CASE STUDY

REDUCING DATA CENTER COST AND ENVIRONMENTAL IMPACT BY

DEPLOYING SIX EFFECTIVE CABINET AIRFLOW MANAGEMENT MEASURES

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EXECUTIVE SUMMARY

Data center owners and operators are under unprecedented pressure to improve energy efficiency. Explosive growth in online applications and generative AI workloads are forcing them to build new capacity at an accelerated rate and utilize energy faster than ever before. Consider these statistics:

- North America sees 70% jump in data center supply in construction. CBRE report says | Reuters
- According to Goldman Sachs, AI alone is expected to drive a 160% increase in data center power demand by 2030, as a single ChatGPT query draws 10 times as much electricity to process as a Google search.
- Data centers are putting enormous demands on national grids. In 2022, data centers accounted for more than 4% of U.S. electricity use. According to an International Energy Agency report, that number is expected to climb to 6% in 2026.

This level of power consumption exacerbates the already heavy burden on data center owners and operators to control costs, meet global environmental standards, and help businesses reduce their environmental footprints.

Inefficient power utilization makes these problems worse.

There has never been a greater need for well-designed and maintained data center infrastructures. Airflow management and optimization are key to any data center energy efficiency improvement project.

After reading this white paper, you will have a better understanding of six effective measures every data center owner or decision-maker must consider when deploying IT cabinets to boost energy efficiency. Some of these measures are straightforward but somewhat unknown. Others are highly innovative.

All these measures prevent the mixture of hot and cold air flows at the cabinet level, mitigating well-known issues, including bypass and recirculation airflows. Minimizing these problems, at scale, is vital to optimizing data center energy efficiency.

The measures include:

1. Cabinet airflow package
2. Blanking plates
3. Sealing cable entry points in the cabinet roof layout
4. Air seal plinths for raised cabinets, sealing the space between the floor and the cabinet
5. Sealing cable entry points as part of the cabinet airflow package
6. Sealing-kits between cabinets

Later in this paper, we will quantify the ability of cabinets to maintain airtight seals between the hot and cold sides of IT equipment. We will also demonstrate how these measures result in substantial energy-efficiency improvements for both data centers and computer room new builds and upgrades.

With the support of a third-party testing company specialized in air flow measurements, we discovered that by investing in cabinet airflow packages in a data center with 4x in-row coolers and 18 cabinets, each cabinet producing 10kW of heat load, an organization can save more than $1,400 a year by minimizing wasted cooling capacity.

The ROI of this investment is as little as 21.5 months. An IT cabinet's economic lifetime can easily reach 20 years, which means solving cooling challenges will continue to save money well over 18 years after the initial deployment.

Let's look at how.

CHAPTER 1 - AI, INDUSTRY GUIDELINES, AND RISING TEMPERATURES FORCE SUSTAINABILITY CONSIDERATIONS ON INFRASTRUCTURE GROWTH

Data center owners and operators face a complex web of challenges, including end-user demands, global regulations, destabilized energy grids, and cooling costs.

Generative AI and ensuing technologies are stretching our national grid. U.S. electric utilities are bracing for a tsunami of new demands from data centers to power these technologies, projecting electricity sales growth many times higher than previous estimates.

According to a Reuters report, nine of the top ten U.S. electric utilities reported data centers as a primary source of customer growth, leading many to revise capital expenditure plans and demand forecasts.

AI aside, the digital transformation explosion is well documented. In 2015, there were an estimated 3 billion internet users; in 2021, there were 4.9 billion. Over the same period, Internet traffic rose from 0.6 zettabytes to 3.4ZB, estimated data center workloads increased from 180 million to 650 million, and data center energy use went from 200TWh to as much as 320TWh. Data centers are indeed the digital factories of the 21st century.

Global trends in digital and energy indicators, 2015-2021

	2015	2021	Change
Internet users	3 billion	4.9 billion	+60%
Internet traffic	0.6 ZB	3.4 ZB	+440%
Data centre workloads	180 million	650 million	+260%
Data centre energy use (excluding crypto)	200 TWh	220-320 TWh	+10-60%
Crypto mining energy use	4 TWh	100-140 TWh	+2 300-3 300%
Data transmission network energy use	220 TWh	260-340 TWh	+20-60%

Sources: Internet users [ITU (2022)]; internet traffic [IEA analysis based on Cisco (2016); TeleGeography (2022); Cisco (2019), Cisco Visual Networking Index]; data centre workloads [Cisco (2018), Cisco Global Cloud Index]; data centre energy use [IEA analysis based on Malmodin & Lundén (2018); ITU (2020); Masanet et al. (2020); Malmodin (2020); Hintemann & Hinterholzer (2022)]; cryptocurrency mining energy use [IEA analysis based on Cambridge Centre for Alternative Finance (2022); Gallersdörfer, Klaaßen and Stoll (2020); McDonald (2022)]; data transmission network energy use [Malmodin & Lundén (2018); Malmodin (2020); ITU (2020); Corcoma (2021); GSMA (2022)].

Source: https://www.iea.org/reports/data-centres-and-data-transmission-networks

RISING TEMPERATURES

As computing demands rise, so are our temperatures that make it more challenging to cool data centers. Coming off one of the hottest summers on record last year, weather officials predict another scorcher, with most of the U.S. expecting above-normal temperatures. At least 20 states, including Washington, Texas, Colorado, and almost the entire Northeast, expect hotter than normal temperatures, with only Alaska catching a break.

Hotter temperatures produce higher energy costs and increased demands that destabilize energy grids. When consumers become overheated about their energy bills and suffer through rolling blackouts, data centers can become seemingly power-hungry villains, even if they're being built in response to consumer demands to power consumer devices and applications.

Regulators are sitting up and taking notice. There are close links between data center design and operational best practices, climate change, and regulatory decisions.

REGULATORY DEMANDS

In the U.S., national standards accompany state and regional directives. For example, The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards cover data center temperatures, humidity, security, and electricity.

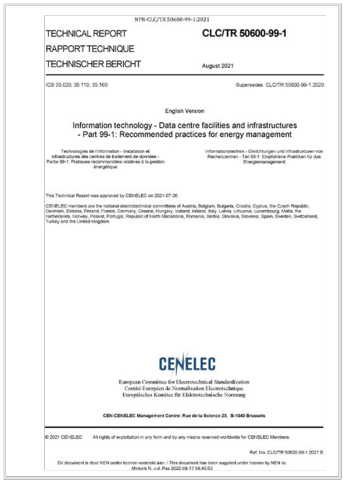
The standard recommends that data center temperatures range between 65- and 80-degrees Fahrenheit, a dew point between 41.9- and 59-degrees Fahrenheit, or a maximum relative humidity of 60%.
In 2023, California signed into law the Climate Corporate Data Accountability Act that requires large businesses to disclose their direct and indirect greenhouse gas (GHG) emissions. Under the law, data center operators must report the emissions from their facilities, considering the carbon footprint of all of their servers, storage, networking, UPS, HVAC, and other equipment in the data center.

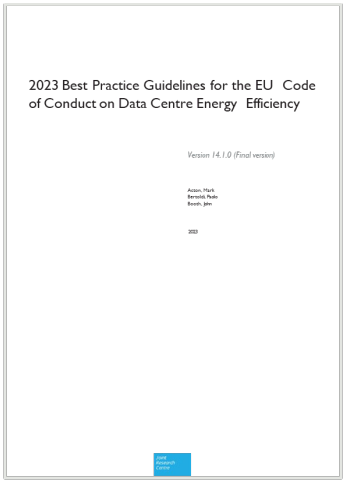
Also, an older rule by California Department of General Services (DGS) requires data centers with a Power Usage Effectiveness (PUE) of more than 1.5 to reduce their PUE by a minimum of 10% per year until they achieve a 1.5 or lower PUE.

The Federal Energy Management Program (FEMP) encourages agencies and organizations to improve data center energy efficiency in accordance with the Office of Management and Budget's Smart Cloud Strategy and M-16-19 Memorandum.

Legrand has an impressive track record in creating global data center infrastructure solutions designed to help customers meet and exceed the standards outlined above, in addition to and complying with the legal requirements of the EU Energy Efficiency Directive.

Additionally, Legrand helps data center owners and operators pursue their energy efficiency compliance objectives as a significant part of their respective journeys towards net zero, as detailed in the Paris Climate Agreement.


TECHNICAL REPORT
RAPPORT TECHNIQUE
TECHNISCHER BERICHT
CLC/TR 50600-99-1
August 2021
English Version
Information technology - Data centre facilities and infrastructures
- Part 99-1: Recommended practices for energy management
CENELEC


2023 Best Practice Guidelines for the EU Code of Conduct on Data Centre Energy Efficiency
Version 14.1.0 (Final version)
2023


INTERNATIONAL STANDARD
ISO/IEC 22237-3
Information technology — Data centre facilities and infrastructures —
Part 3:
Power distribution


CLIMATE
NEUTRAL
DATA
CENTER


SUSTAINABLE
DEVELOPMENT
GOALS


3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
7 AFFORDABLE AND CLEAN ENERGY
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13 CLIMATE ACTION
17 PARTNERSHIPS FOR THE GOALS

CHAPTER 2 - INTRODUCTION TO CABINET OPTIMIZED AIRFLOW MANAGEMENT

Like the links between data center design, operational best practices, and climate change goals, operational optimization and cost reductions depend on data center energy efficiency and sustainability.

Sustainable and energy-efficient infrastructure airflow cabinet designs and practices improve data center performance and save money.

Data center owners and operators who remain skeptical of the link between voluntary environmental and operational enhancements and data center cost savings should be aware that improvements could be mandated in the future.

There is a growing industry consensus that no matter the local measures for energy efficiency and sustainability, global legislation will eventually require data centers to 'clean up' their act.

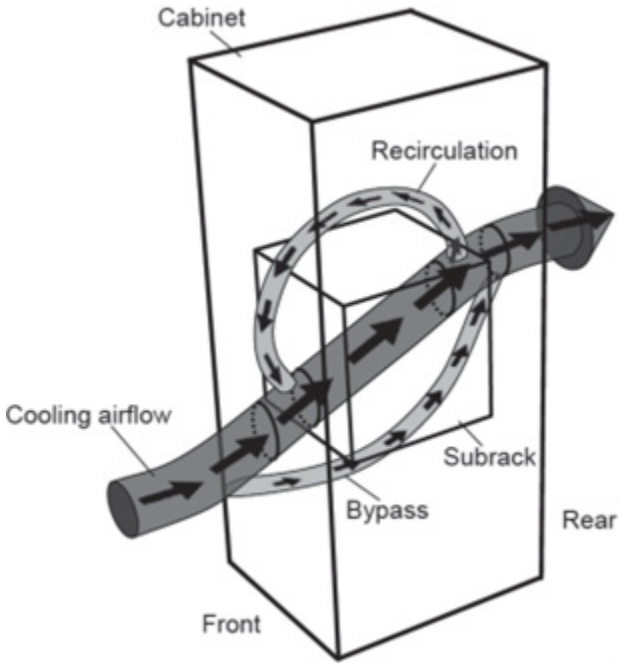
As data centers operate for a decade or more, owners and operators should explore the energy efficiency opportunities outlined in this white paper rather than reacting at the eleventh hour to adhere to enforceable environmental requirements with costly consequences.

We recommend optimizing cabinet airflow to avoid bypass airflows and recirculated airflows.

BYPASS AIRFLOWS

Bypass airflow consists of cold, conditioned air that doesn't travel through IT equipment. Instead, it goes through several gaps in and around the cabinet. Cold air is not only wasted, in the sense that it's been cooled for no actual useful purpose, it is also transported into the hot aisle without absorbing the heat of the IT equipment. Therefore, it cools the hot aisle. Energy is wasted in producing unused cold air, and the energy efficiency of the hot aisle is compromised because the higher return of temperatures going into the cooling system results in higher cooling capacities.

Figure 1 - Schematic of Bypass and Recirculation airflows according to IEC 62610-6



RECIRCULATION AIRFLOWS

The second problem, recirculation airflow, happens when cooled air goes from the front to the back of the rack, through the IT equipment, is heated, and then leaks to the front of the cabinet/ IT equipment instead of being removed from the hot aisle. The leakage from the rear of the cabinet can return to the front and pass through the IT equipment again, reducing cooling efficiency and potentially causing throttling and hotspots.

Avoiding bypass and recirculation airflow is an important element of reducing energy consumption in air-cooled data centers. Legrand has taken special measures to ensure that our customers can solve these challenges.

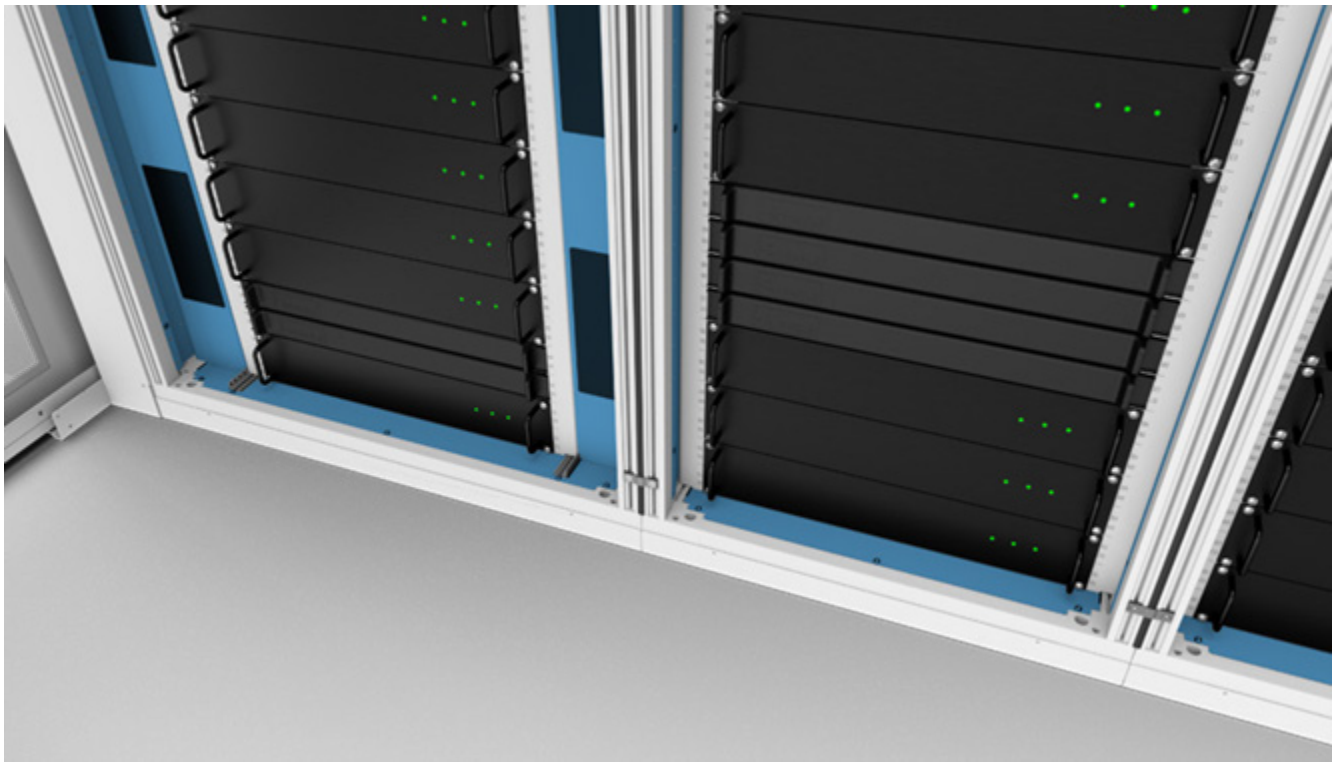
CHAPTER 3 - SIX EFFECTIVE MEASURES THAT ENABLE ENERGY EFFICIENT DATA CENTER NEW-BUILDS AND UPGRADES

The new Legrand cabinet airflow optimization platform consists of everything from the basic blanking plate that seals between two or more adjacent cabinets, floor sealing solutions, and game-changing airtight cable entry innovations that, when coupled with the energy-efficient, gap-eliminating design of the Legrand cabinets, provide significant advantages.

The result of this combination is a truly sealed cabinet package housed in any Legrand hot or cold aisle containment design that offers data center owners and operators the most complete, cost-effective, energy-efficient infrastructure solution available on the market.

1. CABINET AIRFLOW PACKAGE

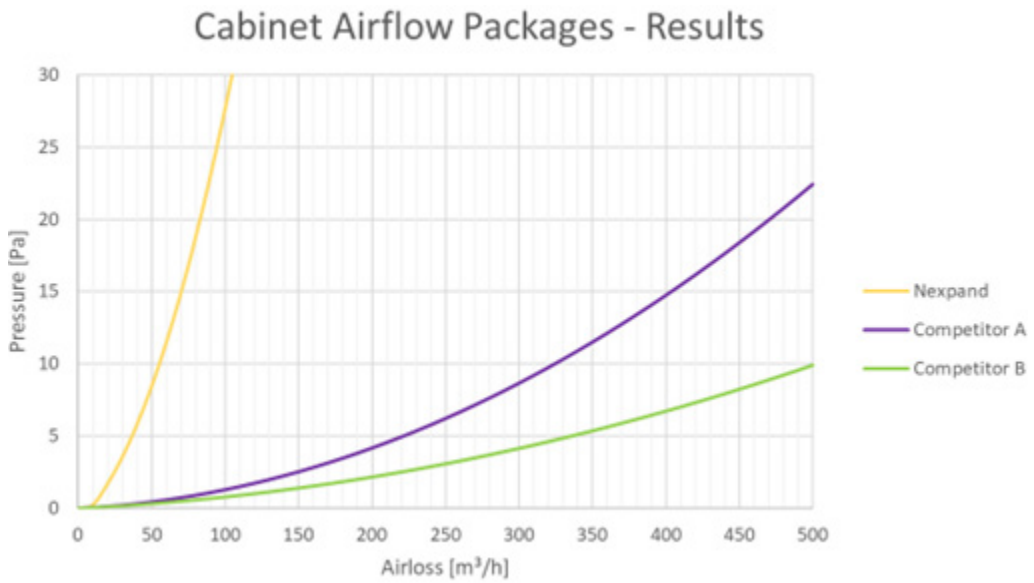
The most important measure with the largest effect on cabinet airflow efficiency is the cabinet airflow package, which creates a perfect seal between equipment rails and the cabinet's exterior.



Sealing packages around the 19" area (left 600mm wide right 800 mm wide)

To assess the advantages of our approach, we arranged for independent testing of airflow management solutions, comparing our new Nexpand platform with premium designs from two of our global competitors. All cabinets were equipped with their respective airflow management solutions.

The graph below shows the benefits of Legrand's Cabinet Airflow Packages



At a pressure differential of 5Pa, we see 35m3/hr of air loss with the Nexpand cabinet versus 225m3/hr of air loss for competitor A.

Legrand leads the competition. The graph shows that, compared to the A and B solutions, the Nexpand solution provides an 85-91% performance increase. This finding demonstrates the importance of proper sealing in IT cabinets. These differences in air loss come from two key problematic design issues.

- Considering brushes around the 19" perimeter to be airtight.
- Not sealing all gaps and holes from the 19" perimeter to the cabinet outer shell.

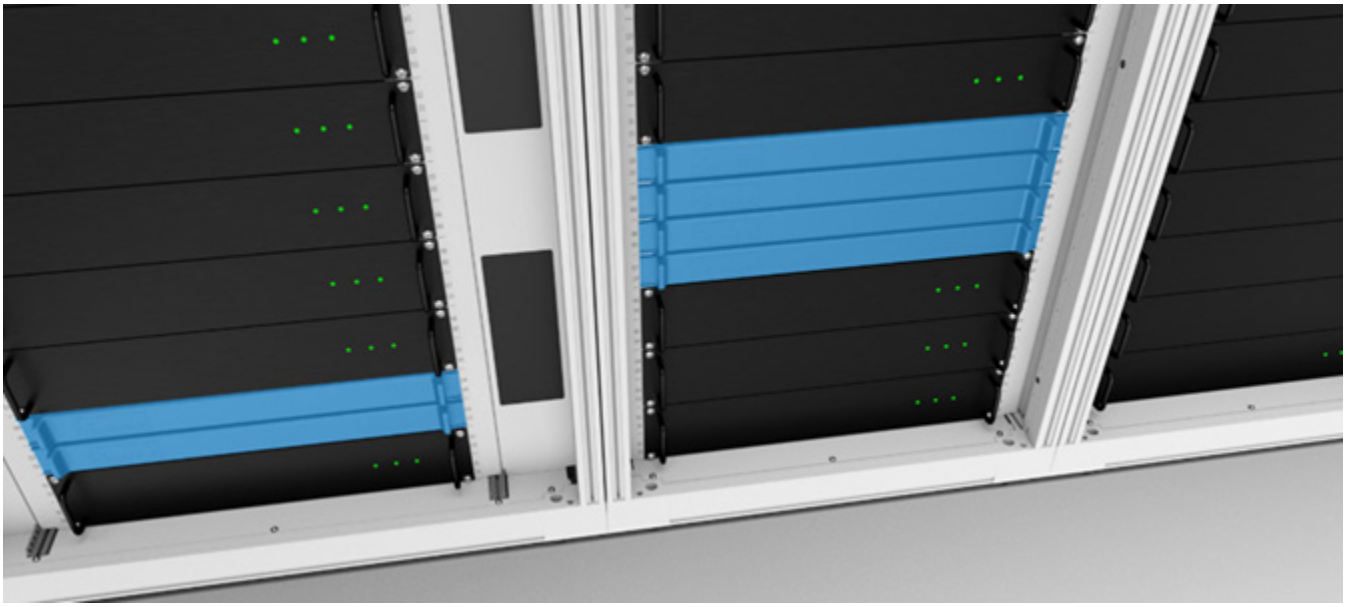
As you can see, the benefits of installing air-optimized cabinets versus a standard cabinet are substantial.

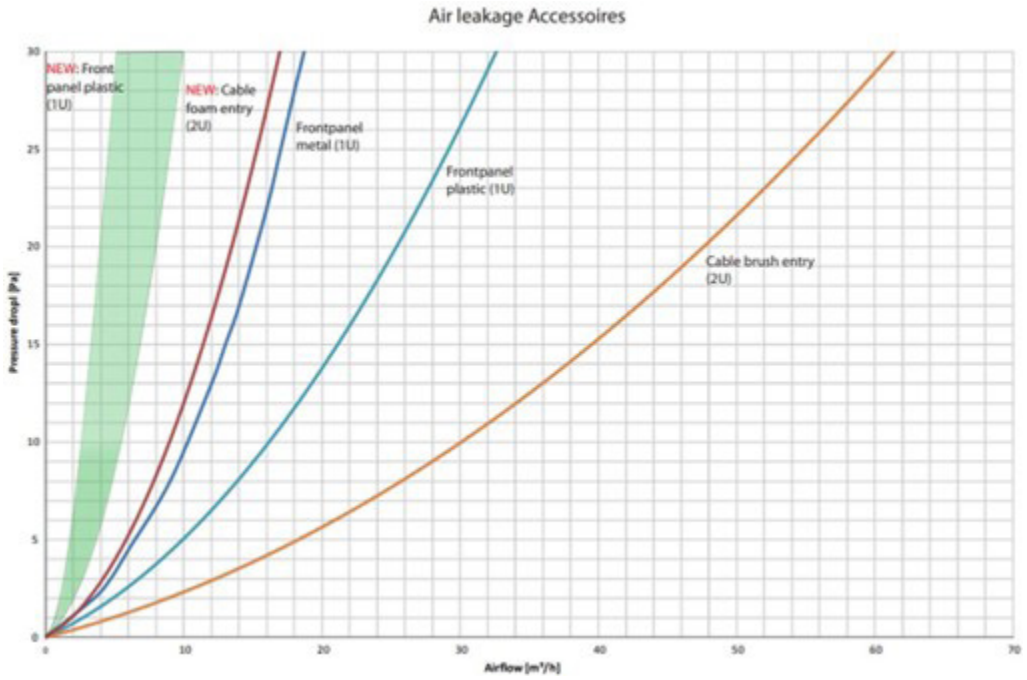
2. BLANKING PLATES

One of the simplest solutions to implement, yet still not carried out in a surprising number of data centers, is the use of properly fitted blanking plates, preventing open spaces in a standard 19-inch compartment matters for airflow management.

CLC/TR 50600-99-1:2021
5.1 Existing Data Centers

Index	Task set	Description Value	Value
5.1.14	Cabinet/rack airflow management – Blanking Plates	Install blanking plates in locations within cabinets/racks where there is no equipment. NOTE This helps to minimize the waste heat from one device contaminating the intake air of another device (re-circulation) which reduces cooling efficiency.	4



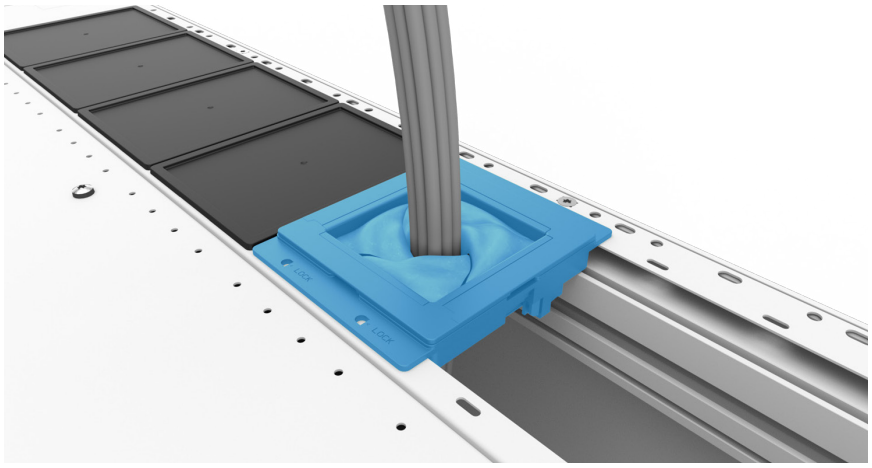


3. CABLE ENTRY SEAL FOR ROOF LAYOUTS

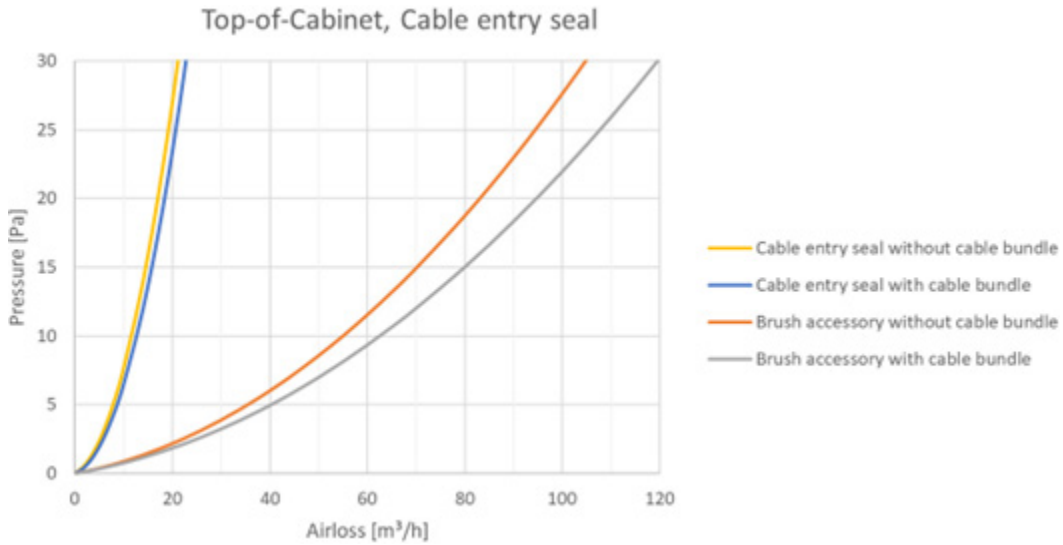
Here, we highlight the importance of true airtight cable entry. Many brush-based, supposedly airtight cable entry systems still allow hot air to leak (hot aisle containment). This mixing of hot and cold air diminishes energy efficiency and cooling capacity. Legrand's innovative airtight cable entry system acts as a true seal, allowing cable entry with no accompanying hot air.

This Legrand patented solution and the graph below provide compelling evidence of its performance compared to brush-based alternatives. Users can retrofit the Legrand innovation to make existing cable bundles airtight or deploy it as part of a new data center design, ready to receive cables and be opened and closed as needed.

The Legrand design results in an 80% reduction in airflow leakage compared with the traditional method of running cables through a brush. That 80% benefit can be multiplied by the number of times the accessory is installed on each cabinet within a data center, and the number of cabinets in the data center.

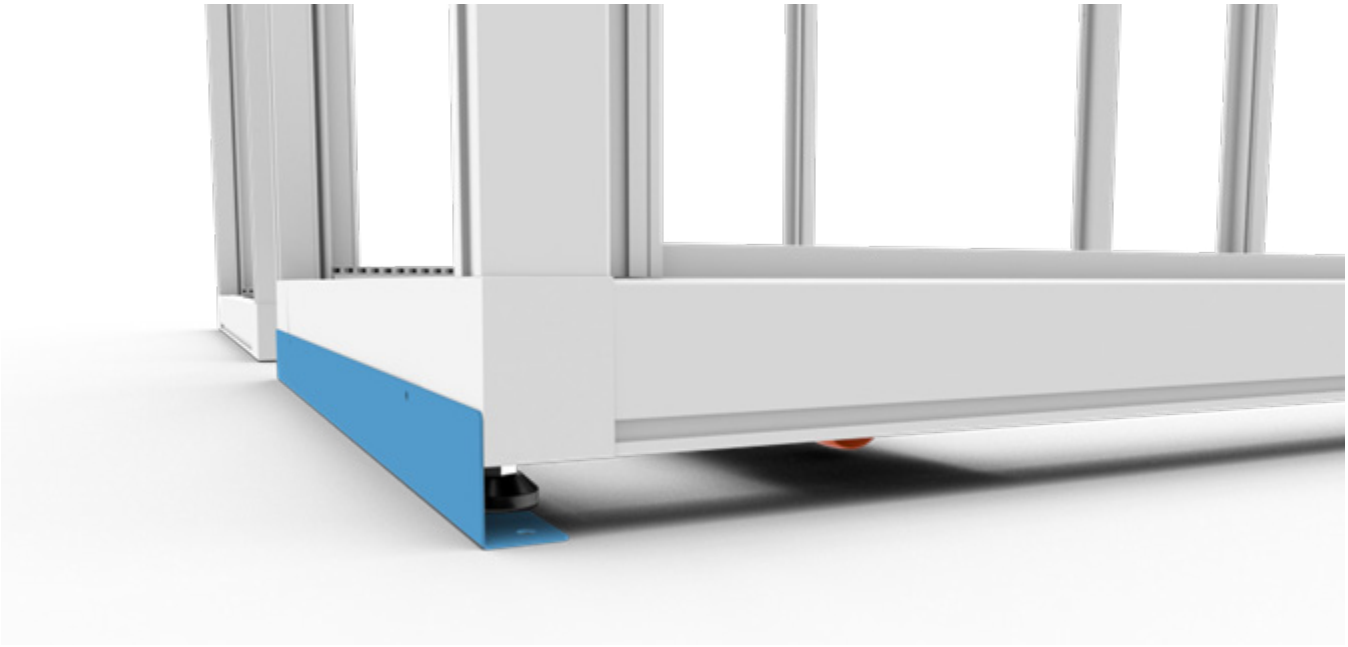


Cable Entry Seal for Top-of-Cabinet application



4. AIR SEALING PLINTH FOR RAISED/LEVELED CABINETS

It's not unusual to have a gap between the cabinet and the data center floor. Such a gap is the perfect environment for recirculation airflows. To prevent this, Legrand came up with a simple solution using an air blocker under the cabinet called an air skirt to create an air-tight seal



Air sealing plinths when cabinets are raised

5. AIRFLOW PACKAGE CABLE ENTRY SEAL

This cable entry accessory is placed in the side-skirts of the airflow package. With the foam version cable entry accessory, we guarantee the highest degree of air tightness while providing cable throughput.

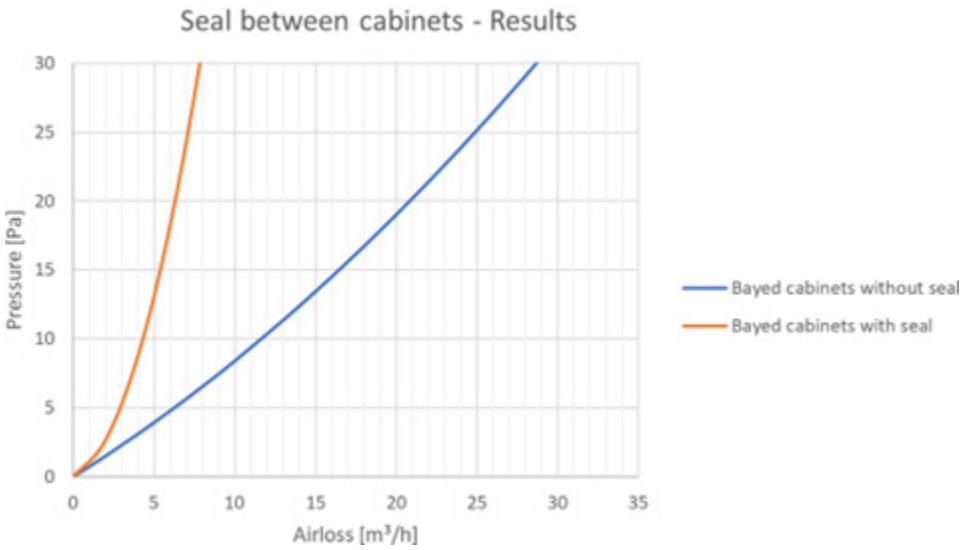
Cable Entry Seal for side-skirts

6. SEALING STRIP FOR BAYED CABINETS

Legrand manufactured a special test housing to examine the various types of gaps that can occur when two cabinets are secured together. And then we produced a seal to perfectly close all of them.

In the case of the seal between cabinets performance comparison, testing was done with and without the seal at a range of pressures. From the graph below, you can see that applying the seal at five pascals provides a 53% benefit or decrease in airflow loss – a very significant benefit. And that's just for one cabinet. Imagine the benefits of an entire data center's worth of cabinets with seals between them. And then consider how many years this benefit can be in place. While the IT equipment might be replaced approximately every two to five years, the cabinets could be in place for 10 to 30 years.

Sealing kit between bayed cabinets



When these measures are included in the cabinet design and configuration, our customers save money and energy, making their data centers more sustainable and reliable. Other benefits include:

- More constant cold aisle temperatures.
- With more control over the cold aisle temperature, potentially raising cold aisle temperatures with less energy.
- Higher return air temperatures by eliminating bypass airflows lead to higher cooling capacity.
- Preventing hotspots by stopping recirculation airflows.

In summary, whether it's a Legrand-designed hot or cold aisle containment solution with optional in-row coolers, we can offer additional cabinet-level energy efficiency solutions. At the simplest level, we can supply blanking plates. We also provide sealing between cabinets and sealing between cabinets and the flooring. The energy-efficient design of our Nexpand cabinets is an integral part of our solution. Legrand also offers an innovative cable entry seal for roof applications.

CHAPTER 4 - FAST ROI JUSTIFIES CABINET AIRFLOW MANAGEMENT

Based on the performance values derived from testing, we can quantify the financial savings for a data center. Consider the results with the following specifications:

Full Legrand solution including Nexpand Cabinets, containment, and row-based cooling solution.

- 18x Cabinets with size 800x1200x47U (w x d x h). Each cabinet contains 5kw of IT equipment.
- 4x Row-based coolers based on Chilled Water in an N+1 configuration
- Outside free cooler with mechanical cooling
- Horizontal containment with sliding doors at both ends of the aisle
- Bypass airflow of the containment setup is estimated at 5%

The simulation methodology used for the ROI calculation in this white paper follows the same methodology and calculations described in the Legrand white paper nr 8 – ROI Calculation Tool by Niek van der Pas. For more insights and an in-depth understanding of this methodology, we kindly refer to this white paper.

The calculations were performed with the following inputs and assumptions:

- Energy cost: 10 cents/kWh (new assumption is 10cents/kWh)
- Location: Chicago
- Indoor: n+1 configuration EN 50600 Class 3 /Tier class 3 (concurrent maintainable)
- Outdoor: DX-based Free cooling setup n+1 Class 3 /Tier class 3 (concurrent maintainable)

Based on these inputs, the following simulations have been performed:

- Simulation of Legrand's cabinets versus the same setup with Competitor A cabinets
- Simulation of Legrand's cabinets versus the same setup with Legrand's cabinets without airflow package @ 104 degrees return air temperature
- Simulation of Legrand's cabinets versus the same setup with Legrand's cabinets without airflow package @ 92.3 degrees return air temperature

1. SIMULATION LEGRAND WITH AIRFLOW PACKAGE VERSUS COMPETITOR A WITH AIRFLOW PACKAGE

- Annual savings with 800mm wide Nexpand Cabinets 47U high compared to competitor A Row
- Based coolers run at 15-21 water trajectory
- Return air temperature at 40 degrees.

Additional cost of roughly $140 compared to competitor A, change to 2.73 years, $1100 per year.

ΔP Pa [in. H_2O]	Cabinet load [kW]	Cabinet width [mm]	ROI [Years]	Annual Saving per cabinet [$]
5 [.02]	5	800	2.73	51
5 [.02]	10	800	2.69	52
10 [.04]	5	800	2.09	67
10 [.04]	10	800	1.84	76

This means that at 5kW heat load per cabinet with @ 5 Pa of pressure differential, we achieve a saving of $140 per cabinet on an annual base compared to the best-performing competitor according to the test results.

The ROI is based on an additional cost of roughly $86 compared to competitor A. This minor additional investment is already returned after 22 months. Given that IT cabinets outlive IT equipment by more than 10 years, each Nexpand cabinet equipped with an airflow package will continue to save cost long after the investment has been done.

A data center of this size (18 cabinets) will easily save a total of $1,400 a year.

2. SIMULATION CABINETS WITH AIRFLOW PACKAGE VERSUS CABINETS WITHOUT AIRFLOW PACKAGE (RETURN AIR @ 104 DEGREES FAHRENHEIT AND 5PA)

The same calculation has been done comparing the same data center layout, this time comparing Nexpand cabinets with and without airflow packages.

- Annual savings with 600 and 800mm wide Nexpand Cabinets 47U high
- Row-based coolers run at 15-21 water trajectory
- Return air temperature to 104 degrees Fahrenheit

ΔP Pa [in. H_2O]	Cabinet load [kW]	Cabinet width [mm]	ROI [Years]	Annual Saving per cabinet [$]
5 [.02]	5	600	1.75	80
5 [.02]	10	600	1.67	84
5 [.02]	5	800	3.33	90
5 [.02]	10	800	3.03	99

We now also include the 600mm wide cabinets. The space between the 19" area and the outer shell of the cabinets is less, with a 600mm wide cabinet. Hence, the airflow package is less of an investment and therefore we see Return on Investments within two years.

Even when we compare the results of 800mm wide cabinets, we see that compared to cabinets excluding an airflow package, we have an ROI of approximately 3 years.

3. SIMULATION CABINETS WITH AIRFLOW PACKAGE VERSUS CABINETS WITHOUT AIRFLOW PACKAGE (RETURN AIR @ 92.3 DEGREES FAHRENHEIT AND 5PA)

We have done the same calculation under different return air conditions (92.3 degrees F hot aisle

ΔP Pa [in. H_2O]	Cabinet load [kW]	Cabinet width [mm]	ROI [Years]	Annual Saving per cabinet [$]
5 [.02]	5	600	2.22	63
5 [.02]	10	600	1.80	78
5 [.02]	5	800	3.90	77
5 [.02]	10	800	3.85	78

There is a slightly higher ROI calculated in this scenario. More air volume is needed to dissipate the heat with lower Delta T's as in the previous example. Higher air volumes would suggest more leakage and, thus, faster payback times. However, increasing cooler power consumption to generate larger volumes of air negatively impacts the ROI and hence, we arrive at longer payback times but still well within approximately three years for 800mm wide cabinets and approximately two years for 600mm wide cabinets.

The above examples demonstrate the importance of proper airflow management in data center cabinets. If not for the ROI, many benefits can be seen when it comes to increasing reliability, predictability, and performance.

Apart from the benefit of cost optimization and energy reduction, when these measures are included in the cabinet design and configuration, numerous additional benefits contribute to the data center's sustainability and reliability.

- Increased reliability of the data center as we eliminate by-pass and re-circulation airflows.
- Increased performance of the data center as we open the potential to raise both cold and hot aisle temperatures.
- Lowered data center PUE by reducing cooling infrastructure power consumption.
- As a result, the potential to shift cooling power to IT power, especially in cases where the data center is reaching its limits regarding total available power capacity.

We can also conclude that where we see many of our peers in the market using brushes as a seal between the 19" area and the outer shell of the cabinet, this solution cannot prevent bypass and recirculation airflows.

Although we can understand the reasoning for choosing brushes, such as cost, flexibility, and ease of retrofitting, it does not create an airtight seal between the hot and cold sides of your cabinet.

In an era where it is our collective responsibility to maximize data center energy efficiency, it's remarkable to observe our industry peers' limited focus on cabinet airflow performance.

CONCLUSIONS

Based on the results of the independent tests on Legrand's range of data center infrastructure accessories and the company's airflow package versus our best-performing competitor, Legrand's solutions can prevent leakage of more than 3,400 cubes per hour.

This conclusion is based on a data center with two rows of nine cabinets. That equates to a minimum saving of $1,400 a year. With the additional cabinet airflow package cost, ROI should be comfortably achieved within two to three years.

Additionally, users of Legrand's data center infrastructure solutions can improve their overall data center energy efficiency, meet the heavy computing demands associated with AI and other leading technologies, reduce the impact on energy grids, save money, and help comply with the increasingly stringent requirements of the various data center standards and legislation.

Legrand's continuous innovation program demonstrates what is possible regarding data center energy efficiency at an infrastructure component level.

As such, we believe that properly educated end users will know what is possible and what to demand from their data center infrastructure supply chain.

We also hope that our innovation lead will inspire other vendors to contribute to the pool of energy efficiency knowledge and practical expertise that will be crucial to the success of the data center industry in meeting its challenging net-zero targets.

Contact Legrand here for more information on our cabinet offerings.

APPENDIX A - QUANTIFYING THE PERFORMANCE OF AIRFLOW-OPTIMIZED CABINETS

To measure is to know. With that in mind and to demonstrate improvements made in the recently introduced Nexpand Cabinet range, the air leakage was tested by an external company
(Raak energie advies, https://www.raakenergie.nl/).

In our white paper number 4 on rack airflow optimization, we already demonstrated a significant improvement (up to 86%) on preventing air leakage at the cabinet level. At Legrand, we continuously search for improvements that will help our customers to create more energy-efficient data centers. With Nexpand, as is clearly visible from the measurements, we have been able to raise the bar again, setting a new standard on cabinet airflow management efficiency.

Tests were performed with a RetroTec Ductester system.

Testing setup to quantify air leakage outside the 19" area

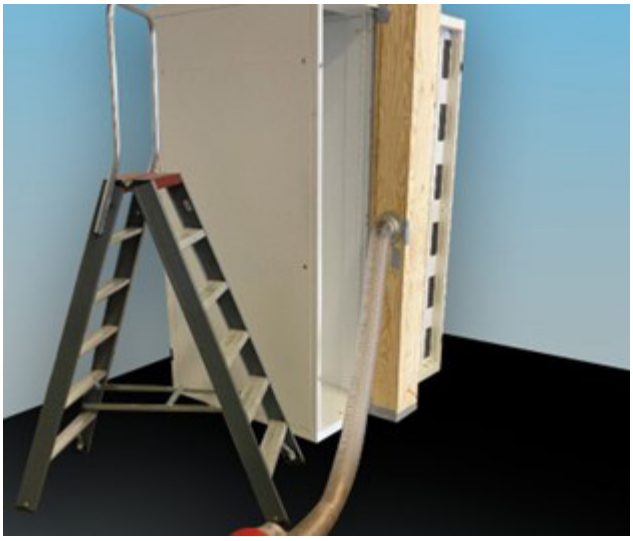
By providing air to the front of the 19" area and measuring the pressure difference before and after the front 19" area, we can measure the degree of 'air tightness'. These tests were performed comparing a Nexpand cabinet with the air tightness levels of Nexpand versus 2 competitor cabinets, including their airflow package solutions.

Testing setup to quantify air leakage for the Cable Entry Seal accessory

Testing setup to quantify air leakage for the brushing

Testing setup to quantify air leakage for the brushes

Testing setup to quantify air leakage for the brushes



Testing setup to quantify air leakage for the brushes

FOOTNOTES/LITERATURE

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