Energy Centric Communications

D. Kilper

Bell Labs, Alcatel-Lucent
GreenTouch Consortium

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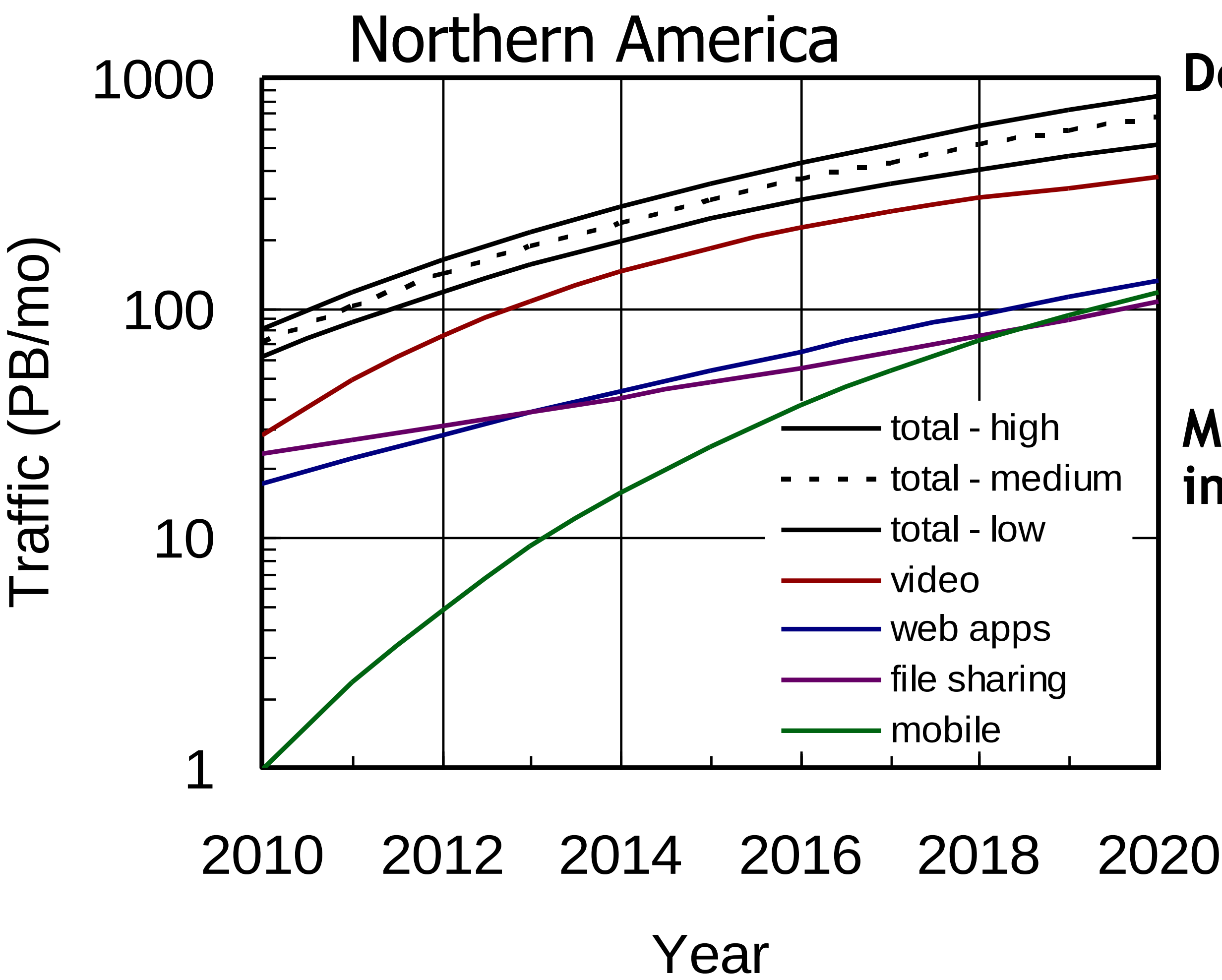
Why?

Answer #1:

Traffic & Services

Continued Exponential Traffic Growth



Doubling every 2 years

- **40% per year**
- **30x in 10 years**
- **1000x in 20 years**

Mix of services is important:

- **Mobile less efficient than fiber optics**
- **More devices**
- **More boxes/service**

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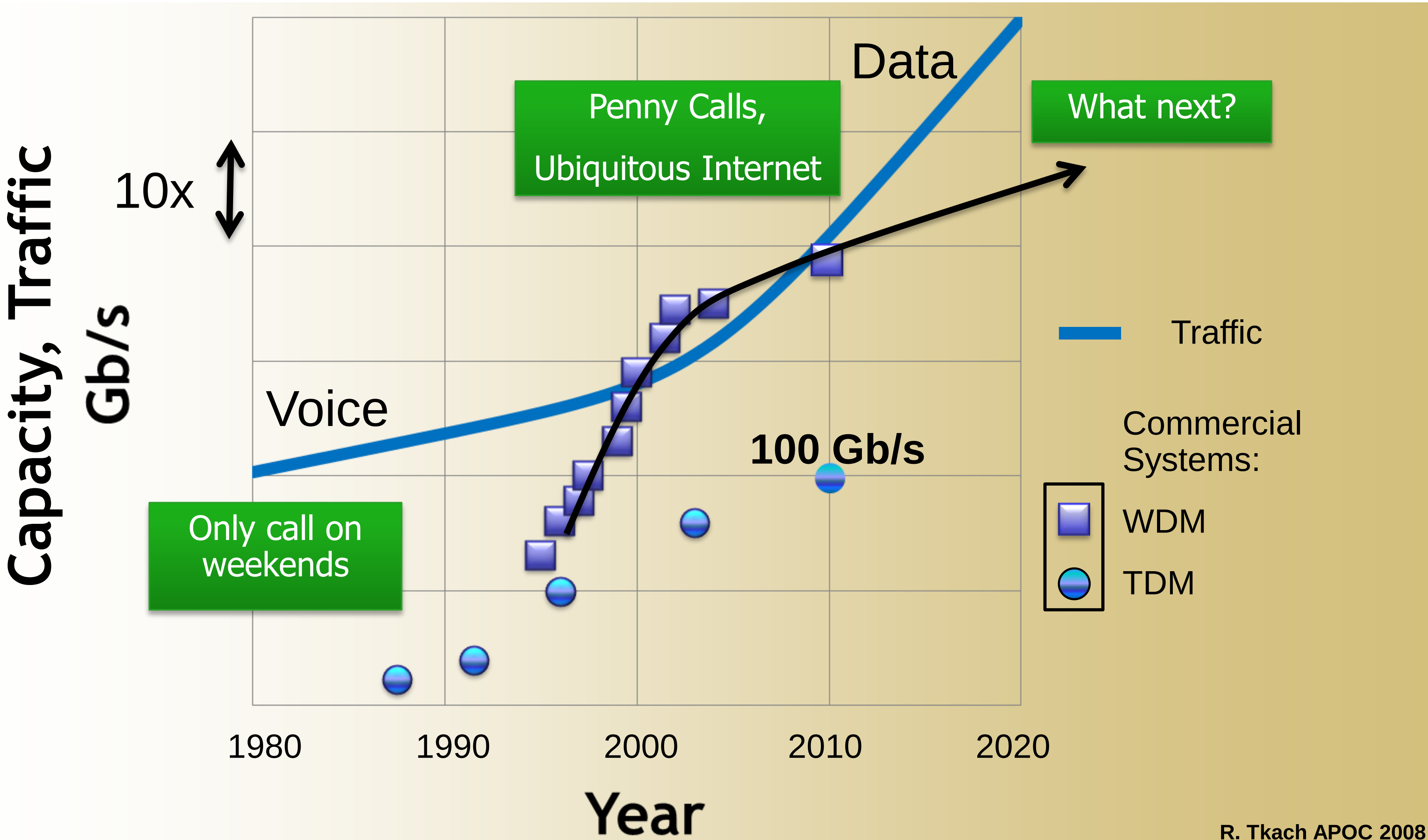
Fiber Capacity Deficit or "Crunch"



R. Tkach APOC 2008

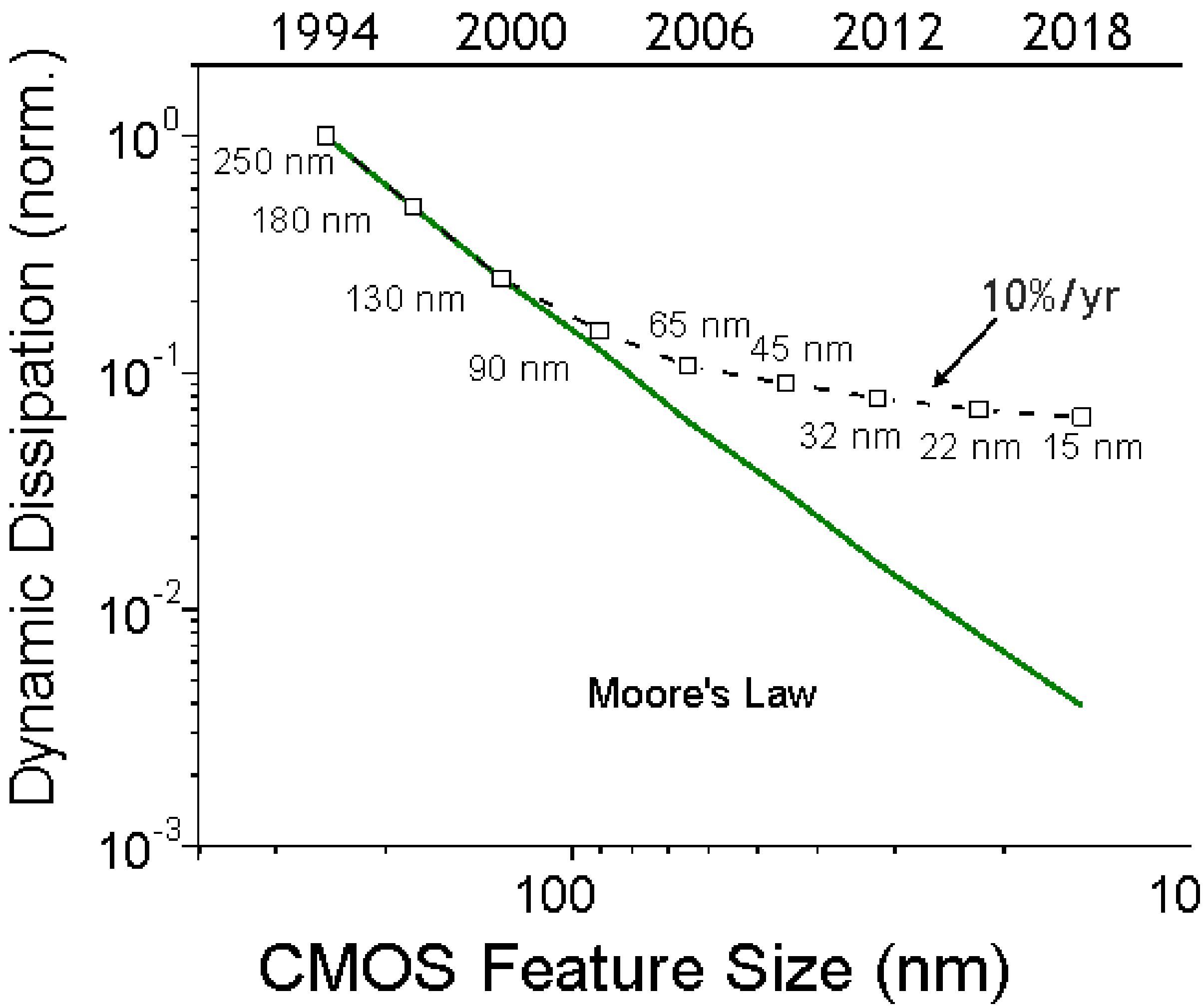
Answer #2:

Technology Slowdown

(thermal density bottleneck)

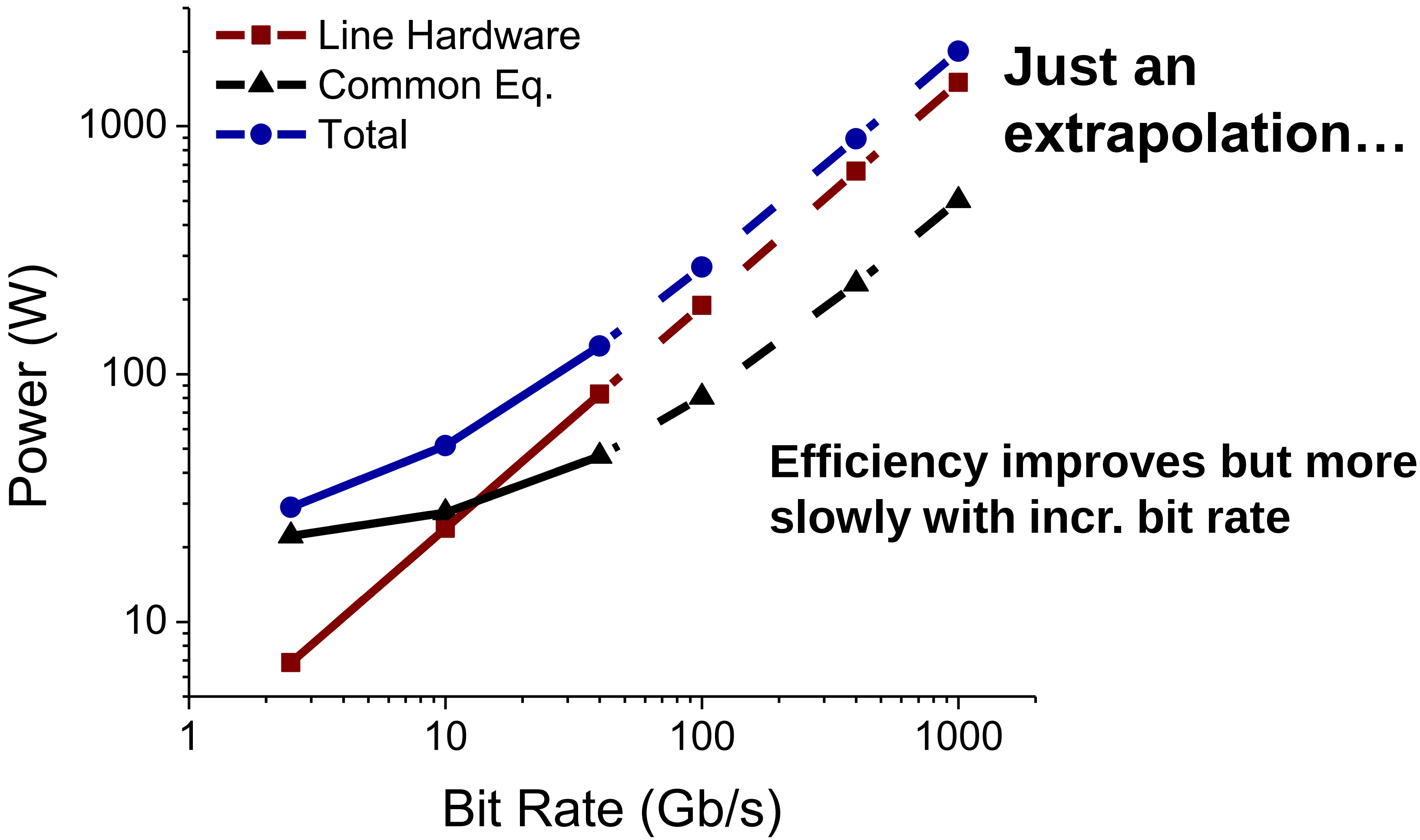
Slowdown in Electronics: Power is Not Scaling

- Reduction in dynamic dissipation with feature size is slowing



Dusan Suvakovic

Transceiver Line Card Energy Rising Steeply



- Line card controller similar to computer: ~ 30 W

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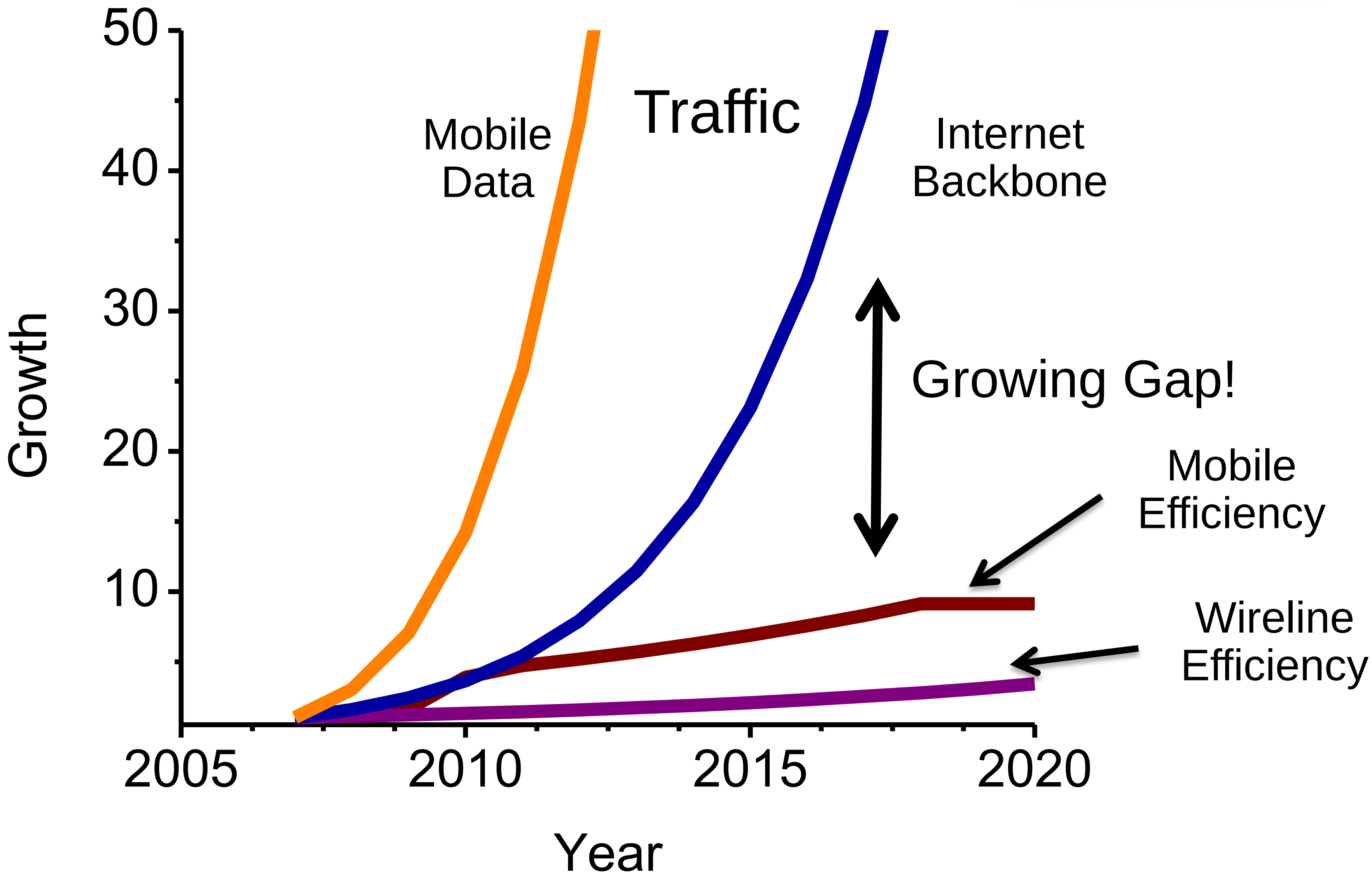
The Network Energy Gap

$P = T/\eta$



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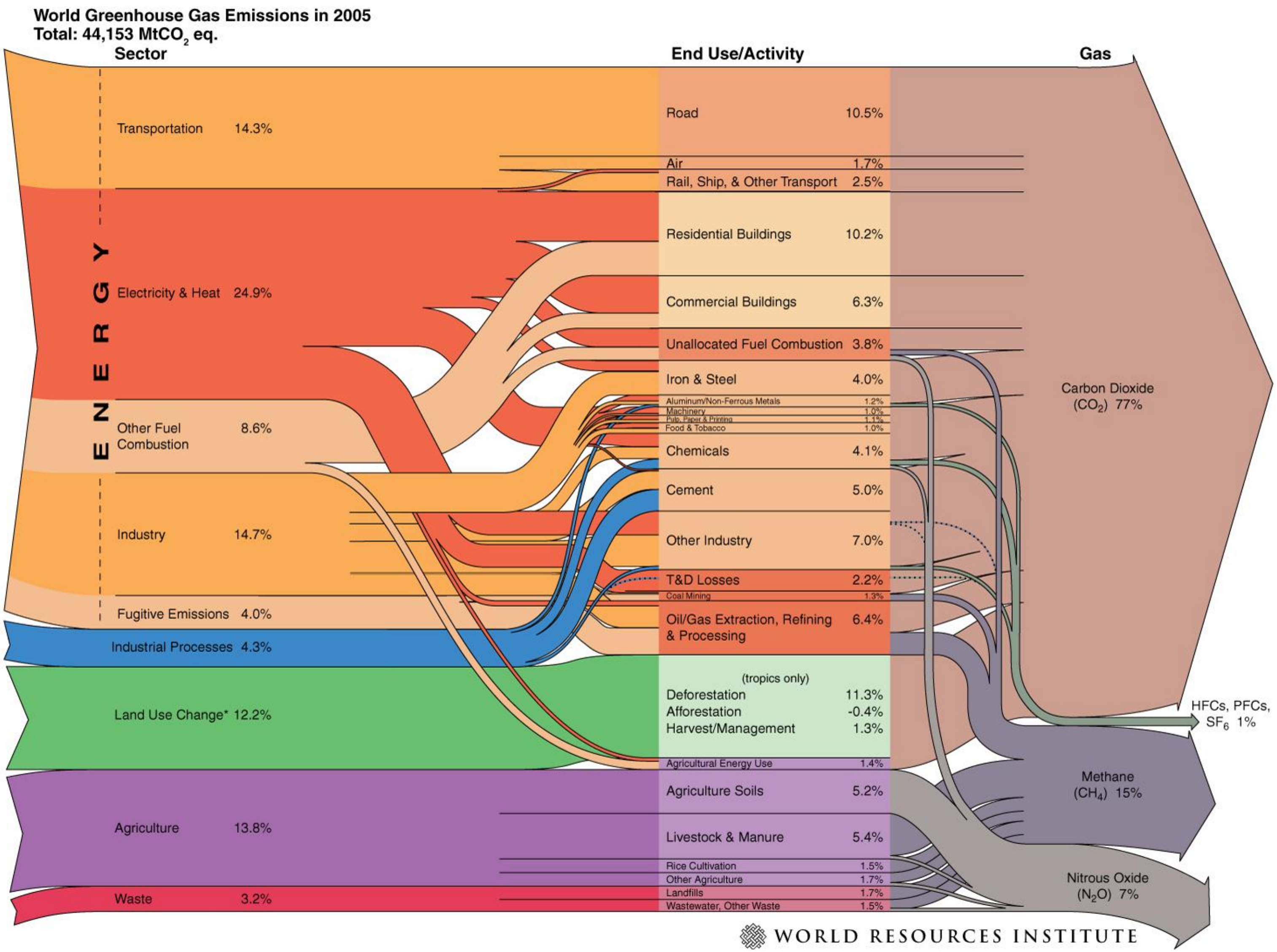
Near Term?

World Greenhouse Gas Emissions (yr 2005)



ICT “nonexistent” in 2005….

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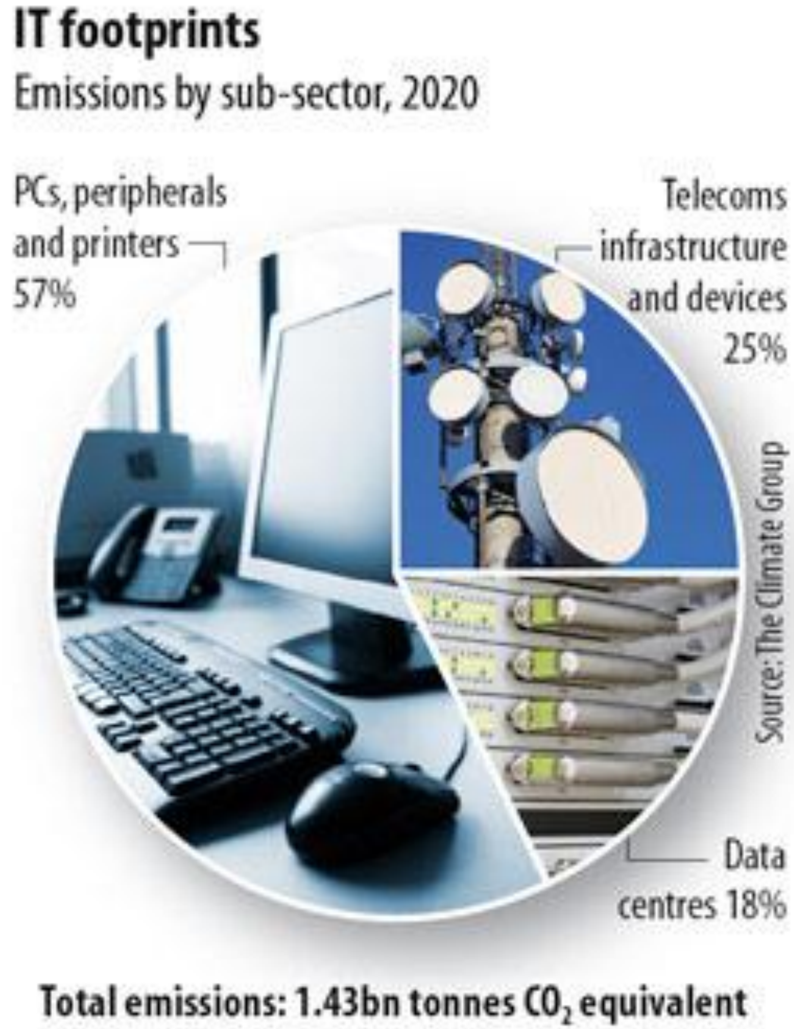
2020 ICT Carbon Footprint

Power/User: ~ 10 W !!

820m tons CO_2

2007 Worldwide ICT carbon footprint:
2% = 830 m tons CO_2

Expected to grow to 4% by 2020



360m tons CO_2

260m tons CO_2

The Climate Group, GeSI report “Smart 2020”, 2008

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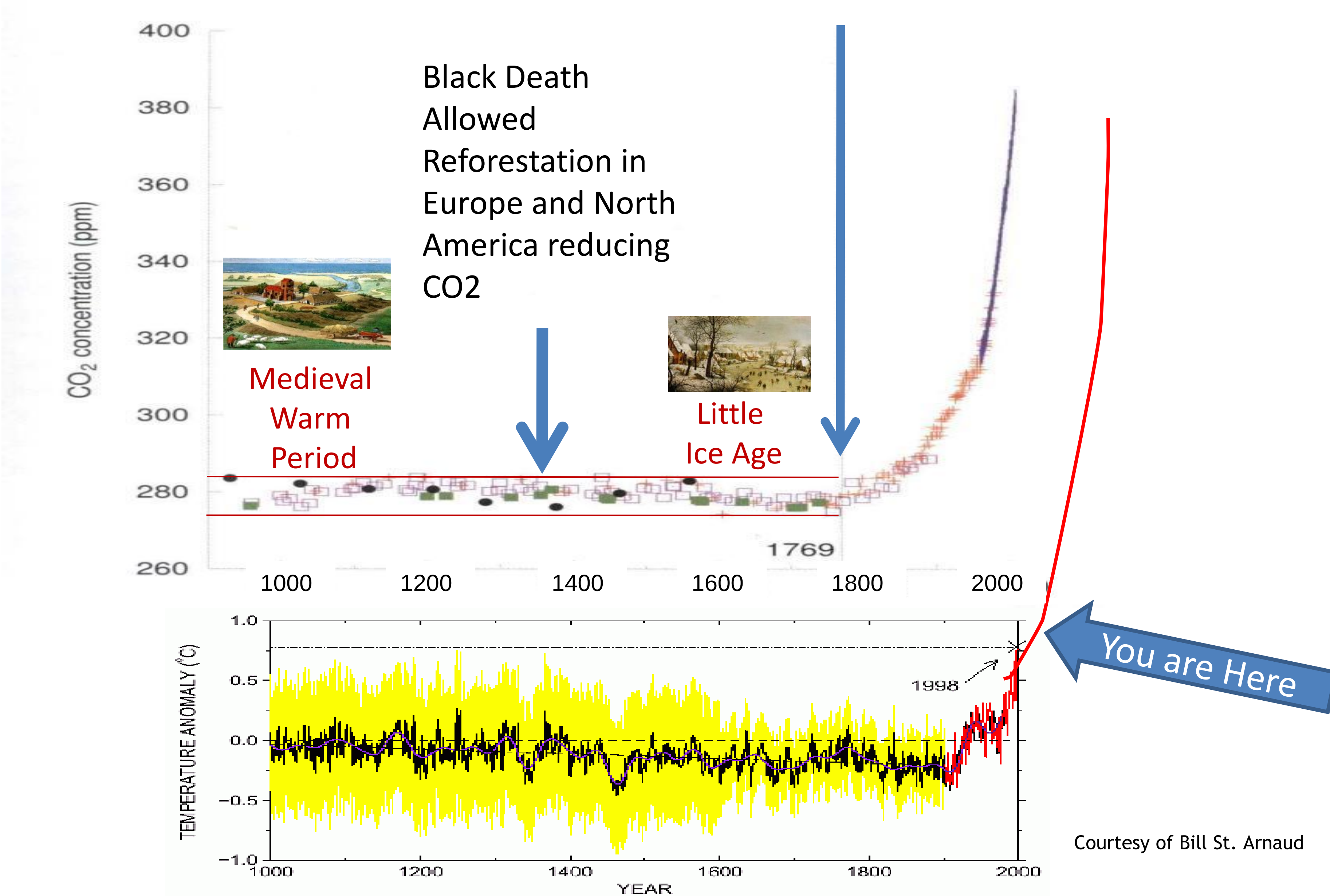
Rapid Increase in the Greenhouse Gas CO_2 Since Industrial Era Began

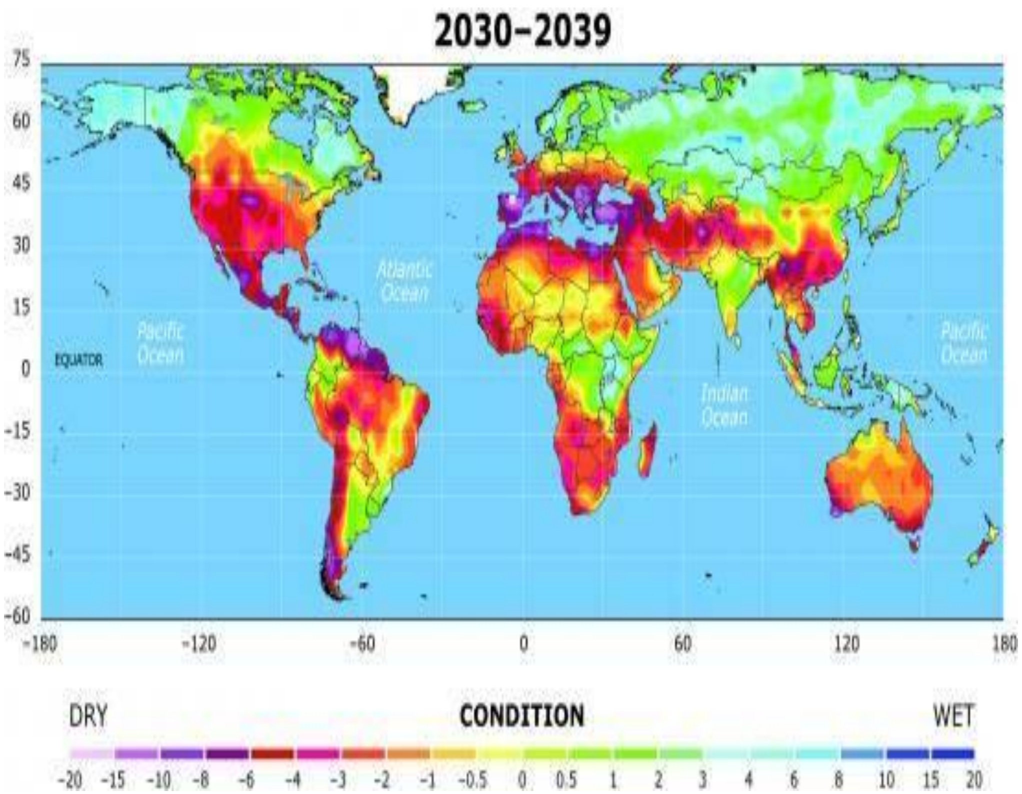


Courtesy of Bill St. Arnaud

Its not just about stopping climate change, its about dealing with climate change!

Future Droughts

- Palmer Drought Severity Index, or PDSI.
- The most severe drought in recent history, in the Sahel region of western Africa in the 1970s, had a PDSI of -3 or -4.
- By 2030 Western USA could see -4 to -6
- By 2100 some parts of the U.S. could see -8 to -10 PDSI, while Mediterranean areas could see drought in the -15 or -20 range.



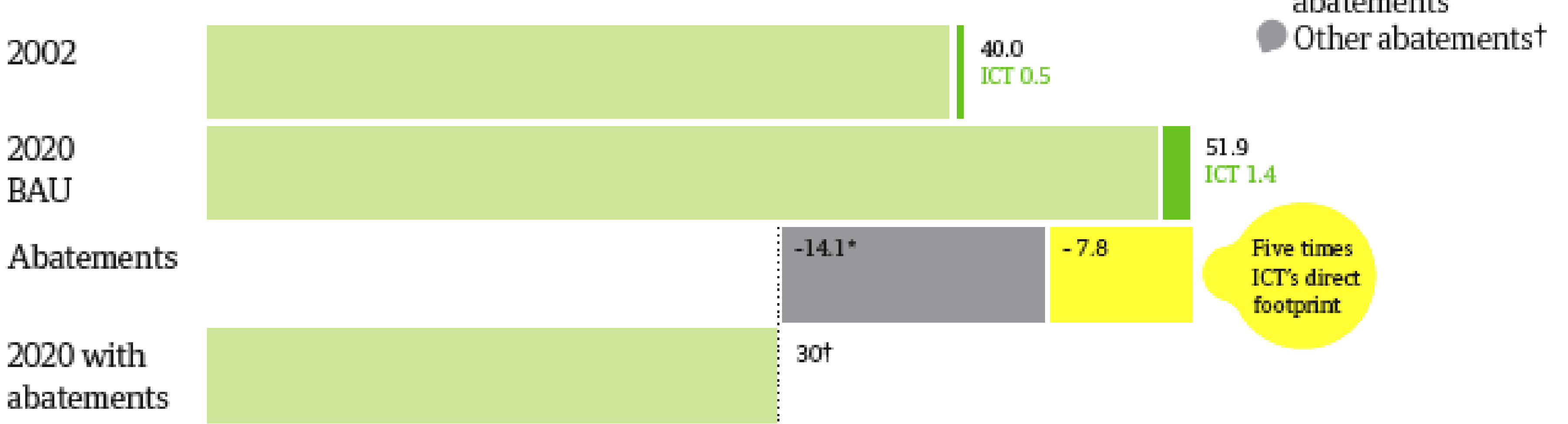
http://www.msnbc.msn.com/id/39741525/ns/us_news-environment/

Courtesy of Bill St. Arnaud

Opportunity: Greening with ICT

ICT IMPACT: THE GLOBAL FOOTPRINT AND THE ENABLING EFFECT

SMART 2020 identified savings of **7.8 Gt CO_2e** that could be delivered by ICT solutions in 2020 – **FIVE** times the sector’s footprint and **15%** of global emissions.



* For example, avoided deforestation, wind power or biofuels.
† 21.9 $GtCO_2$e abatements were identified in the McKinsey abatement cost curve and from estimates in this study. Source: Enkvist P., T. Naucler and J. Rosander (2007), ‘*A Cost Curve for Greenhouse Gas Reduction*’, The McKinsey Quarterly, Number 1.

THE CLIMATE GROUP

GeSI GLOBAL e-SUSTAINABILITY INITIATIVE

THE ENABLING EFFECT

SMART 2020 EXAMINED:

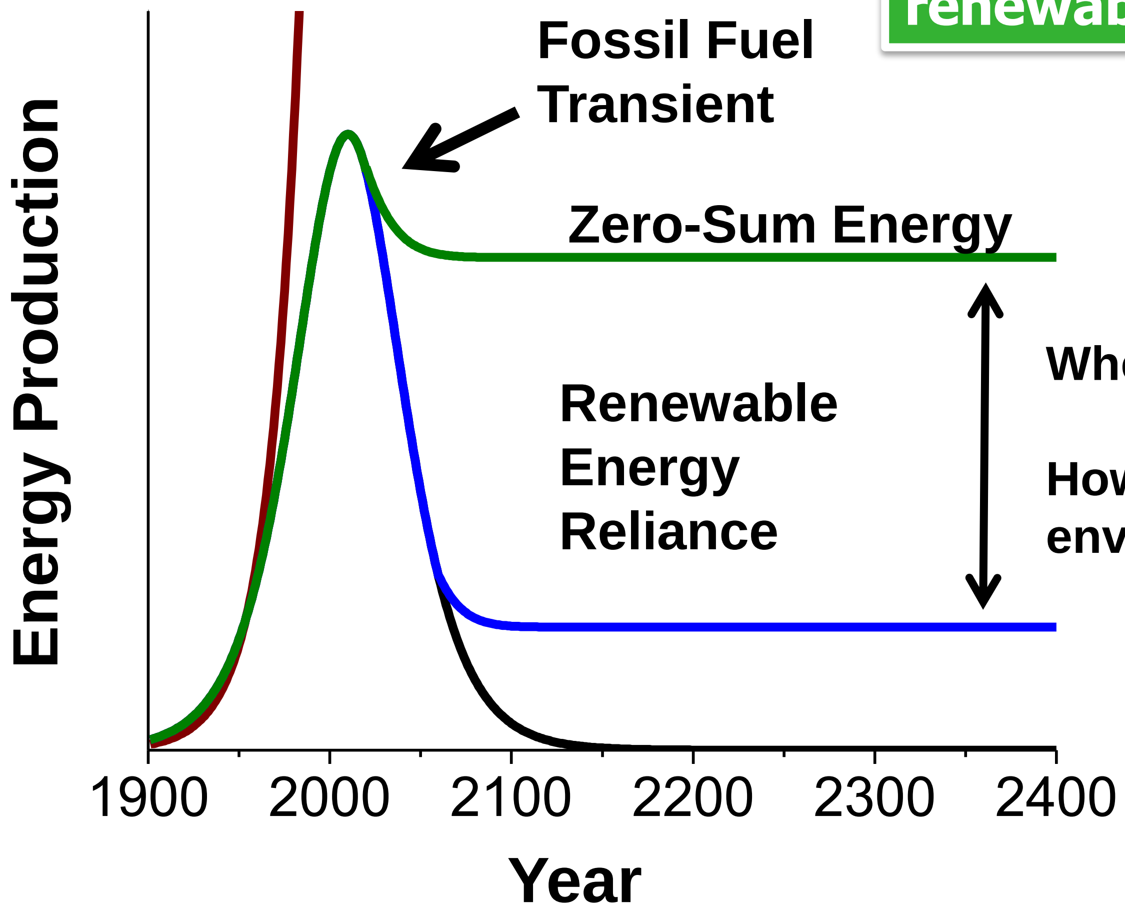
> DEMATERIALISATION
> SMART MOTORS
> SMART LOGISTICS
> SMART BUILDINGS
> SMART GRIDS

Ubiquitous ICT—networks are key—is central to many sustainability initiatives

Long Term?

Energy Production: Where Will We End Up?

How much bandwidth can be sustained on renewable energy?



Where will we end up?

How much nuclear/ environmental cost?

Hubbert 1962

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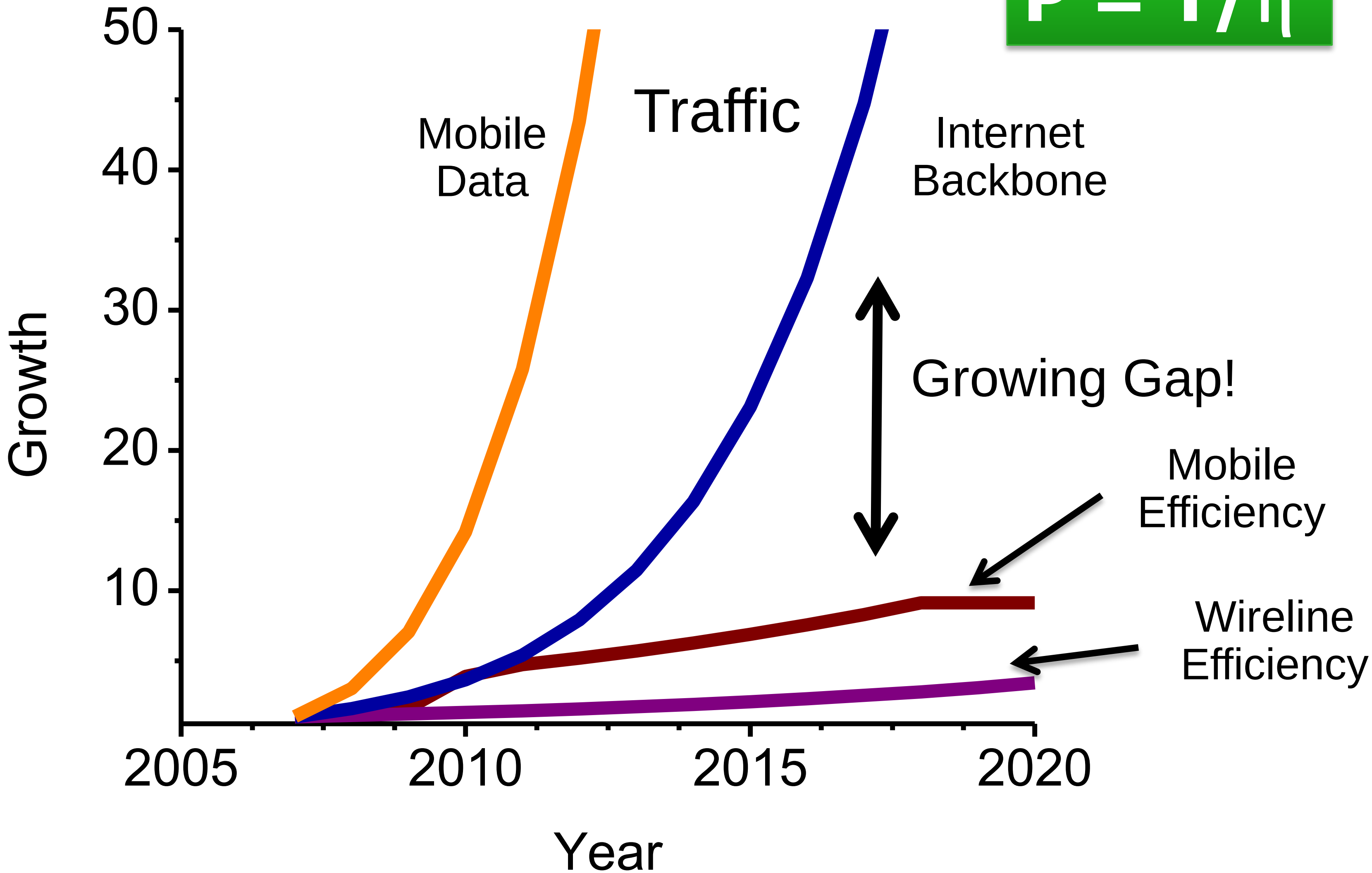
Need to Address Network Scaling Challenges

$P = T/\eta$



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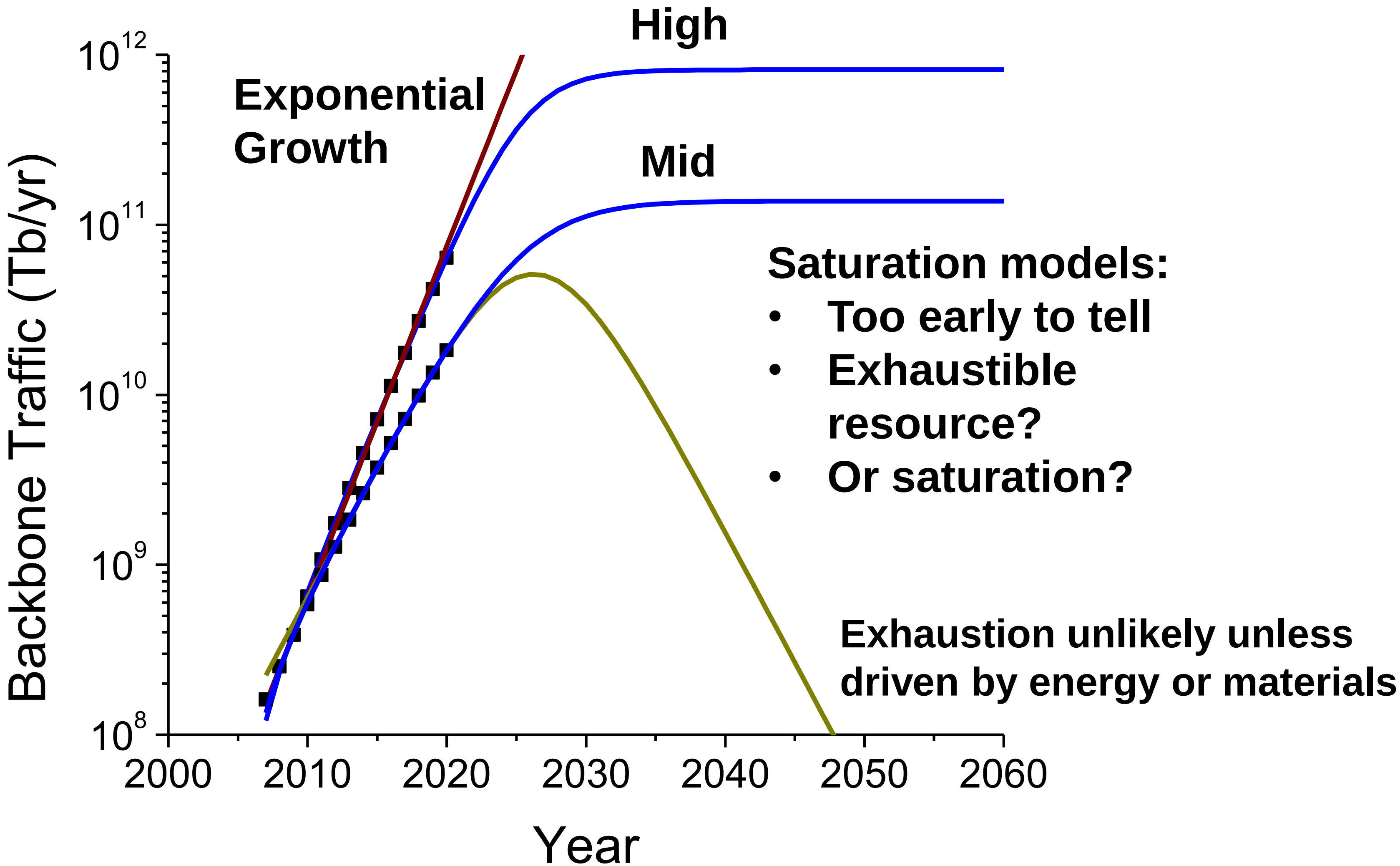
Is Bandwidth an Exhaustible Resource? Capacity?

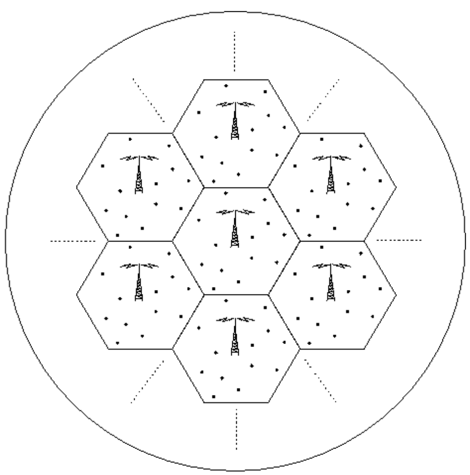


- Physical quantity tied to energy and the natural resources in the devices

Many Degrees of Freedom to Work With…

Wireless

- Move from km scale cells to m scale cells
- 10^6? available BW



Optical

- 1000-10000 fibers/cable
- 10? cores per fiber
- 10? modes per fiber

>10^6 ? available BW

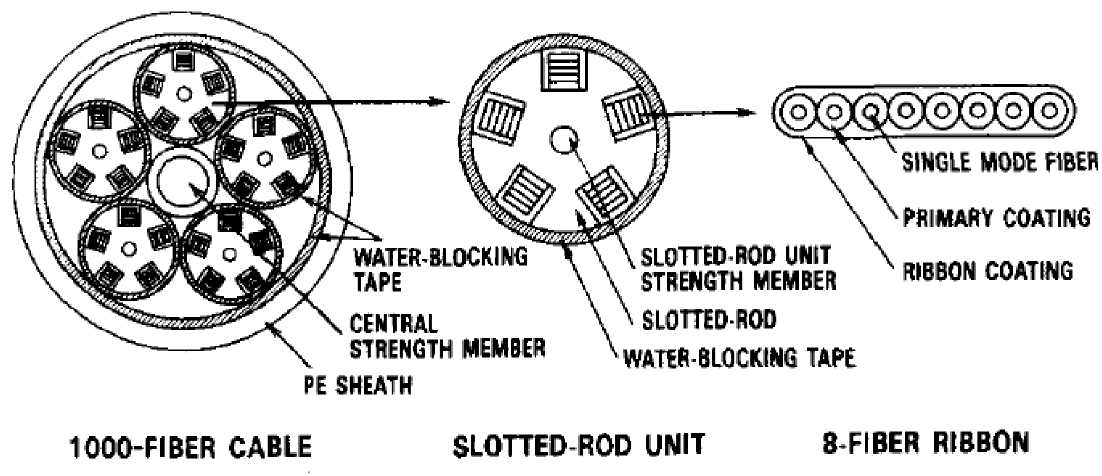


Fig. 1. Nonmetallic 1000-fiber cable structure.

K. Hogari, et. al. JLT 1992

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We have a long way to go before we have a capacity crunch, real problem: energy

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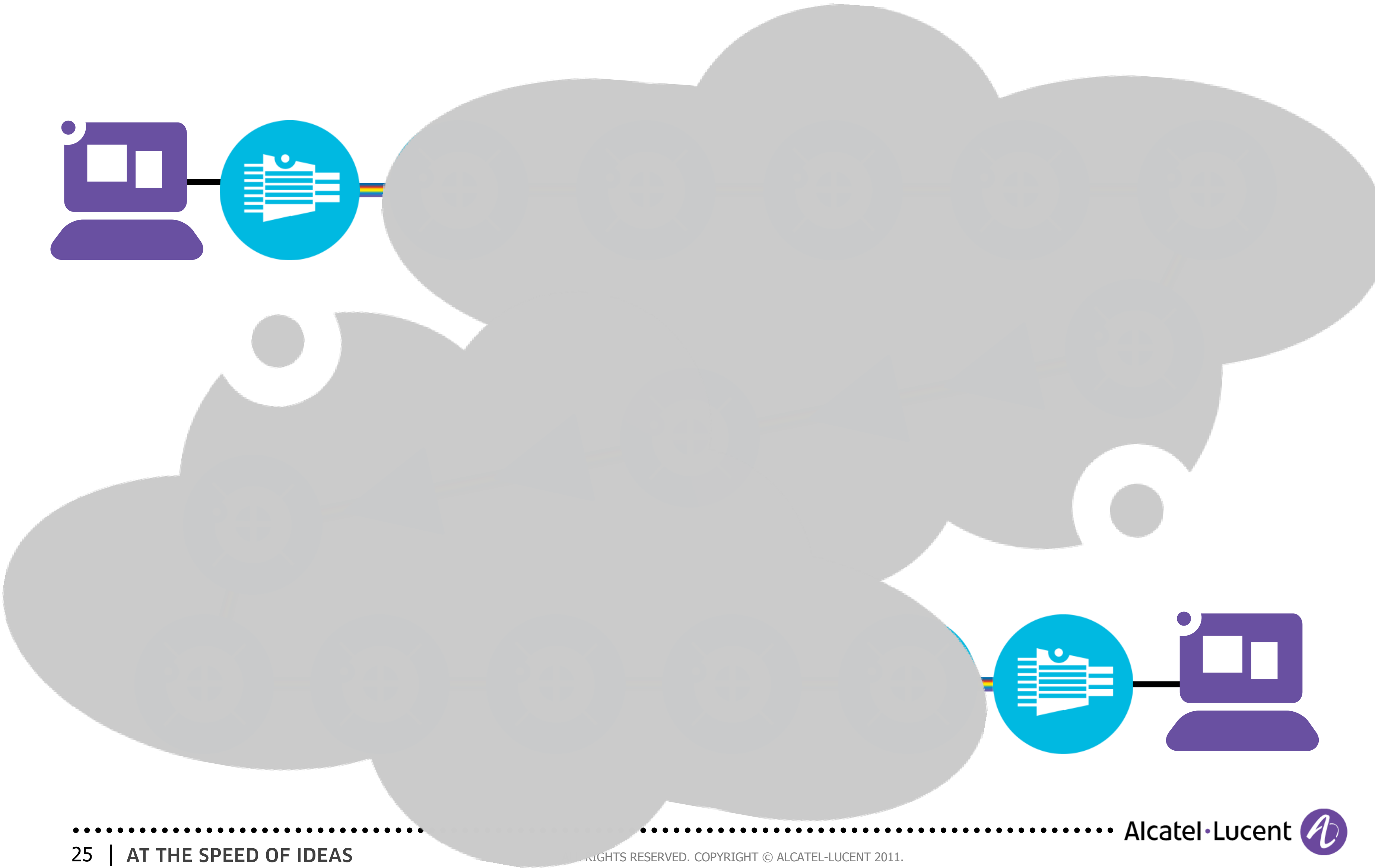
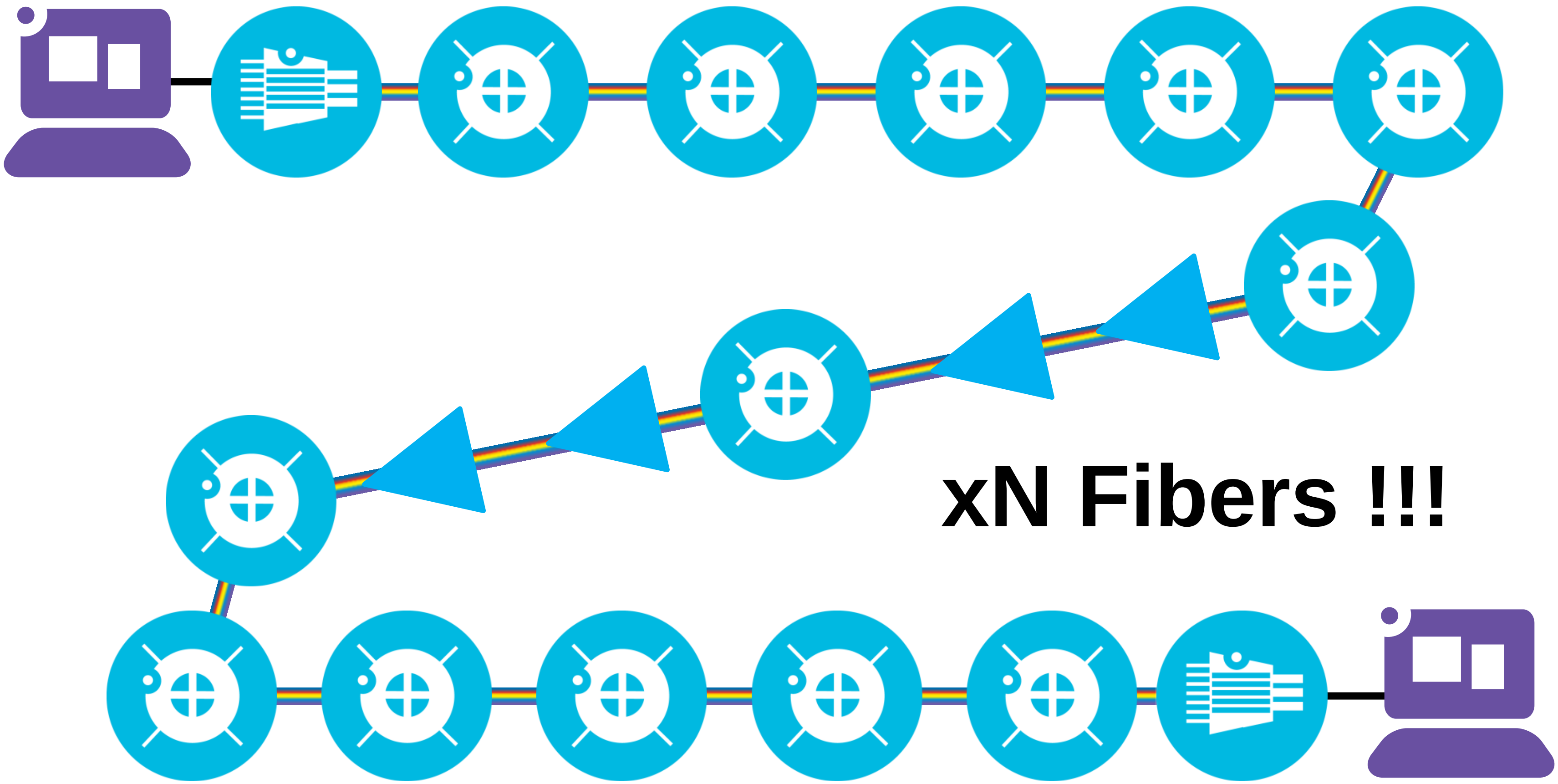
What's behind the clouds?



Networks Today: 10-20 Router/Node Hops, 10-100 Amplifiers



xN Fibers !!!

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Optical Line Systems: Thermal Density Limited

Many Configurations

- Line cards: ~ 50 W
  - Incl. OAs, ~10G OOK
- Fans: ~ 200 W
- Contr. & power: ~ 100 W

- 16 slot shelf: 50x14+100+200= 1 kW

Telcordia CO (NEBS) standard:

995 $W/m^2/m$ (forced air cooling)

Line system energy already constrained by thermal limits

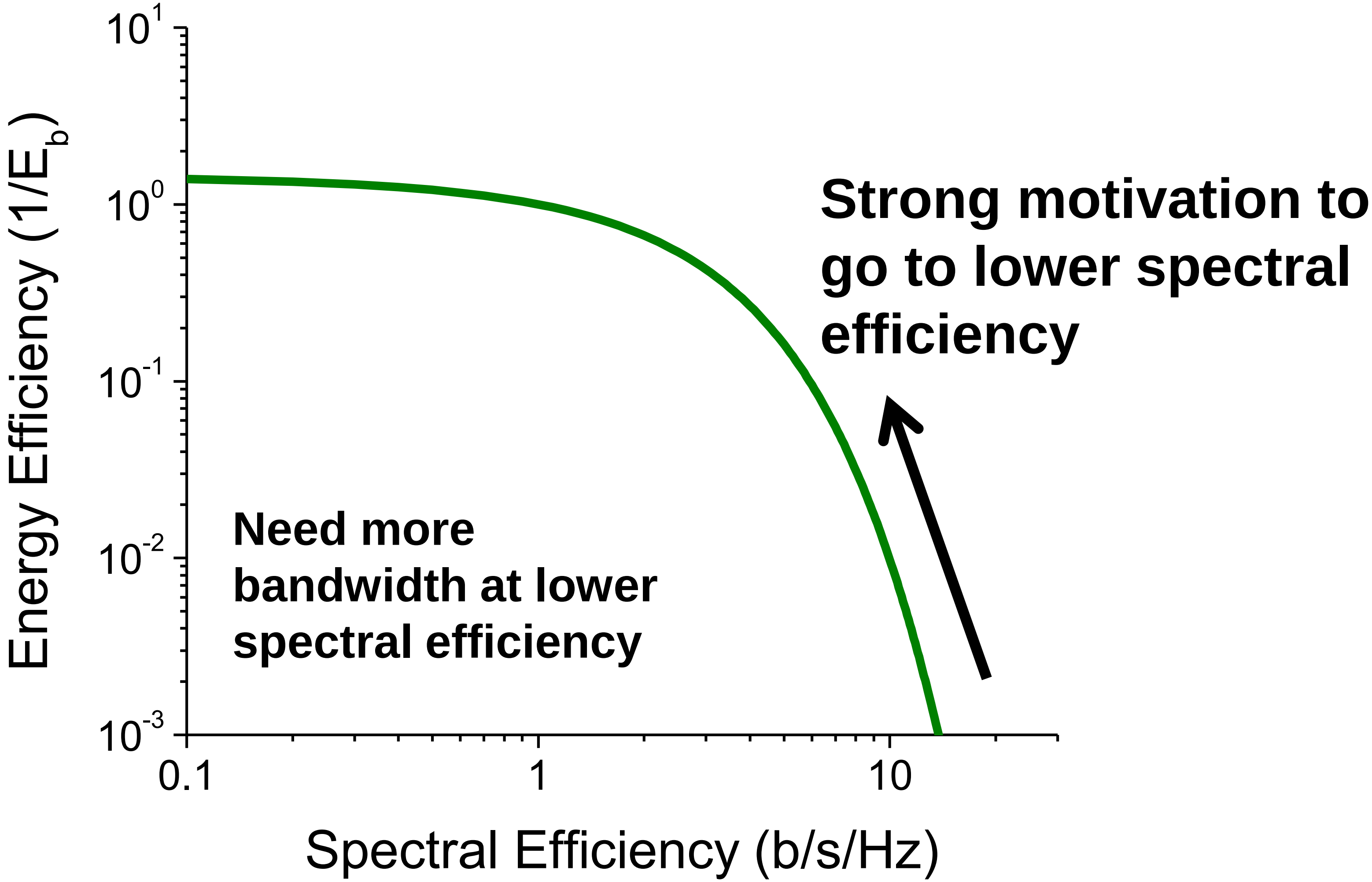
Key Question:

How is communication bandwidth tied to energy?

Virtual worlds/dematerialization rely on physical devices

- Virtual economies also bounded by physical limits
  - Natural resources: rare metals in electronics, displays
  - Energy use: computers, routers, base stations

Shannon Limit:
Fundamentally Connects Energy and Capacity



Relative to energy/bit required for SNR = 1

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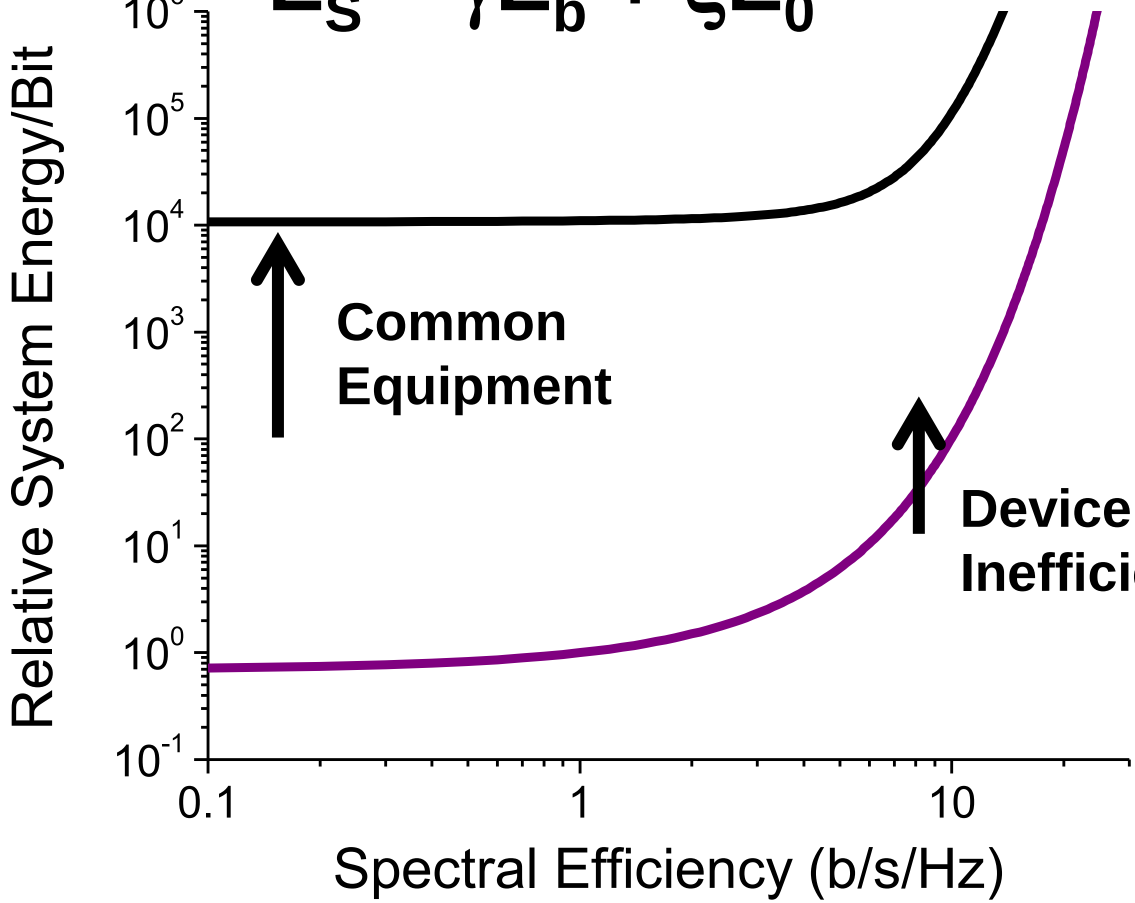
Common equipment—not related to the transmission energy/bit—limits the equation

$$E_S = \gamma E_b + \zeta E_0$$



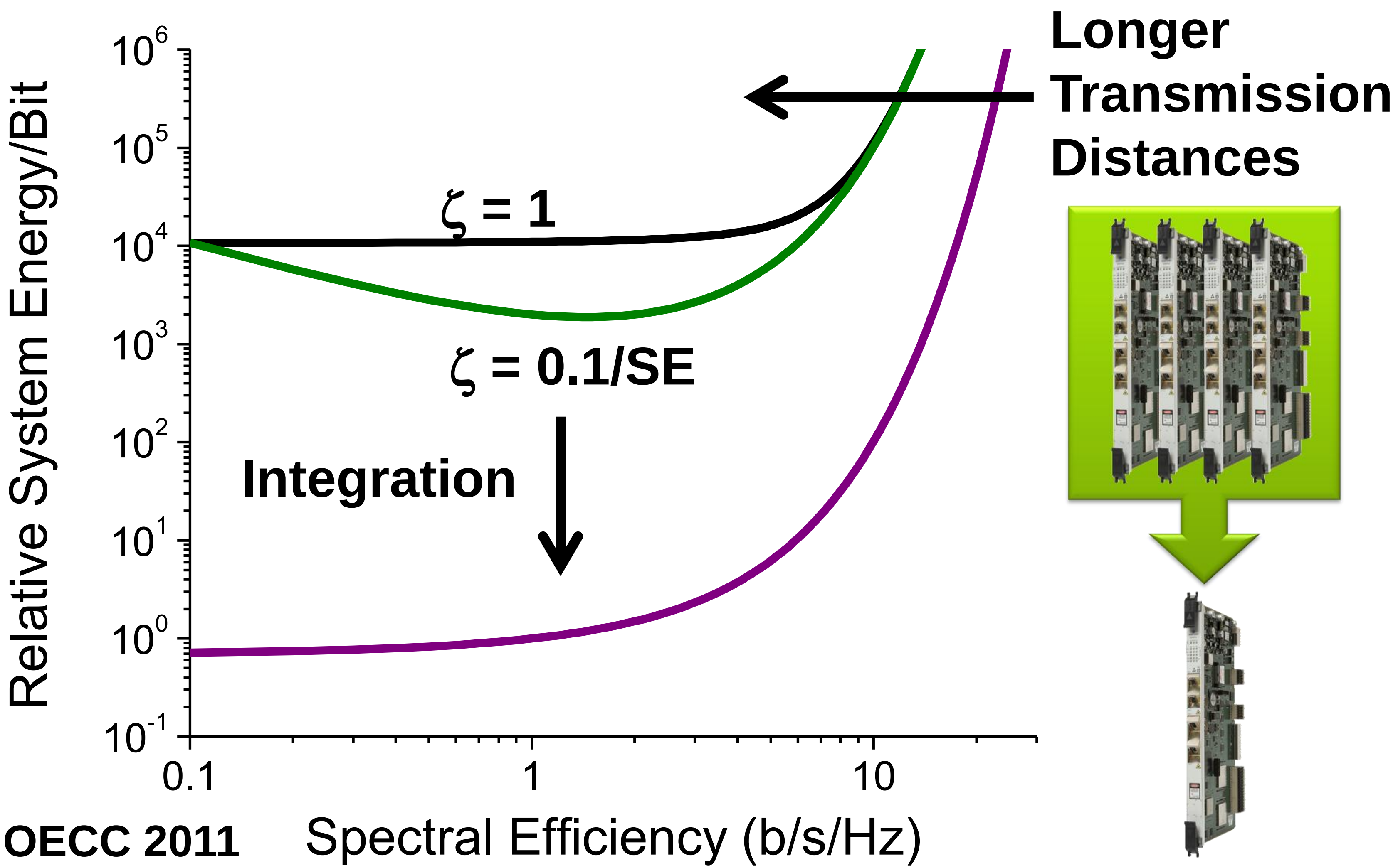
E_b , E_0 are bit energy dependent and ‘common’ equip. energy/bit

$$\zeta E_0 >> \gamma E_b$$

D. Kilper, et. al. OECC 2011

Using Integration to Minimize Energy

$\zeta = F / SE$, F = Integration factor



Kilper, OECC 2011

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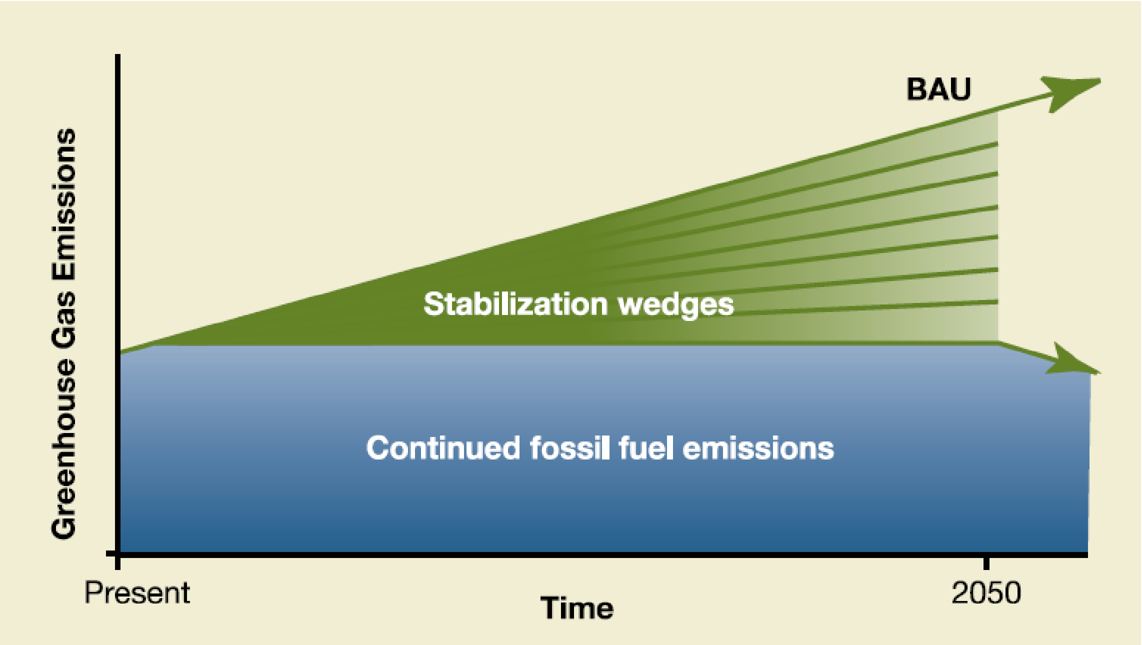
System, Board, Component, & *Photonic Integration* Are Central to Efficiency in Optical Networks

Efficiency?

Really?

Technology, Investment, & Policy



Use multiple wedge technologies to add up to total

WRI Report: 'Scaling Up: Global Technology Deployment to Stabilize Emissions' , F. Wellington, R. Bradley, B. Childs, C. Rigdon, J. Pershing; *Pacala and Socolow, Science, 2004*.

- Solution includes *Use Reductions* & *Efficiency Improvements*
- Jevon's Paradox, Kazoom Brookes Postulate: increases in efficiency lead to increases in use such that the total energy consumption increases
  - Not clear if this is significant or common (quantifying impact is complicated)
- *While rebound effects might happen, this problem is primarily tackled through policy and investment side, not technology*

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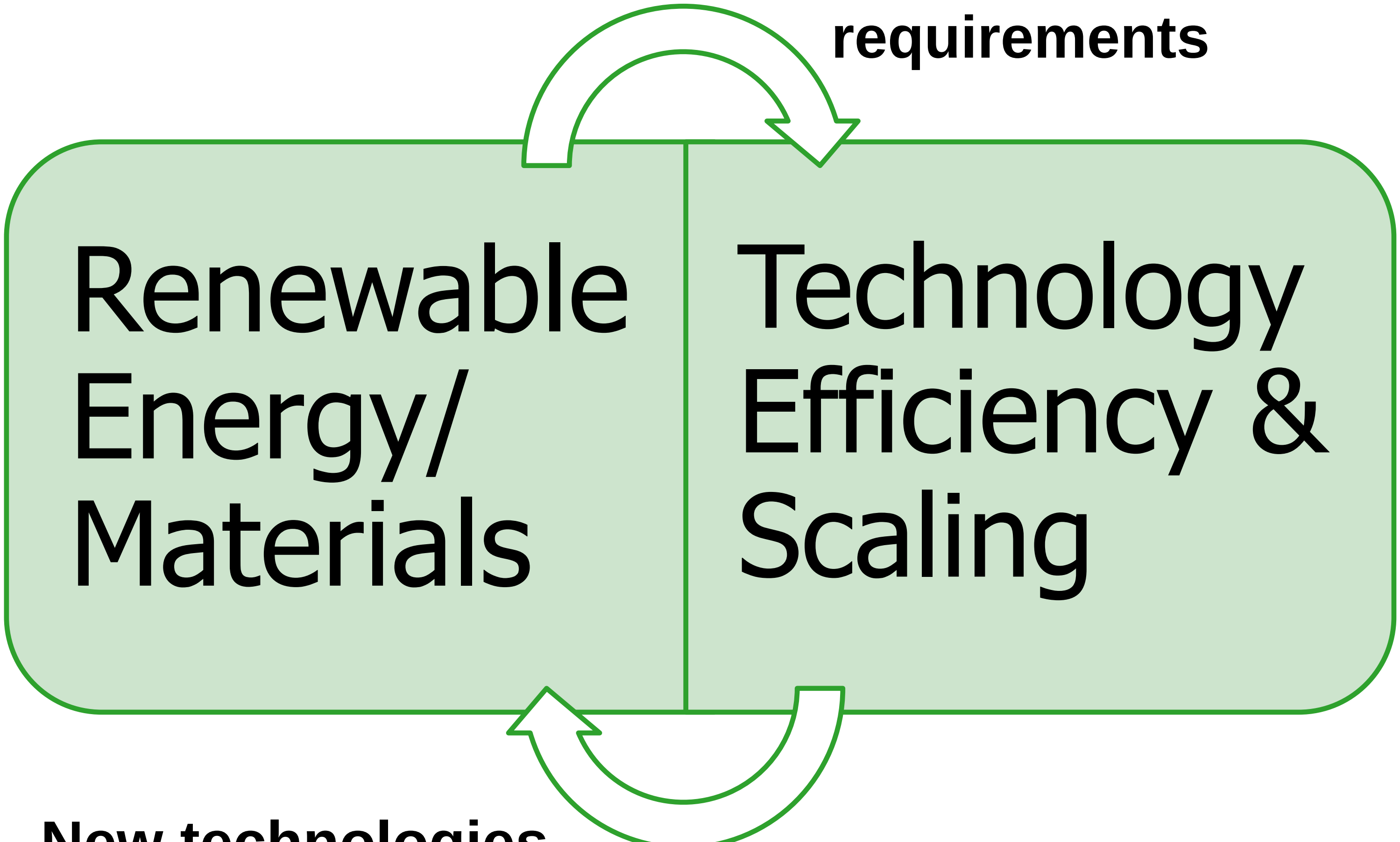
Finding a Balance

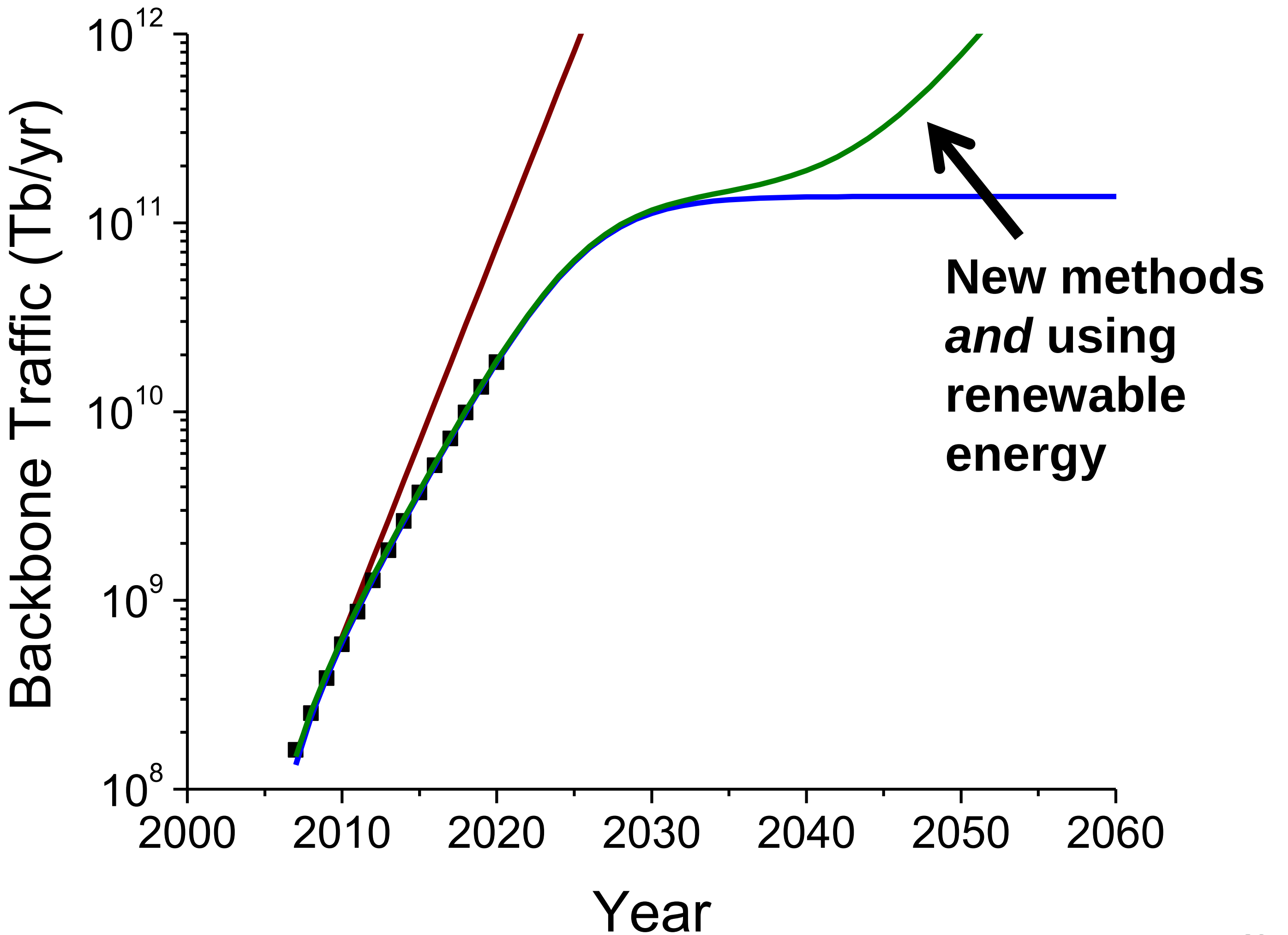
Directions, requirements



New technologies, capabilities, efficiency

Technology Innovation in a Zero-Sum World

- Will need technologies that can scale networks in a zero-sum energy economy



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GreenTouch Mission

By 2015, our goal is to deliver the architecture, specifications and roadmap — and demonstrate key components — needed to increase network energy efficiency by a factor of 1000 from current levels.

- Broad, open and global consortium executing research projects to achieve aggressive goal
- Roadmap organization establishing reference architectures and research targets to overcome major challenges facing network scaling and energy
- Venue for cooperation and enabling demonstrations among research organizations
- Forum for the exchange of information on energy trends, challenges, & research on communication networks

GreenTouch Members

- Athens Information Technology (AIT) Center
- Bell Labs, Alcatel-Lucent
- Broadcom
- CEA-LETI Applied Research Institute for Microelectronics
- China Mobile
- Chunghwa Telecom
- Columbia University
- Commscope/Andrew
- Dublin City University
- ETRI
- ES Network/Lawrence Berkeley Labs
- Fondazione Politecnico di Milano
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- France Telecom
- Fujitsu
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- IMEC
- Indian Institute of Science
- IIT Delhi
- INRIA
- KAIST
- Karlsruhe Institute of Tech.
- Katholieke Universiteit Leuven (K.U. Leuven)
- King Abdulaziz City for Science and Technology
- KT Corporation
- National Chiao Tung University
- National ICTA Australia
- Nippon Telegraph and Telephone Corp
- Politecnico di Torino
- Portugal Telecom Inovação, S.A.
- Samsung (SAIT)
- Seoul National University
- Shanghai Institute of Microsystems & Information Technology
- Swisscom
- TNO
- Tsinghua University
- TTI
- TU Denmark
- TU Dresden
- University College London
- University of Cambridge
- University of Delaware
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- University of Leeds
- University of Manchester
- University of Maryland
- University of Melbourne CEET
- University of Missouri-KC
- University of New South Wales
- University of Paderborn
- University of Rochester
- University of Toronto
- Utah State University
- Vodafone Group
- Waterford Institute of Technology
- ZTE

Conclusions

Cost is the market driver
Energy is the technology driver

- ICT networks are growing rapidly
  - Scaling networks is becoming more difficult
  - Brings focus to energy efficiency

- ICT promises low carbon solutions across economy
- Need high efficiency, high bandwidth solutions that enable use of renewable energy

- Capacity crunch is really an energy crunch
  - Photonic integration is an key to energy efficiency

- Yes to efficiency: that's one of the key roles of communication research

Collaborators & Contributors

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Thank you!

AT THE SPEED OF IDEAS