European Data Centre Association's
Technical Committee

Data Centre Waste Heat and PUE Updates

EUDCA Viewpoint

EUROPEAN DATA CENTRE ASSOCIATION

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Executive Summary

Harnessing data centre waste heat for reuse in other systems such as district heating networks and industrial processes has been promoted as a way for the sector to increase efficiency and reduce waste. However, without changes to the way that heat reuse systems are accounted for, and data centre PUE is calculated, such schemes could prove costly and ultimately, unsustainable.

PUE is used as a key performance indicator in contractual agreements between data centre operators and their end clients to assess and value energy efficiency. It is therefore critical that the definition and calculation of PUE rely solely on relevant parameters that the operator can define and commit to contractually.

The current PUE standard provides a well understood efficiency metric that compares the total measured energy consumed by a data centre with the energy consumed by the IT equipment itself.

But recent PUE standards updates, such as some examples within the ISO/ IEC 30134-2 2025, would require data centre operators to include some heating or cooling plant in the PUE calculation not for data centre cooling, but for compatibility with external heating or cooling networks.

The position of the EUDCA is not to adopt this method, but to decouple the PUE calculation from the grade of energy necessary for heat recovery and export. The EUDCA proposes that intended heat for operating efficiency purposes of the data centre should be separated from recovered heat for export to heating networks.

Doing so will align data centres with EU taxonomy metrics, which go on to quantify community emissions reductions via recovered waste heat. This functional barrier for the data centre vs external heat networks is also allowed for in the current draft of the ISO/ IEC 30134-2. This opinion paper and examples describe a concept for this calculation method.

Operators should be able to leverage improvements in PUE via innovation and investment - PUE should not be a barrier to participation in heat exchange markets. Additionally, in line with data centre growth and the transition to renewable power generation, the EUDCA advocates an accessible and transparent heat exchange market to be established.

Heat Reuse and Data Centres

Heat reuse, also known as waste heat recovery, captures and reuses heat generated by various processes. For example, heat from a data centre can be used to warm buildings, provide hot water, or provide base heat for industrial processes. Instead of rejecting the heat to atmosphere, it can be harnessed to save energy and reduce environmental impact for those requiring heat, reducing the demand from more traditional heat sources and ultimately reducing carbon emissions.

To realise the savings a heat network must be installed to connect the source of heat to the heat users. As with all energy transmission systems, there are losses as heat is transferred between systems.

Data centres offer a large potential source of heat due to the power demands of the IT load. However, this heat is usually at around 25°C – 30°C for air-cooled IT equipment and 40°C – 48°C for liquid-cooled IT equipment. Therefore, for data centre waste heat to be useful additional energy is required to boost (increase the temperature) of the heat.

However, and for the avoidance of doubt, irrespective of its physical location the heat exchanger is not logically part of the data centre; it is logically part of the third-party heat network and should be accounted for as such. The rationale for this is that:

- The heat exchanger performs no function in terms of the operational efficiency of the data centre.
- The heat exchanger simply upgrades warm air that has left the facility so that is fit for the purposes of a third party.

Temperature		**Network Type**	**Uses**
Supply	Return		
< 20°C	<20°C	District Cooling Systems	Cooling
<45°C	25-15°C	5th Generation Very Low-Grade Heat	Pre-heating only with significant heat boosting required
60-45°C	30-15°C	4th Generation Low Grade Heat	Space heating and low temperature industrial processes with some heat boosting required
90-60°C	50-40°C	3rd Generation Useful Heat	Hot water systems with no heat boosting required

- The power consumed by a heat exchanger is not part of the data centre system; it is part of the external heat network system. It must be accounted for within the heat network system to ensure that the use of waste heat from the data centre is both carbon and cost-effective.

- If carbon and cost accounting of heat upgrade and heat reuse are not within the same system, perverse outcomes will result: if the cost or carbon impacts of upgrading the heat exceed the savings delivered to the network this will not be apparent if the heat exchangers are allocated to the data centre operating system and not to the heat network.

There is a clear precedent for this as the German government, after detailed consideration, has already determined in legislation that the heat pump is not part of the data centre system.

Viability of heat reuse should be viewed from both a cost and emissions perspective since the objective of using waste heat is to decarbonise, as far as possible, the heat requirement of the end user. Heat networks are frequently fossil-fuel dependent so waste heat that has been recovered from data centres can significantly reduce a heating network's carbon footprint.

Current Standards

Data Centres operate as efficiently as possible to reduce the amount of energy consumed which is not directly used to power the IT equipment. The key metric that is used to define this efficiency is Power Usage Effectiveness (PUE) which is defined within ISO/IEC 30134-2 and the European equivalent EN 50600-4-2 as follow:

$$PUE = \frac{\text{Total Data Centre Energy}}{\text{IT Equipment Energy}} = \frac{E_{DC}}{E_{IT}}$$

These standards note that only the energy associated with the data centre infrastructure, within its boundaries: including IT and supplemental equipment, power delivery, cooling system, lighting and other energy sources (such as gas, diesel and other fuels) are considered for the Total Data Centre Energy.

Both standards note that PUE does not take into account the re-use of waste by-products (such as heat).

A further standard within the same series provides a KPI to measure and record the benefit of exporting heat from a data centre: the Energy Reuse Factor (ERF). This is standardised in ISO/IEC 30134-6 and the European equivalent EN 50600-4-6. Defined as follows:

$$ERF = \frac{\text{Energy Reused}}{\text{Total Data Centre Energy}} = \frac{E_{Reuse}}{E_{DC}}$$

This provides a simple factor which determines how much energy is reused outside of the data centre boundary. Within the ERF standards, diagrams are provided which show that with a heat pump connected to a heat network, the energy provided to the heat pump and the cooling which is provided is therefore excluded from PUE.

PUE Standard Update

ISO/IEC 30134-2 is currently being reviewed, and as part of the update, the wording within the standard has been amended such that the description now reads:

Cooling system (electrical energy required to export other non-electric energy sources outside the data centre boundary shall be included in EDC and ERF should be reported, see ISO/IEC 30134-6 Energy Reuse Factor)

Therefore, in the update of the standard, any heat reused outside of the data centre, and any heat boosting which is applied outside of the data centre must now be included within the PUE.

However, the draft is contradictory as later in the same document it is stated that PUE does not take into account the re-use of waste by-products (such as heat). The updated standard currently references only spatial and logical considerations. However, it could allow for a functional boundary with the following wording:

> *"Boundary conditions may be based on spatial and logical considerations **or include other parameters**. (see 30134-1)"*

The allowance, that the boundary of the data center can be functional and not physical allows alignment of performance KPIs relative to the workload in question. For example, a temperature lift on server heat to make it usable to heat networks is not part of the data center operating model and should not affect efficiency metrics. Clear definition of these notional and functional boundaries will remove entry barriers and be a catalyst for data centres participate in community heat exchange programs.

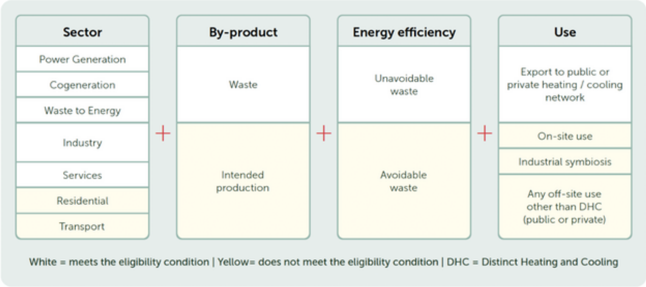
By decoupling data centre performance metrics from systems used for community heat exchange, the Data Centre PUE metric is restricted to critical operations, aligning with the associated energy footprint, emissions and energy cost. Participation in a heat exchange market would have no effect on established efficiency metrics for the data centre critical operation.

So, in summary, a clear functional boundary is an enabler for scalable and accessible heat exchange markets and helps redefine data centres as levers to emissions reduction.

Operational Implications

Legislation on minimum standards for data centres is current in some regions with PUE used as the metric in determining allowable efficiency. Other metrics include Waste Heat Reused (E_REUSE) and Average Waste Heat Temperature (T_WH), indicating recognition of waste heat's importance.

The Renewable Energy Directive provides definitions of waste heat and intended heat. 1These definitions are used to define emissions reduction through sector coupling, recognising that heat energy recovered from other processes reduces aggregate community emissions.



Taxonomy of waste heat. Source: Lyons et al. (2021)22 and nLighten-FEEM elaboration 2024.

1. Intended heat is produced by the data center critical load and its temperature regulation, this is comparable to any data center not exporting recovered heat and can be used to observe efficiency.
2. Waste heat is a volume of heat which can be exported to a heating customer using the data center as heat source. This volume of heat can reduce community emissions by offsetting higher carbon heat sources, often requiring an increase in temperature.

The data centre operating efficiency can still be calculated via the existing PUE metric by separating intended heat from waste heat (and recovered heat). This has the following advantages:

1. PUE remains a measurement not a calculation of data centre cooling efficiency based on the volume of **intended heat**.
2. Heat export for reuse is transferrable through the same system of calculation to define the ERF metric.
3. The energy allocation between data center cooling and upgrading of heat to higher temperatures is possible for any configuration by addressing the "intended heat" volume to define PUE.
4. This calculation method is compatible with higher data centre maturity levels where the data centre includes an energy centre and supplies power, heat or cooling to multiple entities.

This approach can provide regulatory clarity while encouraging heat reuse practices that can significantly contribute to decarbonization efforts. With well-defined functional boundaries, data centres can maintain competitive PUE values while still operating active plant to participate in trading of heat and cooling energy.

PUE calculation using Intended Heat - Example

The aggregate temperature lift between district heating and chilled water can be achieved by single or multiple heat pumps – which can be within or outside the physical data centre operation and energy supply. The boundary, therefore, between datacentre operating loads and district heating or cooling loads is dependent on function and temperature, not the physical location of plant. The following examples:

1. For simplicity of discussion:

a. Group ancillary mechanical loads (e.g. room cooling, pumps and filtration) into the heat pump (or chiller) COPs.

b. Split out units such as a heat pump, dry cooler or heat exchanger, where these represent the functional boundary between intended and recovered heat.

c. Represent the cooling system partial PUE and do not address front of house loads unaffected by the calculation method change.

2. Allow exclusion of energy attributable to increases in the grade of heating from the Data Centre PUE through isolation of intended heat from the recovered and total heat volumes.

3. Provide a PUE which is unaffected by heat recovery, regardless of the location of heat pumps, heat grade increases and whether they are powered from the data centre or externally.

For calculating PUE with a generic formula, we can normalise the server load E_{IT} to 1 p.u. (per unit). This reduces PUE to be the same as E_{DC}, whereby E_{DC} is 1 + the cooling load as a fraction E_{IT}.

$$PUE = \frac{E_{Reuse}}{E_{DC}} = E_{IT} + \frac{E_{IT}}{COP_1} = 1 + \frac{1}{COP_1}$$

Where E_{IT} = 1 and COP_1 is the coefficient of performance for the cooling of intended heat (kW_{th}/kW_{el})

E_{IT}: Server Energy also converted to heat = Hh +Hc

H_h: Server heat volume exported to a heat user (recovered heat) - net of cooling system heat e.g. Crah or pump losses.

H_c: Server heat cooled but not exported (intended heat) – net of cooling system heat e.g. CRAH or pump losses.

E_c: Electrical Chiller or Heat Pump Energy

E_f: Electrical Dry Cooler Fan or Cooling Tower Energy

E_{DC}: Total Electrical Energy of the Data centre critical operation (excluding heat systems)

COP: Coefficient of Performance Eth/Eel of all assets on the boundary including heating and cooling equipment. Also known as EER.

COP_1: COP all components of cooling system for intended heat.

COP_2: COP all components of cooling system for exported (waste) heat.

COP_{1c}: partial coefficient of performance of the chiller (Heat Pump) for cooling of intended heat.

COP_{1f}: partial coefficient of performance of the heat rejection (dry cooling) or equivalent side for cooling of intended heat.

Practical Implementation of Partial COPs

The separation of intended heat and recovered heat is done by measuring electrical and heat energy volumes in the cooling and heat recovery systems. This provides both the energy consumption and the separation of intended heat. See the worked diagrams for measurement points in the cooling topology.

1. **Measuring Points (refer to diagrams)**:
- Electrical energy to each system E1, E2 and components Ec, Ef thereof (e.g. pumps, heat pumps, chillers)
- Thermal energy H_c and H_h at key interfaces

2. **For Parallel Connected Systems** (see Appendix A – "Parallel Connection – at CHW circuit"

Recovered Heat H_h and Intended Heat Hc are processed by separate systems with a point of common coupling to the total server energy volume E_{IT}. The efficiency of the intended heat system COP_1 can be used to define the PUE ratio for the entire data centre cooling volume.

$$PUE = 1 + \frac{1}{COP_1}$$

The energy p.u. (per unit of E_{IT}) required for upgrading heat for export purposes is the efficiency difference between the cooling systems for intended heat and recovered heat respectively. Because these are electrical loads they are expressed as the inverse COPs i.e. 1/COP (kW_{el}/kW_{th}). These are comparable to additional PUE points.

$$\textit{Energy allocated to Heating System} = \frac{1}{COP_2} - \frac{1}{COP_1}$$

Alternatively, one can take the electrical volume consumed at the data centre p.u. (per unit where E_{IT}=1) and subtract the PUE.

3. **For Series Connected Systems**: (see Appendix A – "Series Connection – in Cooling Water Circuit"

As with parallel connected systems, cooling of intended heat is calculated from the COP of the system which lifts the temperature as required for rejection to atmosphere i.e. without heat export. Where series connected components may only reject the intended heat as a proportion of total heat, the electrical load is allocated to that proportion of cooling volume. For example, the dry cooler in this diagram:

$$\frac{1}{COP_{1f}} = \frac{E1_f}{\frac{H_c}{H_e + H_f}}$$

Once the partial coefficient of performance COP1 for the cooling of intended heat is defined, the resulting formula for PUE is always the same.

$$PUE = 1 + \frac{1}{COP_1}$$

As are the formulas for energy applicable to the heat upgrade system.

Other System Configurations

When implementing waste heat recovery, different system configurations affect the measurement and definition of the partial COPs. In Appendix A some different configuration examples are given and with the associated equations.

Summary and Conclusion

The Power Usage Effectiveness (PUE) metric, used as the industry standard for data centre energy efficiency, compares total energy consumption of a data centre to the energy used directly by IT equipment.

With a growing focus on decarbonisation and sector coupling, reusing data centre waste heat through district heating networks has become a viable pathway to reducing overall community emissions.

However, heat reuse often requires additional energy (via heat pumps or heat exchangers) to raise the temperature of waste heat to useful levels. This energy is external to the core data centre function.

If the flawed PUE definition is used in regulatory frameworks, several negative consequences could follow:

Misleading Efficiency Ratings: Data centres participating in heat reuse will appear less efficient, harming their reputation and competitiveness in energy labelling schemes (e.g., under the Energy Efficiency Directive (EED)).

Perverse Incentives: Operators may avoid investing in heat reuse infrastructure to protect their PUE scores, undermining EU climate and decarbonisation goals. This would disincentivise innovation, creating barriers to sector coupling and renewable integration.

Regulatory and Contractual Conflicts: PUE is commonly used in client contracts and performance guarantees. An inflated PUE due to heat recovery could result in contractual disputes and compliance challenges.

Market Inaccessibility: Smaller or new data centres might be excluded from community heating schemes due to fear of "penalised" PUE values, reducing the potential for scalable and equitable heat exchange markets.

The current draft standard risks distorting PUE's role, undermining climate-positive behaviours, and introducing harmful policy implications. A redefinition that separates internal efficiency from external heat reuse is essential to align efficiency metrics with decarbonisation objectives. For this reason, The EUDCA advocates for the **functional separation of "intended heat"** (cooled within the data centre for operational efficiency) from **"recovered heat"** (exported externally), enabling:

- **Preservation of PUE as a valid internal KPI,** independent of external energy systems.
- **Clear alignment with EU taxonomy** and environmental performance metrics.
- **Fair and logical allocation of energy use** between data centres and heat networks.

This approach aligns with existing standards such as **ISO/IEC 30134-6** (Energy Reuse Factor or ERF) and supports the inclusion of data centres in **decarbonisation frameworks**, without penalising them via inflated PUE metrics.

Detailed examples and formulae are presented to show how PUE can be calculated by isolating the energy for internal cooling (using a partial Coefficient of Performance, COP_1) from that used for external heat recovery (COP_2). This allows data centres to continue improving their internal efficiency while also contributing to heat reuse initiatives.

Appendix A – Worked examples
(source: nLighten B.V. Dec 2024)

Use of partial COPs for PUE measurement – for discussion

nlighten

1. This is a suggested option to prevent PUE movement due to export or import of heat, with the intention to reduce possible barriers to a heat exchange market, where efficiencies of district or 3rd party plant are outside the control of the datacenter operator:
   1. *PUE is unaffected by location of heat pump and supply of these from inside or outside the datacenter.*
   2. *Energy attributable to increases in the grade of heating is excluded from the DataCenter PUE*
2. For the discussion the Server Load is normalised to 1 p.u. (1 "per unit").
   1. *This reduces the PUE calculation to top line only (denominator is 1)*
   2. *The partial PUE is then the same as the sum of 1 + Mechanical Load (top line only)*
   3. *Whereby the mechanical load is the inverse of the COP (coefficient of performance) in units (kWh_e/kWh_{th})*
   4. *Whereby the inverse of the system COP is the sum of inverse partial COPs*
3. Inverse COPs and partial COPs are electrical kWh divided by thermal kWh on hourly basis to ensure seasonal and momentary accuracy
4. This is suggested additional to existing measurement and calculation practices, this presentation excludes ancillary loads, and groups circulation pumps, fans and heat pumps for simplicity of discussion.

PUE Measurement using partial COPs

Chad McCarthy, CTO, nLighten B.V.

Parallel Connection – at CHW Circuit

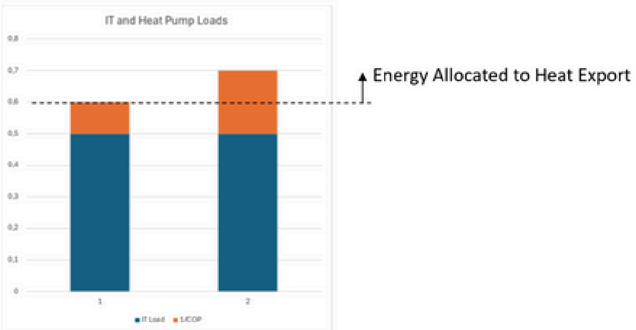
Server Load Eit = heat volumes Hh + Hc
whereby Hh is a proportion of server heat recovered for heat reuse

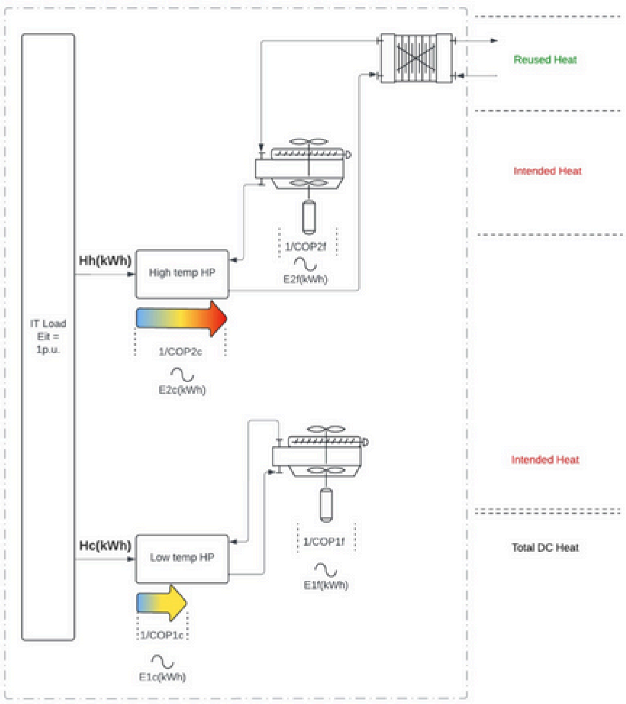
Eit = 1 p.u. (per unit), for this example the measured COP1 = 5

measurement of COP1:
1 / COP1c = E1c(kWh) / Hc(kWh)
1 / COP1f = E1f (kWh) / Hc(kWh)
1 / COP1 = 1 / COP1c + 1 / COP1f

Edc = Eit + (Hc + Hh) / COP1
= 1 + 1/5
= 1.2 p.u. (1.2 PUE awarded to DC)

1/COP2 - 1/COP1 = energy allocated to heating customer kWh_e/kWh_{th}





PUE measurement using partial COPs

Parallel Connection District Cooling & Heating

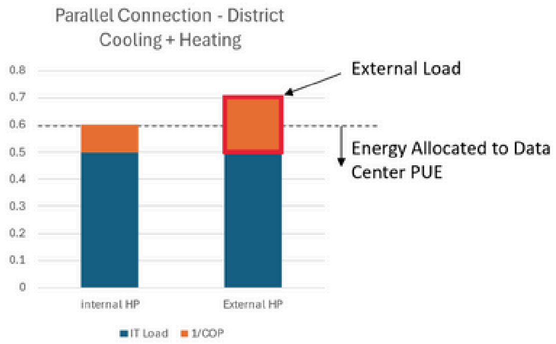
Server Load Eit = heat volumes Hh + Hc
whereby Hh is a proportion of server heat recovered for heat reuse

Eit = 1 p.u. (per unit), for this example the measured COP1 = 5

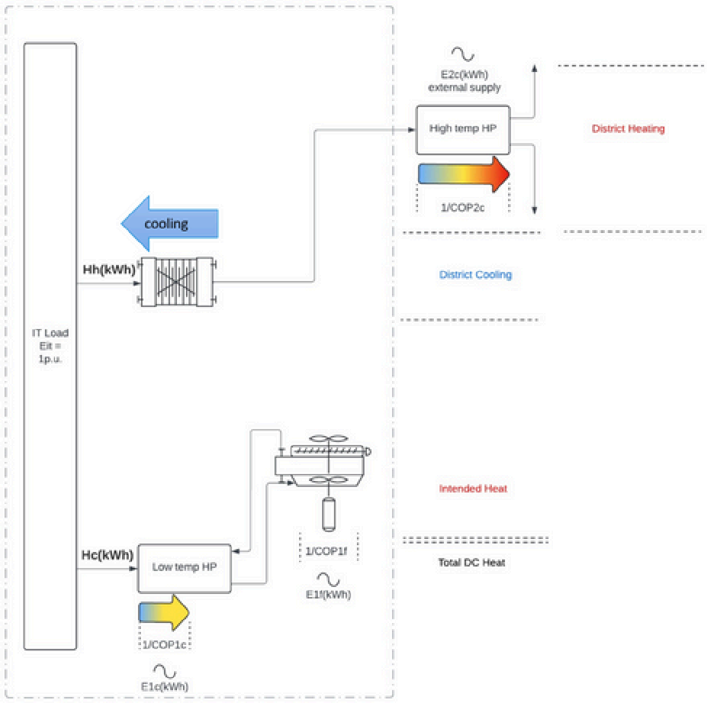
measurement of COP1:
1 / COP1c = E1c(kWh) / Hc(kWh)
1 / COP1f = E1f (kWh) / Hc(kWh)
1 / COP1 = 1 / COP1c + 1 / COP1f

Edc = Eit + (Hc + Hh) / COP1
= 1 + 1/5
= 1.2 p.u. (1.2 PUE awarded to DC)

1/COP2 - 1/COP1 = energy allocated to heating customer kWh_e/kWh_{th}



PUE measurement using partial COPs



Series Connection – Chilled Water Circuit

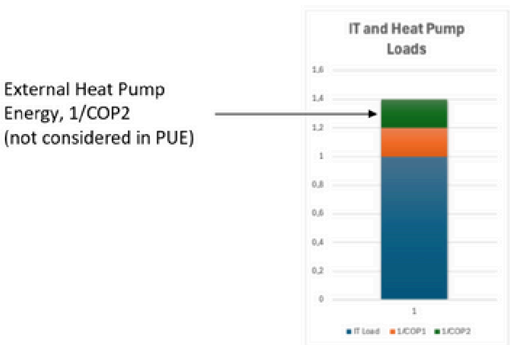
Server Load Eit = heat volumes Hh + Hc
whereby Hh is a proportion of server heat recovered for heat reuse

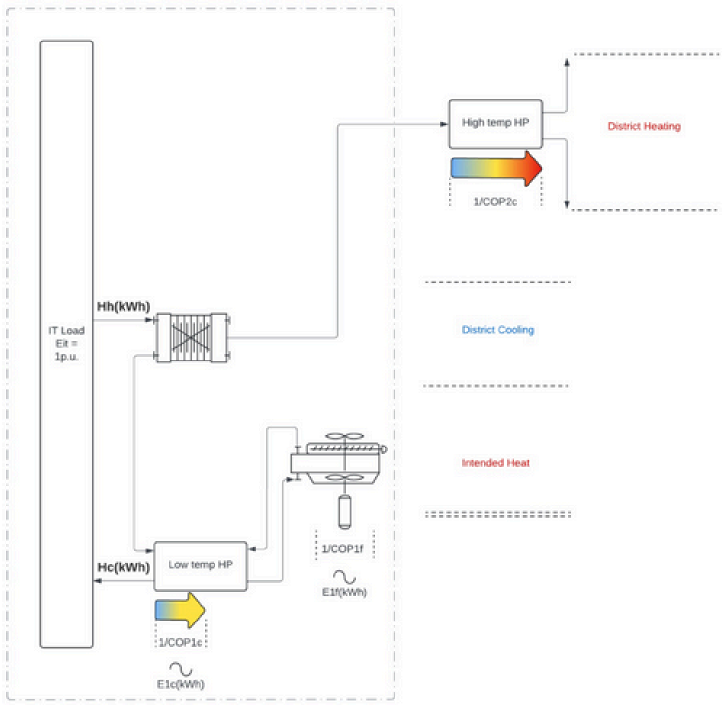
Eit = 1 p.u. (per unit), for this example the measured COP1 = 5

1 / COP1c = E1c(kWh) / Hc(kWh)
1 / COP1f = E1f (kWh) / Hc(kWh)
1 / COP1 = 1 / COP1c + 1 / COP1f

Edc = Eit + (Hc + Hh) / COP1
= 1 + 1/5
= 1.2 p.u. (1.2 PUE awarded to DC)

1/COP2 = energy allocated to heating customer kWh_e/kWh_{th}
1/COP1 = energy allocated to DC cooling kWh_e/kWh_{th}
DC PUE determined by own plant and operating point





PUE measurement using partial COPs

Series Connection – in Cooling Water Circuit

Server Load Eit = heat volumes Hh + Hc
whereby Hh is a proportion of server heat recovered for heat reuse

Eit = 1 p.u. (per unit), for this example the measured COP1 = 5

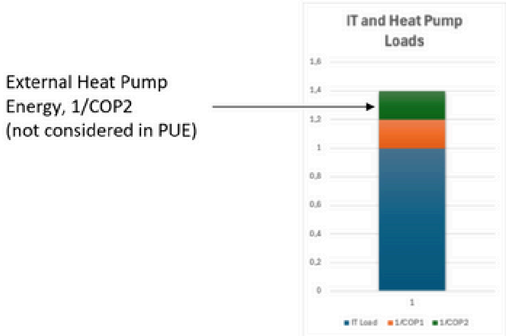
1 / COP1c = E1c / (Hc + Hh)

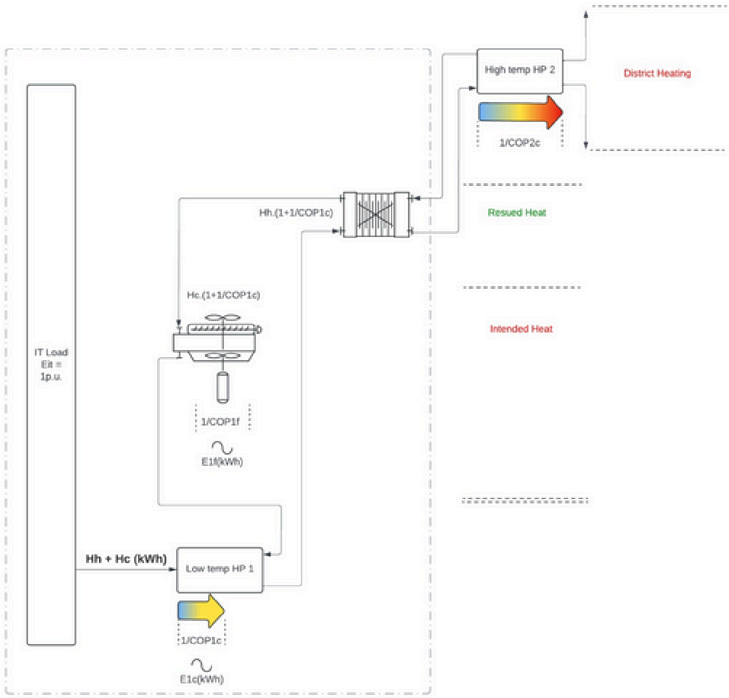
1 / COP1f = E1f/(Hc/(Hc+Hh)) where (Hc+Hh = Eit = 1)
=E1f/Hc

1 / COP1 = 1 / COP1c + 1 / COP1f

Edc = Eit + 1 / COP1
= 1 + 1/5
= 1.2 p.u. (1.2 PUE awarded to DC)

1/COP2 = energy allocated to heating customer kWh_e/kWh_{th}
1/COP1 = energy allocated to DC cooling kWh_e/kWh_{th}
DC PUE determined by own plant and operating point





PUE measurement using partial COPs