Benefits and Drawbacks of Prefabricated Modules for Data Centers

White Paper 163

Version 4

Data Center Research & Strategy

by Wendy Torell
Dennis Bouley
Scott Neal

Executive summary

Standardized, pre-assembled and integrated data center modules, also referred to in the data center industry as containerized or modular data centers, allow data center designers to shift their thinking from a customized "construction" mentality to a standardized "site integration" mentality. Prefabricated modules are faster to deploy, more predictable, and can be deployed for a similar cost to traditional stick-built data centers. This white paper compares both scenarios, presents the advantages and disadvantages of each, and identifies which environments can best leverage the prefabricated module approach.

RATE THIS PAPER ★★★★★

Introduction

Data center stakeholders are often faced with the challenges of how to manage the growing demand and the need to expand their data center capacity. Typically, they are faced with the decision to invest in a new facility, or to expand or retrofit the existing facility. This usually results in a difficult financial and technical analysis to determine which is the best decision for the business. But an alternative for data center construction exists that can be more cost-effective and less complex to deploy – prefabricated data center modules for IT, power, and cooling infrastructure.

Prefabricated modules are pre-engineered, pre-assembled / integrated, and pre-tested data center physical infrastructure systems (i.e. racks, chillers, pumps, cooling units, UPS, PDUs, switchgear, transformers, etc.) that are delivered as standardized "plug-in" modules to a data center site. This contrasts with the traditional approach of provisioning physical infrastructure for a data center with unique one-time engineering, and all assembly, installation, and integration occurring at the construction site. The benefits of prefabricated modules include more predictable costs & efficiencies, time savings, space savings, simplified planning, improved reliability, improved agility, and a higher level of vendor accountability.

Prefabricated modules may take the form of traditional ISO shipping containers or, more likely, the form of a purpose built enclosure. Modules can also be built on a skid. Because of the variations in form factors, **this paper will use the term "prefabricated modules" and not "containers" when describing the various solutions.**

Deployment of prefabricated modules can be 60% faster but has approximately the same capital cost when compared to a traditional build out of the same infrastructure. The cost analysis in White Paper 218, *Quantitative Analysis of a Prefabricated vs. Traditional Data Center*, demonstrates that while the material cost comes at a premium for prefabricated systems, the installation and space savings off-set the premium, and overall costs are approximately equal. If the costs are assumed equal than what is the value of implementing a prefabricated solution over a tradition built data center? **This paper provides data center professionals with the information needed to justify a business case for prefabricated modules.**

Capex considerations

In this section, we provide a qualitative discussion about the cost differences between prefabricated modules and traditional data center physical infrastructure.

Hardware / software costs

When comparing a prefabricated solution to a traditional brick and mortar data center build, the physical infrastructure hardware (racks, PDUs, cable trays, switchgear, UPS, panel boards, heat exchanger, air-cooled chiller, pumps, filters, lighting, security and fire suppression) are basically the exact same components. Generally, the costs of these infrastructure components are the same regardless of where they are installed. Since the modules include the infrastructure, it is difficult to separate and compare the costs to traditional data center construction. The initial system costs are higher for prefabricated modules because of the cost of the additional materials (such as the container shell) and the cost of pre-assembling / integrating the hardware, software, and controls together.

Design costs

Prefabricated modules are designed in a research and development area, are verified with the customer, and then released to manufacturing. Once in manufacturing, the design is built in a factory and shipped to the end user. In the traditional approach, multiple parties play a role in developing the design. Numerous meetings are held as electrical contractors, mechanical contractors, designers, end users, facilities departments, IT departments, and executives are all involved. Design points are argued back and forth, politics play a significant role, and decisions often have to be made serially.

"Design" costs include equipment selection & layout, and site plan de-sign/engineering. In the case of prefabricated modules, the equipment selection and layout are already done in the factory (rolled into system cost), and site plan design/engineering is reduced, compared to the traditional build because site layout and planning becomes much simpler and will generally involve 5 trades – structural engineer, civil engineer, electrical engineer, mechanical engineer, and an architectural review. In traditional data center builds, site plan design/engineering can be 5% of the total project expense.

Installation costs

"Installation" costs include all work performed in the field to assemble, integrate, and commission the system for operation. Specifically, this includes:

Systems project management – The cost to oversee the project is significantly less for a prefabricated facility based on the decreased complexity of the project and having a single vendor for the entire physical infrastructure to manage.

Site prep and site project management – This includes steps like digging trenches for pipes and electrical conduits, grading and laying concrete pads, and other general site expenses. This type of work must happen regardless of the approach taken, and therefore the cost is approximately the same.

Site installation – Typical infrastructure hardware installation includes the expense of un-packaging components, taking inventory, laying out and assembling components, making inter-connections between components and starting the system up. For prefabricated modules, many of these tasks are eliminated (work consists only of placing the modules on cement slabs, wiring the modules up to existing building switchboards, plumbing for the cooling, and starting up the systems). Another related expense savings is shipping. It is significantly less expensive to ship a pre-assembled module compared to shipping the individual parts and pieces of a traditional field-assembled system. Simpler, consolidated shipping also results in less shipping damage, which can be an added expense and an unwelcome time delay.

Management / controls installation and programming – In a traditional data center, installation and programming of the management software and controls system can be a significant expense and includes the cost to integrate the management system dashboard/interface with the power and cooling infrastructure and to tune the controls of the system to achieve desired performance (i.e. controlling cooling set points for optimal energy economizer mode hours and energy consumption). For many custom data centers, this is an end goal that is never achieved because of the complexities in controlling the system. For prefabricated facilities, this expense is brought primarily into the factory, where programming and optimization of software and controls are standardized so onsite work is nearly eliminated and operating performance of the data center improves.

Commissioning – Commissioning involves documenting and validating the result of the data center's design / build process. The detailed steps of commissioning vary from data center to data center, but often includes steps like factory witness testing, quality assurance & quality control, start-up, functional testing, and integrated systems testing. For prefabricated facilities, steps like factory witness testing and quality assurance are generally brought into the factory which reduces on-site time and expense.

Space cost – Another key cost benefit of the prefabricated module approach is the reduction or elimination of on-site “brick & mortar” facility construction to house the physical infrastructure. Even at the low end for simple core-and-shell construction – typically on the order of \$100–\$150 per ft² (\$1,076–\$1,614 per m²) – this space is costly and disruptive to deploy (see **Figure 1** and **Figure 2**).

Figure 1

Traditional approach for expanding existing data center

Figure 2

Raised floor installation for “brick and mortar” data center

With prefabricated modules, the construction work is less invasive and less complex, no core and shell needs to be built or interior space retrofitted, so the field installation is significantly reduced. **Figure 3** illustrates a prefabricated module being placed on-site on a cement pad with a crane. Once in place, electrical power is connected to the main switchgear, to the cooling facility module, and to the IT space, and chilled water piping is connected to the air handlers in the IT space).

Figure 3

Installation of pre-assembled, pre-engineered data center power module

In a scenario where facility power and cooling modules will be supporting the data center, much of the traditional up-front design and construction management burden shifts from the data center owner / end user to the solution provider, as Figure 4 illustrates (*note*, a design-build firm could perform all these tasks in the traditional case). The manufacturer designs and then "stamps and repeats" data center power and cooling modules for multiple customers. The data center power and cooling physical infrastructure becomes part of the manufacturing supply chain instead of an on-site custom build. This has a significant impact on the installation expense.

In a traditional approach, the owner / end user is responsible for either developing the design, assembling the components of the solution, engaging the various vendors for equipment acquisition, or for hiring and managing contractors to perform this work. In contrast, since prefabricated modules are pre-built in the factory, the owner / end user avoids time consuming tasks (no need to chase down the individual pieces of equipment needed, one or few delivery schedules to manage, very few, if any, construction contractors to interface with).

For help on comparing the cost tradeoffs between prefabricated and traditional data centers, use Schneider Electric's TradeOff Tool, *Prefabricated vs. Traditional Data Center Cost Calculator*.

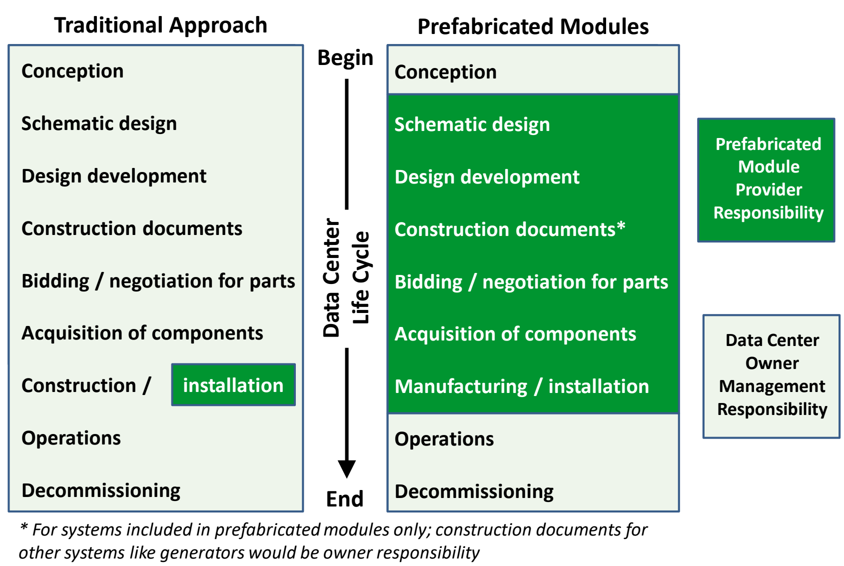


Figure 4

In the traditional approach, the data center owner is burdened with either performing or contracting out much of the planning and solution assembly work

Opex considerations

The above discussion focused on capex, but there are also opex considerations when comparing prefabricated modules to traditional power and cooling.

Maintenance costs

The potential exists to reduce prefabricated module maintenance costs. Even though maintenance must now be done in a tighter space, the end user would save by contracting for "one stop shop" module maintenance. Rather than having to write up an assortment of terms and conditions with different vendors, only one contract could be drawn up to support the one or two "big box" prefabricated modules.

In such a scenario, one organization would be held accountable for the proper function of the module. This is a simplified approach as the data center owner no longer has to preoccupy himself with trying to track down which organization is responsible for resolving a mishap. In a traditional data center, many of the parts and pieces (plumbing, electrical, power system, cooling system, and racks) are supported by different suppliers and finger pointing is a common occurrence.

The cost savings could also extend to software / management upgrades. Instead of custom written code for a large assortment or products, the prefabricated modules could make available to the customer one set of standard firmware upgrades.

Energy costs

Traditional mechanical and electrical rooms consume more energy than comparable power and cooling prefabricated modules. Energy savings exists primarily because the pre-engineered design of the modules allows for better integration of power and cooling system controls (this advantage is especially pronounced when it comes to the coordination of the cooling system controls).

Consider the example of controls for a chiller plant. The programming required to properly coordinate chillers, cooling towers, pumps and valves, for example, is extensive. Adding economizer modes increases the complexity. In fact, often times, economizer modes are disabled in designs because of this complexity, which results in added energy expense.

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) publishes standards for Coefficient of Performance (COP) for chiller plants. A higher COP indicates a better overall system performance. Although the individual parts that make up the chiller plant may achieve the published standards, most chiller plants achieve a much lower COP. This is a symptom of problems encountered when attempting to integrate the controls of the various components involved. The ineffectiveness of custom designed / integrated controls implemented in the field often means significantly less time operating in economizer mode and higher energy consumption overall.

"The PUE of a prefabricated data center is predictable because the equipment has been extensively pre-tested using standard components and the controls have been coordinated ahead of time."

The complexity of the controls makes it difficult to predict Power Usage Effectiveness (PUE) within a traditional setting. The PUE of a prefabricated data center is predictable, however, because the equipment has been extensively pre-tested using standard components and the controls have been coordinated ahead of time. Consider the PUE of a traditional 1 MW data center located in St. Louis, Missouri, USA at 50% load with an average density of 6 kW per rack, raised floor, chillers, variable frequency drives (VFD), water control, and economizers. In such a data center a PUE of about 1.75 would be typical. Comparable prefabricated module configurations have been tested and analyzed and a measured PUE of 1.4 or better is expected. That difference translates into an electrical bill reduction of 20%.

Prefabricated module benefits

Beyond the cost advantages of prefabricated modules, data center owners have additional reasons for pursuing the prefabricated approach:

Predictable efficiency – The module approach allows the consumer to specify and for the manufacturer to publish expected efficiencies based on real measurements of the design. This predictability is attractive for businesses with a focus on energy efficiency initiatives. A frequent challenge with new data center construction is managing unforeseen site issues and changes that have negative results in achieving the expected efficiency as designed. Prefabricated modules are much more likely to achieve efficiency targets because the solution is not subject to as many on-site construction issues.

Predictable cost – The more complex a construction project, the higher the likelihood of change orders and cost overruns. Since the majority of the data center infrastructure is integrated within a controlled factory environment, there is significantly less chance for changes and delays on-site.

Portability – If portability represents a high value, then the prefabricated modules may make some sense. Consider the example of a business that needs to deploy data center power and cooling but whose lease runs out in 18 months. If their lease is not renewed, they can physically move their data center physical infrastructure (power and cooling) investment with them instead of leaving it behind.

Financial flexibility – From an accounting standpoint, prefabricated modules could be classified as "equipment" as opposed to being designated as a "building". This would likely offer tax, insurance and financing benefits. Obviously, tax law, insurance policies, and purchase/leasing contracts vary from place to place and from region to region. So, this potentially substantial benefit should first be verified before assuming it exists for your given circumstances.

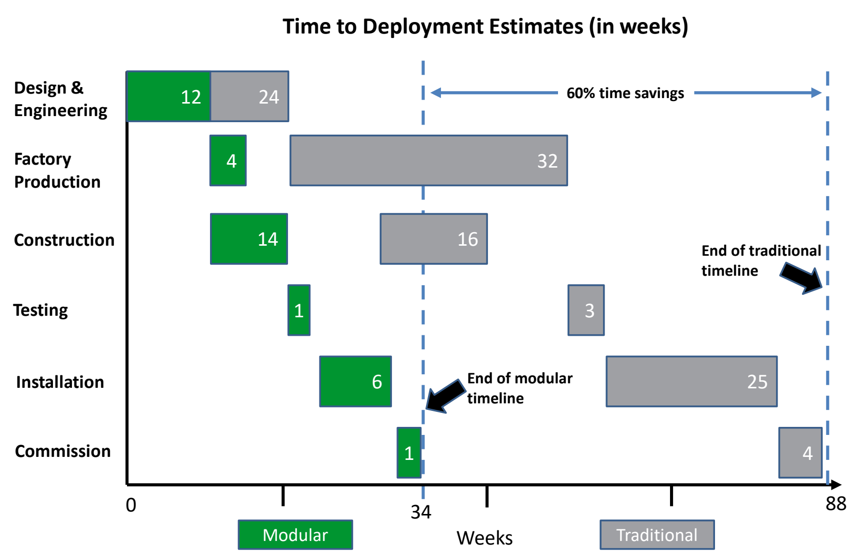
Hedge against uncertainty – Prefabricated modules are a viable option if a high degree of uncertainty exists regarding future growth. The flexibility of scaling and rightsizing helps to minimize risk.

Reclamation of valuable space – In many cases, the physical space that a data center occupies may be better suited to support an organization's core function. Universities, hospitals, call centers, and factories are primary examples where a data center expansion can threaten to consume value building space and create challenges to justify financially. Moving the data center outside the building or to a less important space can be a financial win-win for the organization's CIO and CFO.

Speed of deployment – Traditional data centers can take up to two years, from concept to commissioning, depending on size and complexity of the data center. Speed of implementation is oftentimes critical to a business. Cost of time is important to organizations that place a high value on early delivery (e.g., companies who want to be first to market with new products). Data centers built with prefabricated modules can be deployed (concept to commissioning) up to 60% faster (See Figure 5). Utilizing subsystems that have already been designed and integrated together can save 50% of the design/engineering time because the prefabricated module vendor absorbs the design process for the client, using repeatable processes. In addition, with prefabrication, more tasks can be done in parallel saving significant time. For instance, the site prep work can be done at the same time the modules are being built in the factory. Testing, installation, and commissioning in the field is also completed faster because modules are pretested in the factory and delivered as a subsystem instead of individual components.

Figure 5

Comparison of deployment time estimates (modular vs. traditional)



Simplified training – The prefabricated module approach allows the training of the staff to be greatly simplified since the modules are standardized with a system-level interface. This also means there is less risk to the data center operation when transitions in staff occur.

Prefabricated module drawbacks

If prefabricated modules offer flexibility, shorter time of deployment, and cost advantages, then why aren't prefabricated modules a solution for everyone? Consider some of the challenges that prefabricated modules can present:

Existing investment in a building – When evaluating prefabrication for the IT space, it is important to note the existence or planned investment in a traditional building, as it will have a strong impact on the cost analysis. Since a prefabricated module already has a weather-proof shell, the added cost of locating them in a "finished" space has minimal cost benefit.

Distance between the prefabricated modules and the internal data center – In cases where outdoor facility power and cooling modules supply an indoor IT space, distance is an important factor. If the indoor IT space is located next to an outdoor perimeter wall or a roof, expense to connect the data center to the prefabricated modules is minimized. However, if the data center is located deep within the building, the cost of running cable and piping (breaking through multiple walls, floors, and/or ceilings) could quickly become prohibitive.

Physical risks – Prefabricated modules can be exposed to outside elements such as severe weather, malicious intent, vehicle traffic (if placed in parking lot), and animal / insect infestation. Risks for a particular site should be assessed before choosing to deploy prefabricated modules. In these cases, similar considerations must be made for other support systems, such as generators, chillers, or condensers.

Arrangements for power provisioning and network connectivity – When prefabricated modules are installed, arrangements for additional power distribution (additional breakers / switchgear) and fiber connections need to be established.

Restrictive form factor – Prefabricated modules are large and heavy, and although mobile, they do present some challenges when it comes to placement and relocation. Modules may be too heavy to place on the roof of a building or may present logistical challenges in tight city streets.

Local code compliance – Since prefabricated modules present a new technology, local municipalities may not yet have established guidelines for restrictions on modules. Inconsistencies could exist regarding how different municipalities classify power, cooling, and IT modules. Local codes impact the level of module engineering and customization required to secure Authority Having Jurisdiction (AHJ) approvals.

Transportation – The Transportation Security Administration (TSA) stipulates width (11.6 feet, 3.5 meters) and length limitations in the United States in order for truck and train loads to pass over curved roads, under bridges, and through tunnels. Outside of North America, roads can be even smaller, further restricting the mobility of containers. Non-standard wide loads require special permits and in some cases escorts which increases the cost of transporting the prefabricated modules.

Table 1 summarizes the differences between a traditional data center build out and prefabricated modules across various factors. (Note that the cells with a checkmark indicate the best perform-er for each factor.)

Table 1

Summary comparison of traditional and prefabricated module approaches

Factor	Traditional data center build out	Prefabricated module
Time to deploy	12 to 24 months represents a typical timeframe	Can be designed, delivered, installed, and operational within 8 months or less
Cost to deploy	High up front capital cost with extensive field assembly, installation, and integration	Allows data center to be built out in large kW building blocks of pre-manufactured power and cooling capacity
Regulatory roadblocks	Regulatory approvals on an ad-hoc basis for the various steps of the infrastructure layout. This approach often results in delays that impact the initiation of downstream construction. The end user is responsible for securing approvals.	Data center owners who choose to install prefabricated modules should check with local authorities prior to installation. Permitting processes may vary greatly across different geographies.
Security	Physical security is enhanced when assets are located deep within the building, away from the outside perimeter.	Location of physical infrastructure assets outside of the building increases exposure to outside physical security and weather threats.
Installation	From a physical infrastructure perspective, a retrofit can be more complex and more invasive than a build out of a new data center. Infrastructure components need to be installed individually, started up individually and then commissioned.	Specialized equipment (such as a crane) is needed to maneuver prefabricated modules. Since much of the hardware installation is done in the factory, the on-site work is dramatically simplified.
Tax implications	Recognized as permanent part of the building	Reported as temporary structure which can be more attractive from a tax perspective (see Schneider's White Paper 115, Accounting and Tax Benefits of Modular, Portable Data Center Infrastructure)
Reliability	The solution is assembled on site from various parts and pieces provided by multiple vendors. This increases the need for coordination and creates more chances for human error.	More predictable performance because components are pre-wired and are factory acceptance tested before shipping. Smaller modules reduce risks of human error, since the entire data center doesn't go down during a failure.
Efficiency	Existing structures often limit the electrical efficiencies that can be achieved through optimized power and cooling distribution; complex custom configured controls often result in suboptimal cooling operation, reducing efficiency.	Prefabricated modules can utilize standard modular internal components and can be specified to a target PUE.
Carbon footprint	Construction materials utilized are high in carbon emissions. Brick, insulation and concrete are all carbon emission intensive materials. Concrete is often used for floors, walls and ceilings. Constraints of a building's infrastructure can impact the PUE resulting in sub-optimized energy consumption.	Steel and aluminum produce about half the carbon emissions of concrete. Concrete is only used to pour a support pad. Significantly less concrete is needed for prefabricated modules as opposed to a comparable building shell data center. Optimized and tested controls ensure a predictable PUE, reducing energy.
Serviceability	Traditional data centers have more room for service people to maneuver. All servicing is protected from harsh weather.	Servicing is more limited because of space constraints. In some cases, equipment can only be accessed by opening a door from the outside and exposing equipment to outside elements.

Types of prefabricated modules

Schneider Electric classifies prefabricated modules based on three attributes that, together, define the majority of prefabricated modular data centers. These three attributes are:

- Functional block
- Form factor
- Configuration

Functional block – The functions of a data center can be broken down into three major categories – the power plant, the cooling plant, and the IT space. Prefabricated data center modules sometimes provide multiple functions (referred to as all-in-one configurations), but often they provide one function of the data center

Form factor – This refers to the type of structure, size, and shape. The form of a particular solution impacts the transportability of it, the placement of it, and its location (inside vs. outside on the ground vs. on a rooftop). The three general forms of prefabricated data center modules are; ISO container, enclosure, and skid-mounted.

Configuration – There are several ways the functional blocks can be implemented in a data center.These approaches fall under three main categories:

- Semi-prefabricated – A data center comprised of a combination of prefabricated functional blocks and traditional "stick built" systems
- Fully prefabricated – A data center comprised completely of prefabricated IT, power, and cooling modules
- All-in-one – A data center that is self-contained in a single enclosure, with IT, power, and cooling systems

For more information on the types of prefabricated modules, see White Paper 165, *Types of Prefabricated Modular Data Centers*.

Applications of prefabricated modules

The following is a list of some typical prefabricated data center module applications:

Colocation facilities seeking faster, cheaper ways to "step and repeat" computer power and support systems for their customers – Prefabricated modules provide colos with a solution to cost effectively upsize and downsize in large kW modular building blocks when demand for their services fluctuates as a result of market conditions.

Data centers that are out of power and cooling capacity or out of physical space – The prefabricated modules can quickly add cooling and power capacity so that additional servers can be placed into existing racks, creating a higher density per rack, which can now be handled by the supplemental power and cooling.

New facilities with tight time constraints – Cost of time is important to organizations that place a high value on early delivery (e.g., companies who want to be first to market with new products).

Data center operators in leased facilities – If a business has a lease, they may not want to pour money into a fixed asset that they would have to leave behind. If their lease is not renewed, modules can physically move with them.

IT departments whose staff is willing to manage power and cooling – Not relying on the stretched resources of corporate facility departments can leverage prefabricated facility modules to control their own chilled water supply.

Data center facilities saddled with existing infrastructure characterized by poor PUE – These facilities may only be marginally improved within the constraints of their existing physical plant. Adding prefabricated modules provides an alternative to help solve problems inherent to the inefficient data center design they may have inherited.

An organization with vacant space – For example, an empty warehouse space can populate the space with a series of pre-packaged modules. They leverage utilization of the space and avoid the delays and construction costs of building a new brick and mortar wing.

An organization with limited space – Trying to financially justify constructing a new building or expanding an existing space can be difficult for a data center operator. This is even more challenging in organizations where the building space can be used to generate revenue (hospital, university, or factory). For these organizations, a prefabricated data center offers an alternative to traditional construction.

Conclusion

The introduction of prefabricated data center modules presents an alternative to the traditional "craft industry" approach of designing and building data centers. New economic realities make it no longer possible to bear the brunt of heavy upfront costs and extended construction times for building a traditional data center. The availability of pre-engineered, prefabricated modules allows the planning cycle to switch from an onsite construction focus to onsite integration of pre-manufactured, pre-tested blocks of power and cooling. The result of this change in focus is quicker deployment, reduced space, and greater predictability and flexibility, for the same overall cost.

The ideal applications for prefabricated modules are as follows:

1. A new data center seeking faster ways to "step and repeat" computer power and support systems (especially when load growth is uncertain).
2. An organization with vacant space (i.e. warehouse space) that can be leveraged for a more quickly deployed new data center without the expense of brick and mortar construction.
3. Existing data centers that are constrained by space and power / cooling capacity.

Prefabricated modules can offer several benefits versus a typical brick and mortar data center, but these benefits depend on the specific business challenges of an organization. Prefabrication provides a "tool" for data center operators and CIOs to manage growth, capex, and speed of deployment. Among leading edge corporations, a migration from brick and mortar to modular "parks" are taking place. Cloud computing business models will also accelerate the deployment of rapid prefabricated module provisioning

About the authors

Wendy Torell is a Senior Research Analyst in Schneider Electric's Data Center Research & Strategy group, bringing 30 years of data center experience. Her focus is analyzing and measuring the value of emerging technologies and trends: providing practical, best practice guidance in data center design and operation. Beyond traditional thought leadership, she championed and leads development of interactive, web-based TradeOff Tools. These calculators help clients quantify business decisions, while optimizing their availability, sustainability, and cost of their data center environments. Her deep background in availability science approaches and design practices helps clients meet their current and future data center performance objectives. She brings a wealth of experience across Schneider Electric's broad portfolio and with the market at large. She holds a BS in mechanical engineering from Union College and an MBA from University of Rhode Island. Wendy is an ASQ Certified Reliability Engineer.

Acknowledgements

Special thanks to **Dennis Bouley** and **Scott Neal** for co-authoring the original content of this white paper.

Resources

Accounting and Tax Benefits of Modular, Portable Data Center Infrastructure
White Paper 115

Economizer Modes of Data Center Cooling Systems
White Paper 132

Data Center Projects: Growth Model
White Paper 143

TCO Analysis of a Traditional Data Center vs. a Scalable, Prefabricated Data Center
White Paper 164

Types of Prefabricated Modular Data Centers
White Paper 165

Quantitative Analysis of a Prefabricated vs. Traditional Data Center
White Paper 218

Browse all white papers and executive reports
Data Center Research & Strategy Papers

Data Center Capital Cost Calculator
TradeOff Tool 4

Data Center Capacity & Growth Planning Calculator
TradeOff Tool 8

Prefabricated vs. Traditional Data Center Cost Calculator
TradeOff Tool 17

Browse all TradeOff Tools™
Data Center Research & Strategy Tools

Note: Internet links can become obsolete over time. The referenced links were available at the time this paper was written but may no longer be available now.

Contact us

For feedback and comments about the content of this white paper:

Schneider Electric Data Center Research & Strategy
dcsc@se.com

If you are a customer and have questions specific to your data center project:

Contact your Schneider Electric representative at
www.apc.com/support/contact/index.cfm