Containerized Power and Cooling Modules for Data Centers

White Paper 163

Revision 1

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> Executive summary

Standardized, pre-assembled and integrated data center facility power and cooling modules are at least 60% faster to deploy, and provide a first cost savings of 13% or more compared to traditional data center power and cooling infrastructure. Facility modules, also referred to in the data center industry as containerized power and cooling plants, allow data center designers to shift their thinking from a customized "construction" mentality to a standardized "site integration" mentality. This white paper compares the cost of both scenarios, presents the advantages and disadvantages of each, and identifies which environments can best leverage the facility module approach.

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Introduction

When data center stakeholders are faced with the challenge of deploying new data center power and cooling infrastructure (i.e., chillers, pumps, CRACS, CRAHS, UPS, PDUs, switchgear, transformers etc.), is it better for them to convert an existing room within the building (if this is at all an option) or to construct an extension to house additional power and cooling equipment? Or is it more cost effective and technically feasible to source the power and cooling from a series of facility modules?

Facility modules are pre-engineered, pre-assembled / integrated, and pre-tested data center physical infrastructure systems (i.e., power and cooling) 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 facility modules include cost savings, time savings, simplified planning, improved reliability, improved agility, higher efficiency, and a higher level of vendor accountability.

Deployment of facility modules results in a savings of 60% in deployment speed and 13% or more in first cost when compared to a traditional build out of the same infrastructure (see **Figures 1** and **6**). Cost savings are even more dramatic (30% or more) when the traditional data center is overbuilt in capacity and provisioned upfront with typical power and cooling systems and controls.

Traditional 40 ft by 8 ft (12.2 m by 2.4 m) ISO shipping containers are the most recognizable form of facility module. However, facility modules can also be built on a skid or delivered as multiple form factor modular buildings. For this reason, **this paper will use the term "facility modules" and not "containers" when describing the various modular solutions. This paper provides data center professionals with the information needed to justify a business case for data center facility power and cooling modules.**

Upfront cost of standardized vs. customized

Facility modules are faster and less costly to deploy than a "same physical infrastructure" traditional approach for a number of reasons. **Figure 1** compares the first cost of these two approaches using identical design and deploy framework or "apples to apples".

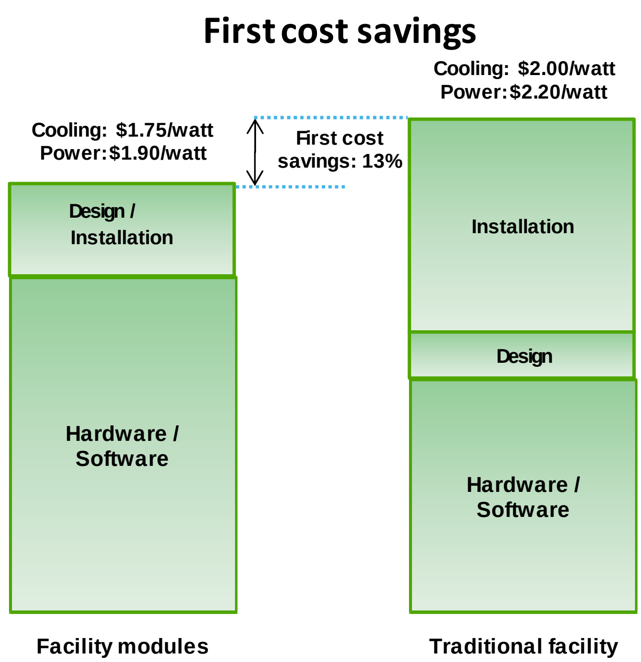

Figure 1

First cost differences between the traditional and the facility module approach

> **Definition of "Traditional"**
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> In this paper, the "traditional" approach has the same physical infrastructure components and sizing as in the power and cooling facility modules. The key difference is that the traditional approach is built out in a building (sometimes called "stick built"). This involves custom engineering and significant onsite work compared to standardized pre-engineered modules.

The costs used in this analysis represent street prices and come from actual projects from design / build firms and component manufacturers, as well as industry averages and rules of thumb. The analysis is based on the following assumptions:

- 500 kW power and cooling capacity
- Packaged chiller with economizer mode
- St. Louis, MO, USA costs of labor with suburban office park site conditions
- No core & shell cost savings included
- No white space infrastructure included (air distribution, power distribution units, racks)
- Identical physical infrastructure for both the facility module and traditional approaches in order to ensure fair comparison of material costs

Facility power and cooling modules offer substantial savings (a difference of $3.65 vs. $4.20/watt first cost) because they offer a standardized means for building and installing the data center physical infrastructure. The standardization of components enables dramatic economies of scale in the production, delivery, and installation of data center power and cooling capacity. The traditional approach, on the other hand, is highly customized with the majority of the work being performed on site. Disparate components from multiple vendors are custom engineered into one unique facility. As can be seen in **Figure 1**, although the materials or "system" cost is higher for the facility modules, the net savings in first cost is 13% because of the significant savings in design and installation costs,

The following sections provide a description of each category in **Figure 1** to illustrate why facility modules are less costly.

Hardware / software costs

The "hardware / software" cost includes the mechanical and electrical room physical infrastructure hardware (switchgear, UPS, panel boards, heat exchanger, air-cooled chiller, pumps, filters, lighting, security and fire suppression) as well as the, management and controls system). These system costs are about 40% higher for facility 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

The facility modules are designed in a research and development area, are tested, and then released to manufacturing. Once in manufacturing, the design is "stamped out" 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 plays a significant role, and decisions often have to be made serially.

"Design" costs include two types of costs: equipment selection & layout, and site plan design/engineering. In the case of facility modules, the equipment selection and layout is already done in the factory (rolled into system cost), and site plan design/engineering is reduced by over 80% compared to the traditional build because site layout and planning becomes much simpler and will generally involve 4 trades – structural engineer, civil engineer, electrical 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 modular facility (approximately 60%) 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 expense 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.

Power & cooling system installation – Hardware installation includes the expense of unpackaging components, taking inventory, laying out and assembling components, making inter-connections between components and starting the system up. For modular facilities, 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), resulting in installation cost savings of more than 50%. In addition, since field work is more costly and time consuming than comparable work in the factory, facility modules offer substantial savings. For example, a worker on the assembly line in the factory who installs a pre-engineered standard set of electrical wire in a module costs less than the combination of an electrical engineer and electrician in the field who are tasked with building a "one off" electrical design for that particular project.

Another related expense savings (not factored into the analysis of Figure 1) is associated with the 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 ($0.30/watt or more) 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 modular 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 varies 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 modular facilities, steps like factory witness testing and quality assurance is often viewed as unnecessary since it is a standardized, pre-designed, pre-integrated, and pre-tested complete system. This results in a savings of around 25%.

Although not illustrated in the **Figure 1** analysis, another key cost benefit of the facility module approach is the reduction or elimination of on-site "brick & mortar" facility construction to house the physical infrastructure. Not only is this costly (on the order of $100-$150 per sq ft or $1076 - $1,614 per sq m), it is disruptive to normal facility operations (see **Figure 2 and Figure 3**).

Figure 2

Traditional approach for expanding existing data center

Figure 3

Raised floor installation for "brick and mortar" data center

With facility modules, the construction work is less invasive and less complex as no core and shell needs to be built and field installation is significantly reduced. **Figure 4** illustrates a facility 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 4

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 5** illustrates (note – a design-build firm could perform all of 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 facility power and cooling 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).

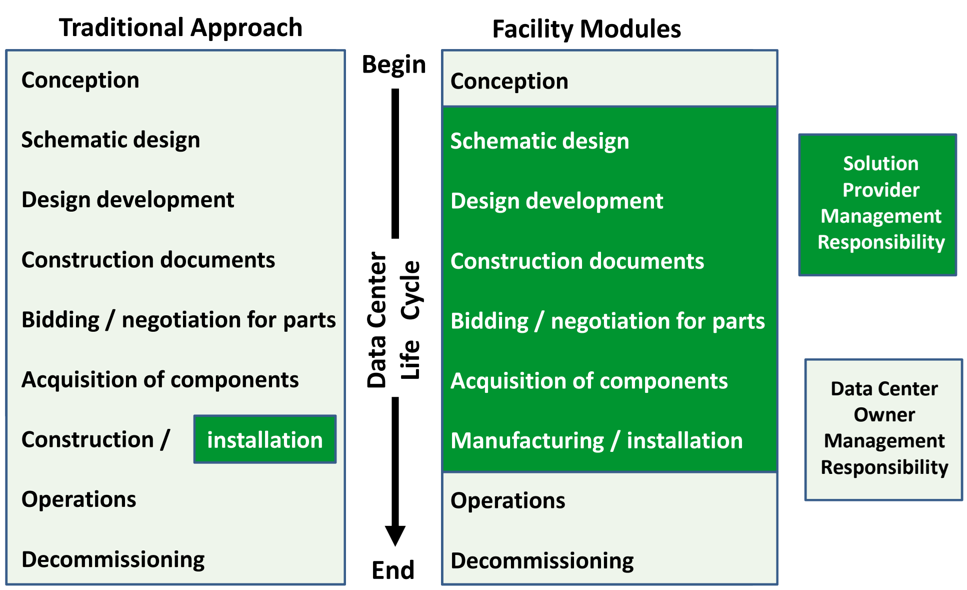


Figure 5

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

Further cost savings of facility modules

The above analysis focused on capital cost, but there are further savings when operating expense is considered.

Maintenance costs

The potential exists to reduce facility 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" container 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" facility modules.

In such a scenario, one organization would be held accountable for the proper function of the facility 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 data center facility power and cooling 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 facility 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 facility module 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 facility module 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 container 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%.

Additional facility module benefits

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

Predictable efficiency – The facility 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.

Portability – If portability represents a high value, then the facility 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.

Other financial benefits – From an accounting standpoint, facility 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 – Facility 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.

Speed of deployment – Traditional data centers can take up to two years, from concept to commissioning, for delivery. 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 facility modules can be deployed in less than half the time from concept to commissioning (see **Figure 6**).

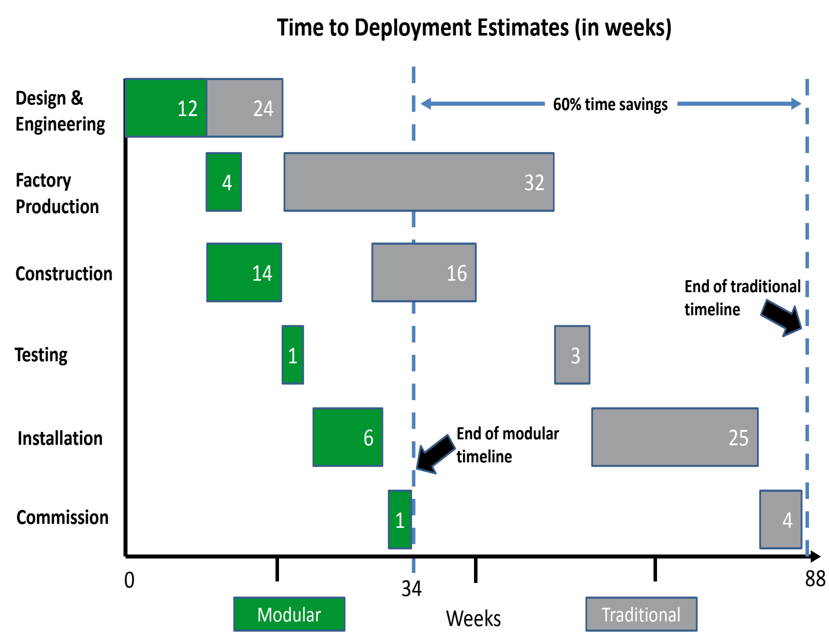


Figure 6

Comparison of deployment time estimates (modular vs. traditional)

Simplified training – The facility 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.

Facility module drawbacks

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

Distance between the facility modules and the internal data center – In cases where outdoor facility power and cooling modules supply an indoor data center, distance is an important factor. If the indoor data center is located next to an outdoor perimeter wall or a roof, expense to connect the data center to the facility 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 – Facility 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 facility modules.

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

Restrictive form factor – Facility modules are big "chunks" of power and cooling capacity and, although mobile, they do present some challenges when it comes to relocation. The blocks are heavy and may be too heavy to place on the roof of a building. The 40 foot by 8 foot (12.2 m by 2.4 m) dimensions of a typical shipping container means that data center owners who experience growth may be confined by width, height, and length restrictions unless they have enough ground space to add more facility modules.

Human ergonomics – Facility modules are designed for remote operations and are less human friendly than traditional brick and mortar data centers. Space inside is very limited (for maintenance personnel for example) and airflow is geared towards equipment and not for the comfort of humans.

Serviceability – Service personnel who work in traditional data centers are accustomed to access to the front and back of equipment in a protected indoor environment. Some facility power and cooling modules, on the other hand, have doors located on the outside which are the means by which service people can access the back of the equipment. When these doors are open, the physical infrastructure equipment is exposed to heat, moisture, dust, cold and other potentially harmful outdoor elements.

Local code compliance – Since facility 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 facility modules.

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

Table 1

Summary comparison of traditional and facility module approaches

Factor	Traditional data center build out	Facility 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 facility 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 20 and 40 foot pre-configured facility modules. A “docking station” needs to be configured for connection to building pipes and electrical. Started up as one integrated unit.
Tax implications	Recognized as permanent part of the building	Reported as temporary structure which can be more attractive from a tax perspective (see Schneider-Electric 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 therefore, 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: If a failure occurs, the entire data center doesn’t go down.
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	Facility 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.	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 facility modules as opposed to a comparable “building shell’ data center.
Serviceability	Traditional data centers have more room for service people to maneuver. All servicing is protected from any harsh weather elements.	Servicing is more limited with facility modules 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 (heat, moisture, cold).

Types of facility modules

Some facility modules are packaged in traditional 40 and 8 foot (12.2 m by 2.4 m) freight containers (**Figure 8a**) and some are packaged as more customized add-on pre-fab "plants" or modular add-ons to existing buildings (**Figure 8b**). Still others are packaged and delivered as skids (**Figure 8c**). Modules could be placed inside of a warehouse for rain protection. Tent-like canopies can be set up to further protect the modules, much like a car port can protect a car that is not garaged.

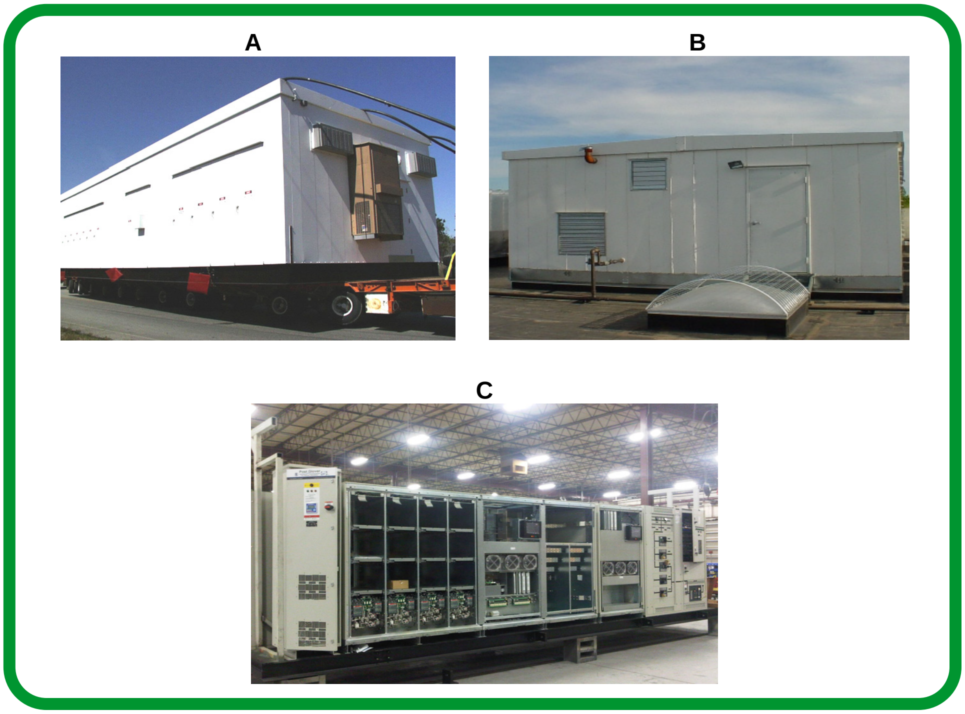


Figure 8a

Exterior view of facility module in transit

Figure 8b

Modular, roof-mounted plant delivered to the site in two sections

Figure 8c

Modular, skid-mounted UPS, battery, and power distribution

Classic ISO (freight) containers and skids

Facility cooling module – These units house modular air-cooled chillers, pumps with variable frequency drives (VFDs), a fluid storage tank, monitoring software, sensors and physical security cameras and can support up to a 500 kW capacity per container (see **Figure 9**).

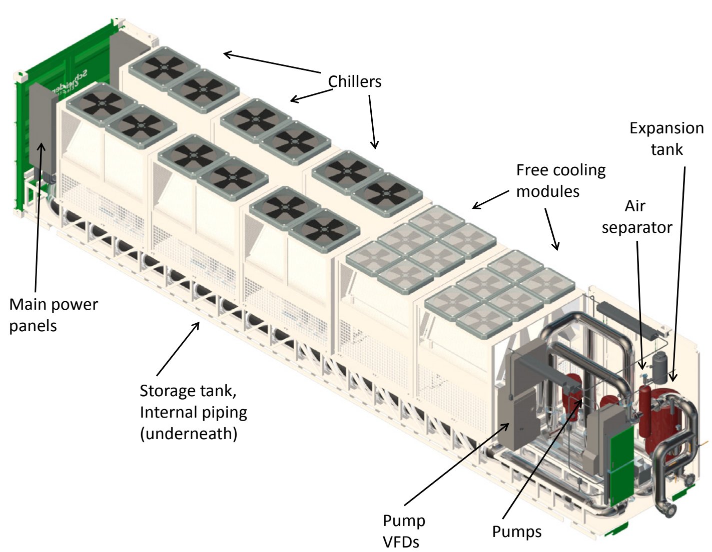


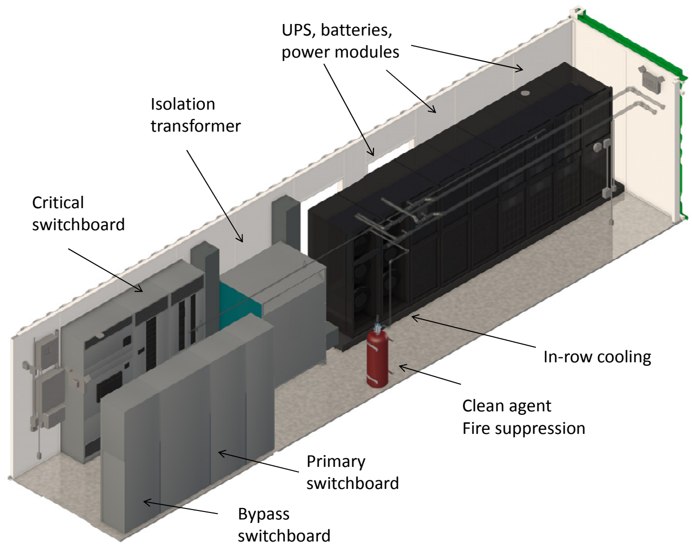
Figure 9

Illustration of Schneider Electric's facility cooling module

Facility power module – As shown in **Figure 10**, these units house UPS and batteries, a transformer, switchgear, panel boards, physical security (access security, cameras, sensors, monitoring software), VESDA fire protection and alarms and row cooling. The facility power module also features hookups for utility power, 'on-site' power, backup (generator) power and data.

Figure 10

Illustration of the interior of Schneider Electric's power facility power module



Modular indirect evaporative cooling modules

When ASHRAE expanded the recommended server inlet temperature range to 27° C (80.6° F), they did so with the intention of allowing more economizer operating hours. A modular indirect evaporative cooling module is designed to live outside the data center and can automatically switch between two forms of economized cooling:

Air-to-air heat exchange – Brings in hot IT air in from the data center through the modules' electronically commutated fans. This air is then passed through internal channels of the indirect evaporative cooler (IEC). While this is happening, cool ambient air is blown across the heat exchanger absorbing the heat energy of the IT air without actually mixing. After the IT air is cooled, it leaves the IEC and passes through the evaporator coil and returns to the data center.

Indirect evaporative heat exchange – When ambient temperatures can't support an air-to-air heat exchange, economized cooling occurs through indirect evaporative cooling which removes heat from the IT air by evaporating water on the outside of the heat exchanger channels. The unit prevents the outside air from coming in contact with the data center air, regardless of which cooling mode is used (air-to air or indirect evaporative).

Link to resource
White Paper 132
Economizer Modes of Data Center Cooling Systems

Though temperate environments will realize the quickest ROIs, nearly all geographies can attain some level of "free cooling" utilizing these cooling modules. An example of a cooling module that applies this cooling method is the Schneider Electric EcoBreeze™. Each module has the capacity to cool approximately 50 kW and up to 8 x 50 kW modules can be configured in one frame (see **Figure 11**). Schneider Electric White Paper 132, *Economizer Modes of Data Center Cooling Systems,* provides further detail as to how this cooling system compares to other systems with economizer modes.

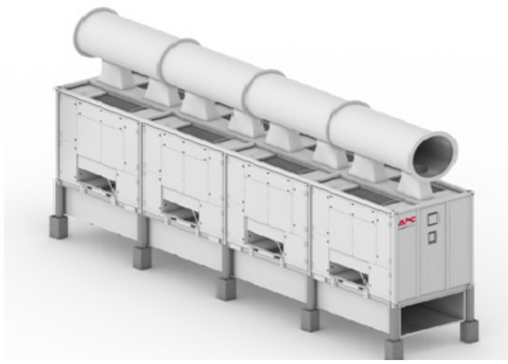


Figure 11

Illustration of air side economizer made up of containerized modules

Applications of data center facility modules

The following is a list of some typical facility module applications:

Colocation facilities seeking faster, cheaper ways to "step and repeat" computer power and support systems for their customers – Facility 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 facility 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 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 facility 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.

Conclusion

The introduction of facility power and cooling 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 facility 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 a lower cost, and faster delivery solution.

The ideal applications for facility modules are as follows:

1. A new data center seeking faster, cheaper 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.

Facility modules can power and cool traditional data center IT rooms that are out of power and cooling capacity. They can also be used to power and cool IT modules (containers of IT equipment). Among leading edge corporations, a migration from brick and mortar to facility module "parks" will take place. Cloud computing business models will also accelerate the deployment of rapid facility module provisioning.

About the authors

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