AI's Soaring Energy Demand

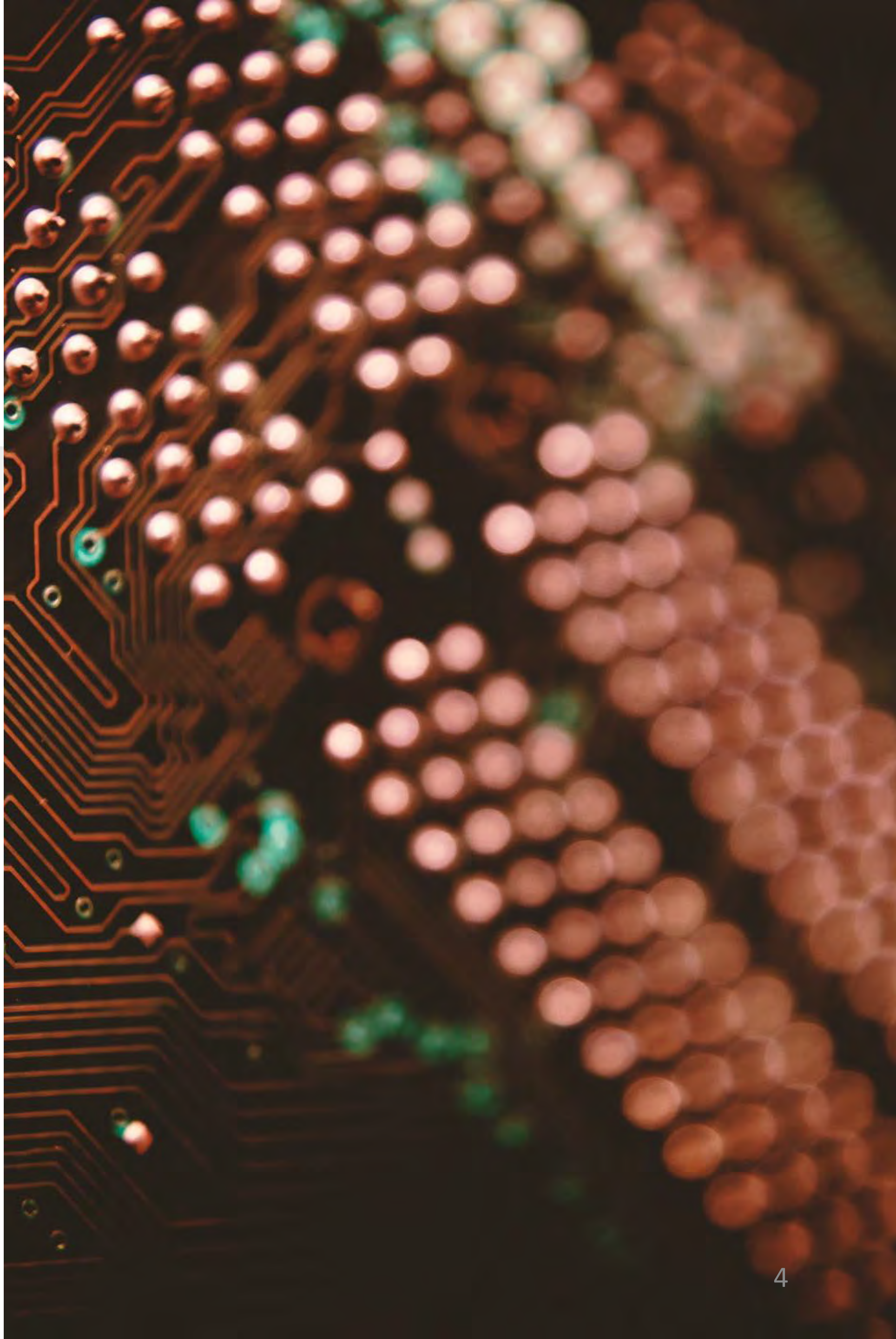
- Global data centre energy use projected to double by 2030 (~945 TWh)
- AI workloads quadrupling electricity consumption by 2030
- AI alone could consume ~146 TWh by 2027 (IDC, 2024)
- Hyperscale AI facilities pushing rack densities towards 1 MW

Hidden Sustainability Challenges

- Traditional efficiency metric (PUE) insufficient alone
- Water Usage Effectiveness (WUE): industry average ~1.8 L/kWh
- Embodied carbon in IT hardware matching operational emissions
- Lifecycle emissions becoming critical sustainability factor

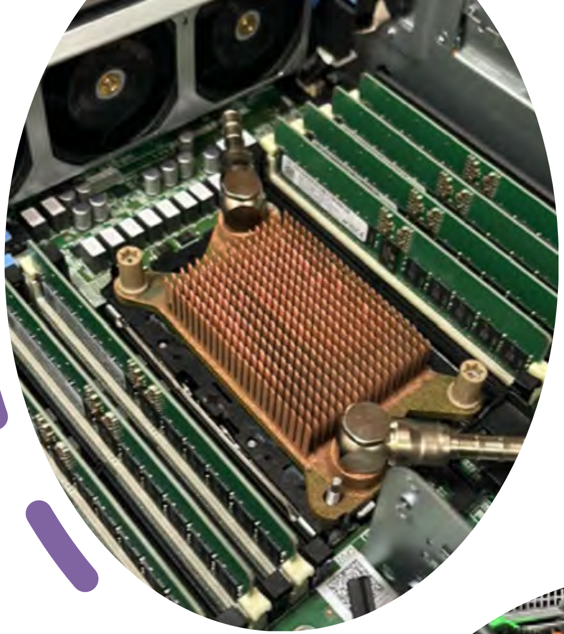
Data Centre Cooling Technologies

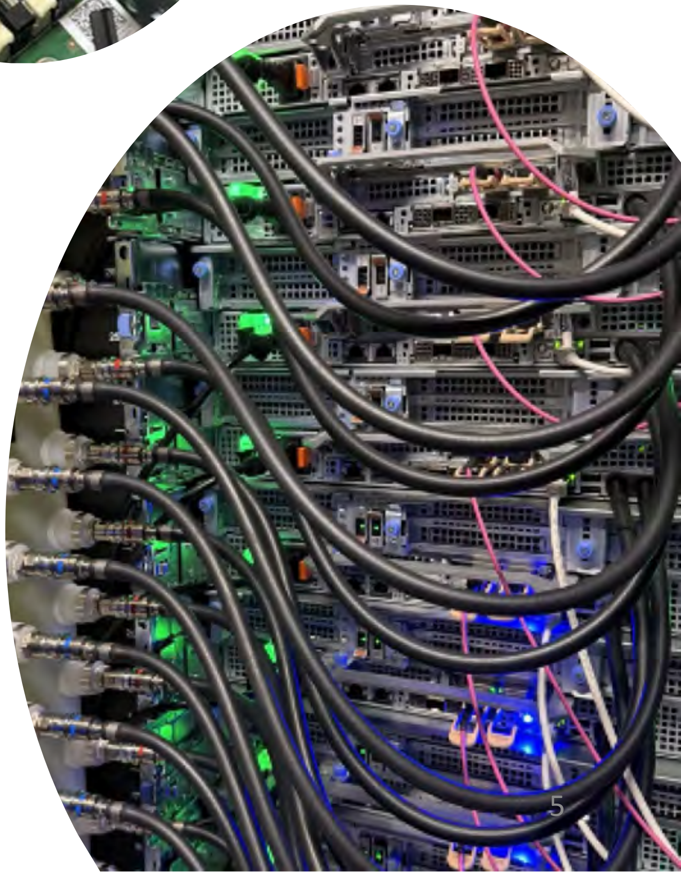
- Traditional air-cooling reaches limits ~120 kW/rack
- Liquid cooling adoption forecast ~40% by 2026
- Direct-to-chip vs. immersion cooling trends
- Challenges: retrofit complexity, fluid standards, upfront cost



Direct-to-Chip Liquid Cooling

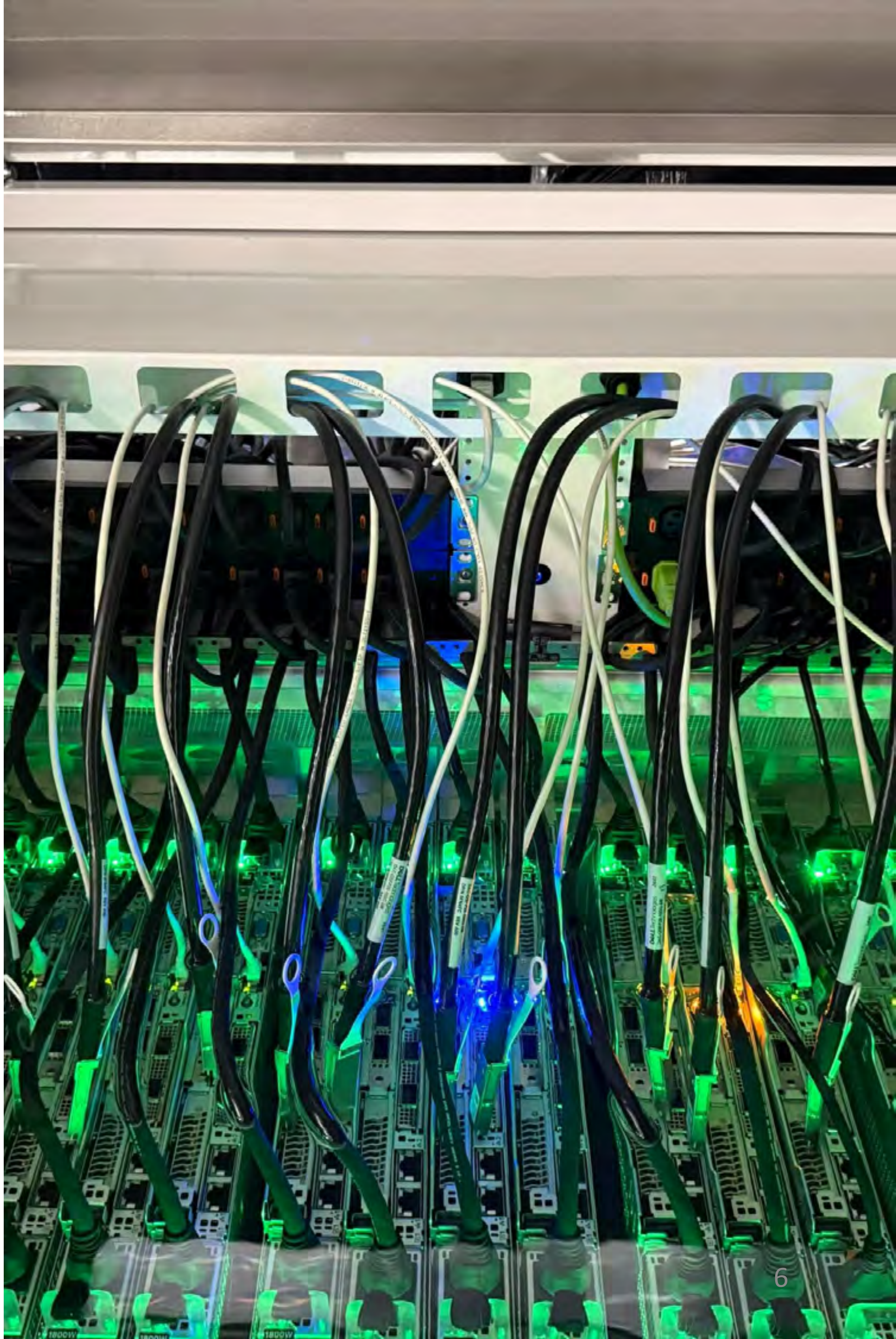
- Direct cold-plate heat removal from GPUs/CPUs
- Enables rack densities ≥300 kW, approaching 1 MW
- Microsoft study: ~20% energy & GHG savings vs. air cooling
- Industry alignment through OCP, ASHRAE standards





Immersion Cooling – Single and Two-phase

- Servers submerged in dielectric fluids for maximum heat removal
- Two-phase (boiling) provides highest thermal performance
- Fluorinated coolants (PFAS) regulatory concerns, seeking alternatives
- Single-phase growing due to environmental & regulatory advantages

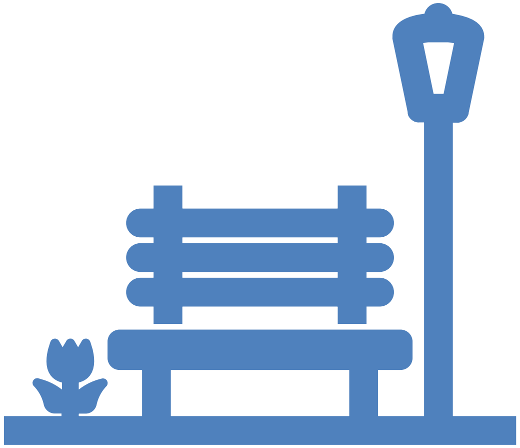


Case Study – Singapore (Tropical Efficiency)

- Green Data Centre Roadmap mandates PUE ≤1.3
- Water efficiency target: WUE ≤2.0 m^3/MWh
- Zero-water cooling innovations (Microsoft Singapore)
- Hydrogen tri-generation & floating data centre concepts

Case Study – Northern Europe (Cold Climate Efficiency)

- Nordic countries leveraging free air-cooling & renewables
- Stockholm Data Parks: 90% heat reuse via district heating
- Google Hamina seawater cooling (PUE ~1.12)
- High Energy Reuse Factor (ERF) benchmarks



Case Study – North America (Renewables & Flexibility)

- Near-100% renewable PPAs by hyperscalers
- Targeting 24/7 carbon-free power (Google, Microsoft)
- Hydrogen fuel cell powered data centres (ECL)
- Flexible ops: Emerald AI, SRP trial

Case Study – Middle East (Solar & Cooling Innovation)

- Moro Hub, Dubai: ~100 MW solar-powered DC
- Khazna Data Centres: adiabatic cooling, biofuels, liquid cooling
- Future: hydrogen tri-generation potential

Case Study – China (Policy-driven Scale)

- 'Eastern Data, Western Computing' strategy
- PUE target ≤1.25 for hyperscalers by 2025
- Large-scale immersion cooling adoption
- Inner Mongolia renewable-powered data centres

Engineering the 1 MW Rack

- Dual-loop direct-to-chip cooling, overhead manifolds
- Additive manufactured leak-proof unibody cold plates
- Two-phase vapor-chamber cooling: 90% pump energy savings
- Integration with advanced coolant distribution units

Baseload Innovations – Nuclear & Geothermal

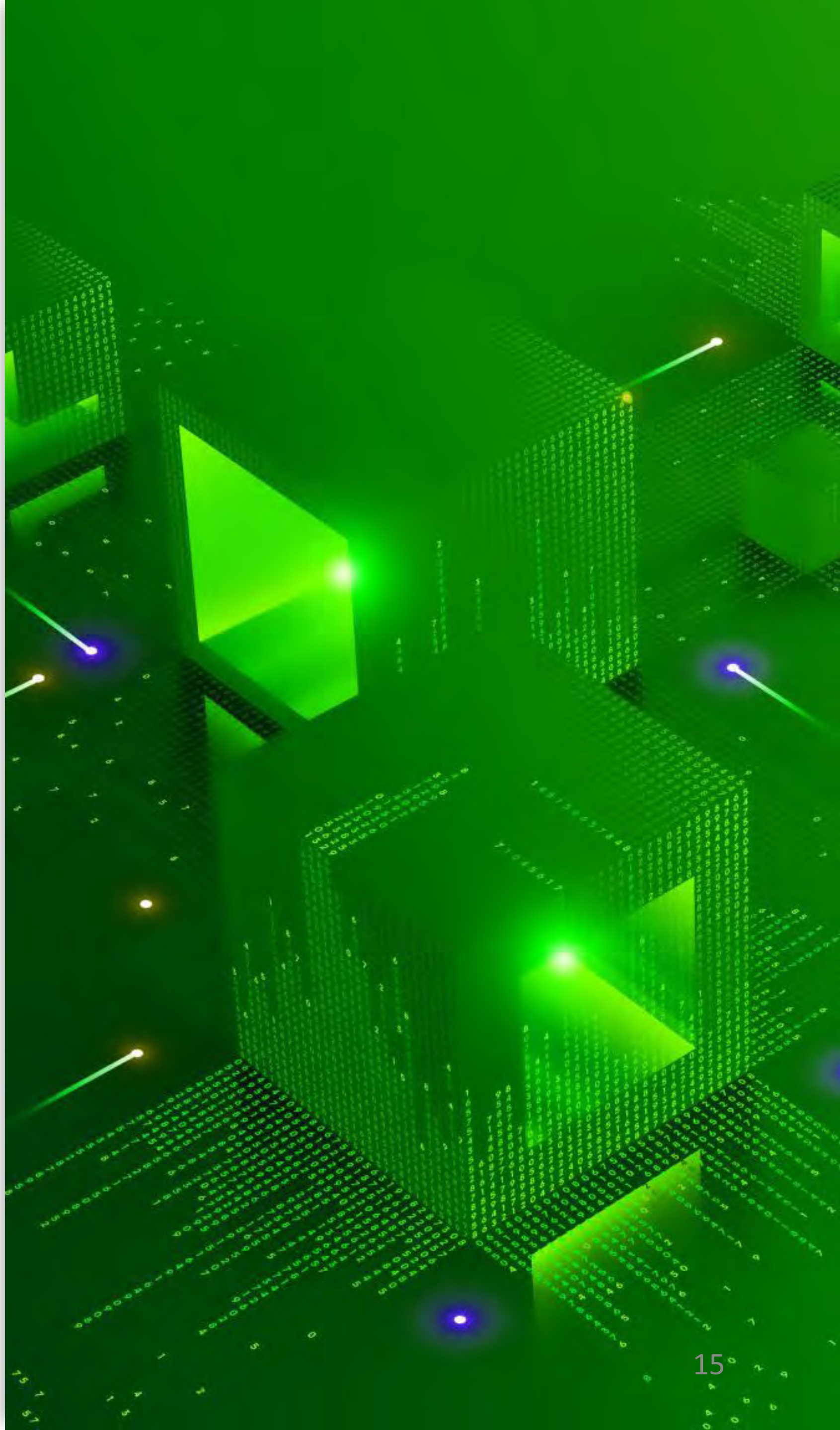
- SMRs (50–300 MW) for dedicated DC power
- Geothermal power in Iceland, Indonesia, Nevada
- Floating SMRs with seawater cooling for coastal DCs

Hydrogen Tri-generation Pathway

- Hydrogen fuel cells: backup & primary power
- Waste heat for absorption chillers
- Hydrogen supply integration scenarios
- Microsoft 3 MW fuel cell pilot

Grid-Interactive Data Centres

- Demand response & ancillary services: Emerald AI/Nvidia
- Google UPS grid balancing project
- Data Centres as Virtual Power Plants
- ASEAN extrapolation: $10–15bn avoided grid upgrades



Waste Heat Reuse & Circularity

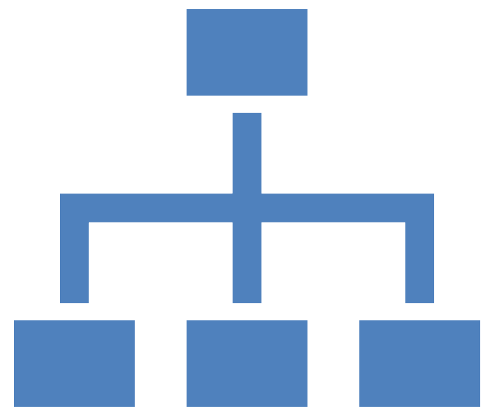
- ISO 23995 Energy Reuse Factor (ERE)
- Nordic reuse for district heating
- Green Mountain aquaculture reuse
- Urban-integrated circular DC future

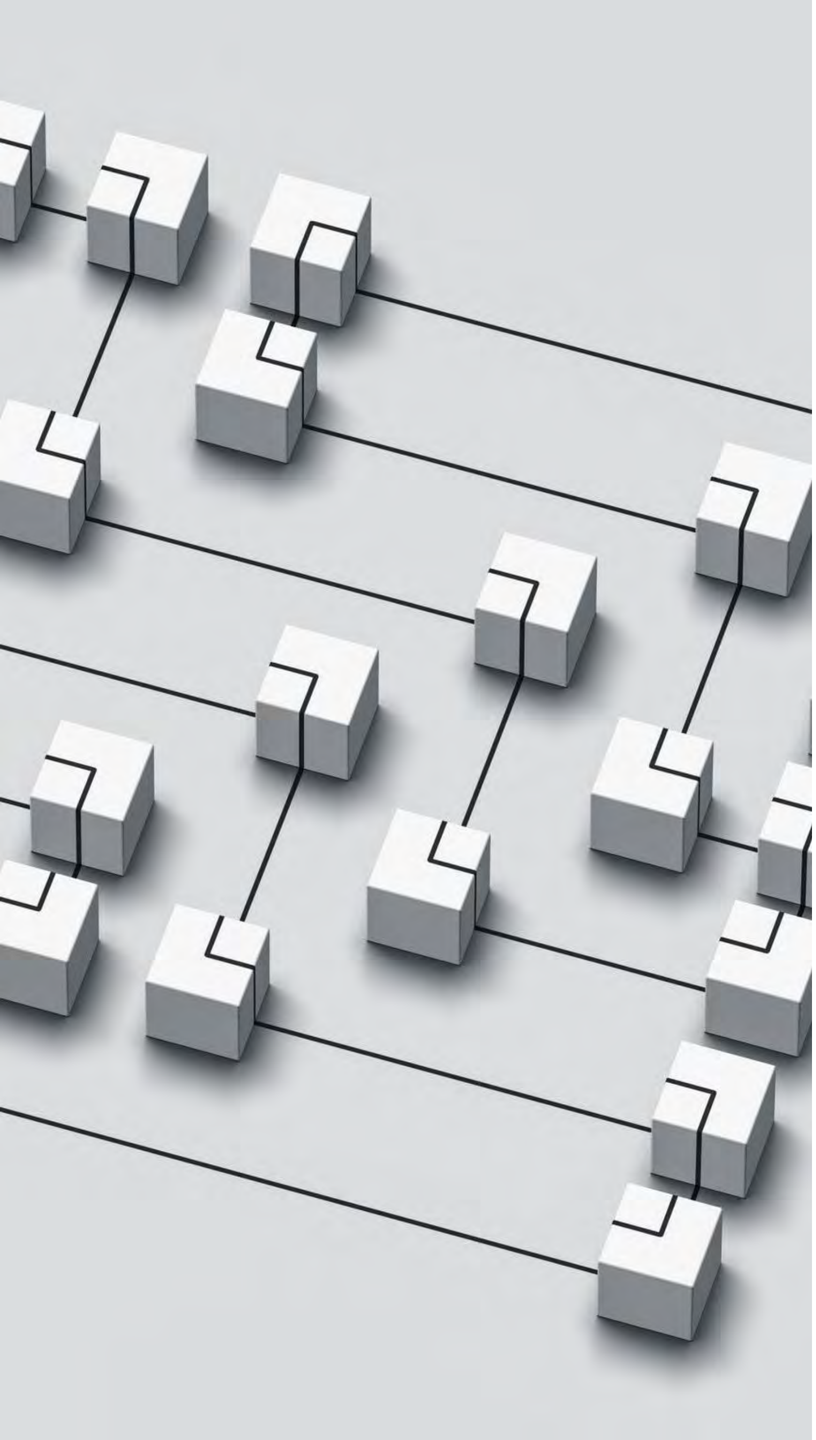
Comprehensive Sustainability Metrics

- Carbon Usage Effectiveness (CUE)
- Water Usage Effectiveness (WUE)
- Embodied emissions: 38–69% of total
- ISO/IEC 30134 for standardized reporting

Standards, Certifications & Policy Levers

- ISO/IEC 30134 (PUE, CUE, WUE, ERF)
- EU Code of Conduct, EU Taxonomy
- Moratoria shaping growth (IE, AMS, SG)
- LEED, BREEAM, Uptime Institute frameworks





Strategic Roadmap to Net-Zero AI Infrastructure

1. Compute & Cooling Efficiency
2. Decarbonised Power (PPAs, H2, SMRs)
3. Grid Flexibility (load shifting, VPP)
4. Circularity (water, heat, materials)
5. Transparency, Standards & Collaboration

Vision & Call to Action

- "The terawatt tsunami is a design brief—let's co-engineer the surfboard"
- 24/7 carbon-free, water-neutral, heat-positive DCs by 2040
- Collaborative approach (STDCT 2.0)

STDCT

Sustainable Tropical Data Centre Testbed

A national platform for co-innovation, validation, and deployment of tropical AI-ready data centre technologies

About us

- A 0.5 MW testbed to **develop, test and refine sustainable data centre (DC) solutions**, expediting their path to commercial deployment
- A **co-innovation platform** to engage diverse stakeholders within the DC industry
- Phase 1 (April 2021 to Dec 2024) focuses on **future-proofing the cooling needs** of tropical data centres
- Phase 2 (Q3/Q4 2025 onwards) focuses on **energy & water efficiency, green energy, green computing** and **AI data centres**

STDCT
Sustainable Tropical Data Centre Testbed

Key features

Industry standard data hall

Liquid-cooled racks

Immersion cooling

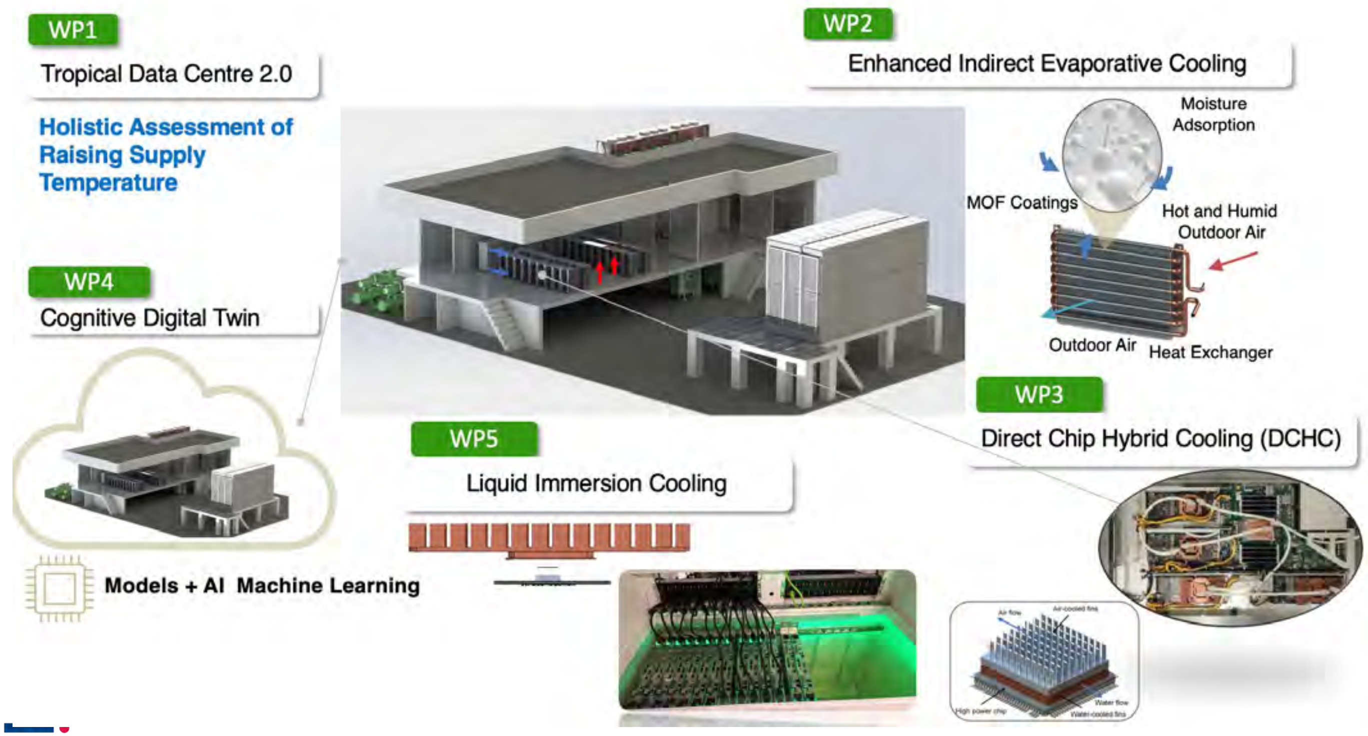
Manifold wall for optimized LC

Fan coil wall coupled with
different heat rejection options

StatePoint liquid cooling system

STDCT
Sustainable Tropical Data Centre Testbed

Projects



STDCT
Sustainable Tropical Data Centre Testbed

Ecosystem approach

Grantor:

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE

Research Performers:

NUS National University of Singapore

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

STDCT
Sustainable Tropical Data Centre Testbed

Companies:

ASCENIX CBRE CoolestDC

ENGINEERING TOMORROW Danfoss DELL Technologies DIGITAL REALTY

EATON Powering Business Worldwide EkkoSense +GF+ GSM PTE LTD

intel Keppel Data Centres AWC M & C ENGINEERING AND TRADING (S) PTE LTD

Meta NALCO Water An Ecolab Company nVent TraceTek RAYCHEM Leak Detection System

RED DOT ANALYTICS Schneider Electric Sygna.

UNICOM Engineering, Inc. A Division of UNICOM Global VERTIV

Phase 2.0

September 2025 (5-year programme)

STDCT 2.0

Focus areas


Sustainable cooling


Waste heat recovery


Alternative heat rejection


Green energy


Direct current data centre


AI-optimized digital infrastructure

Research	Member-directed projects
Technology	Innovation sandbox | Standard development | Validation of best practices & new technologies| Use case demo
Capacity building	Resource hub | Industry roundtable | Events | Conferences | Workforce training | Undergraduate & postgraduate courses

Sustainable AI-ready infrastructure on Jurong Island

- Access to green energy sources, water body
- Proximity to hydrogen-ready CCGT infrastructure, carbon capture and utilization testbed
- Proposed site for the upcoming data centre projects
- Ideal for validating low-carbon, AI-ready infrastructure

Innovations

Low carbon power and cooling

- ❖ Fuel cells/ gas engines with low carbon fuels (biomethane, green hydrogen, ammonia etc.)
- ❖ Cold energy from regassification
- ❖ Carbon capture
- ❖ Direct current power architecture

Advanced cooling, heat rejection and waste heat reuse

- ❖ Two-phase cold plates, immersion cooling
- ❖ Distributed and scalable cooling
- ❖ Seawater heat rejection
- ❖ Waste heat driven direct air capture, water treatment

AI native infrastructure

- ❖ Foundation model-based control
- ❖ Energy-aware workload scheduling

Target outcomes

- PUE <1.1 (two-phase direct chip cooling), PUE < 1.06 (Immersion)
- WUE improved by up to 97% via seawater
- Onsite cogeneration of low carbon power & cooling (fuel cells with carbon capture)
- Green hydrogen and ammonia pathways