Bytes and BTUs: Keys to a Net Zero Data Center

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Presentation Road Map

- A Holistic Approach to Sustainability:
  - Power, Packaging, Cooling, Integration …
- NREL ESIF Data Center.
- Focus on the “1”.
- Longer term view.

Motivation

Data centers are highly energy-intensive facilities

- 10-100x more energy intensive than an office.
- Server racks well in excess of 30kW.
- Surging demand for data storage.
- ~3% of U.S. electricity consumption.
- Projected to double in next 5 years.
- Power and cooling constraints in existing facilities.

Slide information courtesy of Dale Sartor, LBNL

Sustainable Computing

- Choices regarding power, packaging, cooling, and energy recovery in data centers drives sustainability and TCO.

- Why should we care?
  - Carbon footprint.
  - Water usage.
  - Mega$ per MW year.
  - Cost: OpEx > IT CapEx!

- Thus, we need a *holistic* approach to sustainability and TCO for the entire computing enterprise, not just the HPC system.

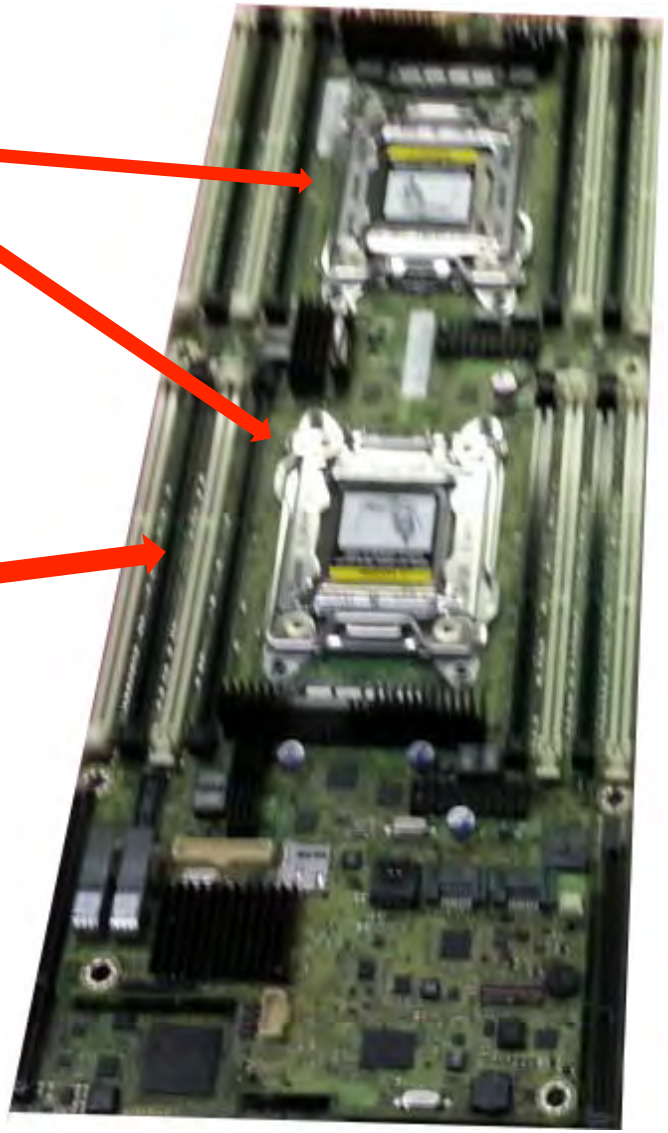
Holistic Thinking

- Approach to **Cooling**: Air vs Liquid and where?
  - Components, Liquid Doors or CRACs, …
- What is your "ambient" **Temperature**?
  - 55F, 65F, 75F, 85F, 95F, 105F …
  - 13C, 18C, 24C, 30C, 35C, 40.5C …
- **Electrical** distribution:
  - 208v or 480v?
- "Waste" **Heat**:
  - How hot? Liquid or Air? Throw it away or Use it?

Safe Temperature Limits

CPUs
~65C
(149F)

Memory
~85C
(185F)

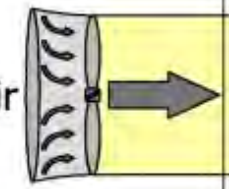


GPUs
~75C
(167F)

CPU, GPU & Memory, represent ~75-90% of heat load …

Cooling Efficiency

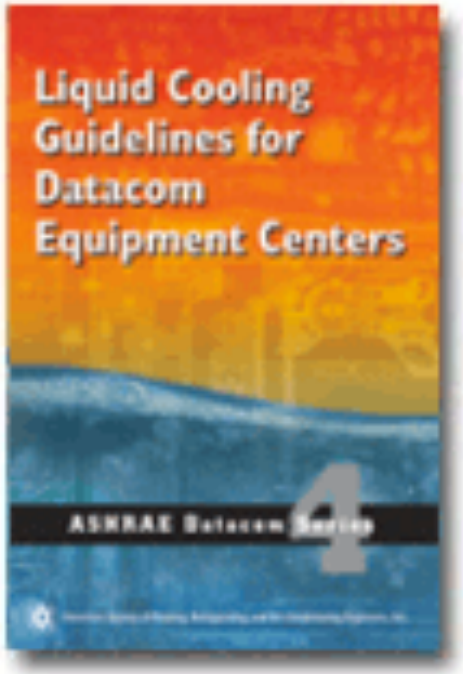
- Heat exchange: liquids are ~1000x more efficient than air.
- Transport energy: liquids require ~10x less energy. (14.36 Air to Water Horsepower ratio, see below).
- Liquid-to-liquid heat exchangers have closer approach temps than Liquid-to-air (coils), yielding increased economizer hours.

Heat Transfer		Resultant Energy Requirements			
Rate	ΔT	Heat Transfer Medium	Fluid Flow Rate	Conduit Size	Theoretical Horsepower
10 Tons	12°F	Forced Air 	9217 cfm	34" Ø	3.63 Hp
		Water 	20 gpm	2" Ø	.25 Hp

Move to Liquid Cooling

- Server muffin fans are noisy and inefficient.
  - Liquid doors are an improvement but we can do better!
- Power densities are rising making component-level liquid cooling solutions more appropriate.
- Liquid benefit:
  - Thermal stability, reduced component failures.
  - Better waste heat re-use options.
  - Warm water cooling, reduce/eliminate condensation.
  - Provide cooling with higher temperature coolant.
    - Eliminate expensive & inefficient chillers

Liquid Cooling – New Considerations



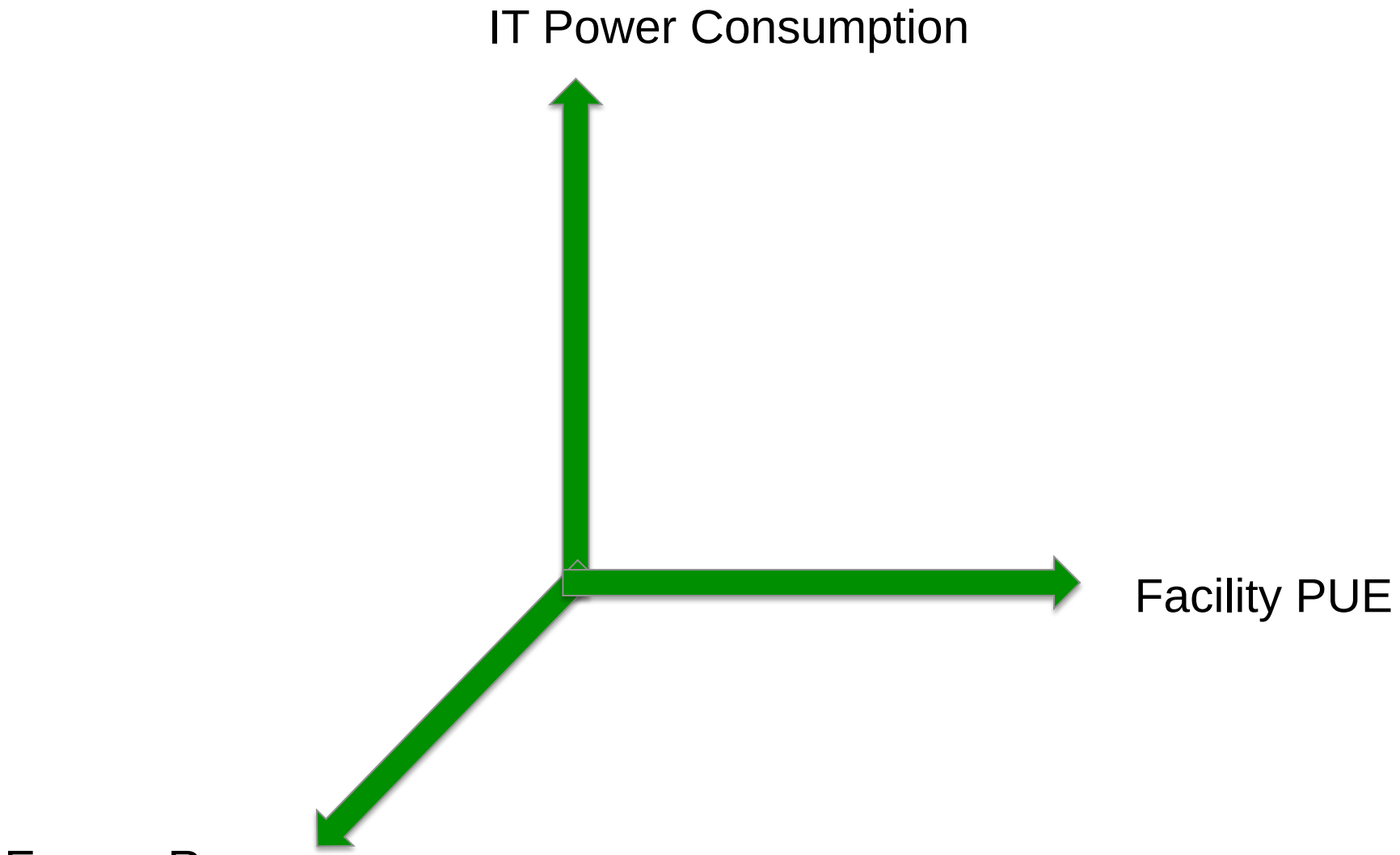
- Air Cooling:
  - Humidity.
  - Air side economizers, particulates.
- Liquid Cooling:
  - pH & bacteria.
  - Dissolved solids.
  - Corrosion inhibitors, etc.
- When considering liquid cooled systems, insist that providers adhere to the latest ASHRAE water quality spec or it could be costly.

Water Considerations

"We shouldn't use evaporative cooling, water is scarce"

- Thermoelectric power generation (coal, oil, natural gas and nuclear) consumes about 1.1 gallon per KW hour, on average.
- This amounts to about 9.5M gallons per MW year.
- We estimate about 2.0M gallons water consumed per MW year for on site evaporative cooling at NREL.
- IF chillers need 0.2MW per MW of HPC power, then chillers have an impact of 2.375M gallons per year per MW.
- Actuals will depend on your site but evap. cooling doesn't necessarily result in a net increase in water use.

Sustainability - Managing Bytes & BTUs



Sustainability requires 3-D optimization.

NREL HPC Data Center

- Showcase Facility
  - 10MW, 10,000 s.f.
  - Leverage favorable climate
  - Use evaporative rather mechanical cooling.
  - Waste heat captured and used to heat labs & offices.
  - World's most energy efficient data center, PUE 1.06!
  - Lower CapEx and OpEx.
- High Performance Computing
  - Petascale+ HPC Capability in 2012
  - 20 year planning horizon
    - 5 to 6 HPC generations.
  - Insight Center
    - Scientific data visualization
    - Collaboration and interaction.

Leveraged expertise in energy efficient buildings to focus on showcase data center.

Chips to bricks approach.

Critical Data Center Specs

- Warm water cooling, 75F (24C)
  - Water much better working fluid than air - pumps trump fans.
  - Utilize high quality waste heat, 95F (35C) or warmer.
  - +90% IT heat load to liquid.
- High power distribution
  - 480VAC, Eliminate conversions.
- Think outside the box
  - Don’t be satisfied with an energy efficient data center nestled on campus surrounded by inefficient laboratory and office buildings.
  - Innovate, integrate, optimize.

Dashboards report instantaneous, seasonal and cumulative PUE values.

NREL ESIF Data Center Cross Section

- Data center equivalent of the “visible man”
  - Reveal not just boxes with blinky lights, but the inner workings of the building as well.
  - Tour views into pump room and mechanical spaces
  - Color code pipes, LCD monitors

PUEs: Reported & Calculated

	PUE
EPA Energy Star Average	1.91
Intel Jones Farm, Hillsboro	1.41
T-Systems & Intel DC2020 Test Lab, Munich	1.24
Google	1.16
Leibniz Supercomputing Centre (LRZ)	1.15
National Center for Atmospheric Research (NCAR)	1.10
Yahoo, Lockport	1.08
Facebook, Prineville	1.07
National Renewable Energy Laboratory (NREL)	**1.06**

Slide Courtesy Mike Patterson, Intel

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It's all about the "1"!

1.06
Focus on driving the 0.06 down?
Or work with the 1.0? How?

- Energy reuse
- Continued improvement in compute performance and delivered flops/watt.

Slide Courtesy Mike Patterson, Intel

PUE & ERE re-sorted….

	PUE	Energy Reuse
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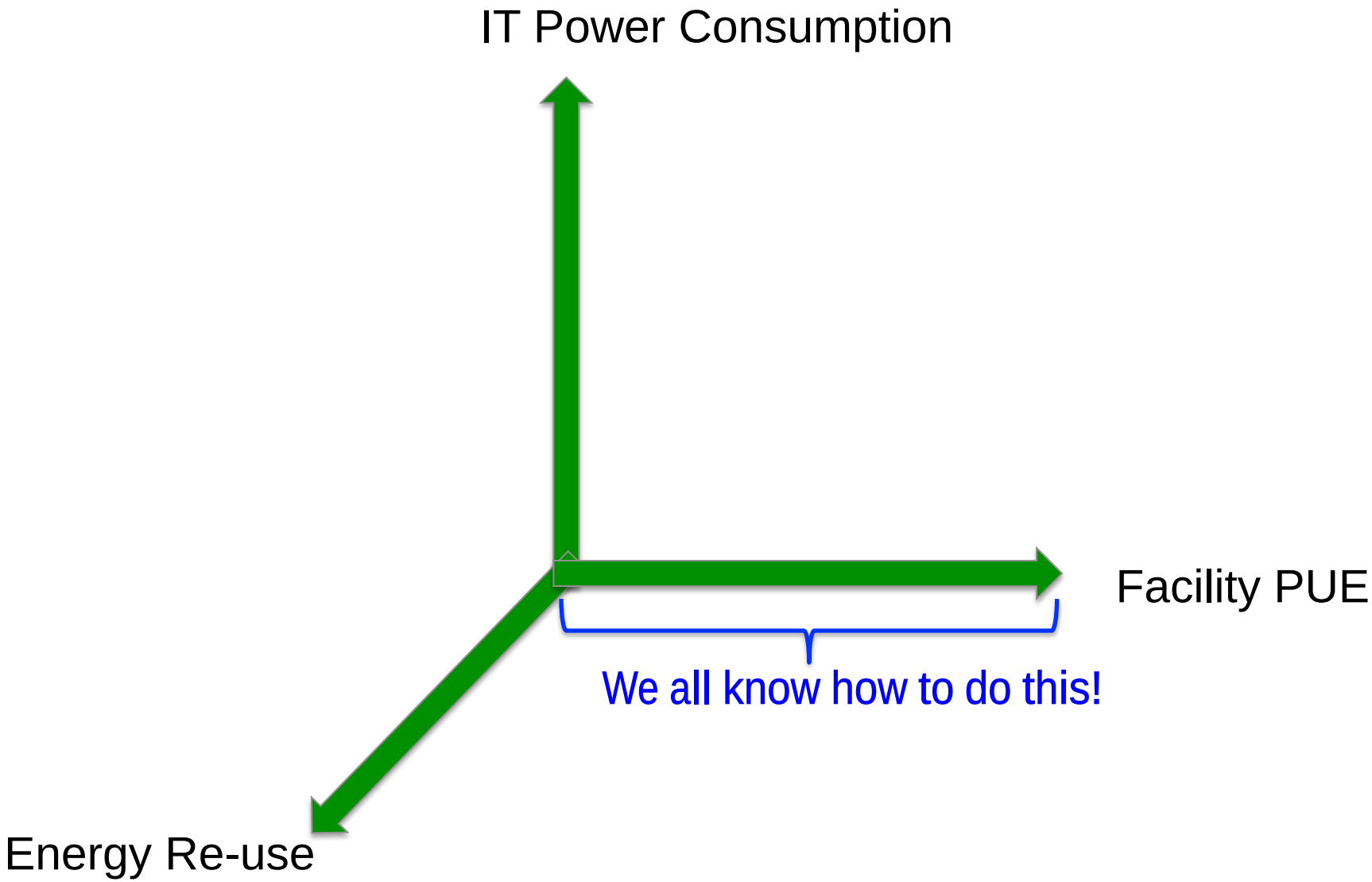

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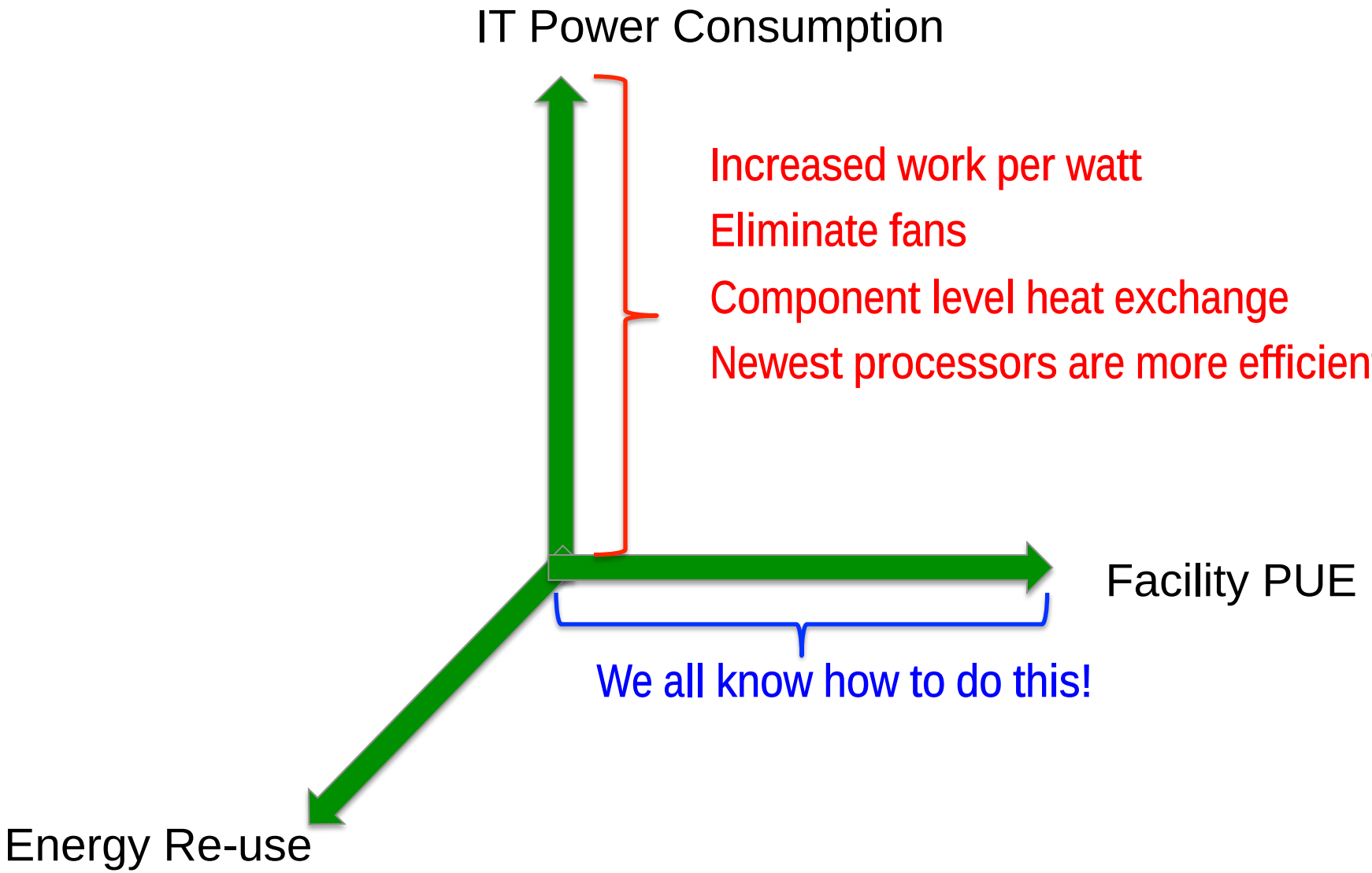

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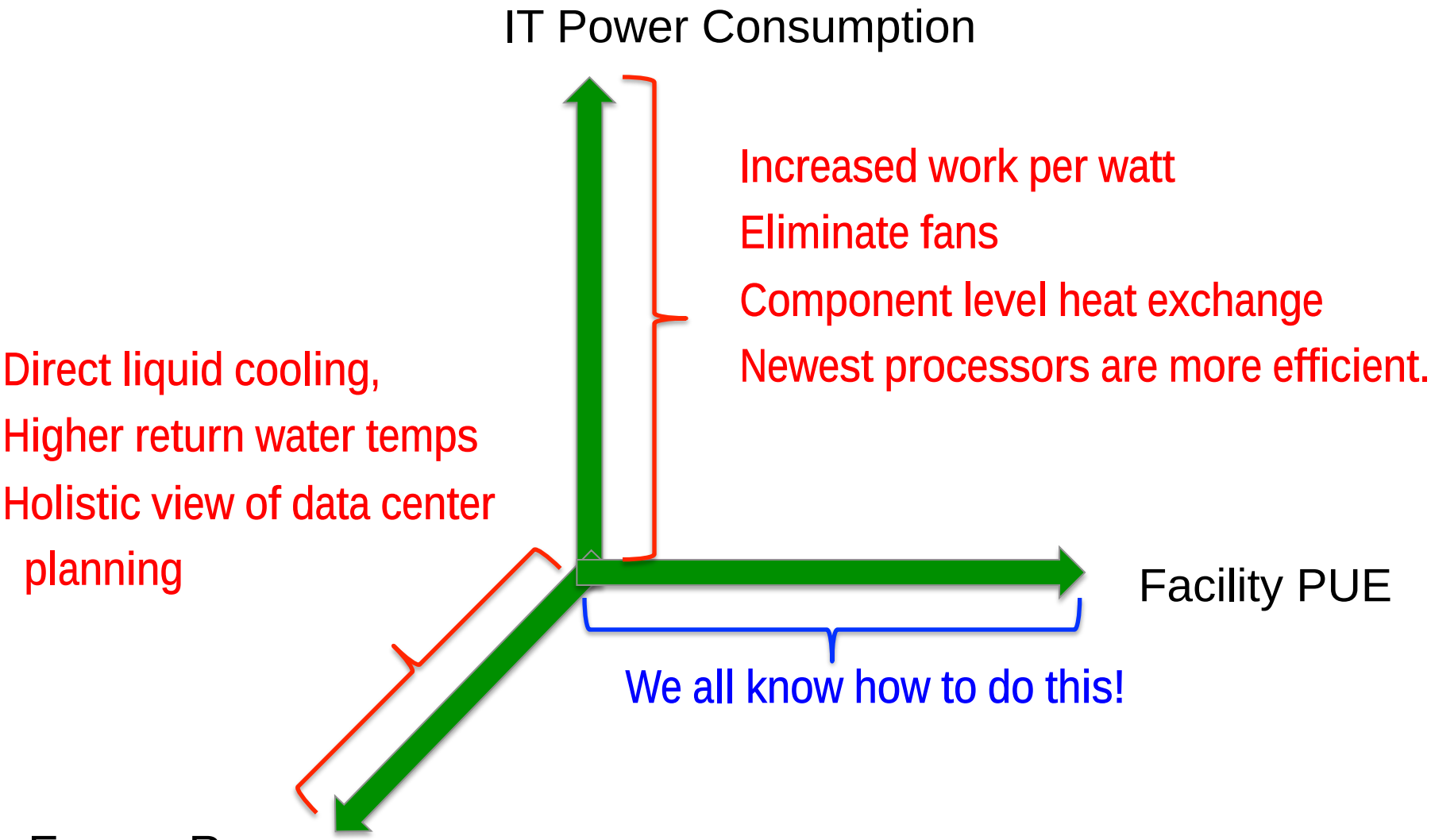

Sustainability requires 3-D optimization.

Parting Thoughts

- **Energy Efficient Data Centers – been there, done that**
  - We know how, let's just apply best practices
- **Metrics will lead us into sustainability**
  - If you don't measure/monitor it, you can't manage it.
  - As PUE has done; ERE, CUE, WUE will help drive sustainability
- **Energy Efficient and Sustainable Computing – it's all about the "1"**
  - 1.0 or 0.06? Where do we focus? Compute & Energy Reuse
- **Holistic and high levels of integration can reduce TCO.**
  - Break down the silos.
  - Don't fear H_20: Liquid cooling will be increasingly prevalent
  - Opportunities for waste heat re-use will drive changes in how we approach computing, even large cloud data centers.

Questions?

Thank you!