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

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

Outside Beijing 11/9/2008

NASA satellite image
“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
California and Himalayan Asia: Snow and Ice are Critical Fresh Water Reservoirs

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

"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
“It Will Be the Biggest Single Peacetime Project Humankind Will Have Ever Undertaken”
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 CO₂-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
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.

SMART 2020: Enabling the low carbon economy in the information age

www.smart2020.org
The Global ICT Carbon Footprint is Roughly the Same as the Aviation Industry Today

But ICT Emissions are Growing at 6% Annually!

<table>
<thead>
<tr>
<th>Year</th>
<th>Embodied carbon</th>
<th>Footprint from use</th>
<th>Total</th>
<th>CAGR(^+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>0.11</td>
<td>0.43</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>0.18</td>
<td>0.64</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>0.35</td>
<td>1.08</td>
<td>1.43</td>
<td>+6%</td>
</tr>
</tbody>
</table>

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
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

% of GtCO₂e

2002
- RoW*: 17
- China: 18
- EIT†: 11
- Others: 13
- US and Canada: 25
  - % of 0.53

2007
- RoW*: 23
- China: 23
- EIT†: 12
- Others: 10
- US and Canada: 14
  - % of 0.83

2020
- RoW*: 27
- China: 29
- EIT†: 10
- Others: 7
- US and Canada: 14
  - % of 1.43

CAGR %
- RoW*: 9
- China: 9
- EIT†: 6
- Others: 3
- US and Canada: 4
  - % of 3

*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)
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 CO₂ 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?

Source: Rod Tucker, U Melbourne
Electricity Usage by U.S. Data Centers: Emission Reductions are Underway

Source: Silicon Valley Leadership Group Report July 29, 2008
The NSF-Funded GreenLight Project
Giving Users Greener Compute and Storage Options

UCSD Structural Engineering Dept. Conducted Sun MD Tests May 2007

UCSD Jacobs School of Engineering

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

- 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
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

www.calit2.net/newsroom/release.php?id=1485
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
New Techniques for Dynamic Power and Thermal Management to Reduce Energy Requirements

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

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

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

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

IBM X60 Power Consumption

- Sleep (S3): 0.74W (88 Hrs)
- Somniloquy: 1.04W (63 Hrs)
- Baseline (Low Power): 11.05W (5.9 Hrs)
- Normal: 16W (4.1 Hrs)
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).
Consolidating Dispersed Faculty Clusters Over the Fiber Connected UCSD Campus Research CI

SDSC Triton Components

Cluster Condo

HPC System

UC Grid Pilot

PetaScale Data Analysis Facility

Digital Collections Lifecycle Management

Research Cluster

OptIPortal

UCSD Storage

Source: Phil Papadopoulos, SDSC/Calit2

DNA Arrays, Mass Spec., Microscopes, Genome Sequencers

N x 10Gbe
Power Management in the Cellular Infrastructure: Calit2 Team Achieves 58% Power Amplifier Efficiency

Standard Commercial Base Station Power Amp is 10% Efficient

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

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

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

http://mscada01.ucsd.edu/ion/
Comparision Between UCSD Buildings: kW/sqFt Year Since 1/1/09

Calit2 and CSE are Very Energy Intensive Buildings
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

- 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:

90% of all Auto Innovations are Now Software-Driven
Reducing Traffic Congestion:
Calit2 California Peer-to-Peer Wireless Traffic Report

- Citizen to Citizen Accident Reports
- Real-Time Freeway Speeds
- “Leave Now” Paging Services

San Diego
(866) 500 0977

LA & OC
(888) 9 CALIT2

Bay Area
(888) 4 CALIT2

http://traffic.calit2.net

Source: Ganz Chockalingam, Calit2
The OptIPuter Creates an OptIPlanet Collaboratory: Enabling Data-Intensive e-Research

Over 50 OptIPortals Worldwide

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

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

Source: Maxine Brown, UIC and Robert Patterson, NCSA
Launch of the 100 Megapixel OzIPortal Kicked Off a Rapid Build Out of Australian OptIPortals
Just in Time OptIPlanet Collaboratory:
Live Session Between NASA Ames and Calit2@UCSD

Feb 19, 2009

View from NASA Ames
Lunar Science Institute
Mountain View, CA

Virtual Handshake

HD compressed 6:1

From Start to
This Image in
Less Than 2
Weeks!

NASA Interest
in Supporting
Virtual Institutes

Source: Falko Kuester, Calit2; Michael Sims, NASA

End User OptIPortal

Instruments

National LambdaRail

10G Lightpath

Campus Optical Switch

Data Repositories & Clusters

HD/4k Video Images

HPC

TeraGrid

HD/4k Video Cams

UCSD

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

Symposium on Sustainability of the Internet and ICT

November 25 & 26, 2008, The University of Melbourne

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