



Energy Centric Communications

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Bell Labs, Alcatel-Lucent

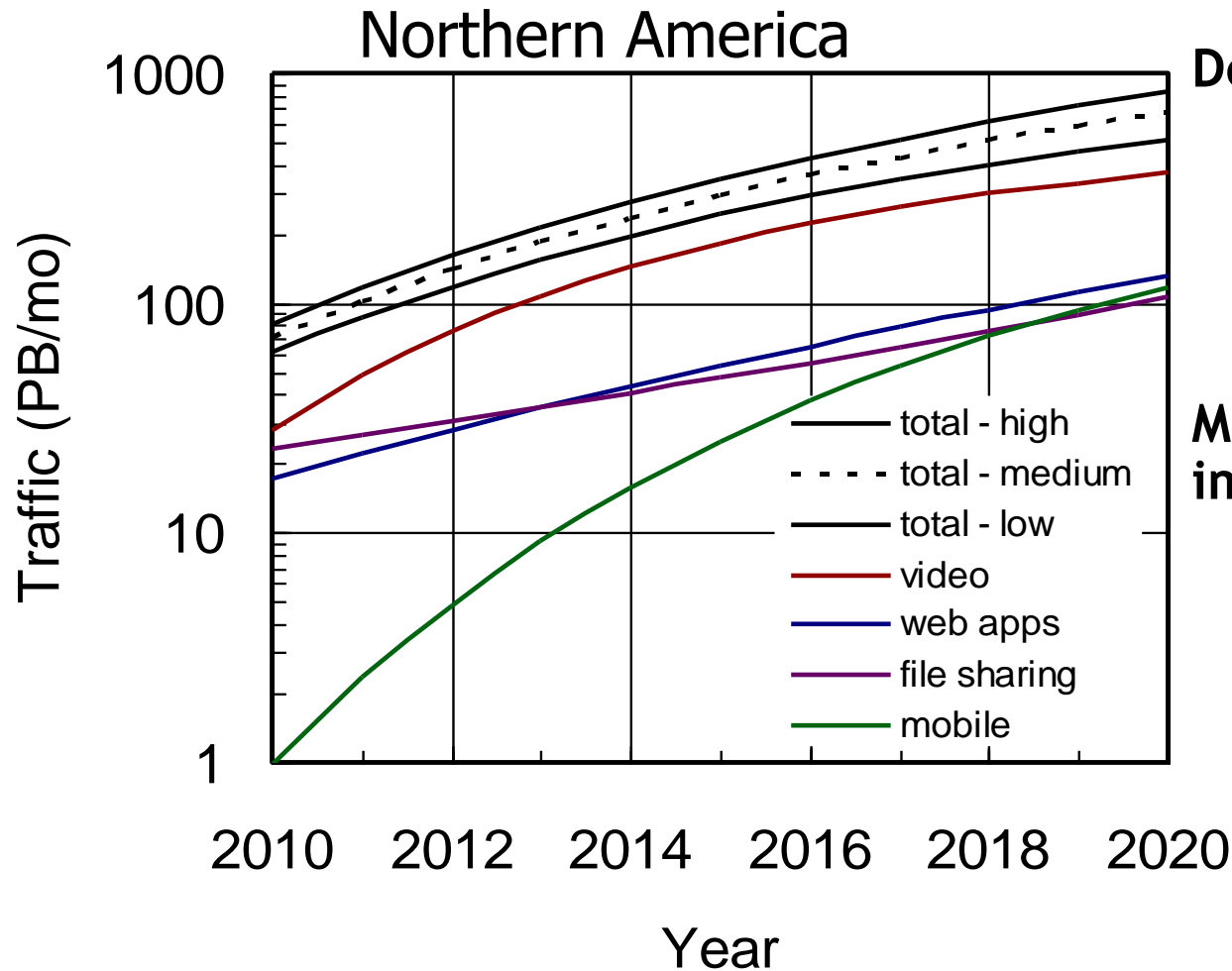
GreenTouch Consortium

..... Alcatel-Lucent 

Why?

Answer #1: Traffic & Services

Continued Exponential Traffic Growth



Doubling every 2 years

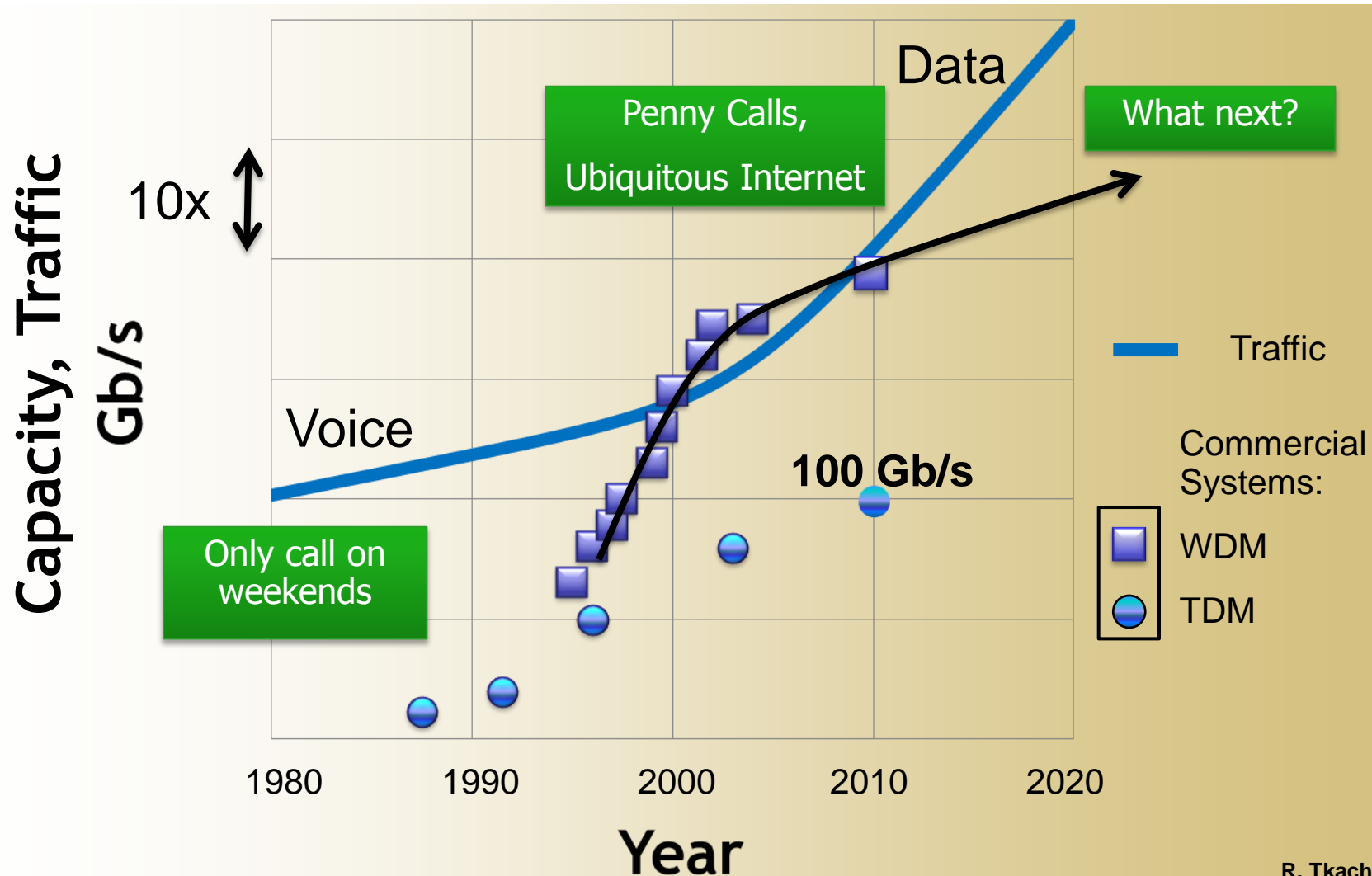
- 40% per year
- 30x in 10 years
- 1000x in 20 years

Mix of services is important:

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



Fiber Capacity Deficit or "Crunch"



R. Tkach APOC 2008

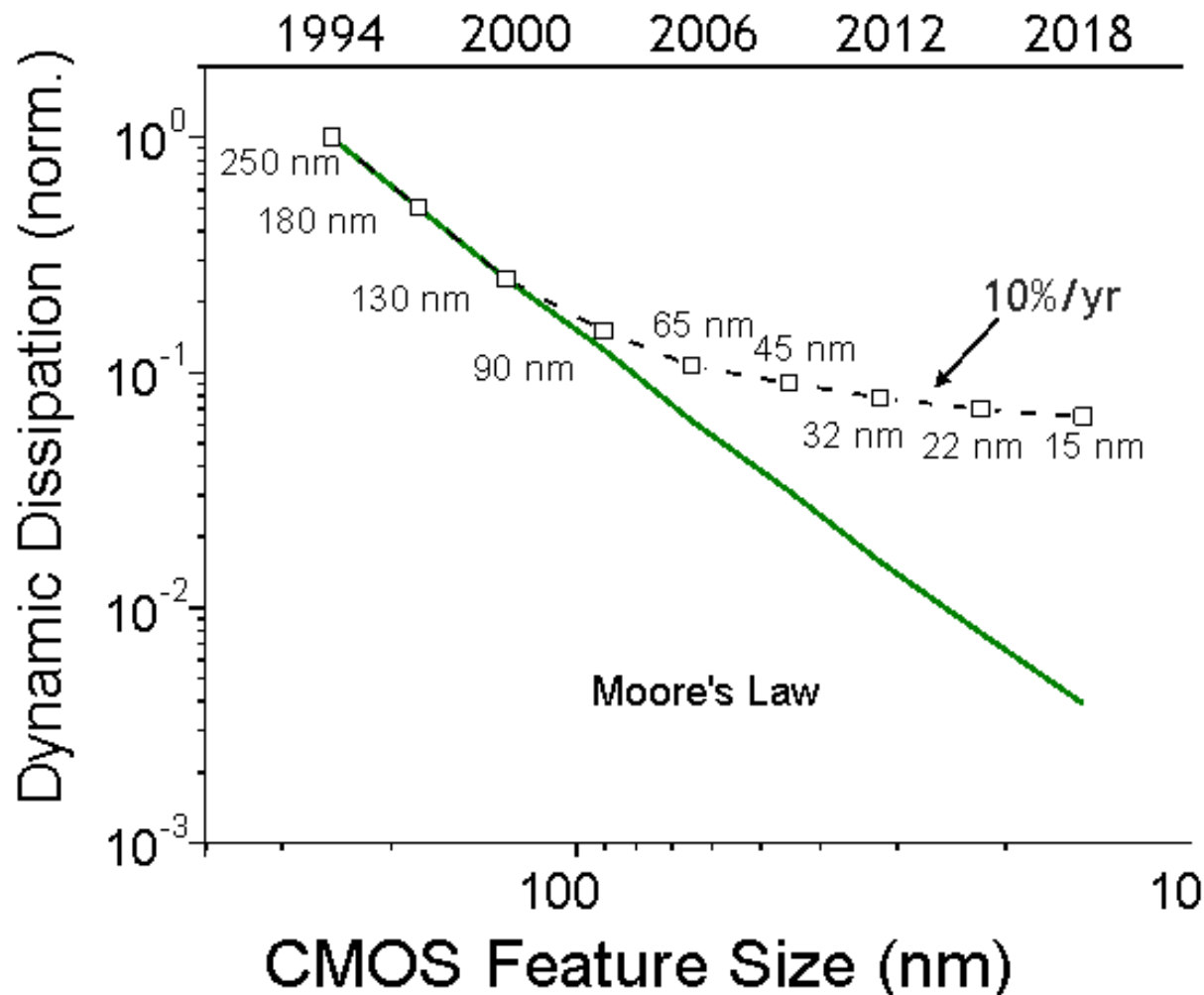
Answer #2:

Technology Slowdown

(thermal density bottleneck)

Slowdown in Electronics: Power is Not Scaling

- Reduction in dynamic dissipation with feature size is slowing

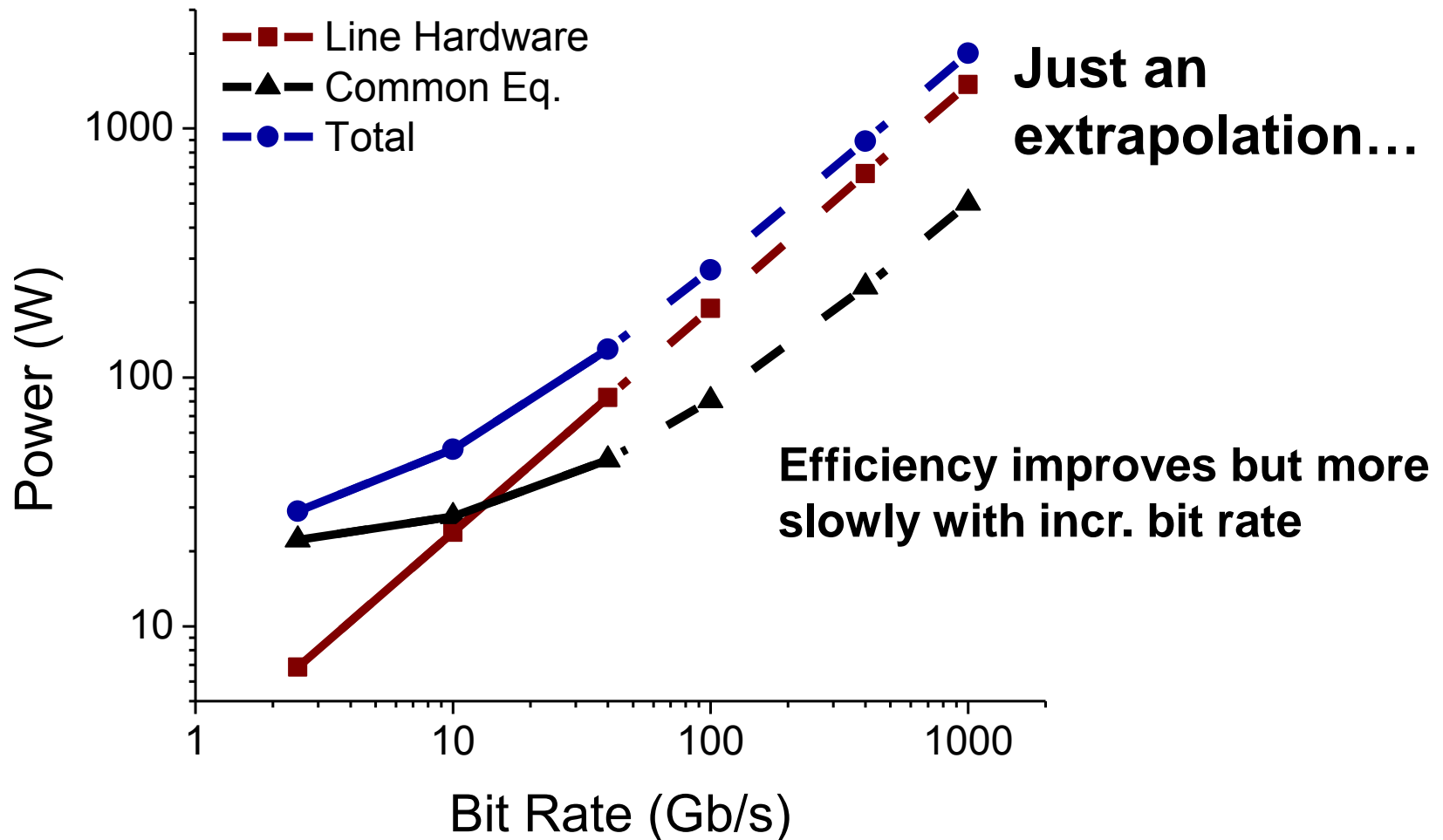


Dusan Suvakovic

Alcatel-Lucent



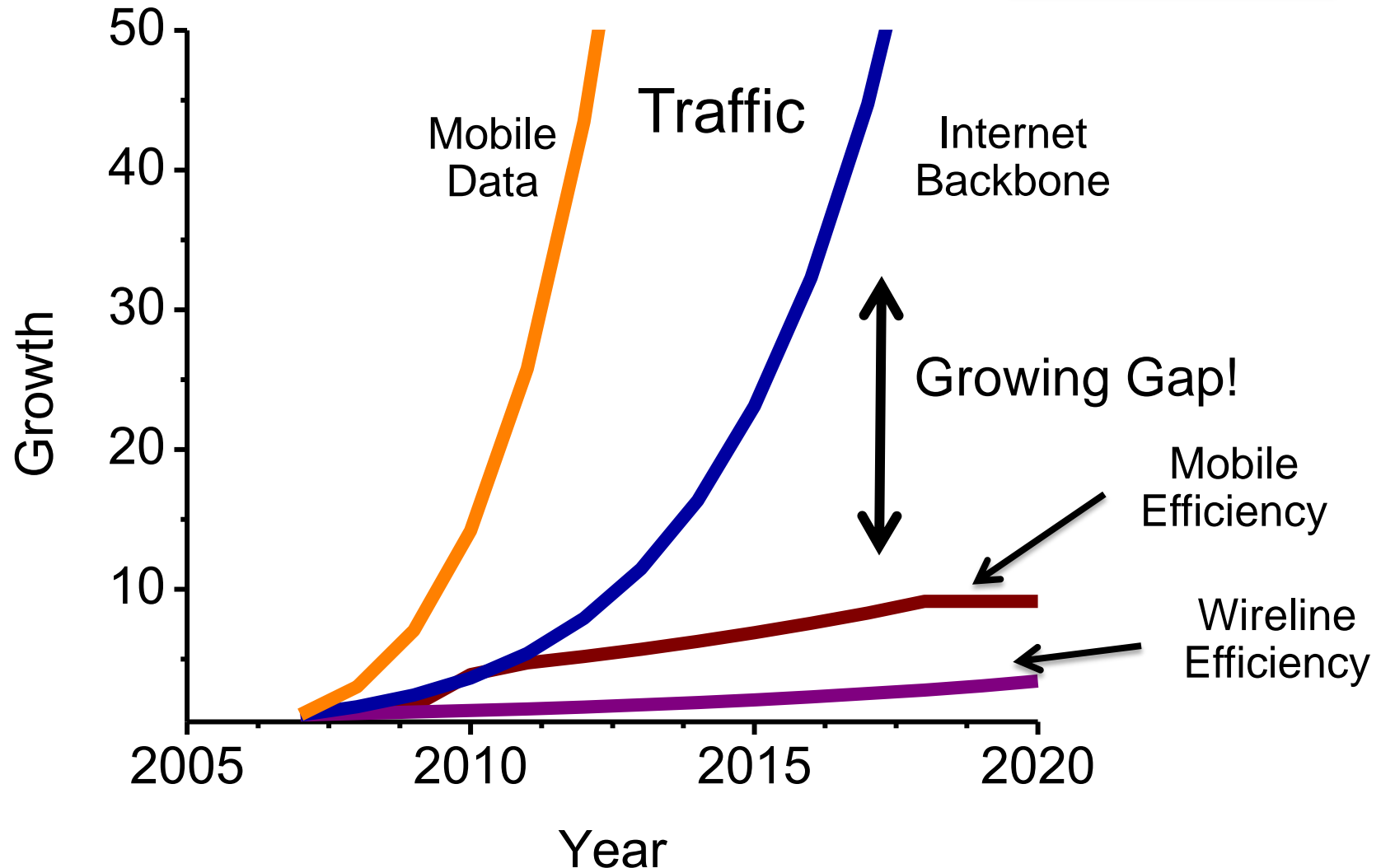
Transceiver Line Card Energy Rising Steeply



- Line card controller similar to computer: ~ 30 W

The Network Energy Gap

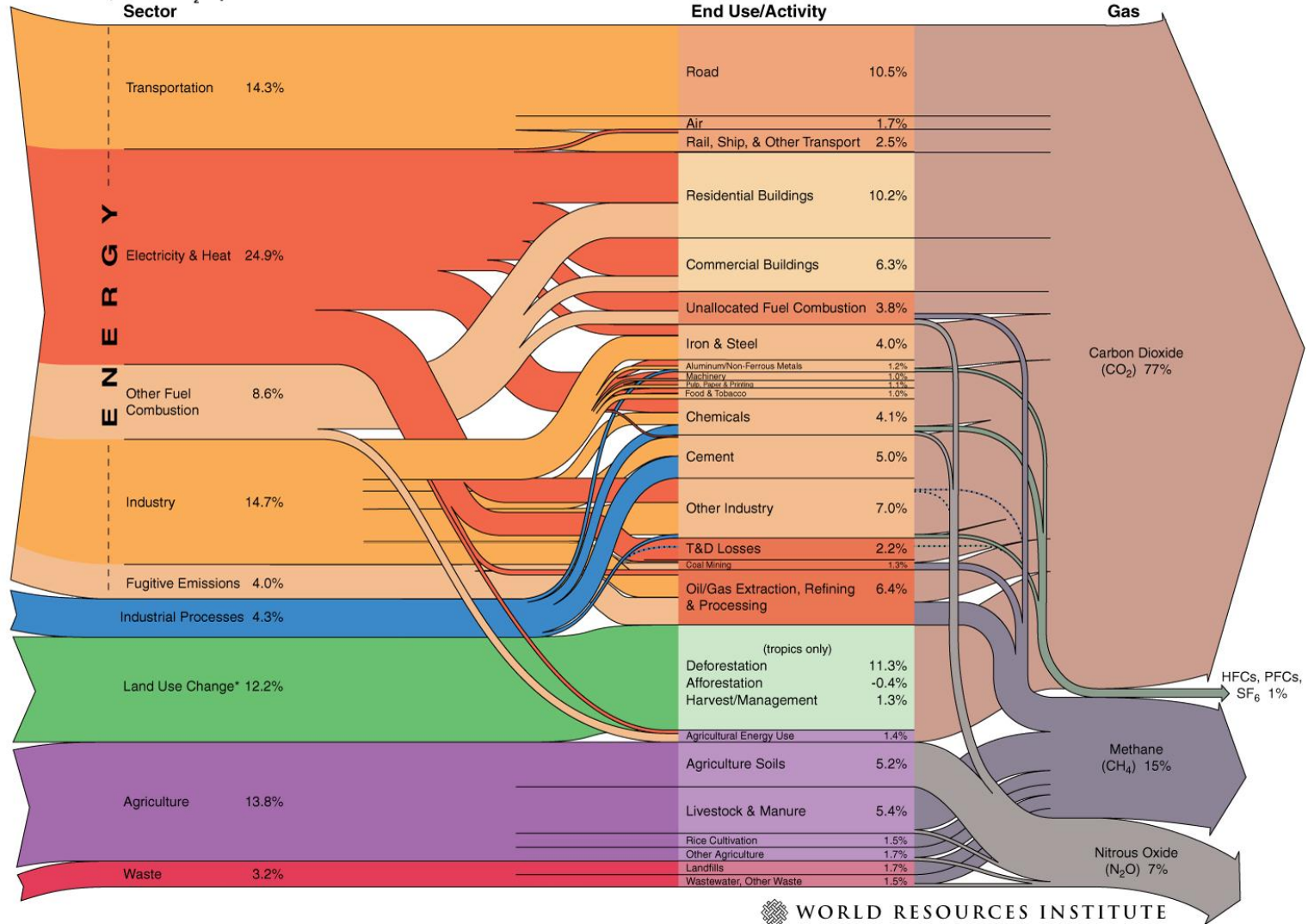
$$P = T/\eta$$



Near Term?

World Greenhouse Gas Emissions (yr 2005)

World Greenhouse Gas Emissions in 2005
Total: 44,153 MtCO₂ eq.



WORLD RESOURCES INSTITUTE

ICT “nonexistent” in 2005....

2020 ICT Carbon Footprint



**Power/User:
~ 10 W !!**

360m tons CO₂

260m tons CO₂

IT footprints

Emissions by sub-sector, 2020

PCs, peripherals
and printers
57%

Telecoms
infrastructure
and devices
25%

Data
centres
18%



Total emissions: 1.43bn tonnes CO₂ equivalent

820m tons CO₂

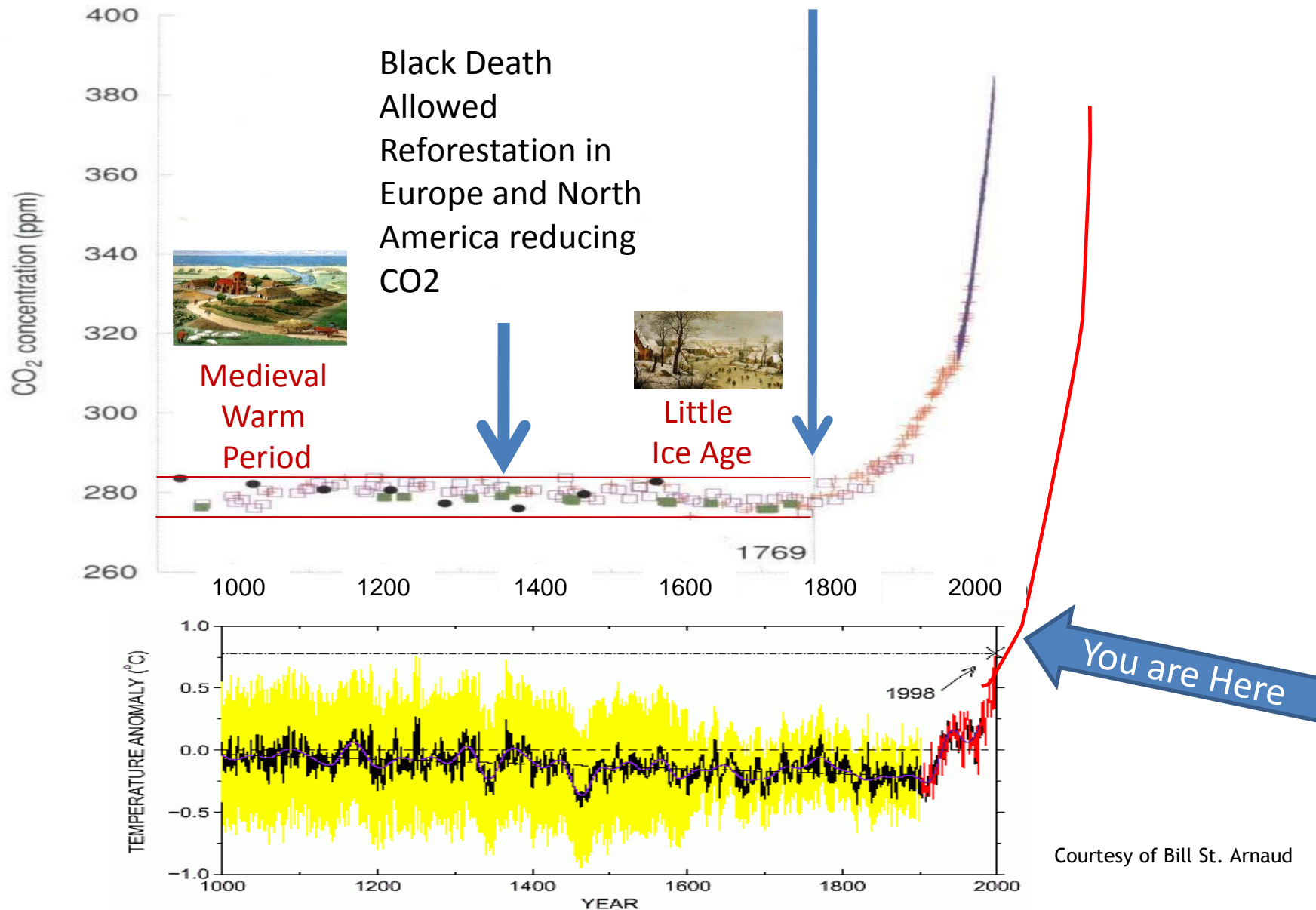
2007 Worldwide ICT
carbon footprint:
2% = 830 m tons CO₂

Expected to grow
to 4% by 2020

The Climate Group, GeSI report "Smart 2020", 2008



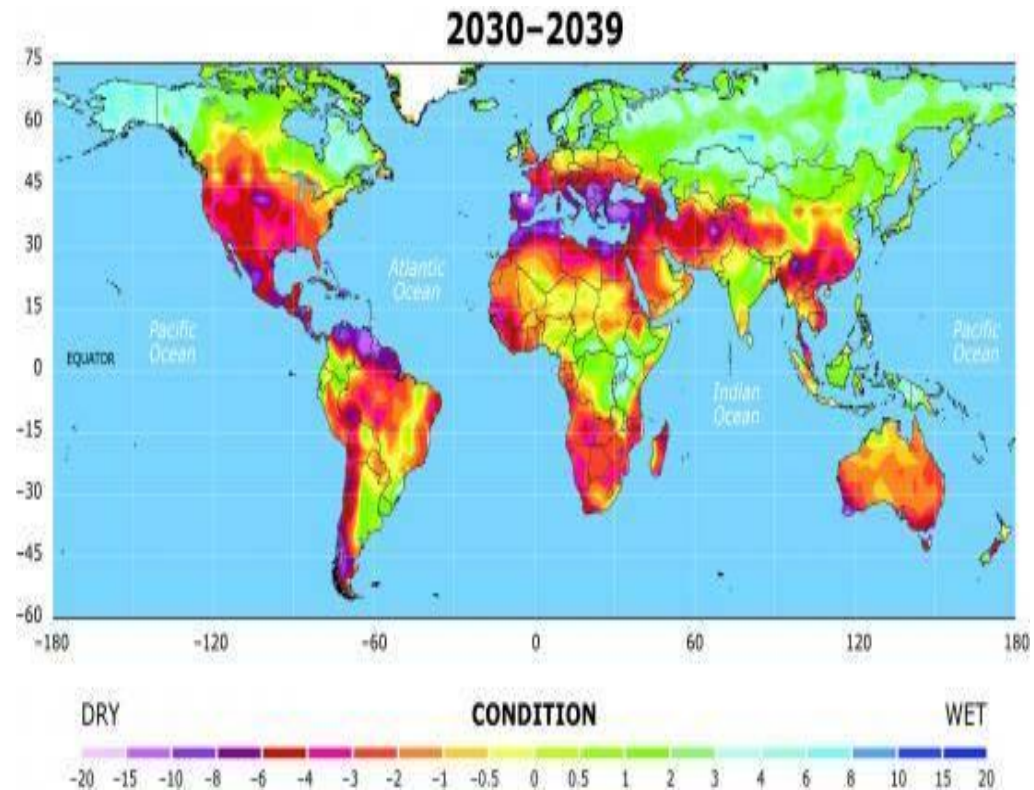
Rapid Increase in the Greenhouse Gas CO₂ Since Industrial Era Began



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

Future Droughts

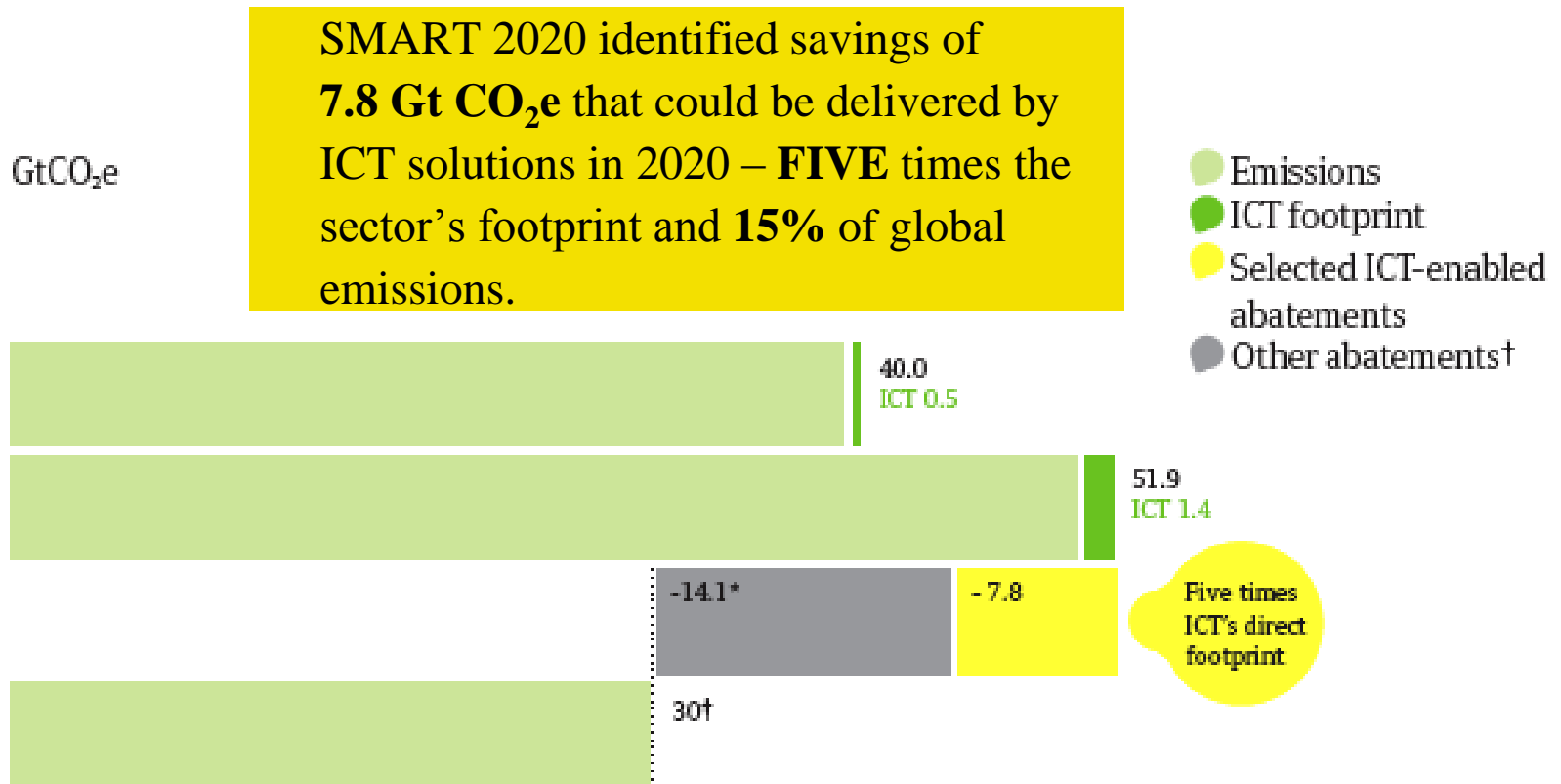
- Palmer Drought Severity Index, or PDSI.
- The most severe drought in recent history, in the Sahel region of western Africa in the 1970s, had a PDSI of -3 or -4.
- By 2030 Western USA could see -4 to -6
- By 2100 some parts of the U.S. could see -8 to -10 PDSI, while Mediterranean areas could see drought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



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

Opportunity: Greening with ICT

ICT IMPACT: THE GLOBAL FOOTPRINT AND THE ENABLING EFFECT



* For example, avoided deforestation, wind power or biofuels.

† 21.9 GtCO₂e 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 ENABLING EFFECT

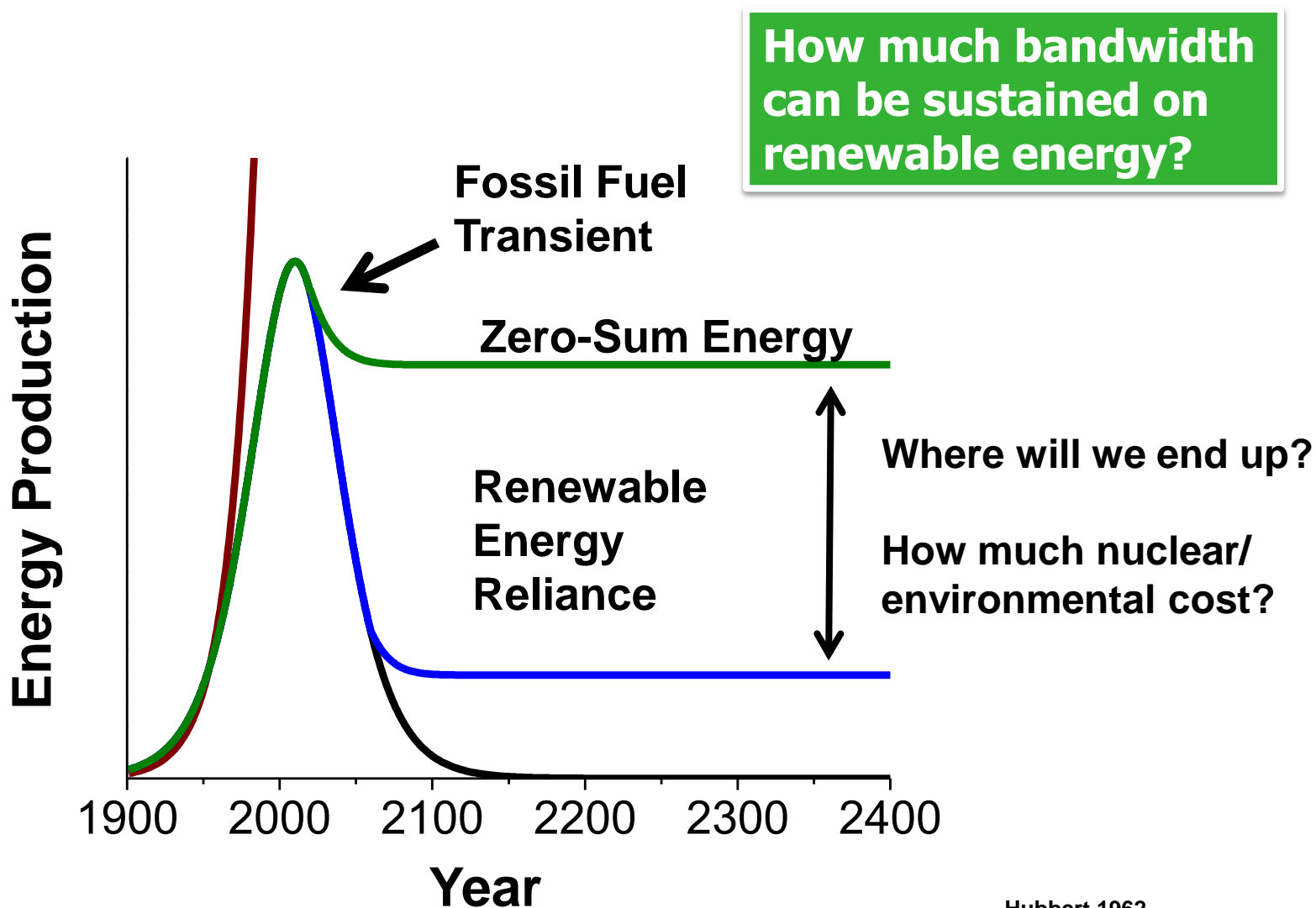
SMART 2020 EXAMINED:

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

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

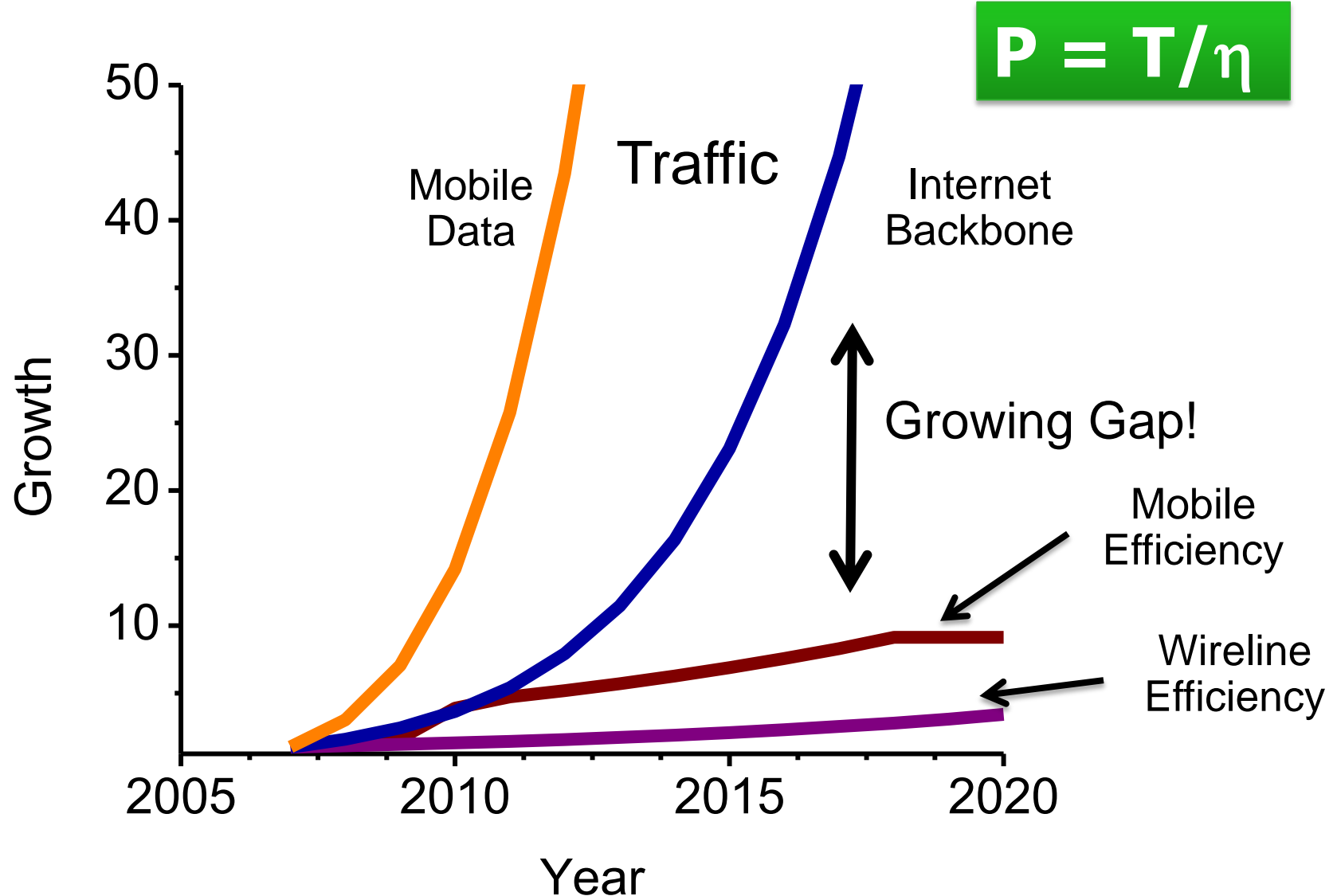
Long Term?

Energy Production: Where Will We End Up?

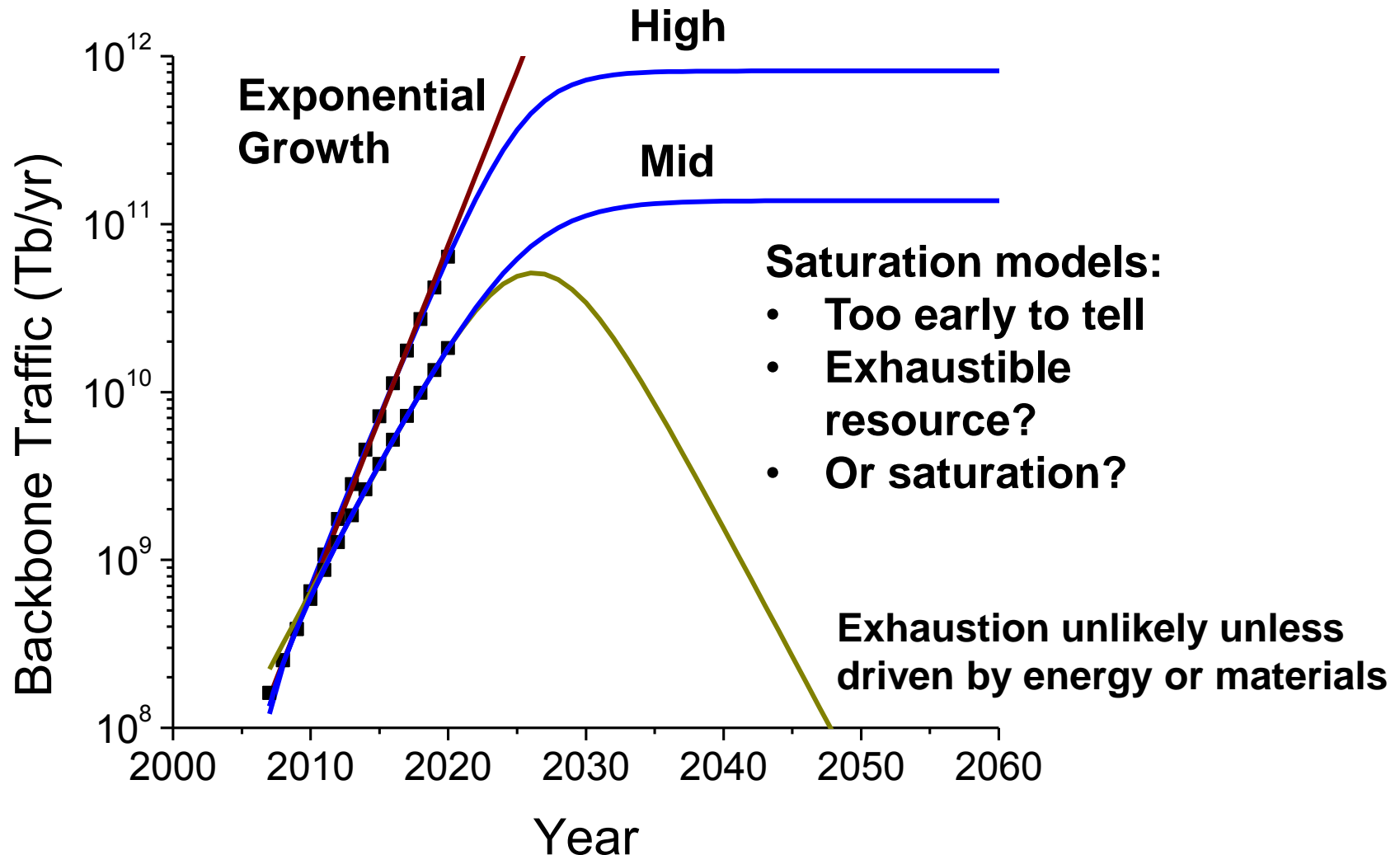


Hubbert 1962

Need to Address Network Scaling Challenges



Is Bandwidth an Exhaustible Resource? Capacity?

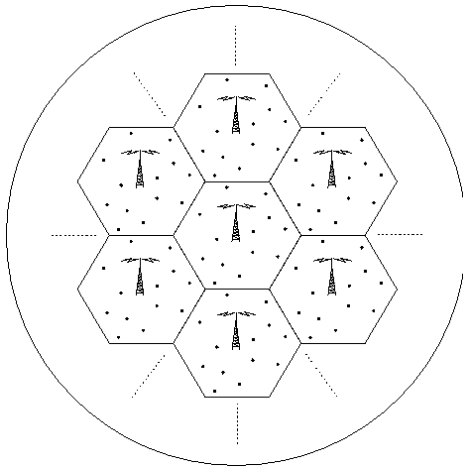


- Physical quantity tied to energy and the natural resources in the devices

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

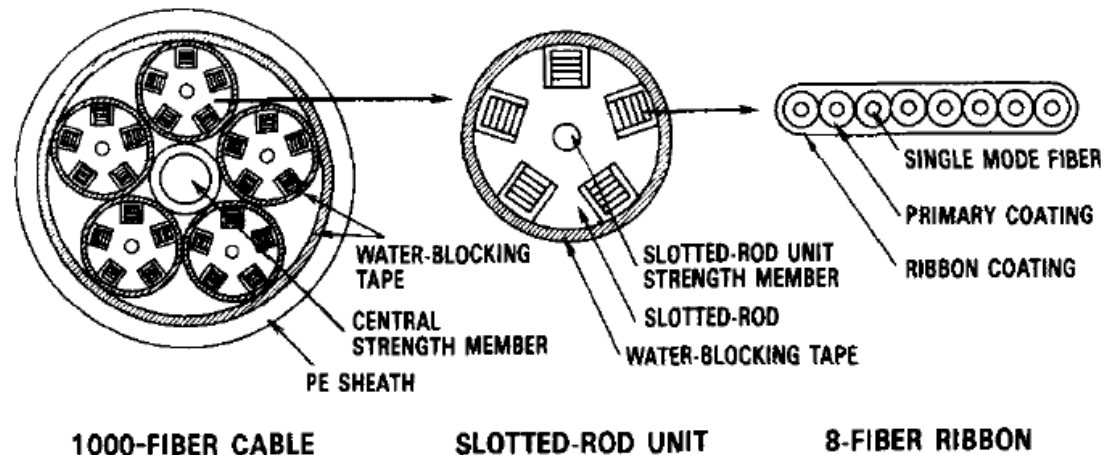


Fig. 1. Nonmetallic 1000-fiber cable structure.

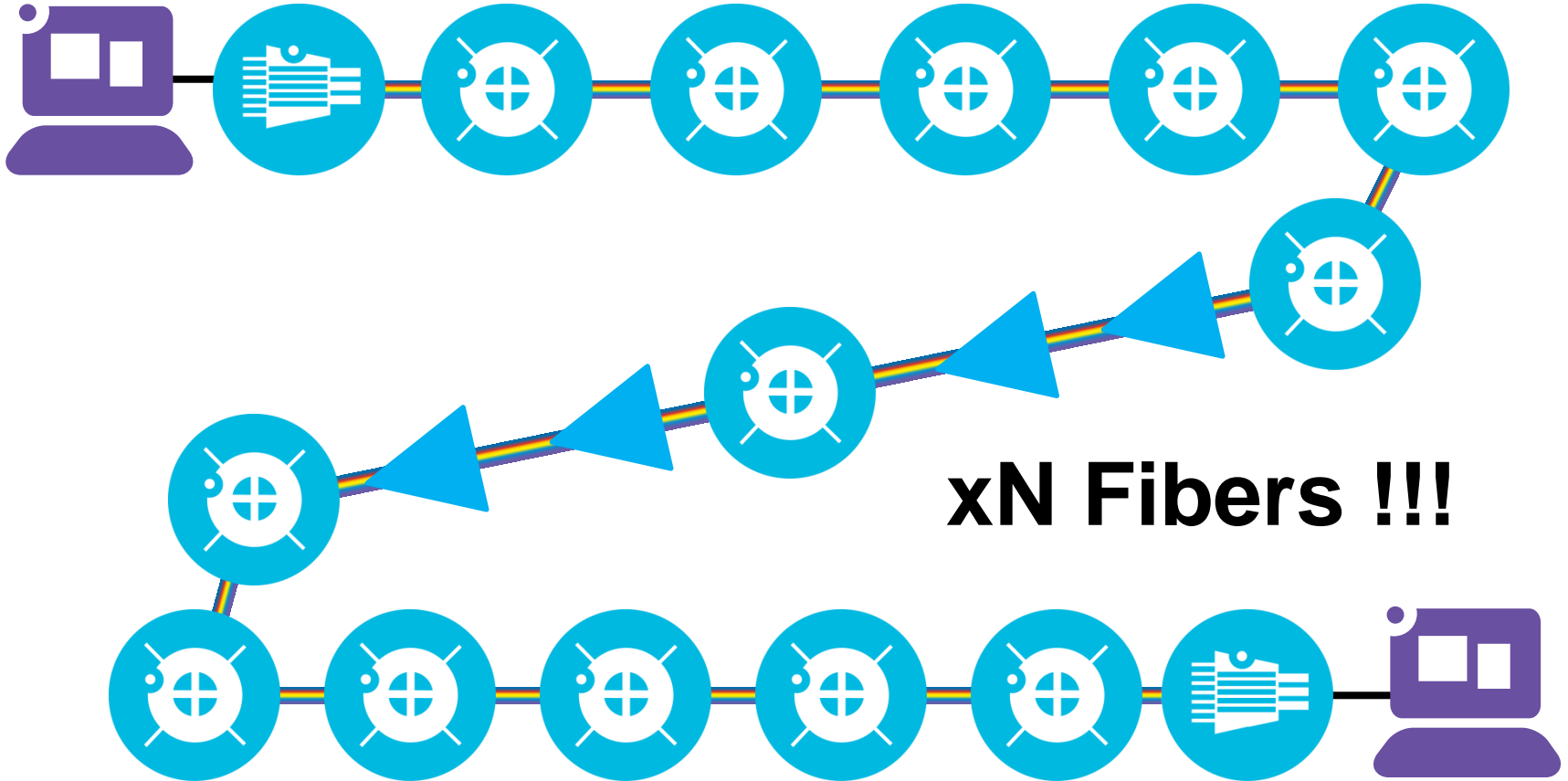
K. Hogari, et. al. JLT 1992

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

What's behind the clouds?



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



Optical Line Systems: Thermal Density Limited

Many Configurations

- Line cards: ~ 50 W
 - Incl. OAs, ~ 10 G OOK
 - Fans: ~ 200 W
 - Contr. & power: ~ 100 W
-
- 16 slot shelf: $50 \times 14 + 100 + 200 = 1$ kW

Telcordia CO (NEBS) standard:

$995 \text{ W/m}^2/\text{m}$ (forced air cooling)

Line system energy already constrained by thermal limits



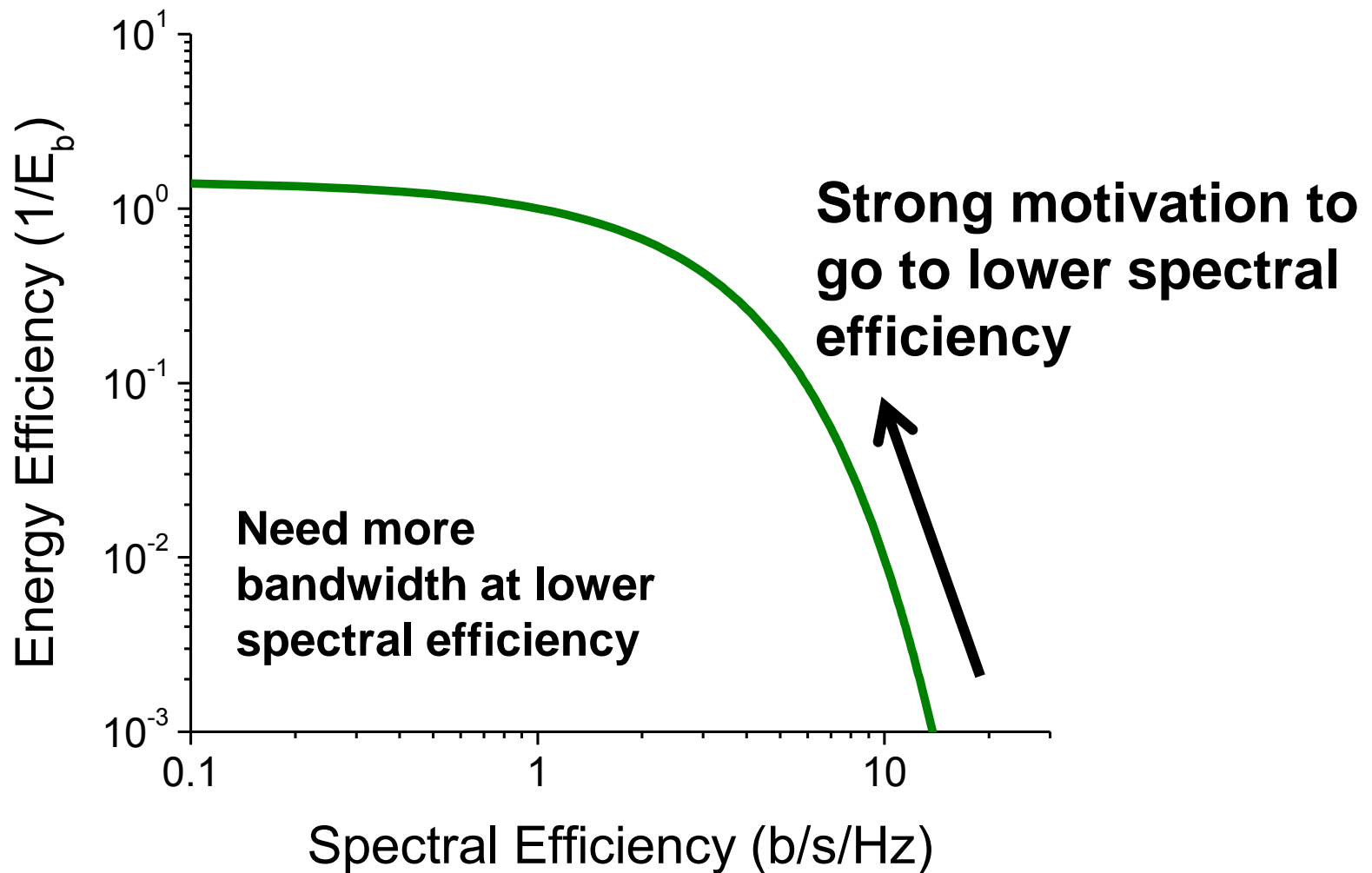
Key Question:

How is communication bandwidth tied to energy?

Virtual worlds/dematerialization rely on physical devices

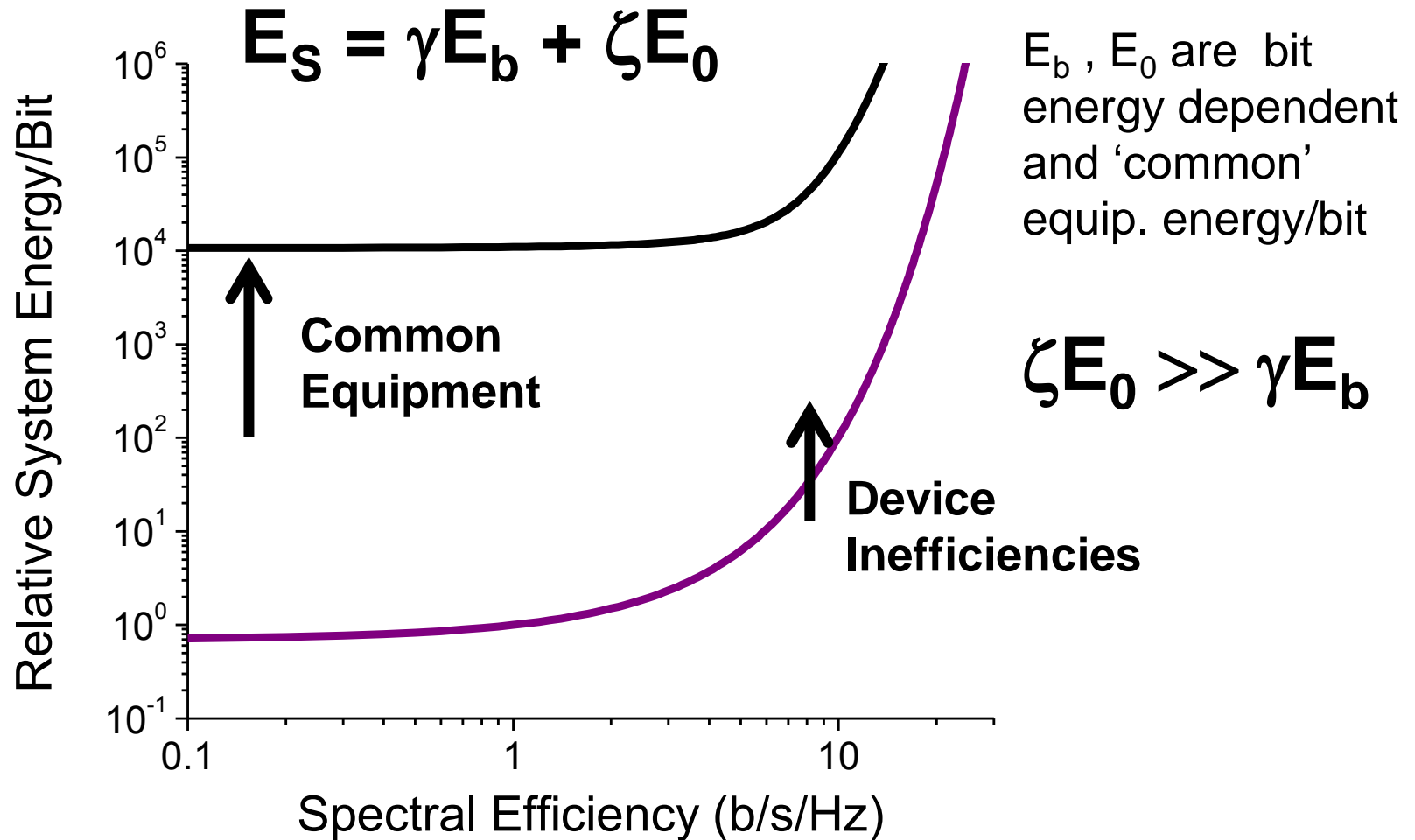
- Virtual economies also bounded by physical limits
 - Natural resources: rare metals in electronics, displays
 - Energy use: computers, routers, base stations

Shannon Limit: Fundamentally Connects Energy and Capacity



Relative to energy/bit required for SNR = 1

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



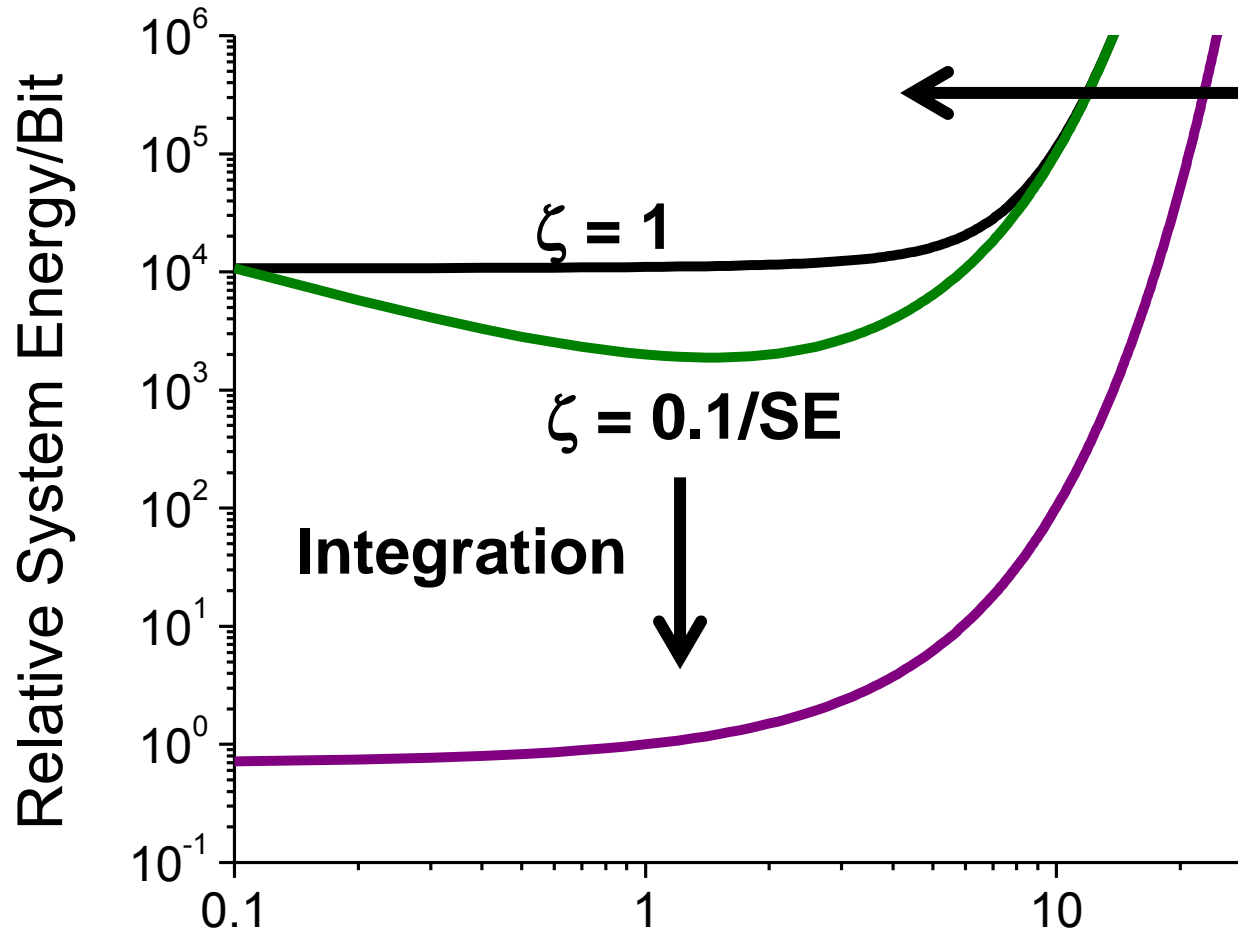
D. Kilper, et. al. OECC 2011

Alcatel-Lucent

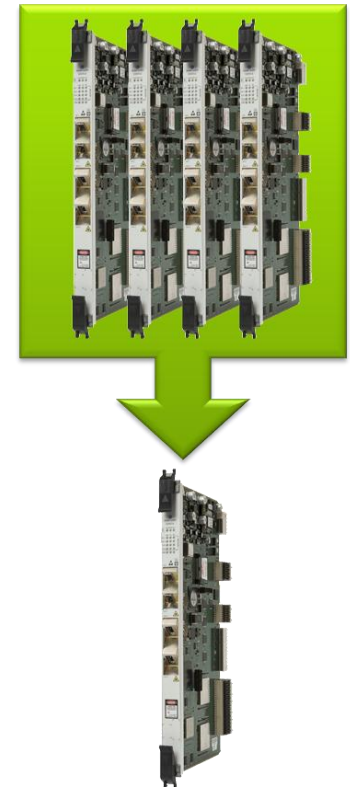


Using Integration to Minimize Energy

$$\zeta = F / SE, F = \text{Integration factor}$$



Longer
Transmission
Distances



Kilper, OECC 2011

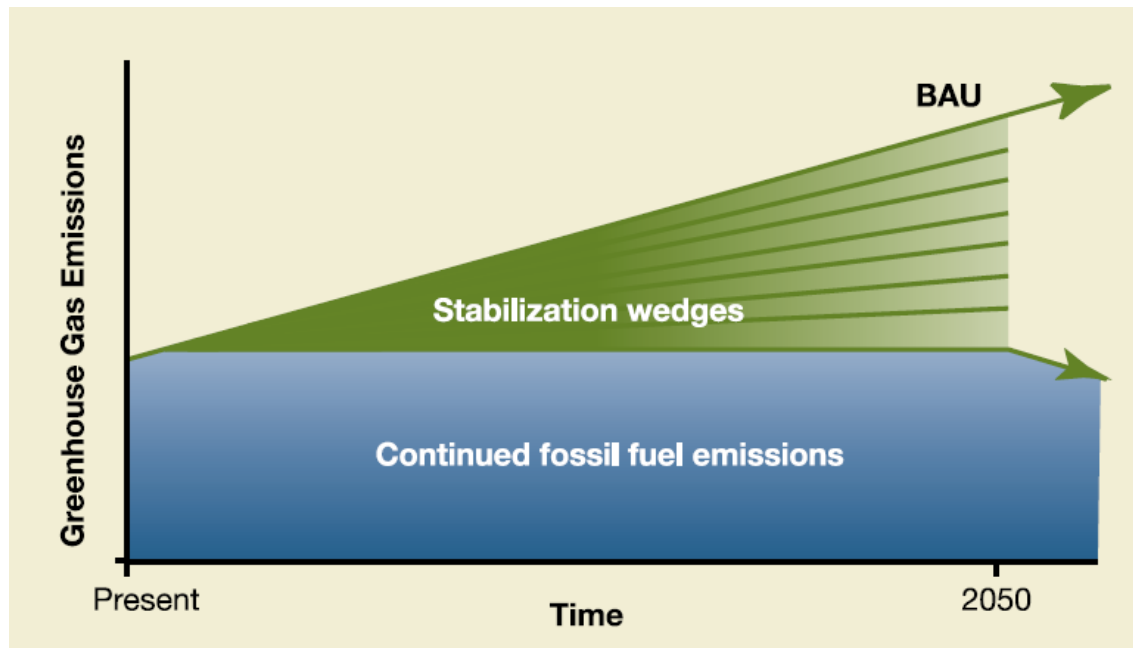
Spectral Efficiency (b/s/Hz)

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



Efficiency? Really?

Technology, Investment, & Policy

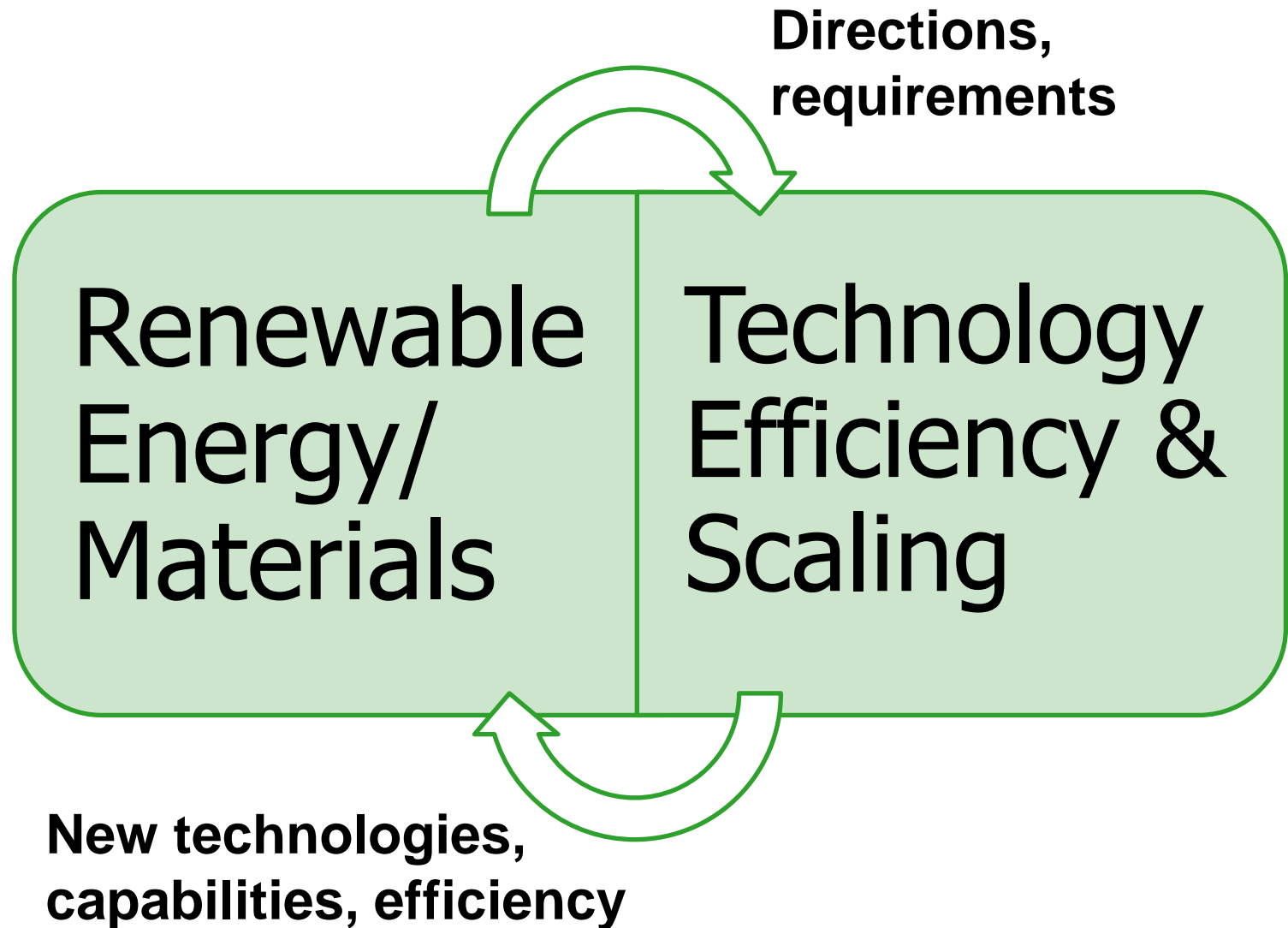


Use multiple wedge technologies to add up to total

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.*

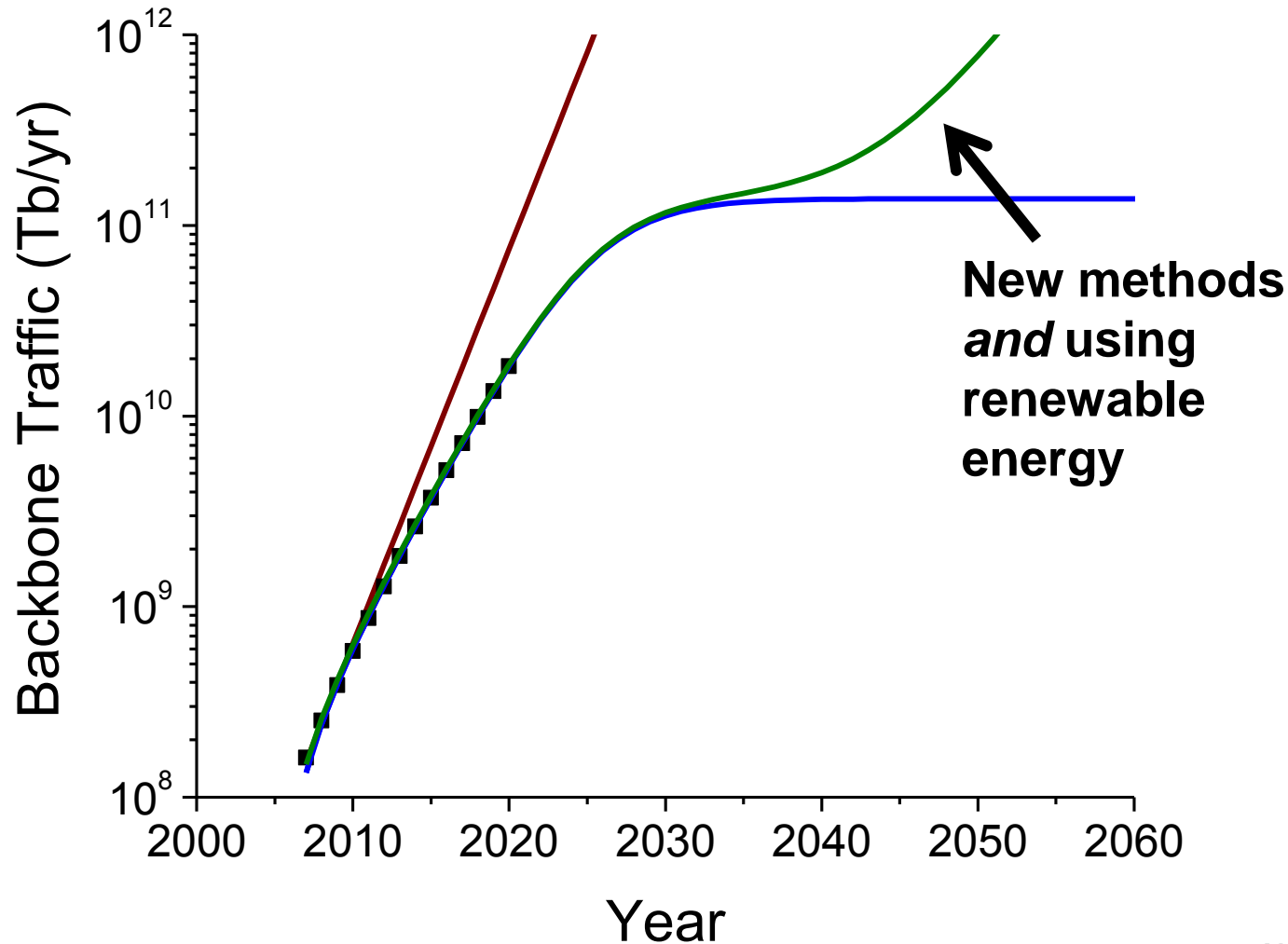
- Solution includes *Use Reductions & Efficiency Improvements*
- Jevon's Paradox, Kazoom Brookes Postulate: increases in efficiency lead to increases in use such that the total energy consumption increases
 - Not clear if this is significant or common (quantifying impact is complicated)
- *While rebound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

Finding a Balance



Technology Innovation in a Zero-Sum World

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



GreenTouch

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
- Fraunhofer-Gesellschaft
- France Telecom
- Fujitsu
- Huawei
- IBBT
- 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
- University of L'Aquila
- 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