Energy intelligence – Tapping the potential of a smart energy world

A guide towards a smart energy world
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1. Preface:
This is a revolution!
Let’s act and create impact.

The energy sector is in the midst of a significant transformation that affects all of us. After all, having an affordable and fully reliable supply of electricity has been a key driver for society and for prosperity for well over 100 years. Throughout this period, the power grid has undergone countless technological changes. New in our times are the tremendous dynamics of the advances that are now being made. And digitalization will ensure that the ongoing transformation will continue at a fast pace.

We at Siemens want to actively shape the energy transition – boldly, collaboratively and ingeniously. We are firmly convinced that we can achieve much by infusing more intelligence into power grids. These smart capabilities can turn challenges into opportunities, improve business performance and mitigate environmental impact. Digital technology is the key to mastering the new complexity.

Today, we must escape silos and think in terms of comprehensive systems. And advanced energy systems already reflect this growing complexity. We now have to manage a wide range of assets: central and distributed generation facilities, substations, electric-vehicle charging points, intelligent “prosuming” buildings, behind-the-meter solar generation, campus-based storage solutions and microgrids, critical infrastructure, and commercial and industrial sites. In addition, smart, data-driven solutions and services are stabilizing grid operations and creating exciting growth opportunities.

In this process, the energy system’s versatility and complexity is presenting a new opportunity for intensive cooperation between suppliers and operators. No one can manage all this alone. We’re in this revolution together. In collaboration with all stakeholders, we can create an ecosystem that “intuitively” responds to people’s needs and helps our customers achieve their business goals.

We are presenting this publication to explain our perspective on the future of energy systems and to stimulate an open dialogue. Taking a broad view of the issues at hand, this resource outlines the trends and disruptions that are reshaping the energy landscape. It also shows how “Energy Intelligence” can help avoid potential pitfalls, capitalize on emerging opportunities and jointly create environments that care!

Michael Weinhold
CTO Siemens Smart Infrastructure
2. Global trends – the 3Ds of the energy world

As a result of social and economic developments such as urbanization and climate change, electricity will have to account for an increasing share of our general energy consumption. This is leading to a radical transformation of the energy landscape that is shaped by three major trends: decarbonization, decentralization and digitalization. A deep understanding of each of these trends is essential so that every market player can take the right decisions and actions to maximize value creation.

**Decarbonization:**

The commitment towards a green future has never been stronger. Political agendas, new regulations, industry initiatives and a broad societal consensus support the significant reduction of CO₂ emissions. This can be achieved by further electrifying all major energy-consuming sectors – transportation, buildings, and commercial as well as industrial facilities. But we must ensure that this electricity is generated by renewables like wind or solar and that energy efficiency potential is used to the fullest extent. Several examples show that this development is already underway:

- The European Commission has raised the ambition to reach net zero emissions by 2050. From 30% today, renewable generation is expected to meet over 80% of the EU’s future energy needs.\(^1\)
- In the US, 11 states and over 200 cities have already committed to 100% renewable energy targets, and major utilities have pledged to reduce their carbon emissions by 80% in 2050.\(^2\)
- Large companies like Walmart, Apple, and Microsoft have contracted more than 19.5 GW of clean energy to achieve their 100% renewable goals.\(^3\)

Decarbonization will be driven by the growing share of renewables in the energy mix, advances in storage technologies and changes in demand patterns. Connecting renewable generation and loads like power2heat, e-mobility or buildings, which are responsible for 40% of global energy consumption\(^4\) alone, will change the traditional load and production profiles (e.g. residual duck curve) or could overload the current infrastructure. The resulting voltage and frequency balancing as well as congestion management require new investments into the grid, but also new ideas and principles relating to system planning and operation. Although this makes grid operations more complex, it offers attractive business opportunities like providing energy management services, smart hardware for consumers (e.g. smart thermostats, intelligent HVAC, private storage) or new flexibility solutions for the grid. Private and commercial consumers can actively contribute to climate protection and capitalize on lower energy consumption or the active participation in energy markets.

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2 UCLA Luskin Center for Innovation (2019): Progress towards 100 % Clean Energy 2019


Decentralization:

An inherent effect of decarbonization is the dramatic transformation of the energy system into a heterogeneous, interconnected network of large- as well as small-scale generation sites, storage facilities and other flexible loads (e.g. electric vehicles, smart buildings). Driven by more data, bi-directional communication and smart devices, the focus of attention moves further to the edge of the grid, where intelligent prosumers play an increasingly important role. The economic benefits (e.g. ease of financing and faster time-to-grid of small-scale, decentralized assets) and the positive effects on the environment as well as a higher degree of independence from the grid are strengthening the robust position of distributed energy resources (DERs). It is estimated that the vast majority of all distributed energy resources are and will most likely continue to be connected at distribution grid level, in the form of many small-scale installations from commercial and industrial (C&I) and private households.5 In Germany alone, the approximately 245 fossil power plants (with over 50 megawatts each) are offset by over 31,000 wind power plants and 1.7 million PV plants.6

This enables new market roles and business models. Aggregators can pool and manage these DERs to ensure a secure, cheap and reliable power supply. The combination of generation, storage and loads in a microgrid can help developing countries to leap-frog centralized energy systems and electrify rural areas with local value added efficiently and sustainably. In a next step, the availability of DERs may lead to peer-to-peer-trading solutions. The electrification of our society and the rise of DERs directly create the urgent need to balance demand and production more actively than ever before. Large-scale, fossil and pumped-storage hydro power generation resources will focus on providing backup power and stabilizing the grid. Close collaboration and a seamless exchange of information between transmission and distribution system operators will play a key role in successfully managing the grid. A modern digitalized infrastructure and intelligent software solutions are cornerstones for a future-proof, decentralized and decarbonized electricity grid.

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5 Eurelectric (2019): Eurelectric’s vision for DSOs: From pipes to platforms
Digitalization:

The rise of smart devices and the utilization of the billions of data points has already disrupted many industries and the energy world will not be excluded. Just imagine that the amount of data from one million smart meters, which collect data every 15 minutes, accumulates to over 2,900 terabytes per year. A networked system of smart energy infrastructure (e.g. generation units, storage, buildings, electric vehicles, automated distribution equipment) is often referred to as the “Internet of Energy (IoE)”. The aim of IoE is to collect and organize the information from individual devices at the edge of the grid across the network and make it available to all relevant participants. On a grid level, a digital representation of the physical infrastructure, advanced data analysis and forecasting (e.g. weather, traffic, consumption patterns) can be leveraged to plan and use the infrastructure more efficiently, defer grid investments, manage constraints, detect faults, minimize outage times, and enhance flexibility. Together with operational data from the substation, condition monitoring and predictive maintenance can prolong the lifespan of the equipment and reduce maintenance costs. Connected, controllable actuators allow the coordination of supply and demand autonomously, perfectly leveraging the available resources. The combination of data and automation even enables new business models (e.g. energy-as-a-service) and revenue streams. But with more and more connected devices, the energy systems become susceptible to cyber-attacks. Ensuring the highest security standards regarding systems and customer data is a huge challenge, which requires the collaboration of all involved parties from regulators to system operators as well as prosumers and device manufacturers.

The effects of these trends vividly manifest at the grid edge, as we move from a centralized energy system to one that is more decentralized, decarbonized, intelligent, local and efficient. When we speak of the grid edge, we refer to the many connected technologies that exist at the interface between the energy supply side (grid) and the energy demand side (industry, buildings and consumers). These technologies include those for local consumption and production as well as for the storage of energy. A recent study of the World Economic Forum quantifies the magnitude of the grid edge in one, impressive number: US $2.4 trillion. This will be the economic value created through investments, new jobs and new revenues through the adoption of grid edge technologies in the OECD countries over the next ten years.8 A prime example of this is a microgrid across a whole community or facility (e.g. energy village Wildpoldsried).

As the boundaries between consumers, producers and distributors become increasingly blurred, the grid will evolve into a platform that allows decentralized sources of all kinds to use it to their best advantage. A mind-shift towards consumer-centric strategies, cooperation at all levels, new business models and the creation of intelligent management systems for the diverse assets at the grid edge will help all players to tap into potential new revenue streams.

8 WEF (2017): The Future of Electricity: New Technologies Transforming the Grid Edge
3. Opportunities for everyone

In the face of these dynamics, the different market players and stakeholders of the energy ecosystem pursue their specific strategic agendas and multiple business objectives:

- **Competitiveness:** Growing importance of energy as a key competitive advantage (e.g. reduced energy costs, higher reliability) for commercial and industrial facilities (C&I), campuses and cities. Alteration of the competitive landscape through the rise of new competitors and performance-based regulations in the traditional playing field of system operators (TSO, DSO) and independent power producers.

- **Profitability:** Securing traditional sources of income and transforming the organization to tap new business opportunities like energy management for third parties, virtual power plants, reserve and flexibility market or platform models.

- **Reliable and affordable energy supply:** System operators and municipalities must provide reliable and affordable energy in the face of natural disasters, grid congestion or intermittent renewable generation. Commercial consumers need to leverage energy as a key resource (power quality, saving potential, autarky).

- **Climate and environmental protection:** Investments in renewable energy sources and more efficient energy consumption help to save the planet. On the other hand, becoming CO2-neutral and reducing impact on the environment (e.g. land usage, recycling) can provide a significant economic and image boost for companies and cities alike.

- **Safety and security:** As a critical infrastructure, the energy system needs to be protected against all kinds of outside risks. This is true for physical as well as cyber-attacks. In addition, a highly user-centric design approach ensures safe operations for all market players.

As self-evident as these goals seem, as demanding it is to achieve them. Our customers are confronted with a variety of challenges that they must master to serve society and remain ahead of the competition.
Taking new routes to grid stability

The influx of more renewable energy sources – especially into the medium- and low-voltage levels – and the connection of more electrified devices are putting pressure on the energy system. A mismatch of supply and demand, congestion, reverse power flows from the distribution to the transmission grid, as well as voltage and frequency fluctuations can be the result. Yet, as many challenges as there are, as many opportunities exist for far-sighted market participants.

Innovative solutions and services (e.g. digital substations, smart meters, software platforms) offer a plethora of advantages:

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<th>Utilities/ grid operators/ municipalities</th>
<th>Commercial &amp; industrial sites/ campuses/ cities</th>
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<td>Better forecast of load and production profiles</td>
<td>Control consumption and increase efficiency</td>
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<td>Improved utilization of the grid infrastructure</td>
<td>Generate and store electricity to reduce costs</td>
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<td>Optimized matching of demand and supply</td>
<td>Participate in the energy market</td>
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<td>Simplified aggregation &amp; management of DERs</td>
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Building an Internet of Energy and ensuring power quality

The grid needs investments in hardware as well as software to cope with the energy transition and the speed of transformation. The utilization of “digital twins” of power grids can help to pinpoint where, how and when investments yield the greatest benefits. The digital twins mirror the physical electrical network and enable operators to simulate different developments, show the consequences, and test potential solutions. Insights from this scenario mapping can be combined with technological, societal, political, economic and environmental trends to identify the points where grid elements intersect with value-creating solutions. The integration of connected assets (e.g. storage, actuators, digital substations) and software applications such as a demand response program can cost-effectively meet growing grid needs. But the most important prerequisite for digitalization to really work is a high level of cyber security. Issues that must be addressed include the connectivity of diverse devices that require a high level of protection, the communication network between the different nodes, the privacy of the data, and the security of the software running the different sub-systems.

Tapping new business opportunities of the energy transition

Energy is becoming more expensive and managing the grid more complex. At the same time, profitability is high on the strategic agenda and freeing up resources for important investments is necessary. Therefore, our customers are looking for ways to save on their capital expenditures (CAPEX) and operational expenditures (OPEX) as well as to tap new revenue potential. Advanced, digital solutions, cost-parity of renewable generation, and intelligent energy management tools, in combination with new financing models, are the perfect answer. The intelligent combination of generation, storage, energy management, and energy efficiency measures into a microgrid, for example, can be realized with next-to-no upfront costs, thanks to energy-as-a-service concepts. Microgrids can reduce costs and lead to new revenue streams, e.g. by selling off excess energy. Grid operators and dedicated aggregators can build virtual power plants, install demand-side management software, or simply offer their energy expertise to prosumers to create additional revenues, minimize operating costs or defer investments in their grid.
4. Pioneering the new era with energy intelligence

It is a new energy world and the dynamics at the grid edge are driving its evolution with force. We at Siemens are committed to joint market success and follow a unique approach to support our customers in becoming “grid edge natives”. The central idea to achieve this is energy intelligence, which will be the key to successfully designing, installing and operating smart grids. This comprises of three core elements:

1. **Intelligent system**: The multitude of devices and connections demand more transparency and insights. Therefore, the grid needs to be optimally designed for bi-directional communication and power flows, e.g. through sensors at critical nodes, or AI-powered analytics.

2. **Intelligent management**: State-of-the-art energy management software collects data and suggests optimal strategies. Assets, e.g. substations, machines or heat pumps, become more intelligent, can be pooled and even actively managed.

3. **Intelligent collaboration**: Close collaboration between market players and ecosystems will foster an open exchange of know-how and ensure energy intelligence with real impact.

The ultimate endurance test for the smart grid of the future will happen right at the grid edge. Our truly end-to-end approach ensures that all relevant entities in the new energy system optimally play together. Our solutions cover the whole spectrum from the macro to the micro level, from physical products, components and systems to connected, cloud-based digital offerings and services. Therefore, they seamlessly fit into any system and create value at the most critical points.

The decisive factor here is a working information technology (IT)/operational technology (OT) integration. The OT (e.g. switchgear, transformers, energy automation devices, operating software) must be able to efficiently and securely communicate with the IT infrastructure to make optimized grid management possible.

Our customers can rely on our broad pool of dedicated energy experts and their first-hand knowledge of the requirements of generation facilities, the connection of new assets to the distribution grid and its future-proof planning and management. Furthermore, we have in-depth expertise in behind-the-meter installations of photovoltaic (PV) modules, EV-charging solutions, the management of intelligent buildings, city lighting and the set-up of microgrids. Like bringing together different technologies and devices, we at Siemens believe in close collaboration with our partners and customers, forming ecosystems that drive growth and value creation.
5. The Siemens portfolio – our offerings to secure your success

Our portfolio covers the whole spectrum of applications to design, build, operate and maintain a modern smart grid.

Consulting and planning – ideas and ingenuity for a perfect blueprint

With our expertise and broad portfolio of tools (e.g. PSS® Grid Simulation and Planning software, Energy Business Advisory, Power System Consulting), we help our customers find the best solutions and set-up to realize their strategic agenda. This includes optimizing grid development and expansion, modernizing the hardware and software infrastructure, pushing automation and intelligence in system planning and operation, leveraging flexibility potential at all system levels, identifying cost-cutting opportunities and monetizing new value streams, and ultimately securing reliable grid operation and energy supply for all end-consumers.

Reference Snapshot

All information at the fingertips for Fingrid

ELVIS, Fingrid’s digital twin, allows planning on a solid information basis, making decision processes faster, more efficient, and highly sustainable.

Read more

Smart grid operation – intelligent, flexible, secure, and cost-efficient

With our broad suite of applications including metering, diagnostics, trading and virtual power plants, we help our customers to simply connect, integrate and manage all levels of the traditional grid as well as distributed energy systems – even in the cloud and with an “as-a-service-model”. Key building blocks are our open and scalable grid control platform Spectrum Power, automation solutions based on SICAM, IoT-based solutions like the Grid Diagnostic Suite or EnergyIP meter data management.

Reference Snapshot

Boosting grid reliability for CAISO

Utilizing Siemens Spectrum Power Energy Management System and Energy Market Management module, CAISO (California Independent System Operator) can reduce complexity in day-to-day trading, lower the cost of power, and significantly increase the stability and resilience of the grid.

Read more
Digital substations – the heart of the digital transformation of the energy grid

We at Siemens offer a whole spectrum of solutions to make our customers’ infrastructure digital and intelligent, e.g. PowerLink for secure and efficient communication, SIPROTEC and SICAM for energy automation and protection as well as power quality analytics. Many of these components come together in our digital substations, allowing customers to generate data that is visualized and analyzed in the cloud, to enable more reliable, sustainable and profitable grid operation.

Reference Snapshot
Digital ingenuity for more resilience in Con Edison’s grid
Con Edison became the first US utility to install power network “storm hardening” technology. Siemens’ distribution feeder automation technology keeps power flowing in areas of lower Manhattan, including Wall Street, even during severe weather events like flooding.
Read more

Renewables management – highest flexibility where it matters

The efficient integration of renewables is not easy. Our photovoltaic electrical balance of plant (PV eBoP) solution includes all necessary electrotechnical equipment for PV systems, storage components and even complete microgrids, along with comprehensive offerings for end-to-end planning, engineering, financing and service. The Siemens’ Decentralized Energy Management System and the Distributed Energy Optimization Software enable a comprehensive view of the system, real-time actions or even participation in the secondary energy market.

Reference Snapshot
Instant adaptation to changing needs at the Blue Lake Rancheria
Installation of a local energy solution, consisting of solar power, storage and a back-up diesel generator controlled within a microgrid helps to reduce costs and ensure the uninterrupted operation of the infrastructure during outages by automatically managing demand and supply.
Read more
Distributed energy solutions and performance services – the power of integrated diversity

We help our customers manage local energy generation and consumption with an intelligent network of decentralized power, heating and cooling elements such as renewables, storage, combined heat and power (CHP), microgrid controllers or advanced building management systems. We bring our experts from our Power System Consulting and Energy Business Advisory, advanced simulation techniques and the Siemens Energy Configurator to the table to find the optimal solution for each issue. Our SIESTORAGE solutions or the SICAM and SIPROTEC portfolios make every endeavor more energy-intelligent. In combination with control and management software from EnergyIP or Spectrum Power, customers can take their energy future in their own hands.

Storage – energy whenever it’s needed

Storage is one of the key technologies for a successful energy transition. It helps to smooth peak demands, increase self-consumption, avoid grid expansions, and significantly reduce energy costs. Together with global power company AES, we launched the joint venture Fluence and designed the products Advancion, SIESTORAGE and SunFlex for the most demanding applications for transmission and distribution systems as well as industries and campuses. While these legacy systems continue to be in operation throughout the world, they also served as precursors to Fluence’s sixth-generation technology stack launched recently, making it simpler for customers to deploy storage faster and more cost-effectively without sacrificing quality and configurability.

Reference Snapshot

Evolution of power on the Galapagos

The installation of a hybrid system on Isabella island, consisting of a solar farm, a storage solution and a biodiesel generation facility, allows the biological sanctuary to switch its power supply to an environmentally compatible alternative.

Read more

Reference Snapshot

Sello: A truly powerful shopping center

Sello and Siemens identified areas for optimum use of energy resources. The system is made up of a microgrid based on Sello’s building technology, a 550 kW peak solar panel system, intelligent LED lighting, charging station for electric vehicles, and about 2 megawatts of electricity storage capacity. Sello can significantly save energy costs, reduce CO₂ emissions, sell excess energy, and be an active part of the electricity reserve market.

Read more
EV charging – powering tomorrow’s mobility

An electric vehicle charging platform that allows companies, municipalities or homeowners to take care of electric vehicle charging is something many are looking for. By partnering with others, we are creating the most powerful combination of hardware, software and services in this area. We consult our customers on the ideal charging landscape. Our solutions like the E-Car Operation Center can offer services to multiple clients in the electromobility market, thus reducing running and delivery costs.

Reference Snapshot
The Electric Avenue in London

Westminster City Council teamed up with Siemens and ubitricity to unveil the UK’s first fully converted lamppost charging street in March 2020 – Sutherland Avenue, W9. Residents can now charge their electric vehicles at 24 lampposts at various locations along the street.

Read more

Cyber security – resilience in a digitally-connected world

Cyber-attacks on critical infrastructure are a very real threat. Siemens’ unique Security Circle – a holistic, four-pillar concept (trusted partner, product security, system security, operational security) supports our customers across the energy landscape in establishing a resilient cyber security approach. We analyze the technical customer requirements, consider their policies, and ensure a secure implementation of all components, verified and validated in factory acceptance and site acceptance tests, and we offer security services to keep the whole system up to date. Across our portfolio, we meet strict cyber security requirements, like the IEC 62443 and IEC 62351 security standards, tested security architecture, and regular security updates. Our secure substation blueprint is certified to be IEC 62443-2-4- and IEC 62443-3-3-compliant.

Reference Snapshot
Locked Shields: Handle a massive cyber-attack

Locked Shields constitutes the largest, and most advanced, international live-fire cyber defense exercise in the world. Since 2017, Siemens has teamed-up with NATO Cooperative Cyber Defense Center of Excellence (CCDCOE) to include power grid scenarios in the annual Locked Shields exercise. Spectrum Power, the grid management platform, the SICAM A8000 remote terminal units (RTUs) and SIPROTEC protection devices provide a realistic simulation of a power grid infrastructure.

Read more
Financing – making the impossible possible

With the power of our Siemens Financial Services unit, we have the right experts at hand who can help our customers with their individual energy transitions. Our experience in the energy, industrial and infrastructure sectors allows us to offer financing solutions and advisory services, grounded in in-depth understanding of our customers’ market environments. Adaptability and flexibility are part of our operational mindset and we offer traditional and innovative financing options, tailor-made to the project at hand.

Reference Snapshot
Shaping the energy transformation in Brazil

Siemens Financial Service (SFS) invested in the Brazil-based start-up Micropower-Comerc (MPC) to deliver solar and battery storage to commercial and industrial clients (C&I).

Read more

6. Open invitation – let’s ideate and create together!

Energy intelligence is all about perfectly aligning different assets and capabilities to form a cohesive and cooperating unity – across technologies, businesses and people. In this paper, we present you with our take on the new energy world and share some key ideas on how we can bring together the right resources to support the different stakeholders in reaping its benefits. We want to conclude by issuing an open invitation to all players in the energy market to get in touch with us and embark on a journey towards this new era.

You can contact us 24/7. We are ready to help you with a concrete project, a quote for any of our products or solutions, or direct support for installed equipment.

E-mail: support.energy@siemens.com; phone: +49 180 524 70 00
Siemens Smart Infrastructure intelligently connects energy systems, buildings and industries to adapt and evolve the way we live and work.

We work together with customers and partners to create an ecosystem that intuitively responds to the needs of people and helps customers to better use resources.

It helps our customers to thrive, communities to progress and supports sustainable development.

Creating environments that care.
siemens.com/smart-infrastructure