

IT@Intel: Fuel Cells – An Alternative Energy Source for Intel’s Data Centers

To solve challenges relating to data center power resiliency, quality, capacity, sustainability and efficiency, Intel IT has enabled disruptive fuel cell technology to augment the power grid at data centers globally

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Executive Summary

In several proofs of concept, fuel cell technology has proved to be a reliable, stable, efficient and sustainable source of electricity for Intel’s data centers. Intel IT joined forces with Intel’s Corporate Services and Global Supply Chain groups to enable fuel cells to meet Intel’s redundancy and capacity expectations.

For some of Intel’s data centers, fuel cells are the primary source of power (as opposed to the power grid). To date, we have fuel cell installations at Intel data centers in Bangalore, India, as well as in Santa Clara in the U.S. Fuel cells are now part of Intel IT’s plan of record for new data center design and expansion scope.

Intel IT’s experience with fuel cells has illustrated their many benefits, including the following:

- Efficient use of real estate
- Reliable and high-quality power
- Scalable modular installations
- Affordability
- Faster deployment time
- Reduced carbon dioxide emissions

This white paper provides details about our innovative value proposition of fuel cell use at Intel IT and shares some best practices that we have implemented or deployed over the last several years.

Terms to Know

Base load. The minimum or constant amount of electrical demand that is required by the facility for its operations over 24 hours.

Capital Expenditure (CapEx). Funds used to acquire, upgrade and maintain physical assets such as buildings or power infrastructure.

Data center load. Also called IT load, the amount of electricity consumed by servers and network equipment.

Diesel generator. The combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy.

Grid-independent. A power supply system in which the alternative power source is always available, regardless of whether the grid is available.

Grid-parallel. A power supply system in which, if the grid is available, the alternative power source (such as fuel cells) is also available. If there is a power outage, the alternative power source also disconnects.

Load shedding. The deliberate shutdown of electric power to part of a data center, usually to prevent the failure of the entire system when electrical demand strains available system capacity.

Non-IT load. The amount of electrical consumption by things other than IT equipment. This can include lighting, communication equipment, office heating and cooling and so on.

Operational Expenditure (OpEx). The costs a company incurs for running its day-to-day operations, such as rent, marketing and insurance.

Power usage effectiveness (PUE). A ratio that describes how efficiently a data center uses energy. It is calculated by dividing total facility energy usage by the IT equipment energy usage.

Uninterruptible Power Conditioning Module (UPCM).

Optional device that allows fuel cells to supply constant, stable power to protected loads during grid outages or disturbances. It is a modular addition that enables delivery of high-quality, grid-independent power for business and operational continuity.

Uninterruptible Power Supply (UPS). Electrical apparatus that provides emergency power to a load when the input power source or main power fails. The UPS runtime is generally short, but long enough to start standby generators.

Data Center Energy Source Considerations

Intel IT is committed to continually seeking ways to make its data centers' performance metrics best in class, such as increasing energy efficiency and reducing costs, as well as improving sustainability. We work closely with Intel's Corporate Services and Global Supply Chain groups, sharing IT and operations technology expertise to achieve these goals.

We consider many dimensions, and the choice of energy source impacts all of them to varying degrees.

- **Real estate usage.** Every data center facility has a limited amount of real estate space to use for its expansion and growth. The choice of power source can significantly affect how much land is available for building footprint expansion versus energy generation and its backup equipment requirement.
- **Power quality.** Data center equipment can be sensitive to voltage disturbances and frequency fluctuations.
- **Power reliability.** Intel's data centers require a continuous power supply to achieve higher uptime. Downtime caused by power outages equates to loss of revenue.
- **Power capacity.** While Intel has some of the most efficient data centers in the world,¹ they encompass tens of thousands of IT devices that consume several megawatts (MW) of electricity. The power grid or on-site generators are the primary power supply source for constantly meeting electrical demand for Intel's data center operations.
- **Data center tier level.** Intel data centers are categorized as tier 1, 2, or 3 according to guidelines from the Uptime

Institute.² Each tier defines criteria for maintenance, power, cooling and fault capabilities that are directly affected by the quality of the power supply source.

- **Capacity planning.** Intel's business is growing, so Intel's data centers are experiencing immense increases in electrical demand. Decisions made about data center power supply sources not only have to meet today's needs, but must be able to effectively scale to meet future needs.
- **Cost model.** Data center spending can be either CapEx or OpEx. OpEx has the advantage of transferring the commercial and operational risk to technology providers with guaranteed equipment performance and higher uptime. However, choosing CapEx or OpEx depends on the regulatory policies, market maturity and financial costs (including cost of money, incentives and tax rebates).
- **Rules and policies.** Every locality, state, or country has its own codes, regulations and industry standards that affect the construction of fuel cell power source systems and operation of data center facilities. Examples in the U.S. include Authority Having Jurisdiction (AHJ), such as the fire marshal or local health department; state and federal Occupational Safety and Health Administrations (California OSHA and U.S. OSHA); American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE); the Department of Energy; and the Uptime Institute.
- **PUE.** PUE is the primary metric used to determine data center energy efficiency; it is very important as we explore alternative energy supply sources to improve metrics to achieve lower infrastructure and operational cost.

The location, size and tier level of a data center can bring several more of these aspects to the forefront, as described in the following two sections.

¹ "Intel IT Redefines the High-Density Data Center: 1,100 Watts/Sq Ft" [intel.com/content/www/us/en/it-management/intel-it-best-practices/intel-it-redefines-high-density-data-center-1100-watts-per-sqft-paper.html](https://www.intel.com/content/www/us/en/it-management/intel-it-best-practices/intel-it-redefines-high-density-data-center-1100-watts-per-sqft-paper.html)

² Uptime Institute, uptimeinstitute.com/tiers

Intel IT's Experience: Adopting Fuel Cell Technology as a Primary Power Source

Part of Intel IT's charter and its mission is to monitor technology advancements to determine if they can be used to improve operational efficiency, productivity and sustainability at a competitive cost. Therefore, several years ago we assessed the maturation of fuel cell technology (see the sidebar below) from its inception to commercialization. At that time, it seemed that fuel cell technology offered a unique solution to solve certain data center challenges. We also evaluated the potential of other energy supply options, such as tri-generation, diesel-powered generators and gas turbines. However, we determined that fuel cells offered the highest efficiency for Intel's IT power demand. At some of our data centers, solar power partially displaces grid power, but it cannot meet reliability and capacity requirements to serve as a primary power source.

As the next two sections describe, we conducted a proof of concept with fuel cells in our Bangalore data center. Based on the concept's success, we then decided to use fuel cell technology as an alternative to the power grid in the U.S. to help solve a different set of challenges for our Santa Clara data center.

Based on our operational experience during these proofs of concept, fuel cell technology is now our plan of record for Intel data center design where feasible, which is fairly unique in the industry.

Addressing the Global Environmental and Sustainability Challenge

Intel IT is committed to helping Intel be a recognized leader in environmental sustainability.

When making decisions about power, cooling and construction, Intel's data center designers consider the environmental impact as a decisive factor that influences our infrastructure decisions. We strive to continuously improve energy efficiency, including the source of that energy and its carbon footprint. It is in this context that fuel cells, as a cleaner energy source alternative, are one of many initiatives in Intel IT's journey to help Intel achieve its long-term sustainability goals. Other focus areas include improving the energy-efficient performance of our products and collaboration with others to develop innovative ways that technology can address long-term environmental challenges. For example, over the past several years, our sustainable power management efforts have enabled us to procure over 7.1 billion kWh of green power, which is equivalent to 82 percent of Intel's global electricity use. Our new goal is to achieve 100 percent of our global energy use through green power by 2030.³

As we evaluate alternative energy sources and make decisions about power, we determine the sources' impact on Intel's carbon footprint and the reduction of hazardous waste.

³ Intel and the Environment, [intel.com/content/www/us/en/environment/intel-and-the-environment.html](https://www.intel.com/content/www/us/en/environment/intel-and-the-environment.html)

A Closer Look at Fuel Cell Technology

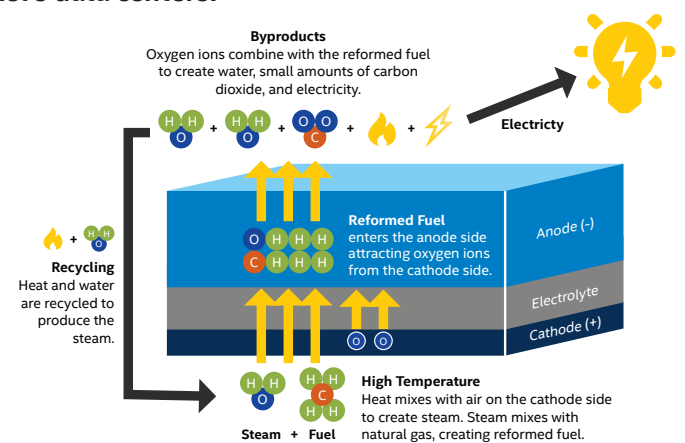
After years of innovation, fuel cells now help power Intel's data centers.

The first fuel cell was invented in 1839, and generated electricity by combining hydrogen and oxygen into water. Fuel cell technology has come a long way since then, but the basic design is the same: two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. A fuel cell generates electricity through an electro-chemical reaction that includes mixing fuel and air to create electricity and water without combustion. Today, hydrogen is not the only fuel used by fuel cells. They can also generate electricity using propane, natural gas and biogas. The fuel cells at Intel's data centers use natural gas to generate power.

Fuel cells are similar to batteries in that they have no moving parts, but they do not run down or need recharging. They produce electricity and heat as long as fuel and air are supplied.

In much the same way as Intel® silicon has followed Moore's Law—packing more compute power in ever-smaller spaces—fuel cell technology continues to pack more capacity in every square foot. When we installed our first fuel cell in 2015, the 2.5 MW fuel cell occupied about 15,000 square feet with a series of 200 kW systems. In just three years, fuel cell manufacturers had cut that in half, to 7,000 square feet for the same capacity with higher power-density modules. We expect that trend to continue, making fuel cells more compact and yet more efficient.

Citing another evolutionary trend, back in 2015 only a few fuel cell products were available in the market. Today, fuel cell suppliers offer a number of different fuel sources, capacities and configurations with improved output, which will help us reduce space requirements considerably. For example, we reduced the footprint by about 50 percent when we upgraded our first fuel cell installation.





Case Study: Intel, Bangalore

To meet Intel's rapid expansion goals in Bangalore, we decided to scale the site infrastructure to include the two existing data centers and multiple labs as well as two new Smart Buildings capable of housing several thousand employees. To support the electrical demand for this level of growth, we would have needed a new, high-voltage substation.

Challenge

Setting up the high-voltage substation infrastructure posed two show-stopping problems:

- Building the new substation would have taken between 18-36 months, and we could not afford to postpone the energization of the buildings and labs for that long.
- The new substation would have occupied more than 30,000 square feet, reducing the available real estate for the new Smart Buildings. We would have needed to compromise on our expansion plans, balancing space for employees against space for utilities.

Solution

Corporate Services and Global Supply Chain groups and Intel IT collaborated to introduce fuel cell technology to Intel India. In a pioneering effort (no other company in India or Asia had ever used fuel cells to power its data centers), we worked with a known U.S. fuel cell supplier and local governmental entities to approve the technology as a potential distributed energy-generation technology option, in addition to the other available technologies. This involved working at the most basic infrastructure level to influence the central and local governments to set up natural gas infrastructure, and helping the supplier establish its operations in India. We negotiated with various departments in the New Energy and Natural Gas Ministry to lay all the groundwork, and it was worth the effort. The gas infrastructure enablement eliminated the need for a substation, partially offset fuel cell technology investment and saved time and space resources—all while still meeting our expansion and power capacity goals.

During the initial phase, the electricity from fuel cells fed power to the data center through an existing UPS. But the high quality and reliability of the power generated by the fuel cells enabled us to power the data center directly from the fuel cells without a UPS.

Currently, the fuel cell installation at the data center in Bangalore is unique because the fuel cells serve as the primary source of power to data centers and labs, while the grid serves as the backup (see Figure 1). This configuration differs from conventional practices in that the grid source acts as the primary power source and other electricity-generation sources provide backup power to ensure reliability for mission-critical operations. Approximately 65 percent of the Bangalore campus' power needs are supplied by a fuel cell power source, with both grid-parallel and grid-independent configurations. Fuel cells have decreased diesel consumption and therefore reduced the need for on-site diesel storage. Fuel cells have also reduced the generation cost and complexity of backup source capacity requirements.

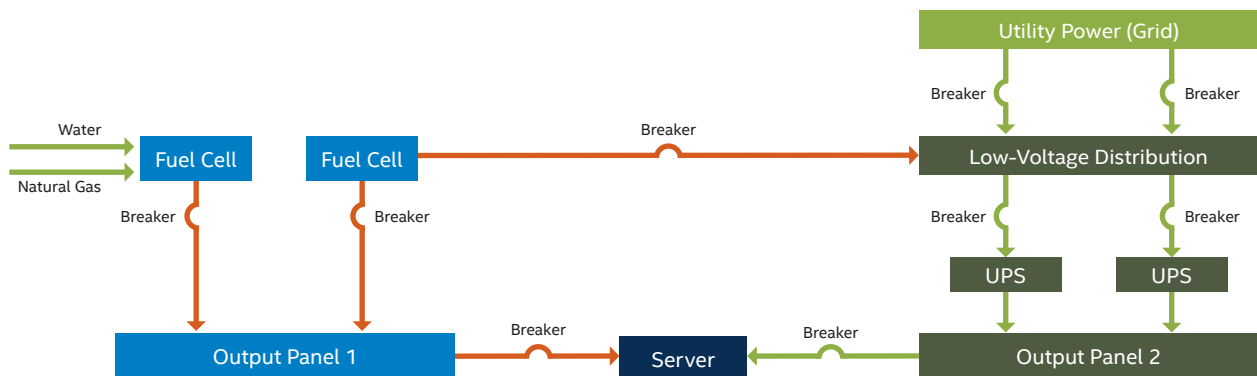


Figure 1. In the Bangalore installation, the fuel cells serve as the primary source of power to data centers and labs, while the grid serves as the backup.

“The high quality and reliable power output of fuel cell systems installed at Intel helped to power its data centers directly, eliminating the need of UPS for specific loads.”

Results

There are several advantages of switching to fuel cells as the primary source of power at our Bangalore facility:

- **Reliability.** The reliability of fuel cell technology meets the capacity and availability requirements to operate mission-critical data center and lab workloads. We also considered introducing backup power systems such as UPSs and diesel generators. However, both of these systems require CapEx and/or OpEx as well as frequent maintenance and replacement. Adding a fuel cell power source into Intel's energy supply mix helps eliminate this issue.
- **Quality.** A grid power source can have power quality issues such as voltage sags and frequency fluctuations. Therefore, we use power-stabilization systems with built-in filters to improve the quality of power supplied to the servers. Using a fuel cell power source helps to eliminate these issues because the power generated is of high quality, making power-stabilizing equipment redundant.
- **Efficiency.** UPS equipment is “lossy”—that is, an older-generation UPS loses about 14 percent due to overhead and leakage. A current-generation UPS loses 4-6 percent. Eliminating those losses has improved overall data center efficiency.
- **Time to market and cost reduction.** Instead of spending 18–36 months to build a substation to enable additional capacity, fuel cells can be set up within six months (assuming a source of natural gas is available and all required permits are in place). This “plug-and-play” power-generation technology can provide a substantial advantage to Intel by enabling rapid data center growth or quick release of a new innovative product.
- **Scalability.** Most data center or lab electrical loads increase organically. Grid power, however, must be increased in large “slabs,” depending on the site's total power requirements. When existing power substation capacity to support demand growth is limited or capped for phased development, meeting the power needs of phased growth can be more expensive and complex. However, fuel cells allow us to increase or decrease power capacity as necessary, especially as the fuel cell footprint continues to shrink with technology maturation.
- **Sustainability.** Our reduced dependency on low-efficiency backup diesel generators during power outages has helped lower carbon dioxide emissions because fuel cells provide a cleaner and more efficient energy power source. Integrating fuel cells into Bangalore's data center enabled us to reconfigure the way UPSs are used and improved PUE from 1.84 to about 1.62 (under ideal conditions). This has reduced power usage by approximately 12 percent. The total power output of installed fuel cell capacity is equivalent to nearly 12 MW of freed-up generation capacity in the utility's source that can be made available to support growth of other companies in the ecosystem. This extra capacity is important because during the time we installed the fuel cell, the electrical demand/supply gap in the power network system exceeded 10 percent.

Working with the Industry to Evolve Standards

Deploying fuel cells in India required policy and standards formulation and decisions.

Intel India was the first company to include fuel cells into its roadmap for reducing emissions in India. At the time, standards were still being established in India for fuel cells. Intel worked with the Central Power Research Institute (CPRI) to identify and define reasonable, relevant standards for fuel cells, instead of using standards established for gas engines. Intel also worked with the Ministry of Environment, Ministry of Petroleum and Natural Gas, and the Ministry of New and Renewable Energy (MNRE).



In 2018, our second fuel cell pilot focused on capacity growth. This 5 MW fuel cell installation enabled us to shift some of our utility power consumption to the fuel cells. This grid-parallel system provides power to a high-density data center. Any unused capacity is transferred to the other building on site. This fuel cell system also prevents loss of IT load by protecting against short power quality events whenever they occur.

We expanded the utilization of fuel cells by creating a grid-independent system to protect a third data center (1 MW) and, subsequently, a fourth data center (5 MW with capacity to expand to 10 MW) using fuel cells as the primary source of power (See Figure 2). In the 1 MW installation, we used redundant STS. For the 5 MW, we connected both power sources (fuel cell and utility) directly to redundant power supplies within the server. The design choices reflect cost and reliability concerns. Fewer components (elimination of switches) lead to lower cost, without compromising redundancy.

Case Study: Intel, Santa Clara

The installation of fuel cells in our Santa Clara data center helped solve multiple challenges and provides benefits across several metrics.

Challenge

Our data centers in Santa Clara have space limitations, making construction difficult and expensive. They also have the standard data center challenges regarding redundancy and capacity. Erecting new substations involves many regulatory entities, and labor costs are high.

Solution

Our first pilot with fuel cells focused on redundancy. We installed grid-parallel, 1 MW fuel cells to support a data center. The fuel cells provided primary power, using the power grid as backup. The two sources connected to a Static Transfer Switch (STS), which is designed to transfer the load to the grid if the fuel cells fail for some reason.

Results

The benefits of using fuel cell technology to help power our Santa Clara data centers are similar to the ones we realized in Bangalore. These benefits include reduced time to market for deployment; more efficient use of real estate; avoidance of substation upgrades; modular design for scalability; and lower PUE due to elimination of inefficient UPSs, transformers, and diesel generators.

In 2020 (and first half of 2021), the fuel cell availability in Santa Clara was 100 percent—that is, we experienced zero downtime while maintaining all routine maintenance and repairs. In fact, during one power outage that lasted about 50 minutes, the data center remained energized during the entire time thanks to the fuel cells. In contrast, a UPS provides power for only about 10–15 minutes.

In addition, our Santa Clara fuel cell projects demonstrate that fuel cells are highly flexible—they provide excellent redundancy capabilities and help us to meet growing capacity needs in a short amount of time.

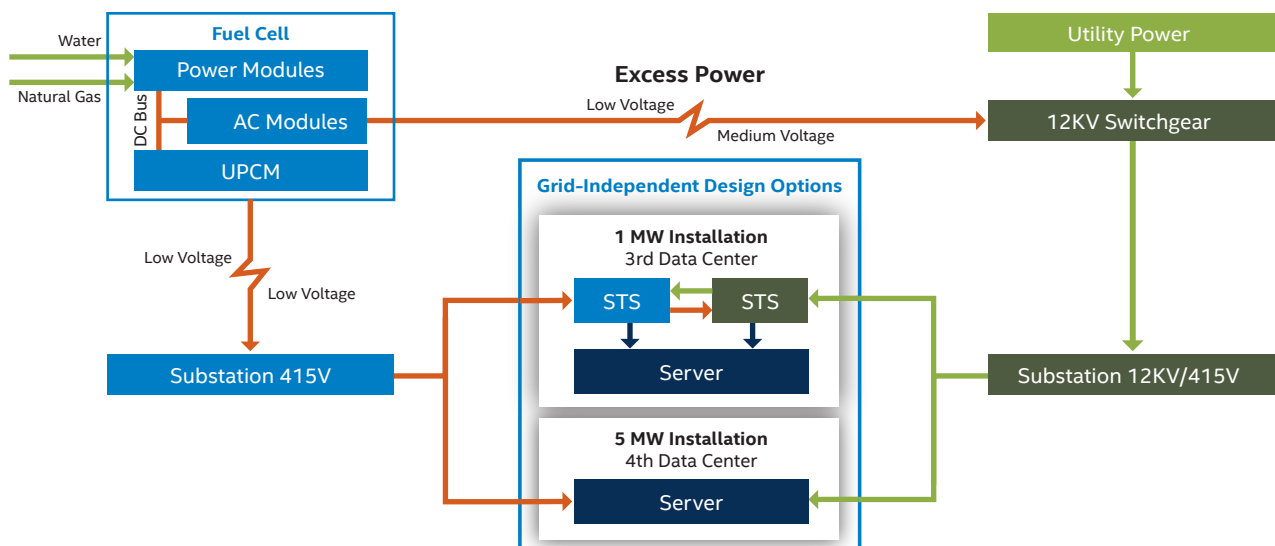


Figure 2. In the Santa Clara installation, the fuel cells help provide both redundancy and capacity.

Five Best Practices for Using Fuel Cell Technology for Data Center Power

The following best practices are based on Intel IT's own experience, both in Bangalore and Santa Clara.

Best Practice #1: Plan for Scale

We work to ensure that our fuel cell installations are modular so that the system can be augmented or reduced to meet long-term changes in base load demand. We discovered that using 250 kW fuel cells enables us to flexibly adjust capacity up or down. This approach also enables phased installations and allows the replacement of small parts without impacting the whole system. We conduct periodic reviews to ensure that the appropriate ramp up/down of the fuel cell capacity is carried out.

Best Practice #2: Avoid Exporting Power to the Grid

We don't export power back to the grid. In India, regulations don't support net metering for fuel cell systems, so we do not get paid for power that is exported to the grid. Therefore, it would be a direct loss to Intel. In Santa Clara, commercial grid customers are not permitted to generate power and export it back to the grid. We use a sensing system that disconnects the fuel cells if power is about to be exported to the grid.

Best Practice #3: For Grid-independent Systems, a UPCM Can Replace the UPS

The DC bus feeds the UPCM (which acts like a UPS) first, due to its criticality. The UPCM provides a grid-independent power source to the critical load. Adding a UPCM into our design helps eliminate the need for a UPS for the data center. In the event of a grid failure, the UPCM continues to supply power to the data center. Additionally, replacing the UPS with a UPCM helps save money, reduce PUE, eliminate inefficient components, and reduce maintenance.

UPCM, power module and AC module redundancy allows for maximum uptime and power production. In addition, if any part of a power module needs to be replaced or repaired, the remaining power modules can remain operational.

Best Practice #4: Synchronize Fuel Cells with the Grid and the Backup Generator

In situations that involve using a backup diesel generator, we synchronize the fuel cells with the grid and the backup diesel generators. This capability is especially useful in locations where grid blackouts or prolonged load shedding is common.

Fuel cells require a reference source to which the power-generation frequency can be synchronized. Initially, our fuel cells were synchronized with only the grid. During grid blackouts, therefore, fuel cells would go into standby mode and continue to consume natural gas to maintain the temperature of the system. If the system temperature dropped below a threshold, it would take four to eight hours to ramp up again, consuming even more natural gas in the process. We would have to run the backup diesel generators for the entire campus, resulting in higher diesel consumption and associated emissions, and we would also need to use natural gas to keep the fuel cells running in standby mode.

To overcome this issue, we enabled parallel synchronization of the fuel cells with the backup diesel generators *and* the grid whenever the campus experiences a grid blackout. Synchronization with the generators usually prevents the fuel cells from going into standby mode. According to the fuel cell supplier with whom we collaborated, this capability was the first of its kind across its worldwide installations. The solution allowed us to reduce the number of on-site diesel generators we use as well as decrease our diesel consumption and the associated emissions (carbon dioxide and sulfuric gases). It even helps improve the life and efficiency of the fuel cell because the system seldom goes into standby mode.

Best Practice #5: Achieve Fixed Operations Cost and Guaranteed Generation and System Output

The operations and maintenance costs, including replacing the fuel cell during the service period, are fixed for guaranteed system performance and uptime. This helps ensure that the system operations cost is hedged, which allows Intel to pre-purchase fixed gas volume at a reduced rate under long-term future pricing contracts. Furthermore, the system operations cost usually continues to drop during the term of the service period due to access to new-generation, high-efficiency fuel cell modules that can help achieve higher generation output with improved efficiency.

Fuel Cells are Flexible Enough for the New Normal

Advance planning prevented pandemic from affecting fuel cell utilization.

During the design stage for the Bangalore fuel cell installation, the project team—consisting of Intel IT and Corporate Services and Global Supply Chain groups—ensured that fuel cell capacity was established for the base load to support only the data center and lab operations. We did not want the building load to determine the capacity of the fuel cells, because we knew it fluctuated quite a bit. So, during the pandemic, when the majority of employees transitioned to working from home, there was no impact (positive or negative) on the utilization of the fuel cells.

Although we don't yet know what the "new normal" and office of the future will look like, we're confident that fuel cell technology will be able to support it. The fuel cell construction is completely modular, so we can add modules to increase capacity or take out modules to reduce capacity. Future business decisions may require us to downsize the capacity of the base load, which could impact the system. Fortunately, the system's flexibility allows us to remove a few modules and keep the rest operational.

Conclusion

Intel IT continually seeks to increase data center efficiency and accommodate changes in electrical demand. After several successful proofs of concept, Intel IT now considers fuel cell technology a reliable and stable source of electricity for Intel's data centers—even using them as the primary power source in some situations. We have found that we can deploy a fuel cell system significantly faster than we can obtain a new power source from the local utility company. Additional benefits include fewer emissions compared to diesel generators and lower CapEx costs and less square footage compared to traditional electrical substations. Fuel cell technology continues to emulate Moore's Law, as the size and cost of fuel cells continues to decrease while efficiency increases.

Intel IT, working with Intel's Corporate Services, has developed several best practices for configuring and deploying fuel cells as a power source for Intel's data centers. These best practices help us get the most out of our investment in fuel cell installations.

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