Study of highly efficient cooling and heat-reuse for computing and electronics at LHCb/LHC-Point8

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98% of the energy consumed by a datacenter is rejected in the form of heat into the atmosphere.

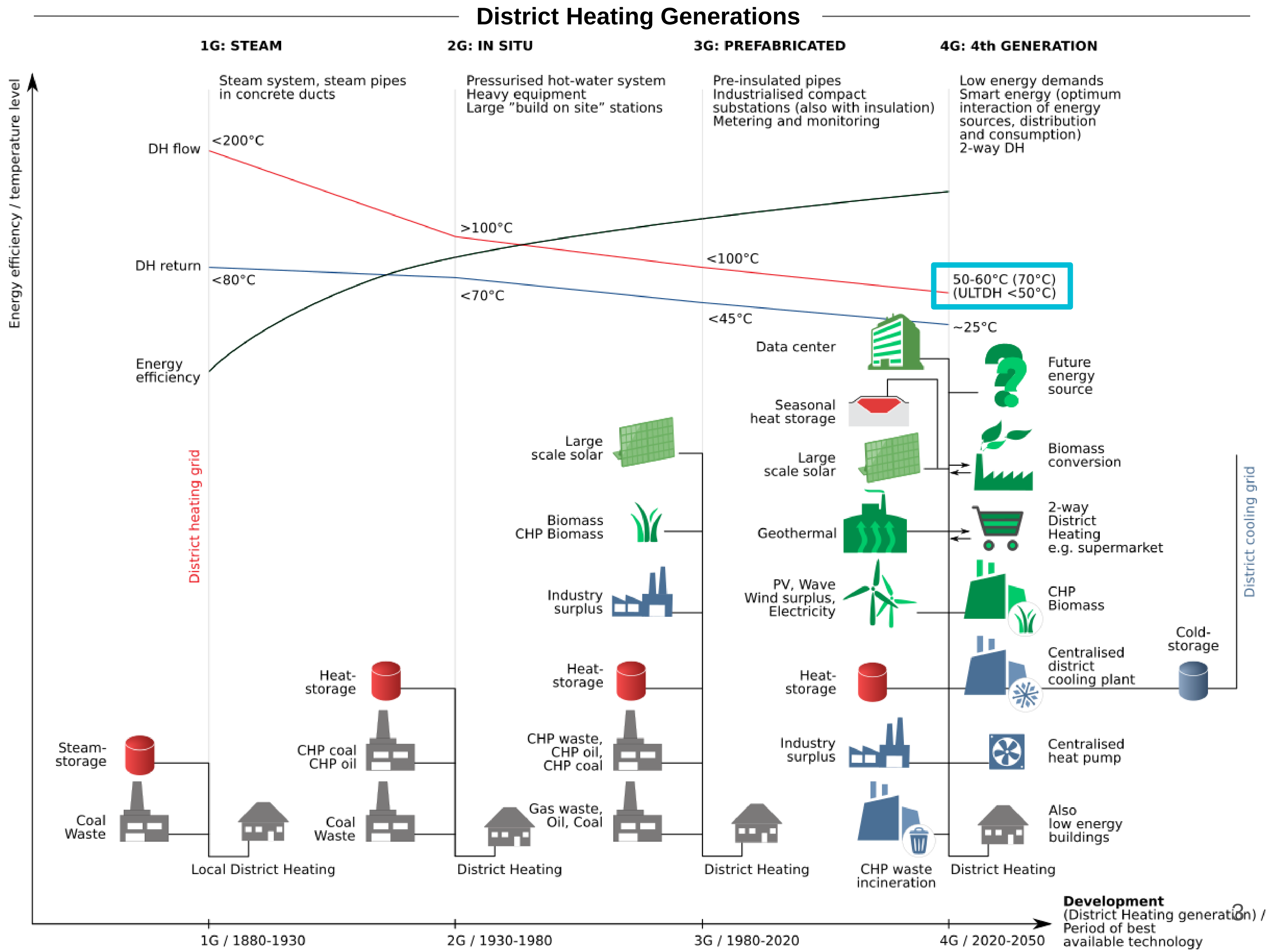
There's a massive opportunity-cost by **not re-using it**.

Traditional air cooling technology **only allows to capture <5%** in the form of low-grade heat (max 25 ºC supply).

https://www.planet.veolia.com/en/waste-energy-data-centers-braunschweig-germany

Why now?

1. From all energy entering a DC **98% is rejected** as waste heat
2. Traditional DC technologies can only capture **<5%** of total heat generated in the form of low-grade heat (max 25C supply) (see example).
3. Previous generations of district heating networks required high supply temperatures (>100C)
4. 4th Gen District Heating **requires 70C supply**
5. ESG and Scope3 imply that Heat Reuse is inevitable
6. Immersion **can deliver 70C** without the need of heat pumps
7. First Utilities are already willing to pay **35-50€/MWh**. Translates into **44M€/year** for a 100MW DC



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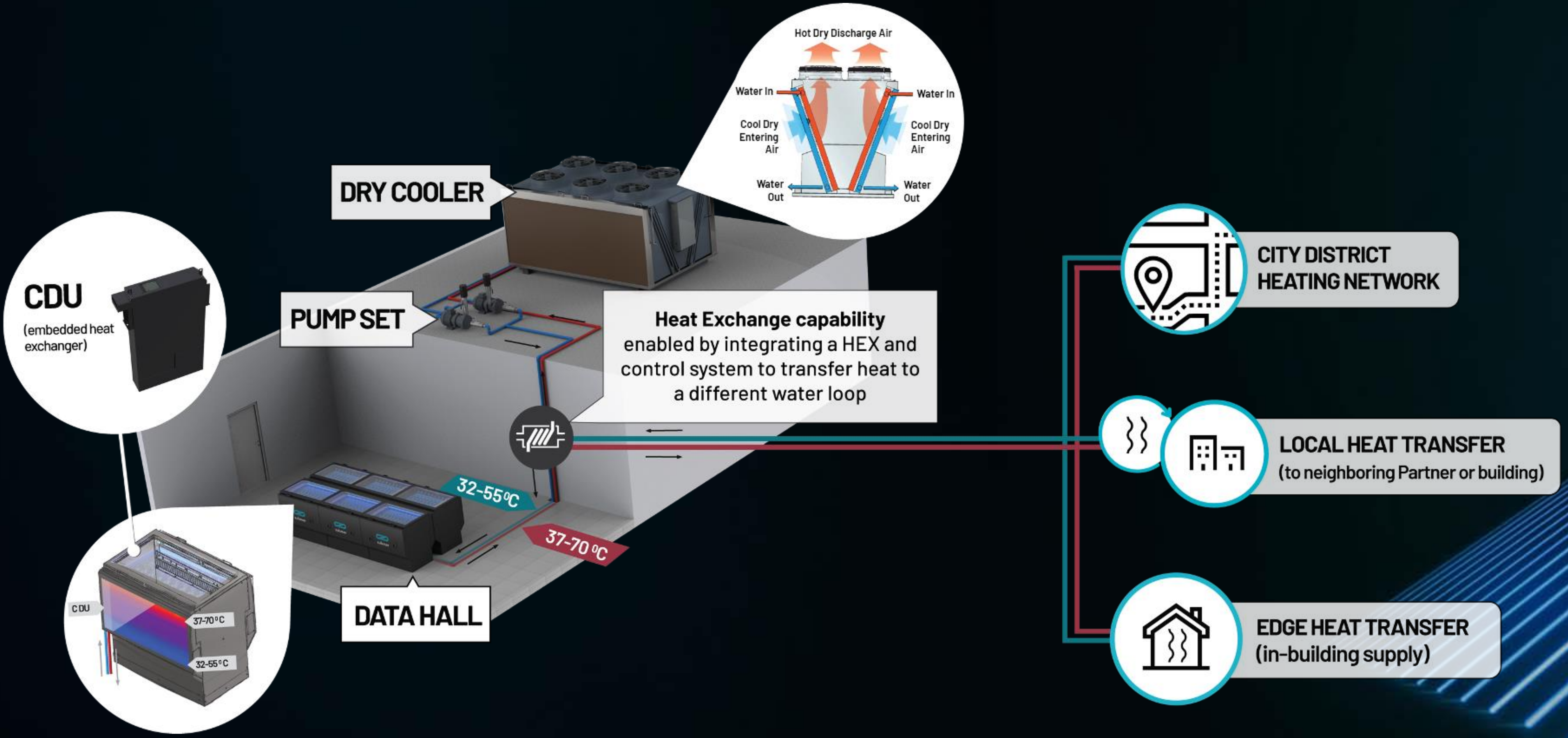
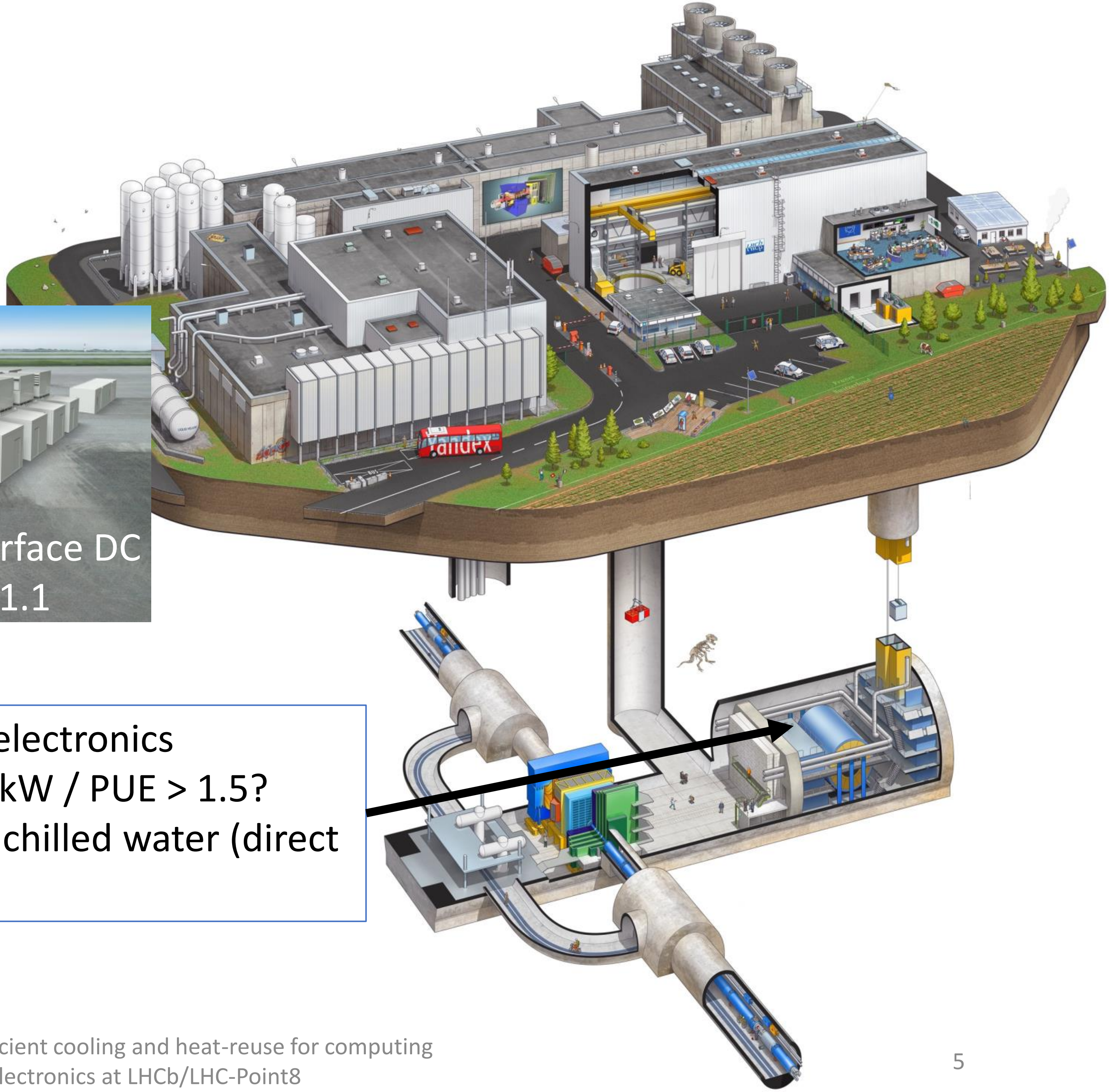
Immersion Cooling + heat reuse



At Point 8

1. Replace / complement legacy infrastructure in UX85 with immersion cooling
2. Evaluate heat-reuse for heating of hall
3. Secondary cooling loop can be provided by water from cooling towers (available)
4. Test if other (off-detector) electronics can be immersion cooled and operated as well



Underground IT / electronics Infrastcture ~ 700 kW / PUE > 1.5? Mixed water from chilled water (direct expansion)

Submer SmartPods

submer

- Up to 100 kW of heat dissipation
- 45U or 22U, 19” or 21” Open Compute (OCP)
- Local and remote management interfaces
- Simplified maintenance
- Submer Cloud (remote monitoring & management)
- DCIM API - integrate with monitoring tools
- Compact form factor
- Tier III and tier IV compatible
- Vertically Stackable configurations available
- Optional IP65 (water/dust proof)
- **Zero waste of water**
- **Possibility of heat reuse**

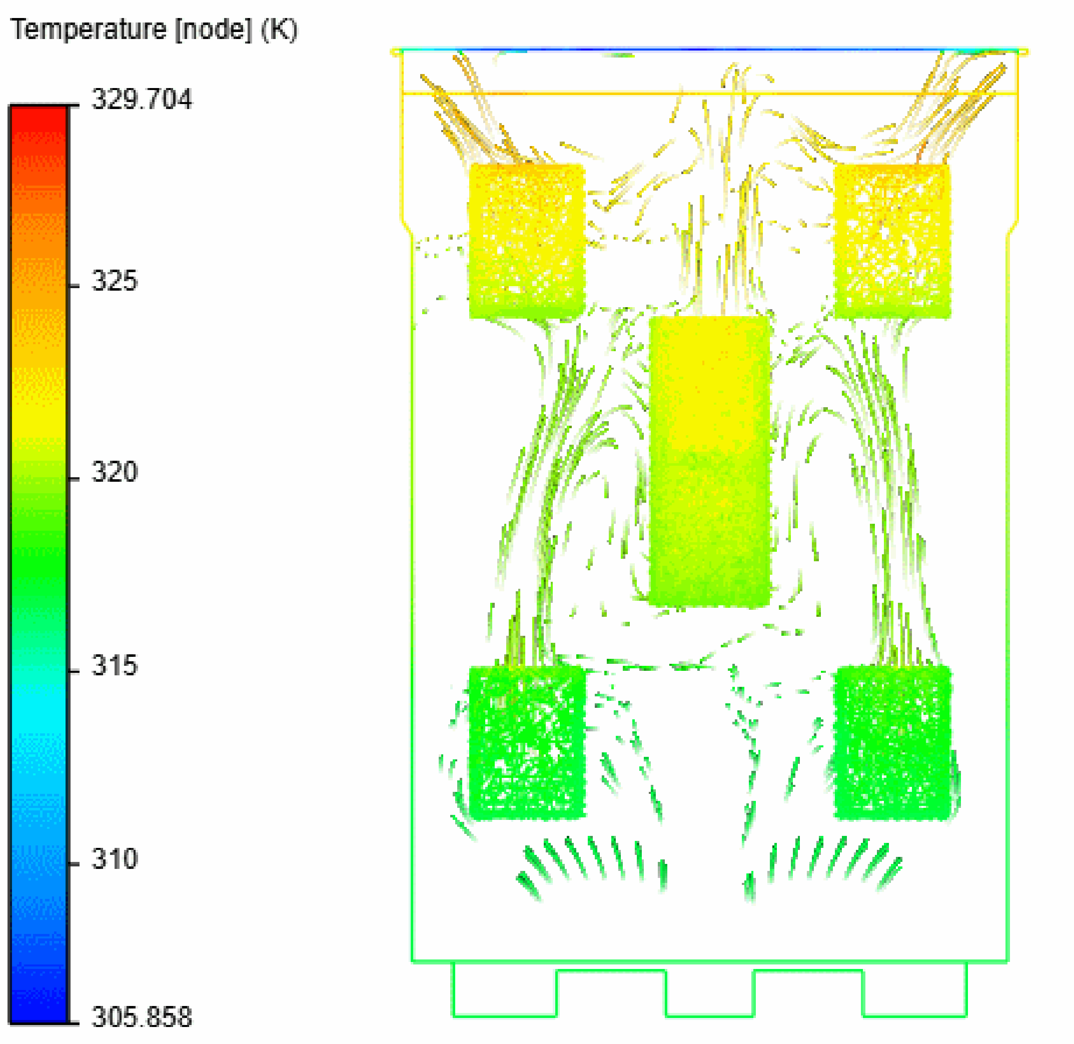
Achieve a PUE < 1.03 and reduce energy consumption

Increase computing density per sqm

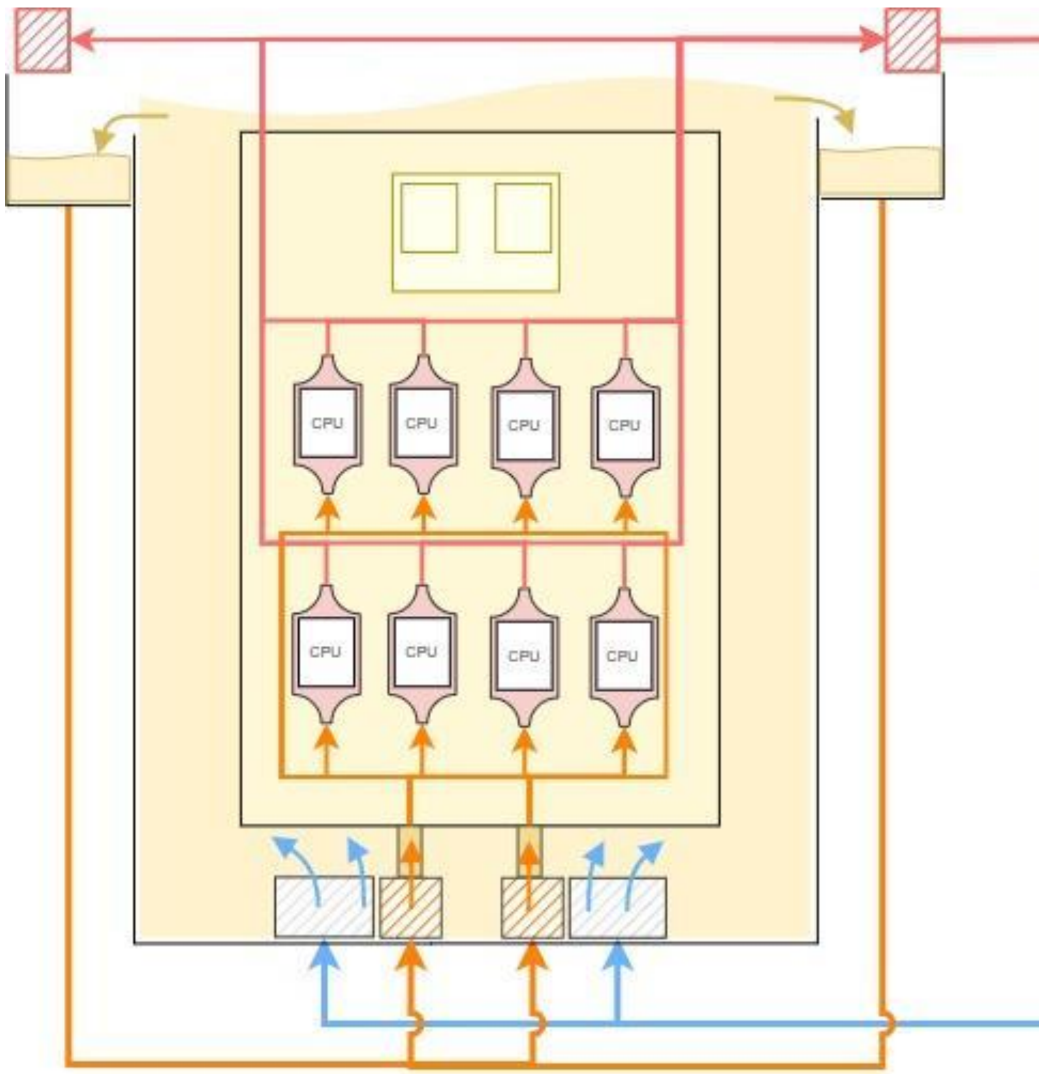
Zero waste of water

Reuse of the heat

Micro design for localized precision control

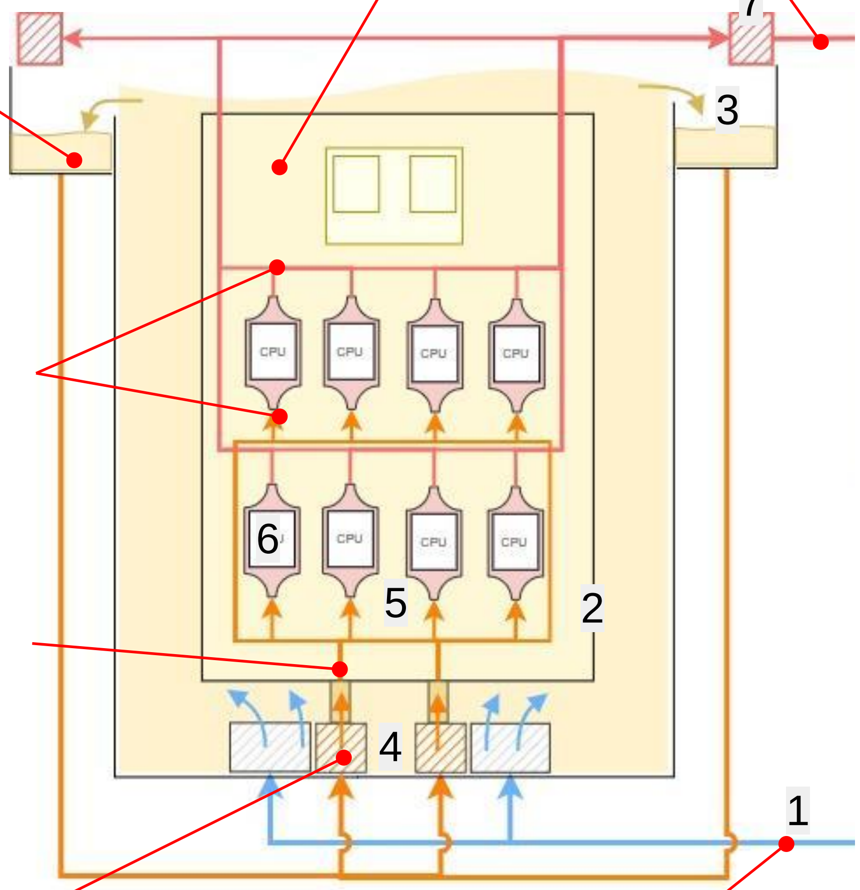


SmartPod



SmartPod Modular

Hybrid approach: immersion + precision cooling



Workflow

(1) Immersion flow → Inlet distributor (55ºC)
↓
(2) Bath, submerged motherboard and other components - Mix of forced + natural convection (56-57ºC)
↓
(3) Warmer fluid overflows (56-57ºC)
↓
(4) Distributor + CSU-controlled valves (56-57ºC)
↓
(5) Encapsulation of the various CPU/GPU
↓
(6) CPU/GPU/FPGA - Forced convection (70ºC)
↓
(7) Outlet collector (70ºC)
↓
(8) Pump (fluid is sucked)
↓
Heat exchanger (70ºC → 55ºC)

Goals and Objectives

- Set a common framework for sustainable computing:
  - Configuration and baseline of a production IT (Online) environment
  - Study and improvement on efficiency using energy efficiency scheduling techniques and KPI comparison, breaking the barrier of air-cooling.
  - Study on heat reuse techniques to improve energy recovery factor KPI’s
- Set the next in efficient data acquisition and analysis in LHCb.
  - Testing of existing detectors and elements in immersion cooling, validating the feasibility of an immersion cooling system as a compact data acquisition system in an underground setting
- Set the next in Immersion Cooling: First production system enabling precision immersion cooling
- Study maximization techniques for Energy Reuse Factor (ERF → see appendix for definition)

Appendix: more material

The ERF Standard

$$\mathrm{ERF} = \frac{E_{\mathrm{Reuse}}}{E_{\mathrm{DC}}}$$

ERF = Energy Reuse Factor

Standard-number: ISO/IEC 30134-6:2021

KPI to measure and report the energy reusage in a data center – basically it is the ratio between reused energy and consumed total amount of energy in a data center.

ERF value is numerical value between 0 to 1 – The numerical value tells practically the amount of reused energy in percentage in ratio to consumed total amount of energy in a data center.

Consumed energy is measured when it arrives inside the data center boundary and reused energy is measured when it exits the data center boundary.

Because the amount of reused energy has seasonal variations, ERF is measured and informed in annual period.

Energy reused inside the data center boundary is not calculated to ERF-value, because it is already been calculated to PUE-value (Standard ISO/IEC 30134-2:2016 – Power Usage Effectiveness).

The ERF Standard

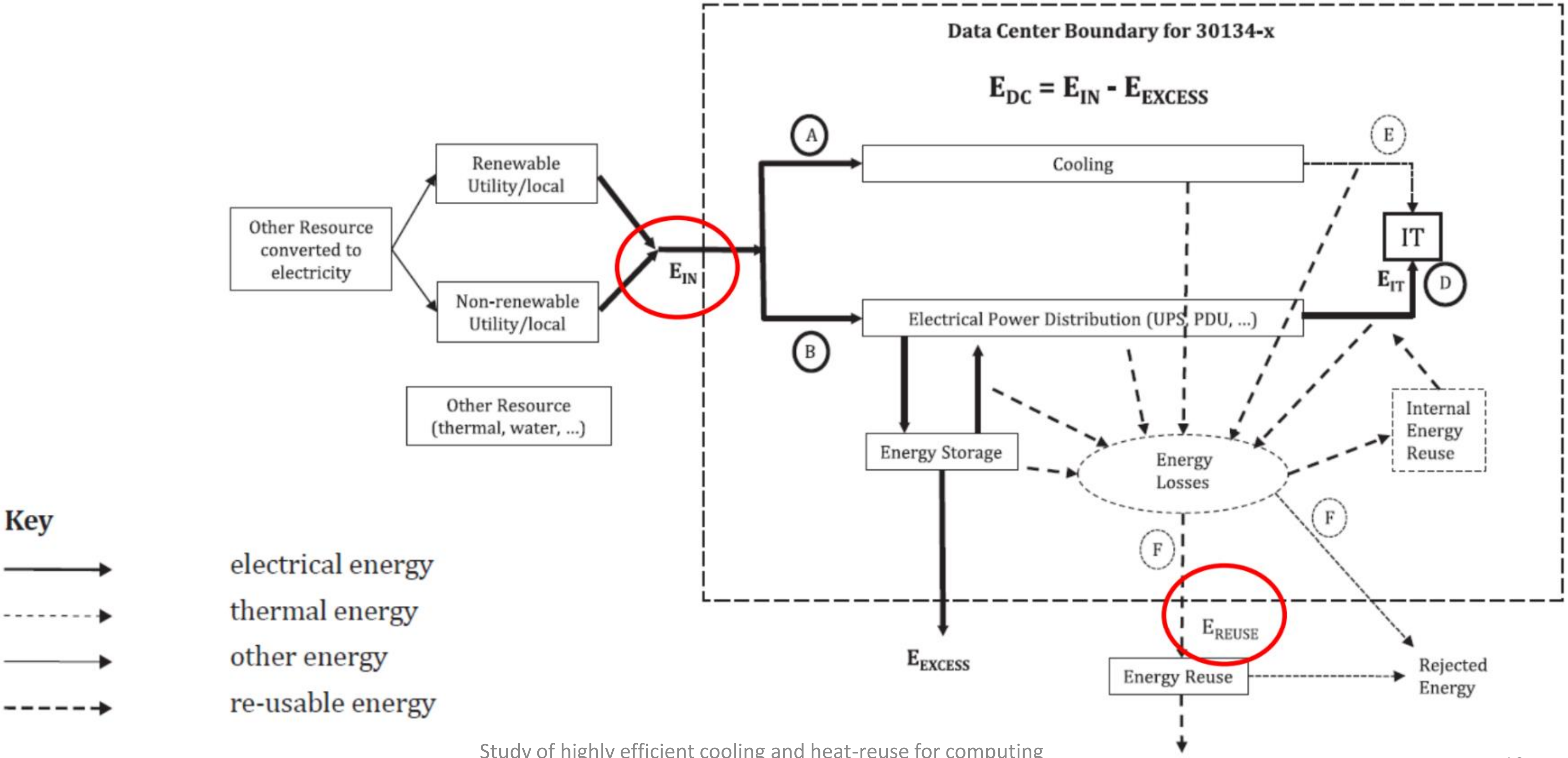


Figure 1 — Simplistic data centre components and boundary

EAR Framework

EAR is an Energy Management Framework for the efficient energy control of a cluster of interconnected nodes. EAR provides control, accounting, monitoring and optimization of energy on both the applications running in the cluster and on the overall global cluster.

At EAR's core is a monitoring tool which gathers data on the nodes and on the applications running on the cluster. So, in addition to optimizing the energy consumed by the applications running on the cluster, EAR reports the system and application performance metric information.

With the latest version, EAR has reported energy savings of more than 10% on average across a set of applications evaluated in collaboration with SURF Open Innovation Lab (SOIL)