

## An Energy-Efficient Data Centre with Heat Recovery at Queen Mary University of London

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4<sup>th</sup> – 8<sup>th</sup> May 2026, CERN

From  
refurbishment  
to operation:  
efficiency,  
heat reuse,  
and carbon  
impact

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Motivation & Context

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The Refurbished Data Center

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Final Design

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Capacity, Efficiency & Resilience

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Operational Experience

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Power Measurements

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PUE & Heat Recovery Performance

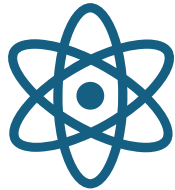
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Carbon Accounting

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Integrated Outcomes

# Motivation & Scientific Context



## Scientific drivers

Long-term Tier-2 support for **GridPP and WLCG workloads**

Preparation for **next-generation data-intensive science**:

- HL-LHC, LSST, SKA



## Operational context

Sustained growth in compute and storage demand

Increasing power density and thermal loads

Requirement for **reliable, on-campus infrastructure** with low operational overhead



## Institutional context

Data centers among the largest energy consumers on campus

University commitment to **reducing operational carbon emissions**

Opportunity to align scientific computing growth with sustainability goals

# Refurbishing the Data Center (Motivation)

## Original Facility (~2004)

- ~200 kW capacity, ~20–25 racks
- Open racks; no aisle containment
- Ageing cooling and power infrastructure

## Drivers for Refurbishment

- Growing scientific compute demand
- Cooling/power systems reaching end of life
- Need for low operational Carbon
- Requirement lifetime extension (> 15 years)

## Constraints

- Existing Building footprint had to be reused

## Refurbishment Objectives

- Increase IT capacity & thermal headroom
- Improve cooling efficiency & resilience
- Enable waste-heat recovery integration

## Outcome

- Modern water-cooled data center
- Designed for future growth & heat recovery
- Long-term low-carbon resilient scientific computing platform

# Data Center Post Refurbishment

## Facility and Cooling

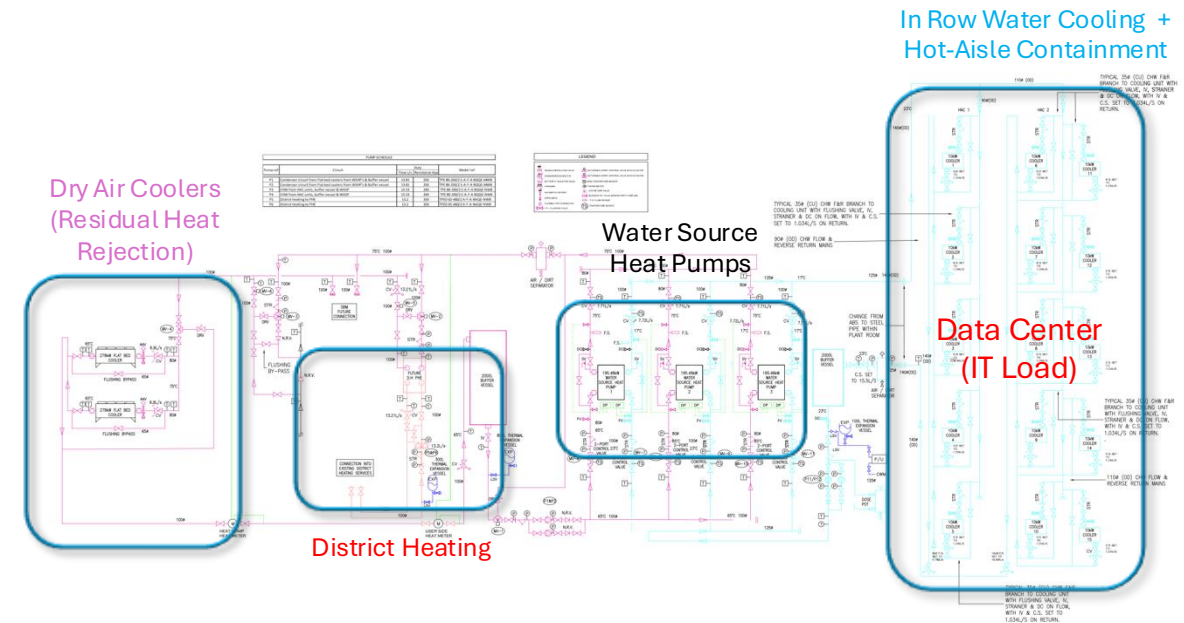
- **39 racks** across three rows,
- Average **~10 kW per rack, scalable up to 20 kW**
- **Hot-aisle containment** with in-row water cooling (N+1 per row)
- Overhead power and cooling distribution

## Heat Recovery Architecture

- Chilled water loop: **17 °C → 23 °C**
- **Three 200 kW water-source heat pumps (N+1)**
- Hot water loop: **65–75 °C**
- Heat routed to:
  - **University district heating** (via 500 kW heat exchanger)
  - **Dry air coolers** when heat reuse is unavailable

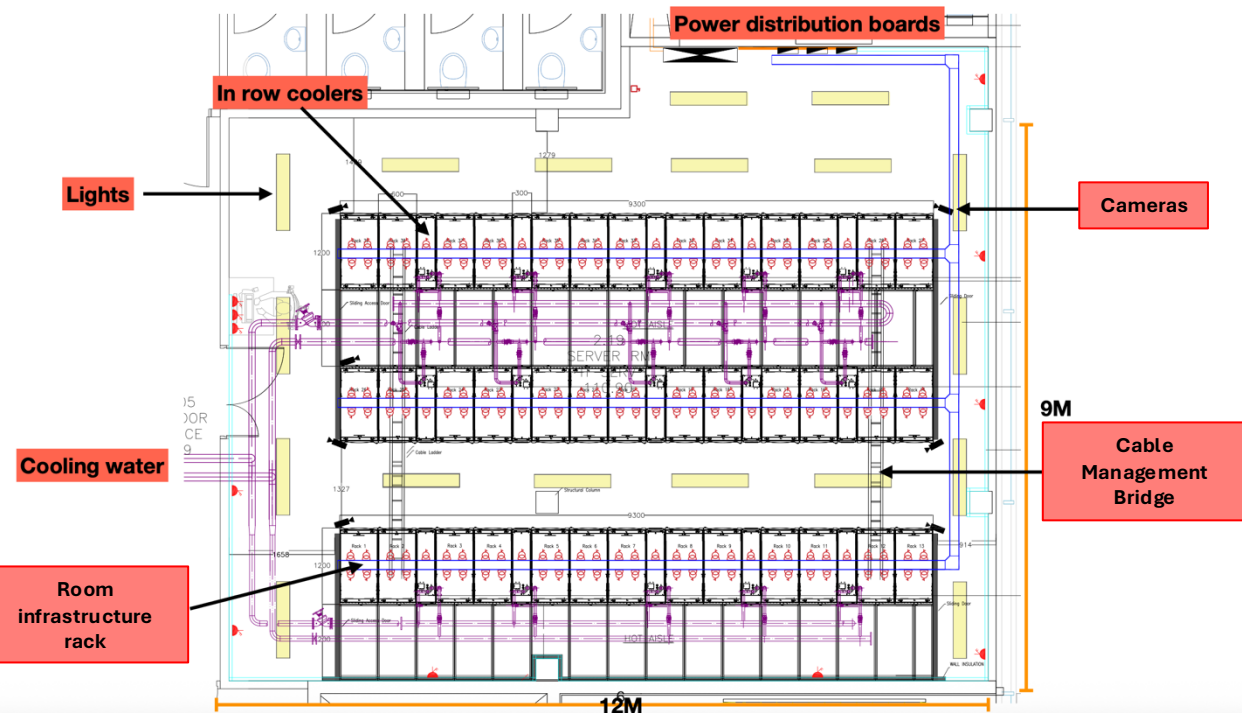
## Integrated Design

- Multiple operating modes for flexibility & resilience
- Capacity growth, efficiency, and heat reuse designed together



# Inside the Data Center (2024)

- Room hosts GridPP, SPCS (School) and IT Services (ITS) Clusters together.
  - Room capacity 390kW; GridPP shares with SPCS and ITS.
- Hot-aisle containment with in-row water cooling
- Overhead power and cooling infrastructure
- Designed for high-density, scalable scientific workloads



# Capacity, Efficiency, and Resilience

## (Post Refurbishment)

### Increased Capacity

- Usable racks increased: ~**15** → **38**
- IT power capacity: ~**150 kW** → **390 kW**
- Flexible rack power up to **20 kW**
- Supports GridPP and future growth beyond **2035**

### Efficiency by Design

- Hot-aisle containment improves thermal efficiency
- Transition from CRAC to **water-based CRAH cooling**
- Optimised temperature set-points:
  - Cold aisle ~**26 °C**
  - Hot aisle ~**45 °C**
- Cooling and heat recovery scale dynamically with IT load

### Resilience & Operational Flexibility

- A/B electrical feeds per rack
- N+1 redundancy for:
  - In-row coolers
  - Heat pumps
- Multiple heat rejection paths
- Independent metering of IT power, cooling energy, and recovered heat enables validation and operational control

# Operational Experience Post-commissioning

## System Behaviour

- System populated in phases under increasing workloads
- Scales predictably with increasing IT load
- Stable operation across load range

## Cooling validation

- Predictable PUE behaviour vs load
- Clear mode transitions (single ↔ dual heat pump) cleanly visible

## Heat Recovery

- Tracks IT power and remains bounded
- Improves with higher return temperatures
- Heat recovery effectiveness depends on operating conditions and demand

## Operational Insight

- Integrated Monitoring enabled validation, fault detection and tuning
- Increased confidence in long-term scaling and recovery operation

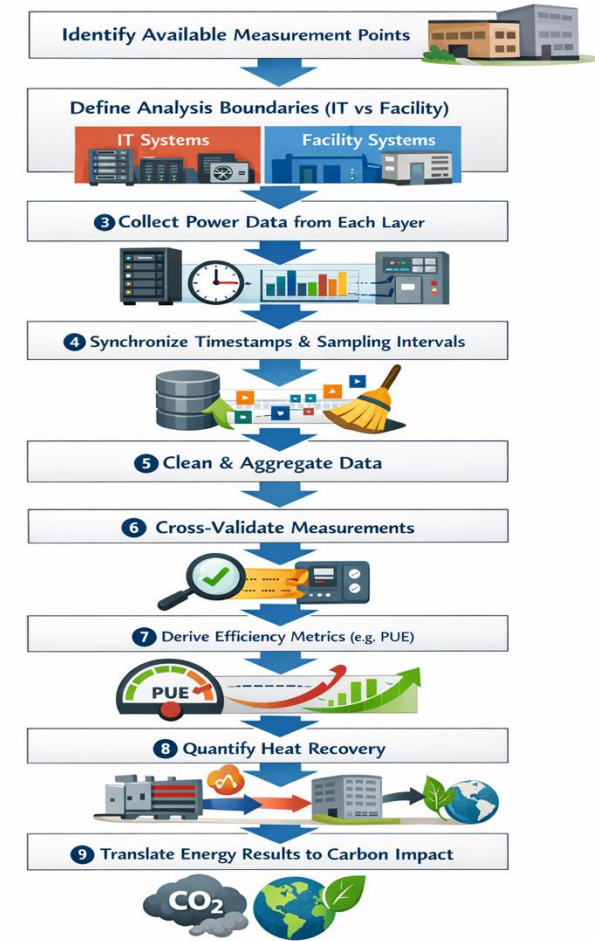
# Power Measurement Strategy

## Power Measurement at Multiple Levels

- **Server-level:** IPMI telemetry
- **Infrastructure-level:** PDU & IRC IT power
- **Facility-level:** Room / site electricity meters
- **Heat side:** District heating heat meters (not available yet)

## Why multiple measurements

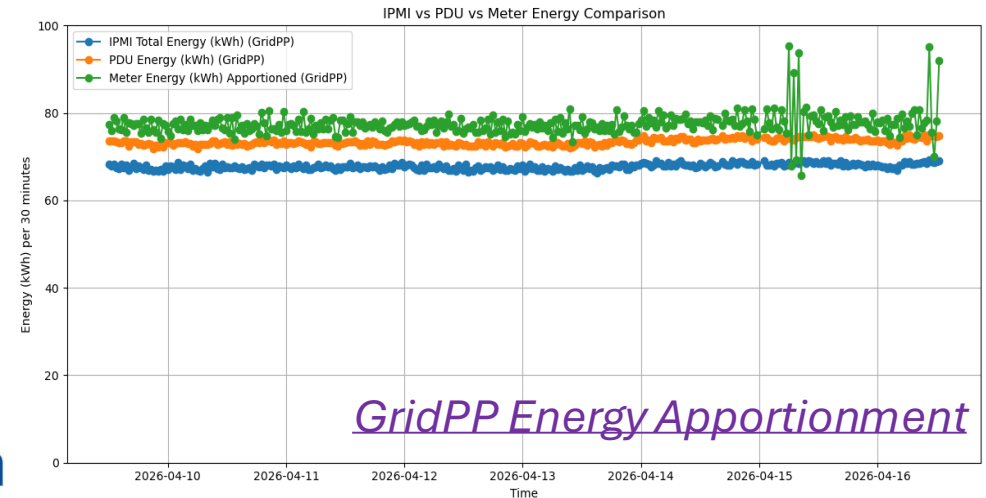
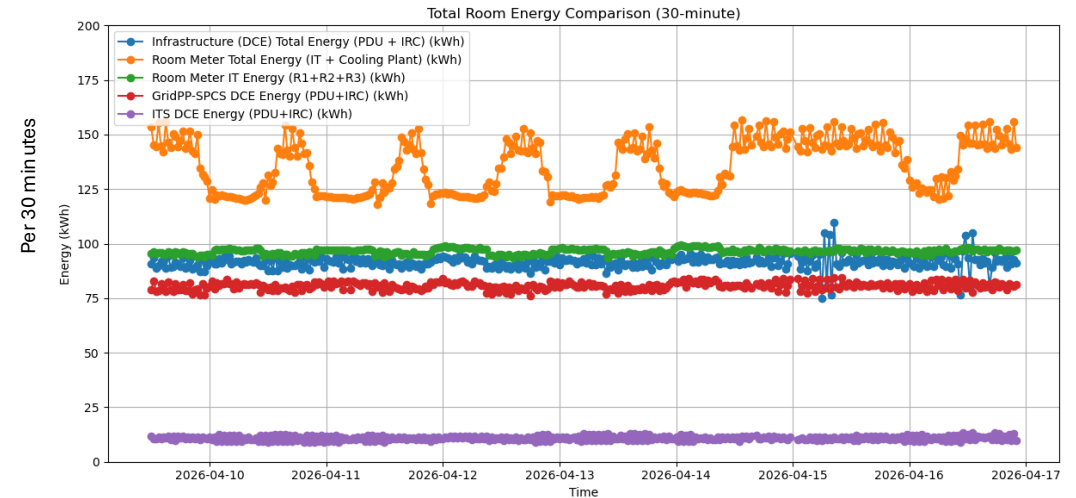
- Independent attribution of IT and facility energy
- Cross-checks for consistency
- Basis for efficiency and carbon accounting



# Power Measurement Consistency

## Observations

- Total IT energy (PDU + IRC) split into GridPP+SPCS and ITS contributions
- Room-level IT electricity measurements agree with PDU + IRC totals within ~ 3–6%
- Residual differences likely due to
  - non-IT loads (e.g. lighting)
  - meter calibration and resolution



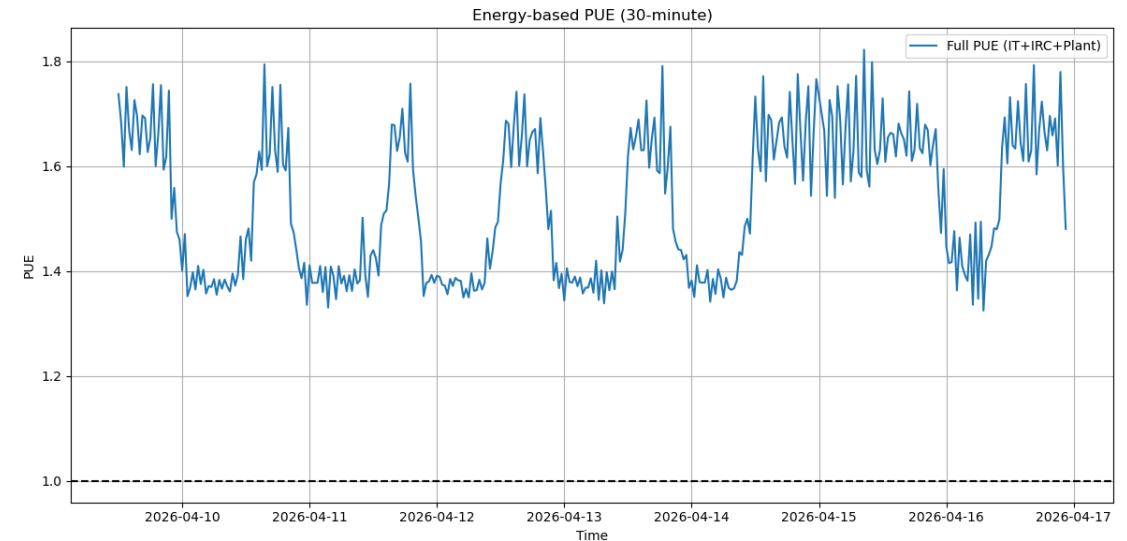
# Power Usage Effectiveness (PUE) & Cooling Validation

## Observed PUE Performance

- PUE varies approximately **1.3–1.8**
- Variation correlated with:
  - IT load,
  - cooling plant operating mode

## Key Insight

- Switching between single and dual heat-pump operation is visible in PUE
- PUE reflects cooling strategy as much as IT efficiency



# Heat Recovery Validation

## Heat Generation

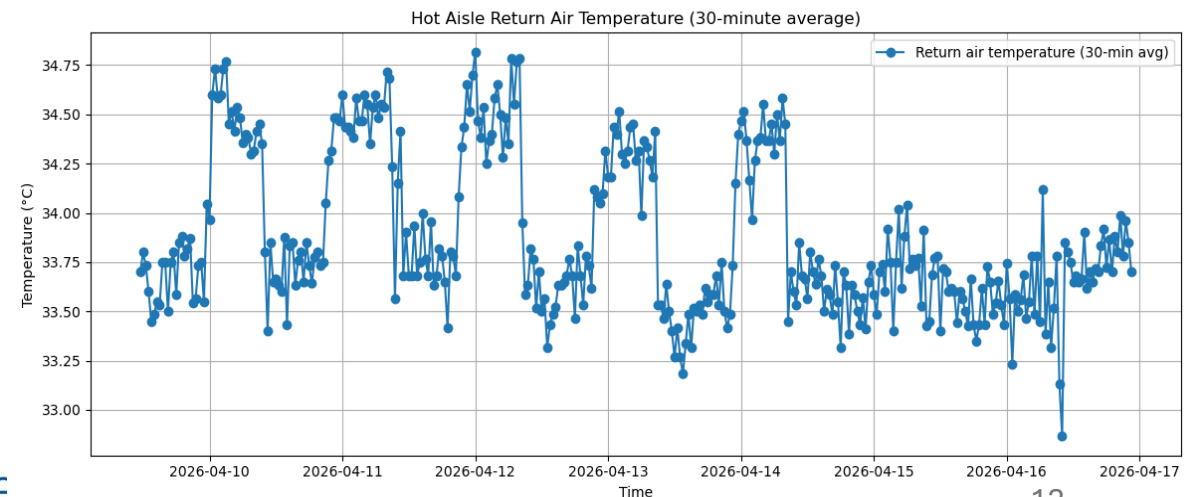
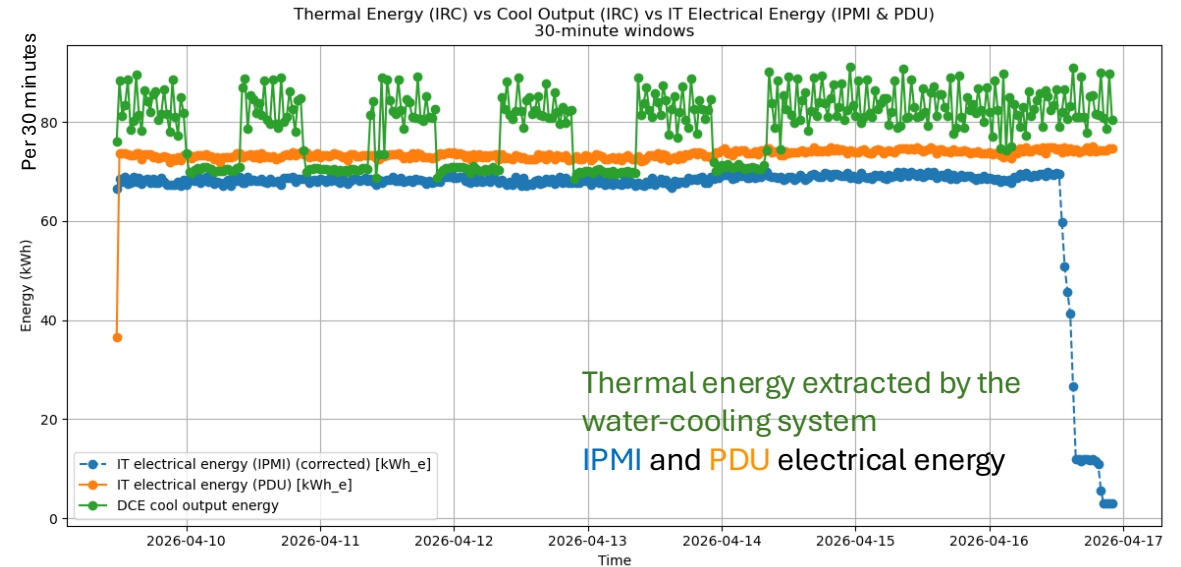
- IT power tracks heat removed by water cooling
- Thermal load Increases with compute and demand
- High return temperatures enabled by hot-aisle containment

## Heat Recovery Behaviour

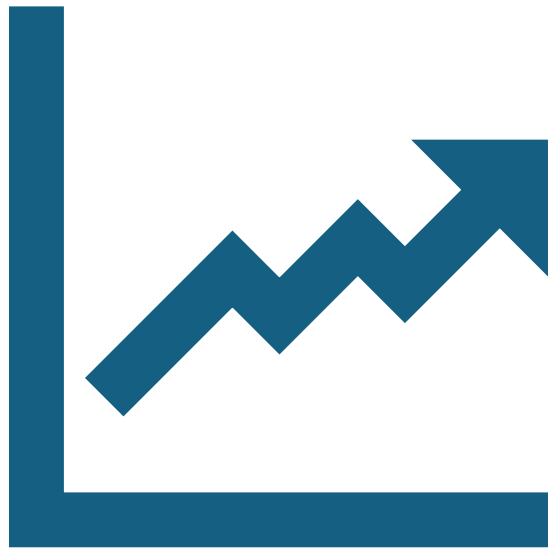
- Recovered heat bounded by IT heat
- Higher return temperatures -> higher recovery
- Recovery performance influenced by cooling plant mode
- Follows IT demand

## Validation

- Recovered heat consistent with IT power
- Energy balance confirms order-of-magnitude accuracy
- Minor discrepancies under investigation



# Operational Carbon



Considering UK grid carbon intensity data from <https://carbonintensity.org.uk>, for the period of 9<sup>th</sup> April-16<sup>th</sup> April 2026, the data center's operational (Scope 2) Carbon emissions over the measured week were:

- Total operational carbon: **4.58 tonnes CO<sub>2</sub>e**
- Energy-weighted average carbon intensity: **95 gCO<sub>2</sub>e/kWh**

## Carbon Accounting Scope

- Operational carbon only (Scope 2)
- **Basis:** Time-aligned (30-minute) grid carbon-intensity data and **measured electricity consumption**

# Integrated Outcomes

## Design & Capability

- Water-cooled, heat-recovering data centre
- Built for long-term scientific workloads

## Operational Performance

- Increased capacity with stable cooling
- Predictable PUE behaviour
- Heat recovery coupled to IT load and temperatures

## Energy & Carbon Impact

- Reuse of server waste heat
- Reduced reliance on gas heating
- Lower operational carbon footprint

## Key Takeaway

- Sustainable HPC requires integrated design of cooling, heat recovery, and operations
- Measured data validates system behaviour and long-term scalability

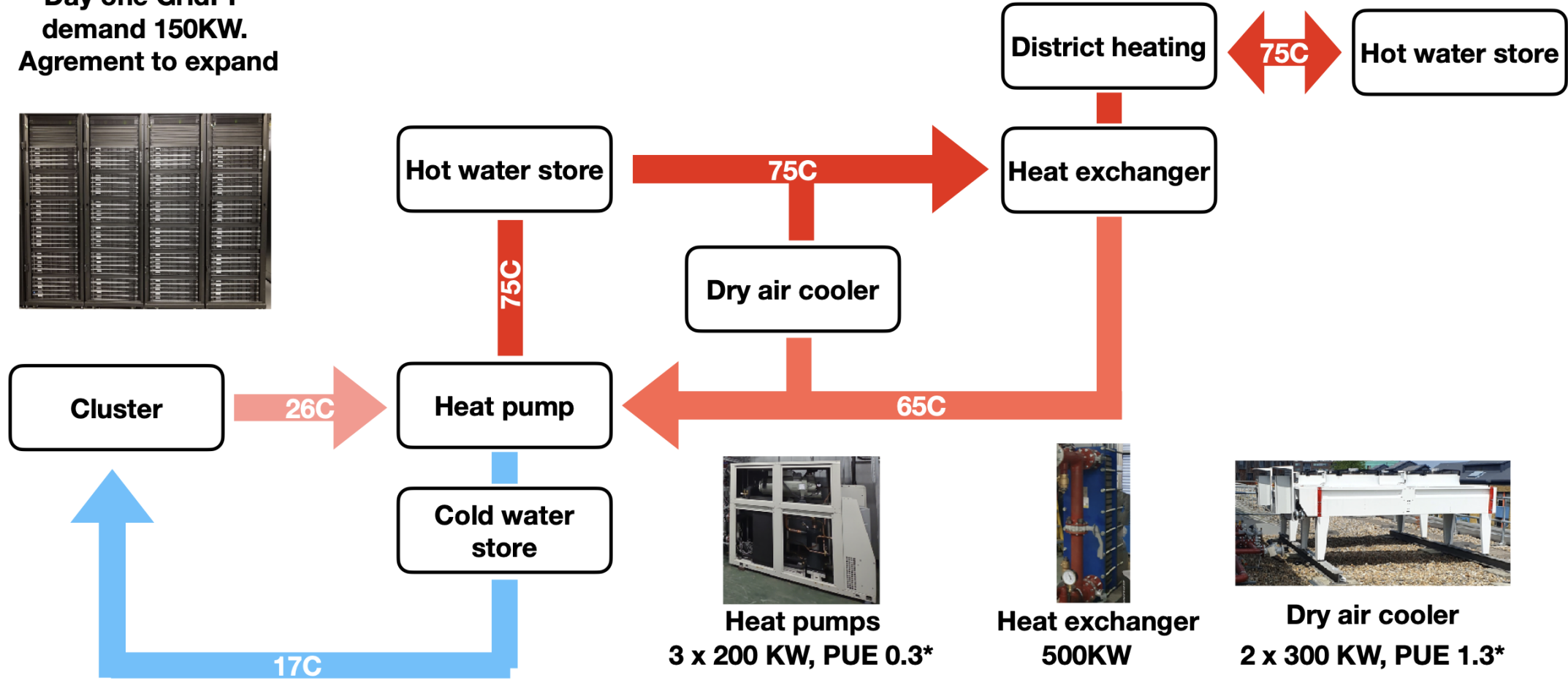
# Back Up

Room capacity 390KW  
 GridPP will share with  
 SPCS / Research IT

Day one GridPP  
 demand 150KW.  
 Agreement to expand



# Basic Design



**Heat pumps**  
 3 x 200 KW, PUE 0.3\*



**Heat exchanger**  
 500KW



**Dry air cooler**  
 2 x 300 KW, PUE 1.3\*

\* Heat pumps consume apx 30KW for every 100KW transferred