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Hardware Upgrade considerations, Green, ROI, Do the math.

Larry Bolhuis

Frankeni Technology Consulting, LLC

lbolhuis@frankeni.com

Frankeni Technology Consulting, LLC

7220 N Robertson Rd

Middleville, MI 49333

616.855-1658

IBM Certified™

Advanced Technical Expert

Why are we here?

- Over time data grows.
- Over time computational needs grow.
- Over time the number of applications, servers, storage systems, all grow.
- Competing with this electricity costs are increasing.
- How do we save some Green?

Note: For purposes of this discussion, Green can be defined as your footprint on the environment, or your footprint on the budget… or Both!

What We'll Cover …

- What is this "Green"?
- Cost Components
- Processor Costs
- I/O
- Common Datacenter Mistakes
- The Greenness of your datacenter
- Server Consolidation
- Cooling - The 800 lb gorilla.
- Alternative cooling
- Wrap up.

What is this 'Green' of which you speak?

- You may or may not be concerned with terms like 'Carbon Footprint' or 'Climate Change'.
- Either way, chances are very good you ARE concerned with your budget ☺
- The two fit together hand and glove so we'll treat them together.
- Probably the dumbest reason for NOT doing things right in the data center (and is seen far too often):
  - **It's not MY budget.**
  - This is what I call 'Crap', because it all comes out of the same balance sheet eventually.

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Cost Components of your system

- **The true Total Cost of Ownership for of any computing system consists of the sum of many different items including:**
  - Cost of Acquisition
  - Cost of Maintenance
  - Cost of Power to run it
  - Cost of Systems to keep it (usually) cool.
  - Cost of Space to keep it.
  - Cost of software that runs on it including
    - Operating Systems
    - Application Systems
  - Cost of staff to manage the system.

Things in the Datacenter that cost money

- **Available space for equipment, measured in Square Feet**
  - Server and equipment racks
  - UPS equipment and batteries
  - HVAC equipment
  - Walking space, service clearances, entry doors and often ramps.
- **Electricity.**
  - Service panels, cables, conduit, receptacles, PDUs
  - Backup Generator(s)
- **UPS Equipment**
  - Newer is more efficient!
  - Batteries do not live forever – 3 to 5 years then runtime falls.

Things in the Datacenter that cost money

- Heating Ventilation and Air Conditioning (HVAC)
  - Components include Ductwork, blowers, compressors
  - HVAC Consumes plenty of power
    - Normally not on UPS
    - Must be on Generator
  - The heat has to go somewhere: condenser and fan unit
    - Often on the roof
  - Plumbing
    - Pipes for the working fluid (such as R134a or Puron)
    - Water for humidifier components
    - Drain for dehumidifier components
- Water Cooling?

Things in the Datacenter that cost money

- **Fire surpression**
  - Old: Halon
  - Newer: Inert gas or Clean agents
  - Possible: Water.
- **Cable, cable, cable.**
  - Even a small datacenter can hold miles of cable.
  - Assure it is all Plenum rated or CMP (Communications Plenum)
  - Assure it is not made in China. Much of even their Plenum rated cable burns like crazy.
    - Why am I not surprised!?

Datacenter costs

- General costs are about $500 per square foot.
- Premium datacenter costs $1000 per square foot.
- Google reportedly spent $3,000 per square foot on a 100K Square Foot center in the Carolinas.
- Higher power (and therefore cooling) densities raise the cost.
- Standard Racks used to be about 5KW per rack
  - Today 25KW per rack is possible with Blades!
  - This is about the limit for air cooling

The costs of what's in your Racks.

- What do you spend money on to fill your racks?
  - Processors
  - Licenses
  - Storage
  - Maintenace

- Let's look through these items considering what the $Green impacts are on your datacenter.

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Considering Processors

	POWER7 750	POWER6+ 550	POWER5+ 550
Power Consumption	1400 Watts	1500 Watts	1100 Watts
Heat Output	4778 BTU	5120 BTU	3754 BTU
Processor Cores	32 POWER7 @ 3.55Ghz	8 POWER6+ @ 5Ghz	4 POWER5+ @ 1.9Ghz
CPW	182,850 (est)	37,950	14,000
Max Memory	512 GB	256 GB	64 GB
CPW per KW	130 (est)	25	13
Power Management	Enhanced TPMD	TPMD	None

- **As you consider your replacement processor there are multiple reasons that a newer system is a better choice.**
- **Simple Summary: Power Server 750 provides five times the compute per watt of input power as POWER6+ 550.**
  - **TEN times the compute per watt as POWER5+ 550**

What does it really cost to run the system?

(Note: At $0.10/KWH)	POWER7 750	POWER6+ 550	POWER5+ 550
CPW	182,850	37,950	14,000
KVA	1.4	1.5	1.1
Cost/Mo (Max)	$100.80	$108.00	$79.20
Cost/Yr (Max)	$2,725.33	$2,920.00	$2,141.33
Cost/W HVAC & UPS	$224.00	$240.00	$176.00
W/ HVAC & UPS/Yr	$2,725.33	$2,920.00	$2,141.33
Cost/Mo/1000 CPW	$1.23	$6.32	$12.57
Cost/Yr/1000 CPW	$14.90	$76.94	$152.95

- **The 'Schtuff' in the typical DC uses about 45% of the power.**
- **HVAC, UPS, lighting etc. consume the other 55%**
- **Multiply power usage by 2.22 to get actual cost to run.**
  - **Costs/Yr here reflect this multiplier**

Beyond base cost to run

- Numbers on previous charts are maximum configurations with CPUs running flat out, drives churning and cards cranking.
  - Expect 50 to 70% of these numbers as realistic.
- Can we go lower?
  - Newer technologies in POWER6 and enhanced with POWER7 allows power usage to be reduced when load is reduced.
    - Reductions are accomplished by lowering clock rates and processor voltage. Both result in less input power.
  - Both can cap power usage when used with IBM Director.
  - Hard Caps and 'Soft Caps' (Targets) are available
  - POWER7 also enables Processor Sleep and Smart fan control.
  - POWER7 is first server system "Energy Star" Rated.

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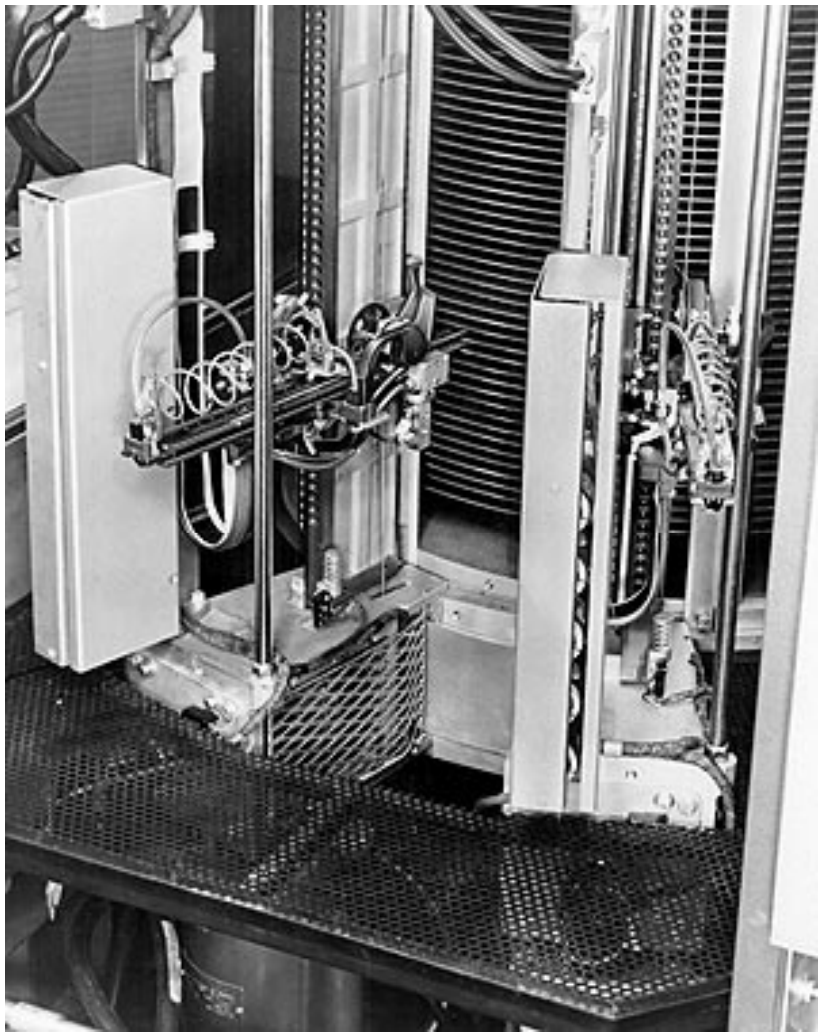
Do you I/O?

- Of course it works out that you'll need data to make use of all that compute power!
- How that data is stored will also contribute mightily to your power bill, space requirements, maintenance dollars and of course reliability and performance as well.
- Consider the first 'black' AS/400 machines still had some 1GB disk units available which were 1.6" form factor drives. 100GB back then was ex-pen-sive!
- Today we have drives over 400GB available that are ¾" thick, spin a minimum of twice as fast, have interfaces two orders of magnitude faster and cost a mere fraction!

The very first commercial disk unit - 1956

- 60” long, 68” tall, 29” deep
- 50 platters!
- 1,000 100 byte sectors each
- 5M 6 bit character capacity
- 1,200 RPM- 8,800 cps transfer
- 600 ms seek time
- 20 tpi
- The heads not only had latency and seek time but platter time.
- It had an air compressor!



IBM 350 Disk Storage Unit

www-03.ibm.com/ibm/history/exhibits/storage/storage_350.html

Storage Costs – comparison #1

(Note: At $0.10/KWH)	4-#0595 48-#4328 140G SCSI	1-#5790 2-#5786 48-#4328 140G SCSI	1-#5790 4-#5886 48-#3677 140G SAS	1-#5790 2-#5886 24-#3678 280G SAS	3-#5802 48-#1888 140G SAS SFF
Usable GB RAID 5	5,600	5,880	5,600	5,600	5,838
KVA	1.36	1.59	1.55	0.87	2,231
EIA U	20	12	12	8	12
Cost/Yr (Max)	$1,175.00	$1,379.00	$1,340.00	$750.00	$1,931.00
Cost/W HVAC & UPS/Yr	$2,140.00	$2,508.00	$2,437.00	$1,368.00	$3,510.00
Cost/Mo/TB	$ 31.80	$ 35.55	$ 36.26	$ 20.36	$ 50.11
Cost/Yr/TB	$381.61	$426.68	$435.22	$244.41	$601.37
Maint $/Mo	$964.00	$578.00	$582.00	$316.00	$651.00
Total Annual $	$12,928.00	$8,533.00	$8,535.00	$4,663.00	$10,046.00

Storage Costs – comparison #2

(Note: At $0.10/KWH)	1-#5790 2-#5886 12-#3658 428G SAS +6 70GB SSD	1-#5790 4-#5886 48-#3677 140G SAS	1-#5790 2-#5886 24-#3678 280G SAS	3-#5802 48-#1888 140G SAS SFF
Usable GB RAID 5	5,058	5,600	5,600	5,838
KVA	0.87	1.55	0.87	2,231
EIA U	8	12	8	12
Cost/Yr (Max)	$750.00 *(1)	$1,340.00	$750.00	$1,931.00
Cost/W HVAC & UPS/Yr	$1,368.00	$2,437.00	$1,368.00	$3,510.00
Cost/Mo/TB	$ 20.36	$ 36.26	$ 20.36	$ 50.11
Cost/Yr/TB	$244.41	$435.22	$244.41	$601.37
Maint $/Mo	$568.00 *(2)	$582.00	$316.00	$651.00
Total Annual $	$7,183.00	$8,535.00	$4,663.00	$10,046.00

- **(1) Likely less as SSDs use less power and half the slots in that drawer are empty.**
- **(2) SSD carries a MMC.**

Total Storage Cost Calculations

- **Total cost for storage is several components.**
  - Acquisition for the equipment.
  - Power and cooling for the equipment.
  - Space for the equipment.
  - Maintenance dollars for equipment.
  - Potential License costs for SAN storage.
- **Additional considerations**
  - Expansion capabilities!
    - Don’t set yourself up with NO expansion capability!
    - Consider the type of outage required (if any) to expand.

Other considerations on DASD and power.

- Some drawers such as the EXP24 and EXP12S are not connected to the SPCN loop.
  - This seems like a problem because they have hard power on/off switches.
- Turns out that such drawers power on (and off) when activity is detected (or not.)
  - These can significantly reduce power and cooling load for partitions that need not run 24x7.
  - Powering off the partition (PWRDWNSYS) sets the drawer to idle power and cooling (just a handful of watts)
- Consider these partitions for shutdown when power usage is high or cooling load is high.

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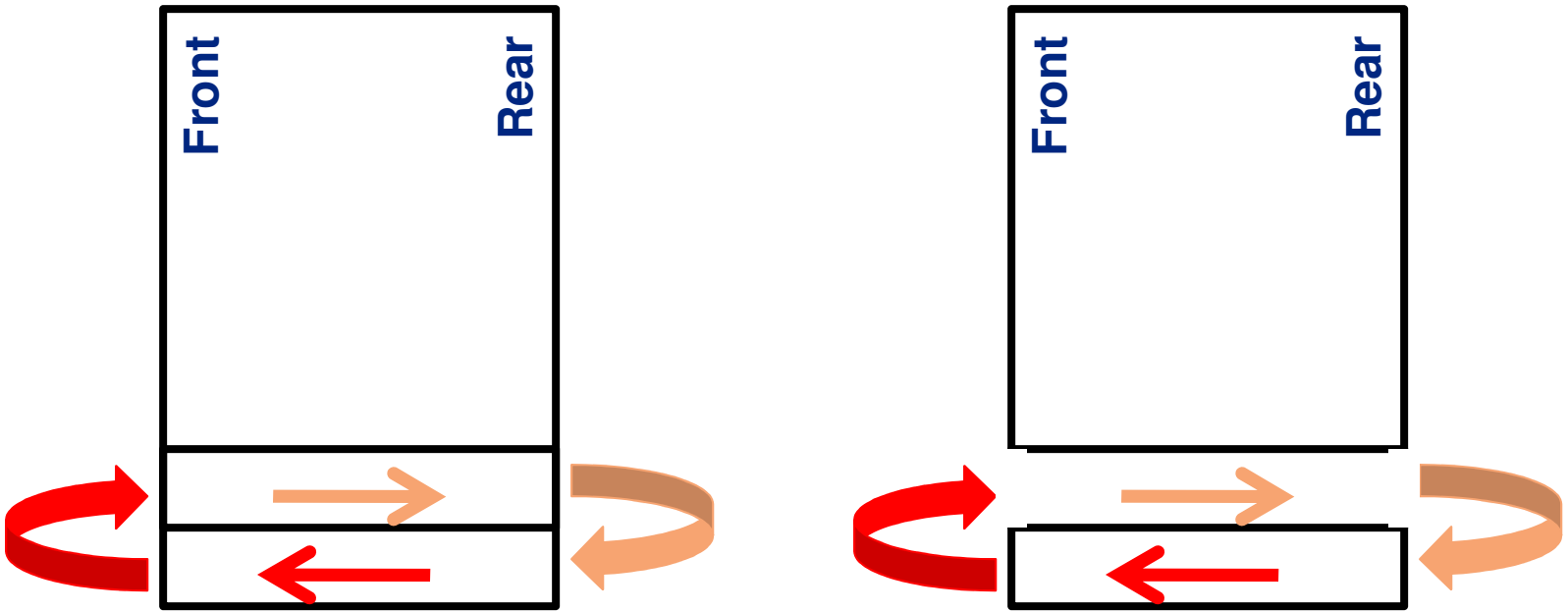
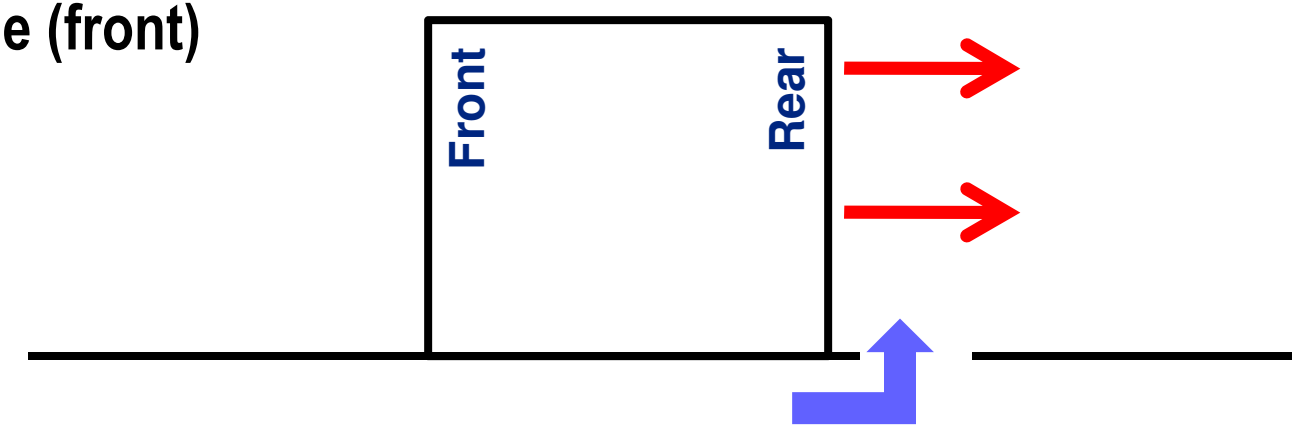
Common Datacenter Mistakes

- **Incorrect rack stacking.**
  - Units in racks blowing air both ways, i.e. unit in eia 1 and 2 blow air front to rear while unit in eia 3 and 4 blows air rear to front.
    - Creates a heating loop.
  - Open spaces in racks with no covers
    - Creates air flow loops again.

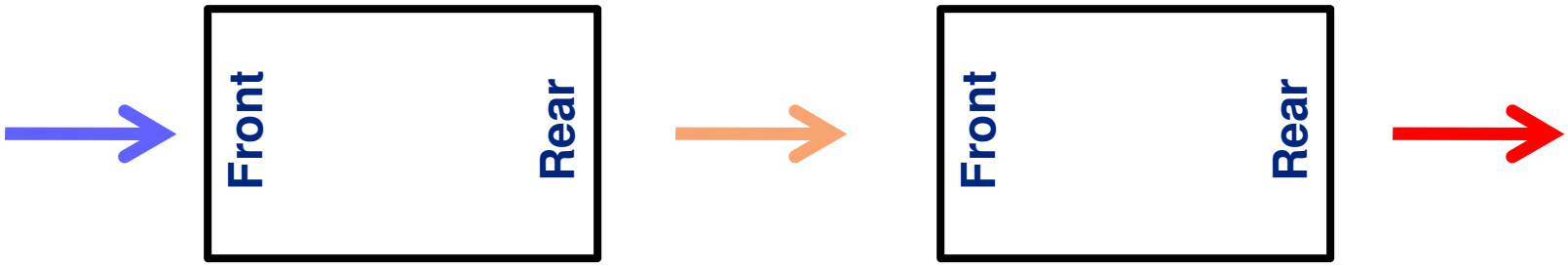


Common Datacenter Mistakes

- **Incorrect rack alignment with respect to cooling.**
  - Cooled air directed at the hot side (rear) of racks instead of cold side (front)



  - Racks rows front to back, that is the front of Rack 2 faces the rear of Rack 1 allowing Rack 2 to input the heat ejected from Rack 1



Your Current Data Center

- **Only you know how your data center is positioned for future needs but the components are:**
  - **Available space for equipment, usually racks.**
  - **Available inbound electricity to run the UPSs**
  - **Available output power of the UPSs**
  - **Availability of backup power for the UPS such as generators**
  - **Availability of cooling and possibly backup cooling.**
- **How efficient is your data center?**

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The 'Greenness factor'

- When a higher percentage of the power used in your data center is used to run the servers your data center is said to be 'more green'.
- Two terms are used:
  - Data Center Infrastructure Efficiency DCiE
    - IBM Favors this metric.
  - Power Usage Effectivness PUE
- The calculation and relationship between them is:

$$DCiE = \frac{1}{PUE} = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}}$$

The 'Greenness factor'

- **Total facility power is all power used:**
  - HVAC, UPS, Lighting, Security, Network, Servers, SAN….
- **IT equipment power includes:**
  - Servers, Network switches, tape drives, monitors, SAN
- **Perfect DCiE would be 100.0%**
- **A 'Greenness gauge' would look like this:**

Improving 'Greenness'

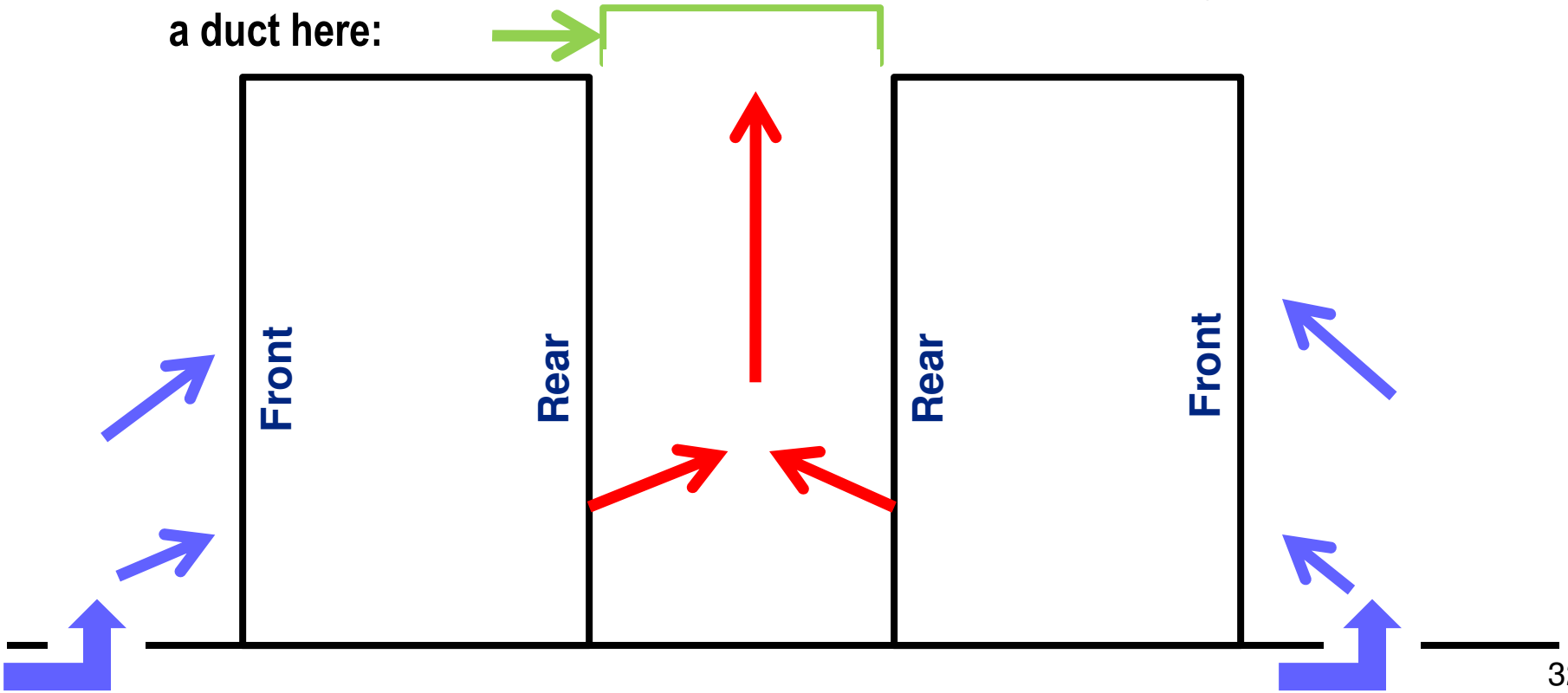
- **Lots of things can be done to improve greenness**
  - Energy efficient lighting such as T8 fluorescent or even LED lights.
    - And turn them off when not in use with motion sensors.
  - Do not block airflow under floors with cables. Restricted airflow reduces HVAC efficiency and costs power.
    - Worse it could damage equipment!
  - Add localized cooling for hot spots rather than large new HVAC systems.
    - These include rear door heat exchangers for example.
    - These are essentially large water filled aluminum heat sinks that cool the output air from the equipment on the spot, thus reducing cooling load.

Improving 'Greenness' (cont)

- Replace piles of little UPSs with one or two Large UPSs
  - UPS run most efficiently at high percentage loads
  - Many small UPSs also means many small points of failure. While they won't take down the entire DC they may take down just enough to make it look like it's all down.
  - Big UPS are also more likely to be generator friendly
- Consider flywheels instead of batteries in UPSs.
  - No environmental impact.
  - Don't need replacing.
  - Short backup times work best with generators.
    - *If the Generator won't start in 5 seconds or less it's unlikely to start period, so 20 or 30 minutes of battery won't truly help you much.*

Improving 'Greenness' (cont)

- Look at rack placement in the DC
- Hot and Cold Aisles are required
- Heat rises so cool air blows up from below and hot air rises to be pulled out of the room
  - Collect hot air at the HIGHEST point in the room or directly at it's source with a duct here:



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Server Consolidation

- One of the most wasteful uses of power is servers at very low utilizations
  - CPUs can throttle back but nearly the entire remainder of the server chews up full power all the time.
  - Both processor compute power and disk storage are important.
- Consolidating servers with virtualization technology improves utilization of CPUs.
- Consolidating disk storage with SAN improves utilization of disk storage.
  - Can also dramatically improve performance for servers where low GB are required but sufficient arms could not be configured

Advanced consolidation

- Advanced consolidation allows for movement of active servers from one piece of hardware to another.
  - Technologies like IBM's Live Partition Mobility or VMWare's Vmotion.
- This means that during low workload periods some servers could be completely shut down saving all of their power and cooling loads.
- Such technology requires disk storage is on SAN and connected to each server.
- Also means that during maintenance windows nobody needs to go down as all servers move off the hardware requiring maintenance.

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Cooling – the 800 lb Gorilla in the DataCenter

- **Consider a power density of 40 Watts Per Square Ft (PSF) will raise the temperature 25 degrees in 10 Minutes with no cooling.**
  - This is due to the low energy density of air.
  - Note that by volume water is 4,000 times more energy dense.
- **300 Watts PSF will raise temperature 25 degrees in under 1 Min!**
  - Makes Redundant Cooling Imperative!!
- **Hot spots are trouble.**
  - Equipment in such areas can be damaged
  - Cooling is often cranked up just to eliminate such problem areas.
    - Running HVAC units harder costs energy, money and life span of equipment.
  - Plan the layout to eliminate the hot spots.
  - Add perforated floor tiles where needed and remove them where unneeded.
  - Close off with brushes or pillows areas that should not be open allowing cool air to escape where it is not effective.

Cooling – the 800 lb Gorilla in the DataCenter

- **Increase DC temps to save money.**
  - If hotspots are eliminated this works quite well without equipment damage.
  - Intel has tested using only ambient air to cool up with air up to 80 degrees.
    - Failure rates were the same for these test cells as for traditionally cooled cells!
- **Replace aging units.**
  - New equipment is on average 50% more efficient than that from 15 years ago!
- **Use higher efficiency cooling**
  - Piston or Reciprocating compressors are least efficient
  - Rotating compressors are considerably better.
  - Screw compressors are most efficient and most variable allowing them to match to the cooling load.

Where does the heat go?

- **Once the compressor heats the working fluid, the heat is pumped from the DC to…?**
  - **Air. This is traditional for smaller applications. Outside air is blown across a condenser coil heating the air and cooling the fluid.**
    - **Why is this dumped outside in winter? We just paid 1 American Currency Unit to create the heat in the computer. Then we paid an additional 1.25 units to move the heat from the DC to… outside?**
    - **Why not put this heat to work in some other portion of the building thus offsetting heat requirements there!**
  - **Water. Water is often used in larger facilities because it's 4000 times greater heat density means less space required to move the heat around.**
  - **Water also is often cooled in cooling towers where evaporation is used to cool. This of course works best in dry climates.**

Where does the heat go?

- The heated water can also have other uses.
  - Pre-heat for hot water
  - Heat for other portions of buildings
  - Or it can be evaporated outside for much lower cost than typical AC.
- Storage.
  - The hot water can be stored and the heat used at night or the water cooled at night when cooler air and lower utility costs mean less $$s spent.
  - SteelCase the office furniture company has been doing this at it's corporate HQ since the 1970s!
    - *The large water tanks are buried beneath the front lawn.*

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Do we need chillers at all?

- When cold air is available what is the point of making 'new' cold air?
- Can cold outside air simply be routed through the data center?
  - Filter out dust and dirt
  - Possibly add humidity
  - Blow it through the DC
  - Reduce cooling costs by 50% or more
  - Typically chillers are still installed for times when outdoor air is not 'cold enough'.
    - Sadly this means installation cost savings are not as great as they could be.

Alternate cooling - example

- **Intel has run parallel tests with chilled and non-chilled data centers – using 'Economizers'**
  - 900 high usage servers in a high density data center
  - 100% air exchange at up to 90 degrees outside air
    - No humidity control and minimal filtration
  - 67% over-all power savings for data center cooling!
    - 74% when cooling only with outside air
  - Failure rates rose from 3.83% to 4.46% - less than 1%
  - At the site the four summer months average highs above 80 degrees, two over 90!
    - Many localities have much lower temps!
- Complete article here:

www.intel.com/it/pdf/reducing_data_center_cost_with_an_air_economizer.pdf

Another example in a ‘cooler’ climate

- Quebecor a Canadian meat company
- Located in Winnipeg, Manitoba
- 3,200 SqFt full of mostly System p.
- Air temps here get to -22 (f)
  - At this temp the heat from the servers is used to PRE-heat the incoming air!!
- Outbound heat from the DC goes first to offices
  - If the offices are warm enough it goes to the warehouse.
- Article here:

searchdatacenter.techtarget.com/news/article/0,289142,sid80_gci1246084,00.html

- Costs like energy density per square foot
- Cooling power per square foot
- Backup power costs
- Units of Measure.
- 1 BTU = 3.412 Watts
- Cooling 'Ton' = 12,000 BTU/Hr or 3517 Watts.
- Consider: 40 Watts PSF will raise temp 25 in 10 Min.
  - 300 Watts PSF will raise temp 25 in under 1 Min!
    - Makes Redundant Cooling Imperative
- http://searchdatacenter.techtarget.com/news/article/0,289142,sid80_gci1314324,00.html
- Processor Sleep and Nap
- Memory Power Down
- Power Capping

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Resources

- **Power Systems Infocenter:**

http://www.ibm.com/systems/i/infocenter

- **Power Systems Power Calculator:**

http://publib.boulder.ibm.com/infocenter/powersys/v3r1m5/index.jsp?topic=/iphdl/systemcalculators.htm

Key Points to Take Home

- Do you really need all stand-alone servers?
  - Consider consolidation.
  - Potentially allows entire servers to shut-down
- Are your older servers actually costing you money?
  - Higher power usage and maintenance costs due to older technology
- Does everything in the DC need to be powered on 24x7?
  - Start with obvious things like Lights and CRTs
  - Look for disks and other peripherals as well
- Can servers be throttled back?
  - Power capping by frequency reduction
- Is the temp set too low to deal with cooling hot spots?
  - Fix the hot spots and raise the temp.
- Consider other cooling options or at least other places to ‘dump’ the heat.
  - Can you cool with an economizer?
  - Can you dump the heat into a warehouse or factory?
- REFUSE to accept “We’ve always done it this way.”

Hardware Upgrade considerations, Green, ROI, Do the math.

"If we can do *that* with an old iSeries, imagine what we can do with IBM i on Power!"

Contact Information:

Larry Bolhuis

Frankeni Technology Consulting, LLC.

lbolhuis@frankeni.com

www.frankeni.com

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Advanced Technical Expert