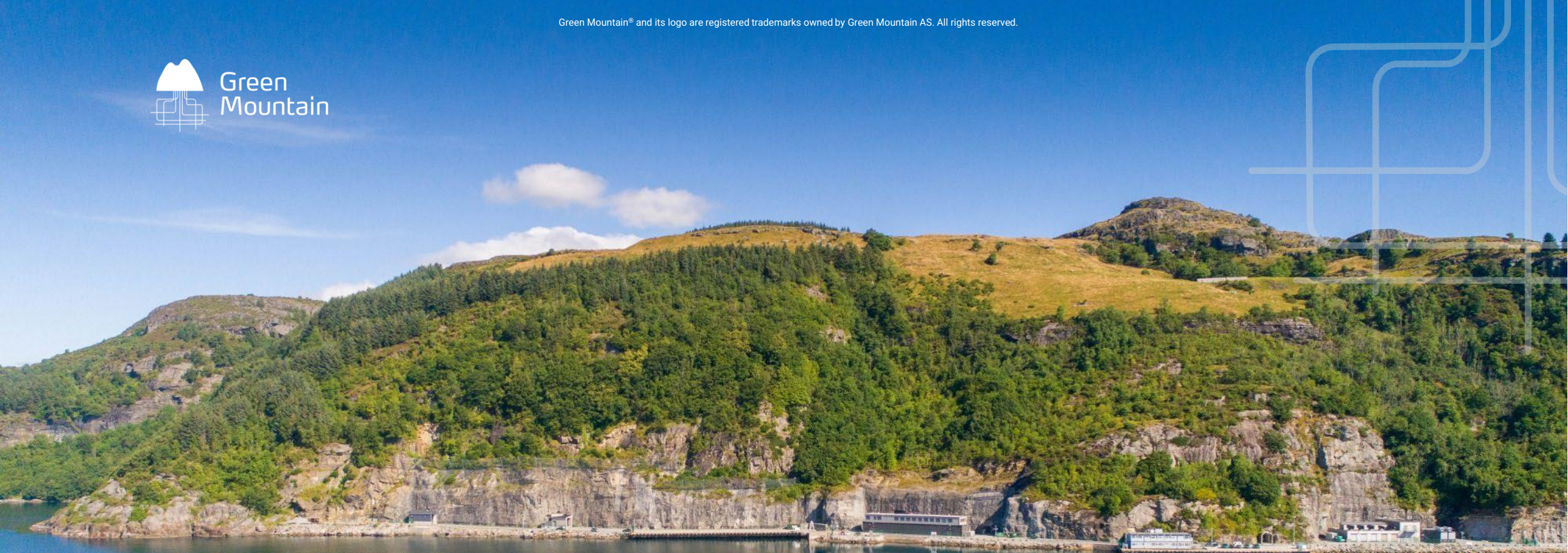
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UiO – Green Mountain

Industry perspective in designing and operating green datacenter

19.02.2026 – Ole Sten Volland

AGENDA

- Please ask questions during the lecture

- **Green Mountain**
- **What is a data center?**
  And why do we have them in Norway?
- **What is sustainability for the data center industry?**
- **Heat reuse from surplus heat**
- **Designing a sustainable data center**
- **Operating a data center**

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Ole Sten Volland

Chief Technology Office (CTO)

Head of the department for :

- Site Selection & Acquisition
- Solution & Engineering
- Innovation & Technical
- Commissioning & QA/QC for Design and Build

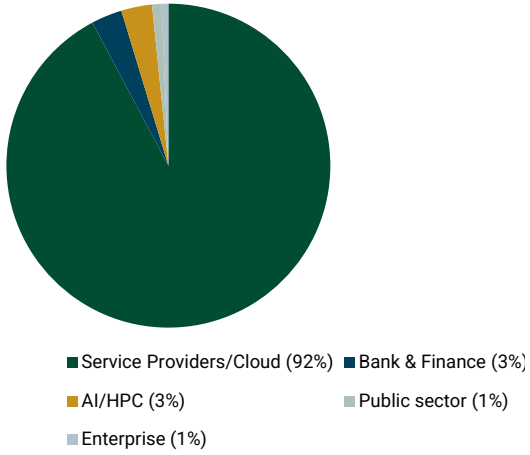


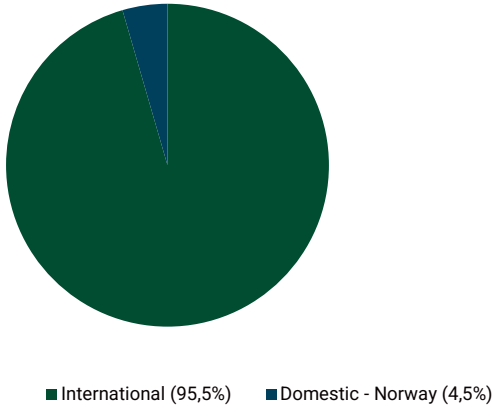
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- Financially secure
- World-Class Efficiency
- 100% renewable energy
- Superb client satisfaction
- Operational Excellence with 100% uptime
- Among the lowest power prices in Europe
- Uptime Tier III, ISO9001, ISO14001, ISO27001, ISO45001, ISO50001, EN 50600 ISAE 3000 Type II & PCI-DSS

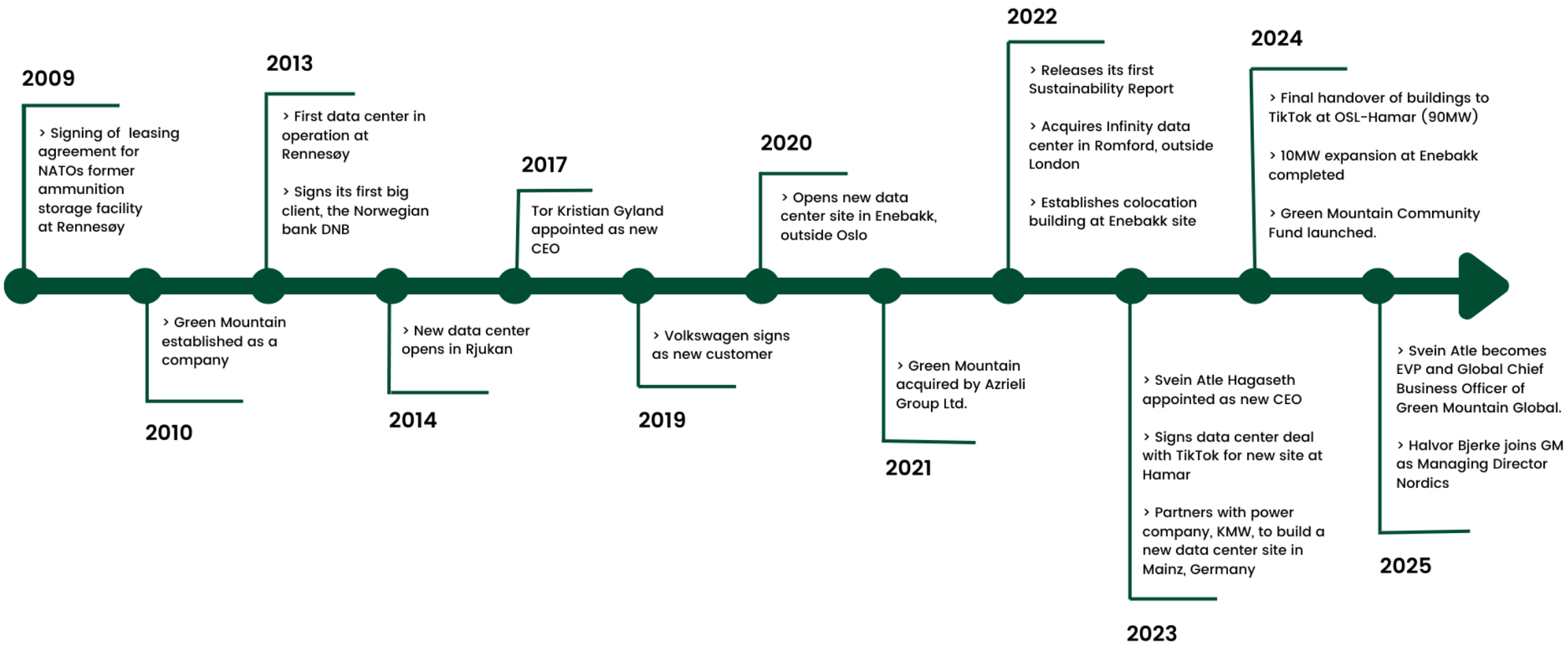






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History of Green Mountain



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The Green Mountain Values

Customer in focus



- Satisfied customers are the most important goal of our business.
- Client satisfaction of 5.85 out of 6

Reliability and honesty



- In our business, trust is one of the main keys for success. We should always act in a manner to gain customers' trust. Always act in an honest and trustworthy manner.

Knowledge



- To be a winner, we need to know and understand our own business as well as our customers' businesses.
- We encourage knowledge and training to raise the skills of our personnel within relevant busienss areas.

Enthusiasm



- When developing a new business, enthusiasm is of essence.
- Awarded as a leading data center provider in Europe the last 5 years
- Awarded as the most sustainable datacenter provider yearly since 2017



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Seks høy-kvalitets datasentre i Norge, UK og Tyskland

Overview | SVG1-Rennesøy | RJU1-RJUKAN | OSL1-Enebakk | OSL2-Hamar | LON1-East | FRA1 - Mainz









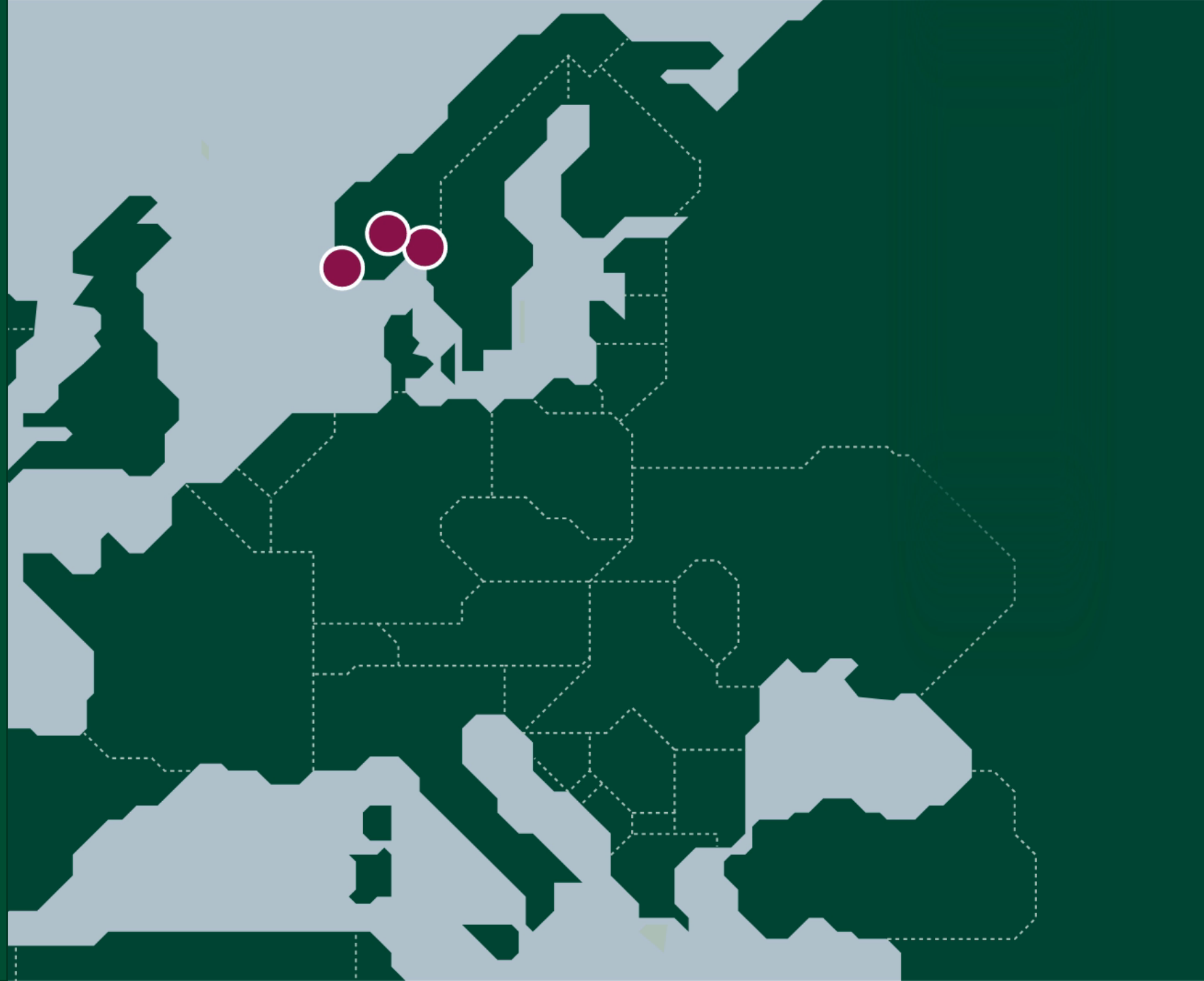
Campus Overview	A former NATO ammunition storage facility converted into a unique, high-security colocation mountain hall data center	Colocation data center located at the nexus of hydro-electric power in a historic region of Norway	Newest data center located 20 km outside Norway's capital	Built-to-suit project for client.	Refurbished storage facility, transformed into a modern DC with scale in Europes largest market	Germanys first truly circular datacenter site, located in the FLAP markets
Build Date	2013	2014	2020	2024	2009	Under consstruction
Land Lease Maturity	~58 Years	Owned	Owned	Owned	40 years	50 years
Maximum Capacity	25 MW	40 MW	93 MW	150 MW	40 MW	54 MW
IT Power Sold	17.8 MW	8.9 MW	25.8 MW	90 MW	7.8MW	0
Maximum IT Capacity Sold	~71%	~22 %	~27%	60%	19%	0
Client Type	Hyperscaler / Local & Int'l Enterprises	HPC / Local & Int'l Enterprises	Hyperscaler/ Local & Int'l Enterprises	Hyperscaler	Hyperscaler/ Local & Int'l Enterprises	Hyperscaler/ Local & Int'l Enterprises
Campus Footprint	23,000 m^2	29,000 m^2	72,200 m^2	-		24500m^2
Independent Feeds	3	2	2	-	2	2
PUE/Cooling Method	1.15 / Water	1.08-1.20 / Air	1.20 / Air	-	1.7	Sub 1.2 design
# of Fiber Providers	19	18	3	-	11	-

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Low European Latency

- Close to all major European markets
- Ability to meet 54 % of all European businesses in under 20 ms round trip
- Can support >90 % of all typical client workloads in Europe

Workload	Latency Requirement	Fit
High Performance Computing	2sec +	✓
Content Delivery Network	2sec +	✓
CCTV + Analysis	~1-2sec	✓
IoT Data Aggregation	~100-1000ms	✓
Imaging (e.g. Healthcare)	2sec +	✓
Backup and recovery	2sec +	✓
Cloud based application use	~20-50ms	✓
Cloud Gaming	~1-10ms	✗
Financial Trading Tools	<1ms	✗



Datasenter er grunnlaget for det digitale samfunnet;

NSM: «Grunnleggende Nasjonale Funksjoner»

I hverdagslivet

- Sosiale Medier 
- Underholdning - TV / Film / Sport 
- Gaming 
- Varehandel 
- Feriereiser

Samfunnskritisk infrastruktur

- Helse 
- Bank og finans 
- Offentlige tjenester 
- Transport 
- Arbeid 

Vi bruker **40 forskjellige** datasentre daglig

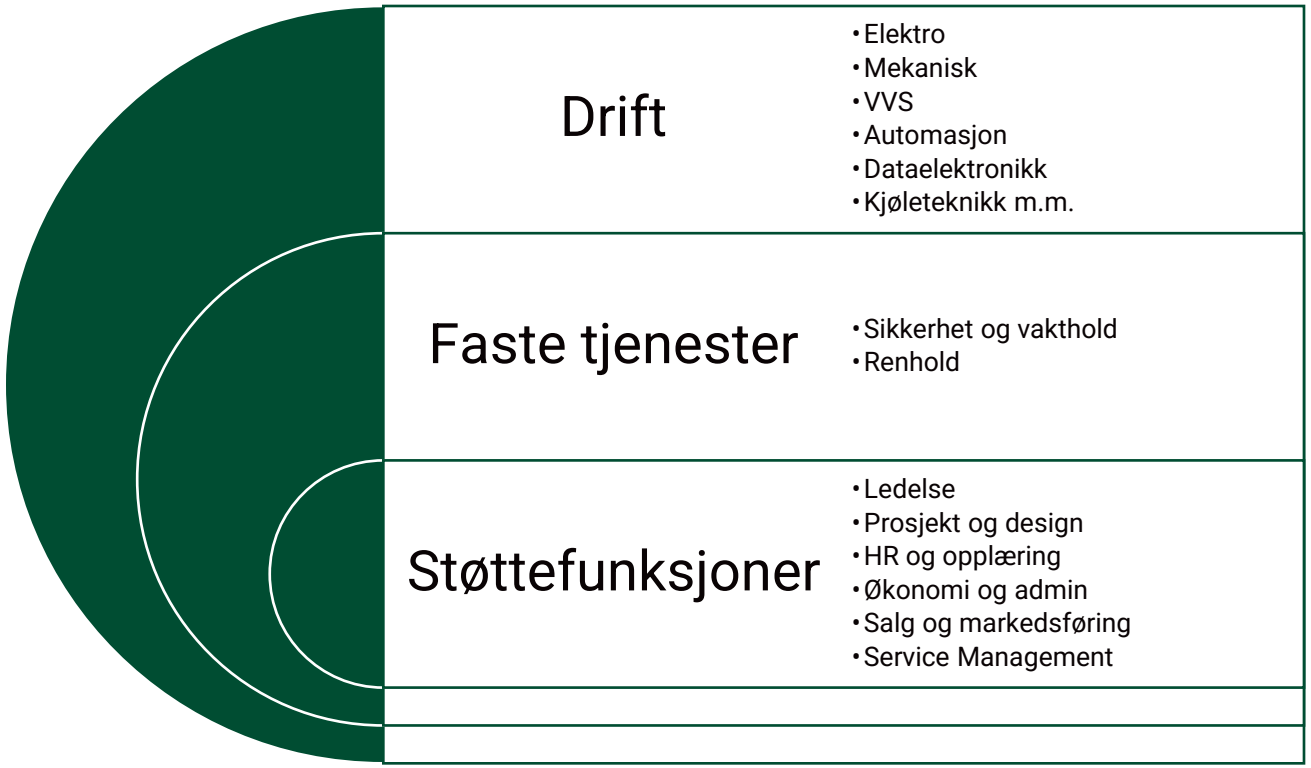
(Abelia – 2023)

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Hvem jobber i et data senter?

Stor bredde i kompetansen som trengs,
flertallet har **yrkesfaglig** bakgrunn



Drift	• Elektro • Mekanisk • VVS • Automasjon • Dataelektronikk • Kjøleteknikk m.m.
Faste tjenester	• Sikkerhet og vakthold • Renhold
Støttefunksjoner	• Ledelse • Prosjekt og design • HR og opplæring • Økonomi og admin • Salg og markedsføring • Service Management



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Key decision criteria in our market



Sustainability

Every click improves the future.

Setting the green standard.

Transparency and reporting.



Time-to-market

Time to market is decreasing.

Hard to plan capacity.

Always thinking to small, reality is bigger.



Expansion

Not what you have, but what you have the ability to provide.

Always next step forward.

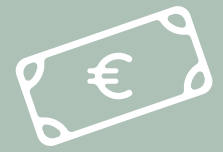


Credibility

Proven capability to deliver.

Do what you say.

Flexibility to adapt and change.



Cost

Cost optimal solutions.

Always look at continuous improvement.

Easy and flexible financial models.

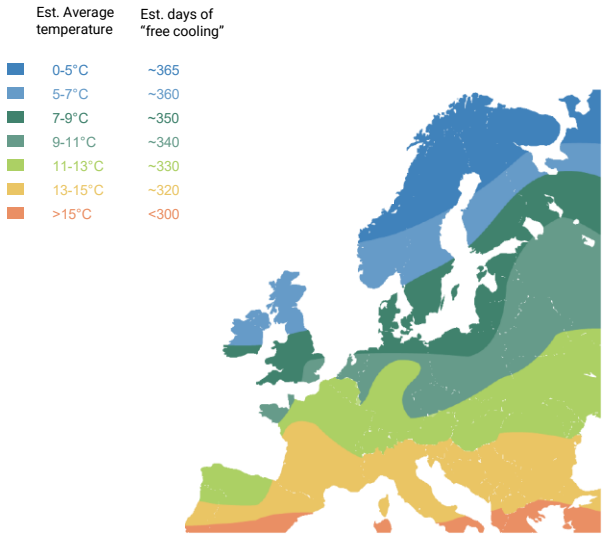
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Norway is the clear leader in ESG compliance

Norway is among the world's most sustainable countries in terms of environmental, social and governance compliance

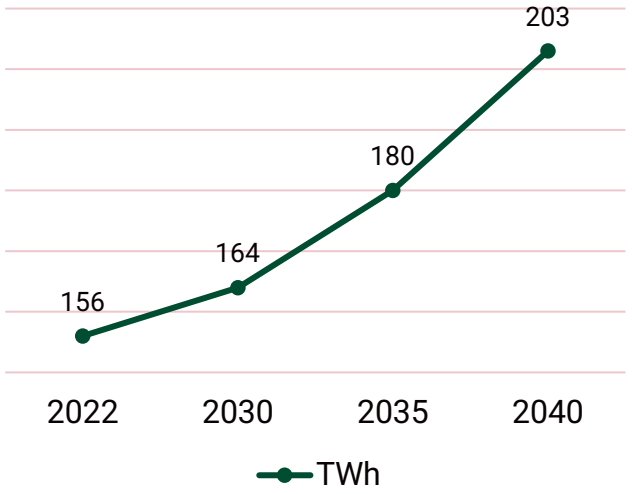
Efficient and Sustainable Cooling

Climate Map

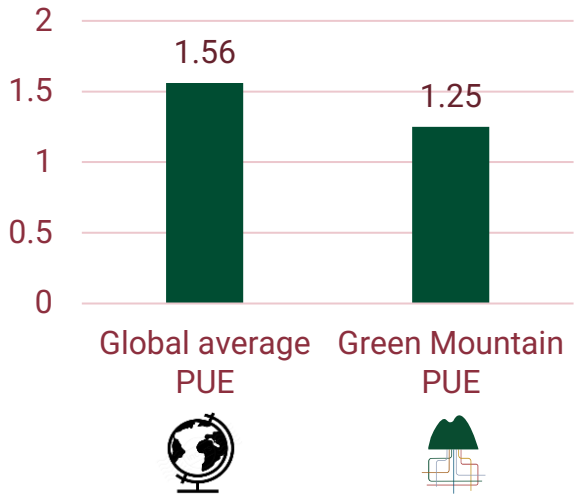


Renewable Power Generation

Energy production in Norway (TWh):



Low PUE

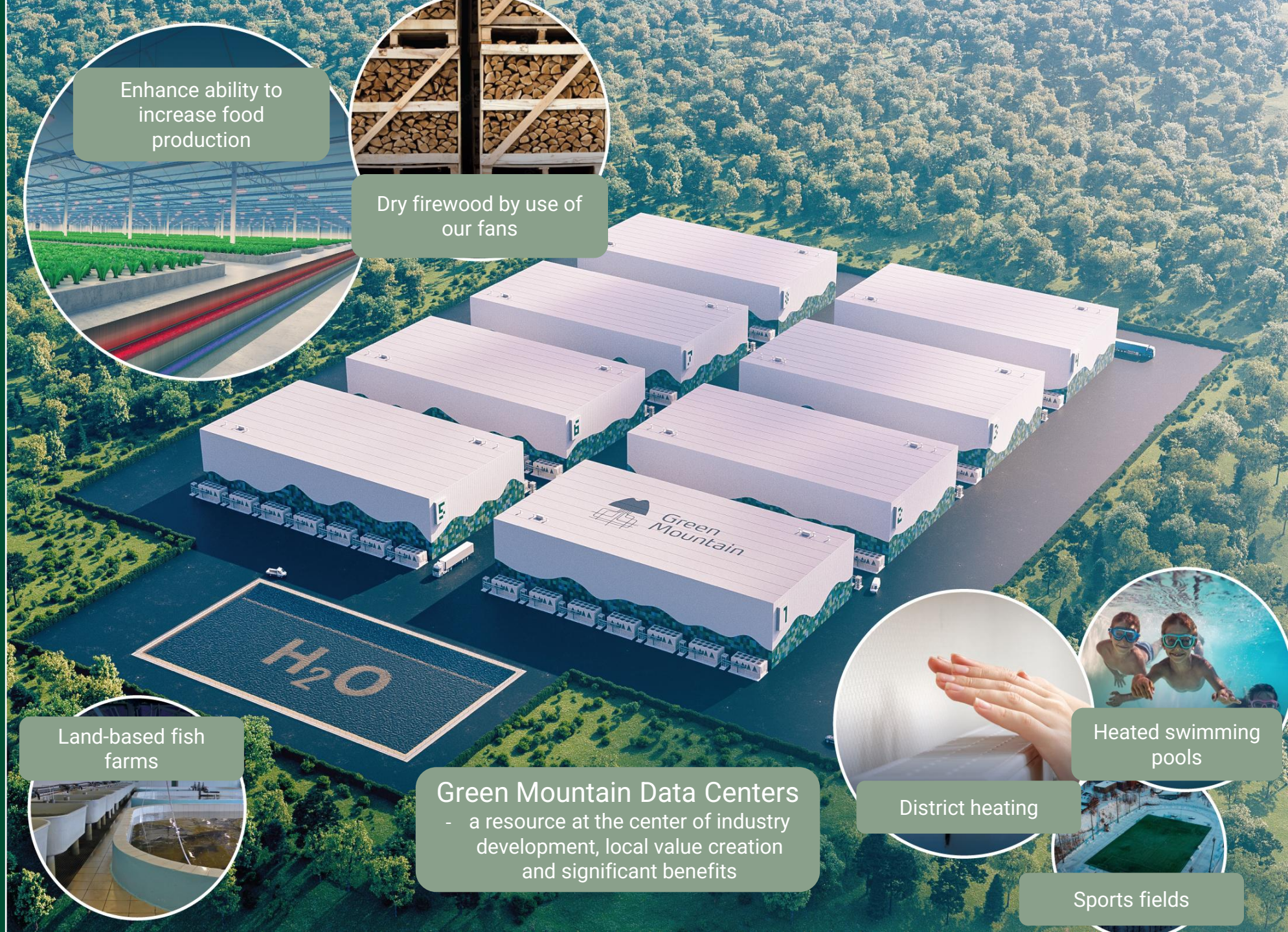


Source: NVE – Long-term power marked analysis 2023. Global data center average annual PUE 2007-2024 (Statista, 2024)

Sustainability

A sustainable approach to building new sites with focus on:

- Energy efficiency and certified renewable power.
- Re-using the large amounts of excess heat in a symbiosis between different industries.
- Aim is to reduce and eventually eliminate the total CO2-emissions to the benefit of the businesses, society, and the environment.
- Applying for BREEAM certification for buildings.



Focus Areas and Objectives

Energy.



Industry leading on renewable energy and energy efficiency

GHG emissions.



Carbon neutrality (scope 1+2) by the end of 2028

Water.



Secure sustainable water consumption

Waste.



Operate according to circular economy principles

Biodiversity.



Minimize negative impact on land & biodiversity

Governance.



Control risk and ensure accountability, transparency and integrity across the organization

Social responsibility.



Integrate social responsibility into all aspects and levels of our business

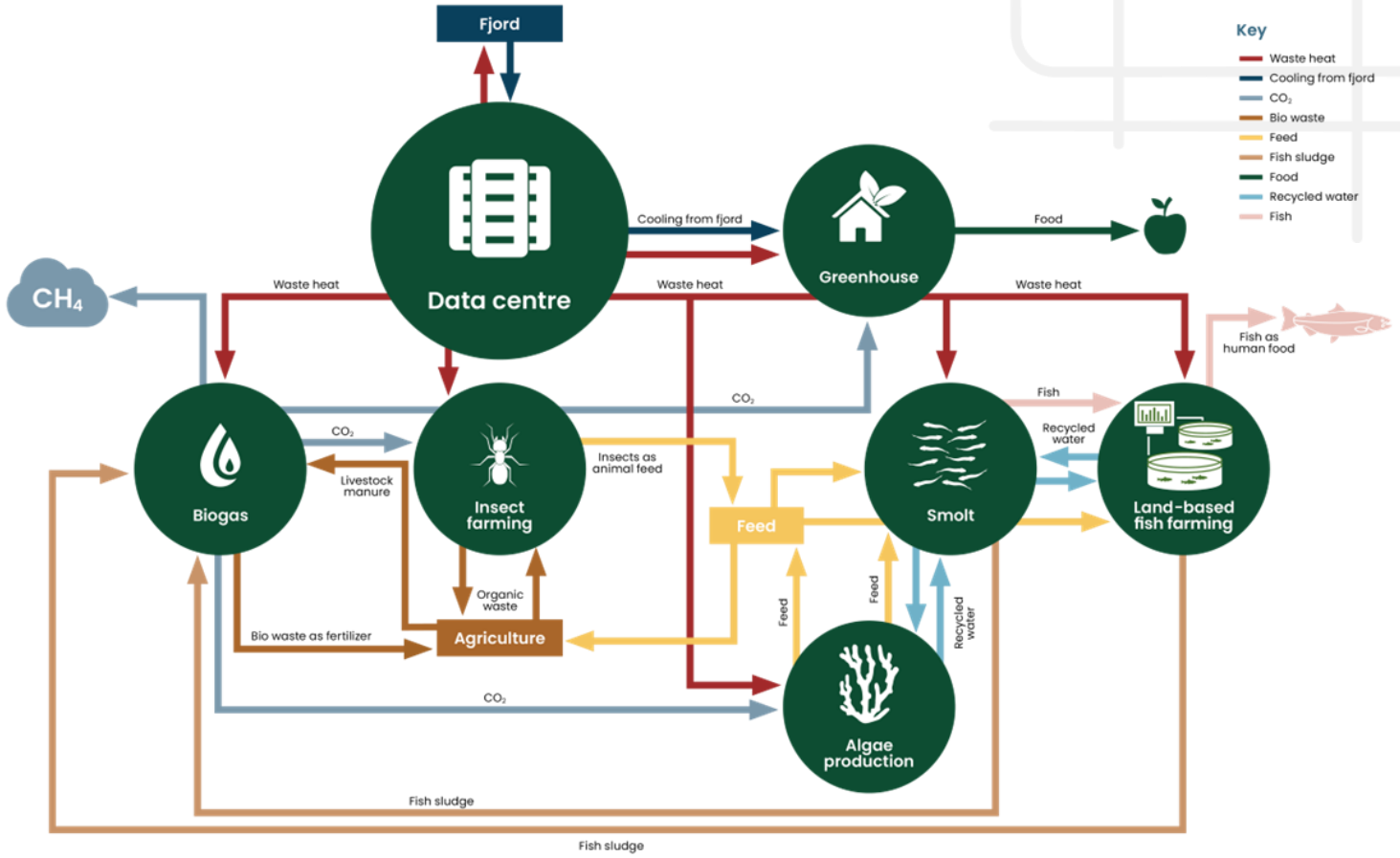
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Heat Reuse Potential

Finding the right projects

- Data centers are large consumers of electrical power. Most of this energy transforms to low temperature heat (25℃).
- By exploiting and creating value from this resource we will be able to achieve more efficient use of renewable power - the energy will be used twice.
- Ongoing dialogues with several potential industry players and research institutions to find the ideal projects.



Trout farming at Rjukan

- HIMA Seafood is constructing a production facility with an annual capacity of 9000 tons
- Needs fresh water at 12 - 15°
- Energy need (heat) – 10 MW



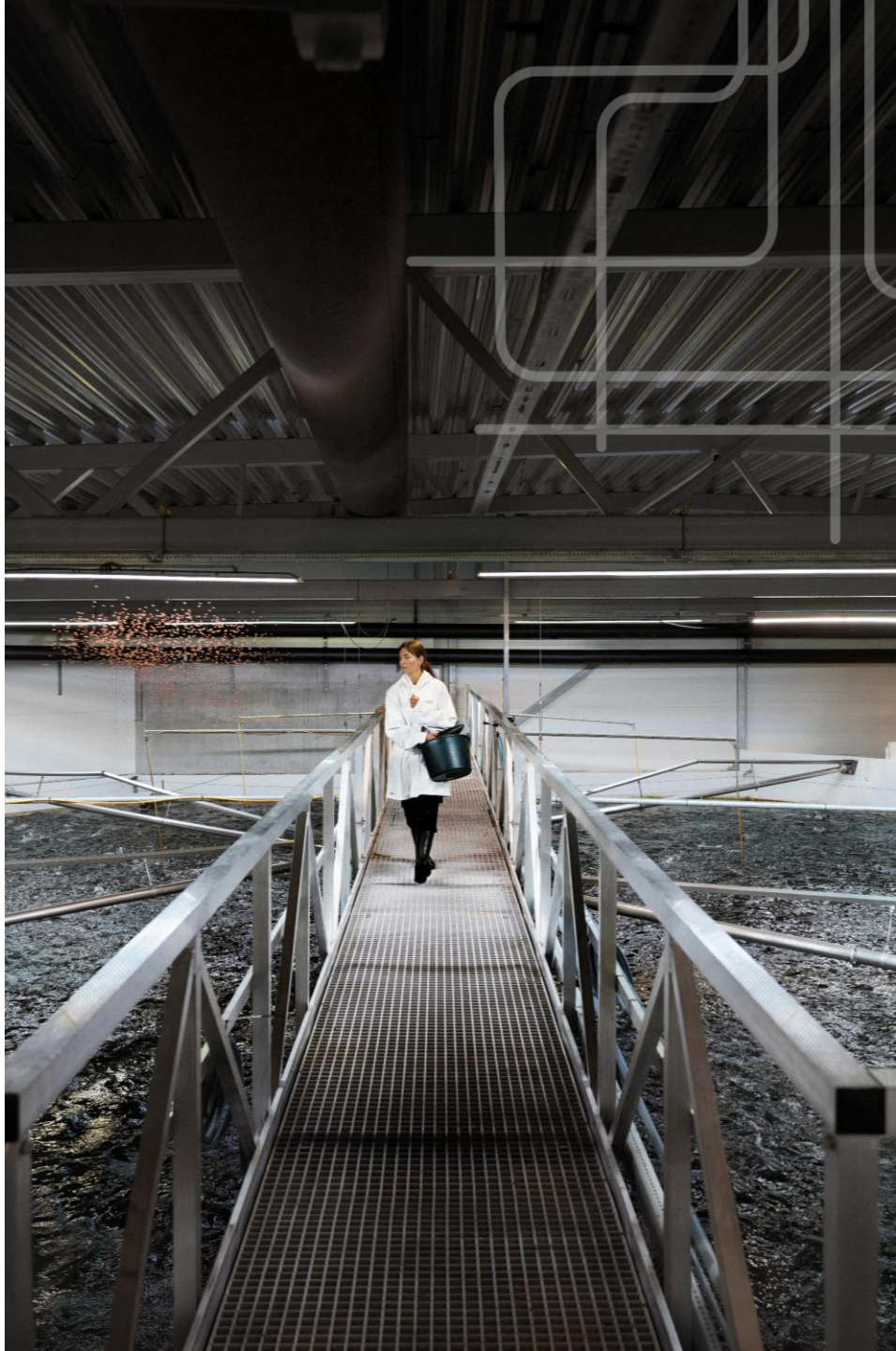
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Heat reuse project with Hima Seafood

Turning waste heat into real value

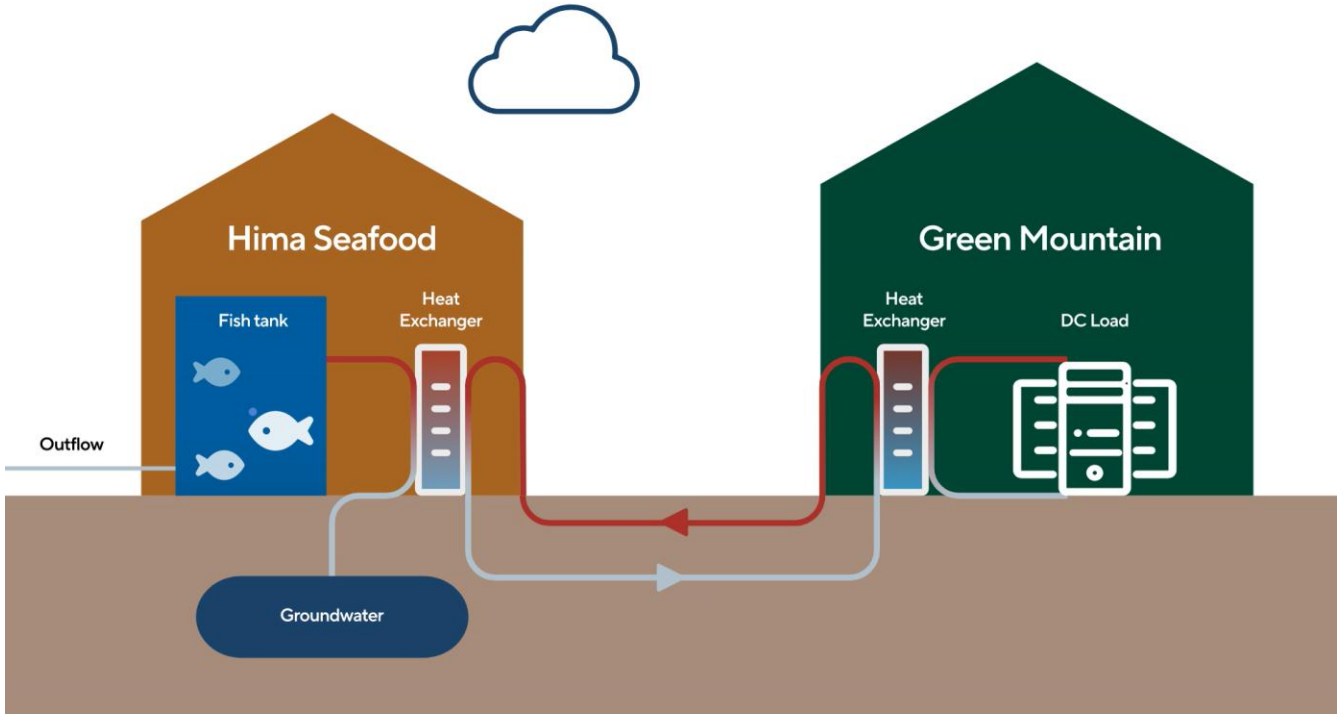
- Just 800 meters separate our TEL-Rjukan data center from Hima Seafood’s land-based trout farm.
- By connecting the two facilities with underground pipelines, we can send warm water from our cooling processes directly to their aquaculture system.
- This stable, low-carbon heat helps maintain optimal water temperatures in fish production, reducing the need for additional electricity.



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How does it work?

- Our data center generates excess heat during normal operations.
- This warm water is piped to Hima seafood in a closed-loop system, where it improves temperature stability in the production tanks.
- After use, the cooled water is returned to us and integrated back into our cooling process.



Menon Economics

Economic Impact of OSL-Hamar Constructions

Milestone Report

By Jonas Erraia, Aljoscha Schöpfer, Aria Khosravi

Menon-publication No. 96

Summary: The construction of the first three data center buildings at OSL-Hamar has supported NOK 6.1 billion in value added and 4,700 full-time equivalents (FTE)

At Green Mountain's data center in Hamar municipality, TikTok is the sole tenant. This means that Green Mountain designs, builds, and operates the data center, while TikTok leases capacity. TikTok owns its own servers and related equipment.

In this milestone report, we calculated the economic impact of the **construction** of the first three data center buildings at Green Mountain's OSL-Hamar site. **We found that the construction has contributed NOK 6.1 billion in value added and approximately 4,700 FTEs.**[1]

Of the total economic impact, NOK 5.7 billion in value added and 4,400 FTEs have already been realized through completed investments. The remaining NOK 400 million in value added and 300 FTEs are expected to be realized by the end of 2025 and during 2026.

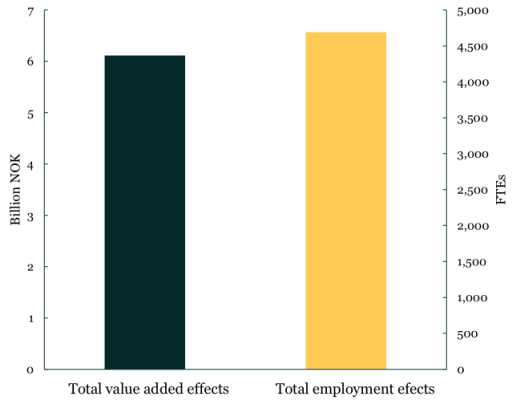
6,1 billion
NOK in value added*

4 700 FTEs
in employment effects*

**Total economic impact of the construction of three data center buildings between 2022 and 2026*

The economic impact are generated by Green Mountain's **total investment of NOK 9.7 billion** in the three buildings. The majority of the investments have gone to CTS Nordics, which is the main contractor for the data center development. Nearly 90 percent of the investment funds have been channeled through CTS Nordics, while the rest consists of direct investments made by Green Mountain outside the main contractor agreement. Nearly the entire investment amount was realized in 2023 and 2024.

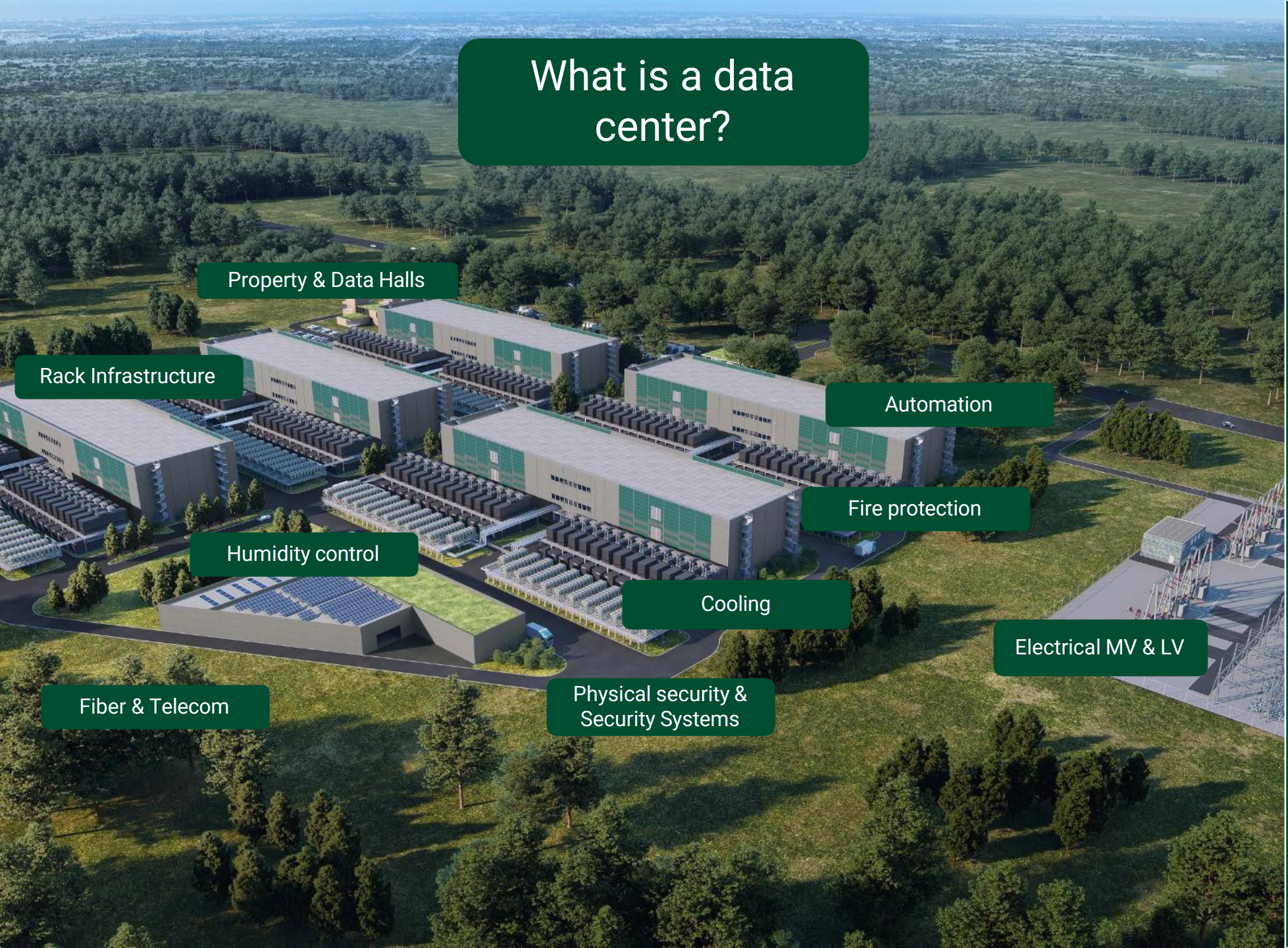
Figure A: Total value added effects and FTEs supported by the construction of OSL-Hamar. Source: Menon Economics



[1]These findings include the economic impact of the remaining investments required to complete the construction of the three data center buildings. The figures do not include investments related to the two additional data center buildings planned for construction. Furthermore, the figures do not include any economic impact related to TikTok's investments. More information on TikTok's investments is provided on page 25.

Bilde: iStock

What is a data center?



Green Mountain Responsibilities:

- Site selection and acquisition
- Site masterplan
- Zoning
- Legislation and compliance
- Design & build quality
- Operation and maintenance
- 100% on SLA (Service Level Agreement)
  - power, temperature, humidity, security
- Redundancy, concurrent maintainability
- Security of site
- Service Management

Clients' Responsibilities:

- Racks
- Servers
- Operation of IT-services (e.g. cloud, AI)

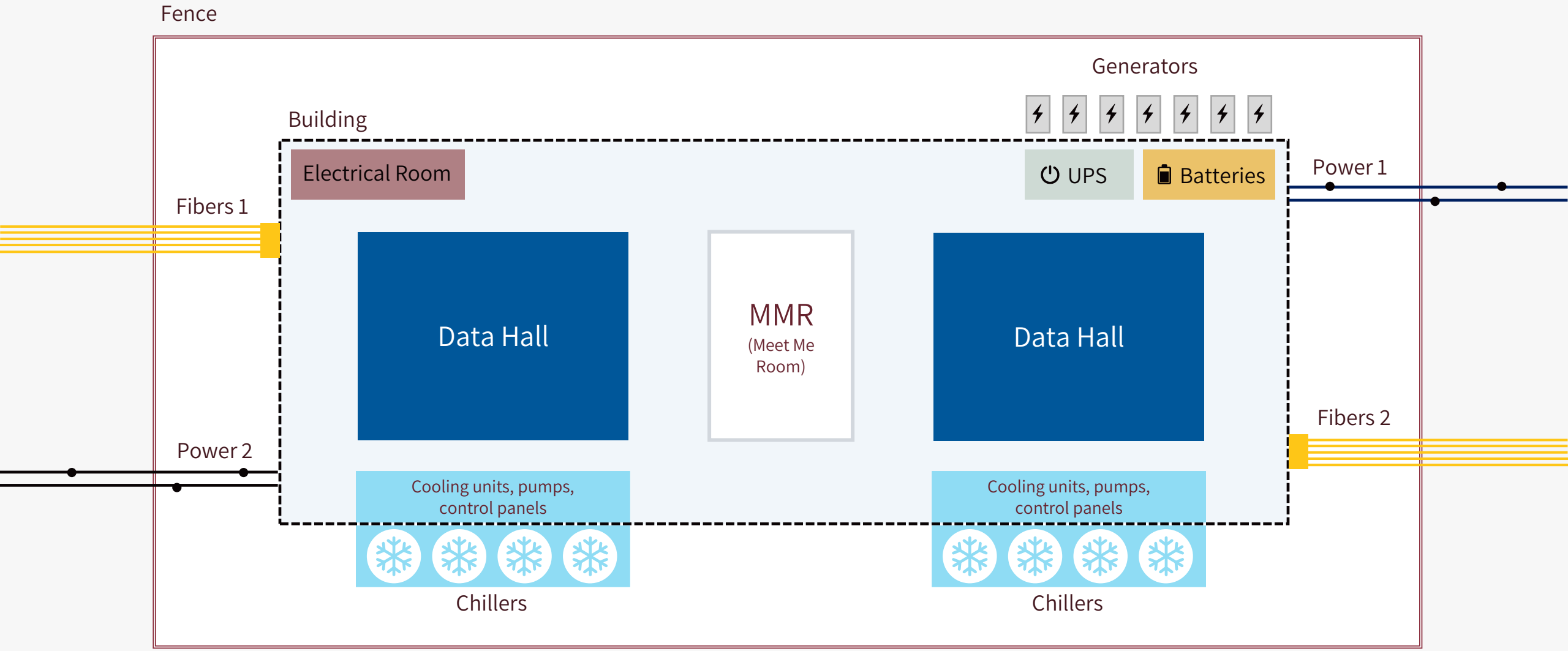
What to consider when designing a data centre

Green Mountain

- Design standards
  - Uptime institute
  - EN50600
  - TIA-942
- Overall efficiency
  - Cooling methodology – geographical restrictions?
- Location
  - Access to power – Out of the city?
  - What gives you less loss.
    Transport of electricity or IP traffic ?
- Customer requirements
  - Tier I, II or Tier III, maybe Tier IV
- Certifications
  - Uptime Inst./ EN50600
  - ISO9001/14000/20000/27000…..
  - Other
- Connectivity

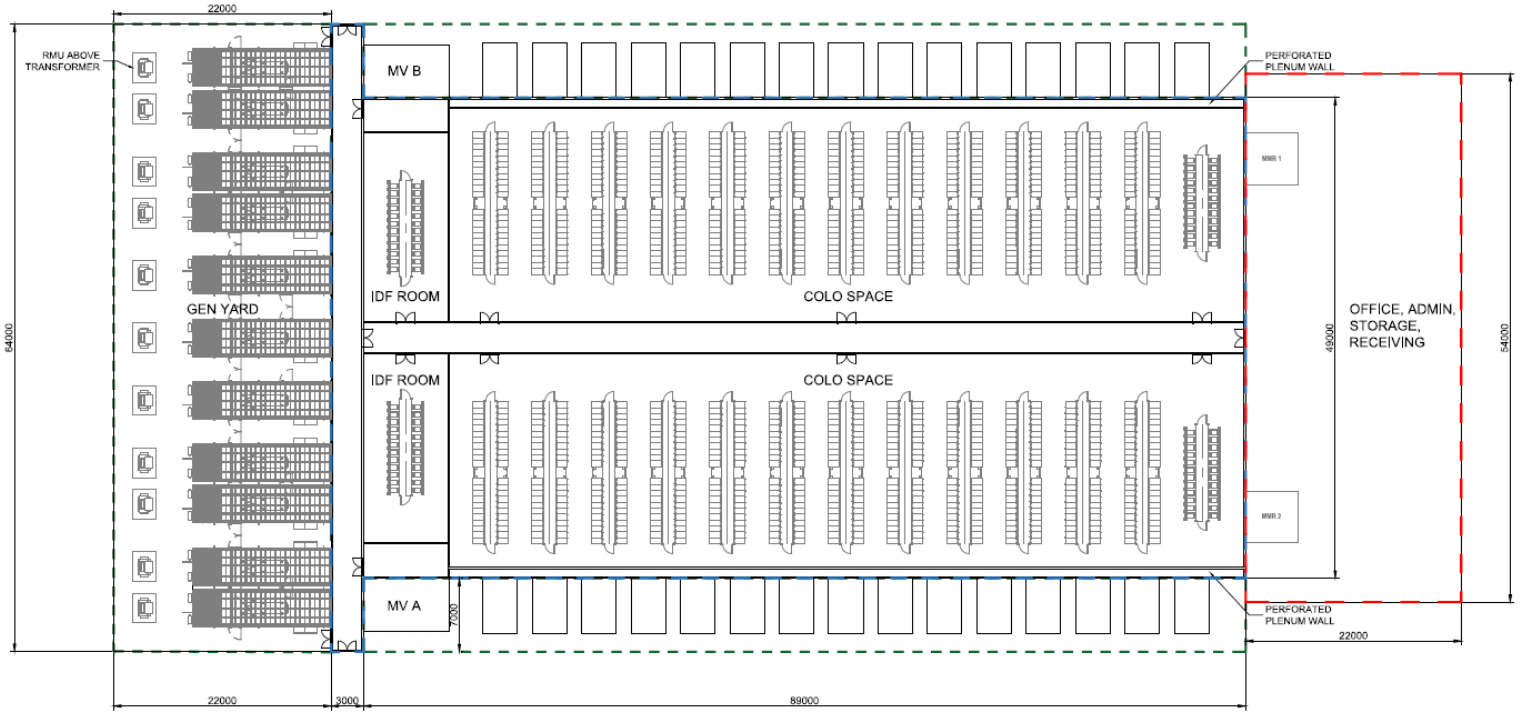


What is a Data Center

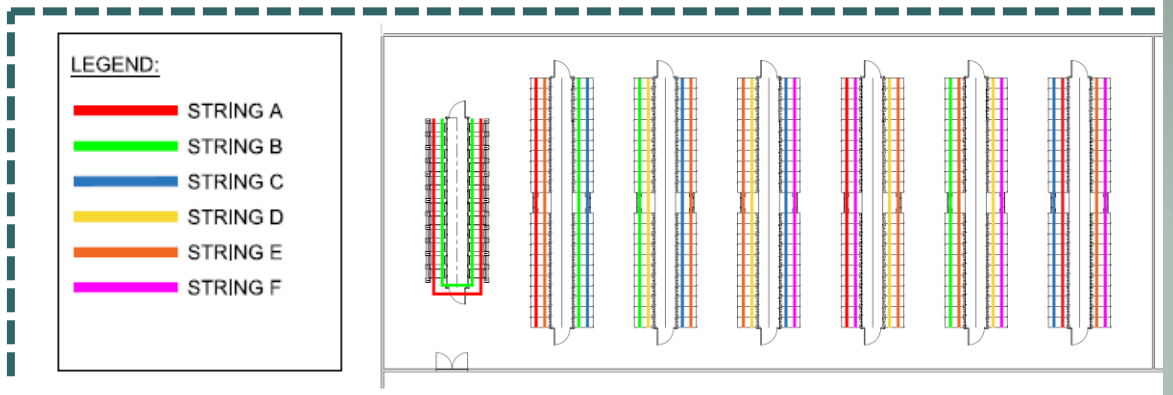


1. Redundancy 2. Landlord vs Customer responsibilities

Example – 10 MW build
Distributed Redundancy – 10 from 11.



COLO FLOOR AREA	4560 M^2
ADMIN/STORAGE/RECEIVING AREA	1170 M^2
EQUIPMENT YARD AREA	2730 M^2
TOTAL ROOFED AREA	5730 M^2

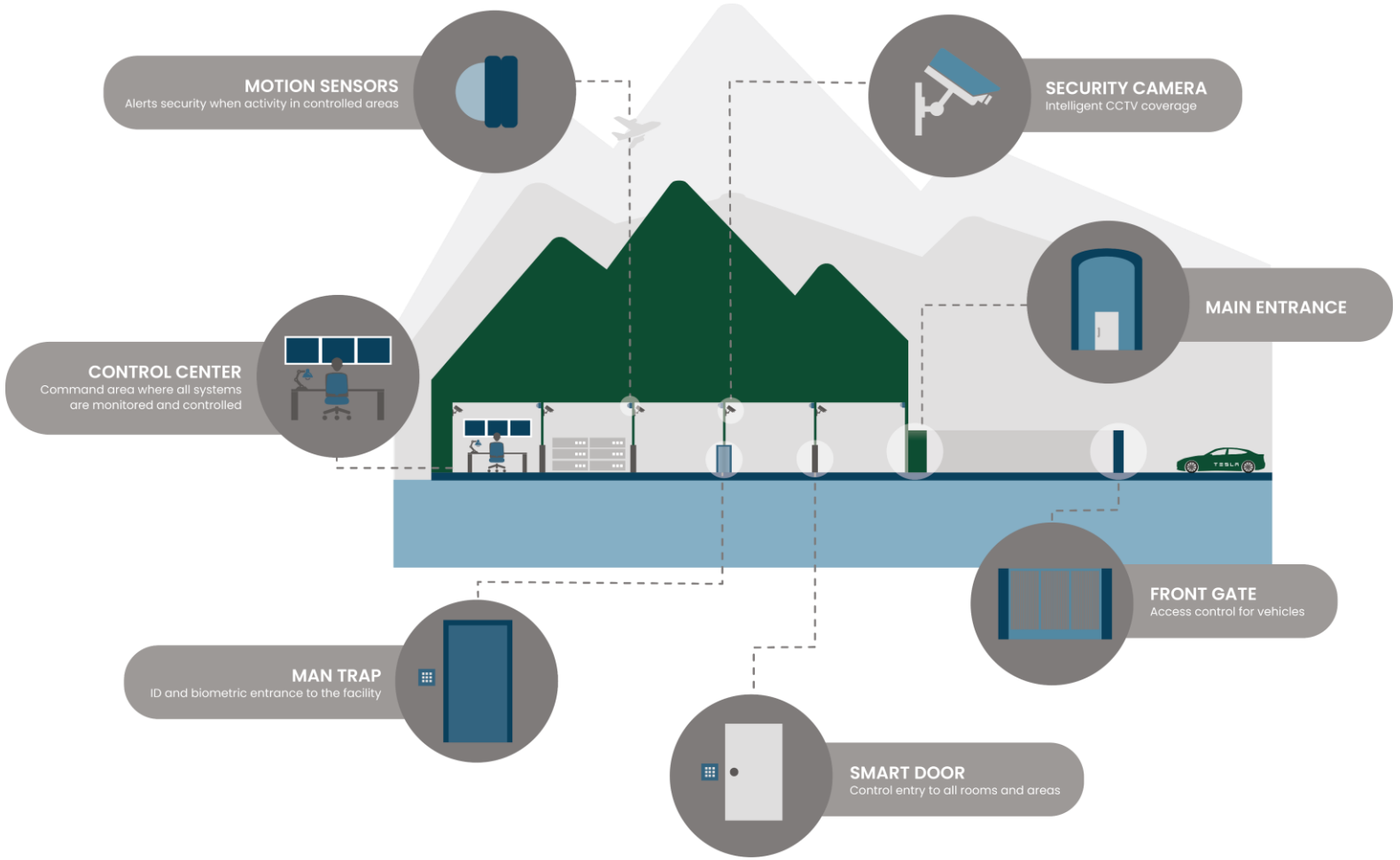


Solution proposal:

- All solutions could be built on all three proposed locations, but is dependent on choice of location what is best suited
- Difference is redundancy specification
  - 10 to 11
  - 2 x (5 to 6)
- All Tier III equivalent design
- SLA up to 99.999%
- Concurrently maintainable in a N+1 configuration.
- Indirect adiabatic cooling solution

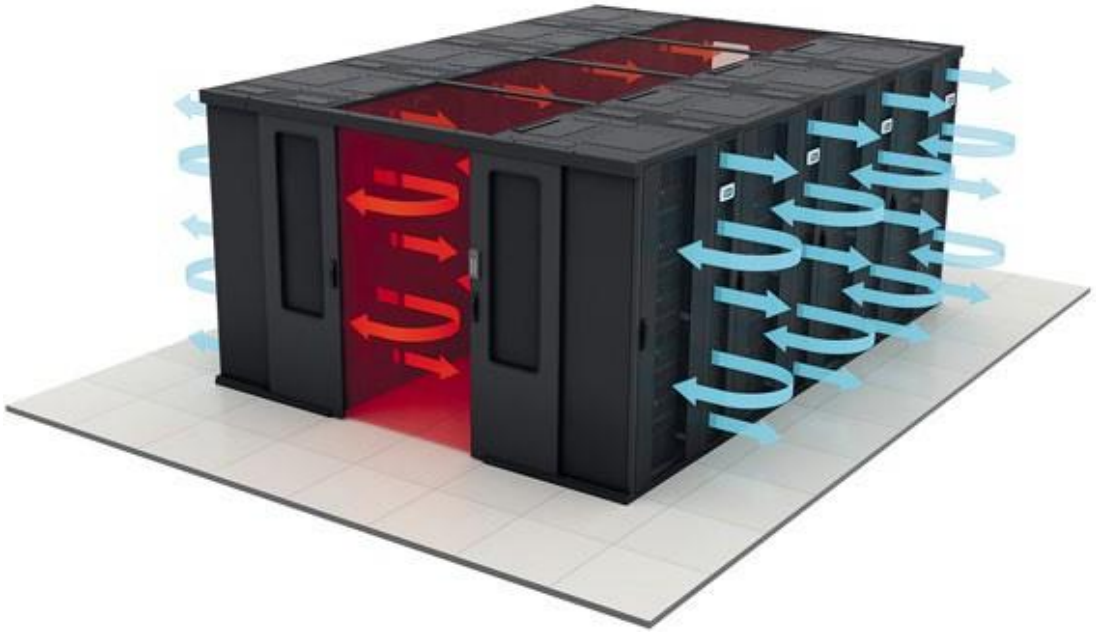
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World Class Security



IT room efficiency

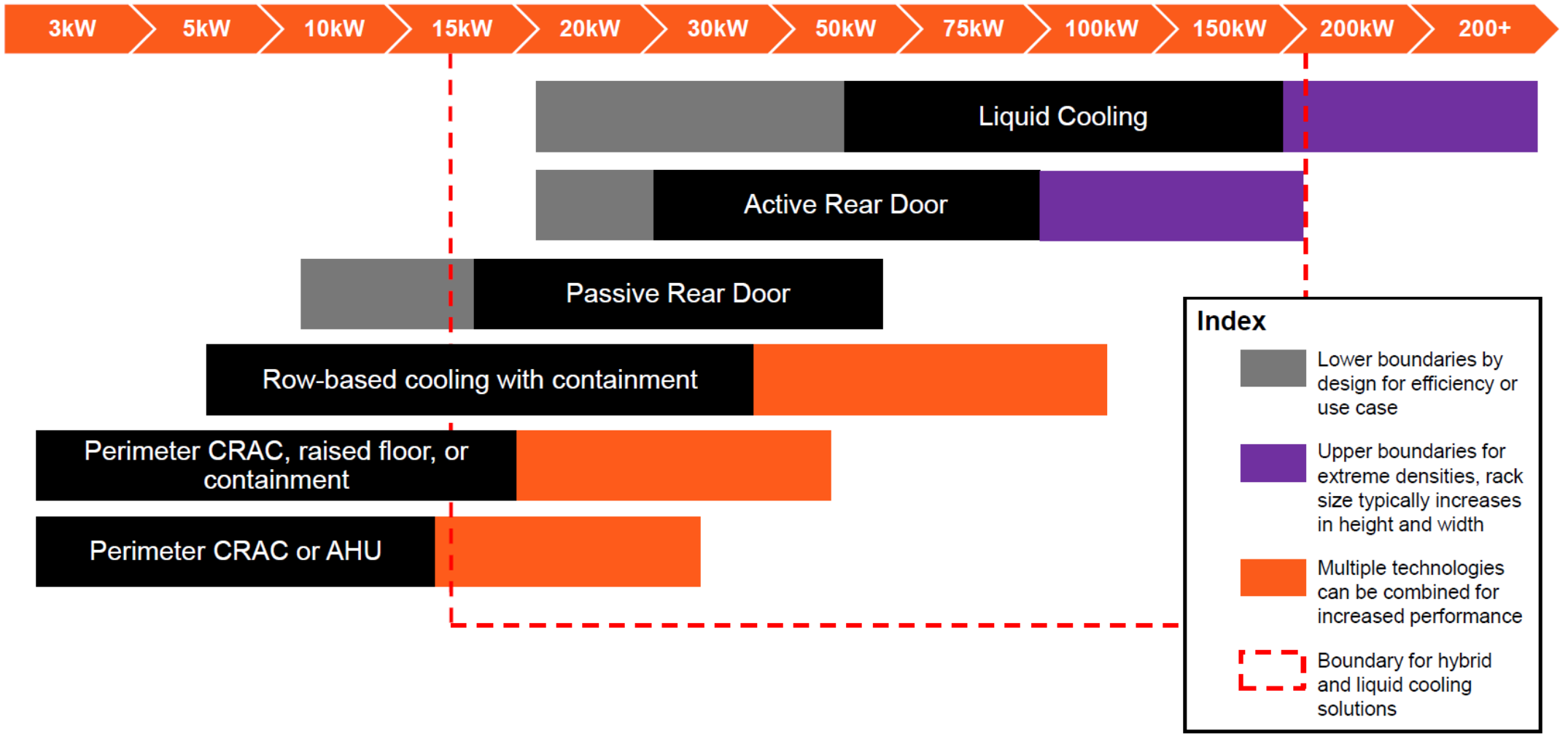
It’s all about moving air!





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Cooling Density Progression – per Rack



Ashrae thermal guidelines (www.Ashrae.org)

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- Defines the environmental metrics for a datacentre.
  - Temperature ranges
    - Allowable ≤32° C
    - Recommendable ≤27° C
  - Humidity ranges

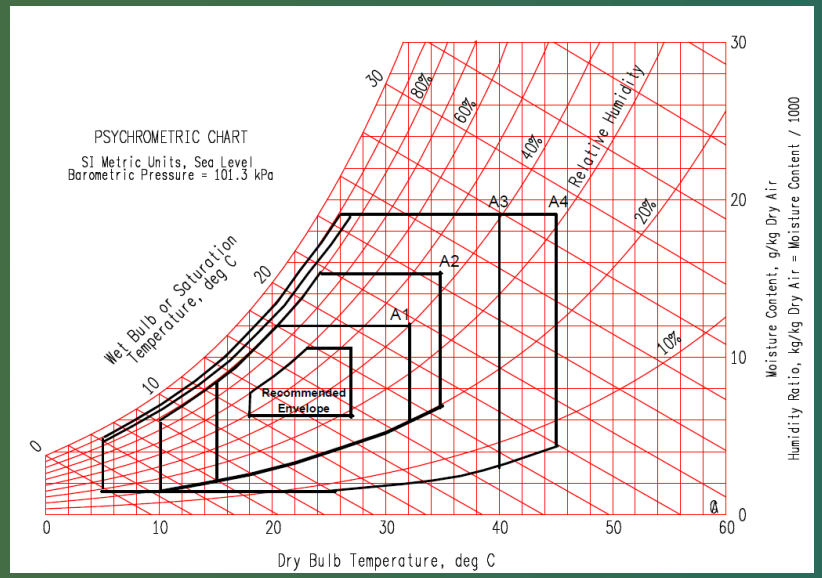


Table 1. ASHRAE 2008 Thermal Guidelines

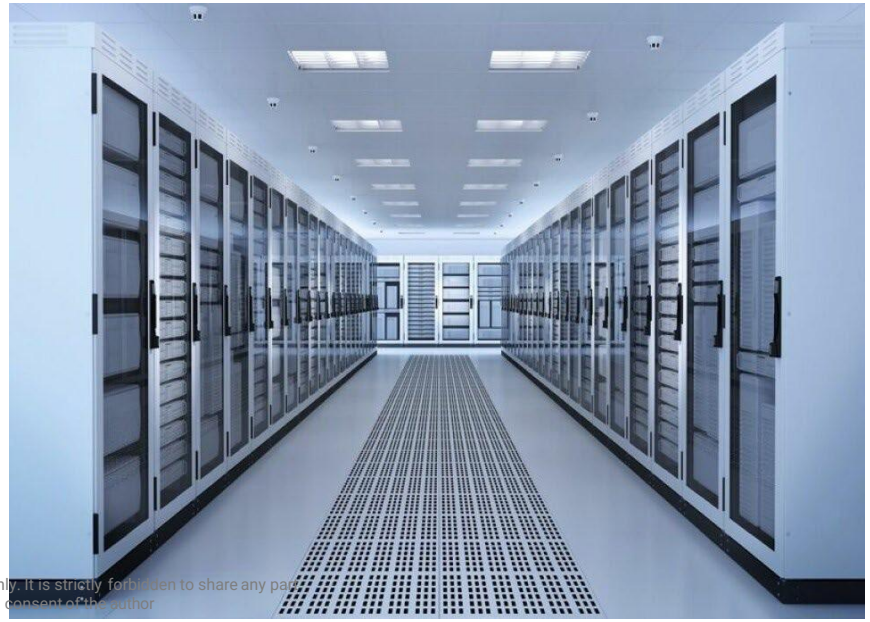
Class	Equipment Environment Specifications									
	Product Operation [a, b]							Product Power Off [b, c]		
	Dry Bulb Temperature (°C)		Humidity Range, Non Condensing		Maximum Dew Point (°C)	Maximum Elevation (m)	Maximum Rate of Change (°C/h)	Dry-Bulb Temperature (°C)	Relative Humidity (%)	Maximum Dew Point (°C)
	Allowable	Recommended	Allowable (% RH)	Recommended						
1	15 to 32 [d]	18 to 27 [e]	20 to 80	5.5°C DP to 60% RH and 15°C DP	17	3050	5/20 [f]	5 to 45	8 to 80	27
2	10 to 35 [d]	18 to 27 [e]	20 to 80	5.5°C DP to 60% RH and 15°C DP	21	3050	5/20 [f]	5 to 45	8 to 80	27
3	5 to 35 [d, g]	NA	8 to 80	NA	28	3050	NA	5 to 45	8 to 80	29
4	5 to 40 [d, g]	NA	8 to 80	NA	28	3050	NA	5 to 45	8 to 80	29

Kilde: Ashrae

What kind of cooling do we use today at GM sites?

SVG-Rennesøy	Chilled water(fjord) Air cooling, CRAH and Inrow
TEL-Rjukan	Chilled water(chillers), Adiabatic air to air, DLC Liquid cooling, Rear Door Heat Exchanger
OSL-Enebakk	Chilled water(colo), Adiabatic Air to Air(Ex1-3), Chiled water(Oyster), CRAH, Rear Door Heat Exchanger
OSL-Hamar	Chiller water, Fan Walls, CRAH



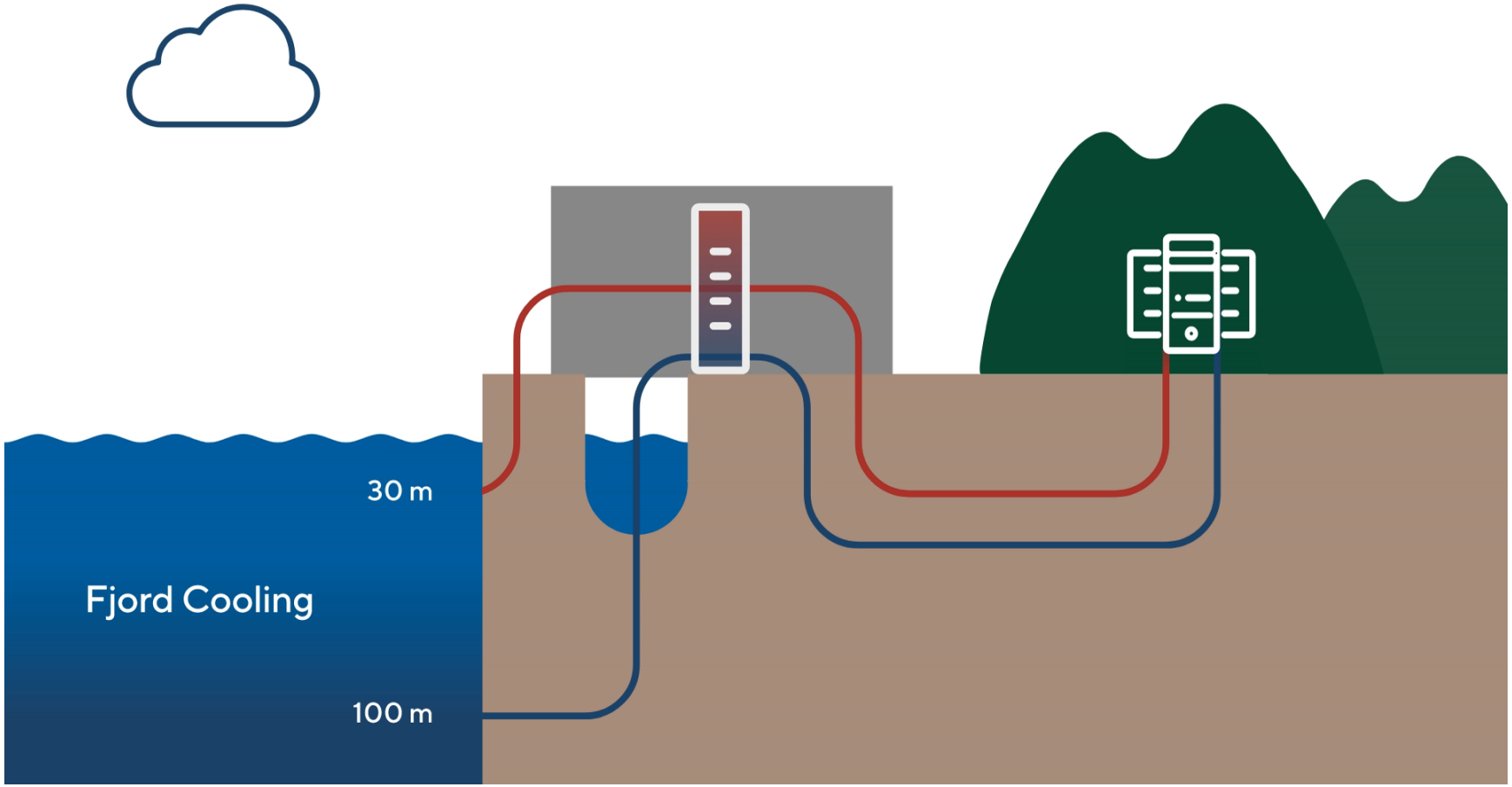


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The World’s most Energy-Efficient Cooling Solution

1kW of power = 100kW of cooling



Sustainability metrics for the data center industy

- ERF – Energy Reuse Factor
- PUE – Power Usage Effectiveness
- REF – Renewable Energy Factor
- WUE – Water Usage Effectiveness
- CUE – Carbon Usage Effectiveness
- CER – Cooling Efficiency Ratio



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BREEAM-NOR

Building Research Establishment Environmental Assessment Methodology

BREEAM® NOR

GRØNN BYGGALLIANSE
NORWEGIAN GREEN BUILDING COUNCIL

BREEAM rating	% score
Outstanding ★★★★★	≥85
Excellent ☆★★★★	≥70
Very good ☆☆★★★	≥55
Good ☆☆☆★★	≥45
Pass ☆☆☆☆★	≥30
Unclassified ☆☆☆☆☆	<30

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Building Research Establishment
Environmental Assessment Method

BREEAM

BREEAM Communities at Heggvin site

- Working together with Heggvin Utvikling AS to ensure the best possible approach to an enviromentally aligned development of the whole Heggvin Industrial Park
- Aiming to find good solutions to reuse our excess heat from our data centers, contributing in reducing the total CO2-emissions to the benefit of the businesses, society, and the environment
- Working towards the development of new innovations to ensure best possible allignment to BREEAM and future sustainable solutions to our data centers, the society and the environment
- **Ambition: Very Good**

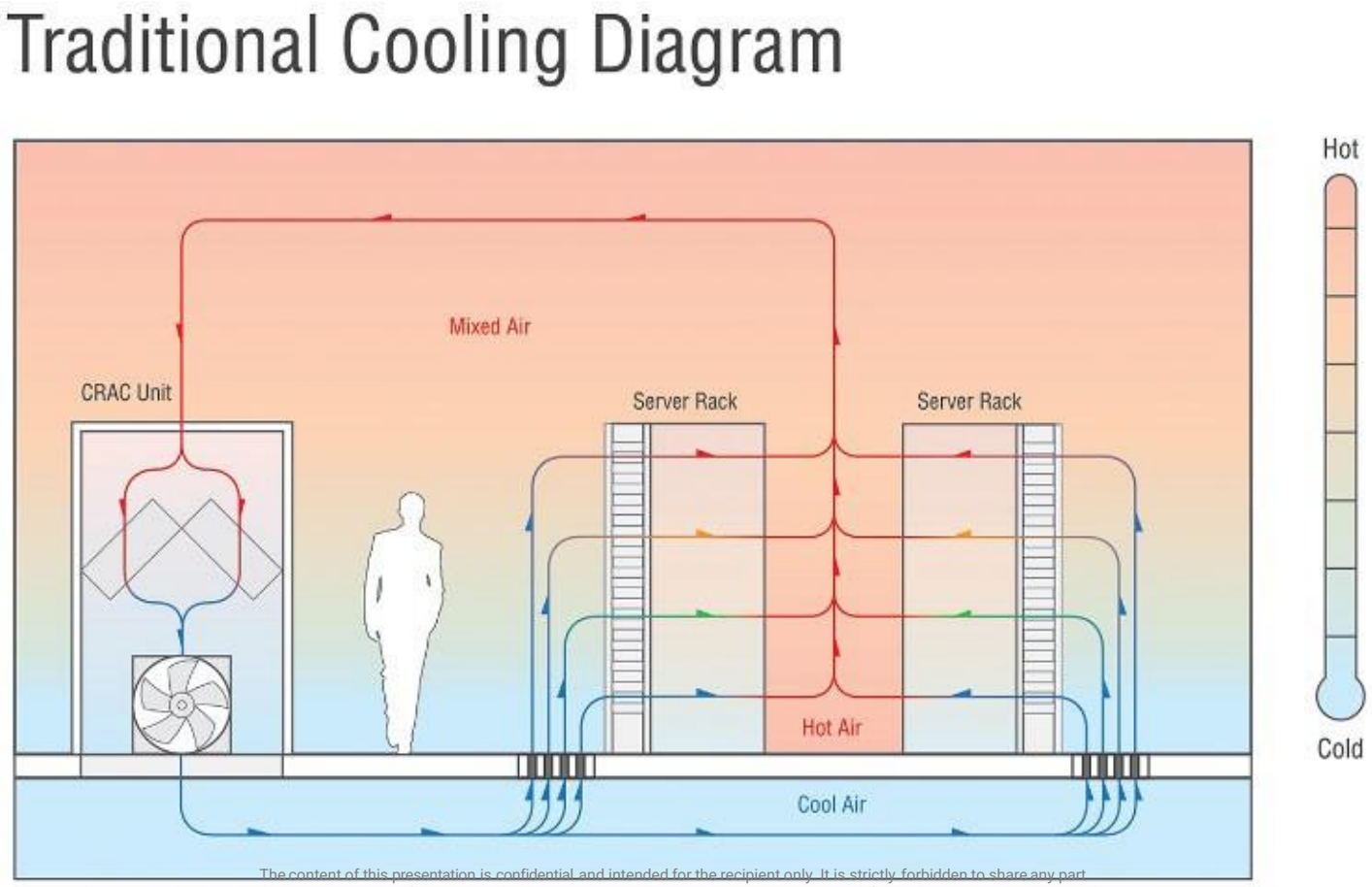


BREEAM Rating	% score
OUTSTANDING	≥ 85
EXCELLENT	≥ 70
VERY GOOD	≥ 55
GOOD	≥ 45
PASS	≥ 30
UNCLASSIFIED	< 30

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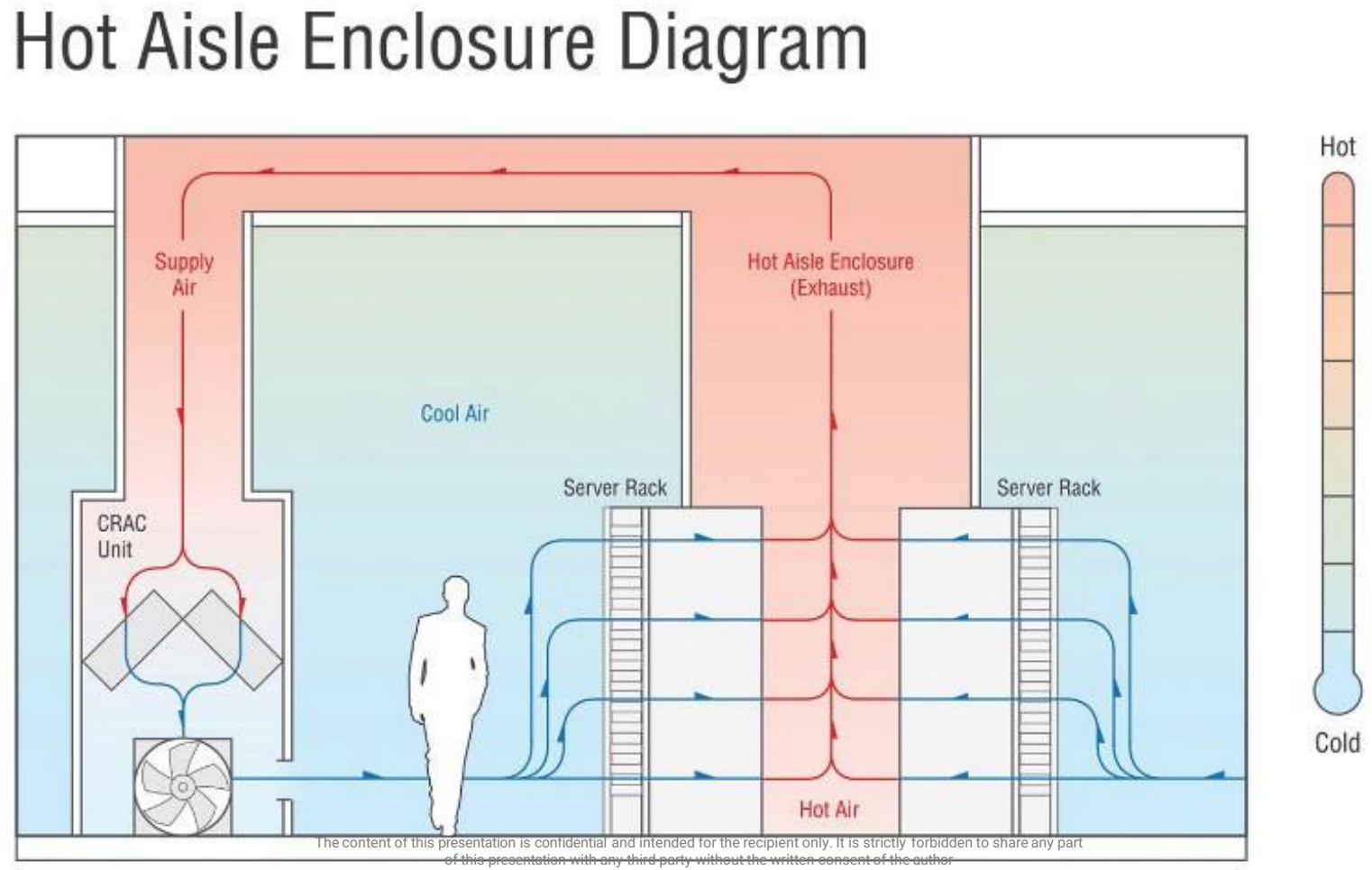
Cooling technologies – The old way?



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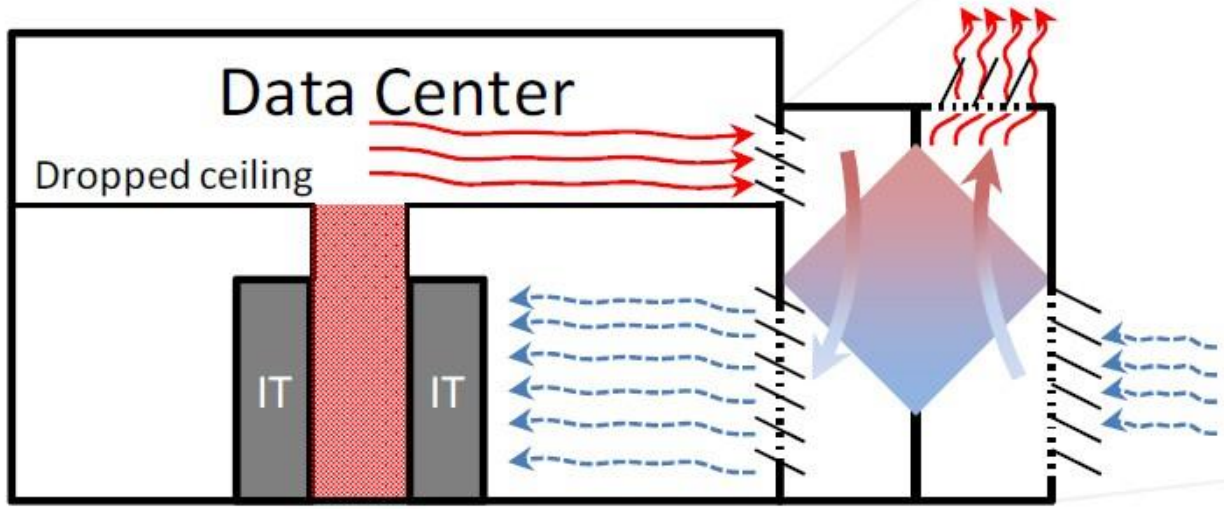
Cooling technologies - HACS

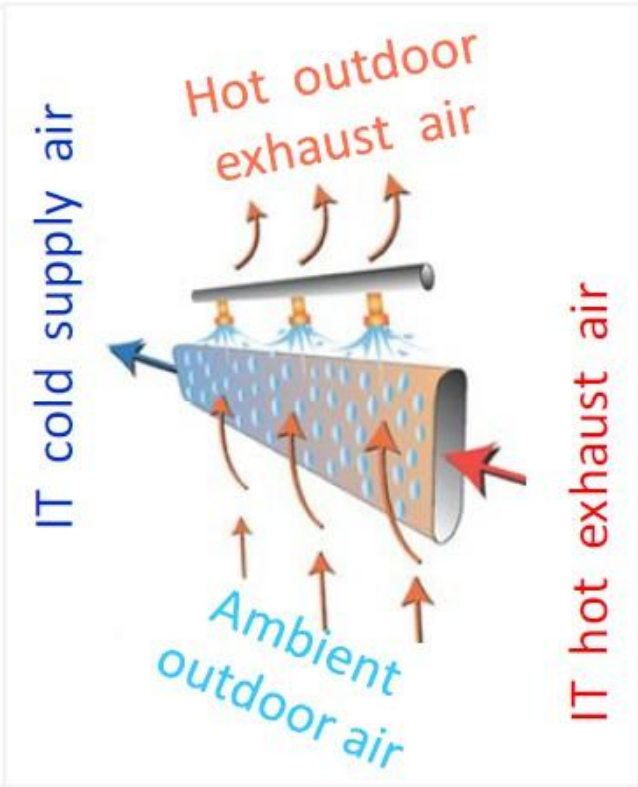


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Cooling technologies – Indirect evaporative cooling

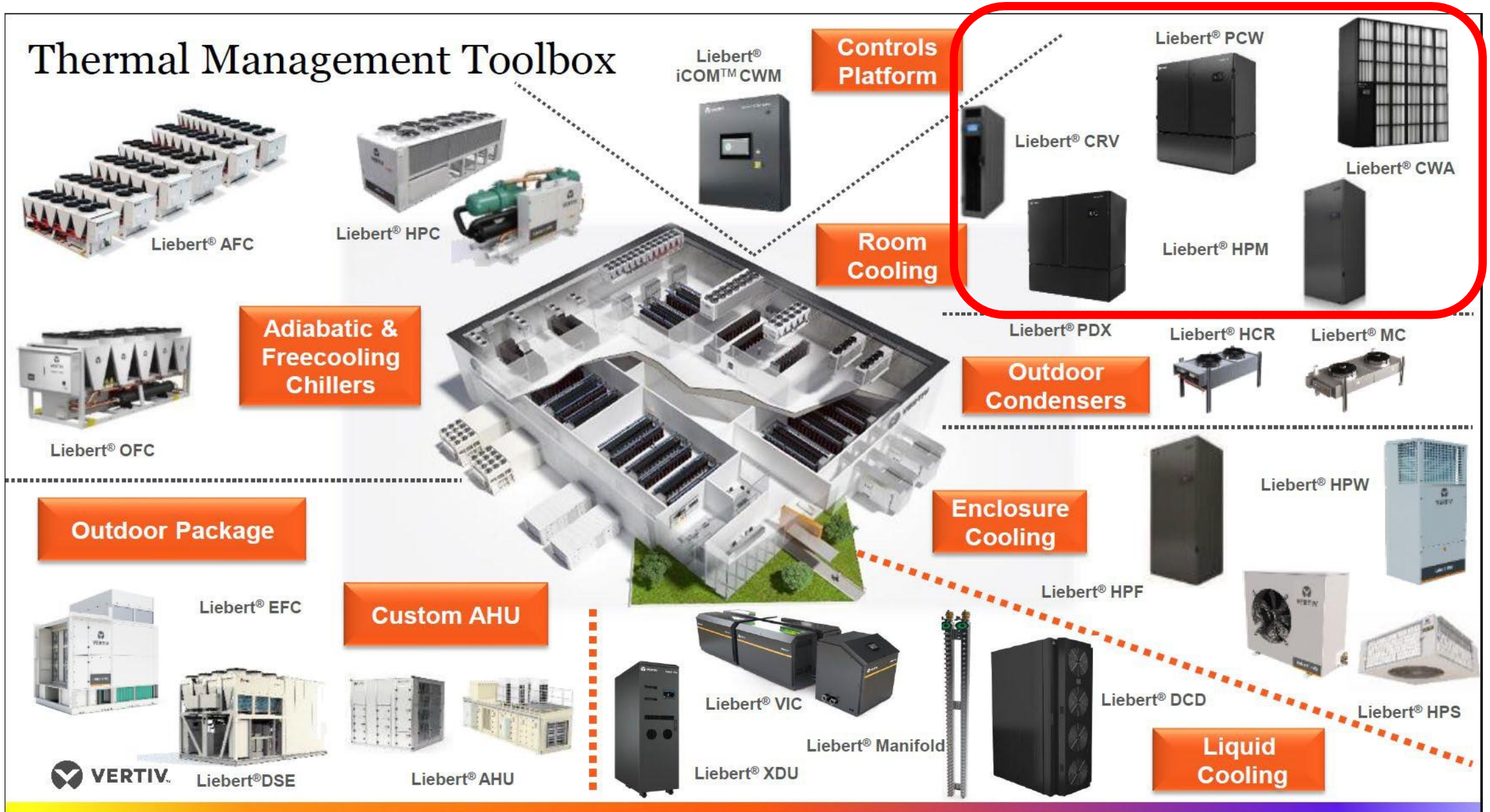




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Cooling technology

CFM!!!



Liquid Cooling Infrastructure

4 Coolant Distribution Units

1 & 2 Phase Row & Rack mounted CDUs to manage temperature liquid quality to server cold plates

5 Chillers, Condensers & Fluid Coolers

Free cooling chillers, fluid coolers and condensers to reject heat for single and 2 phase air and liquid cooling



3 Row & Rack Manifolds

Row and Rack Manifolds distribute liquid to IT or other Liquid Cooling products



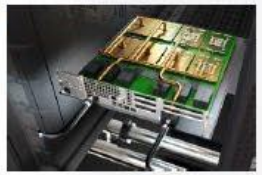
6 Indoor Chilled Water

Chilled Water room cooling units to address residual heat from liquid cooled racks



2 DTC Cold Plates

Single- and Two-Phase Cold Plates to remove heat from the processor into the liquid



7 Immersion Tanks

Immersion Racks to support server compaction and High -Density IT



1 Heat Rejection

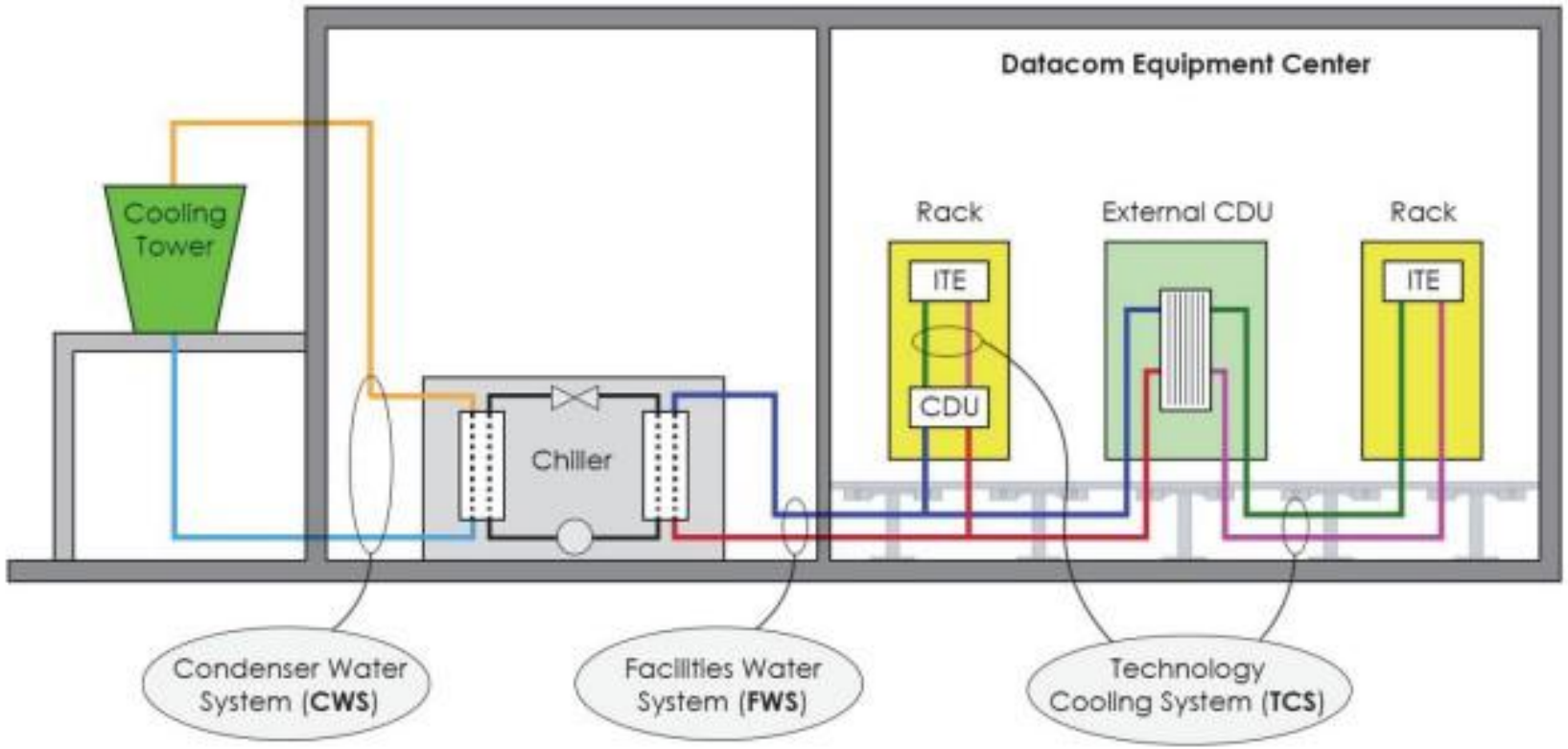
Raised temperature Fluid Cooler & Efficient Chillers to reject heat outdoors

Liquid Cooled Facility with Hybrid Air and Liquid Cooling

VERTIV.

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Cooling technologies – CDU Liquid cooling



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Liquid cooling - two methods







Liquid to Chip Cooling

- Liquid-flow heat sink on CPU, GPU
- Other heat sources can be connected
- Approx. 20% of the heat load remains air-cooled
- Heat transfer station / hydraulic separation
- Chilled water rack and row manifold
- Drip-free couplings
- High cooling capacity due to forced convection
- Modification of the server, complex cold plates
- Evaporative cooling possible
- 100kW per server and more

Immersion Cooling

- Servers are immersed in liquid
- 100% of the heat in liquid
- Immersion tank and heat transfer unit
- Cooling by free convection
- Cooling with phase change possible
- Very quiet operation
- Modified servers, simple heat sinks
- Attention - fire protection
- Up to 200kW per immersion tank

Rear door heat exchanger





Model	DCD35	DCD47 **	DCD50
Cooling Capacity *	35kW	47kW	50kW
Capacity Modulation	0 - 100%	0 - 100%	0 - 100%
Nominal Airflow	3700 cfm	3700 cfm	5300 cfm
Power Consumption	980 W	980 W	1185 W
Power Supply	Single or Dual	Single or Dual	Single or Dual
Widths	600, 800 mm	600, 800 mm	800 mm

** 21C (69F) ambient air temperature, 12C (53F) entering water temperature, 50% RH*
*** DCD47 only available with Active Module*

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Certifications and awards



































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Operating a data center

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Best of breed Operational Excellence

Green Mountain delivers

- Average PUE 1,17-1,34 across all data centers
- Standardized processes
- Proprietary monitoring system

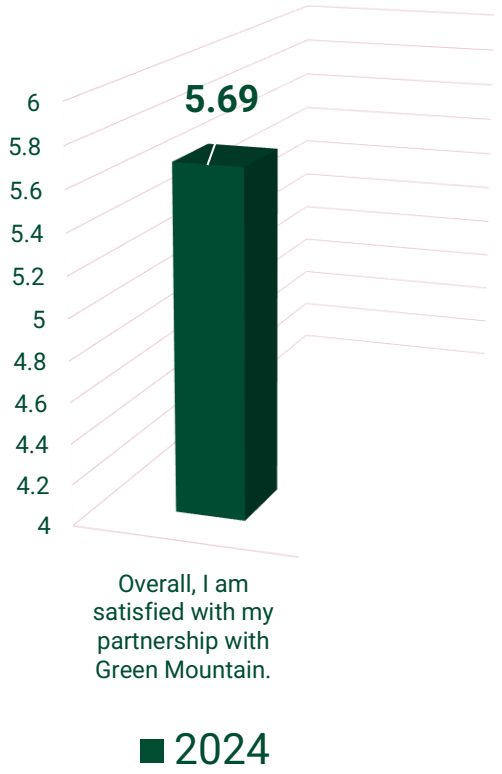
- Tier III and EN50600 certifications
- 100% uptime & 100% SLA compliance
- Strict controls & reporting in place

- 100% green renewable energy
- Liquid cooling solutions available

- High client satisfaction
- Integrated sales & execution teams
- Tailor-made, client-centric approach

- Management team with 25+ years of industry experience
- The Green Academy for training personnel

Client Satisfaction Score

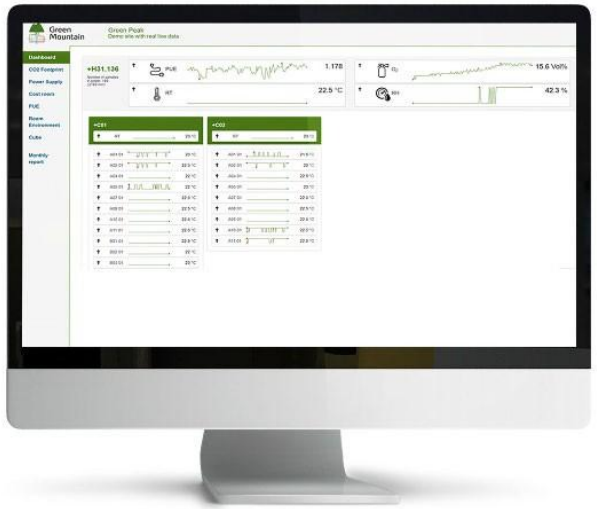


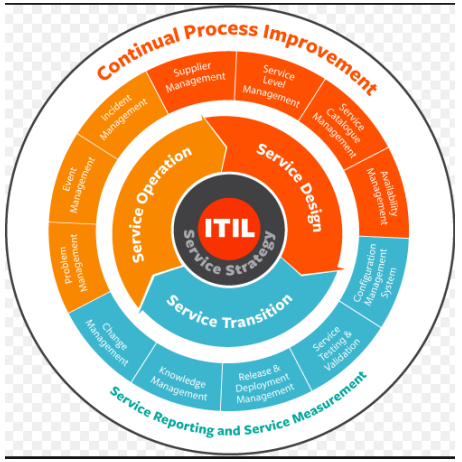
Operational Excellence

- Efficiency
- Reliability
- Sustainability
- Dedication
- Expertise

Operation

- It’s all about “Total Control”
- Measure everything, use the data!
- DCIM system – Data centre infrastructure management.
  - System developed by Green Mountain
  - Fully automated facility
- Using Citect Scada and GAPIT to operate and manage the datacentre
- Using several infrastructure dependent system to manage
  - Cellwatch – battery monitoring
  - RFcode – Wireless environmental monitoring
  - Leak detection
- ITIL and ServiceNow
- GreenPeak™
  - Online web portal for infrastructure information





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Proprietary DCIM solution with real-time monitoring

Data Center Infrastructure Management

- Proprietary system used in data centers to monitor, report and analyze infrastructure performance, avilable 24 hr per day, 7 days a week.
- Fully integrated with more than 600.000 sensors/measurement points.
- Real-time data of all key deliverables like PUE, temperature, humidity, O2-level and power consumption.
- Real-time insight into the cost of power and carbon footprint.

Green Peak™

- An award-winning real-time dashboard solution
- All the KPIs shared with clients through Green Peak™
- Real-time insights via a standard web user interface
- Access to detailed historical data and analytics of all the client deliverables including CO2 footprint, energy efficiency and system data
- Automatic generation of monthly reports

Energy Management in Green Mountain

Energy management team is responsible for setting objectives and targets, maintaining policy and securing resources for meeting our objectives. Energy management team will meet regularly 2-3 times per year. Execution og annual plans will be done in respective departments.



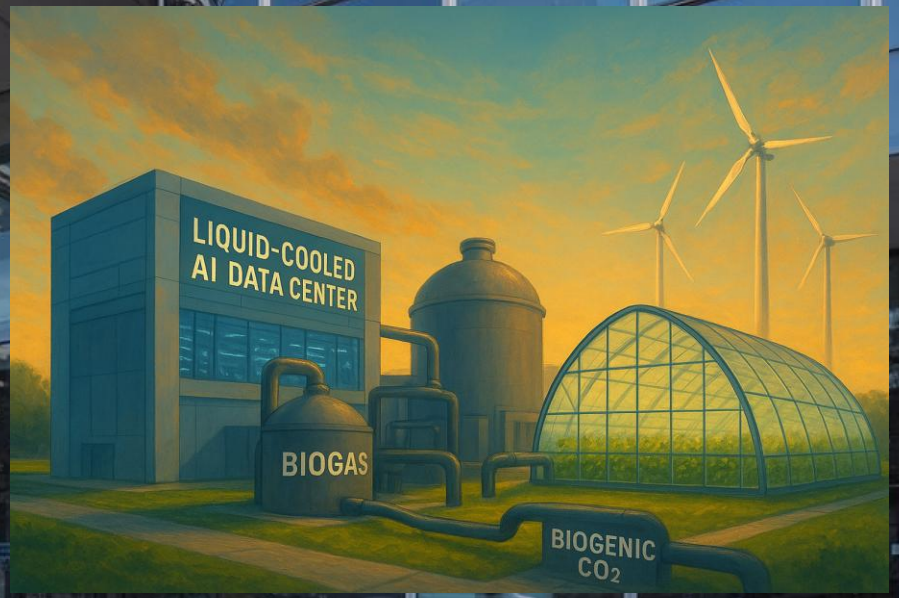
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Fremtidens datasentre (DC)

- Egen energiproduksjon eller *Power as a service*?
  - Saltsmeltereaktor, biogassturbiner, batterier, sol, geotermisk ?
- Symbiotiske/sirkulære ressurskjeder; varme, CO2, avfall, gjenbruk, gjenvinning, matproduksjon, varmekrevende industriprossesser
- Væskekjøling 3.0 – immersive cooling?
- Gjennombrudd på ***lavenergi*** prosessering og lagring av data?
- Anerkjent global industri, Norge fortsatt del av det *Grønne Beltet*?
- Tech-selskapene med store utviklingsmiljøer nær de store DC-clusterne?





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