The Growing Interdependence of the Internet and Climate Change

Invited Talk
MITRE Innovation Speaker Series
McLean, VA
September 16, 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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The global Information and Communication Technology (ICT) industry produces GHGs equivalent to that produced by the aviation industry (~2-3 %). 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 application of ICT to electricity grids, logistic chains, intelligent transportation and building infrastructure, and other social systems can reduce global GHG emissions by ~15%, five times ICT's own footprint! I will discuss three campus testbeds for exploring these complex tradeoffs. The first testbed is the NSF-funded GreenLight Project deployed at UCSD, which creates an instrumented data center allowing for detailed real time data measurements of the critical subcomponents and then making that data publically available on the web, so that the results can guide users who wish to lower the energy cost of computation and storage. The second testbed is the use of dedicated optical networks (operating at 10,000 Mbps) coupled to large tiled walls (with fractions of a billion pixels) and high definition (2 Mpixel/frame) or digital cinema (8Mpixel/frame) as "telepresence" systems for "sewing remote rooms together" as a way to reduce the need for transportation for national or global collaboration. Finally, I will analyze the use of campuses themselves, which are functionally small towns with their own power grids, commuter transportation systems, hospitals, and populations in the tens of thousands and so are at-scale Green IT Living Laboratories of the Greener Future.

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ICT Could be a Key Factor in Reducing the Rate of Climate Change

Applications of ICT
could enable emissions reductions
of 15% of business-as-usual emissions.
But it must keep its own growing footprint in check
and overcome a number of hurdles
if it expects to deliver on this potential.





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www.smart2020.org

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I Will Cover Four Topics

- How Bad is Our Current Climate Situation?
- How Unusual is the Climate We are Heading Toward?
- What Role Can ICT Play in Slowing Down the Increase in Greenhouse Gases?
- What Do We Need to Do to Clean Up ICT's Greenhouse Gas Emissions?

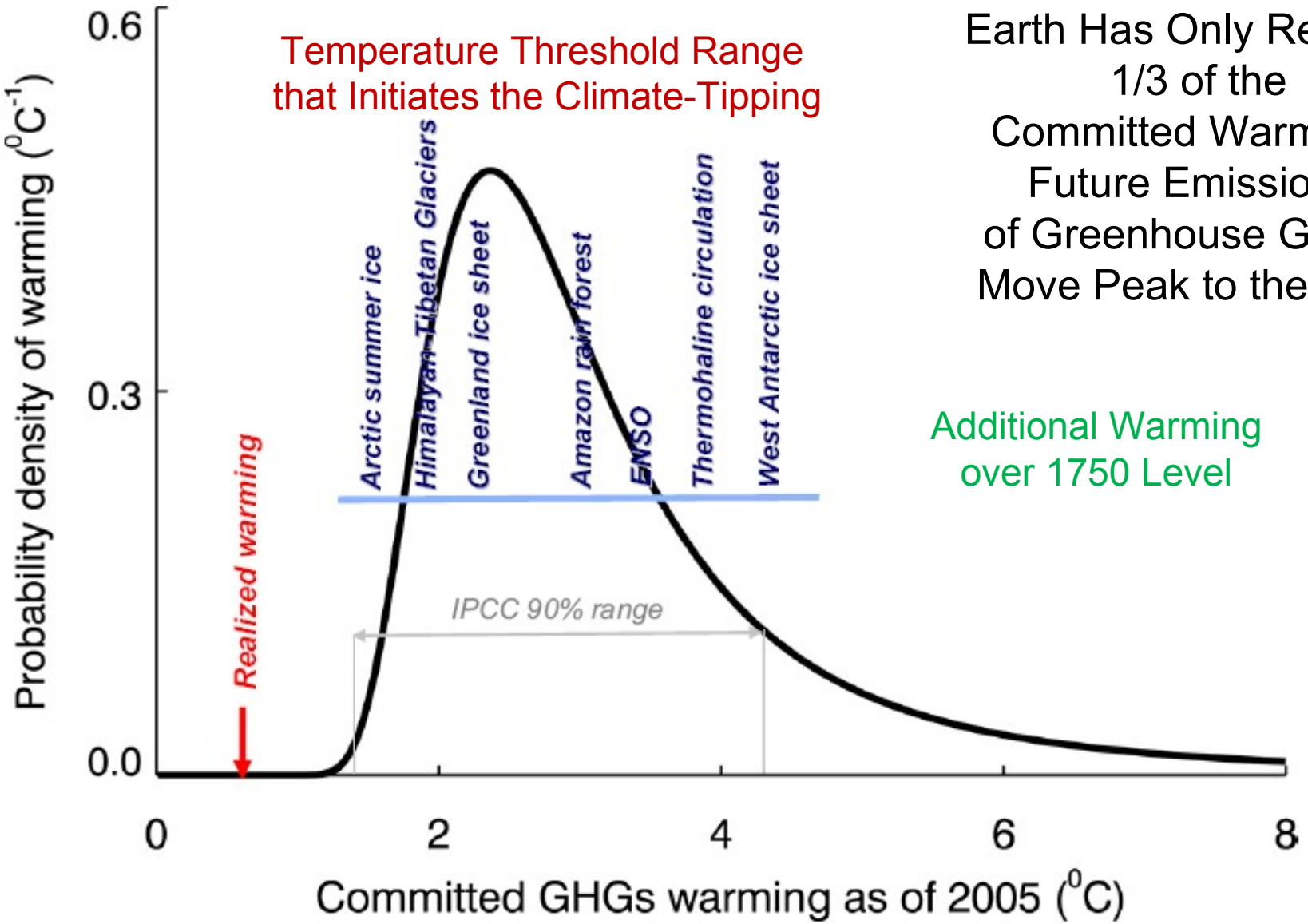
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How Bad is Our Current Climate Situation?

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A Brief Review of Climate Change: The Planet is Already Committed to a Dangerous Level of Warming



Earth Has Only Realized
1/3 of the
Committed Warming -
Future Emissions
of Greenhouse Gases
Move Peak to the Right

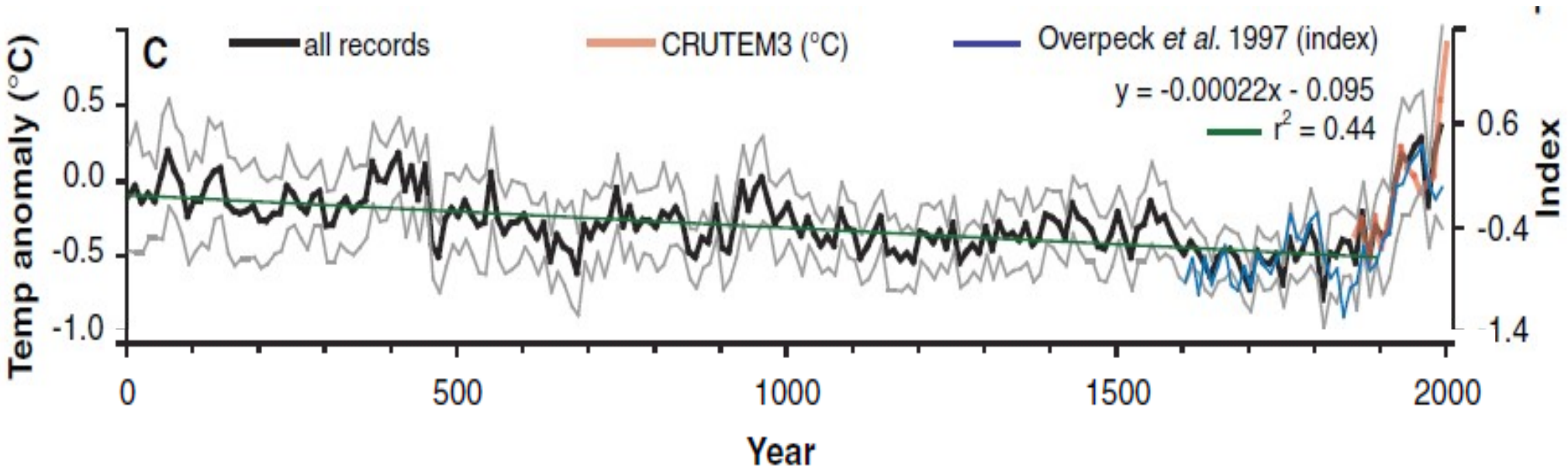
Additional Warming
over 1750 Level

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

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Global Climate Disruption Example: The Arctic Sea Ice

"A pervasive cooling of the Arctic in progress 2000 years ago continued through the Middle Ages and into the Little Ice Age. It was reversed during the 20th century, with four of the five warmest decades of our 2000-year-long reconstruction occurring between 1950 and 2000. The most recent 10-year interval (1999–2008) was the warmest of the past 200 decades."



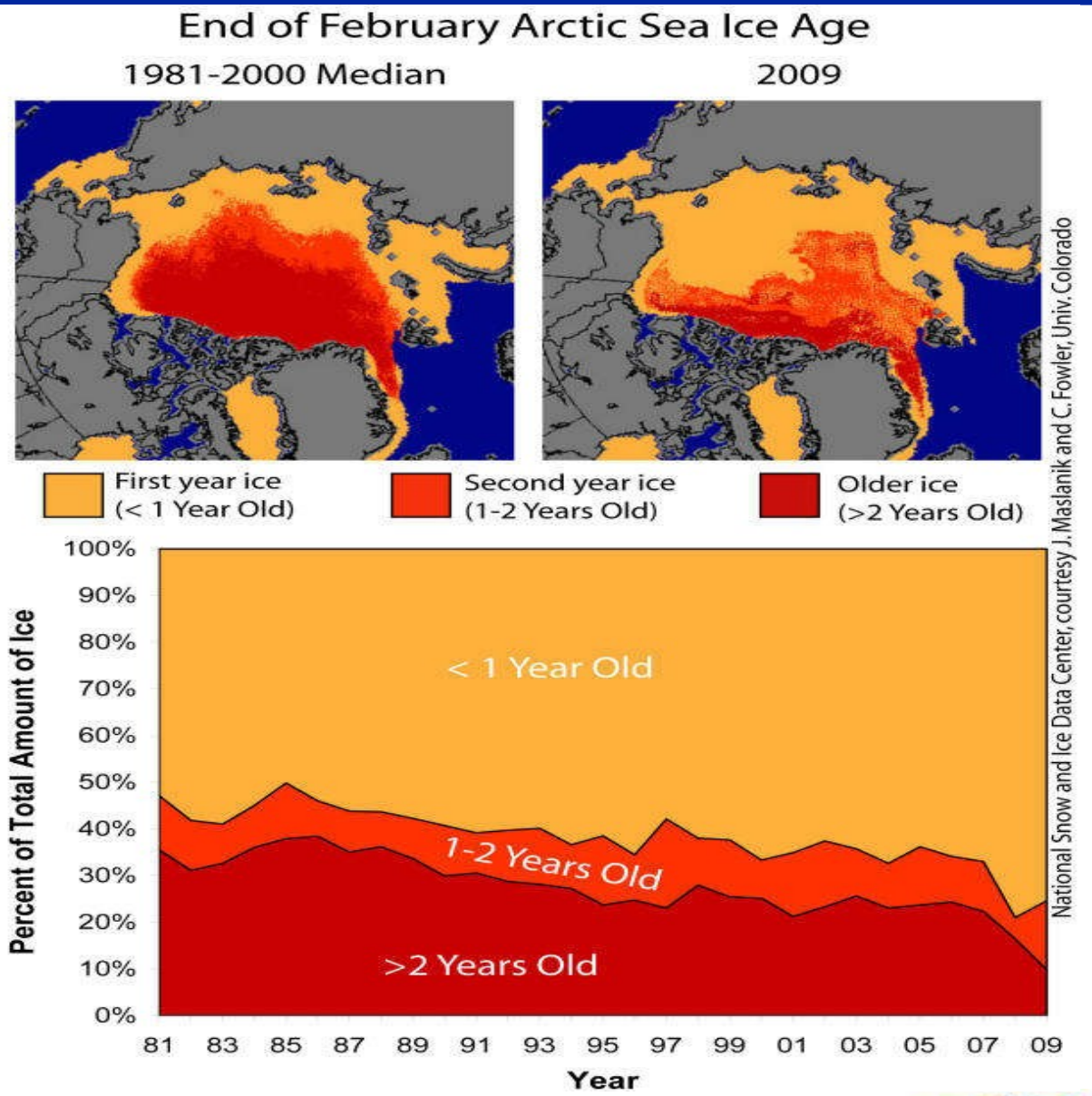
Mean of all records transformed to summer temperature anomaly relative to the 1961–1990 reference period, with first-order linear trend for all records through 1900 with 2 standard deviations

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Science v. 325 pp 1236 (September 4, 2009)

Global Climate Disruption Early Signs: Arctic Summer Ice is Rapidly Decreasing

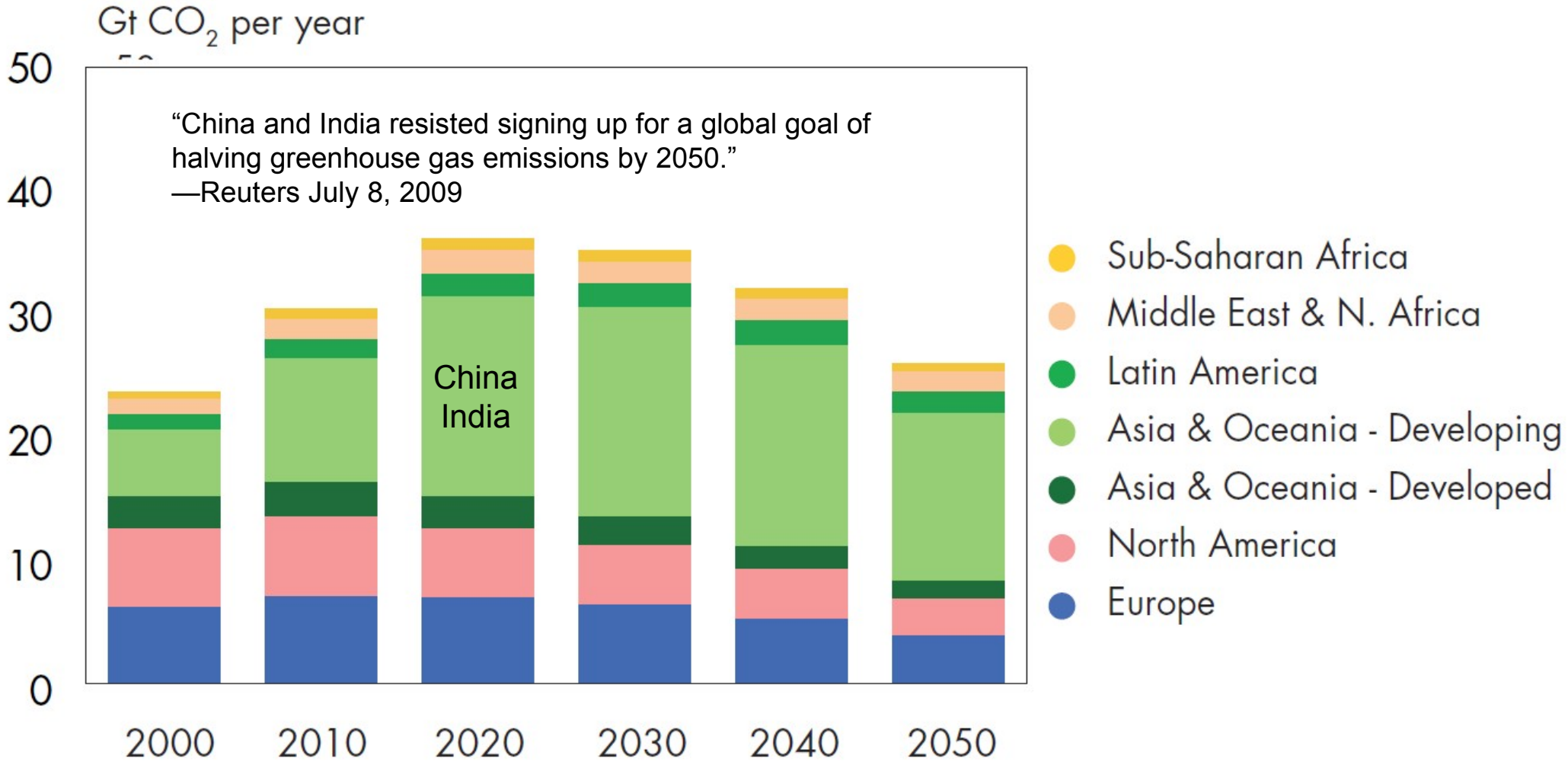
"The Arctic Ocean will be effectively ice free sometime between 2020 and 2040, although it is possible it could happen as early as 2013."
--Walt Meier, Research Scientist at the National Snow and Ice Data Centre at the University of Colorado



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

Future Estimates of CO_2 Emissions From Energy: 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

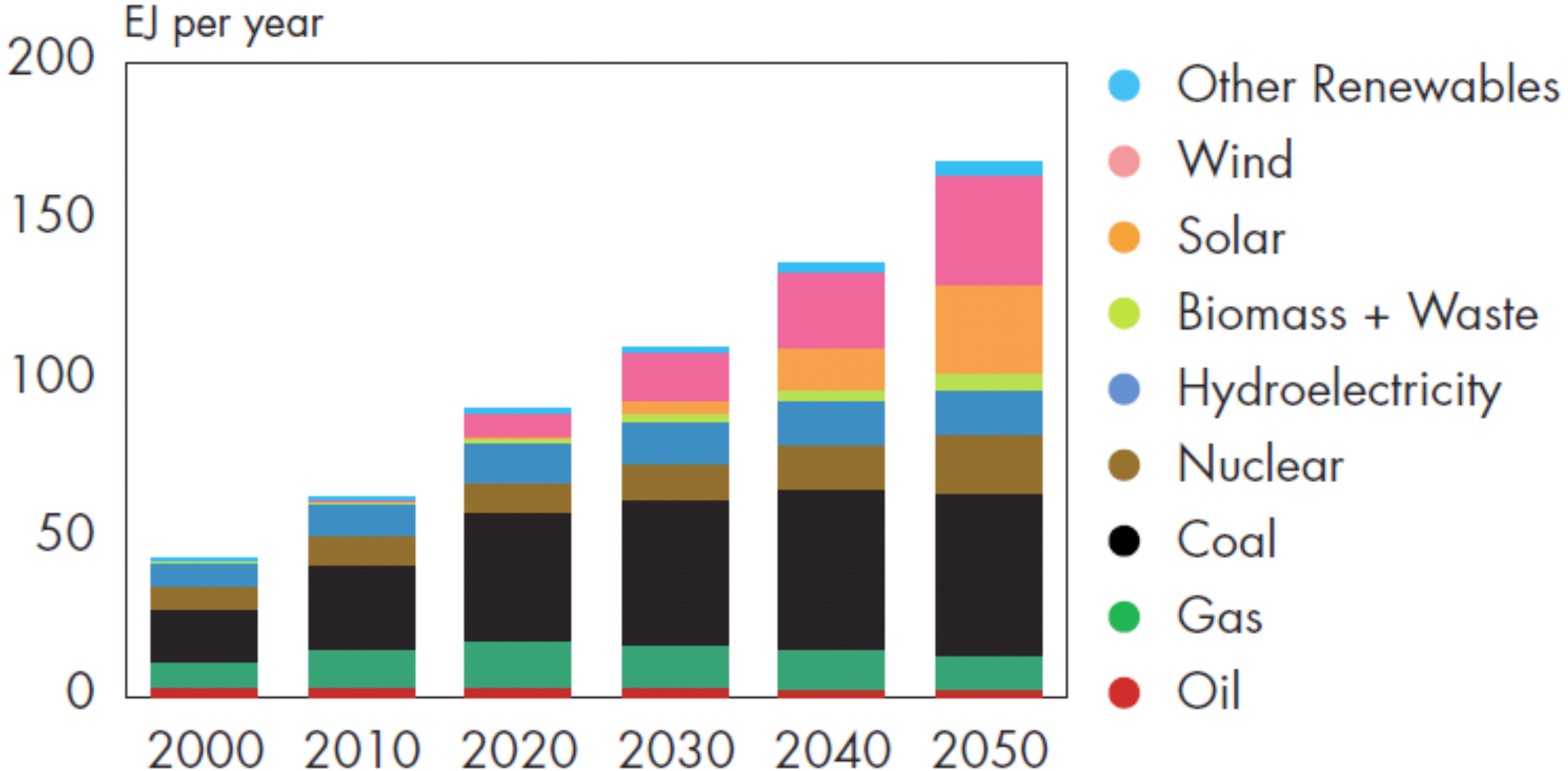
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Current CO_2 Level is 386 ppm

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In Shell's "Blueprints" Scenario, 60% of Electricity is Generated by Renewables by 2050

90% of All OECD Coal and Gas Power Plants
Use Carbon Capture and Sequestration

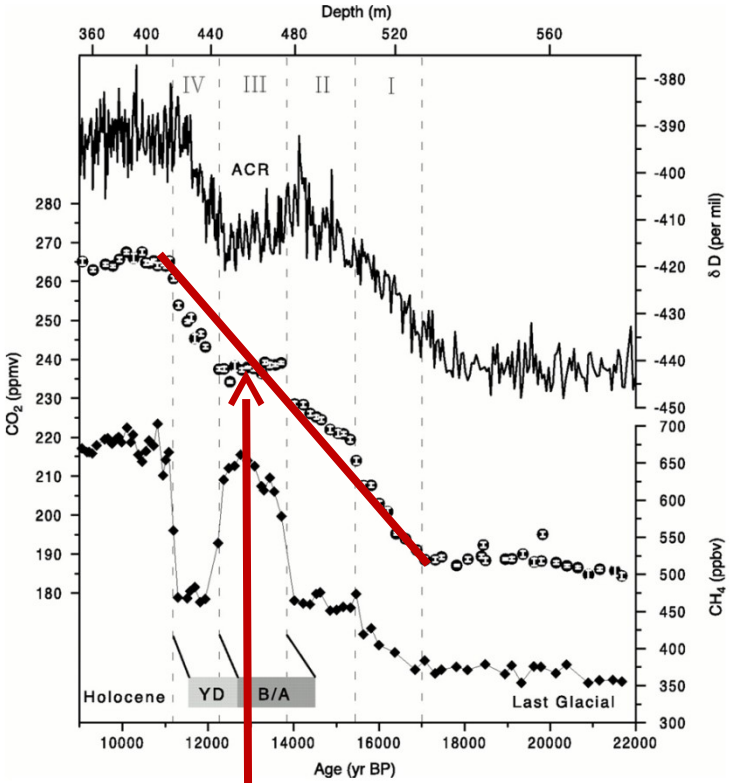


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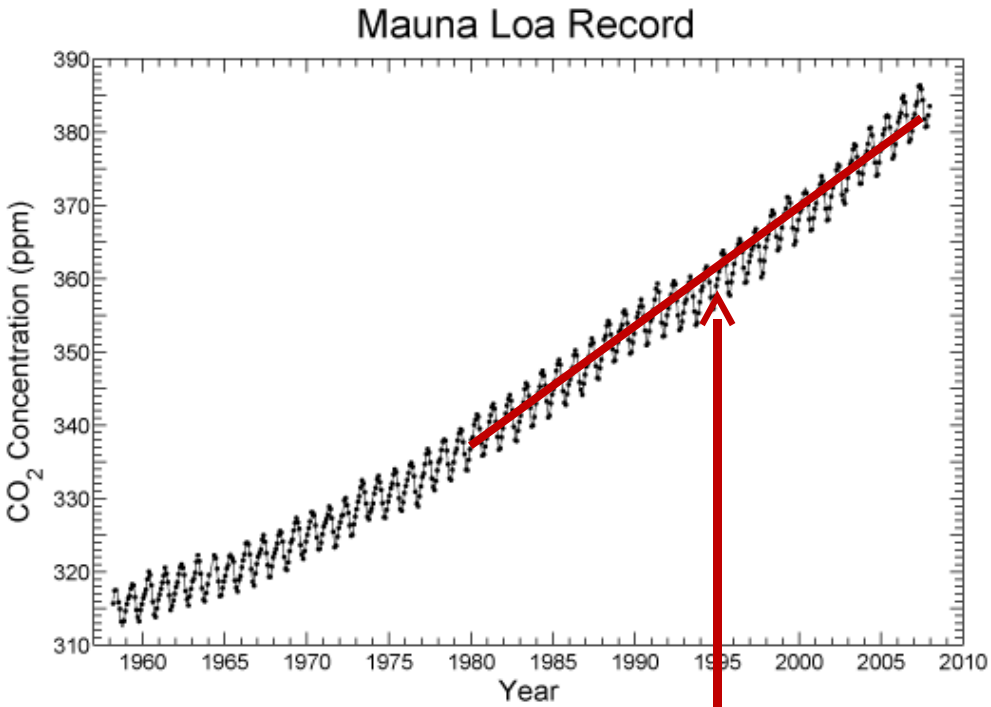
The Earth is Warming Over 100 Times Faster Today Than During the Last Ice Age Warming!

Monnin, et al., Science v. 291 pp. 112-114, Jan. 5, 2001.



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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How Unusual is the Climate We are Heading Toward?

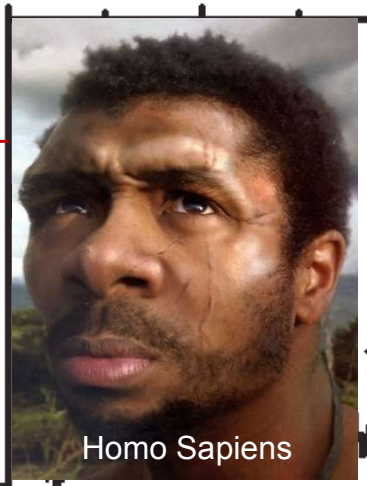
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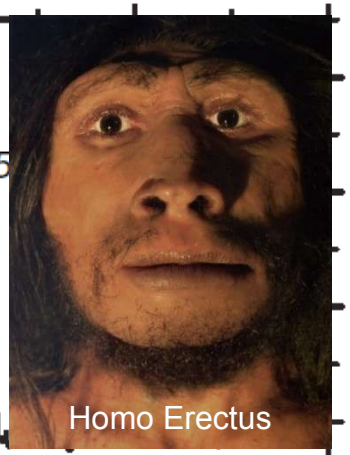
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Antarctic Ice Cores Show CO_2 and Temperature Have Oscillated For 800,000 Years in a Narrow Range

Today 386

Vertical Range 170 to 300 ppm





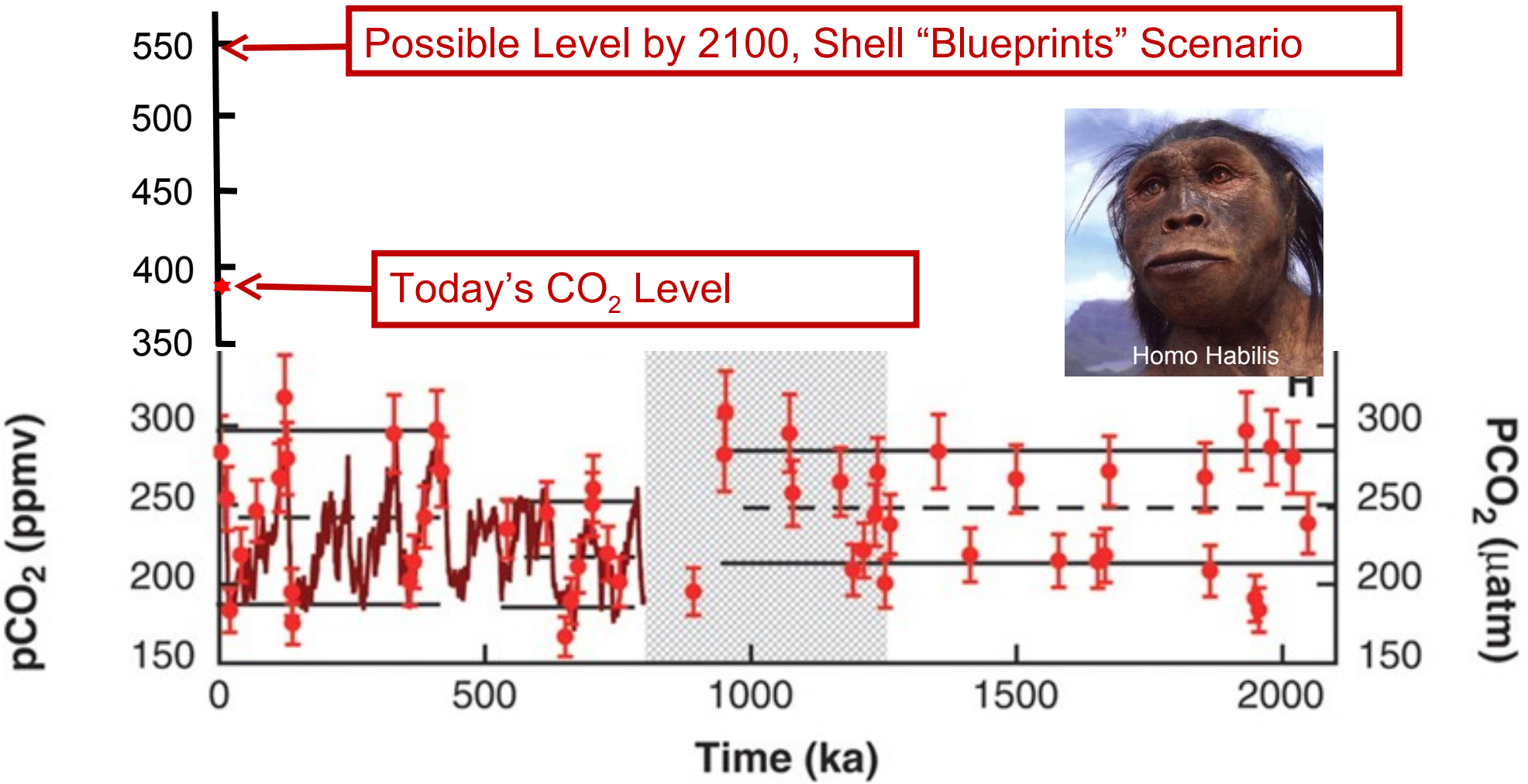
Ice Cores: Luthi, et al. Nature may 15, 2008 v. 453 pp379-82

Homonid Images: *The Last Human*, G.J. Sawyer and V. Deak

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Ice Core Record Has Been Extended Using Plankton: Today's CO_2 is Higher Than in Last 2 Million Years!



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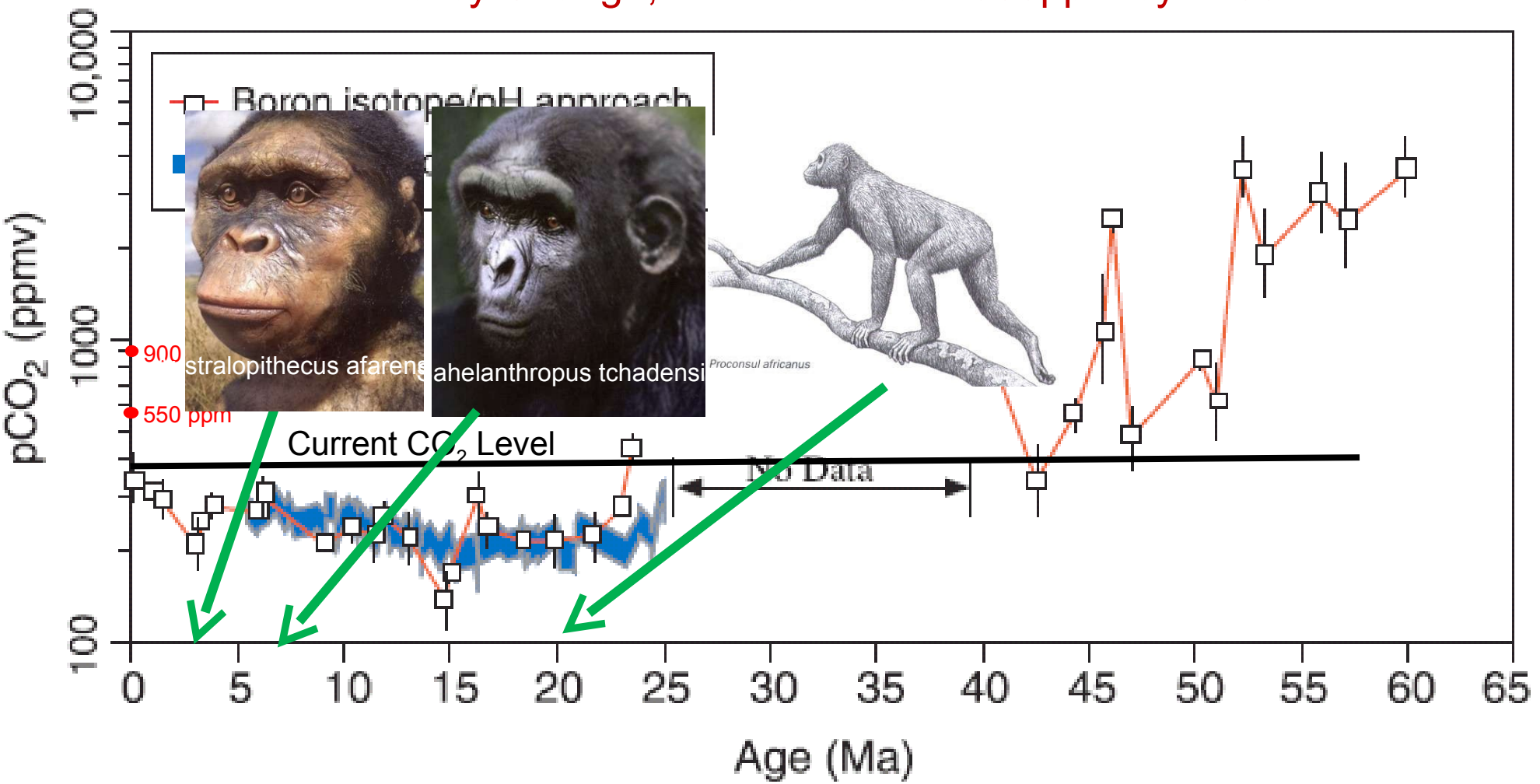
CO2: Hönisch, et al. Science 19 June 2009 Vol. 324. pp. 1551 - 1554

Homonid Images: *The Last Human*, G.J. Sawyer and V. Deak

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Earth's Climate Hasn't Seen the Current Level of CO_2 During the Entire Evolution of Homonids!

With No Policy Change, MIT Estimates ~900ppm by 2100



Estimates of Cenozoic atmospheric pCO_2 based on two independent proxies as measured in subtropical deep-sea sediment cores from the Pacific

CO_2: James Zachos, et al. Science v. 292 p. 686 27 Apr. 2001

Homonid Images: *The Last Human*, G.J. Sawyer and V. Deak

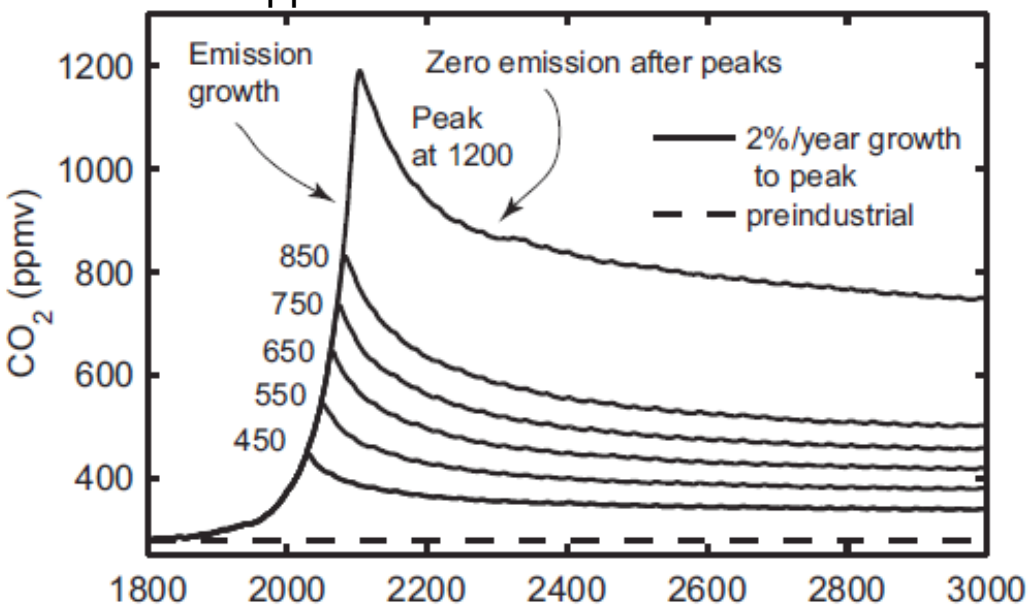
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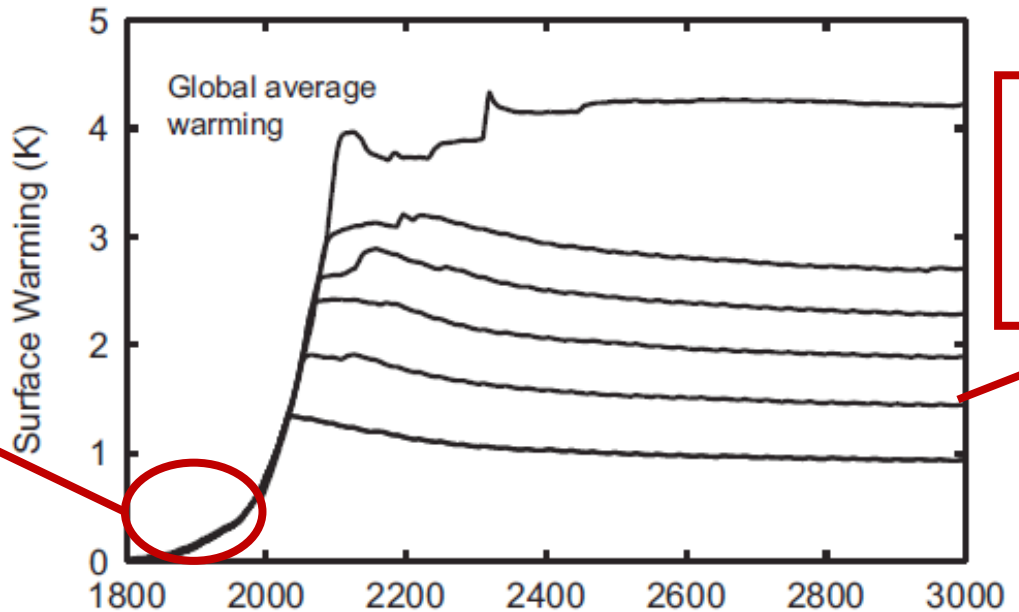
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We Are Transitioning to a New Climate State -- Unlike the Rapid Recovery with Acid Rain or Ozone Hole

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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Earth's Climate is Rapidly Entering a Novel Realm Not Experienced for Over 20 Million Years

"Global Warming" implies gradual, uniform, mainly about temperature, and quite possibly benign.

What's happening is rapid, non-uniform, affecting everything about climate, and is almost entirely harmful.



A more accurate term is 'global climatic disruption'

This ongoing disruption is:

- Real without doubt
- Mainly caused by humans
- Already producing significant harm
- Growing more rapidly than expected"

-John Holdren, Director Office of Science and Technology Policy
June 25, 2008

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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)**

- **Neither the U.S. or Canada has an Official Target Yet**
  - **President Obama Has Endorsed the AB32 2020 Goal**

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What Role Can ICT Play in Slowing Down the Increase in Greenhouse Gases?

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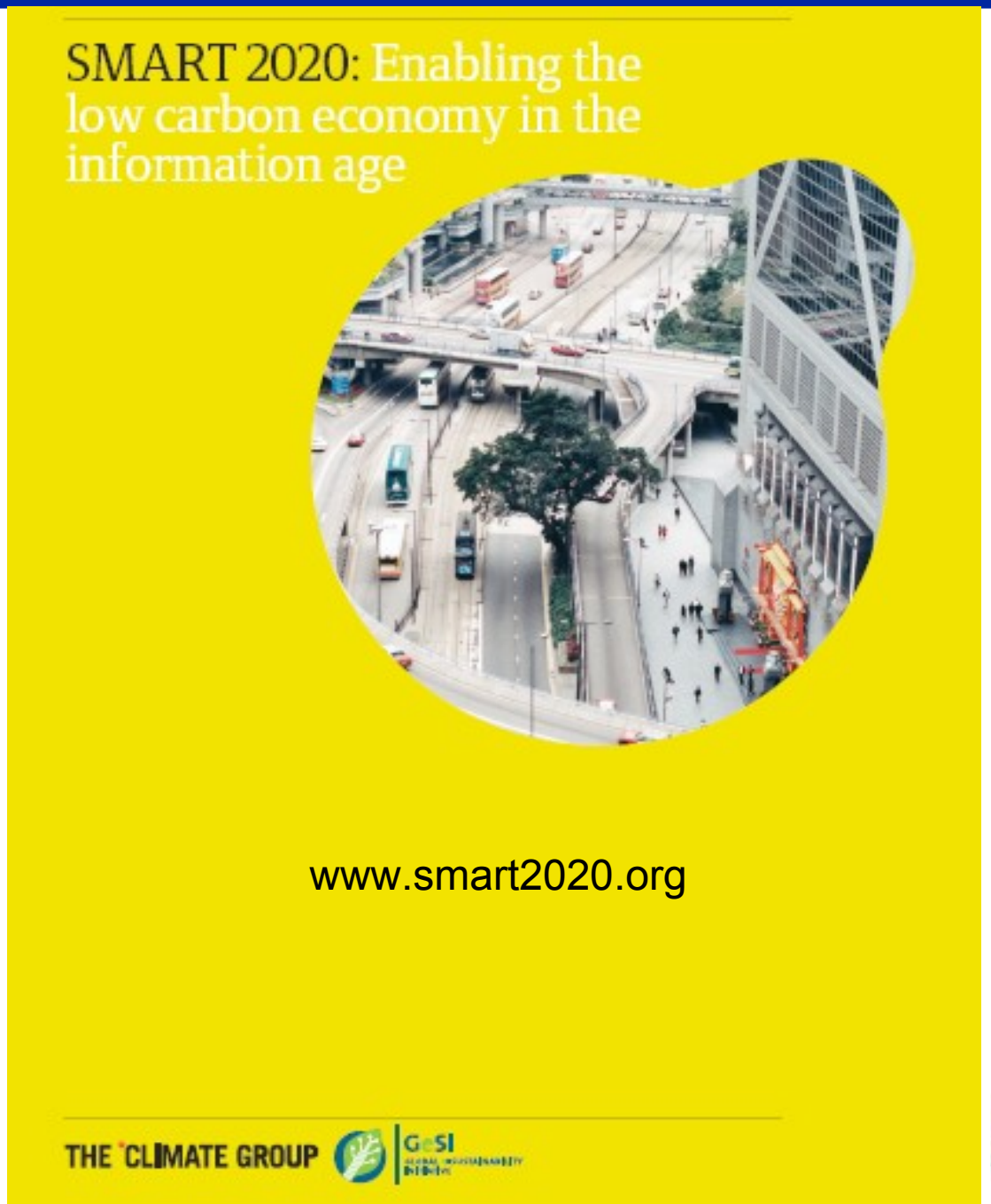
ICT is a Critical Element in Achieving Countries Greenhouse Gas Emission Reduction Targets

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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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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Developing Greener Smart Campuses as Societal Prototypes: Calit2 (UCSD & UCI)

- **Coupling the Internet and the Electrical Grid**
  - Choosing non-GHG Emitting Electricity Sources
  - Measuring Demand at Sub-Building Levels
  - Reducing Local Energy Usage via User Access Thru Web
- **Transportation System**
  - Campus Wireless GPS Low Carbon Fleet
  - Green Software Automobile Innovations
  - Driver Level Cell Phone Traffic Awareness
- **Travel Substitution**
  - Commercial Teleconferencing
  - Next Generation Global Telepresence

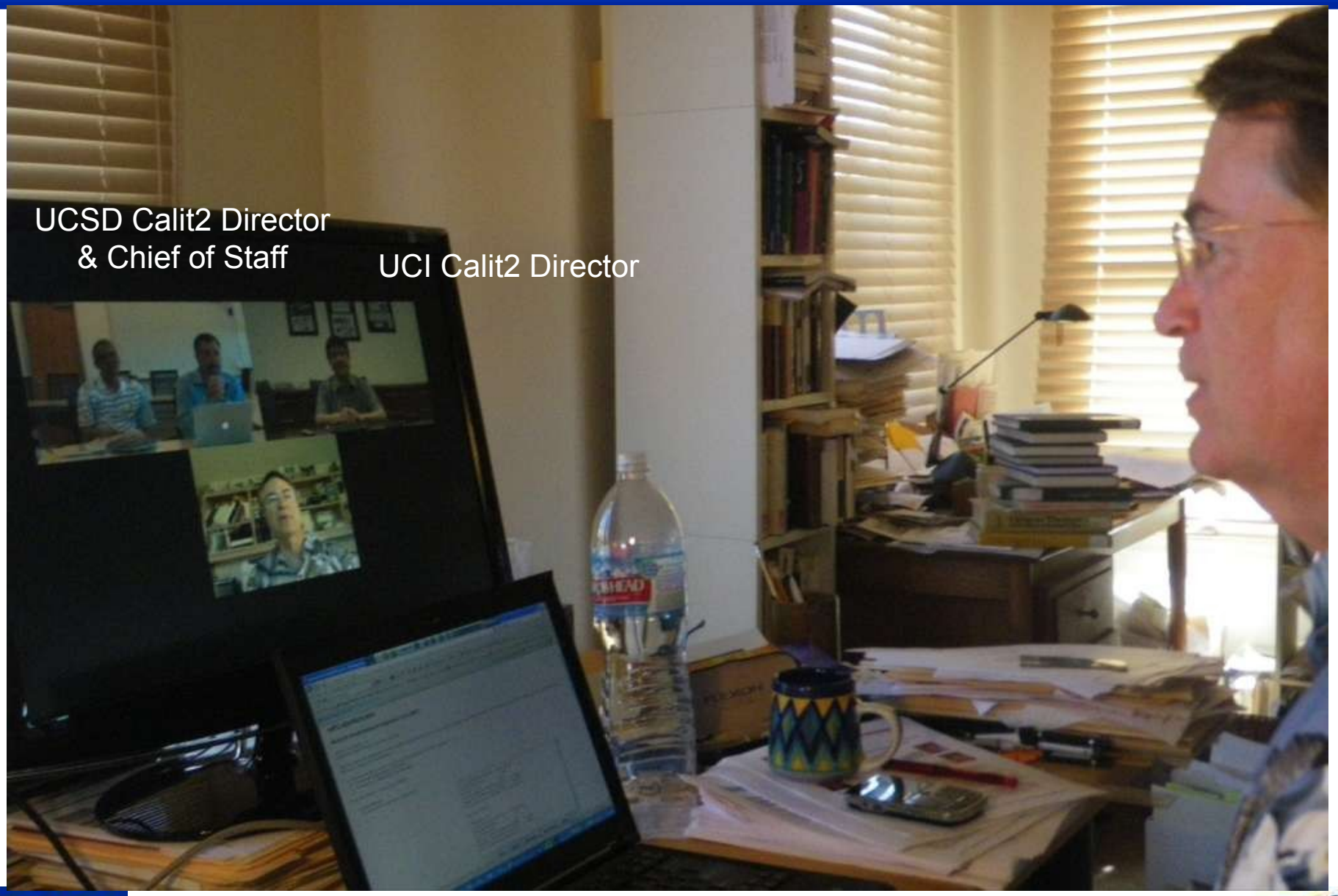
Student Video -- UCSD Living Laboratory for Real-World Solutions
www.gogreentube.com/watch.php?v=NDc4OTQ1 on UCSD

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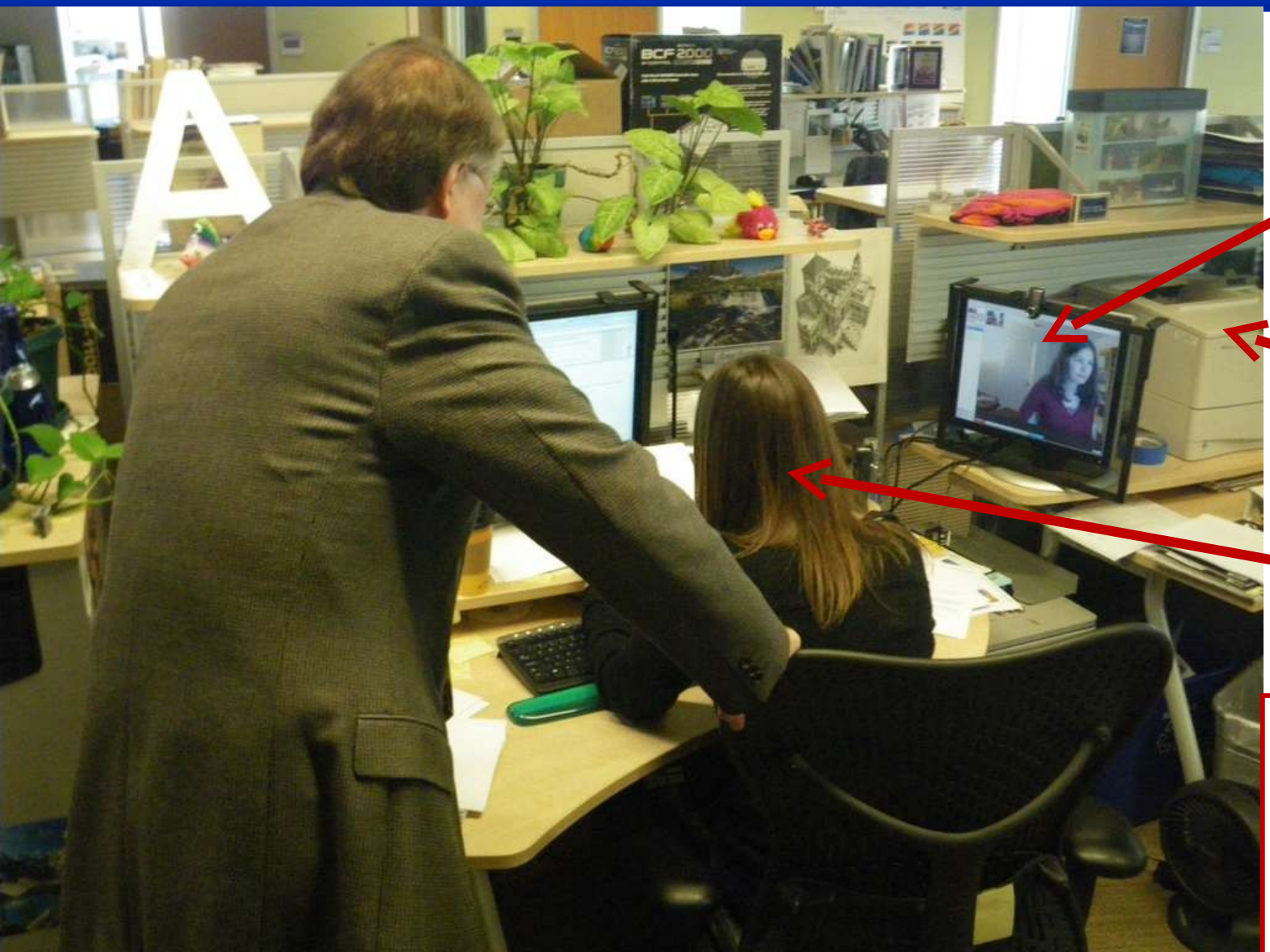
UCI Named 'Best Overall' in Flex Your Power Awards
www.today.uci.edu/news/release_detail.asp?key=1859

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I Link Into Commercial H.323 Videoconfernces From My Laptop at Home



Work at Home is the Same As at the Office



Virtual Kristen

Kristen Prints Here For Amy

Real Amy

Kristen Reads My Email, Sets My Calendar. Works With Amy on My Trips

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We Run Video Sykpe Continuously During Office Hours

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Linking the Calit2 Auditoriums at UCSD and UCI with HD for Shared Seminars

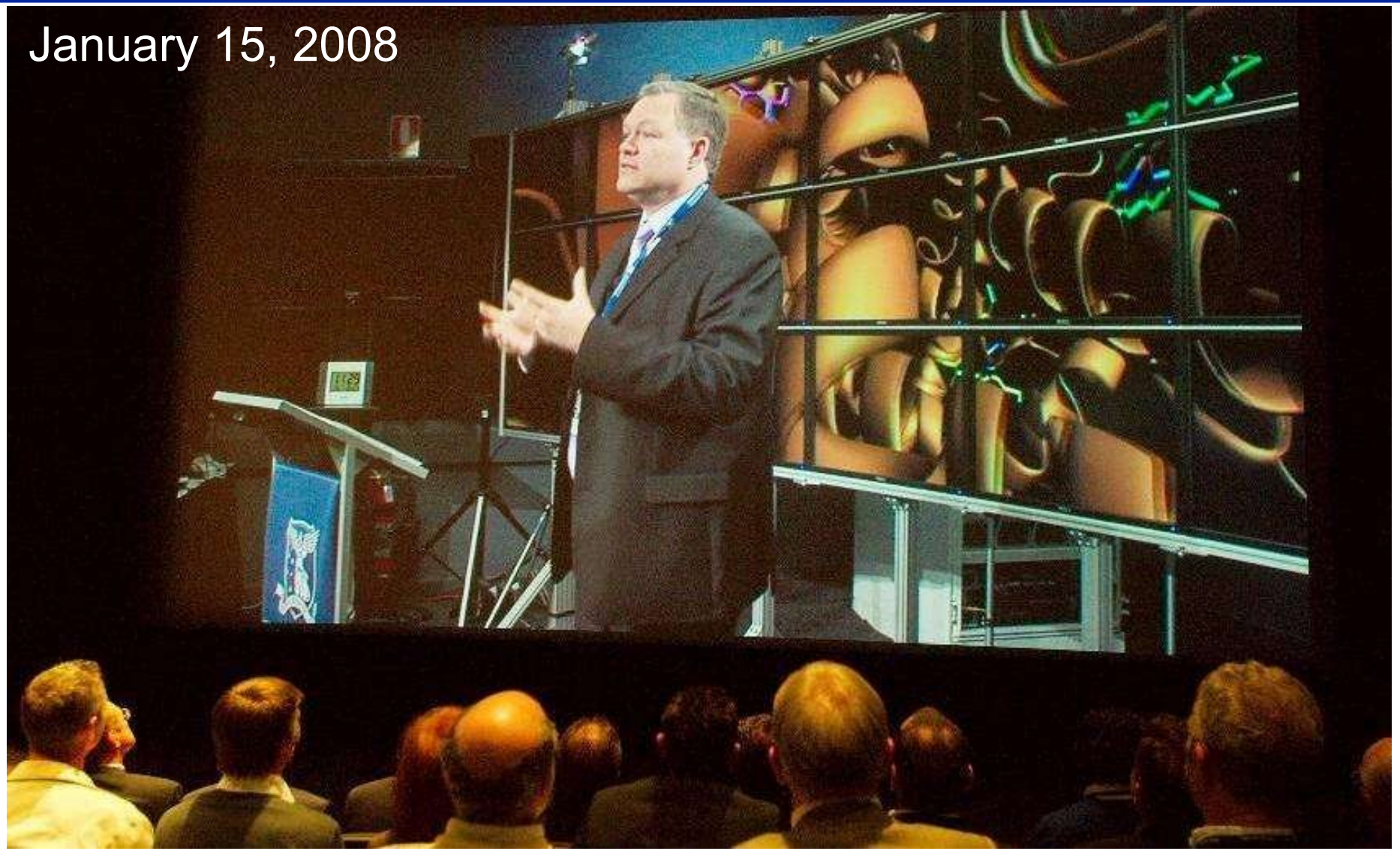


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Photo by Erik Jepsen, UC San Diego

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



No Calit2 Person Physically Flew to Australia to Bring This Up!

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Covise, Phil Weber, Jurgen Schulze, Calit2
CGLX, Kai-Uwe Doerr , Calit2
http://www.calit2.net/newsroom/release.php?id=1421

HD Talk to Australia's Monash University from Calit2: Reducing International Travel



Qvidium Compressed HD ~140 mbps

Source: David Abramson, Monash Univ

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OptIPlanet Collaboratory Persistent Infrastructure Between Calit2 and U Washington



OptIPuter

Ginger Armbrust's Diatoms: Micrographs, Chromosomes, Genetic Assembly

ROCKS

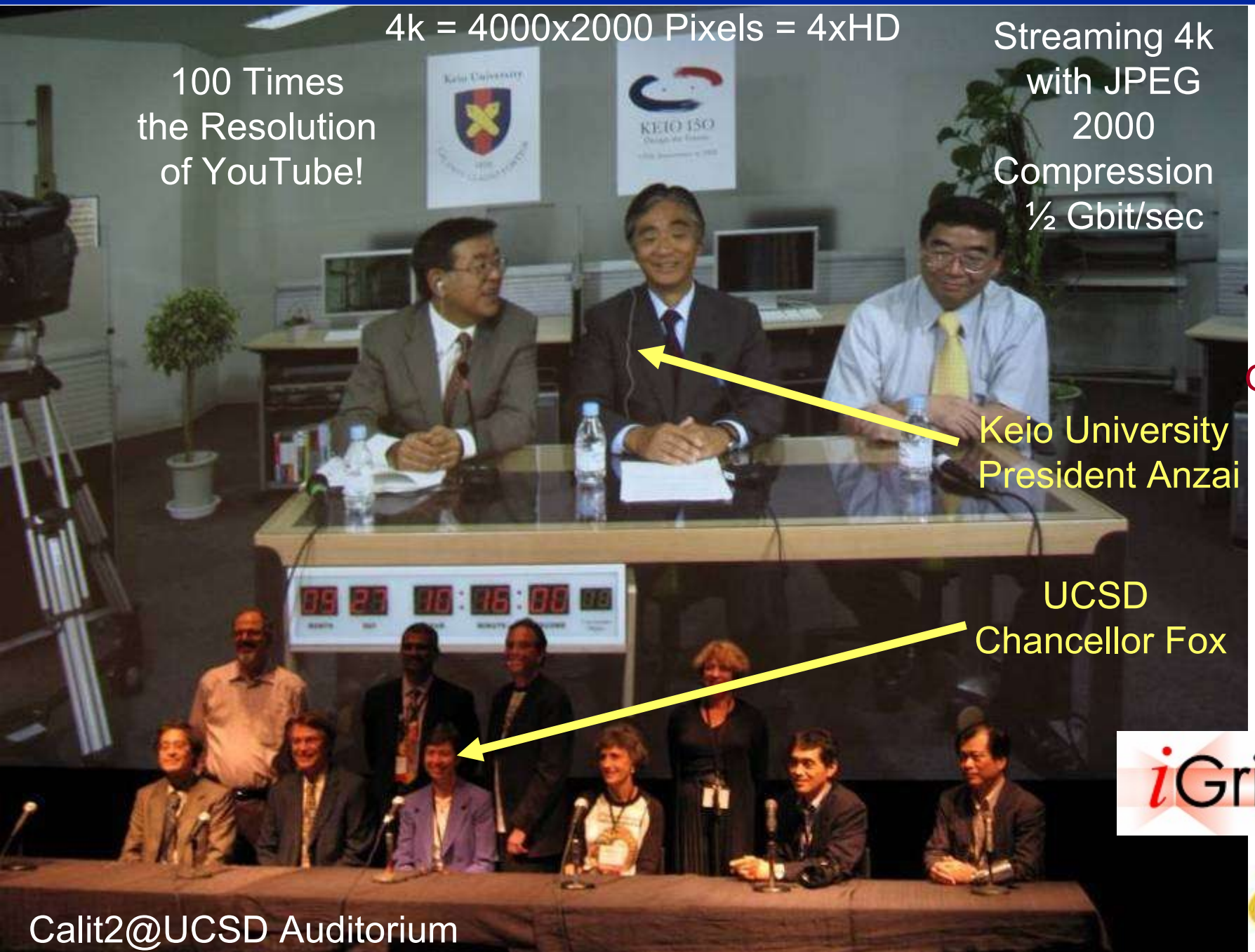




iHDTV: 1500 Mbits/sec Calit2 to UW Research Channel
Over 10,000 Mbps
Pacific Wave/CENIC
Dedicated Optical Fiber

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Telepresence Meeting
Using Digital Cinema 4k Streams



CineGrid

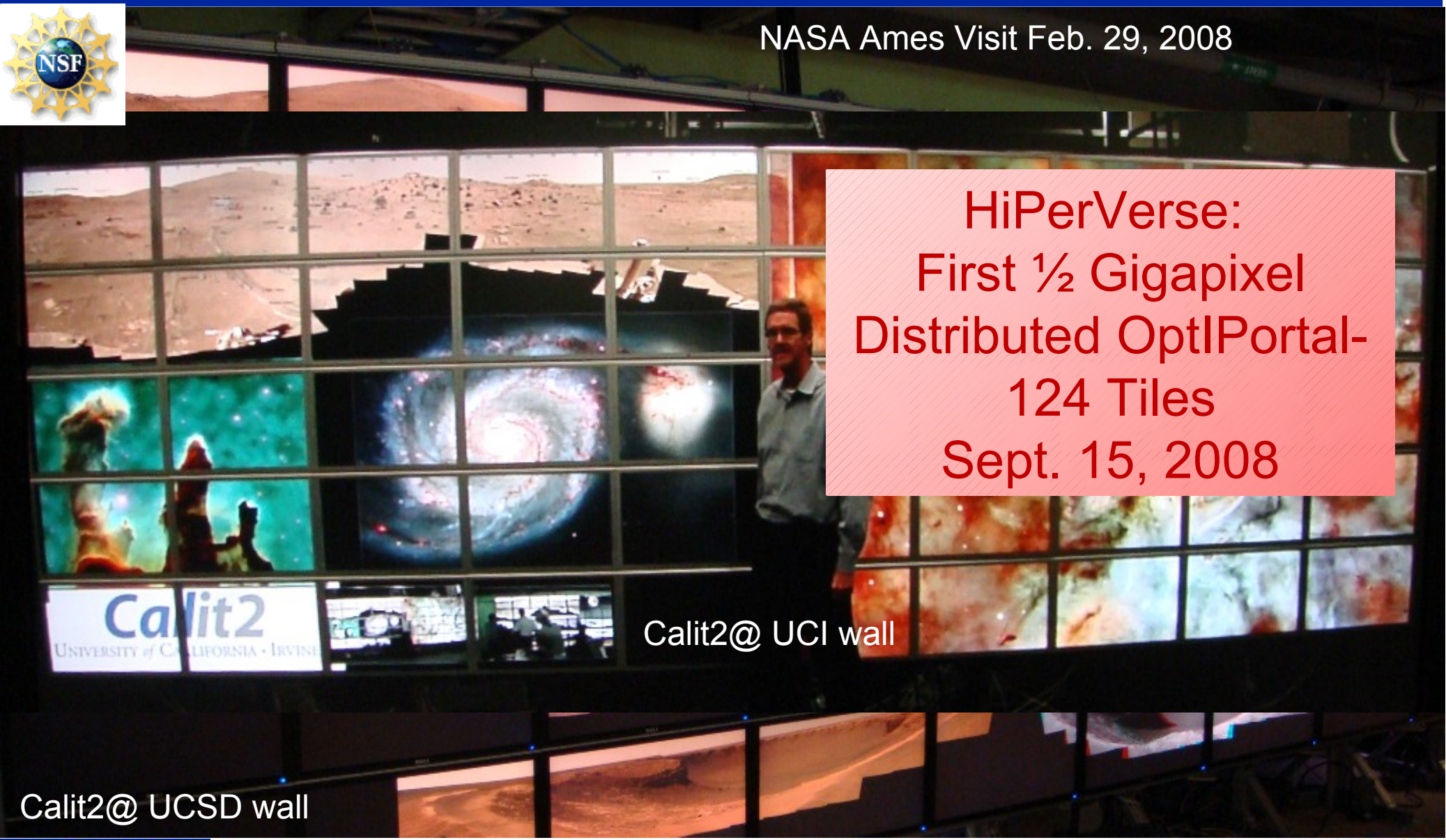
Lays
Technical
Basis for
Global Digita
Cinema

Sony
NTT
SGI

iGrid 2005

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Toward a Data and Visualization Intensive Working Environment Across Remote Sites



UCSD cluster: 15 x Quad core Dell XPS with Dual nVIDIA 5600s
UCI cluster: 25 x Dual Core Apple G5

Building a Mixed Virtual/Physical Working Space: NASA Ames Adopts OptIPuter Collaboratory



From Start to This Image in Less Than 2 Weeks!

View from NASA Ames Lunar Science Institute Mountain View, CA

Virtual Handshake

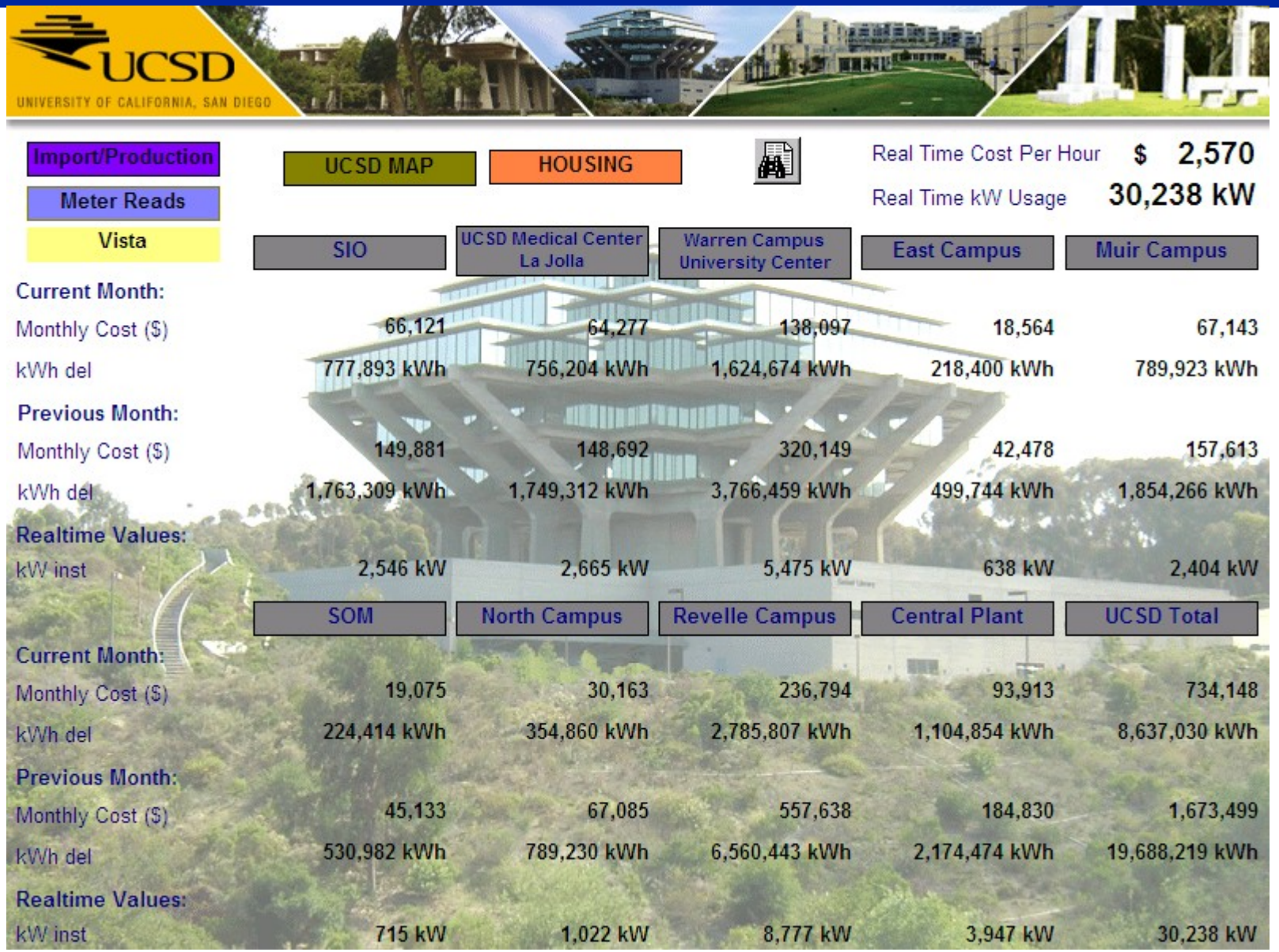
LifeSize High Defn. Video Integrated With OptIPortal and Spatialized Audio

NASA Interest in Supporting Virtual Institutes

NASA Astrobiology Institute Is Next

Source: Falko Kuester, Calit2; Michael Sims, NASA

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

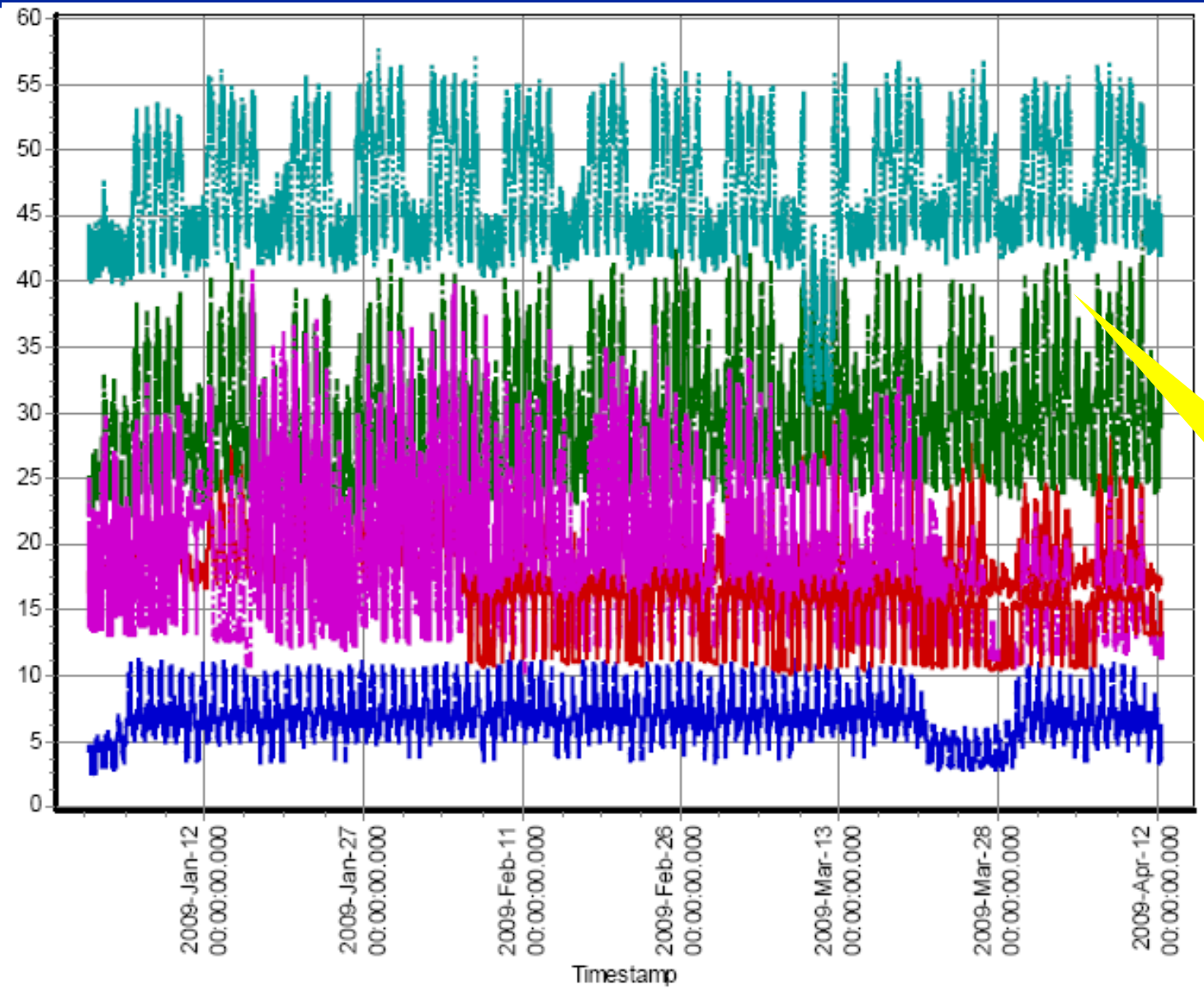


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http://mscada01.ucsd.edu/ion/

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



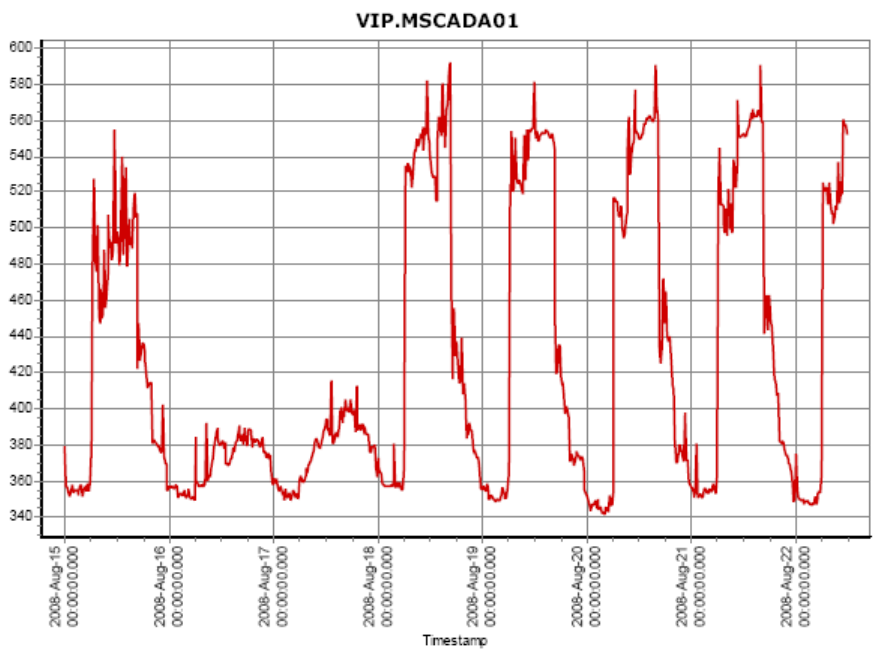
Calit2 and CSE are Very Energy Intensive Buildings

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

- 500 Occupants, 750 Computers
- Detailed Instrumentation to Measure Macro and Micro-Scale Power Use
  - 39 Sensor Pods, 156 Radios, 70 Circuits
  - Subsystems: Air Conditioning & Lighting
- Conclusions:
  - Peak Load is Twice Base Load
  - 70% of Base Load is PCs and Servers
  - 90% of That Could Be Avoided!





Source: Rajesh Gupta, CSE, Calit2

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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

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









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Universit

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

TUDIES

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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

UCSD
UCIrvine

January 22-23, 2009

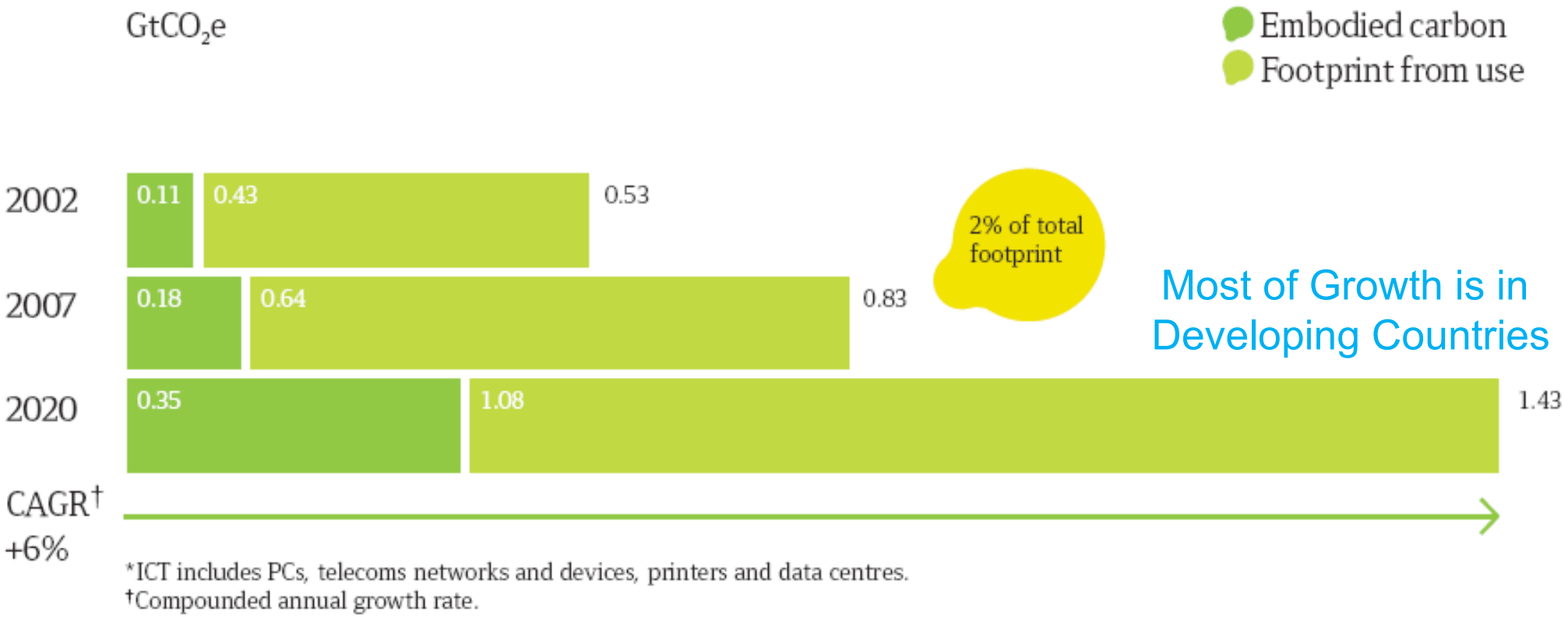


What Do We Need to Do to Clean Up ICT's Greenhouse Gas Emissions?

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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

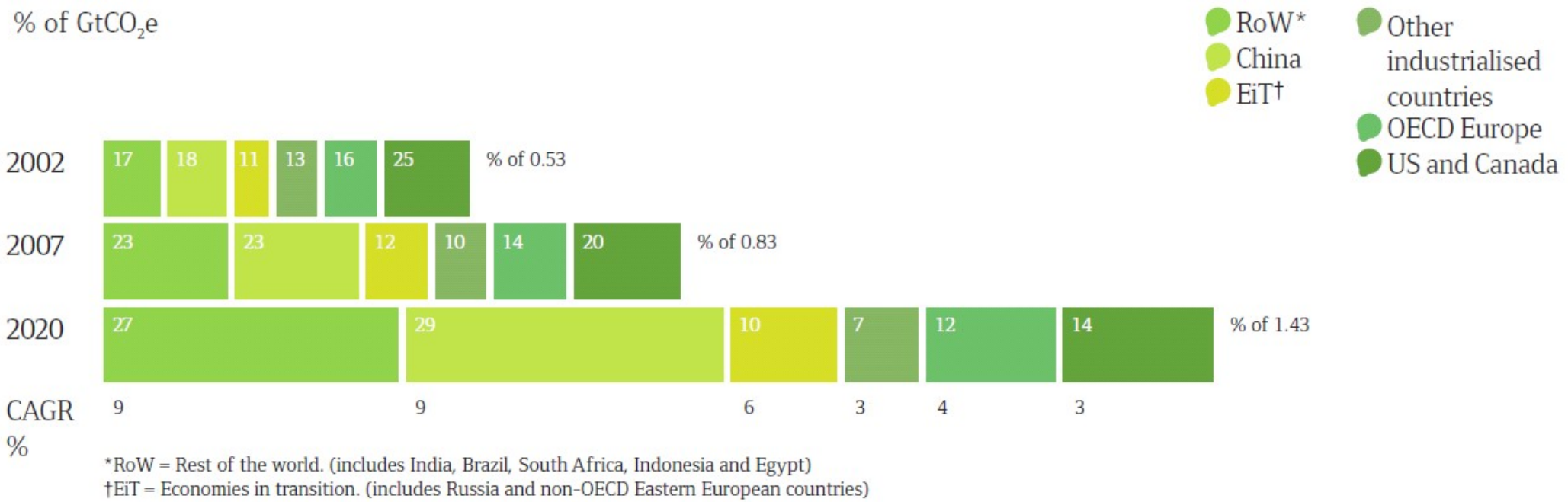
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Reduction of ICT Emissions is a Global Challenge – U.S. and Canada are Small Sources

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



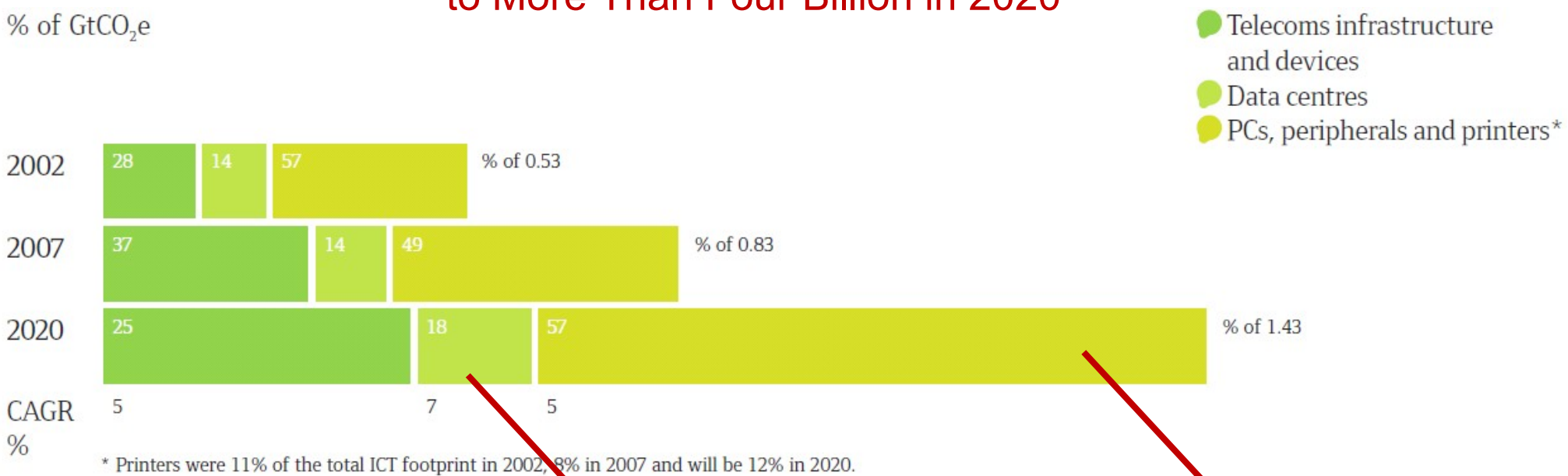
*RoW = Rest of the world. (includes India, Brazil, South Africa, Indonesia and Egypt)
†EiT = Economies in transition. (includes Russia and non-OECD Eastern European countries)

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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



Data Centers Are Rapidly Improving

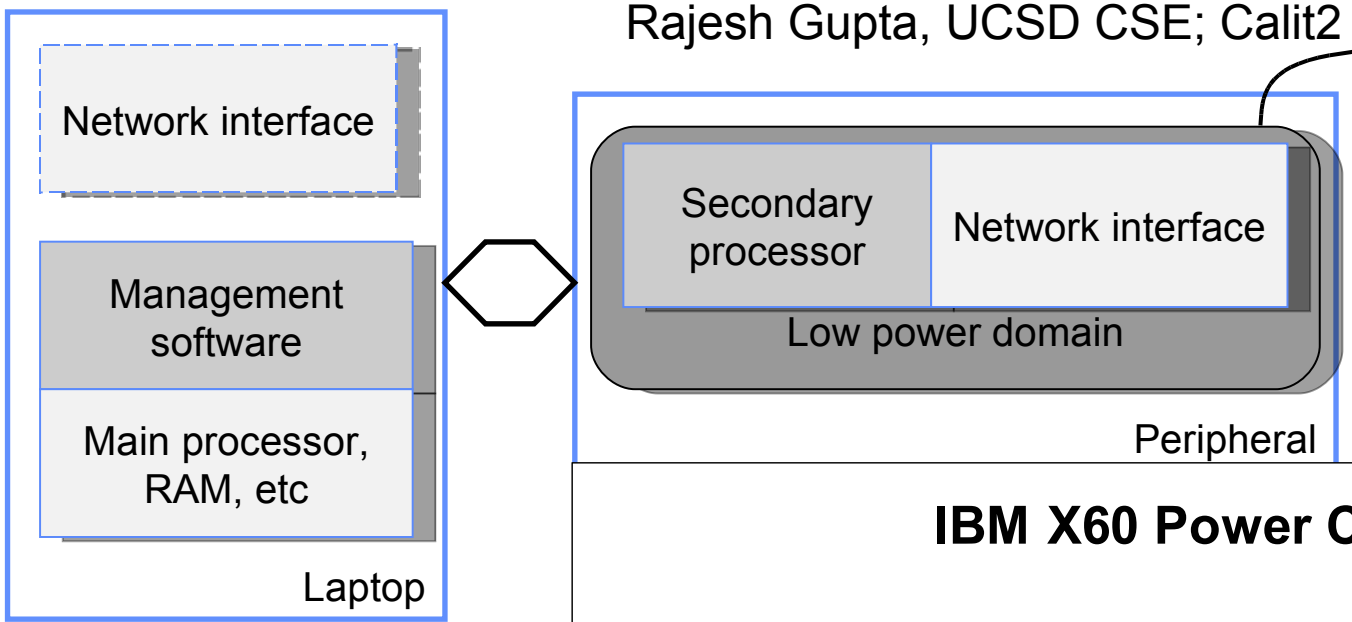
PCs Are Biggest Problem

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www.smart2020.org

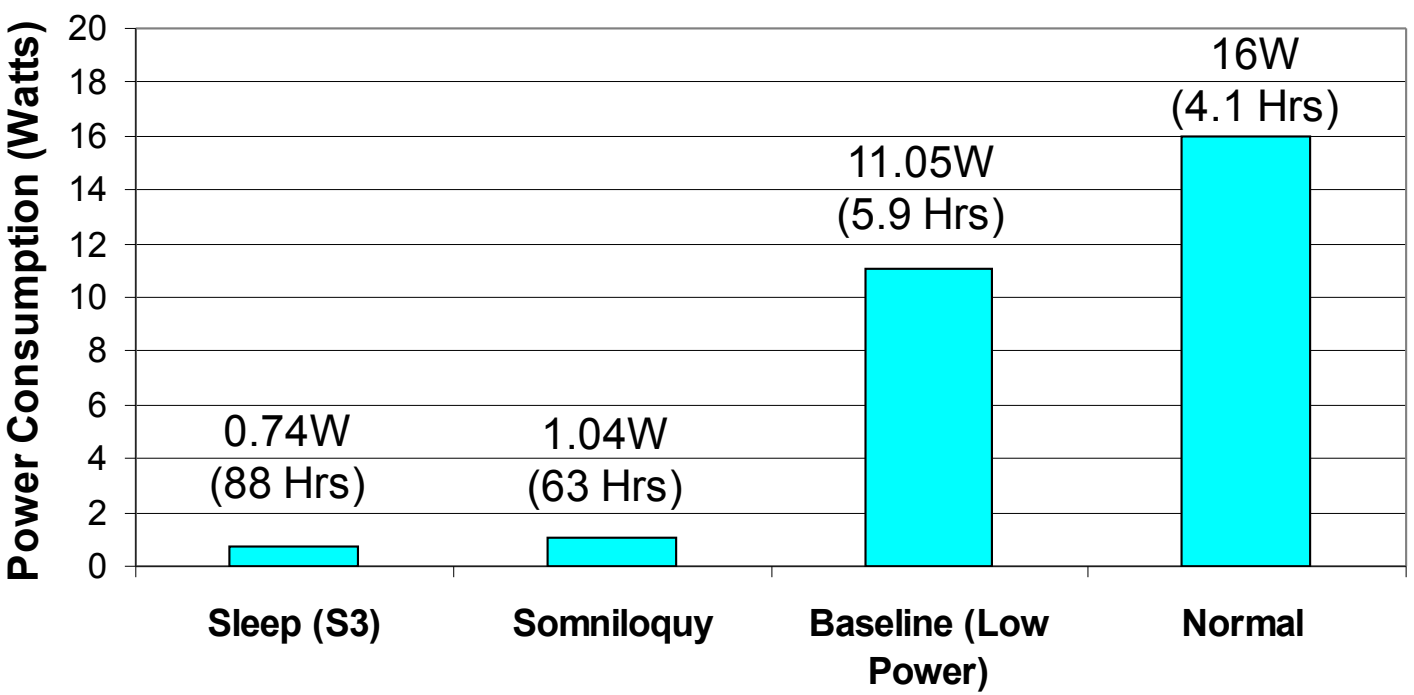
Can We Reduce the Energy Used By PCs Via Putting Machines To Sleep Transparently?

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.



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,

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

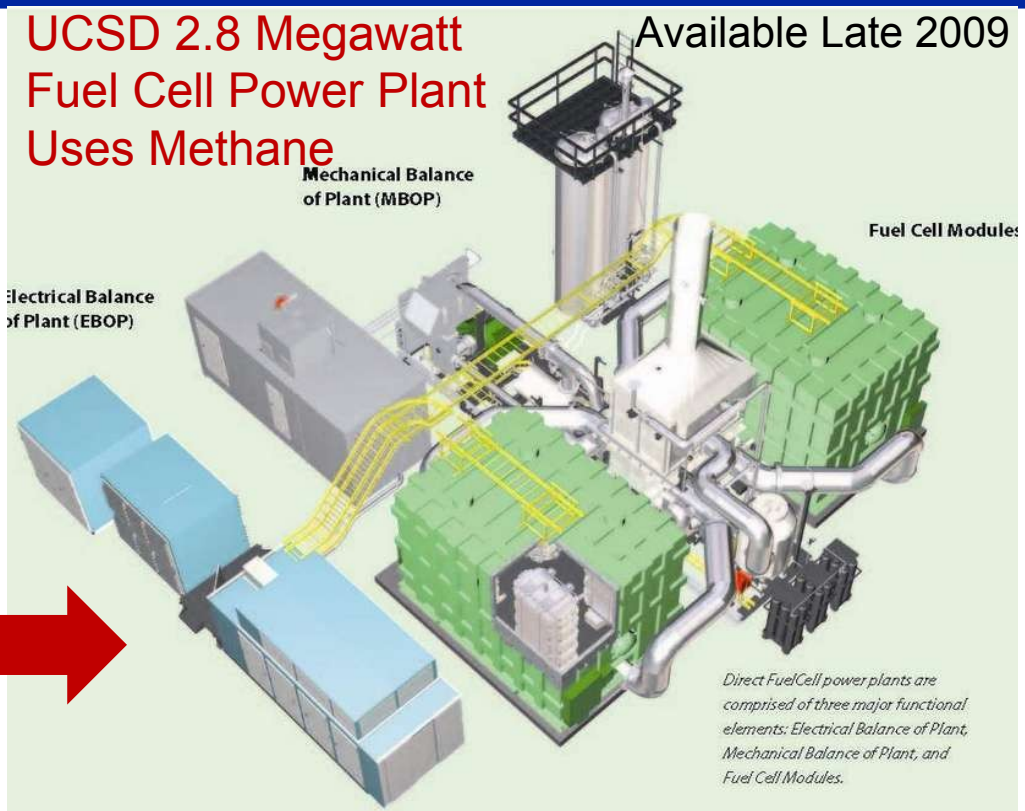
UCSD is Installing Zero Carbon Emission Solar and Fuel Cell DC Electricity Generators

San Diego's Point Loma Wastewater Treatment Plant Produces Waste Methane



UCSD 2.8 Megawatt Fuel Cell Power Plant Uses Methane

Available Late 2009



Use to Power Local Data Centers



2 Megawatts of Solar Power Cells Being Installed

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Zero Carbon GreenLight Experiment: DC-Powered Modular Data Center

- **Concept—Avoid DC to AC to DC Conversion Losses**
  - Computers Use DC Power Internally
  - Solar and Fuel Cells Produce DC
  - Both Plug into the AC Power Grid
  - Can We Use DC Directly (With or Without the AC Grid)?

Sun Box <200kWatt

- **DC Generation Can Be Intermittent**
  - Depends on Source
    - Solar, Wind, Fuel Cell, Hydro
  - Can Use Sensors to Shut Down or Sleep Computers
  - Can Use Virtualization to Halt/Shift Jobs
- **Experiment Planning Just Starting**
  - Collaboration with Sun and LBNL
  - NSF GreenLight Year 2 and Year 3 Funds

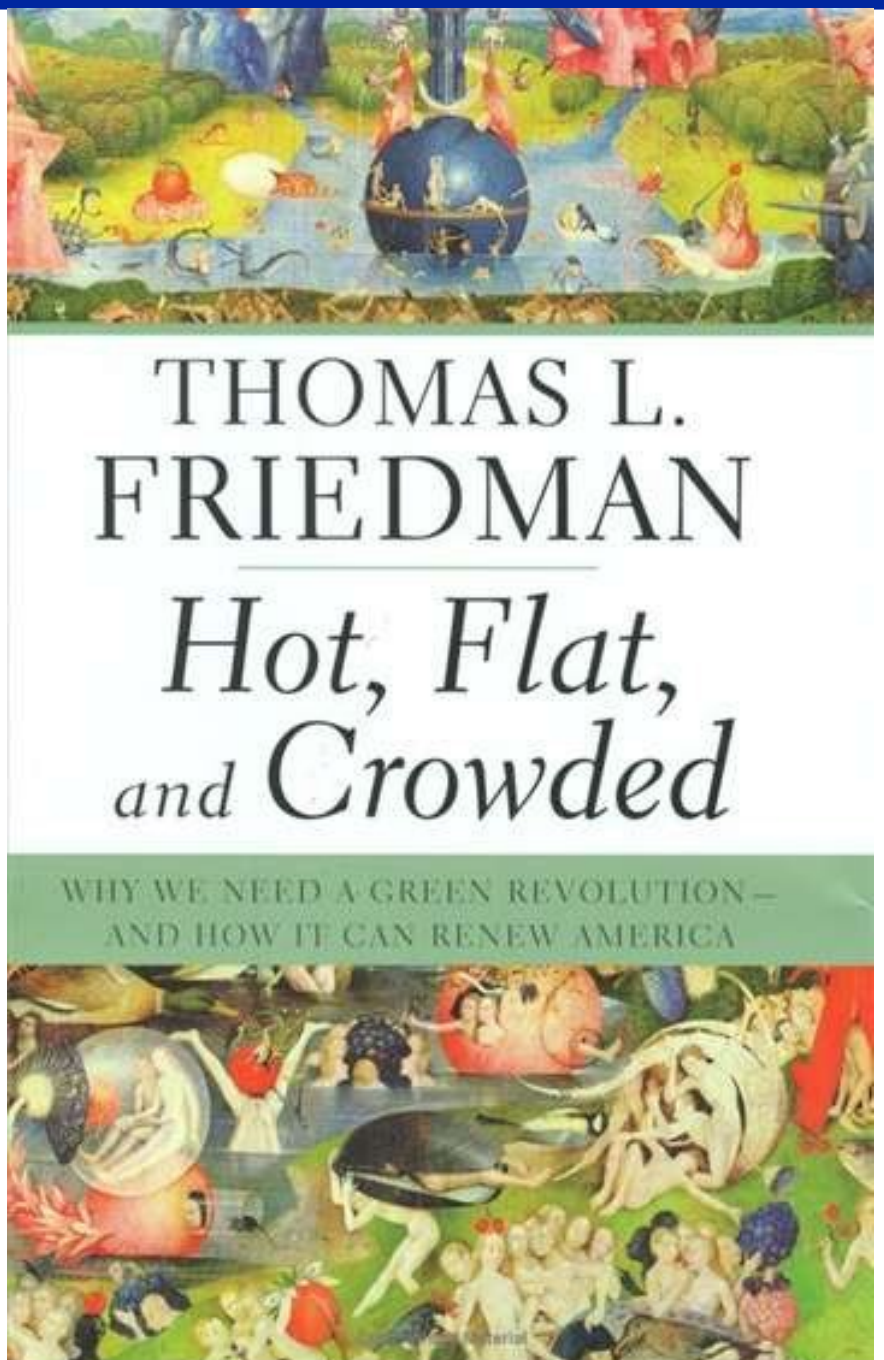


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Source: Tom DeFanti, Calit2; GreenLight PI



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



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