Towards Net Zero Infrastructure

Sustainable and Energy Proportional Networking

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Datacenters have Gone Green, Haven't they?   When will Networks Follow?
Workshop at Super Computing, Nov 13, 2011

"How Energy Efficient is the Information Industry?
New perspectives on Networks and Datacenters

How bad is the problem?

What can we do?
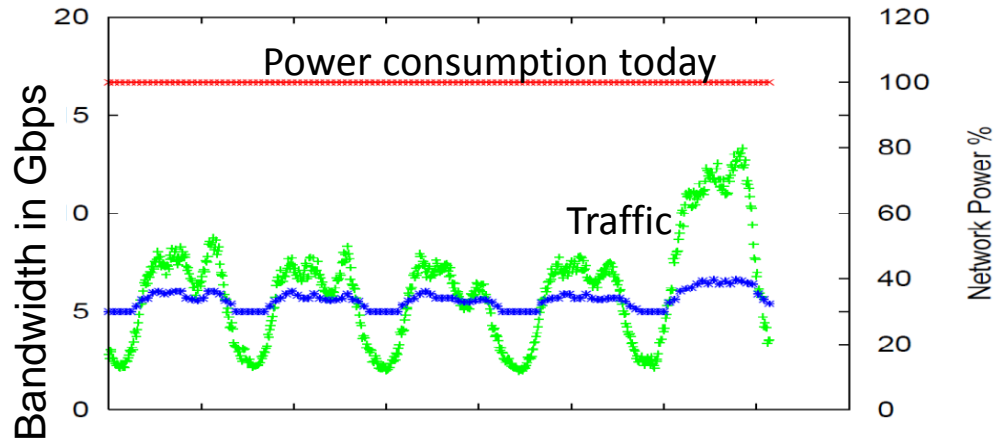
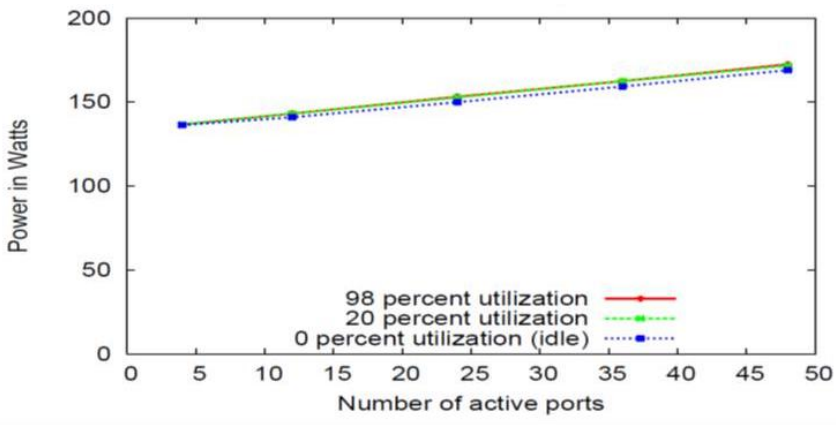**Redesign and improve existing devices**

Whole network design, management

Holistic energy management

How bad is the problem?

– Measure, Model, Monitor, Project

– Amdahl's law

Efficiency and Proportionality

Type	EPI (in %)	mWatts/Mbps
10/100 Hub	8.59	10.7
Edge LAN switch	24.2	4.1
Edge LAN switch	23.7	3.7
Edge LAN switch	25.1	2.1
Core switch	15.4	13.7
Edge router	19.8	8.75
Wireless AP	37.3	153.7

What can we do today?

- Turn off anything that you can: low hanging fruit
- Operational practices: handling legacy

Small savings per component, but high volume

\# of switches/chassis in network   (150-2000 W per switch)

Number of active linecards (30-60W per card)
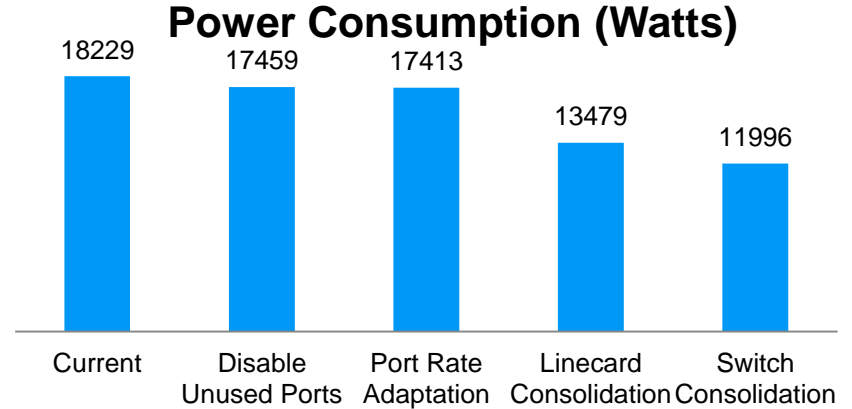
Number of active ports (1-2 W per port)

Port rate adaptation   (0.2-0.8W per port)

Power Consumption (Watts)

Current	Disable Unused Ports	Port Rate Adaptation	Linecard Consolidation	Switch Consolidation
18229	17459	17413	13479	11996

Power Draw = 211 W

Power Draw = 97 W

Disable unused ports (4%)
Port rate adaptation (4.5%)
Linecard consolidation (26%)
Switch consolidation (35%)

Redesign and improve existing devices

– New energy efficient products and technology

– Standards, certification, initiatives

Hardware, software
Monitoring support
Expose energy knobs
Hyper-x, Flattened Butterfly topologies
Optics, exploit dynamic range of links

Generation	Port BW	Core Type	Radix 64	Radix 100	Radix 144
45nm	80Gbps	Electronic	41.8	72.7	120.7
		Optical	13.2	17.4	31.9
32nm	160Gbps	Electronic	38.0	65.9	109.0
		Optical	22.9	27.7	50.9
22nm	320Gbps	Electronic	52.4	91.9	153.8
		Optical	34.2	41.3	76.3

The Role of Optics in Future High Radix Switch Design
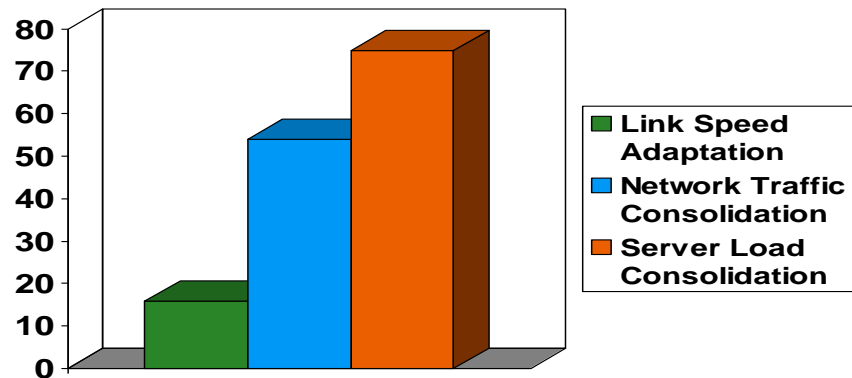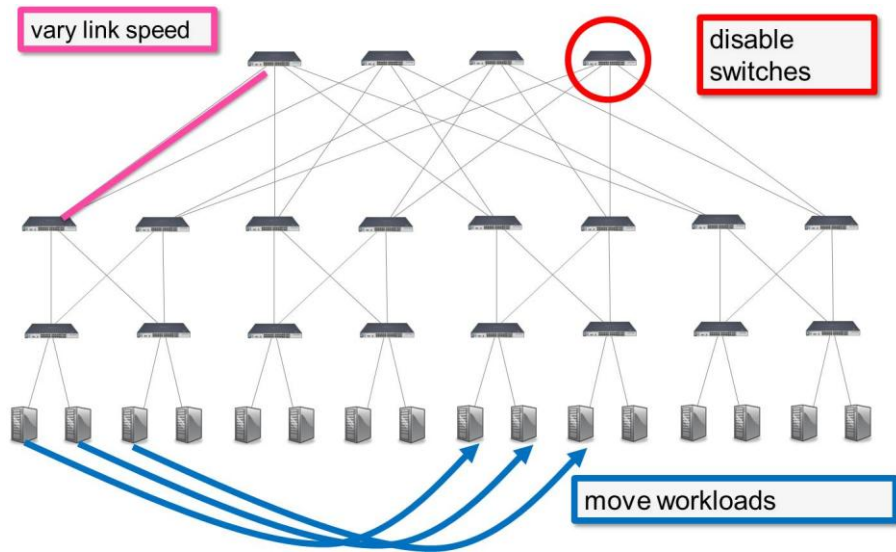Nathan Binkert et. al., Proc. ISCA 2011

EPA (Energy Star), GreenGrid, CSCI, ATIS, METI, GreenTouch, IETF MAN wg, BBF, ITU-T, European Union (Broadband code-of-conduct, Datacenter code-of-conduct), Energy Consumption Rating (ECR) Initiative, IEEE: 802.3az (EEE), ECMA standard 393 ProxZzzy, Miercom Green certification

"The wonderful thing about standards is that there are so many of them to choose from."   Grace Hopper

Whole network design, management

- static and Dynamic power management
- leverage energy knobs across a network
- program networks for energy savings

vary link speed

disable switches

move workloads

Link Speed Adaptation

Network Traffic Consolidation

Server Load Consolidation

ElasticTree: Saving Energy in Data Center Networks
B. Heller, et. al. Proceedings of the Usenix NSDI, April 2010

On Network Energy Efficiency for Data Centers and Enterprise Networks
P. Mahadevan, et. al., IEEE Communications Magazine, August 2011

Holistic energy management

- Sustainability, Energy Proportionality
- Lifecycle perspective – we tend to focus just on operational energy
- Balance energy supply and demand

Focus on **end-to-end sustainability** will lead to lowest-cost solutions.

Enable construction and operation of a data center that consumes **net-zero energy** from the grid over its *lifetime*, with a payback over a target number of years, while meeting service-level agreements.

Evaluation metric:

$$E_{net} = E_{embedded} + E_{op} - E_{op,renewable}$$

A net-zero energy infrastructure is one where $E_{net} \rightarrow 0$

Balancing supply and demand
Integrated Supply-Demand Management based on Service Level Agreement

- **Supply Side**:
  - Lifecycle perspective
    - available energy **(exergy)** required in extraction, manufacturing, operation and reclamation
  - Utilize **local sources of available energy** to minimize destruction of available energy in transmission and distribution; examine available energy in waste streams
- **Demand Side**:
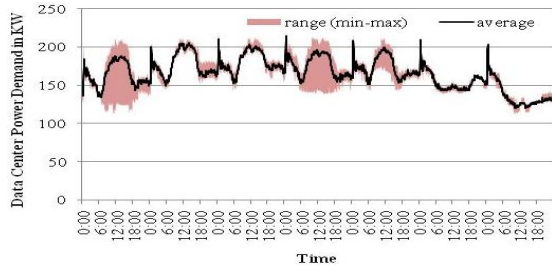 - Provision resources based on the needs of the users/services
    - pervasive sensing, communications, knowledge discovery, and policy based control
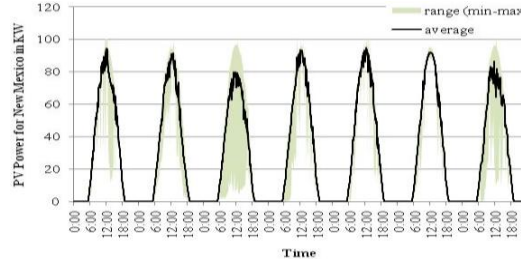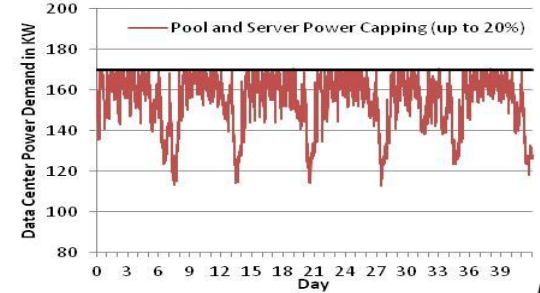
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Integrated Control: Supply and Demand

Capacity planning to exploit sustainable energy

Power Demand Profile

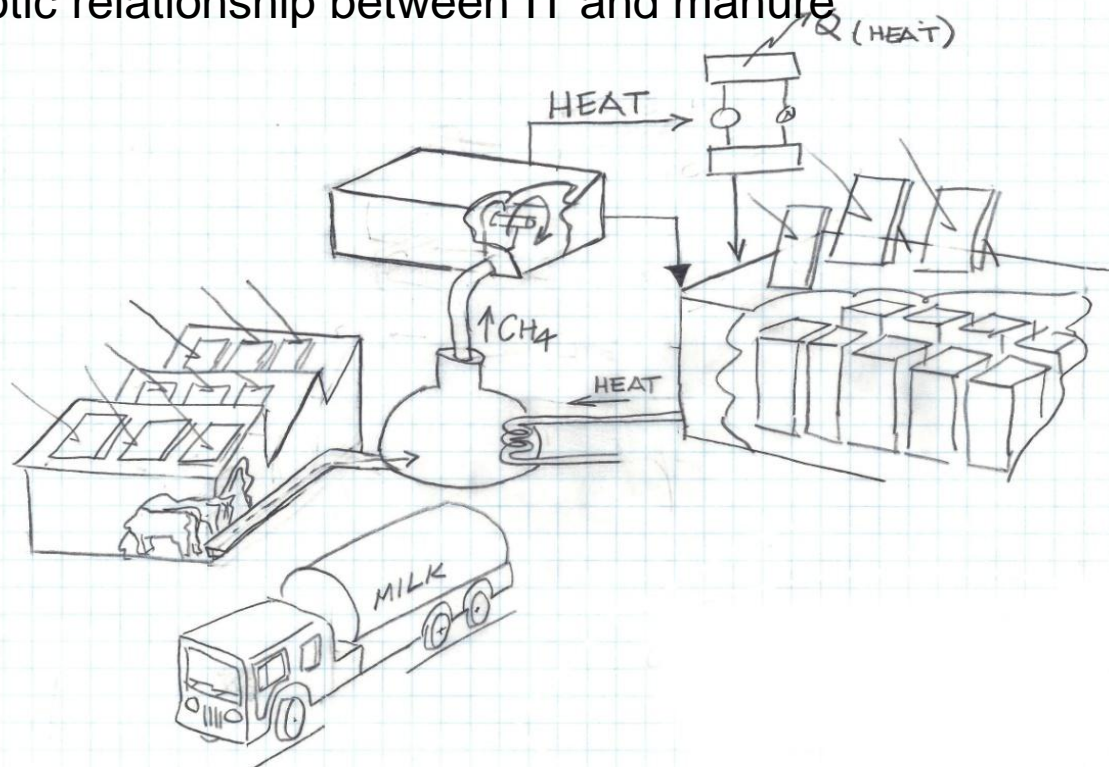**Power Supply Profile**

Power Demand Shaping

Energy Mgmt. Plan

- Design and Sizing
- Ongoing management
- Automated control

Example Power Microgrid:
Server Farm at the Dairy Farm
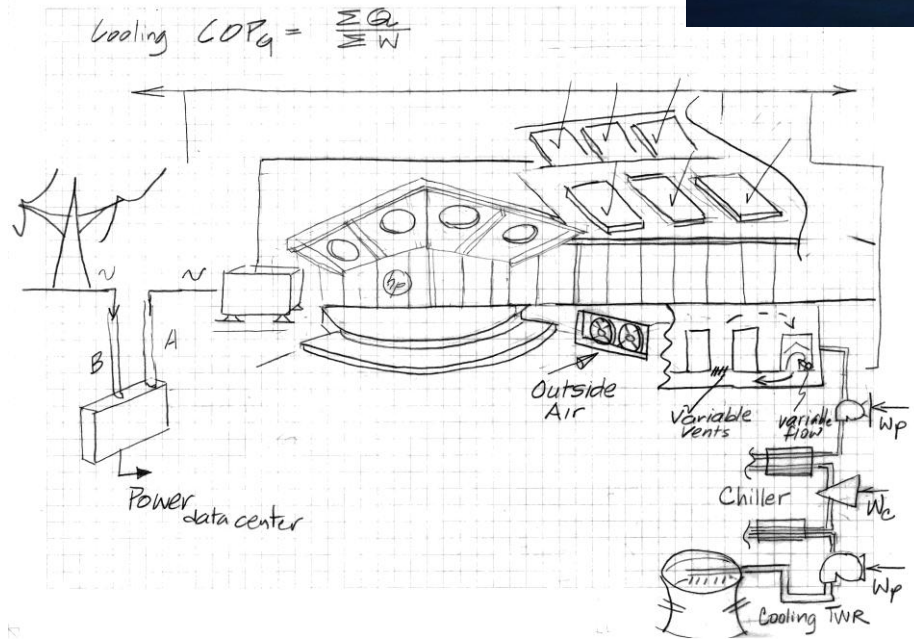
symbiotic relationship between IT and manure

Exergy in heat energy applied to the "soup" in the digester

Exergy in heat energy from the generator used for adsorption refrigeration to cool the data center

Ref: Ratnesh Sharma, Tom Christian, Martin Arlitt, Cullen Bash, Chandrakant Patel, "Design of Farm Waste-Supply Side Infrastructure for Data Centers, ASME 2010-Energy Sustainability, ES 2010-90219

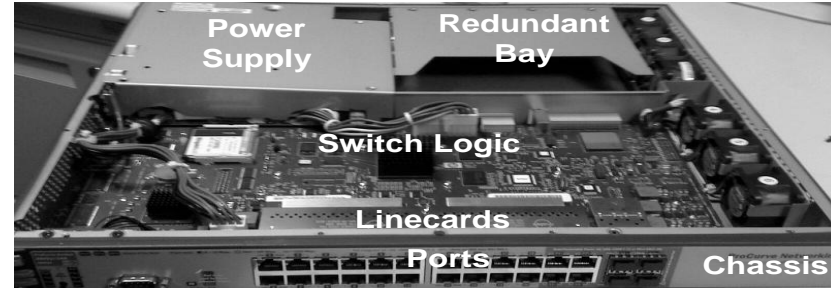# HPLabs Palo Alto Data Center

Power Micro-grid

Sustainable network devices

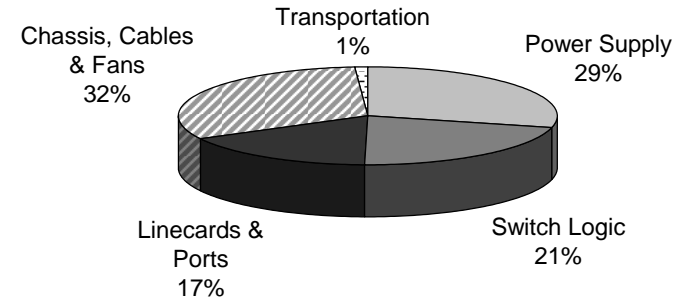## Lifecycle analysis

Disassemble switch, Identify each component

Compare to published impact factors [ecoinvent 2.0]

Scale based on functional components

Total embedded energy ~ 2.8 GJ

Type	Embedded Energy	Operational Energy*	Infrastructural Energy*
Edge Switch	2.8 GJ (11%)	16.5 GJ (64%)	6.6 GJ (26%)
Aggregation Switch	4.7 GJ (8%)	38 GJ (66%)	15 GJ (26%)
Core Switch	7.9 GJ (4%)	227 GJ (68%)	90 GJ (27%)

"Reducing Lifecycle Energy Use of Network Switches"
P. Mahadevan et. al., Proc. ISSST, May 2010.

An Illustrative Cloud Service Dashboard

Services	Economic (cost per M transactions)					Ecological (per hour)			
	IT	cooling	ntwk	support	econo. overall	CO₂ (kg)	water (Gal)	Resource Use (MJ-eq)	ecolog. overall
Service 1	$0.72	$0.35	$0.16	$0.43		0.6	2.6	8.3	
Service 2	$1.27	$0.59	$0.21	$1.11		0.68	3.3	9.6	
Service 3	$1.05	$0.47	$0.12	$1.07		0.59	2.3	8.1	
Service 4	$0.27	$0.13	$0.05	$0.09		0.43	2.4	5.9	
Service 5	$1.82	$0.77	$0.11	$1.17		1.02	4.3	14.2	
Service 6	$1.23	$0.54	$0.11	$0.98		1.50	4.4	19.2	
Service 7	$0.55	$0.26	$0.10	$0.16		0.69	2.6	9.5	
Service 8	$1.01	$0.44	$0.10	$0.83		0.53	2.5	7.4	

Enable sustainability-aware management
– e.g., Thermal-aware workload placement

Sustainability Metrics
(Energy, Cost, CO₂, Water, Resource,…)
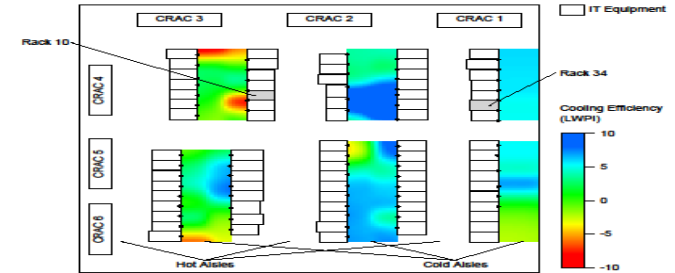
Sustainability Models

(Economic, Ecological)~f (power supply, cooling, COP, workload, resource usage, location, dynamic pricing, management policies,…)

Mixed Power Supply
Electricity Pricing

Thermal
Information

Utilization
Configuration

Utilization,
Configuration

Utilization,
Configuration

Topology
Workload

Power	Cooling	Computing	Networking	Storage	Services

Data Center or a Cloud

Arlitt, M.; Banerjee, S.; Bash, C.; Chen, Y.; Gmach, D.; Hoover, C.; Mahadevan, P.; Milojicic, D.; Pelletier, E.; Vishwanath, R.; Shah, A.; Sharma, R. Cloud sustainability dashboard: dynamically assessing the sustainability of cloud computing Poster, ISSST 2010

Parting Thoughts
We are at the beginning

Every drop counts
- need to quantify impact of every drop – direct and indirect
- requires holistic and inter-disciplinary thinking
- balancing supply and demand

Sustainable IT vs IT for sustainability
- sustainable networks vs networks for sustainability
- network as an enabler of sustainability

Sustainable Devices → Clusters → Datacenters → Cloud
Homes → Buildings → Campus → Cities → Planet

THANK YOU