Digital Transformations Over the Next Decade in Energy and the Environment

The New Science of Management in a Rapidly Changing World

PwC's DiamondExchange

Tucson, AZ

October 4, 2011

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 at Ten Years





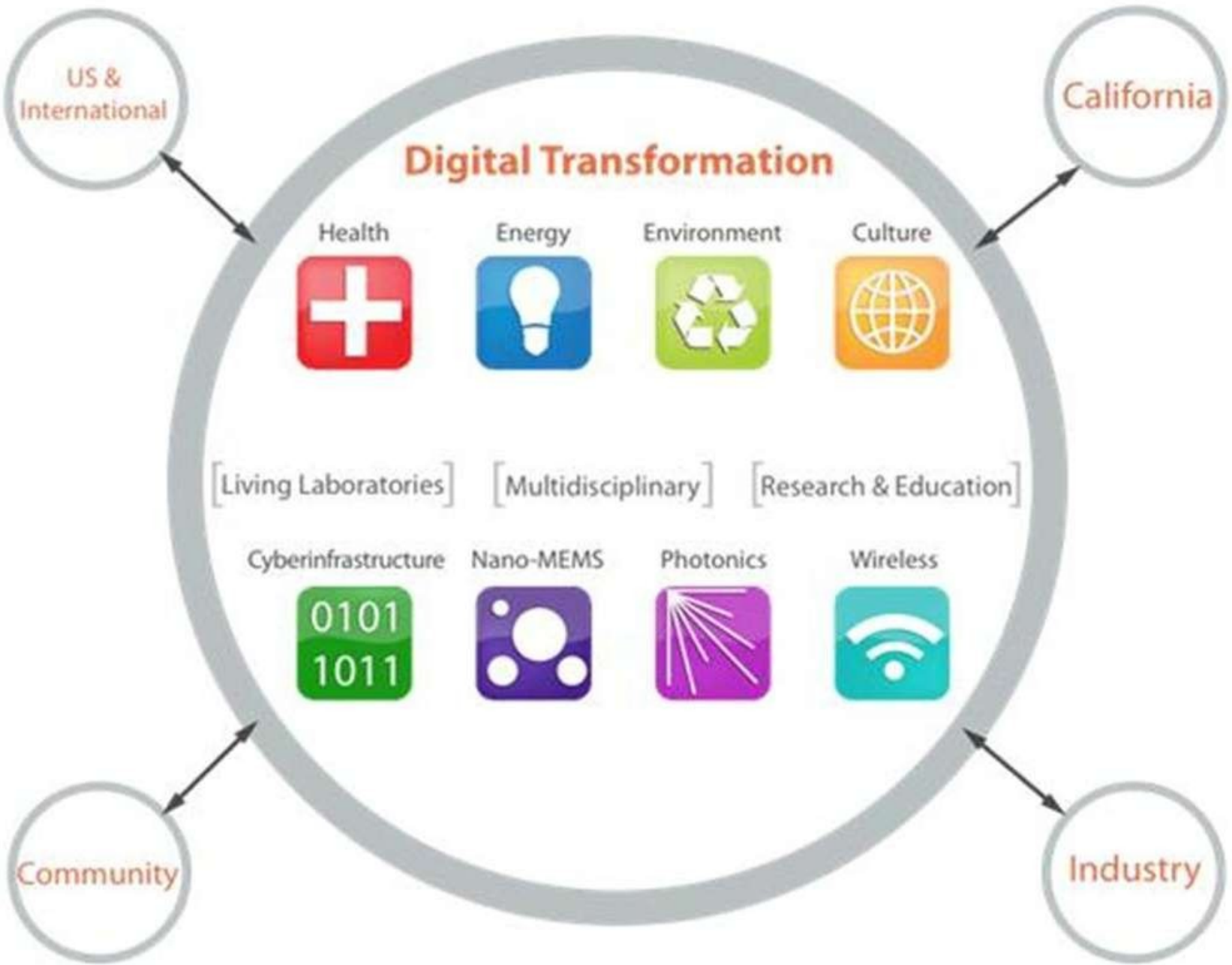
Ten-Year Review Report
from the
California Institute for Telecommunications
and Information Technology (Calit2)

to the
UC Office of the President
August 29, 2011

UC San Diego UC Irvine

- 600 Faculty from 24 Departments on Two UC Campuses
- 1000 Federal, State, Not-For-Profit, Industrial, and International Grants
- Engaged 300 companies & Interacted with 1,000 More
- Involved Over 1,000 undergraduates and 700 Graduate Students

Calit2:
the Next Decade's Path Forward

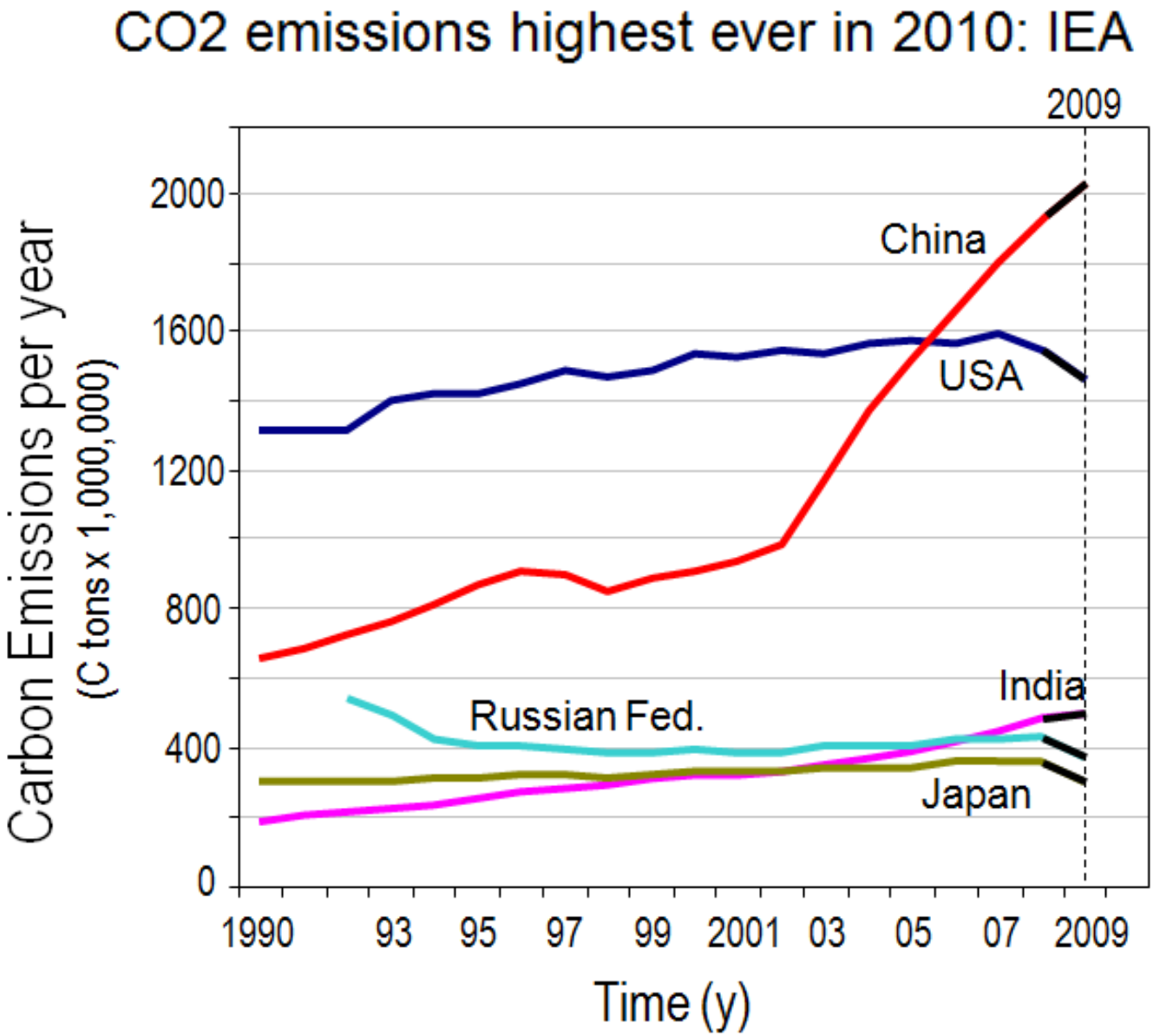


The Digital Transformation of Energy

- Trends in Future Energy Sources and Climate Change
- Moving Energy Sources from High Carbon to Low Carbon
- Increasing Energy Efficiency via Smarter Infrastructure
- Campus as Living Laboratories for the Greener Future

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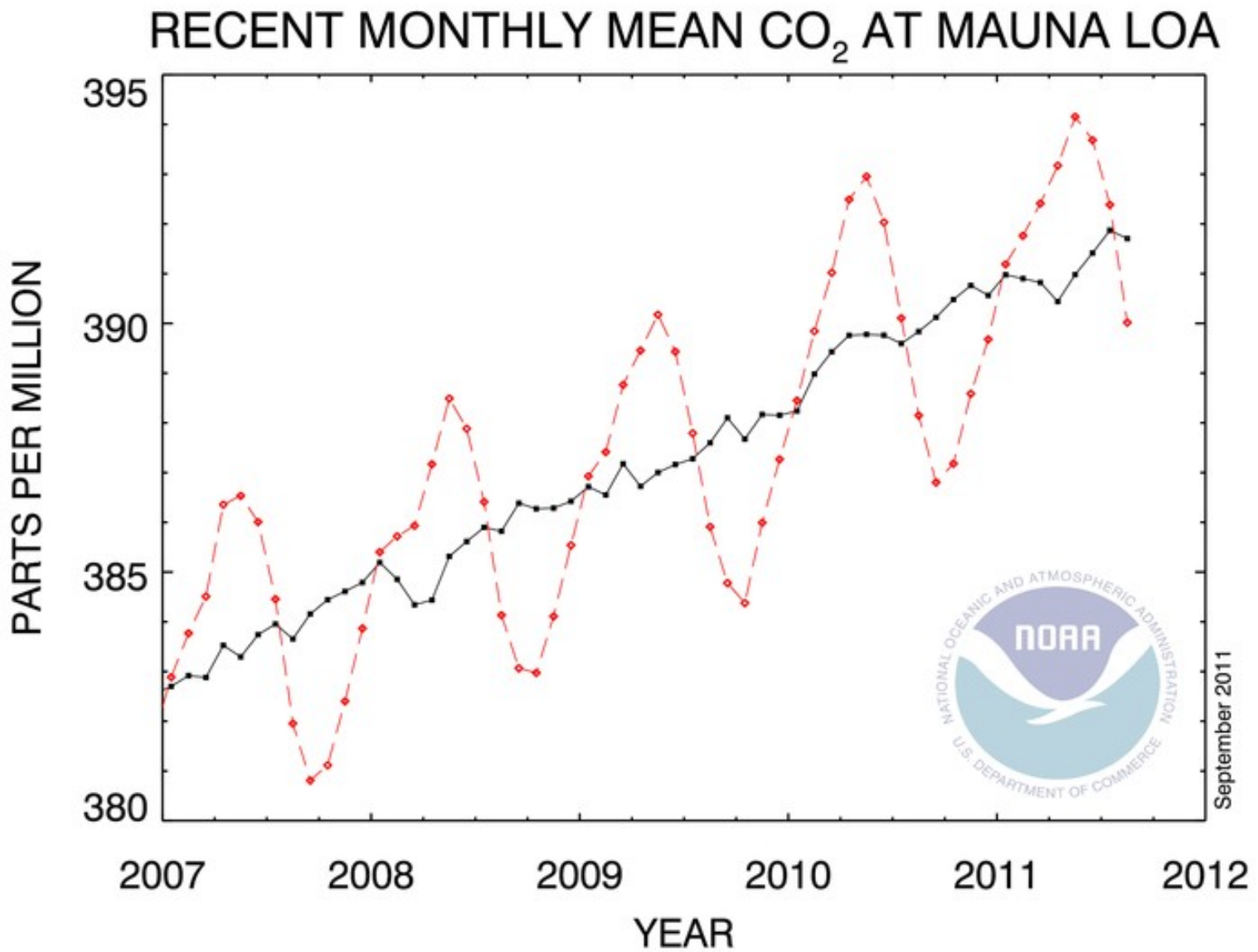
China Has Become the Most Important Driver of CO2: U.S. and China Dominate Global Emissions



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The Unrelenting Climb of CO_2
In Spite of Clear Understanding of the Problem

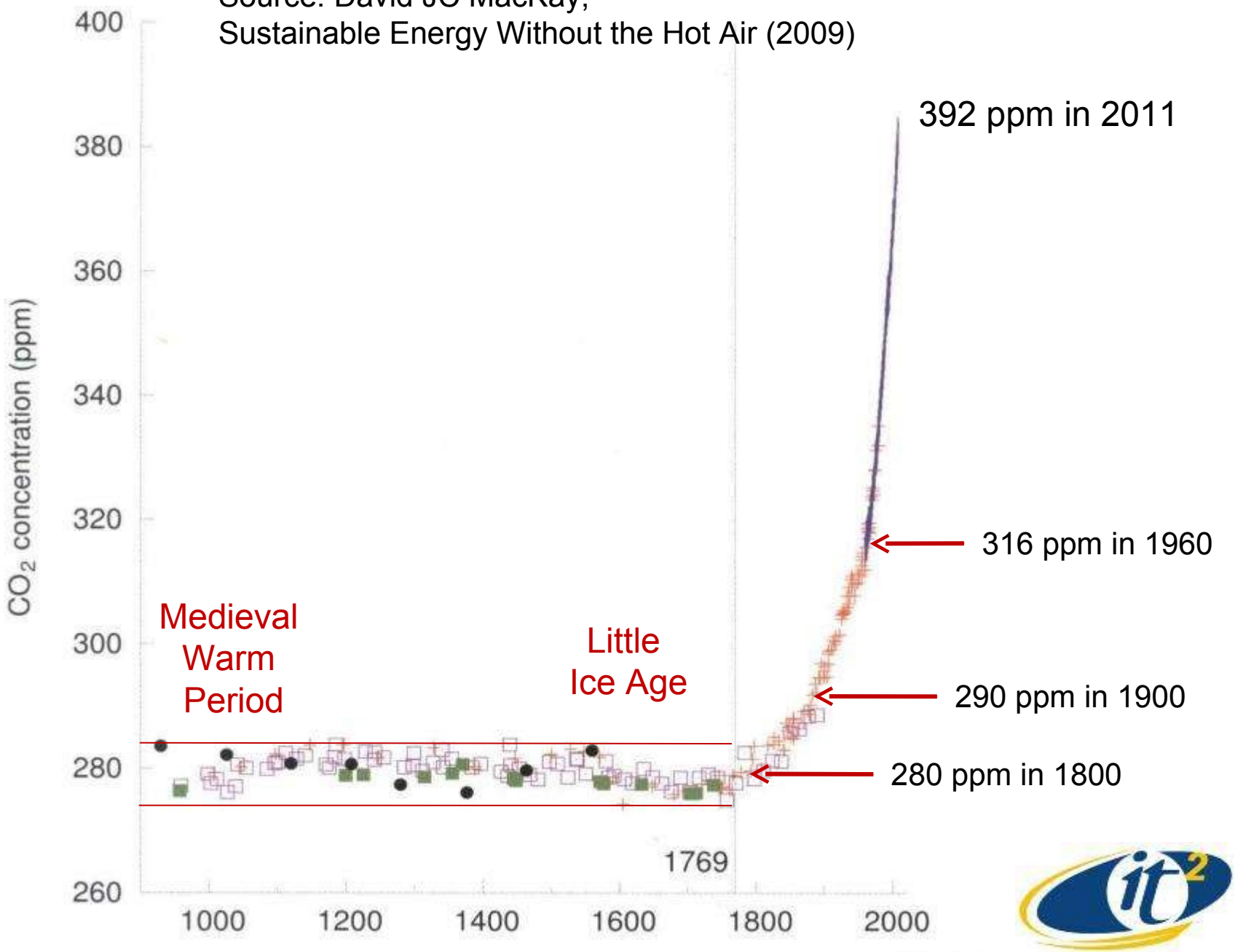


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Accelerating Increase in the Greenhouse Gas CO_2 Since Industrial Era Began

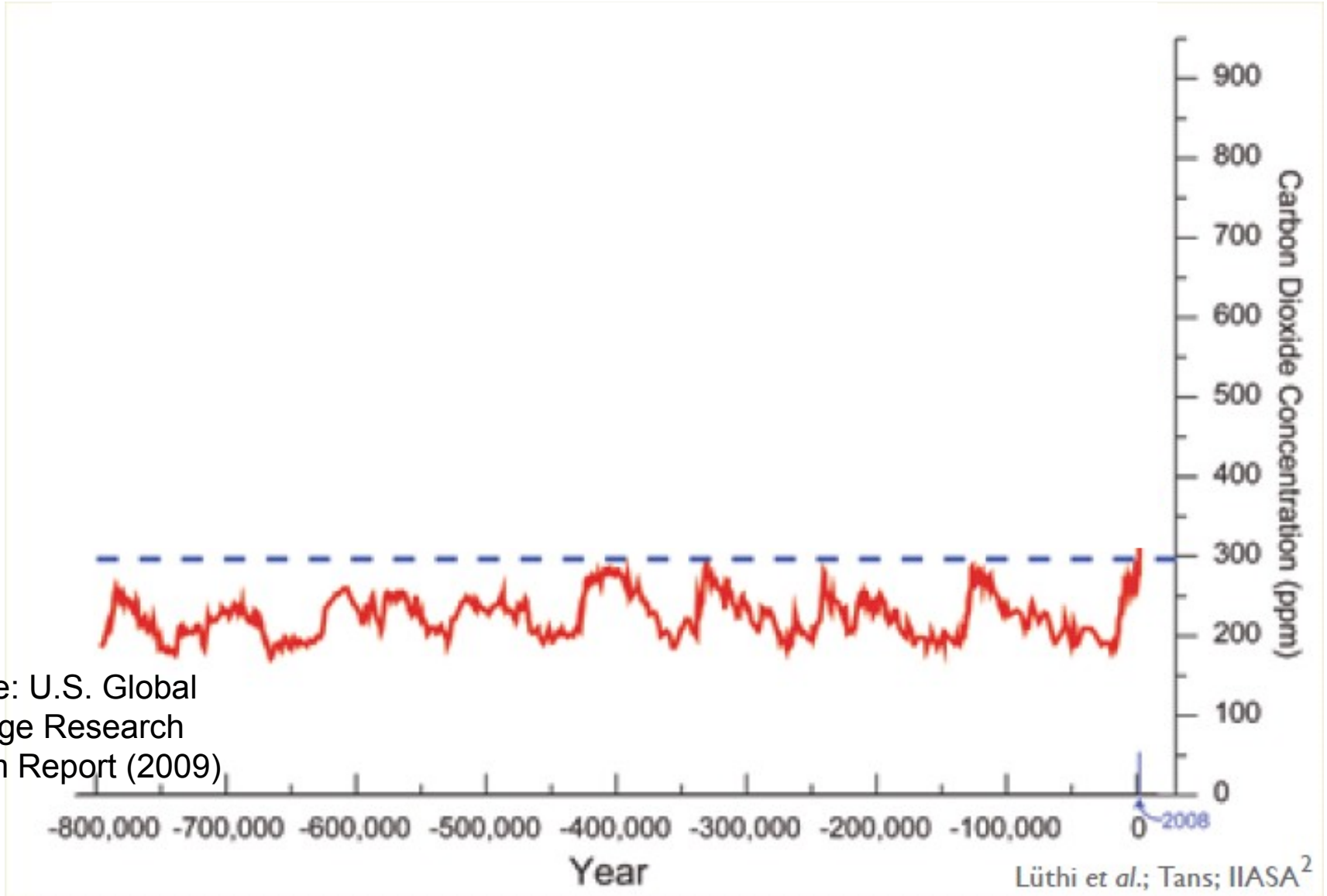
Source: David JC MacKay,
Sustainable Energy Without the Hot Air (2009)



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Atmospheric CO_2 Levels for Last 800,000 Years

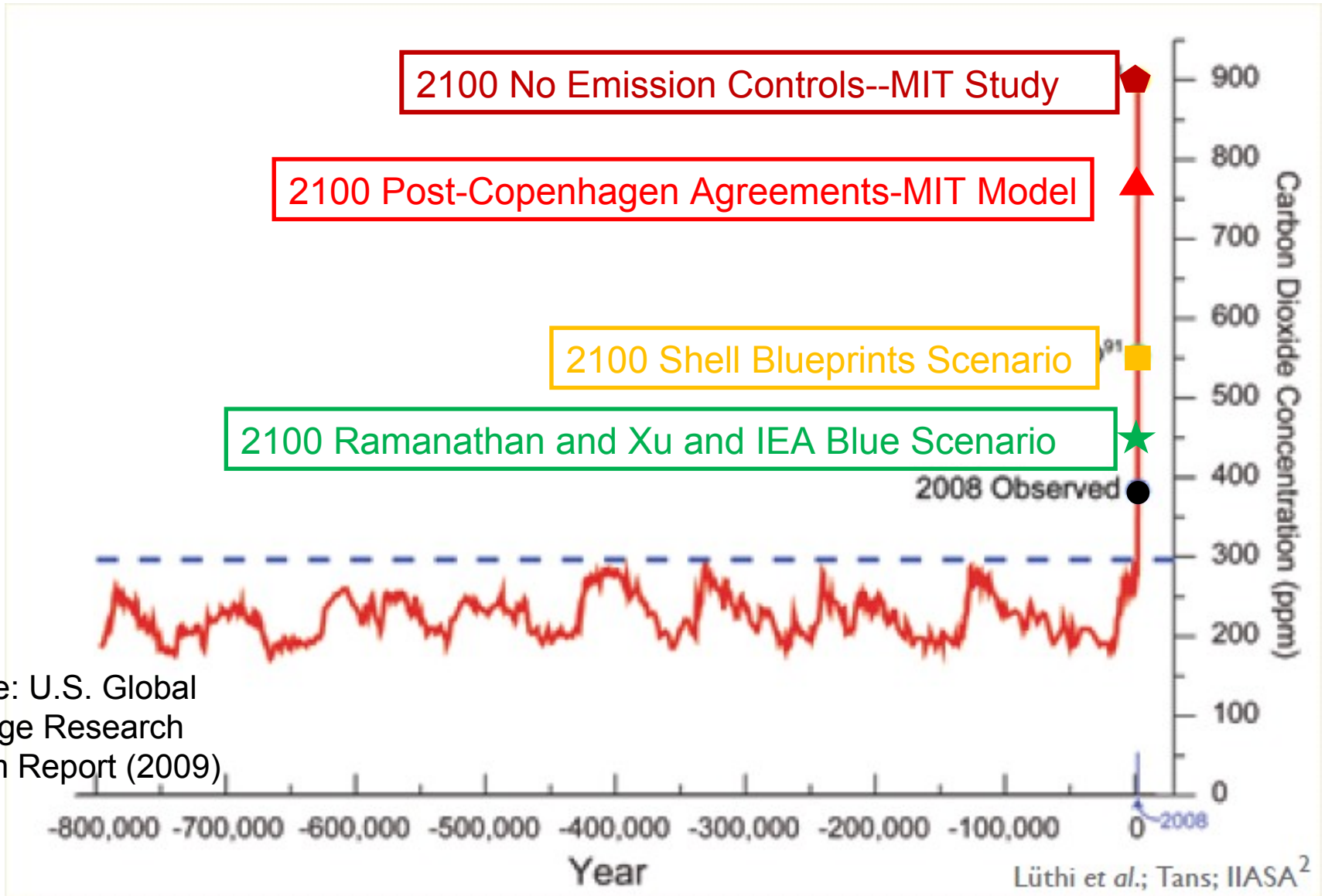


Source: U.S. Global Change Research Program Report (2009)

Graph from:
www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/download-the-report

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Atmospheric CO_2 Levels for Last 800,000 Years and Several Projections for the 21st Century



Source: U.S. Global Change Research Program Report (2009)

Graph from:
www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/download-the-report

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Limit of 2° C Agreed to at the UN Climate Change Conference 2009 in Copenhagen

"To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change."
--*the Copenhagen Accord of 18 December 2009*

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What Must the World Do To Limit CO_2-Equivalent Emissions Below 450ppm?

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

"Limiting GHG concentrations to 450 ppm CO_2-equivalent is expected to limit temperature rises to no more than 2°C above pre-industrial levels. This would be extremely challenging to achieve, requiring an explosive pace of industrial transformation going beyond even the aggressive developments outlined in the Blueprints scenario.

It would require global GHG emissions to peak before 2015, a zero-emission power sector by 2050 and a near zero-emission transport sector in the same time period…"

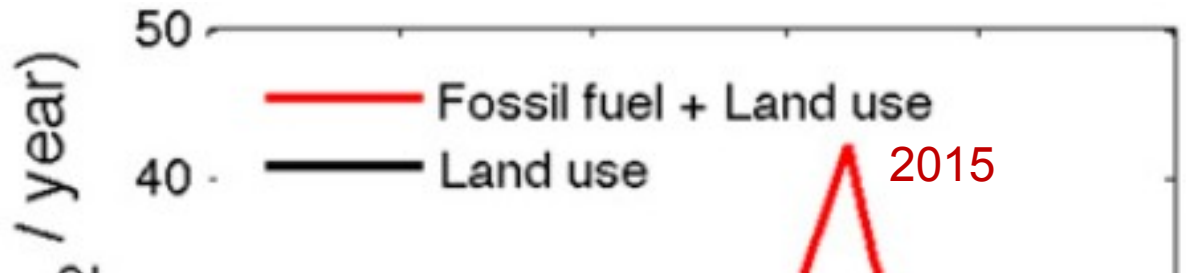


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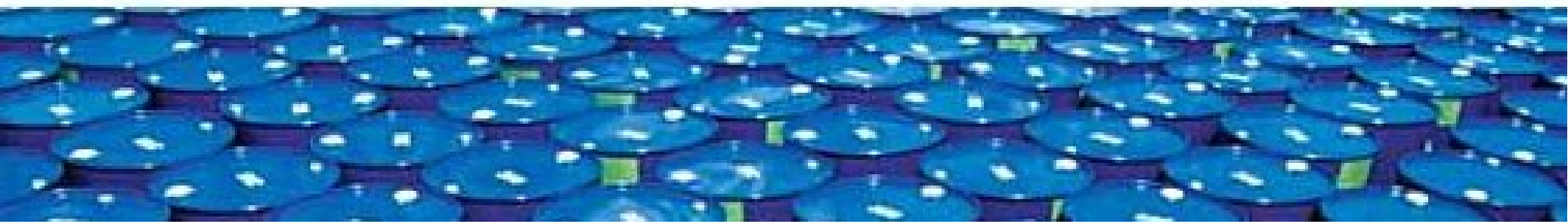
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What is Required to Limit CO2 to 450 ppm: Peak in 2015, 50% Lower by 2050 & 80% by 2100

Reduction Path 3



A THOUSAND BARRELS A SECOND



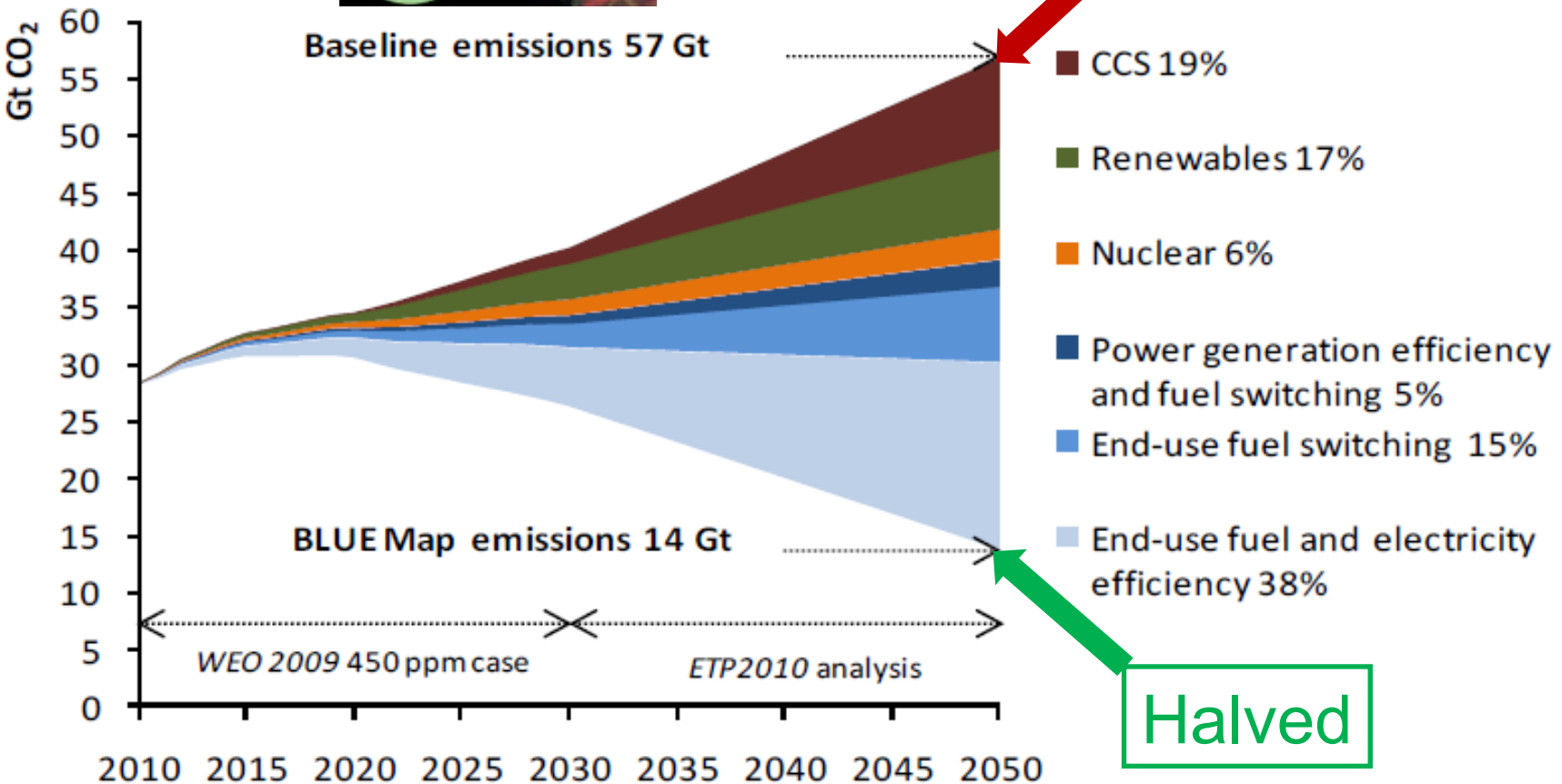
What Changes in the Global Energy System Are Required to Accomplish This Reduction Path?

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"The Copenhagen Accord for limiting global warming: Criteria, constraints, and available avenues," PNAS, v. 107, 8055-62 (May 4, 2010)
V. Ramanathan and Y. Xu, Scripps Institution of Oceanography, UCSD

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To Cut Energy Related CO_2 Emissions 50% by 2050 Requires a Radically Different Global Energy System



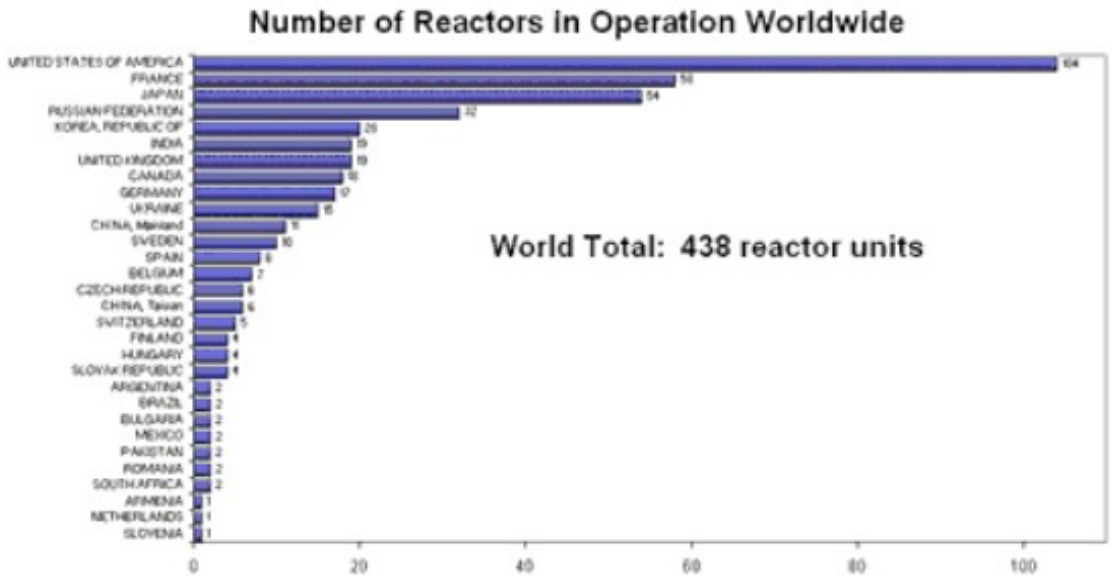


IEA BLUE Map Scenario: Abatement Across All Sectors to Reduce Emissions to Half 2005 Levels by 2050

Before Japan, Nuclear Reactors Were Being Constructed

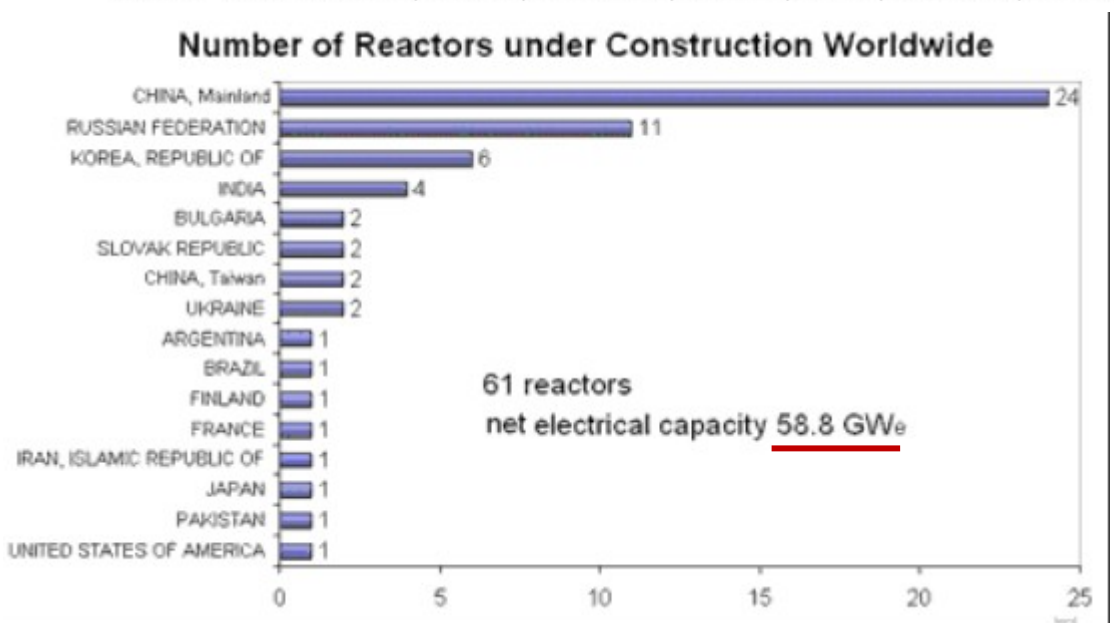
At Roughly the IEA Blue Required Rate

www.euronuclear.org/info/encyclopedia/n/nuclear-power-plant-world-wide.htm



Number of reactors in operation, worldwide, June 30, 2010 (IAEA 2010, modified)

IEA Blue Requires 30GW Added Per Year



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Must Greatly Accelerate Installation of Off-Shore Wind and Solar Electricity Generation

Each of These Projects Has Been Underway for a Decade with Intense Public Controversy





Need to Install ~30 “Cape Wind’s” (170 Turbines, 0.5 GW) Per Year Off-Shore Wind Farms: ~15GW Total Every Year Till 2050

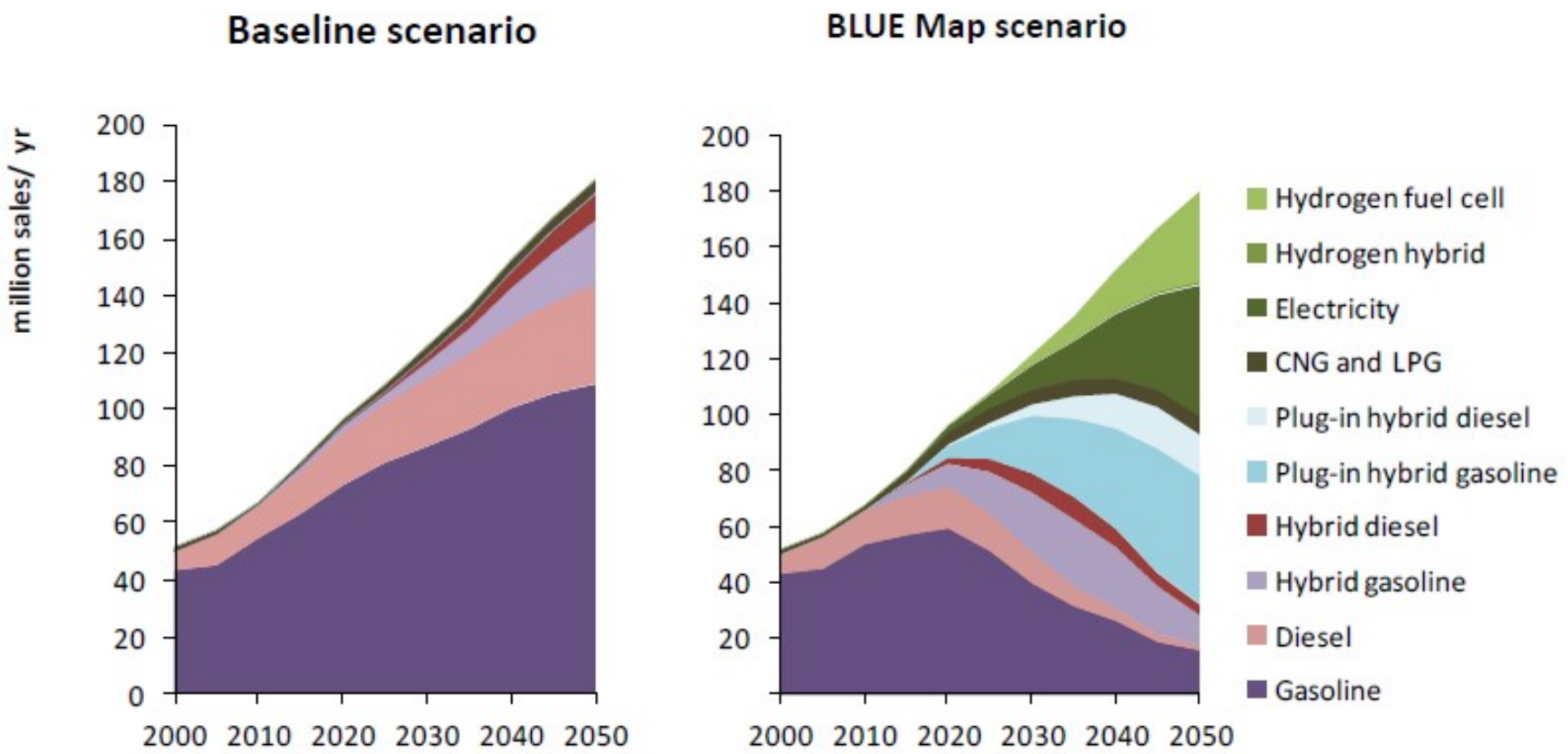
Need to Install ~20 “Anza Borrego” Arrays (30,000 Dishes, 0.75 GW) Per Year of Concentrated Solar Power: ~14 GW Total Every Year Till 2050

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IEA Blue Requires Rapid Transformation of Light Duty Vehicle Sales

Plug-In Hybrid, All-Electric & Fuel-Cell Vehicles Dominate Sales After 2030



OECD Transport Emissions are ~60% Less Than in 2007,
But Those in Non-OECD Countries are ~60% Higher by 2050



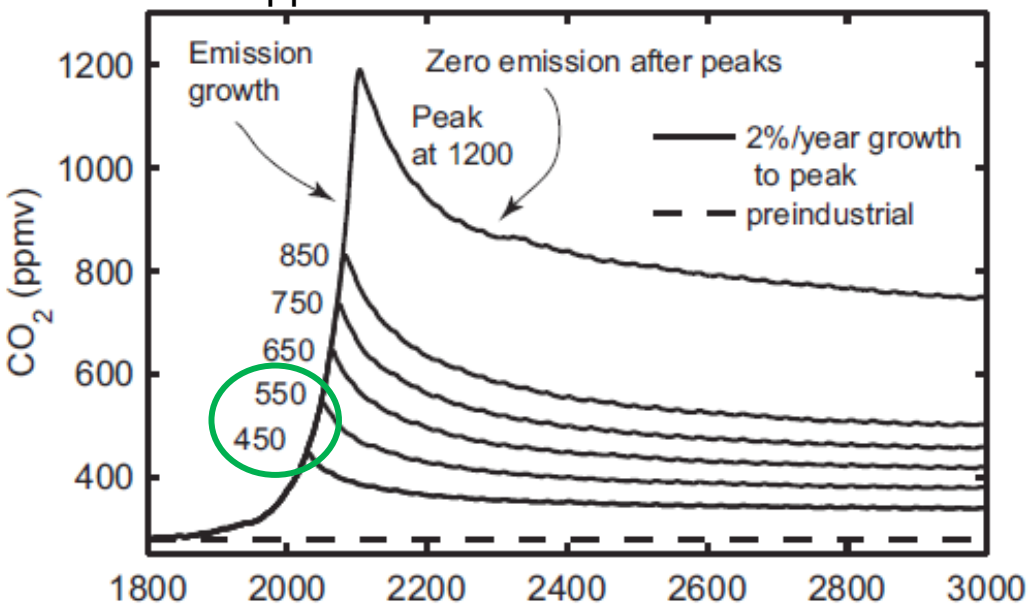
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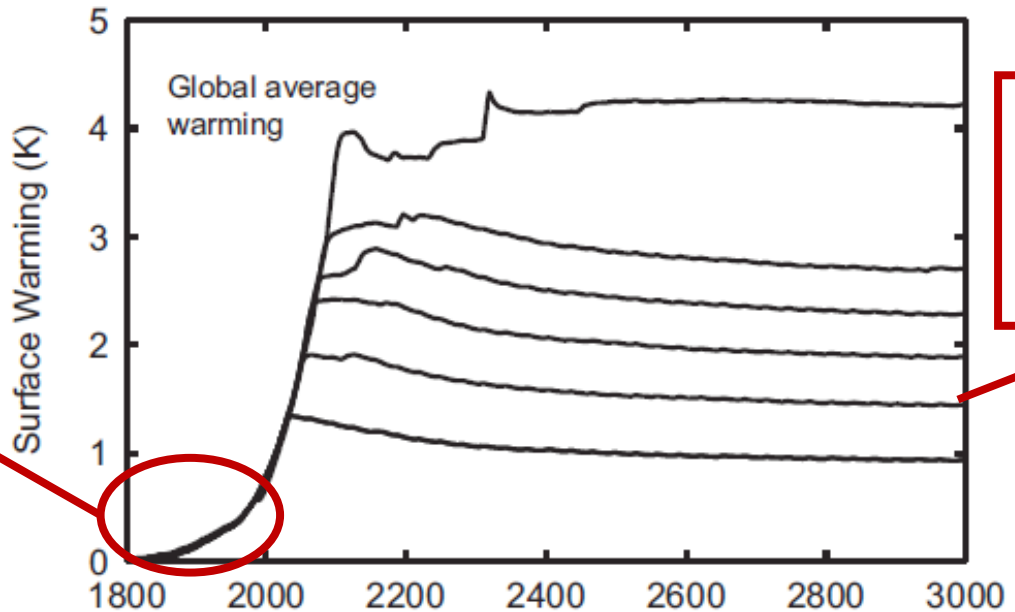
We Are Transitioning to a New Climate State -- Unlike the Rapid Recovery with Acid Rain or Ozone Hole

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

Assumes
CO_2 Increases
to a Maximum
and Then Emissions
Abruptly Stop



25% of CO2 Will Persist for 100,000 Years



Warming Persists for Over 1000 Years

Warming During the Industrial Age -- Last 200 Years

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The Disruptive Transition to Intelligent, Secure, Low Carbon, and Climate Adaptive Infrastructure

- **The First Wave:**
  - **Infrastructure Will Gradually Become "Intelligent"**
- **The Second Wave:**
  - **From High to Low Carbon Emissions**
- **The Third Wave:**
  - **Climate Change is Now Occurring on a Time Scale Commensurate With the Lifetime of Infrastructure**

Changing Infrastructure is Key to Future:
40% of U.S. CO2 Emissions Are From Buildings

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Over 670 College and University President's Have Signed the Climate Commitment Pledge

Can Universities Live 5-10 Years Ahead of Cities -- Helping Accelerate the Climate Adaptation of Global Society?



- **"We recognize the need to reduce the global emission of greenhouse gases by 80% by mid-century.**
- **Within two years of signing this document, we will develop an institutional action plan for becoming climate neutral."**

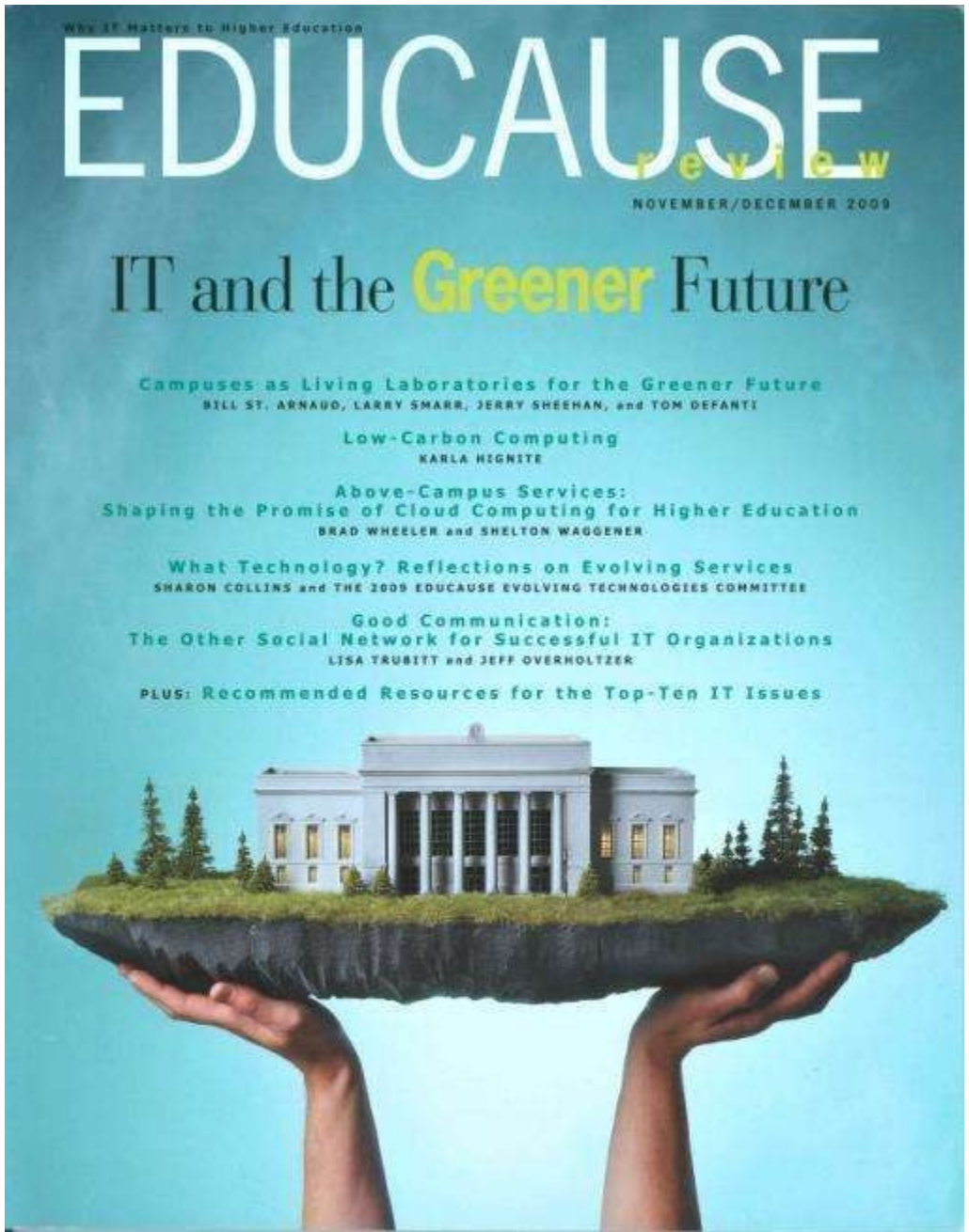
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www.presidentsclimatecommitment.org

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Making University Campuses Living Laboratories for the Greener Future

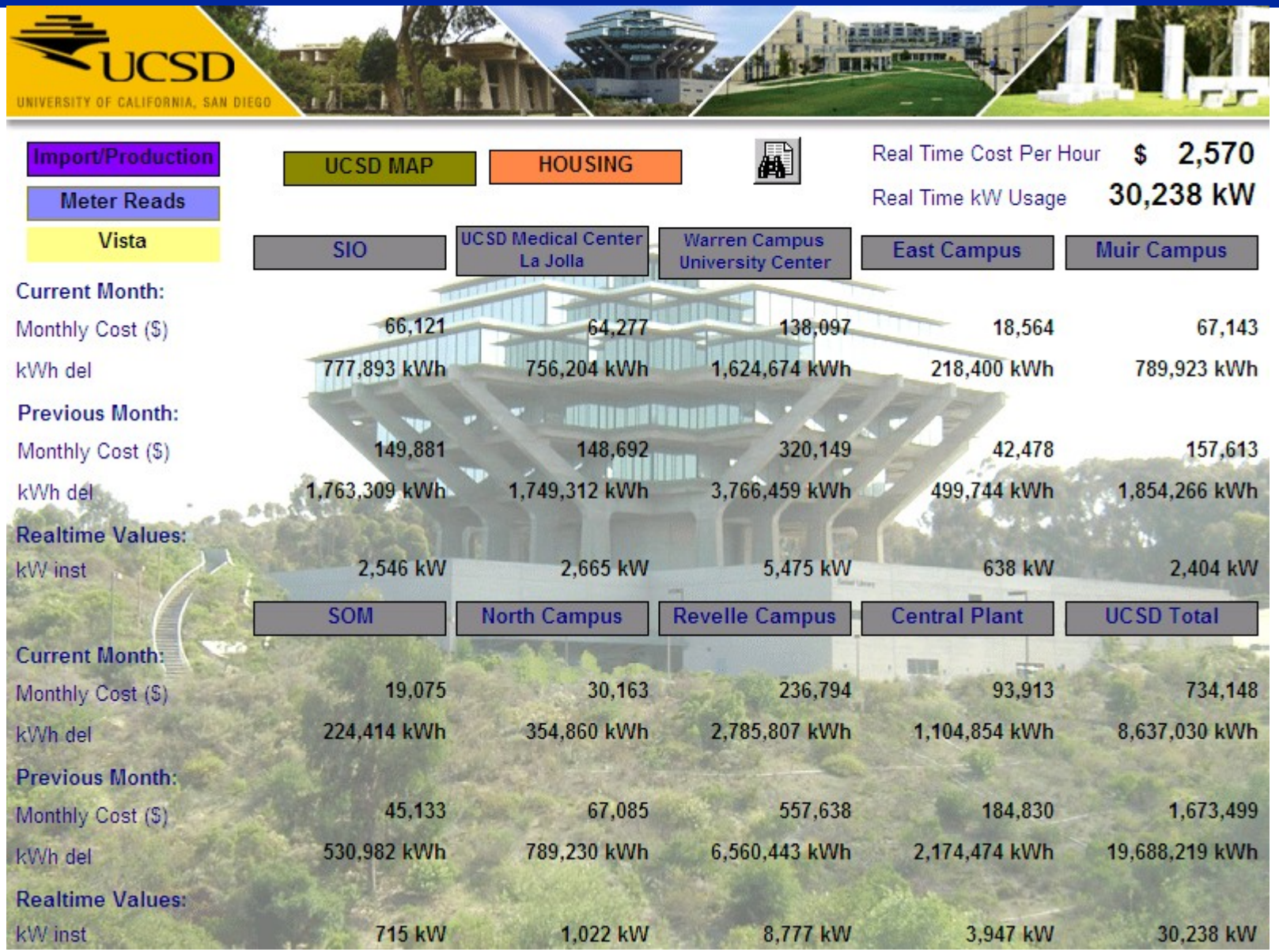
www.educause.edu/EDUCAUSE+Review/EDUCAUSEReviewMagazineVolume44/CampusesasLivingLaboratoriesfo/185217



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Real-Time Monitoring of Building Energy Usage: Toward a Smart Energy Campus



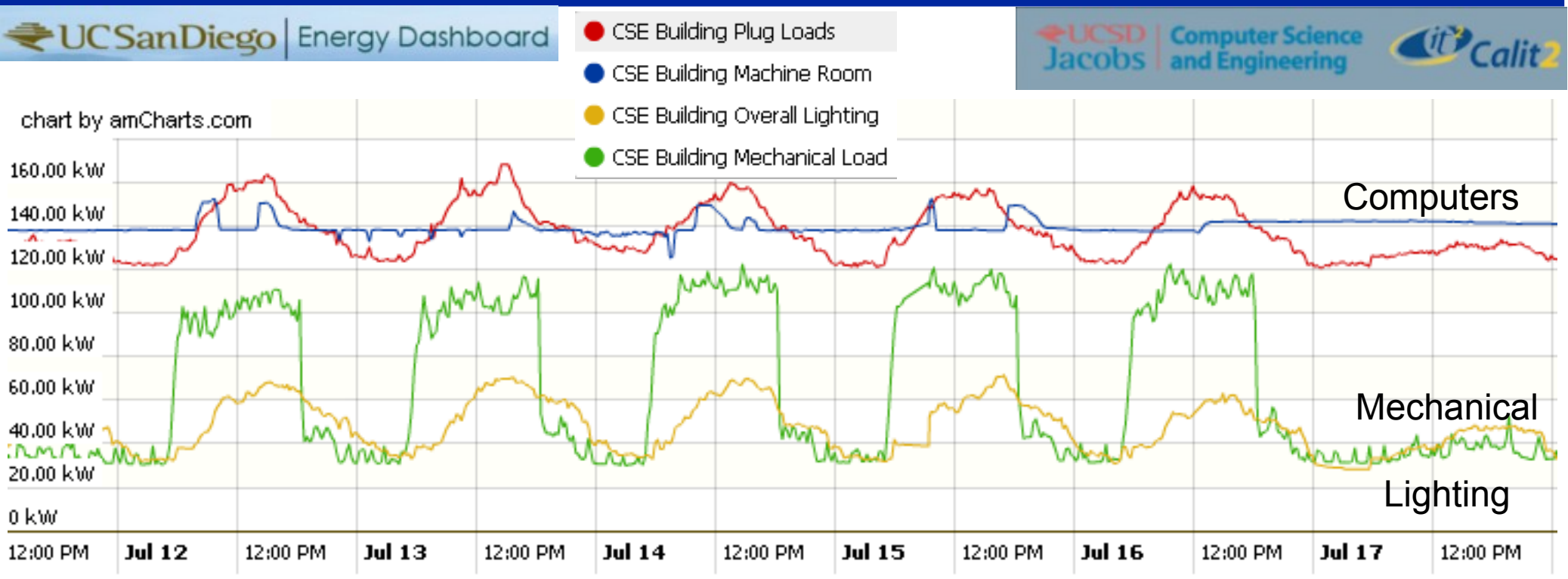
	SIO	UCSD Medical Center La Jolla	Warren Campus University Center	East Campus	Muir Campus
Current Month:					
Monthly Cost ($)	66,121	64,277	138,097	18,564	67,143
kWh del	777,893 kWh	756,204 kWh	1,624,674 kWh	218,400 kWh	789,923 kWh
Previous Month:					
Monthly Cost ($)	149,881	148,692	320,149	42,478	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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Contributors to Base Load
UCSD Computer Science & Engineering Building



- **IT Loads Account for 50% (Peak) to 80% (Off-Peak)!**
- **Using IT to Save Energy:**
  - **SleepServer: 50-70% Savings on Plug Load and Machine Room**
  - **Estimated 40% HVAC Savings if Deployed Across Entire CSE!**
  - **LED Savings on Lighting**

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Source: Yuvraj Agarwal, Thomas Weng, Rajesh Gupta, UCSD

http://energy.ucsd.edu

Toward Zero-Carbon Research Buildings: Beyond Platinum LEED



J. Craig Venter Institute,
UCSD, Sustainability Laboratory



NASA Ames Sustainability Base

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Calit2's GreenLight Project: Remotely Reducing Data Centers Energy Consumption



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Source: Tom DeFanti, GreenLight PI

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Reducing CO_2 From Travel: Linking the Calit2 Auditoriums at UCSD and UCI



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Photo by Erik Jepsen, UC San Diego

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Calit2's Two Campuses, UCSD and UCI, Are Among the Greenest Campuses in the U.S.



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In August 2011 the Sierra Club ranked UCI #6 and UCSD #3 among the Top 100 U.S. Greenest Colleges and Universities

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

www.calit2.net/newsroom/article.php?id=1498

First Southern California Smart Grid Symposium

Tuesday April 7, 2009



Greening the Internet Economy

ICT & GLOBAL CHANGE

January 22-23, 2009



California Public Utilities Commission

Co-Hosted By Calit2 & CPUC

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

Countries, States, and Cities are Beginning to Conceive of a New Low Carbon Future

Australian Sustainable Energy
Zero Carbon Australia
Stationary Energy Plan

ZEROCARBONBRITAIN
A NEW ENERGY STRATEGY

CARBON NEUTRAL BRITISH COLUMBIA

Masdar City: Zero Carbon, Zero Waste

Seattle as North America's First Carbon-Neutral City
ALEX STEFFEN, 3 DEC 09

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Corporate Leaders are Far Ahead of Governments: A Business Plan for America's Energy Future

Norman Augustine
Former CEO
Lockheed Martin



Ursula Burns
Chairman and
Chief Executive
Xerox
Corporation



John Doerr
Partner
Kleiner Perkins
Caufield & Byers



Bill Gates
Chairman
Microsoft



American Energy Innovation Council

A BUSINESS PLAN FOR AMERICA'S ENERGY FUTURE

Chad Holliday
Chairman
Bank of America



Jeff Immelt
Chairman & CEO
General Electric



Tim Solso
Chairman & CEO
Cummins Inc.



OUR RECOMMENDATIONS

Create an independent national energy strategy board.
Invest $16 billion per year in clean energy innovation.
Create Centers of Excellence with strong domain expertise.
Fund ARPA-E at $1 billion per year.
Establish and fund a New Energy Challenge Program to build large-scale pilot projects.

www.americanenergyinnovation.org

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The Digital Transformation of Environment

- **Water, Fire, & Changing California Climate**
  - **Global Climate Change Drives Regional Climate Disruption**
  - **Common "Mirror World" of Southern California for Fire and Water Management**
  - **Advanced IT/Telecom to Accelerate Response to Wildfires**



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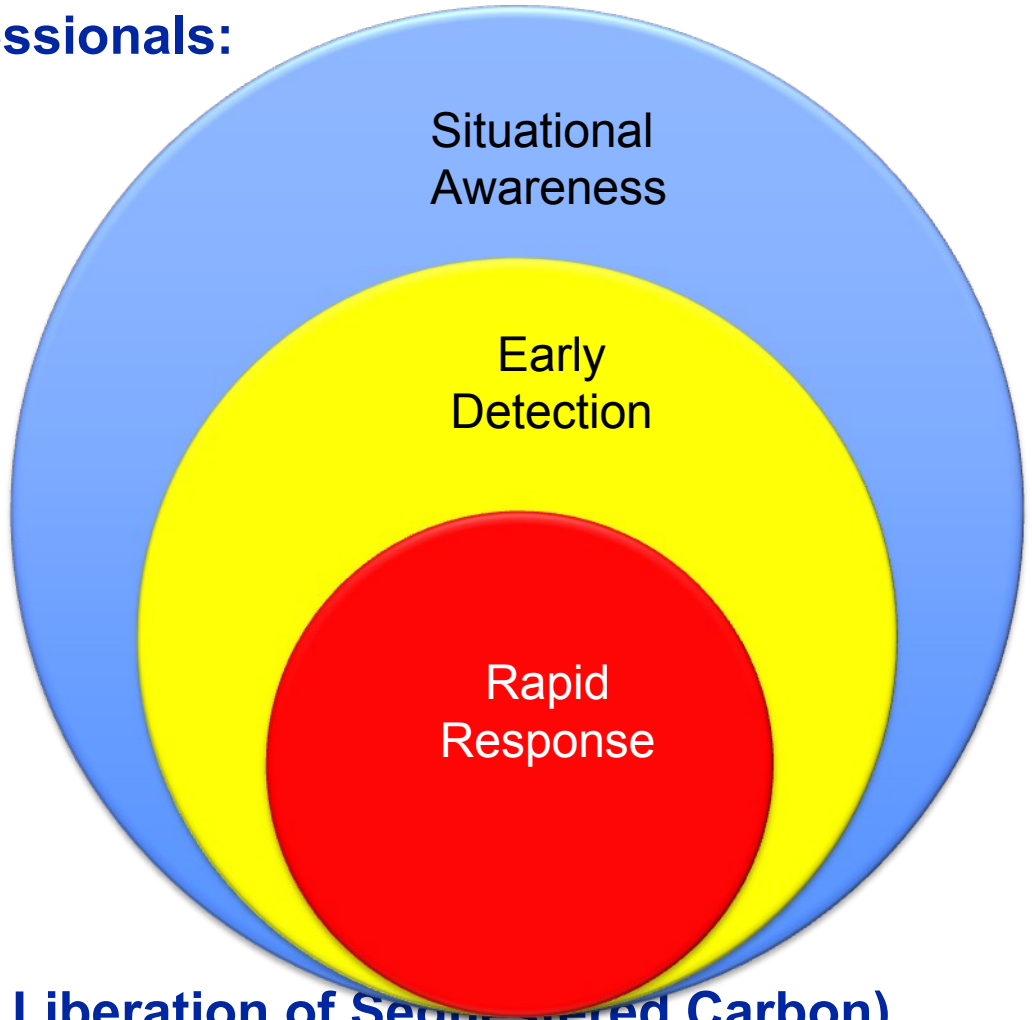
Early on October 23, 2007, Harris Fire San Diego

Photo by Bill Clayton, http://map.sdsu.edu/

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Problem Statement From First Responders

- **Focus on Fire Storms--Wildfires Driven by Santa Anna Winds**
  - **Questions Posed by Fire Professionals:**
    - **Where is the Fire Now?**
    - **Where is it Going?**
    - **When Will it Get there?**
- **Objectives:**
  - **Situational Awareness**
  - **Early Detection**
  - **Rapid Response**
- **Benefits**
  - **Save Lives**
  - **Save Property**
    - **Reduce Insurance Costs**
    - **Improve Building Codes**
  - **Slow Climate Change (Prevent Liberation of Sequestered Carbon)**



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SoCal's Santa Anna Wildfires: View From NASA's Aqua Satellite's MODIS Instrument

Calit2, SDSU, and NASA Goddard Used NASA Prioritization and OptIPuter Links to Cut time to Receive Images from 24 to 3 Hours



Moderate Resolution Imaging Spectroradiometer (MODIS)

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NASA/MODIS Rapid Response
www.nasa.gov/vision/earth/lookingatearth/socal_wildfires_oct07.html

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MODIS Images Provide Targeting Information to NASA's EO-1 Satellite Which Cuts Through Smoke

Composite of the
Red, Blue, and Green Channels



Three of the
Shortwave Infrared Channels



October 23, 2007 Witch Wildfire south of Escondido, California

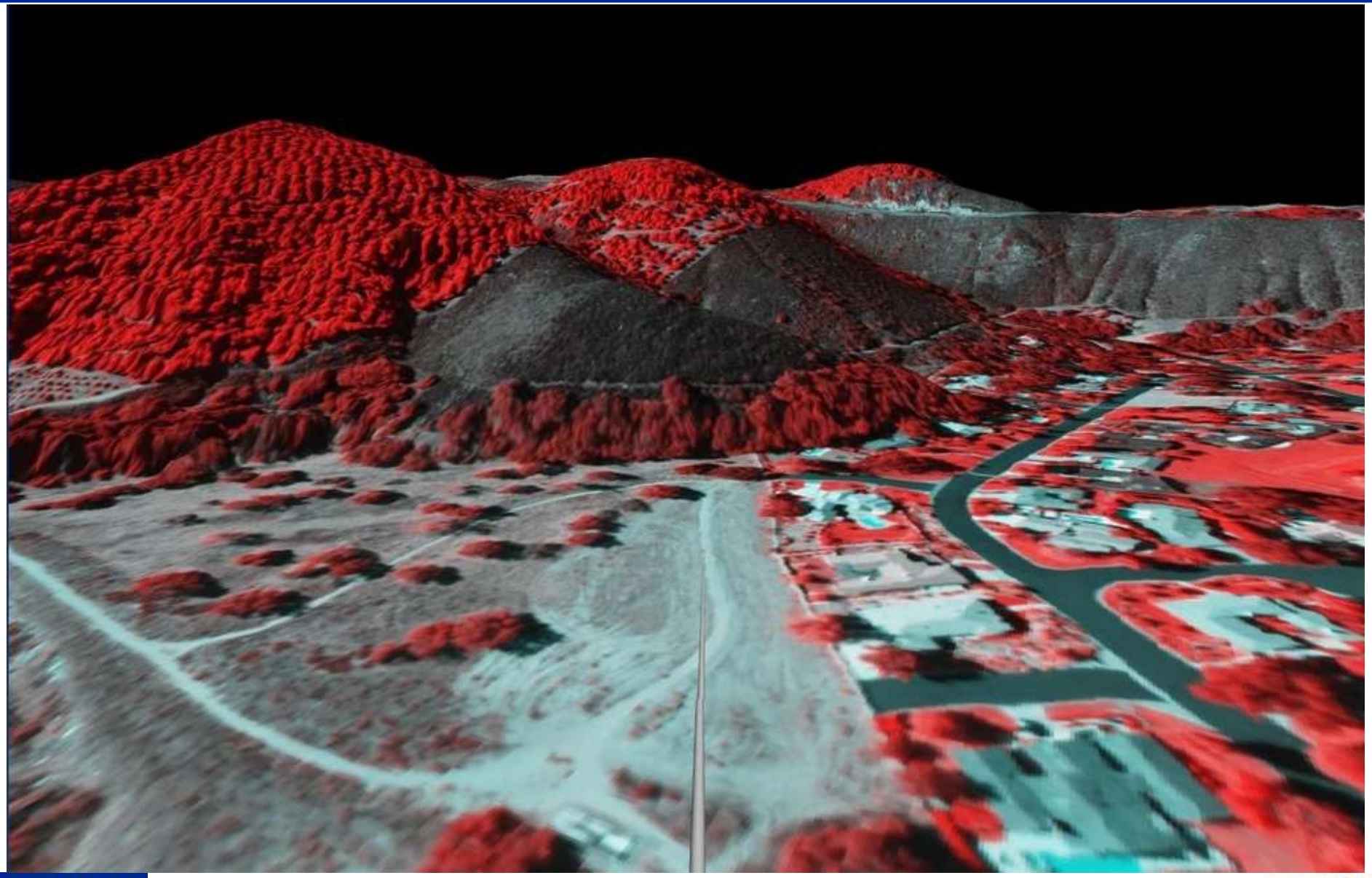
EO-1's Hyperion Spectrometer Observes 220 Contiguous Wavelengths
From Visible Light To Shortwave Infrared

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NASA/EO-1 Team
www.nasa.gov/vision/earth/lookingatearth/socal_wildfires_oct07.html

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Creating a Digital "Mirror World": Interactive Virtual Reality of San Diego County

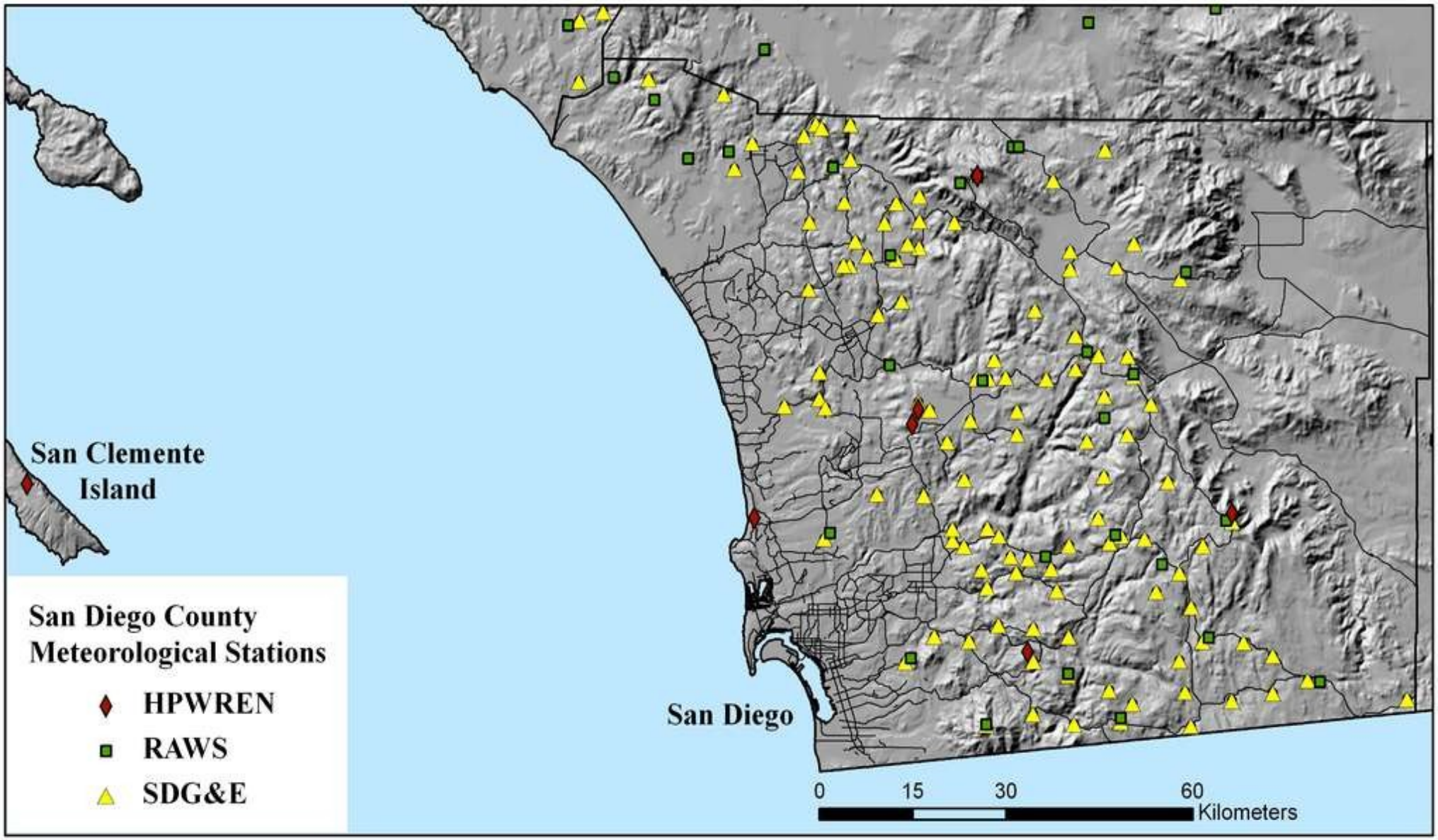


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0.5 meter image resolution.
2meter resolution elevation

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Creating a Micro-Atmospheric Model Using Real-Time Weather Stations in San Diego County



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San Diego Wildfire First Responders Meeting at Calit2 Aug 25, 2010



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SDSC's Hans-Werner Braun Explains His
High Performance Wireless Research and Education Network

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Situational Awareness for Wildfires: Combining Satellite Images, Live Cameras, HD Video

Ron Robers, San Diego County Supervisor





Howard Windsor, San Diego CalFIRE Chief

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Powered by Rocks ROCKS

Source: Falko Kuester, Calit2@UCSD

CGLX

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Calit2 Has Introduced Innovative Wireless Systems to Support SoCal First Responders





















Aug. 22, 2006 MMST Disaster Drill at Calit2@UCSD Involved Over 200 First Responders

HPWREN: Taking High Speed Internet to the Firefighters from the Sky



Ron Serabia
Fire Captain
Semi-Retired

CALIFORNIA DEPARTMENT OF FORESTRY & FIRE PROTECTION
CAL FIRE
SINCE 1885

D C Firefighters F
TM
Local 2881

HPWREN
High Performance Wireless Research & Education Network

RAMONA AIR ATTACK

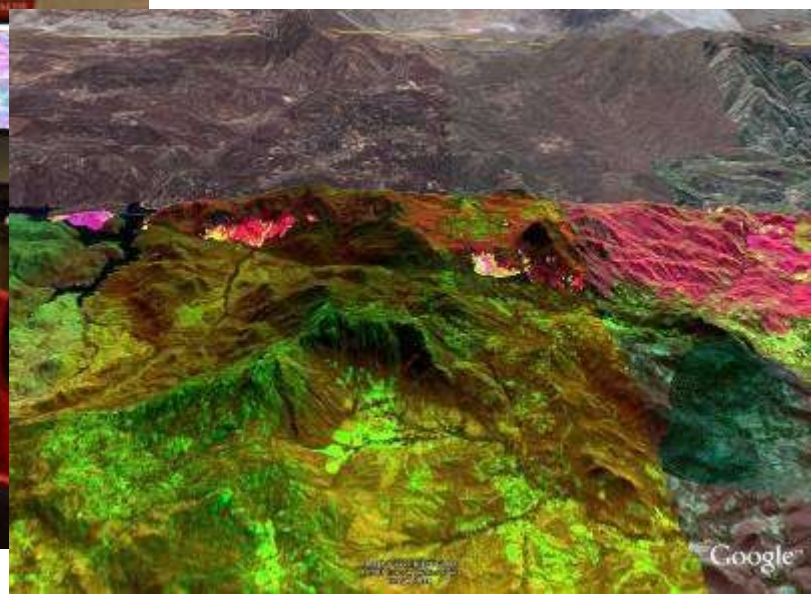
CALIFORNIA FIRE ASSOCIATION PILOTS

Upgraded Command Center Integrating Early Detection, Rapid Response, Situational Awareness

www.nasa.gov/centers/dryden/news/Features/2007/wildfire_socal_10_07.html



Flight Plan and Ikhana Data Displayed in San Diego Emergency Operations Center's Situation Room



Pilot Flies Predator B from NASA Dryden in Edwards AF Base





NASA Ikhana Carrying Autonomous Modular Scanner on 8 Hour Flight, Coordinated with the FAA, Downlinks to NASA Ames

NASA Ames Overlaid Thermal-Infrared Images on Google Earth Maps, Transmitted in Near-Real Time to the Interagency Fire Center in Boise, Idaho