# Optical Technology and Climate Change

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# The Climate Change Threat

**Obama's National Science Advisor John Holdren on Global Climate Disruption**

http://greenmonk.net/john-holdren-on-global-climatic-disruption/

**Stephen Chu – new head of DoE – "Wake up America!!"**

http://www.thedailygreen.com/environmental-news/latest/california-agriculture-global-warming-47020402

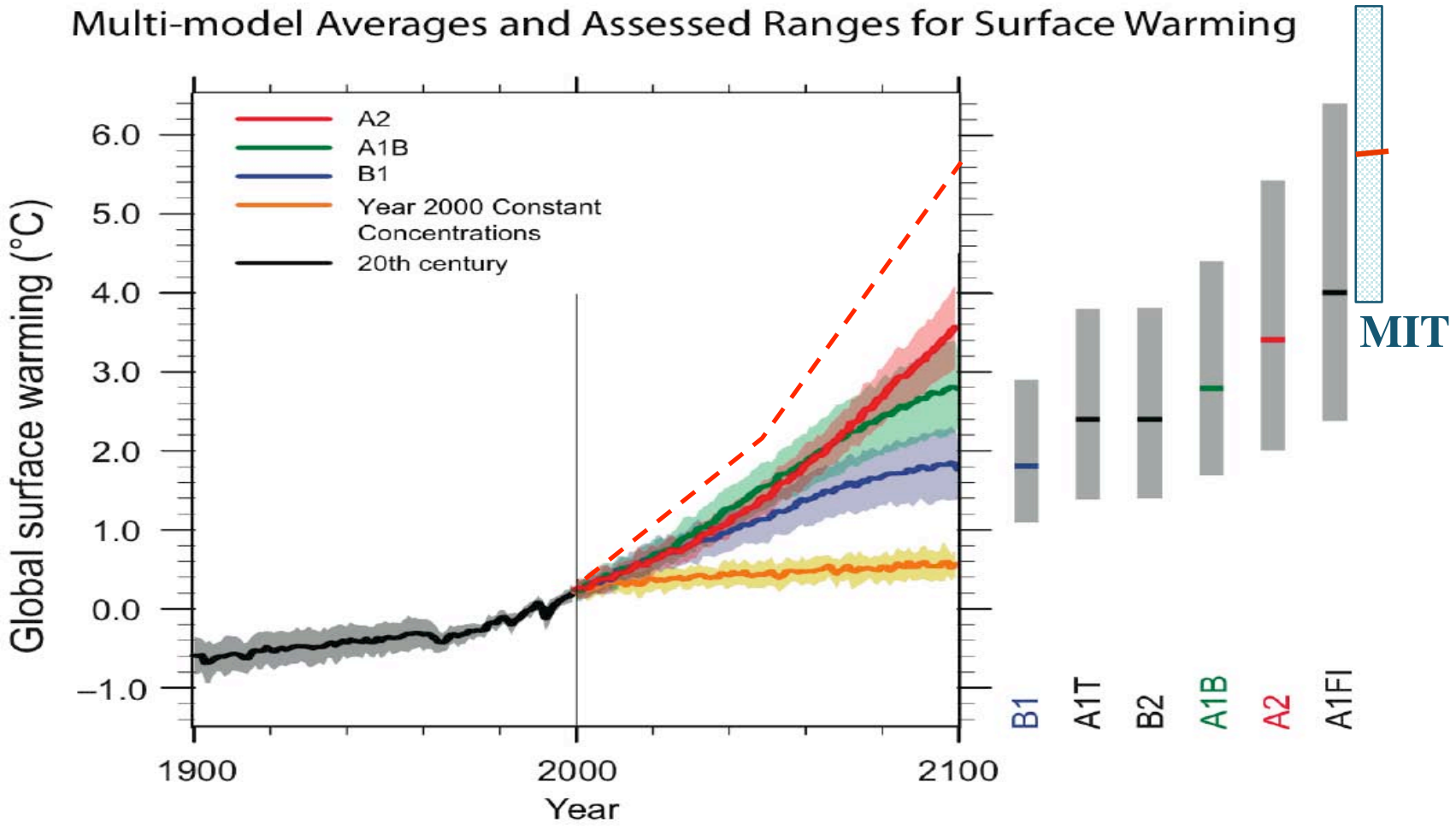
**USGS Abrupt Climate Change report finds that future climate shifts have been underestimated and warns of debilitating abrupt shift in climate that would be devastating.**

http://www.climatescience.gov/Library/sap/sap3-4/final-report/default.htm
http://climateprogress.org/2008/11/24/what-are-the-near-term-climate-pearl-harbors/

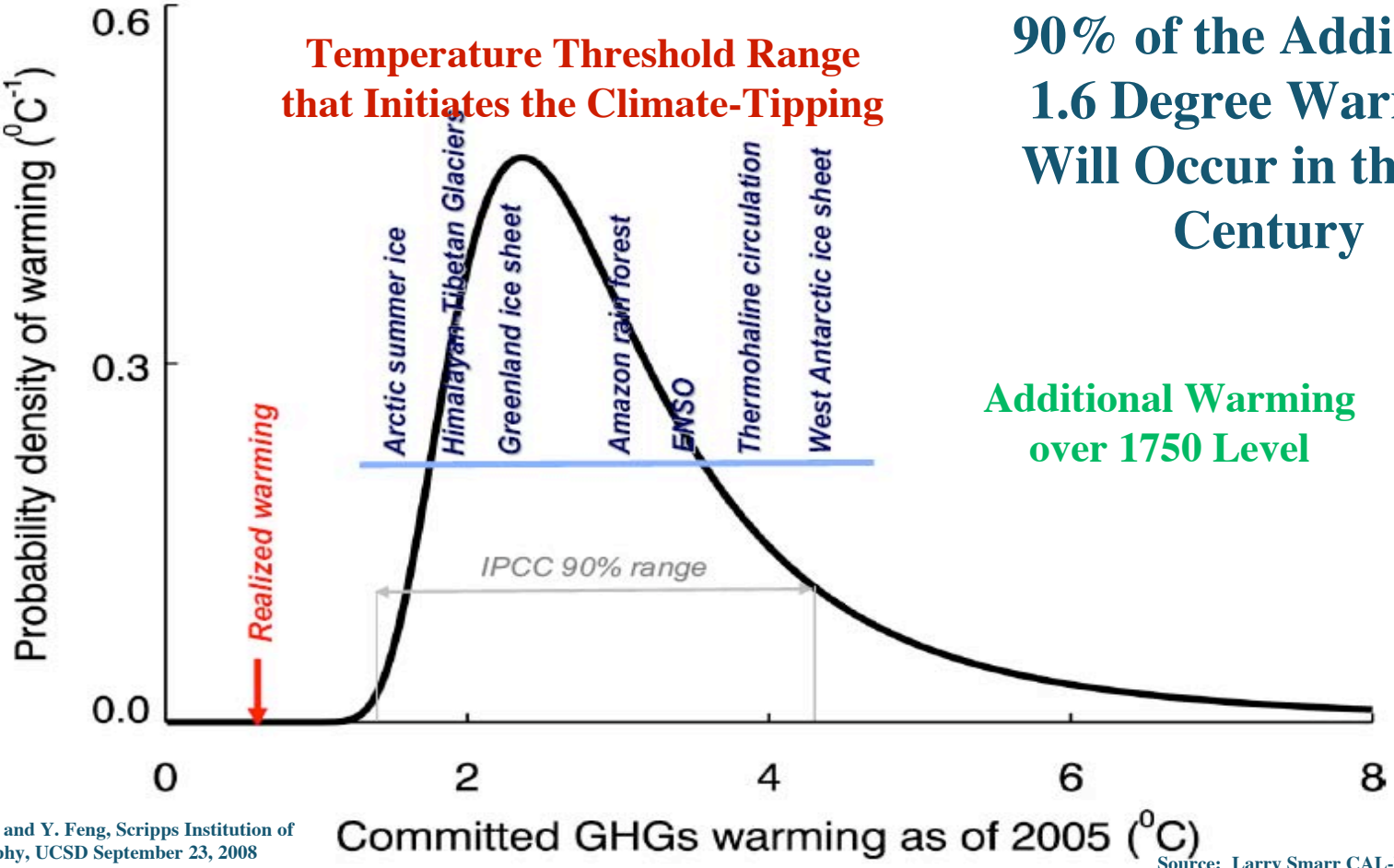
**MIT report predicts median temperature forecast of 5.1C**

http://globalchange.mit.edu/pubs/abstract.php?publication_id=990

# Climate Forecasts



# The Planet is Already Committed to a Dangerous Level of Warming



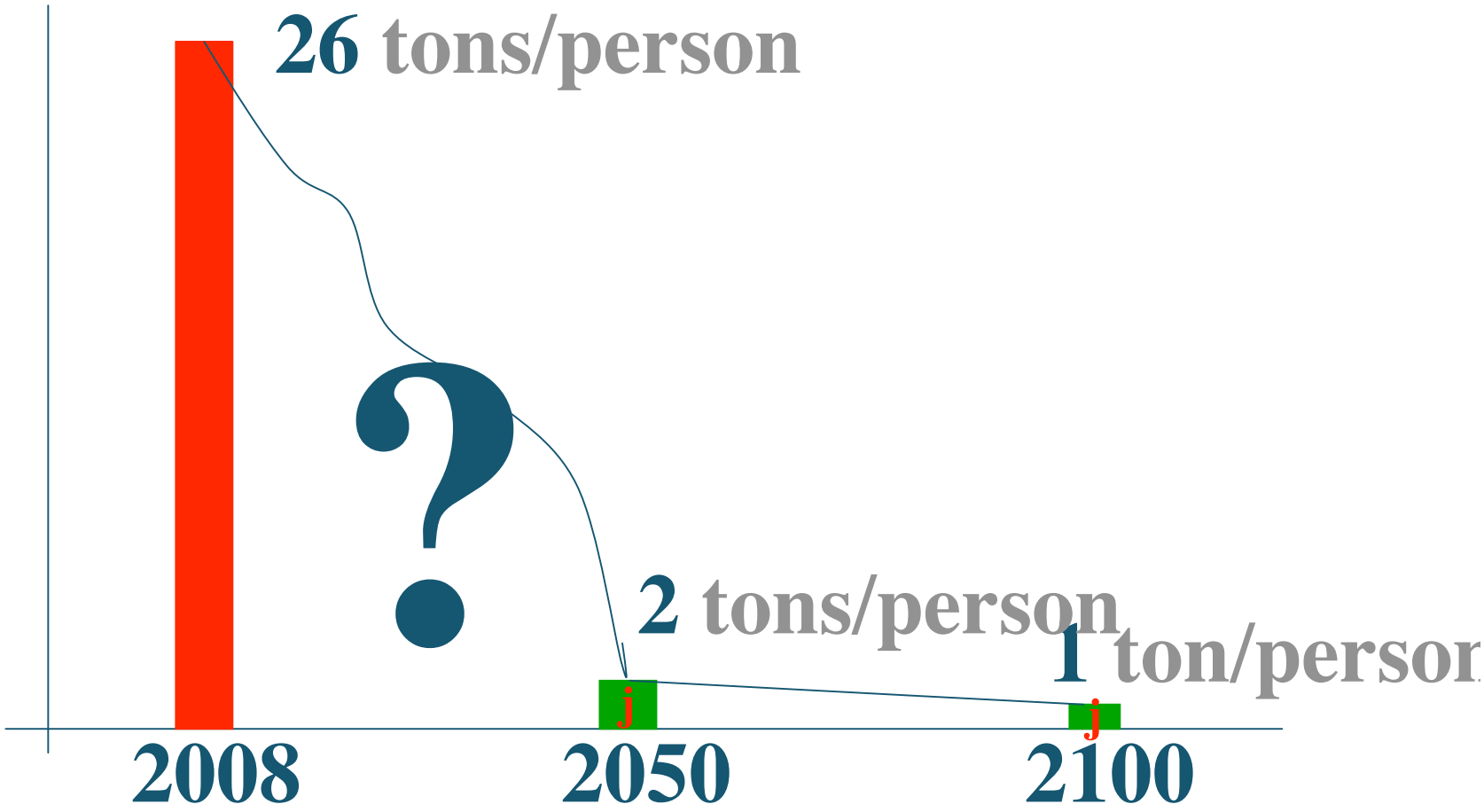

**90% of the Additional 1.6 Degree Warming Will Occur in the 21st Century**

**Additional Warming over 1750 Level**

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

Source: Larry Smarr CAL-It2

# Our Challenge




Source: Stern 2008

# First we must clean up our own act

- **ICT is 2-3% of GHG emissions mostly through consumption of electricity produced by coal powered generating stations**
- **ICT represent 8-9.4% of total US electricity consumption, and 8% of global electricity consumption**
  - http://uclue.com/index.php?xq=724
- **Future Broadband- Internet alone is expected to consume 5% of all electricity**
  - http://www.ee.unimelb.edu.au/people/rst/talks/files/Tucker_Green_Plenary.pdf

# Growth Projections

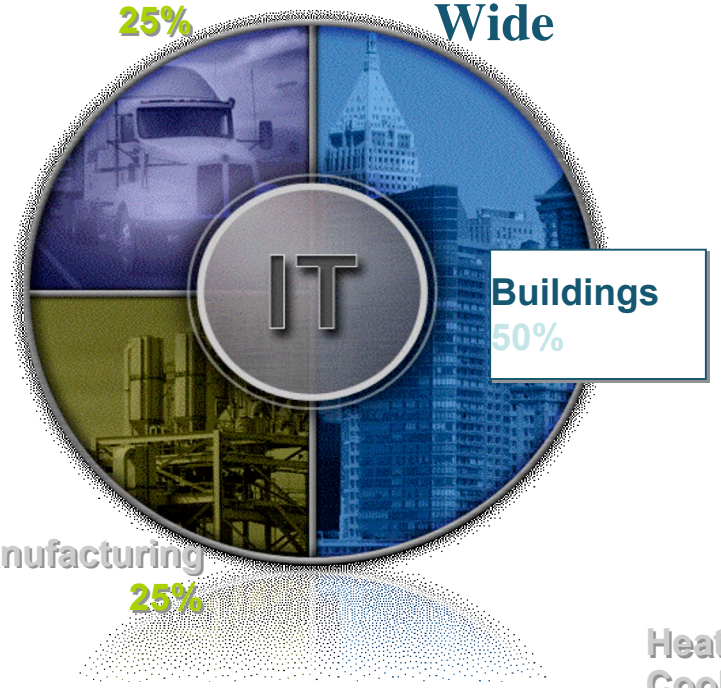
- 2008, 50% of today's data centers will have insufficient power and cooling capacity to meet the demands of high-density equipment
- By 2008, 50% of today's Data Centers and major science facilities in the US will have insufficient power and cooling;*
- By 2010, half of all Data Centers will have to relocate or outsource applications to another facility.*
- During the next 5 years, 90% of all companies will experience some kind of power disruption. In that same period one in four companies will experience a significant business disruption*

Source: Gartner; Meeting the DC power and cooling challenge

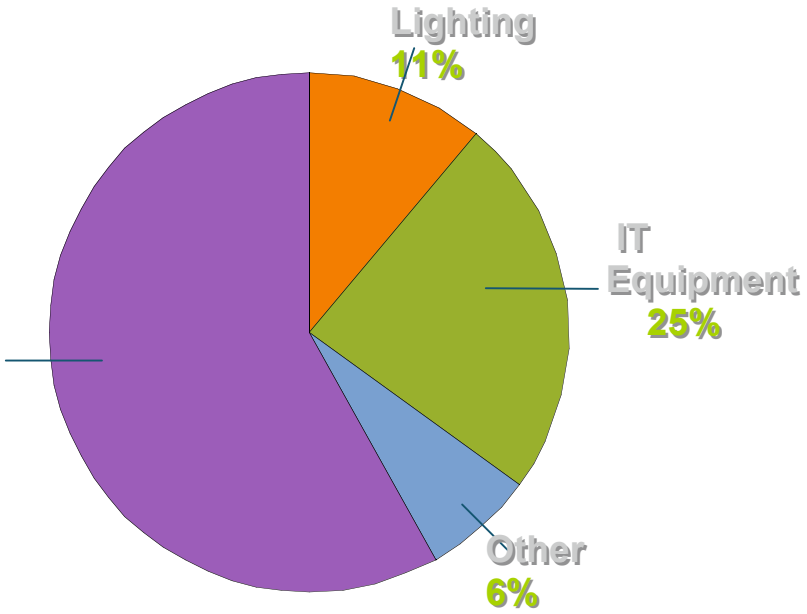
*Sourcce: http://www.nanog.org/mtg-0802/levy.html

# IT biggest power draw

## Energy Consumption World Wide




## Energy Consumption Typical Building




Sources: BOMA 2006, EIA 2006, AIA 2006

# ICT and Internet is critical to reducing CO2

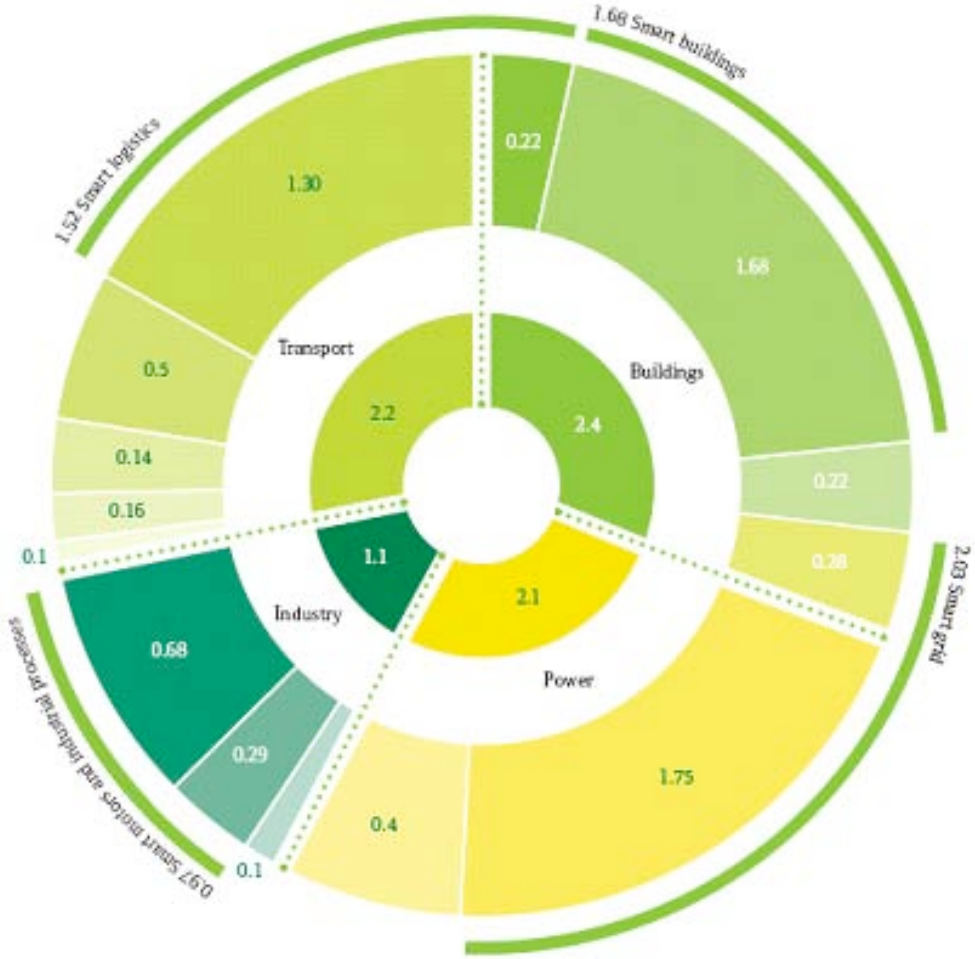
- Direct emissions of Internet and ICT are important at 2-3% of world emissions but, in order of impact, the most significant contribution we can make is through leveraged, or indirect, emissions reductions.

- According to SMART 2020 these represent as much as a 15% reduction opportunity in global emissions.

- (And SMART 2020 is one of the most conservative reports on the topic. Others identify even higher potential for savings).

# ICT's Enabling Effect is Significant

- **Can deliver carbon emission reductions five times size of sector's own footprint by 2020**
  - 7.8 Giga-tons carbon dioxide equivalent
  - Greater than US or China's current annual emissions
- **Key sectors include Transportation, Buildings, Industrial Processes, and Power**
- **No other sector can achieve this enabler effect !!**




Source: SMART 2020: Enabling the low carbon economy in the information age, 2008

# Why is this important?

- RFPs from customers to include shadow carbon accounting
- UK government is planning to link the funding available to universities and colleges with their performance in reducing carbon emissions.
- All Government RFP responses  must include shadow cost carbon accounting
- EU and other nations expected to follow soon
- http://www.carbonoffsetsdaily.com/global/government-funding-to-reward-greenest-universities-3996.htm
-

# The Carbon Economy

- $500 billion - Value of low-carbon energy markets by 2050
- $100 billion - Demand for projects generating GHG emissions credits by 2030
- Global carbon market expected to grow 58% in 2008 to $92 billion
- $57 trillion - Carbon Disclosure Project signatories, 1000s of companies participating, expanding to supply chain accounting
- Carbon economy has potential to pay for several bank bail-out's and 3 or 4 Iraq like wars
- Carbon economy could underwrite costs of national broadband, healthcare and mortgage defaults

Source: ClimateCheck

# The Falsehood of Energy Efficiency

- **Most current approaches to reduce carbon footprint are focused on increased energy efficiency of equipment and processes**
- **But growth in ICT deployment of equipment and services is outstripping any gains made in efficiency**
  - Which is likely to accelerate as ICT is used to support abatement in other fields such as smart homes, smart buildings, smart grids etc
- **Also greater efficiency can paradoxically increase energy consumption by reducing overall cost service and therefore stimulates demand**
  - Khazzoom-Brookes postulate (aka Jevons paradox aka rebound effect)
  - In last Energy crisis in 1973 Congress passed first energy efficiency laws (CAFÉ) which mandate minimum mileage for cars, home insulation and appliances
  - Net effect was to reduce cost of driving car, heating or cooling home, and electricity required for appliances
  - Consumer response was to drive further, buy bigger homes and appliances

# Zero Carbon strategy essential

- **Zero carbon strategy using renewable energy critically important if governments mandate carbon neutrality, or if there is a climate catastrophe**
- **With a zero carbon strategy growth in demand for ICT services will not effect GHG emissions**
  - Anything times zero is always zero
- **Wind and solar power are most likely candidates because of opportunity cost/benefit analysis especially time to deploy**
  - Nuclear has high opportunity cost because of time to deploy
  - http://climateprogress.org/2008/12/14/stanford-study-part-1-wind-solar-baseload-easily-beat-nuclear-and-they-all-best-clean-coal/
- **But renewable energy sites are usually located far from cities and electrical distribution systems are not designed to carry load**
  - http://www.americanprogress.org/issues/2008/12/pdf/renewable_transmission.pdf

# “Zero Carbon” Computing and data centers

- **Purchasing green power locally is expensive with significant transmission line losses**
  - Demand for green power within cities expected to grow dramatically
- **ICT facilities DON’T NEED TO BE LOCATED IN CITIES**
  - -Cooling also a major problem 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 and high costs in wheeling power
  - Savings in transmission line losses (up to 15%) alone, plus carbon offsets can pay for moving ICT facilities to renewable energy site
- **ICT is only industry ideally suited to relocate to renewable energy sites**
  - Also ideal for business continuity in event of climate catastrophe

# Optical networks, SOA and Virtualization are key

- Optical networks (as opposed to electronic routed networks) have much smaller carbon footprint
- Significant reduced CO2 impacts are possible through use of SOA, clouds, web services, virtualization, UCLP, grids, Web 2.0, NGI etc.
- Computer and networks architectures to connect remote computers, databases and instruments will be essential for zero carbon ICT

# Many examples


**Wind powered data centers**

**Ecotricity in UK builds windmills at data center locations with no capital cost to user**

**Data Islandia**
**Digital Data Archive**

**Hydro-electric powered data centers**

**ASIO solar powered data centers**

# Relocation of Nordic HPC facilities to Iceland

# CANARIE Green-IT Pilot

- **$3m - $4m allocation for Green cyber-infrastructure-IT pilot testbed**

- **Two objectives:**
  - Technical viability and usability for relocating computers to zero carbon data centers and follow the sun/follow the wind network
  - Business case viability of offering carbon offsets (and or equivalent in services) to IT departments and university researchers who reduce their carbon footprint by relocating computers and instrumentation to zero carbon data centers

- **International partnership with possible zero carbon nodes using virtual router/computers in Spain, Ireland, California, Australia, British Columbia, Ottawa, Quebec and Nova Scotia**

# Renewable power is not reliable

- **How do you provide mission critical ICT services when energy source is unreliable?**
  - Ebbing wind or setting sun
- **Back up diesel and batteries are not an option because they are not zero carbon and power outages can last for days or weeks**
- **Need new network architectures and business models to ensure reliable service delivery by quickly moving compute jobs and data sets around the world to sites that have available power**
  - Will require high bandwidth networks and routing architectures to quickly move jobs and data sets from site to site

# Vertical Windmills for networks


**MAGENN AIR ROTOR SYSTEM (M.A.R.S.)**

**Verticainc**

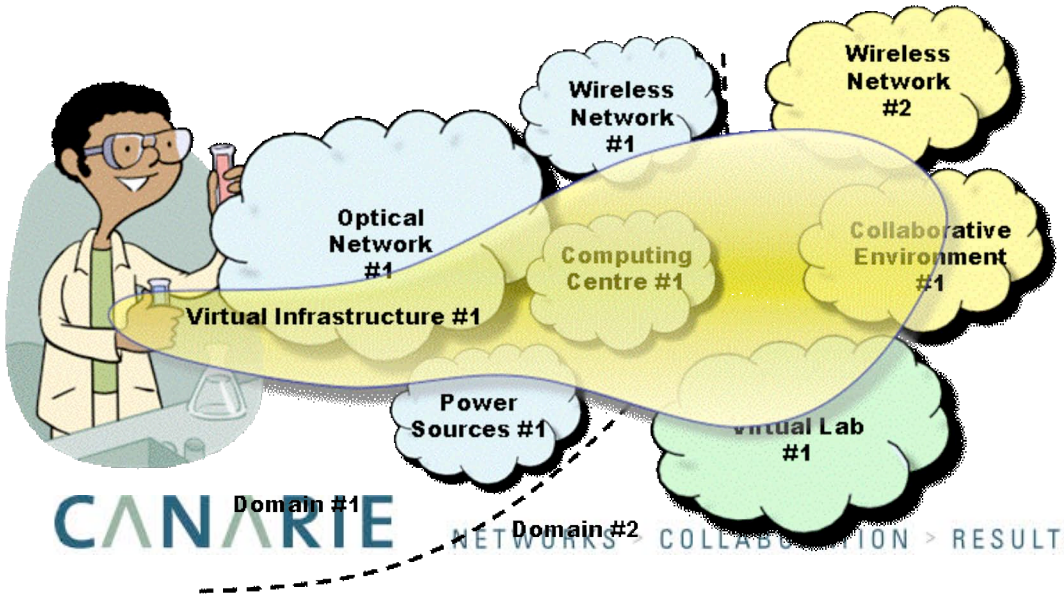
**Windports**

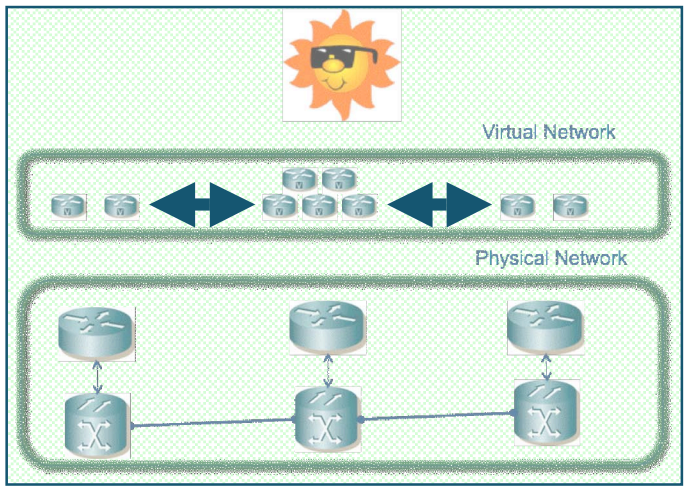
# PROMPT – Next Generation Internet to Reduce Global Warming

**Technology, Products and R&D**

Virtualization, SOA and Hypervisors
Audit and Monitoring
Infrastructure as a Service (IaaS)
Wireless & Optical Networks
Cognitive Networks
IP Multimedia Subsystem
Smart Systems
Lifecycle Management

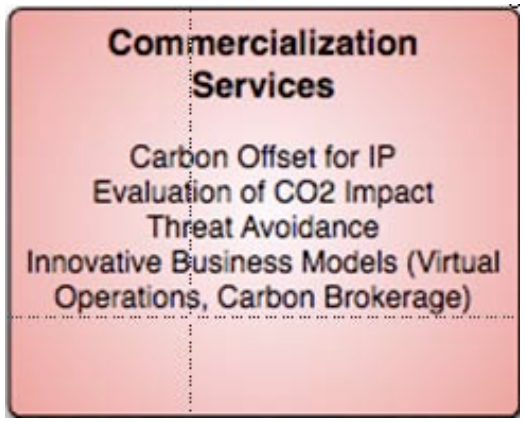
- Research on router, optical, W/W-less and distributed computing architectures, applications, grids, clouds, Web services, virtualization, dematerialization, remote instrumentation and sensors, etc.
- Share infrastructure & maximize lower cost power by "following wind & sun" networks.

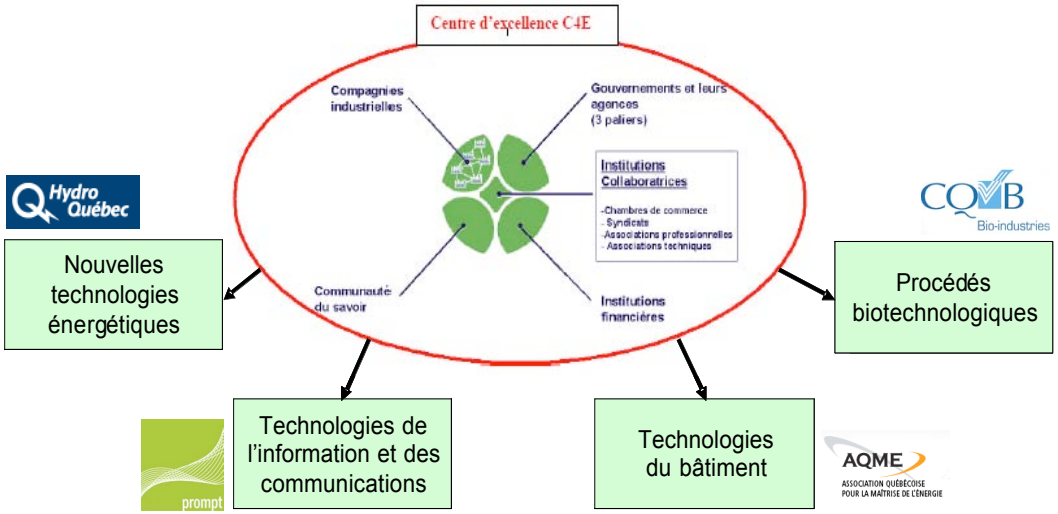



Sources: GENI and Inocybe

# Innovative Research funding model




- Virtual carbon trading systems where carbon offsets are traded for access to grid computational cycles, wide area network bandwidth, research funding and or other virtual services;
- Creation of a multi-sector pilot of a generalized ICT carbon trading system including government, industry, and universities;

# Strong Interest worldwide

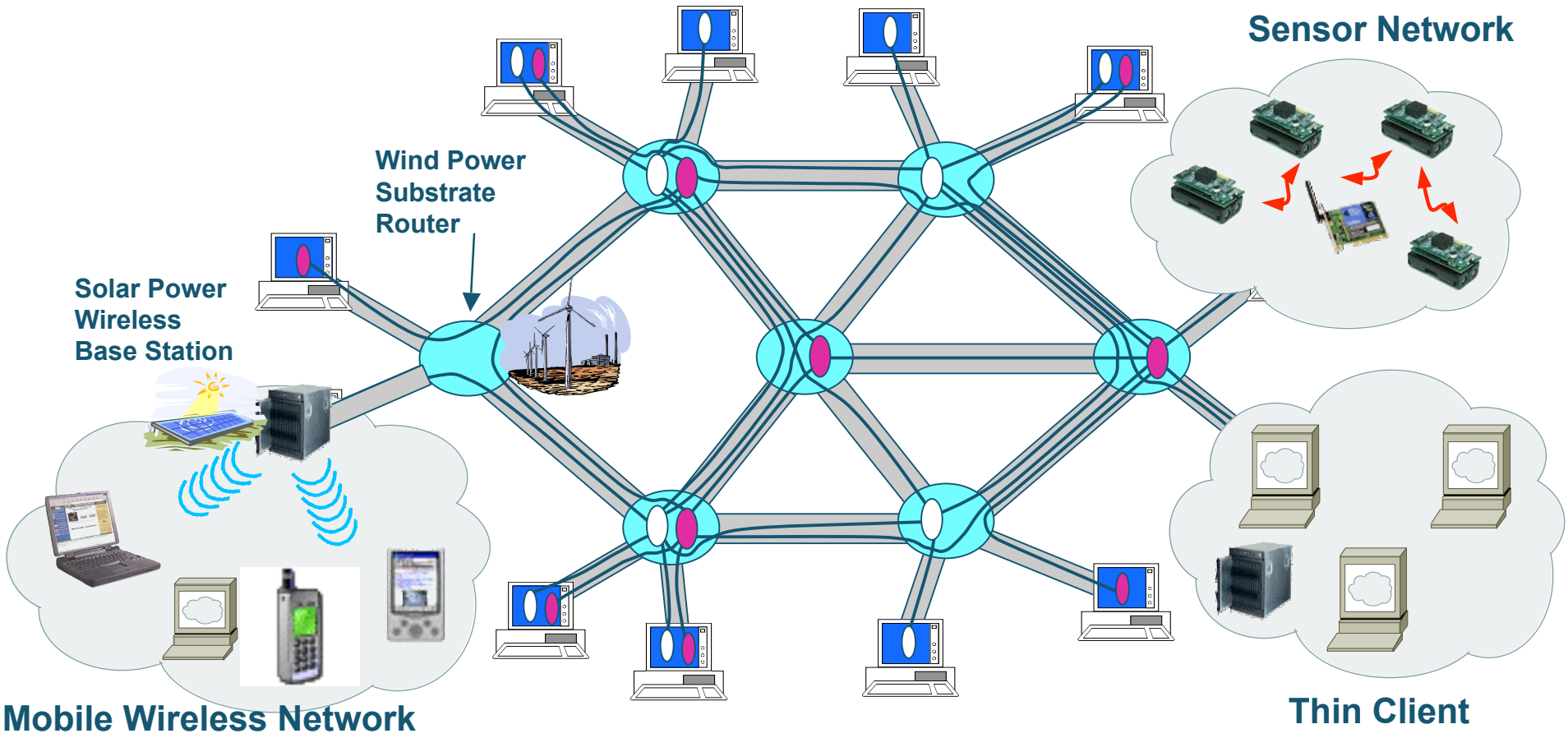
- **Over $15M commitments by 11 companies, 15 Canadian universities & institutions and 11 international organizations;**
- **Open initiative: Expanding MOU across California, Canada & ROW.**

# Possible research areas

- Dynamic all optical networks with solar or wind powered optical repeaters
- Wireless mesh ad-hoc networks with mini-solar panels at nodes
- New shortest energy path Internet architectures with servers, computers and storage collocated at remote renewable energy sites such as hydro dams, windmill farms, etc
- Topology and architecture issues to stretch the network and move routers and switches from major intersections
- New routing and resiliency architectures for wired and wireless networks for massively disruptive topology changes due to setting sun or waning winds that power routers and servers
- New stats and measurement analysis of bits per carbon (bpc) utilization, optimized “carbon” routing tables, etc

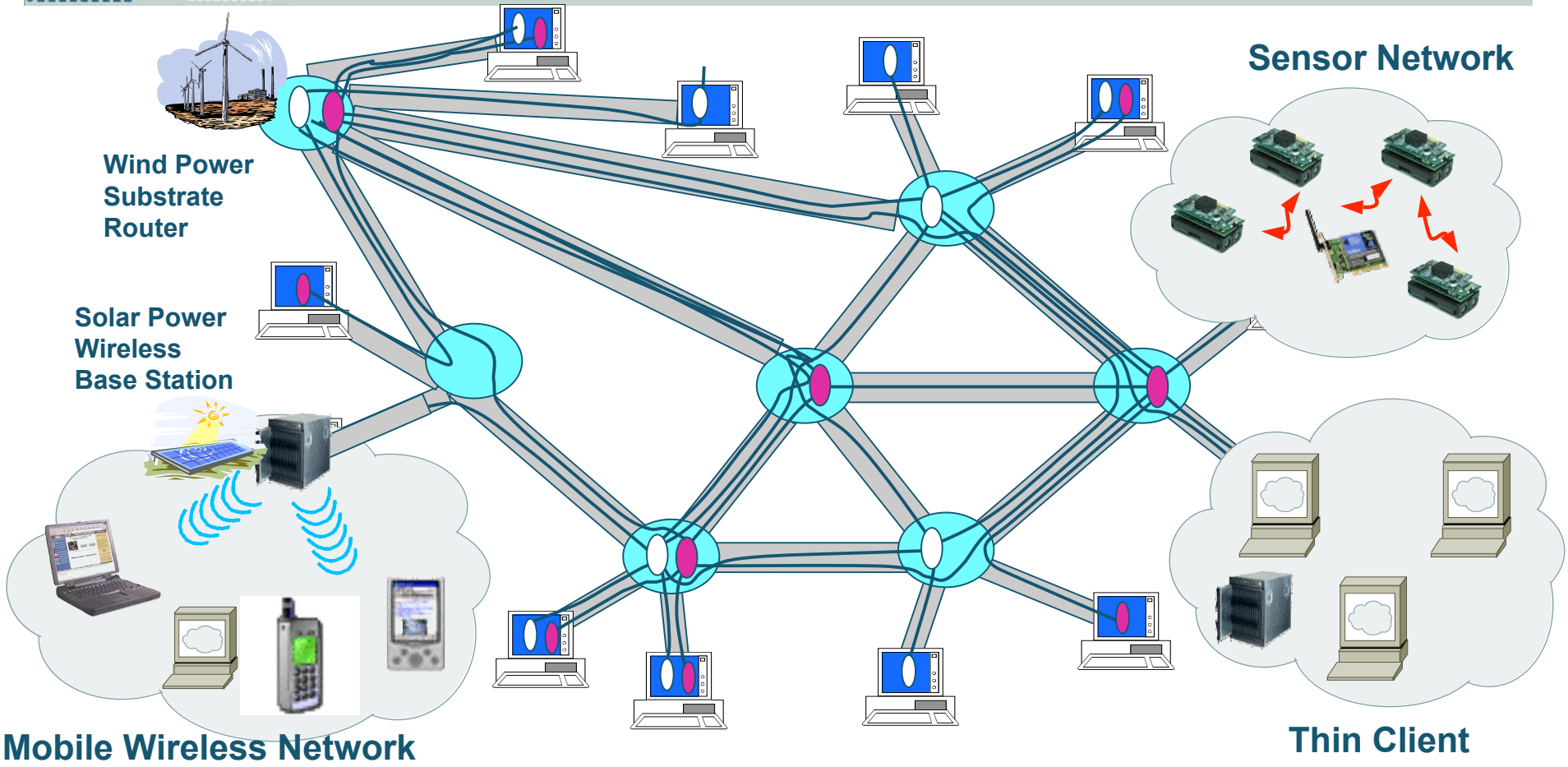
# GENI

## Topology optimized by source destination




Source: Peter Freeman NSF

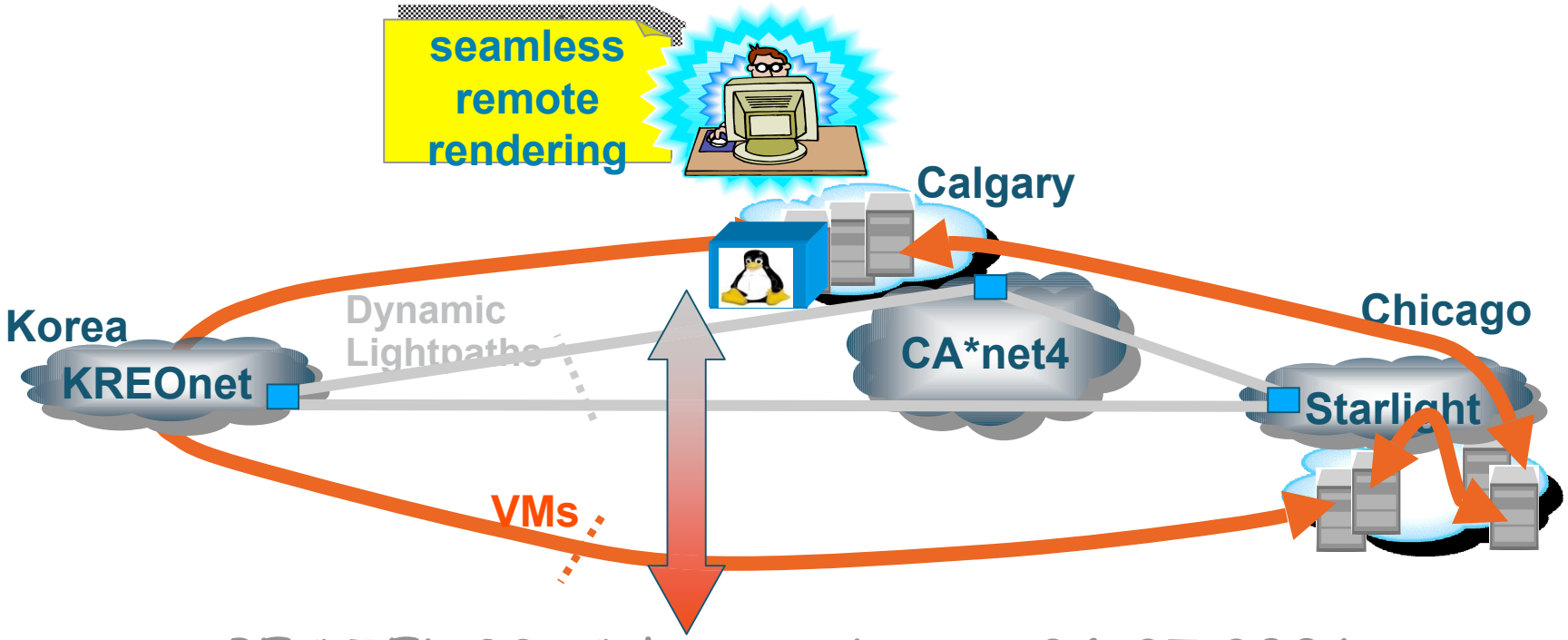
# GENI with remote nodes at renewable energy sites




**Topology optimized by availability of energy**

Source: Peter Freeman NSF

# The "VM Turntable" Demonstrator




APEC TEL 33, Calgary, AL, Apr 24-27 2006

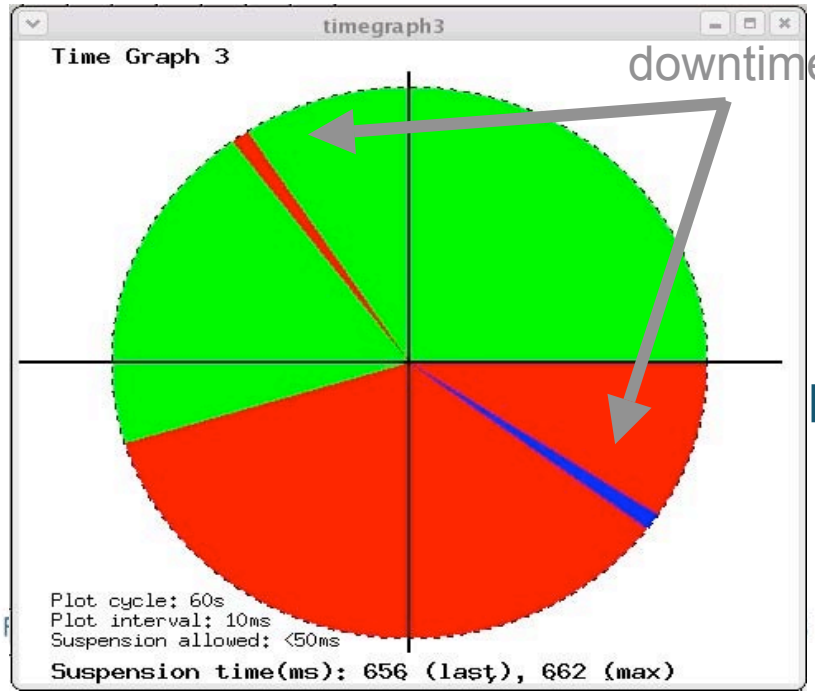
Live VMs migrated from Calgary to Chicago with transit through S. Korea, resulting in just a 1.011 second of application downtime.

DRAC sets up and tears down a lightpath w/ each migration.

# In the Blink of an Eye

- Virtual Machine teleported over thousand miles
- Seamless to external clients, w/ just a tiny ~1s glitch
- Downtime is limited despite high RTTs
  - **Calgary–Korea–Chicago, 1GE, RTT = 310 msec, downtime = ~1 sec**
  - **Back to back, 1GE, RTT = 0.2 - 0.5 ms, downtime = ~0.2 sec**

***downtime is only ~5x***
***while RTT is ~1,000x !!!***




- Lightpath is a virtualized
- Its determinism (not the bw!) bling technology

# Policy approaches to reducing CO2

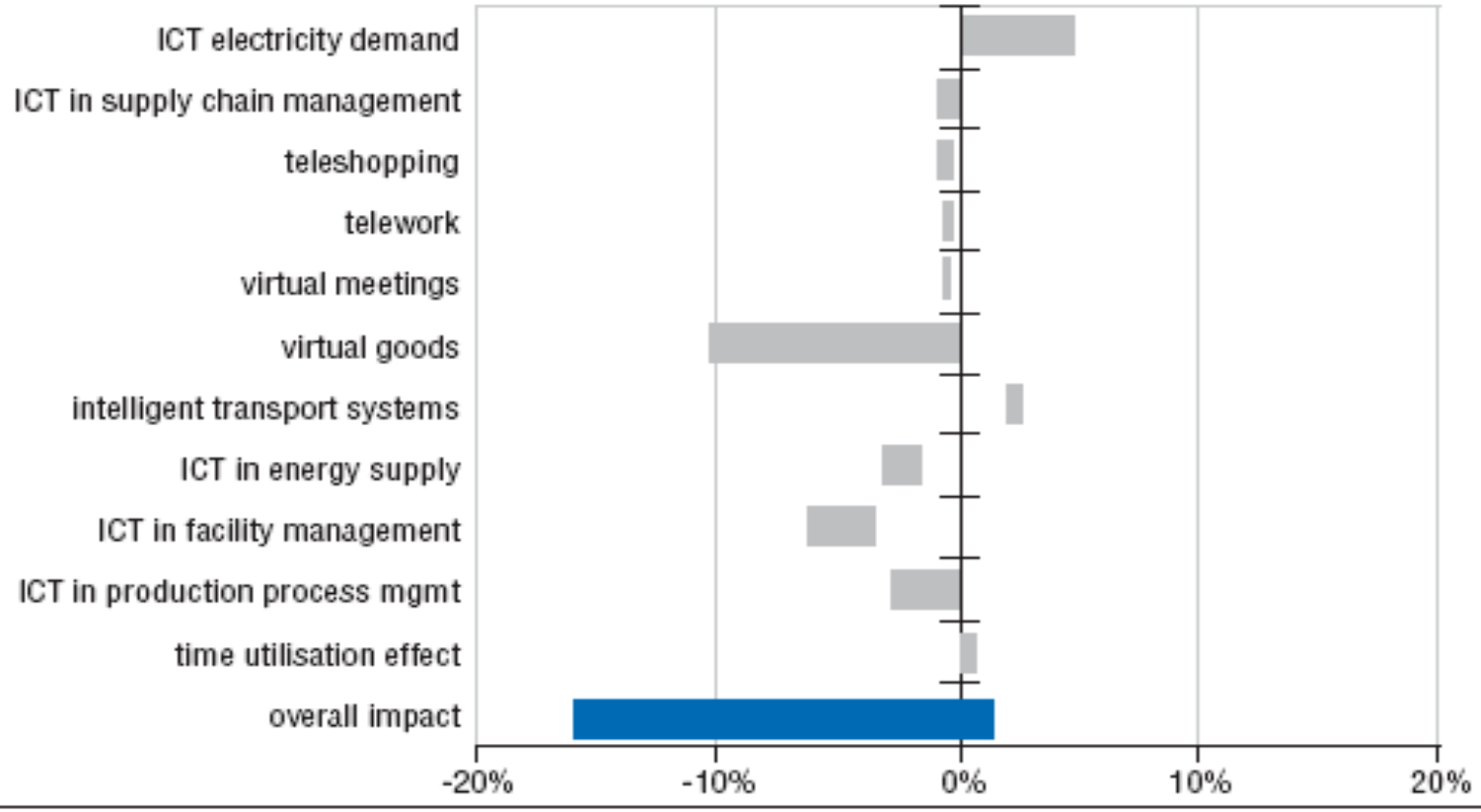
- **Carbon taxes**
  - Politically difficult to sell
- **Cap and trade**
  - Useful for big emitters like power companies
  - Addresses only supply side of CO2
- **Carbon Neutrality imposed by law**
  - Growing in popularity especially as protests over gas tax escalates
- **But there may be an additional approach….**

# Carbon Rewards rather carbon taxes – “gCommerce”

- **Although carbon taxes are revenue neutral, they payee rarely sees any direct benefit**
  - No incentive other than higher cost to reduce footprint
- **Rather than penalize consumers and businesses for carbon emissions, can we reward them for reducing their carbon emissions?**
- **Carbon rewards can be “virtual” products delivered over broadband networks such movies, books, education, health services, collarboartive education and research technologies etc**
- **Carbon reward can also be free ICT services (with low carbon footprint) such as Internet, cellphone, fiber to the home, etc**

# Virtualization and De-materialization

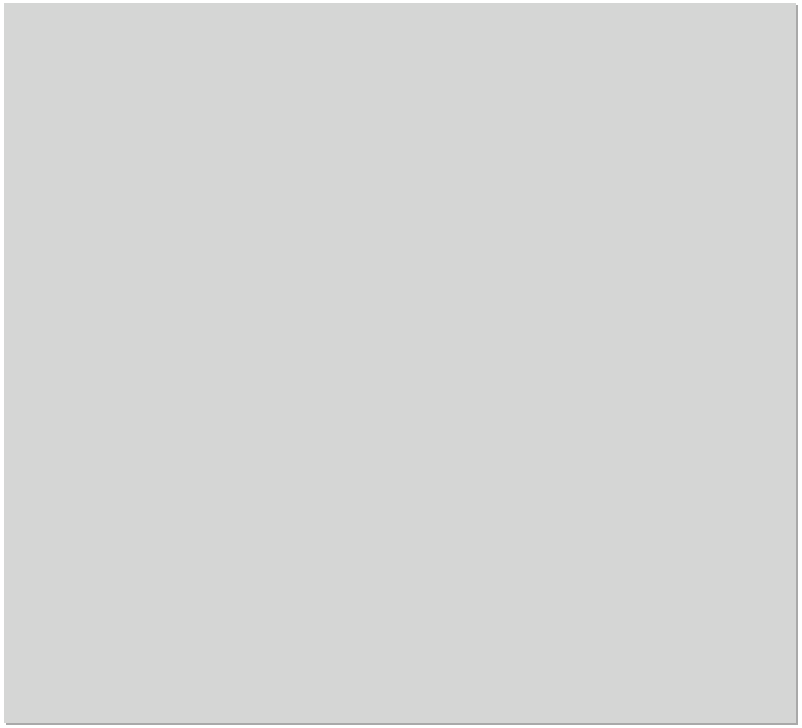
## Direct replacement of physical goods – 10% impact




*Source: European Commission Joint Research Centre, "The Future Impact of ICTs on Environmental Sustainability", August 2004*

# Virtualization is key

- Movies and music delivered over Internet
- Virtual applications
  - Google docs,
- University Internet “culture” and early adoption



MIT’s Sixth sense

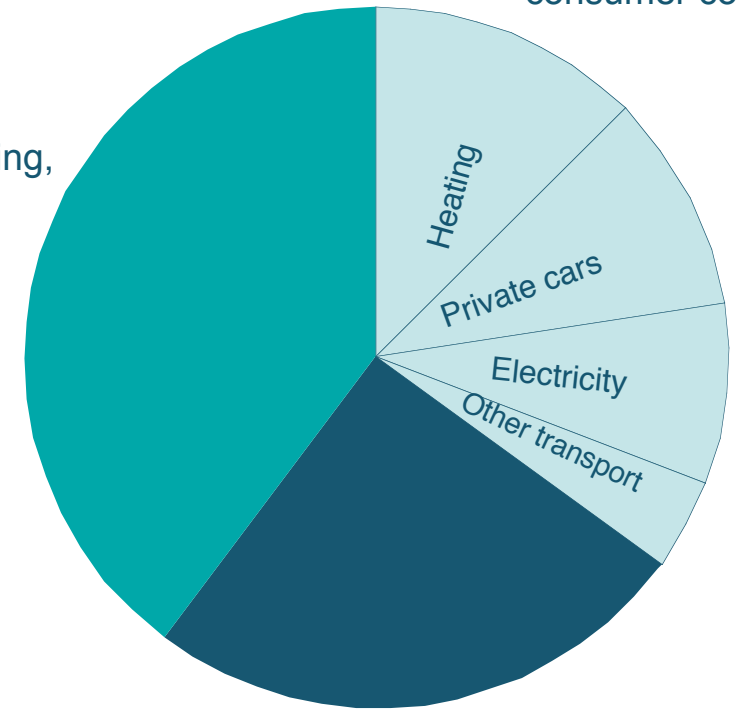
# Case Western pilot with Kindle DX

- One pound of printer paper generates 4 pounds of CO2
- One pound of newspaper produces 3 pounds of CO2
- One pound of textbooks produces 5 pounds of CO2
- Babcock school of Management textbooks for 160 students alone produces 45 Tons CO2
- http://www.stewartmarion.com/carbon-footprint/html/carbon-footprint-stuff.html
- Carbon is currently $20 ton, with cap and trade it could be $100 ton

# Consumers control or influence 60 per cent of emissions

Emissions under direct consumer control (35%)

Other sectors (40%)
(e.g. manufacturing, coal mining, export transport)




Consumer influenced sectors (25%)
(e.g. retail, food and drink, wholesale, agriculture, public sector)

http://www.cbi.org.uk/pdf/climatereport2007full.pdf

# Free Wifi on Buses

- There's a school bus service called The Green Bus in Birmingham, UK which operates double-decker, low-carbon emissions buses that carry over 1400 kids to school every day (saving over 2000 car journeys).

- In addition to encouraging kids to play peer-to-peer games, the access points allow the bus company to monitor where the buses are in the city in real time. Parents as well as staff can follow the progress of any bus via Google maps.

- Business bus service in San Francisco offers  office on the move – free wifi, femto cell service etc

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- http://www.muniwireless.com/2009/01/14/school-kids-enjoy-wi-fi-on-green-bus/

# Carbon Reward Strategy for last mile infrastructure

- **Provide free high speed Internet and fiber to the home with resale of electrical and gas power (ESCOs)**
  - http://www.newamerica.net/files/HomesWithTails_wu_slater.pdf
  - Pilots in Cleveland, Switzerland, Ottawa, etc
- **Customer pays a premium on their gas and electric bill**
- **Customers encouraged to save money through reduced energy consumption and reduced carbon output**
- **Customer NOT penalized if they reduce energy consumption**
  - May end up paying substantially less then they do now for gas + electricity + broadband + telephone + cable
- **Network operator gets guaranteed revenue based on energy consumption rather than fickle triple play**

# Final remarks

- The problem we face is NOT energy consumption, but carbon emissions
- Think carbon, not energy
- Optical networks and components will play a critical role in helping us move to a zero carbon society

# Thank you

- More information
- http://green-broadband.blogspot.com
- http://free-fiber-to-the-home.blogspot.com/