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WHITE PAPER

What you need to know about digital energy

Modernizing grid infrastructure, security, and resilience

Building trust for a connected world.

Contents

Introduction

The ability for an average citizen to be an active participant in the digital energy economy is just around the corner.

Digital technologies are transforming energy infrastructure into connected, intelligent, efficient, reliable and sustainable systems.

The digital energy revolution is giving "power to the people" to generate electricity for the grid and to make money along the way—but that's not all, digital energy has given rise to a variety of new business models that give you many alternatives to be an active participant in the energy sector.

This document is an overview of the digital energy landscape, its components, and its implications for various stakeholders. It aims to delve into the fast-paced transformation happening in the energy sector due to digital technologies, along with highlighting the benefits, challenges, and emerging opportunities associated with this transition. It is intended to serve as a resource for individuals and organizations looking to leverage the opportunities presented by the digital transformation of the energy industry.

Digital technologies are transforming energy infrastructure into connected, intelligent, efficient, reliable and sustainable systems. Digital energy is the convergence of old energy frameworks, such as an old coal plant that generates electricity, and digital technologies, such as cameras and temperature sensors monitoring the performance of such a plant.

Advances in data, analytics and connectivity are bringing a new range of digital applications such as smart appliances—think of a modern refrigerator with a screen that monitors the freshness of the food inside. Such advances can also be applied to any part of the energy infrastructure; with digitized energy systems, we are able to identify who needs energy in real time and then deliver it at the lowest cost.

Furthermore, digital energy improves the safety, productivity, accessibility, and sustainability of energy systems by collecting information across the entire energy framework. The intelligence gathered can then be used to maintain and improve energy generation across all energy sources in an infrastructure. However, with all this data and ways of collecting data, energy digitization is also creating wider attack surfaces and new security and privacy risks. It is also changing market trends and business models.

New business opportunities are emerging, and old models are disappearing. For example, new technologies are causing the energy industry to experience a situation in which energy is no longer a commodity and energy monopolies are simply roadblocks in the evolution of the more efficient energy delivery methods. Digital energy is fostering an environment where technology startups can deliver innovative ways to manage energy production, delivery and consumption.

Governments and regulatory agencies at the local and global, level face new and complex decisions to balance private citizen information management with grid modernization. Formerly archaic physical infrastructure is evolving at an exponential pace due to new energy applications, such as electric vehicles charging stations.

The power of digitizing the energy industry

The purpose of digitizing the energy industry is multifaceted, driven by the need to modernize infrastructure, enhance efficiency, promote sustainability, and meet evolving consumer demands.

By embracing digital technologies and data-driven solutions, the energy industry aims to overcome many challenges. Modernizing aging infrastructure, reducing operational costs, creating new energy products and services, enhancing customer and participant connections and communication are just some of the difficulties. Other issues include mitigating safety risks, creating new business models, scaling and flexing infrastructure, achieving data compliance, capitalizing on evolving opportunities, and transitioning towards a smarter, more resilient energy system.

Energy digitalization is changing market trends and business models.

The power of data in digital energy

The power of data in digital energy is that it functions as the central nervous system in energy production, distribution, and consumption.

The smart grid is at the heart of the digital energy revolution, where data plays a pivotal role in transforming traditional electricity grids into intelligent, dynamic networks.

In today's hyperconnected world, data from smart meters, sensors, and IoT devices holds immense potential for optimizing energy systems, improving efficiency, and enabling smarter decision-making across the entire energy value chain.

The smart grid is at the heart of the digital energy revolution, where data plays a pivotal role in transforming traditional electricity grids into intelligent, dynamic networks. Smart infrastructure enables utilities to collect real-time information on energy consumption patterns at the individual consumer level. This granular data allows for more accurate billing, improved load forecasting, and better demand response strategies.

Data analytics and machine learning algorithms analyze vast datasets to uncover insights that were previously inaccessible. Predictive analytics, for instance, can forecast energy demand fluctuations, anticipate equipment failures, and optimize asset performance. By leveraging historical data and real-time information, utilities can proactively address issues, minimize downtime, and enhance grid reliability.

In addition to grid optimization, data is empowering consumers to take more control over their energy usage through demand response (DR) programs. Demand response initiatives incentivize consumers to adjust their energy consumption in response to price surges based on grid conditions. Real-time data from smart meters and IoT devices enable consumers

Data-driven grid control and insights are driving the proliferation of decentralized energy systems andinnovative business models such as peer-to-peer energy trading, microgrids, energy as a service (EaaS) and virtual power plants (VPPs).

to monitor their energy usage and make informed decisions about when to reduce or shift electricity consumption to off-peak hours, thereby reducing costs and relieving strain on the grid.

Another fundamental data impact in the energy sector is causing the de-monopolization and de-commoditization of the industry. Data-driven grid control and insights are driving the proliferation of decentralized energy systems and innovative business models such as peer-to-peer energy trading, microgrids, energy as a service (EaaS) and virtual power plants (VPPs). These are business models empowering you to be an active participant in the energy revolution. We will cover these business models in more detail later on.

Finally, the security and traceability of information is a key component of data-driven energy business models. For example, data generated by participants of a virtual power plant includes information such as how much energy they have generated, where they live, their names, their account information, and how much they are paid for the energy they deliver. This data needs to be protected.

Blockchain technology, combined with smart contracts, enables secure and transparent transactions between energy producers and consumers. This means, for example, that VPP participants with rooftop solar panels can sell excess energy directly and securely to their neighbors, while simultaneously, the VPP aggregates distributed energy resources (DERs) to provide grid services such as power delivery optimization.

Renewable energy

One force driving digital energy is the crucial need to consume power from renewable energy to mitigate the impact of global warming.

Renewable energy involves the integration of five major energy sources: solar energy from the sun, wind energy from temperature fluctuations in the atmosphere, geothermal energy from heat inside the earth, biomass from burning plants, and hydropower from flowing water.

Each of these energy sources poses unique challenges and opportunities for the digital energy industry, but collectively, digital energy delivers advanced forecasting algorithms that play a crucial role in predicting renewable energy output with greater accuracy, enabling grid operators to optimize energy dispatch and balance supply-demand dynamics.

For instance, wind farms utilize sophisticated forecasting models to anticipate wind patterns and adjust energy production accordingly, thereby maximizing energy yield and grid reliability. Additionally, advancements in renewable energy integration technologies, such as grid-scale battery storage systems, facilitate the storage and dispatch of excess renewable energy, further enhancing grid flexibility and resilience.

Grid automation

Grid automation is a method for optimizing power distribution, enhancing grid reliability, and mitigating disruptions. This is similar to what your car does when you turn it on. The car has a computer that checks that the engine is working properly, that it has enough oil, that the brakes and lights work properly etc. If the car has an issue, the engine light comes on to let you know something needs attention and repairs.

Similarly, through automated fault detection and response mechanisms, grid automation enables utilities to identify and isolate grid disturbances promptly, thereby minimizing downtime and improving overall service reliability. A very specific type of grid automation system is called Distribution Management Systems (DMS) which integrates smart meters and other grid sensors to enable utilities to gather real-time data on grid conditions, facilitating proactive grid management strategies.

As utilities transition towards more decentralized energy systems, such as microgrids, grid automation plays an important role in ensuring the seamless integration of renewable energy resources. Grid automation depends heavily on smart meters which function as the key link for enhanced communication and data exchange between utilities and consumers.

One way to use smart meters involves Demand Response (DR). DR initiatives incentivize consumers to curtail or shift their energy consumption during periods of peak demand, thereby reducing strain on the grid and avoiding costly infrastructure upgrades.

Advanced metering infrastructure (AMI) facilitates real-time monitoring of energy consumption patterns, enabling utilities to gain insights into consumer behavior and optimize grid operations. Hence AMI enables the fundamental function of grid automation and it is also a key ingredient in empowering you to be an active participant in the energy industry. New digital business models can also leverage AMI data to implement dynamic pricing schemes, encouraging consumers to shift their energy usage.

Smart physical infrastructure

There are many components to the grid. Most are simple mechanical and electrical devices to support the generation and transmission of electricity. The most familiar ones are the transmission tower and the electricity pole, but in the context of digital energy, namely, the free flow of real-time information exchanged between energy suppliers and consumers, the critical components are OT and IT frameworks. In a nutshell, IT refers to computers, their software, and communication networks.

OT refers to monitoring sensors that collect data and control switches that automate physical actions. OT collects raw data from the field and it can also start or shutdown a system. IT aggregates data and processes it to deliver insights—more on this when we cover the role of artificial intelligence in digital energy.

At a practical level, there are two prominent physical frameworks that are essential for supporting digital energy. One stores electrical power and the other one collects critical data:

Energy storage systems
Energy storage systems (ESS) represent a key enabler of grid flexibility and resilience, allowing utilities to store surplus energy during periods of low demand and discharge it during peak hours. Grid-scale battery storage systems, in particular, have emerged as a promising solution for mitigating the intermittency of renewable energy sources and enhancing grid stability.

By integrating ESS with renewable energy generation assets and grid infrastructure, utilities can optimize energy dispatch, alleviate grid congestion, and improve overall system efficiency. ESS opens up new revenue streams through ancillary services such as frequency regulation and demand response, further incentivizing investment in grid-scale energy storage solutions.

Internet of Things
The Internet of Things (IoT) plays a crucial role in optimizing energy efficiency and enhancing demand-side management capabilities. IoT sensors and devices enable real-time monitoring and control of energy usage within buildings, industrial facilities, and smart homes. Integration with smart grid infrastructure enables IoT fabrics to support grid-balancing initiatives, contributing to overall grid stability and resilience. Granular secure IoT data collection empowers energy companies and users to identify energy-saving opportunities, optimize equipment performance, and reduce operational costs.

New energy business models

Traditional business models are giving way to a new era of energy solutions that prioritize flexibility, sustainability, and customer empowerment.

Utility companies invest in infrastructure to meet peak demand, often resulting in excess capacity and inefficiencies.

The current range of innovative and prominent business models that are reshaping the energy landscape and driving the transition towards a cleaner, more decentralized energy system are disrupting—as well as complementing, the traditional energy business model.

- Traditional energy business model
- Energy as a service (EaaS)
- Peer-to-peer (P2P) energy trading
- Virtual power plants (VPPs)
- Microgrids
- Subscription-based energy services
- Electric vehicle (EV) charging solutions

Traditional energy business model
First, let's take a look at the typical features of the energy business model we have relied on for over a century. Traditional energy businesses revolve around centralized power generation and distribution, where large-scale power plants generate electricity from fossil fuels or nuclear sources.

These power plants are typically owned and operated by vertically integrated utilities, which control both the generation and distribution of electricity within a specific geographic area. Consumers receive electricity through a regulated grid infrastructure, and utility companies bill customers based on their energy consumption.

In this traditional model, consumers have limited control over their energy usage and are largely passive participants in the energy system. Utility companies invest in infrastructure to meet peak demand, often resulting in excess capacity and inefficiencies. The reliance on centralized generation from non-renewable sources poses environmental challenges such as air pollution, greenhouse gas emissions, and natural resource depletion. Moreover, in some regions of the world traditional energy businesses function as impenetrable monopolies that prevent any significant competition.

Peer-to-peer energy trading

Another transformative business model gaining traction is peer-to-peer (P2P) energy trading. Enabled by blockchain technology, P2P energy trading platforms facilitate direct transactions between energy producers and consumers within local communities. Consumers with rooftop solar panels or other distributed energy resources (DERs) can sell excess energy to nearby consumers at mutually agreed-upon prices, bypassing traditional utility intermediaries. P2P trading fosters community engagement, promotes renewable energy adoption, and enhances transparency in energy transactions, ultimately leading to greater efficiency and sustainability in the energy market.

Virtual power plants

Virtual power plants (VPPs) represent a novel approach to grid management and optimization. VPPs aggregate and coordinate distributed energy resources, such as rooftop solar, battery storage, and demand response, to provide grid services and optimize energy supply and demand. By harnessing the flexibility of DERs, VPPs enhance grid stability, support renewable energy integration, and participate in energy markets. VPP operators monetize the aggregated flexibility of DERs by offering services such as demand response, frequency regulation, and capacity reserves to utilities and grid operators, thereby contributing to a more reliable and resilient energy infrastructure.

Despite these drawbacks, the traditional energy model has provided reliable and affordable electricity to billions of people worldwide for decades. However, as the energy landscape evolves and stakeholders demand greater sustainability, resilience, and choice, the shortcomings of the traditional model are becoming more apparent, paving the way for innovative alternatives. Here are the most prominent new digital energy business models in service today, but note that this is just the tip of the iceberg. More innovative digital energy frameworks will evolve in the next few years.

Energy as a service

One of the most prominent emerging business models in the energy industry is energy as a service (EaaS). EaaS represents a departure from traditional asset ownership towards a service-oriented approach, where consumers pay for energy outcomes rather than physical assets. Companies offering EaaS solutions provide comprehensive energy services, including energy efficiency upgrades, renewable energy installations, and ongoing maintenance, under long-term service contracts. By shifting the burden of ownership and maintenance to service providers, EaaS models lower upfront costs, provide predictable energy expenses, and facilitate access to cutting-edge technologies without the capital investment typically required.

Microgrids

Microgrids are localized energy systems that can operate independently from the main grid or connect and disconnect as needed. By integrating various distributed energy resources, including renewables, storage, and backup generators, microgrids provide electricity to specific geographic areas or communities. Microgrids enhance energy resilience, reliability, and security by providing backup power during grid outages and enabling islanding capabilities in case of emergencies. As a result, microgrids play a critical role in supporting critical infrastructure, remote communities, and commercial facilities, particularly in areas prone to natural disasters or grid instability.

Subscription-based energy services

Subscription-based energy services offer consumers access to energy products and services for a fixed monthly fee, similar to subscription services in other industries like streaming media or software. Examples include subscription-based solar installations, where customers pay a monthly fee for solar energy generated on their behalf, and energy management platforms that provide ongoing monitoring, optimization, and support services.

Subscription-based models provide consumers with predictable energy costs, hassle-free maintenance, and access to the latest energy technologies without the need for upfront investment. This is an extremely dynamic model with nascent capabilities. Since a subscription gives you access to a range of energy services, why not combine it with your phone or internet bill? This means that communication and media companies could collaborate with energy companies to deliver a unified smart home solution that encompasses all the ingredients to enable an intelligent home.

Moreover, such a unified solution enables the utility, communication, and media companies to share data about you amongst themselves, thereby optimizing their services depending on your

lifestyle. This of course also opens up a number of critical data protection vulnerabilities. It is in this business model that we see the convergence of cybersecurity, the smart home, and the services that empower the smart home, such as the internet, electricity and media. This is why this segment of the new digital energy industry is so dynamic: it entails a number of urban infrastructure components that were traditionally isolated. For the first time in history, we see the possibility of integrating all these components—no pun intended—under one "roof."

Electric vehicle charging solutions

With the growing adoption of electric vehicles (EVs), new business models are emerging to support EV charging infrastructure deployment and management. Companies offer EV charging-as-a-service, providing installation, operation, and maintenance of charging stations for residential, commercial, and public use.

EV charging networks may incorporate smart charging features, demand response capabilities, and integration with renewable energy sources to optimize charging operations and minimize grid impacts. By expanding EV charging infrastructure and promoting sustainable transportation options, these models contribute to reducing greenhouse gas emissions and promoting energy independence.

Contrasting traditional and new models

While the traditional energy model prioritizes centralized control and economies of scale, the new models emphasize decentralization, flexibility, and customer empowerment. In the traditional model, utility companies own and operate large-scale power plants and transmission infrastructure, dictating energy supply and pricing to consumers.

In contrast, the new models enable distributed energy resources, such as rooftop solar panels, battery storage, and demand response, to play a more prominent role in the energy system.

The traditional model relies heavily on non-renewable sources of energy, such as coal, natural gas, and nuclear power, which contribute to environmental degradation and climate change. In contrast, the new models prioritize renewable energy integration, energy efficiency, and grid optimization, thereby reducing greenhouse gas emissions, enhancing resilience, and promoting sustainability. This model is also characterized by a top-down, centralized approach to decision-making and infrastructure investment, with limited opportunities for consumer participation and innovation. In contrast, the new models embrace a bottom-up, decentralized approach, empowering consumers to become active participants in the energy market, make informed choices about their energy usage, and contribute to grid stability and sustainability.

Blockchain

Blockchain technology has emerged as a disruptive force in the energy sector, offering decentralized and transparent solutions for energy trading and peer-to-peer transactions.

Blockchain-based energy trading platforms enable consumers to buy, sell, and trade energy directly with one another, bypassing traditional intermediaries and enabling greater market efficiency. By leveraging smart contracts and digital tokens, blockchain platforms facilitate secure and verifiable energy transactions, fostering a more inclusive and democratized energy market.

Blockchain holds the potential to streamline energy settlement processes, reduce transaction costs, and enable new business models such as community-based microgrids and energy cooperatives. In a nutshell, without blockchain, it is not feasible to keep track of transactions securely in a decentralized energy economy. An essential data security synergy arises by paring cybersecurity with blockchain.

Cybersecurity and data governance

Critical infrastructure such as power plants, substations, and grid control systems are prime targets for cyberattacks. Attackers may seek to disrupt operations, cause equipment failures, or steal sensitive information.

It is essential to fortify data and physical frameworks with end-to-end data security that protects data at rest and in transit.

A breach in one part of the energy infrastructure can cascade across the entire network, leading to widespread disruptions and potential safety hazards. Coupled with large and complex amounts of data generated by smart meters, IoT sensors, and digital devices that contain valuable insights into energy consumption patterns, grid performance, and operational efficiency an attack can create a catastrophic infrastructure event.

In addition to firewalls, intrusion detection systems, and access controls, it is essential to fortify data and physical frameworks with end-to-end data security that protects data at rest and in transit. Furthermore, it is critical to authenticate IoT devices and to protect them from unauthorized access, theft, or manipulation. Finally, it is crucial to maintain trust and compliance with privacy regulations.

Compliance with cybersecurity regulations and industry standards is another crucial aspect of cybersecurity in digital energy. Energy companies must adhere to regulatory requirements such as the North American Electric Reliability Corporation (NERC), Critical Infrastructure Protection (CIP) standards, and the European Union's Network and Information Security (NIS) Directive. Additionally, adopting cybersecurity frameworks such as the NIST Cybersecurity Framework or the ISO/IEC 27001 standard can help organizations establish comprehensive cybersecurity programs and best practices.
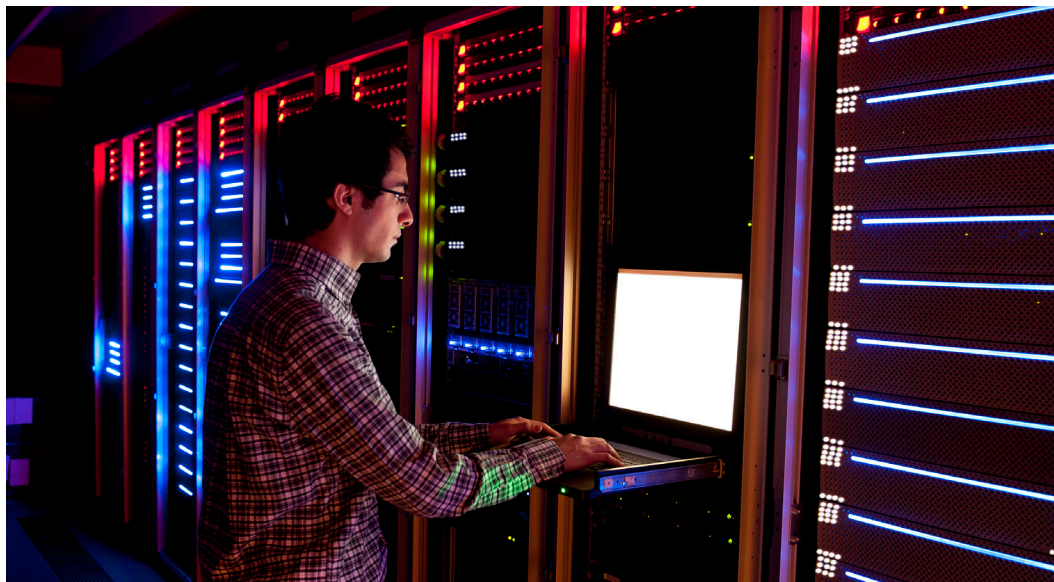
Artificial intelligence

AI algorithms analyze large and complex amounts of data generated by smart meters, sensors, and IoT devices to uncover insights, patterns, and trends that were previously inaccessible.

By leveraging machine learning and data analytics techniques, AI enables predictive maintenance of energy infrastructure, optimizing asset performance, and minimizing downtime. For example, AI algorithms can analyze historical data and sensor readings to predict equipment failures in power plants or transmission lines, allowing operators to proactively address issues before they escalate, thereby enhancing reliability and reducing maintenance costs.

Furthermore, AI enhances energy efficiency and grid optimization by optimizing energy consumption, demand response, and renewable energy integration. AI-powered energy management systems analyze real-time data on energy usage, weather conditions, and grid demand to optimize energy consumption patterns in buildings, industrial facilities, and smart homes.

For instance, AI algorithms can adjust heating, cooling, and lighting based on occupancy patterns, ambient conditions, and energy prices, maximizing energy savings while maintaining comfort and productivity.

AI enables the development of advanced energy trading platforms, virtual power plants, and peer-to-peer energy trading networks. AI algorithms analyze market trends, demand patterns, and consumer behavior to optimize energy trading strategies, facilitate peer-to-peer transactions, and aggregate distributed energy resources into VPPs. By leveraging AI, energy companies can optimize energy supply and demand, participate in energy markets, and maximize the value of DERs, thereby enhancing grid flexibility, reliability, and sustainability.

Conclusion

The digital energy industry encompasses a diverse array of interconnected components that collectively drive innovation, efficiency, and sustainability within the energy sector.

From smart meters and grid automation technologies to renewable energy integration and artificial intelligence, each component plays a crucial role in reshaping traditional energy systems and ushering in a new era of digitized, decentralized, and democratized energy. By understanding the technical intricacies and business implications of these components, you can capitalize on emerging opportunities, navigate regulatory challenges, and accelerate the transition towards a cleaner, smarter, and more resilient energy future.

Contact us, if you want to learn more about how we can support your journey into digital energy.

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