TECHNOLOGY PERSPECTIVE

BUILDING A RESILIENT SMART GRID

IT infrastructure solutions for the energy sector

Supporting infrastructure of this breadth and scope will require a mix of advanced technologies and components. These solutions include edge devices and sensors relaying data through IoT gateways to datacenters, as well as middleware applications to aggregate, filter, and analyze massive volumes of data.

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THE ENERGY SECTOR TRANSFORMED

As energy needs evolve, aging power plants and energy infrastructure need to be updated and modernized. IT infrastructure modernization can help energy providers stay competitive, strengthen the security and resilience of their distribution networks, and develop innovative products and services.

Emerging technologies—including the Internet of Things (IoT) and hybrid cloud infrastructures, smart grid networks, and advanced data analytics—offer new capabilities to help energy providers with IT modernization. These technologies can provide and support energy resource management and distribution across a transcontinental electric grid. For example, microgeneration—small-scale generation of heat and electric power by individuals, small businesses, and communities—is the fastest growing area in the energy industry. As far back as 2008, new micropower installations provided approximately 90% of added sources of electricity generation around the world, with an increasingly large potential market as renewable energy costs continue to shrink.

To take advantage of microgeneration, some utilities are exploring demand flexibility with intelligent distribution matching sources against demand-side loads.[1] The ultimate goal is to use these emerging technologies to build a resilient smart grid, re-engineering methods that support electric grid operations and developing IT infrastructure to track, monitor, and manage energy distribution.

Data is also vital to IT modernization of the energy sector. An extended ecosystem that connects smart meters and appliances, grid exchanges, energy distribution systems, analytics engines, sensor networks, transmission lines, reserve storage systems, and other components can dramatically improve energy efficiency. This ecosystem can connect resources in new ways to balance supply and demand and take advantage of intelligent microgrid operations to mitigate large-scale power outages.

Intel and Red Hat, working collaboratively with other partners, have established reference architectures and IoT and hybrid cloud infrastructures that perform reliably in large-scale implementations and can rapidly adapt to evolving conditions and business models. Better collection, distribution, and storage of data can be achieved using Intel® hardware and Red Hat® software, as well as data collection and connection technologies co-engineered by both companies. As a result, energy providers can embrace digital transformation and establish strong IoT ecosystems to resolve energy challenges and improve electric utilities services.

CHALLENGES IN ENERGY TRANSMISSION AND DISTRIBUTION

Traditionally, transmission and distribution of electricity is primarily performed through monolithic, centralized plants that generate electricity from coal, oil, natural gas, or fissionable materials. Transmission line losses occur as electricity travels from source to customer over hundreds of miles of high-voltage transmission lines and then to lower-voltage distribution lines. The U.S. Energy Information Administration estimates average transmission and distribution losses of around 6% of the electricity distributed annually in the United States.[2]

However, the energy landscape is becoming much more dynamic. Thousands of prosumers—independent individuals, communities, and small businesses that generate electricity by means of geothermal, wind turbines, photovoltaic solar panels, and other methods—are adding power back into the grid, quickly making the classic analog grid model obsolete.

Several other factors emphasize the need for digital transformation across the industry, including:

- **Greater interconnectivity.** In the U.S. and Europe, energy agencies, public utility commissions, and electric utilities are recognizing the need for a more federated and flexible grid structure with interconnectivity across continental regions.
- **Renewable energy sources.** Many renewable energy sources are quickly gaining parity with fossil fuel sources as increasing numbers of residential, commercial, and industrial users produce surplus power that is fed back into the grid. These suppliers require grid management to ensure load-shedding and demand-response capabilities are adequate.

1 *Lovins, Amory B., Mathias Bell, Lionel Bony, et al. "Reinventing Fire: Bold Business Solutions for the New Energy Era." Chelsea Green Publishing. 2011.*

2 *"How much electricity is lost in transmission and distribution in the United States?" U.S. Energy Information Administration. 2016. eia.gov/tools/faqs/faq.cfm?id=105&t=3*

- **System fragmentation**. The legacy grid infrastructure is become more complex and increasingly fragmented. Many smaller systems—ranging from high-voltage super grids to very low-voltage micro- and pico-grids—are being introduced. Numerous devices connecting into the grid edge—such as electric vehicles and home battery storage systems—create unpredictability that must be managed in a responsive way.

The smart grid can be the key to much of the transformation of energy systems around the world. According to the Rocky Mountain Institute (RMI), smart grids can be described using the following definition:

"[W]e use the term to describe the hundreds of technologies and applications that provide new level of communication, information, and control to utilities and customers. For example, smart meters and related infrastructure can send price signals to customers, enabling them to adapt their usage to save money if they wish. The smart grid can also correct a longstanding limitation of classic grid design: Transmission lines routinely handle power flow in both ways, but distribution lines don't because their protective equipment is typically designed for one-way flow only, from central generators to dispersed users. A smart distribution system will switch that 'tree structure' to a 'web' that can gracefully handle power flows in all directions."[3]

However, energy providers must adapt their IT infrastructures to meet the unique needs of smart grids. According to Intel, an effective strategy for IT modernization requires new technology:

"To add intelligence to existing infrastructure, new digital equipment and devices are strategically deployed to complement existing equipment. This new layer of digital equipment connects all assets in what can be described as an 'Internet of Watts'—but which is in fact an example of the Internet of Things (IoT) in action.

"The IoT is built by integrating Internet-connectivity into all kinds of plant, equipment and devices, connecting those devices in intelligent networks, and using data analytics to extract meaningful and actionable insights from them. … In the context of the smart grid, this [approach] means distributing computing intelligence throughout the infrastructure. This includes everything from embedded sensors in wind turbine vanes that control its pitch, rotation and function in real-time response to changing wind conditions, to substation control systems that respond quickly to events and minimize production downtime associated with network disturbances—in both cases without human intervention."[4]

Creating infrastructure of this breadth and scope will require a mix of advanced technologies and components, including edge devices and sensors relaying data through IoT gateways to datacenters, as well as middleware applications to aggregate, filter, and analyze massive volumes of data. This infrastructure will also require modern storage systems for data, hybrid cloud technologies to bridge network systems and provide visibility across complex infrastructures, and virtualization applications to maximize resources for optimal use.

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3 Lovins, Amory B., Mathias Bell, Lionel Bony, et al. "Reinventing Fire: Bold Business Solutions for the New Energy Era." Chelsea Green Publishing. 2011.

4 Donitzky, C., O. Roos, and S. Sauty. "A Digital Energy Network: The Internet of Things & the Smart Grid." Intel. 2014. intel.com/content/www/us/en/energy/iot-smart-grid-paper.html.

INFRASTRUCTURE SOLUTIONS FROM INTEL AND RED HAT

Intel and Red Hat offer several robust hardware and software solutions to help utilities and energy companies meet the challenges of developing infrastructure for nationwide smart grid operations.

CYBERSECURITY

Red Hat Insights uses prescriptive analytics to help organizations proactively identify and resolve threats to security, performance, and stability. With this solution, IT risks and vulnerabilities are cross-referenced with Red Hat's comprehensive knowledgebase of known issues.

The smart grid is a critical target and essential component of national security, making multilayer cybersecurity protections against intrusions, malicious code, hacking, and other cybersecurity threats essential.

Intel® Trusted Execution Technology (Intel® TXT) integrates silicon-based protections into chipsets, processors, and other platform components. Prelaunch validation checks ensure that the basic input output system (BIOS), operating system, and critical applications have not been tampered with or include malicious code. Integrated technologies from Wind River and McAfee also strengthen infrastructure security. McAfee Data Exchange Layer (DXL) compiles collective threat intelligence and provides adaptive threat prevention techniques for securing massively scalable networks. Wind River provides embedded solutions that secure runtime environments and reduce threats from uncontrolled software. These solutions, based on an integrity management architecture, ensure applications are signed to run on a specific device before being loaded into memory or installed on file systems.

Red Hat offers a variety of security measures to protect data and systems. At the operating system level, Security-Enhanced Linux® (SELinux) offers built-in protection, including mandatory access controls to protect against malicious or hacked applications and services. In addition, fine-grained controls grant security beyond typical UNIX permissions and help enforce data confidentiality and file integrity. SELinux is built into Red Hat Enterprise Linux, and robust additional identity management features in Red Hat Enterprise Linux also protect security. These controls help energy providers adhere to industry standards and regulatory mandates that minimize risk to national infrastructure assets, such as the Critical Infrastructure Protection Plan (CIPP) and the National Infrastructure Protection Plan (NIPP).

CONTAINER AND MICROSERVICES TECHNOLOGY

Seventy percent of the existing inflexible, monolithic energy delivery infrastructure is more than 30 years old.[5] This infrastructure lacks the agile, responsive capabilities to handle volatile supply and demand fluctuations or accommodate hundreds of thousands of microgrid inputs from prosumers. Containers and microservices offer a way for electric utilities to rapidly design and deploy interoperable applications to enhance infrastructure operations.

As a leader in container technology and microservices, Red Hat offers effective software solutions for supporting smart grid infrastructure requirements. Red Hat OpenShift Container Platform is a complete Platform-as-a-Service (PaaS) that helps developers improve IT service delivery, create and launch microservices, and securely manage open containers. Red Hat OpenShift Container Platform is designed to streamline developer tasks in a standardized operating environment (SOE) and support advanced container technology with orchestration and management tools.

In addition, Red Hat offers enterprise middleware and messaging services—including Red Hat JBoss® Enterprise Application Platform, Red Hat JBoss Web Server, and Red Hat JBoss A-MQ—to help energy providers effectively manage and connect their container and microservices environments.

5 *"Building a Smarter Smart Grid: Counteracting Cyber-Threats in Energy Distribution." Wind River. 2015.*

RISK MANAGEMENT

Public utilities must ensure consistent and continuous electricity delivery while complying with regulatory mandates imposed by federal and local agencies.

Red Hat Insights uses prescriptive analytics to help organizations proactively identify and resolve threats to security, performance, and stability. With this solution, IT risks and vulnerabilities are cross-referenced with Red Hat's comprehensive knowledgebase of known issues. As a result, issues can be identified and corrected across complex hybrid cloud environments that may include physical and virtual components, containers, public and private clouds, and other components. With these capabilities, smart grid operators can avoid downtime and resolve IT infrastructure issues before they interrupt service delivery.

REMOTE MONITORING AND CONTROL

Red Hat Mobile Application Platform offers a framework for supporting rapid development and launch of secure mobile applications. This platform follows agile development models and DevOps principles that integrate seamlessly with enterprise infrastructures.

Using this platform, electric utilities can connect existing data stores to a mobile framework to share operational details and information with technicians, administrators, field personnel, and other staff members, unlocking opportunities to introduce new services. In addition, mobile applications can be integrated with enterprise systems and services to complete a variety of tasks, such as control of unmanned aerial vehicles for data collection, inspections, and maintenance. Administrators can remotely monitor operations by zone, access back-end data from any location, make adjustments, and perform data-supported decision making.

APPLICATION PROGRAMMING INTERFACE (API) MANAGEMENT

Development of a smart grid supported by modern IT infrastructure will also require robust API management tools to develop cloud and mobile apps and integrate infrastructure architectures, including microservices.

Red Hat 3scale API Management Platform can be deployed to increase interoperability between on-premise and cloud-based components (Figure 1). This platform provides policy management for tracking and controlling APIs across complex infrastructures and bridges IoT devices and components with the enterprise. As a result, energy providers can take advantage of rapid, flexible development models.

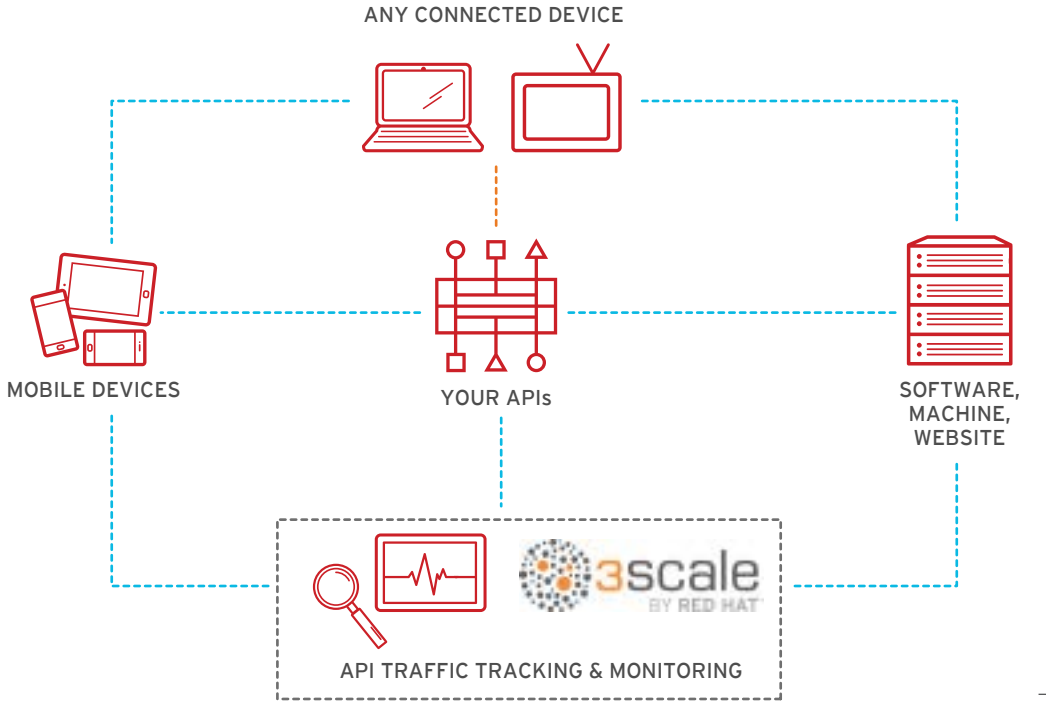


Figure 1. Red Hat 3scale API Management Platform overview

Utilities can also gain competitive advantages through IT modernization by integrating IT operations and business processes. Red Hat JBoss BPM Suite combines business process management (BPM) and business rules management to provide a common language between technical and business users. This compatibility offers fine-grained control over business logic and a fluid structure for mapping procedures and policies.

INTERNET OF THINGS

Intelligent systems that take advantage of IoT technologies can help utilities providers manage the electrical grid and reduce infrastructure costs for utilities.

Intel® IoT Platform solutions can help accelerate the design, development, and deployment of smart grid applications. Intelligent grid devices from a number of manufacturers can be integrated with switch and sensor hardware to control operations from the edge of a microgrid. Ultra low power processors from Intel and embedded operating systems that reside in many of these devices offer a high degree of intelligence at the edge of the IoT infrastructure. In addition, Intel® Xeon® processors play a key role in datacenters, where big data analytics help utilities providers gain visibility into events across grid networks. Intel has collaborated on end-to-end synchrophasor solutions, devices that measure waves on an electrical grid against a common time source and support multiple, remote measurements of different points on the grid.

In addition to Intel platform solutions, Intel architecture hardware offers a robust foundation for big data applications that filter and analyze massive volumes of input from IoT devices. Combined with middleware components from Red Hat and a modern operating system, such as Red Hat Enterprise Linux, Intel® architecture-based hardware can be used to create an SOE for a dynamic, responsive smart grid infrastructure.

Intel IoT gateways are key to building these infrastructures. Used with Red Hat middleware solutions, they integrate IoT components and specialized services and equipment from other experienced ecosystem partners. As a result, utility companies can develop comprehensive, end-to-end solutions to track and manage assets more precisely, achieve centralized control over operations, improve security across complex infrastructure, and use innovative business models to establish new revenue channels.

APPLIED TECHNOLOGY USE CASES

DEMAND FLEXIBILITY

A nationwide intelligent electric grid created with IoT technology presents opportunities to connect home and business devices—such as HVAC systems and smart hot water heaters—with a collection of power generators tied to a grid consisting of a mix of renewable and traditional energy producers.

Demand flexibility can yield unprecedented energy efficiency by providing the ability to adjust to system-wide peak demands, lower the overall cost of electricity, and make power use responsive to electricity price signals.

According to the RMI, new communication tools and technologies can buffer the dynamic balance between supply and demand:

"Demand flexibility uses communication and control technology to shift electricity use across hours of the day while delivering end-use services (e.g., air conditioning, domestic hot water, electric vehicle charging) at the same or better quality but lower cost. It does this by applying automatic control to reshape a customer's demand profile continuously in ways that either are invisible to or minimally affect the customer, and by leveraging more-granular rate structures that monetize demand flexibility's capability to reduce costs for both customers and the grid.

"Importantly, demand flexibility need not complicate or compromise customer experience. Technologies and business models exist today to shift load seamlessly while maintaining or even improving the quality, simplicity, choice, and value of energy services to customers."[6]

In the residential sector, RMI projects that widespread implementation of demand flexibility can reduce potential grid costs by 10-15% and help customers cut their electric bills by 10-40% with existing rates and technologies. Similarly, savings are projected for business and industrial implementations.

Hardware and software technologies pioneered by Intel and Red Hat offer new ways to handle the continual challenge of balancing energy supply, distribution, and demand by offering broad control with real-time intelligence and analysis.

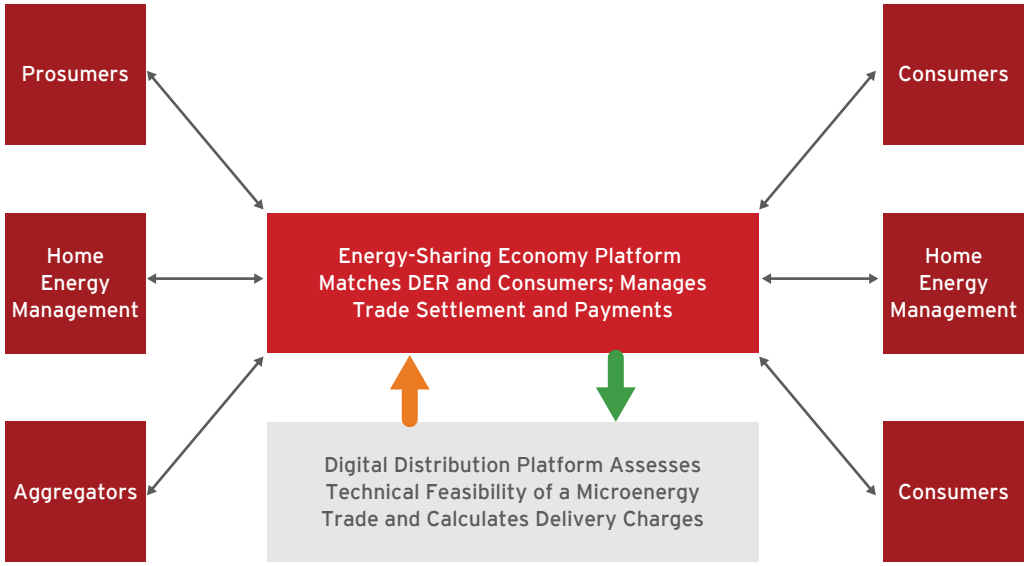
6 *Bronski, Peter, Mark Dyson, Matt Lehrman, et al. "The Economics of Demand Flexibility." Rocky Mountain Institute. 2015. rmi.org/electricity_demand_flexibility*

NEW SERVICE OPPORTUNITIES

According to Gartner, electric utilities can broaden their service offerings by using digital technologies and updated infrastructures to create an ecosystem for energy sharing.[7] By uniting stakeholders and integrating prosumers into the energy market using IoT and hybrid cloud technologies, utilities providers can profit from exchanges as participants deliver energy back into the smart grid.

Gartner visualizes two separate platforms to support this vision, both of which could be developed using Intel and Red Hat technologies (Figure 2).

- **An energy-sharing financial platform** that would unite participants using a combination of IoT and hybrid cloud technologies and handle data involved from thousands of daily microenergy transactions, including payments, monitoring, financial management, and algorithms for performing consumption and predictive analytics.
- **A digital distribution platform** that would host operational tasks across the distribution grid. The platform providers in this scenario will earn revenue for maintaining the IT infrastructure and delivering services over the smart grid for participants.



Source: Gartner (May 2016)

Figure 2. Gartner framework for energy-sharing and digital distribution platforms

7 *Sumic, Zarko. "Industry Vision: Utilities as Platform Providers for the Energy-Sharing Economy." Gartner. 2016.* gartner.com/doc/3306421/industry-vision-utilities-platform-providers

INTELLIGENT ENERGY DELIVERY WITH NEW TECHNOLOGIES

As more loads, batteries, and distributed generation sources—such as smart appliances and electric vehicles—become connected and their orchestration into highly valuable energy services improves, demand-side flexibility will continue to grow, both as a tool for customers to save money and for grid operators to reduce infrastructure expenses. As these trends become embedded in the power grid, the electric system can be built not to meet occasional peaks but to help supply and demand respond to each other dynamically, benefiting customers, utilities, grid operators, and the environment.

Through advanced technologies based on open standards, Red Hat and Intel deliver solutions that can support electric utility companies as they modernize their IT infrastructures and build a framework for smart grid implementations. Taking advantage of modern, open architectures can help energy providers attract new customers and provide entry into markets where these kinds of services were technologically impossible a decade ago.

"Importantly, demand flexibility need not complicate or compromise customer experience. Technologies and business models exist today to shift load seamlessly while maintaining or even improving the quality, simplicity, choice, and value of energy services to customers."

PETER BRONSKI
AUTHOR
ROCKY MOUNTAIN INSTITUTE

ABOUT INTEL

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ABOUT RED HAT

Red Hat is the world's leading provider of open source software solutions, using a community-powered approach to provide reliable and high-performing cloud, Linux, middleware, storage, and virtualization technologies. Red Hat also offers award-winning support, training, and consulting services. As a connective hub in a global network of enterprises, partners, and open source communities, Red Hat helps create relevant, innovative technologies that liberate resources for growth and prepare customers for the future of IT.

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