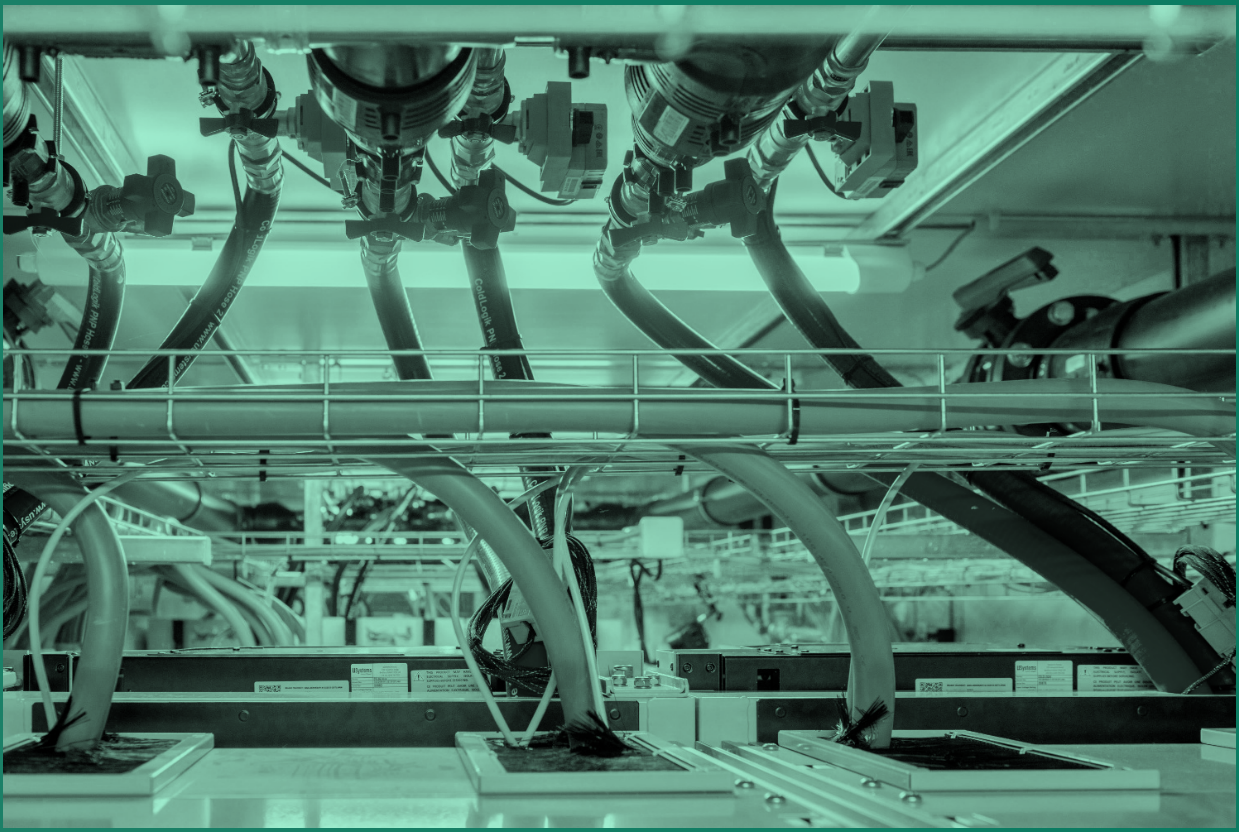

KONNECT Modular DCs

Conditional Pricing Matrix

Version 1.0 – March 17, 2025

1. Introduction

This document is based on rational assumptions to provide a clearer understanding of the cost impact across different iterations of ITE load sizing. Many interdependent factors influence each other, creating downstream effects on overall design and cost. Therefore, this document serves as a guideline rather than a definitive plan, and final specifications may vary based on project requirements.

2. Overview

2.1. Design Overview

- **Unit Configuration:** 28 racks total (2 rows × 14 racks per row).
- **IT Load average per rack Scenarios:**
  - Air-cooled: 50 kW/rack, 75 kW/rack.
  - Direct Liquid Cooling (DLC): 75 kW/rack, 100 kW/rack, 150 kW/rack.
- **Power Distribution:** Delta InfraSuite Cast Resin Busway BR Series (250A–2000A, copper conductors).
- **UPS:** ABB MegaFlex DPA (1000 kW, 1250 kW, 1500 kW frames, 250 kW modules, N+1 redundancy).
- **Cooling ITE:** DLC and air-cooled
- **General cooling:** Chiller modules
- **Redundancy:** N+1 (on chiller, UPS and busway configurations).

3. The Matrix

options 28 rack setup	Busbar Sizing (A)	Tap-off Box Sizing (A)	rPDU Sizing (A)	RDHx Type	Piping Sizing (DN)	UPS Sizing (kW)	Pump Skid Flow (L/min)	Cooler Type	Battery Config (Li-Ion)	Cost Increase	Cooling Load (kW)	Chiller Optimization Consideration
Air-cooled, 50 kW/rack	1250	100 (Custom)	80	High end	DN110	1750 (7× 250)	3108	5× TCS 310A XHT, 2× Grundfos TPE 100-390/2	7× REVO TP 240, 700 Ah EOL	100% (Baseline)	1400	3–4 units (500 kW each), high flow
Air-cooled, 75 kW/rack	2000	150 (Custom)	112	High end	DN160	2500 (11× 250)	4620	7× TCS 310A XHT, 3× Grundfos TPE 100-390/2	10× REVO TP 240, 1000 Ah EOL	140%	2100	4–5 units (500 kW each), high flow
DLC, 75 kW/rack	2000	150 (Custom)	112	Average	DN110	2500 (11× 250)	1165	7× TCS 310A XHT, 1× Grundfos TPE 100-390/2	10× REVO TP 240, 1000 Ah EOL	145%	2100	3–4 units (500 kW each), low flow, higher efficiency
DLC, 100 kW/rack	2000 (2 lines)	200 (Custom)	2×112	Average	DN110	3250 (14× 250)	1554	9× TCS 310A XHT, 1× Grundfos TPE 100-390/2	13× REVO TP 240, 1300 Ah EOL	170%	2800	5–6 units (500 kW each), low flow, higher efficiency
DLC, 150 kW/rack	2000 (2 lines)	250 (Custom)	2×112	High end	DN160	4500 (20× 250)	2331	14× TCS 310A XHT, 2× Grundfos TPE 100-390/2	18× REVO TP 240, 1800 Ah EOL	225%	4200	8–9 units (500 kW each), moderate flow, higher efficiency
COST INDUCER	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**	**LOW**	**HIGH**	**LOW**	**HIGH**	**HIGH**	**/**	**/**	**REDUCES OPEX**

4. Kontena Proposal

We propose a flexible system design that aligns with current high-density deployments while maintaining scalability. At this stage, we consider an average 150kW rack density excessive and recommend a more balanced approach.

4.1. Load example for NVL72 GB200 setup

Reference clusters show different design possibilities containing a mix of compute and networking racks:

TYPE	Comp	Comp	Comp	Comp	NW	NW	NW	NW	Comp	Comp	Comp	Comp
#	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12
kW	73	73	73	73	34	34	34	34	73	73	73	73
A	106,9	106,9	106,9	106,9	49,8	49,8	49,8	49,8	106,9	106,9	106,9	106,9

For 12 racks this has a total row density of 767kW at 415V. A proposed dual busway configuration delivers up to 1600A redundant capacity yo each row.

4.2. Outfitting suggestions

Busway

We would suggest implementing a 1600A busway from the start. It has little impact on price. A 2000A busway is also possible, but more bulky and does constrain us to 1 supplier.

Tap off boxes

For power distribution to individual racks, we suggest deploying tap-off boxes rated at 125A or 200A, equipped with configurable circuit breakers to support up to 160A per rack. Alternatively, dual 63A breakers can be used for enhanced flexibility, particularly for mixed rack types (compute vs. networking).

rPDU

We propose provisioning standard 112A rPDUs or dual 63A rPDUS power distribution units within the racks. The dual 63A systems offers modularity and redundancy while accommodating diverse load profiles.

RDHx

To ensure uniform cooling performance across all racks, we recommend deploying identical high-end RDHx units on every rack. This approach:

- Guarantees adequate cooling capacity along the entire row.
- Enhances rack placement flexibility (e.g., mixing compute and networking racks).
- Simplifies spare parts inventory and maintenance procedures.

Piping

For cooling distribution, we suggest using DN110 piping for each 7-rack section. These prefabricated pipe segments will include pre-installed 2-inch threaded tap-off points, facilitating rapid deployment. At a delta T of 7°C, this piping configuration can handle an average cooling load of approximately 480 kW per section, providing ample capacity for the proposed rack densities.

UPS + batteries

Suggestion 1

Single E-House with Expansion Potential

- Deploy a single E-house to feed both busway rows, sized with a 2000 kW UPS frame (1750 kW N+1 redundancy).
- Include a battery set sized for 5-minute autonomy at End of Life (EOL).
- For future expansion, a second E-house can be added on the opposite side of the whitespace, reconfiguring the setup to dedicate one E-house per row. This upgrade would increase the supported average rack density to 125 kW.

Suggestion 2

Modular E-House Deployment

- Start with one or two smaller E-house units, each equipped with a 1500 kW UPS frame (1250 kW N+1 redundancy), positioned on the same side of the whitespace. The UPS units are interconnected to feed both ITE busway rows.
- As demand increases, add a third or fourth E-house unit, we now split the 1600A busways into four independent sections (per 7 racks), each fed by a dedicated UPS. This configuration supports a theoretical maximum average rack density of 178 kW.

- For cost optimization, the number of UPS modules per frame can be reduced to lower the maximum supported density, tailoring capacity to actual needs.

Batteries are sized to match the requested power demand, ensuring 5-minute autonomy at EOL.

Pumpsystem

For cooling system design, we recommend:

- Configuring the pump system to support an average rack load of 75 kW using Direct Liquid Cooling (DLC).
- Designing the piping infrastructure to accommodate a future average rack load of 100 kW (DLC), ensuring scalability.
- Including flange connections on pump skids to facilitate the integration of additional pump sets as needed.

Chiller configuration

- Design the piping system to support an average rack load of 100 kW (DLC), ensuring future-proofing and easy hook up of extra chiller modules.
- Implement a minimum chiller capacity sized for an average rack load of 75 kW, balancing initial capital expenditure with operational efficiency. Additional chiller capacity can be added as rack densities increase.

5. NEO: Breakdown of The Matrix

5.1. Busbar Sizing

Busbars are sized for the IT load per row (14 racks) without including PUE, as chillers are on a separate electrical system.

- **Formula:** Current per row = (Total kW per row) ÷ (Voltage × √3 × PF).
- **Assumptions:** Voltage = 400V, PF = 0.9, no PUE factor.

  Calculation Example (Air-cooled, 50 kW/rack):
  - Total kW per row = 50 kW/rack × 14 racks = 700 kW.
  - Current = 700,000 ÷ (400 × 1.732 × 0.9) ≈ 1121A.
  - Busbar sizing: 1250A (next available size).

  Calculation Example (DLC, 150 kW/rack):
  - Total kW per row = 150 kW/rack × 14 racks = 2100 kW.
  - Current = 2100,000 ÷ (400 × 1.732 × 0.9) ≈ 3366A.
  - Busbar sizing: 2000A per row (A+B redundancy, so total 4000A capacity, sufficient).

5.1.1. Busbar Sizing Recalculation and Alignment with Delta BR Series

The Delta BR Series offers busway ratings of 250A, 400A, 600A, 800A, 1000A, 1250A, 1600A, and 2000A (copper or aluminum conductors). We calculate the current per row (14 racks) for each iteration and select the closest Delta busway rating that meets or exceeds the requirement, ensuring compatibility with the 400V, 3-phase system (power factor = 0.9).

Formula:

Current per row (A) = (Total kW per row × 1000) ÷ (Voltage × √3 × PF)

- Voltage = 400V
- PF = 0.9
- Total kW per row = kW per rack × 14 racks

Calculations:

1) Air-cooled, 50 kW/rack:
   (a) Total kW = 50 × 14 = 700 kW
   (b) Current = (700 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 1121A
   (c) Delta Busway: 1250A (next available size)

2) Air-cooled, 75 kW/rack:
   (a) Total kW = 75 × 14 = 1050 kW

   (b) Current = (1050 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 1682A
   (c) Delta Busway: 2000A (next available size, as 1600A is insufficient)

3) DLC, 75 kW/rack:
   (a) Total kW = 75 × 14 = 1050 kW
   (b) Current = 1682A
   (c) Delta Busway: 2000A

4) DLC, 100 kW/rack:
   (a) Total kW = 100 × 14 = 1400 kW
   (b) Current = (1400 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 2243A
   (c) Delta Busway: 2000A (max rating, requires A+B redundancy or additional busway)

5) DLC, 150 kW/rack:
   (a) Total kW = 150 × 14 = 2100 kW
   (b) Current = (2100 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 3366A
   (c) Delta Busway: 2000A (max rating, requires A+B redundancy or multiple busways)

Notes:

- For loads exceeding 2000A (e.g., DLC 100 kW and 150 kW), the Delta BR Series maxes out at 2000A per busway. To handle higher currents, we need to split the rows.
- We use copper conductors for better conductivity (99.9% purity, tin-plated per Delta specs) unless aluminum preference is specified.

Scenario	kW per Rack	Total kW per Row (14 racks)	Current per Row (A)	Busbar Sizing (A)
Air-cooled	50 kW	700 kW	1121 A	1250A (Cu)
Air-cooled	75 kW	1050 kW	1682 A	2000A (Cu)
DLC	75 kW	1050 kW	1682 A	2000A (Cu)
DLC	100 kW	1400 kW	2243 A	2000A (Cu, A+B)
DLC	150 kW	2100 kW	3366 A	2000A (Cu, A+B)

5.2. Tap-off Box (Plug-in Unit) Specification

Delta's plug-in units (Rv and Rh types) are customizable, with standard amperage ratings of 16A, 32A, and 63A, and options for higher ratings via custom configurations (with circuit breakers from major vendors). The tap-off box must handle the load per rack, distributed via the busway's successive plug-in slots.

Formula:

Current per rack (A) = (kW per rack × 1000) ÷ (400 × 1.732 × 0.9)

Calculations:

1) Air-cooled, 50 kW/rack:
   a) Current = (50 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 80A
   b) Delta Plug-in Unit: Custom 100A (63A insufficient, next standard size requires customization)

2) Air-cooled, 75 kW/rack:
   a) Current = (75 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 120A
   b) Delta Plug-in Unit: Custom 150A

3) DLC, 75 kW/rack:
   a) Current = 120A
   b) Delta Plug-in Unit: Custom 150A

4) DLC, 100 kW/rack:
   a) Current = (100 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 160A
   b) Delta Plug-in Unit: Custom 200A (or 2×100A)

5) DLC, 150 kW/rack:
   a) Current = (150 × 1000) ÷ (400 × 1.732 × 0.9) ≈ 240A
   b) Delta Plug-in Unit: Custom 250A (or 2×125A)

Notes:

- Standard tap-off units are insufficient for these loads. Custom units are required.
- For higher loads (100 kW and 150 kW), dual tap-off boxes per rack (2×80A or 2×125A) could be used if single units exceed practical breaker sizes.

Scenario	kW per Rack	Current per Rack (A)	Tap-off Box Sizing (A)
Air-cooled	50 kW	80 A	100A (Custom)
Air-cooled/DLC	75 kW	120 A	150A (Custom)
DLC	100 kW	160 A	200A (Custom)
DLC	150 kW	240 A	250A (Custom)

5.3. rPDU sizing

Scenario	kW per Rack	Current per Rack (A)	rPDU Sizing (A)
Air-cooled	50 kW	80 A	80A
Air-cooled/DLC	75 kW	120 A	112A
DLC	100 kW	160 A	2x112A
DLC	150 kW	240 A	2x112A

We have taken rational assumptions in sizing the PDU's, electrically. However we do not take into account the physical sizes and if there would be any restrictions in a 1200mm deep cabinet. The feasibility depends on the ITE specifications, which may necessitate a different PDU configuration, potentially impacting costs.

5.4. Cooling Setup Specification

We will specify the cooling setup for each iteration, ensuring compatibility with the design conditions (Detroit climate, 40% glycol, cooling loads).

5.4.1. Cooling System Differences: Air-Cooled vs. DLC

For the same IT load, the cooling approach air-cooled versus DLC significantly affects coolant flow, delta T, and chiller efficiency:

- **Air-Cooled (Active RDHx)**:
  - Requiring higher coolant flow to maintain lower delta T (~6-10°C).
  - Higher flow rates (2010 L/min for 75 kW/rack) ensure adequate heat transfer but demand larger pumps and piping (DN160).
  - Chiller efficiency is lower due to the smaller delta T, as chillers work harder to cool cooler return water (~20°C inlet).

- **DLC (Passive RDHx)**:
  - Relies on direct liquid cooling with no fans, allowing a higher delta T (~15–20°C) due to warmer outgoing water (~35-45°C).
  - Lower flow rates (e.g., 510 L/min for 75 kW/rack) suffice because the larger delta T transfers the same heat with less coolant, reducing pump size and using smaller piping (DN110).
  - Chiller efficiency improves with warmer return water, reducing energy use (COP increases by ~10–20% compared to air-cooled).

Impact:
- For 75 kW/rack (2100 kW total IT load):
  - Air-cooled: 2010 L/min per row, larger cooling infrastructure.
  - DLC: 510 L/min per row, smaller footprint and better chiller performance.
- These differences are due to the heat transfer efficiency of liquid cooling versus air, affecting system design and operational costs.

5.4.2. Piping Sizing

Piping is sized based on the cooling load handled by the RDHx or RDHx + DLC with loops serving 7 racks. Flow rates depend on the heat load, temperature delta (ΔT), and glycol properties.

Note: For systems incorporating DLC, an RDHx is required to dissipate residual heat. Since the DLC component operates at higher temperatures, the RDHx can be placed in series with the DLC system.

The amount of residual heat varies across vendors and systems. To ensure a conservative approach in fluid flow calculations, we assume that 25% of the total cooling load remains as residual heat requiring RDHx cooling.

Formula: Cooling load = (kW per rack) × (Total racks) × (Cooling fraction).

Air-cooled: Cooling fraction = 1.0 (100% of IT load)

DLC: Cooling fraction = 0.25 (25% residual heat)

1) Calculation Example (Air-cooled, 50 kW/rack):
    a) Cooling load = 50 kW/rack × 28 racks × 1.0 = 1400 kW.
2) Calculation Example (DLC, 150 kW/rack):
    a) Cooling load = 150 kW/rack × 28 racks × 0.25 = 1050 kW.

The required flow rate over the RDHx corresponds to the calculated fractional cooling load. This flow rate serves as the basis for sizing pumps and piping to ensure adequate heat dissipation.

Assumptions: ΔT = 10°C (standard for datacenter cooling loops), 40% glycol reduces heat capacity by ~10% compared to water.

Formula: Flow rate (L/min) = (Heat load in kW) × 1000 ÷ (Specific heat × ΔT × 60).

Specific heat of 40% glycol ≈ 3.8 kJ/kg·K (vs. 4.18 for water).

1) Calculation Example (Air-cooled, 50 kW/rack, 7 racks/loop):
    a) Heat load per loop = 50 kW/rack × 7 racks = 350 kW.
    b) Flow rate = 350,000 ÷ (3.8 × 10 × 60) ≈ 154 L/min.
    c) DN110 is sufficient (typical capacity ~200 L/min).

2) Calculation Example (DLC, 75 kW/rack, 7 racks/loop):
   a) Residual heat per loop = (75 kW/rack × 0.25) × 7 racks = 131.25 kW.
   b) Flow rate = 131,250 ÷ (3.8 × 10 × 60) ≈ 58 L/min.
   c) DN110 is sufficient.

3) Calculation Example (DLC, 150 kW/rack, 7 racks/loop):
   a) Residual heat per loop = (150 kW/rack × 0.25) × 7 racks = 262.5 kW.
   b) Flow rate = 262,500 ÷ (3.8 × 10 × 60) ≈ 115 L/min.
   c) DN160 is required for higher flows.

Notes: DLC systems require lower flows due to the reduced load on RDHx, allowing smaller piping compared to air-cooled systems.

Scenario	RDHx Type	Piping Sizing (DN)
Air-cooled	Active	DN110 (50 kW), DN160 (75 kW)
DLC	Passive	DN110 (75 kW, 100 kW)
DLC	Active	DN160 (150 kW)

5.4.3. Pump Sizing

The pumps are VFD-controlled to dynamically adjust flow based on cooling demand, using differential pressure as the control parameter. The pump skid must be sized to handle the worst-case flow scenario, ensuring sufficient capacity for peak cooling loads.

The total pump skid flow is calculated as the sum of all cooling loop flows (4 loops for 28 racks).

Formula

The formula is derived from the basic heat transfer equation:
Q = m × c × ΔT

Where:

Q = Heat energy (in kcal/h, converted from kW using the factor 860)
m = Mass flow rate of the fluid (related to volumetric flow rate in L/min)
c = Specific heat capacity of the fluid (4.18 kcal/L·°C for water)
ΔT = Temperature difference (°C)

We now have the heat transfer for the fluid, but do not account for any losses in the RDHx. This factor is not linear, but we empirically assume;

2,22L/min/kW for a delta T of 7°C

1) **Calculation Example (Air-cooled, 50 kW/rack)**:
   a) Total heat load = 50 kW/rack × 28 racks = 1400 kW.
   b) Total flow = 1400 * 2,22 ≈ 3108 L/min.
2) **Calculation Example (DLC, 150 kW/rack)**:
   a) Residual heat = 150 kW/rack × 0.25 × 28 racks = 1050 kW.
   b) Total flow = 1050 * 2,22 ≈ 2331 L/min.

Scenario	Pump Skid Flow (L/min)
Air-cooled, 50 kW	3108
Air-cooled, 75 kW	4620

DLC, 75 kW	1165
DLC, 100 kW	1554
DLC, 150 kW	2331

5.4.3.1. Real world example, SABER 56

The Grundfos TPE 100-390/2 pump has a rated flow of 202 m^3/h (3367 L/min) and a rated head of 25 m. We need to determine the number of pumps required to meet the total flow requirements (from the "Pump Skid Flow" column), ensuring N+1 redundancy.

Formula: Number of pumps = *Roundingup*(Total flow ÷ Pump capacity) + 1 (for N+1).

1) Calculation Example (Air-cooled, 50 kW/rack):
   a) Total flow = 3108 L/min (from previous matrix).
   b) Pump capacity = 3367 L/min.
   c) Number of pumps = *Roundingup*(3108 ÷ 3367) + 1 = *Roundingup*(0.9) + 1 = 1 + 1 = 2 (1 active, 1 standby).
2) Calculation Example (DLC, 150 kW/rack):
   a) Total flow = 2331 L/min.
   b) Pump capacity = 3367 L/min.
   c) Number of pumps = *Roundingup*(2331 ÷ 3367) + 1 = *Roundingup*(0.7) + 1 = 1 + 1 = 2 (1 active, 1 standby).

Notes: Pump skids must be sized for redundancy (e.g., N+1 pumps) and glycol viscosity (higher than water).

5.4.4. Buffer Tank

Buffer tanks are utilized to stabilize flow and temperature fluctuations, which is particularly critical for managing unsteady loads. To ensure adequate volume for handling flow variations and providing thermal inertia, we must determine the appropriate number of tanks required.

The inclusion of buffer tanks is expected to have a negligible impact on the pricing of this system, so their cost will not be factored into the pricing matrix.

5.4.5. Chiller Sizing

The sizing of chillers is influenced by several factors, including the total cooling load, the type of cooling system (direct liquid cooling or air-cooled => influences flow and temps), the geographic location, and other operational parameters. These factors determine how heat is managed and how chillers are sized to meet the cooling demands of the system.

Air-Cooled Systems

In air-cooled systems, 100% of the heat generated by the IT equipment (the IT load) is removed by RDHx units. For example, with a cooling load of 75 kW per rack across 28 racks, the total heat load is 2,100 kW.

Chiller Impact: The cooling water absorbs heat from the RDHx units and returns to the chiller at with a relatively small temperature rise (approximately 10°C). This results in a high demand for water flow to remove the entire heat load. For instance, at 75 kW per rack, the required flow rate is approximately 2,010 liters per minute (L/min). Consequently, the chiller must be sized to handle this full heat load and high flow rate, leading to increased energy consumption and the need for a larger chiller capacity.

Direct Liquid Cooling (DLC) Systems

In DLC systems, the cooling process is split between the RDHx units and the DLC components. The RDHx units are prioritized, receiving cool water directly from the chiller and removing approximately 25% of the total heat load. The remaining 75% of the heat is handled by the DLC components. For example, at 75 kW per rack across 28 racks (total heat load of 2,100 kW), the RDHx units cool 525 kW, while the DLC components handle the remaining 1,575 kW. A specialized three-way valve ensures a consistent temperature delta rise across the inlet and outlet of the DLC system (typically 15–20°C), resulting in warmer return water.

Chiller Impact: The flow rate in DLC systems is determined by the RDHx units. For instance, at 75 kW per rack, the flow rate is approximately 510 L/min, and the DLC components utilizes at max the same flow. Although the chiller must still cool the full 2,100 kW, the higher return water temperature and lower flowrates reduces the chiller's workload, leading to improved energy efficiency.

the reduced flow and higher return temperature improve efficiency by 10–20%, potentially allowing fewer or smaller chillers compared to air-cooled systems.

5.4.5.1. Real world example, SABER 56

The TCS 310A XHT chiller has a cooling capacity of 309.79 kW at selection conditions (external air temp 35°C, evaporator water in/out 25°C/20°C (we get these temps by using the buffer tanks, also creating inertia), 40% glycol). We need to determine the number of chillers required for each iteration, ensuring N+1 redundancy (i.e., one extra chiller for failover).

Formula: Number of chillers = *Roundingup*(Cooling load ÷ Chiller capacity) + 1 (for N+1).

1) Calculation Example (Air-cooled, 50 kW/rack):
   a) Cooling load = 1400 kW.
   b) Number of chillers = *Roundingup*(1400 ÷ 309.79) + 1 = *Roundingup*(4.52) + 1 = 5 + 1 = 6 (5 active, 1 standby).

Scenario	Cooler Type
Air-cooled, 50 kW	5× TCS 310A XHT, 2× Grundfos TPE 100-390/2, 2× TTV 4000A
Air-cooled, 75 kW	7× TCS 310A XHT, 3× Grundfos TPE 100-390/2, 3× TTV 4000A
DLC, 75 kW	7× TCS 310A XHT, 1× Grundfos TPE 100-390/2, 1× TTV 4000A
DLC, 100 kW	9× TCS 310A XHT, 1× Grundfos TPE 100-390/2, 1× TTV 4000A
DLC, 150 kW	14× TCS 310A XHT, 2× Grundfos TPE 100-390/2, 2× TTV 4000A

5.5. UPS System Sizing

The ABB MegaFlex DPA UPS offers power ratings of 1000 kW, 1250 kW, 1500 kW and 2000kW per frame, built from 250 kW modules (4, 5, or 6 modules per frame, respectively). It supports N+1 redundancy within a single frame or 2N redundancy with parallel frames.

Be aware, we only calculate for ITE loads. So no coolsystem is included in these calculations. This is still open for discussion

Formula:

Total IT Load per Unit (kW) = kW per rack × 28 racks

1. Example 50 kW/rack:
    a. IT Load: 50 kW × 28 racks = 1400 kW.
    b. Minimum Modules: 1400 ÷ 250 = 5.6 → 6 modules (1500 kW).
    c. N+1 Redundancy: 6 + 1 = 7 modules.
    d. Total Capacity: 7 × 250 kW = 1750 kW.
    e. Excess capacity: 1750 kW – 1400 kW = 350 kW.

Notes:

- **Single Frame Limit**: The MegaFlex DPA maxes out at 2000 kW per frame. Loads exceeding 1750 kW (N+1) require multiple frames. (a 2000kW frame can hold 8 modules)
- **Parallel Frame limit**: 4500kW UPS system
- **Redundancy**: N+1 is now assumed to be allowed in the same frame.
    - We proposed a redundant 250kW module in EACH frame. (if we need 2 frames, we propose 2 redundant modules)

Scenario	IT Load (kW)	Minimum Modules (250 kW)	N+1 Modules	Total Capacity (kW)	Excess capacity (kW)	Configuration
Air-cooled, 50 kW/rack	1400 kW	6 (1500 kW)	7	1750 kW	350 kW	1 frame, 7× 250 kW modules
Air-cooled/DLC, 75 kW/rack	2100 kW	9 (2250 kW)	11	2500 kW	750 kW	2 frames, 5× 250 kW modules each
DLC, 100 kW/rack	2800 kW	12 (3000 kW)	14	3250 kW	800 kW	2 frames, 6× and 7× 250 kW modules
DLC, 150 kW/rack	4200 kW	17 (4250 kW)	20	4500 kW	800 kW	3 frames, 6× 250 kW modules each

5.6. Battery system sizing

The focus will be on the Vision REVO 2.5 TP series Lithium-Ion batteries, as referenced by ABB with 5-minute autonomy at End of Life (EOL).

Assumptions:

Each REVO TP 240 cabinet delivers ~250 kW of power over 5 minutes to support the load demand aligning with the UPS system.

Per Cabinet Energy:

1. 5 cabinets deliver 104.125 kWh → 104.125 kWh ÷ 5 = 20.825 kWh per cabinet over 5 minutes.
2. Power per Cabinet: 20.825 kWh ÷ 0.0833 hr = 250 kW (average power delivery during discharge).

Formulas:

1. Energy (kWh) = IT Load (kW) × 0.0833 hr ÷ Efficiency (0.95).
2. Cabinets = Energy ÷ 20.825 kWh per cabinet, rounded up + 1 for N+1.

50 kW/rack (1400 kW):

a. Energy: 1400 × 0.0833 ÷ 0.95 ≈ 122.77 kWh.

b. Cabinets: 122.77 ÷ 20.825 ≈ 5.9 → 6

c. Total Power: 6 × 250 kW = 1500 kW (matches UPS).

d. Capacity: 6 × 100 Ah = 600 Ah EOL.

6. ADDITIONAL CONSIDERATIONS

- Increasing the UPS power also raises the costs associated with incoming and outgoing distribution boards (DBs). We have made careful and rational assumptions to provide a realistic cost estimation.
- In the Detroit area, a hybrid chiller system or pre-cooling with dry coolers could be a viable solution to improve energy efficiency and reduce PUE during certain periods of the year. However, it is important to note that full chiller capacity is still required to ensure sufficient cooling under worst-case conditions.
- Busbar sizing is matched to the Delta BR Series ratings, which include options for 1250A and 2000A. For DLC systems operating at 100 kW and 150 kW per rack, the maximum busbar rating of 2000A is insufficient to handle the full load requirements (e.g., 2243A for 100 kW/rack and 3366A for 150 kW/rack). To address this, two 2000A busways per row are recommended to ensure adequate capacity and system reliability.
- Copper conductors are specified for optimal electrical conductivity and long-term reliability. The busbars are designed with Class F insulation, rated for a maximum operating temperature of 155°C, in accordance with Delta specifications. Price can be brought down if we go for aluminium bars.
- Keep in mind that tap off boxes can be added and removed at later stages, and thus do not need to be in the initial costing if opted.
    - Custom plug-in tap-off boxes are specified to match rack loads, with options including 100A, 150A, 200A, and 250A units. These units are designed to be compatible with circuit breakers from all major vendors, providing flexibility and ease of integration.
    - For higher rack loads (e.g., 150 kW per rack), a single 250A tap-off box is assumed as the baseline configuration. However, an alternative approach using dual tap-off boxes (e.g., 2 × 125A) may be considered if preferred, depending on space constraints and cost considerations.
- Piping costs are also very dependable on the sectioning request on the mainlines => amount of valves.

Spacing and Infrastructure Considerations

- DLC systems significantly reduce piping and pump skid requirements due to the lower heat load handled by RDHx units (25% of the total load => lowers the flow). This makes DLC systems more efficient and practical for higher rack loads (e.g., 100 kW and 150 kW).
- Higher rack loads require substantial UPS capacity. Such capacities may necessitate the use of multiple E-house modules to accommodate the UPS frames, batteries, and associated

infrastructure. Space planning and modular design should be prioritized to ensure scalability and operational efficiency.