Assessing the Energy Costs of Computing Devices in Developing Countries

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Abstract

Competition, technological developments, and economies of scale have together brought down the price of a PC to under $500. Projections of even lower prices raise the possibility of bringing the benefits of online access and computing to even remote villages in the developing world. However, PC's consume significant power. While cost of ICT equipment has been a limiting factor in the past (and even now), we argue that the power generation requirements for powering computing devices is a more difficult limiting factor. The resulting energy implications suggest that alternative devices might be more appropriate for developing countries, which trajectory is already underway. The purpose of this paper is to assess such energy requirements and to present energy-conserving options for a variety of computing applications.

1 Introduction

Information and Communication Technology (ICT) is a relatively recent entrant to the suite of tools and approaches to development promoted by academics, activists and governments. Under the rubric of closing the "digital divide[1]," ICTs are promoted as an important tool to help developing countries accelerate the pace of development. Several examples and case studies have been presented to assess this viewpoint, see for example [4, 5] and the new online Journal of Information Systems in Developing Countries[2]. The vast majority of papers in this area review experiences from particular projects or study social implications.

[1] The term "digital divide" ironically appears to be first used in the context of developed countries, and is often attributed to reporters covering the impact of the world wide web. Indeed, there is some debate about the origins of the term itself [1]

[2] http://www.ejisdc.org/

In this paper, we take up what we believe is a neglected issue: rationales for selecting among the various technologies available to build the ICT infrastructure. There is little discussion of exactly which technologies ought to be considered and rarely is there a critical appraisal. Understandably, development programs are keen to minimize the cost of technology and with declining costs, the desktop PC appears to be an obvious choice for the end-user. However, the development community must also be aware of the energy implications of such a choice, the focus of this paper.

We first discuss accessibility of the Internet to a general user, with numbers being taken from the Indian experience. While costs of ICT equipment have been limiting, we next discuss why power generation limitations will be the next challenging problem unless this is systematically addressed. We present some simple calculations outlining power consumption in a desktop PC and, for a systemic comparison, compare energy consumption of online access of a newspaper with that of a conventional print version of the newspaper. We then examine trends in low-power computing and identify open research issues. Our conclusion is twofold: (1) economies of scale and newer designs can and have helped reduce the cost of computing devices such as PC's but unless low-power devices (consuming an order of magnitude lower power) also become widely available and used, it will be difficult to power these devices in developing countries. (2) the energy-efficient design of large information systems, appropriate for e-governance, is little understood today.

2 Making the Internet Accessible

It is said that at Rs 700 (approx $17.50 at Rs 40/$) total monthly cost (leasing cost of computing device and telecommunication costs), Internet will become accessible to at least 100M urban users in India and the Internet can become qualitatively different and introduce newer models of social interaction. Some attempts are being made to get to this cost by a public utility model and the next few years will be interesting to watch how this would be achieved. As of now, the leasing model has not taken hold and Internet expansion is primarily limited by the rate of purchase of PCs (about 1.5M to 2M per year), a costlier capital proposition for the majority of the population as computers are still expensive: a low end system being approx Rs 20,000 and the per capita income in India being around Rs 25,000 per annum, with the median income for a family (of 4) being close to Rs 50,000.

Note that before the deregulation of the Internet in 1998, Internet expansion was limited by high ISP costs (high license fees on ISPs that were passed onto the consumer). An alternate device, the cellular phone, seems likely to be the agent for penetration of Internet. Cellular phones have started to make a penetration in the country (esp in towns and cities) as they have become increasingly affordable and Internet that rides on it will become most likely the face of the Internet in India in large parts of India. In the near future, it will be the first device for access to the Internet for a large number of users. According to a recent report in the Hindu newspaper (Feb'06), there will be 250M cellular phone users by '07 with 1.75M added every month. Economics is the principal mover here. A basic GSM phone chipset is only about $5 (Rs 225) while it sells for approx $40 (Rs 1800). Currently, using the Internet through cellular phones is still the exception as it is costlier per minute of airtime but the economics in the future is likely to be compelling.

2.1 Cost of PC as one bottleneck for Internet expansion

For a typical Indian family, discretionary or entertainment costs of not more than around Rs 500 per month is just about manageable; cell phones are therefore just about becoming affordable. With respect to the Internet, current costs are still too high to be affordable: till recently, the cost of a PC has been around Rs 20,000 (at an average of approx Rs 200 per month if taken on loan) and Internet costs would be approx Rs 300 per month (assuming just one hour of use at Rs 10 per hour). Given that voice communication (and hence, cell phone) is a priority, Internet would not be so much of a need. Hence, only families that have an annual income of more than Rs 100,000 can afford the Internet (currently only 2-3% of population). There are currently only about 14 computers available for every 1,000 people, a good number of these being in the non-household market with about 4-5M PCs being bought per year. If PCs are to be truly affordable by a substantial part of the population, we need to bring the cost of PCs and the Internet about 2-4 times lower, either in its current architectural form or in new ways.

Given the considerable pockets of populations that do not have either the access or purchasing power in the current models of ICT, a significant exercise in redesigning the delivery of ICT has begun to happen. Some of the cost reducing approaches are:

- The use of free software, such as GNU/Linux operating system, applications such as OpenOffice (suitably localized), to reduce software costs. The OLPC project has developed a children's laptop for about Rs 8000 using such software.
- The design of thin clients that is closer to Rs 4000-5000 per seat. Thin clients are access devices without disk storage but with processing and network capabilities; such a design simplifies management and also cuts down the costs, as storage is difficult to manage and accounts for about 25% of the cost of a PC. Without a monitor, the cost can be low: Novatium has introduced a thin client for Rs 2000 and Rs 400 per month for software services with a TV as the display.

The cost of devices to access services may also be not a barrier with innovative services such as the GSM phone service through a village postman. With BSNL recently providing 256kbps circuits at Rs 250 per month, it is possible that designs based on sharing of bandwidth will be affordable. Hence, a systematic study of shared infrastructure may be a more suitable model rather than owned devices. Since current processors are much more powerful than needed for simple tasks like e-mail, a PC with multiple independent displays can be designed for the kiosk market; the cost per seat will be significantly lower. Another low cost non-PC solution is the use of cell phones and using USB devices for external keyboard and display. Currently, such a solution is expensive for accessing the Internet, especially for high usage, but this may change soon.

We next discuss the costs of a family owning a PC.

2.2 Economic costs of owning a PC

Reliable, attractively packaged desktop PC's are now available for under $500, a price that often compels large scale purchases in schools, government offices and, as development projects show, even rural areas in developing countries. However, this price is a little misleading. An assessment of the "Total Cost of Ownership" (TCO) [7] reveals that, in an office setting, the hardware cost is often as small as 21% of the total cost. Developing countries must also consider the cost of providing the communications infrastructure that adds to the PC hardware cost.

Consider some revealing numbers for India, based on recent data. A typical cost for a low-end desktop PC is Rs. 20,000 which together with a UPS and associated cables can be conservatively estimated as Rs. 25,000. Assuming an unrealistic five-year cycle of no-repair, this amounts to Rs. 5000/year in PC hardware investment per PC. The capital cost per telephone line is around Rs. 25,000 in rural areas and around Rs 7000 in urban areas[8]. Assuming 30% of the capital costs in maintenance and operation, this amounts to approximately Rs. 8,000 per year in rural areas and Rs 2000 in urban areas. Thus, the cost of simply obtaining and maintaining the hardware is at least Rs. 13,000 ($325) per year in rural areas and Rs 7000 ($175) in urban areas, and does not include the software and is nowhere near the total cost of ownership. Assuming even a conservative TCO rate of 200% (as opposed to the 400% cited in [7], the total annualized cost of providing Internet access via a desktop PC is Rs. 26,000 ($650) in rural areas and Rs 14,000 ($350). Given that the Indian government is providing subsidies for the rural telephone lines to the providers of the telephone services, the rural consumer costs are around the same costs as for the urban consumer. Hence the consumer costs is around Rs 15,000 which is one-third of the median annual family income in India. However, such costs have been declining for the past decade and we can expect further reductions so that 100M users (around 10% of the population) will be able to access the Internet.

Note that we have not ascribed all the required costs to anyone. Part of the cost would be borne by individuals in the case of private access. However, for a government agency setting up Internet access in a village, the entire cost would be borne by the government. However, generating power for 100M users is non-trivial unless computing devices use much lower levels of power. With this background let us next consider energy consumption and its corollary, power generation.

2.3 Energy consumption of a PC

Energy is at a premium in developing countries. Energy that is saved can reduce costs, allowing expenditures on other priorities. Furthermore, lower energy usage also results in less pollution (and less global warming) and less dependence on energy-producing countries. However, power availability constraints are an important aspect that has not received attention. It has proved to be sufficiently problematic how to power the devices needed for the Internet in many developing countries. Many villages in India have power only for a few hours. Starting new power plants is expensive and they may also have negative effects such as pollution and global warming. The grids in many parts of the world are likely to be overloaded with the introduction of additional devices needed for Internet services.

The cost of setting up additional electric power capacity in India is currently Rs. 40M per megawatt (MW). For every 120W needed for a PC (a conservative estimate), an investment of Rs 4800 is required; essentially a tax of Rs 480-960 per annum (assuming interest and maintenance costs are between 10% to 20%) that has to be paid by society. The cost of electricity is estimated at Rs 4 per unit (KWh). A PC that is used about 40 hours/week consumes 250 units over a year, resulting in a cost of Rs 1125. Including the cost of capital, this is approx Rs 1800 per year. (We assume that there are no cooling costs.) This comes to Rs 150 per month, a not insubstantial amount given that average discretionary income is only Rs 500 per month.

By estimating the power consumption required for a PC with online access, we can derive a per-PC energy cost. We use the detailed estimates provided in a recent U.S. government sponsored report [6]. A PC consumes anywhere between 70W and 150W, inclusive of processor, memory, CD/DVD drives and network card. A printer averages 50W when powered on (partially in active use and partially in sleep mode). Furthermore, CRT displays average about 90W while LCD displays average 45W. These figures do not include the energy cost of cooling, the consumption of power supplies, and the energy cost of large servers used in support of PC's, which can be larger than 250W per server.

Using the conservative figure of 120W per PC, and the above capital costs of $0.715 per Watt, results in a capital cost of $85.8 per PC. The cost of producing electricity is estimated at $0.04 per kW-hour [2] A PC that is used about 20 hours/week consumes 124.8 kW-hours over a year, resulting in a relatively modest cost of around $5. While this cost seems to be manageable, the bottleneck is the capital required to support, say, 100 million PCs (with 1 PC per 4 families) which would be close to $8.6 billion. With the current steep rise in the cost of oil, the above costs will all increase. Hence, there is a critical need to reduce the power consumption of computational devices so that the investment required for powering the devices is not the bottleneck.

There are many new approaches that are being investigated. For example, to power wireless networks, miniwindmills 10cm across using piezoelectric effect have been proposed. Similarly, some attempts to power computer devices have been to incorporate a crank in the device itself such in the OLPC project.

The Green Wifi project has attempted to use solar devices to power rural Wifi networks.

In India, there is also one another attractive approach. A biofuels program that uses certain inedible seeds (such as honge, neem) for production of locally generated power can be part of an integrated program for the delivery of Internet services. A project at Indian Institute of Science (Bangalore), SUTRA (Sustainable Transformation of Rural Areas), has been able to energize tens of villages in Adilabad (AP) through locally generated power using honge and the implications of such a model for delivery of Internet services are intriguing.

Finally, NEC [6] estimates that the manufacturing of a single PC requires 120-300 kW-hours of energy, and results in 128 kg of CO_2-equivalent environmental products.

If Internet is to become widespread in a resource constrained economy such as India, many social/technical solutions have to be analyzed for being socially and environmentally benign. For example, the current PC as the vehicle of Internet use needs to be reevaluated, as it is not currently power efficient.

2.4 An example analysis: online newspapers vs. print editions

To see the need for alternate mechanisms, we consider online newspapers vs. print editions to evaluate societal cost of information dispersal through traditional paper based mechanisms and digital/computer mechanisms. First, let us consider the use of PC's for reading online newspapers. While intuition suggests that web-browsed news is far superior to carrying the costs of printing and distributing newspapers, some simple calculations reveal a more complex story. Of course, the actual value of online browsing to the user may be higher with additional information provided conveniently through links.

We estimate the energy costs of delivering news through the traditional print media as follows, using figures from the *The Hindu* group of newspapers in India [3]:

- *Energy cost of paper.* The energy costs of making newsprint paper are estimated [3] to be 10 GJ/tonne. Thus, using 8 newspapers/kg, we obtain 0.375 kWh per newspaper[3]. For comparison with reading screenfuls, we will estimate the cost per A4-sheet-sized paper. Assuming 20 pages per newspaper, and 3.5 A4 pages per newspaper sheet, we see that a single A4 sheet-equivalent requires 2.75 Wh for the production of the paper itself (without printing).
- *Printing.* The *Hindu* group in Bangalore, India, cites an energy consumption figure of 300 kWh per day for printing 75,000 newspapers. This amounts to approximately 0.06 Wh per A4 sheet[4].
- *Distribution.* We use the figure of 2 million Joules per tonne-km for road transportation, which is approximately equivalent to 0.55kWh per tonne-km.

[3] 10 GJ/tonne = approx 3kWh/kg = 0.375 kWh per newspaper (8 newspapers/kg)

[4] Assuming 20 pages per newspaper, and 3.5 A4 pages per newspaper sheet

Assuming 200 km of travel for distributing the paper, we get 0.025 tonne-km per A4 sheet[5]. Thus, the transportation energy spent per A4 sheet is 0.35Wh[6].

Thus, adding the three energy costs of paper-production, printing and transportation gives us a total energy cost of approximately 3.2 Wh per page.

Next, let us consider online browsing of the same newspaper: Using the 80 W power consumption (a conservative estimate) for an online PC and an average of five minutes of reading per page results in 6.7 Wh per page. This is already twice the per-page energy cost of the print version. The PC browsing energy cost above is actually underestimated because the 80 W power consumption is an average. Nor have we done a complete life-cycle analysis for the PC as we have done for the a print newspaper. Note also that newspapers are extensively recycled in India and also used to wrap goods; hence, its ecological impact could be considered mild when compared to the toxic waste produced in non-recyclable electronics.

By way of contrast, consider the energy consumption of small devices such as cellphones, that operate at 1 Watt or below[7]. Even assuming twice the reading time per page, this results in 0.16 Wh per page. With this contrast in mind, let us consider options for low power computing appropriate for developing countries.

3 Low Power Solutions

Low-power computing devices include PDA's and cellphones. Many such devices now come with USB interfaces that allow a keyboard to be attached. However, it may be difficult to convince the staff of a government office to sit in front of small PDA's and use those as the primary means of electronic paperwork.

Let us consider the possibility of using laptops instead of desktop PC's. The higher price tag of laptops (slightly over twice the cost) is usually a deterrent, along with a perceived shorter lifespan and lower resilience. However, let us examine the energy saved using laptops. In India, the price difference is about Rs. 10,000 ($238). First, laptops consume power in the range of 15-20 W, a significantly lower number than the lowest of desktop PC's (60-80 W). Thus, with a difference of 60 W, the savings in energy are approximately $54[8]. The laptop also results in a hardware cost savings of $72 per UPS. Thus, the price difference is not as large as it may first appear.

The price difference notwithstanding, one real impact is in the capital cost of power generation: $0.715 per Watt, and therefore, $42.9 saved per laptop

[5] 8 newspapers per kg, or 0.125kg/newspaper is equivalent to 0.025 A4 sheets, as described above

[6] 0.025 times 0.55 kWh/40 = 0.35 Wh

[7] Example: Nokia Communicator 6110 in 2000 required 1 Watt.

[8] 60 W at 8 hours/day for 300 workdays = 144 kWh/year, or 576 kWh over a four-year replacement cycle. At a cost of $0.095 per kWh, this results in savings of approximately $54.

substituted for a desktop. Furthermore, in many developing countries with hot climates, we must account for the cost of cooling. A standard two-ton air-conditioner that could be used for 40 office PC's consumes 7 kWh at a cost of approximately $800. Assuming 30% in overhead and maintenance and usage (thus, $267/year) for 2400 hours results in a cost of $1,863 per year[9]. Therefore, substituting laptops that use roughly a fourth of desktop power, will result in saving $1,397 or $140 per laptop substitution[10].

Accounting for these four factors, results in a total savings of $308 per laptop substitution[11], which easily overwhelms the initial price difference. Through bulk negotiation and opting for power-efficient models, governments of developing countries can further reduce the price difference.

4 Summary

In this paper, we have examined some of the hidden costs in the deployment of desktop PC's as part of IT infrastructures for developing countries. The analysis shows that the added cost of power generation is a significant factor that must be considered in the overall cost. We also showed that the simple substitution of a seemingly more expensive hardware (laptops) in office settings can result in overall savings. The use of even lower power devices such as PDA's or handheld computers can further increase energy savings.

The design of optimal IT solutions is in general a challenging problem, even for OECD countries. In developing countries, it is all the more challenging. This is clearly an area that begs further investigation and research.

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[9] 2400 x 7 kW hours = 16,800 kWh = $1,596 (at $0.095 per kWh). Add to this the maintenance cost of $267.

[10] $1,397 saved over 40 laptops = $35/laptop = $140 over the four year cycle.

[11] $54 for laptop energy consumption, $72 per UPS, $42 in power infrastructure and $140 for cooling.