

Greener ICT: Feasibility of Successful Technologies from Energy Sector

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Abstract— Advances in Information and Communication Technologies (ICT) over the past few years have shown an exponential growth in technology and global presence. Hence, there is a need for solutions to optimize energy consumption in the ICT sector. Such solutions are collectively referred to as Green ICT. New technologies are perennially coming up, and hence a comprehensive research and analysis on the feasibility and effectiveness of the existing measures to control the carbon footprint of these new technologies is quintessential.

In this paper, an overview of the existing strategies and policy recommendations is presented, but the principal focus is laid upon the analysis of successful eco-friendly methodologies such as Waste Heat Recovery, Smart Grids etc., that are implemented in the energy sector; and their effectiveness and feasibility in the ICT realm is discussed. Finally a comprehensive overview is presented on the overall best practices and strategies that could help the ICT sector towards technological and economic advancements.

Keywords— Green ICT, Emissions, Energy, Efficiency, Environment, Carbon Footprint

I. INTRODUCTION

Concern regarding Global Warming and its appalling impact on earth's climate is increasing by the day. The carbon emissions of the United States alone account for over 6 billion tons as of today, and analysts say that, if the current trends continue, the figure might go up to 6.4 billion tons by 2020 [13]. The temperatures have already raised 1.40F since the 20th century [3]. Needless to say, if this is allowed to happen, the climate of the planet will be fundamentally altered, and the resulting climate change is likely to have a major impact on the ecosystems and economies of the world, more so on the poor and developing nations [15]. In fact, based on the IPCC and Hadley Center analysis, the Stern Review suggests that, the developed countries alone need to reduce their emissions by 20-40% below the 1990 levels ([12], [16]). Hence, there is a pressing need to cut down the carbon emissions, use energy efficient methods and manage the resources intelligently and efficiently. Given that, there is a considerable research going on regarding reducing the carbon footprint [17], and analysis shows that the field of Green ICT could be a major player in doing the same. Therefore, it is essential to know how energy could be efficiently managed in the ICT sector. In this paper the current status of the field of Green ICT is presented, and an analysis of some of the best practices from the Energy

Sector is done, and their feasibility in the greening of the ICT sector is discussed.

II. WHAT IS GREEN ICT

Green or eco-sustainability is *"the ability of one or more entities, either individually or collectively, to exist and thrive (either unchanged or in evolved forms) for lengthy timeframes, in such a manner that the existence and flourishing of other collectivities of entities is permitted at related levels and in related systems"* [18]. ICT (Information and Communication Technologies) mainly includes PCs, telecommunication equipment, printers and data centers. Thus defined, Green ICT can include not only the hardware technologies but also the systems, software, and product lifecycle management practices that could help in the energy efficient sustainability of the ICT Sector. Thus, if properly implemented, Green ICT can help cut the product development costs and save significant amount of energy. Also, in the current scenario with more and more people feeling strongly about the environmental causes, and Governments imposing legal restrictions, implementing Green ICT practices can help enhance a company's image, also adhering to the legal standards at the same time.

III. IMPACT OF GREEN ICT

Of late, ICT has been at the forefront of technology advancements and innovation. It is one of the fastest growing sectors of the economy, and is expected to continue to grow at a more rapid rate in the future. These advances in technology come at the price of increased energy consumption and increased carbon footprint. Hence ICT has a significant impact on the production, utilization and disposal of equipment [10]. Analysts say that ICT contributes to approximately 2% of the carbon footprint of the world [4]. Between 2007-2020, the ICT share of carbon emissions in the U.S alone is expected to rise from 2.5% to 2.8%, comprising an annual growth rate of 1.4% [13]. Hence it is apparent that ICT has a huge global presence, which is why the Green-ing of ICT is a very important issue. Studies have shown that as much as 65% of the people are unaware of their energy usage [6]. Therefore it is essential to analyze what percentage of ICT actually contributes to the productivity. Once this is figured out, we can then analyze

ways of Green-ing the ICT sector more effectively. The global footprint of the ICT sector can be better understood from Figure 1.

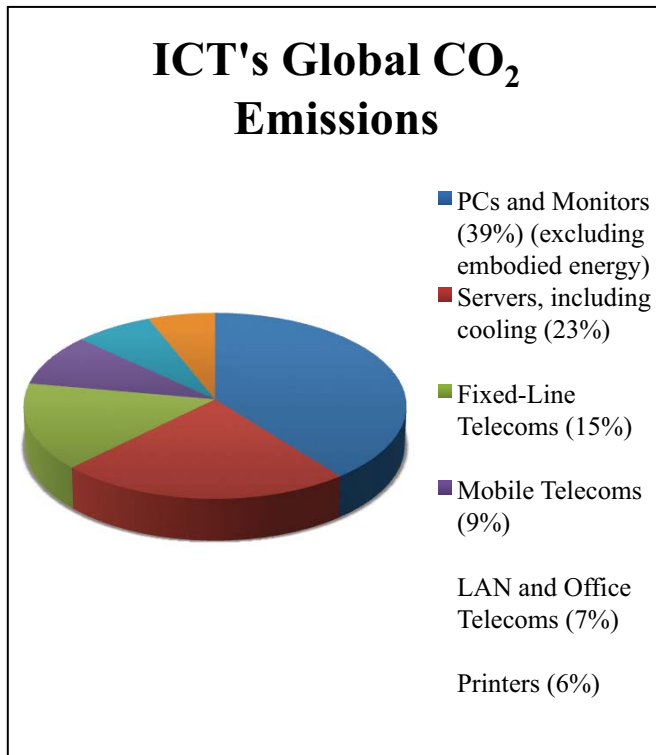


Figure 1. ICT's Carbon Footprint [4]

IV. MAJOR CAUSES OF CARBON FOOTPRINT IN ICT

In general, the carbon footprint of the ICT sector can be measured in terms of electricity usage, paper and printing costs, equipment recycling and disposal costs. Amongst other things, data centers, personal computers, e-waste, telecommunication infrastructure and printing contribute significantly to the carbon footprint of the ICT industry. Other minor contributors include bad decisions in life cycle management and original equipment manufacture, HVAC (Heating, Ventilation and Air Conditioning), UPS (Uninterrupted Power Supply) etc.

A. Personal Computers:

Personal computing is the main factor of ICT footprint in homes, universities and offices. According to analysts, "a typical PC and monitor ensemble contains around 20kg of materials, and generates 66kg of waste and 1,096kg of CO₂ during its lifetime" [11]. Also, the number of personal computers is ever increasing; it is expected to increase from 592 million in 2002 to more than 4 billion in 2020 [12].

B. Telecommunication Infrastructure:

Mobile phones, chargers, IPTV boxes and broadband routers contribute to the telecommunications infrastructure. According to analysts, the global footprint of the telecom devices was 18 MtCO₂e in 2002, and is expected to increase to

51MtCO₂e by 2020. Obviously, this is due to the ever-increasing usage of the said devices.

C. Printing:

Research suggests that a considerable amount of printing is easily avoidable, and efficient document management and sharing systems aid to a large extent in reducing the ICT footprint due to printing. It is quite disturbing to know that leaving a copier switched on overnight uses as much power as it takes to make 1500 copies [14]. Factors affecting the environmental impacts of the imaging equipment in use, and the best & worst case environmental impacts from printing are given in [11].

D. e-Waste:

As mentioned earlier, the ICT sector is at the forefront of innovation in the current global scenario. As a result of rapid innovation and fast changing technological trends, products are quickly becoming obsolete. Due to this, a large chunk of waste is resulting from this electronic equipment. This electronic waste, or e-Waste, contributes significantly to the carbon footprint of ICT.

E. The Advent of Cloud Computing & Data Centers:

With the growing use of Internet media, online learning, cloud computing etc, the demand for data center capacity is rising rapidly. The year 2010 has been cited by the ICT industry as the 'Year of the Cloud' [8]. In cloud based computing, data is delivered to your device in real time from the Internet. The storage of data on the cloud is realized through data centers. The construction and maintenance of data centers requires significant amounts of energy. In 2002, the global data center footprint was 76MtCO₂e and this is expected to more than triple to 259MtCO₂e by 2020, making data centers the fastest growing contributor of ICT's carbon footprint [12]. A more detailed comparison of significant data centers can be found in [8]. The two major factors that impact the energy utilization of the data centers are energy consumption and load. Analysis shows that Germany's data centers alone consume over 10TWh of power a year, and it is expected that by 2013, it might increase by nearly half unless measures are taken to improve energy efficiency in data centers [14]. A more detailed study of data center energy efficiency scenarios, and the efficiency scenarios of data center energy crisis can be found in [11], and an analysis on why we need to care for data center energy efficiency is given in [4].

V. HOW GREEN ICT CAN REDUCE ICT SECTOR'S CARBON FOOTPRINT

It is evident that the ICT sector has a significant carbon footprint. Much research is going on about ways and means of Green-ing the ICT sector, but we must understand that it is still in nascent stages, at least as far as implementation is concerned.

A. Energy Efficient Options in Telecommunications Networks, Data Centers and Printing:

The running of a telecommunications network requires a significant amount of energy. The telecommunication service

providers can work with OEMs to increase energy efficiency of the network equipment. The energy utilization in data centers can be significantly managed by the consolidation of fragmented legacy data centers as discussed in [14]. Techniques like virtualization make it possible to shut down idle servers, thereby cutting operational costs. More energy efficient and smarter cooling mechanisms could be implemented. In January 2010, when Facebook decided to go with a coal powered data center in Oregon, the decision invited a lot of criticism. The chief reason for this was the argument that more eco-friendly options were available. The data centers can be migrated to places where renewable sources of energy are readily available, or to places whose geographical topology helps facilitate more efficient cooling of the data centers, and changing the layout of the data centers would also help. For example, Yahoo! has a data center outside Buffalo, NY, that is powered by a hydroelectric power plant [8]. The footprint of the printing and imaging devices is reduced by making the equipment as energy efficient as possible, and by making use of effective print management techniques.

B. Reuse and Recycle:

Research shows that the manufacture of a PC may generate up to 4 times the carbon footprint of its lifetime use [1]. So it is always better to tweak the existing equipment rather than opting for new equipment. OEMs (Original Equipment Manufacturers) must also analyze the amount of resources and energy consumed by a product, or, in other words, take the entire product life cycle into consideration in order to assess the ecological profile of the product. A detailed schematic of the lifecycle of ICT can be found in [10]. Recycling must be implemented wherever possible, even in manufacturing. Also, one might consider the recycle feasibility of the product packaging. Needless to say, significant energy and financial gains can be obtained by choosing the right ICT equipment and making use of it in an energy efficient manner. Users can make these decisions intelligently if they are aware of the ecological impact of the ICT equipment they use.

C. Energy Efficient Equipment Manufacture and Usage:

It is necessary to emphasize the issue of climate change hazard to reduce emissions from ICT equipment manufacture. In the manufacture of the ICT equipment, reducing water and solid waste generation, using biodegradable, recyclable non-toxic materials, and usage of new materials and alloys that are more energy efficient is a step towards greener ICT. Also mercury free screen technologies could be used, and the equipment could be made power efficient at every level – from processor to the operating system. Power consumption and energy efficiency could be included in the design stage of the equipment so as to achieve greener ICT.

D. Dematerialization:

Dematerialization basically means substituting the products or activities that have a higher carbon footprint with the ones that have a lower carbon footprint. For example, face-to-face meetings can be done via video and tele-conferencing, which significantly reduces the carbon footprint due to commute. Or eBilling can be substituted for paper billing. Dematerialization

is possible through the implementation of Green ICT practices. A more detailed impact of dematerialization, and its use in ICT to reduce the carbon footprint can be found in [12].

E. Renewable Energy Sources:

The ICT sector uses a significant amount of energy for the maintenance of data centers, usage of computers, etc. The ICT sector can significantly reduce its carbon footprint by purchasing green energy from the grid ([2], [19], [24]). This approach is more so useful for the developing nations. For example, in Ghana, the telecommunication services offered to people in rural areas are powered by renewable energy [2]. A comprehensive analysis on the feasibility of renewable energy sources in ICT sector is discussed in [18].

VI. STRATEGIES AND POLICY RECOMMENDATIONS ICT SHOULD SUPPORT

The ICT sector cannot act in isolation if it is to effectively reduce its carbon footprint. It must work with the Government and policy makers to raise awareness amongst the OEM and the common people about ways to effectively reduce the carbon footprint of ICT. Focus should be on the longer-term green ICT strategies. Developing a common standard for the ICT sector's emissions might be a first step towards this.

Energy conservation, modernizing the energy infrastructure, and maximizing the energy supplied without malicious environmental impact are already some of the key objectives of the current US National Energy Policy Report. There are also several EU initiatives (e.g. [5]) that promote cleaner ICT practices; like The EU Ad-Hoc Advisory Group for Energy Efficiency, The ICT Policy Support Program of the EU Commission's Competitiveness and Innovation Framework Program, The EU Commission ICT21EE Project, The Sustainable Energy Europe Campaign etc. A more detailed analysis of the current ICT related policies that are already being implemented in universities and colleges, and the policy recommendations for Funding Councils, JISC and other sector bodies could be found in [11].

Although there are these, and some more policies under implementation currently, like the National Greenhouse and Energy Reporting Act of 2007, along with standards like the energy star, EPEAT Gold etc, these policies and standards do not take into consideration the ICT life cycle as a whole. Hence more targeted policies are needed. For example, smart grids could be implemented such that in the grid, renewable and energy efficient sources are the primary suppliers. The Government could collaborate to a larger extent with organizations in setting up energy efficient infrastructure for ICT, and also to bring about more awareness regarding the green ICT practices such as the benefits of intelligent manufacturing techniques, dematerialization etc. Energy efficient equipment usage must be emphasized, and Government incentives might be given for the same. Also, monetizing carbon emissions effectively on a global standard could be an idea. There are several non-governmental organizations that proposed much more targeted policy

recommendations on various selected issues in specific (e.g. [2], [5], [8], [11], [12], [16]).

However, for the strategies and policies to be especially tailored to optimize the energy efficiency in ICT sector, further research is needed, and also, the change should be brought about in various cross functional sectors, like design, manufacturing, material usage, and also the mindset of the end user.

VII. MAJOR CHALLENGES FACED BY THE ICT SECTOR IN IMPLEMENTING ECO-SUSTAINABLE METHODS

Despite considerable ongoing research about the Green-ing of the ICT sector, there are still a considerable number of policy, market and behavioral hurdles preventing the ICT sector from making further efficiency gain. There is a plethora of challenges regarding design, manufacturing, availability of technical alternatives, fragmentation of the markets, etc.

One of the major problems is that there is a limited maturity of technical knowledge and lack of interoperability amongst the diverse fields involving ICT. Moreover, there isn't any accurate information about the emissions of the ICT industry and the actual percentage of productivity of the ICT industry, so OEMs and service providers do not know the energy consumption of specific services or products. There are also certain operational and behavioral challenges that need to be overcome. Studies show that not everyone using the ICT equipment is aware of the equipment's energy efficiency and ways to increase this energy efficiency. For example, the person in charge of buying the equipment would only look for the price factor, but may not take into account the operational costs or energy effectiveness of the equipment. So this lack of awareness must effectively be tackled.

Also, currently, there are no unified emission norms, energy consumption standards or global policies to measure the carbon footprint of ICT industry and maximize its energy gain. Extensive research alone is not enough to overcome these hurdles. There must also be effective implementation of the techniques suggested by the research, in addition to changes in the outlook and behavior of the end user.

VIII. ENERGY SECTOR: BEST PRACTICES

Energy sector has been one of the foremost sectors to embrace Green Technology and emission reduction in order to abide by the stringent rules laid on pollution control. It is noteworthy that the aviation and energy industries conducted studies on environmental impacts decades ago. Initial implementations in aviation industry like 'NOx' tuning were later adopted in energy sector to reduce emissions of power production units based on fossil fuels. Recent trends of alternative energy, sustainable energy and waste heat recovery are steps towards a greener emission free environment. Hence in this section an analysis of the best practices from the Energy Sector is done, and their feasibility in ICT sector is discussed.

A. Waste Heat Recovery

A typical gas engine power generation set has about 36% of the total intake energy being converted to electrical energy. About 49.5% of the thermal energy generated would otherwise be wasted. A large quantity of this waste heat can be recovered from the flue gases, water-cooling jackets, lubricating fluid, and inlet air coolers. Organic Rankine engines implement the Rankine cycle with organic liquid instead of water as working fluid. Organic fluids have lower boiling point than water and hence are useful for heat recovery from lower heat sources for power production.

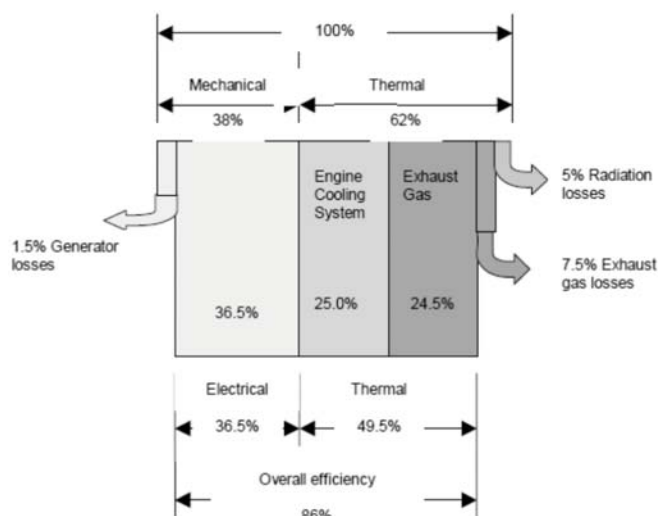


Figure 2. Heat Balance Break Down of a Generic Gas Engine [26]

An energy balance analysis for the gas engine has been shown in Figure 2. It is suggested that an overall efficiency improvement of 3-5% on the efficiency of gas engine set (e.g. [24], [25]). Organic Rankine Engines are retrofit solutions to reuse waste heat energy to produce electric power. Such retrofit waste heat recovery units can be used for extracting heat from large-scale servers and data centers in order to reuse energy.

However, it must be noted that organic fluids are generally volatile in nature hence require establishments that can contain such hazards. Economic and environmental feasibility studies are to be conducted before implementing such energy efficiency improvements.

B. Sustainable Energy for Air Conditioning

Solar energy has been one of the promising sources for sustainable energy. Developments like 'photo voltaic cells' have existed for decades now. However, the efficiency of photo voltaic cells has been quite low, approximately 10%. Hence large surface area and high installation cost were involved in producing viable solutions. Alternate approaches of producing heat energy instead of electric energy were found to be far more efficient. Vast mirrors are constructed to redirect and concentrate solar energy upon a column of water, converting it to superheated steam. The superheated steam thus produced is directly used to run vapor compression cycle of air conditioners. This approach is economically viable and being utilized by the industries [26].

C. Small Scale Low Speed Wind Energy Harvesting

A host of companies like Suzlon, Vestas, Honeywell etc. have started providing low speed wind turbines that can be installed on high-rise buildings for electricity generation. These are available for power production for wind speeds as low as 3km/h to 68km/h. There are various technologies in blade and rotor construction that resulted in attaining the novel designs for low speed wind energy production.



Figure 3. Honeywell Low-Speed Wind Turbine [27]

Studies show that 60% of the available wind sources are of the low speed. Hence the low speed wind turbines are a viable option for alternate energy in various ICT infrastructures. Figure. 3 depicts Honeywell's wind turbine that has been launched especially for the low wind speeds.

D. Smart Grids and Smart Metering

Smart Grids are interactive infrastructure of power distribution networks to improve efficiency as well as the economics of power generation and consumption. Smart grids include a combination of 'scheduling of power usage', 'giving back power to the grid' from domestic power production units like wind turbines, solar energy etc., 'smart metering' for analysis of power utilization and advisory for efficient usage [29].

A smart grid optimizes the routing of power and intelligently handles the power distribution and monitoring. With Smart Grids, one can get real time data from the grid, reduce the distribution losses significantly, and intelligently integrate various power sources like fossil fuels and renewable energy. Smart grids are in fact more useful in the developing nations. For example, in India, analysis [12] shows that electricity generation currently accounts for 57% of the country's total emissions, and is expected to stay the same till 2020. India's power network is highly inefficient and much of the generated power is wasted. It is estimated that in 2007 alone, India lost 32% of its total generated power [23]. Smart grids are beneficial in situations like these. A detailed summary of the impact of smart grids on ICT can be found in ([11] - [13]).

Figure. 4 describes a split-up of power usage as depicted by "Google Power Meter". Such analysis can help the consumer understand the major sources of his power consumption. There are also products like Microsoft Hohm [21], which can be used for smart metering at homes. Another such facility is

priceXtra [20], created by UK CEED, which allows purchasers to compare the environmental impact of certain products including computers.

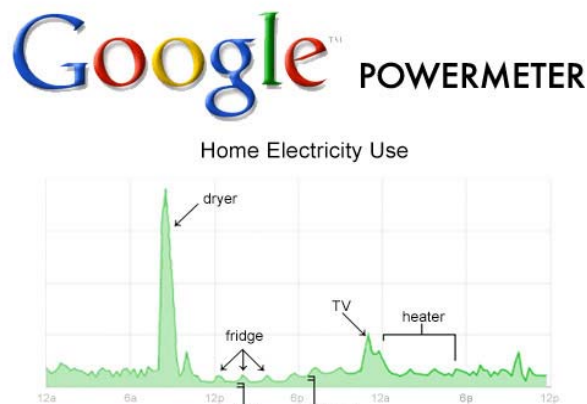


Figure 4. Google's Power Meter [28]

Implementation of alternate energy sources like small scale wind energy, waste heat recovery, solar energy sources shall equip the ICT firms to adapt to Smart Grids at a higher pace and avail the benefits associated. Also, the tasks in ICT firms can be scheduled to utilize power in off-peak times. This is already successfully implemented in companies like T-mobile [14].

IX. CONCLUSION

It is evident that, as sustainable energy and energy efficient methods gained prominence, the green-ing of technology is also gaining considerable attention. It is also evident that the ICT sector contributes significantly to the global carbon footprint. Hence, in order to tackle climate change and reduce the global footprint of the ICT sector, Green ICT practices are quintessential. To maximize energy gains and increase the efficiency, an understanding of the current scenario in the field of Green ICT is needed. Once this awareness is attained, we can implement methods, strategies and policies to help attain the goal, and tweak technology to realize the same.

Currently, the green-ing of the ICT sector faces many challenges right from the stages of design and manufacturing to the stage of efficient energy consumption and usage. Also, the current policies in existence must be better tailored as per the evolving needs and latest technologies in the ICT sector. Since the energy sector is one of the first to implement emission control norms and embrace green technology, it is viable to analyze how the best practices in the energy sector can be tailored to suit the ICT sector.

Hence, in the current paper an overview of Green ICT is presented, and an analysis of the feasibility of some of the best practices from the energy sector to the field of ICT is done. Nonetheless, considerable further research is needed to

efficiently implement the idea of Green ICT, in order to handle the impending energy crisis.

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