Project GreenLight

Measuring the Energy Cost of Applications, Algorithms, and Architectures

CENIC Awards Presentation
Long Beach, CA
March 10, 2009

Larry Smarr, Tom DeFanti, Greg Hidley
California Institute for Telecommunications and Information Technology, UCSD

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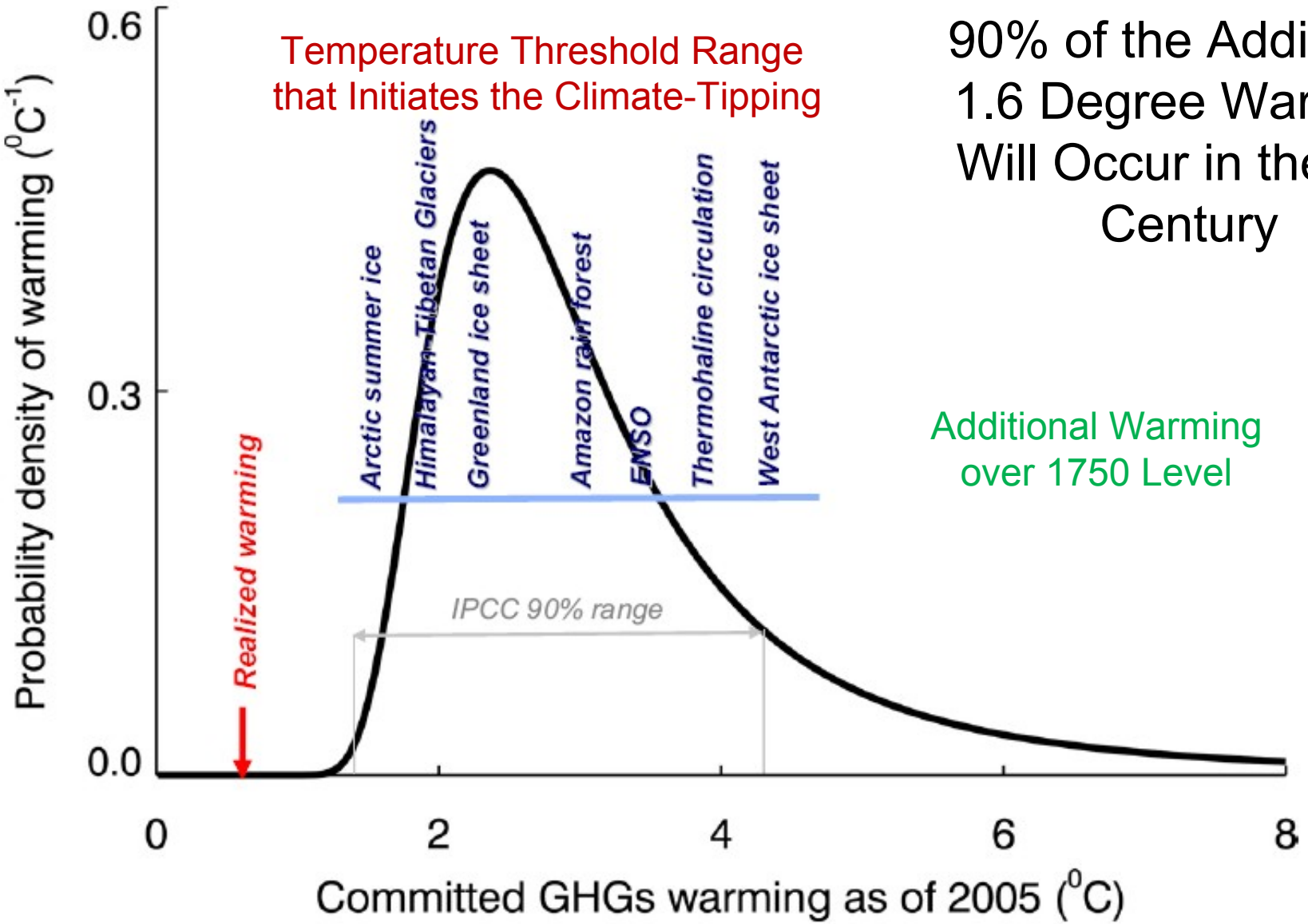
Calit2's GreenLight Project Receives CENIC's 2009 Innovations in Networking Award--Experimental-Developmental Applications



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

The Planet is Already Committed to a Dangerous Level of Warming



90% of the Additional 1.6 Degree Warming Will Occur in the 21st Century

Additional Warming over 1750 Level

V. Ramanathan and Y. Feng, Scripps Institution of Oceanography, UCSD
September 23, 2008
www.pnas.org/content/105/38/14245.abstract

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 to 1990 Levels
    - 15% Reduction from 2008 Levels
    - 4 Tons of CO_2-equiv. 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 Elect Obama Has Endorsed the AB32 2020 Goal

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

Applications of ICT
could enable emissions reductions
of 7.8 Gt CO_2e in 2020,
or 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.



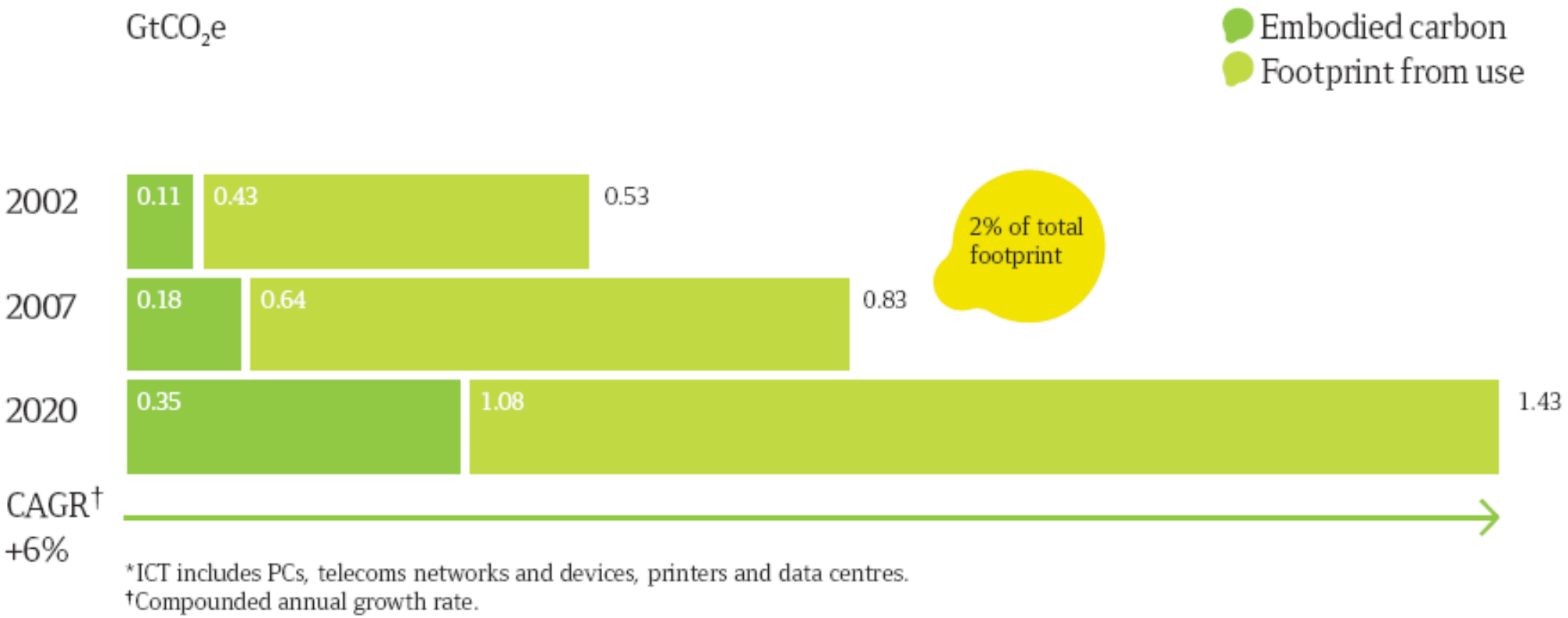


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www.smart2020.org

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



But ICT is Growing at 6% Annually!

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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

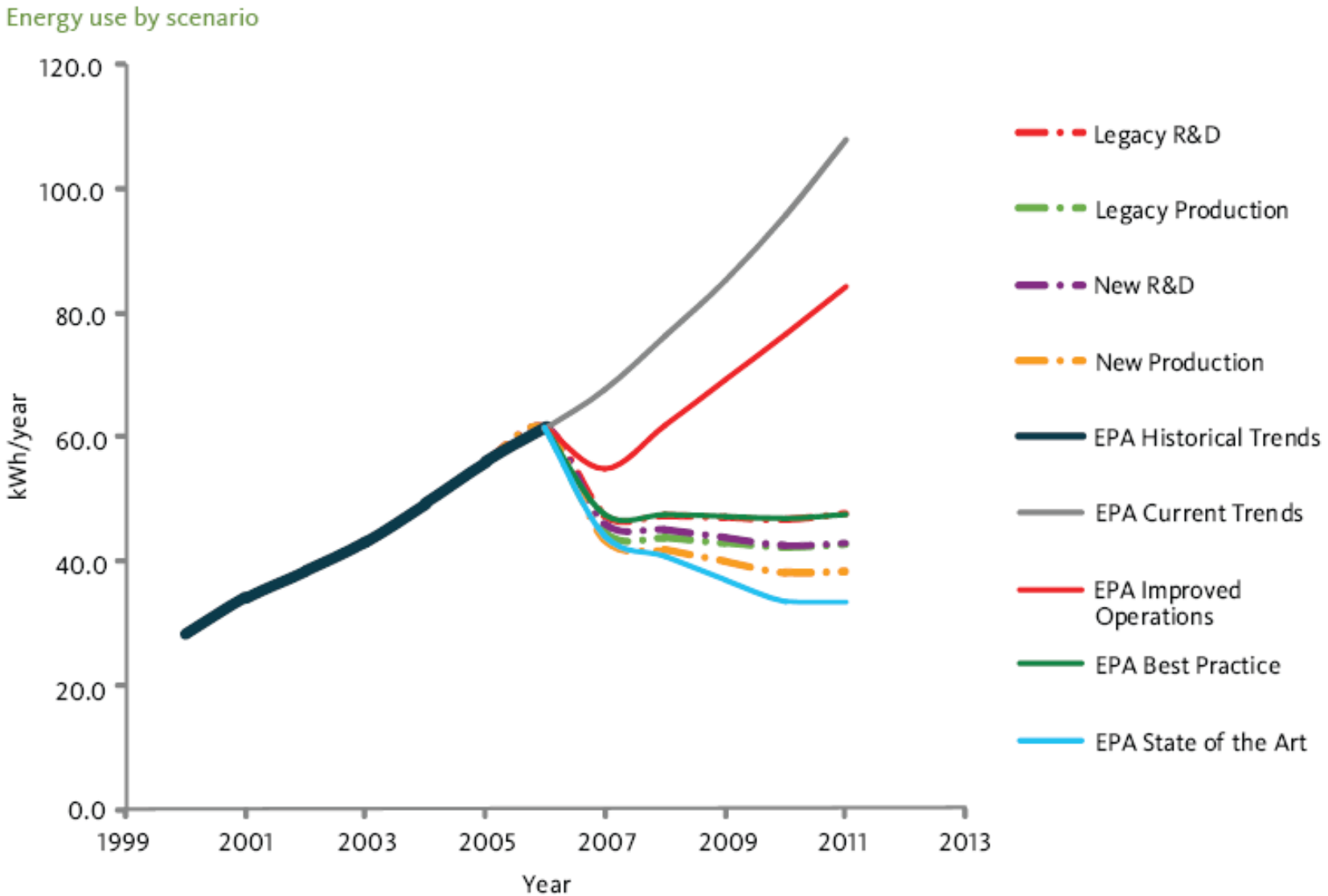
By John Fontana , Network World , 01/09/2008

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,

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

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 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**



$2M NSF-Funded GreenLight Project

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

Source: Tom DeFanti, Calit2; GreenLight PI

The GreenLight Project: Instrumenting the Energy Cost of Computational Science

- **Focus on 5 Communities with At-Scale Computing Needs:**
  - **Metagenomics**
  - **Ocean Observing**
  - **Microscopy**
  - **Bioinformatics**
  - **Digital Media**



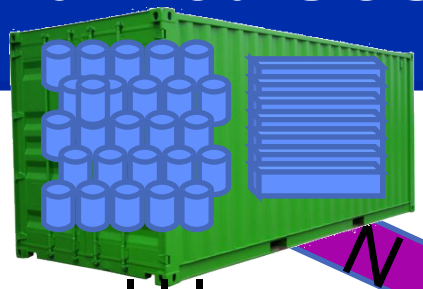


- **Measure, Monitor, & Web Publish Real-Time Sensor Outputs**
  - **Via Service-oriented Architectures**
  - **Allow Researchers Anywhere To Study Computing Energy Cost**
  - **Enable Scientists To Explore Tactics For Maximizing Work/Watt**
- **Develop Middleware that Automates Optimal Choice of Compute/RAM Power Strategies for Desired Greenness**
- **Partnering With Minority-Serving Institutions Cyberinfrastructure Empowerment Coalition**

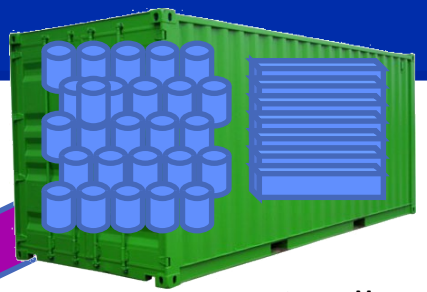
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Source: Tom DeFanti, Calit2; GreenLight PI

Planned UCSD Energy Instrumented Cyberinfrastructure



Active Data Replication



N x 10 Gbit

N x 10 Gbit

Eco-Friendly Storage and Compute

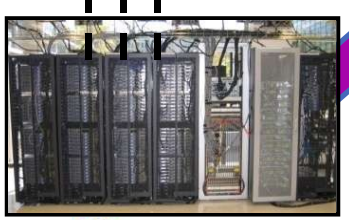
"Network in a box"
- > 200 Connections
- DWDM or Gray Optics



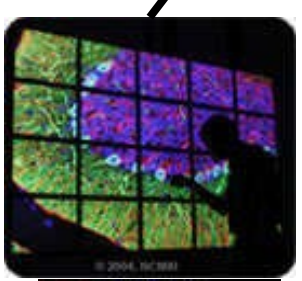
10 Gigabit L2/L3 Switch

Wide-Area 10G
- Cenic/HPR
- NLR Cavewave
- Cinegrid
- …

On-Demand Physical Connections



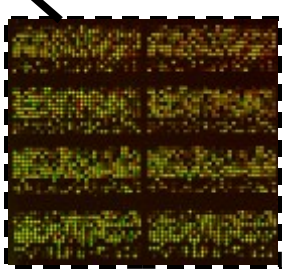
camera Marine Microbial Ecology



NCMIR NATIONAL CENTER for MICROSCOPY and IMAGING RESEARCH at San Diego an NIH supported resource center



NBCR



Microarray

Your Lab Here

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ROCKS www.rocksclusters.org

Source:Phil Papadopoulos, SDSC/Calit2

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Threat to CI Deployment—CSE 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

http://greenlight.calit2.net

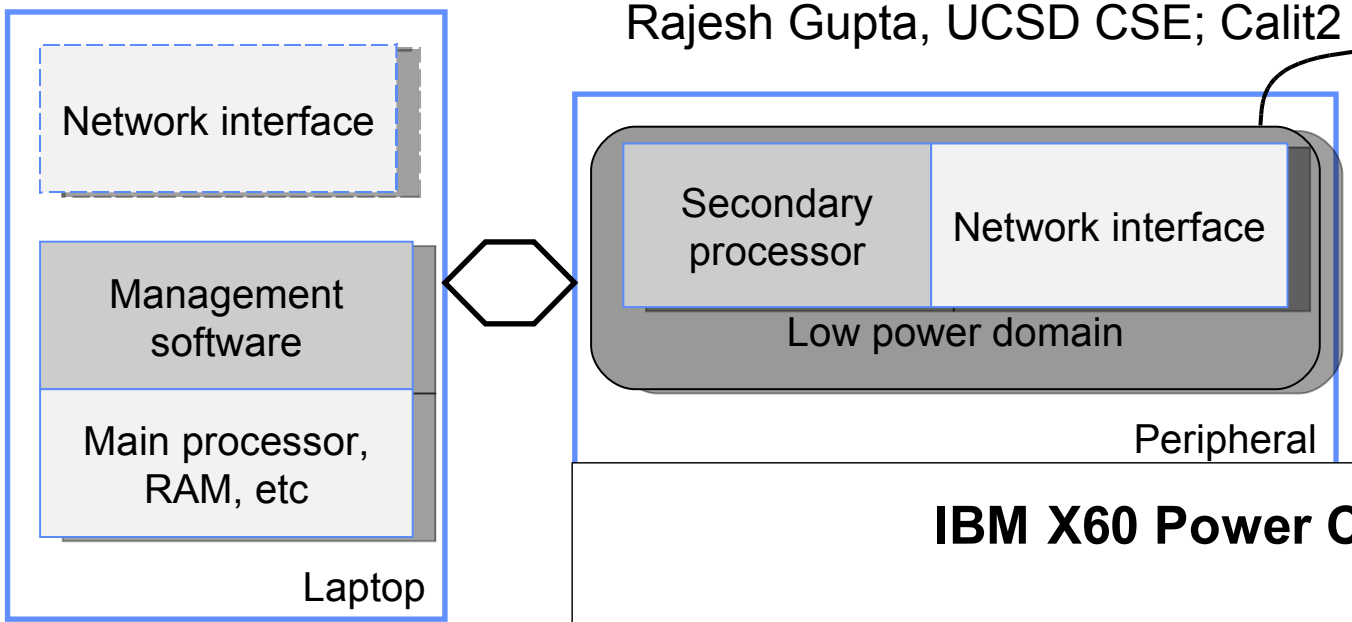
Source: Tom DeFanti, Calit2; GreenLight PI

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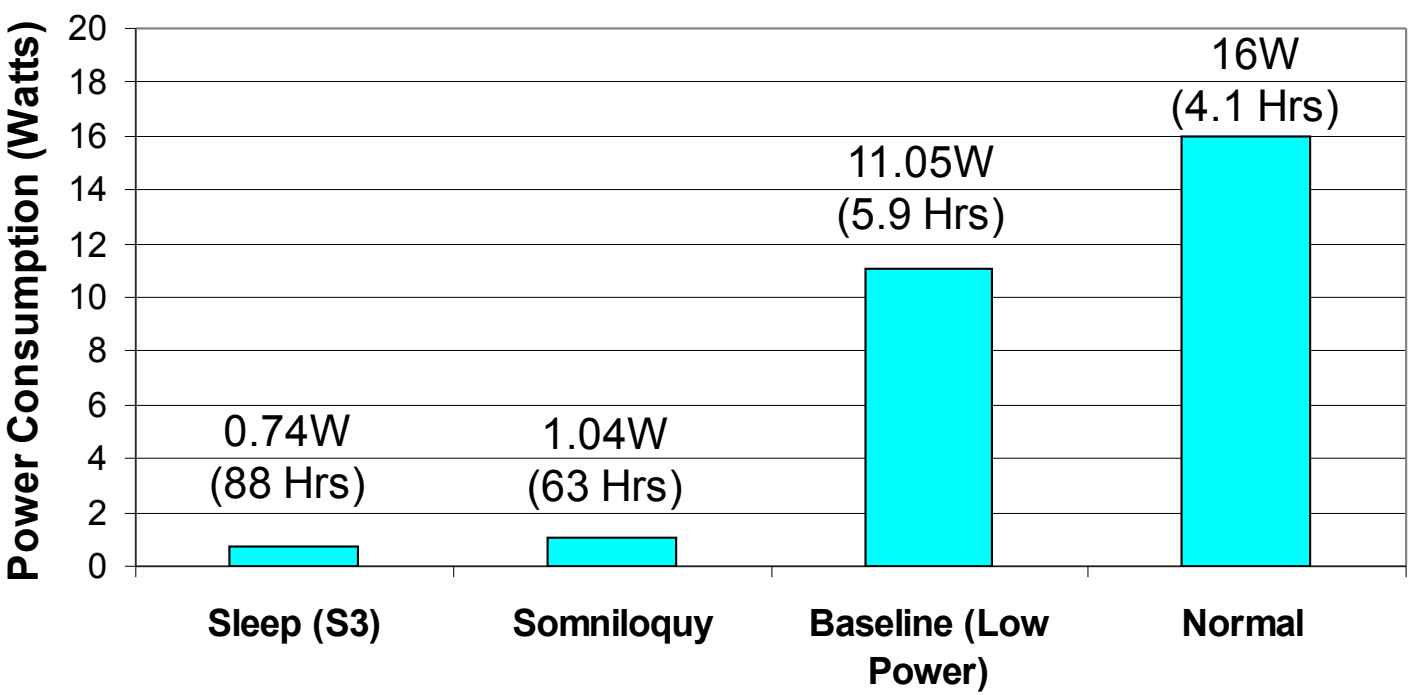
GreenLight Project: Putting Machines To Sleep Transparently

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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Improve Mass Spectrometry's Green Efficiency By Matching Algorithms to Specialized Processors

- **Inspect Implements the Very Computationally Intense MS-Alignment Algorithm for Discovery of Unanticipated Rare or Uncharacterized Post-Translational Modifications**
- **Solution: Hardware Acceleration with a FPGA-Based Co-Processor**
  - **Identification and Characterization of Key Kernel for MS-Alignment Algorithm**
  - **Hardware Implementation of Kernel on Novel FPGA-based Co-Processor (Convey Architecture)**
- **Results:**
  - **300x Speedup & Increased Computational Efficiency**

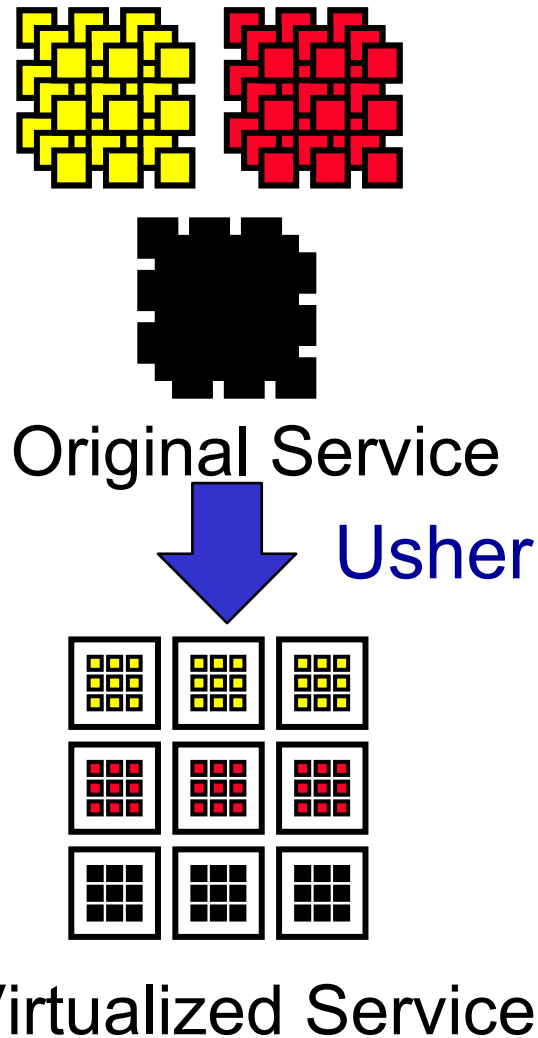
Large Savings in
Energy Per Application Task

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Virtualization at Cluster Level for Consolidation and Energy Efficiency

Source: Amin Vadhat, CSE, UCSD



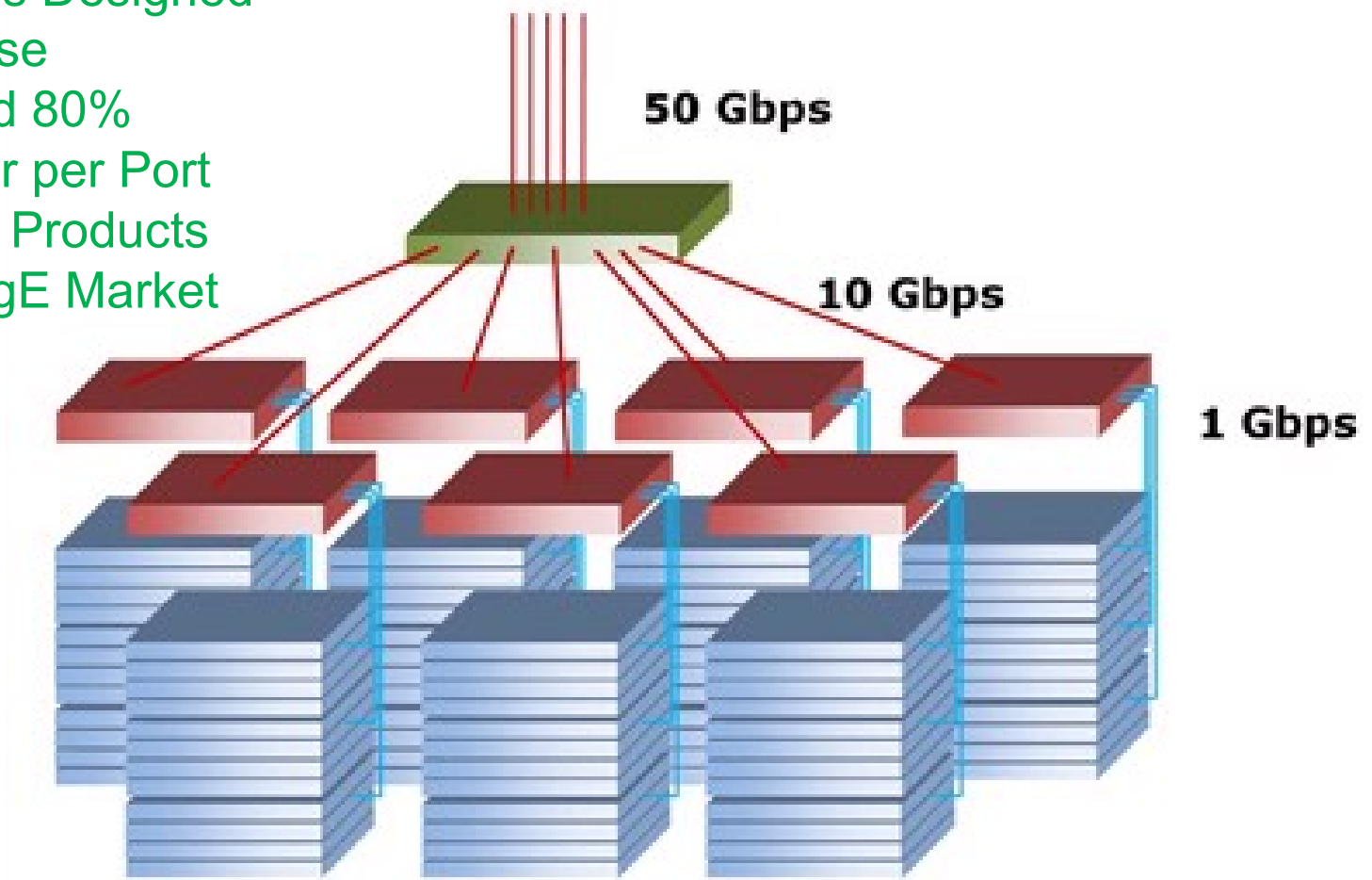
- **Fault Isolation and Software Heterogeneity, Need to Provision for Peak Leads to:**
  - **Severe Under-Utilization**
  - **Inflexible Configuration**
  - **High Energy Utilization**
- **Usher / DieCast enable:**
  - **Consolidation onto Smaller Footprint of Physical Machines**
  - **Factor of 10+ Reduction in Machine Resources and Energy Consumption**

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cns center for networked systems it²

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).

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

The GreenLight Project Focuses on Minimizing Energy for Key User Communities



- Microbial Metagenomics
- Ocean Observing
- Microscopy
- Bioinformatics
- Digital Media—CineGrid Project
  - Calit2 will Host TB of Media Assets in GreenLight CineGrid Exchange to Measure and Propose Reductions in the "Carbon Footprint" Generated by:
    - File Transfers and
    - Computational Tasks
  - Required for Digital Cinema and Other High Quality Digital Media Applications

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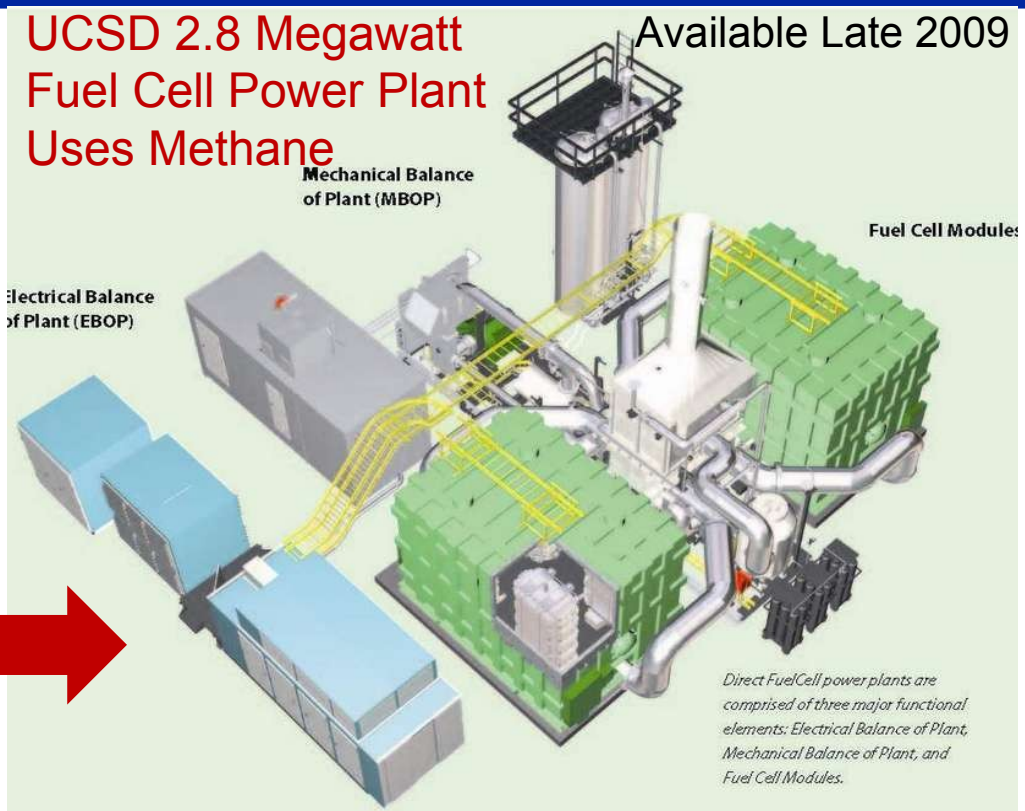
UCSD is Installing Zero Carbon Emission Solar and Fuel Cell DC Electricity Generators

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



UCSD 2.8 Megawatt Fuel Cell Power Plant Uses Methane

Available Late 2009





2 Megawatts of Solar Power Cells Being Installed

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Zero Carbon GreenLight Experiment: Direct 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)?

DC Fuel Cell 2800kWatts
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

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Toward "Zero Carbon" ICT
Green Cloud Computing and Storage

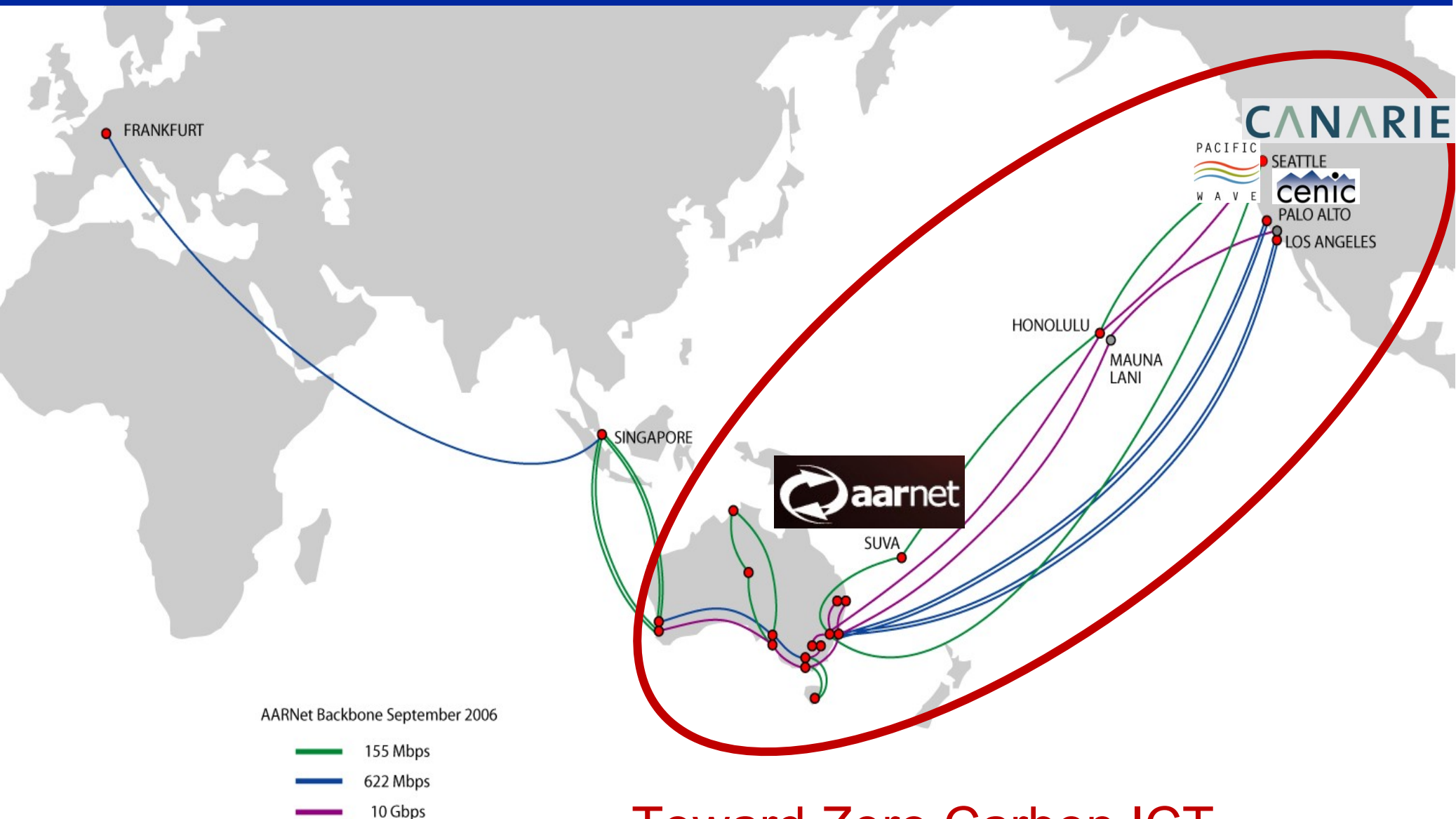
- **Purchasing Green Power Locally is Expensive with Significant Transmission Line Losses**
  - **Demand for Green Power Within Cities is Growing Dramatically**
  - **ICT Facilities Don't Need To Be Located In Cities**
- **But Most Renewable Energy Sites are Very Remote and Impractical to Connect to Electrical Grid**
  - **Can be Easily Reached by an Optical Network**
  - **Provide Independence from Electrical Utility**
  - **Savings in Transmission Line Losses (Up To 15% Alone)**
  - **Plus Carbon Offsets Can Pay for Moving ICT Facilities to Renewable Energy Site**
- **Calit2 is Discussing Partnering with Canada**
  - **Move a GreenLight Facility to Hydro Site in British Columbia,**
  - **Link by 10Gbps Optical Fiber to Calit2—Offer to Remote Users**

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Source: Bill St. Arnaud, CANARIE, Canada

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Coupling AARNet - CENIC/PW - CANARIE Optical Nets: An Australian-U.S.-Canada Green Cloud Testbed



Toward Zero Carbon ICT

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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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International Symposia on Green ICT

CUBIN

Symposium on Sustainability of the Internet and ICT

THE UNIVERSITY OF MELBOURNE

November 25 & 26, 2008, The University of Melbourne

January 22-23, 2009

Greening the Internet Economy

ICT & GLOBAL CHANGE



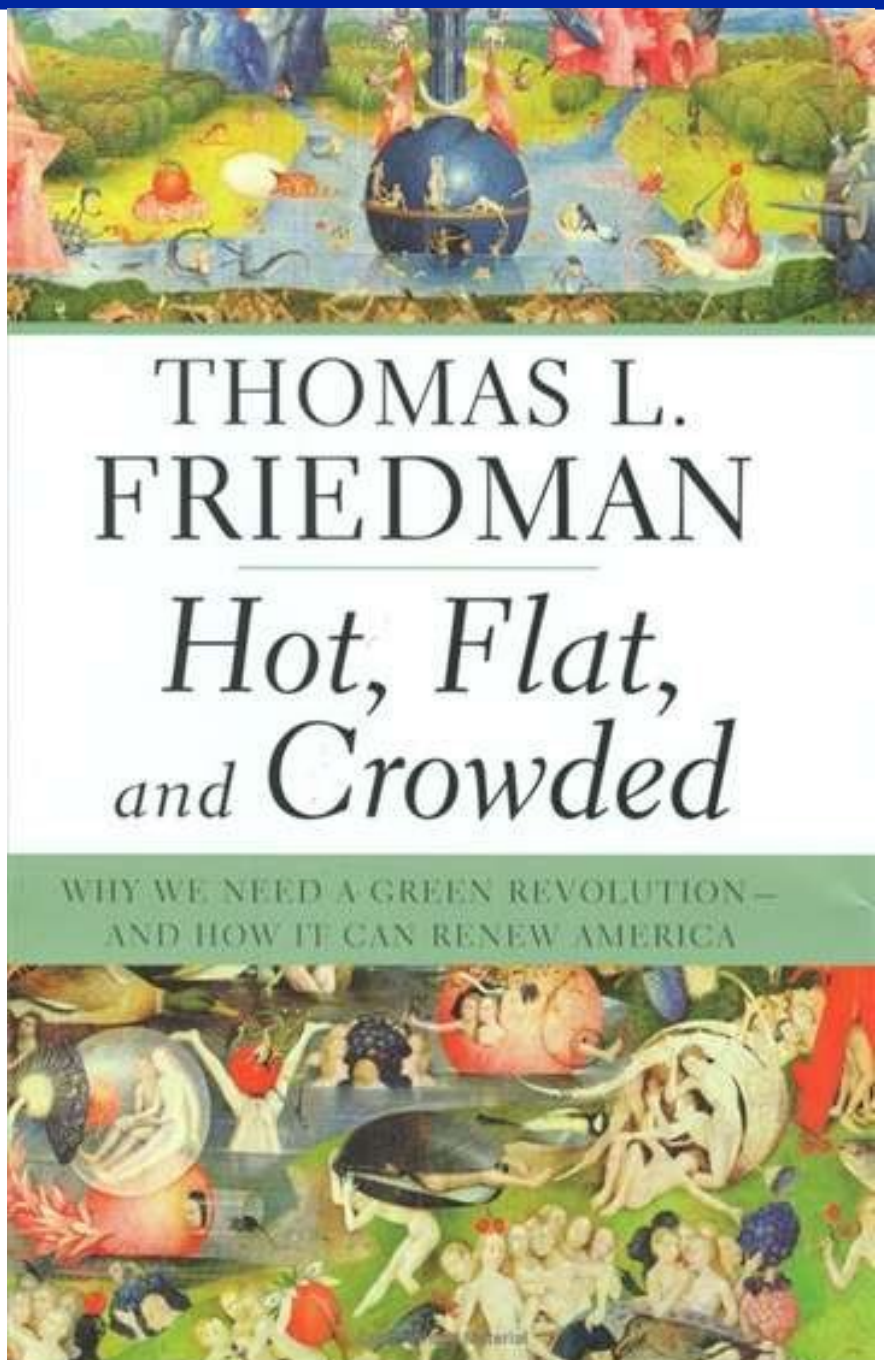
California Public Utilities Commission

Calit2

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Co-Hosted By Calit2 & CPUC

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



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