Intel IT Brief
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IT@Intel

Intel IT Redefines the High-Density Data Center: 1,100 Watts/Sq Ft

Compute Density Comparison

51% ▲ HIGHER PERFORMANCE PER CORE

Intel IT has used design best practices to convert a 5,000-sq-ft wafer fabrication facility into a high-density data center, achieving the following results:

- A rack power density (up to 43 kW per rack) that is 1.5 times greater than what we have delivered in the past for high-density computing
- The ability to use only free-air cooling except for 39 hours or less per year and to run our servers at an air intake temperature of up to 95°F (35°C)
- An 1,100 W/sq ft cooling density and a 1,300 W/sq ft electrical density (10 times the industry average)

Our newly designed data center has a total power capacity of three legacy data centers. The commodity Intel® architecture-based servers installed in this facility offer 51 percent higher performance per core than previous models,[1] which enables us to significantly increase compute density. The higher cooling and electrical density will enable us to support the large growth in compute demand associated with electronic design automation tools. This growth is a result of an increase in circuit design complexity and the workload required for comprehensive silicon design and testing.

[1] Internal Intel IT tests, June 2014.

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Acronyms

PUE power usage effectiveness

Business Challenge

Increasingly complex silicon chip designs are driving 30 to 40 percent growth in compute demand at Intel—more than 45 million compute-intensive design workloads run every week. There is also increasing pressure industry-wide to reduce data center operating costs and increase data center energy efficiency. To address these challenges, we have been looking at ways to increase data center efficiency and capacity without increasing the cost of operation.[2]

We considered the following possibilities:

- Build a new data center.
- Retrofit an existing data center.
- Purchase a container-type data center solution.
- Use external hosting providers.

After evaluating the available options, we decided to repurpose existing surplus space (in this case, decommissioned wafer-fabrication space).

Solution

The building we chose to convert to a data center has several characteristics that made it a logical choice:

- The building is multistory with high ceilings and available plenums. The upper floor provides access to outside walls that have a favorable exposure for exhaust air venting.
- Underutilized site resources are available for utility power, chilled water, and rooftop air handlers.
- The building is located near a global design computing hub, which provides access to network infrastructure and optimizes support activities.

Due to our use of commodity IT equipment, we were able to use free-air cooling even though the building is located in a climate with an average high temperature of 85°F (29°C).[3]

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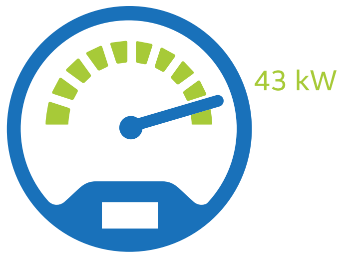
[2] To learn more about our design best practices for high-density data centers, read the Intel IT white paper "Facilities Design for High–density Data Centers."

[3] For more information about how we choose where to locate Intel data centers, read the Intel IT white paper "Selecting a Data Center Site: Intel's Approach."



RACK POWER DENSITY

up to **43 kW**

per rack using state-of-the-art Intel® architecture-based servers

The resulting data center is classified as a batch high-performance computing facility. It contains no storage servers and has no requirements for high-tier reliability. As shown in Figure 1,[4] our newly designed data center has a total power capacity of three legacy data centers.

The use of the following design components helped us meet the requirements for high-density computing in the most cost-efficient way:

- **Custom rack design.** We used a custom design, instead of an off-the-shelf design, which enabled us to better optimize space and power density.
- **100-percent free-air cooling.** We used and extended innovations for high-density air cooling designs that we had perfected in past facility projects and retrofits. Examples of such innovations include flooded supply air, hot-aisle enclosures for air segregation management, and direct hot-air exhaust to the building's exterior.
- **State-of-the-art electrical density and distribution system.** We used 800-amp 415/240-Vac rack power distribution and achieved a single-path rack power density of 25 to 43 kW per rack.

Each of these design components is described in subsequent sections.

[4] The net square footage of the data center's production area is 4,545. The balance of 5,000 comprises access areas.

Figure 1. Our high-density design allows for an increase in watts per square foot. Economies of density work similar to Moore's Law: the cost per kW goes down as more kW are put into each square foot of production area.

Because the regional operating utility substation has high-quality power, we determined that the use of utility power was not a significant risk. However, we did provide for easy tie-in of an uninterruptible power supply or generator in the future should a business need or power quality necessitate this change.

Custom Rack Design

We are maximizing our investment by increasing the density rather than scaling out, and we have more than doubled our previous server capacity per row. The off-the-shelf commodity Intel® architecture-based servers installed in this facility offer significant advantages over previous server models: 51 percent higher performance per core and advanced small form factor design for extremely high rack capacity. The combination of higher performance per core and high server rack density enables us to increase the capacity without increasing the data center footprint.

We increased the rack height to 60U and decreased the rack width to less than 20 inches, resulting in 12 rows with an average of 18 racks per row with 209 usable compute racks, 8 of which are network racks. This design resulted in an overall cooling density of 1,100 W/sq ft and a rack power density of up to 43 kW/rack—1.5 times what we have delivered for high-density computing in the past.

Free-Air Cooling

We chose a flooded air design that provides supply air to the cold aisles by flooding the room with air at a slightly positive pressure. This design allows any amount of air required by any server to be available. The building was already equipped with rooftop air handlers. These repurposed units provide the airflow filtering and supplemental cooling. The supply air demand for the room is 542,324 cubic feet per minute. The facility more than meets this demand, providing 572,000 cubic feet per minute. We also reconfigured the existing rooftop supply air plenums to connect to the room's overhead supply air plenum, which is large enough to accommodate two school buses parked side by side (see Figure 2).

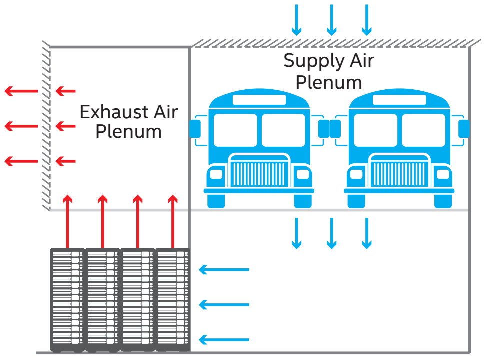


Figure 2. The overhead supply air plenum is large enough to accommodate two school buses parked side by side.

Newer server platforms allow for a wider range of thermal operating conditions—from 32°F (0°C) to 104°F (40°C). The specific equipment we are using is designed to operate between 41°F (5°C) and 95°F (35°C). In the data center, the supply air temperature averages 60°F (16°C) in the winter and 90°F (32°C) in the summer. Taking into account our testing and the manufacturer's published operating conditions, we have found that we can now run servers at higher temperatures—no cooling is necessary unless the outside air is hotter than 95°F (35°C). Except for an estimated 39 hours per year, free-air cooling completely cools the facility.

If the outside temperature exceeds 90°F (32°C), we begin to augment free-air cooling using the available chilled water supply. Doing so ramps up the supplemental cooling before it is actually needed, when the outside temperature reaches 95°F (35°C).

Two more design components—mixing fans and in-room sensors—make our free-air cooling design more efficient.

- **Mixing fans.** We use these fans to return hot air if we want to increase the supply temperature to eliminate extremely cold air or manage the temperature dew point.
- **In-room sensor array.** We use a variety of sensors to help keep our IT equipment operational. We have in-room temperature sensors for both supply air and exhaust air. We also employ pressure differential sensors that control the positions of the supply air dampers. This equipment maintains the positive pressure that our flooded air design requires, helping to manage the volume and flow of supply air.[5]

Hot-Aisle Enclosures

As shown in Figure 3, the facility uses alternating hot aisles (exhaust air) and cold aisles (supply air). Airtight doors at the end of each hot aisle and the translucent air segregation enclosure materials above the server racks are made of a material similar to that used for heavy-duty greenhouse roofs and walls. Hot aisles average 110°F (43°C) in the winter and 125°F (52°C) in the summer. The range of temperatures for the supply and exhaust air in the room makes the environmental conditions acceptable for the few staff that work occasionally in the room.

Direct Hot-Air Exhaust

As part of the building conversion, we added 1,100 sq ft of louvers along a long wall of the building. As shown in Figure 3, after the supply air enters the cold aisles and passes through the servers, the exhaust air from the hot aisles enters the exhaust-air plenum and is vented

[5] Additional sensors that are not directly related to cooling include high-sensitivity smoke detection sensors.

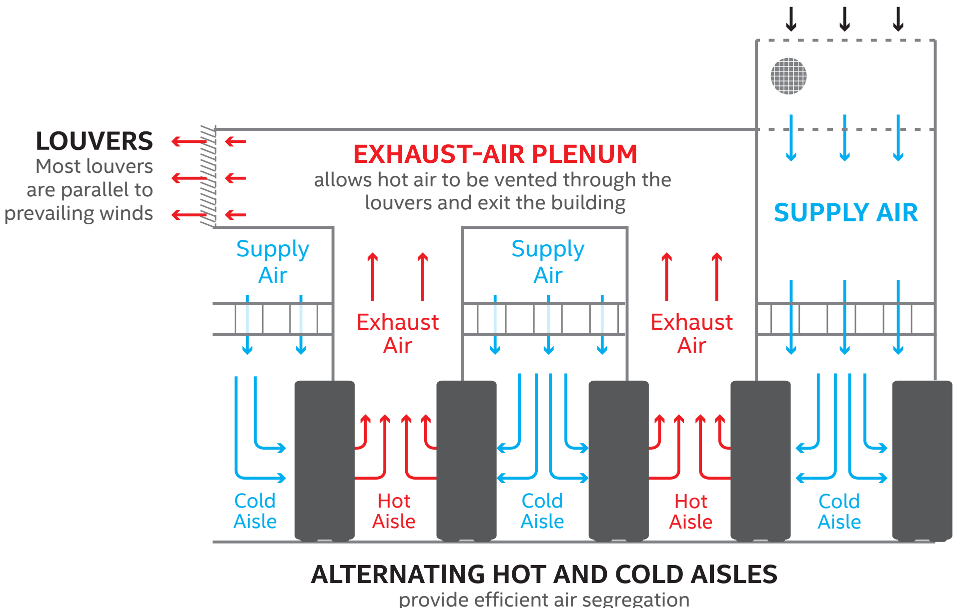


Figure 3. Alternating hot aisles (exhaust air) and cold aisles (supply air) provide efficient air segregation, and the exhaust-air plenum allows hot air to easily exit the building.

through the louvers. We positioned these louvers parallel to prevailing winds so that the exhaust air can easily exit the building. To accommodate the occasional significant change in wind direction, we added 300 sq ft of exhaust-air vent louvers perpendicular to the prevailing winds.

Electrical Distribution

Our new design's 575-kW paths power 400 sq ft compared to a standard 575-kW path that typically provides electrical distribution for 4,000 sq ft The electrical density of the new facility is 10 times greater than the industry average.

COOLING DENSITY AND ELECTRICAL DENSITY

10x industry average

for an 1,100 watts/sq ft cooling and 1,300 watts/sq ft electrical density

To achieve outstanding rack power distribution, we used a power strip designed by Intel and built for Intel by an OEM. This 3-phase 60-amp 415/240-Vac power strip has the highest capacity in the industry, providing 12 individual subcircuits with a total capacity of 43 kW at a delivered cost of less than USD 1,100 each. The strip design itself provides for phase balancing of the load. The power strip, in conjunction with the busway plug-in unit, reduced our installation cost by 75 percent compared to previous solutions.

The facility's electrical design has three other noteworthy aspects:

- **Ease of use.** The design is flexible and allows for easy configuration and connectivity for attaching server power and configuring the layout of equipment in the rack. As equipment footprints change, we can easily adjust and scale the racks and connectivity solution.
- **Flexibility.** The busway and power strip design enables us to support not only the current generation of IT equipment but also legacy, lower-amperage equipment without having to rewire branch circuits.
- **Reliability.** Based on our business requirements and the power quality of the current utility provider, we are using utility power to operate our data center. The electrical distribution equipment was designed with the capability to easily switch the power source to uninterruptible power supply or, if necessary, generator support in the future. We can make this tie-in in less than one day per single bus without impacting any other electrical distribution in the room.

FREE-AIR COOLING
99.6%
PER YEAR

Results

Using the basic design principles described above, we achieved the following results:

- A rack power density of up to 43 kW/rack, which is 1.5 times greater than the density of what we previously delivered for high-density computing
- The ability to rely on cost-effective 100-percent free-air cooling for all but 39 hours per year
- A cooling density of 1,100 W/sq ft, which is 10 times the industry average—a density that the industry has referred to as “impossible” and “remarkable” for an air-cooled facility

We anticipate that after we gather the operating data over the next 12 months our design will result in a power usage effectiveness (PUE) that is sub 1.1. We also expect the capital cost avoidance and operation cost savings to be significant due to the reduced amount of mechanical cooling capacity required (and therefore reduced electricity requirements), a small footprint, and the reuse of an existing building shell.

Next Steps

Having completed the first construction phase of the project—14,000 servers and 3.2 MW—we expect to add another 16,000 servers and another 1.8 MW before the end of summer 2014. After construction is complete, we plan to gather data over the subsequent months. We have installed power monitoring according to The Green Grid Category 3 requirements, which will enable us to gather data about the facility’s PUE.

Over the next 12 months, the operational data we gather, which will include variations in outside temperature and load demand, will help us verify the operational integrity of the facility design. We will be able to determine whether we met expected loads and operational cost and efficiency goals, and we plan to use the data to improve this facility and any new facility design specifications. We anticipate that the data will reveal a PUE that is sub 1.1.

Conclusion

By converting a decommissioned wafer-fabrication building into a data center instead of building a new facility, we achieved significant capital investment cost avoidance. Through careful design and the use of the latest Intel architecture-based technology, we achieved a high-density compute facility with the following characteristics:

- A small footprint
- Best-in-class cost and operational efficiency
- Low construction and sustaining cost per kW

The design components include the following:

- Custom rack design using commodity Intel architecture-based servers, which have 51 percent higher performance than previous models
- Low-cost free cooling (including hot-aisle enclosures and direct hot-air exhaust to the building's exterior)
- State-of-the-art electrical system

These design components have enabled us to increase the maximum supply air intake temperature to 95°F (35°C) and achieve a cooling density of 1,100 W/sq ft, a 1,300 W/sq ft electrical density (10 times the industry average), and a rack power density of up to 43 kW/rack.

For more information on Intel IT best practices, visit www.intel.com/IT.

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