Business white paper

A new approach to industrialized IT

HP Flexible Data Center

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Introduction

Data center design is changing. Designers are eager to reduce capital expenditures (CAPEX), operating expenses, and the time spent in planning and construction. Yet they also want to retain flexibility for expansion.

For reasons like these, innovative designers are focusing on a modular approach for data center facilities. The advantages of using standardized designs and techniques, industrialized precast assemblies for construction, and prefabricated power and cooling components are becoming clear. Besides the benefits of lower expenses and reduced time to commissioning, modular design makes it easier to offer mixed levels of capacity within the same facility, and allows expansion in phases as requirements change over time. Modular design is also a perfect complement to the modern trend toward infrastructure convergence and cloud computing.

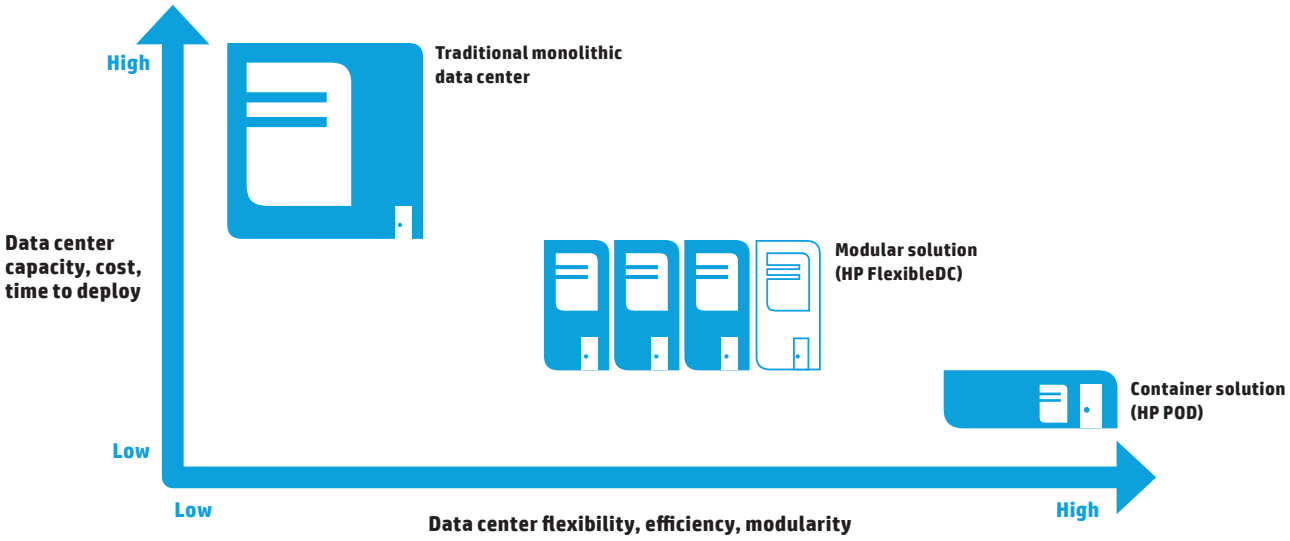
This white paper explores data center modularity as demonstrated in HP Flexible Data Center (also known as FlexibleDC or FDC). You'll learn in detail about how HP FlexibleDC challenges conventional thinking about data center design. And you'll come to understand how FDC delivers on the promise of flexibility, and provides faster, less costly construction, lower capital expenditures, and improved operating expenses.

Levels of modularity

Figure 1 shows the basic levels of data center modularity. At one extreme you'll find the typical monolithic "brick-and-mortar" data center. This type of data center is usually custom-built onsite. It can be costly and not very scalable. It often requires a long deployment time. Its design has one goal in mind: build it now for all future eventualities.

Even though it's possible to construct such a center using a phased approach that allows for some expansion, you still need to plan several years in advance. At the same time, the custom-designed data center offers many advantages, including a very traditional environment. It's specifically tailored to your needs and even offers a good measure of creature comforts for operators.

Figure 1
Levels of modularity



At the other end of the scale is the containerized data center such as HP Performance Optimized Datacenter (POD). This solution takes a minimalist approach, with racks of servers preinstalled in an industrial-type container. An excellent choice when speed of deployment is important, the containerized data center works best for small-scale data center environments or emergency situations. The container solution enables very rapid deployment of IT assets when the capabilities of a more permanent facility aren't required.

Then there's the third, industrialized option: a comprehensive, turnkey solution, with a modular architecture, and built using tilt-up, precast, or prefabricated construction techniques. A wish list of ideal characteristics for this data center would include a menu-driven selection of mechanical and electrical components, and perhaps cooling that would take advantage of local climate. Such a data center would offer scalability to meet changing demands for critical IT power. It would be ready for use in much less time and at a lower cost than would be possible using traditional, onsite brick-and-mortar construction methods—but without compromising quality. In other words, this solution would offer the best of both worlds: the large capacity and creature comforts of the traditional data center, along with some of the flexibility and efficiency found in a container.

That wish list is fulfilled in the HP FlexibleDC. This data center solution takes advantage of the flexibility afforded by a modular architecture, along with modern industrial construction techniques. The result is a facility that's built in less time and at lower cost, and is comfortable for its operators. What's more, it lowers operating expenses and is easier to align with the business goals of your organization. And it's available from HP.

What is HP FlexibleDC?

HP FlexibleDC is an adaptable, cost-effective solution that's ideal for the requirements of today's speed- and cost-driven business environment. With a range of capacities for critical IT power that start at 500 kilowatts (kW) and are scalable to 6 megawatts (MW), this facility can handle a wide range of loads. Plus, you can assemble individual data center buildings in a campus configuration that's limited only by property boundaries.

HP FlexibleDC includes data hall space, along with a choice of modular cooling and electrical power distribution systems mounted in external containers. A central core provides administration and support functions. You get customizable capacity, enhanced energy efficiency, and reduced total cost of ownership. And this solution moves you from the conceptual stage to commissioning in less than a year, at a capital cost that's lower than a similarly sized traditional data center build.

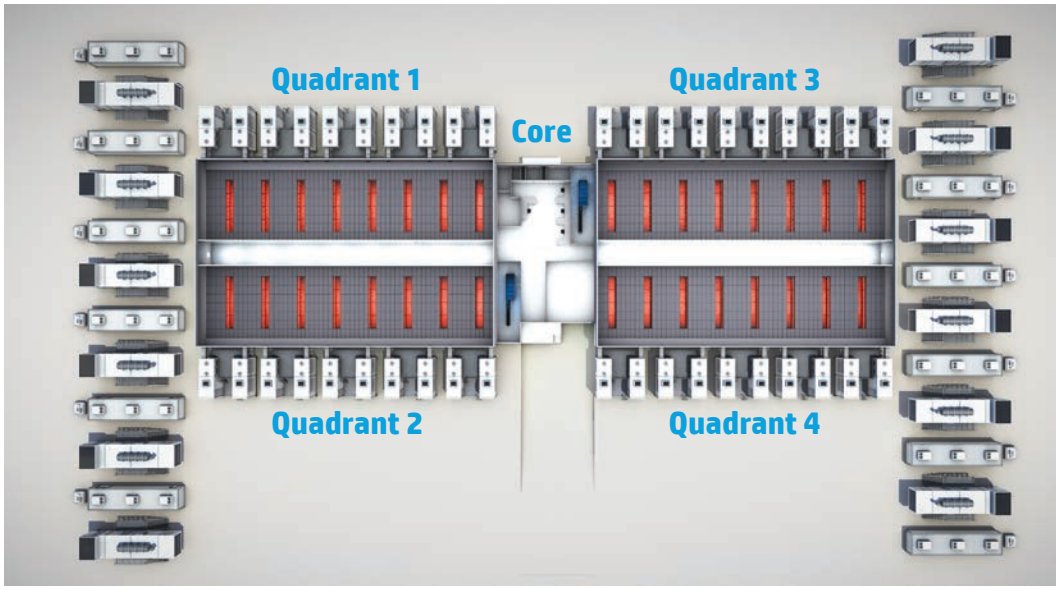
Because it's modular, you gain flexibility without the initial cost of trying to design and provision for an uncertain future. You benefit from significant reductions in operational costs, as well. Moreover, HP is your single point of contact to facilitate the process of conceptualizing, building, and commissioning your new data center.

HP FlexibleDC features

This modular solution is designed to simplify planning and speed construction. It depends on modern techniques of industrialization and supply chain management, along with a set of standardized components and options for power and cooling. As a result, the data center physical plant is lower in cost and faster to build. Features include:

- **Modular design**
  Including a choice of options that allow meeting today's requirements, then building out in phases as your information technology needs grow
- **Future scalability**
  With the capability of adding capacity as necessary
- **Efficient tilt-up, precast, or prefabricated construction**
  Based on standardized materials and processes that minimize bidding and reduce time and field labor requirements; you can even include traditional brick-and-mortar construction, if desired
- **Menu-driven selection**
  Using a standardized set of construction materials and prefabricated components for easier, more straightforward planning and reduced onsite installation time
- **Variable density**
  Allowing future flexibility and growth within IT space that's configured to load variable density requirements
- **Integrated security**
  Including physical security, along with fire protection for the entire data center
- **Economical cooling**
  Designed for minimum possible energy consumption, especially during part-load operating conditions
- **Efficient power supply chain**
  With variety of uninterruptable power supply (UPS) systems, and whenever possible with a minimum of superfluous equipment, conversions, and transformations
- **Excellent operational efficiency**
  Demonstrated by PUEs of 1.2 or lower that signal OPEX cost savings
- **Concurrent maintainability and fault tolerance**
  Eliminating single points of failure (SPOFs) and providing capability for maintenance procedures
- **Broad turnkey options**
  Upon request, we can even integrate a full IT infrastructure (hardware, storage, networking and software) into the data center solution

Figure 2
The FDC building consists of a central core surrounded by up to four quadrants



The core-and-quadrant building

Basic HP FlexibleDC architecture is shown in figure 2. The data center consists of a central core administrative area surrounded by quadrants, or "quads," that are the data halls for housing IT equipment. This modular structure allows one, two, three, or as many as four quads around the core. You can construct all quads at once, or add them in phases as needed. So you have an avenue to deal with unpredictable changes in technology today while deferring remaining data center build-out until the appropriate time in the future.

The quadrants

Figure 3 shows details of one quadrant. Each quad contains a data hall to house racks of IT equipment, and includes external assemblies for power and cooling. A quadrant can be configured for a critical load capacity of 500, 750, 900 or 1,500 kW. The smallest minimum configuration for a data center deployment is one 500 kW quadrant; however, with all four quads constructed and fitted out, the facility can deliver anywhere from 2 to 6 MW of critical IT power.

Figure 3
Details of a quadrant

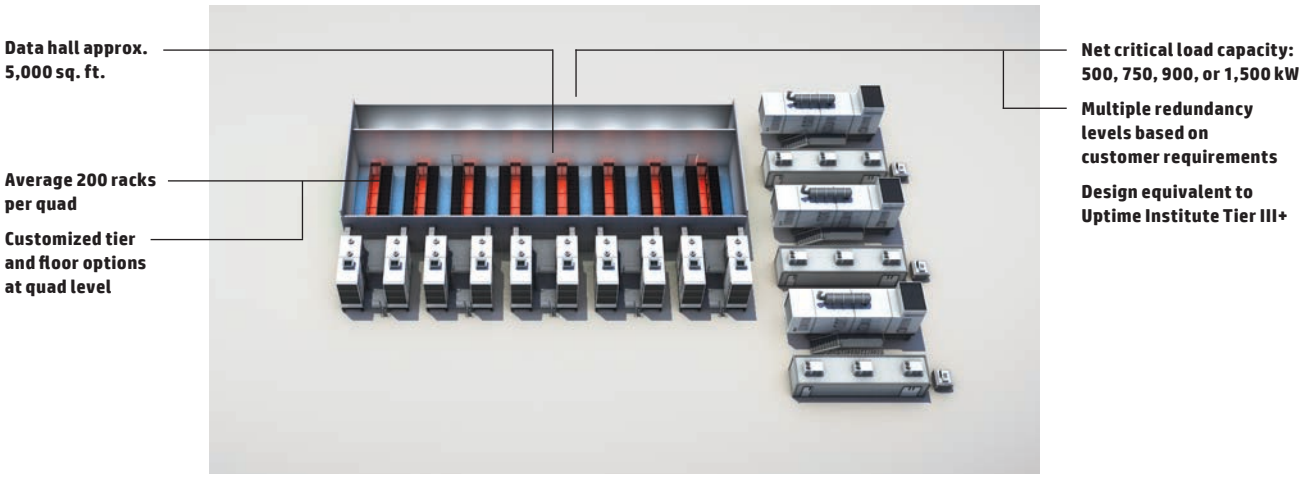
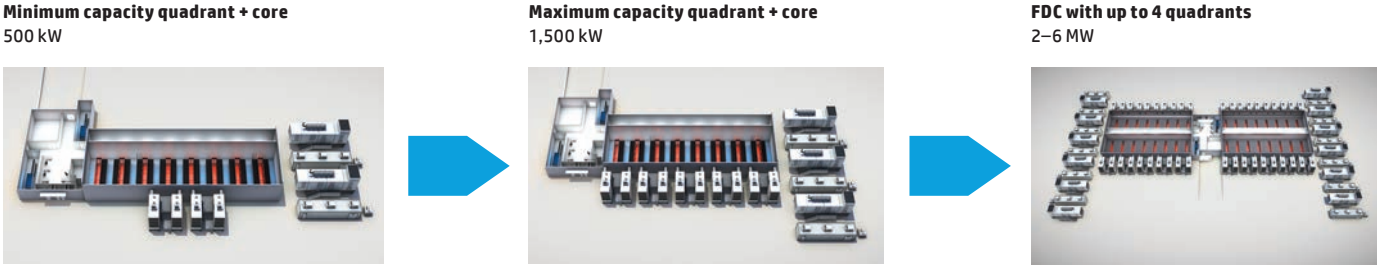


Figure 4
Expand by adding capacity to individual quads, or by adding quads to the data center



Mechanical and electrical components are mounted in external containers that allow easy access for maintenance. Outdoor mounting preserves indoor space for IT equipment and allows for quick and easy deployment of future electrical and mechanical containerized infrastructure. External mounting also removes potential sources of equipment failure (such as smoke) from shutting down a quadrant. Containers have plenty of space for testing and equipment, too.

The core

The core is configured to house a variety of support functions, such as operations, facility security, fire suppression, shipping and receiving, staging, telecommunications, and network connectivity. It can also incorporate the water main, as well as restrooms for the facility. Because we design the core to customer specifications, it can contain administration office rooms, storage rooms, meeting rooms, or whatever else you require in this central space.

Multiple deployment models

HP FlexibleDC is flexible in construction and in deployment. You can change the capacity on an individual quadrant basis, or build quads in phases and add quads as needed to keep pace with business needs.

Building from a minimum configuration

As shown in figure 4, you can start with a core and a single quadrant, beginning with a 500 kW quad. To expand that quad to 750 kW or 1,500 kW, you add more prefabricated power and cooling modules. This design allows for future changes in an individual quad without modification to the building.[1]

You can even deploy a standalone quad without a core, if necessary. This option is ideal if core functions are already part of an existing data center and you need just one quad for expansion.

[1] The only requirement is to specify the maximum capacity (for example, a maximum of 750 kW or 1,500 kW) before construction. This will allow future expansion to that capacity.

Mixing capacity in the data center

If desired, you can configure each quadrant to a different level of power density and redundancy. One of the best features of this highly flexible solution is the ability to support data center consolidation by arranging IT assets logically. You might want to separate assets according to group, security level, or even function type—for example, software development, production, or disaster recovery.

Implementing mixed levels of capacity within the data center is comparatively easy and straightforward, simply by configuring each quad differently. This approach can reduce costs via strategic alignment of infrastructure and capacity requirements.

Configuring a campus

For large installations, your organization can combine core-and-quadrant buildings to create a campus consisting of multiple HP FlexibleDC structures of any configuration. Figure 5 illustrates such a campus, this one consisting of 10 buildings. These can be interconnected with dual feeds for power and communications, providing virtually unlimited total critical power capacity for the entire campus.

Figure 5
Start with a single quad and extend to a multi-building campus

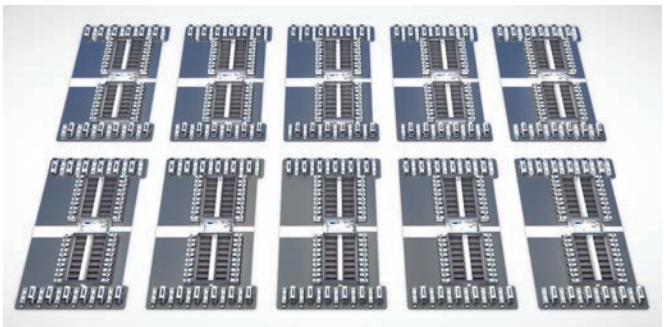
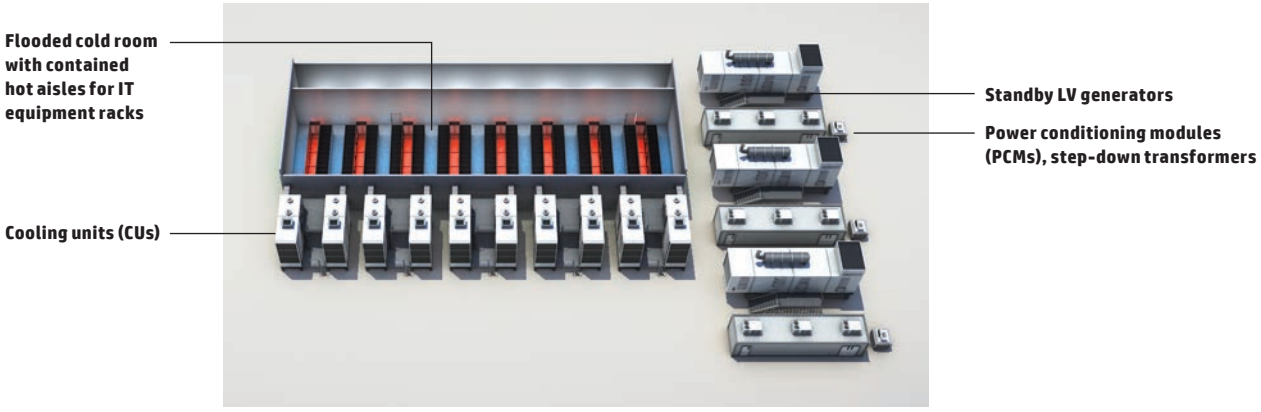


Figure 6
Mechanical and electrical systems



Energy-saving cooling design

We designed HP FlexibleDC with energy efficiency in mind. Power and cooling equipment have been selected for the minimum possible energy consumption, with a major focus on part-load operating conditions. Figure 6 shows the mechanical and electrical systems.

Mechanical cooling components include prefabricated self-contained air handlers with air-to-air heat exchangers. Overhead convection cooling, using a flooded cold room and hot aisles, reduces power and water consumption. Options include DX refrigerant cooling to assist during periods of the year that the local environment can't provide all necessary cooling for the data center IT space.

Maximum use of external cooling

This solution takes advantage of the expanded data center environmental standards published by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)[2]. It uses the types of cooling typically seen in industrial environments, adapting them to the data center.

The data center is designed to work with the external environment, using an air economizer as the primary cooling source. That is, the building obtains the majority of its cooling by relying on the local climate to absorb and dissipate the heat it generates. This cooling is especially effective in locations that have large differences in the dry-bulb and the wet-bulb temperatures (e.g., large wet-bulb depression), a condition normally found in arid or dry climates. An HP FlexibleDC located in such an environment can operate successfully without using much, if any, mechanical refrigeration, saving not only energy, but also water. (Although they use outside air as much as possible, all HP FlexibleDC cooling systems are designed to be effective and provide high efficiencies in all environments.)

[2] For details, see: tc99.ashraetcs.org/documents.html

Choice of cooling technologies

Table 1 shows menu choices for cooling technology. Each of these technologies utilizes the local environment to its maximum potential and provides high-efficiency cooling. All are able to maintain the data center environment within recommended limits. Furthermore, these technologies limit the entry of environmental contaminants into the data center, which can occur with typical outdoor air economizers.

The DX system can be sized for full or part load depending upon the required system redundancy level. Air handlers are located on the exterior walls in prefabricated weatherproof housings, providing cost-effective and timely installation.

The cooling capacity of the system decreases as the temperature rises. But due to the sensible heat reduction of the evaporative water, the evaporative cooling system efficiency increases as the exterior temperature increases. Moreover, locations that normally experience high humidity can still fully utilize any of these cooling systems; that's because heat is transferred across an air-to-air heat exchanger, which provides isolation between the data center space and the local environment.

Cooling design features

We've designed mechanical systems for optimum benefit from a variety of cooling technologies, with features such as:

- Server rack rows up to 25 feet in length
- Server racks arranged in a hot aisle containment (HAC) configuration
- No raised floor air distribution
- Air handlers distributed across a common plenum along the exterior wall of the building for even air distribution
- Supply air diffusers directing air down each aisle, minimizing hot spots. These diffusers line up with the aisles to promote better air circulation.

Table 1
FDC cooling options

Type of cooling	Details	Best application
Overhead convection cooling	Cooling coils with associated chilled or condenser water cooled mechanical system	No air side supply fan system required; provides isolation from outdoor environment
Direct expansion (DX) + direct evaporative cooling	Supply fan, filters, direct evaporative media, and direct expansion cooling assembly	Most efficient in cold to moderate temperature environments with low to moderate humidity levels
DX + indirect evaporative cooling	Supply fan, filters, indirect evaporative media, and direct expansion cooling assembly	Provides separation between environments with high levels of air pollution due to 100% recirculation, allowing the unit to run a closed air circuit
Air-to-air heat exchanger with DX	Multiple supply and exhaust fans, filters, heat transfer media, and direct expansion cooling assembly	Excellent solution when access to water and/or sewer is limited. Isolates interior from outdoor air, reducing data center contamination

- Flooded cold room with hot aisles ducted to a plenum
- Server racks thoroughly sealed to reduce the recirculation of waste heat back into the inlets of nearby servers
- Air handler controls set to maintain maximum temperature difference between the supply and return air distribution streams, helping to maximize the efficiency of the cooling system

Result: a smaller environmental footprint

A typical data center uses about 0.5 gallons (1.90 liters) of water per kWh of total electricity. That means a one-megawatt data center with a PUE of 1.50 running at full load for one year will require 13 million kWh of electricity, and will consume 6.5 million U.S. gallons of water during that period.

The air-based cooling options available with HP FlexibleDC dramatically reduce the consumption of water and meet the challenges of corporate and government sustainability programs. This ability to trim energy and water usage lowers costs for electricity, water, even sewer. It also means reduced greenhouse gas (GHG) emissions, and a smaller carbon footprint for the data center.

Efficient power design

The electrical configuration suits a variety of data center power needs. Each FDC quadrant supports several choices of capacity for critical power, and, as noted earlier, individual quads within the same building can have different capacities.

The electrical distribution system is a block redundant scheme based on a flywheel UPS system that's located in prefabricated self-contained external housings. Standby generators are mounted on the exterior of the facility, also in prefabricated external containers, with belly tank fuel storage below.

Electrical configurations

You have a choice of UPS technologies for distributing power from the utility to your critical loads in the data center. You can tailor the data center for various levels of redundancy, based on the criticality of applications, your risk tolerance, the types of loads, and your budget. Table 2 shows the available choices.

Table 2
FDC power options

Type of power configuration	Details	Best application
Distributed redundant	2-out-of-3 redundancy. Tier III+ equivalent.	Typically for data center above 1 MW. Allows concurrent maintenance and is fault tolerant. Reduced UPS expense vs. 2N. Used in the 1,500 kW capacity option.
Redundant reserve	An additional set of power infrastructure to serve as a "catcher" system. Tier III+ equivalent.	Allows concurrent maintenance and is fault tolerant. Used in the 500 kW, 750 kW and 900 kW capacity options.
Custom redundancy	Custom redundancy can be designed for each option (2N, N+1, N+2, etc.)	Our standard topologies have been optimized for reliability and availability, concurrent maintainability and fault tolerance. A custom topology may be designed for each option, per customer request.

Table 3
UPS options for FDC

Type of UPS configuration	Efficiency rating
Rotary UPS	94% to 95% energy efficient
Flywheel UPS	95% energy efficient
Delta Conversion UPS	97% energy efficient
Double Conversion UPS	94.5% to 97% energy efficient
Efficient Mode (Eco-mode) UPS	98% energy efficient

UPS configurations

Lowering utility and distribution costs for the electrical systems means using more efficient equipment, especially the uninterruptable power supply (UPS) modules. Table 3 shows the available UPS options.

Electrical design features

The right selection of electrical equipment helps keep both capital expenses and operating costs down, and also speeds up the construction phase. HP FlexibleDC design features include:

- Power units located near the IT space, decreasing fan losses
- Electrical power modules located near loads, shortening feeders lengths and lowering losses
- Standardized electrical equipment (mainly UPS and standby generators), selected to be cost-effective in terms of $/kW, size, and delivery
- All equipment options selected according to best practices for energy efficiency, and sized based on "sweet spots" for cost and equipment capacity

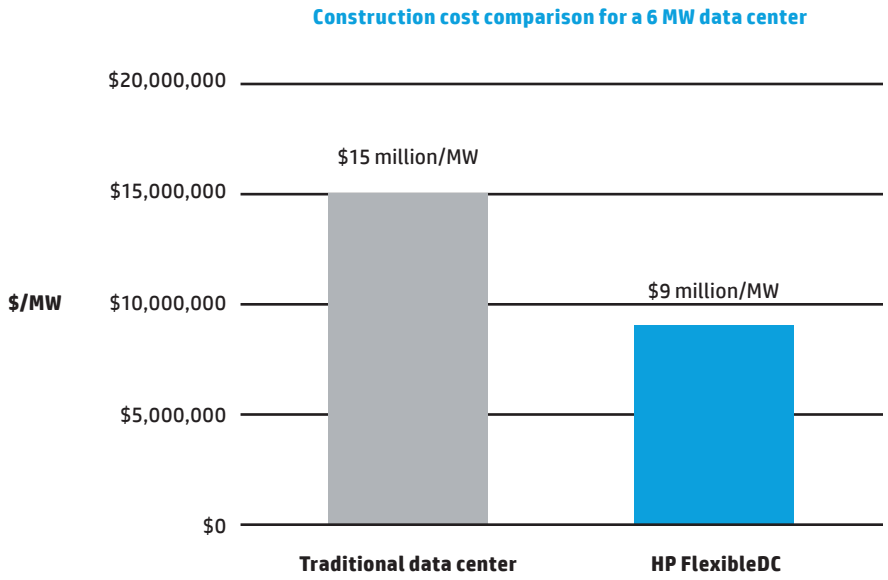
Where applicable, the data center receives power at medium voltage and transforms it directly to a server voltage of 415V/240V. This reduces losses through the PDU transformer and requires less electrical distribution equipment, saving energy and reducing construction costs. An additional benefit is a higher degree of availability because of fewer components between the utility and the server.

Saving time and CAPEX at construction

The modular design and construction of HP FlexibleDC can significantly improve time-to-commissioning. In fact, after concept and commissioning, you can occupy the data center within a year.

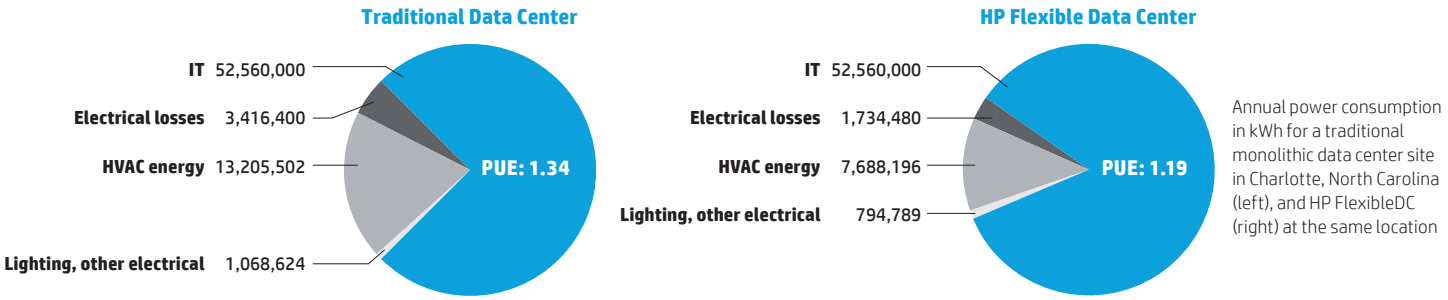
Cost is another advantage. Because of a number of factors, meaningful comparisons of actual construction costs for data centers is difficult. However, based on a mid-level estimate of capital costs for a traditional data center at about $15 million per megawatt, building a 6 MW data center appropriate for enterprise use would require an outlay of $90 million. With a median estimate of around $9 million/MW for a modular design, however, this number is reduced by as much as 40 percent. Figure 7 gives a graphical representation of the difference in cost compared to constructing a traditional data center.

Figure 7
FDC's modular construction can cut capital expenditures by up to 40% compared to a traditional data center



Estimated costs for a data center with 6 MW of IT load. Costs for the traditional monolithic data center are based on "The Economics of Prefabricated Modular Datacenters," 451 Research, May 2012; costs for the modular DC are based on HP research.

Figure 8
FDC offers lower energy consumption and a better PUE compared to the traditional data center



Annual power consumption in kWh for a traditional monolithic data center site in Charlotte, North Carolina (left), and HP FlexibleDC (right) at the same location

Saving OPEX during operation

Energy is the major cost component of data center operating expenses. For that reason we've developed a state-of-the-art energy evaluation program to help you plan for and select your data center systems.

During the planning phase, once you've made your preliminary selections for FlexibleDC capacity, power, cooling, and other systems, engineering professionals from our Data Center Facilities arm use the evaluation software to perform a comprehensive review of the energy requirements of your facility. The software provides insight into the potential performance of various data center choices. It allows running extensive "what-if" scenarios, and is invaluable in the final system selection process.

This software illustrates the advantages in efficiency of our modular solution over a conventional data center. As an example, we've used this program to evaluate energy usage for a traditional data center and a FlexibleDC located in Charlotte, North Carolina.

Construction details

- **Traditional data center**
  The configuration includes a large chilled water plant with water-side economizer. The cooling system takes advantage of free cooling when the outside air wet-bulb temperature is lower than the chilled water temperature, which is typically 50° F (10° C).
- **HP FlexibleDC**
  This example assumes a cooling system using indirect evaporation with air-to-air heat exchangers and DX assist. The cooling system takes advantage of free cooling when the outside air wet-bulb temperature is lower than the supply air temperature (typically 75° F/24° C).

Figure 8 illustrates the energy consumption and efficiency of HP FlexibleDC compared to a traditional data center.

Analysis of energy consumption and efficiency

It's clear that on an annual basis HP FlexibleDC will use less power than the conventional data center. Moreover, PUE for the modular data center is also lower (1.19 vs. 1.34), indicating its superior efficiency compared to the monolithic structure.

Not all of the benefits of the modular data center are apparent in this one analysis. For example, the indirect evaporation system of HP FlexibleDC not only provides more hours of free cooling, it also results in minimal water consumption.

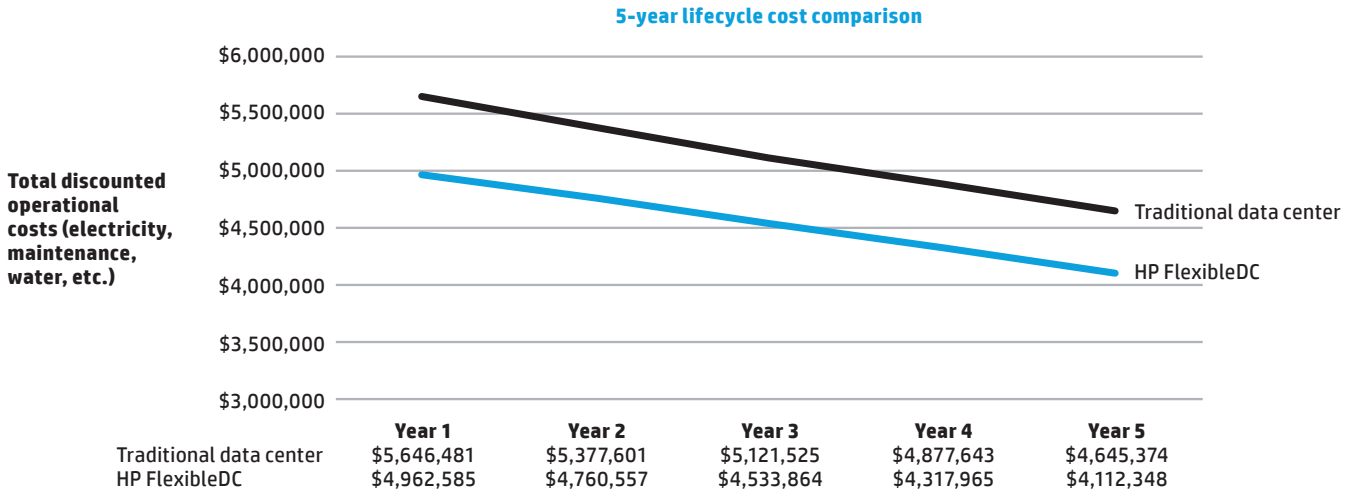
Analysis of energy costs

A second component of the energy analysis process is to predict actual energy costs over many years. Figure 9 shows a comparison of discounted operating expenses over a five-year period. Compared to an equivalent 6 MW traditional data center in Charlotte, North Carolina, the FlexibleDC saves more than 10 percent in costs the first year, and the savings continue throughout the data center's lifetime.

Much of the savings is the result of HP FlexibleDC's indirect evaporation, air-to-air heat exchanger cooling system. When you figure in both the significantly lower first cost of FlexibleDC, plus its lower ongoing energy and maintenance costs, the evaporatively cooled FlexibleDC can have five-year costs that are $24 million less than a traditional data center relying on water-cooled chillers with water economizers.[3]

[3] Based on estimates of total cumulative discounted benefit, including first-time costs plus five years of operational costs. Note that results vary from customer to customer and can be affected by climatic and other factors.

Figure 9
Employing FDC in a typical location results in substantially lower energy costs every year of operation



	Year 1	Year 2	Year 3	Year 4	Year 5
Traditional data center	$5,646,481	$5,377,601	$5,121,525	$4,877,643	$4,645,374
HP FlexibleDC	$4,962,585	$4,760,557	$4,533,864	$4,317,965	$4,112,348

Estimated operational costs for 6 MW data centers in Charlotte, North Carolina

Benefits in the supply chain, too

Underpinning the HP FlexibleDC concept is a foundation of innovative supply-chain management techniques that cut time-to-commissioning and reduce CAPEX. The reduced speed to deployment and lower construction costs stem from many factors, including standardization of components, the menu-driven selection process for selecting those components, even the single point of contact you enjoy when you engage HP for this solution.

Our supply chain focus has other advantages, too. For instance, the use of standardized assemblies is augmented by HP's ability to leverage purchasing agreements and volume purchasing—a capability lacking in companies that may construct only one or two data centers a year. In fact, very few organizations have our ability to capitalize and manage the building of data centers on a large scale—in effect to "commoditize" the data center build. At HP, our vision is to make building a data center a streamlined, seamless process from beginning to end.

Summary

When you consider the benefits of an engineered modular data center and the advantages of working with the experienced professionals of HP Data Center Facilities, there is only one conclusion: HP FlexibleDC. Now you can realize a data center that provides the capacity and customization of a traditional design, but with additional flexibility, more rapid time-to-commissioning, and better return on your data center investment. Whether you're building a greenfield facility or seeking to transition from an existing monolithic data center, the HP FlexibleDC numbers make an inescapable business case.

For more information on HP FlexibleDC, visit:
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4AA2-1533ENW, May 2015, Rev. 2