Can a Greener Internet Help Us Moderate Climate Change?

High Definition Remote Presentation to the

Monash Undergraduate Research Projects Abroad (MURPA) Program

Located at Monash University, Australia

From Calit2@UCSD

May 13, 2009

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

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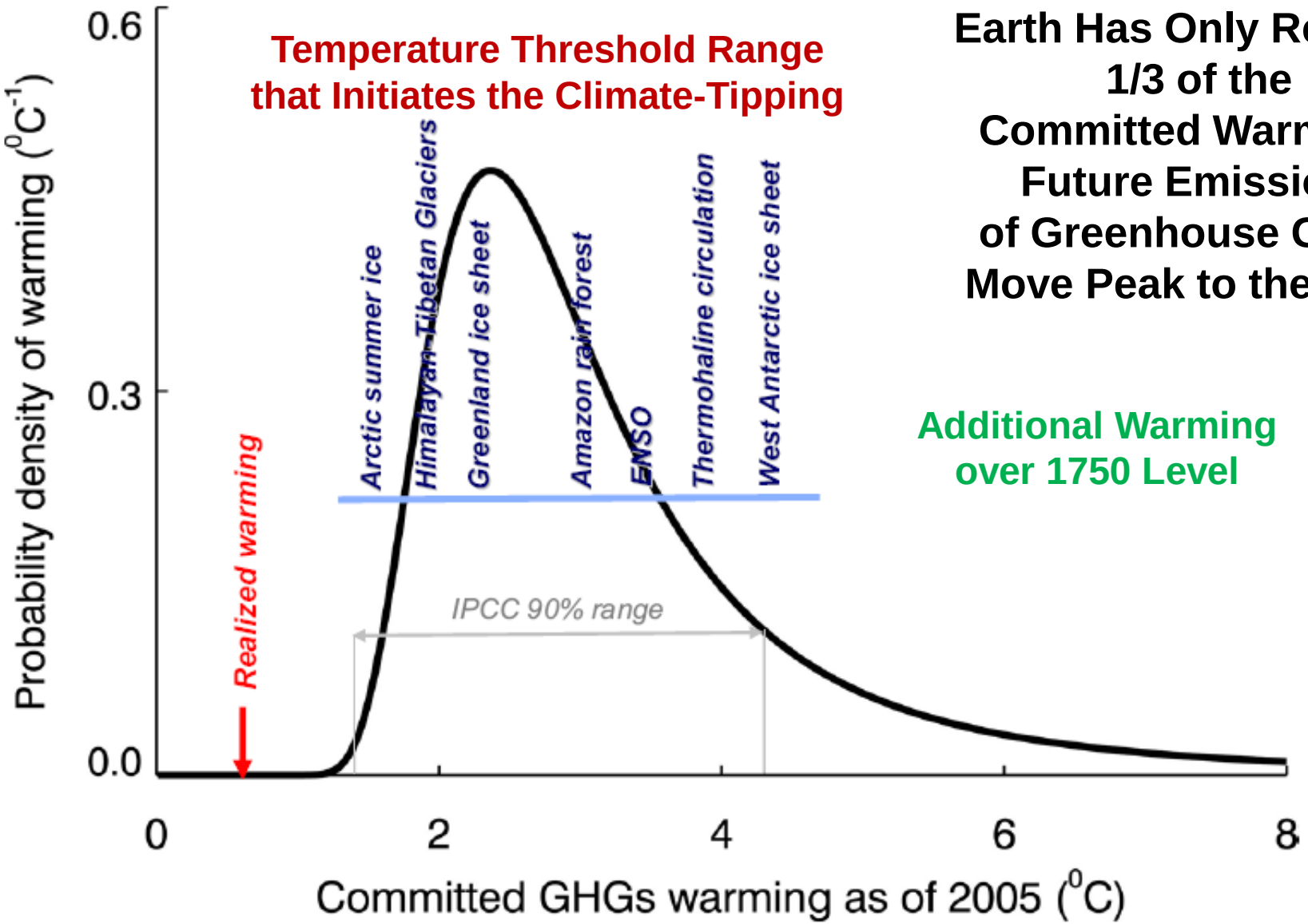
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Abstract

This year marks a turning point in the debate on global climate change. The focus of the discussion is rapidly moving from a scientific analysis of how human activity effects climate change to a political process on how best to regulate greenhouse gas emissions. The Climate Group's Smart 2020 study reveals that the global Information and Communication Technology (ICT) industry produces greenhouse gases equivalent to that produced by the aviation industry (~2-3 percent). Furthermore, the ICT sector's emissions will nearly triple, in a business-as-usual scenario, from 2002 to 2020. On the other hand, the Climate Group estimates that transformative applications of ICT to electricity grids, logistic chains, intelligent transportation and building infrastructure, and other social systems can reduce global greenhouse gas emissions by about 15 percent— five times ICT's own footprint! I will discuss initiatives on university campuses in the US and Australia to innovate new solutions to these challenges.

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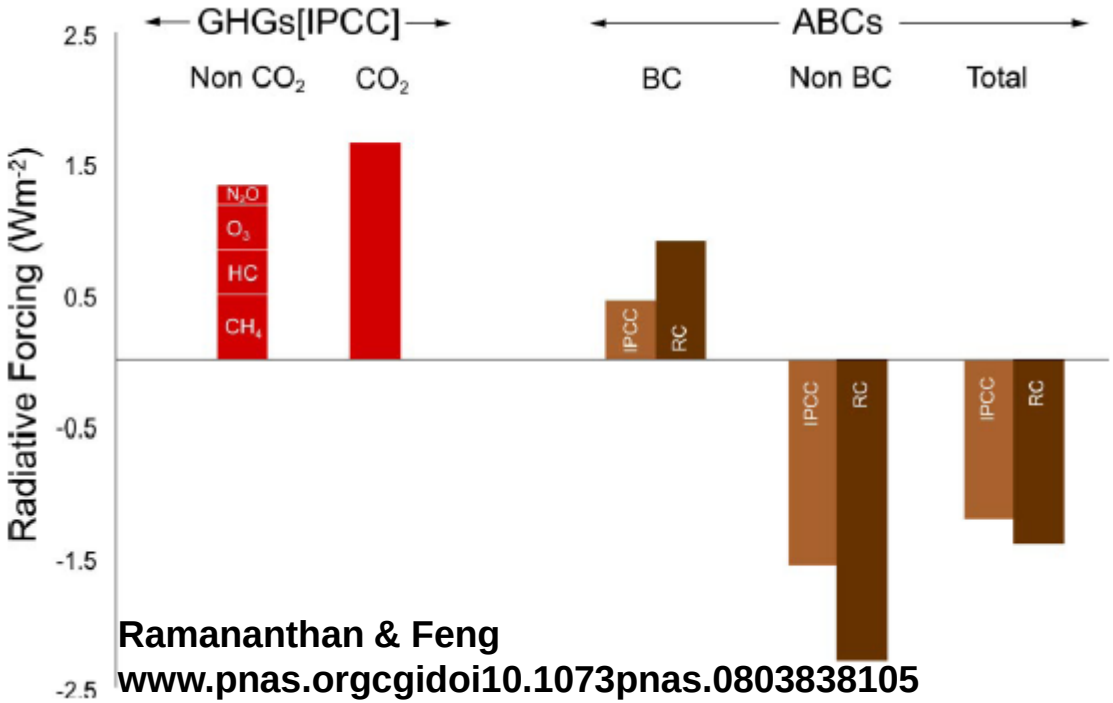
The Planet is Already Committed to a Dangerous Level of Warming



V. Ramanathan and Y. Feng, Scripps Institution of Oceanography, UCSD
September 23, 2008
www.pnas.orgcgidoi10.1073pnas.0803838105

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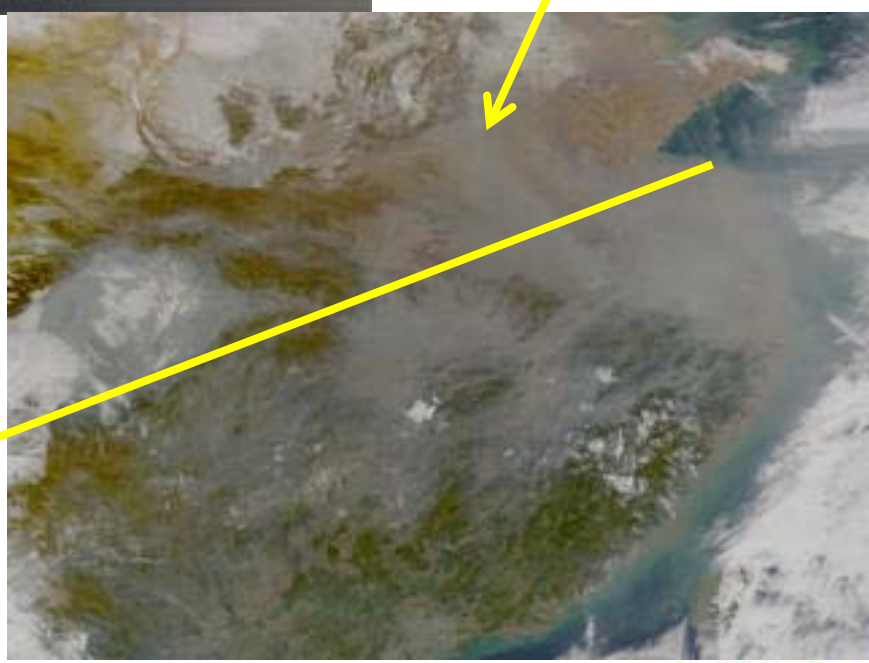
Atmospheric Aerosols Cool Climate—Cleaning Air Pollution will Accelerate Warming!



Ramananthan & Feng
www.pnas.orgcgidoi10.1073pnas.0803838105







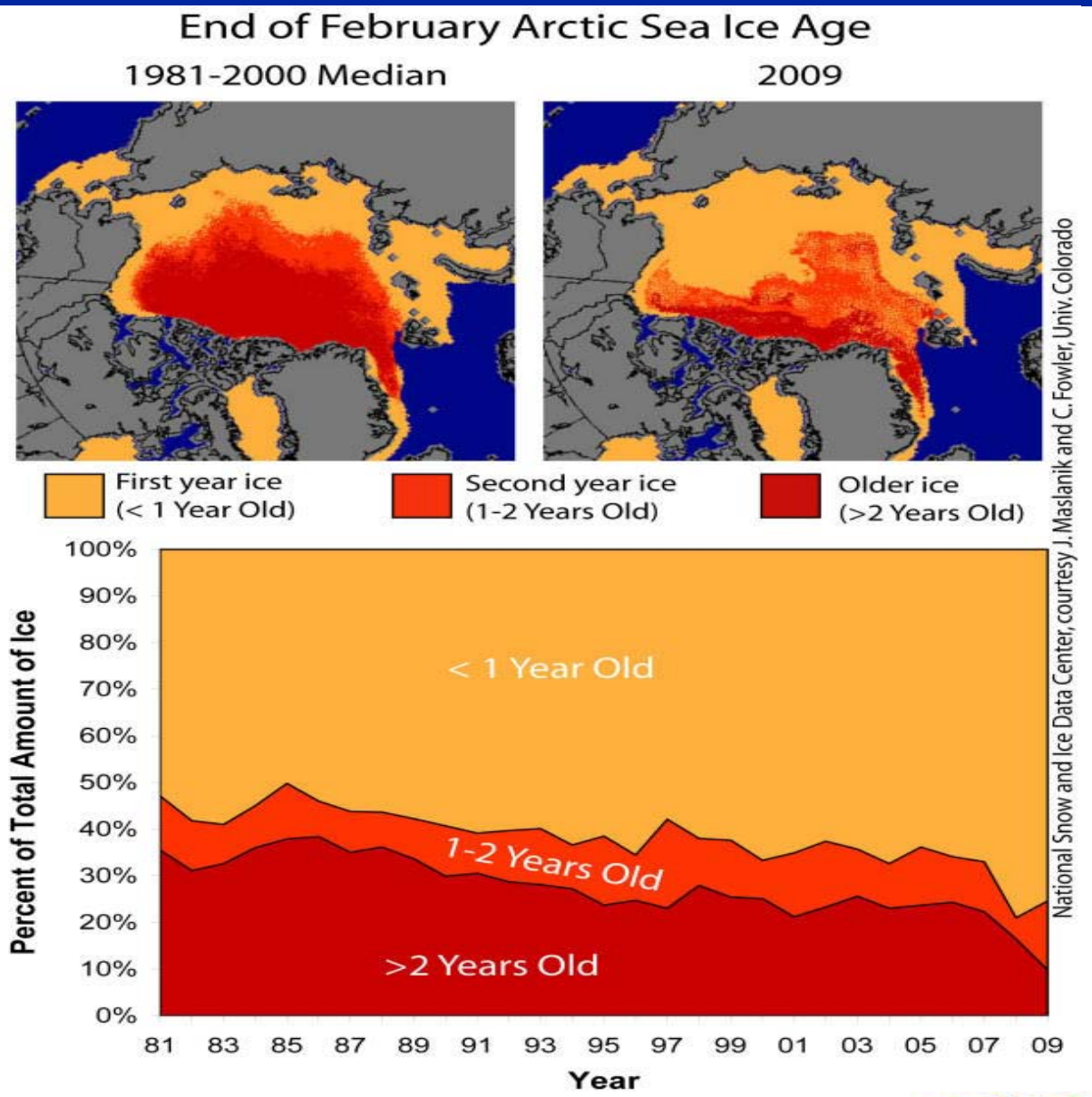


NASA satellite image

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Arctic Summer Ice is Rapidly Decreasing

"The Arctic Ocean will be effectively ice free sometime between 2020 and 2040, although it is possible it could happen as early as 2013."
--Walt Meier, Research Scientist at the National Snow and Ice Data Centre at the University of Colorado



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http://news.cnet.com/8301-11128_3-10213891-54.html

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The Hindu Kush/Himalayan Plateau Has the Most Snow and Ice Outside of the Polar Regions

Gordon and Betty MOORE FOUNDATION

UNIVERSITY OF CAMBRIDGE

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"Water Towers of Asia"
Impact
40% of the
World's Population

UCSD-Cambridge Workshop
May 4 – May 6, 2009
University of California San Diego
La Jolla, CA

Ice, Snow, and Water

Impacts of Climate Change on California and Himalayan Asia

"California Faces Water Rationing, Governor Proclaims Drought Emergency"
--February 27, 2009

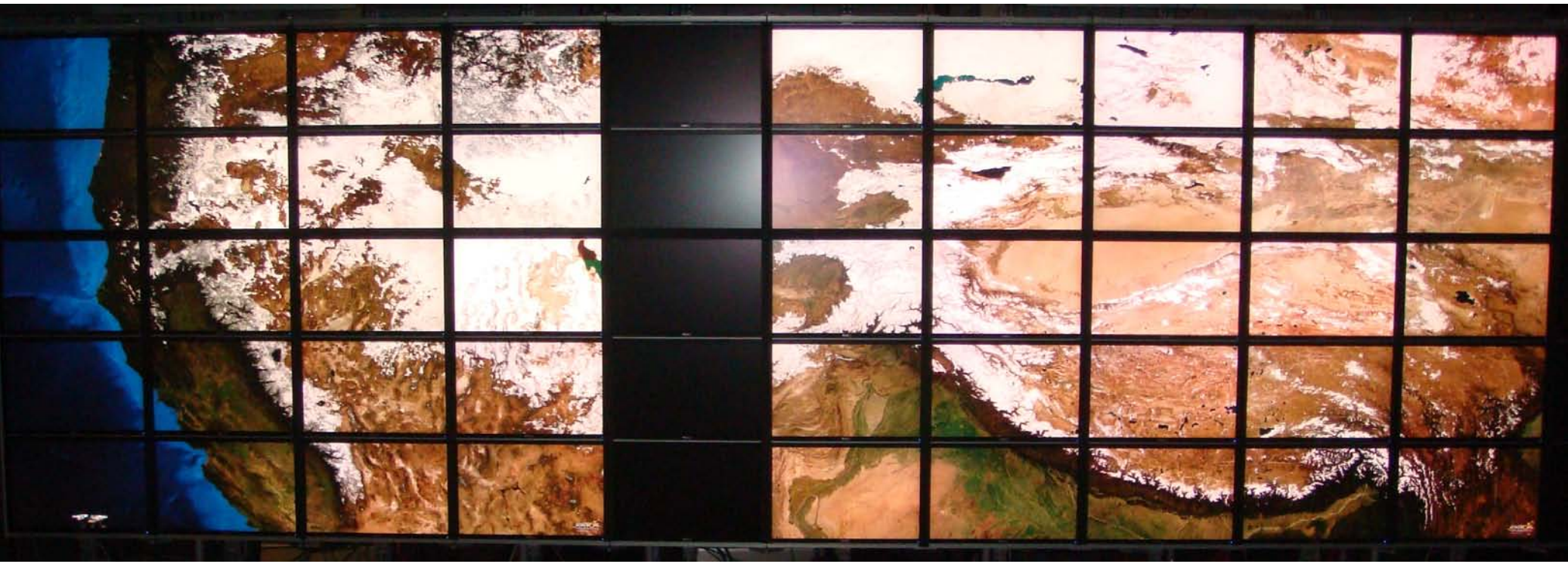


HKH Map with major river basins

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California and Himalayan Asia: Snow and Ice are Critical Fresh Water Reservoirs

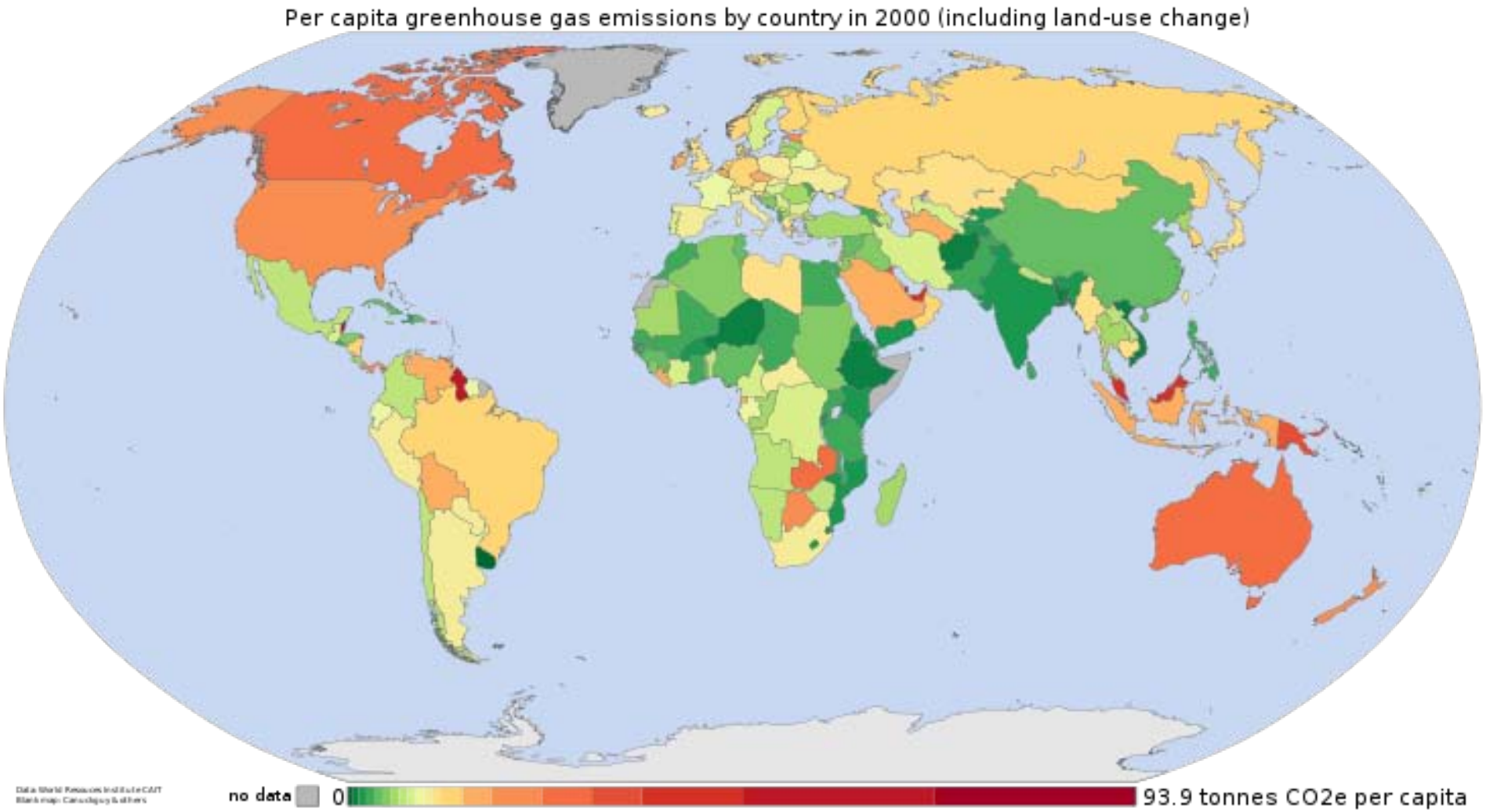


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NASA Blue Marble Data Set January 2004
Falko Kuester, HiPerSpace, Calit2

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Australia, the U.S., and Canada Share a Problem: Top 3 Developed Countries For Per Capita GHG Emission



"Australia's Total Emissions Exceed Those of France and Italy"
--Australia Institute

http://en.wikipedia.org/wiki/File:GHG_per_capita_2000.svg

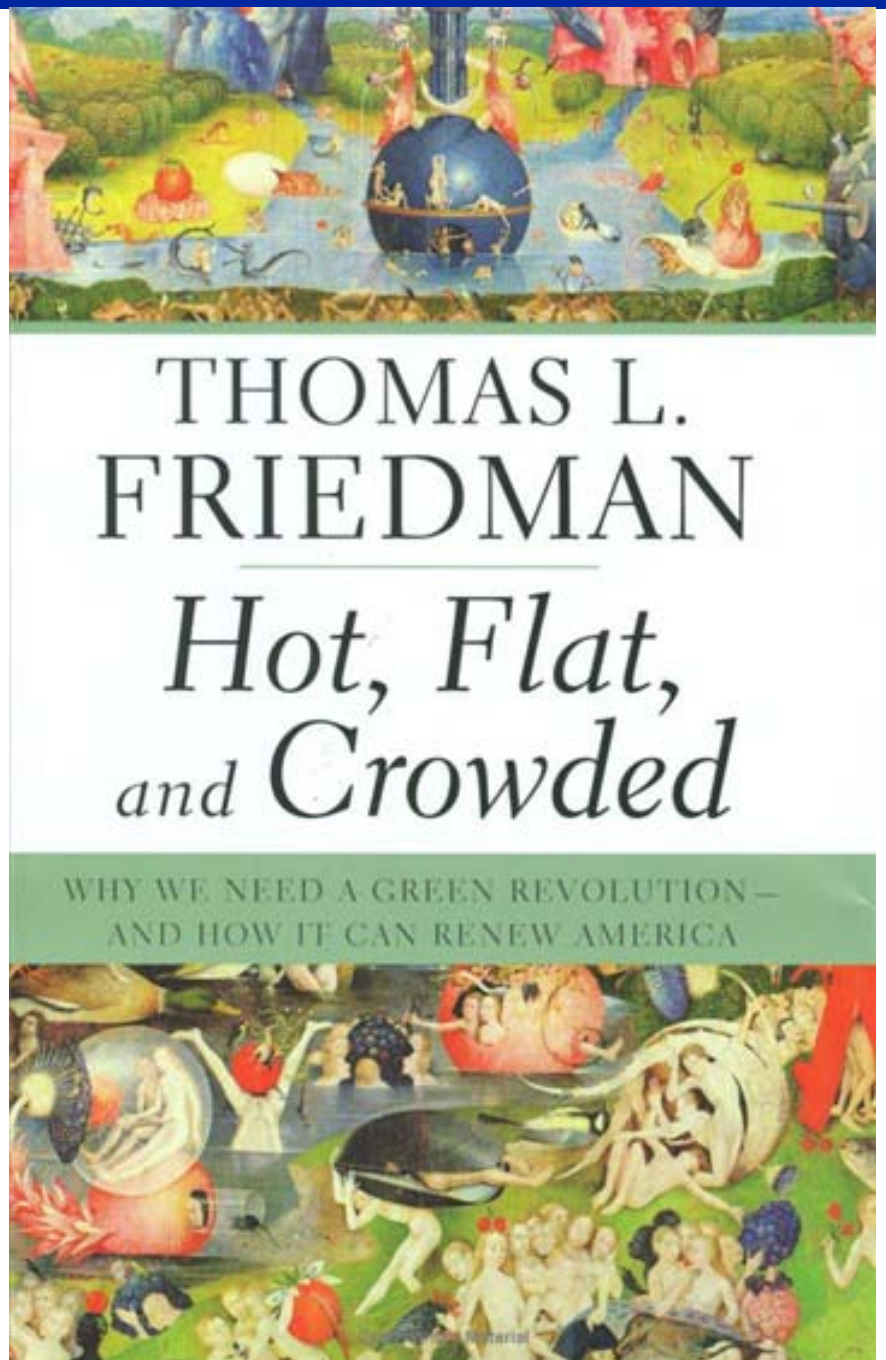
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Countries and States are Setting Aggressive Greenhouse Gas Reduction Goals

"Australia is today the biggest carbon polluter in the developed world on a per capita basis, yet we are the developed country with the most to lose from climate change. Without action on climate change, Australia faces a future of parched farms, bleached reefs, and empty reservoirs."
--Australian Prime Minister Kevin Rudd

www.guardian.co.uk/environment/2008/dec/15/climate-change-australia

“It Will Be the Biggest Single Peacetime Project Humankind Will Have Ever Undertaken”



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The IPCC Recommends a 25-40% Reduction Below 1990 Levels by 2020

- **On September 27, 2006, Governor Schwarzenegger signed California *the Global Warming Solutions Act* of 2006**
  - **Assembly Bill 32 (AB32)**
  - **Requires Reduction of GHG by 2020 Only to 1990 Levels**
    - **10% Reduction from 2008 Levels; 30% from BAU 2020 Levels**
    - **4 Tons of CO_2-equiv. Reduction for Every Person in California!**
- **The European Union Requires Reduction of GHG by 2020 to 20% Below 1990 Levels (12/12/2008)**
- **Australia has Pledged to Cut by 2020 its GHG Emissions 5% from 2000 Levels via the World's Broadest Cap &Trade Scheme (12/15/08) [~5% Below 1990 Levels]**
- **Neither the U.S. or Canada has an Official Target Yet**
  - **President Obama Has Endorsed the AB32 2020 Goal**

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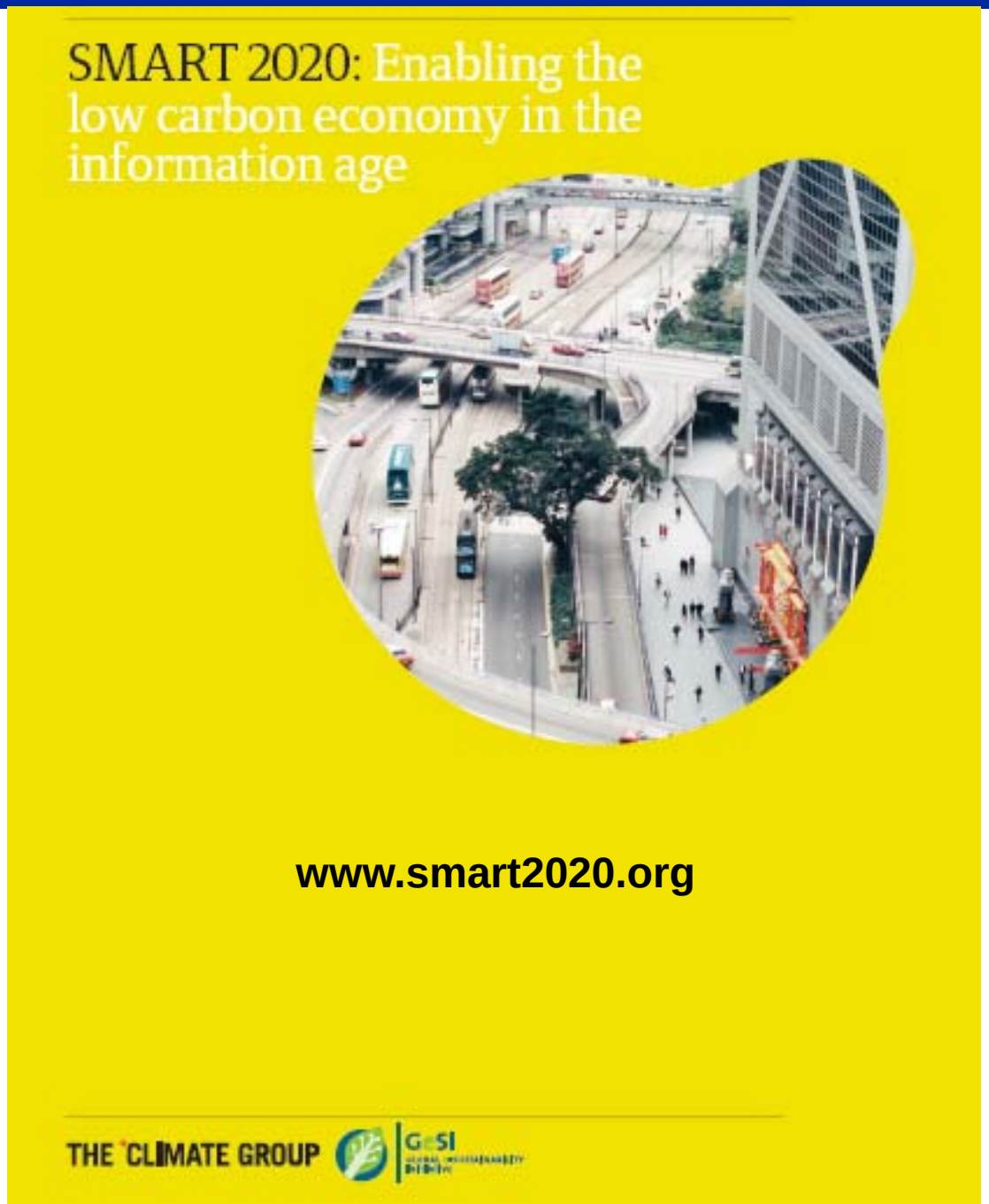
ICT is a Critical Element in Achieving Countries Greenhouse Gas Emission Reduction Targets

GeSI member companies:

- **Bell Canada,**
- **British Telecomm.,**
- **Plc,**
- **Cisco Systems,**
- **Deutsche Telekom AG,**
- **Ericsson,**
- **France Telecom,**
- **Hewlett-Packard,**
- **Intel,**
- **Microsoft,**
- **Nokia,**
- **Nokia Siemens Networks,**
- **Sun Microsystems,**
- **T-Mobile,**
- **Telefónica S.A.,**
- **Telenor,**
- **Verizon,**
- **Vodafone Plc.**

Additional support:

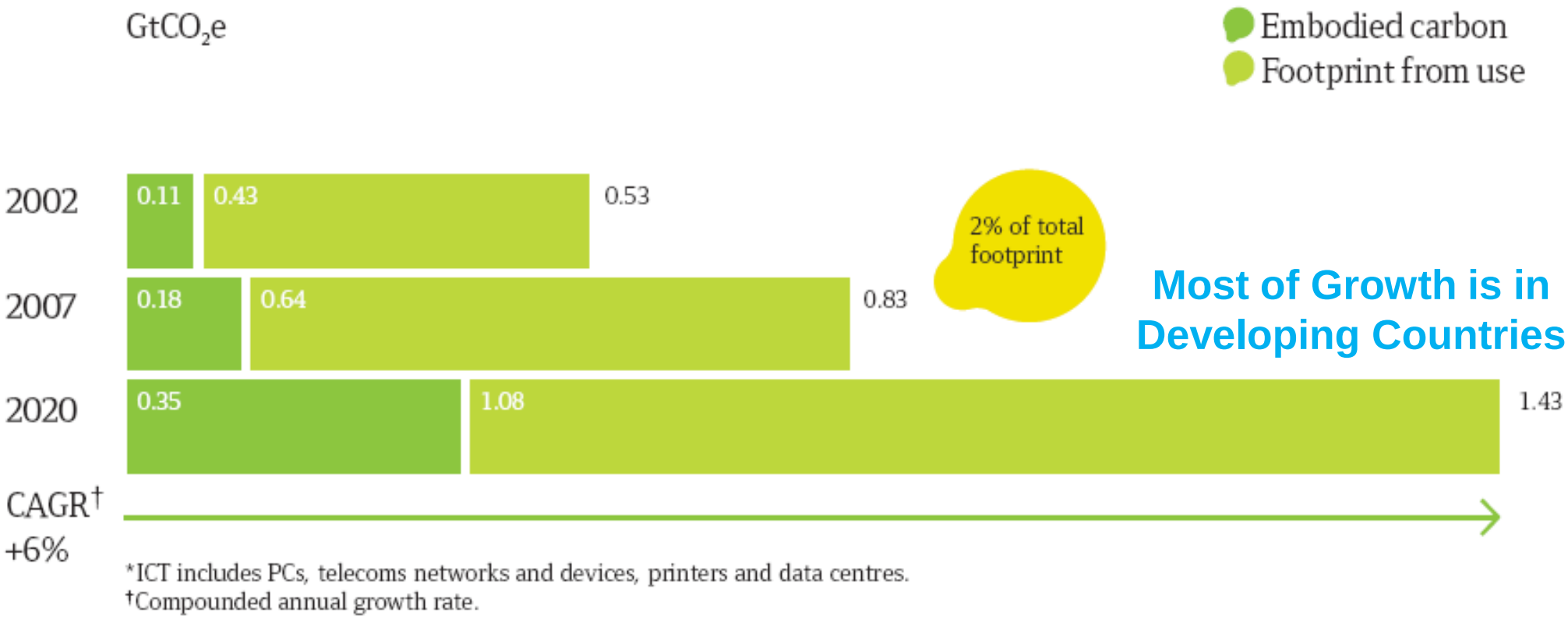
- **Dell, LG.**



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The Global ICT Carbon Footprint is Roughly the Same as the Aviation Industry Today

But ICT Emissions are Growing at 6% Annually!



Most of Growth is in Developing Countries

the assumptions behind the growth in emissions expected in 2020:

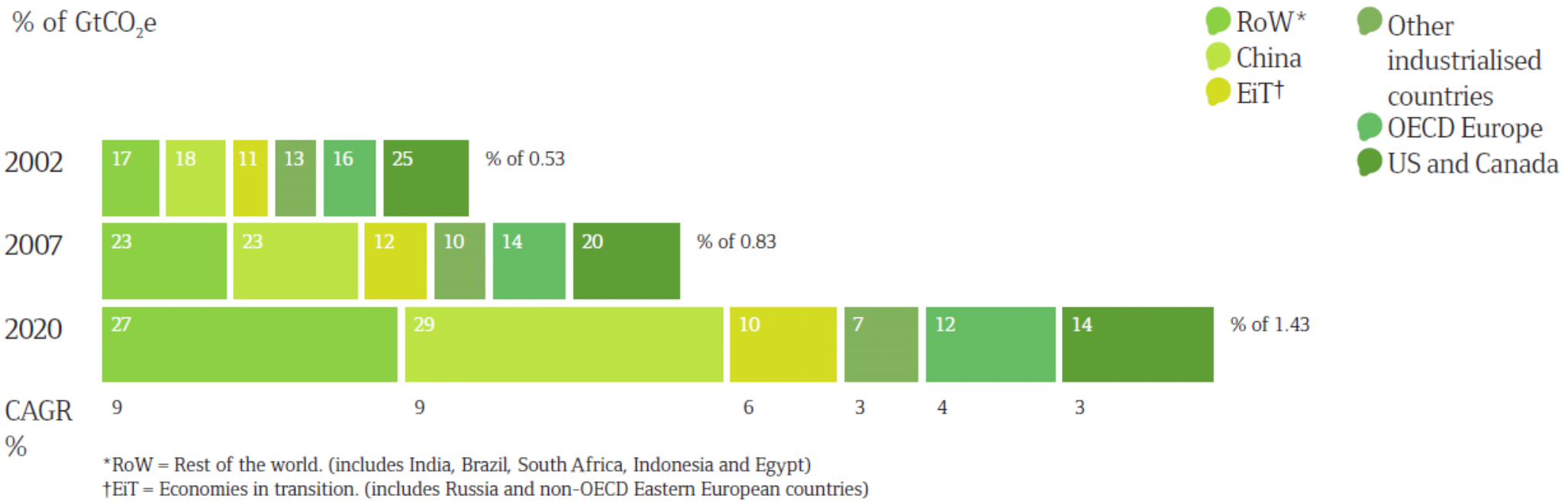
- **takes into account likely efficient technology developments that affect the power consumption of products and services**
- **and their expected penetration in the market in 2020**

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www.smart2020.org

Reduction of ICT Emissions is a Global Challenge – U.S. and Canada are Small Sources

U.S. and Canada Together Fall From 25% to 14% of Global ICT Emissions by 2020



*RoW = Rest of the world. (includes India, Brazil, South Africa, Indonesia and Egypt)
†EiT = Economies in transition. (includes Russia and non-OECD Eastern European countries)

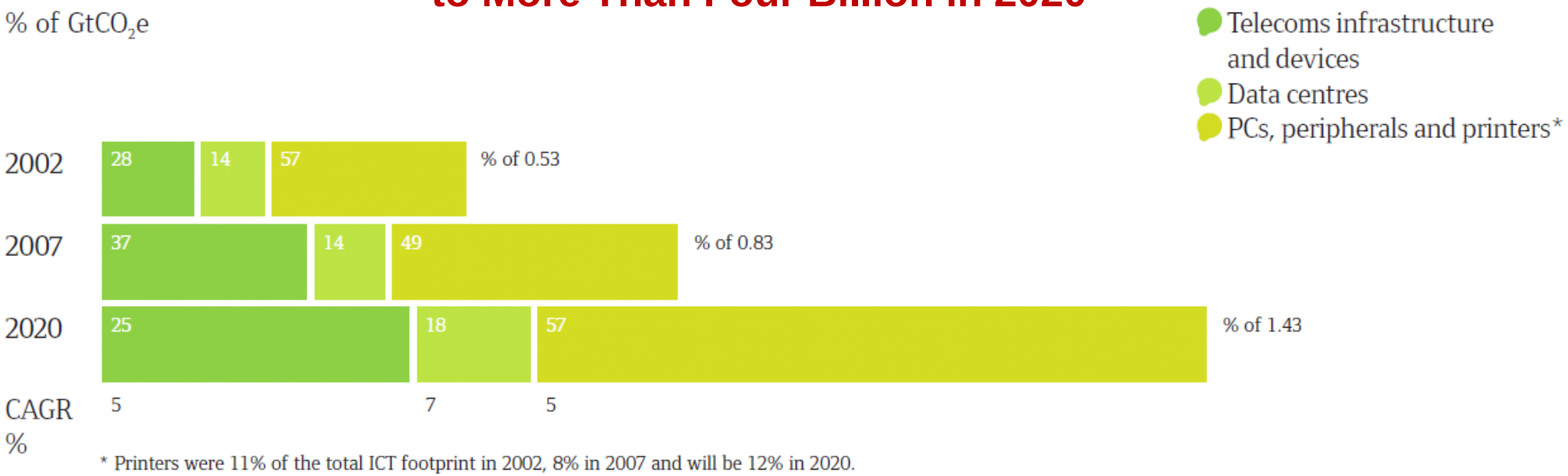
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www.smart2020.org

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The Global ICT Carbon Footprint by Subsector

The Number of PCs (Desktops and Laptops) Globally is Expected to Increase from 592 Million in 2002 to More Than Four Billion in 2020



* Printers were 11% of the total ICT footprint in 2002, 8% in 2007 and will be 12% in 2020.

A System Approach is Required to Reduce Internet's Greenhouse Gas Emissions

- **Estimates Needed for CO_2 Emissions from Each Subcomponent**
- **Beware of Tradeoffs:**
  - **"I will clean up my campus by getting rid of clusters and computing in the cloud"**
  - **Is This a Net Reduction?**



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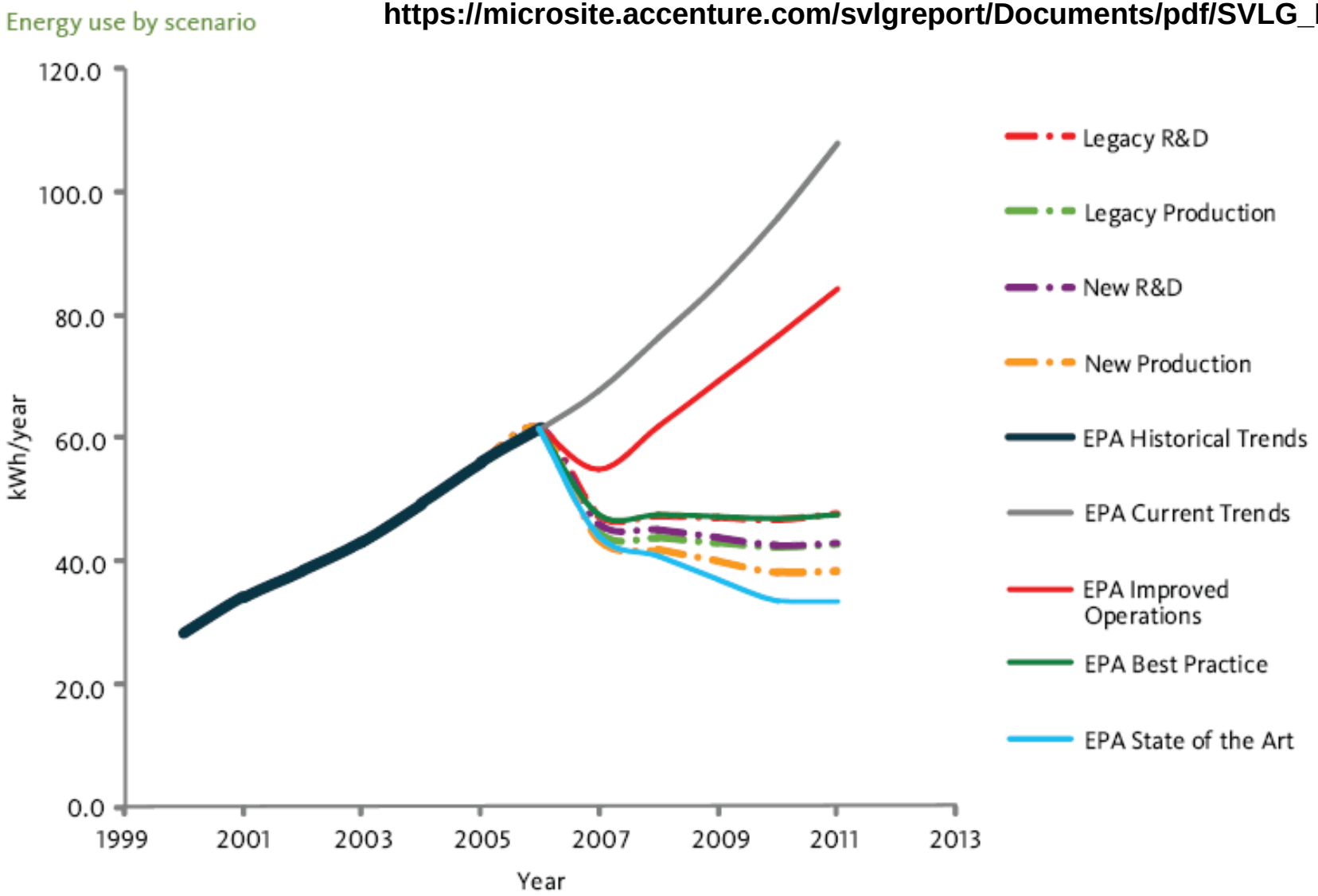
CUBIN

Source: Rod Tucker, U Melbourne

it²

Electricity Usage by U.S. Data Centers: Emission Reductions are Underway

Source: Silicon Valley Leadership Group Report July 29, 2008
https://microsite.accenture.com/svlgreport/Documents/pdf/SVLG_Report.pdf



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The NSF-Funded GreenLight Project
Giving Users Greener Compute and Storage Options

UCSD Structural Engineering Dept. Conducted Sun MD Tests May 2007



7 Racks plus Network



Takes up 2 Parking Spaces



Data Power Cooling

- **Measure, Publish, and Control Energy Usage:**
  - **Sun Has Shown up to 40% Reduction in Energy**
  - **Active Management of Disks, CPUs, etc.**
  - **Measures Temperature at 5 Levels in 8 Racks**
  - **Power Utilization in Each of the 8 Racks**
  - **Chilled Water Cooling Systems**



Source: Tom DeFanti, Calit2; GreenLight PI

UCSD (Calit2 & SOM) Bought Two Sun MDs May 2008

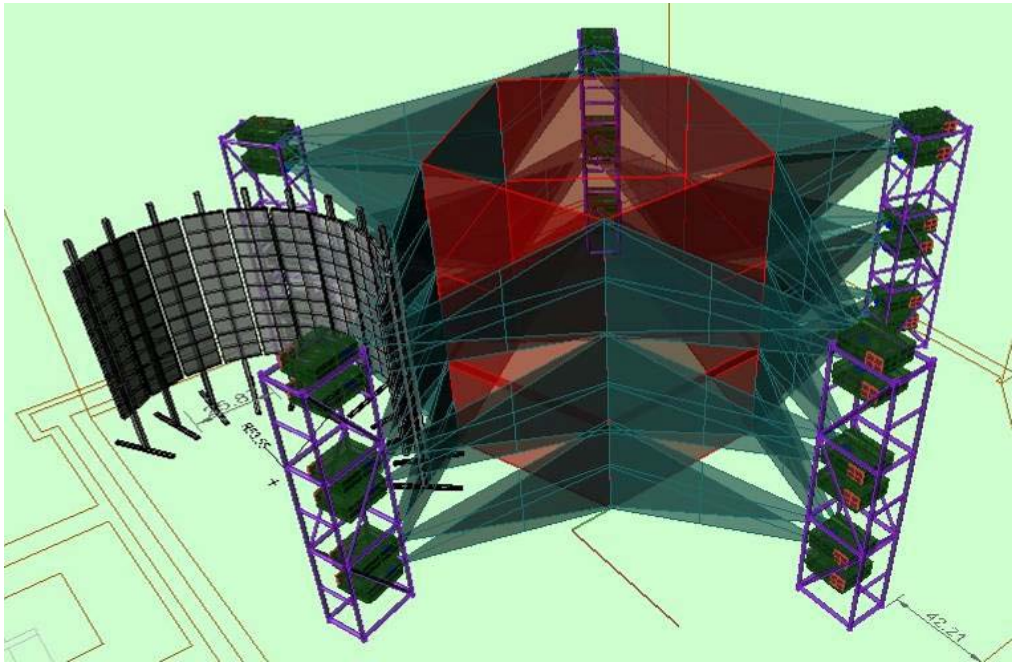
GreenLight's Data is Available Remotely: Virtual Version in Calit2 StarCAVE







30 HD Projectors!



Connected at 50 Gb/s to Quartzite

Source: Tom DeFanti, Greg Dawe, Jurgen Schulze, Calit2

Calit2's GreenLight Project Receives CENIC's 2009
Innovations in Networking Award--Experimental-Developmental Applications



Winning smiles: (l-r) CENIC President & CEO Jim Dolgonas; Calit2 Director Larry Smarr; GreenLight PI Tom DeFanti; Calit2 Technical Director and GreenLight team member Greg Hidley; and CENIC conference chair Doug Hartline

www.calit2.net/newsroom/release.php?id=1485

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Research Needed on How to Deploy a Green CI



- **Computer Architecture**
  - Rajesh Gupta/CSE
- **Software Architecture**
  - Amin Vahdat, Ingolf Kruger/CSE
- **CineGrid Exchange**
  - Tom DeFanti/Calit2
- **Visualization**
  - Falko Kuster/Structural Engineering
- **Power and Thermal Management**
  - Tajana Rosing/CSE
- **Analyzing Power Consumption Data**
  - Jim Hollan/Cog Sci
- **Direct DC Datacenters**
  - Tom Defanti, Greg Hidley

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http://greenlight.calit2.net

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New Techniques for Dynamic Power and Thermal Management to Reduce Energy Requirements



NSF Project Greenlight

- Green Cyberinfrastructure in Energy-Efficient Modular Facilities
- Closed-Loop Power &Thermal Management

Dynamic Power Management (DPM)

- Optimal DPM for a Class of Workloads
- Machine Learning to Adapt
  - Select Among Specialized Policies
  - Use Sensors and Performance Counters to Monitor
  - Multitasking/Within Task Adaptation of Voltage and Frequency
  - Measured Energy Savings of Up to 70% per Device

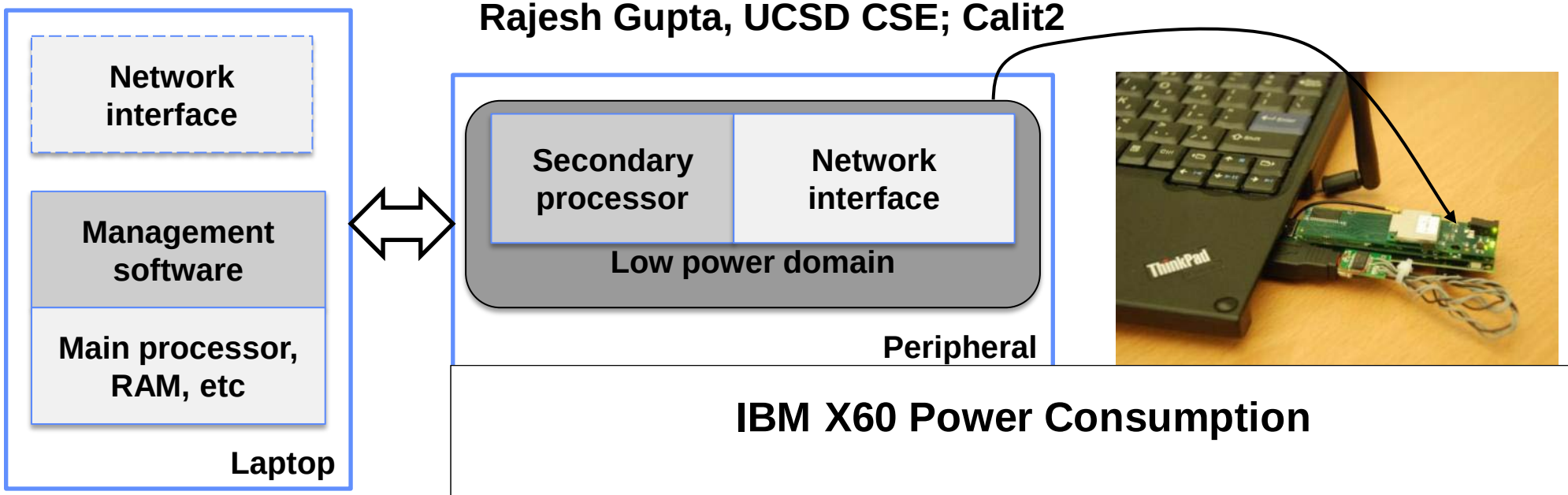
Dynamic Thermal Management (DTM)

- Workload Scheduling:
  - Machine learning for Dynamic Adaptation to get Best Temporal and Spatial Profiles with Closed-Loop Sensing
  - Proactive Thermal Management
  - Reduces Thermal Hot Spots by Average 60% with No Performance Overhead

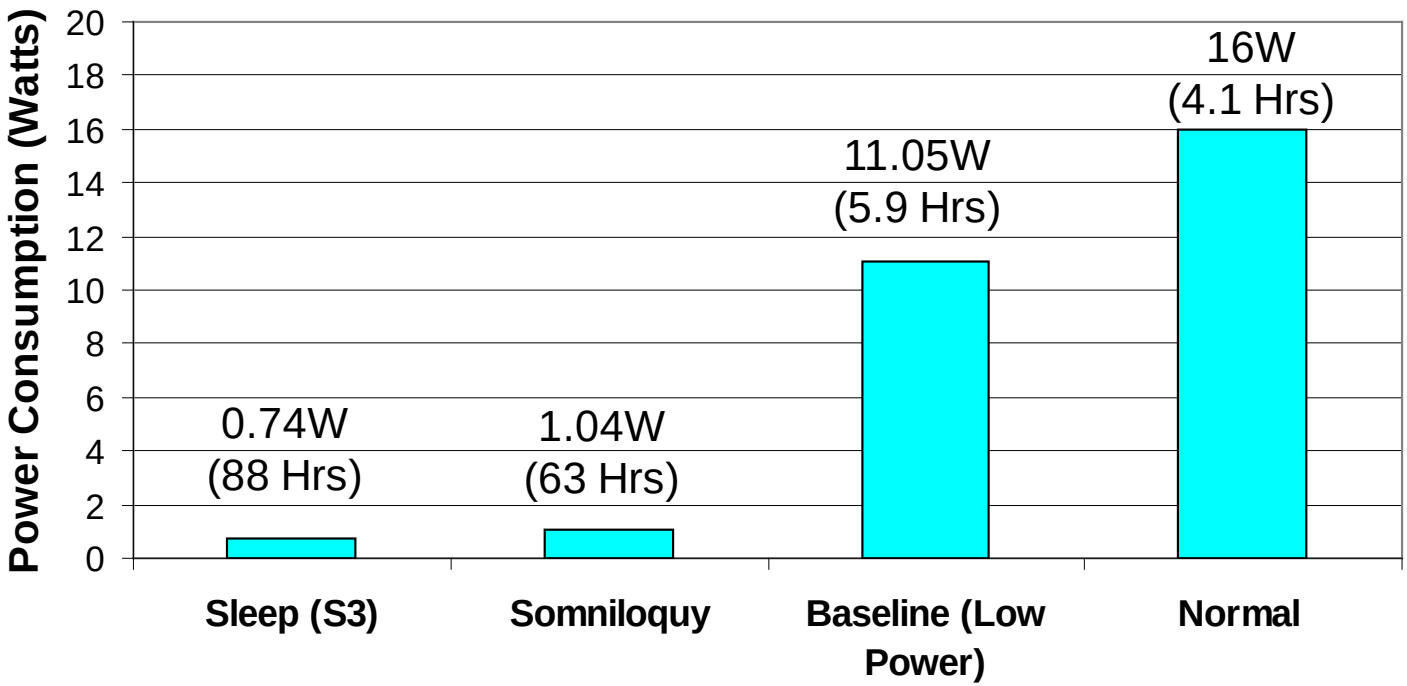
System Energy Efficiency Lab (seelab.ucsd.edu)
Prof. Tajana Šimunić Rosing, CSE, UCSD

GreenLight Project: Putting Machines To Sleep Transparently

Rajesh Gupta, UCSD CSE; Calit2



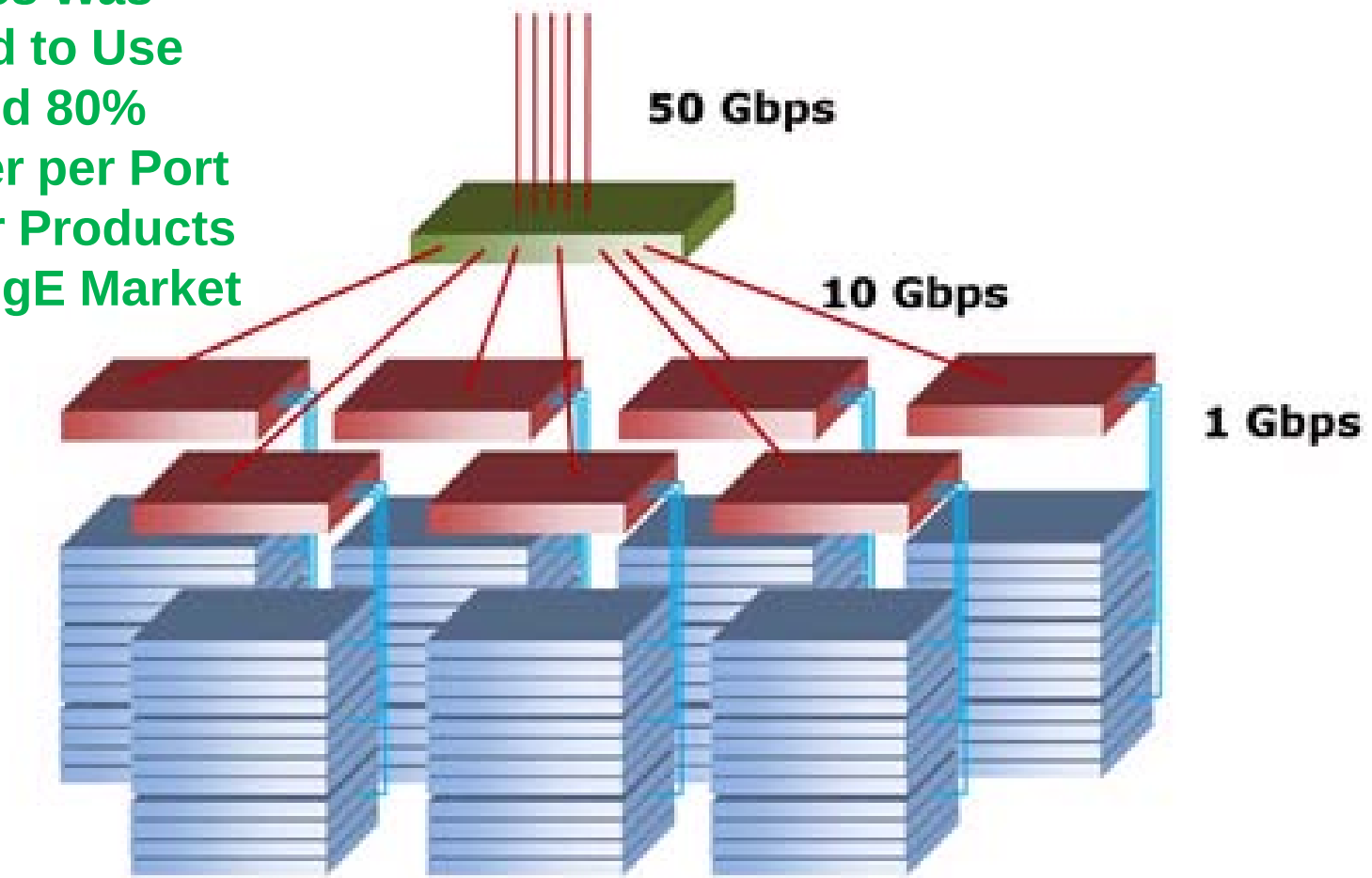
Somniloquy Enables Servers to Enter and Exit Sleep While Maintaining Their Network and Application Level Presence



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GreenLight Provides a Environment for Innovative "Greener" Products to be Tested

Quadrics Was Designed to Use 20% and 80% Less Power per Port Than Other Products in the 10 GigE Market

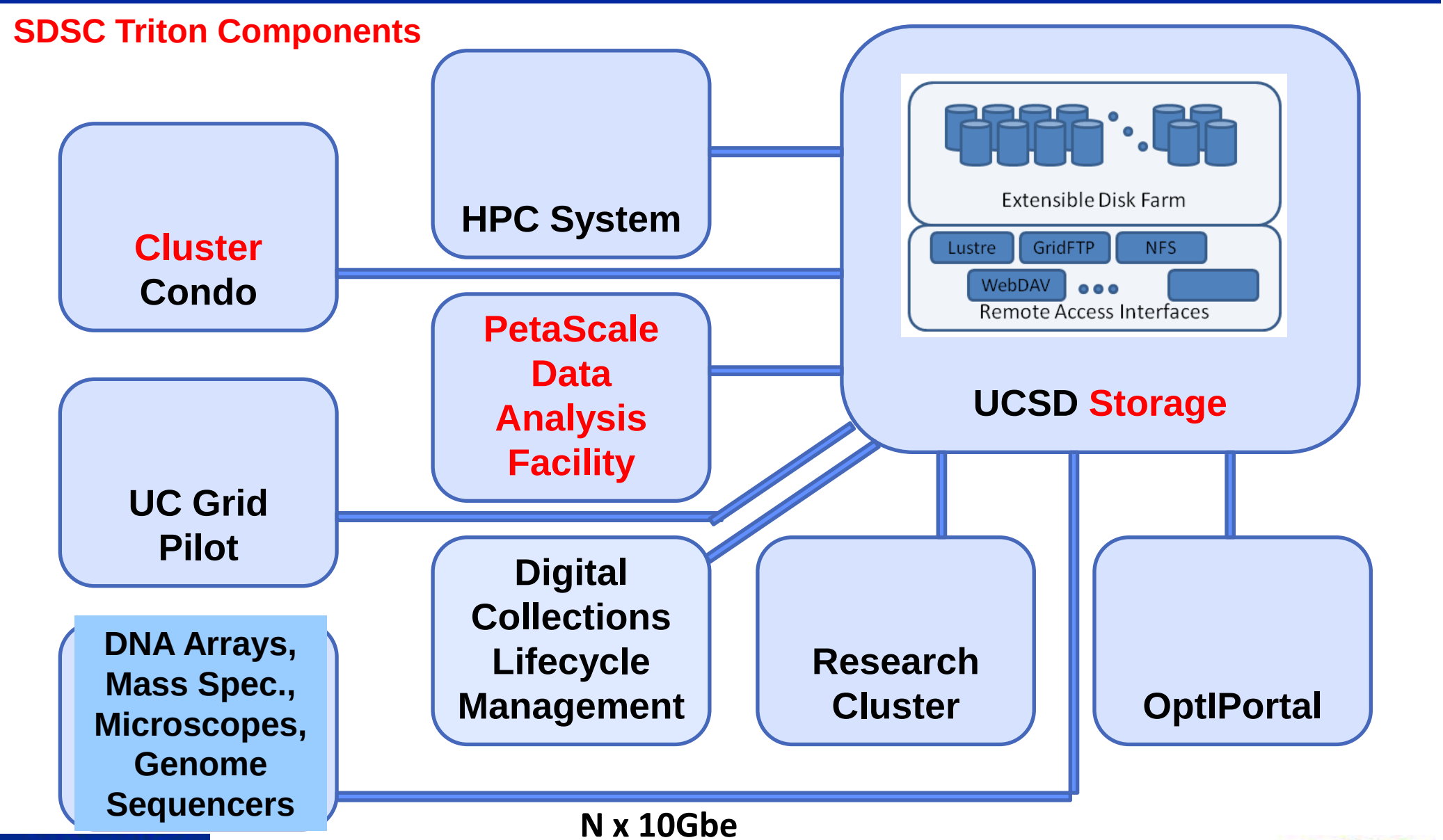


GreenLight topology for 10GE link aggregation: When complete, the servers (blue) will connect to edge switches (red) via 1 Gbps links, and the edge switches will connect to each other via the 10 Gbps links of the Quadrics TG201 switch (green).

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www.calit2.net/newsroom/article.php?id=1482

Consolidating Dispersed Faculty Clusters Over the Fiber Connected UCSD Campus Research CI



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Source: Phil Papadopoulos, SDSC/Calit2

Power Management in the Cellular Infrastructure: Calit2 Team Achieves 58% Power Amplifier Efficiency

Standard Commercial Base Station Power Amp is 10% Efficient

Calit2
High-Power
Amplifier Lab

freescale semiconductor

TriQuint SEMICONDUCTOR

HUAWEI

ERICSSON

Power Transistor Tradeoffs:

Si-LDMOS, GaN, & GaAs

Price & Performance

Eudyna

Power Amplifier Tradeoffs:

WiMAX & 3.9GPP LTE

Efficiency & Linearity

STMicroelectronics

Digital Signal Processing Tradeoffs:

Pre-Distortion, Memory Effects & Power Control

MIPS & Memory

NOKIA

QUALCOMM

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www.universityofcalifornia.edu/news/article/19058

Source: Don Kimball, Calit2; Peter Asbeck and Larry Larson, ECE

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Leading Edge Photonics Systems Laboratory Has Demonstrated Multiple World Records

- **Networking "Living Lab" Testbed Core**
  - **Terabit Networking**
  - **Micro LIDAR/Spectroscopy**
  - **Silicon Frequency Conversion**
  - **320Gbps Real Time Processing**
  - **Advanced Transmission Coding**

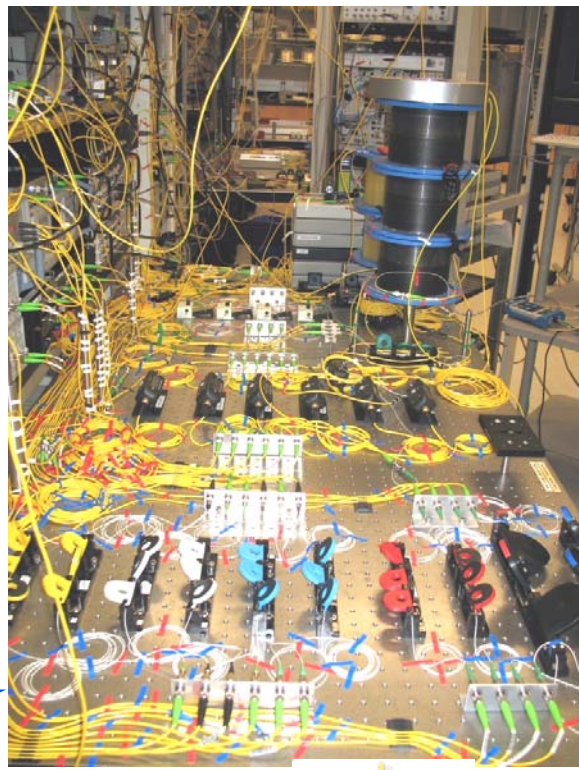
Alcatel·Lucent

AVANEX

ofs
A Furukawa Company

SUMITOMO ELECTRIC
LIGHTWAVE

LOCKHEED MARTIN



ECE Testbed Faculty



Stojan Radic
Optical communication networks; all-optical processing; parametric processes in high-confinement fiber and semiconductor devices.



George Papen
Advanced photonic systems including optical communication systems, optical networking, and environmental and atmospheric remote sensing.



Joseph Ford
Optoelectronic subsystems integration (MEMS, diffractive optics, VLSI); Fiber optic and free-space communications.



Shaya Fainman
Nanoscale science and technology; ultrafast photonics and signal processing



Shayan Mookherjea
Optical devices and optical communication networks, including photonics, lightwave systems and nano-scale optics.



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PARAMETRIC OPTICAL PROCESSES & SYSTEMS

DARPA

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UCSD Photonics

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Application of ICT Can Lead to a 5-Fold Greater Decrease in GHGs Than its Own Carbon Footprint

While the sector plans to significantly step up the energy efficiency of its products and services, ICT's largest influence will be by enabling energy efficiencies in other sectors, an opportunity that could deliver carbon savings five times larger than the total emissions from the entire ICT sector in 2020.

--Smart 2020 Report

Major Opportunities for the United States*

- Smart Electrical Grids
- Smart Transportation Systems
- Smart Buildings
- Virtual Meetings

*** Smart 2020 United States Report Addendum**

www.smart2020.org

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Real-Time Monitoring of Building Energy Usage: UCSD Has 34 Buildings On-Line



Import/Production
Meter Reads
Vista

UCSD MAP | HOUSING

Real Time Cost Per Hour $ 2,570
Real Time kW Usage 30,238 kW

	SIO	UCSD Medical Center La Jolla	Warren Campus University Center	East Campus	Muir Campus
Current Month:					
Monthly Cost ($)	66,121	64,277	138,097	18,564	67,143
kWh del	777,893 kWh	756,204 kWh	1,624,674 kWh	218,400 kWh	789,923 kWh
Previous Month:					
Monthly Cost ($)	149,881	148,692	320,149	42,478	157,613
kWh del	1,763,309 kWh	1,749,312 kWh	3,766,459 kWh	499,744 kWh	1,854,266 kWh
Realtime Values:					
kW inst	2,546 kW	2,665 kW	5,475 kW	638 kW	2,404 kW

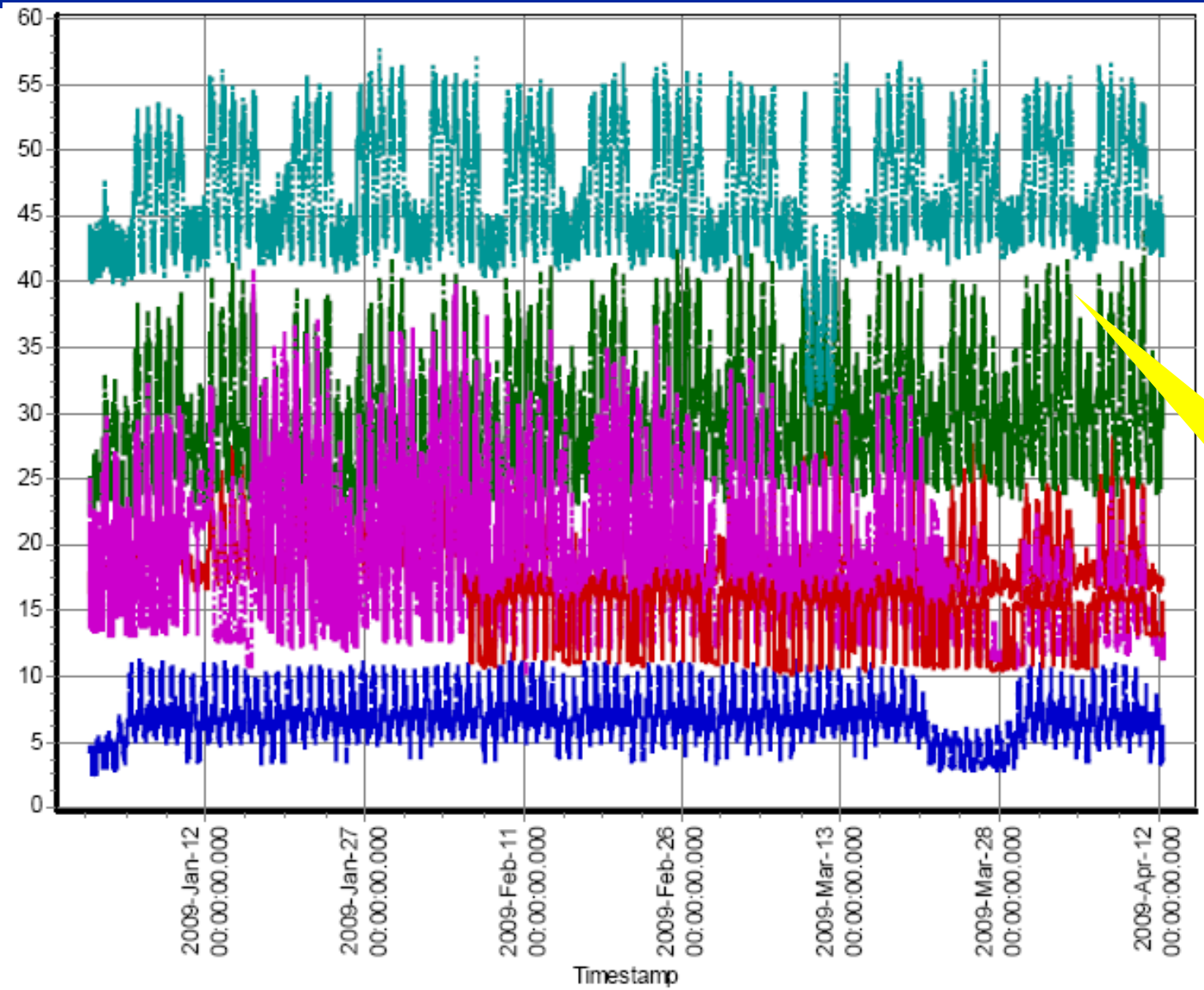
	SOM	North Campus	Revelle Campus	Central Plant	UCSD Total
Current Month:					
Monthly Cost ($)	19,075	30,163	236,794	93,913	734,148
kWh del	224,414 kWh	354,860 kWh	2,785,807 kWh	1,104,854 kWh	8,637,030 kWh
Previous Month:					
Monthly Cost ($)	45,133	67,085	557,638	184,830	1,673,499
kWh del	530,982 kWh	789,230 kWh	6,560,443 kWh	2,174,474 kWh	19,688,219 kWh
Realtime Values:					
kW inst	715 kW	1,022 kW	8,777 kW	3,947 kW	30,238 kW

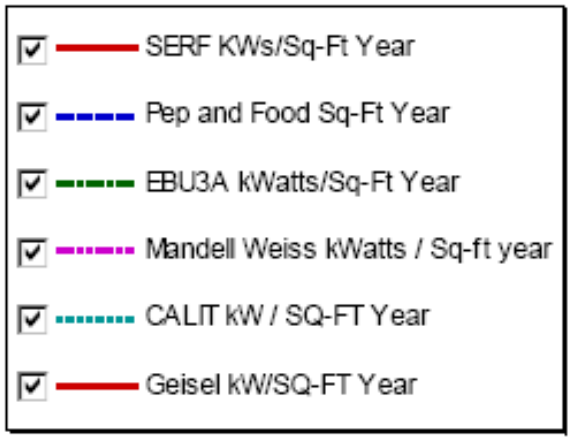
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http://mscada01.ucsd.edu/ion/

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Comparision Between UCSD Buildings: kW/sqFt Year Since 1/1/09





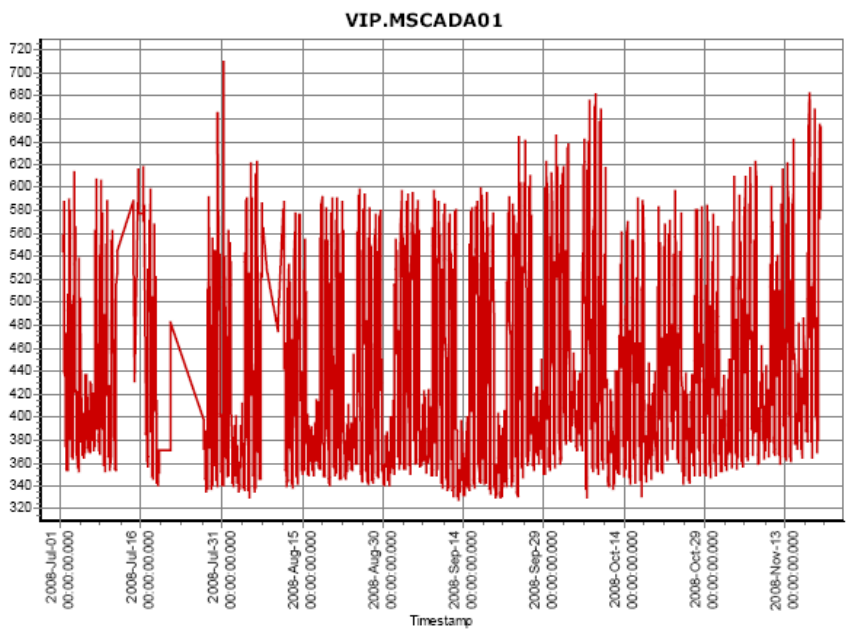
Calit2 and CSE are Very Energy Intensive Buildings

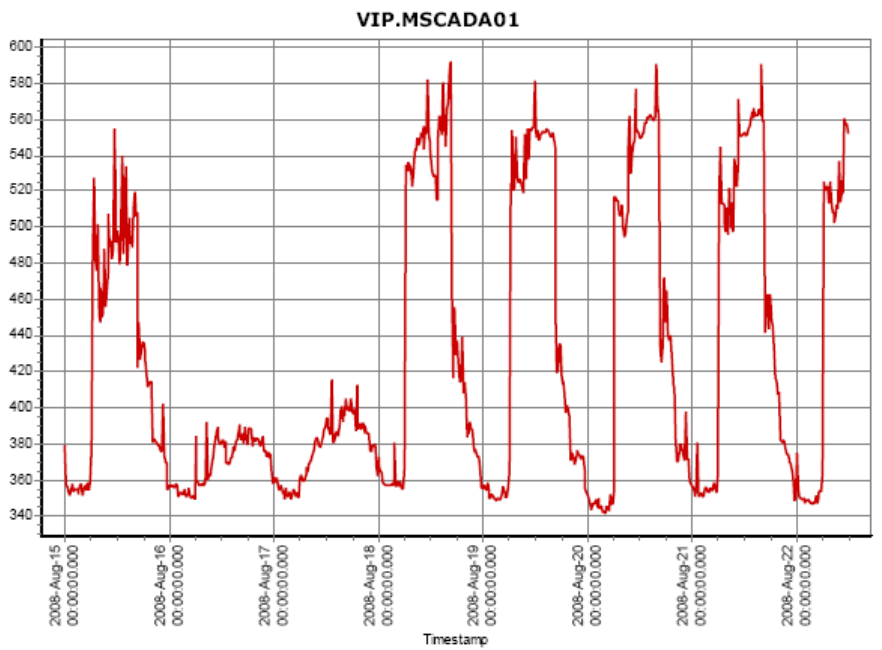
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Power Management in Mixed Use Buildings: The UCSD CSE Building is Energy Instrumented

- **500 Occupants, 750 Computers**
  - **More Computers Than Humans!**
- **Detailed Instrumentation to Measure Macro and Micro-Scale Power Use**
  - **39 Sensor Pods, 156 Radios, 70 Circuits**
  - **Subsystems: Air Conditioning & Lighting**







Calit2 is Being Re-Designed as an "Internet of Things" Building

Source: Rajesh Gupta, CSE, Calit2

Making Cars Greener Requires Software Engineering--Calit2 Established the Automotive Software Workshop

Source: Ingolf Krueger, Calit2



AUTOMOTIVE SOFTWARE WORKSHOP SAN DIEGO 2006

90 % of all Auto Innovations are Now Software-Driven

- Over 10 Million Lines of Code in Your Car!
- Sponsors: Calit2, NSF, EU, DFG
- 50:50 Participation Industry/Academia
- Next Instance Planned For 2009
- Industry Participants Include:

vector

Ford

BMW

TOYOTA InfoTechnology Center, U.S.A., Inc.

DAIMLER

VALIDAS validated quality

TOYOTA

GM

BOSCH

AbsInt Angewandte Informatik

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SAINT Software & Systems Architecture & Integration Team

S3EL Service-Oriented Software & Systems Engineering Lab

UCSD

California Institute for Telecommunications and Information Technology : Computer Science and Engineering, University of California, San Diego

Reducing Traffic Congestion: Calit2 California Peer-to -Peer Wireless Traffic Report

- **Citizen to Citizen Accident Reports**
- **Real-Time Freeway Speeds**
- **"Leave Now" Paging Services**

20,000+ Users
> 1000 Calls Per Day

San Diego
(866) 500 0977



LA & OC
(888) 9 CALIT2



Bay Area
(888) 4 CALIT2



http://traffic.calit2.net

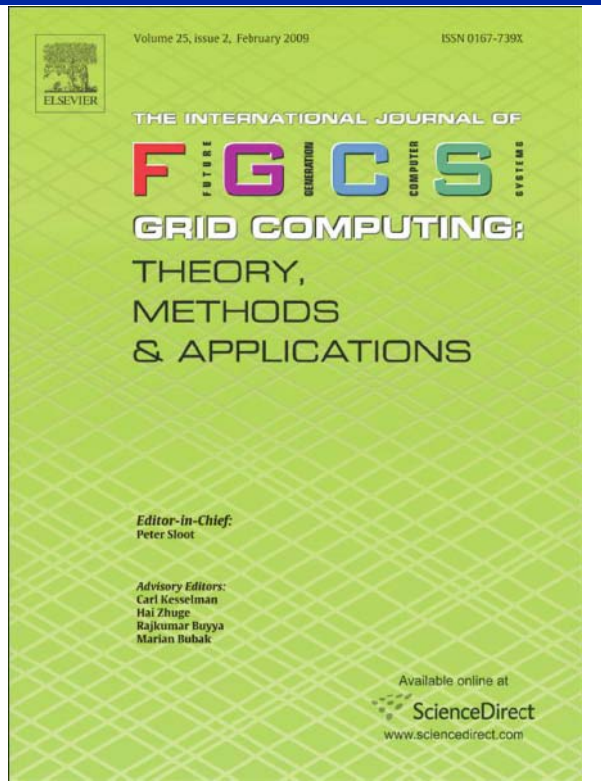
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Source: Ganz Chockalingam, Calit2

it²

The OptIPuter Creates an OptIPlanet Collaboratory: Enabling Data-Intensive e-Research





"OptIPlanet: The OptIPuter Global Collaboratory" –
Special Section of Future Generations Computer Systems, Volume 25, Issue 2, February 2009

evl electronic visualization laboratory

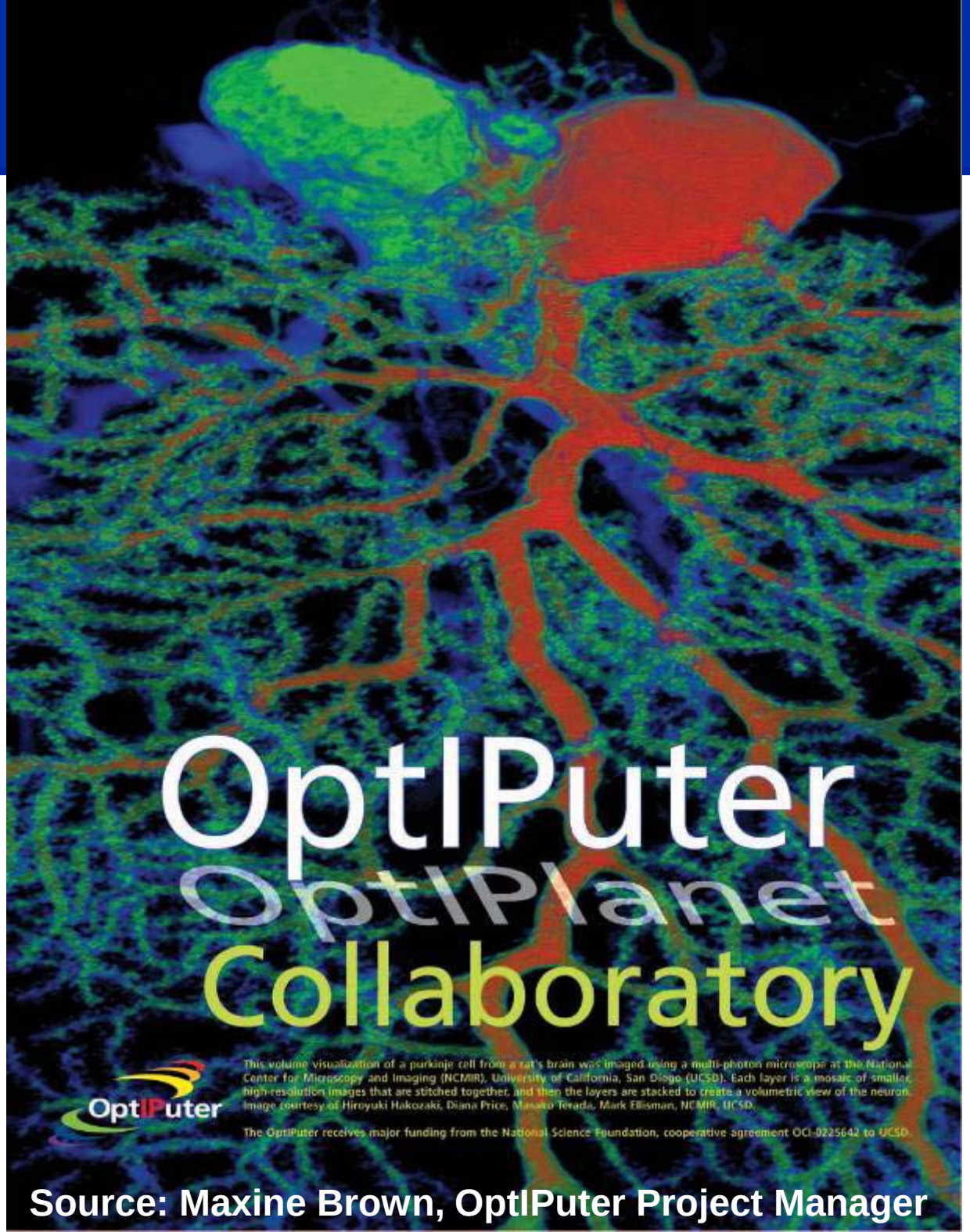
NSF

Over 50 OptIPortals Worldwide

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Calit2 (UCSD, UCI), SDSC, and UIC Leads—Larry Smarr PI
Univ. Partners: NCSA, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST
Industry: IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent

it²

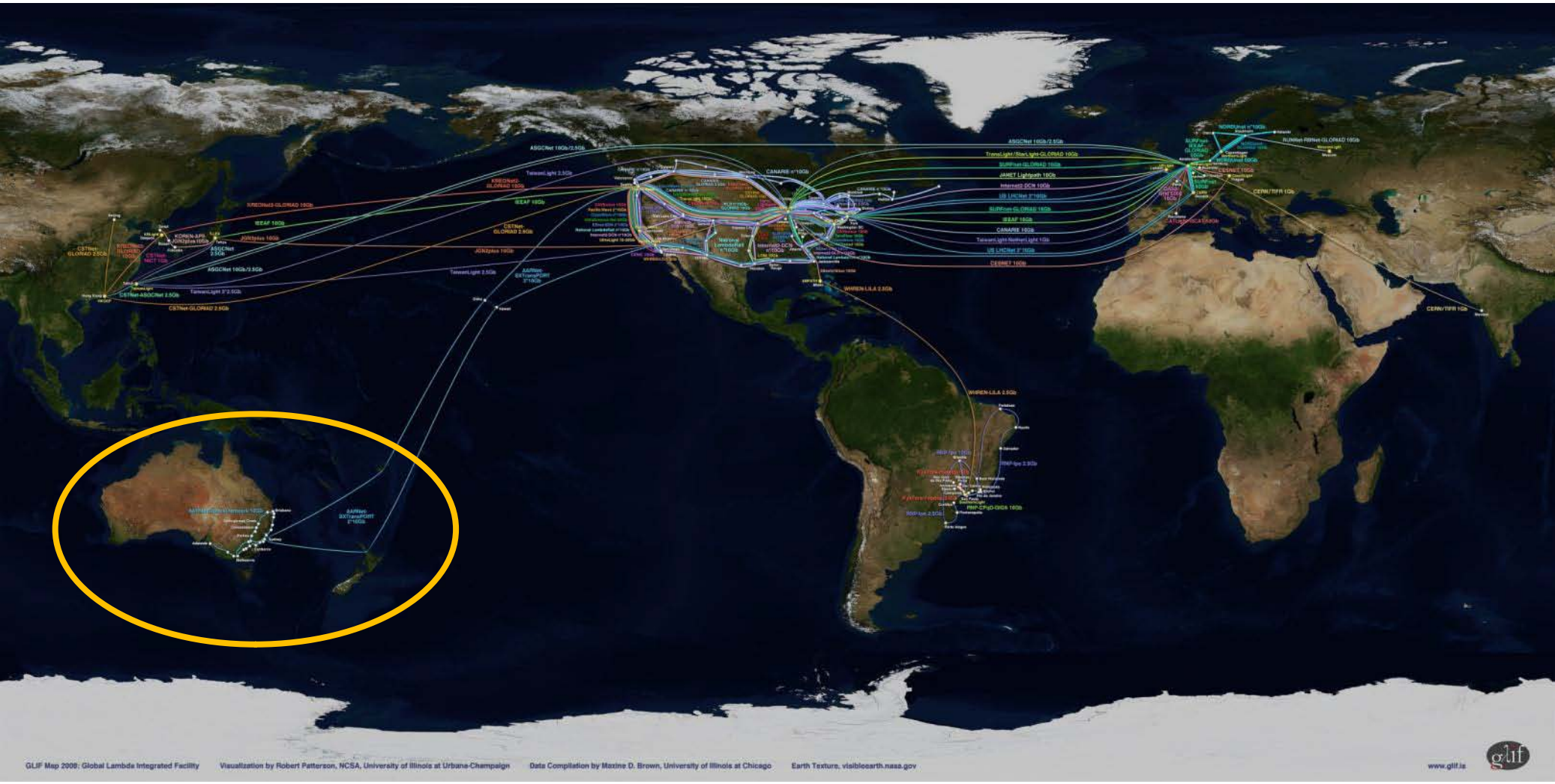


Source: Maxine Brown, OptIPuter Project Manager

Green Initiative:

Can Optical Fiber Replace Airline Travel for Continuing Collaborations ?

Global Lambda Integrated Facility
1 to 10G Dedicated Lambda Infrastructure



Interconnects Global OptIPortals at Public Research Innovation Centers

UCSD
UCIrvine

Source: Maxine Brown, UIC and Robert Patterson, NCSA

Launch of the 100 Megapixel OzIPortal Kicked Off a Rapid Build Out of Australian OptIPortals



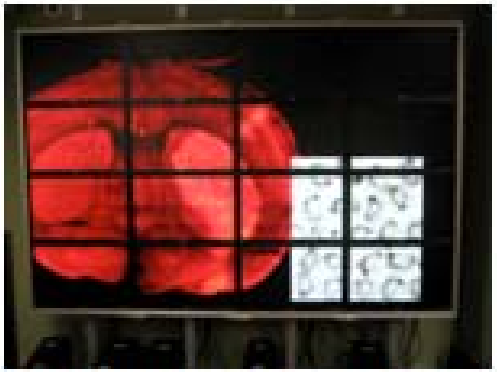
ANU



U Queensland



AARNet



Monash U-Caufield



CSIRO



Monash U-Clayton

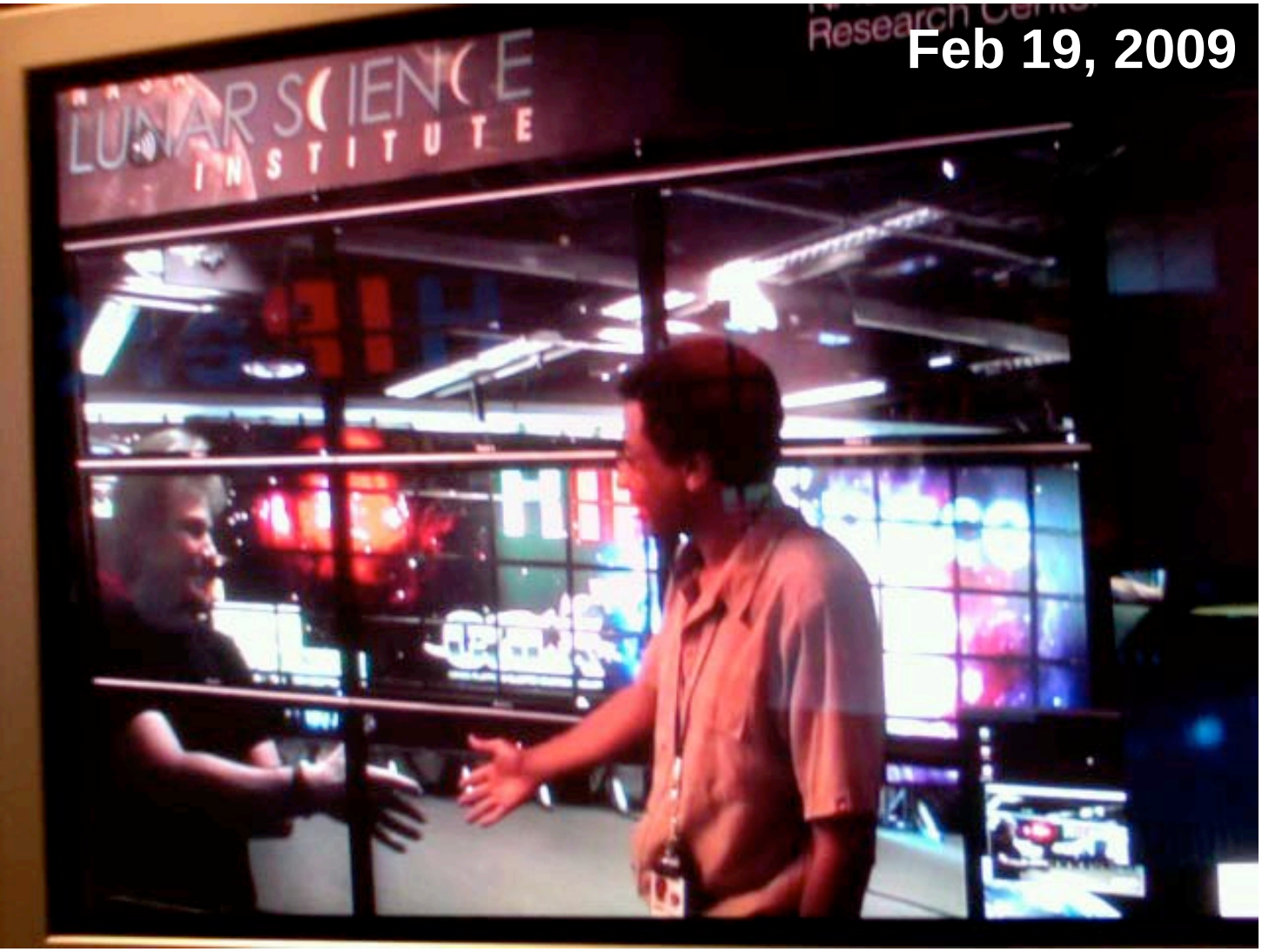


U Wellington, NZ

OptIPuter

it²

Just in Time OptIPlanet Collaboratory: Live Session Between NASA Ames and Calit2@UCSD



From Start to This Image in Less Than 2 Weeks!

View from NASA Ames Lunar Science Institute Mountain View, CA

Virtual Handshake

HD compressed 6:1

NASA Interest in Supporting Virtual Institutes

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CGLX

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Source: Falko Kuester, Calit2; Michael Sims, NASA

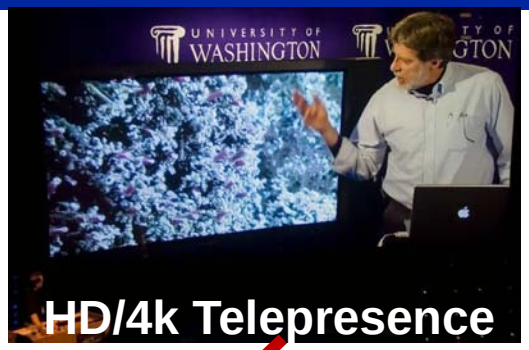
Academic Research "OptIPlatform" Cyberinfrastructure: A 10Gbps Lightpath Cloud



End User OptIPortal



Instruments



HD/4k Telepresence

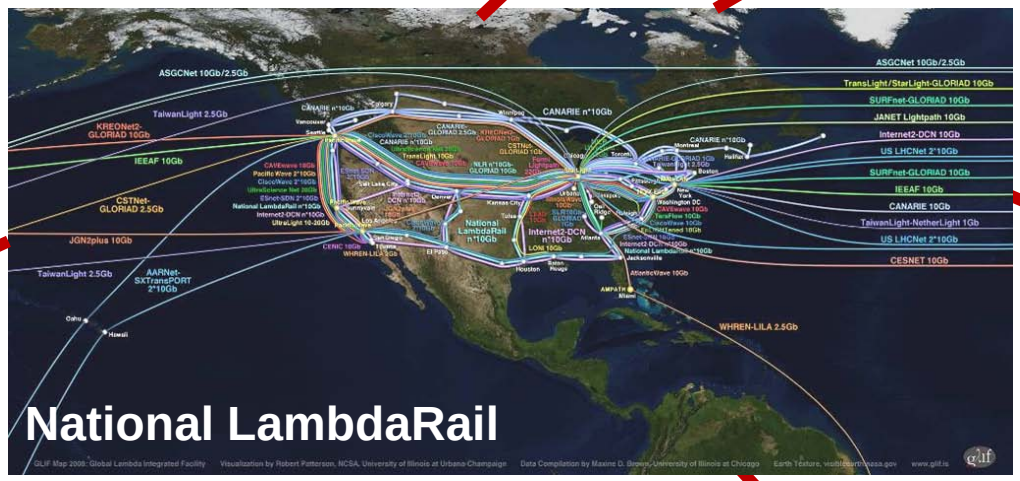


HD/4k Video Cams

HPC



10G Lightpath



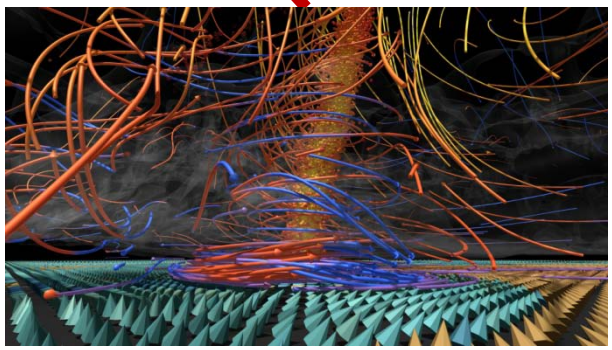
National LambdaRail

TeraGrid™

Campus Optical Switch



Data Repositories & Clusters



HD/4k Video Images

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International Symposia on Green ICT: Greening ICT and Applying ICT to Green Infrastructures

CUBIN

Symposium on Sustainability of the Internet and ICT

THE UNIVERSITY OF MELBOURNE

November 25 & 26, 2008, The University of Melbourne

Webcasts Available at:
www.calit2.net/newsroom/article.php?id=1456

Greening the Internet Economy

ICT & GLOBAL CHANGE

California Public Utilities Commission

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Co-Hosted By Calit2 & CPUC

January 22-23, 2009



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