Electrification and the Path to Net Zero

The Crucial Role Digital Technology Will Play

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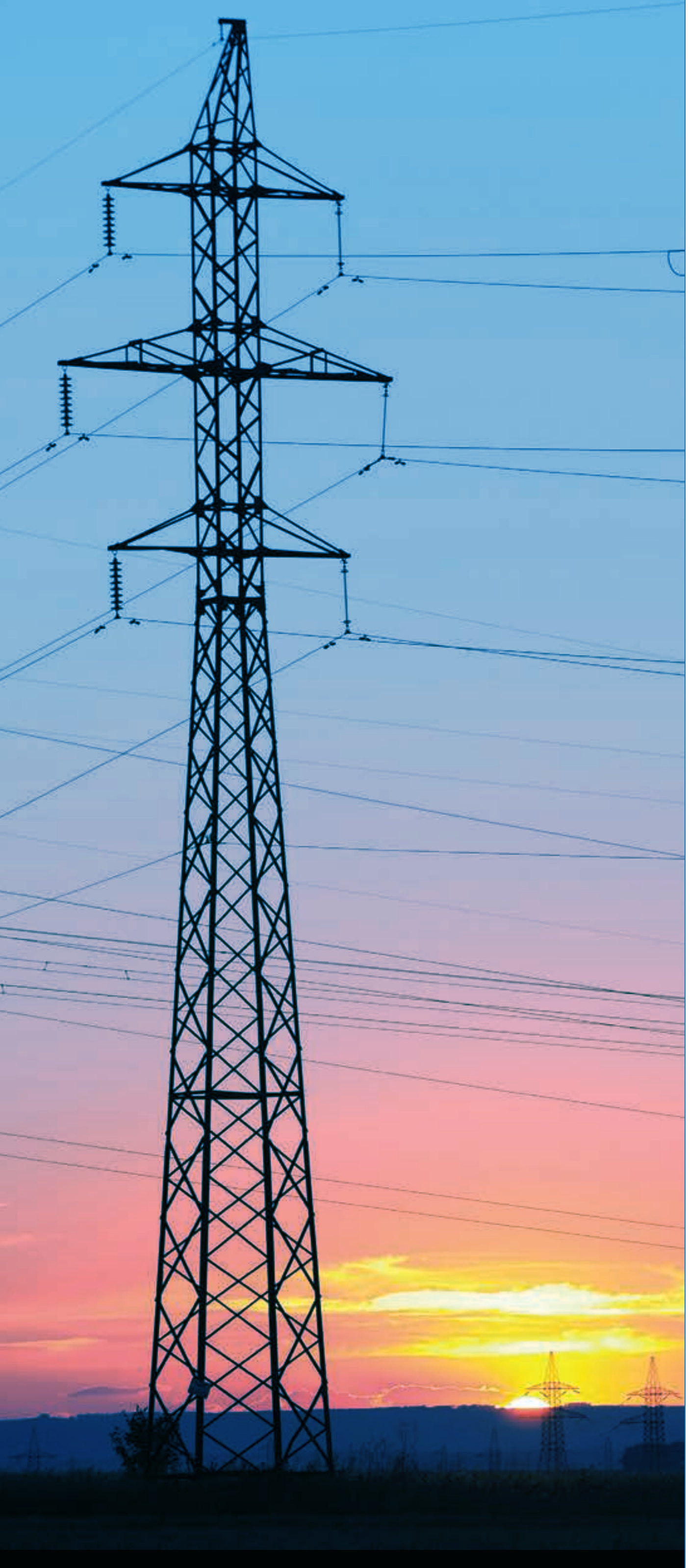
White Paper



Executive Summary

Electrification is accelerating across all economic sectors as the world comes to grips with increased demand for resources, energy and sustainability. The shift from fossil-based systems to electric will drive change within the existing power infrastructure and beyond with new microgrids and self-generation at industrial sites. The existing grid will need to quickly expand and evolve to support the growing electrification trend.

Rapid innovation is scaling and driving down the cost of renewable energy per kilowatt hour to satisfy the growing demand for affordable electricity. With industries such as chemicals, metals and refining accelerating their use of electricity to help achieve zero-carbon manufacturing, the integration of electric power with existing operations will advance, and the optimization of electricity distribution will become increasingly important.

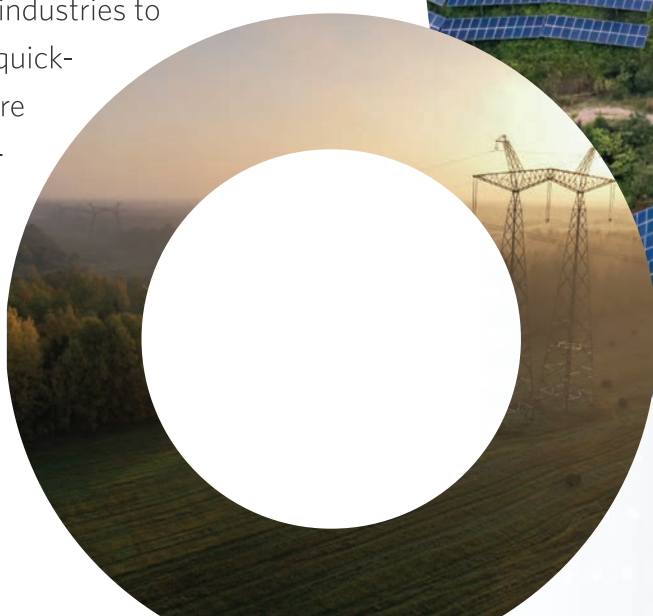
Global electrification will not be possible at the scale and pace required without digital technology that enables the efficient provision and use of electricity while supporting its growth.

As a result, electric utilities are rethinking and expanding their embrace of digital software. At the same time, the energy and chemical industries will need to integrate and optimize electricity along with their respective processes. Digital solutions used in power management will increasingly demand an architecture that:

- Scales as electrification accelerates
- Supports distributed electricity sources and two-way intelligence to drive power requirements
- Facilitates the increasingly important requirements of cybersecurity
- Seamlessly integrates advanced analytics and AI
- Flexibly enables distributed and loosely coupled microgrids and local grids

Fortunately, there are strategic digital software platforms available to help meet this evolving demand. For integrated electric utility systems, the Monarch platform available from AspenTech® business, OSI, provides a single, extensible backbone to plug in generation, distributed generation, transmission and distribution functions. For distributed renewables, there are powerful microgrid and distributed grid solutions and for emerging technologies, such as hydrogen fuel cells and advanced batteries, the concurrent engineering solution from AspenTech can help businesses to embrace innovation, scale and de-risk adopting any of the technologies. In addition, as manufacturing sites look to meet higher energy demand, OSI's suite of software solutions enables users to manage microgrids and integrate with power grids.

The most forward-looking companies are already investing in areas as varied as distributed generation and distribution, microgrids, wind farms, battery technology, industrial site power island optimization, direct air carbon capture and hydrogen fuel cells. These organizations are driving innovation and helping to accelerate adoption of low-carbon energy and electricity, paving the way for electric utilities and companies across all industries to make similar shifts—quickly—regardless of where they are on their electrification journey.



Challenges in an Expanding World

The world is facing a significant resource challenge—a population that will grow from 7.8 billion to 9.7 billion people by 2050, associated growth in the world's middle and upper class of 40% and the consequent need for more resources, all driving a 50% increase in global energy demand by 2050, according to the U.S. Energy Information Administration (Figure 1).

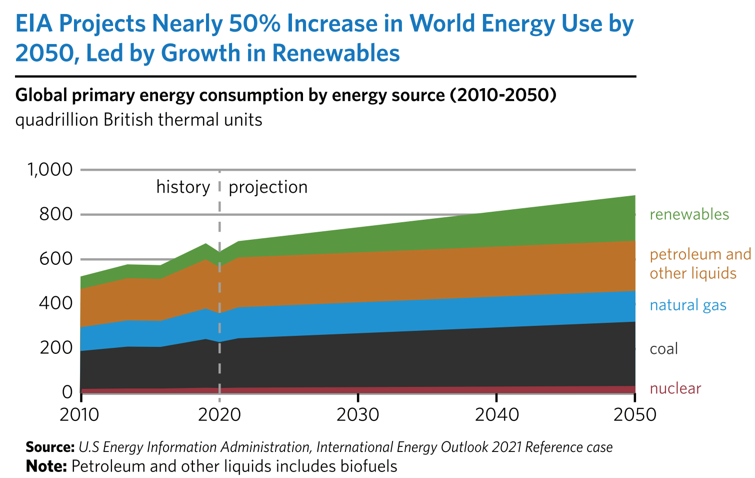


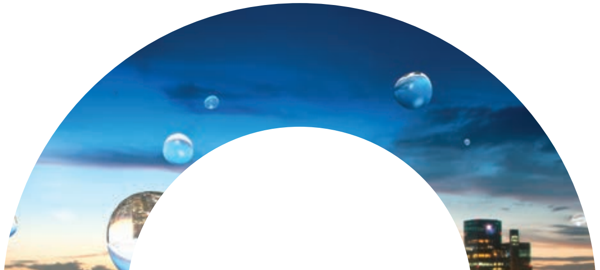
Figure 1. Forecasted growth in global energy consumption (Source: EIA)

Considering that an estimated 770 million people have no access to affordable electricity globally[1], the increased demand for electricity will be even steeper. This population-driven demand is only part of the challenge. Future demand increases when adding the electricity needs of mobility, residential and industrial users worldwide. What about the materials needed for electrical storage? Demand for two materials, lithium and cobalt minerals, is projected to rise by a staggering 600%.[2]

The World Energy Council projects a higher percentage of global energy use will be satisfied through electricity, requiring an investment of nearly $1 trillion USD/year in electricity capacity over the next 35 years, with a shift toward low-carbon generating capacity, transmission and increasingly decentralized distribution.

According to the International Energy Agency (IEA), the world's electricity generating capacity will grow from roughly six terawatts to 12 terawatts by 2040. A significant portion of that growth will support demand from all-electric vehicles (EVs), as well as residential and commercial cooling. Other top growth areas include concentrated uses, such as the massive and growing cloud facilities powering the web from Amazon, Microsoft, Google, Weibo, Baidu and others; large desalination facilities on which the world's potable water supply will increasingly depend; and the potential electrification of large industrial sites. At the same time, there is significant movement toward renewable and distributed power generation sources, driving huge expenditures in transmission and distribution networks, the digital software technologies to enable them and the requisite planning resources for better and increased electricity storage.

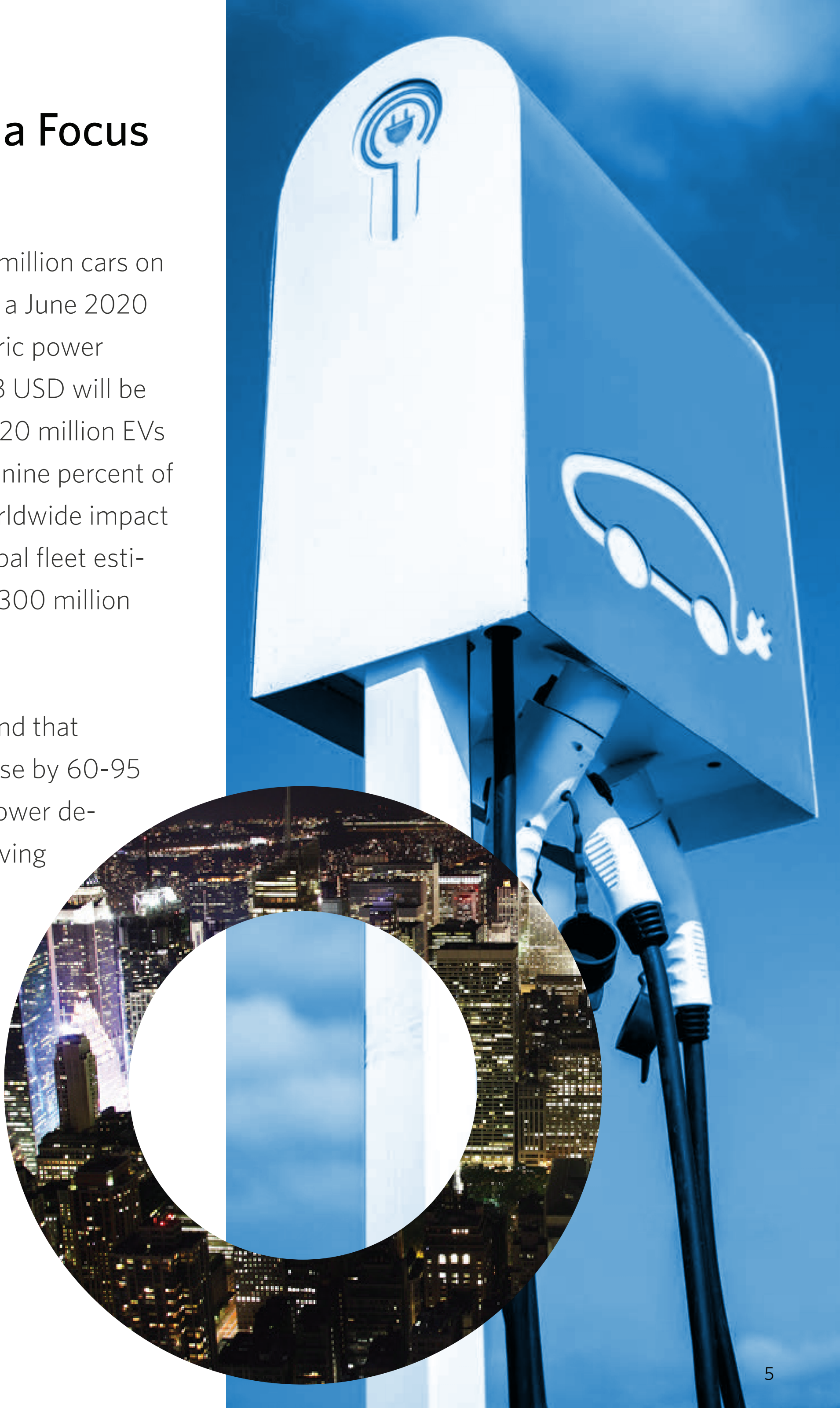
Most of the renewable power options such as solar and wind will be generated away from population centers. As a result, larger capacity and more resilient transmission systems will be key. Distribution systems will need to grow and become more dynamic due to distributed generation and the cyclical nature of renewable power. Importantly, the increasing importance of electric power transmission and distribution could lead to more vulnerability to bad actors, driving cybersecurity concerns.



Electrification with a Focus on Sustainability

There are currently close to 276 million cars on the road in the U.S. According to a June 2020 study by the Brattle Group, electric power sector investments of $75-$125B USD will be needed to support an estimated 20 million EVs on the road in the U.S. by 2030 (nine percent of the total U.S. auto fleet). The worldwide impact is significantly greater with a global fleet estimated at 1.4 billion vehicles and 300 million EVs anticipated by 2030.[3]

The Brattle Group study also found that demand for electricity will increase by 60-95 terawatt-hours/year, and peak power demand by 10-20 gigawatts. Achieving this goal sustainably will require adding 12-18 GW of renewable energy capacity, a 67% increase over current levels. Growth in renewables along with changes in peak power cycles (coinciding with EV charging times) will potentially drive growth with other electric consumers.



However, this formidable requirement for more electrical capacity and more dynamic grids to meet the growth in EVs worldwide considers only one aspect of the net zero electrification challenge. The McKinsey January 2022 report, "The Net-Zero Transition: What it Would Cost, What it Could Bring," highlights other aspects. The report illustrates the 2019 breakdown of greenhouse gas emissions. The top three generators of emissions were from the following three sectors: 30% for power generation, 30% for industry and 19% for mobility, with most emissions coming from the burning of fossil fuels for energy.

These results illustrate why today's focus is primarily on both power generators and industry to invest preferentially in renewable and low-carbon energy sources and electrify industrial processes. By that calculus, the electrification of heavy industry to meet the decarbonization imperative is driving 50% more growth in electricity than from mobility alone.

Of course, for all of this to happen in a way that reduces emissions, electrification will need to come from more sustainable and more efficient

Growing Global Energy Demand and CO_2 Emissions

All electrification activity is occurring within the context of growing global baseline demand for energy. The factors contributing to the 50% rise in energy demand include global population increases and growth of the middle class across developing economies in Asia, South America and Africa (Figure 2).

Increased attention on energy efficiency across all sectors will mitigate this growth somewhat. Digital technologies will be instrumental in achieving a 10-20% increase in energy efficiency. Rising demand for energy from an increasingly energy-hungry planet—including industry, mobility, commercial and residential use—leads to greater pressure to more effectively and sustainably deliver affordable energy to meet the demand.

In support of net zero targets, capital-intensive industries such as oil and gas, refining, chemicals and metals are focused on electrifying energy production and process heat, while ensuring that electrical generation aligns with their own sustainability initiatives.

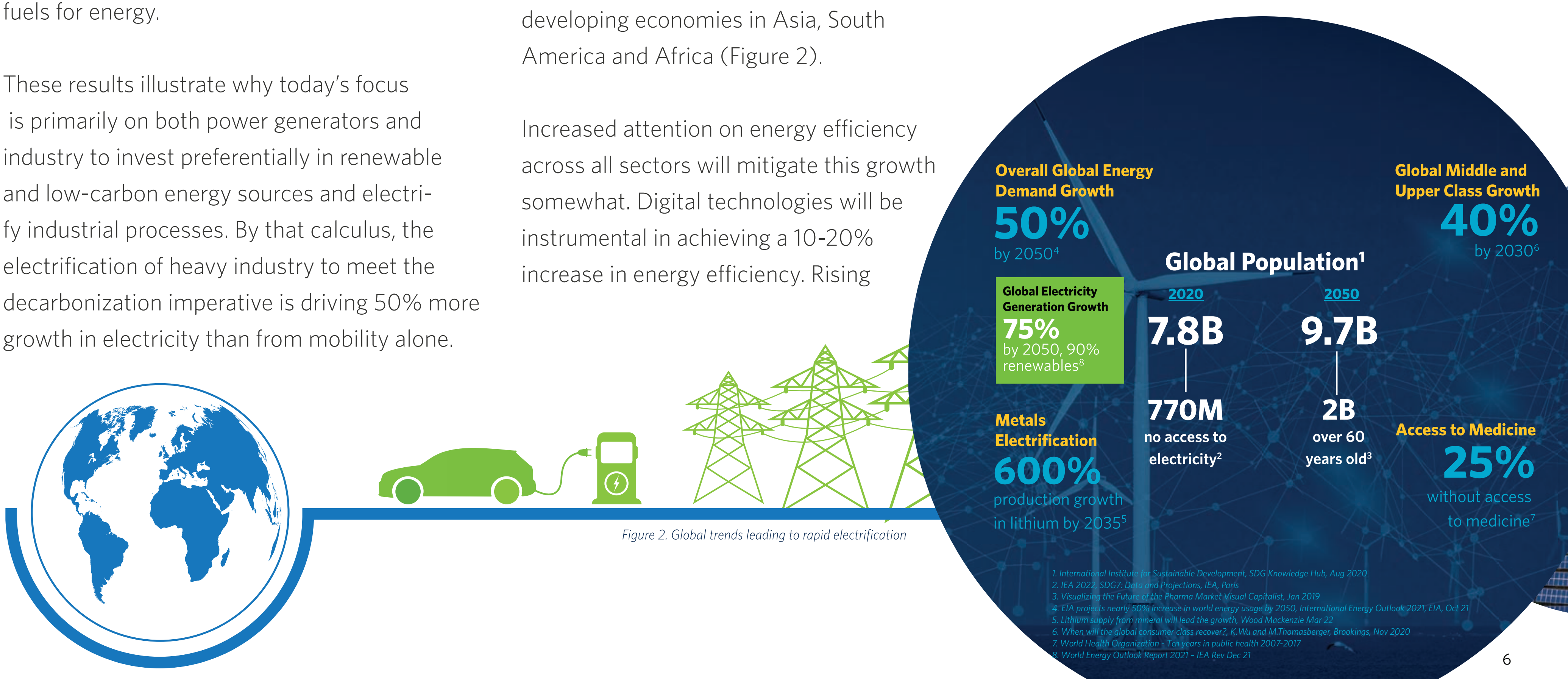


Figure 2. Global trends leading to rapid electrification

From a global perspective, carbon trading and carbon tax emissions-cutting policies are increasingly crucial in providing access to the right levels of capital for decarbonization investment in the most challenged economic zones. Investments in renewables and intelligent grids go hand-in-hand with carbon trading. Digital solutions supporting those distributed generation sources and grids are crucial for tracing carbon emissions from renewable source to industrial end use and onward to calculation and tracking of carbon intensity of finished products produced via renewable energy.

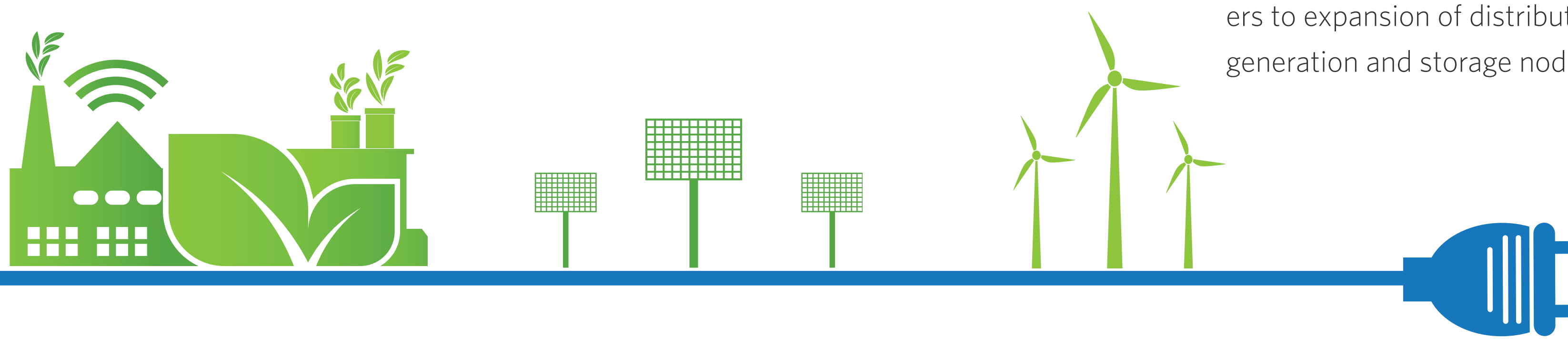
There are numerous challenges and technology opportunities that accompany the shift to widespread adoption of electrification. Fossil fuels will continue to be a significant source of global energy through 2050. Carbon capture, utilization and storage (CCUS) will also play an increasingly important role[4]. That said, electrification is playing, and will play, a key role in reducing carbon emissions looking ahead, especially as new investments will almost exclusively be in low-carbon electricity sources and the replacement of older, CO_2-emitting plants. This shift in investment will drive a new generation of digital solutions to support the growing appetite for electrification.

Turning Challenges into Opportunities

Here are a few key challenges and opportunities to consider:

- **Distributed Power Production.** Grids will need to accommodate rapidly expanding and evolving distributed power production, storage and consumption models. Evolving power networks are already demonstrating that they are much more dynamic, complicated to manage or predict, and challenging to scale. Operators will need to forecast and dispatch renewables and manage peak loads with high renewable penetration in the power network. With increasingly deregulated and open markets, including carbon trading, more entities such as community microgrids and industrial power islands can bid their power into markets.

  Digital Opportunity. New digital software rapidly keeps pace with the innovation of the power generation system. The intelligence being embedded in both generation and storage solutions needs to be integrated into an increasingly smart and two-way network. Also, digital upgrades are essential to support new pricing and revenue models for electricity, and to remove current barriers to expansion of distributed generation and storage nodes.



- **Power Grid Expansion.** Grids will need to grow steadily beyond their current capacity and change in their structure to eliminate single points of failure. There will be challenges in safely and securely managing a grid with less control and visibility due to renewable and power-electronics controlled generation and distributed energy resources. Movement in the marketplace toward distributed power suppliers will lead to challenges with transforming grids into systems that can manage higher capacity and at the same time, be more flexible, redundant and intelligent.

  Digital Opportunity. Traditional grids are expensive to upgrade and digital solutions commonly used for transmission and distribution management are not sufficient. Advanced distribution management, already adopted by forward-looking companies, will eventually be required for all companies to provide reconfigurable capacity, visibility into distributed generation, resiliency amid increasingly dynamic supply and demand, advanced situational awareness for operators and managers, and enhanced grid support for smarter meters, generators and storage nodes. Optimization technology must be advanced to satisfy power production and consumption growth more efficiently at both normal and peak demand. The underlying solutions must be structured to accommodate increasing adoption of AI-driven solutions to further optimize and protect electrical networks. The opportunity will be there to achieve growth for grid operators (Figure 3).

- **Reliability.** Electricity is increasingly integral to finance, business, government and the public. Banking and stock systems, cryptocurrencies, news, social media and governmental portals are all increasingly linked with reliable, non-stop electricity. Given the current spotlight on the reliability challenges introduced by the stochastic nature of renewable power, there is increasing scrutiny and higher expectations for rapid diagnosis and resolution of outages. With the increasing complexity of distribution systems, reliability and outage prevention becomes more challenging to manage with traditional approaches. These concerns are already

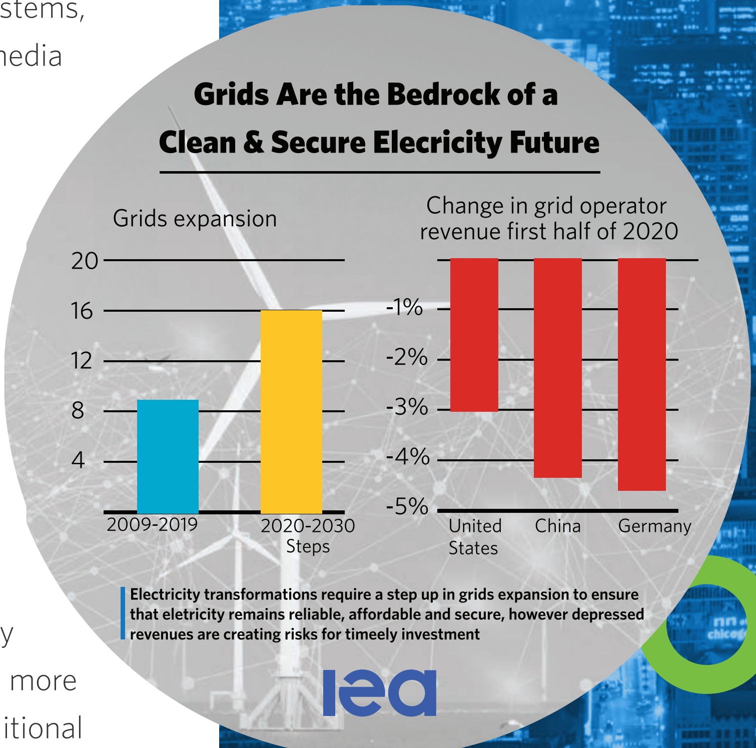


Figure 3. The imperative and challenges for electrical grid expansion

driving entities to be more self-sufficient and less dependent on electric utility power.

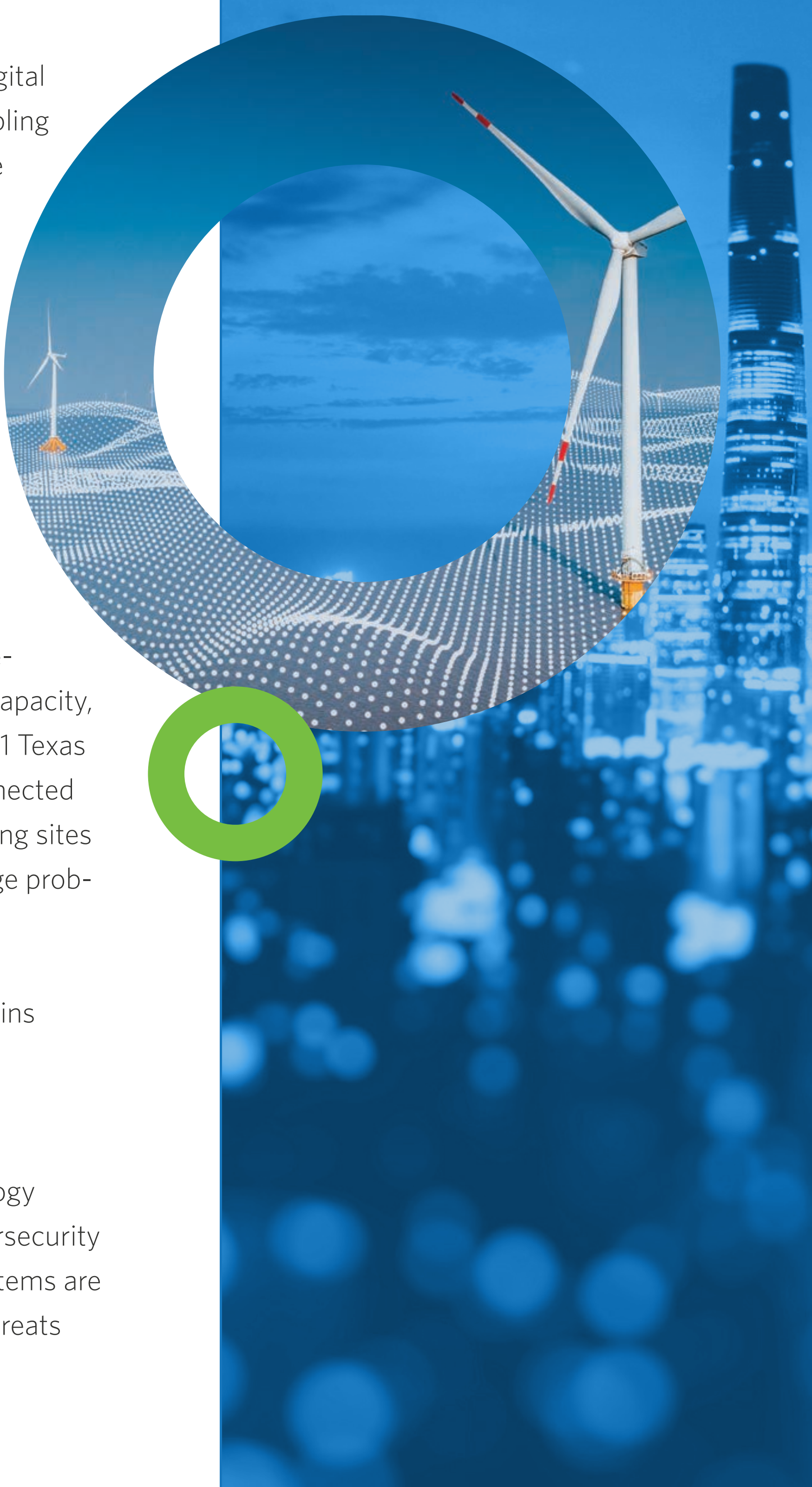
Digital Opportunity. Digital technology based on advanced data analytics and AI will become essential to respond quickly and effectively to situations across a diverse system. Operators need to ensure high reliability of a more complex, two-way distribution network with distributed energy resources. Situational awareness (providing instant and interpretable visibility into incidents and intrusions) becomes an increasingly important, with intuitive visual systems enhanced by AI-powered decision support. Outage management systems (incorporating mobile technology) must coordinate field repair work with central teams to resolve problems rapidly. To succeed, digital management systems will need to provide granular views of the customer distribution network.

- **Monetization of Distributed Power.** With more intelligence and innovation built into distributed renewables and storage arrays, grid intelligence becomes critical. Without visibility into the performance and condition of these distributed systems, managing the complexity and dynamics is difficult.

  Digital Opportunity. Advances in digital software provide this visibility, enabling distribution companies to monetize operations, optimization, maintenance and pricing of distributed power and storage. As vehicle batteries increase their capacity and capabilities, the mobility network—equipped with new capabilities and insights—can also be monetized as a storage element of the connected grid. This will further enable industrial sites to better manage peak requirements and excess self-generation capacity, as exemplified by the February 2021 Texas ice storm power outage, when connected cogeneration at chemical and refining sites contributed to a mitigation of outage problems.

- **Cybersecurity.** As electrification gains momentum, cybersecurity become increasingly important.

  Digital Opportunity. Digital technology must meet the most exacting cybersecurity standards, and increasingly the systems are expected to react quickly as new threats



are identified. Software providers like OSI have a proven track record in not just meeting standards but also reacting rapidly and updating systems for electric utility providers.

- **Community and Industrial Microgrids**. A key concern among industry experts is the growing vulnerability and complexity of an increasingly dynamic and distributed grid of power generation, storage and consumption, especially as many regional grid operators have been slow to adopt digital technology. Microgrids have emerged as a key investment area to fill the regional void while meeting demand from large power consumers, communities and localities.

  Digital Opportunity. The right digital solution enables efficient, optimized development of microgrids, integrated with regional grids and developed in a more cohesive, intelligent way. This approach promotes and enables entrepreneurial investment and innovation in new power generation strategies and connected storage innovation. In addition to battery storage, innovations, such as commercialization of hydrogen fuel cell storage, can be integrated easily.

- **Cogeneration.** Distributed power generation in industrial facilities—pursued by the world's largest refining, chemicals and mineral processing owners for several decades—is another important electrification opportunity. Cogeneration, when run effectively, makes optimal use of waste heat during the power generation process and can use excess heat from power generation for supplemental process heat.

  Digital Opportunity. Using the same adaptive process control and digital twin technologies applied to process equipment, an optimized amount of electricity is produced and predictively available. Digital software technologies are key in this area to make cogeneration practically available to a wider spectrum of industrial entities. These include energy management, electric utilities optimization and self-maintaining advanced process control.

- **Storage and Batteries.** As renewables continue to feed the dynamic and stochastic nature of distributed grids, power storage has become a focus area within the distribution network. Demand for the underlying essential metals for battery storage, lithium and cobalt, are projected to increase 600% over the next three decades. This is an unrealistic estimate from both an environmental and economic perspective. Mineral supplies will be far below EV demand by 2030 according to a Benchmark Minerals assessment.[5]

Consequently, innovation is a high priority in this area to improve material efficiency, performance and recycling. In fact, innovation is ongoing to help develop new storage management strategies and uses. Specific areas of innovation include battery technology and battery recycling to reduce the need for additional resources, as well as new energy storage approaches such as hydrogen fuel-cell-based systems and gravity-based potential energy.

Digital Opportunity. Between distributed generation, batteries, storage and integration, digital technology is a critical enabler of innovation and proactive planning for navigating the risks posed by increasingly interconnected grids. AI, advanced analytics and system risk analysis are essential to understanding and planning for complex systems. Modeling and optioneering of new battery chemistry and industrial scale fuel cells with rigorous digital models are playing a crucial role in enabling the ecosystem of startups and innovators.

Simulation software—combining chemical and electrical first principles and incorporating advanced AI and analytics in hybrid models—is currently providing several industry leaders with a strong competitive advantage. Simulation modeling technology is crucial for evaluating battery chemistry and systems designs. High-performance computing and hybrid models are playing key roles in optioneering for new designs at both the process and systems levels.

Energy Management and Electrification of Energy and Chemicals Process Units

As the chemicals, refining and midstream sectors are transforming to operate in a low-carbon future, they are also looking to electrify. Due to macroeconomic, sustainability and geopolitical trends, product mixes are shifting from transportation fuels to new sustainable materials. Natural gas and bio feedstocks are positioned for the midterm and hydrogen for the long term. To support this trend, microgrids will become increasingly valuable for energy management at industrial sites.

Reliable power and energy have always been a concern for chemical and refining producers. Unplanned interruptions in power can lead to a variety of issues including process safety, forced release of greenhouse gases and

other emissions, and process unit and metal fatigue caused by forced cooling and restarting of process reactor units.

In the near term, there are substantial opportunities to optimize self-generated power and steam, and to reduce emissions while generating electricity more predictably so excess power can be sold back to the grid on the deregulated spot markets. Traditionally, power islands have been optimized in isolation, while energy-consuming process units have been separately optimized. There are huge opportunities to look at the power islands in an integrated way with process units from an energy efficiency perspective.

Microgrids are an important digital tool for optimizing across the energy production and energy consumption aspects of a site, and for incorporating locally managed renewables and storage. Some of the very high-energy-consuming processes currently being invested in, such as LNG trains, ethylene and fertilizers, are all areas where this approach will be increasingly fruitful.

Industrial power producers have three top priorities:

1. **Align the renewables component** of electric power consumed and generated on site, with the associated carbon footprint benefit.
2. **Optimize power generation and use** through effective digital technology for energy management, electric utilities planning and optimization.
3. **Satisfy a significant fraction of process energy requirements** from electricity instead of from process heat and steam where possible and feasible.

Some of the areas which are being invested in heavily from an R&D perspective include electrification of ethylene cracking, heat exchangers powered by electricity instead of process heat sources and refining cracking units. The technical challenges are significant and will, under any scenario, require substantial renewable energy to drive such modified and innovative processes.

For example, with respect to electric process heaters, most of the conventional heat exchanger suppliers are working in this area. This is only practical for some classes of process problems, and the key challenge will be to improve the heat transfer economics. Special types of ultra-efficient arrangements such as helical flow are candidates in this area. In ethylene cracking, the challenges are even greater. Digital technology that models innovative processes accurately using hybrid models with rigorous first principles and advanced machine learning will play a key role, as will rigorous modeling that combines chemical and electrical interactions to explore integration and efficiency.

When compared to mobility, the electrification of industrial facilities, in particular bulk chemical and refining sites, is realistic only in a longer time horizon.

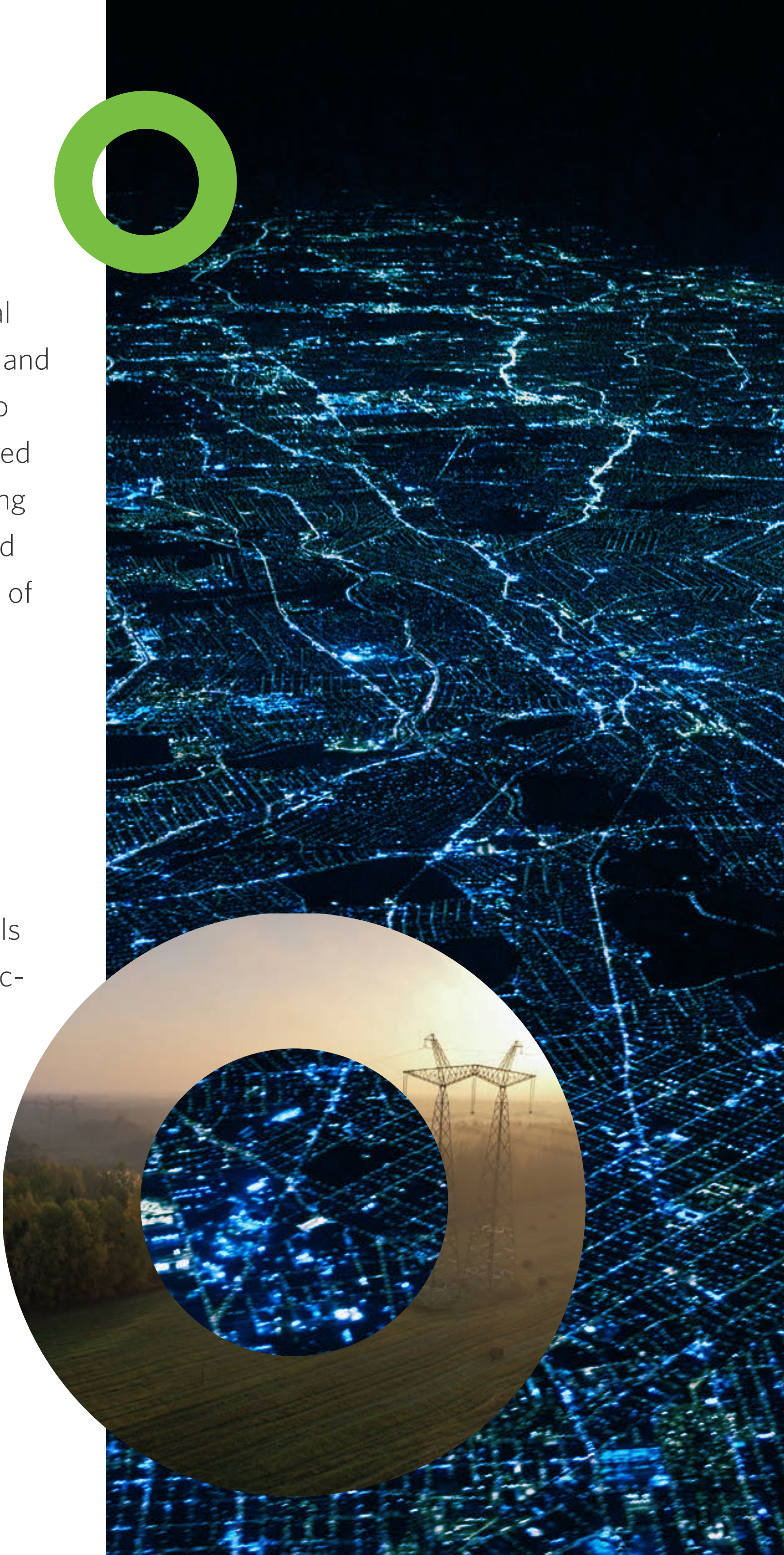
Renewable solar and wind generation is already being added by asset owners, both to satisfy site energy demands and as separate energy transition business lines, and sometimes for both purposes at the same time. Optimization between these electricity sources and process unit energy demands is a complex task, requiring microgrids and associated optimization methods.

As the complexity, dynamism and growth of the wider electricity system increases, it benefits from more active management. However, these same factors increase the complexity of options and of decision-making parameters. In this increasingly volatile and uncertain environment, there is a growing imperative and benefit from digital technology that has a common architecture and end-to-end data visibility, from generation to end use. Additionally, system-wide, risk-based modeling becomes a strategic asset in gaining insight into reliability, vulnerability points and a quantitative understanding of the best use of capital to address weak points.

Reducing the Carbon Intensity of Power

The electrification of mobility and industrial energy production will only advance the goals of decarbonization to the extent that the electricity grid can supply low-carbon intensity power and continue to improve that curve. Today, the ability of power grids to supply low-carbon intensity electricity is mostly regional and country dependent.

Industrial energy consumers have several alternative strategies to reduce the carbon intensity of their supplied power.



First, the power consumer needs to understand the current and real-time intensity of the supplier and regional grid. A tool such as an electricity map provides a real-time scoreboard of performance.

Second, the consumer can consider self-generating renewably sourced power and steam. This can include low-carbon cogeneration, co-located or contracted renewables sources and use of biofuels to fire cogeneration and steam generation.

Third, they can integrate power storage technologies, such as advanced battery arrays, to smooth peak energy requirements.

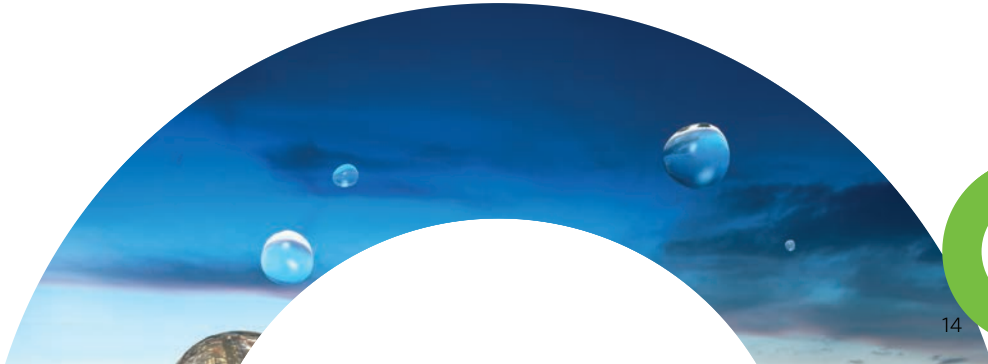
Lastly, they can further optimize the dynamic selection of the most sustainable and profitable options through a combined use of digital energy management and electric utilities optimization.

To better manage such distributed power capabilities, microgrids can use an approach that can simplify and optimize the integration of self-power generation, local power storage, renewables, integration with the grid and monetization of surplus power.

Customer Success Stories

There are excellent examples of digital technology at work today, enabling electric utility generation and distribution operators as well as industrial power users to optimize electricity use and prepare for further electrification.

Salt River Project, the third largest U.S. public utility, uses advanced distribution management systems and transmission management technology to modernize its electrical grids, accommodate growing electricity demand and position itself to handle distributed renewables generation and storage.



Sardinia-based wind farm operator, **Sardeolica,** takes advantage of the famous Sardinian winds to generate significant levels of renewable power in Southern Italy. Sardeolica uses AI-driven predictive maintenance solutions to maximize wind turbine uptime, reduce maintenance cost and extend wind generator lifetime. With winds in Southern Italy typically seasonal and predictable, the advanced technology enables them to schedule required maintenance during low wind periods, maximizing power production.

Dow Chemical, the world's largest non-utility power producer, uses Adaptive Process Control integrated with rigorous digital twin models (Aspen Plus® online) to improve efficiency of co-generation and predictability of produced power. As a result, the company has greater confidence in its grid-supplied power and the peace of mind to sell excess power back to the deregulated Texas grid.

Alcoa, the leading bauxite processor and producer of the world's only low-carbon alumina brand, is on a constant mission to increase the green content of its produced aluminum. The company currently uses a digital online utilities model and digital twin to optimize the use of energy in its processes as well as the utilization of its power island.

Doosan Hydrogen Fuel Cell Company employs rigorous digital simulation modeling to improve the design and performance of industrial skid mounted hydrogen fuel cells, reducing design time and the cost of delivering standardized skid-mounted fuel cells.

Next Steps

Across multiple industrial sectors—including refining, chemicals, upstream and power utilities—electrification offers significant opportunity for carving out competitive advantage and market differentiation. Digital software provides a key lever in accelerating adoption of electrification strategies, deciding which technologies to select, enabling power grids, regional and microgrids, and driving overall growth in electrification.

AspenTech is at the forefront of enabling energy and chemicals companies to achieve lower carbon manufacturing and product mixes. In addition, the company's digital software solutions—with the breadth and depth across both utility and industry business functions—are uniquely suited to meeting evolving electrification demands. Combining digital grid and advanced distribution solutions with asset optimization solutions focused on performance engineering, production optimization and asset performance management, AspenTech offers a powerful, strategic digital platform to lead the growth of electrification across the globe.

Consider AspenTech for all your digital software needs as you begin or continue the journey to electrification and net zero carbon.

Citations:

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4. Carbon capture technologies and solutions are the focus of a companion white paper, available by visiting www.aspentech.com.
5. Benchmarkminerals.com, 2022

About AspenTech

Aspen Technology, Inc. (NASDAQ:AZPN) is a global software leader helping industries at the forefront of the world's dual challenge meet the increasing demand for resources from a rapidly growing population in a profitable and sustainable manner. AspenTech solutions address complex environments where it is critical to optimize the asset design, operation and maintenance lifecycle. Through our unique combination of deep domain expertise and innovation, customers in capital-intensive industries can run their assets safer, greener, longer and faster to improve their profitability and operational excellence.

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