Telecommunications Policy 39 (2015) 861–874

Contents lists available at ScienceDirect

Telecommunications Policy

URL: www.elsevier.com/locate/telpol

IT and sustainability: New strategies for reducing carbon emissions and resource usage in transportation

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ARTICLE INFO

Available online 12 August 2015

Keywords:
Information technology
Moore's law
Rates of improvement
Sustainability
Transportation
Buses
Phones
GPS
Telecommunications
Bike sharing
Electric vehicles
Autonomous vehicles
Wireless
Charging
Power electronics
Cameras

ABSTRACT

This paper describes how rapid rates of improvement in smart phones, telecommunication systems and other forms of IT enable solutions for sustainability and how this provides opportunities for the fields of telecommunication and information systems. While reports from the Intergovernmental Panel on Climate Change focuses on technologies with rates of improvement less than 5% per year, most types of information technologies are experiencing annual rates of improvement that exceed 30% per year. These rapid rates of improvement are changing the economics of many activities of which this paper describes four examples in transportation. The paper concludes by discussing challenges for universities and in particular for the fields of telecommunications and information systems.

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1. Introduction

Creating a more sustainable world through reducing carbon emissions and resource usage in general have become important challenges for governments, firms, and universities. The Intergovernmental Panel on Climate Change (IPCC) focuses on learning curves for alternative energy technologies such as solar, wind, geothermal, and ocean energy and how costs fall as cumulative production increases. It largely ignores the potential impact of continued improvements in smart phones, telecommunication systems, and other forms of IT (information technology) on the better design of transportation, logistics, office, and home systems. Implicit in their report is that sustainability is a substitution rather than a design problem and thus the goal is to stimulate the production of new energy technologies in order for their costs to fall, even though the rates of improvement for these technologies are very slow. For example, according to the IPCC, the annual rate of cost reduction for wind turbines has been 2% per year over the last 30 years and the rate has dropped to zero in the last few years (IPCC, 2013). Even for solar cells, the rate of improvement is about 7% per year when the cost is for installed solar as

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http://dx.doi.org/10.1016/j.telpol.2015.07.007
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Table 1
Information Technologies with recent rapid rates of improvement.
Sources: Wikipedia (2014); Preil (2012); Suzuki (2010); Miller (2012); Chader, Weiland, and Humayun (2009); Stasiak, Richards, and Angelos (2009); Hasegawa and Takeya (2009); Franklin (2013); Fujimaki (2012); Devoret and Schoeldopf (2013); Evans et al. (2011); Nordhaus (2007); Koomey et al. (2011); D-Wave (2013); SingularityHub.com (2013); ICKnowledge (2009); ISSCC (2013); Francis (2011); Yoon (2010); Brown (2011); ISSCC (2013); Azevedo, Morgan, and Morgan (2009); Haitz and Tsao (2011); Lee (2005; Sheats et al. (1996); Martinson (2007); Economist (2012); Kwak (2010).

Technology domain	Sub-technology	Dimensions of measure	Time period	Rate per year (%)
Integrated circuits (or related) for processing	Microprocessor	Number of transistors/ chip	1971–2011	38
	Camera chips	Pixels per dollar	1983–2013	49
		Light sensitivity	1986–2008	18
	Power ICs	Current density	1993–2012	16
	MEMS: Artificial eye	Number of electrodes	2002–2013	46
	MEMS: inkjet printers	Drops per second	1985–2009	61
	Organic transistors	Mobility	1982–2006	109
	Single walled carbon nanotube transistors	1/Purity (% metallic)	1999–2011	32
		Density	2006–2011	357
	Superconducting Josephson junction-based transistors	1/Clock period	1990–2010	20
		1/Bit energy	1990–2010	20
		Qubit lifetimes	1999–2012	142
		Bits per Qubit lifetime	2005–2013	137
	Photonics	Data Capacity per chip	1983–2011	39
Electronic products	Digital computers	Instructions per unit time	1979–2009	36
		Instructions per time-cost	1979–2009	52
	Quantum computers	Number of Qubits	2002–2012	107
Information storage	Dynamic RAM	Memory bits per chip	1971–2010	44
	Flash memory	Storage capacity	2001–2013	47
	Resistive RAM		2006–2013	272
	Ferroelectric RAM		2001–2009	38
	Magneto RAM		2002–2011	58
	Phase change RAM		2004–2012	63
	Magnetic Storage	Recording density of disks	1991–2011	56
		Recording density of tape	1993–2011	32
		Cost per bit of disks	1956–2007	33
Information trans-mission	Last mile wireline	Bits per second	1982–2010	48.7
	Wireless, cellular	Bits per second	1996–2013	79.1
	Wireless, WLAN		1995–2010	58.4
	Wireless, 1 m		1996–2008	77.8
Electronic Lighting and Displays	Light emitting diodes (LEDs)	Luminosity per Watt, red	1965–2008	17
		Lumens per Dollar, white	2000–2010	41
	Organic LEDs	Luminosity/Watt, green	1987–2005	29
	GaAs Lasers	Power density	1987–2007	30
		Cost per Watt	1987–2007	31
	Liquid Crystal Displays	Square meters per dollar	2001–2011	11.0
	Quantum Dot Displays	External Efficiency, red	1998–2009	36

Acronyms: RAM (Random access memory) and WLAN (wireless local area network).

opposed to just solar modules (UCS, 2014). Given the higher costs of solar and wind energy than of fossil fuel-based electricity generation, there seems to be long road ahead.

This paper discusses an alternative that is never mentioned by the IPCC, an alternative that may end up having a larger impact on sustainability than do the technologies emphasized by the IPCC. It focuses on smart phones, telecommunication systems and other forms of IT that are experiencing rapid rates of annual improvement and that lead to improvements in higher level systems. For example, as shown in Table 1, microprocessors, memory, cameras, lasers, and new displays have experienced annual rates of improvement of greater than 30% and these improvements have enabled similar magnitude improvements in computer and telecommunication systems. Even software development costs have fallen as open source software has become available; a noteworthy example is the Linux operating system from which the Android operating system was developed. Taking this one step further, improvements in software, computers and telecommunications have enabled improvements in higher level systems such as retail, wholesale, logistics, financial trading, and education (Cortada, 2004, 2005). Theoretically speaking, ICs, lasers, displays, and open source software can be thought of as components (Funk,

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