The Coupled Climate-Energy System: Limiting Global Climatic Disruption by Revolutionary Change in the Global Energy System

Invited Seminar

National Center for Atmospheric Research (NCAR)

Boulder, CO

July 23, 2010

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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Abstract

The continual increase in Greenhouse gas (GHG) emissions is largely caused by our civilization's use of high carbon forms of energy. I will review three studies on possible evolutions of the global energy system this century that yield end points for CO_2 concentrations of 900ppm (MIT), 550ppm (Shell Oil and the International Energy Agency-IEA), and 450ppm (IEA). The later target, which would keep temperature rise to less than 2 degrees C, is extremely challenging to reach, requiring rapid and revolutionary changes in energy systems. I will explore a quantitative model for achieving this goal by synthesizing the recent research of SIO's Ramanathan and Xu on required changes in GHG emissions with the IEA's Blue Scenario on required changes in the energy sectors. While moving from a high-carbon to a low-carbon energy system is the long term solution, more energy efficient cyberinfrastructure can provide important short term relief. The Information and Communication Technology (ICT) industry currently produces ~2-3 % of global GHG emissions and will nearly triple, in a business as usual scenario, from 2002 to 2020. On the other hand, the Smart2020.org report estimates that transformative application of ICT to our electrical, logistic, transportation, and building infrastructures can reduce global GHG emissions by ~15%, five times ICT's own footprint! I will review the findings of the Smart2020 report and then discuss several projects which Calit2 is carrying out with our UCSD and UCI faculty in energy-efficient data centers, personal computers, smart buildings, and telepresence to show how university campuses can be urban testbeds of the low carbon future.

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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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However, Current Global Emission Reduction Commitments Imply ~4° C Temperature Rise

- **According to the MIT C-ROADS model:**
  - **Continuing business as usual would lead to an expected temperature increase of 4.8 °C (8.6 ° F) (CO_2 950ppm).**



John Sterman, Jay W. Forrester Professor in Computer Science Professor of System Dynamics Director, MIT System Dynamics Group

  - **But even if all the commitments for emissions reductions made by individual nations at the Copenhagen conference were fully implemented, the expected rise in temperatures is still 3.9 °C (7.0 °F) above preindustrial levels (CO_2 770ppm).**
  - **To stabilize atmospheric concentrations of greenhouse gases and limit these risks, Sterman says that global greenhouse gas emissions must peak before 2020 and then fall at least 80% below recent levels by 2050, continuing to drop by the end of this century until we have a carbon neutral economy. Doing so might limit the expected warming to the target of 2 °C (3.6 °F) (CO_2 450ppm).**

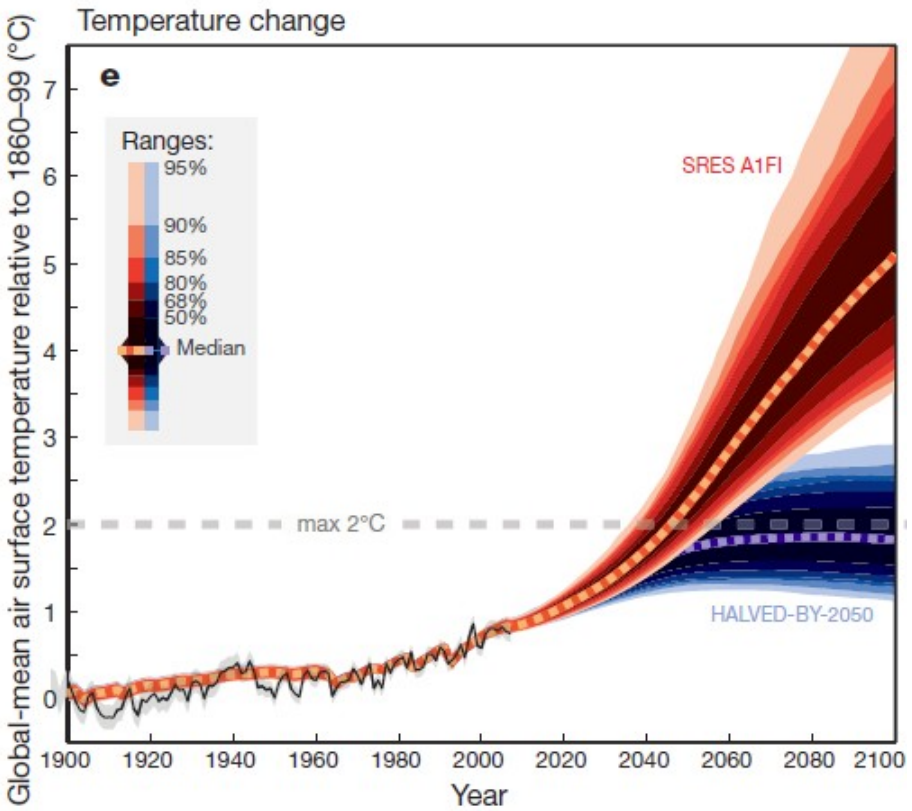
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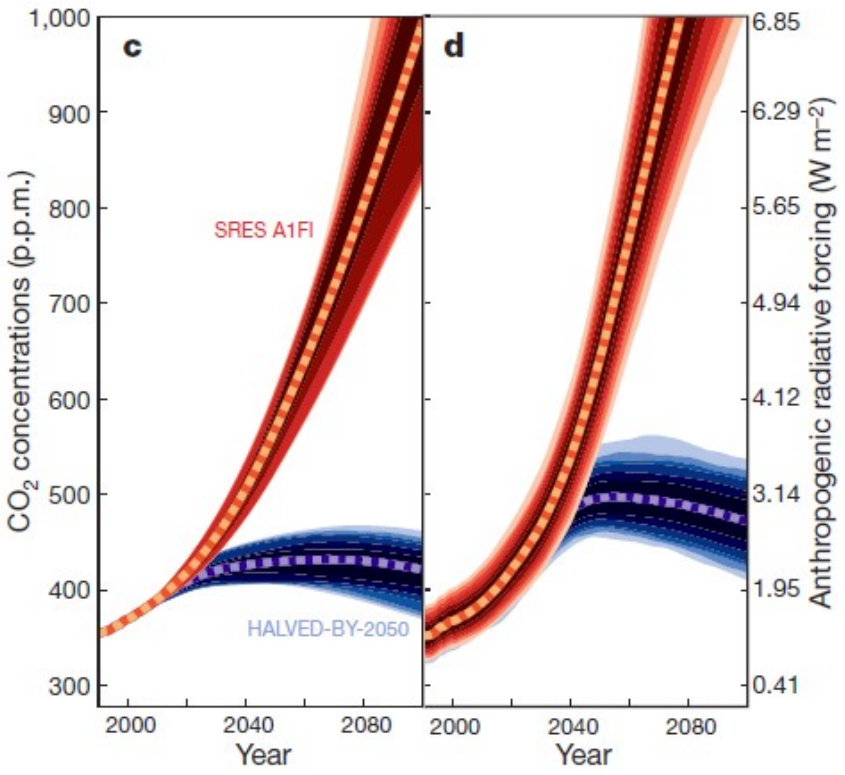
http://mitsloan.mit.edu/newsroom/2010-sterman.php

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There are Paths to Limiting Warming to 2° C, CO_2 to 450ppm, and Radiative Forcing to 2.5Wm^{-2}

"If Emissions in 2050 are Half 1990 Levels,
We Estimate a 12–45% Probability of Exceeding 2°C (Table 1)
Under These Scenarios"



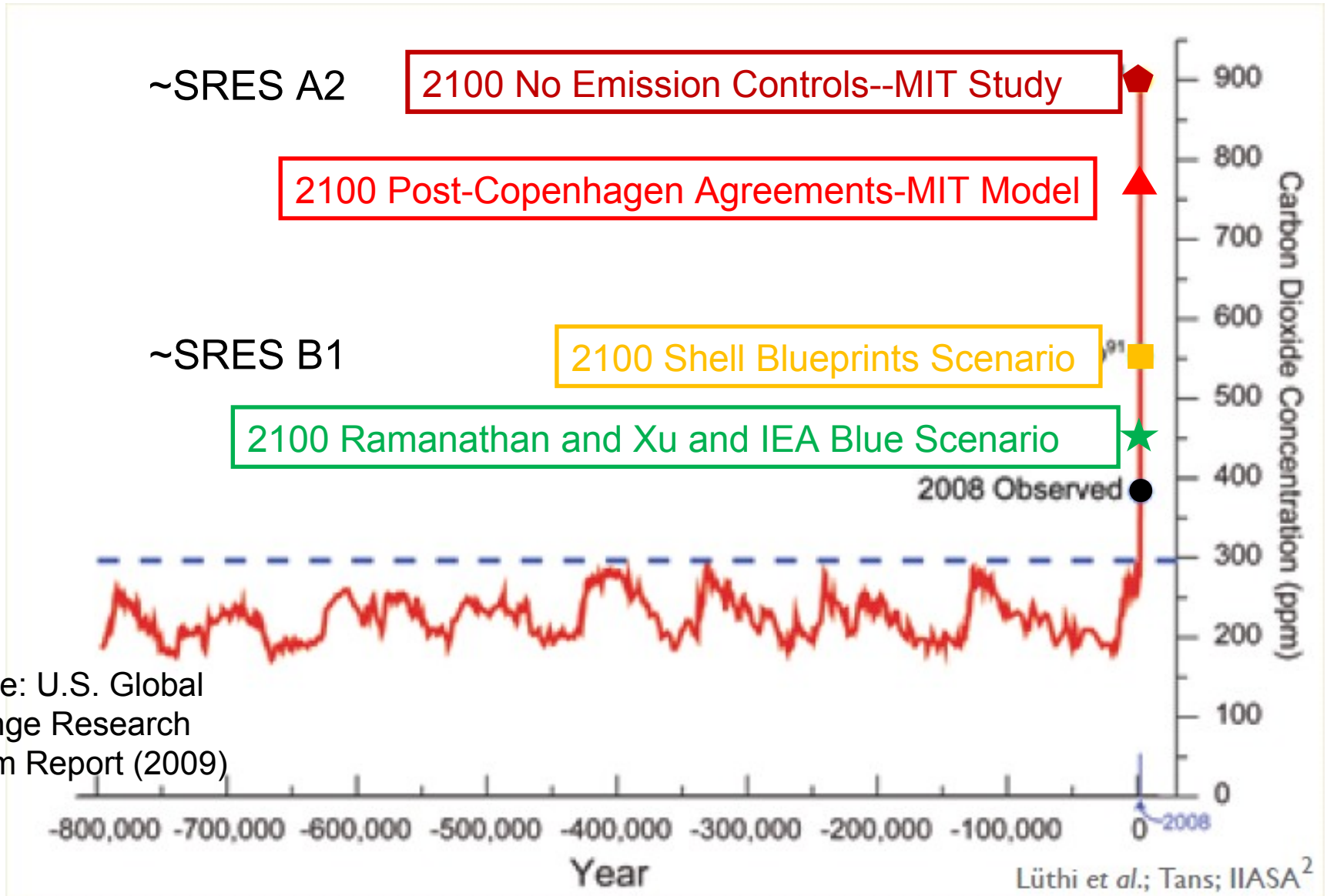


Target
2.5 Wm^{-2}

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Malte Meinshausen, et al., Nature v. 458, 1158 (April 2009)

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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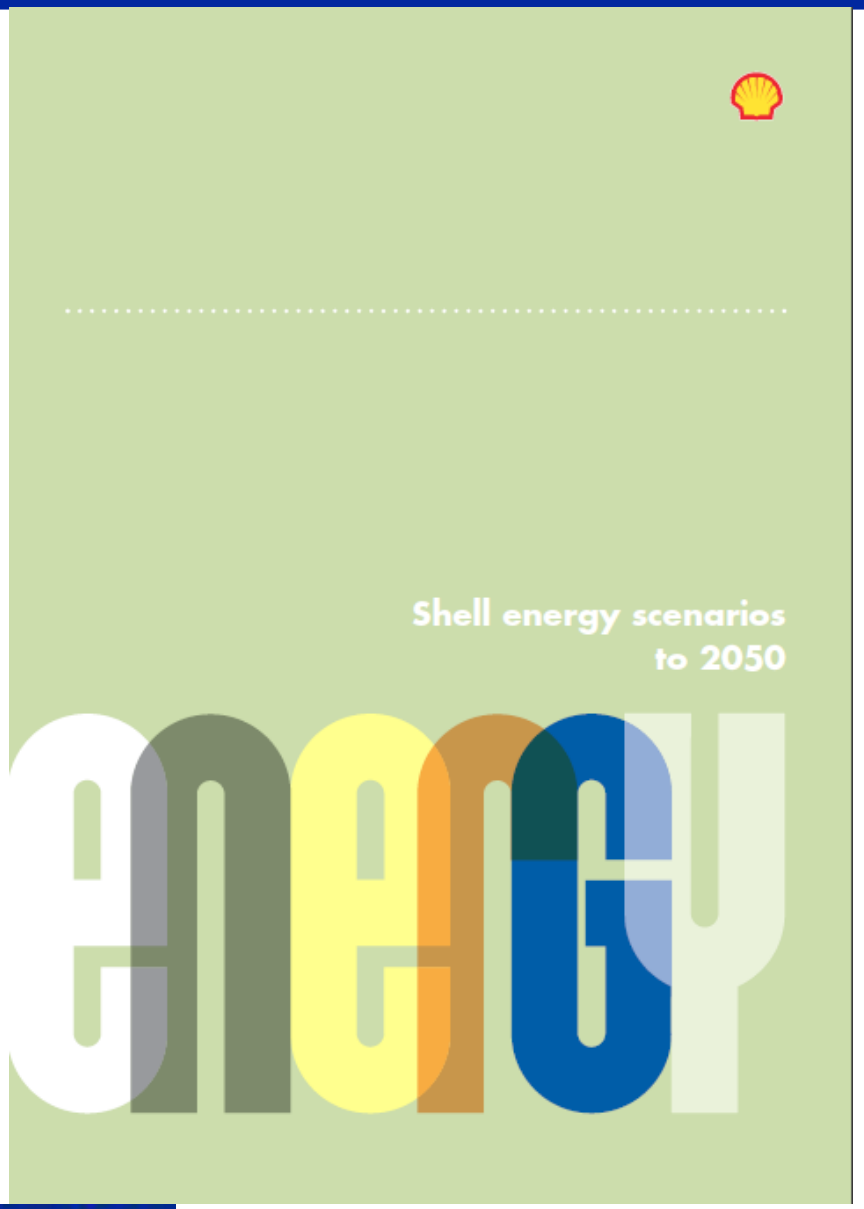
What Changes to the Global Energy System Must be Made by 2050 To Limit Climate Change?

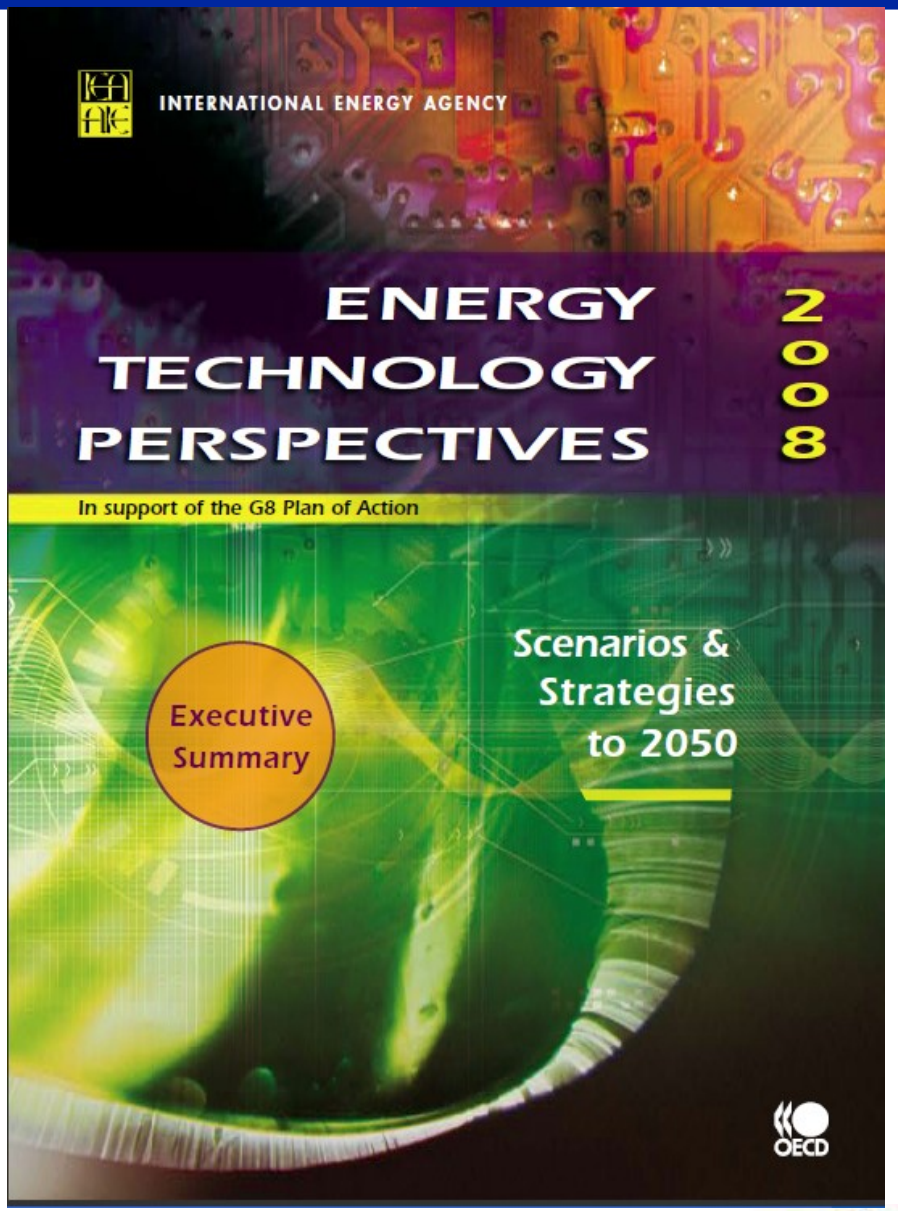
- **Consider Two Targets**
  - **550 ppm**
    - **Shell Oil Blueprints Scenario**
    - **International Energy Agency ACT Scenario**
    - **Bring CO_2 Emissions by 2050 Back to 2005 Levels**
  - **450 ppm**
    - **Ramanathan and Xu Reduction Paths**
    - **IEA Blue Scenario**
    - **Bring CO_2 Emissions by 2050 to 50% Below 2005 Levels**

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Two Global Energy System Scenarios For Limiting CO_2 to 550ppm





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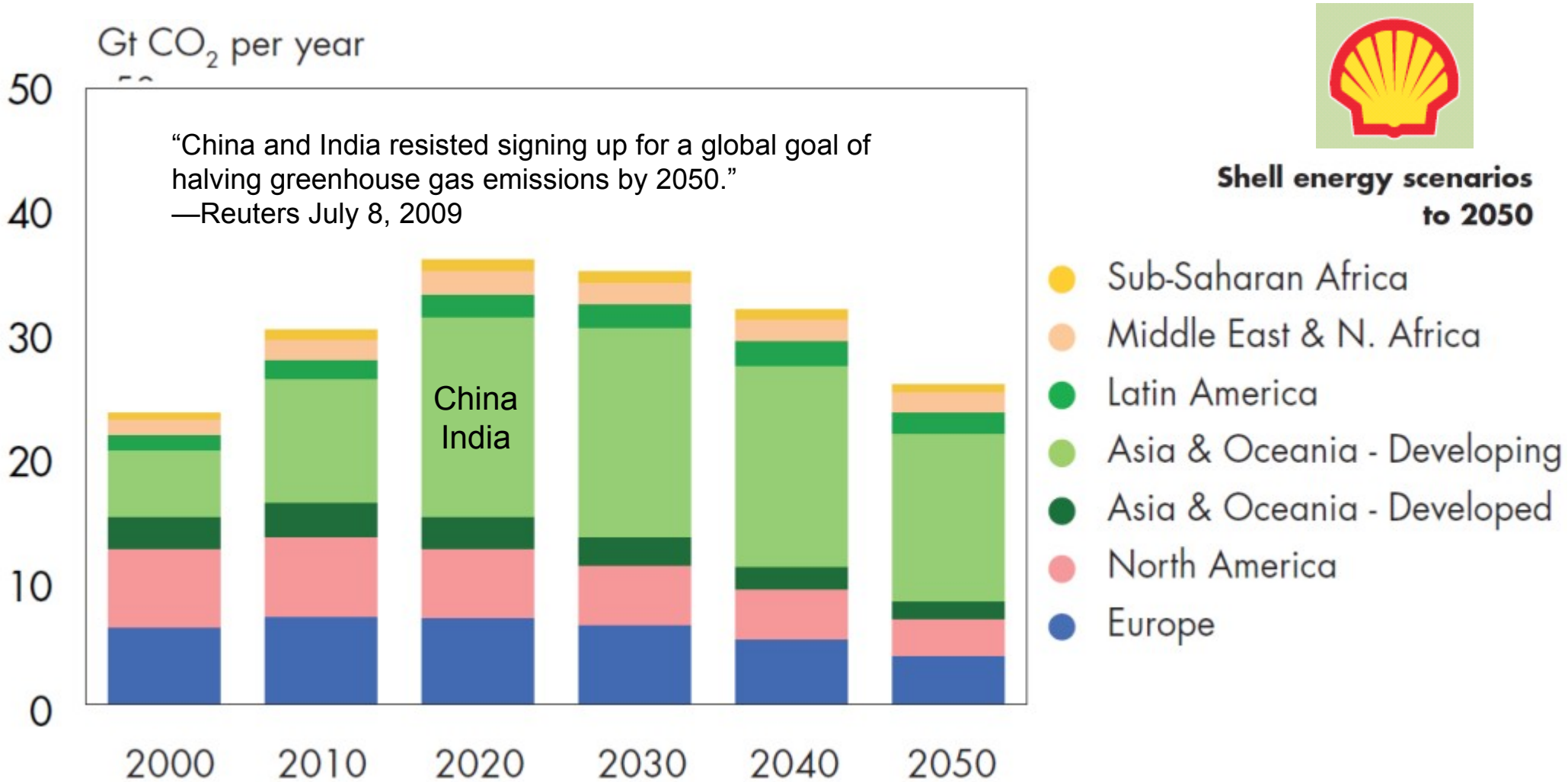
Blueprints Scenario

ACT Scenario

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Shell Blueprints Scenario: Bring CO_2 Emissions by 2050 Back Down to 2005 Levels

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



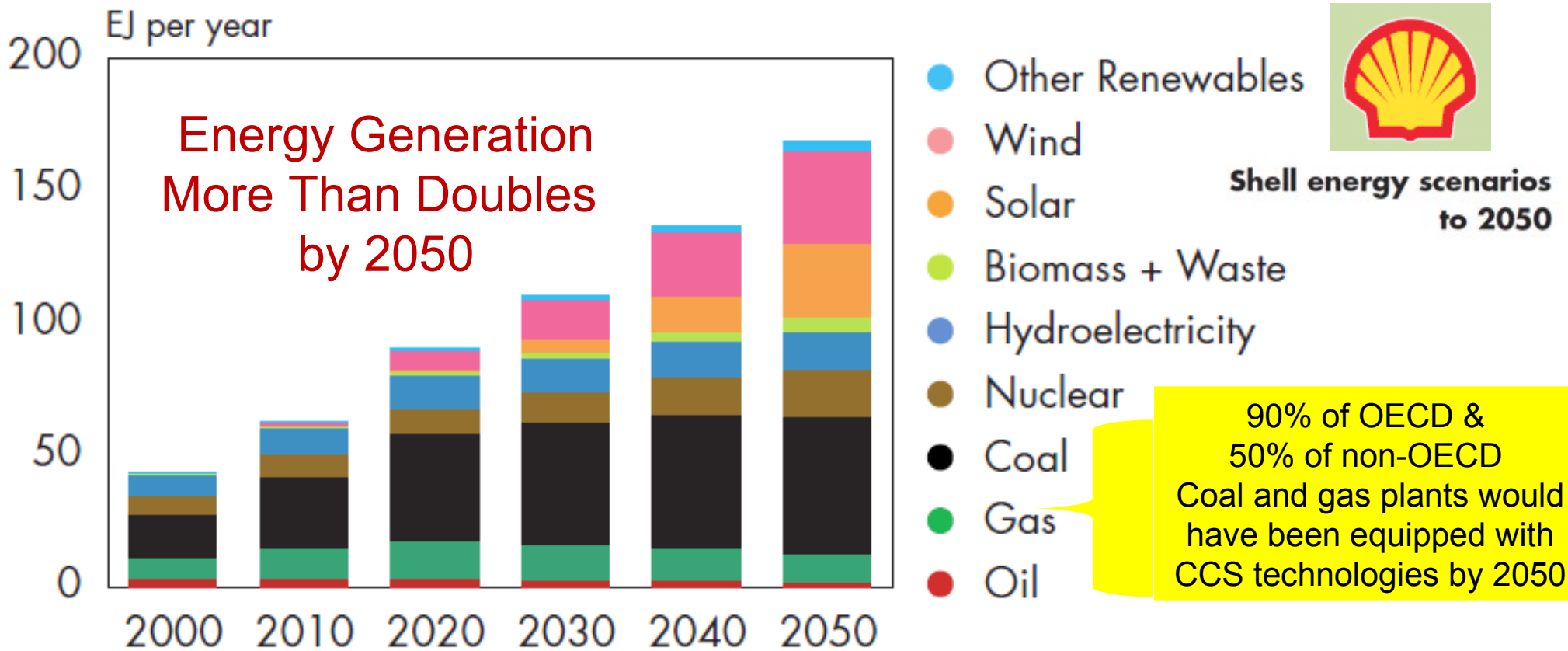
Estimated CO_2 Level in 2100 is 550ppm

Estimated Temperature Rise is 3°C

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In Shell Blueprints Scenario Use of Coal Grows Through 2050 – But With Rapid Deployment of Carbon Capture and Sequestration

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



"Reaching an Annual Storage Capacity of 6 G Tons of CO_2
Would Require an Enormous Transportation and Storage Site Infrastructure Twice the Scale
of Today's Global Natural Gas Infrastructure"

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



Shell energy scenarios to 2050

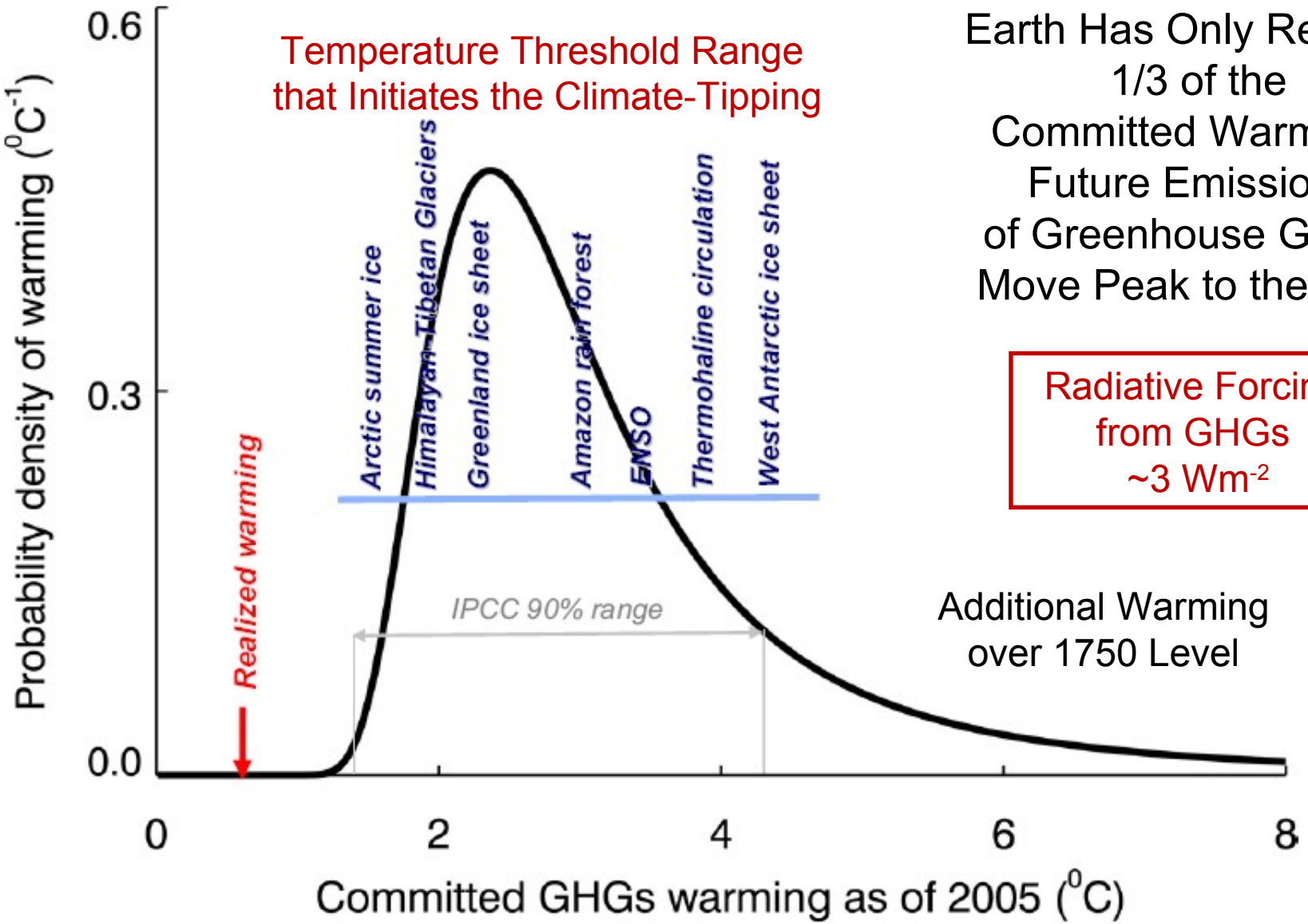
"Limiting GHG concentrations to 450 ppm CO_2-equivalent is expected to limit temperature rises to no more than 2°C above pre-industrial levels. This would be extremely challenging to achieve, requiring an explosive pace of industrial transformation going beyond even the aggressive developments outlined 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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Paradox: Current Greenhouse Gases Already Commit Earth to More Than 2° C Warming



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

Radiative Forcing from GHGs ~3 Wm^{-2}

Additional Warming over 1750 Level

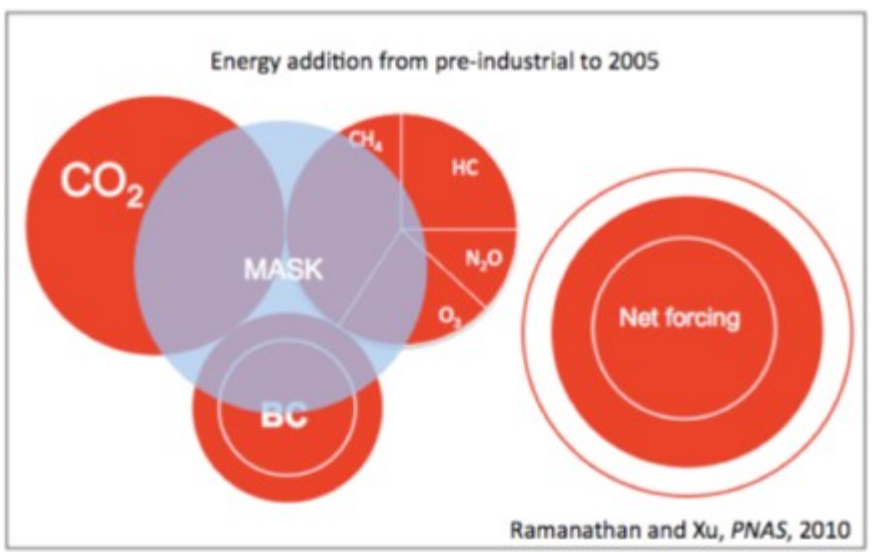
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V. Ramanathan and Y. Feng, Scripps Institution of Oceanography, UCSD
PNAS v. 105, 14245 (Sept. 2008)

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Quantitative Actions Required to Limit Global Warming to Less Than 2 Degrees Centigrade

- **Three Simultaneous Reduction Paths:**
  - **Reduce Air Pollution--Balancing Removing Cooling Aerosols by Simultaneously Removing Warming Black Carbon & Ozone**
  - **Greatly Reduce Emissions of Short-Lived GHGs-Methane, Nitrous Oxide & Halocarbons**
  - **Rapidly Reduce Long-Lived CO_2 Emission Rate**
- **Will Reduce Radiative Forcing to ~2.5 Wm^{-2}**



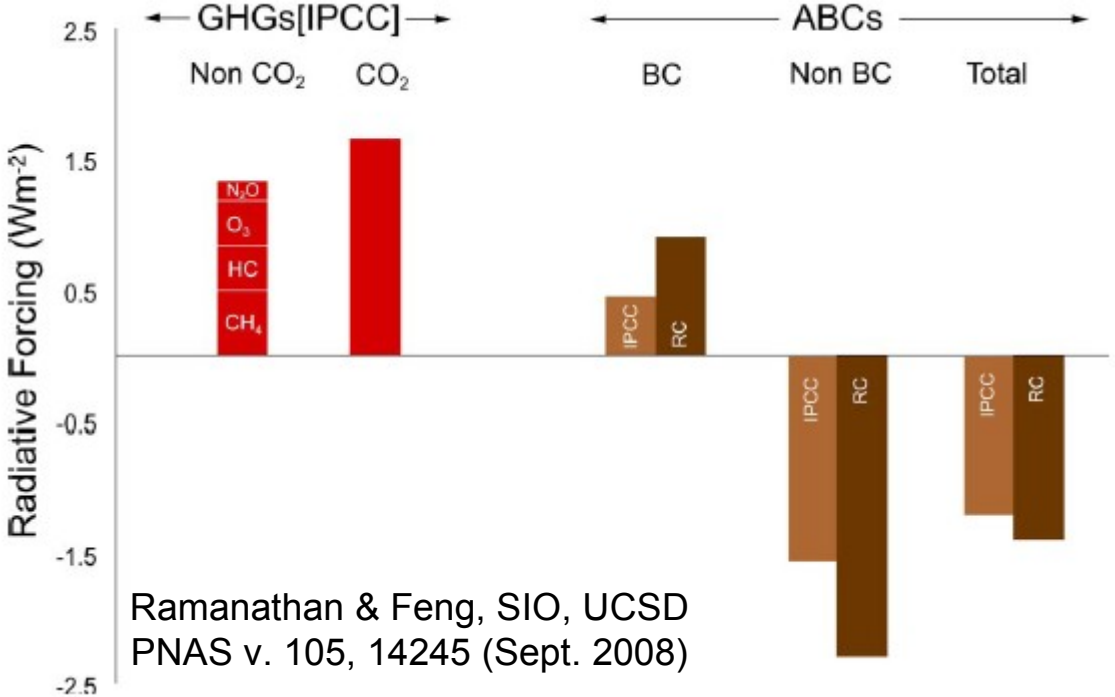
Currently ~3 Wm^{-2}

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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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As We Remove Atmospheric Aerosols Which Cool Climate, Must Balance by Removing Black Carbon Which Adds to Warming

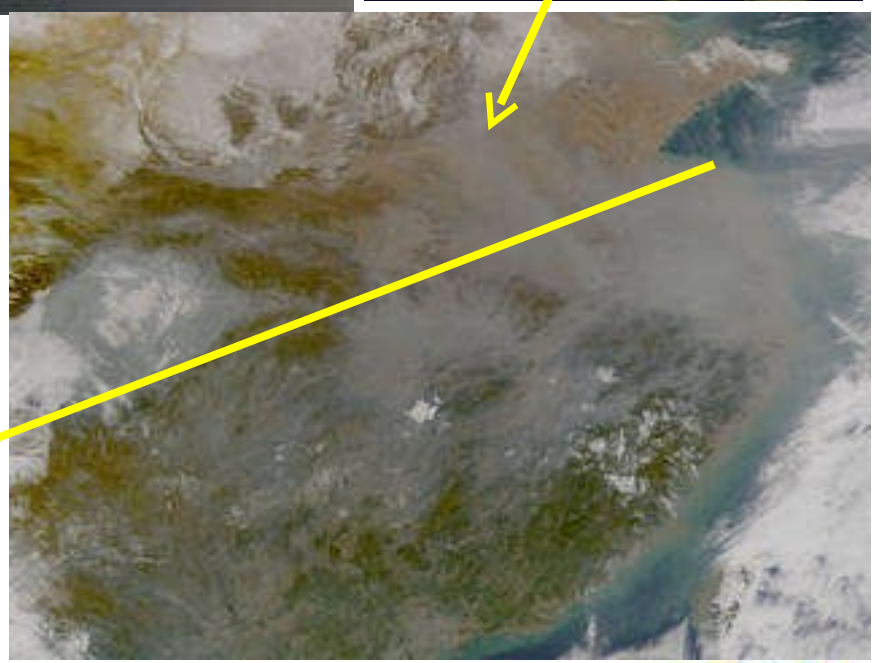


Ramanathan & Feng, SIO, UCSD
PNAS v. 105, 14245 (Sept. 2008)



Reduction Path 1





NASA satellite image



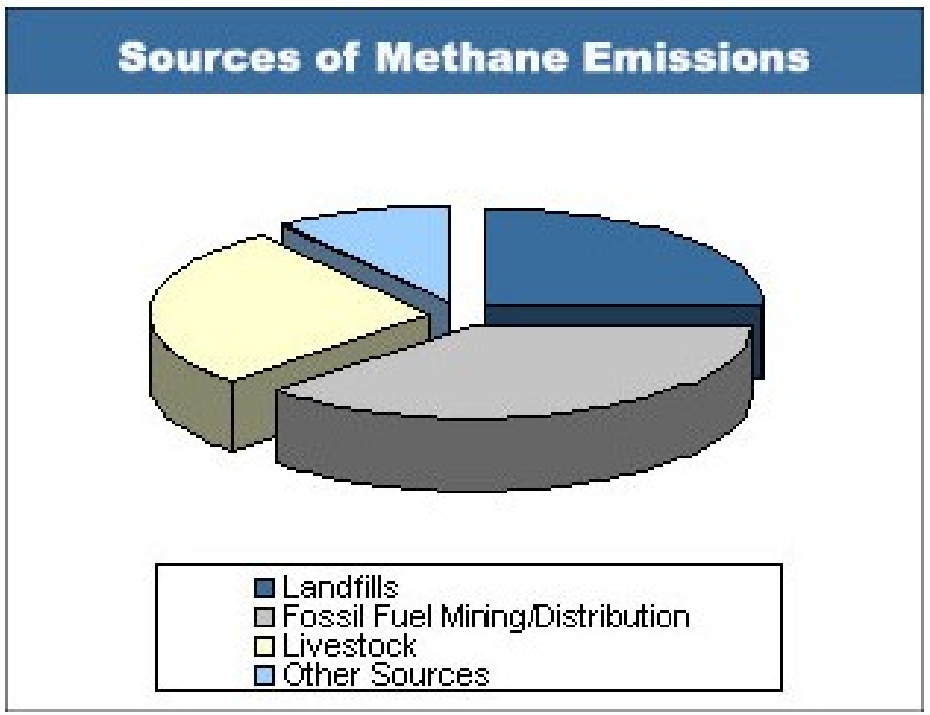
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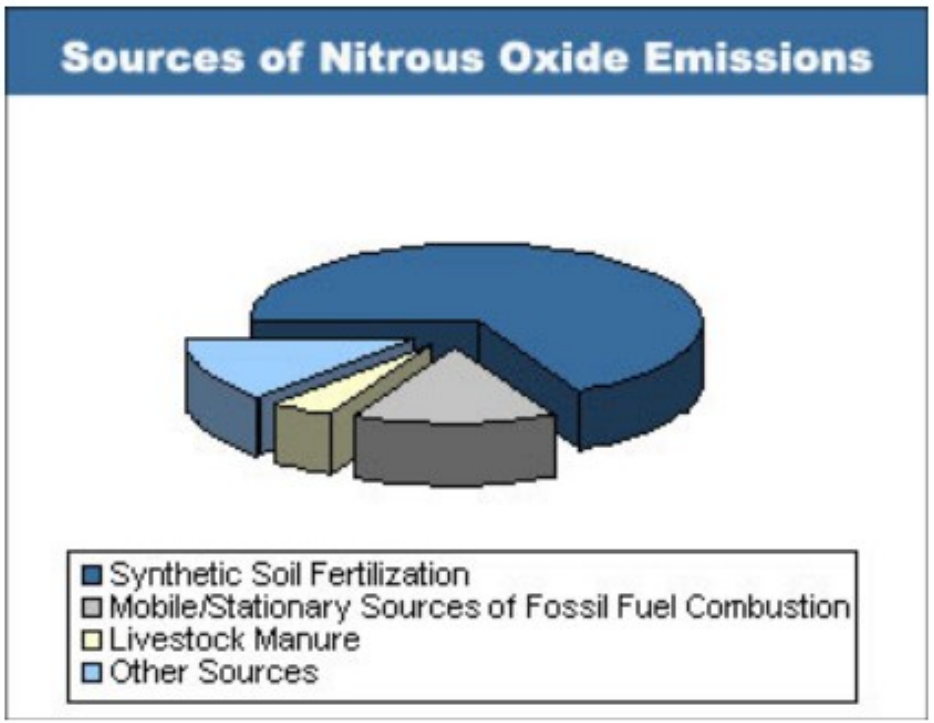
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Eliminating Short Lived GHGs, Such as Methane & Nitrous Oxide, Will be Challenging Given Food Needs of Growing Population

Reduction Path 2

World Population Will Grow
from ~6 Billion People Today to 8.3 Billion People In 2030





Factor of Two Increase in Meat Consumption* by 2030

Worldwide Consumption of Nitrogenous Fertilizers Will Increase 37.5% by 2030

Environmental Monitoring and Assessment , v. 133, 437 (2007)

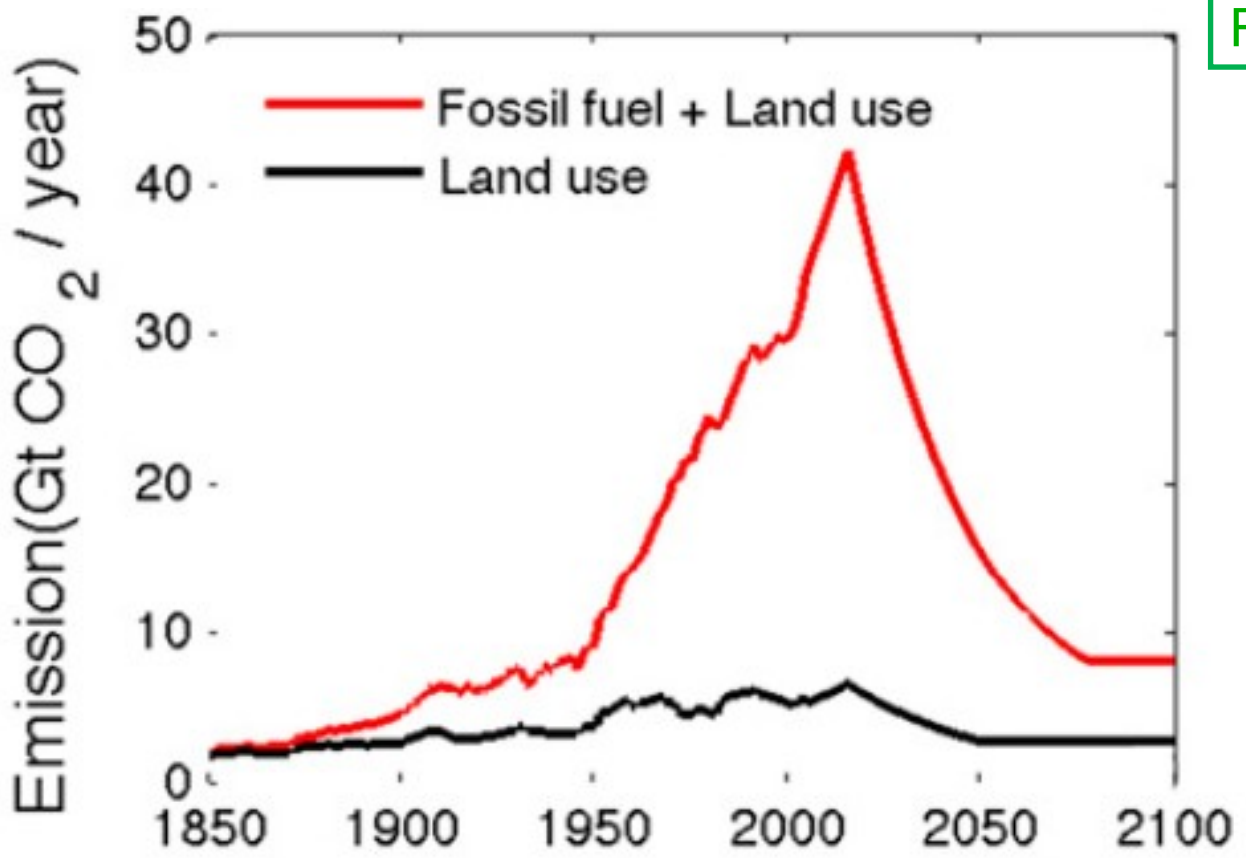
* Meat Consumption was 26 kg in 1997-99. It is projected to rise to 37 kg/person/year in 2030—FAO UN

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Pie Charts: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2008

Rapidly Reduce Annual CO_2 Emissions: Peak in 2015, 50% Lower by 2050 & 80% by 2100

Reduction Path 3



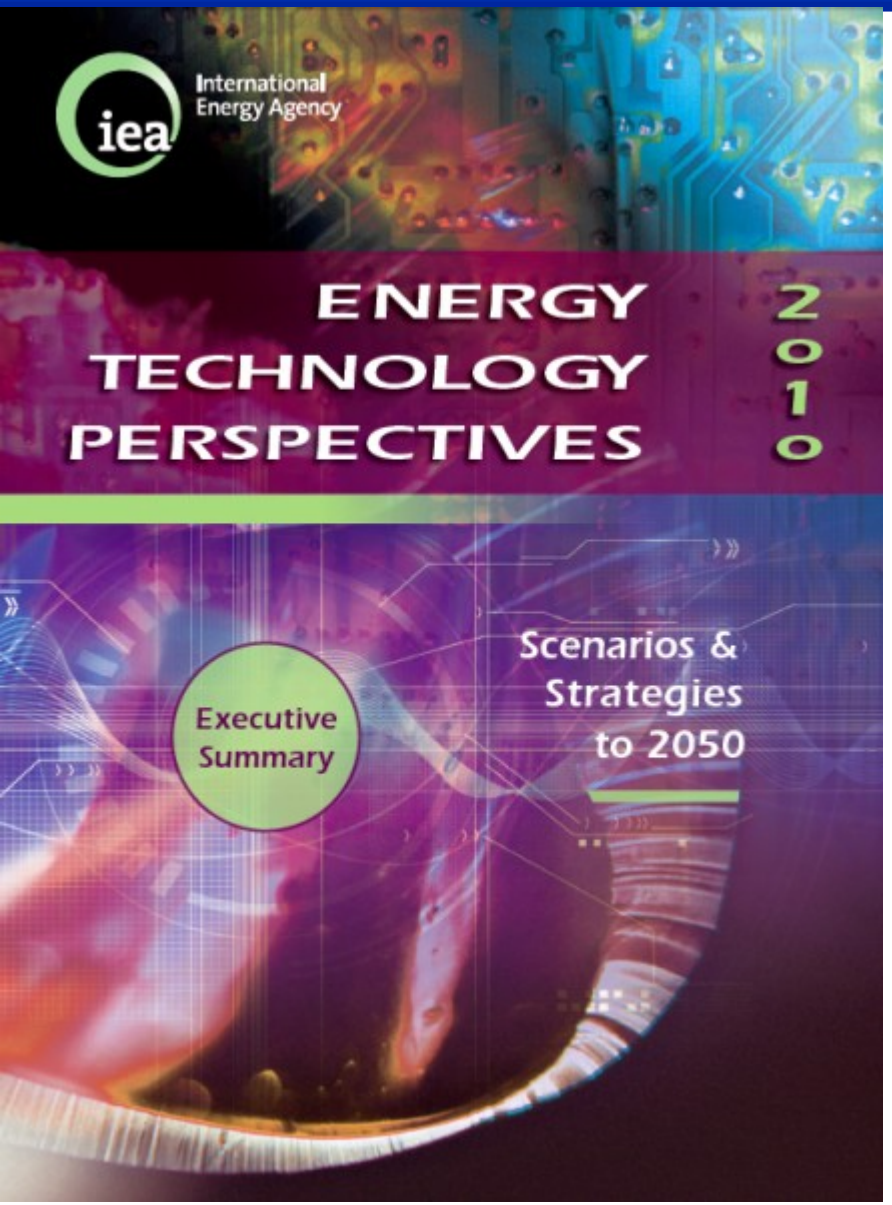
What Changes in the Global Energy System Are Required to Accomplish This Reduction Path?

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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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IEA BLUE--A Global Energy System Scenarios For Limiting CO_2 to 450ppm

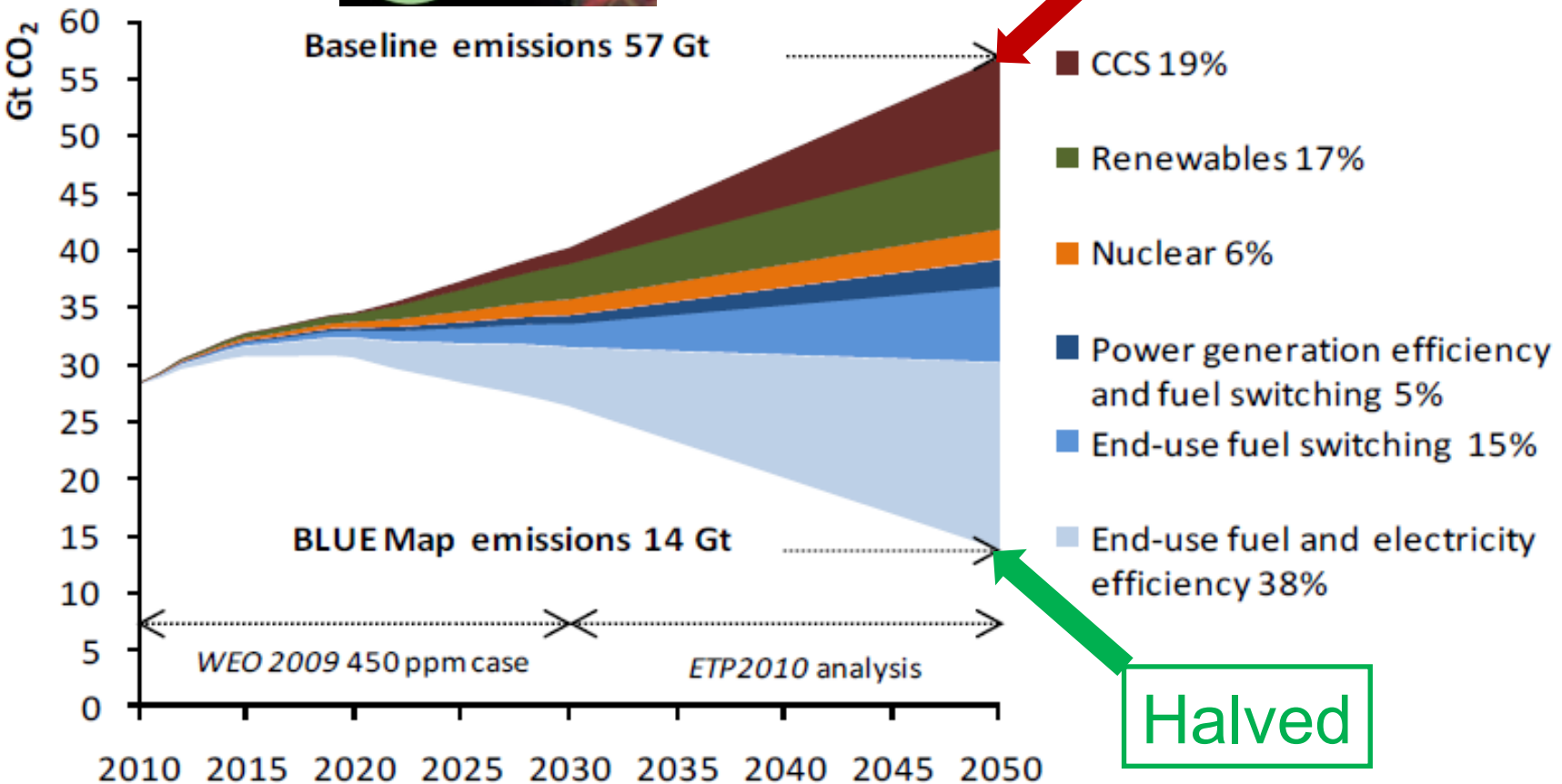


"The next decade is critical.
If emissions do not
peak by around 2020 and
decline steadily thereafter, achieving
the needed 50% reduction by 2050
will become much more costly.
In fact, the opportunity
may be lost completely.
Attempting to regain a 50% reduction
path at a later point in time
would require much greater
CO_2 reductions, entailing much more
drastic action on a shorter time scale
and significantly higher costs than may
be politically acceptable."

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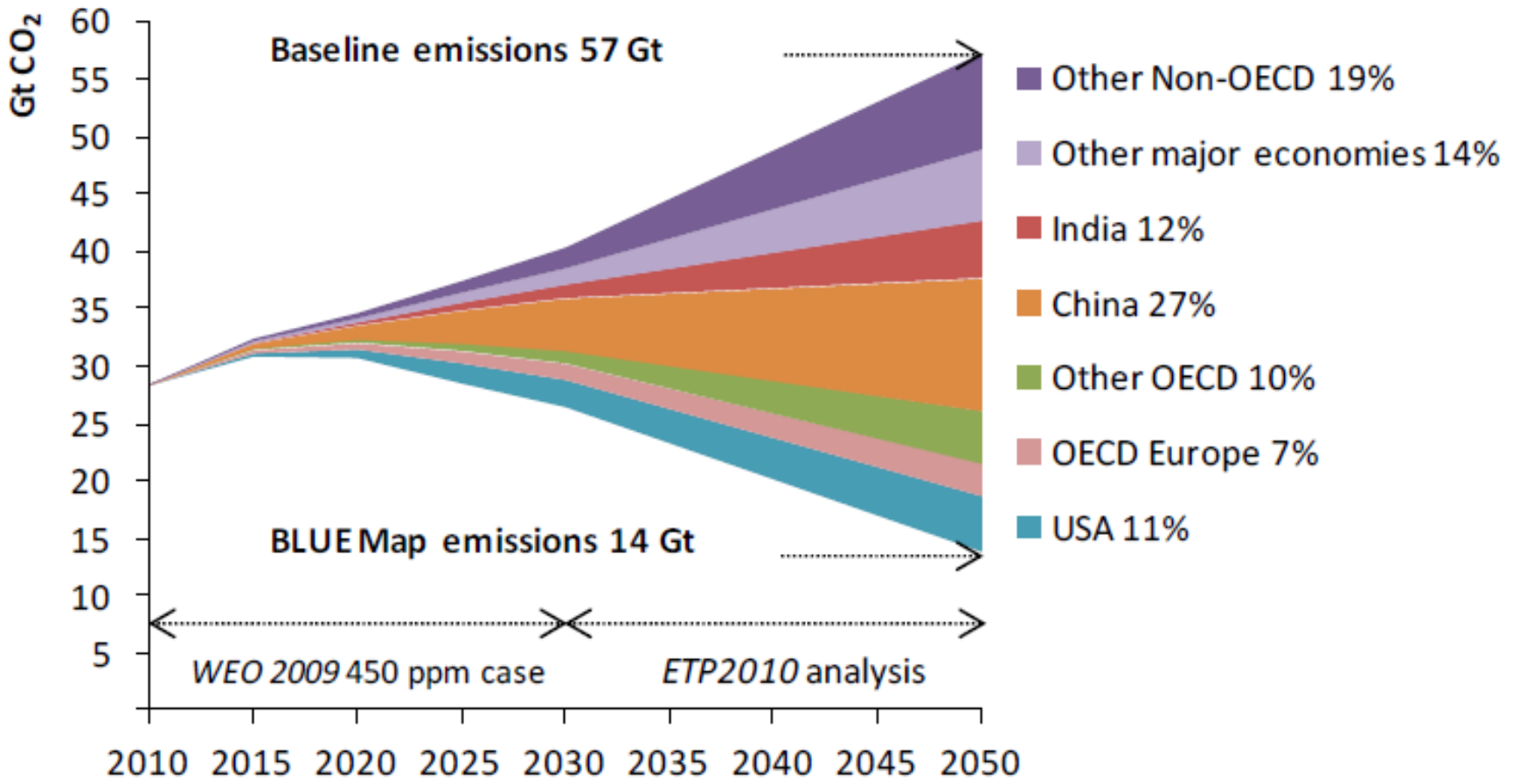
To Cut Energy Related CO_2 Emissions 50% by 2050 Requires a Radically Different Global Energy System





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

World Energy-Related CO_2 Emissions Abatement by Region



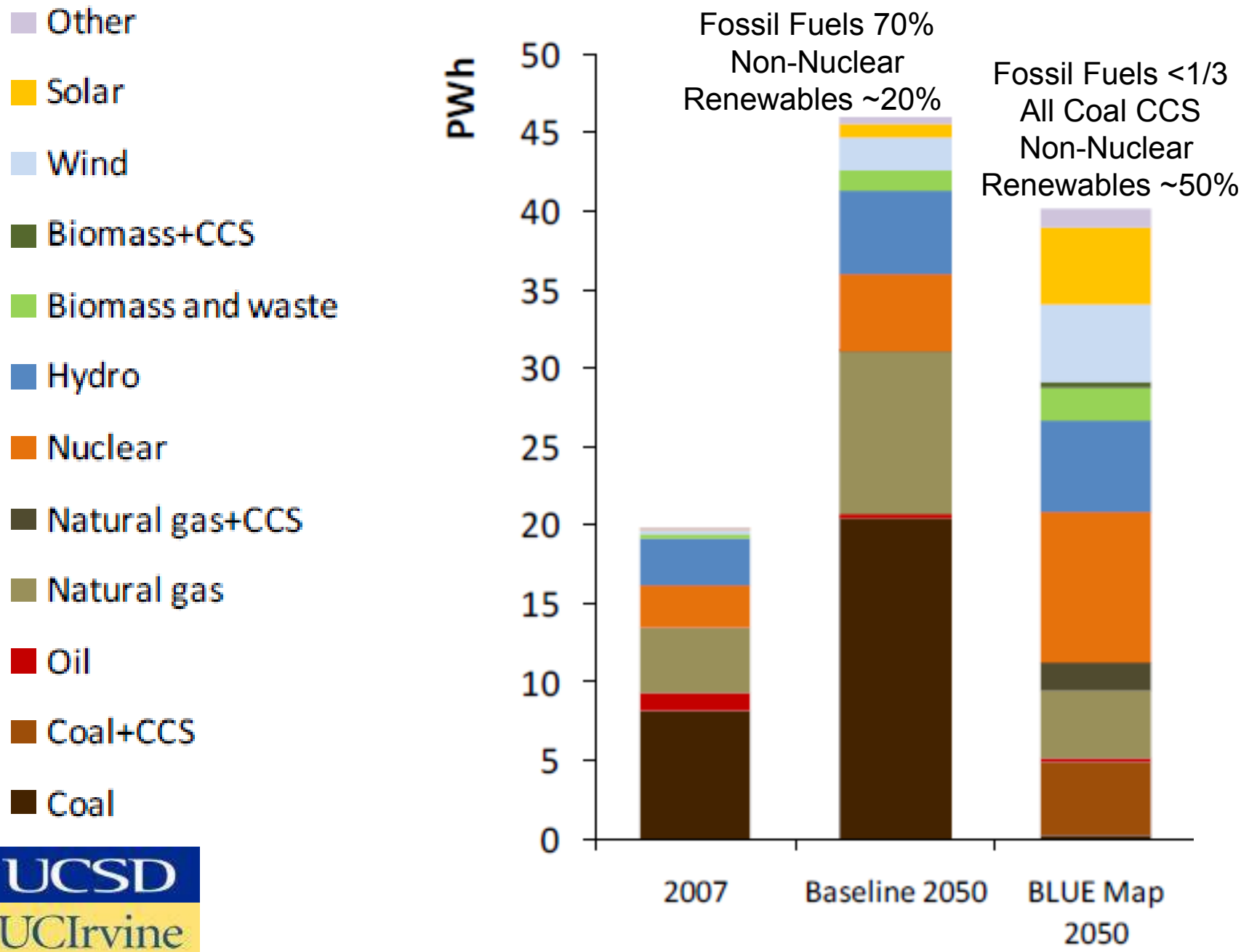
Most Abatement is Outside of OECD Countries
~40% China and India



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IEA Blue Map Requires Massive Decarbonising of the Electricity Sector



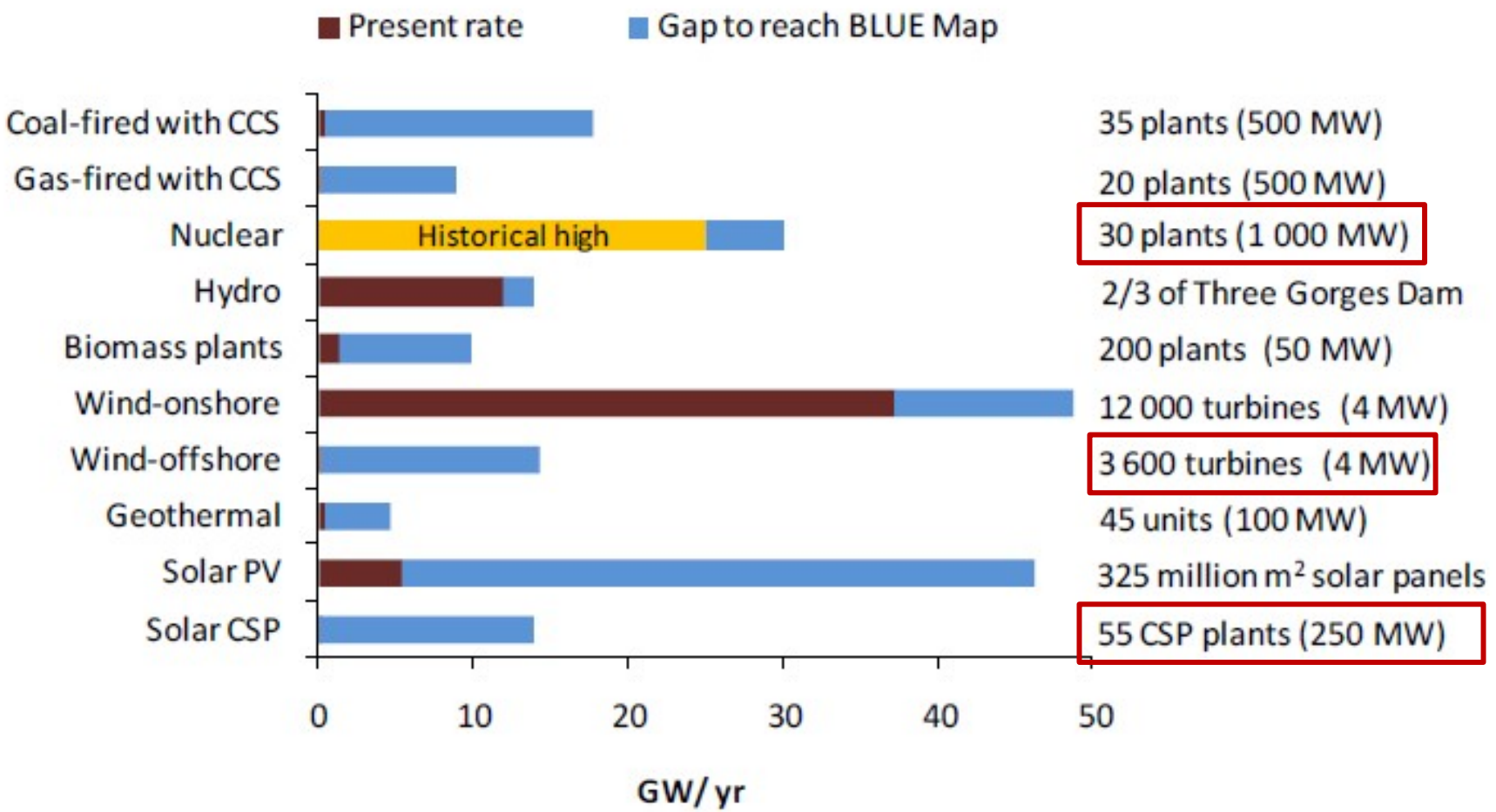


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Average Annual Electricity Capacity Additions To 2050 Needed to Achieve the BLUE Map Scenario

Well Underway with Nuclear, On-Shore Wind, and Hydro, Massive Increases Needed in All Other Modes



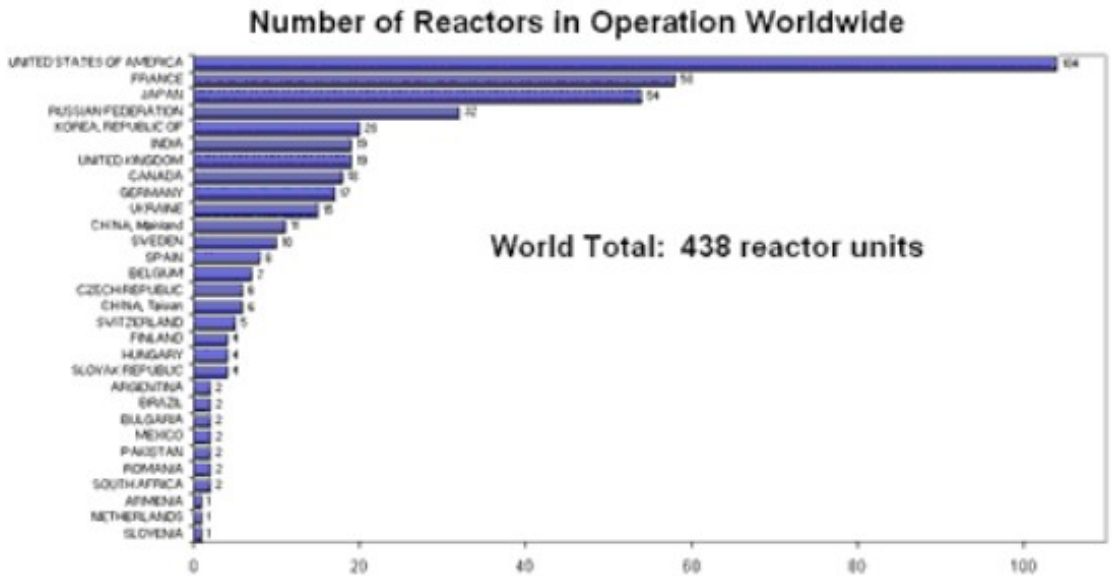


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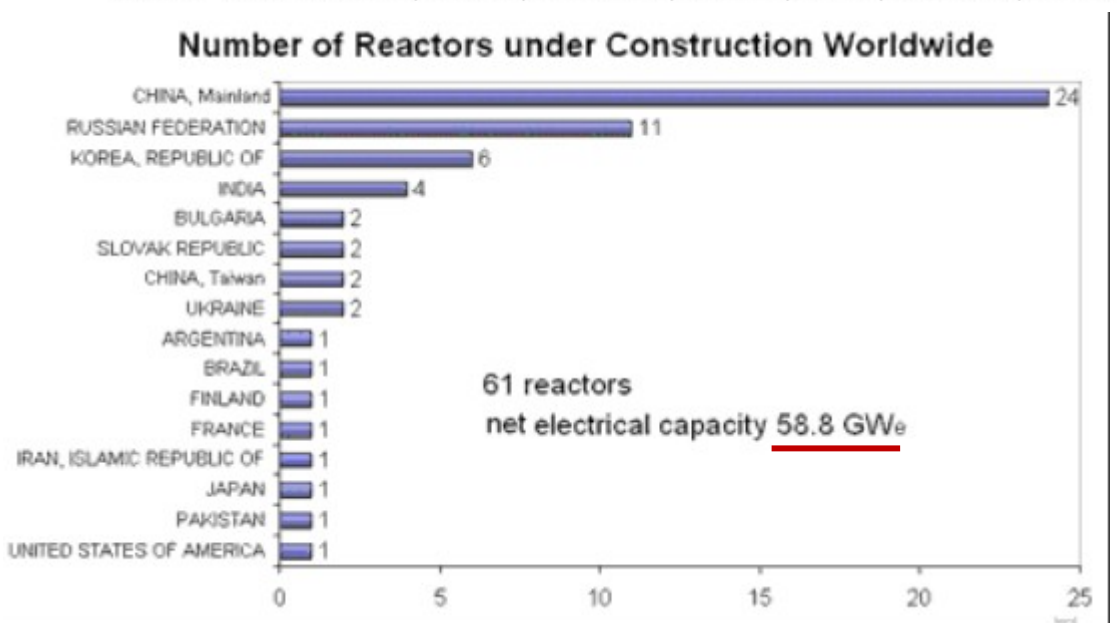
Nuclear Reactors Are Being Constructed At Roughly the IEA Blue Required Rate

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

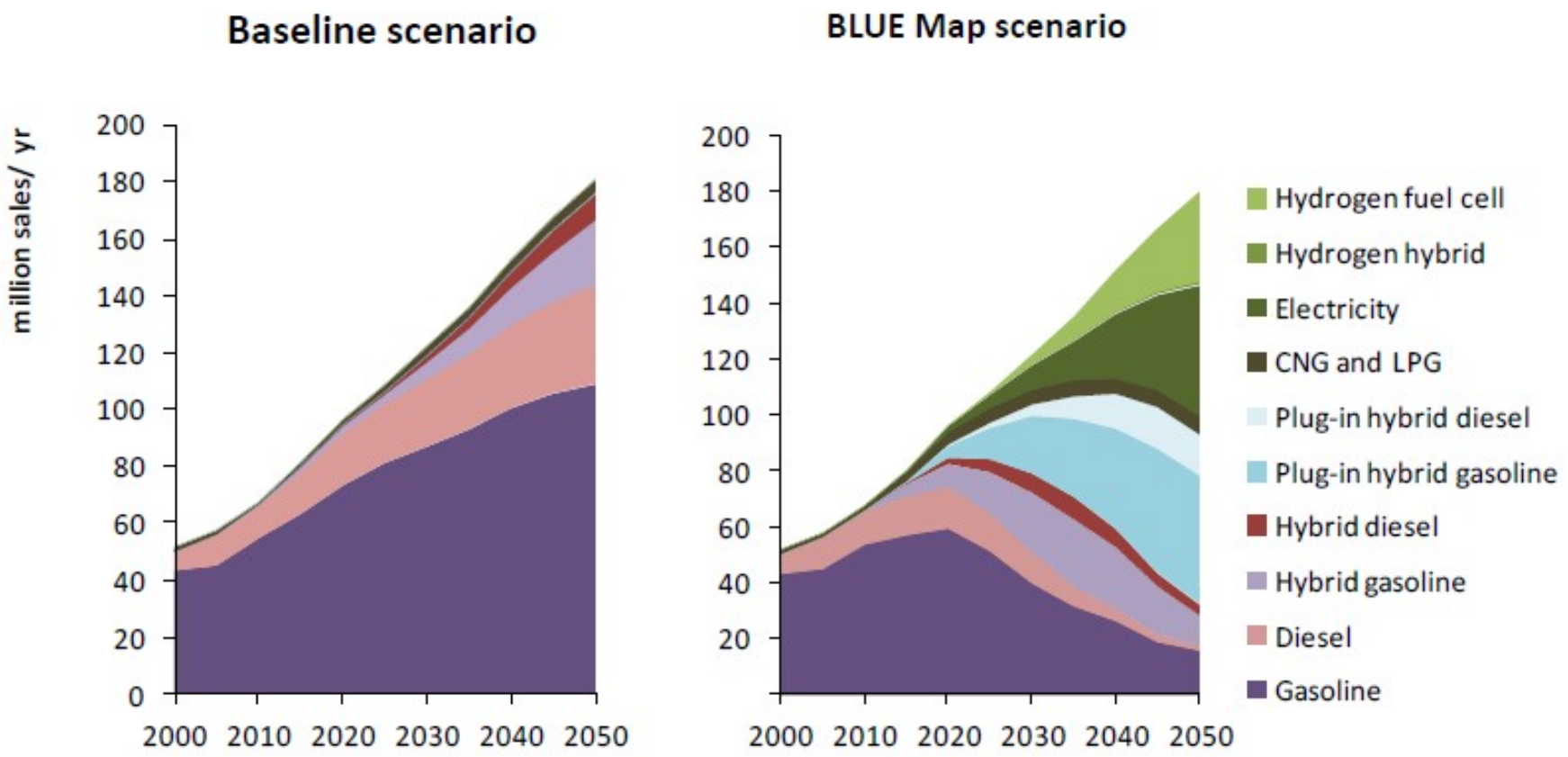
Need to Install ~20 “Anza Borrego” Arrays (30,000 Dishes, 0.75 GW) Per Year of Concentrated Solar Power: ~14 GW Total Every Year Till 2050

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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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Transition to Low Carbon Infrastructure: Race for Low-Carbon Industries is New Driver

Europe must up CO_2 cuts to 30%: EU

July 15, 2010 - 7:04PM

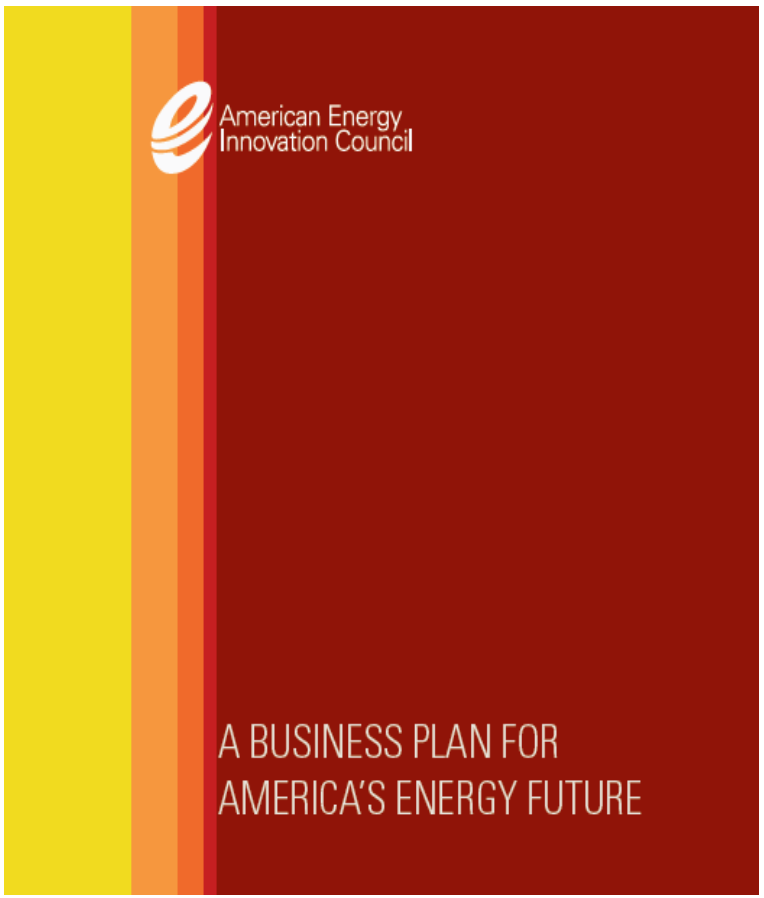
Previous Goal—By 2020, 20% Cut Below 1990 Levels

"If we stick to a 20 per cent cut, Europe is likely to lose the race to compete in the low-carbon world to countries such as China, Japan or the US - all of which are looking to create a more attractive environment for low-carbon investment," --British, French, and German Climate and Environmental Ministers

Source: Sydney Morning News

Top Corporate Leaders Call for Innovation Funding: A Business Plan for America's Energy Future







Our Recommendations (June 2010)

- 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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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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Visionary Low Carbon Infrastructure Plan: Zero Carbon Australia Decarbonizing Electricity Generation in Ten Years

FIGURE 6
ZCA2020 Proposed 100% Renewable Grid

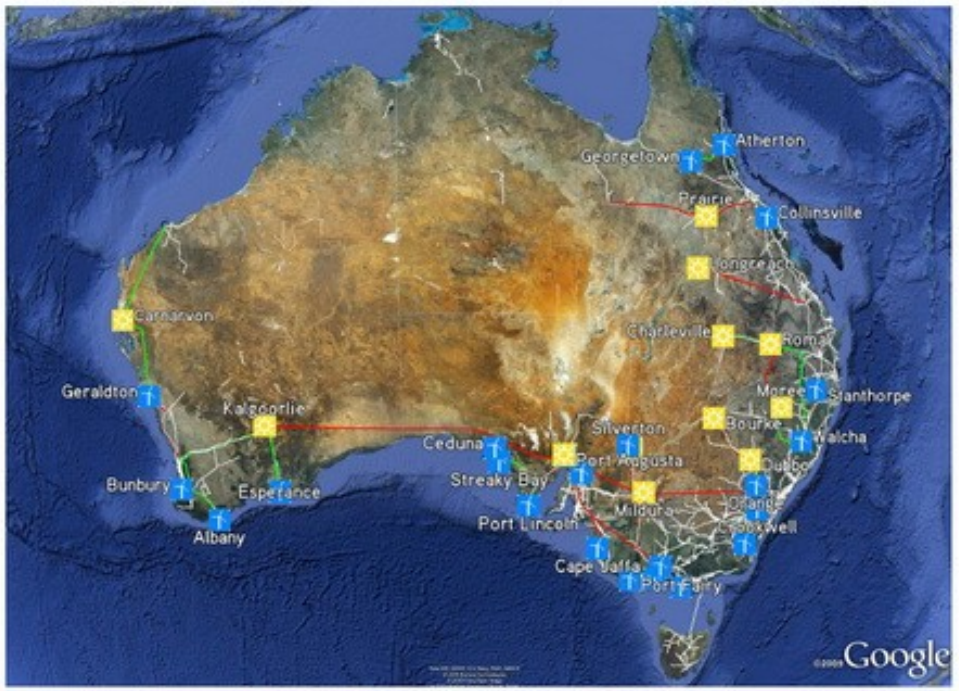


FIGURE 9
ZCA2020 Model Results (daily average data). 'Excess' is combined solar and wind energy in excess of demand.

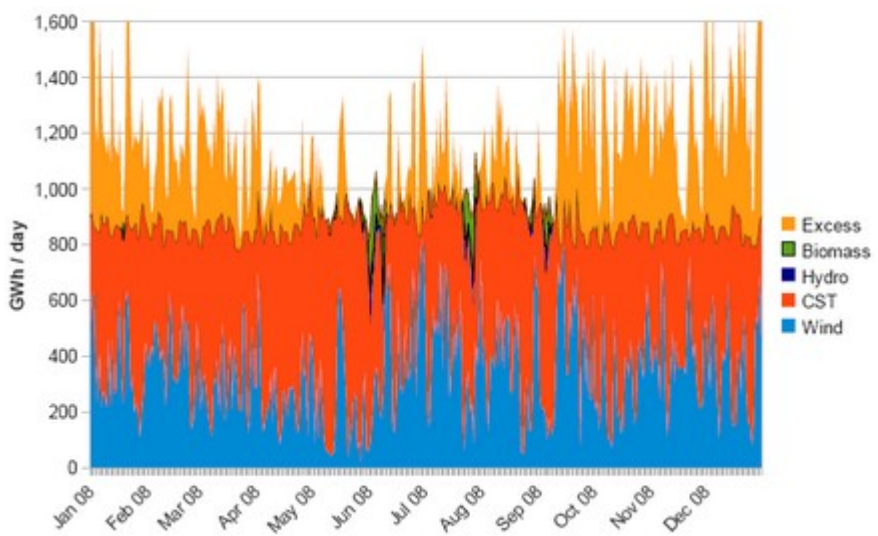
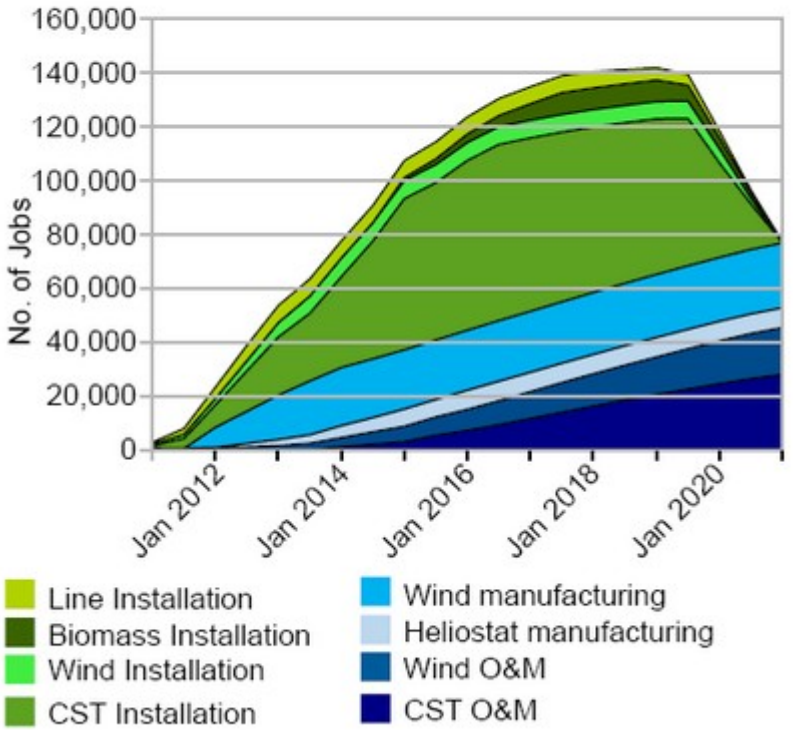


FIGURE 15
Total Jobs created by the ZCA2020 Plan



http://beyondzeroemissions.org/

Wind & Concentrating Solar Thermal (CST) Are Major Renewable Energy Sources

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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."**

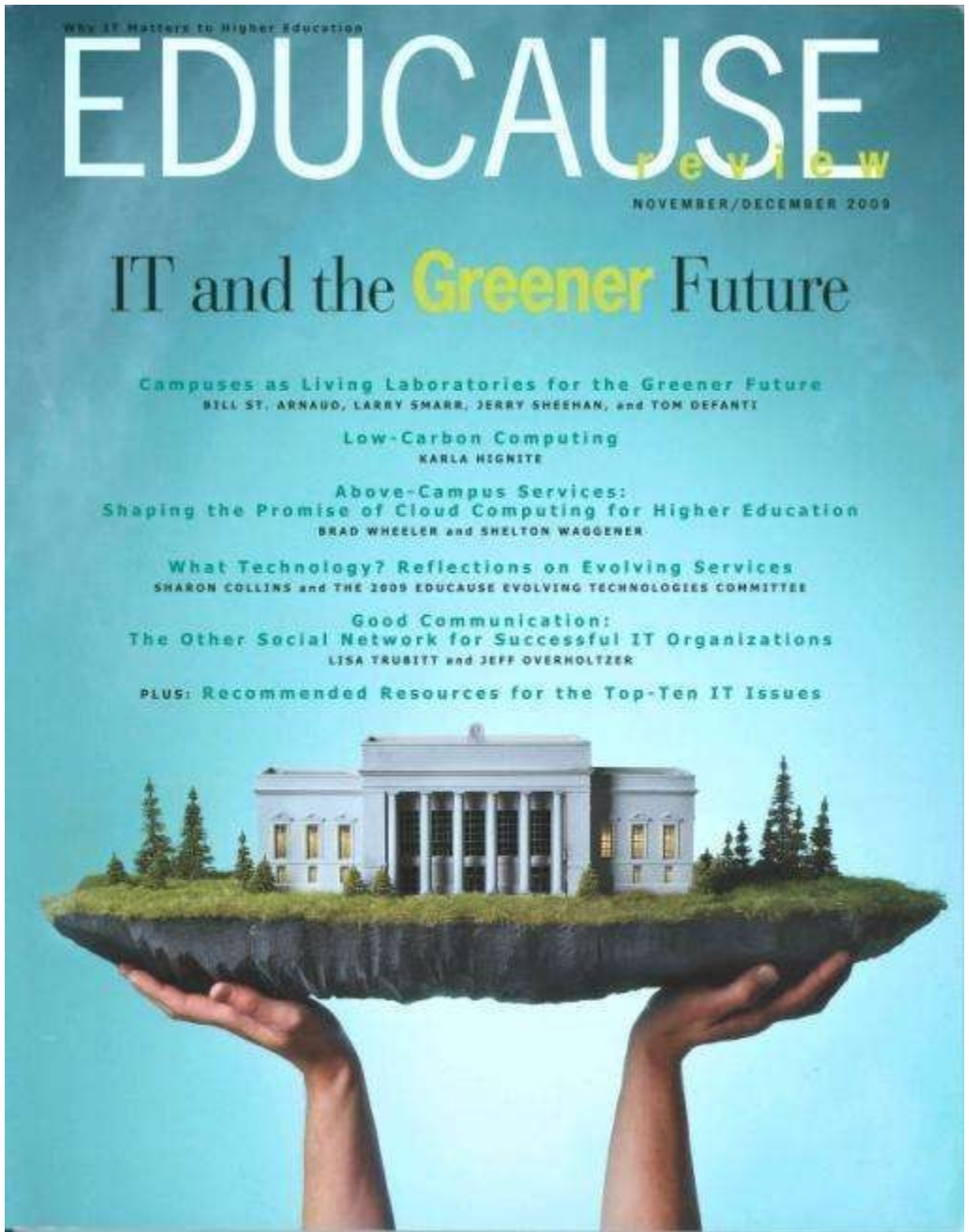
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www.presidentsclimatecommitment.org

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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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UCSD
as a Model Green Campus

- **Second-Largest User Of Electricity (~40 MW) In San Diego**
  - 45,000 Daily Occupants
  - After the City Itself, the Seventh-Largest City in the U.S.
- **Aggressive Program to De-Carbonize Generating Electricity**
  - Natural Gas Co-Gen Facility Supplies ~90% of Campus Electricity
    - Saves ~$8 Million Annually in Energy Costs
  - Installed 1.2 MW Of Solar Panels (With an Additional 2 MW Likely)
  - Acquiring a 2.8 MW Fuel Cell in 2011
    - Powered by Methane from San Diego Waste-Treatment Plant
  - Exploring Use of Cold Seawater for Cooling to Reduce Energy and Freshwater Use
- **This Program Will Allow UCSD to Move ~15% of its Fossil Fuel Power Generation to Renewable Energy in Just a Few Years**

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

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UC Irvine
as a Model Green Campus

- **California's "Flex Your Power" Statewide Energy-Efficiency Campaign December 2008**
  - **Only University Campus Cited in "Best Overall" Category**
  - **UCI Led in Efficiency-Saving 3.7 Million KWh of Electricity During 07–08**
    - **Reducing Peak Demand by up to 68%**
    - **Saving Nearly 4 Million Gallons Of Water Annually.**
  - **UCI's 2008 GHG Reduction Program Annually Eliminates 62,000 $MtCO_2e$**
    - **Saves the Campus ~$30 Million**
- **SunEdison Financed, Built, & Operates Solar Energy System**
  - **In March 2009, UCI Began Purchasing Energy Generated by System**
  - **Will Produce >24 GWh over 20 Years**
- **18 MW Combined Heating, Power, & Cooling Co-Gen Plant**
  - **Employs 62,000 Ton-Hour Chilled-Water Thermal Energy Storage System**
  - **Capable of Reducing up to 6 MW of Electrical Peak Demand**

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

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The Transformation to a Smart Energy Infrastructure: Enabling the Transition to a Low Carbon Economy

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.





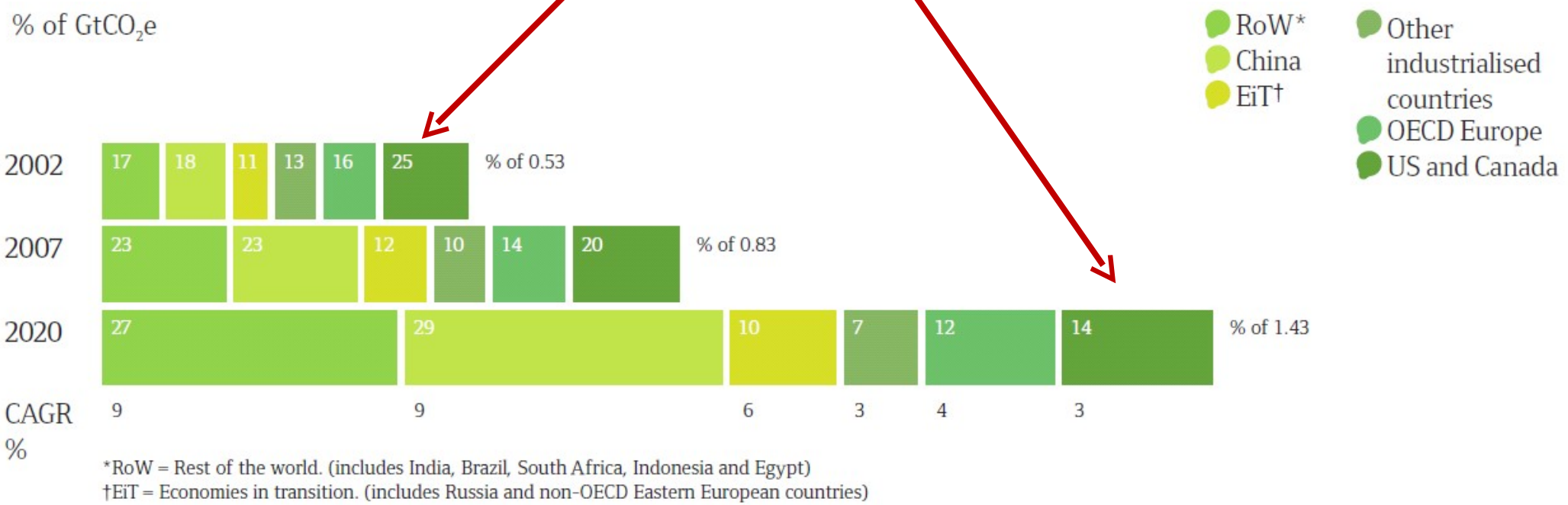
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www.smart2020.org

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

U.S. plus Canada Percentage Falls From
25% to 14% of Global ICT Emissions by 2020

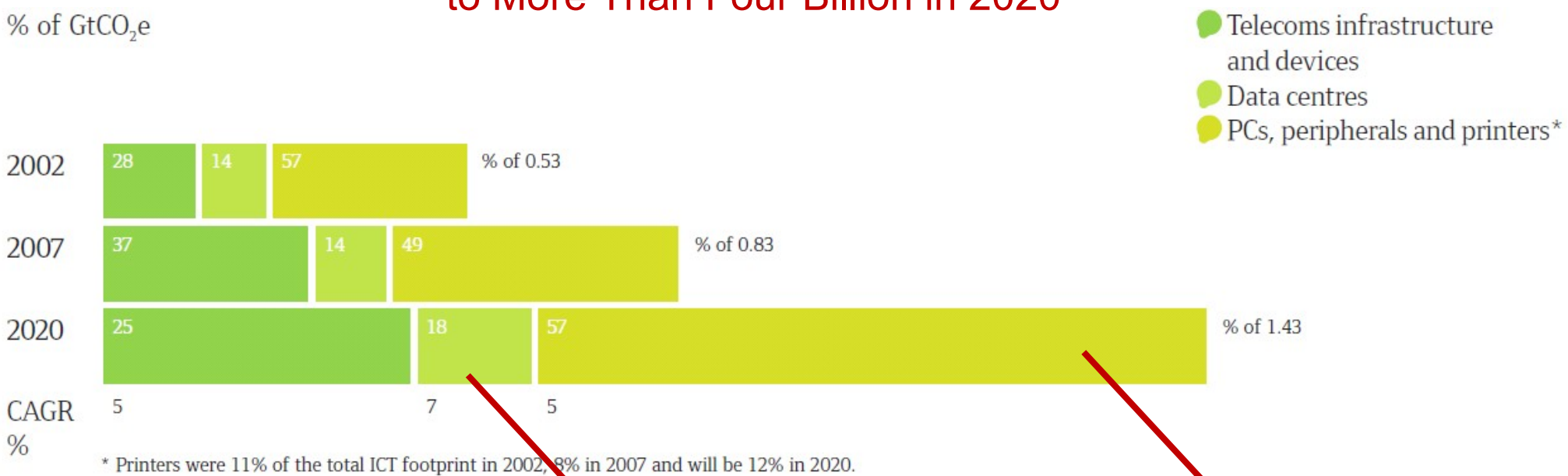


*RoW = Rest of the world. (includes India, Brazil, South Africa, Indonesia and Egypt)
†EiT = Economies in transition. (includes Russia and non-OECD Eastern European countries)

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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

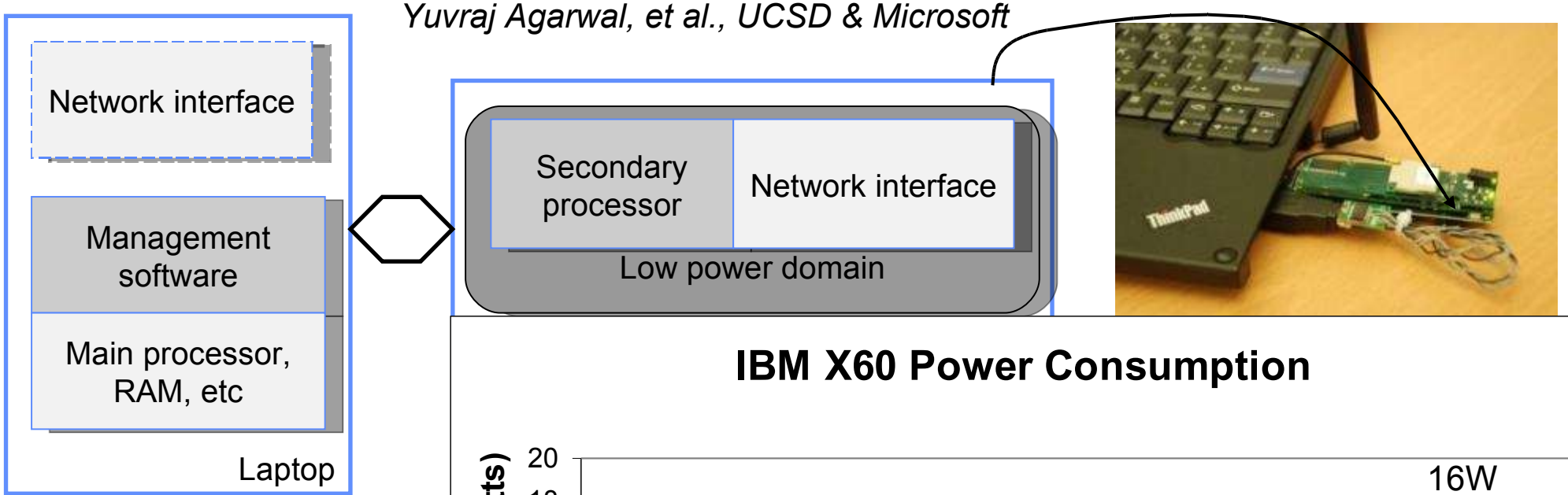
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www.smart2020.org

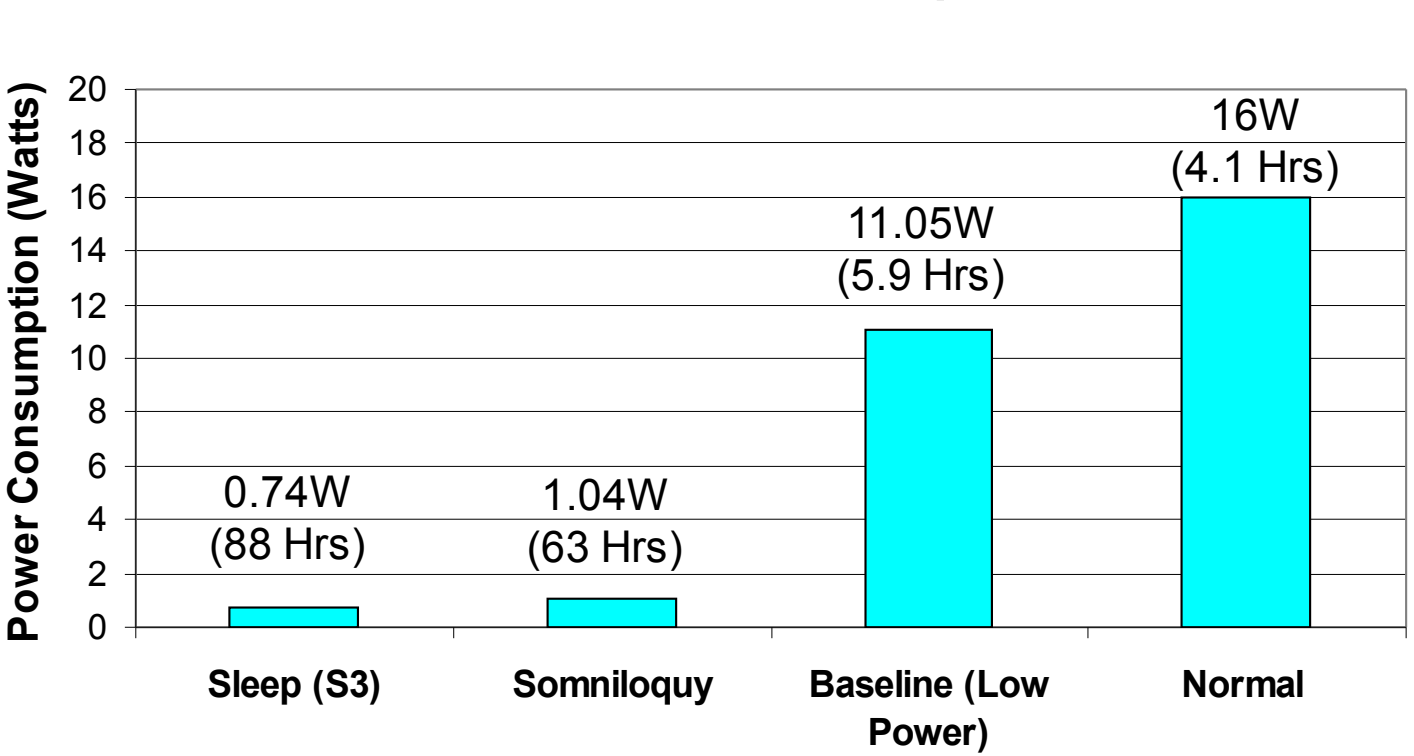
Somniloquy: Increasing Laptop Energy Efficiency

http://mesl.ucsd.edu/yuvraj/research/documents/Somniloquy-NSDI09-Yuvraj-Agarwal.pdf

Yuvraj Agarwal, et al., UCSD & Microsoft



Somniloquy Allows PCs in "Suspend to RAM" to Maintain Their Network and Application Level Presence



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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

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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

QUALCOMM hp invent Texas Instruments Inc. YAHOO! DARPA NSF Los Alamos NATIONAL LABORATORY EST. 1943 U.S. DEPARTMENT OF ENERGY Sun microsystems CISCO National Institutes of Health The Nation's Medical Research Agency SRC Semiconductor Research Corporation

UCSD UCIrvine CNS

System Energy Efficiency Lab (seelab.ucsd.edu)
Prof. Tajana Šimunić Rosing, CSE, UCSD

see it2

GreenLight Experiment: Direct 400v DC-Powered Modular Data Center

- **Concept—avoid DC To AC To DC Conversion Losses**
  - Computers Use DC Power Internally
  - Solar & Fuel Cells Produce DC
  - Can Computers & Storage Use DC Directly?
  - Is DC System Scalable?
  - How to Handle Renewable Intermittency?

UCSD DC Fuel Cell 2800kW
Sun MDC <100-200kW

- **Prototype Being Built in GreenLight Instrument**
  - Build DC Rack Inside of GreenLight Modular Data Center
    - 5 Nehalem Sun Servers
    - 5 Nehalem Intel Servers
    - 1 Sun Thumper Storage Server

All With DC Power Supplies

  - Building Custom DC Sensor System to Provide DC Monitoring
  - Operational August-Sept. 2010

Next Step: Couple to Solar and Fuel Cell

Source: Tom DeFanti, Greg Hidley, Calit2; Tajana Rosing, UCSD CSE

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**

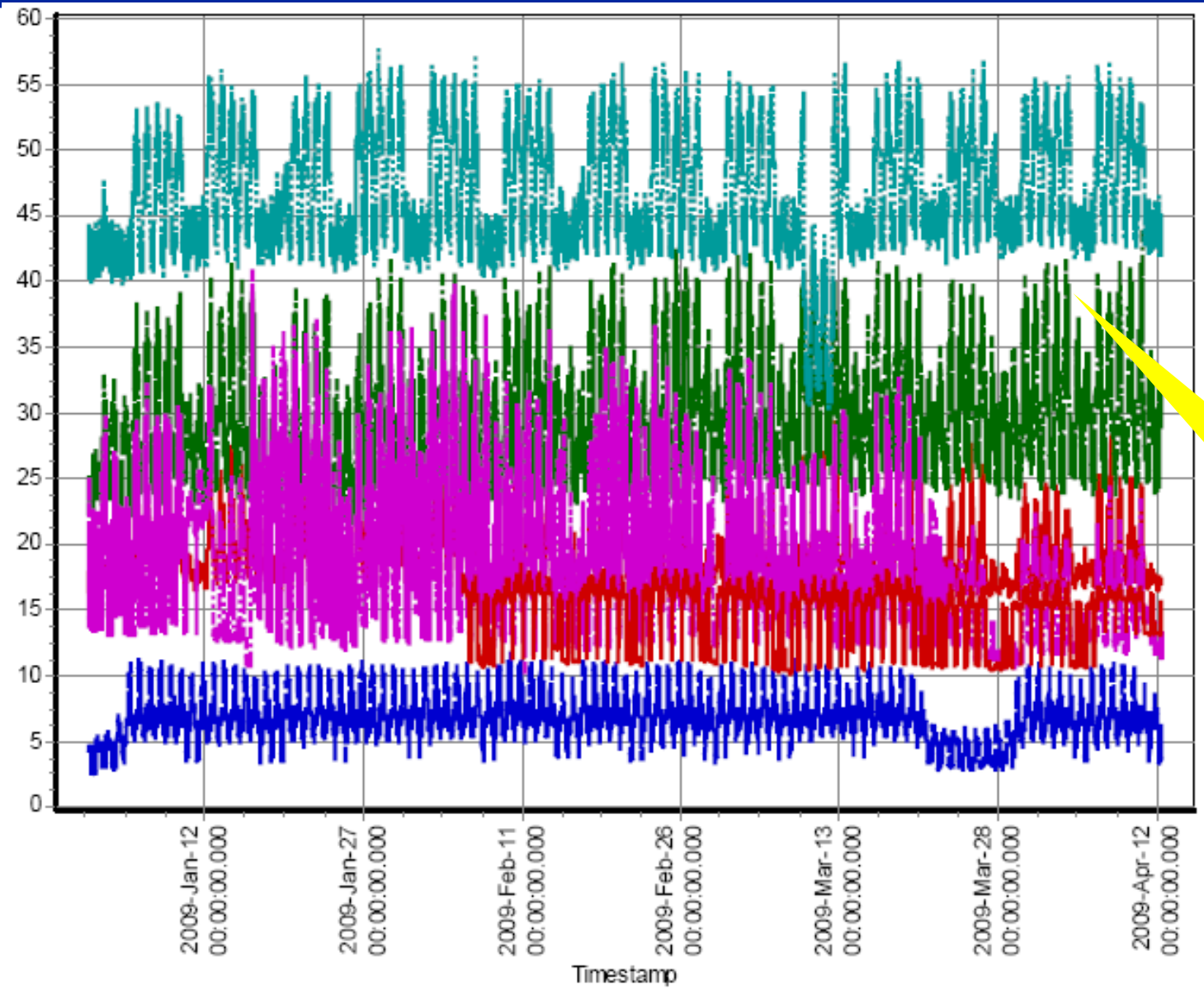
*** Smart 2020 United States Report Addendum**

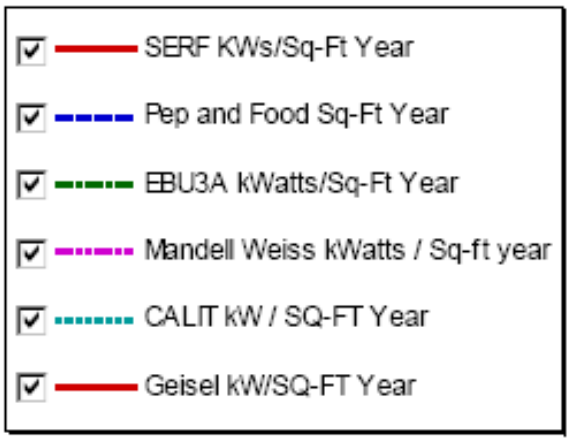
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Using the Campus as a Testbed for Smart Energy: Making Buildings More Energy Efficient





Calit2 and CSE are Very Energy Intensive Buildings

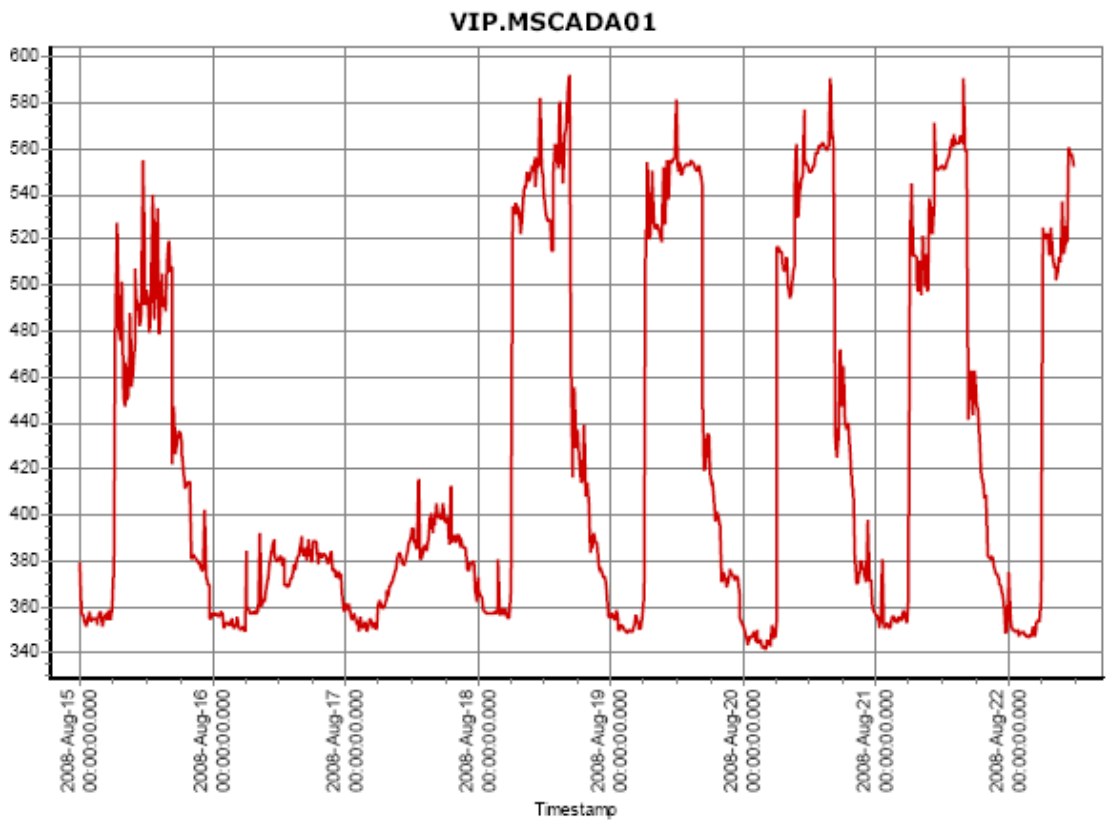
kW/sqFt Year Since 1/1/09

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Smart Energy Buildings: Active Power Management of Computers

- 500 Occupants, 750 Computers
- 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



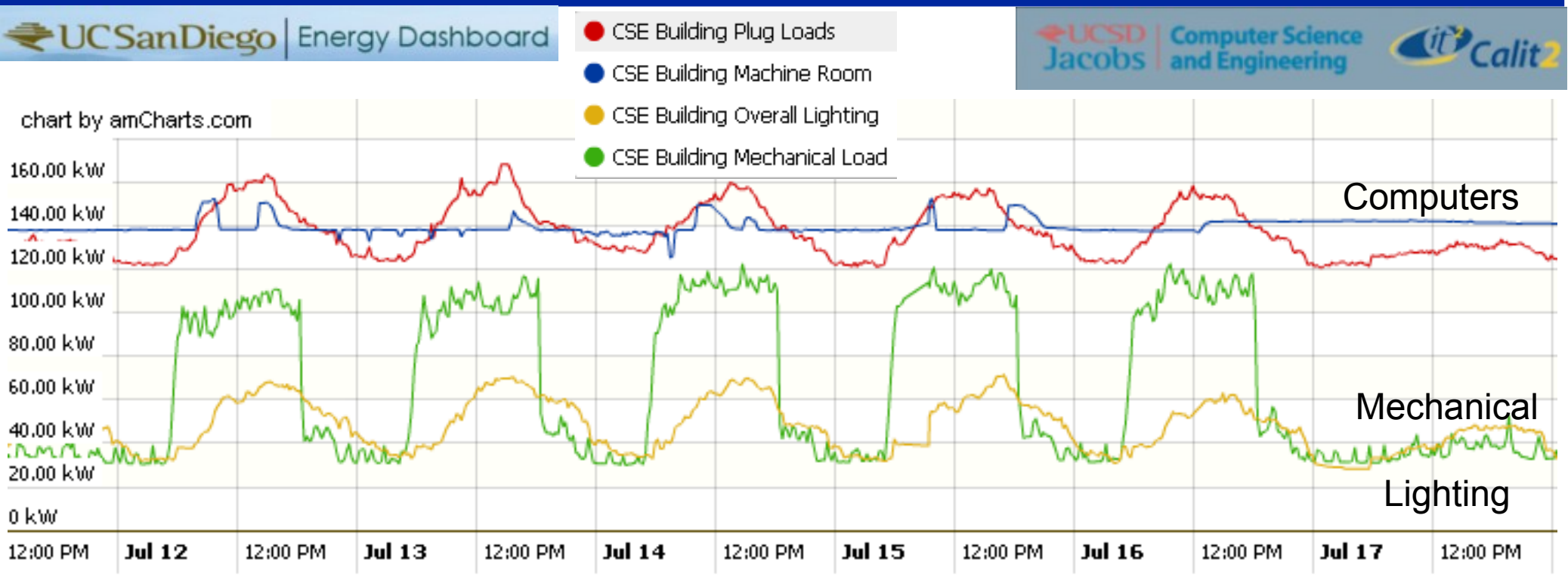


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Source: Yuvraj Agarwal, Thomas Weng, Rajesh Gupta, UCSD

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Contributors to Base Load
UCSD Computer Science & Engineering Building



- **IT Loads Account for 50% (Peak) to 80% (Off-Peak)!**
  - **Includes Machine Room + Plug Loads (PCs and Laptops)**
- **IT Equipment, Even When Idle, Not Put to Sleep**
- **Duty-Cycling IT Loads Essential To Reduce Baseline**

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

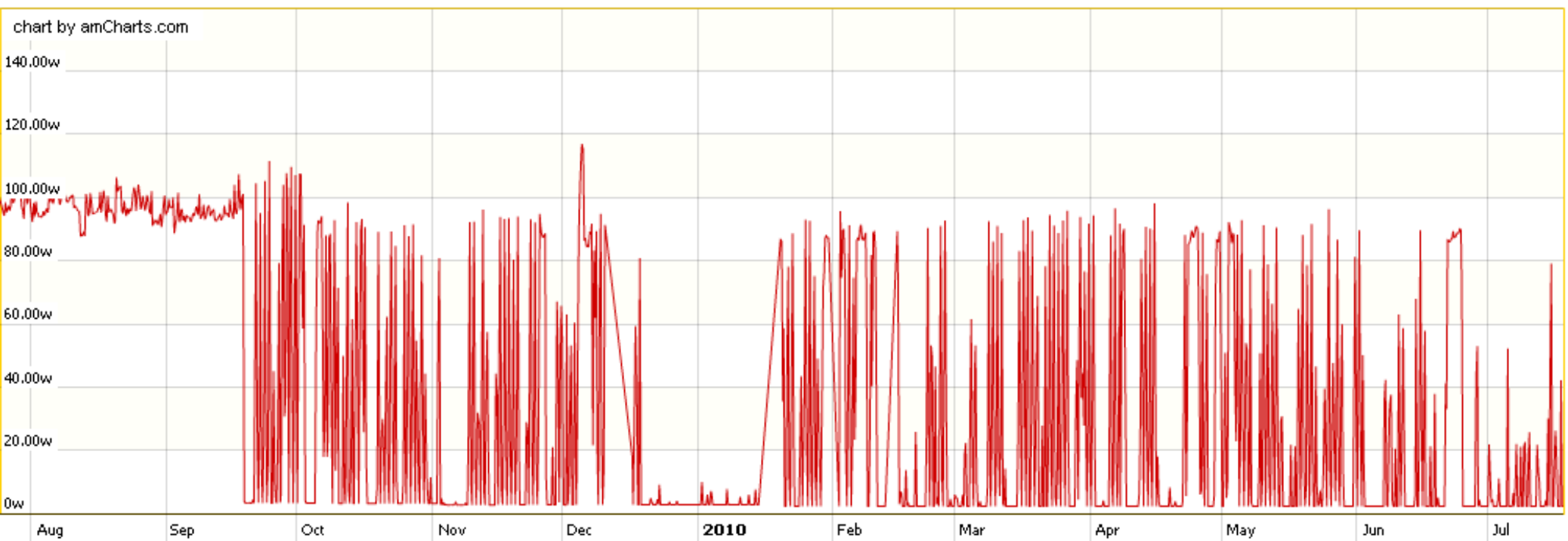
http://energy.ucsd.edu

Reducing Energy Requirements of Networked PCs: UCSD's Enterprise "Sleep Server" System



http://energy.ucsd.edu/device/meterdisplay.php?meterID=3091420330&mode=pastyear

Estimated Energy Savings
With Sleep Server: 46.64%



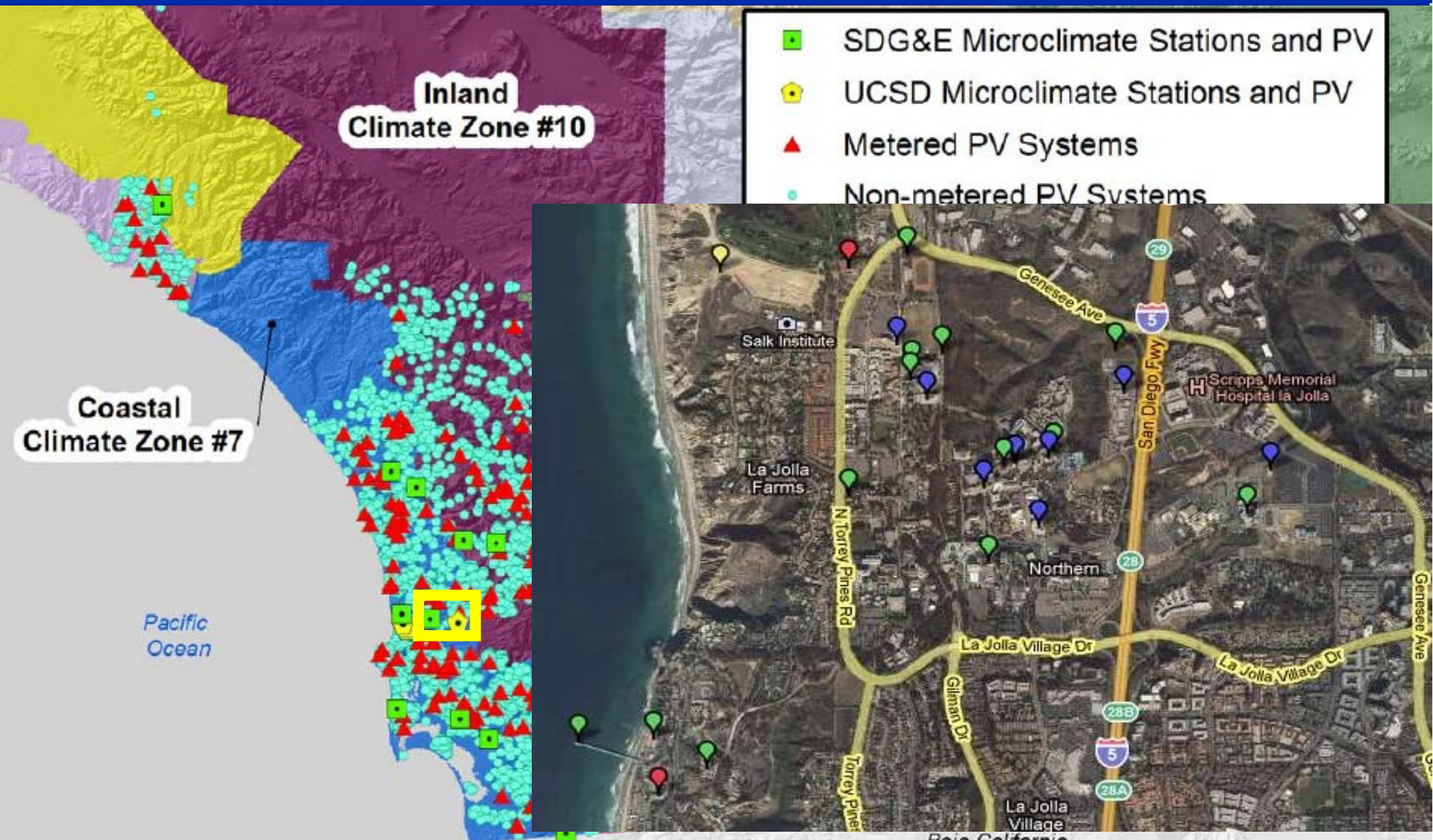
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UCSD Jacobs School of Engineering | Computer Science and Engineering | Calit2

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

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Solar PV Systems in San Diego County
UCSD "Living Laboratory" for Solar System Optimization



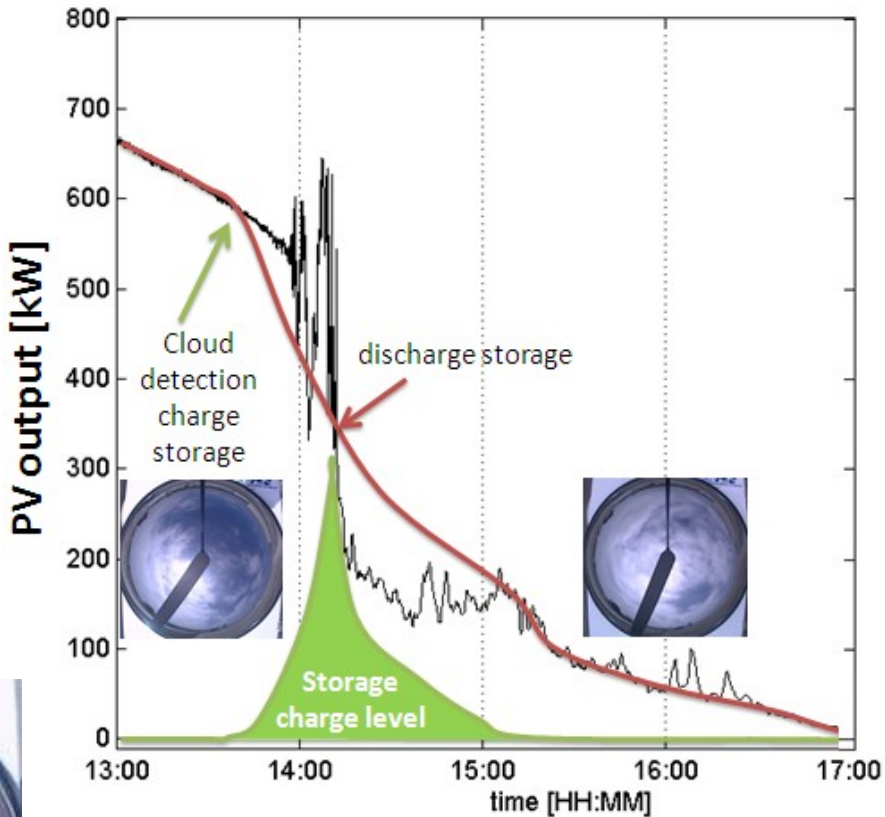
Source: Jan Kleissl, UCSD
Map courtesy of CCSE

Solar Forecasting for Energy Storage Optimization

- **Develop Solar Forecast Using Sky Trackers**
- **Integrate into Sanyo Smart Energy Systems**
- **Evaluate Benefit To Consumer and Utilities**

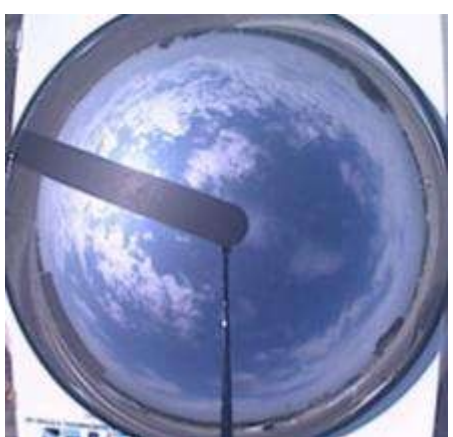


max($)



Total Sky Imager: Cloud Detection & Forecasting





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Source: Jan Kleissl, UCSD
http://solar.ucsd.edu

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UCSD and UCI Smart Energy Transportation System and Renewable Energy Campus Fleets

- **Calit2@UCSD Developed the California Wireless Traffic Report**
  - http://traffic.calit2.net/
  - Deployed in San Diego, Silicon Valley, and San Francisco
  - Thousands/Day Reduce Congestion
- **UCSD Campus Fleet 45% Renewables**
  - 300 Small Electric Cars
  - 50 Hybrids
  - 20 Full-Size Electrics by 2011
- **UCI First U.S. campus to Retrofit its Shuttle system for B100 (Pure Biodiesel),**
  - Reducing Campus Carbon Emissions ~480 Tons Annually

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



Nov. 2007

- **EPA Environmental Achievement Award for its Sustainable Transportation Program,**
  - Eliminates >18,000 $mTCO_2e$ Annually by Promoting Alternative Transportation
  - 2008 Governor's Environmental and Economic Leadership Award

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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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High Definition Video Connected OptIPortals: Virtual Working Spaces for Data Intensive Research



NASA Interest in Supporting Virtual Institutes

CGLX

LifeSize HD

NASA Ames
Lunar Science Institute
Mountain View, CA

UCSD
UCIrvine

Source: Falko Kuester, Kai Doerr Calit2; Michael Sims, NASA

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

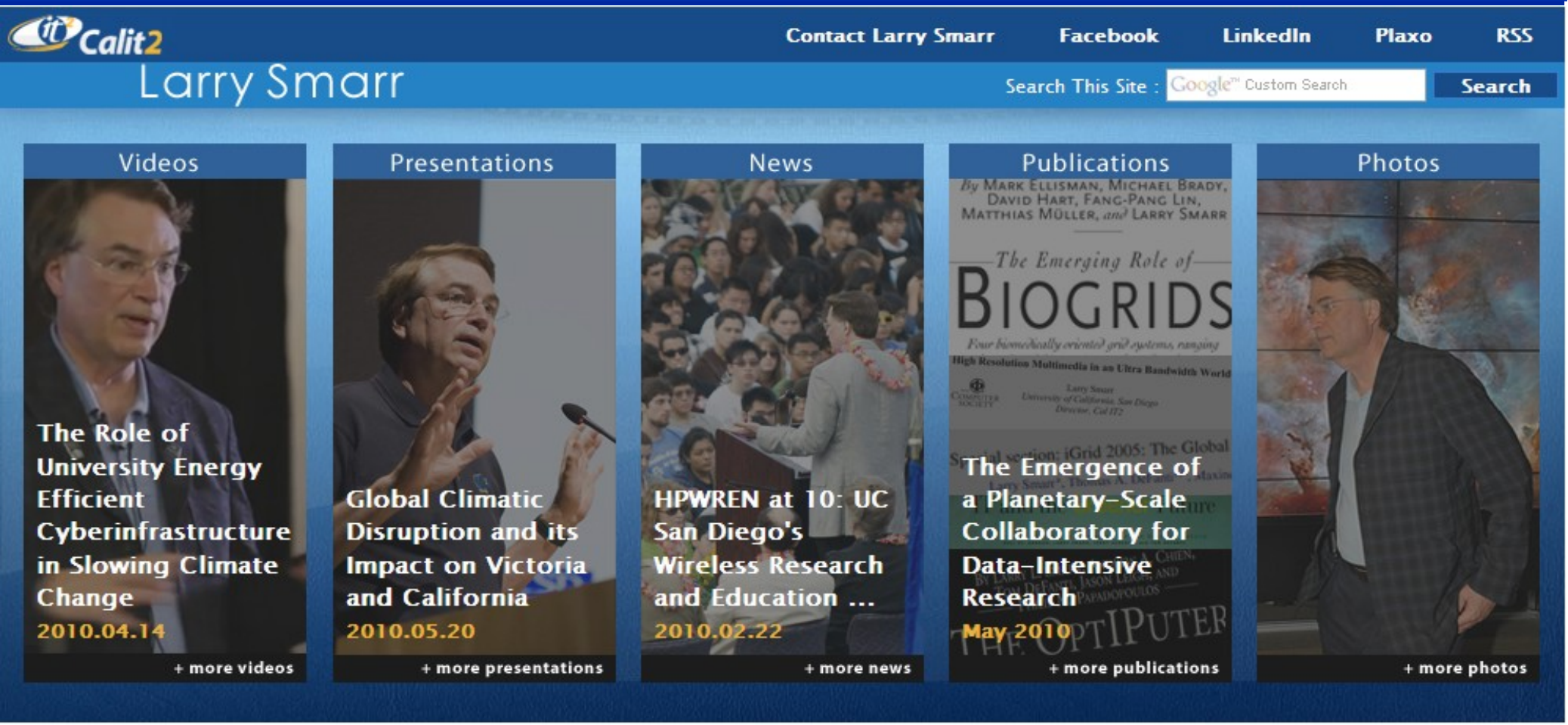


California Public Utilities Commission

Co-Hosted By Calit2 & CPUC

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

You Can Download This Presentation at lsmarr.calit2.net



ABOUT LARRY SMARR

Larry Smarr is the founding Director of the California Institute for Telecommunications and Information Technology (Calit2), a UC San Diego/UC Irvine partnership, and holds the Harry E. Gruber professorship in Computer Science and Engineering

WHAT I'M READING

Complete List of Larry's Recommendations

American College and University Presidents' Climate Commitment

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