True Sustainability, The path to a Net-Zero Datacenter: Energy, Carbon, Water

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DARPA Exascale target: 20 MW

Why not?

- Today's best technology: 70 picojoule per flop
  - $1x10^{18}$ flops * $70x10^{-12}$ joules / flop = $70x10^{6}$ joules * s
  - $70x10^{6}$ joules * s * 1 watt/s = 70 MW
- Darpa Projection: 5 -10 picojoule per flop
  - 5 – 10 MW Exascale SuperComputer!

Not quite.

- Cost of moving 2x 64 bits operands in and out:
  - 1000 to 3000 picojoule per flop
  - Under current assumptions: 300 MW to 1 GW for Exascale

Exascale Computing: today?

Best performing sustained Flops/watts Top10 architecture:

- Tsubame II: 852 $MFlops_{max}$ / watt

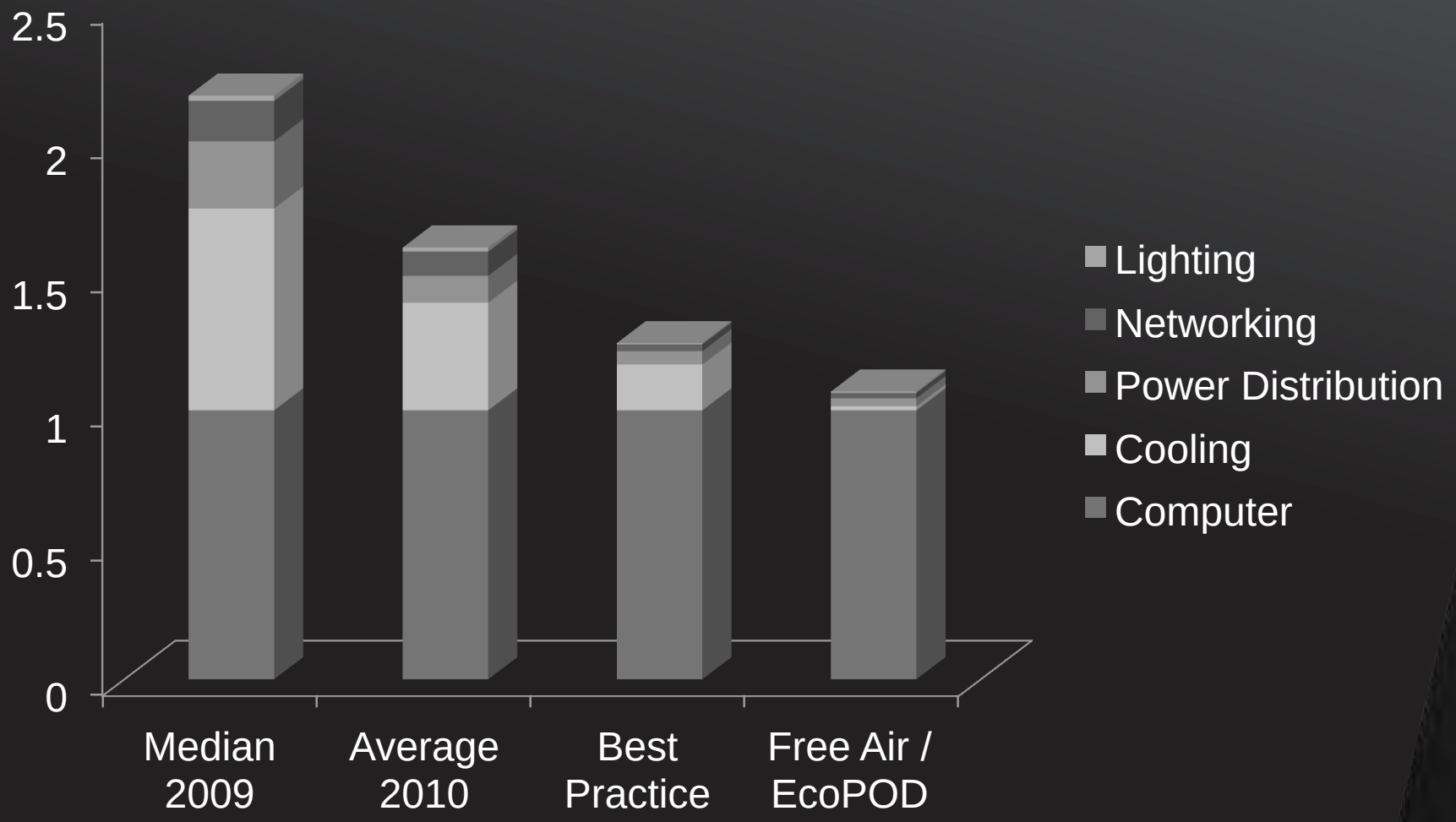
=> Exascale equivalent: 1.2GWatts!

~ 900 000 houses

~ 3M people: Chicago

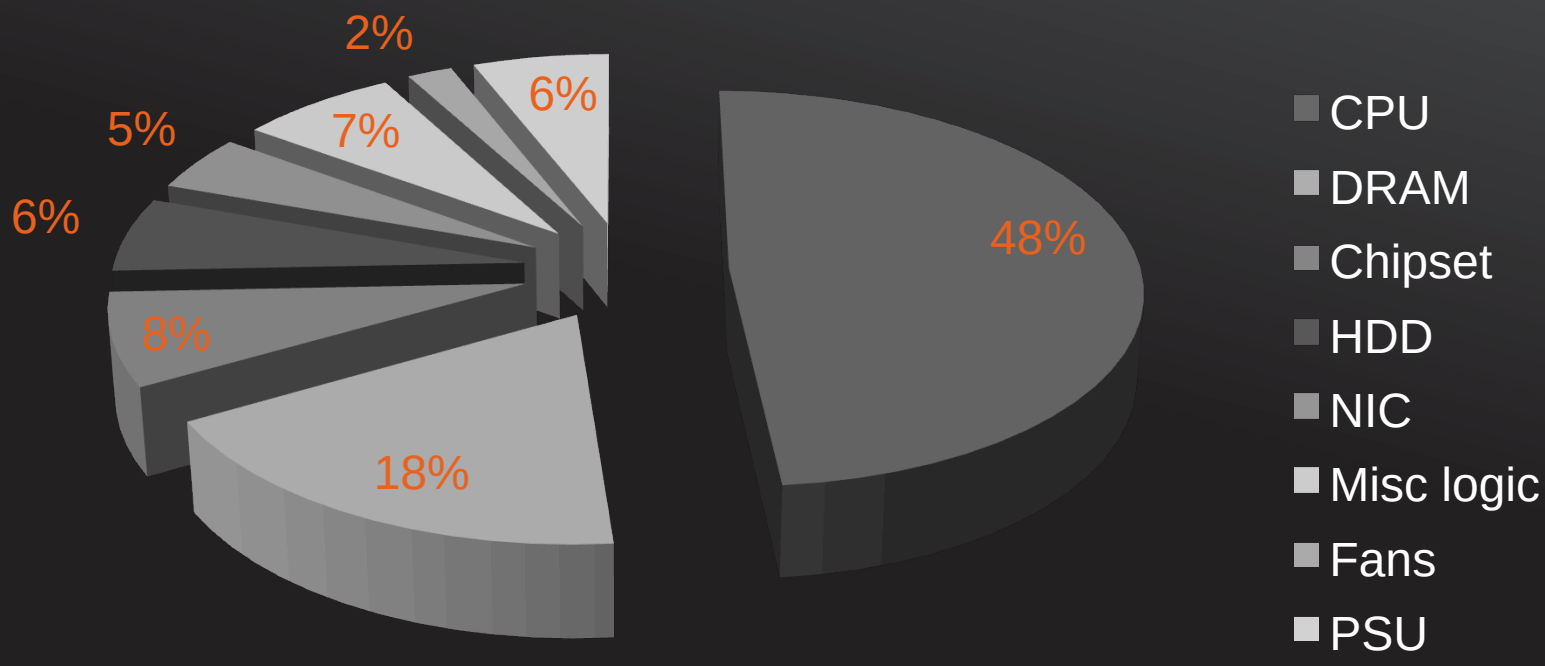
~ 1M Electric Cars @ 100km / day

The PUE “holy grail”



Time to focus on the “1”

Computer Power Usage:



From Energy Efficiency to Sustainability

2001-2010: Energy Effciency

- Exponential growth of data centers: now ~ 3% of total US
- PUE: direct measure for operating cost
- Optimized very inefficient data center designs

2011-2020: Sustainability

- Stop focusing on the “right side of the decimal”
- HyperScale service providers now considering carbon footprint as a business risk
- Data Center now measured much more holistically: power, water, carbon, re-use.

The birth of new metrics

ERE: Energy Re-use Efficiency (rPUE)

$$ERE = \frac{\text{Total Energy} - \text{Reuse Energy}}{\text{IT Energy}}$$

CUE: Carbon Usage Effectiveness

$$CUE = \frac{\text{Total } CO_2 \text{ Emissions}}{\text{IT Energy}}$$

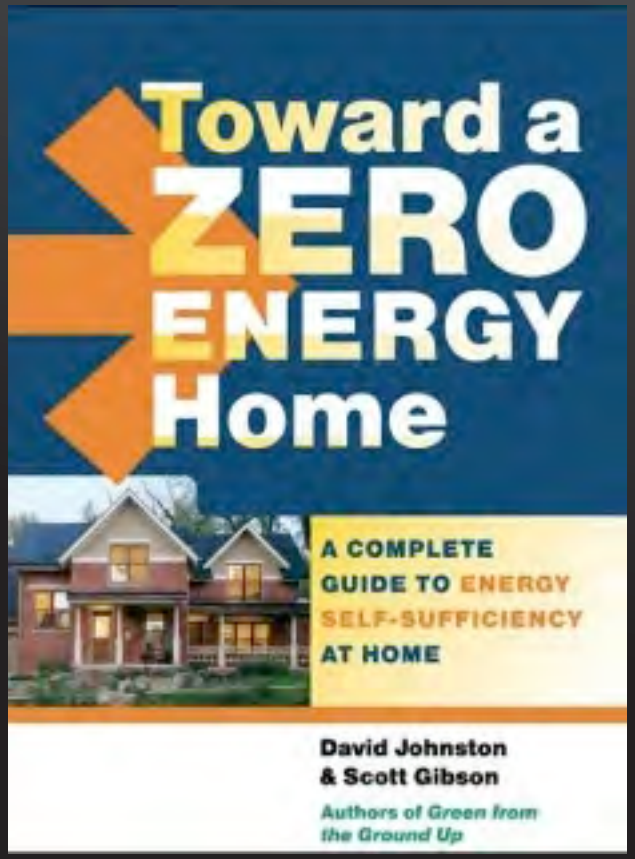
WUE: Water Usage Effectiveness

$$WUE = \frac{\text{Annual Site Water Usage}}{\text{IT Energy}}$$

Source: GreenGrid, www.thegreengrid.org

Zero Energy Construction

- Off-grid or Net-Zero
- 1. Build *very* efficient building envelope first
  - R-40+ walls
  - R-60+ roofs
  - Passive solar, Geothermal, etc.
- 2. Add renewable capacity to offset resulting energy deficit
  - Solar, wind, hydro



Net-Zero DC: Delirium?

How about (yet another) new metric?

NZE

Net-Zero Efficiency

Why target “1”?

Shouldn’t the objective be “0” instead?

- NZE-e
  - net energy consumption
- NZE-c
  - net carbon footprint
- NZE-w
  - net water usage

NZE-e: Net-metering for Datacenters?

Designing a net-zero house:

- Start by building the most energy efficient envelope
- Install auto-production capacity (PV, wind…) to offset energy deficit

Designing a net-zero datacenter?

- Maximize heat re-use to nearby buildings
- Install auto-production capacity (PV, wind…) to offset energy deficit

Net-Zero Efficiency - Energy

$$ERE = \frac{\text{Total Energy} - \text{Reuse Energy}}{\text{IT Energy}}$$

$$\Downarrow$$

$$NZE\text{-}e = \frac{\text{Total Energy} - \text{Reuse Energy} - \text{Site Production}}{\text{IT Energy}}$$

The free air cooling cool-aid

Current community mantra:

"Cool the servers with outside air and blow the heat out: most efficient way to build a datacenter on the planet."

Really?

- As inlet temperatures increase, leakage current increases, system fans spin up, more CFMs, increased demand on the facilities…
- Since when using air has become the most efficient way of removing heat?
- Anybody else is getting heartburns about blowing 10, 20, 30 or 40 MW into the atmosphere?

Think different

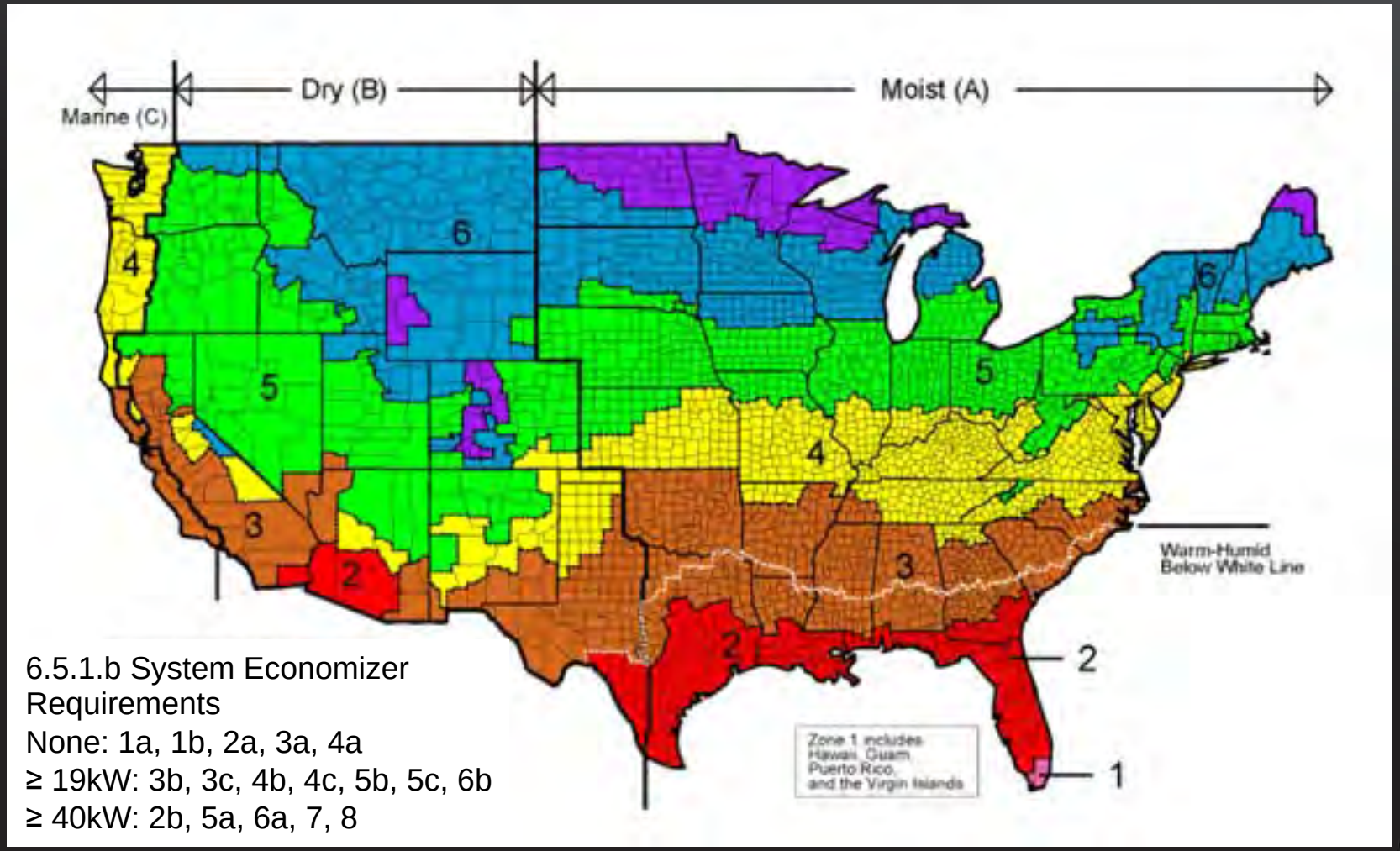
Advantages to water cooling

- Warm water cooling
- Heat re-use
- Overclocking

Time to get rid of chillers...

- Dry-cooling
- Water to water heat-exchangers
- Geothermal wells used as heat-sinks

Location, Location, Location



6.5.1.b System Economizer Requirements

None: 1a, 1b, 2a, 3a, 4a

≥ 19kW: 3b, 3c, 4b, 4c, 5b, 5c, 6b

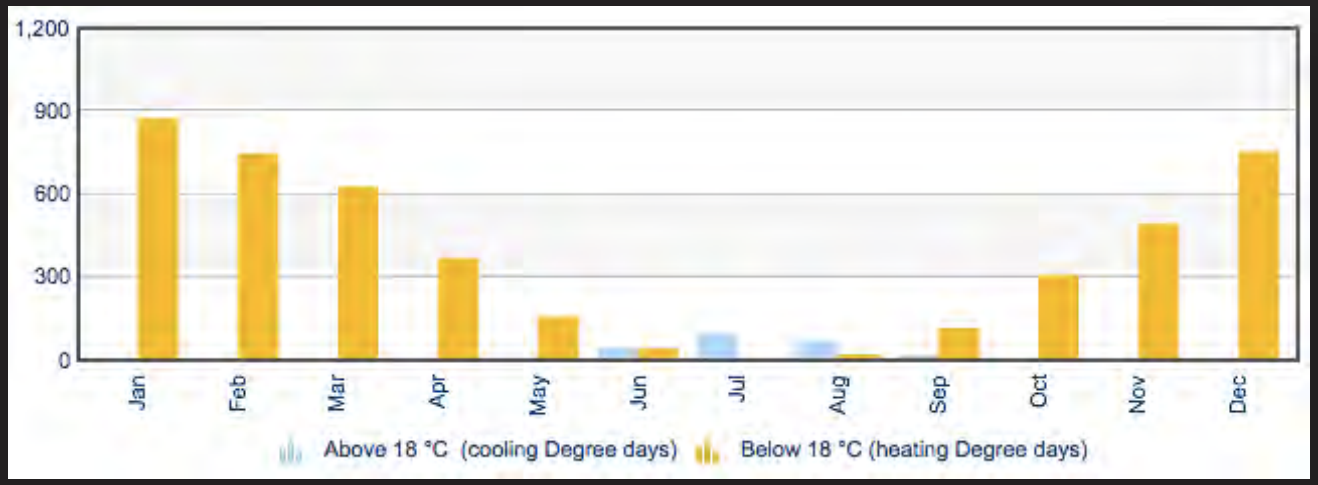
≥ 40kW: 2b, 5a, 6a, 7, 8

Source: ASHRAE 90.1-2010

Location matters

	Las Vegas	Bay Area	Atlanta	Seattle	Montreal
Average Temperature (C)	19	14.4	16	11	6
Average Humidity (%)	20	66	52	62	62
Average Precipitation (cm)	10	53.8	127	86	94
Heating Degrees Days (C)	2407	2597	2991	2055	4518
Cooling Degrees Days (C)	3201	163	1667	145	241

Montreal



Source: the Weather Network

Leveraging heat re-use

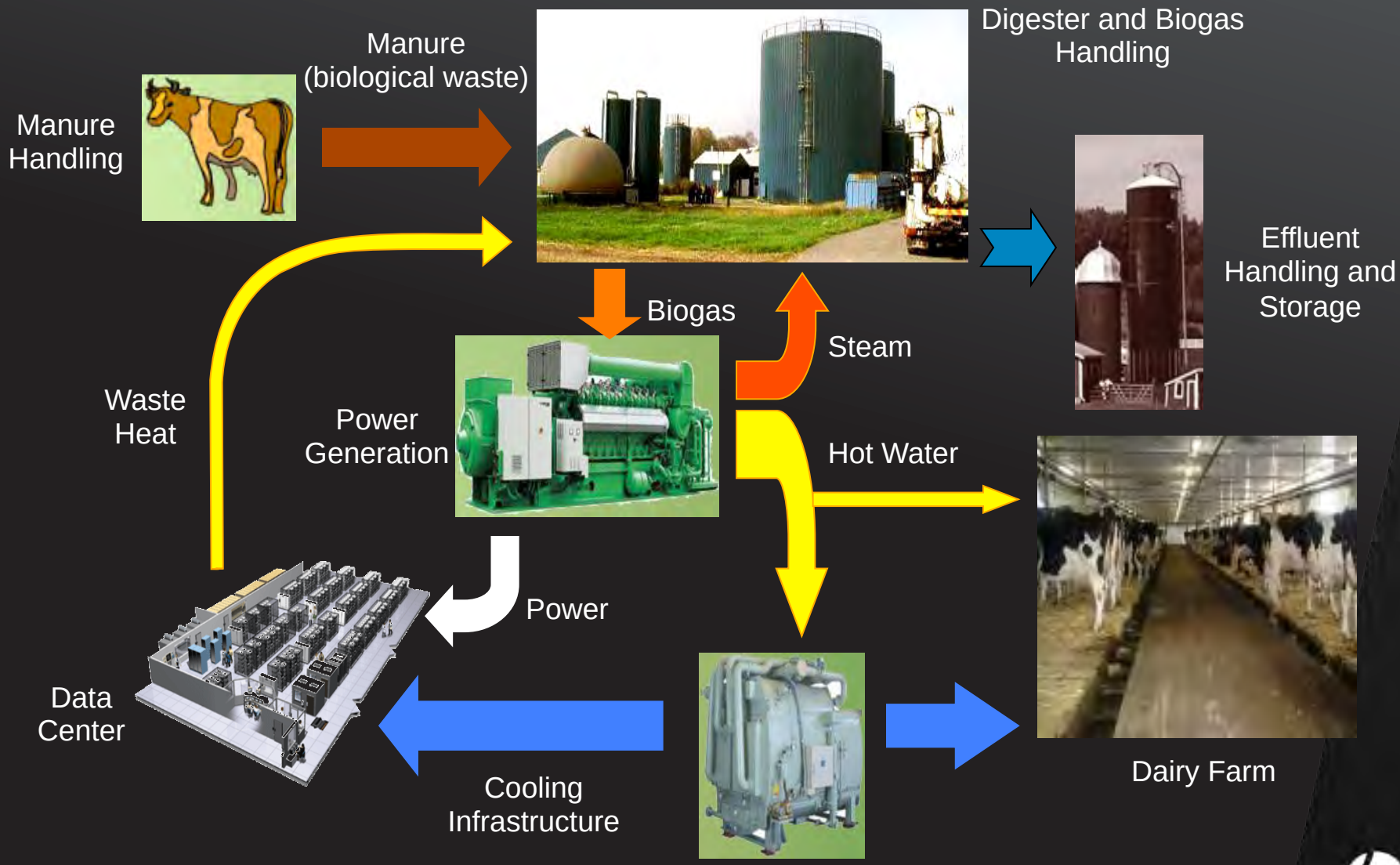
Location

- Colder climates
- Heat “customer” proximity

Heat transfer efficiency

- The higher the delta-T, the better
  - High inlet temp = high CFMs and low delta-T => no good
- Air: 20C inlet -> 60C Tcase -> 37C outlet -> 27C water (best possible coil)
- How about 55C or even 60C water return temperature?

Cow Manure powered Data Center



Source: Martin Arlitt HP Labs, ASME 4th International Conference on Energy Sustainability, May 17–22, 2010 Phoenix, Arizona

From Cow Manure to kWh

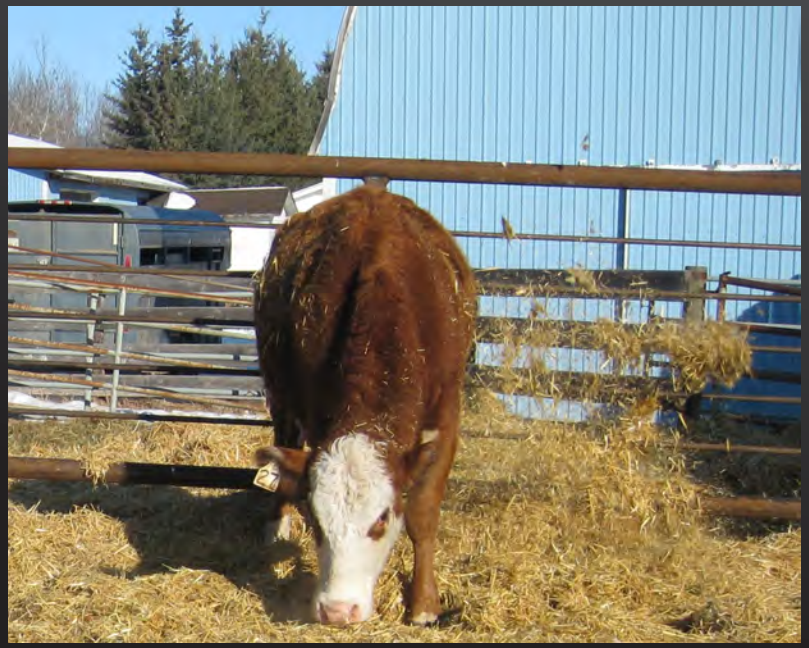
- Cow daily production

  54.7 kg / day

  = 20 metric tons / year
- Anaerobic digester:

  1 cow = 15kWh /day
- 2 000 cows dairy

  => 30 000 kWh / day
- 30MWh / 24h = 1.25MW
- Enough power for a 1MW datacenter with PUE 1.25

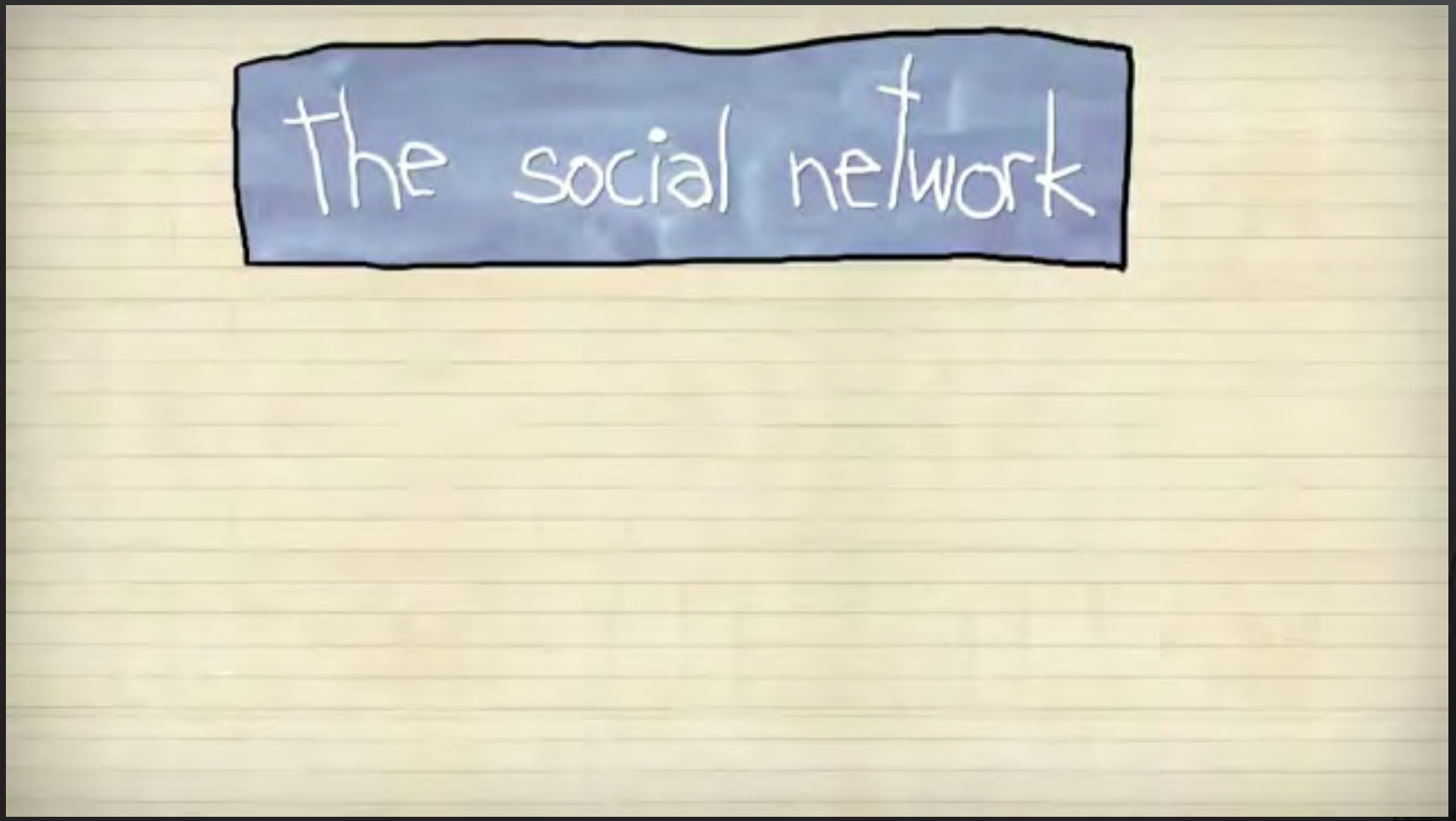


CLUMEQ PUE/ERE data

CLUMEQ Silo PUE Data						
Operating hours						8760
Chilled water hours						720
Free air cooling hours						3660
Free water cooling / re-use hours						4380
	kW	summer	free-air	free-water	hours	energy (kWh)
IT load	330.00	X	X	X	8760	2890800
Fans load	3.60	X	X	X	8760	31536
Chiller load	56.30	X			720	40536
Water tower	9.38	X			720	6756
Water pumps	3.75	X		X	5100	19142
Ultrasonic humidifying	1.75	X	X	X	240	420
Transformer loss	6.60	X	X	X	8760	57816
UPS loss (60 kVA)	7.20	X	X	X	8760	63072
Lighting (daily average)	1.50	X	X	X	8760	13140
Total	**420.09**					**3123218**
Energy re-use	**330.00**				**4380**	**1445400**
Net Energy consumption						**1677818**
Summer PUE						1.27
Free air-side PUE						1.06
Free water-side PUE (heat re-use)						1.07
PUE (year average)						**1.08**
rPUE / ERE (year average)						**0.58**

Energy Re-use: What's next?

Why Carbon Matters.



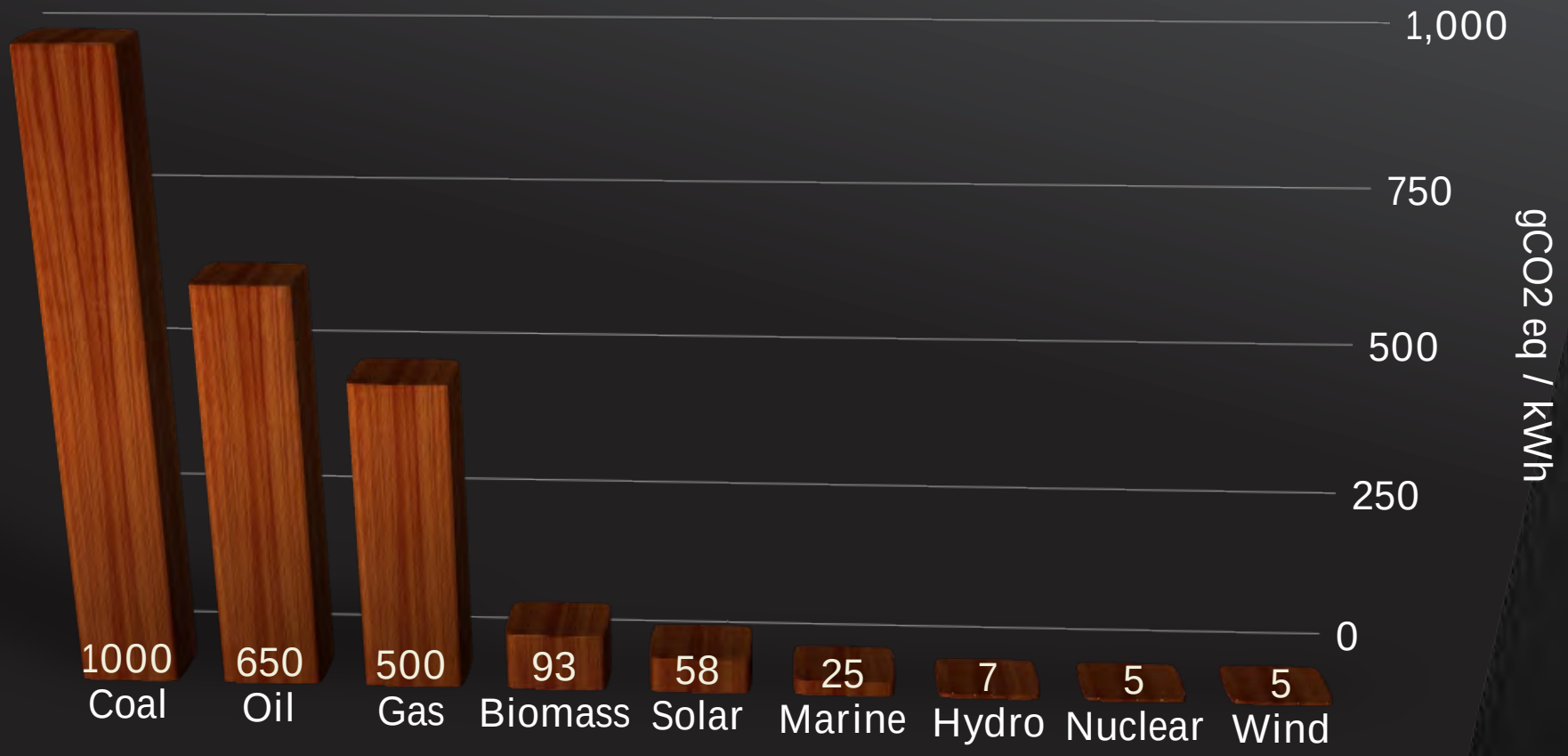
Source: http://www.youtube.com/watch?v=QPty-ZLbJt0

When the Cloud turns into Smog

Comparison of significant cloud data centres		Sq Footage	Estimated number of servers	Estimated power usage effectiveness	% of Dirty Energy Generation of local grid	% of Renewable Electricity of local grid
Google	Lenoir, NC	476,000	-	1.21	50.5% Coal 38.7% Nuclear	3.8%
	Dalles, OR	206,000	-	1.2 -	34.4% Coal 3.3% Nuclear	50.9%
	Apple, NC	500,000	-		50.5% Coal 38.7% Nuclear	3.8%
Microsoft	Chicago, IL	700,000	473,000	1.22	72.8% Coal 22.3% Nuclear	1.1%
	San Antonio, TX	470,000	-	1.2	37.1% Coal	11%
YAHOO!	Lockport, NY	180,000	-	1.16	21.0% Coal 27.0% Nuclear	27.7%
	La Vista, NE	350,000	100,000	-	73.5% Coal 14.6% Nuclear	7%

Source: Make IT Green, Cloud Computing and it's contribution to climate change, GreenPeace, March 30, 2010

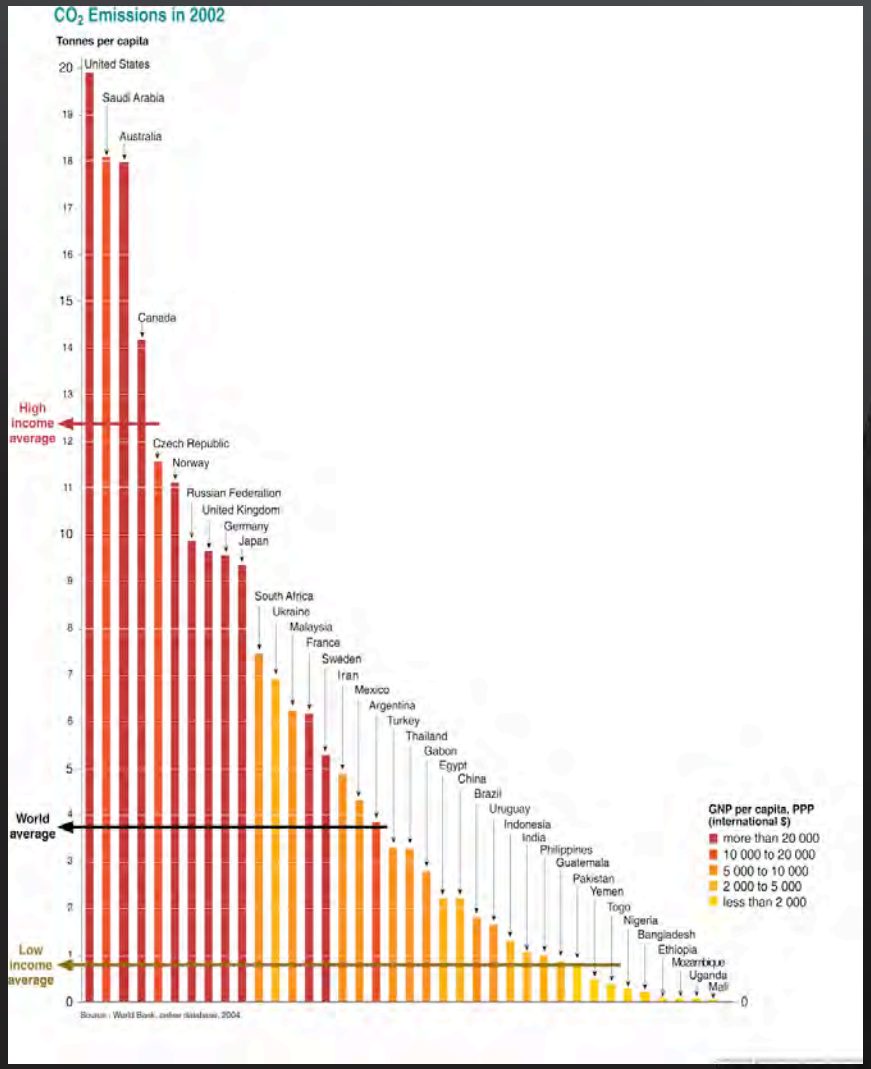
Electricity Sources CO_2 footprint



Source: Carbon Footprint of Electricity Generation, UK Parliament Post, Oct 2006, www.parliament.uk/documents/post/postpn268.pdf

IT Carbon Footprint

- A 20MW data center running on coal emits 175 200 Tons of CO_2 eq /year
- The equivalent annual carbon footprint of 43 800 people
- Same data center on Hydro power: 876 Tons, or 219 people



Source: World Bank, online database, 2004

The Carbon Math

Moving a 20MW Data center from California to NC…

- Carbon Tax current prices:
  - UK at 12£ / ton
- Annual 20 MW Datacenter savings in moving from California to North Carolina:
  - 20 000 * 365 *24 *(0.12-0.06) = 10 512 000$
- 20 MW Carbon Footprint cost (today):
  - 175200 * 20$ = 3 504 000$
- Bottom line: still too cheap to pollute, but longer term?

Net-Zero Efficiency - Carbon

$$CUE = \frac{\text{Total } CO_2 \text{ Emissions}}{\text{IT Energy}}$$

$$\Downarrow$$

$$NZE\text{-}c = \frac{\text{Total } CO_2 \text{ Emissions} - \text{ Carbon Offset}}{\text{IT Energy}}$$

Datacenter as a carbon offsetting tool

Replacing a gas furnace by “compute” Btus

- Datacenter power: 10 MW, 298 904 Mbtus (/year)
- Hydro kWh cost: 5 cents, 4 380 000 $
- Natural gas Mbtu cost (commercial): ~10$, 2 989 040$

Net electrical cost: 1.6 cents !

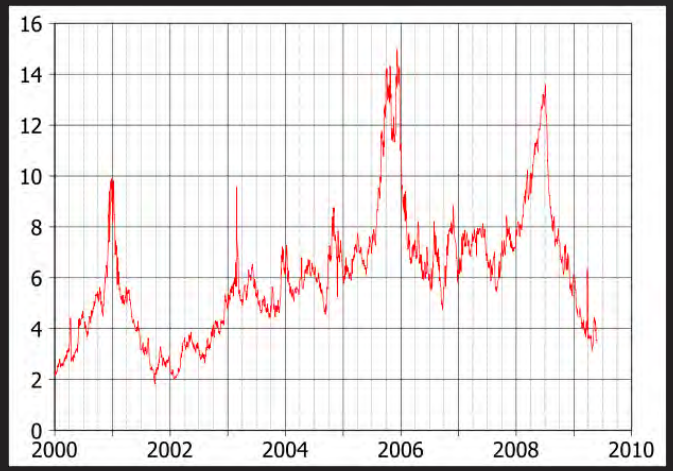
Carbon Offset:

Natural Gas (not burnt): 6 695 tons

- Hydro-Electrical: 438 tons

= 6 257 tons !! (or about 1500 people)

Natural Gas Prices (Henry Hub)



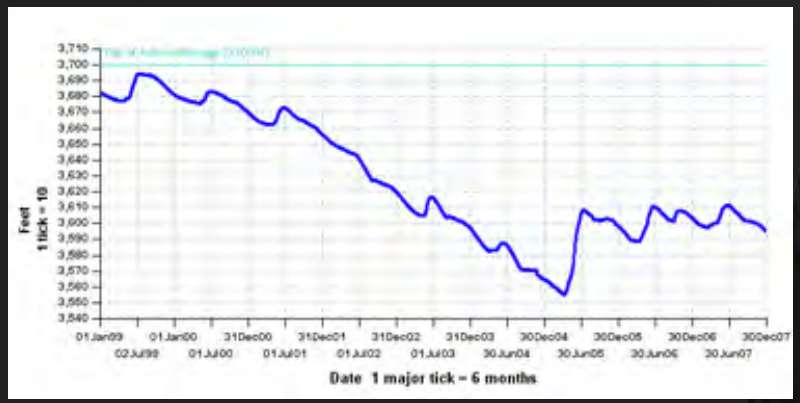
Water

Lake Mead reservoir

The water issue

- 50% chance dry up by 2021
  - From 2008 study
- Last winter helped out

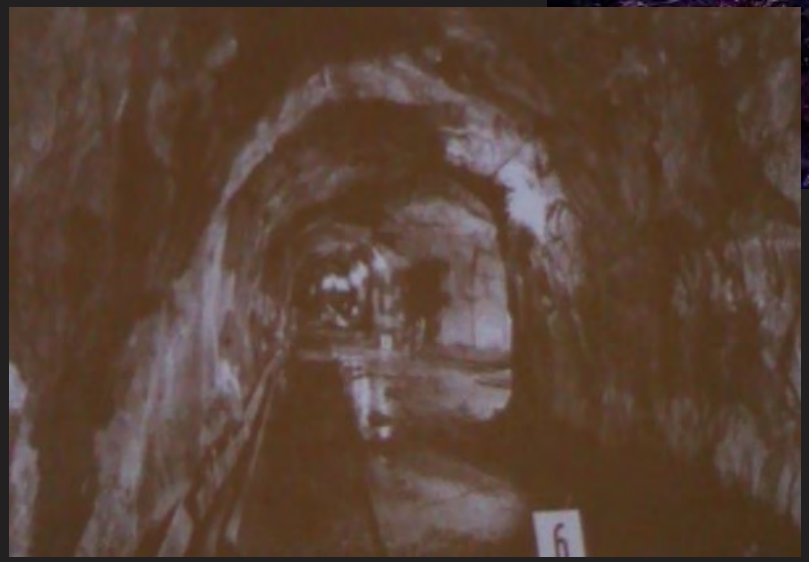
Lake Mead reservoir



Lake Powell

Heating up the Baltic Sea?

- XX MW capacity
- Pumping sea water on primary
- Impact on ecosystems?



Net-Zero Efficiency - Water

$$WUE = \frac{\text{Annual Site Water Usage}}{\text{IT Energy}}$$

$$\Downarrow$$

$$NZE\text{-}w = \frac{\text{Annual Water Usage - Fresh Water Production (?)}}{\text{IT Energy}}$$

Call for action: Zero is the target, not “1”

1. Drive towards Net-Zero Energy Consumption

- The lower the PUE, the better (of course)
- But PUE is not enough, heat re-use is key!
- Time to consider auto-production / net metering for datacenters

2. Shoot for ZERO carbon emissions

- Electricity source is critically important vs embedded
- Carbon taxes are emerging, kWh are not all made equal

3. Use no water

- No more evaporative chillers, nor boiling up the ocean

Top50DC.org

Time to compete on a leveled field:

- Report all metrics:
  - Energy, Carbon, Water
- HPC and Service Providers
- Common submission format
  - Energy
  - Carbon
  - Water
  - Pump power and flow rates
  - Environmentals: Inside and Outside
- Committee to be created

Thank you

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https://sites.google.com/a/lbl.gov/eehpcwg/home