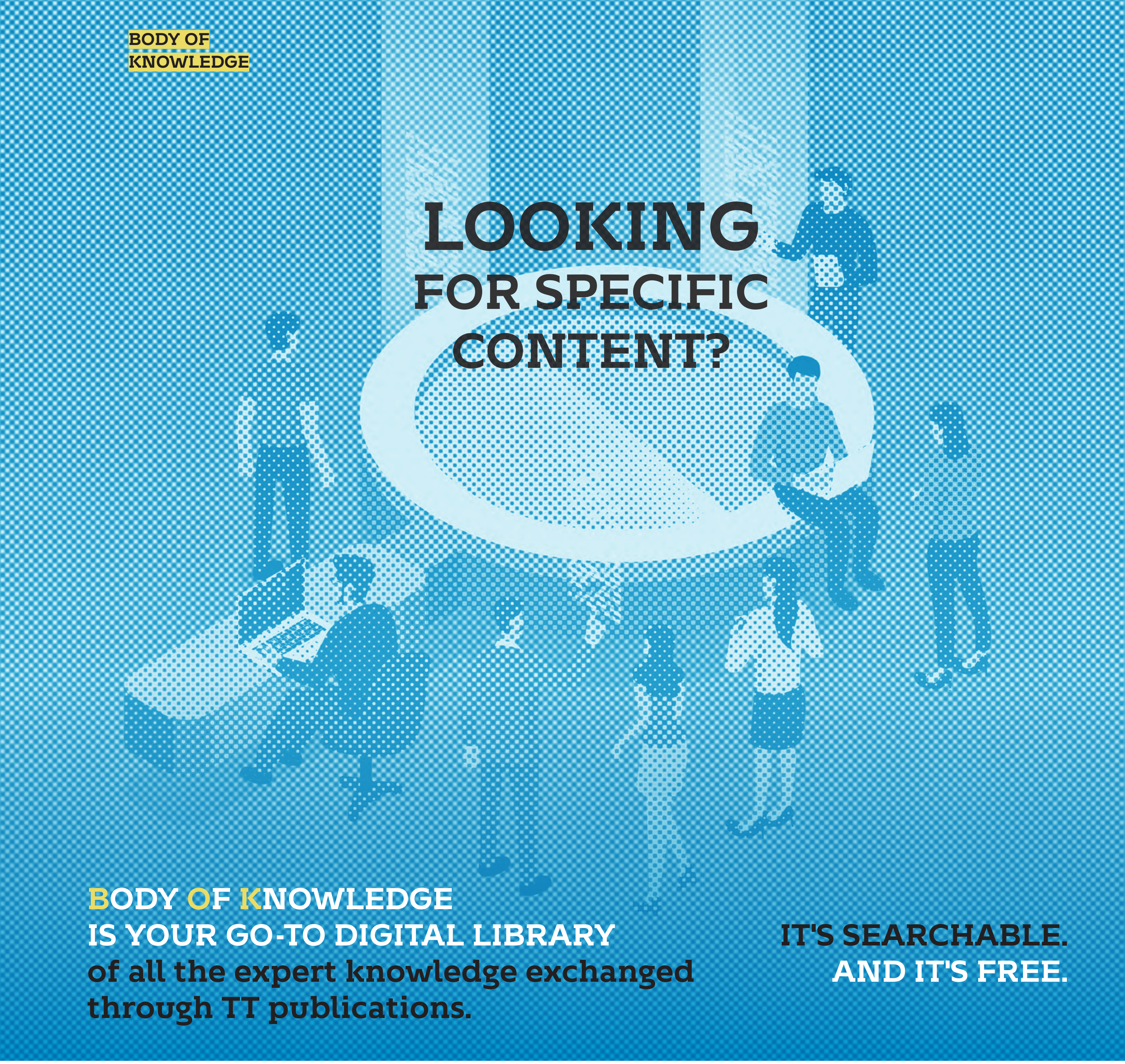

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