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Nordics Prototype Data Hall Free Cooling Design

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Abstract

With the global rise in data center developments where Rack Densities keep rising and demanding more power and accordingly more cooling to reject the increased heat, optimizing energy efficiency and reducing power consumption are paramount. This study investigates an innovative cooling approach leveraging dry coolers and ice Thermal Storage tank systems to enhance data center performance, particularly in cold climates such as Nordics, specifically in this study the city of Pyhajoki in Finland.

Traditional air-cooled chillers (ACCH) dominate cooling infrastructure but consume significant power due to compressors and refrigerants circuits. Dry coolers, on the other hand consisting only of fans and heat exchangers, provide a more sustainable alternative, operating efficiently without refrigerants. However, their cooling capacity is limited by ambient temperature, restricting their standalone use.

The proposed hybrid system integrates dry air coolers with ice tanks to capitalize on Finland's low temperatures, where 96% of the year remains below 20°C. In cold conditions, dry air coolers handle the entire data center cooling load while simultaneously freezing ice tanks. During warmer periods (above 20°C), the ice tanks discharge, maintaining the required supply temperature for fan wall units to cool the Data Halls within ASHRAE Class A Racks (29°C Server inlet Temperature) without relying on chillers. This configuration omits chiller operation all over the year and allow for full free cooling during the 4% of the year, significantly reducing power consumption and supporting sustainability initiatives. The results demonstrate that this system achieves substantial energy savings, enhanced mechanical efficiency and lower environmental impact.

Keywords: Data center cooling, Dry coolers, Energy efficiency, Heat rejection systems, Ice thermal storage tanks, Mechanical cooling, Sustainability, PCM- Phase Changing material

Abbreviation: Power usage effectiveness (PUE); Carbon Usage effectiveness (CUE)

Introduction

The exponential growth of digital services, cloud computing and AI based Data Centers and data-intensive applications has led to an unprecedented rise in global data center construction. As data centers scale to meet increasing demand, energy consumption has emerged as a critical challenge, with cooling systems accounting for a significant portion of operational power use. Traditional cooling methods, predominantly air-cooled chillers (ACCHs), rely on compressors and refrigerants, resulting in high energy usage and increased environmental impact.

Given the urgent need for more sustainable and cost-effective cooling solutions, this study explores an alternative approach combining dry air coolers and ice thermal storage tank technology. Dry air coolers, which operate solely with fans and heat exchangers, eliminate the need for Compressors, significantly improving energy efficiency. However, their performance is inherently constrained by ambient temperatures. To address this limitation, the proposed system strategically integrates ice thermal storage tanks, which store thermal energy by freezing whilst utilizing PCM-Phase Changing Materials during colder periods and discharge cooling power during warmer conditions.

The study focuses on Finland's climate, characterized by long durations of low temperatures, making it an ideal environment for implementing this hybrid cooling strategy. The objective is to analyze operational performance, energy savings and sustainability outcomes, offering insights into scalable cooling solutions for data centers in similarly cold climates. This approach aims to advance the industry's efforts to achieve greener, more resilient infrastructure while reducing reliance on traditional power-intensive cooling systems [1].

Project Brief

One primary determinant of cooling design is the type of servers being cooled. For air-cooled servers — commonly used in cloud computing — the recommended inlet air temperature ranges between 18°C and 27°C, however, for Class A Servers as per the ASHRAE TC 9.9, 29°C server inlet temperature is acceptable to all hyperscale's such as "but not limited to: Microsoft, Google, Amazon, etc. This is typically maintained using air-cooled chillers (ACCHs), which rely on compressors and refrigerants to regulate temperature.

However, these systems consume substantial power, limiting the overall energy efficiency of data halls.

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An alternative heat rejection solution involves dry air coolers. This technology operates with only a fan and a heat exchanger, eliminating the need for compressors. As a result, dry air coolers are exponentially more energy-efficient than conventional chillers and align with the global sustainability objectives by avoiding compressor-based cooling systems altogether. The drawback of this approach is that, without compressors, the supply water temperature is dictated by ambient conditions and cannot fall below the external temperature. Consequently, dry air coolers are typically deployed as supplementary systems to chillers in colder climates. In such configurations, dry air coolers handle the primary cooling load for most of the year (96%) according to ASHRAE bin Weather Data profile, with chillers remaining in standby mode and activating only when ambient temperatures exceed acceptable thresholds, however, this isn't the case in this study as the standby mode will be Ice thermal storage Tank with PCM Material instead to grant Chilled water Supply temperature of 24 C to the Fan Wall Units- FWU and accordingly grant 29 C server inlet temperature during Normal and Failure Scenarios/ operating modes within the Data Halls, whilst considering 5°C approach/ LMTD Temperature [2].

In Finland, regional weather data reveals a peak ambient temperature of 33.8°C at n=20- ASHRAE Handbook 2021 and a minimum temperature below -32°C. Analysis based on the Bin weather data:

Bin Weather data: a method to calculate the building's load by determining the number of hours per year that the average outdoor temperature of the location under study was contained in a temperature band or "BIN". Adding the load for each of these temperature bins determines the yearly energy requirements.

In the bin weather data of the studied city, it indicates that for 96% of the year, ambient conditions remain cold enough to operate without chillers- attached as appendix, For the remaining 4% of warmer days, the proposed solution incorporates ice thermal storage tanks. These tanks absorb heat during the day and re-freeze overnight when temperatures drop utilizing PCM. This design significantly enhances data center energy efficiency, reduces power demand and achieves substantial cost savings in electrical and mechanical infrastructure [3].

Set Up and Design Parameters

The table below tabulates the initial information gathered for the sites and design basis (Table 1 and Figure 1).

Parameter	Value
Peak ambient temperature	33°C
Typical data hall IT capacity	6.25MW
Dry air cooler capacity	1725kW
Max. supply/return water temperature (3.5°C increase from peak ambient)	36.5/46.5°C
Fan wall unit supply/return water temperature	24/34°C
Fan wall unit supply/return air temperature	29/40°C
Ice tank freezing temperature (from catalogue)	23°C

Table 1: Design Parameters.

PCM Type	Phase Change Temperature (C)	Phase Change Temperature (F)	Weight kg/TubeICE	Weight Lb/TubeICE	TubeICE (kWh/TubeICE)	TES Tank Capacity (kWh/m3)	TubeICE (Ton-hr/TubeICE)	TES Tank Capacity (Ton-hr/USG)
S89	89	192	2.7	6.0	0.124	55	0.035	0.053
S83	83	181	2.8	6.2	0.119	52	0.034	0.051
S72	72	162	2.9	6.4	0.113	50	0.032	0.049
S58	58	136	2.7	5.9	0.124	55	0.035	0.053
S50	50	122	2.8	6.2	0.081	36	0.023	0.035
S46	46	115	2.8	6.2	0.148	65	0.042	0.064
S44	44	111	2.8	6.2	0.081	36	0.023	0.035
S34	34	93	3.6	7.9	0.114	50	0.032	0.049
S32	32	90	2.6	5.7	0.135	59	0.038	0.058
S30	30	86	2.4	5.2	0.132	58	0.038	0.057
S27	27	81	2.7	6.0	0.145	64	0.041	0.062
S25	25	77	2.7	6.0	0.143	63	0.041	0.062
S23	23	73	2.7	6.0	0.143	63	0.041	0.062
S21	22	72	2.7	6.0	0.143	63	0.041	0.062
S19	19	66	2.7	5.9	0.109	48	0.031	0.047
S17	17	63	2.7	6.0	0.107	47	0.030	0.046
S15	15	59	2.7	5.9	0.106	47	0.030	0.046
S13	13	55	2.7	5.9	0.105	46	0.030	0.045
S10	10	50	2.6	5.8	0.102	45	0.029	0.044
S8	8	46	2.6	5.8	0.102	45	0.029	0.044
E0	0	32	1.9	4.2	0.177	78	0.050	0.076

Figure 1: Catalogue from phase change materials products limited (23˚C Freezing Temperature).

Sequence of operations

The main cooling circuit is as shown on Figure 2. With this configuration, there are two dry air cooler loops. One loop is for freezing the ice thermal storage tanks (4%) and another loop is for cooling the data halls directly (96%). The ice tank is connected to both loops and depending on the ambient temperature, the tank is either discharging (melting) or recharging (freezing) to maintain a supply water temperature of 24°C to the fan wall units. The following subsections will discuss this in further detail.

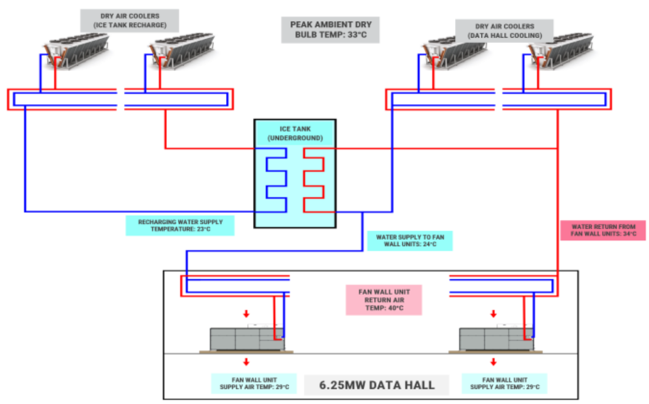

Figure 2: Prototypical data hall set up.

Tank recharge mode

At ambient temperatures of <20°C which occurs 96% of the year, the dry air coolers provide the cooling to the data halls (Figure 3-7 and Table 2-7).

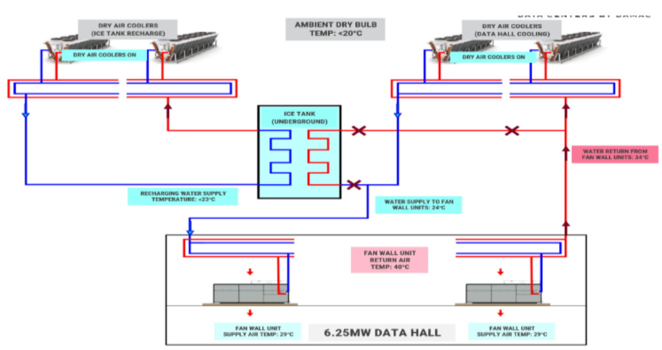

Figure 3: Tank recharge mode operation.

Data hall information		
IT capacity	6250	kW
Total load (+5% fan gains)	6562.5	kW
Total heat rejection (+5% tolerance and additional losses)	6890.6	kW
PUE (Option 1 with air cooled chillers)	1.4	
	8750	
5N/4DR string capacity	2187.5	
PUE (Option 2 with dry air coolers and PCM storage tank)	1.2	
5N/4DR string capacity	1874.77	

Table 2: Data hall information.

Dry air cooler equipment parameters	**Value**	**Unit**	**Remarks**
Cooling equipment	Dry air cooler		
Peak ambient temperature	33.1	deg.C	Based on the average ASHRAE N-20 Peak ambient dry-bulb temperature for the Finland sites.
Min. approach temperature	4	deg.C	Value listed is the max. approach temperature deg. C allowable. Manufacturer to provide lower figure if available.
Facility water operating deltaT	10	deg.C	Facility water deltaT based on optimal temperature difference of data hall cooling units.
Facility water max. supply water temperature at peak ambient temperature	37.1	deg.C	Facility water supply temperature is dependent on the peak ambient temperature and approach temperature of cooler.
Facility water max. return water temperature at peak ambient temperature	47.1	deg.C	Facility water return temperature is dependent on the facility water supply temperature and operating deltaT.
Heat rejection capacity	1723	kW	Max, heat rejection capacity based on the cooling load for one data hall.
Max. power input	manuf. To advise	kW	
Electrical data	400V/3ph/50Hz		
Fluid Flow Rate	41.14	L/s	
Fluid Composition	45%		Based on min. ambient temperature of -28 deg.
Air-cooled chiller equipment parameters (for air-cooled server data halls only)	**Value**	**Units**	**Remarks**
Cooling equipment	Air-cooled chiller		
Compressor type	Magnetic bearing oil-free		
Peak ambient temperature	32.5	deg-C	
Operating CHW temperature (supply/return)	20C/30C	deg-C	
Operating water deltaT	10	deg-C	
Heat rejection capacity	1723	kW	
Max. power input	manuf. To advise	kW	
Electrical data	400V/3ph/50Hz		
Fluid flow rate	41.14	L/s	
Fluid composition	45%		Based on min. ambient temperature of -28 deg C
Free cooling?			Provide two options, with and without free cooling

Table 3: Calculations.

Description	Units	Value	Remarks
Cooling load per data hall	6890.625	kW	Considering additional losses
Equivalent water flow rate	164.57	kg/sec	
PCM storage capacity	40	kW-hr/cu.m	Average based from PCM vendors
Hours of storage (full discharge)	4	hrs	based on Finland worst-day data from HAP weather file
Hours of storage (partial discharge)	10	hrs	based on Finland worst-day data from HAP weather file
Weather bin data worst-day peak temperature	26	deg.C	
Operating water temperature (tank discharge water temp)	24	deg.C	
Operating water return temperature (from fan wall units)	34	deg.C	
Tank supply water temp	23	deg.C	
Ambient temp to start discharge	20	deg.C	Considering 24C/34C operating temperature
Total cooling capacity storage (full discharge)	27562.5	kW-hr	
Total cooling capacity storage (partial discharge)	41343.75	kW-hr	Considering that at other temperatures, partial cooling is provided by the dry air coolers
Total stored capacity requirement	68906.25	kW-hr	
Provision (10% capacity)	75796.88	kW-hr	
Min. volume requirement per data hall	1894.922	cu.M	
Tank quantity (N)	2	nos.	
Tank quantity (N+R)	3	nos.	Uptime requirement N+1
Diameter	8.9679	m	
Height	15	m	
Recharging duration	10	hrs	
Total additional kw capacity on dry air coolers	7579.7	kW	
Additional dry air coolers (for recharging)	4.4	nos.	

Table 4: PCM tank sizing.

Date:	**03-Aug**	
Worst day temperatures		
Hours	**Temp., C**	**Discharging?**
0	19.7	0
100	18.8	0
200	18	0
300	17.6	0
400	17.2	0
500	16.8	0
600	18.1	0
700	19.4	0
800	20.7	1
900	22.1	1
1000	23.6	1
1100	25	1
1200	25.3	1
1300	25.7	1
1400	26	1
1500	26.1	1
1600	26.1	1
1700	26.2	1
1800	25.2	1
1900	24.1	1
2000	23.1	1
2100	20.7	1
2200	18.4	0
2300	16	0
Hours discharging		14
% hours of day discharging		58%

Table 5: Tank sizing for 14 hours.

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Weather summery	
Maximum DB temp, C	28.7
Maximum DB temp, C	-21.7
Max WB temp, C	20.2
Coincident DB temp, C	24.2
Ambient temp, C	Number of hours
52	0
51	0
50	0
49	0
48	0
47	0
46	0
45	0
44	0
43	0
42	0
41	0
40	0
39	0
38	0
37	0
36	0
35	0
34	0
33	0
32	0
31	0
30	0
29	5
28	9
27	12
26	18
25	40
24	44
23	62
22	71
21	88
20	118
19	143
18	188
17	211
16	272
15	290
14	310
13	362
12	315
11	321
10	305
9	270
8	282
7	252
6	279
5	268
4	256
3	264
2	469
1	519
0	2717
Total	8760

Ambient temp, C	Numbers hours
50	0
45	0
40	0
35	0
30	44
25	305
20	932
15	1598
10	1388
5	1776
0	2717
Total	8760

Ambient temp, C	Number of hours
50	0
45	0
40	0
37.6	0
33.8	0
33.2	0
32	0
30.1	1
28.6	18
26.5	55
24.2	116
22	143
20.2	244
18.2	408
16.1	98
15.7	1796
10	1388
5	1776
0	2717
Total	8760

Table 6: Weather summary.

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Operation	Ambient temp. C	No. of hours	% Operation
Full chiller cooling	20.1	349	4%
Full free cooling	20	8411	96%
	Total hours	8760	

Table 7: Annual cooling requirements. **Note:** Consideration is 4C approach temp. for dry air coolers.

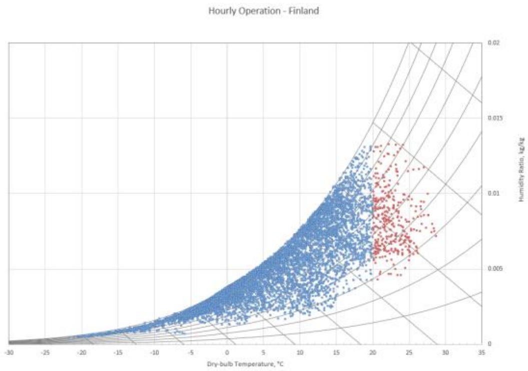

Figure 4: Psychrometric chart.

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2021 ASHRAE Handbook - Fundamentals (SI)

RAAHE LAPALUOTO, FINLAND (WMO: 028720)

Lat:64.6658N Long:24.4069E Elev:2 StdP: 101.30 Time zone:2.00 (EUE) Period:08-19 WBAN:99999

Annual Heating, Humidification, and Ventilation Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		WSF
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
1	-23.2	-20.0	-26.0	0.4	-23.1	-22.6	0.5	-19.9	18.7	-0.3	17.6	-0.5	3.2	70	0.808

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	5.1	24.4	18.5	22.3	17.7	20.6	16.7	19.8	23.1	18.5	21.4	17.3	20.0	4.5	10

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
18.6	13.4	21.5	17.2	12.3	20.2	16.0	11.4	19.1	56.6	23.1	52.3	21.7	48.6	20.0	24.2

Extreme Annual Design Conditions

Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
15.6	13.8	12.2	DB	-25.0	27.8	3.3	3.2	-27.4	30.1	-29.3	32.0	-31.1	33.8	-33.4	36.2
			WB	-24.5	20.9	4.0	2.2	-27.4	22.5	-29.7	23.8	-32.0	25.0	-34.9	26.6

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours		DBAvg	4.1	-7.6	-6.5	-3.7	1.2	8.0	12.6	16.5	15.0	11.1	4.6	0.5	-3.0
		DBStd	9.23	6.29	6.70	4.80	3.07	4.32	3.40	3.28	2.86	2.86	3.25	4.11	5.68
		HDD10.0	2679	547	462	424	264	93	12	1	1	21	169	283	404
		HDD18.3	5222	805	695	682	513	323	177	77	112	217	426	533	662
		CDD10.0	531	0	0	0	1	29	88	202	154	55	1	0	0
		CDD18.3	32	0	0	0	0	2	3	21	7	0	0	0	0
		CDH23.3	127	0	0	0	0	7	15	80	25	0	0	0	0
		CDH26.7	29	0	0	0	0	1	4	19	5	0	0	0	0
Wind		WSAvg	6.0	6.3	6.4	6.4	5.5	5.7	5.7	4.9	5.5	5.9	6.4	6.6	7.1
Precipitation		PrecAvg	544	38	30	27	28	42	51	71	62	52	51	48	43
		PrecMax	666	68	57	57	66	81	111	131	114	102	87	94	94
		PrecMin	405	10	7	5	10	13	5	15	17	19	5	8	13
		PrecStd	78	17	14	13	14	19	28	29	28	25	23	20	19
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		2.9	3.6	6.2	12.4	24.2	25.1	29.5	26.5	20.2	12.6	8.5	5.3
		MCWB		2.3	2.5	2.6	9.2	14.4	18.2	19.3	19.7	15.3	10.9	7.2	4.4
	2%	DB		1.9	2.7	3.7	9.0	19.9	21.5	25.2	22.5	17.6	11.1	7.5	4.1
		MCWB		1.1	1.6	2.0	5.9	13.1	15.8	19.4	18.4	14.3	9.6	6.6	3.0
	5%	DB		1.3	1.9	2.9	6.6	16.6	19.4	23.3	20.5	16.0	9.8	6.3	3.2
		MCWB		0.7	1.0	1.4	4.2	11.9	15.0	18.6	17.2	13.6	8.5	5.5	2.3
	10%	DB		0.4	1.1	2.0	5.3	14.2	17.8	21.6	19.1	14.9	8.9	5.3	2.4
		MCWB		-0.1	0.4	0.8	3.3	10.1	14.1	17.8	16.3	13.0	7.7	4.5	1.6
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		2.5	2.8	3.6	10.0	15.5	18.8	21.9	20.7	16.1	11.5	7.6	4.5
		MCDB		2.7	3.5	5.4	12.0	21.1	22.6	24.6	24.5	18.9	12.2	8.1	5.0
	2%	WB		1.3	1.8	2.3	6.0	13.9	16.9	20.5	19.1	15.0	10.0	6.7	3.2
		MCDB		1.7	2.5	3.4	8.6	18.8	20.2	23.7	22.1	16.8	10.8	7.4	3.8
	5%	WB		0.7	1.2	1.6	4.6	12.2	15.6	19.3	17.7	14.1	8.7	5.6	2.4
		MCDB		1.1	1.8	2.6	6.2	16.5	18.8	22.5	20.0	15.4	9.5	6.2	3.0
	10%	WB		0.0	0.5	1.0	3.5	10.6	14.4	18.1	16.6	13.4	7.9	4.6	1.7
		MCDB		0.5	1.1	1.8	5.0	13.6	17.3	21.1	18.7	14.7	8.8	5.2	2.3
Mean Daily Temperature Range		MDBR		5.2	5.0	5.4	4.8	5.6	5.2	5.1	5.1	4.5	3.9	3.3	3.8
	5% DB	MCDBR		3.1	3.5	4.1	7.0	9.7	8.5	8.4	7.4	6.8	4.3	3.4	3.1
		MCWBR		3.1	3.1	3.1	4.8	5.4	4.8	4.6	4.5	4.5	3.7	3.4	2.8
	5% WB	MCDBR		3.4	3.5	3.8	6.6	8.9	7.2	7.3	6.2	5.4	4.1	3.3	3.0
		MCWBR		3.4	3.2	3.1	4.9	5.4	4.6	4.6	4.3	4.5	3.7	3.4	2.8
Clear Sky Solar Irradiance		taub		0.213	0.279	0.308	0.346	0.347	0.351	0.370	0.355	0.332	0.310	0.343	0.352
		taud		1.967	2.115	2.163	2.222	2.424	2.479	2.446	2.480	2.525	2.362	2.539	2.585
		Ebn at noon		313	605	762	820	862	866	834	814	758	586	286	130
		Edn at noon		25	61	90	108	98	95	96	84	66	49	22	13
All-Sky Solar Radiation		RadAvg		0.12	0.65	2.12	3.78	4.98	5.57	5.12	3.82	2.13	0.77	0.17	0.04
		RadStd		0.01	0.13	0.22	0.31	0.48	0.46	0.47	0.36	0.22	0.13	0.03	0.00

Historical Trends

	DBAvg	Heating		Cooling			Degree-Days			
		99% DB	99% DP	1% DB	1% WB	1% DP	HDD10.0	HDD18.3	CDD10.0	CDD18.3
Station Only	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Regional (0 neighbors)	+0.48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

CDDn	Cooling degree-days base n°C, °C-day
CDHn	Cooling degree-hours base n°C, °C-hour
DB	Dry bulb temperature, °C
DP	Dew point temperature, °C
Ebn,noon Edh,noon	Clear sky beam normal and diffuse horizontal irradiances at solar noon, W/m2
Elev	Elevation, m
Enth	Enthalpy, kJ/kg
HDDn	Heating degree-days base n°C, °C-day
PCWD	Prevailing coincident wind direction, °,0 = North, 90 = East

Figure 5: Ashrae climatic design conditions.

Lat	Latitude, °
Long	Longitude, °
MCDB	Mean coincident dry bulb temperature, °C
MCDBR	Mean coincident dry bulb temp. range, °C
MCDP	Mean coincident dew point temperature, °C
MCWB	Mean coincident wet bulb temperature, °C
MCWBR	Mean coincident wet bulb temp. range, °C
MCWS	Mean coincident wind speed, m/s
MDBR	Mean dry bulb temp. range, °C
WS	Wind speed, m/s

Period	Years used to calculate the design conditions
Sd	Standard deviation of daily average temperature, °C
StdP	Standard pressure at station elevation, kPa
taub	Clear sky optical depth for beam irradiance
taud	Clear sky optical depth for diffuse irradiance
Tavg	Average temperature, °C
Time Zone	Hours ahead or behind UTC
WB	Wet bulb temperature, °C
Hours 8/4 & 12.8/20.6	Number of hours between 8 a.m. and 4 p.m with DB between 12.8 and 20.6 °C
HR	Humidity ratio, g of moisture per kg of dry air

Figure 6: Abbreviations.

DRY COOLER | LV-LA211T6X-096Z105

For Dry cooler V-bank with the selected fluid in some countries (e.g. Germany) a glycol tray is predescribed. Please observe the local regulations and add this option to your selection if required.

When loading or unloading this unit, use Crane and all available lifting Points, do not use Forklift

BASIC DATA

Capacity [kW]	1.739,67	**Pressure drop [kPa]**	54	**Passes (8)**	2
Volume flow rate [m³/h]	168,55	**Ambient [°C]**	32,5	**Ends**	Same ends
Fluid	Ethylene Glycol 45,0 % vol	**Rel. humidity [%] (9)**	66,0	**Internal fouling factor [x10^-4 (m²K)/W]**	0,00
Fluid inlet [°C]	46,5	**Coils x Sections x Circuits**	2 x 1 x 213 (Total circuits X: 426)	**External fouling factor [x10^-4 (m²K)/W]**	0,00
Fluid outlet [°C]	36,5				

AIR DATA

Air volume flow	681.692 m³/h
Fans in stand-by	-
Ext. static pressure	0 Pa
Altitude	0 m
Air outlet temp.	40,3 °C
Coil direction	V-Bank
Air direction	Vertical

HEAT EXCHANGER

Surface	8.107,6 m²
Fin spacing	2,3 mm (11 FPI)
Internal volume	1.346,2 dm³
Int. fluid velocity	0,99 m/s
Max. operating pressure (1)	10 bar

MATERIALS

Tubes	Copper
Fins	Alu
Casing	Galvanised steel
Finish	Painted RAL 7032 (Pebble Grey)
Corrosion class	-

FAN(S)

22 PIECE(S) : 400V/3PH/50-60HZ; IP55	
Operation mode	EC
Fan diameter	960 mm
Range of temp.	-35,0 to 55,0 °C
Sound power LwA [(2)]	101 dB(A)
Sound pressure LpA (10m) [(2)]	68 dB(A)
ErP	2015
Energy efficiency class	

SOUND POWER SPECTRUM	
Sound power spectrum 125 Hz	107 dB
Sound power spectrum 250 Hz	102 dB
Sound power spectrum 500 Hz	101 dB
Sound power spectrum 1 kHz	96 dB
Sound power spectrum 2 kHz	91 dB
Sound power spectrum 4 kHz	87 dB
Sound power spectrum 8 kHz	76 dB

FAN SET SERIAL PLATE DATA (PER FAN) [(3)]	
Speed	1100 rpm
Power nominal	4.400 W
Starting current	7,2 A
Full load current	5,8 A

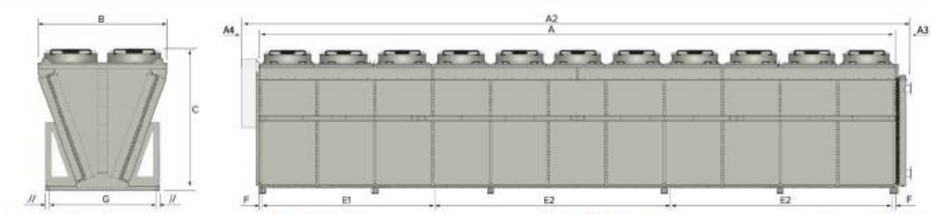
SELECTED SPEED DATA (PER FAN) [(3)]	
Speed	1050 rpm
Power input	3.269 W
Operating current	5,0 A
Control voltage EC	9,5 V

CONNECTIONS	
Connections in & out	4 x 125 mm
Type	Flange

WEIGHT [(4)]	
Dry weight	6.149 kg
Weight incl. fluid	7.581 kg

REGULATION(S)	
PED Category	0

DIMENSIONS [(4)]



A 13.200 mm	B 2.503 mm	C 3.299 mm	A2 13.579 mm
A3 309 mm	A4 70 mm	G 2.180 mm	F 50 mm

OPTIONS AND ACCESSORIES (EXCL. VAT)

CATEGORY		OPTION GROUP	ITEM	ITEM NO.
Coil	016.10	Connections	4 x Flanges, 125 mm	
Fan(s)	371.7	Wiring	Fans wired to two central junction boxes	

DELIVERY TIME

Expected factory lead time EXW, may be increased by selected options. The delivery time is only indicative:

Figure 7: Data sheet.

The flow of water and heat rejection are as listed below starting from the fan wall unit:

1. Warm water from the fan wall unit goes to the dry air cooler.
2. The dry air cooler rejects the heat and cools the water.
3. The cooled water bypasses the ice tank (melted) and goes to the fan wall unit.
4. The fan wall unit receives cold water.
5. The fan wall unit supplies cold air into the servers.
6. The fan wall unit received warm air from the servers.
7. The fan wall unit converts the cold water into warm water.
8. The process repeats from step 1.

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The flow of water and heat rejection for tank freezing are as listed below:

1. The salt mixture in the ice tank is melted.
2. Cold water from the dry air cooler enters the tank.
3. The cold water/glycol mixture comes into contact with the tank.
4. The salt mixture freezes.
5. The water/glycol mixture exits the tank as warm water.
6. The warm water returns to the dry air cooler and converts to cold water.
7. The process repeats from step 1 until the entire tank is frozen.
8. If the entire tank is frozen, the tank can be bypassed.

Tank recharge mode

During hours where the ambient temperature is >20°C, the dry air coolers cannot reduce the supply water temperature to the fan wall units to the required temperature. In this case, the ice tanks will provide the necessary cooling until the temperature drops to <20°C again.

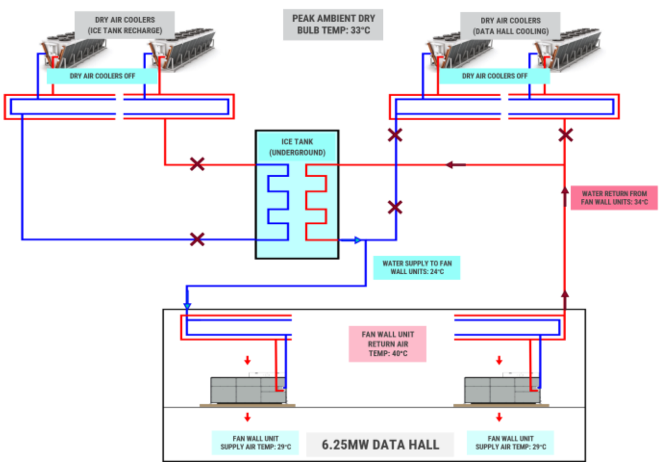

Figure 14: Tank Recharge Mode Operation.

The flow of water and heat rejection are as listed below starting from the fan wall unit:

1. Warm water exits the fan wall unit.
2. The warm water enters the ice tank (frozen) and interacts with the ice.
3. The ice melts.
4. The warm water is converted to cold water and exits the tank.
5. The cold water is supplied to the fan wall units.
6. The fan wall unit supplies cold air into the servers.
7. The fan wall unit received warm air from the servers.
8. The fan wall unit converts the cold water into warm water.
9. The process repeats from step 1.

The dry air coolers for ice tank recharging are shut off while the ambient temperature is >20°C and will operate only once the temperature drops back down and restart the tank recharge mode.

Conclusion

This study presents an innovative, sustainable cooling approach integrating dry air coolers and ice tanks to optimize data center efficiency in cold climates. By leveraging Finland’s favorable temperature profile, the proposed hybrid system demonstrates significant reductions in power consumption, minimizing reliance on traditional air-cooled chillers. With dry air coolers handling the primary cooling load for 96% of the year and ice tanks providing supplemental cooling during warmer periods, chiller operation is limited to just 4% of the year. This configuration not only achieves considerable energy savings but also reduces the mechanical and electrical infrastructure burden, promoting long-term operational sustainability. As data center expansion continues worldwide, this model serves as a scalable, energy-efficient cooling solution adaptable to other cold climate regions, supporting the industry's commitment to greener and more resilient infrastructure. The PUE hence is reduced from approximately 1.4 to 1.2 and the CUE is significantly reduced.

Conflict of interest

The author declares no conflict of interest.

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