National Institute of
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AIST

New Modular Green Data Center combining various energy-saving technologies

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SC13 Booth #3309

Development of New Modular Data Center

Energy-saving technologies developed by NEDO Green IT PJ (2008–2012)

NEDO: New Energy and Industrial Technology Development Organization

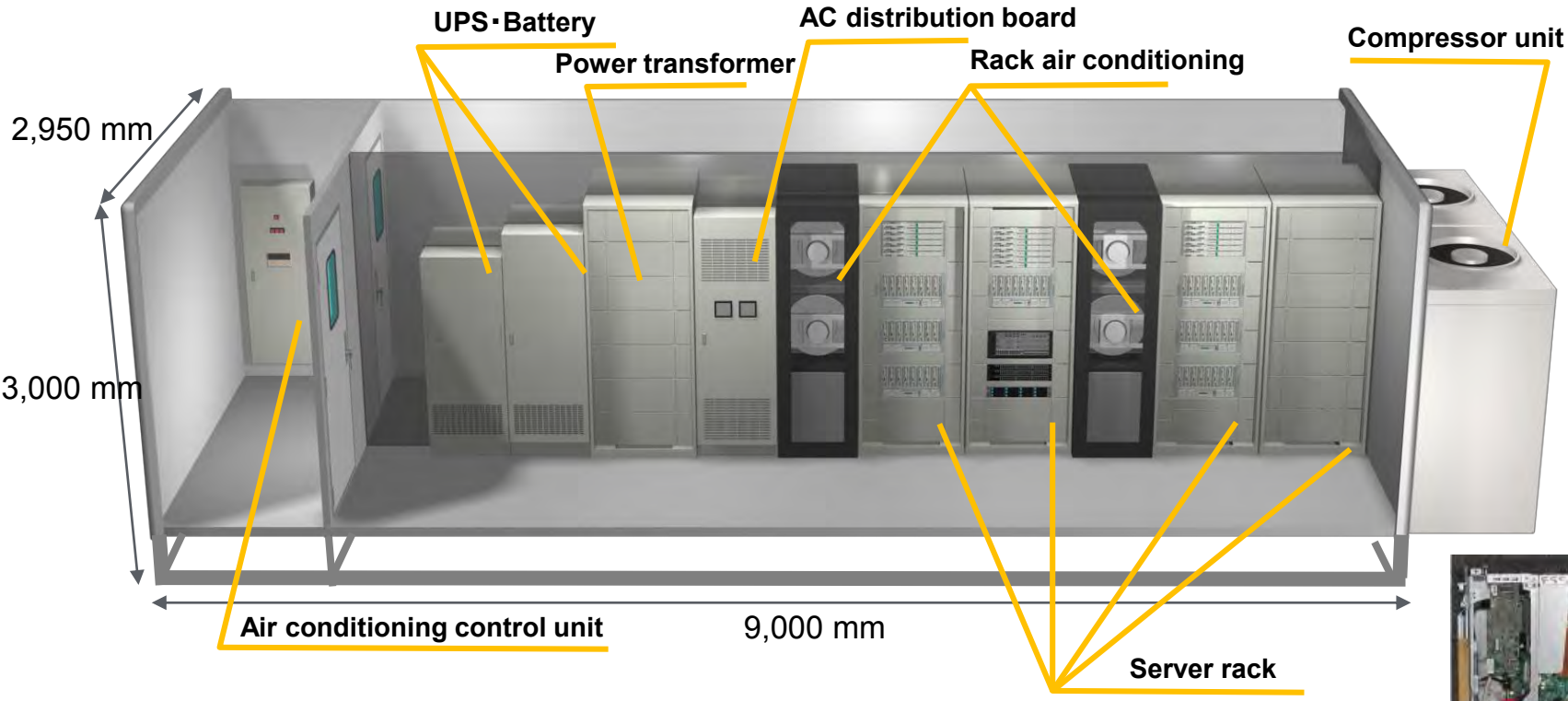
New Modular Data Center was built by combining the following technologies

- **Server Liquid Cooling: SOHKi**
- **Fresh air intake: AIST, NTT Facilities**
- **High-voltage Direct Current: NTT Facilities, Mitsubishi Electric, Nagasaki University**
- **Green Cloud Operation: NEC**
- **Modeling and evaluation: AIST, University of Tsukuba, NTT Communications**

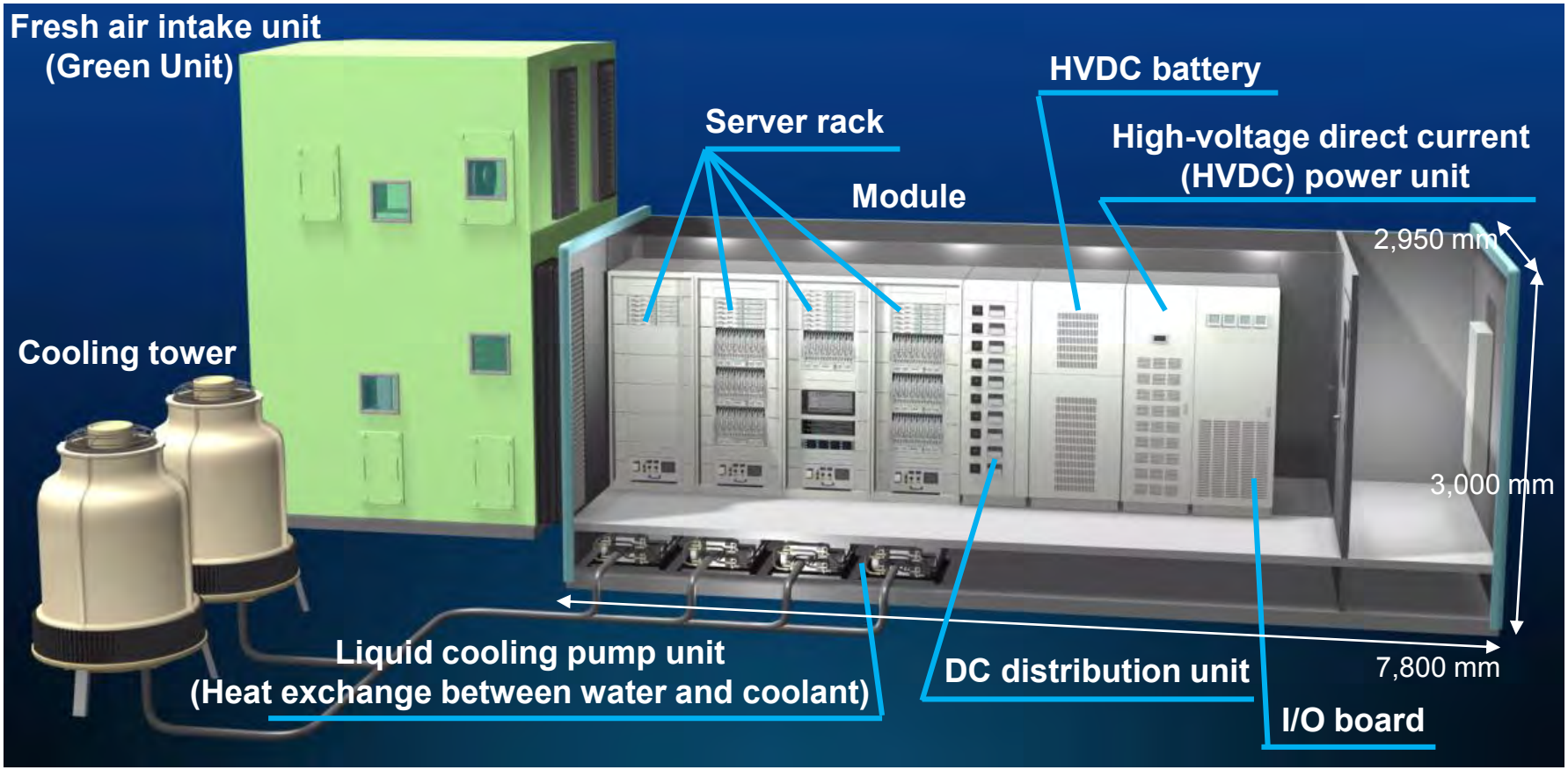
		General Modular DC	New Modular Data Center
Heat removal	Server	Air cooling	**Liquid cooling**
	Room	Air conditioner	**Fresh air intake**
Power supply		Alternating current (AC) All power units always ON	**High-voltage Direct Current (HVDC)** **Adaptive: power units ON/OFF according to power load**
IT Operation		All machines always ON	**Machines ON/OFF according to user access**

General Modular Data Center

- **IT equipment, cooling and power facilities, and module are designed and produced as separate units. There is no optimization across the data center.**



New Modular Data Center



Main IT equipment

Same IT equipment are installed both modular data centers

1U server 20 nodes

- **NEC Express5800/R110d-1E (4C/E3-1270)**
- **Rated power consumption 260 W**

Blade server 7 chassis

- **NEC SIGMA BLADE M**
- **Express5800/Sandy Bridge-EP (115 W) 2 processors 8 nodes/ chassis**
- **Rated power consumption 4027 W**

Network switch 1 chassis

- **ALAXALA AX6604S (-DC)**
- **Rated power consumption 1618 W**

Full view of New Modular Data Center

1. Heat Removal: Liquid Cooling System

General server
Air cooled

Large amount of heat
Large amount of air flow

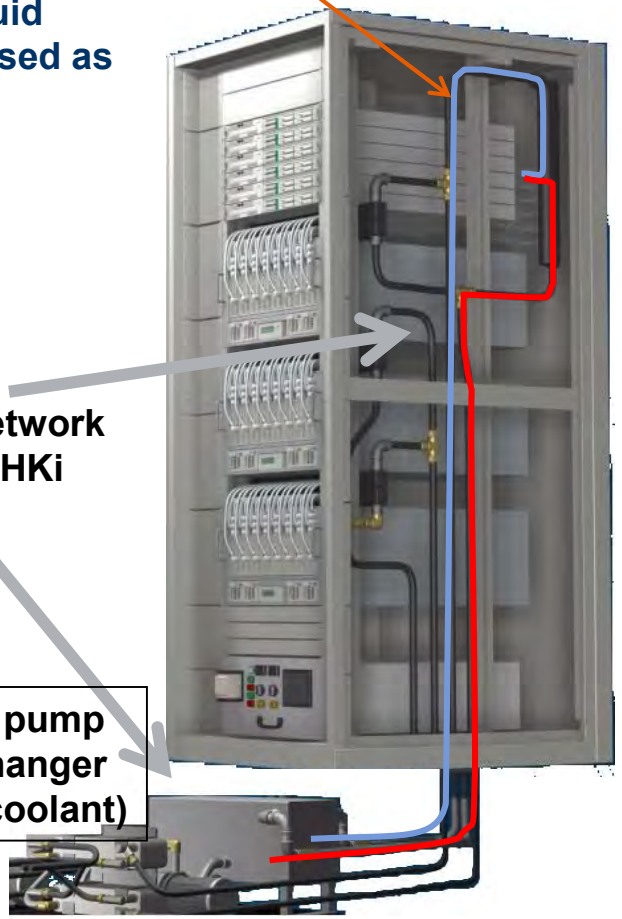
New Server
Liquid cooled & fanless

Less heat
Less air flow

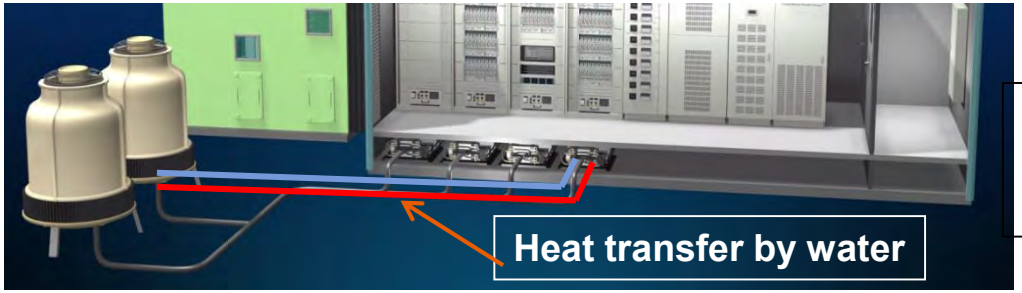
Heat transfer by coolant

Fluorine liquid (Novec) is used as a coolant

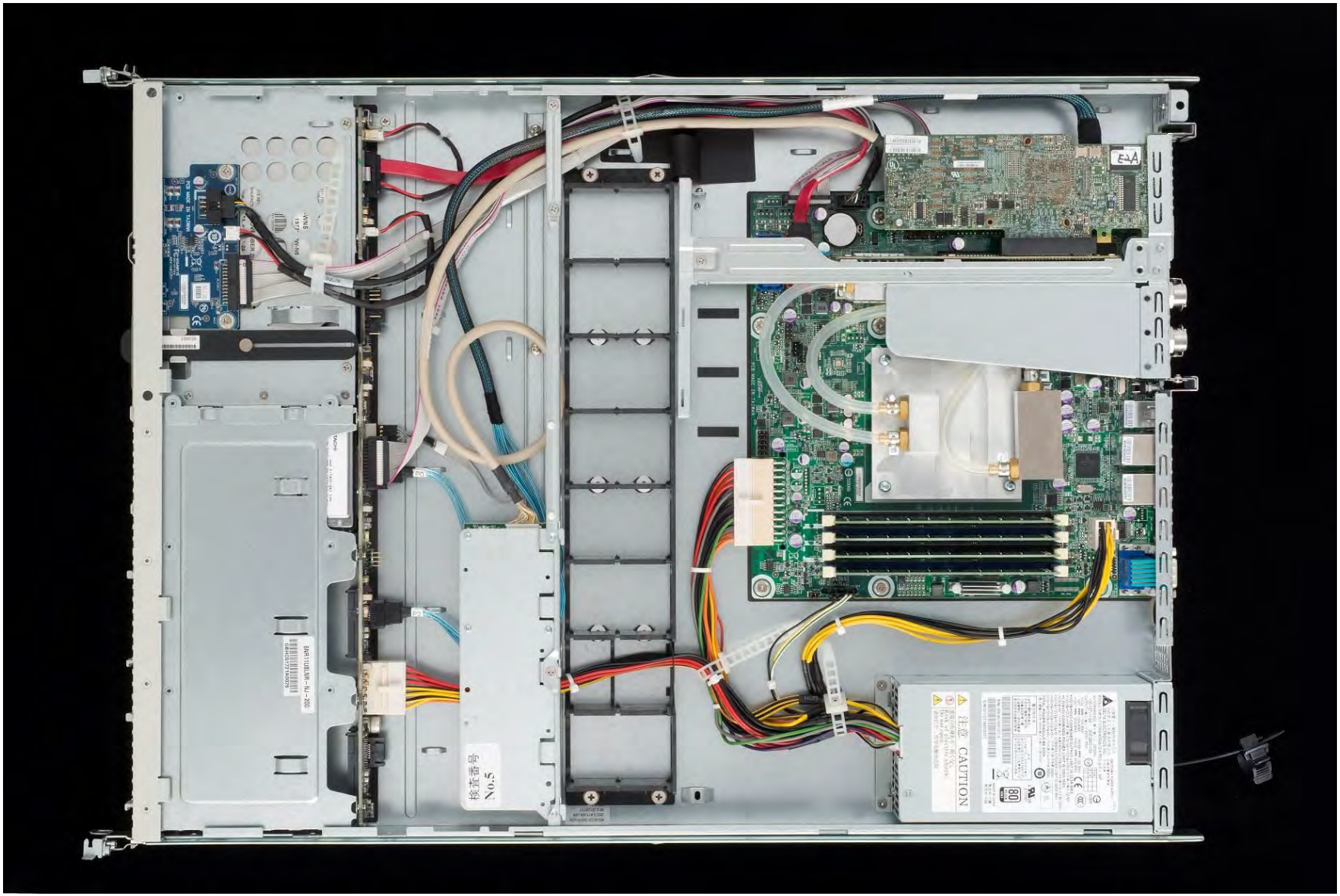
Liquid cooling network developed by SOHKi



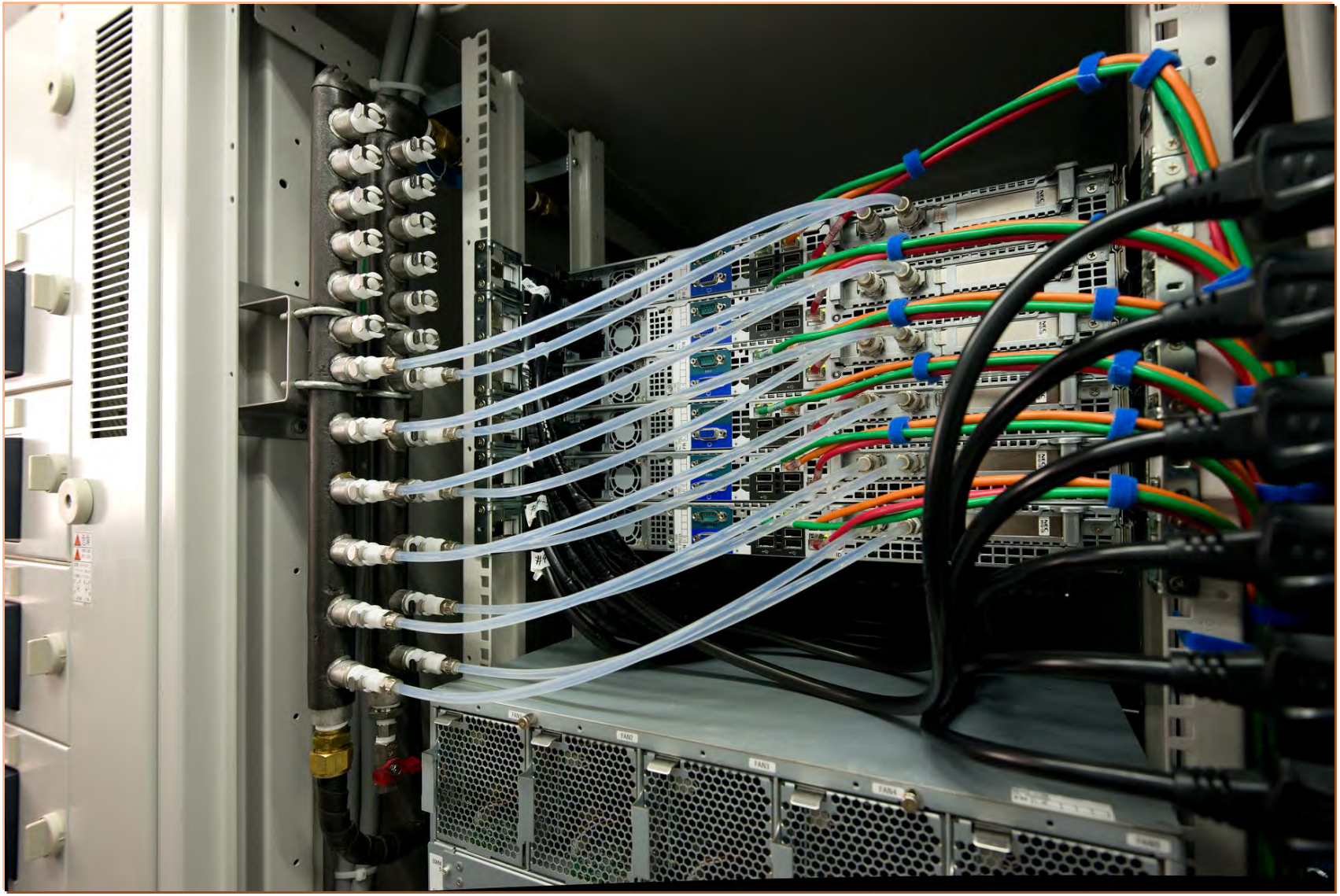
Circulating pump & heat exchanger (water and coolant)



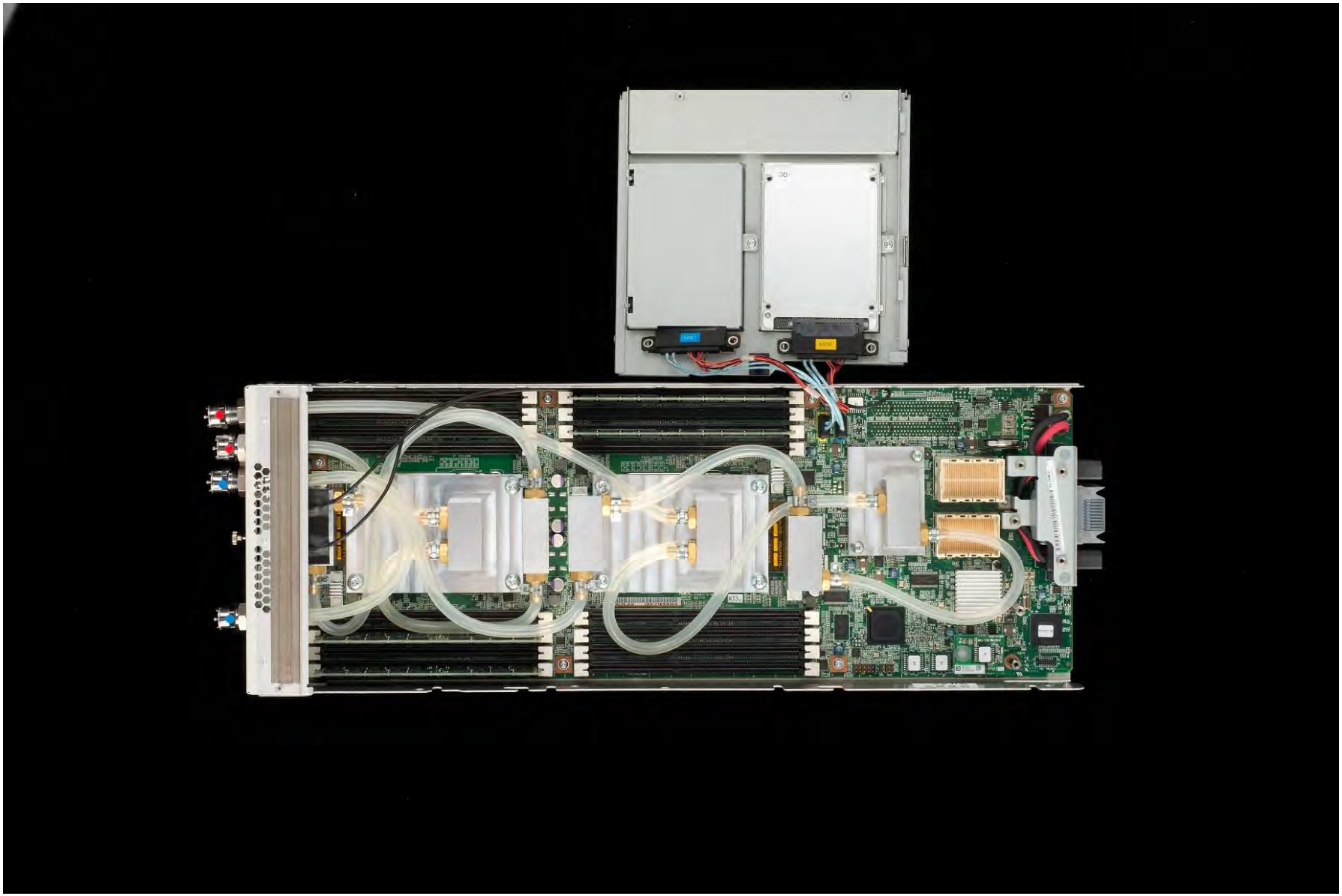
1U Liquid-cooled Fanless Server



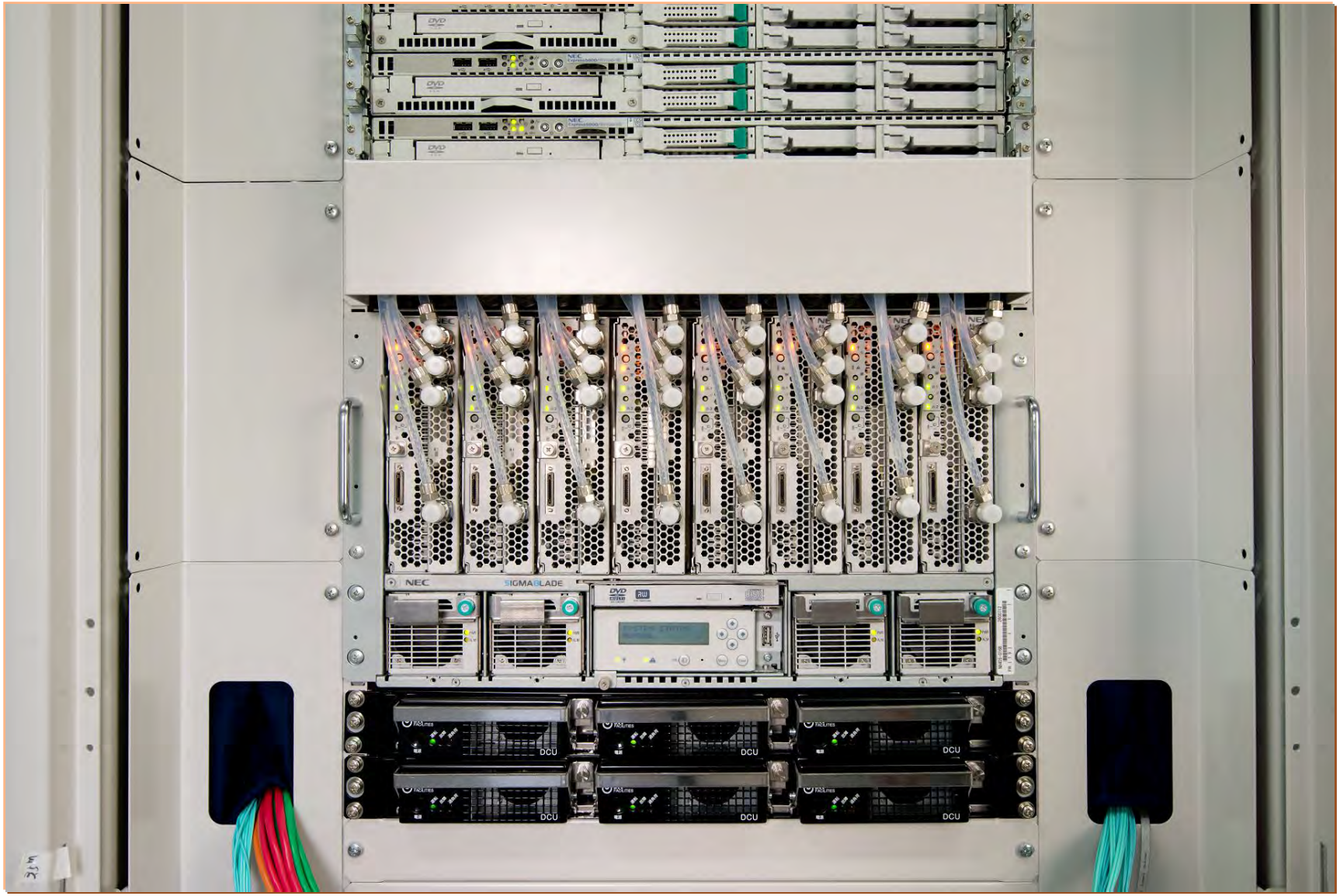
1U Liquid-cooled Fanless Server Racking



Liquid-cooled Blade Server



Liquid-cooled Blade Server Racking



Liquid-cooled Network in Rack

Liquid-cooling Pump and Heat Exchanger

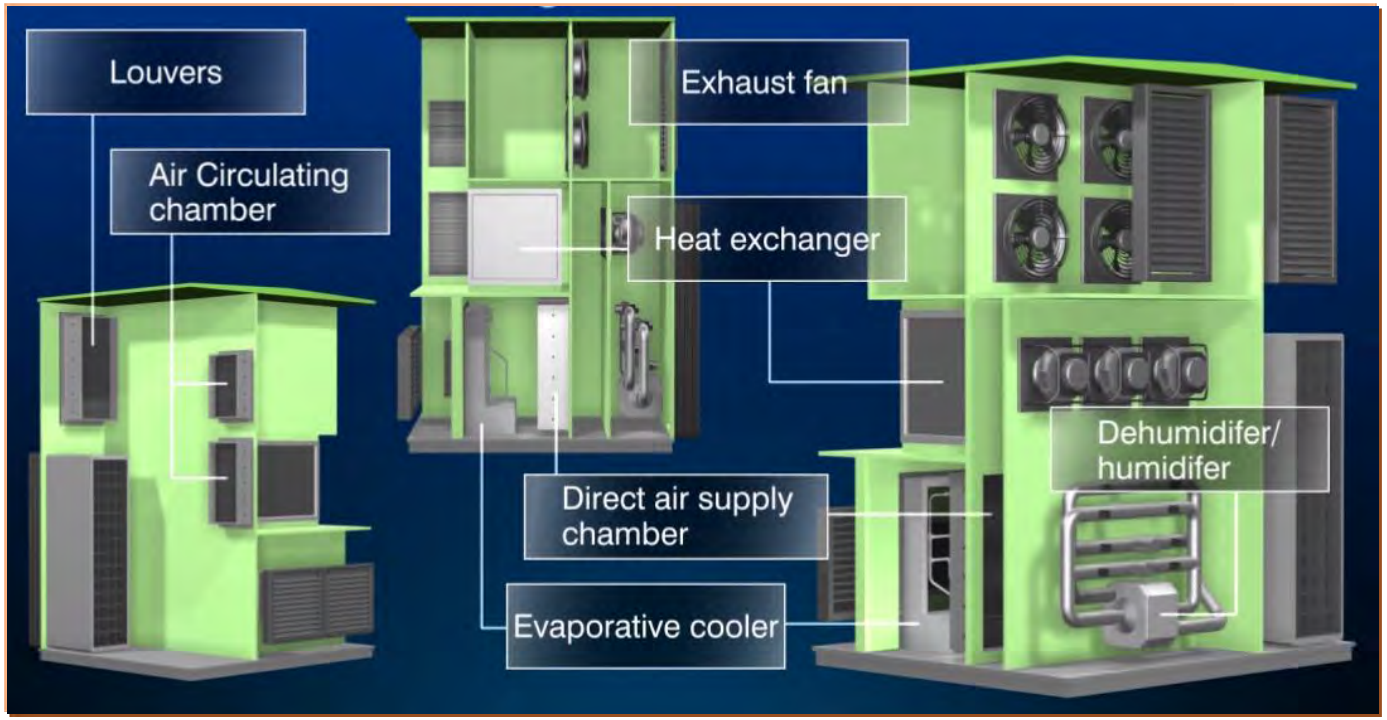
Under the floor, top view

2. Heat Removal: Green Unit

2. Heat Removal: Green Unit Structure

Heat removal from module

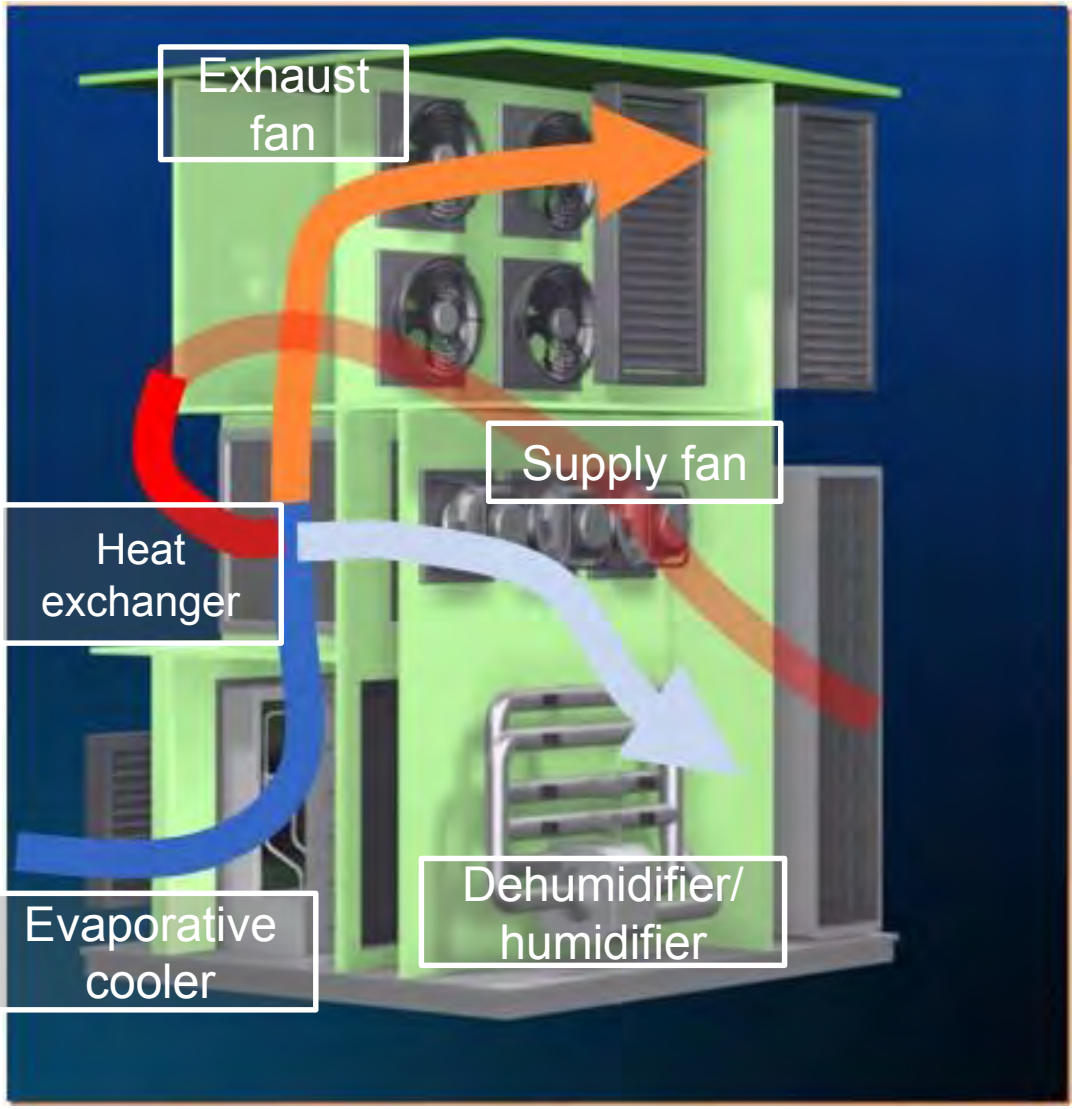
- **Remaining heat is removed by fresh air intake unit (Green Unit)**
- **The Green Unit contains an evaporative cooler, heat exchanger, and dehumidifier/humidifier. This combination of equipment enables air with a suitable temperature/humidity/flow to be supplied to the server.**
- **Large fans for supplying air greatly reduce power consumption and are quiet.**



2. Heat Removal: Green Unit Operation

Basic operation

- **Air from module is cooled by heat exchanger and returned to module**
- **Fresh air is used to remove heat from circulated air through heat exchanger**
- **Evaporative cooler may be used during hot season**



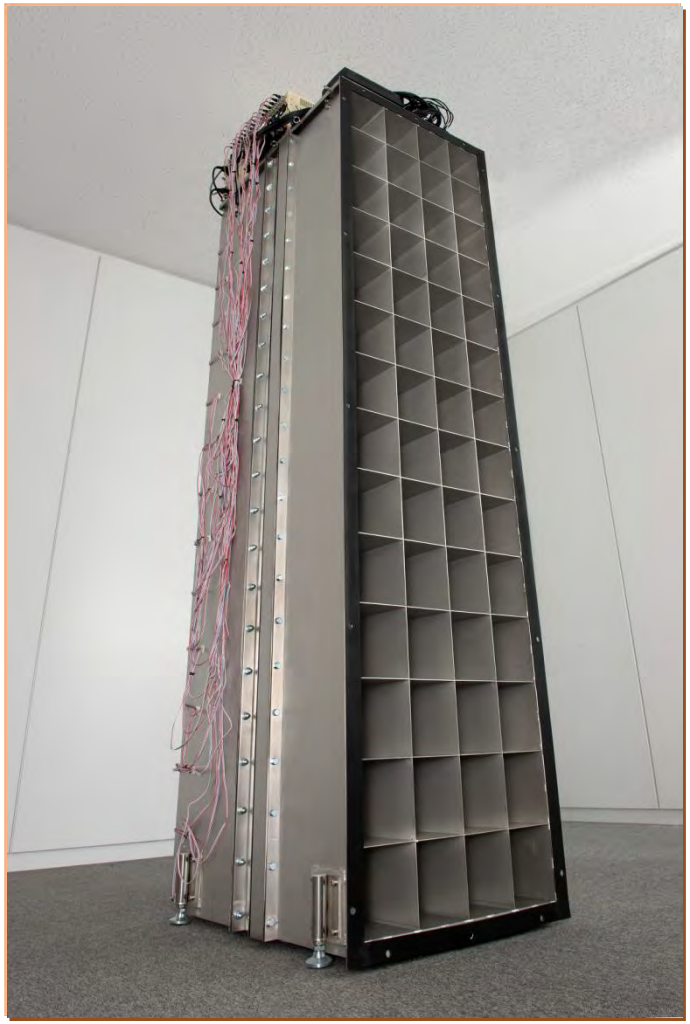
Module and Green Unit Connection

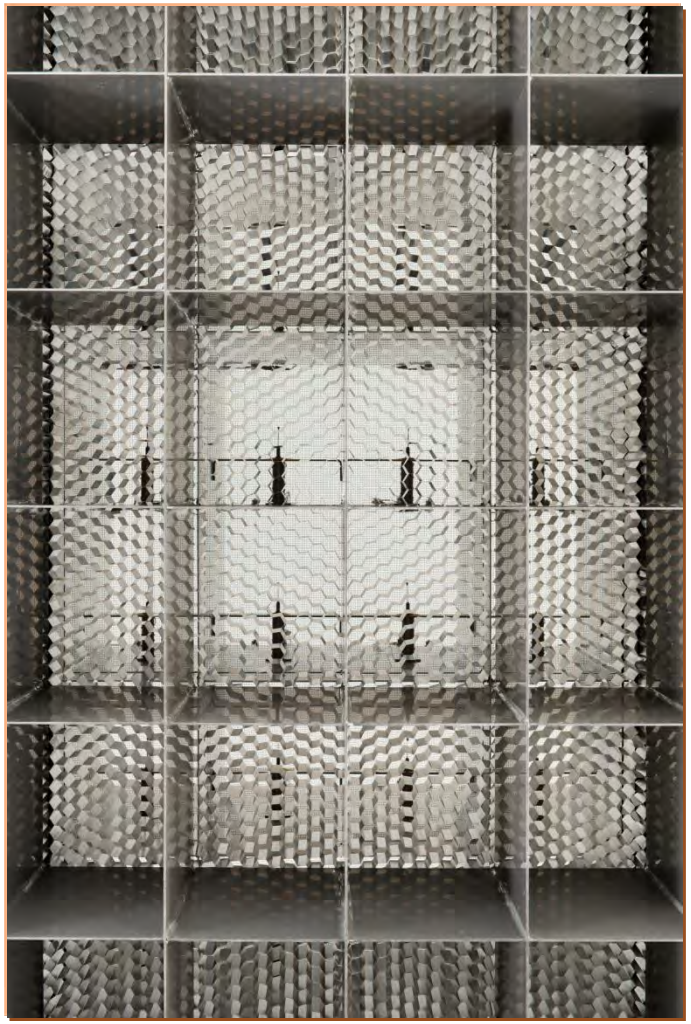
- **Green Unit ⇒ Module**

- Module ⇒ Green Unit

Flow Rate Meter

- **Real-time monitoring of flow rate**





3. Power supply: High-voltage Direct Current

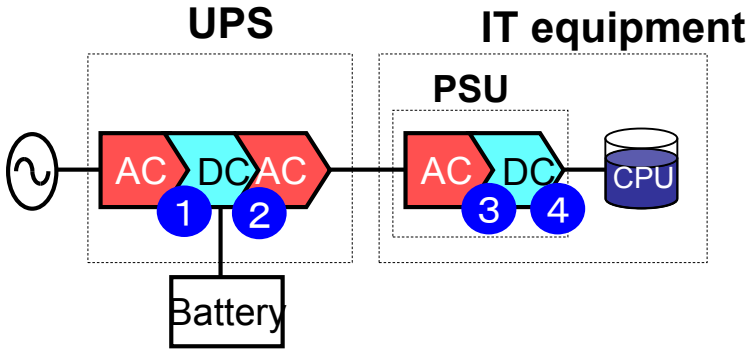
Alternating current (General)

- Alternating current system requires repeated AC/DC conversion for UPS (uninterruptible power supply)
- PSU (power supply unit) in IT equipment transforms AC to DC again
- Huge power loss

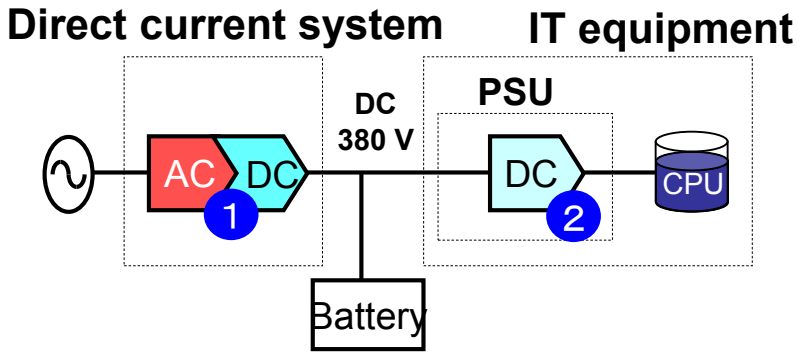
Direct current (New)

- Less AC/DC conversion by using direct current
- Efficient power supply system by using high voltage (380 V)

Alternating current (General)



High-voltage Direct Current (New)



NTT Facilities, Mitsubishi Electric, Nagasaki University

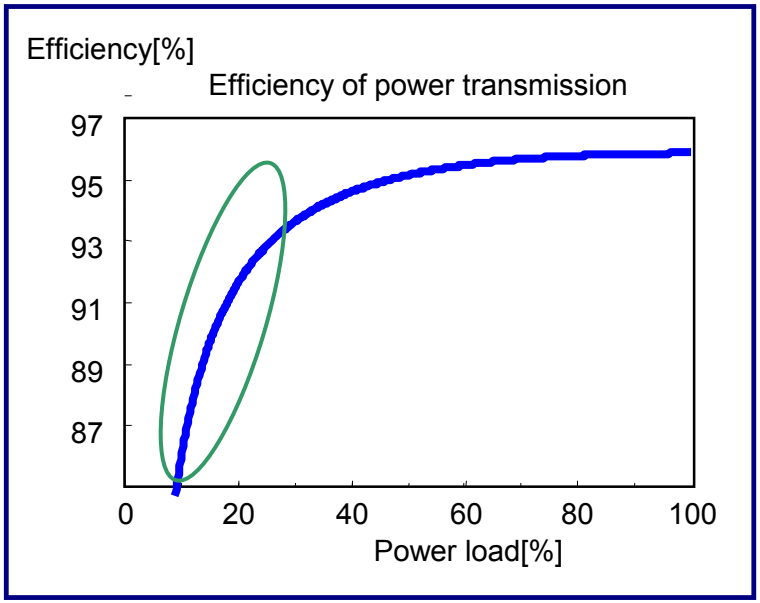
3. Adaptive Management

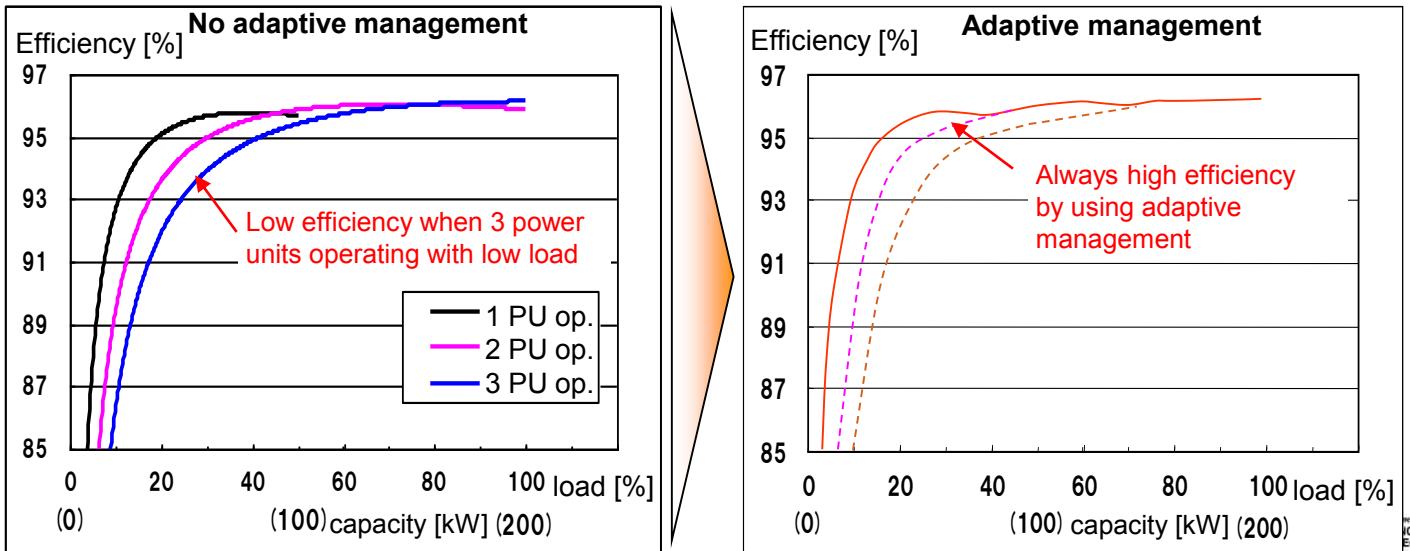
General management

- Power unit is designed according to the rated power of IT equipment.
- Power conversion efficiency is very low when power load is low.

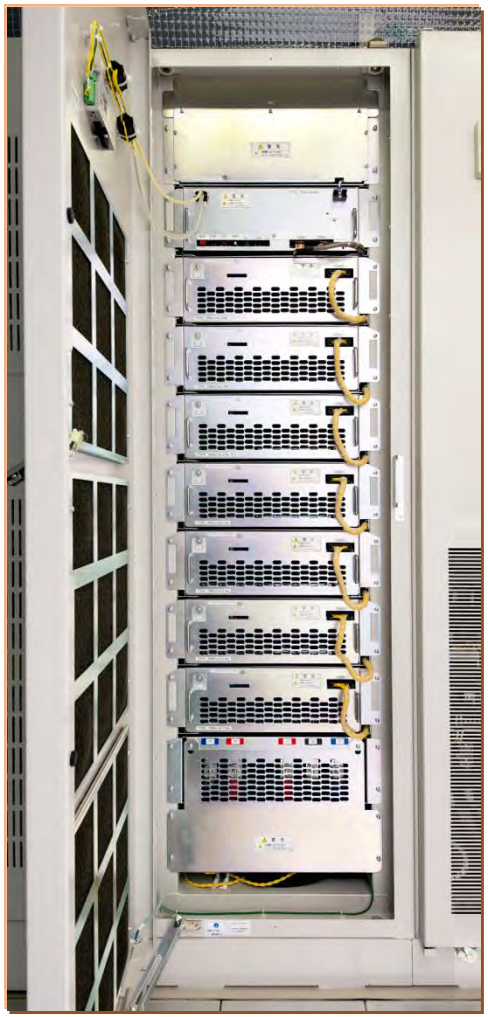
Adaptive management

- Multiple power units are used and number of power units (PU) is optimized to keep the power conversion efficiency high.
- Highly compatible with DC power supply system.





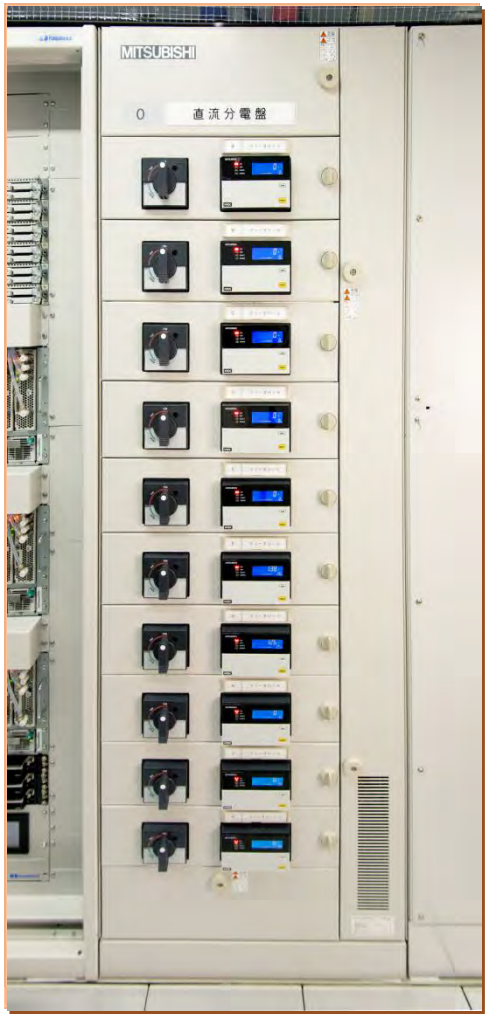
Power Supply Rack



- HVDC unit

- I/O board

Power Wiring

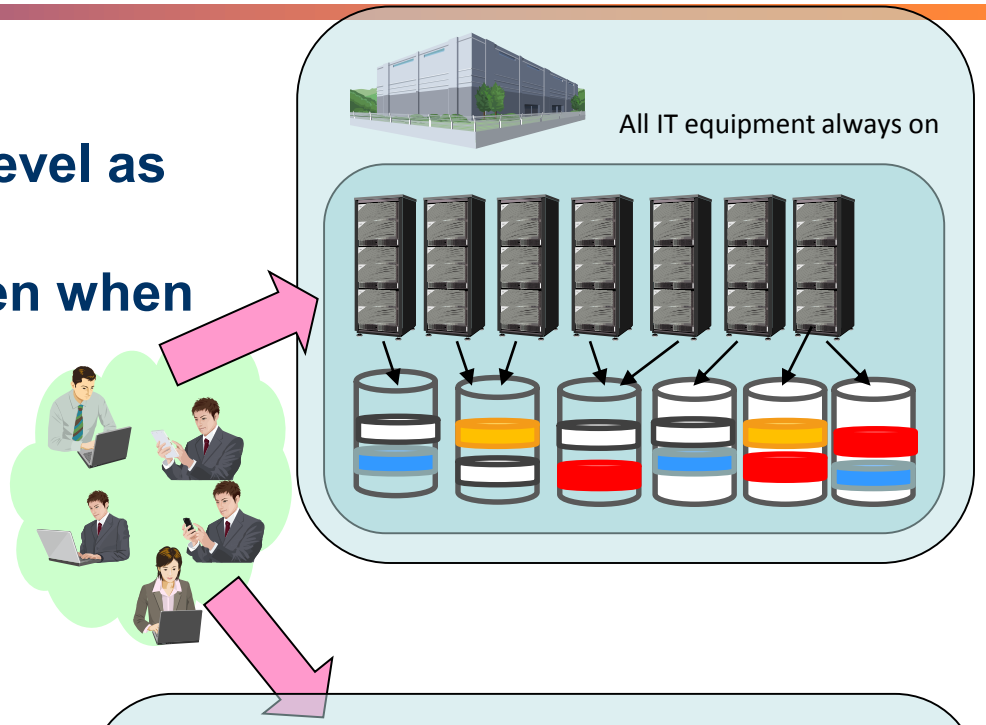


- Direct current power outlet box
- Direct current distribution unit

4. IT Operation: Green Cloud Operation

General Data Center

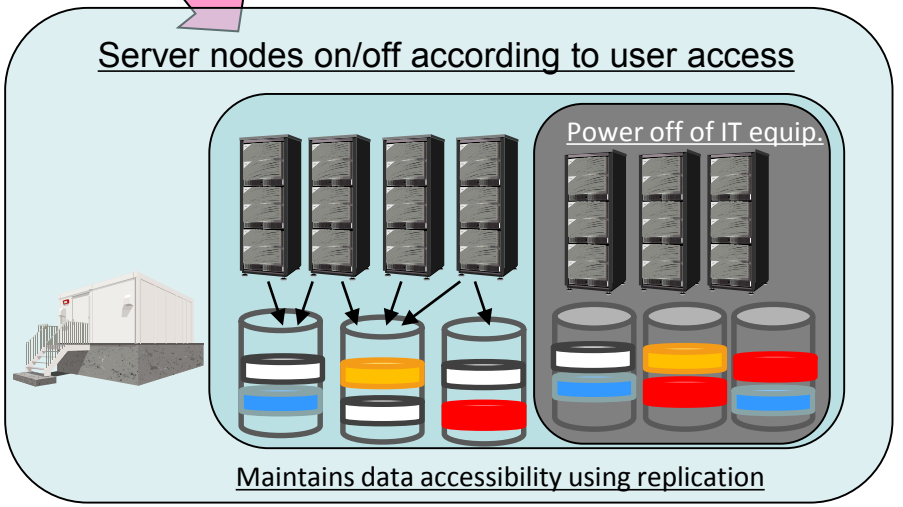
- **Avoids reduction of service level as far as possible**
  → All servers always on, even when user access is low



New Data Center: power saving operation

- **Data services are provided with data replication using distributed storage**

  → Minimizes operation nodes and shuts down unnecessary nodes when user access is low



Developed by NEC

Reduction of Power Consumption

- Real-time monitoring of power consumption and temperatures
- Potential 30% reduction by applying dummy load to servers
- Results will be released of more accurate evaluation done over 1 year

Snapshot of monitoring (not final result)

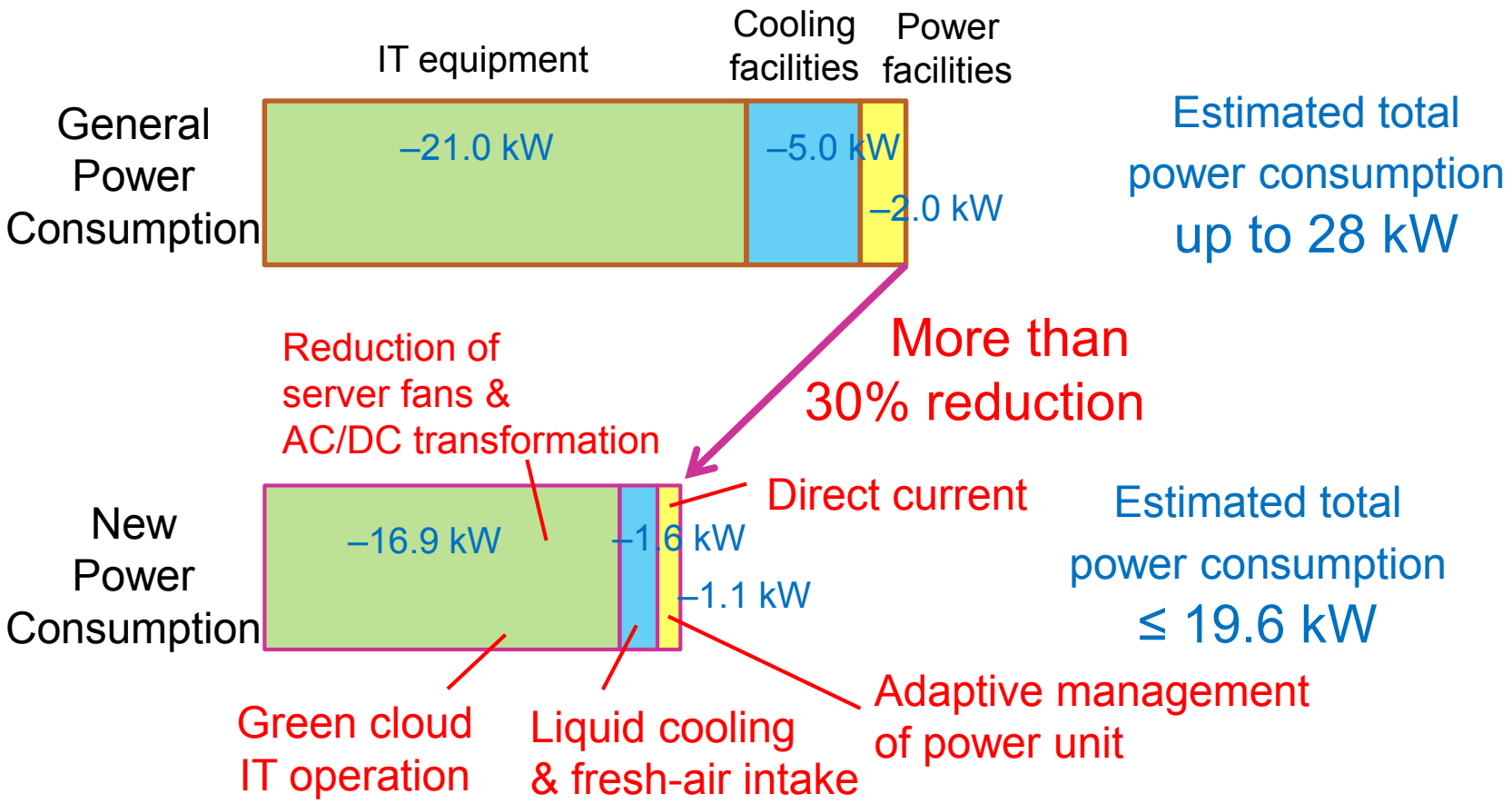
Comparison of power consumption and temperature

Power Reduction Ratio : **30.4 %**

General Modular Datacenter		New Modular Datacenter	
Power consumption	kW	Power consumption	kW
Total Power Consumption	27.6	Total Power Consumption	19.2
IT Equipment	20.7	IT Equipment	16.5
Power Facility	2.4	Power Facility	1.1
Cooling Facility	4.5	Cooling Facility	1.6
		Liquid cooling pump	0.56
		Cooling tower	0.42
		Fresh-air intake unit	0.61
Temperature	°C	Temperature	°C
Cold aisle	20.4	Cold aisle	25.2
Hot aisle	33.7	Hot aisle	33.6

5. Power Consumption and Metrics

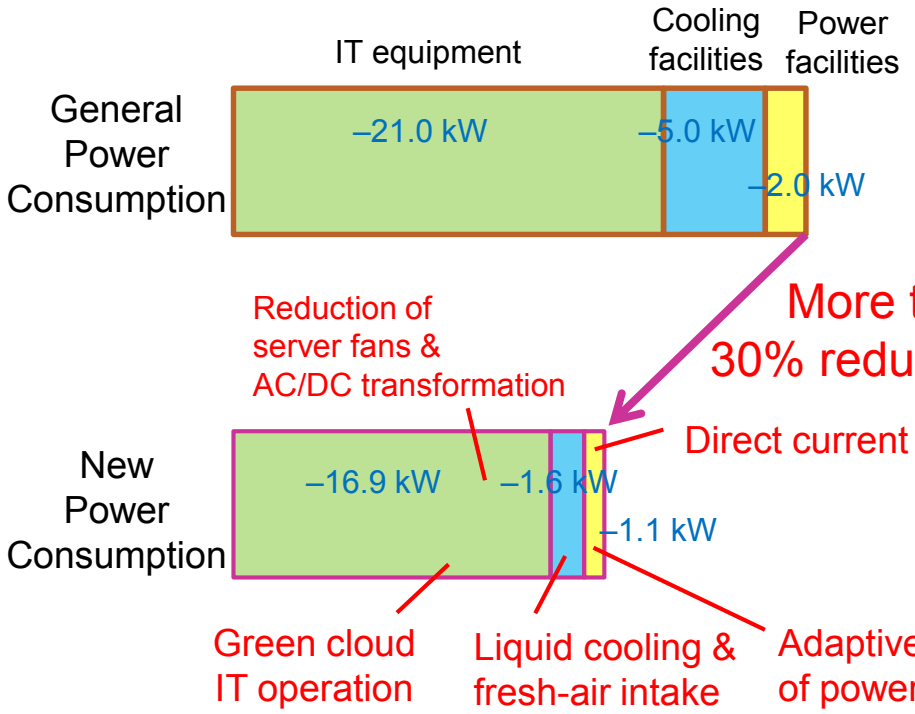
- **Potential power consumption is as follows:**



5. Power Consumption and Metrics; PUE

- **Widely used for evaluation of energy efficiency of data center**
- **Represents energy efficiency of facilities**
- **Not appropriate for evaluating efficiency of IT equipment and operation**

$$\text{PUE} = \frac{\text{Total power consumption in data center}}{\text{Power consumption by IT equipment}}$$



Estimated total power consumption
up to 28 kW

PUE = 28.0/21.0
= 1.33

12.8% improvement

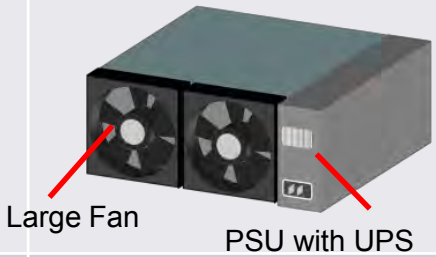
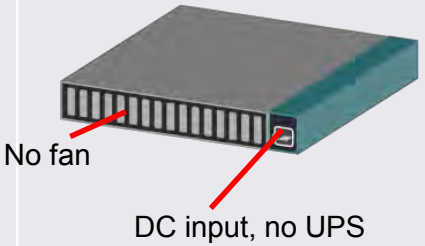
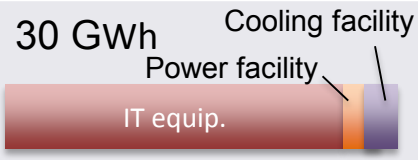
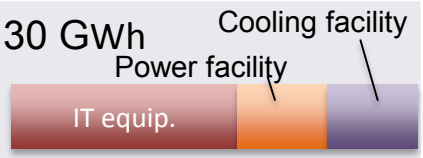
Estimated total power consumption
≤ 19.6 kW

PUE = 19.6/16.9
= 1.16

Improvement seems to be small in PUE

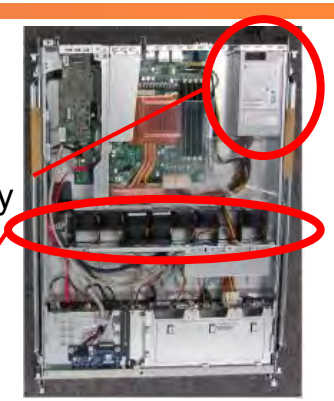
5. Pitfalls in PUE and Existing Metrics

- Data Center A and B have the same performance and total power
- Two green metrics give us different evaluations of energy efficiency

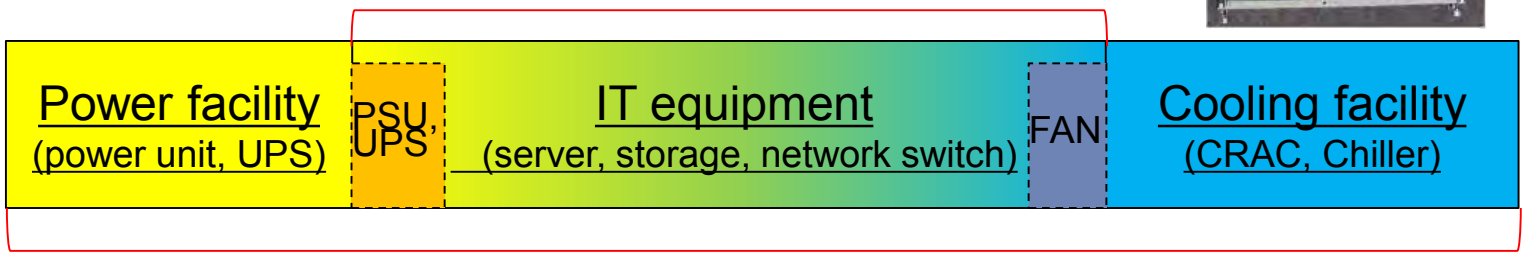
Examples	Data Center A	Data Center B
Server		
Power	250 W	167 W
Performance	50 GFlops	50 GFlops
Performance/Power (GFlops/W)	0.2	0.3
Power facility	Alternating curren No UPS	Direct current With UPS
Cooling facility	Low airflow	Heat removed by high air pressure
Total power/year In data center	30 GWh 	30 GWh 
PUE*	1.2	1.8

5. Proposal of New Metrics

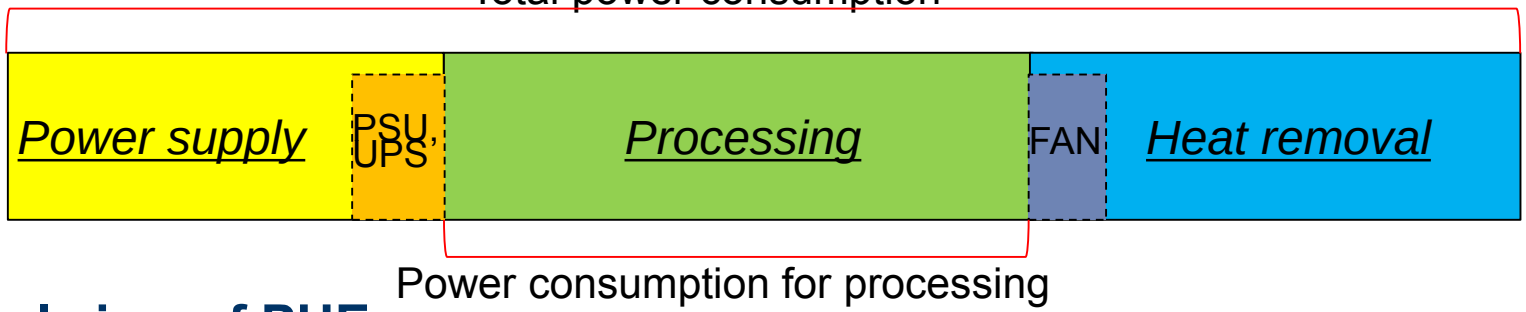
- **Using equipment as the unit of measurement leads to biased, inaccurate evaluation**
- **We propose measurement using function as the unit**



General power decomposition: equipment view



Proposed power decomposition: functional view

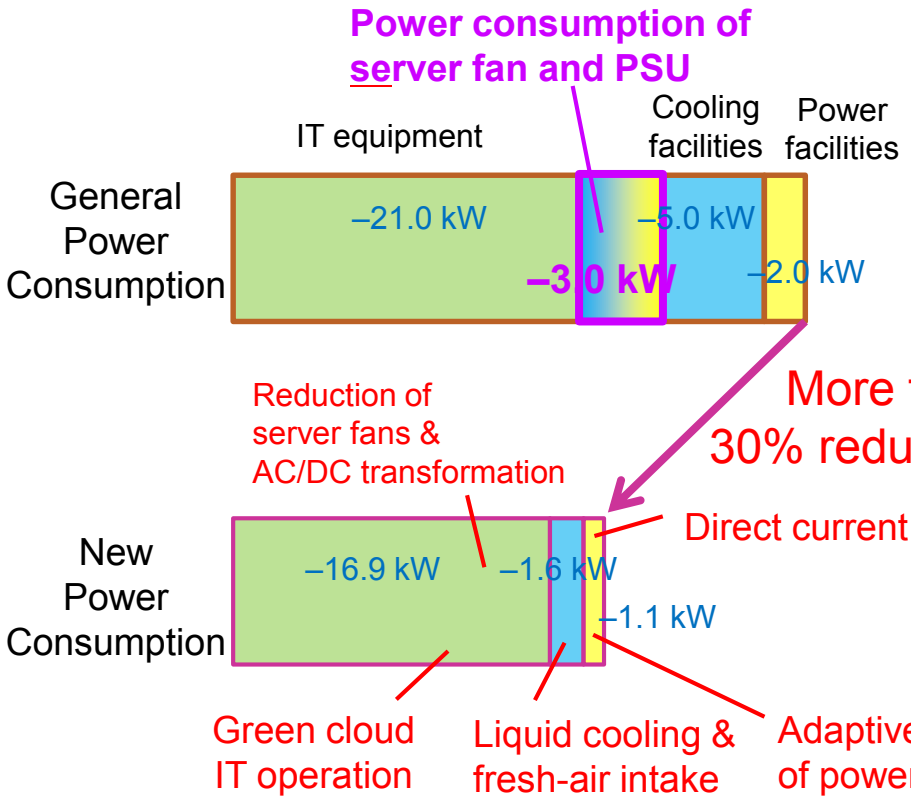


- **Functional view of PUE**

$$\text{Functional PUE} = \frac{\text{Total power consumption in data center}}{\text{Power consumption by information processing}}$$

5. Evaluation Using Functional PUE

- **Power consumption of information processing is roughly 18 kW by subtracting power consumption of server fan and PSU (–3.0 kW)**



	PUE	Functional PUE
Estimated total power consumption	= 28.0/21.0 = 1.33 up to 28 kW	= 28.0/18.0 = 1.56
Estimated total power consumption	= 19.6/16.9 = 1.16 ≤ 19.6 kW	1.16
	12.8% Improve-ment	26% Improve-ment

More valid evaluation is possible using Functional PUE

- ***) DC/DC transformation loss is still included in "information processing"**

Evaluation under different external air conditions

- **Facilities which can change artificially external air condition**
  - Cold air like in Hokkaido
  - Hot and wet air like in Okinawa

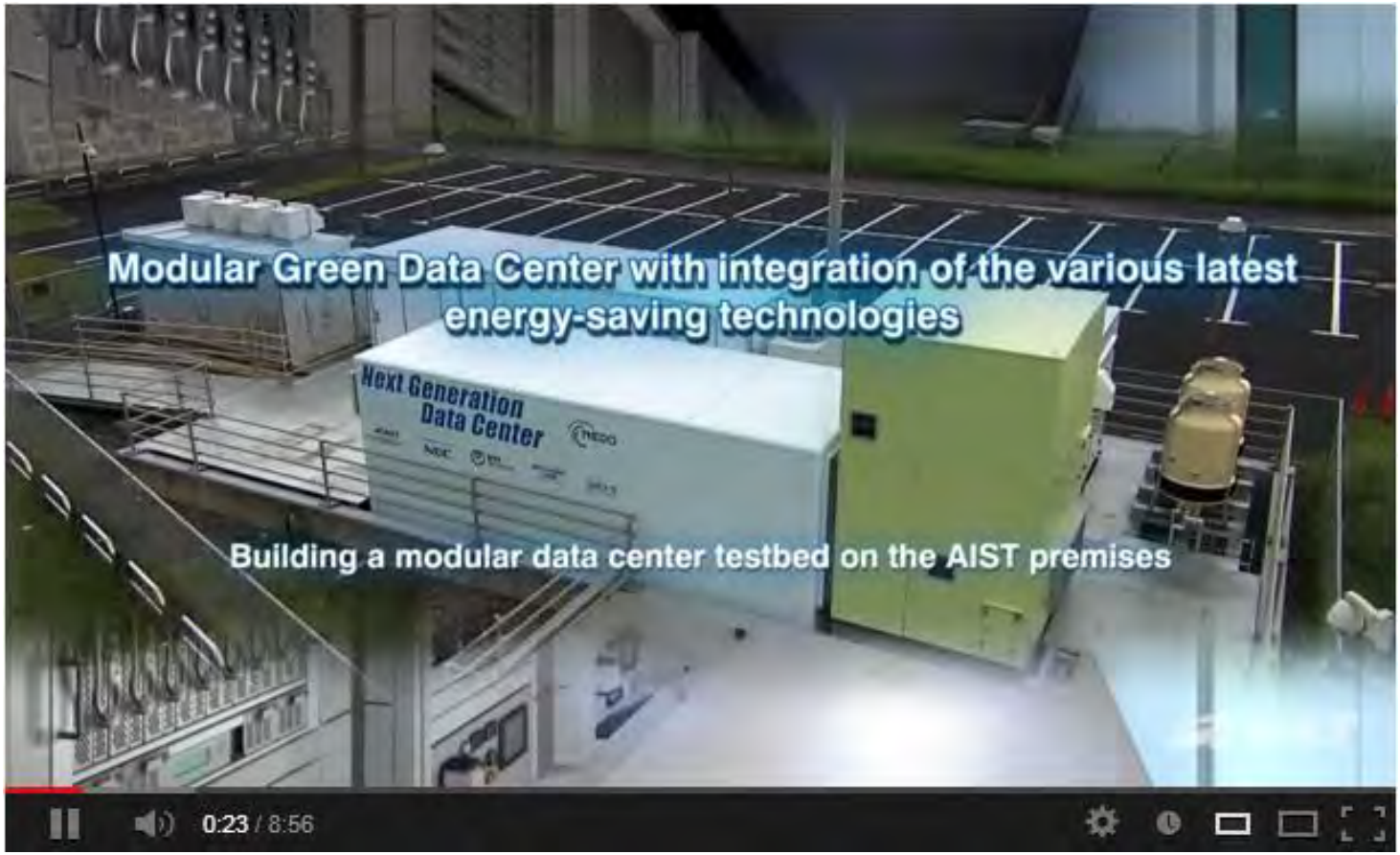
Available sensors in Data Center

- **It is possible to evaluate energy efficiency of several equipment and facilities**
- **Future collaboration with companies, such as, server maker, construction company, and data center related companies**

Type	Measurement point	No. of sensors	Accuracy	Frequency of measurement
Power	Facility and rack	–20 points	1.2% (AC) 2.3% (HVDC)	1 seconds
Temperature	Lattice style	–120 points	2.5 degree	10 seconds
Humidity	Key areas	4	3%	10 seconds
Pressure	Key areas	4	0.3 hPa	10 seconds
Differential pressure	Between hot and cold aisle	2	1Pa	10 seconds
Air flow	Module exit	1	3%	5 seconds
Liquid flow	Liquid cooling pump	5		10 seconds
Liquid temperature	Liquid cooling pump (coming & going)	5 x 2	2.5 degree	10 seconds

Video is available at AIST Video Library

- http://www.aist.go.jp/aist_e/video/
- Modular Green Data Center with integration of the various latest energy-saving technologies (8'56")



Summary

- We built New Modular Data Center by combining various energy-saving technologies developed by NEDO green IT project.
- A goal of the project, “30% reduction of power consumption in Data Center” was almost achieved.
- Evaluation experiments under the various outer air conditions are continued till next February.
- Collaborative framework for shared use of the data center is under construction.

- Please contact me, if you have any further questions

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