



Dollars per kW plus Dollars per Square Foot Are a Better Data Center Cost Model than Dollars per Square Foot Alone

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For many years, the data center industry has used dollars per square foot of computer room space to benchmark the construction cost of a data center. This has led many data center owners to reduce the amount of space in an attempt to control project costs. This approach generally produces disappointing results because it is based on a false premise. After reviewing 16 actual construction projects to identify their primary cost drivers, The Uptime Institute, Inc.[®] (*Institute*) has developed a new and more accurate construction cost model. This model emphasizes the “engine” capacity and functionality aspects of a data center, in addition to the space itself.

This white paper:

- Provides a new and more accurate way of predicting the all inclusive total budget required to build a new data center.
- Is based on 16 actual recent major projects.
- Warns senior executives and project managers to be extremely cautious if their project budget is significantly less than the *Institute's* metric because the “savings” are most likely to result from reductions, often unstated, in infrastructure performance features or delivered capacity.
- Urges project managers to engage Tier technology and cost experts, with multiple project experience, to independently validate the integration of data center design, capacity and uptime performance objectives with their project’s budget for construction, including often overlooked transfer to operations costs, before making irrevocable commitments to senior management.

a distinctive departure from office buildings where mechanical/electrical systems are normally about 15% of the total cost of construction. This fundamental, functional difference between office buildings and data centers is the reason that the traditional office building construction cost benchmarking system of dollars per square foot or per square meter (\$/ft² or \$/m²) is inappropriate for data center construction.

When designing a new data center, two management decisions will determine the cost of the mechanical and electrical systems, which in turn will drive the total project cost. These management decisions are the design objective for power and heat load density, and the concurrent maintainability and fault tolerance functionality of the mechanical electrical infrastructure. Both of these decisions are independent of the square feet in the computer room. Doubling density doesn’t affect the size of the computer room, but it does double the size and cost of the underlying mechanical/electrical infrastructure. Similarly, changing the Tier of functionality (e.g., from Tier II to IV) can effectively double costs without adding any computer room space or increasing the useable UPS kW available for the computers.

Centers Are Not Upgraded Office Buildings

When one examines data center detailed construction cost breakdowns, the mechanical/electrical systems will account for 70% or more of the construction cost (depending upon density and functionality). This is

Data Center Cost Drivers

Detailed analysis has shown there are three primary construction cost drivers for a data center

- The power and cooling capacity or density (total kW, watts per square foot or per square meter (W/ft² or W/m²) or kW/cabinet),



- The Tier of functionality (Tier III Concurrently Maintainable, etc.)¹, and
- The amount of computer room floor space (cabinets or space (ft² or m²).

Consider two “similar” 20,000 ft² (1,900 m²) computer rooms: the first is Tier II at 50W/ft² (538 W/m²)(1,000 kW of useable UPS for computers) and the second is Tier IV Fault Tolerant at 100 W/ft² (1,077 W/m²)(2,000 kW of useable UPS for computers). The computer room floor sizes are identical in both cases. However, the gross building footprint (i.e., the gross building to house the computer room plus the space for the mechanical/electrical infrastructure) is not: the first is about 26,000 ft² (2,400 m²) gross and the second is about 40,000 ft² (3,700 m²) gross. Even more important, the construction cost for the second (higher density Tier IV) solution is approximately triple the cost of the first solution (Tier II at a 50% lower density). This example illustrates how construction costs can change dramatically independent of the size of the computer room, and is the reason why the traditional \$/ft² (\$/m²) cost model now needs to be abandoned.

Institute’s Data Center Construction Cost Model

The *Institute’s* cost model appropriately reflects the unique characteristics of data centers.

The “computer room” component provides raw “tenant” space without any “fitout” of functionality or power/cooling capacity. The cost of this raw space is independent of Tier level and includes a raised floor, building shell and core (incidental office space for facilities, lobby, rest rooms, conference room, interior partitions, loading dock, storage area, etc.), normal interior finishes, lighting, building HVAC for make-up air, fire detection and pre-action sprinklers, and other space items that are not related to kW or functionality Tier. The cost of fitting out the computer room with the “kW distribution and delivering equipment” (basically the power distribution and cooling units) is separately included in the “kW” component above.

What converts a raw computer room into a data center is the “behind the curtain” power and cooling engine which “drives” the computer room space. This engine is sized in “kW” by Tier level and provides for the installation of the underlying and redundant mechanical/electrical infrastructure capacity (measured in kW of uninterruptible power delivered to the

computer and communication load), as well as the distribution equipment required to support the desired Tier of functionality. Cost components include utility switchgear, power distribution backbone switchgear, engine generators, UPS, batteries, PDUs, critical power distribution, chillers, pumping, piping, cooling units, thermal storage, and fuel system plus the gross building space to house all of this equipment. Depending upon density, remember that the space for “back of the house” equipment for Tier IV frequently will exceed the amount of computer room floor space it supports. At 100 W/ft² (1,077 W/m²), the ratio is at least 1 to 1. At 300 W/ft² (3,231 W/m²), the ratio is about 1 to 3.

The *Institute* cost model reduces to just two elements.

- The “kW” component by desired level of functionality
 - Tier I: \$10,000/kW of useable UPS output
 - Tier II: \$11,000/kW of useable UPS output
 - Tier III: \$20,000/kW of useable UPS output
 - Tier IV: \$22,000/kW of useable UPS output
- The “computer room” component. In all cases, \$220/ft² (\$2,400/m²) of computer room floor must be added to the “kW cost” shown above.

Example Using Institute Cost Model

Returning to the earlier example of two computer rooms each 20,000 ft², but one with Tier II at 50W/ft² (1,000 kW of useable UPS for computers) and the second with Tier IV Fault Tolerant at 100 W/ft² (2,000 kW of useable UPS for computers), the costs would be:

- Tier II @ 50 W/ft² = \$15.4 M
(20,000ft² x \$220/ft² + 1,000kW X \$11,000/kW)
- Tier IV @ 100 W/ft² = \$48.4 M
(20,000ft² x \$220/ft² + 2,000kW X \$22,000/kW)

Important Assumptions, Conditions, and Constraints

The *Institute’s* cost model is based on 16 completed projects, each of which had extremely well developed designs that are industry benchmarks. These projects actually delivered their promised capacity, redundancy, concurrent maintenance, or fault tolerance. This historical basis ensures that users of the *Institute’s* model are, in fact, getting more accurate, complete, and more ‘all inclusive’ costs than other alternatives, especially during the early project planning cycle when “volunteers” are providing “free” information without defining assumptions and constraints.

¹ For further information on Tier Levels and functionality, consult the *Institute’s* Tier Classifications Define Site Infrastructure Performance

² For simplicity, the cost for the cooling equipment required to remove the heat generated when kW is converted to BTUs by the computer hardware is included within the kW “engine” cost.



The following assumptions, conditions, and constraints are important:

- This model is intended as a quick tool which can be applied very early in the planning cycle to accurately reflect the primary construction cost drivers.
- For the reasons to be outlined below, the tool may be only \pm 30% accurate for a specific project, but will offer fairly accurate relative tradeoffs within that project.
- The wide accuracy tolerance (\pm 30%) is done with specific management intent because it is not generally conducive to one's career to repeatedly go back to management for more project money. Experience indicates that the normal 'quick' scope descriptions used very early in the project development process are usually incomplete, not very specific, and prone to assumption error. This sets the project up for a stream of incremental cost increases as the scope is made more complete and more specifics are developed.
- The cost model excludes land, unusual permits and other abnormal governmental fees, interest during construction, inert gas fire suppression, and abnormal civil site costs. These can add several millions of dollars to project cost.
- Information Technology hardware costs, swing equipment, cabling, communications, and migration costs are not included.
- The cost model assumes a minimum of 15,000 ft² (1,400 m²) of computer room in an architecturally plain, one-story building, with power backbone sized to achieve ultimate capacity with future installation of additional capacity components or systems. No allowance is made for offices, Command Centers, etc.
- Location cost adjustments are necessary for high cost metropolitan areas in the USA such as NYC, Chicago, or other abnormal cost areas.
- Costs are for 2005 construction. Future year costs should be inflated using Engineering News Record indexes.
- This cost model is based on 100W/ft² (1,077 W/m²) with use of air cooling units on raised floor. Adjustments need to be made for higher density or different cooling methods.

Cautionary Note

Be suspicious of cost claims for functionality or capacity that are significantly less than that shown here. At least once a month the *Institute* learns of grievous

project mistakes made by the selectively (mis)use of *Institute* white papers. It is not appropriate, nor wise to base the financial success of any major multi-million dollar project on "free" information (like that offered in this or other white papers). As a way to avoid these multi-million dollar mistakes and unnecessarily foreshortened project life cycles, the *Institute* urges owners to require early and independent validation of data center project scope and the resulting budgets to determine what might have been left out or misunderstood.³ This effort is different than "peer review," which occurs much too late in the cycle to correct errors in original assumptions.

Availability, reliability, and density goals should be confirmed. Specifics should be developed for the 20 site infrastructure subsystems that are required to achieve site availability; the initial and ultimate system capacities should be double checked against Tier level requirements, site selection, staffing, training, and a number of other factors should be benchmarked to ensure project cost, delivery schedule, and ensuing operational success.

Conclusion

The primary drivers of data center construction cost are power and cooling capacity (or density), the Tier of functionality, and the amount of computer room floor space. Traditional real estate cost models using cost per square foot imply that a square foot reduction will reduce total cost, which is not true. At current densities, cutting computer room space by 50% will reduce total cost by only 5%. To prevent sub-optimal decisions, a new model based on "engine" costs in kW plus square foot cost is proposed. As power and heat densities continue to rise, the cost of the mechanical and electrical infrastructure will become a bigger and bigger proportion of total construction cost. The new model brings these costs explicitly into the cost equation.

Users are warned that the *Institute's* information is often tragically misapplied, and that owners, contractors, and equipment vendors make performance claims for their previous data center construction projects that are not supported by factual examination. To prevent career limiting mistakes, the *Institute* urges independent validation of capacity, redundancy, and functionality performance claims early in the project. If costs are dramatically lower than what is identified in this white paper, it is most likely that necessary systems and

³The *Institute* offers a Site Certification program which will prospectively rate a future data center project by capacity and Tier Level for both design topology and for sustainability of the implementation. Based on actual execution, the *Institute* will provide a final certification. This methodology provides an owner with an independent perspective of the uptime effectiveness, sustainability, and expected life cycle of their multi-million dollar investment. Many of the sixteen projects used in the cost model went through this process which is the reason their design was so well developed early in the justification process. Contact the *Institute* for more information.



The Uptime Institute, Inc.®
Dollars per kW plus Dollars
per Square Foot

capacity are missing, and the resulting project will not be certifiable. Based on the *Institute's* experience, there is no “free lunch.”

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About The Uptime Institute

The Uptime Institute, Inc. is a pioneer in creating and operating knowledge communities for improving uptime effectiveness in data center Facilities and Information Technology organizations. The 68 members of the *Institute's* Site Uptime® Network are committed to achieving the highest levels of availability with many being Fortune 100 companies. They interactively learn from each other as well as from *Institute*-sponsored meetings, site tours, benchmarking, best practices, uptime effectiveness metrics, and abnormal incident collection and trend analysis. From this interaction and from client consulting work, the Institute prepares white papers documenting Best Practices for use by Network members and for the broader uninterruptible uptime industry. The *Institute* also conducts sponsored research and offers insightful seminars and training in site infrastructure management.

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