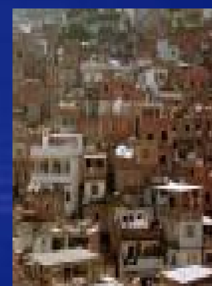
ICT Technology Trends and Opportunities for Sustainable Development



ICT for Sustainable Development

Bangalore, India

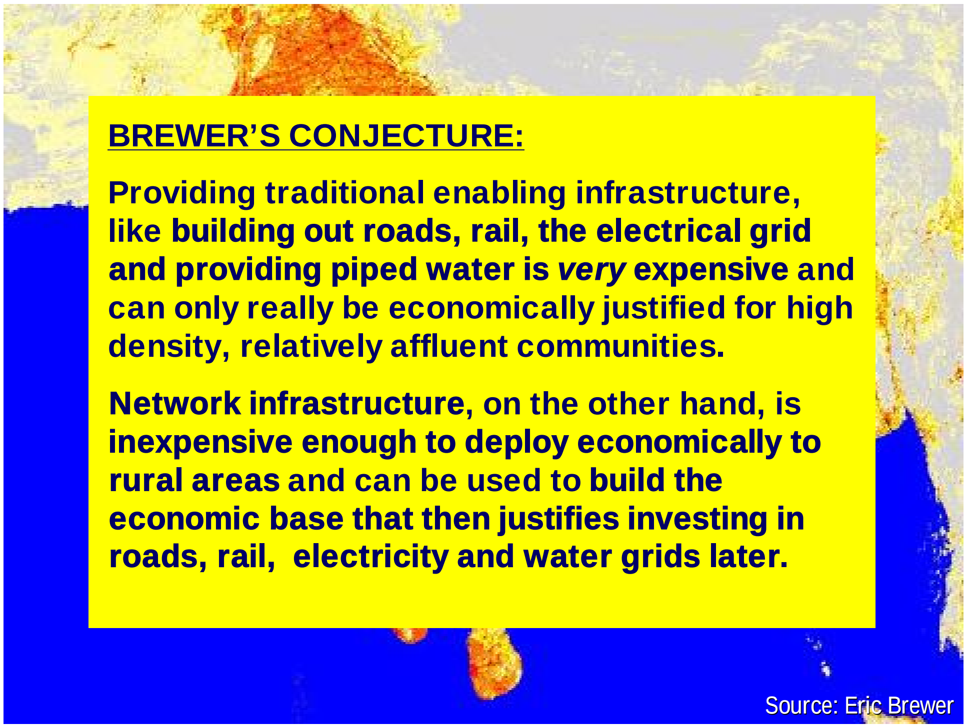
January 14th, 2004

Dean A. Richard Newton

Berkeley

Why ICT for Developing Regions Now?

- Cumulative price-performance advances in technologies are bringing ICT within reach of the global poor
- Emergence of successful business models has spurred commercial interest in these unconventional but large markets
- Many successful pilot applications have demonstrated the positive impact of ICT on global sustainability and quality-of-life
- And many of the very best ICT researchers from throughout the world are passionate about this challenge!



Dean Richard Newton
newton@coe.berkeley.edu

Open, Standards-Based Global ICT Platform: Infrastructure and Basic Services

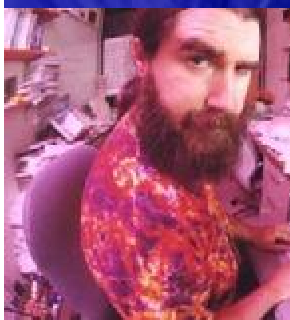
- Very Low Cost, Operates Off the Power Grid, Designed for Intermittent Connectivity, Supports Low Literacy and Multiple Languages, Reliable in Extreme Environments, Supports Shared Access, Private and Secure
- Must support telephony (synchronous and asynchronous) & data communication
- Must support sensor networks (potentially millions of sensors/application)

Network access feels just like power grid access in a developed community: You simply "plug in" (wirelessly, of course!)

Dean Richard Newton
newton@coe.berkeley.edu

"People Are the Killer App of the Internet"

Pavel Curtis, Xerox PARC, 1992



- Online Auctions
- Mega-Player Online Games
- Simple Telecommunications
- Blogs, Friendster, Livejournal, Tribe.net
- Time-Sensitive "Valuable" Data
- SMS to MMS++ to Multimedia Calls
- Distributed Collaborative Environments
- Business Relationships & Negotiation

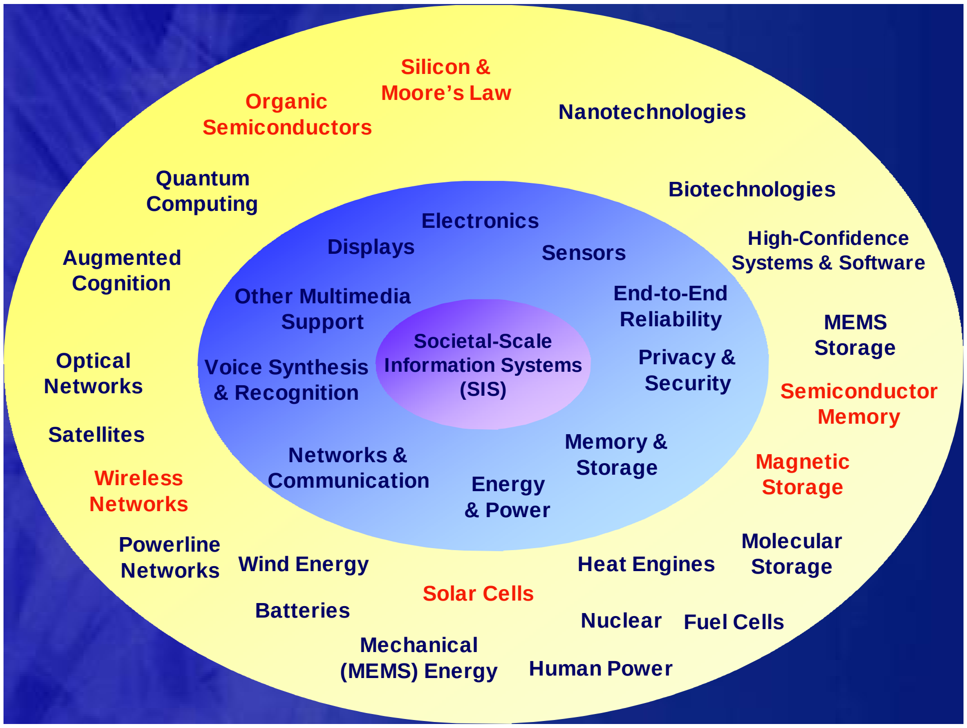
The power of ideas and opportunities, fueled by local entrepreneurial energy, is the most powerful resource available in this resource-scarce part of our world.

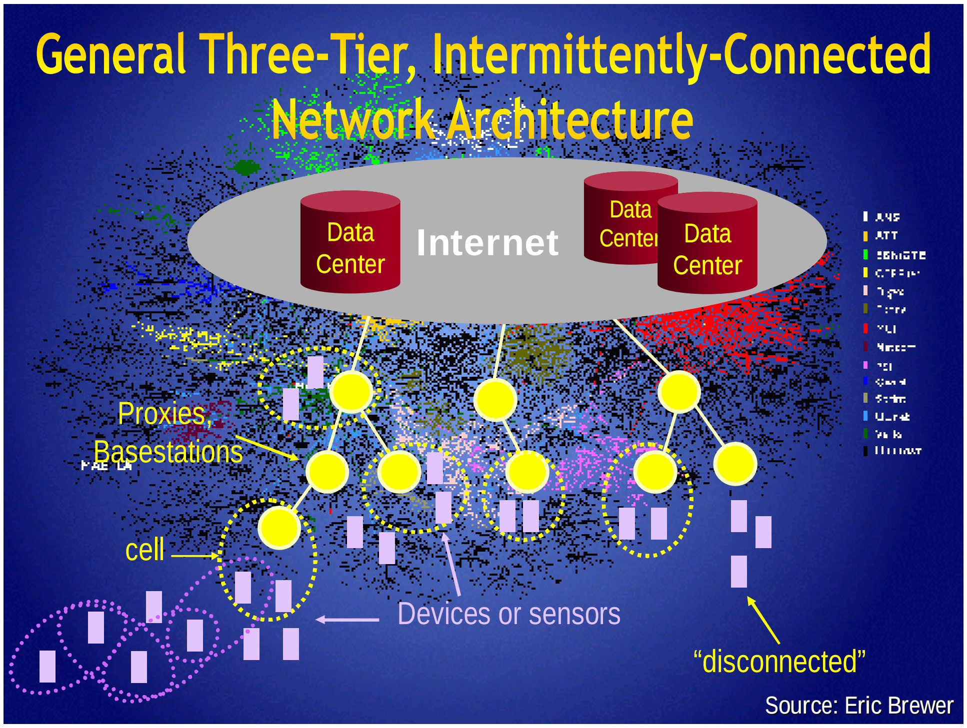
How Much Cached Storage is Enough Per Household?

- 50 Gbytes/household
- 100-1000 households served per basestation
- Would require 5-50 TBytes per basestation

Activity	Hours	Gbytes
Telephone	12	0.35
TV-Movies	20	35.00
Radio	10	0.29
Recorded Music	40	2.30
Newspaper	4	0.28
Books	30	2.10
Magazines	4	0.32
Video games		5.00
Internet		5.00
TOTAL		50 GBytes


August 2001
February 2003
Source: Professors David Culler and Kris Pister


Silicon & Moore's Law
Organic Semiconductors
Nanotechnologies
Quantum Computing
Biotechnologies
Electronics
Displays
Sensors
High-Confidence Systems & Software
Augmented Cognition
Other Multimedia Support
End-to-End Reliability
MEMS Storage
Societal-Scale Information Systems (SIS)
Optical Networks
Voice Synthesis & Recognition
Privacy & Security
Semiconductor Memory
Satellites
Networks & Communication
Memory & Storage
Magnetic Storage
Wireless Networks
Energy & Power
Powerline Networks
Wind Energy
Heat Engines
Molecular Storage
Solar Cells
Batteries
Nuclear
Fuel Cells
Mechanical (MEMS) Energy
Human Power



Data Centers

- Best place to store *persistent* data
  - (device is second best)
  - Can justify backup power, networking, physical security
- Cheapest source of storage/computer per user
  - 100-1000x less expensive than a personal device (!)
  - Factors: shared resources, administration cost, raw costs (power, disks, CPUs)
- Need at least two for disaster tolerance
- Plan about 3 in urban centers (for one region)

Source: Eric Brewer

Networking & Communications

- The key enabler… distribution for information.
- Focus on wireless (e.g. IEEE 802.11, 802.16)
  - Vastly cheaper to deploy
  - Wide range of options
- *Packets* of data allow efficient use of media
  - “multiplexing” (sharing) of channels
- IP = “Internet Protocol”
  - Global names for every device
  - Way to route packets to names

Source: Eric Brewer

Basic Properties of Networks

- Bandwidth = data/sec
  - Modem = 56 kilobits/sec
  - DSL = 384 kilobits/sec
  - IEEE 802.16 WiMAX = >75 megabits/sec per “sector” (~200 DSLs)
    - Limited only by available spectrum
- Latency = transmission delay in seconds
  - Optical Internet = milliseconds
    - Berkeley-CMU: 44ms minimum RT time (actual ~88ms)
    - Berkeley-Bangalore: 200ms minimum RT time (actual ~0.75sec)
  - Satellite = ¼ second per hop
- Power should be mostly tied to transmission
  - Double distance Þ Quadruple power
  - Sequence of short hops usually lower power (but higher latency)

Source: Eric Brewer

Understanding the Range of Wireless Networks

- Range costs power (squared)
- Long distances best covered with directional antennas
  - 10x difference in range for low cost
  - "Point-to-point" links
  - IEEE 802.16 can be used over 50km at reasonable cost
- User density matters:
  - Range also limited by total users
  - Urban areas thus use short-range wireless
  - Rural areas need long-range, high capacity links
- Ideal architecture assumes islands of coverage (with point-to-point wireless)
  - Islands are the dense areas (e.g. villages)

Source: Eric Brewer

Asynchronous Two-Way Communication

- The telephone system was developed when memory and storage was expensive
- Semi-interactive, but potentially much less expensive…
- Savings:
  - No need for dedicated resources
  - Can "store-and-forward" data (like real mail)
  - Can hide problems (e.g. power out) by waiting or redundancy
- Examples: voice messaging, SMS/MMS, correspondence classes, medical diagnosis (non-emergency), coordinating money transfers, e-commerce (e.g. catalogs), e-mail

Devices

- Develop standard chip family for human application Þ $1-7 per chip
  - Processor, memory, radio; network, speech, and display support
- Develop standard chip family for sensor application Þ $1-0.01 per chip
  - Processor, radio, power management, network support, integrated GPS option
  - Low-power version < 200 microwatts
- Novel low-cost organic semiconductors for flexible displays and inexpensive circuits
  - 10-50x cheaper, ultimately more robust

A Village Basestation: 2004

Support 100 simultaneous feeds at > 1Mbps each

- 100M logic gate equivalent
- 1 Gbyte Memory
- 200 Gbytes Disk
- Battery
- Silicon Solar Cells (1.5m^2)
- Mechanical Structure

- Cost US $750
- Dissipate 250W at full load

Dean Richard Newton
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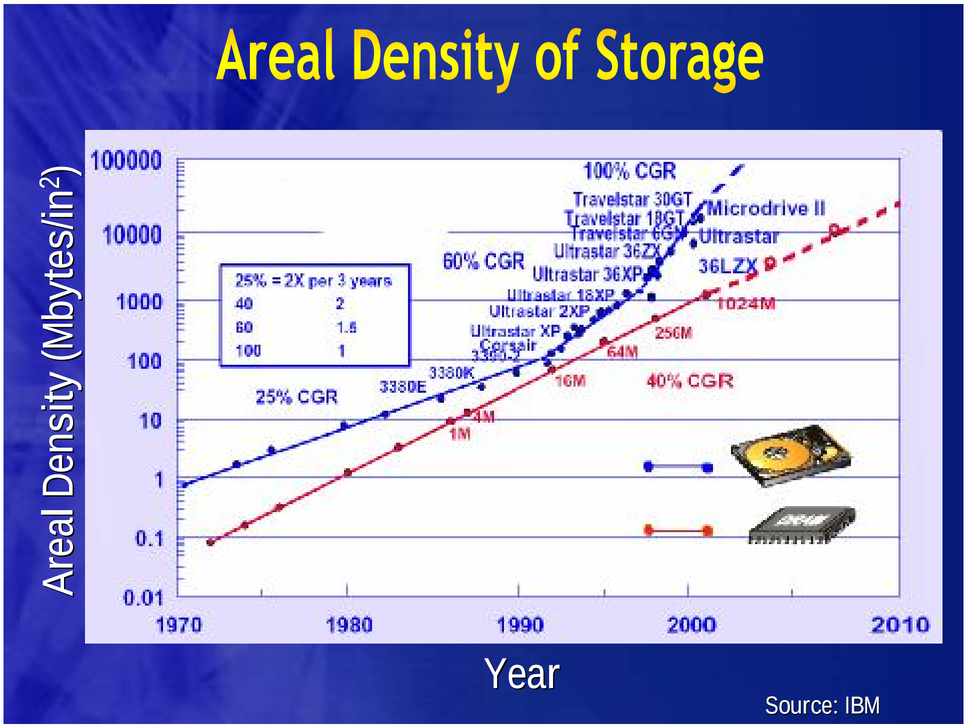
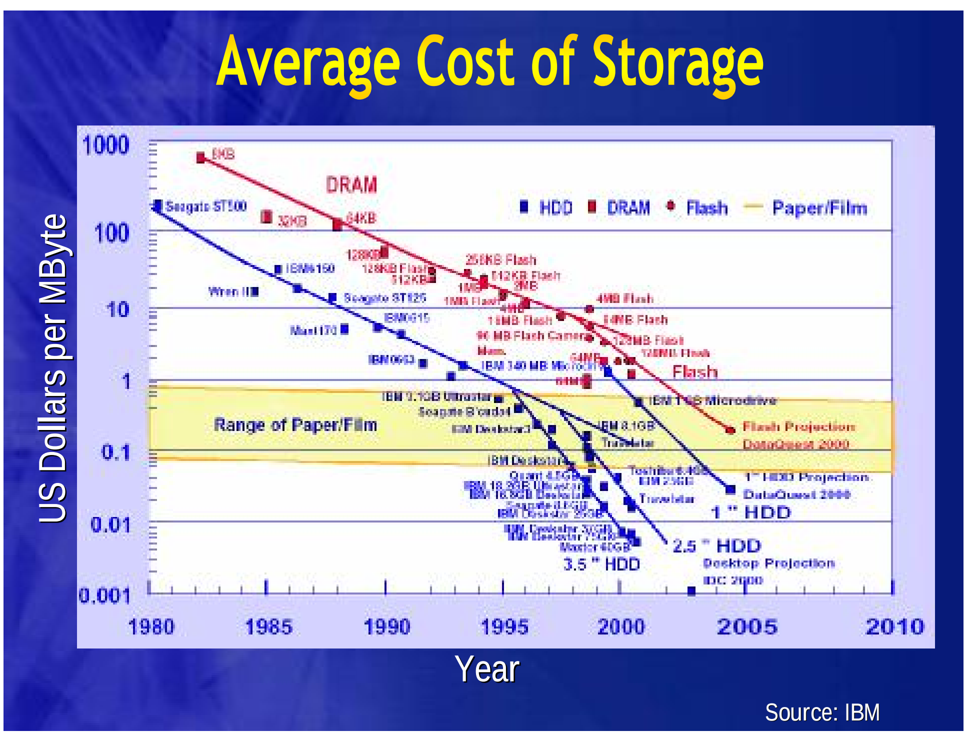
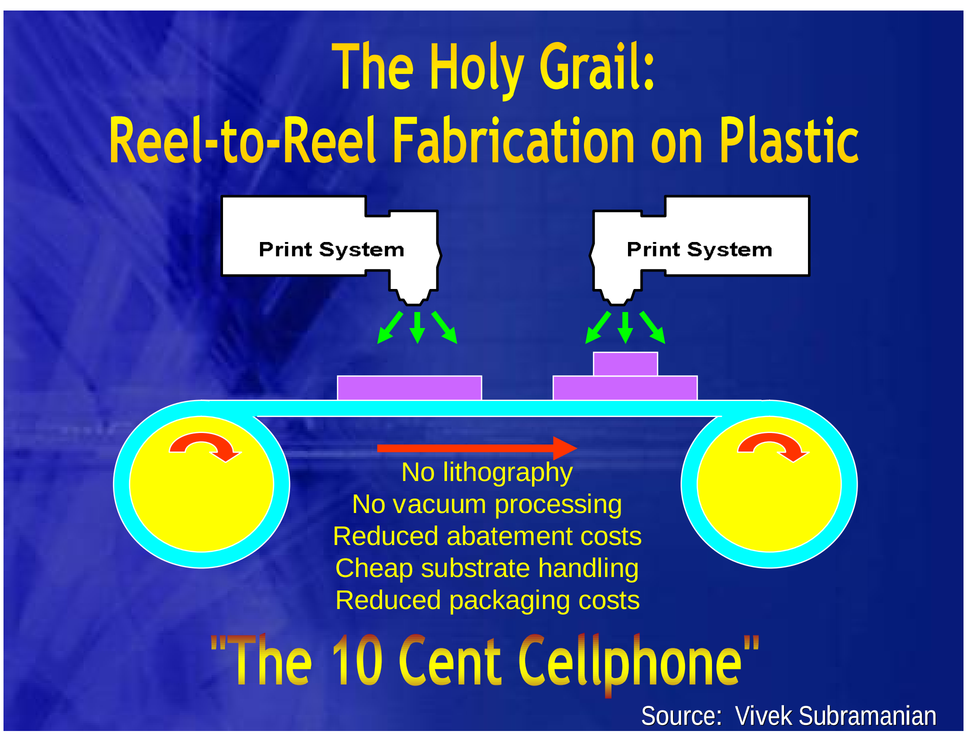




Dean Richard Newton
newton@coe.berkeley.edu


...but Could the End of Moore's Law
be an Economic One?
Ultra Pure White
There is no semiconductor silicon in most things around us
...but there ARE printed laminates and coatings
Courtesy: Campbell's Soup, Behr Paints
Source: Vivek Subramanian


The Holy Grail:
Reel-to-Reel Fabrication on Plastic
Print System
Print System
No lithography
No vacuum processing
Reduced abatement costs
Cheap substrate handling
Reduced packaging costs
"The 10 Cent Cellphone"
Source: Vivek Subramanian

A Village Basestation: 2004

Support 100 simultaneous feeds at > 1Mbps each

- 100M logic gate equivalent
- 1 Gbyte Memory
- 200 Gbytes Disk
- Battery
- Silicon Solar Cells (1.5m^2)
- Mechanical Structure

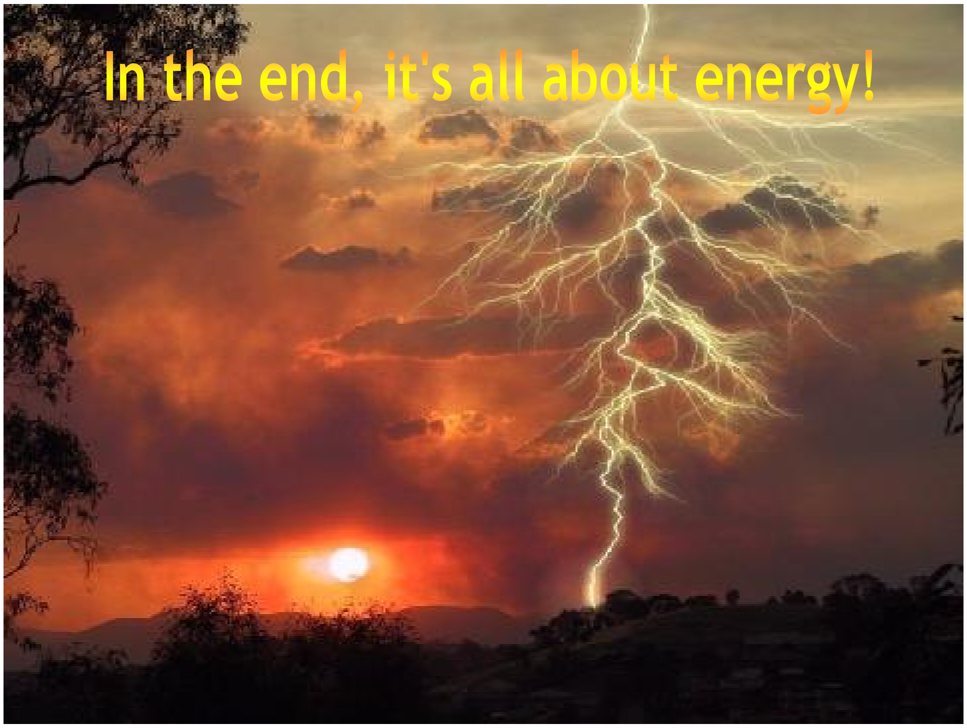
- Cost US $750
- Dissipate 250W at full load

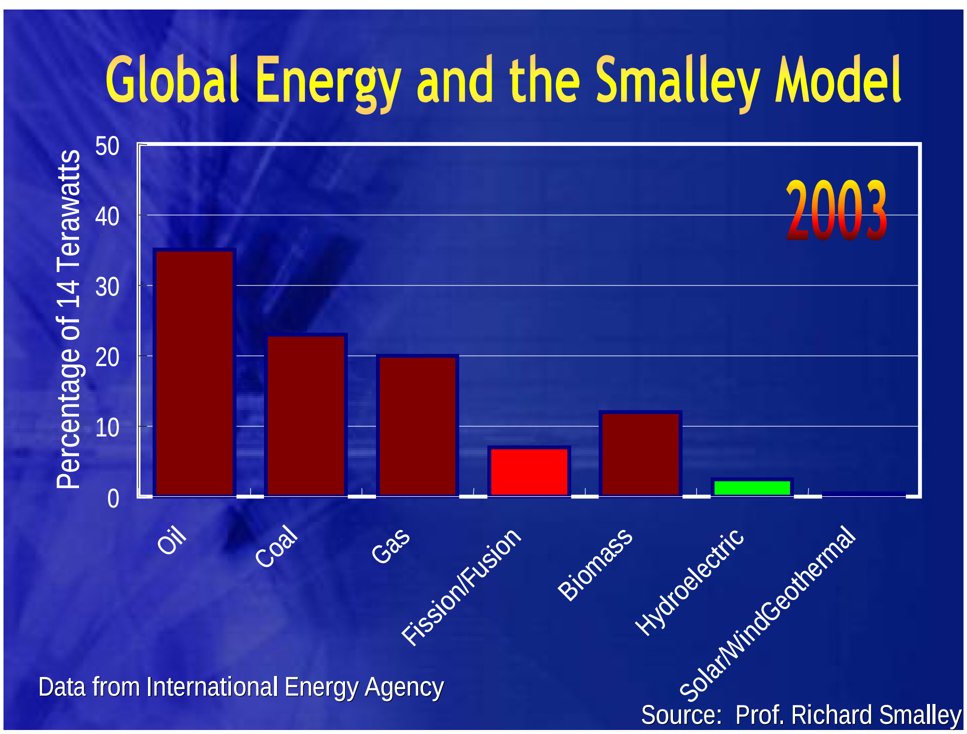
A Village Basestation: 2010

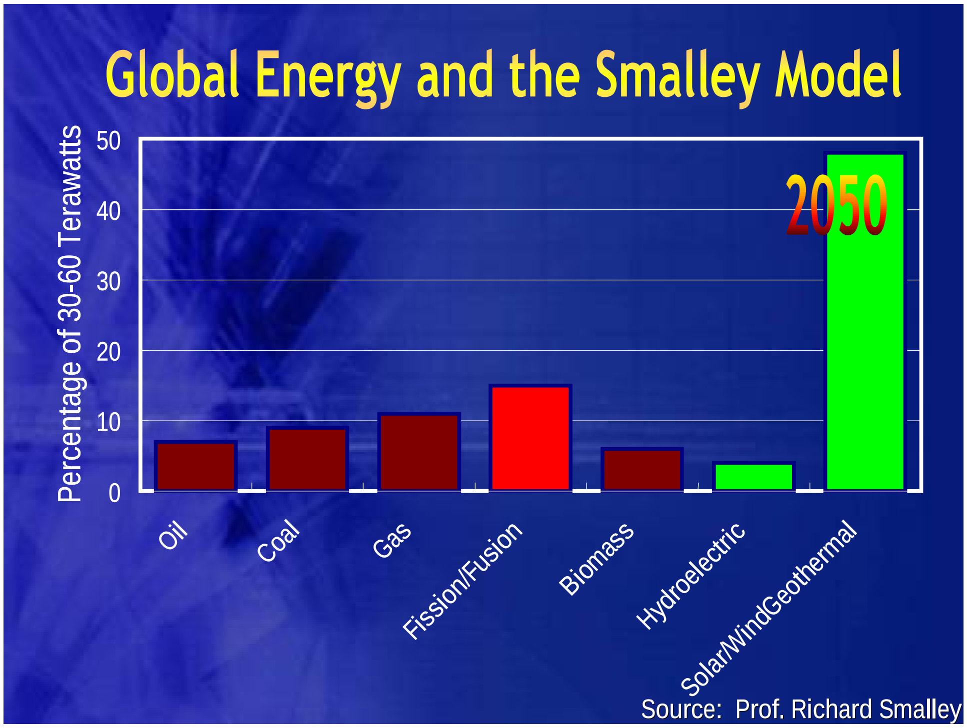
Support 200 simultaneous feeds at > 2Mbps each

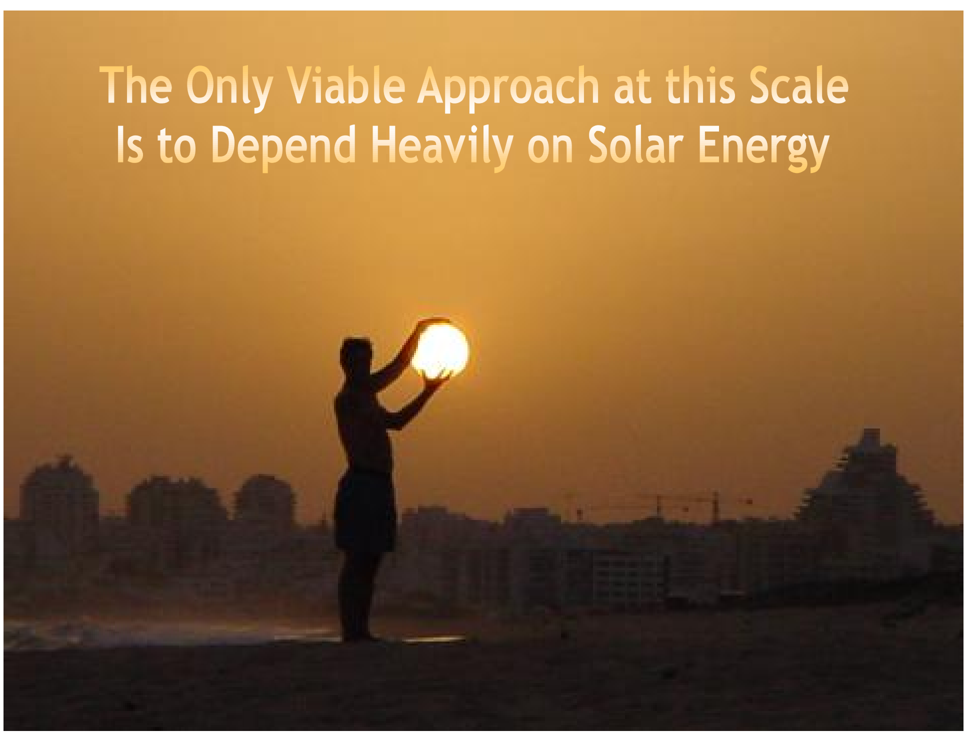
- 300M logic gate equivalent
- 10 Gbyte Memory
- 10,000 Gbytes Disk
- Battery
- Silicon Solar Cells (1m^2)
- Mechanical Structure

- Cost US $500
- Dissipate 150W at full load

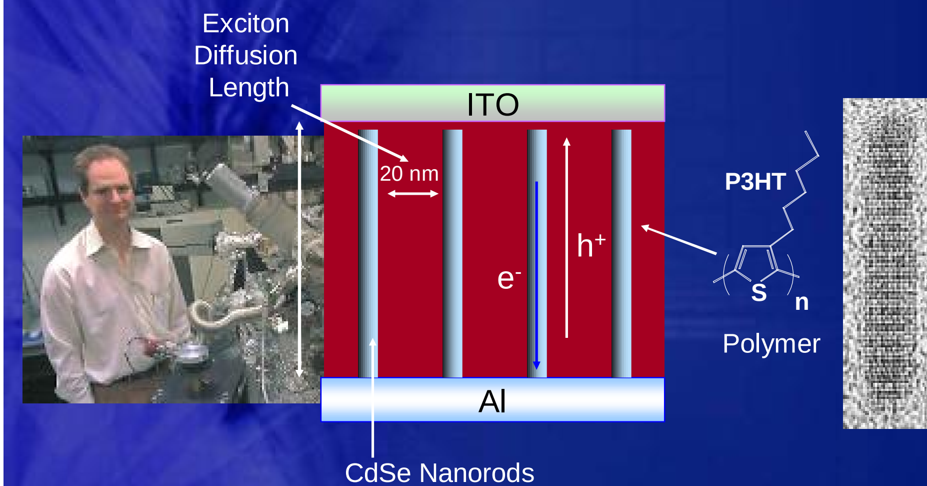

In the end, it's all about energy!


Global Energy and the Smalley Model
2003
Percentage of 14 Terawatts
50
40
30
20
10
0
Oil
Coal
Gas
Fission/Fusion
Biomass
Hydroelectric
Solar/WindGeothermal
Data from International Energy Agency
Source: Prof. Richard Smalley


Global Energy and the Smalley Model
Percentage of 30-60 Terawatts
50
40
30
20
10
0
2050
Oil
Coal
Gas
Fission/Fusion
Biomass
Hydroelectric
Solar/WindGeothermal
Source: Prof. Richard Smalley


The Only Viable Approach at this Scale
Is to Depend Heavily on Solar Energy

Plastic Film Solar Cells - No Silicon!

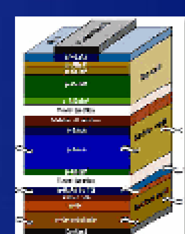


Peng, X. G.; Manna, L.; Yang, W. D.; Wickham, J.; Scher, E. Kadavanich, A. P. Alivisatos, *Nature* **2000**, *404*, 59-61.

Source: Prof. Paul Alivisatos

Our Best Result So Far!

- Low end silicon tandem cells, 12% power efficiency
- High end multi-band gap tandems 34%
- Key considerations:
  - Thermalization to band edge
  - Processing methods



AM 1.5 Efficiency

Power Conversion: 1.7%

Short Circuit Current: 5.8 mA/cm^2

Fill Factor: 0.42

Voc : 0.67 V

Source: Prof. Paul Alivisatos

Dean Richard Newton
newton@coe.berkeley.edu

ICT for Sustainable Development: A Public, Private, University Partnership

- Funding Agencies: International Organizations, National Governments, and Foundations
  - Support research, education, the development and maintenance of test-beds, and community-building activities
- Industry
  - Treat the developing world as a legitimate and important market
  - Launch internal research and development efforts (like HP Labs India)
  - Partner with academia to develop and commercialize promising university research

ICT for Sustainable Development: A Public, Private, University Partnership

- NGOs
  - Experiment with a variety of ICT applications for sustainable development
  - Support the implementation of a Technology “Peace Corps” for the developing world
- Universities: ICT researchers, sociologists, business,
  - Perform long-term, high-risk research and development for the developing world that may lead to order of magnitude improvements in accessibility
  - Perform rigorous and independent evaluation of past and ongoing efforts
  - Can a young faculty member be tenured working on basic research inspired by major challenges for the developing world? Medical informatics is here to stay, how about Development informatics?

ICT for Sustainable Development: Next Steps

Working together, we must establish:

- An active, global research and development community of interested university, industry, NGO, and government participants
- A premier international conference with the highest of academic standards—A World Technology Forum
- An international business plan competition for both developed and developing countries targeted to the developing world
- Develop a research and development roadmap for sustainable development
- A world-class publication accessible inexpensively throughout the world
- An international Engineering "Peace Corps" for students and young professionals to work together to address problems and to learn about the challenges and opportunities in the developing world

Source: Tom Kalil, Richard Newton