

Quantitative Analysis of a Prefabricated vs. Traditional Data Center

White Paper 218

Revision 0

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Executive summary

Prefabricated modular data centers offer many advantages over traditionally built data centers, including flexibility, improved predictability, and faster speed of deployment. Cost, however, is sometimes stated as a barrier to deploying these designs. In this paper, we focus on quantifying the capital cost differences of a prefabricated vs. traditional 440 kW data center, both built with the same power and cooling architecture, in order to highlight the key cost drivers, and to demonstrate that prefabrication does not come at a capex premium. The analysis was completed and validated with Romonet's Cloud-based Analytics Platform, a vendor-neutral industry resource.

Introduction

Choosing a prefabricated data center rather than a traditional “stick built” one is often based on the anticipated benefits of quicker deployment, greater reliability, and improved predictability. White Paper 163, [Prefabricated Power and Cooling Modules for Data Centers](#), discusses these benefits in greater detail.

When it comes to cost implications, however, some believe prefabrication comes at a savings, while others believe it to be at a premium. This tells us there is confusion over the real cost implications of choosing this design approach.

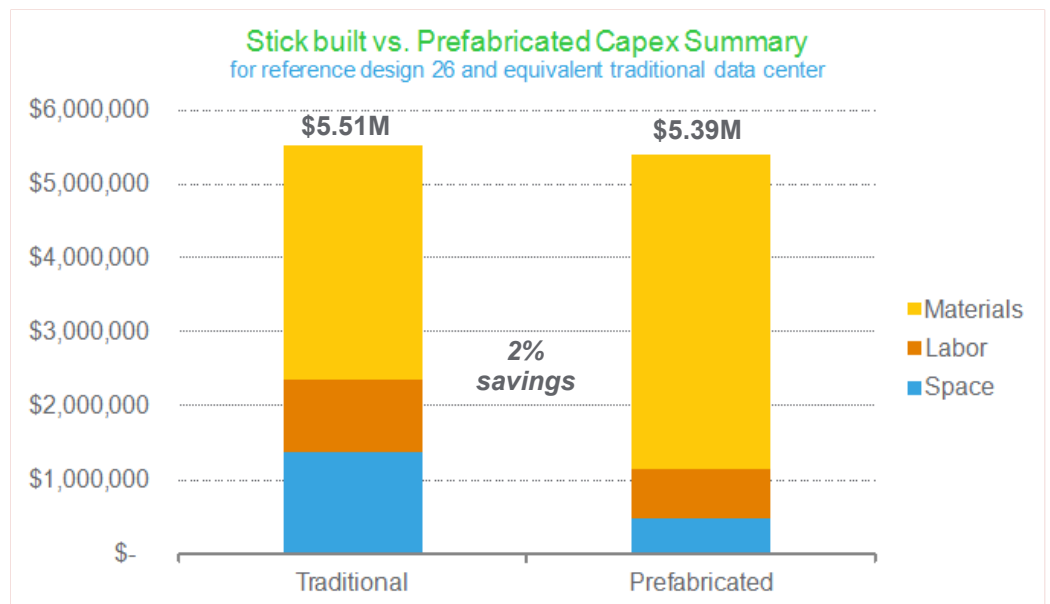
Cost can be more complex to understand, as there are many variables and assumptions that impact the cost differences of a prefabricated vs. a traditional stick-built data center. In White Paper 164, [TCO Analysis of a Traditional Data Center vs. a Scalable, Prefabricated Data Center](#), we demonstrate how prefabrication offers flexibility to scale and optimize a data center design, which can result in significant cost and energy savings compared to building an oversized traditional data center.

In this paper, we quantify the capital cost differences of two data centers with the same capacity, the same cooling and power architectures, the same levels of redundancy, the same density, and the same number of racks. This allows us to isolate the cost differences of the data center approach (prefab vs. stick-built). The analysis is based off of a Schneider Electric reference design (#26) which is described in detail in the following section.

Capital costs in this analysis include material costs, design costs, site prep costs, installation, and commissioning costs. For this particular design, the capital cost savings of the prefabricated approach was 2% (roughly equal in cost to the traditional approach). **Figure 1** illustrates the breakdown by cost type. As the chart illustrates, the materials are more costly for prefabricated data centers, however, this is countered by significantly lower space costs (outdoor vs. building), and lower labor (onsite work) costs. In the Findings section, this is discussed in detail. Romonet’s Cloud-based Analytics Platform¹ was used to complete and validate this analysis.

Figure 1

Cost analysis results show roughly same cost for traditional & prefabricated data center



¹ Romonet is discussed further in the Methodology section. <http://www.romonet.com/>

Architectures analyzed

What is a reference design?

Reference designs are tested, validated, and documented plans for building data centers. They include one-line diagrams, floor layouts, piping diagrams, and equipment lists.

They are valuable as a starting point for project teams because they:

- Simplify planning
- Reduce time to have buildable plans
- Reduce risk, with predictable performance

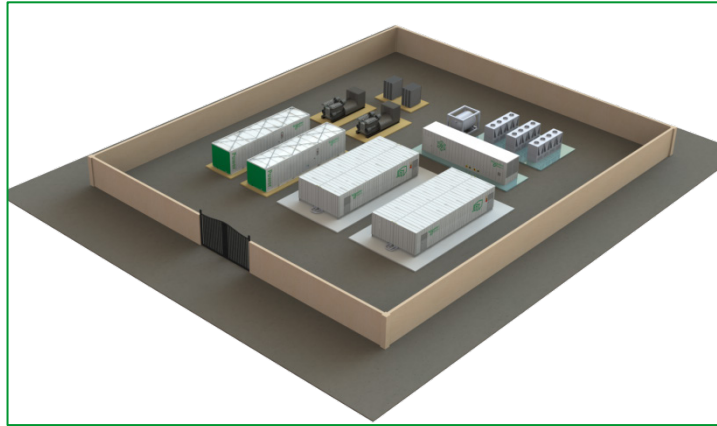
Schneider Electric designs can be found at:

<http://designportal.apc.com/dcrd/pages/filter.html>

We analyzed two 440 kW data centers – a prefabricated data center consisting of power, cooling, and IT modules, and a “stick built” data center using a traditional brick and mortar building to house all of the indoor equipment. **Figure 2** illustrates the conceptual layout of the 2 approaches. The top diagram shows the prefabricated data center, with outdoor power, hydronics (cooling), and IT modules placed throughout an outdoor yard along with data center equipment generally placed outdoors (i.e. generators, chillers). The bottom shows a traditional building with space allocated for IT room, mechanical room, and electrical room, and some equipment placed outdoors like chillers and generators. **Table 1** provides a summary of the two data centers compared, including tier level, power, cooling, and rack design details.

These data centers are based on a documented Schneider Electric reference design, which can be accessed at <http://designportal.apc.com/dcrd/resources/pdf/en/RD26DSR1.pdf>. See the **sidebar** for an overview of the value of reference designs, as well as White Paper 147, [Data Center Projects: Advantages of Using a Reference Design](#), for greater detail. The two designs use the same major components (i.e. same UPS, chillers, rack PDUs, racks, etc.).

Prefabricated spatial view



Stick built spatial view

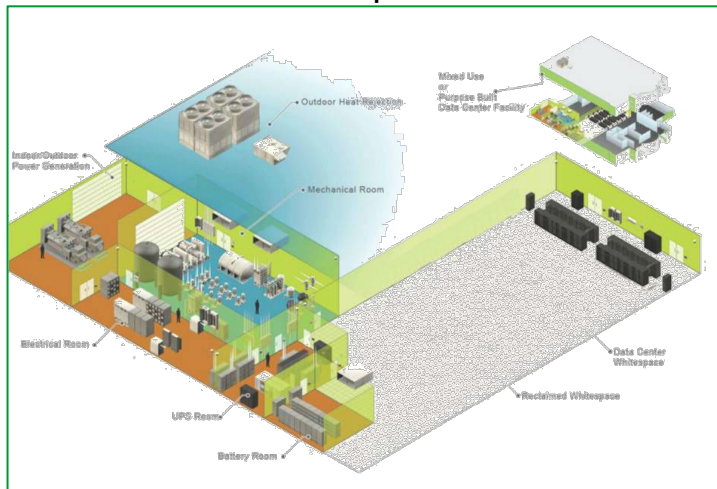


Figure 2

Conceptual layouts of prefabricated and stick-built designs analyzed

Table 1
Architectures compared

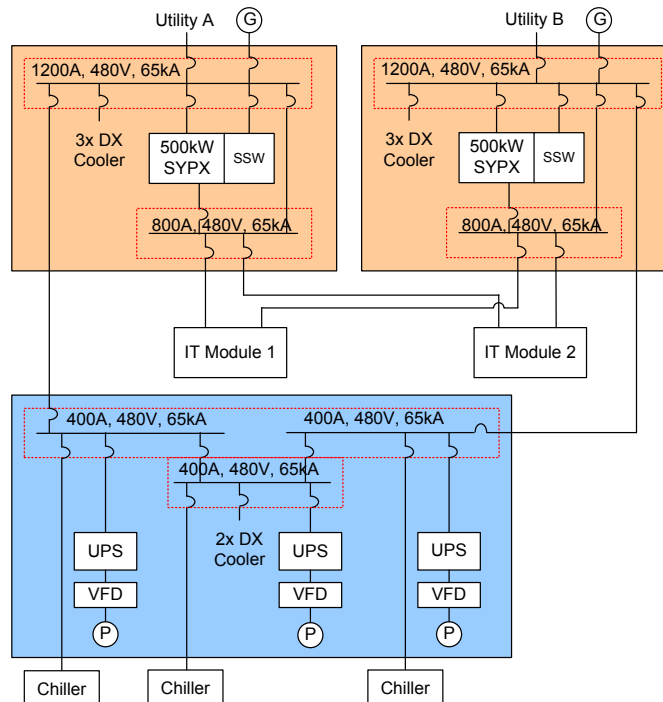
Attribute	Prefabricated	“Stick built”
Design load	440 kW	440 kW
Target availability	Tier III	Tier III
Power architecture	2N power; (2) 500 kW power modules with 5 min backup time, 2N backup generators	2N power; (2) 500 kW power systems with 5 min backup time, 2N backup generators
Cooling architecture	N+1 packaged chiller, water-side economizer, hydronics module, N+1 row-based CRAH	N+1 packaged chiller, water-side economizer, mechanical room, N+1 row-based CRAH
IT configuration	44 racks, 10 kW/rack average, (2) dual bay modules	44 racks, 10 kW/rack average, IT room
Structure	Purpose-built, pre-assembled infrastructure housed in insulated and weather-proof enclosures	Traditional building with dedicated IT room, on-site assembly of infrastructure
Site size	910 sq m (9800 sq ft) of outdoor space	725 sq m (7800 sq ft) of building space*

* Note, our analysis did not consider the additional outdoor space surrounding the building.

Facility power

The data center we analyzed has redundant utility feeds and redundant generators, each feeding a 1200A 480V switchgear bus, 500 kW UPS, and then distributed out to the IT modules via a combination of LV panelboards and 175 kW power distribution units (PDUs). Power is also fed to the mechanicals with separate N+1 UPSs (each 32 kW in capacity). **Figure 3** illustrates the one-line diagram of the power.

Figure 3
Power architecture



Facility cooling

The cooling design of the data centers we analyzed were comprised of three packaged chillers, each 275 kW, in an N+1 configuration. Each chiller has an integrated dry cooler for economizer mode. In the case of the prefabricated design, there is a hydronics module which includes the pumps, valves, controls, and instrumentation needed. In the case of the stick-built design, this equipment is located in a mechanical room within the building. **Figure 4** illustrates the piping architecture and pump configuration for the data centers. They are designed to feed row-based CRAHs in the IT space.

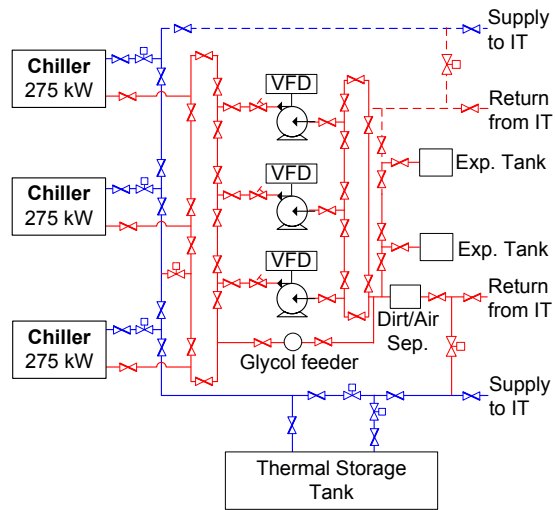


Figure 4

Cooling architecture

IT space

In both designs, the IT space consists of 44 IT racks, each capable of supporting an average of 10 kW/rack of IT load. Redundant (2N) PDUs with isolation transformers feed redundant metered rack-mount PDUs within each rack. Hot aisle containment is used to optimize airflow in the space, and N+1 row-based CRAHs are placed throughout the rows of racks.

The exact arrangement of racks, coolers, and PDUs varies between the two designs. In the case of the prefabricated data center, the IT room is made up of two dual-bay IT modules. **Figure 5** illustrates both dual-bay modules. In the stick built design, one larger IT room is assumed, with all 44 racks and supporting equipment.

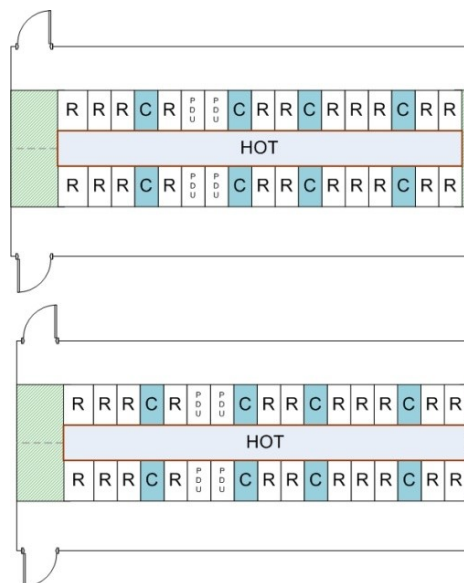


Figure 5

IT space in the prefabricated data center

Methodology

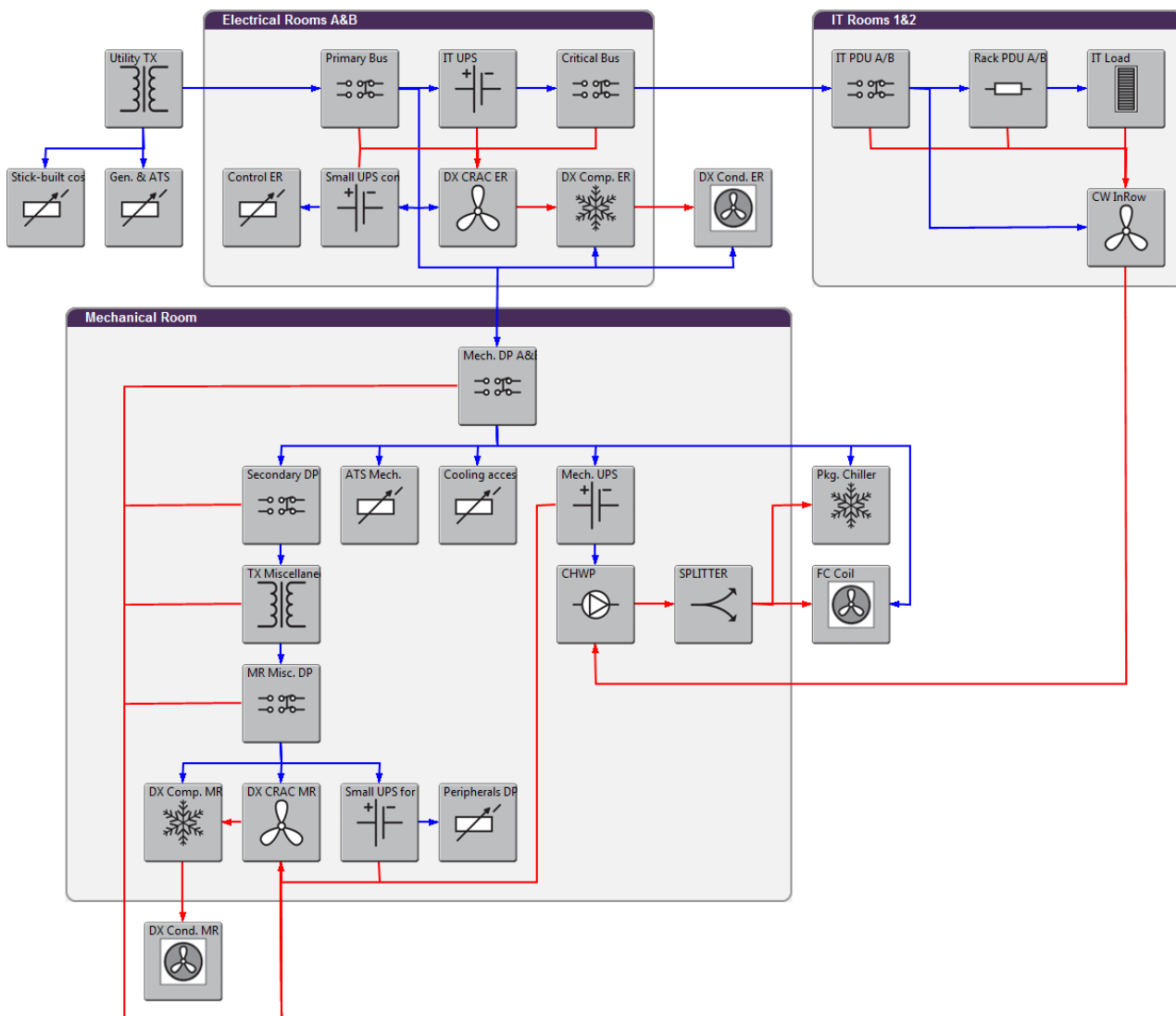
We used a 3rd party data center modeling software by [Romonet](#) to perform this capital cost comparison. **Figure 6** shows the logical layout of the modeled data center. This model describes the energy flow through the data center power and cooling infrastructure. Blue connection arrows indicate a power connection; red arrows indicate a cooling connection. The modeling software is also capable of analyzing energy costs, but for this analysis, since the subsystems used were identical in both designs (and therefore energy differences would be negligible), we focused only on the capex portion of the tool.

Each block represents a data center subsystem, and for each of these blocks, cost data including the capital cost of the materials as well as the installation cost, was applied. Each block is also configured to match the redundancies of the designs, as described above. The shaded areas represent the rooms or modules where the subsystems are located. The components without shading are located outdoors.

Romonet experts reviewed and validated the model.

Figure 6

Model of data center analyzed in Romonet's Analytics Platform



Assumptions

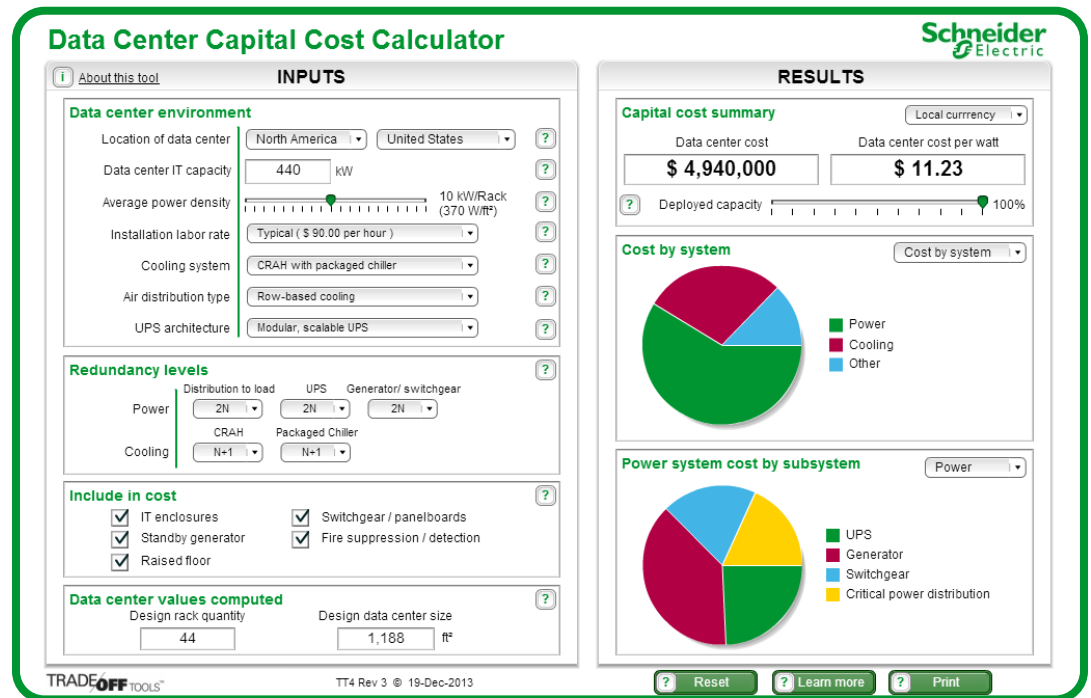
The main assumptions we used in the financial analysis are as follows:

- 440 kW data center equipment installed on day 1, per description and diagrams above
- Data centers are installed in the US with average US labor rates
- Cost for land is \$269/m² (\$25/sq ft)
- Cost for finished building space is \$1,615/m² (\$150/sq ft)
- Prefabricated data center is 865 m² (9310 sq ft) of total outdoor space required (inclusive of clearance space around modules)
- Prefabricated modules are all placed outdoors
- Stick built data center has a building size of 727 m² (7829 sq ft)

Data Sources

Our Schneider Electric [Data Center Capital Cost Calculator](#) was used as a primary source of subsystem material and installation costs. This tool is based off of actual project costs of varying data center sizes. **Figure 7** is a screenshot of the Schneider Electric tool. In addition, installation cost data from three recent prefabricated data center project implementations were used. General, non-vendor specific cost data provided by Romonet was used as a means of validation.

Figure 7
Data Center Capital
Cost Calculator



Findings

Figure 1 summarizes the differences between the two designs at a high level and shows a (negligible) 2% cost savings for the prefabricated reference design over its equivalent stick built data center. Below in **Figure 8**, we show a further breakdown of the costs, by subsystem category and by cost type.

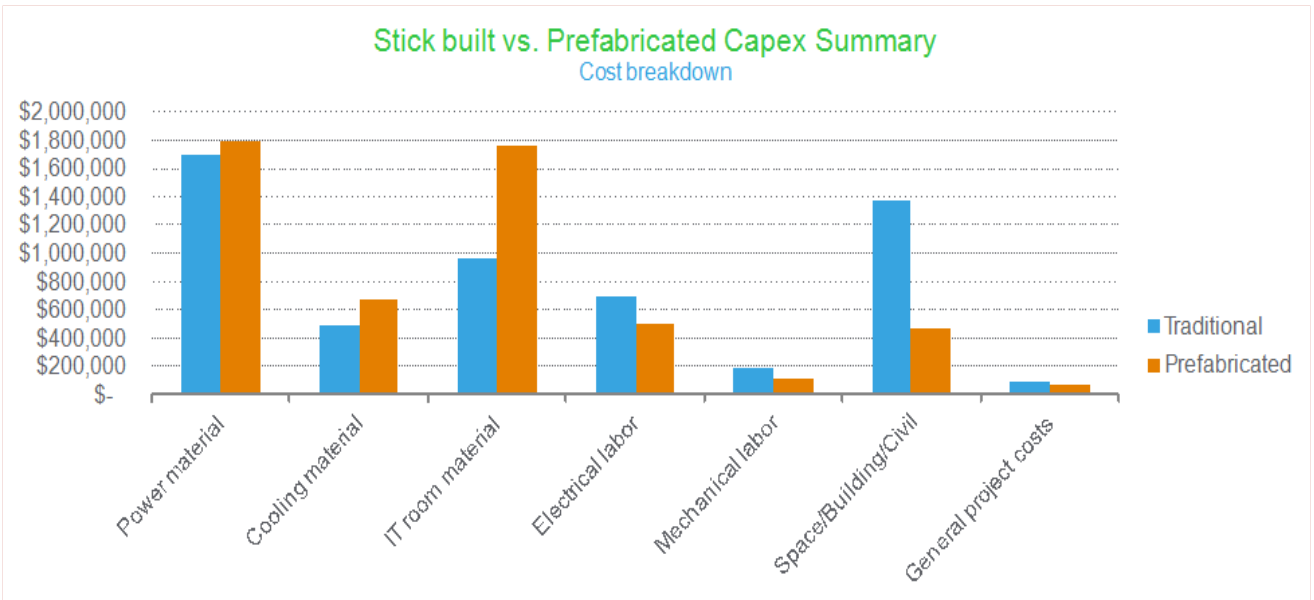
The chart illustrates that the prefabricated systems (materials) come at a capex premium over the traditional systems. Since the prefabricated modules are shipped with the physical infrastructure preassembled, the “materials” cost includes the physical housing (i.e. containers) as well as the factory integration work. The largest material premium for the prefabricated design was for the IT room gear, followed by the cooling system.

The degree of onsite labor (both electrical and mechanical) is reduced for prefabricated designs, since integration work done in the factory results in less field work.

The space cost (cost of the land, building, site prep work) represents the biggest savings opportunity in this analysis. This is based on the building and land costs as stated in the assumptions section.

Figure 8

Breakdown of cost categories for capex comparison



Sensitivity analysis demonstrated that there are two key variables that determine whether traditional or prefabricated is the lower capex approach.

- Building cost
- Average power density / rack

We chose a “typical” building cost in our analysis, but actual costs vary significantly from country to country, and site to site. In addition, the level of finished space within a building needs to be factored into the cost of building construction. In general, prefabricated designs become more cost effective when compared to a traditional data center within a more expensive building or space. Likewise, the traditional approach becomes more economical if there is a low cost space available.

Average power density impacts the cost of the IT space because as density decreases, the number of racks and rack PDUs increases, but more importantly the size of the building and/or containers also increases. A sensitivity analysis was done to illustrate this impact and is presented in the following section.

Impact of rack density

The above analysis assumed an average of 10kW/rack in the IT space, or 44 IT racks. Average density, however, is a significant driver to the cost-effectiveness of prefabricated IT spaces. At higher densities, the savings over a traditional IT room increases since more load can be housed in the same fixed module space. As density decreases, more modules (containers) are needed to house the same IT load, and this represents additional material overhead that diminishes the savings, and may even swing the results in favor of traditional as densities continue to drop. **Figure 9** illustrates the impact of IT density on the cost of typical prefabricated IT room modules.

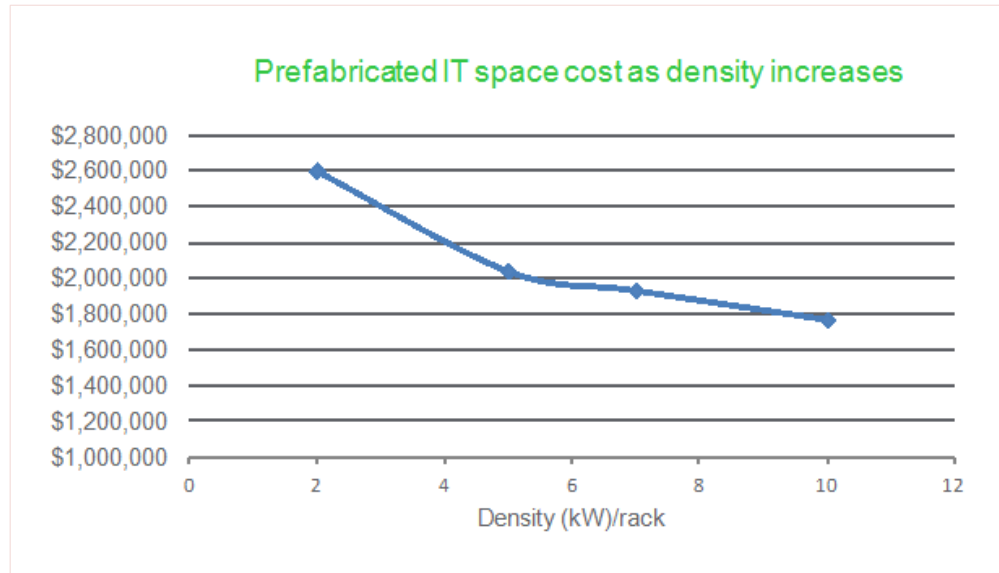


Figure 9

Impact of average density per rack on capex

The graph shows how costs are higher at lower densities. Think about the layout in **Figure 5** which showed the two dual-bay shells. If density was now cut in half to 5 kW/rack, the number of racks doubles and therefore the number of shells doubles. Keep in mind though, that in the traditional design, the racks and associated equipment also doubles. Schneider Electric White Paper 156, [Choosing the Optimal Power Density](#), includes a more detailed cost analysis of data centers at varying densities. Based on the cost analysis findings, the natural break points of rack PDUs, current IT technology trends, and the design complexities that exist for extreme densities, the majority of data centers should design around a peak of 11-11.5 kW/rack.

Conclusion

When challenged with finding suitable space to build a new, or expand an existing data center, prefabricated data centers offer clear benefits. We analyzed two data centers, one prefabricated and one “stick built”, with the same physical infrastructure architecture and components (UPSs, packaged chiller, PDUs, racks, etc.) and concluded that the cost of both approaches are approximately the same. The bottom line is that cost alone generally does not provide a strong case to shift to a prefabricated design approach.

We identified two key cost drivers that influence the comparison – space costs & average power density. The greater the brick & mortar shell cost and the higher the average density requirement, the more likely it is that the prefabricated approach offers financial (capex)

benefits. On the contrary, if you had a building with existing vacant space (i.e. no new building shell cost), the cost analysis would clearly favor the traditional approach.

The discussion around cost comparisons of traditional data centers versus prefabrication can't be reduced to the just building construction costs. Other business drivers need to be considered when evaluating a site. For example, available space that could be used to expand a data center in a hospital, university, or factory should be financially weighed against the potential for revenue generation within the same space. In this case it may make more sense to build a new space outside of the existing building.

The size, location, or business model of the data center will have an impact on the type of solution that fits best - not all data centers are created equal. The specific example in this paper was based on a total capacity of 440 kW at an average of 10 kW per rack with no discussion about the type of building or business it is supporting. If we consider an example of a large service provider (i.e. colocation data center) where 100% of the business is operating a data center, the focus will likely be directly on optimizing the capital cost per rack or kW and minimizing operating costs. An automobile factory, on the other hand, may have a different perspective, where the focus is on adding a smaller amount of data center capacity, and the simplicity and speed of a drop-in-place solution is a key decision criteria.

The decision to pursue a prefabricated data center approach is not as straightforward as simply comparing implementation costs versus a traditional installation. Other factors falling into broad categories of time, space, and data center growth can significantly impact business results over the life of the data center. Most customers who have deployed a prefabricated data center now enjoy the benefits of that solution because this approach met specific challenges in the present while allowing for future flexibility.



About the authors

Wendy Torell is a Senior Research Analyst at Schneider Electric's Data Center Science Center. In this role, she researches best practices in data center design and operation, publishes white papers & articles, and develops TradeOff Tools to help clients optimize the availability, efficiency, and cost of their data center environments. She also consults with clients on availability science approaches and design practices to help them meet their data center performance objectives. She received her Bachelors of Mechanical Engineering degree from Union College in Schenectady, NY and her MBA from University of Rhode Island. Wendy is an ASQ Certified Reliability Engineer.

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[Prefabricated Power and Cooling Modules for Data Centers](#)

White Paper 163



[TCO Analysis of a Traditional Data Center vs. a Scalable, Prefabricated Data Center](#)

White Paper 164



[Data Center Projects: Advantages of Using a Reference Design](#)

White Paper 147



[Practical Considerations for Implementing Prefabricated Data Centers](#)

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[Choosing the Optimal Data Center Power Density](#)

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