Green Cyberinfrastructure on a Carbon-Constrained Planet

Invited Talk
Institute for the Future
Board Meeting
July 27, 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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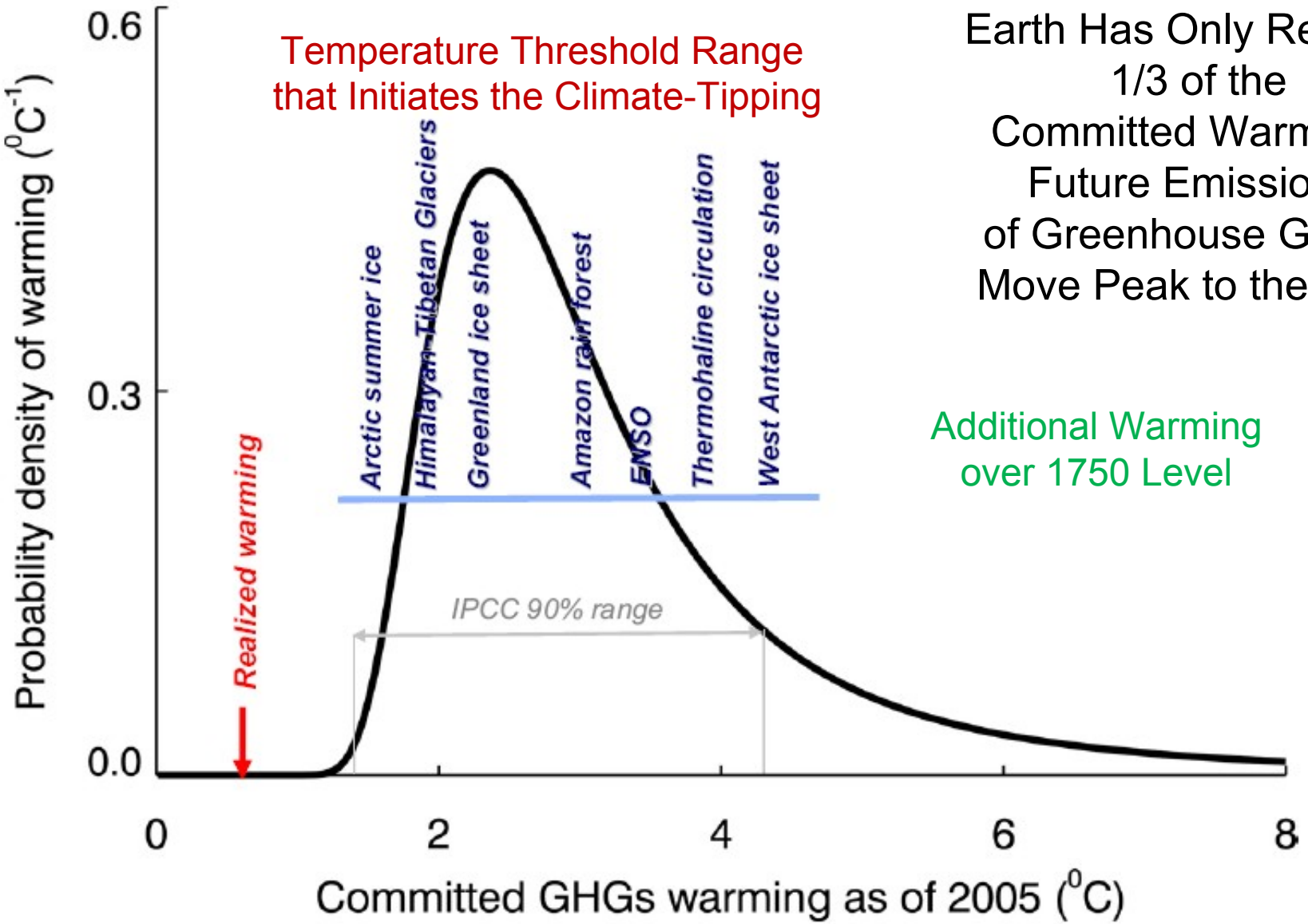
Calit2 Continues to Pursue Its Initial Mission:

Envisioning How the Extension of Innovative Telecommunications and Information Technologies Throughout the Physical World will Transform Critical Applications Important to the California Economy and its Citizens' Quality Of Life.

In the Coming Decade, We Believe that Sustainability and Climate Disruption Will Dominate California's Future

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The Planet is Already Committed to a Dangerous Level of Warming

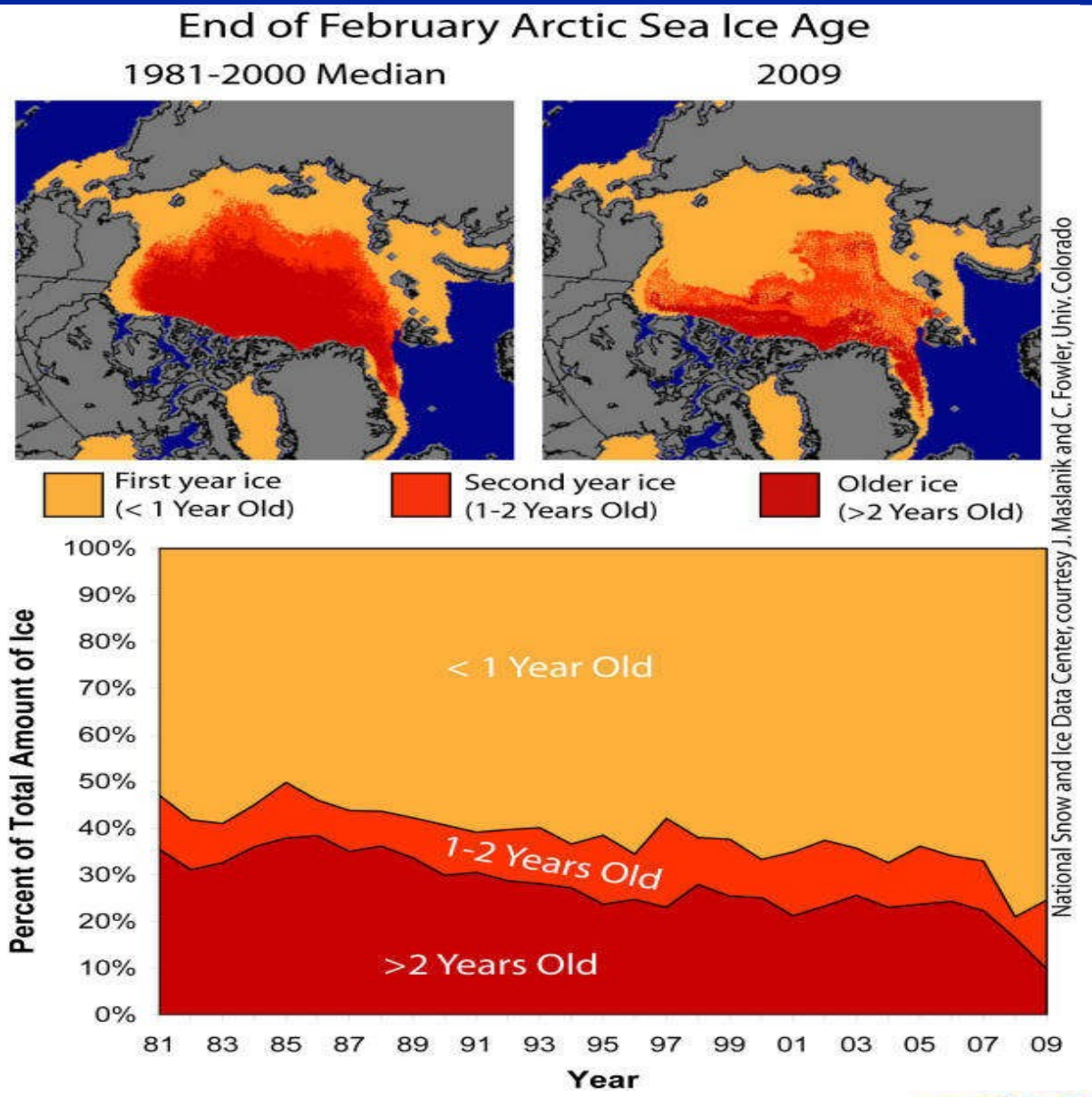


V. Ramanathan and Y. Feng, Scripps Institution of Oceanography, UCSD
September 23, 2008
www.pnas.orgcgidoi10.1073pnas.0803838105

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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



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

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

"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

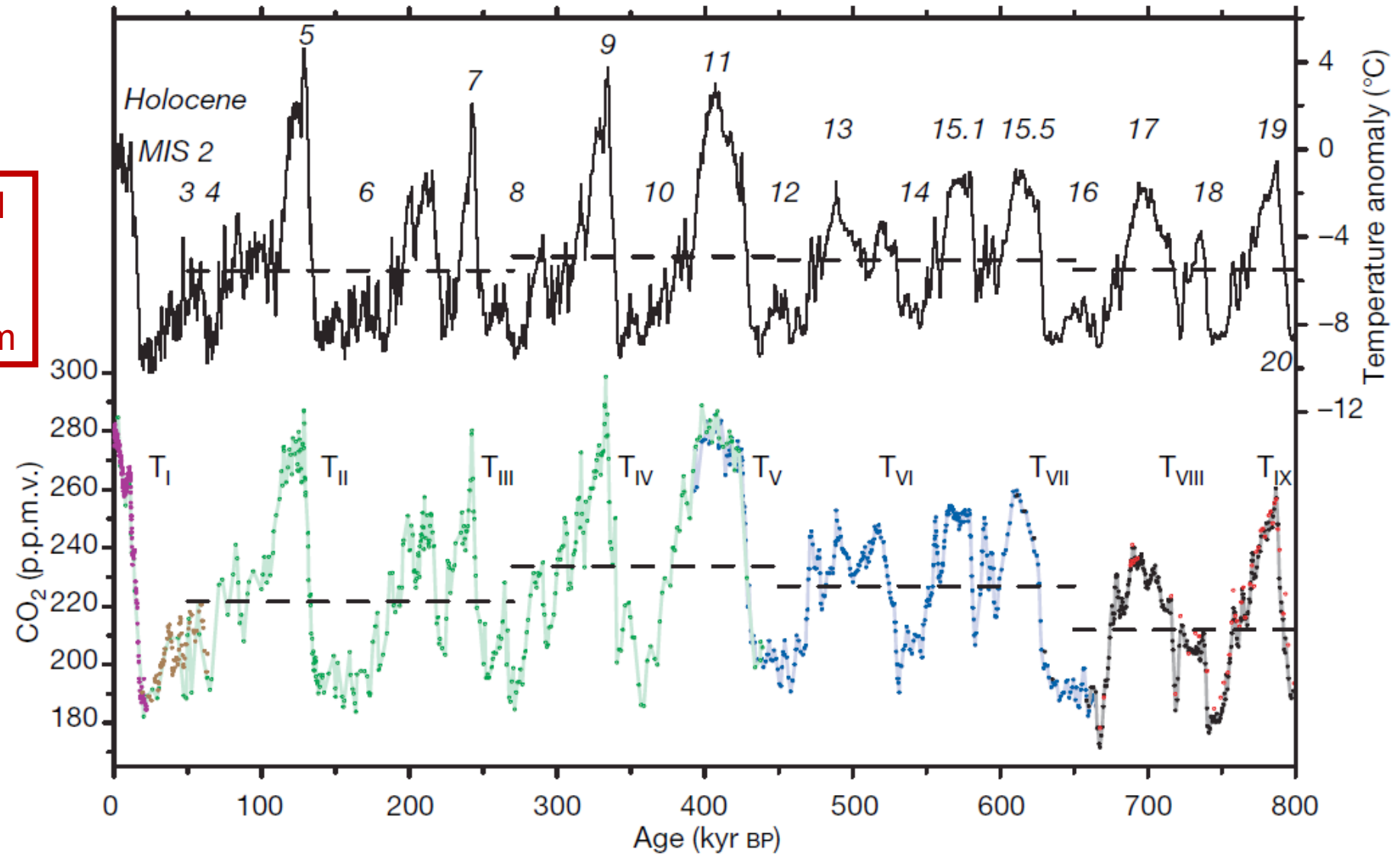
"California Faces Water Rationing, Governor Proclaims Drought Emergency"
--February 27, 2009



HKH Map with major river basins

Antarctic Ice Cores Show CO^2 and Temperature Oscillations Over Last 800,000 Years

Vertical Range 170 to 300 ppm

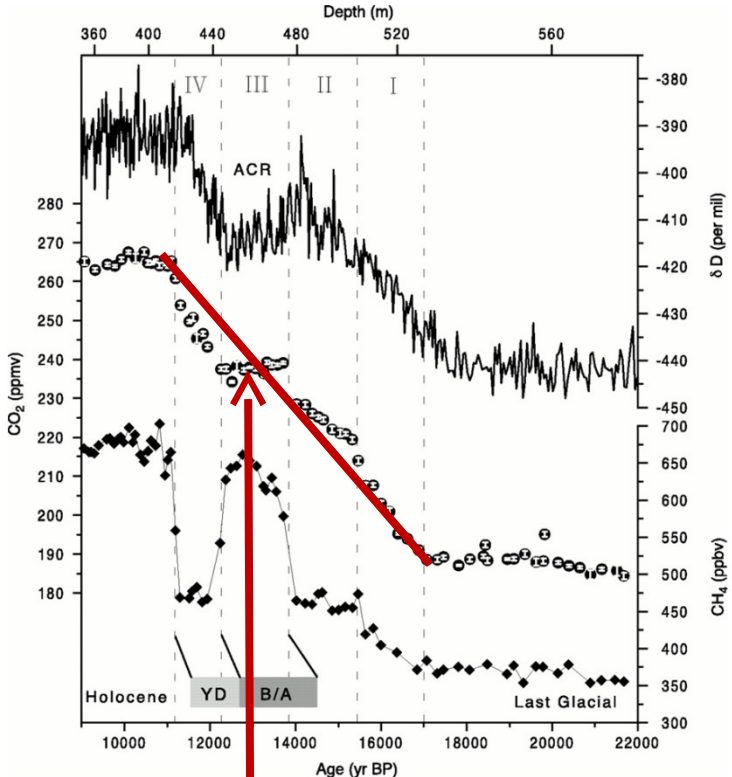


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Luthi, et al. Nature may 15, 2008 v. 453 pp379-82

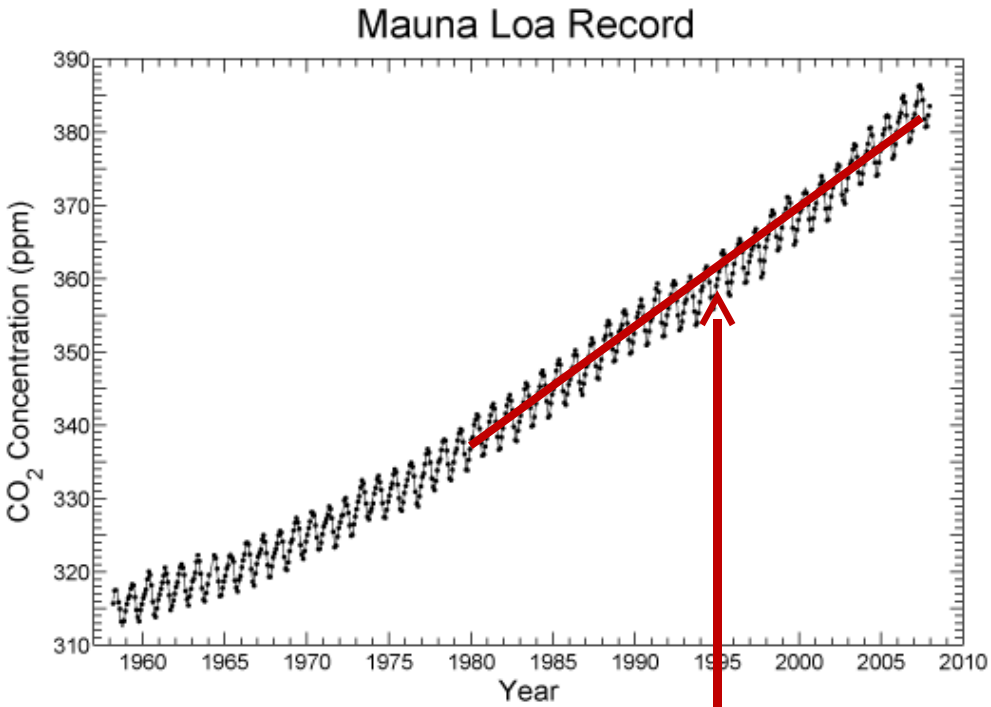
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The Earth is Warming Over 100 Times Faster Today Than During the Last Ice Age Warming!



CO^2 Rose From
185 to 265ppm (80ppm)
in 6000 years or
1.33 ppm per Century

http://scrippsco2.ucsd.edu/program_history/keeling_curve_lessons.html

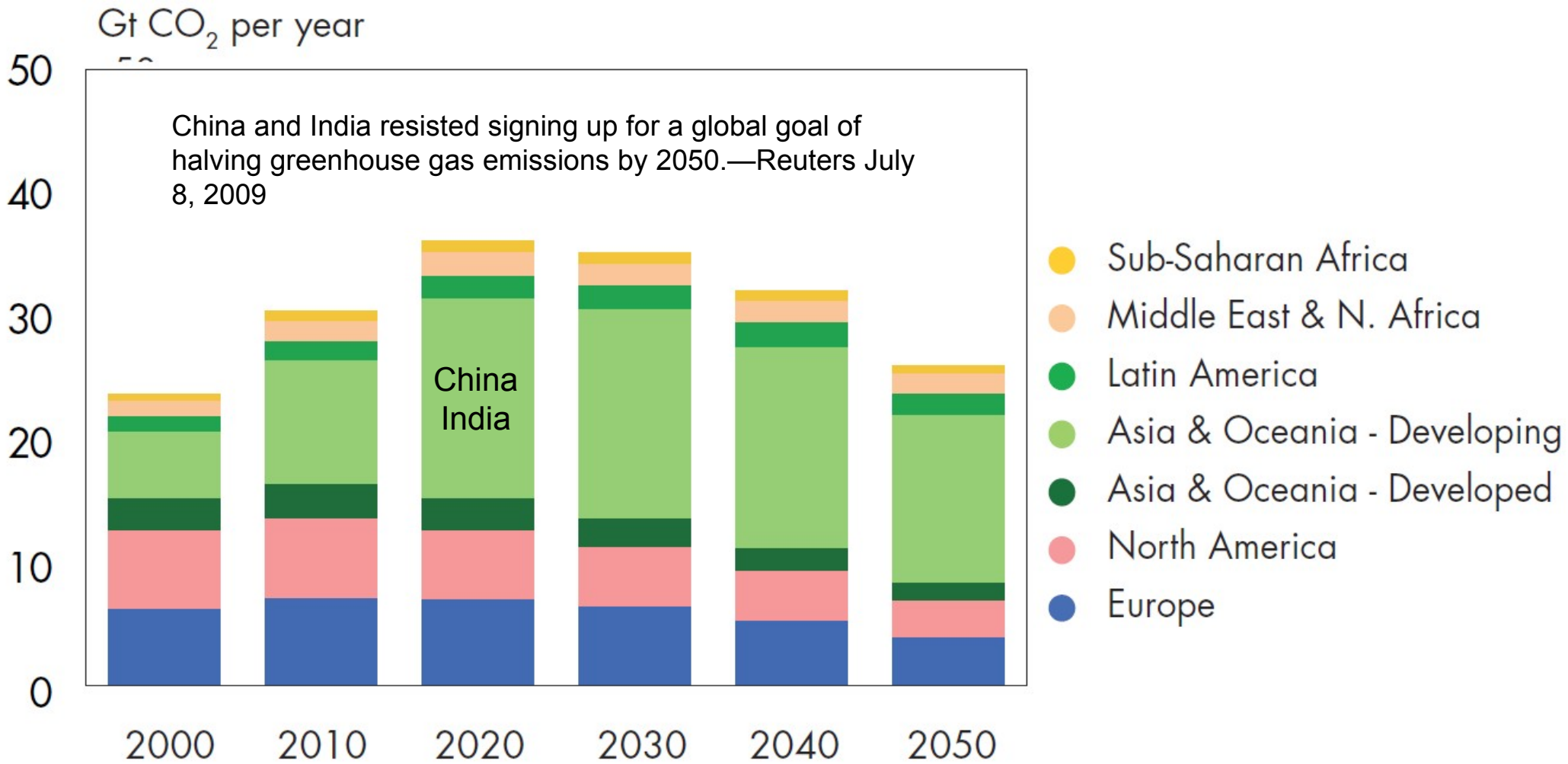


CO^2 Has Risen From
335 to 385ppm (50ppm)
in 30 years or
1.6 ppm per Year

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CO^2 Emissions From Energy in an Aggressive CO^2 Emission Reduction Scenario

www-static.shell.com/static/public/downloads/brochures/corporate_pkg/scenarios/shell_energy_scenarios_2050.pdf

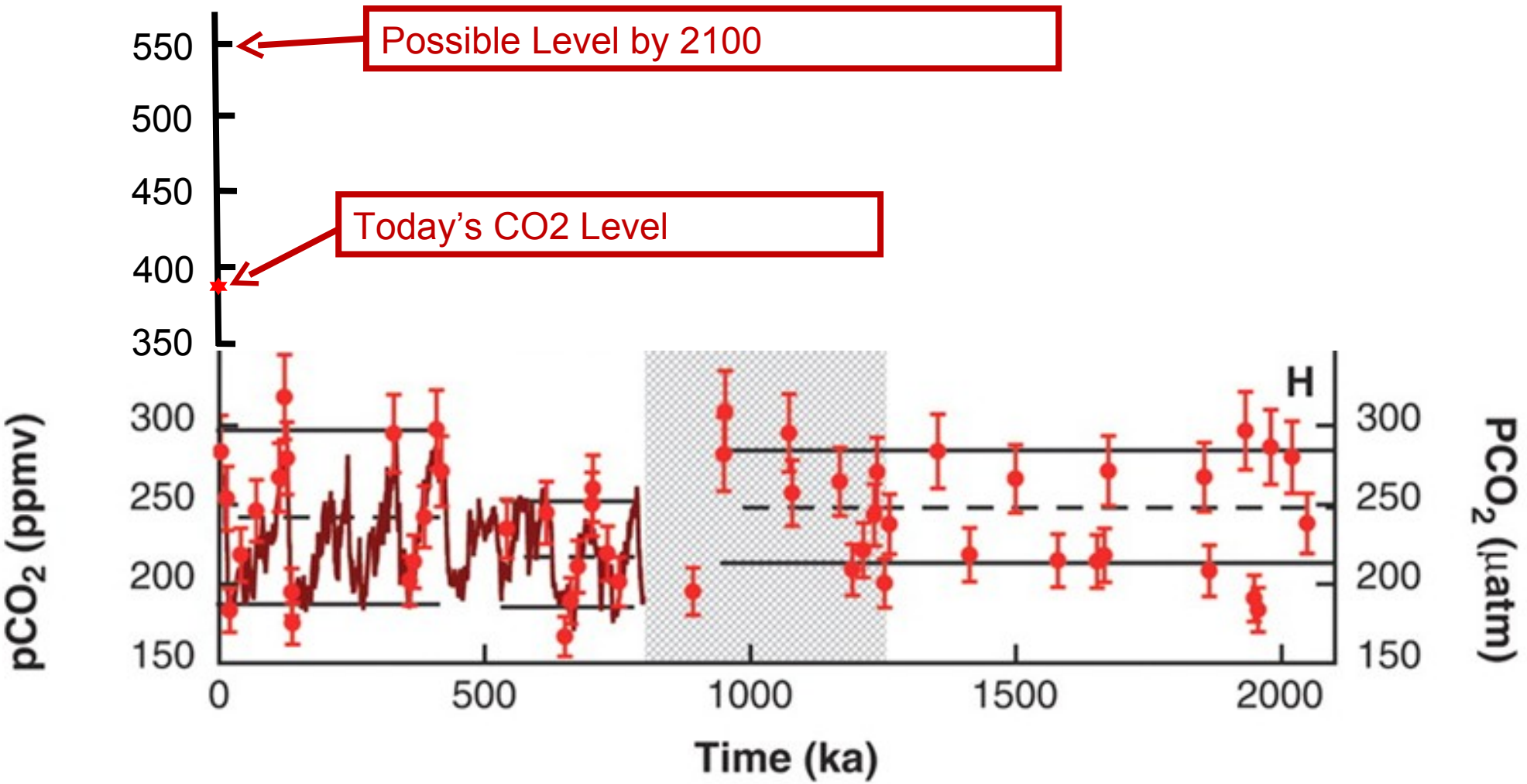


Estimated CO^2 Level in 2100 is 550ppm

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Ice Core Record Has Been Extended Using Plankton: Today's CO^2 is Higher Than in Last 2 Million Years!

Hönisch, et al. Science Science 19 June 2009 Vol. 324. pp. 1551 - 1554

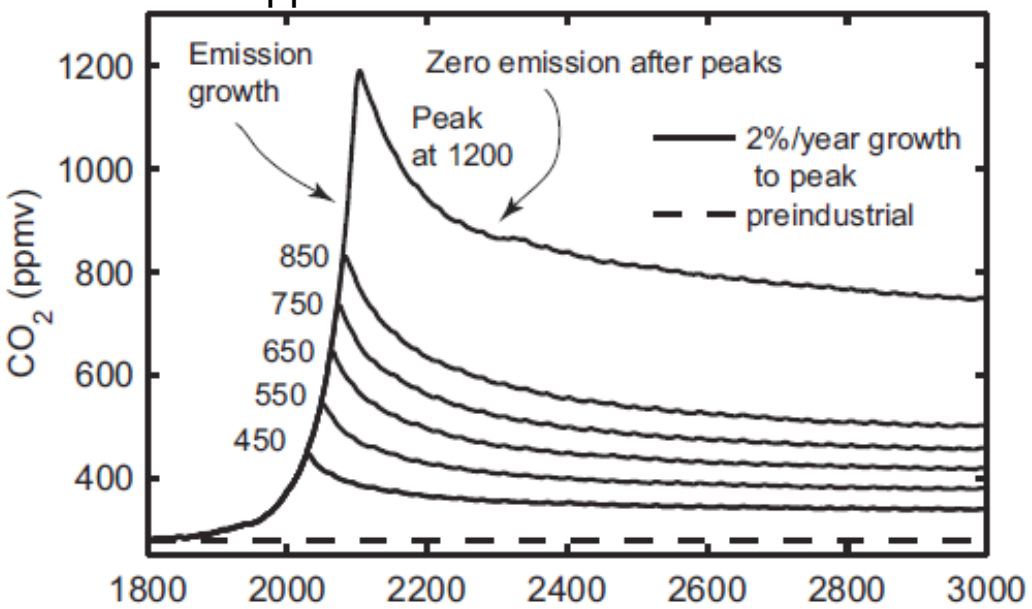


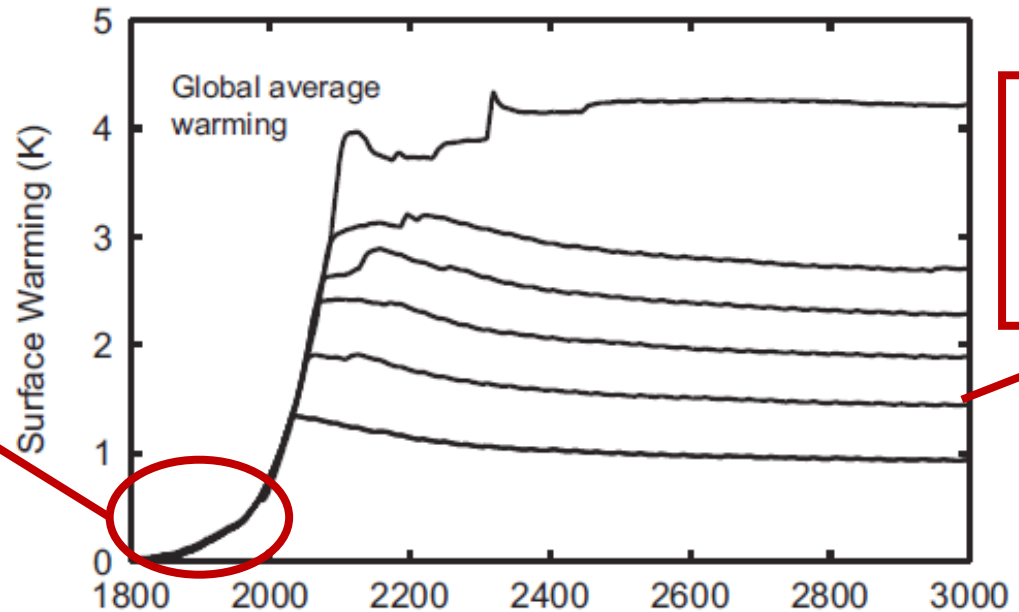
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We Are Transitioning to a New Climate State -- Unlike the Rapid Recovery with Acid Rain or Ozone Hole

Susan Solomon, et al., PNAS 2/10/2009 v. 106 pp1704-9

Assumes
CO^2 Increases
to a Maximum
and Then Emissions
Abruptly Stop



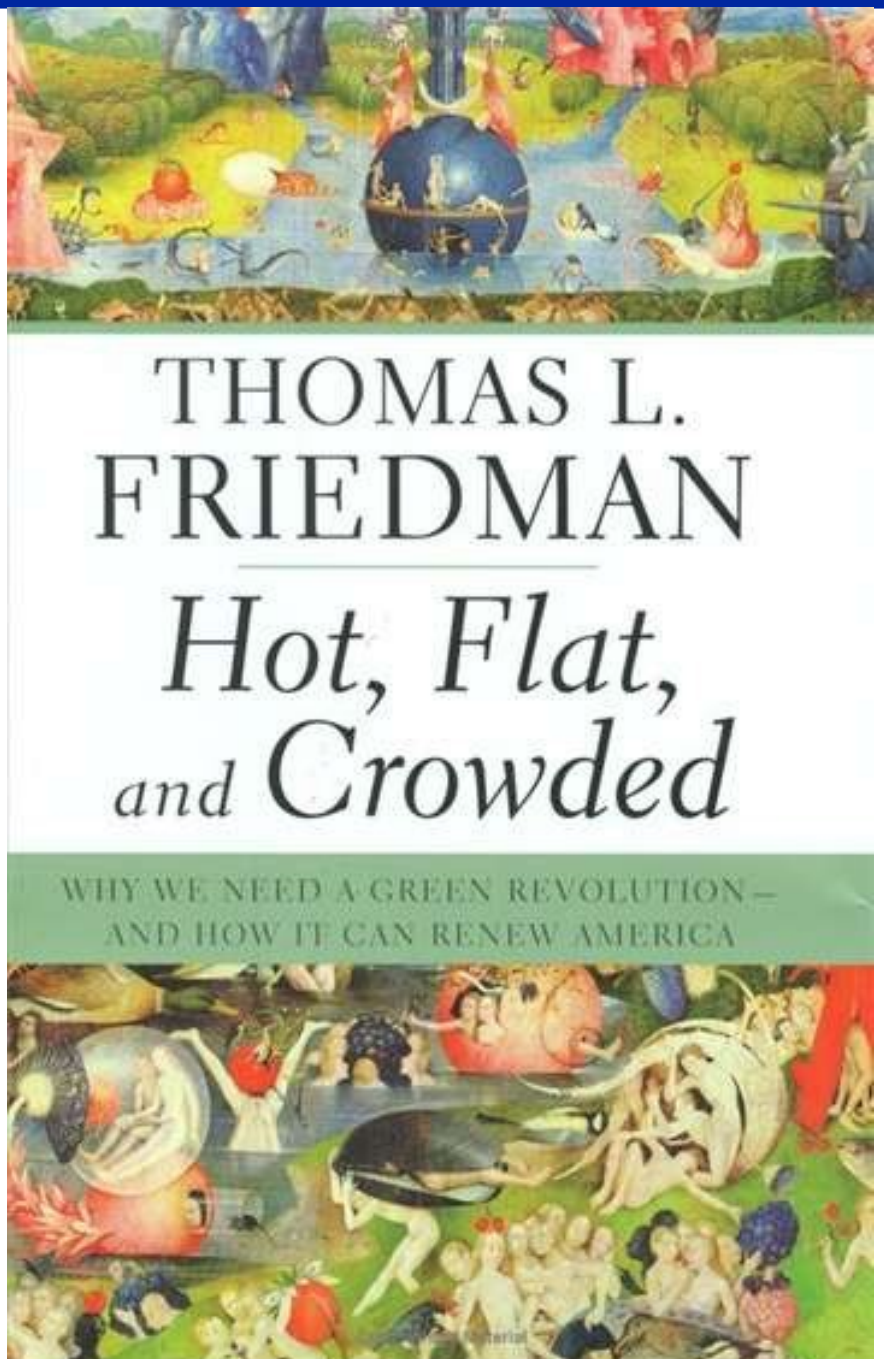


Warming During the Industrial Age -- Last 200 Years

Warming Persists for Over 1000 Years

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



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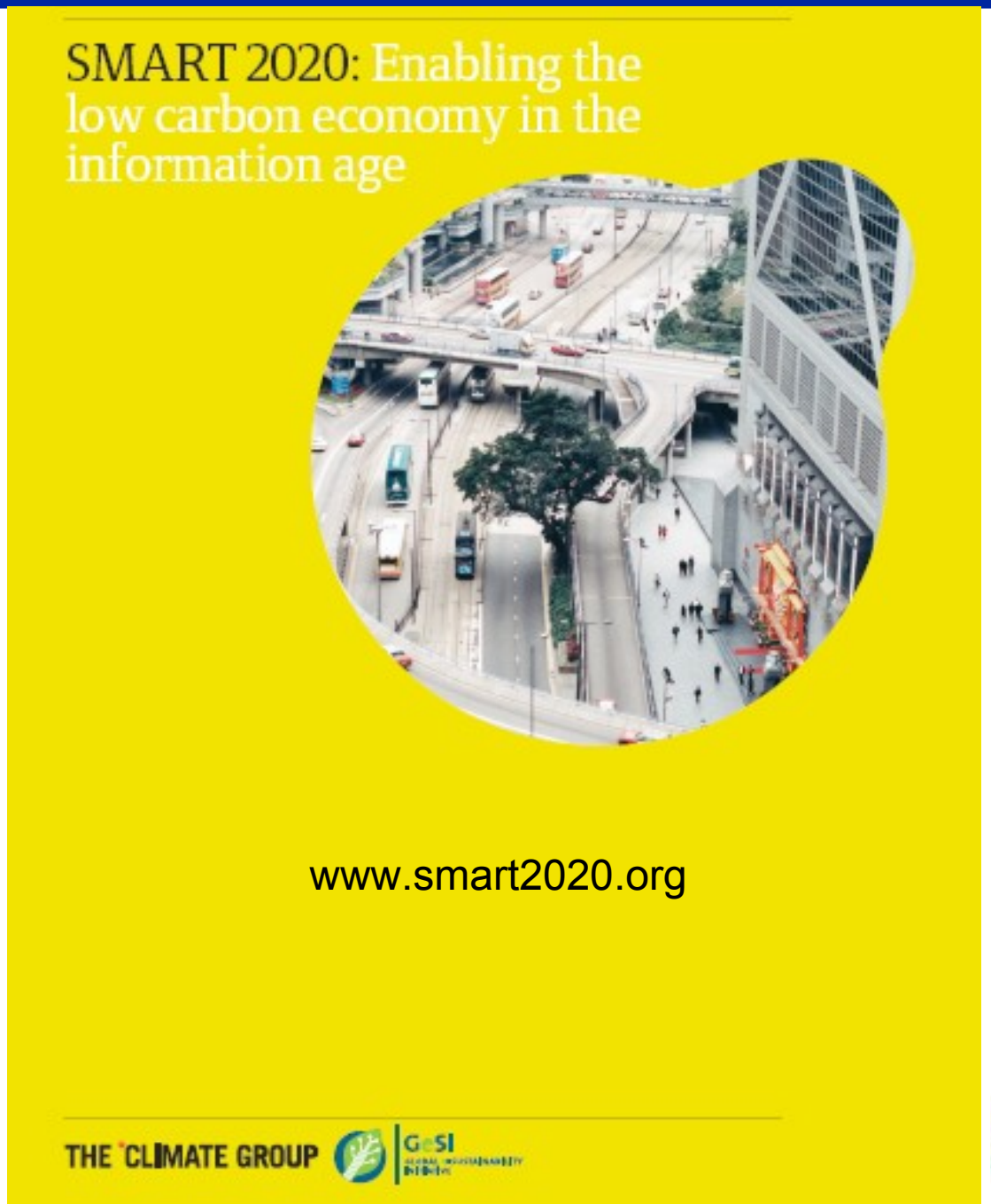
ICT is a Critical Element in Achieving Countries Greenhouse Gas Emission Reduction Targets

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.

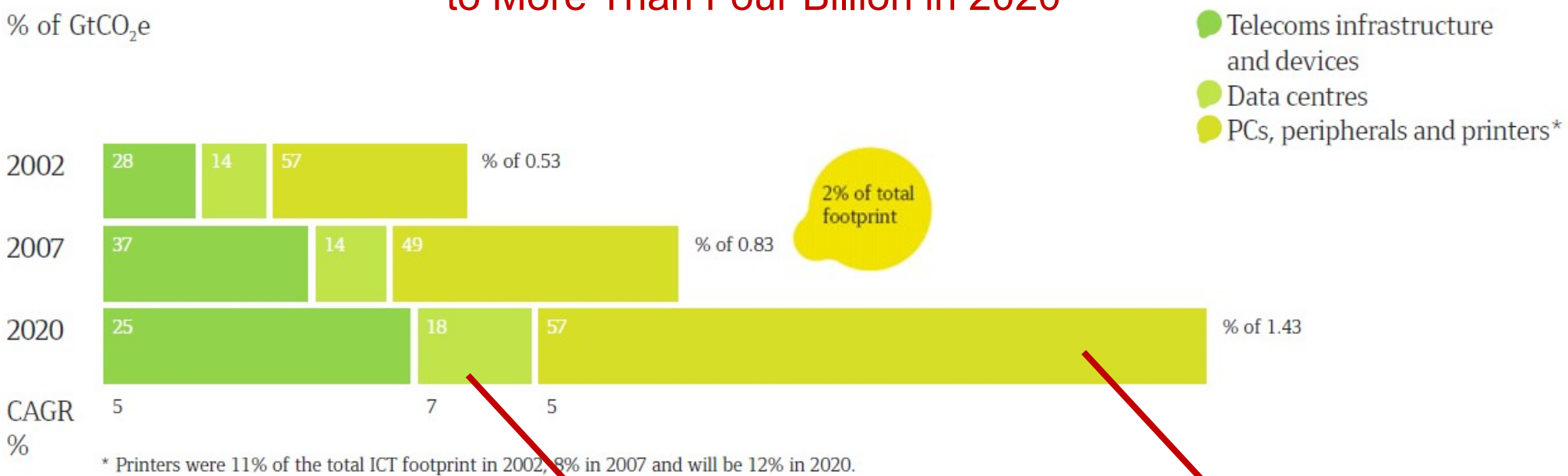


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The Global ICT Carbon Footprint is Roughly the Same as the Aviation Industry Today

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



Data Centers Are Rapidly Improving

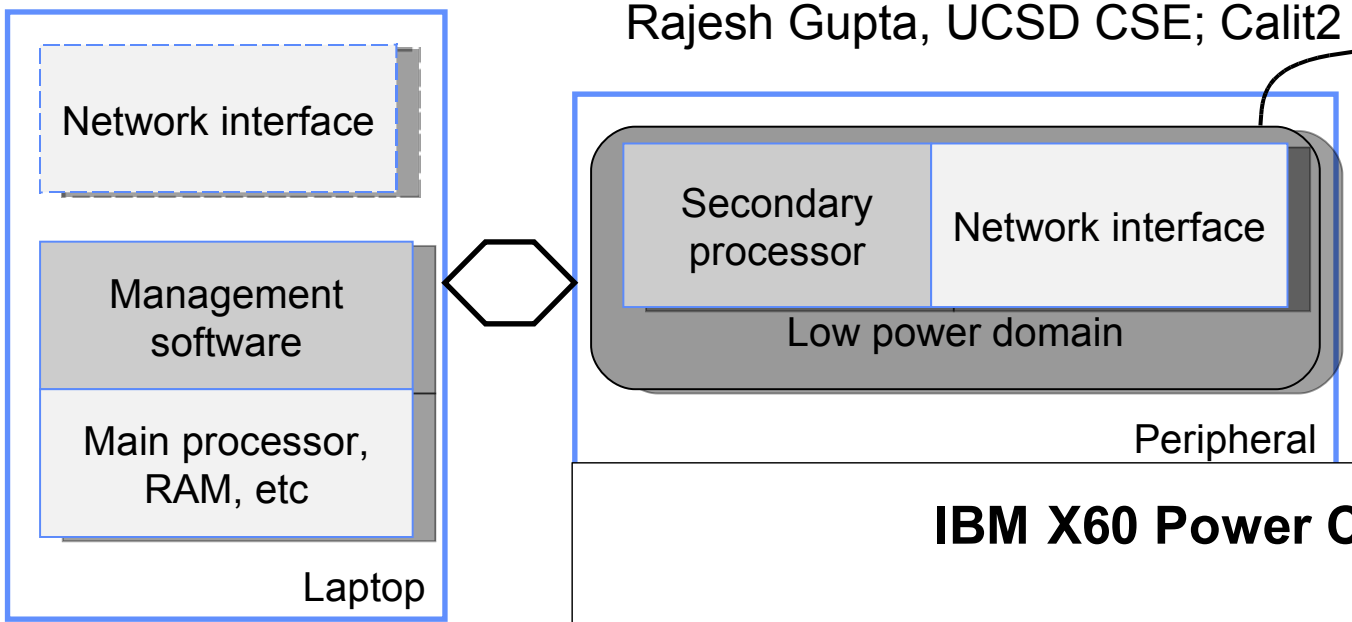
PCs Are Biggest Problem

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www.smart2020.org

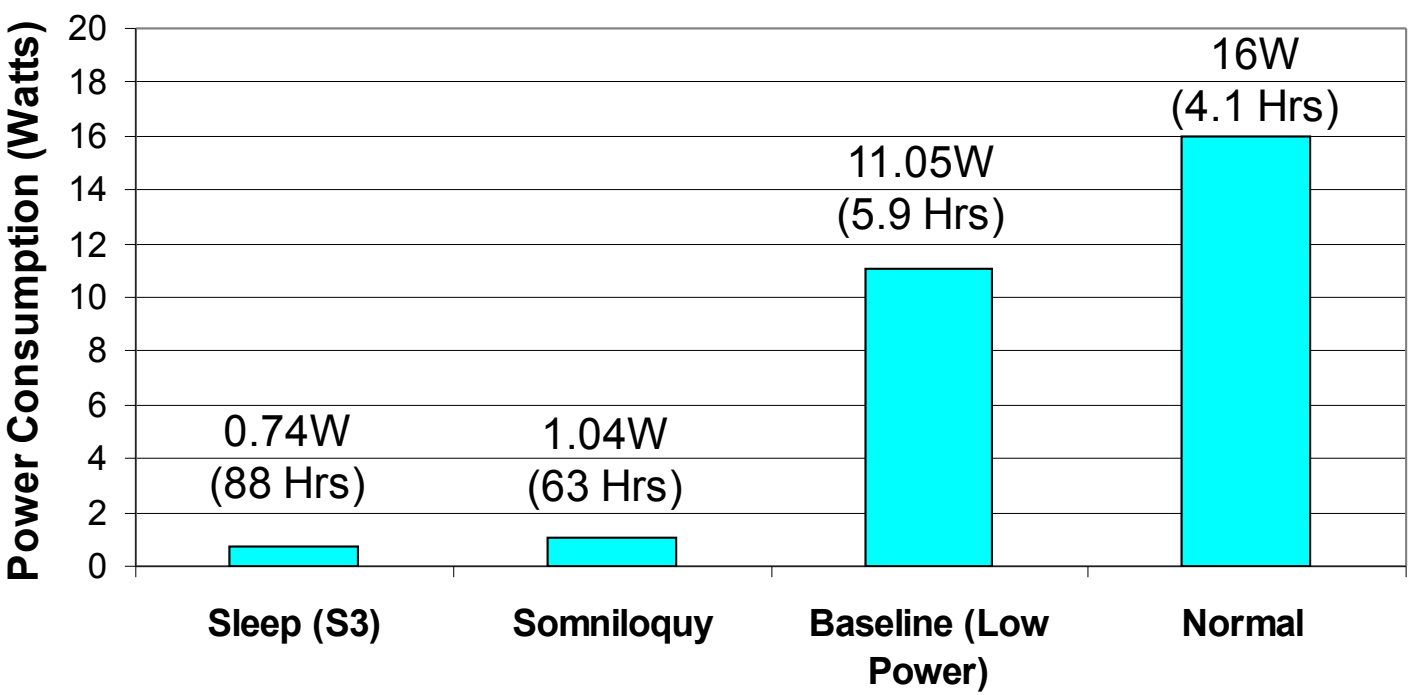
Increasing Laptop Energy Efficiency: Putting Machines To Sleep Transparently

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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ICT Industry is Already Acting to Reduce Carbon Footprint

Sun's 'portable' Blackbox data center

Company unveils new one-box data center

Sun Microsystems' CEO Jonathan Schwartz showed off the company's new "Project Blackbox" in a Menlo Park, Calif., parking lot Tuesday. Sun says the gear is not only preassembled, but it's tough and arrives ready to run.

HP's Green Business Technology Initiative



Innovative Dynamic Smart Cooling

Cut cooling costs in the data center as much as 40%.

» Learn more

Buying Green

updated 10:47 a.m. EST, Wed November 28, 2007

Google pushes 'green' power initiative

Intel Becomes Largest Purchaser of Green Power in the U.S.

Company Tops EPA Green Power Partner List, Vows to Drive for Greater Efficiency While Spurring Growth in Renewable Market

How Microsoft is going green

Biodiesel trucks, solar-powered data centers are just a couple environmentally friendly track

By John Fontana , Network World , 01/09/2008

IBM Project Big Green

Big Green Banner

Project Big Green is a $1 billion investment to dramatically increase the efficiency of IBM products. New IBM products and services,

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

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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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

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Power Transistor Tradeoffs:

Si-LDMOS, GaN, & GaAs

Price & Performance

Power Amplifier Tradeoffs:

WiMAX & 3.9GPP LTE

Efficiency & Linearity

Digital Signal Processing Tradeoffs:

Pre-Distortion, Memory Effects
& Power Control

MIPS & Memory

Eudyna

STMicroelectronics

NOKIA

QUALCOMM

www.universityofcalifornia.edu/news/article/19058

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

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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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Applying ICT – The Smart 2020 Opportunity for Reducing GHG Emissions by 7.8 $GtCO_2e$

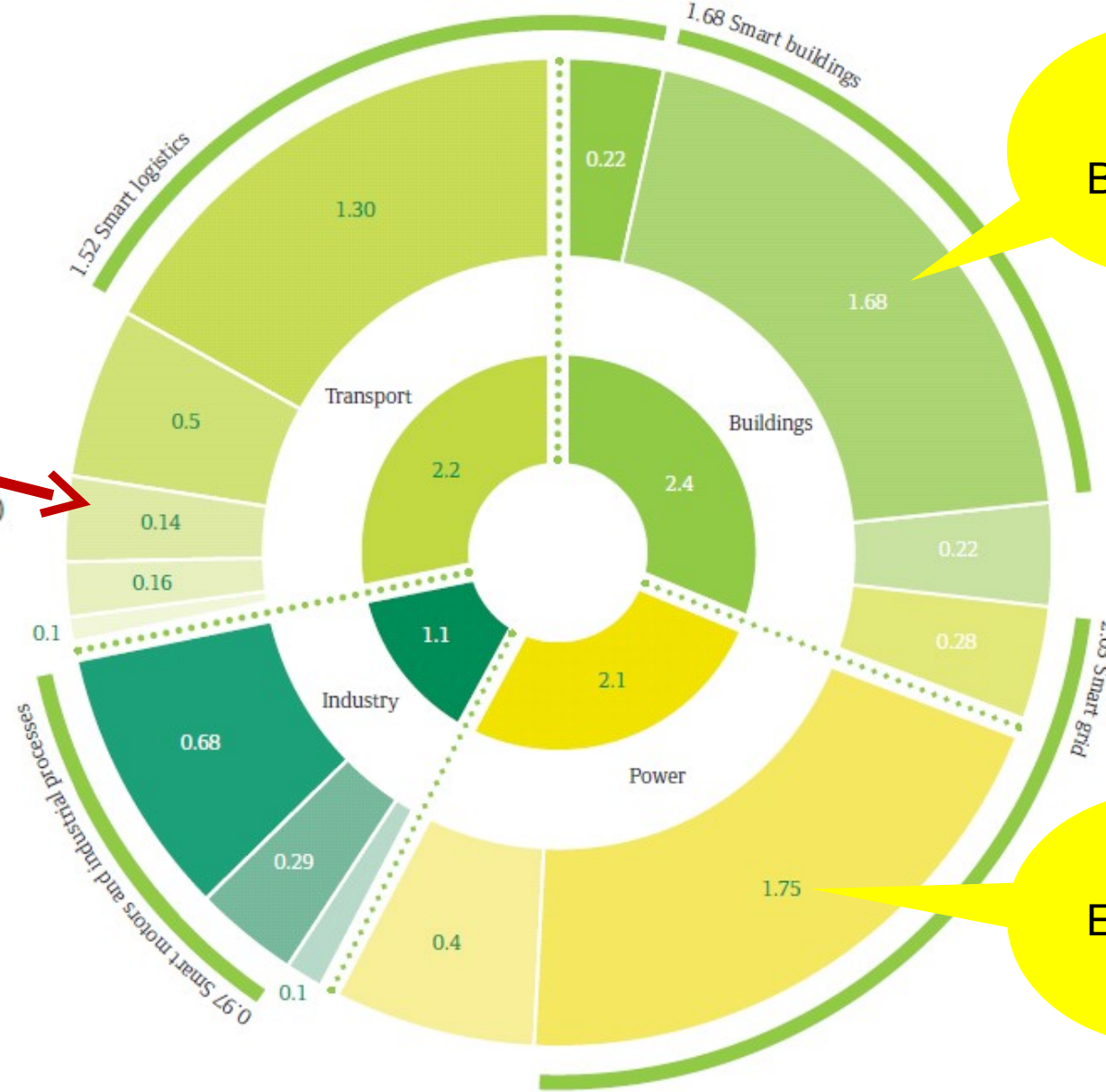
www.smart2020.org

Industry
- Smart motors
- Industrial process automation
- Dematerialisation* (reduce production of DVDs, paper)

Transport
- Smart logistics
- Private transport optimisation
- Dematerialisation (e-commerce, videoconferencing, teleworking)
- Efficient vehicles (plug-ins and smart cars)
- Traffic flow monitoring, planning and simulation

Buildings
- Smart logistics†
- Smart buildings
- Dematerialisation (teleworking)
- Smart grid‡

Power
- Smart grid
- Efficient generation of power, combined heat and power (CHP)



Smart Buildings

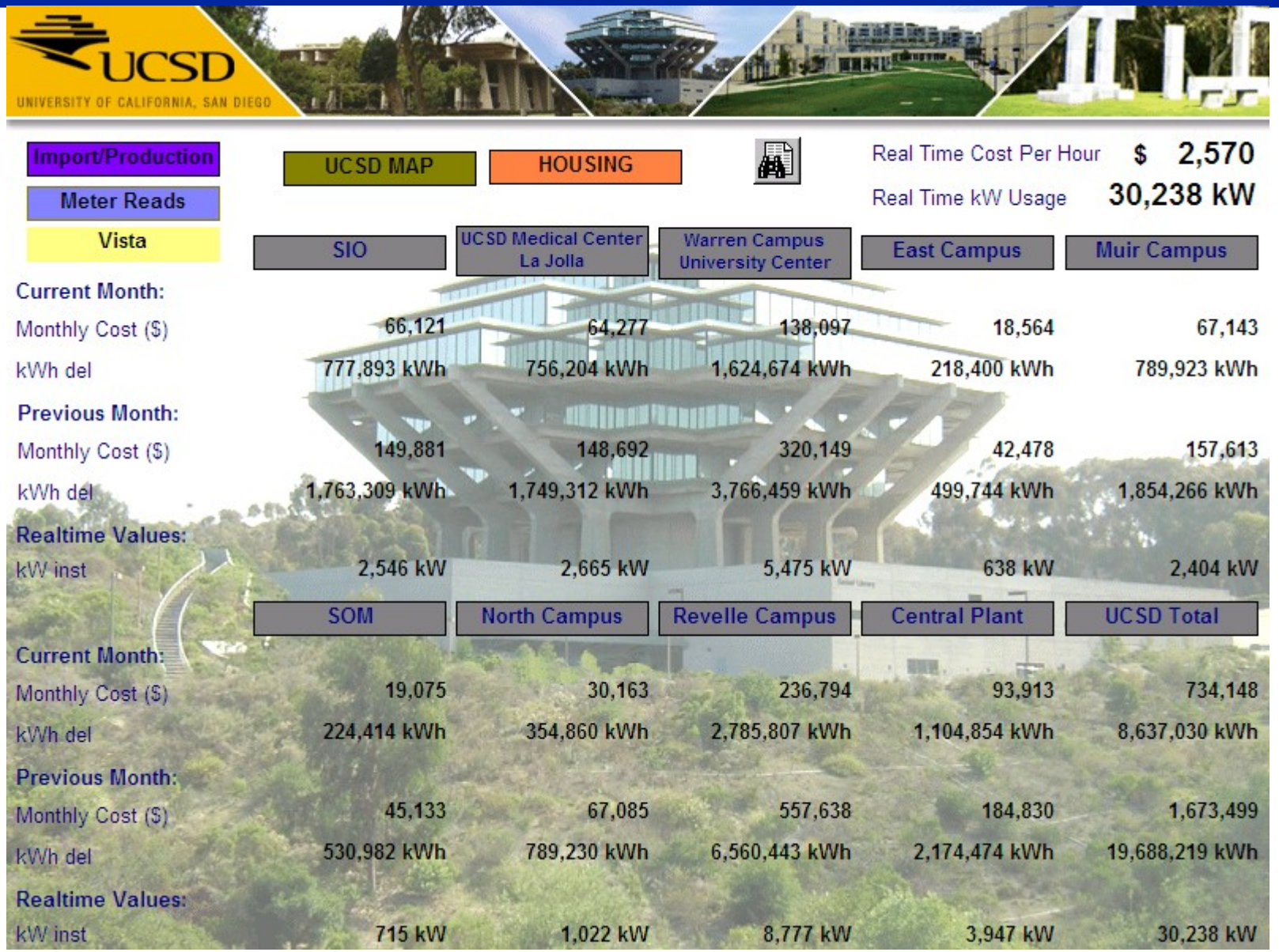
Smart Electrical Grid

Recall Total ICT 2020 Emissions are 1.43 $GtCO_2e$

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

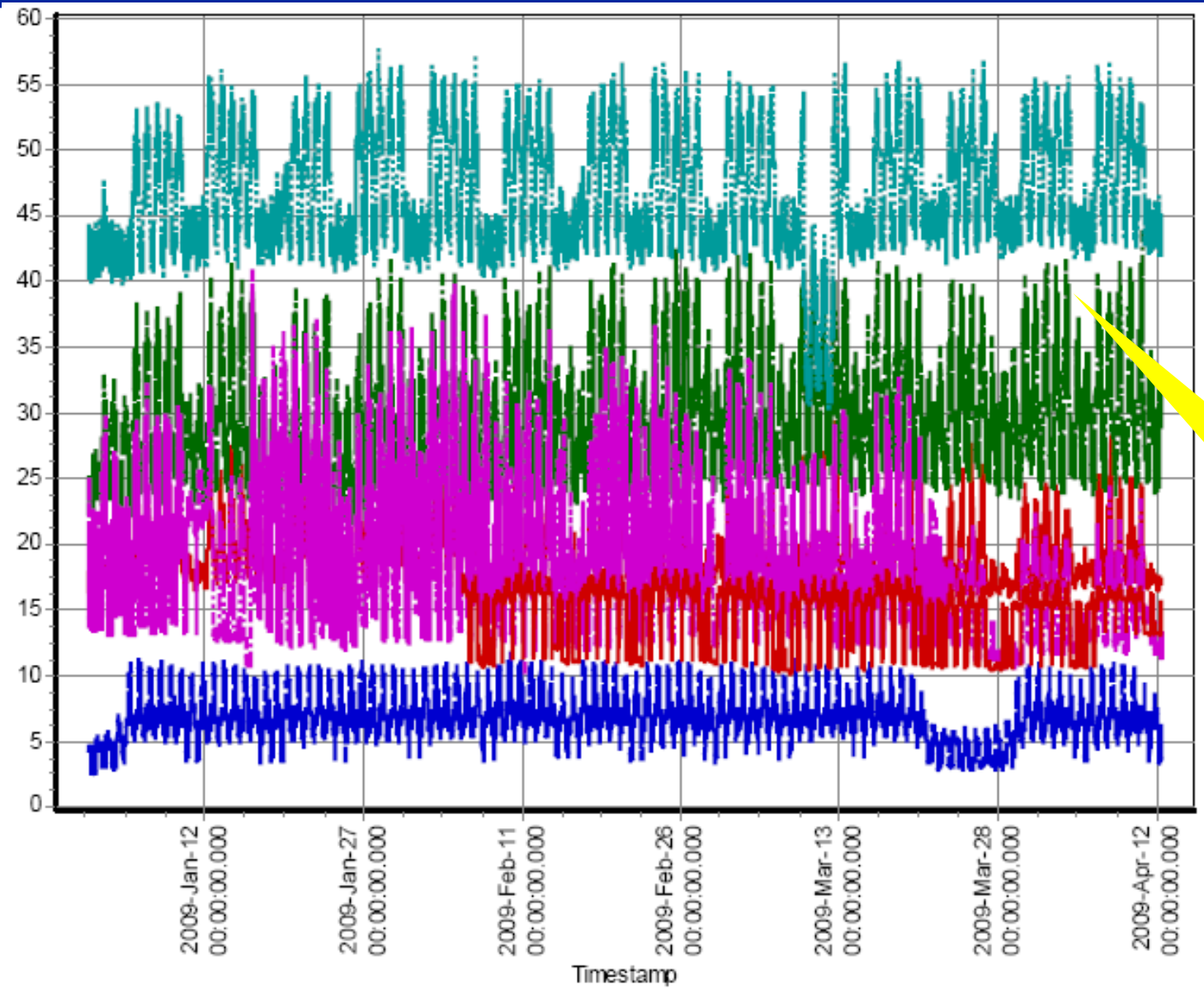


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http://mscada01.ucsd.edu/ion/

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



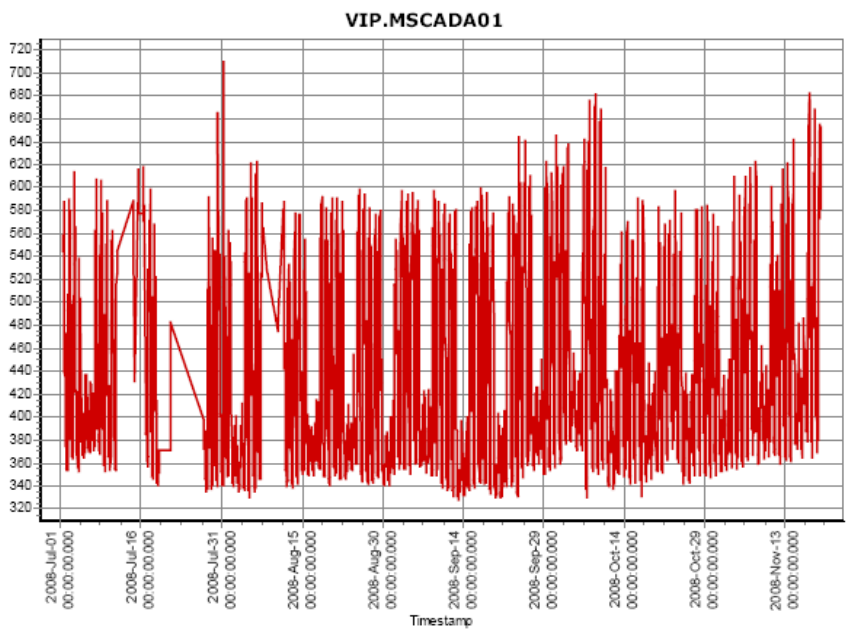
Calit2 and CSE are Very Energy Intensive Buildings

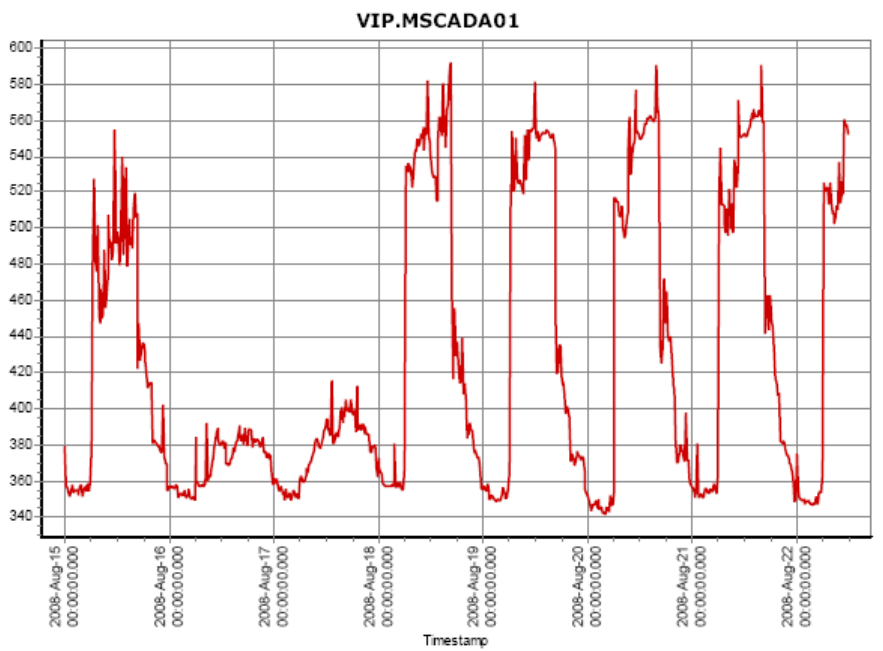
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Power Management in Mixed Use Buildings: The UCSD CSE Building is Energy Instrumented

- **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

Launch of ZEVnet Fleet of Wireless Cars-- First Calit2 Testbed for Intelligent Transportation

TOYO



April 18,
Irvine,
www.zevr

Toyota Delivers Plug-in Prius to UC Irvine and UC Berkeley as Part of Clean Mobility Partnership









TORRANCE, Calif., Nov. 9, 2007 -- Toyota Motor Sales, U.S.A.,

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TUDIES

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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

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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



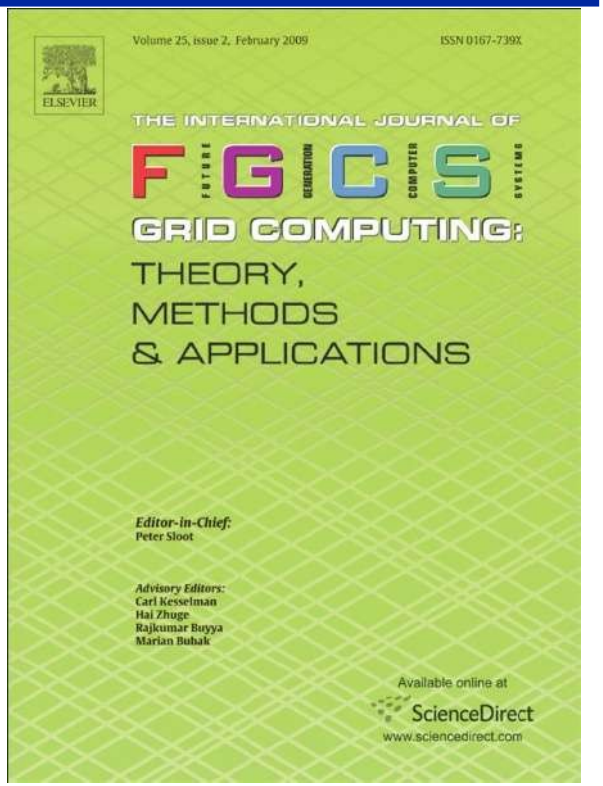
http://traffic.calit2.net

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Source: Ganz Chockalingam, Calit2

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

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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

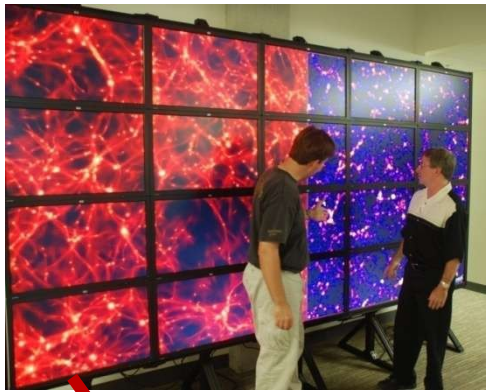
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CGLX

Source: Falko Kuester, Calit2; Michael Sims, NASA

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



End User OptIPortal



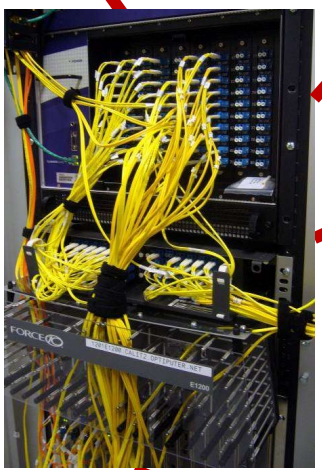
Instruments



HD/4k Telepresence

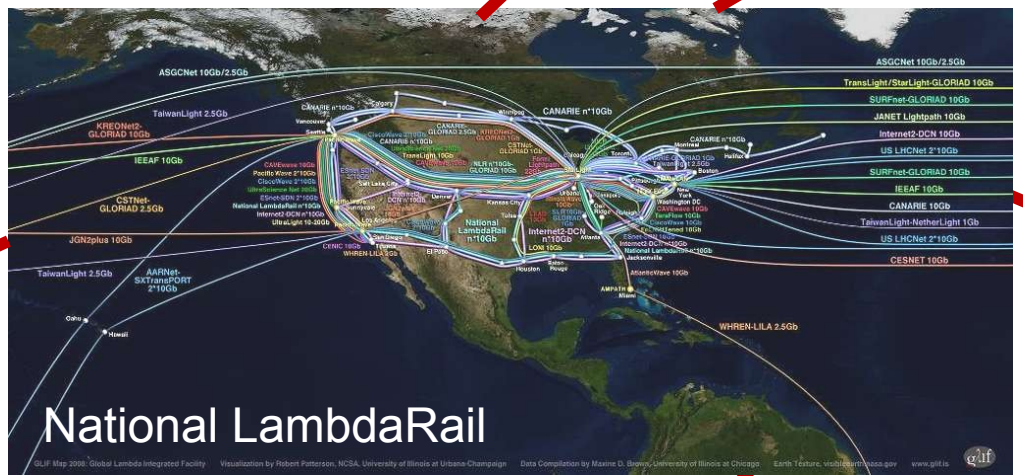


HD/4k Video Cams



Campus Optical Switch

10G Lightpath



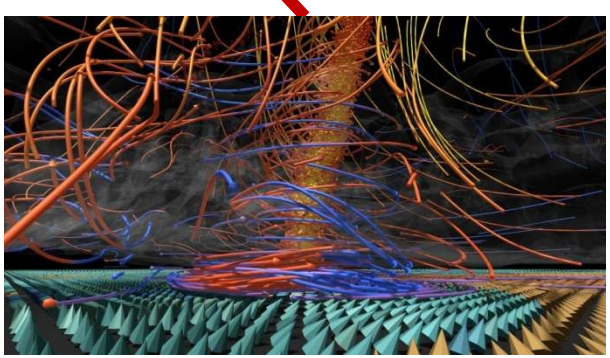
National LambdaRail

HPC

TeraGrid™



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

Calit2

Co-Hosted By Calit2 & CPUC

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January 22-23, 2009

