

WHITE PAPER

# Resilient Microgrids:

Securing a Better Energy Future  
through the Power of Choice



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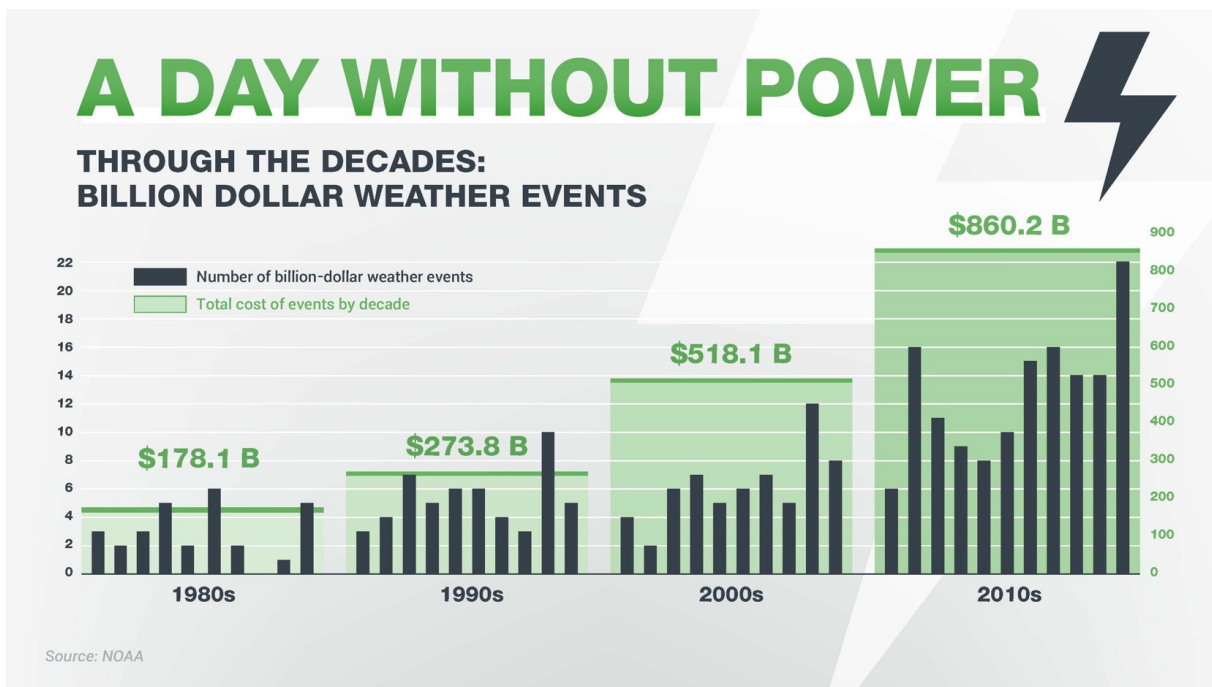


## Introduction

A day without power is hard to imagine. Electricity has become a basic necessity, powering everything from our homes, to our businesses, to our transportation systems. But in a post-climate change world, extreme weather events are happening more frequently and becoming increasingly severe, threatening our access to the 24 x 7 power so integral to our everyday lives. This has caused a shift in thinking from, “the cost of power” to “the cost of not having power.”

Demands of our digital economy coupled with the escalating consequences of our changing climate have created an unprecedented risk landscape. Energy challenges are on the rise and pressure is mounting for our electric system to get cleaner, faster. The sheer financial cost of climate impact is nearly outpacing the billions of dollars utilities are spending to improve the electric delivery system.

### THE COST OF WEATHER EVENTS IN BILLIONS OF DOLLARS



During 2020, there were 22 separate billion-dollar weather and climate disaster events across the United States, breaking the previous annual record of 16 events that occurred in 2017 and 2011.

This is the risk landscape for all of us, but without proper safeguards in place, the consequences of those risks are higher for those whose power choices are directly tied and vital to the functioning of their organizations. Mitigation requires a highly strategic approach to energy management.

Fortunately, we are now in a time where there are multiple options for sourcing and delivering electricity. Distributed generation has completely shifted the energy paradigm, providing a clear path forward for those seeking to gain more control of their electricity supply.

This paper explores this crucial paradigm shift. Its objective is to educate and mobilize individuals, businesses, communities, and policymakers around the importance of resilient power – the challenges we face, the risks we can mitigate, and how leaders can gain control of their energy future through distributed generation and microgrid solutions.

## Energy as a Keystone Metric

Depending on the industry, energy can be a large component of a company's cost structure and a complicated operational issue. It touches every piece of a business' value chain.

Companies are opening the aperture on their energy strategies to meet their corporate objectives, with each company's approach reflecting critical business needs. These critical business needs may be substantially different depending on industry and facility requirements.

Retailers face different challenges than data centers or manufacturers. In some cases, business needs primarily reflect rising energy costs and their impact on other operating margins. In other cases, business needs may be more closely tied to reliability of critical infrastructure and ensuring that the business can continue to operate effectively during a prolonged grid outage.

The critical challenge for businesses in building a cohesive energy strategy is identifying their full scope of electricity-related risk factors. Recognizing risk is one thing. Having a strategy to mitigate it is another. Doing so requires a deeper understanding of the issues and how to address them from the top down.



Over the course of the 20th century, the U.S. electric grid was built as a one-way value chain from fuel supply to end-user consumption. Such infrastructure design created cascading vulnerabilities whereby a failure of any one component can result in disruption of service to end users. Grid hardening programs are underway in every region, but upgrading such a complex system is expensive, and takes years to properly execute. Some might say it's too little too late – that these complexities have left society too heavily reliant on an electric delivery system that has simply not kept pace with the evolution of its surrounding environment.

This aging centralized power grid that is inherently prone to failure, now faces heightened demands of digitization, a rising frequency and intensity of natural disasters and a dangerous cyber-threat landscape.

As a result, companies with mission critical facility requirements must invest heavily in back-up and conditioning devices to ensure a constantly available, high-quality energy stream to power their equipment. However, the few traditional solutions available are prone to their own failures.

But consider the implications of developments in the energy space that have come from the rapid digital transformation over the last few decades. The conventional way of delivering electricity is experiencing a fundamental and promising shift – we are moving away from our centralized present towards a distributed future.

Distributed generation has completely shifted the energy paradigm, providing a clear path forward for those seeking to gain more control of their electricity supply. One solution rapidly gaining traction across industries is the microgrid. Microgrids are a win-win, allowing businesses to meet their own specific electricity needs while helping utilities address the larger challenge of hardening and decarbonizing our nation's grid.

Microgrids are distributed onsite power solutions that can disconnect from the traditional grid to operate autonomously. These are localized sources of power that can pair multiple generation technologies at a single site, enabling facilities to mitigate risk and gain energy independence.

Microgrids are becoming increasingly important because they allow critical loads, facilities or even entire communities to continue operating when the surrounding electrical grid becomes unavailable.

## **The Resiliency Challenge: Eliminating Tradeoffs**

As businesses look to address their critical resiliency needs, growing ambitions of a clean energy future and impacts of rising energy costs have elevated the importance of choice when it comes to power.

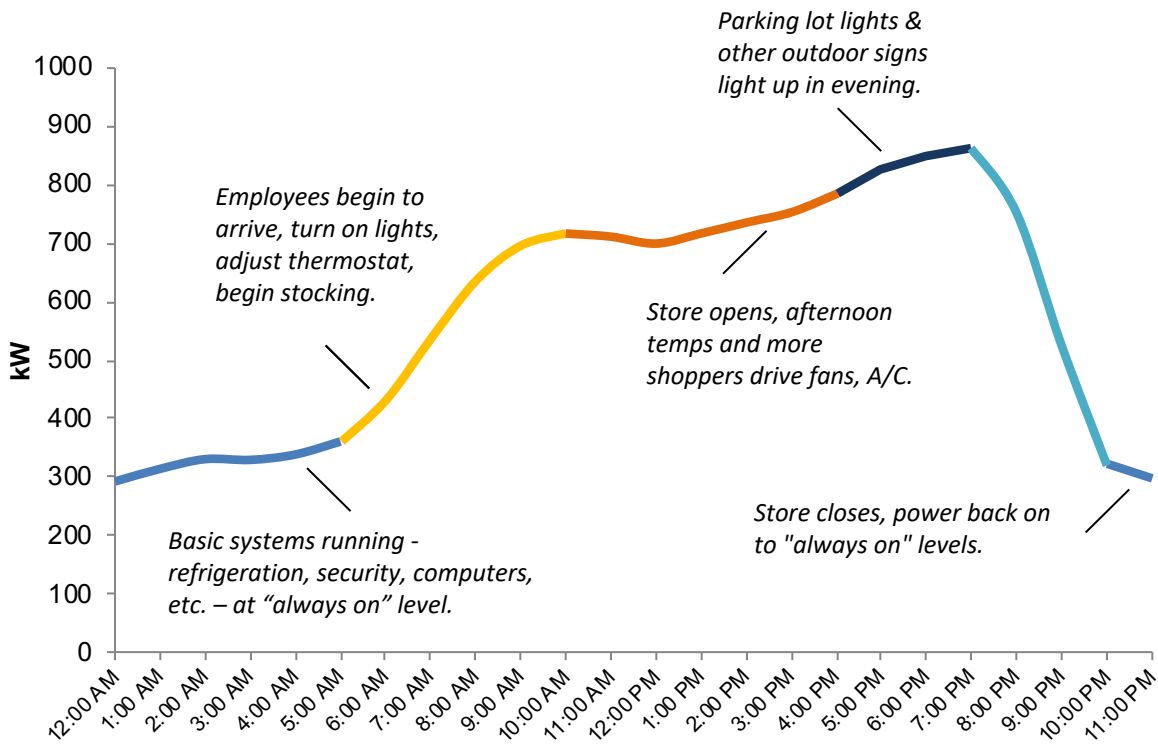
Most distributed energy resources (DER) are self-sufficient, but they are not one-size-fits all. Resiliency is just one benefit among many that microgrids provide, but resiliency decisions should not be made at the expense of environmental concerns and sustainability decisions should not ignore the importance of reliable energy supply. Diesel generators have been the status quo solution for power disruptions for decades. However, they are monolithic machines without inherent redundancy and they produce over 40 toxic air contaminants, including a variety of carcinogenic compounds during operation. What's more, since they are idle assets, they needlessly consume fuel while testing to ensure they can be available when needed. Further, the availability of diesel fuel during an extended outage and the reliability of diesel engines to operate continuously for long periods of time are both risks to the traditional design.

Technologies like solar and wind are great for their renewable profile but due to their inherent intermittency, cannot practically solve resiliency challenges. Their very nature requires some sort of energy storage and today's technology does not cost effectively support the massive load shifts from day to night, and certainly not from summer to winter. Further, the majority of solar (66%) and wind (~100%) are utility scale projects, meaning they still rely on the vulnerable, above ground, transmission and distribution system.

Bloom Energy's distributed, modular architecture produces power 24/7 without particulate emissions. Bloom's distributed solution is onsite and always-on. This is not a UPS or generator sitting idle waiting for an outage event – this is an active asset delivering clean, highly reliable power around the clock. This makes it the ideal solution for solving all of these challenges.

# The Reliability Spectrum

Every building has a distinct energy “fingerprint” based on the needs and requirements of its routine operations. When drilling down to the facility level, understanding the difference between demand and consumption is key to defining its energy characteristics.



Snapshot representation of a energy use for a typical day of business.

A ‘critical load’ is a portion of electricity supply that powers infrastructure directly related to an organization’s ability to operate. Infrastructure that warrants this status must either be kept running when main power supply fails or be powered down in an orderly manner to prevent system crashes, data loss or corruption, and life shortening hardware damage.

The term ‘Mission Critical’ is defined as something that is vital to the functioning of an organization. Operating under these conditions necessitates stronger emphasis on criteria that ties directly into the structural elements of a building’s design.

Special focus must be placed on meeting minimum requirements across several key energy components – utility power supply, back-up generation, UPS modules, and cooling systems – which can come at great cost. Emerging technologies and business models represent a key opportunity to manage costs and mitigate risks. However, they also present an optimization challenge in terms of structuring those options to maximize the economic, reliability, and sustainability benefits.

That’s where Bloom Energy comes in.

## OPERATING A MISSION CRITICAL FACILITY

1

### REDUNDANCY

Secondary system or extra components that become instantly operational, so any failure in primary system doesn't result in mission failure.

2

### FLEXIBILITY

Capacity to scale up or down to support evolving business needs without operational interruption or significant change in physical footprint.

3

### MAINTAINABILITY

Ability to perform routine operation and maintenance on any component without affecting mission or processes of vital business functions.

4

### HARDENING

Protection from physical forces and natural disasters where the electrical grid is unlikely to stand up to a disaster that could cause a power failure.

5

### SECURITY

Built-in safeguarding from security breaches and man-made threats and the serious risks they pose to critical equipment and business processes.

### MISSION CRITICAL KEY CONSIDERATIONS

There are several influencing factors that are key to mission critical infrastructure design.

## Introducing AlwaysON Microgrid Platform

Bloom's AlwaysON Microgrid platform is specifically designed to address the key challenges of traditional mission critical power infrastructure: reliability, energy efficiency, operational cost reduction, phased use of capital, and air and water sustainability.

Bloom Energy's AlwaysON Microgrid Platform takes all the functions of today's centralized power infrastructure – the transmission, the distribution, the substations, the batteries, and the back-up equipment – and integrates them into a single distributed generation platform. Our technology avoids the vulnerabilities of conventional transmission and distribution lines by generating power on-site, where the electricity is consumed. As a critical, always-on solution, microgrids can operate alongside a main grid, but independently of it during a power outage. The system operates at very high availability due to its modular and fault-tolerant design. What does this independence mean? Resilient power.

When the grid is functional, power from the microgrid solution helps control utility costs by offsetting a significant portion of a facility's consumption. When the grid fails, the AlwaysON solution continues to carry the critical load with minimal to no interruption, depending on configuration. Because Bloom Energy Servers are in continuous operation, there is no risk associated with cold starts and load transfers.

### How it Works: Fuel Cell Building Blocks

Fuel cells provide a critical foundation for building microgrids of varying complexity and can provide significant benefits to the communities, businesses, and utilities they are part of. This type of technology targets a customer's 24/7 energy usage whereas technologies like solar or battery storage are intermittent. Bloom Energy's systems utilize an innovative solid oxide fuel cell technology with roots in NASA's Mars program.

The cell itself consists of three parts: an electrolyte, an anode (-), and a cathode (+). The electrolyte itself is a solid ceramic material and the anode and cathode are made from special inks that coat the electrolyte. Through an electrochemical reaction, our servers are able to produce electricity without combustion.

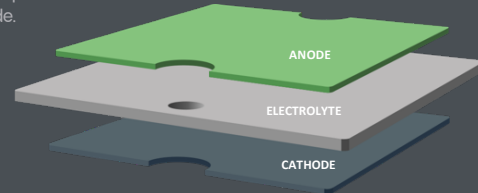
## HOW IT WORKS

# COMBUSTION FREE ELECTRICITY

The anode and cathode layers in the fuel cell are made from special inks (free of precious metals, corrosive acids or molten materials) that coat the electrolyte layer. As oxygen ions react with fuel in the fuel cell, the chemical reaction produces electricity.

### FUEL

Natural Gas, Biogas or Hydrogen passes over the Anode.



### AMBIENT AIR

Air passes over the Cathode

The system starts with a single cell which produces 25W, roughly enough to power a light bulb. The cells are then stacked within the system and assembled into 50 kW power modules – modules that can function independently from each other. These modules are then combined to create a 200, 250 or 300 kW Bloom Energy Server.

Its modular, flexible architecture design allows for any number of Energy Servers to be clustered together, in various configurations, to form solutions from hundreds of kilowatts to many tens of megawatts. Bloom Energy Servers provide significant power in a small footprint, allowing customers to easily scale the solution as their business and demand for power grows.



## RESILIENT POWER

Equipment that can tolerate brief interruptions in power

### Typical Deployments



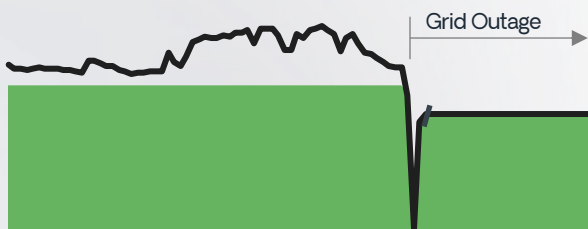
Retailers



Grocery Stores



Cold Storage



## UNINTERRUPTED POWER

Sensitive equipment that requires UPS-quality power

### Typical Deployments



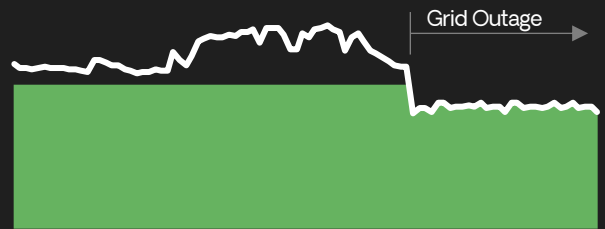
Data Centers



Manufacturers



Technology



Tier I microgrids cover business resilience for a wide range of applications where the facility does not need 100% uninterruptible power. It is a cost-effective, highly resilient solution best suited for facilities that can tolerate a momentary interruption in power when the grid goes down. The Always On solution will carry the load through the outage, indefinitely, following the momentary disconnect.

Tier II microgrids are for customers who cannot tolerate even a brief interruption in power – they provide the ultimate power quality for facilities where sensitive equipment or other business considerations require completely uninterruptible power. Tier II microgrids provide premium, UPS-quality power to support sensitive equipment, and seamlessly provides power when the grid goes out without any interruption.

### Microgrid System Architecture

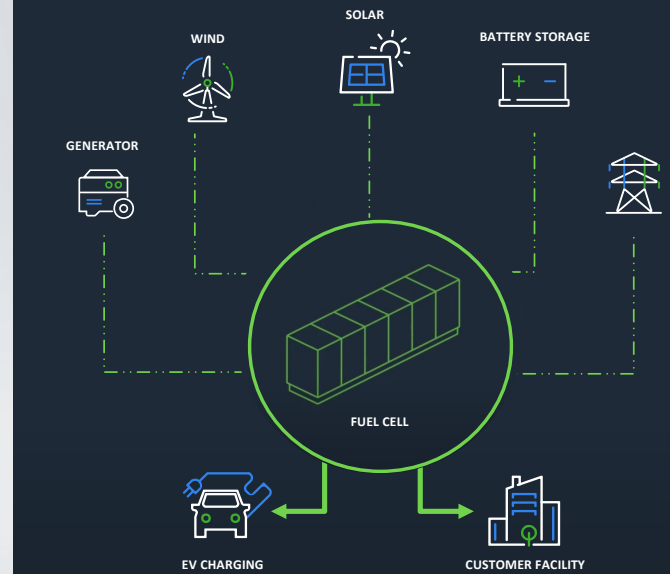
The standard system architecture design interconnects with your facility in a grid parallel configuration. This means Bloom Energy leverages a current mode inverter replicating the frequency and voltage of the grid and will not impact site power quality. Load changes by the site will similarly not impact output; the site will essentially have two utility feeds and anything needed above the fuel cell output will be supplied by the electric grid. A grid parallel interconnection is subject to IEEE 1547, similar to solar, such that when the grid is unavailable or out of IEEE1547 specifications, the Bloom Energy system is required by code to stop exporting power until the grid returns.

A mission critical design topology allows the fuel cells to continue operating during an electric grid outage. The design requires a segmented load to be wired directly into a second set of voltage mode inverters that will be added to the system's architecture.

# Resilient Microgrid Platform

Fuel cells provide a critical foundation for microgrids of varying complexity.

- Bloom Energy AlwaysON Microgrid serves baseload
- Battery storage covers short peaks and enables load shifting
- Solar and wind are used as much as possible
- Backup generator on standby and used sparingly
- Utility can be used for peak shaving when available
- Microgrid controller enables DER technology coordination
- System to load follow depending on site demand
- DER microgrid offsets 100% of site needs



## The Bloom Advantage: Key Differentiators for Mission Critical Support

### Power Quality

The power quality delivered by Bloom Energy Servers is comparable to best-in-class UPS systems deployed in data centers and other mission critical facilities. Bloom Energy utilizes state-of-the-art PWM (pulse-width modulation) inverter technology for conversion of fuel cell DC power to 480V AC power. The waveform of the current supplied to the customer is generated by a sophisticated multi-level current-source inverter control scheme.

The high inverter switching frequency supplemented by a high-performance filter in each inverter module means that harmonics are virtually eliminated.

Bloom Energy Servers are designed to meet or exceed power quality requirements of standards relevant to distributed power generation and distribution such as:

- **UL-1741**
- **IEEE-1547**
- **IEEE-519**
- **Other utility grid interconnection requirements in the USA and other countries around the world.**

## Density

Bloom's Energy Servers provide significant power generation in a small footprint, an ideal power solution for smarter space utilization. Unlike large, multi-megawatt generating combustion engines, Energy Servers can be deployed in increments as small as 200 kW, enabling power sources to be distributed and land to be used for your business. Due to Bloom's minimal footprint compared to other onsite generation technologies, facilities can utilize available land for higher value uses – such as data centers expanding their facility to accommodate more server racks, or a hospital adding a new wing to accommodate more patients.

## Efficiency

Bloom Energy's systems have the highest electrical efficiency commercially available with a cumulative lifetime average efficiency of 54% Lower Heating Value (LHV) net Alternating Current (AC) during the 20 year lifetime of the system. Bloom Energy's modular architecture is fault tolerant, resulting in 99.9%+ availability. The peak efficiency in the first year exceeds 61%; maximizing the number of kWh produced from a single unit of natural gas and minimizing the carbon dioxide emissions.

## O&M

Bloom Energy remotely monitors the performance of its fleet via two independent and geographically diverse Remote Monitoring Control Centers (RMCC) 24 hours a day, 7 days a week, and 365 days a year. Hundreds of key performance parameters are continuously monitored via sensors and sophisticated electronic control hardware and software to allow for active control and rapid response to events.

The modular, redundant architecture makes it such that the system can continue powering facilities while operation and maintenance activities occur on individual modules. Each power module independently connects and feeds power to a DC bus. When a power module needs maintenance, that module will be safely ramped down and shut off while the remaining modules continue producing consistent electrical output. The power module will then be repaired or replaced, and then ramped up to full power, ensuring consistent output from the fuel cells without disruption to a customer's business operations. Bloom Energy field service personnel are able to fully remove, repair, and/or replace any failed or poorly performing component in six hours or less once spare parts, test equipment, and repair personnel are onsite.

## Future-Proof

Our platform runs on natural gas, biogas, or hydrogen. Our flexible and modular platform approach provides a pathway to upgrade existing systems to align with the sustainability goals of our customers over time.

# Case Study

## Proven

Companies deploy Bloom's proven technology to solve their critical challenges and take control of their energy future as they expand their production and service capability. From corporate headquarters, to data centers, to manufacturing facilities, and more, Bloom provides hundreds of MWs of clean, reliable, AlwaysON power.

A large technology company manufactures electronic test and measurement equipment and software that supports the larger digital ecosystem of e-mobility, network monitoring, 5G, LTE, and IOT. Their business needs are closely tied to the reliability of critical systems in operation at their HQ campus, located in a high-risk wildfire zone in Northern California.

The numerous unplanned outages they were experiencing throughout the year were costly and damaging to highly sensitive manufacturing equipment. With backup infrastructure reaching the end of its useful life, they were seeking a new solution with mission critical capability that could power the whole campus independent of the grid.

In the wake of a growing number of outages and elevated risk to its operations, the company implemented an AlwaysON Microgrid, which enabled 2.8 MW of mission critical systems to operate independently when disruption to the electric grid occurs.

In the summer of 2019, California utilities began implementing transmission-level Public Safety Power Shutoffs (PSPS) to mitigate wildfire risk. One instance left millions of customers without power for multiple days. In the summer of 2019, California utilities began implementing transmission-level Public Safety Power Shutoffs (PSPS) to mitigate wildfire risk. Faced with one instance that left millions of customers without grid power for multiple days, Bloom's AlwaysON microgrid kept their campus online and operational throughout, reinforcing the technology's proven resiliency in the field.

## Conclusion

Bloom Energy has been at the forefront of the energy sector since its inception and has been working on offering alternatives to energy generation and delivery for nearly two decades. The versatility of our core solid oxide platform creates distinct advantages that enable applications across the entire energy value chain.

Our solutions have changed the way we look at our critical power infrastructure. Serving as an alternative source of primary power, the AlwaysON microgrid platform helps to alleviate increased pressures on the centralized grid and keeps businesses running and communities safe when clean, reliable energy is needed most.

As we continue to innovate, we are deeply confident in our ability to leverage our scale, experience, continued cost improvements and core efficiency advantages to deliver the greatest value and provide the solutions needed to propel customers towards a better energy future.



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