An Improved Energy Reuse Metric

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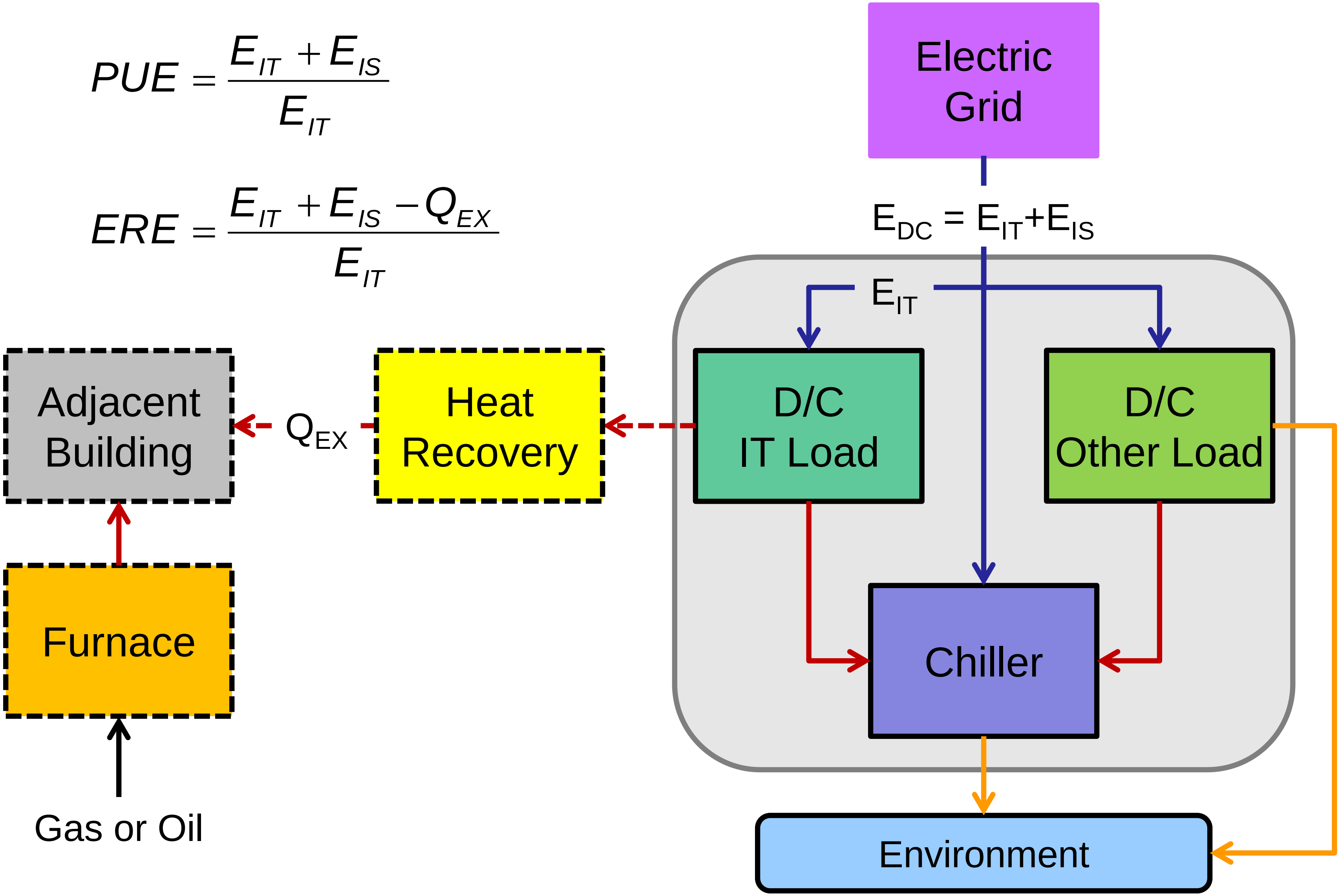
Typical Data Center Energy Flow Block Diagram

$$PUE = \frac{E_{IT} + E_{IS}}{E_{IT}}$$

$$ERE = \frac{E_{IT} + E_{IS} - Q_{EX}}{E_{IT}}$$



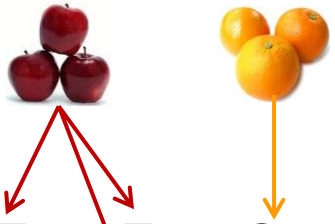
The Green Grid ERE Metric

If there is a nearby user of the data center waste heat…

- In PUE, all energy flows are expressed in terms of electricity:

$$PUE = \frac{E_{IT} + E_{IS}}{E_{IT}}$$

- In ERE as defined by TGG, we subtract heat from electricity!!!



$$ERE = \frac{E_{IT} + E_{IS} - Q_{EX}}{E_{IT}}$$

Heat is not Equivalent to Electricity

A rational definition of ERE must recognized the difference between heat and electricity…

- Heat and electricity are not thermodynamically equivalent:
  - *Electricity is energy of the highest thermodynamic quality. It is work, or "exergy"…*
  - *The thermodynamic quality of heat depends on the temperature at which it is available. The higher the temperature, the higher the quality – the "exergy"…*

- Nor is heat economically equivalent to electricity:
  - *The adjacent building that would use the energy exported by the data center (Q_{EX}) will use this energy to displace heat derived from a fuel-fired furnace or boiler, not from an electric heater.*
  - *A certain amount of energy derived from a fuel (gas or oil) is typically much less expensive than the same amount of electricity (kJ for kJ).*

How to Fix TGG's EER Problem

We need a rational, et simple approach that recognizes the fact that heat and electricity are not of the same worth…

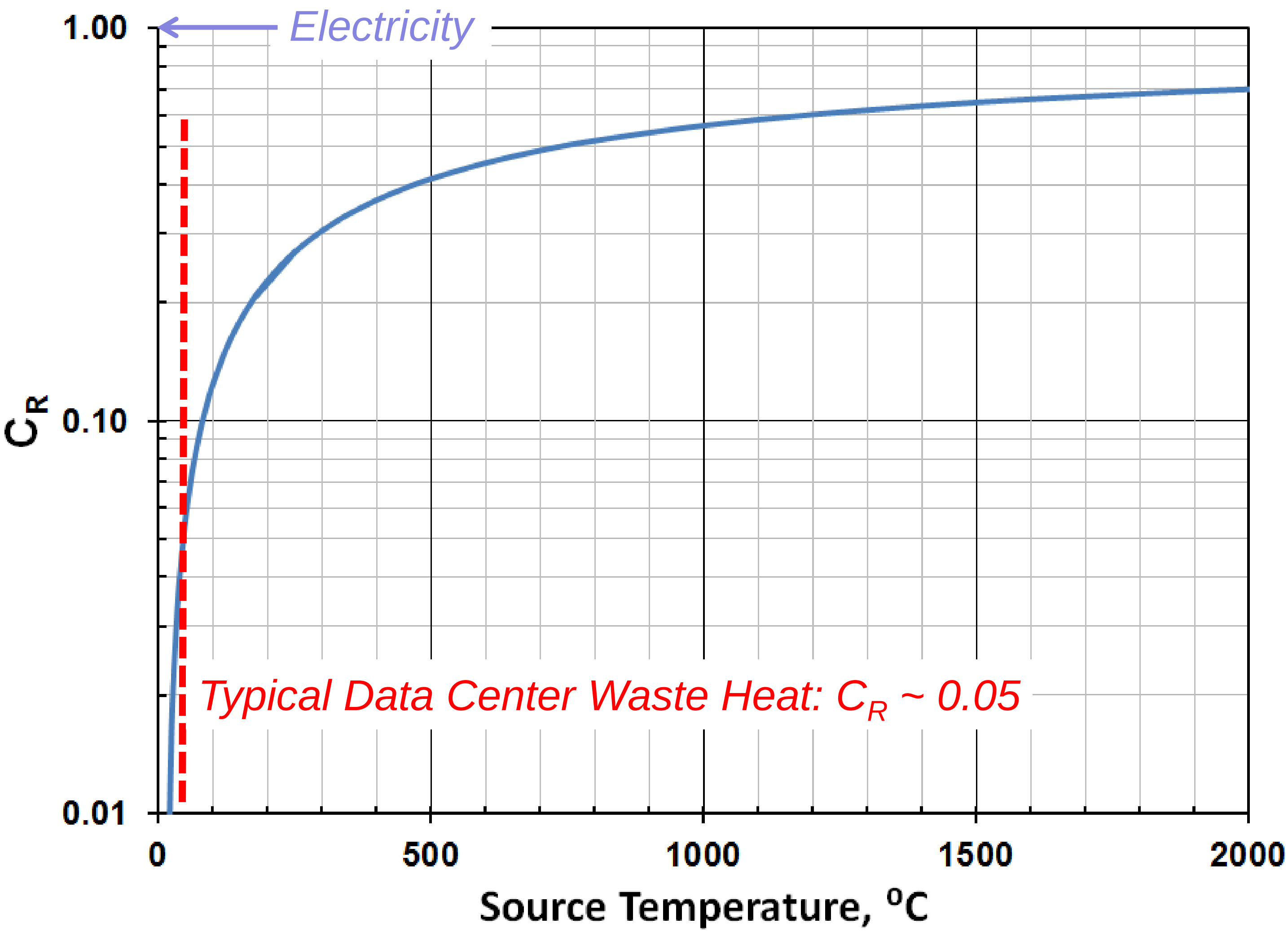
- Introduce a simple Heat-to-Electricity Equivalence Ratio, C_R:

$$ERE' = \frac{E_{IT} + E_{IS} - C_R Q_{EX}}{E_{IT}}$$

- There are three ways to obtain a reasonable estimate of C_R:
  1. *A rigorous thermodynamic estimate based on exergy;*
  2. *A practical thermodynamic estimate based on realizable fuel-to-electricity conversion efficiency;*
  3. *An economic estimate based on the relative price of fuel and electricity.*

The Exergy Approach

Thermodynamically rigorous but not practical…



The Practical Thermodynamic Approach

Based on the fuel equivalent of electricity…

- Assume that the electricity is generated in a thermal power plant whose thermal efficiency is η (efficiency of converting fuel at the power plant to electricity at the data center); *typically $\eta \approx 0.3$*.
- Therefore the fuel equivalent of the various electric terms in the ERE definition are replaced with:

$$ERE' = \frac{E_{IT}/\eta + E_{IS}/\eta - Q_{EX}}{E_{IT}/\eta}$$

- If multiply numerator and denominator by η, we get

$$ERE' = \frac{E_{IT} + E_{IS} - \eta Q_{EX}}{E_{IT}}$$

- This means that $\boldsymbol{C_R = \eta \approx 0.3}$.

The Economic Equivalence Approach

Based on the ratio of fuel cost to electricity cost…

- Here we assume that the waste heat from the data, Q_{EX}, center will displace heat that would have been supplied by a gas-fired furnace with an efficiency η_f ; *typically $\eta_f \approx 0.85$*.
- Therefore the electric equivalent of Q_{EX} term in the ERE definition is replaced with:

$$ERE' = \frac{E_{IT} + E_{IS} - (c_g / c_e) Q_{EX} / \eta_f}{E_{IT}},$$

where c_g and c_e are the gas and electricity prices in \$/MJ. Therefore,

$$C_R = (c_g / c_e) / \eta_f$$

- The commercial gas/electricity price ratio in the US is typically *0.2-0.4*, therefore a value of ***$C_R \approx 0.35$*** is a reasonable average value.

Conclusions

We Propose a simple and rationale redefinition of ERE…

- Both the Practical Thermodynamic Approach and the Economic Equivalence Approach lead approximately to the same vale of C_R.
- We propose to put:

$$C_R = \frac{1}{3}.$$

- This leads to the following ***simple and rational*** definition of a modified Energy Reuse Effectiveness:

$$ERE' = \frac{E_{IT} + E_{IS} - Q_{EX}/3}{E_{IT}}.$$