EMERGING TRENDS FOR ENERGY CONSUMPTION WITHIN ICT DEVICES

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Abstract - The information and communication technology (ICT) is closely related to the future of global energy consumption, not only because the ICT equipment itself increasingly consumes energy, but also because it is a general-purpose technology, which may affect energy use of almost all sectors. The growing demand for ICT devices and services outpaces the efficiency gains of individual devices. Previous studies had alluded that cumulated potentials for ICT-induced savings is several times larger than the entire energy consumption of ICT itself. More studies on ICT-related energy consumption do exist, and an increasing number of studies looking at ICT induced energy efficiency. The few studies, however, considering both aspects, typically do so independently, without relating the two aspects. Moreover, in the energy efficiency discourse, ICT is usually treated as a monolithic block of technologies – only the application areas that are expected to benefit from it being differentiated. It is only by consequently following low energy consumption targets for technologies with a low energy efficiency potential, while at the same time not suffocating technologies with a high-energy efficiency potential through restrictive consumption targets, this paper will discuss the various emerging trends in energy consumptions within ICT devices.

Keywords: Energy consumption, Green ICT, energy efficiency, ICT devices, emerging Trends,

I. INTRODUCTION

Currently, advancements in Information and communication technology (ICT) plays a significant role in modern society [1]. There has been an increased rapid development and diffusion of ICT, the energy consumption of ICT equipment and services is surging. For instance, the ratio of electricity consumption of ICT equipment and services (e.g., communication networks, computers, and data centers) to global electricity consumption has risen from 3.9% in 2007 to 4.6% in 2012. Especially, some recent developments of ICT involve booming energy demand and potentially hinder the global energy sustainability [2]. For example, cloud computing, as the interaction between telecommunications technology and a data center, transfers massive data between devices and data centers and consumes a large amount of energy. Therefore, it is even warned that the widespread use of ICT equipment would make it one of largest energy-use categories. Given the global target of energy-use control, the relationship between ICT development and sustainable energy consumption is vital for the world's sustainable future.

A generic ICT device can be viewed as a machine that processes information while transforming work into heat and heat into work. Pioneering research developed by John Von Neumann and by Richard Landauer in the last century has shown that information processing is intimately related to energy management [3]. An ICT device is a machine that inputs information and, processes both and outputs information and energy. From this perspective energy dissipation via heat production and energy transformation processes are two aspects of the same topic: energy management at the micro- and nanoscales. For our purposes, energy efficiency is defined as the percentage of energy input to a device consumed in useful work and not wasted as heat [3].

However, there are more emerging trends on previous and recent research on ICT devices energy consumption. There are several strategies used to reduce energy consumption for ICT devices, which is discussed in theory [3]. Given these above theoretical meanings, this paper aims to empirically discuss the emerging trends in ICT devices energy consumption, analysing the different literature both past and recent.

II. PAST AND RECENT TRENDS ON ICT DEVICES ENERGY CONSUMPTION

In the mid-1990s, ICT had been established as a relevant electricity consumer, this led to the explosive diffusion of the Internet around the turn of the millennium led to speculations of an excessive growth of future energy demand of ICT, currently this

consumer demand has highly increased due to new advancements in technology [4]. Previous and resent research studies globally shows that electricity demand of ICT is still growing at a faster rate than expected, but in industrialized countries the growth rates are expected to grow at the rate more than 5 percent a figure that could vary any time. This can only be controlled if relevant authorities in various nations introduces regulations through policy measures. Studies have been done to compare results of three studies in US and Germany by official outlook of the Department of Energy (DoE). The study found out that a fraction of ICT electricity steadily increased in both the residential and commercial sectors until 2010. For the US, the official outlook of the Energy Information Administration (EIA) predicted a stabilization by the year 2020 at about 10% in the residential and the commercial sectors, corresponding to 7% of total electricity demand [4].

In Germany, the fraction of ICT electricity is much higher and an increase to more than 25% in the residential sector and to about 20% in the commercial sector is expected by 2020. This corresponds to 12% of total electricity demand in 2020 [4]. The important difference between the US and Germany is primarily due to a higher electricity consumption per capita in the US: In the year 2000, residential electricity consumption per capita in the US was 2.7 times as high as in Germany. The corresponding factors for the commercial sector and for the total electricity demand are 2.8 and 1.8. This method was not the best way to analyse the power consumption, hence the fraction of ICT electricity is not a good indicator for making comparisons between countries [4].

III.   MODERATE GROWTH OF ICT-RELATED ENERGY CONSUMPTIONS

According to a Gartner Group report of 2007 to 2015, the total energy consumption related to ICT has grown at an alarming rate, and its carbon footprint would become comparable to that of airline transportation at approximately 4 percent of the total emissions of carbon dioxide (CO_2) [5]. Current forecast based on earlier prediction trend is that the share of the energy consumption and CO_2 footprint of data centers has become smaller over the years (18 percent) [6], compared with telecommunications (25 percent) and ICT devices (57 percent). If we assume an average value of 400 g of CO_2 emissions for each electricity kWh (Europe's average is 370 g, whereas it is a third of this value for France due to the importance of nuclear assets), the CO_2 emissions that were predicted previously by Gartner Group report of 2015 was

equivalent to a total electricity consumption of 3270 TWh [7].This paper thus highlights that currently there are more recent research on ICT energy consumptions with analysed data not just estimates as Gartner had suggested previously. Furthermore, there is high potential for further improvement through low cost ICT applications, driven by large corporations [8].

IV.   ICT DEVICES ENERGY CONSUMPTION COMPARISONS

Comparing the total amounts of energy consumption by the industries, domestic use or residential, other related areas like transport sectors, the ICT's energy consumptions does not look so critical until when well Analysed. In the year 2005, approximately 4.5% (120 TWh/a) of the electrical power in EU-27 were consumed by consumer electronics (mainly TVs and HiFis) and 3.5% (97TWh/a) for ICT in a narrower sense (PCs, telephones and the communication infrastructure including data centres) [9]. The 2020 business-as-usual (BAU) projection of the same study predicts that ICT-related energy consumption will rise to over 400 TWh, mainly driven by the expected diffusion of larger-screen TVs, higher-speed broadband access, and higher-capacity data centres. Overall, one could conclude that ICT-related energy consumption is less relevant than the energy demand of other types of technologies, such as industrial machines, non-ICT household appliances (heaters, ovens, fridges), and vehicles [10].

After all, ICT will account for 2.55% of EU-27 total energy demand previous projections has been realised, the demand estimates has superseded by 10%. However, the energy demand of ICT is growing much faster than the total energy demand. Previous estimates of the year 2005 compared to current estimates, current estimates have increased by 15.5%, but the former by 84.3%. For specific sub-sectors, some authors predict even much faster growth. For example, the BAU scenario for data centres in Germany, extrapolated previously that by the year 2020, energy demand would have increased 396% , this estimates has grown to 415% [9] .The idea of an information society, on the other hand, raises hopes for solving the dilemma of sustainable development, which is providing quality of life to all people without overusing the ecosystem. This dilemma can only be solved if society manages to create value with much less material and energy input to realise the target percentage consumption rates and demand. Previous discussions dating decades now showed that, a dematerialization of the economic system by a factor of 4 – 10 is a precondition for sustainability. By Creating an information society, most organisations

makes use of ICTs to provide immaterial services where material goods are now produced, transported and disposed of, thus this has positively impacted on production since ICT is the key to economic dematerialization and sustainability [9].

V.   ENERGY CONSUMPTION OF ICT DEVICES

The concern with ICT's energy consumption being older, there are quite a number of previous and recent studies referring to it. Starting from the per-unit consumption of specific technologies, such studies typically use a bottom-up approach to aggregate consumption. The aggregation can be done along two axes: a technological and a geographic one [11]. Technologically, the aggregation can include all instances of a specific technology (e.g.," corporate data centres"), or the sum of similar technologies – all data centres, for example, as in, or all technologies needed for mobile communication – up to the entirety of ICT. It is obvious that the results are sensitive to definitional issues, i.e. the boundary drawn between technologies included or excluded from the system under study. Geographically, the aggregation can be done at a regional, national, supra national (e.g., EU or OECD), or global level. Studies exist to almost any possible combination alongside these two axes, for example, look at data centres in Europe, Asia, and the US. On the other hand, has a narrower geographical scope (the UK), but a larger technology scope, looking at the entirety of commercial and domestic ICTs [12]. The more comprehensive the aggregation, the larger the insecurities of the estimations also get. Although the per-unit consumption is relatively straightforward and the total number of units sold is usually known from statistical data, assumptions have to be made for the usage patterns of the equipment, the intensity of use (as far as energy consumption depends on it), and the service life of the equipment [13].

Recent studies information indicate varied information not the same as what they consider as being ICT in terms of energy consumption rates. As it is outlined herein, other authors just think that this is a non-trivial conceptual issue, as reflected by [14]. When looking at end-user ICT devices, for example, some studies include printers, others do not. TV sets and set-top boxes are sometimes categorized as ICT devices by some users while some users will as well not prefer them to be put together. For data centres, depending on whether their related cooling and lighting services are considered or not, rather different results can be expected. From the studies considering the entirety of ICT, some take into account only servers and end-user devices, while others includes the communication infrastructure with cable connections and network

nodes, we can attributes this to how well the user wants the term ICT devise defined in the context of functionality [14].

Finally, the studies also differ with respect to the life cycle phases of ICT equipment they cover. While most studies consider only the energy consumption in the use phase, some pursue a life-cycle approach. As we have argued in Hilty and Coroama et al. (2009), as for any other product, life-cycle assessment (LCA) is the most comprehensive method that should be used. The usual focus on the use phase of end-user devices reveals only a part of the energy used to finally provide an information and communication service. A study on ICT-related energy consumption in Danish households, for example, provided the following rule of thumb: "When 1 kWh is consumed in the residence 1 kWh is consumed to manufacture, transport and dispose of the hardware and ½ kWh is consumed to run the Internet and the applied ICT infrastructure outside the residence. Willum et al. (2010), pg. 14 in his study he analysed the production, use and disposal of computers and their peripherals as well as the hardware infrastructure needed at telecommunication providers and data centres [12].

VI.   TECHNOLOGICAL APPROACHES USED TO REDUCE ENERGY CONSUMPTION

There are several approaches that can be used to realise reduced energy consumptions for ICT devices, In meeting such set targets a number of strategies can be applied this includes, The consumption of energy by all ICT devices and systems be reduced and use of sustainable energy and, in particular, renewable energy systems must be increased to power the majority of ICT devices. Below is a list of the approaches used to reduce energy consumption by ICT devices.

A.   High-performance computing systems are the ICT-enabling technology for advanced mathematical modelling and numerical simulations that play a key role in scientific discovery and technological innovation. If we want to foster the realization of the next generation of high-performance computing (HPC), we need to increase energy efficiency of computing. Exascale computers capable of reaching 10 operations per second require a substantial decrease for energy dissipated into heat compared to present standards [15]. There is a significant drive for energy efficiency in computing architectures, both for designing next-generation hardware, from the fundamental devices of information processing to data storage architecture

and communication networks, and for developing software tools and algorithms to increase the efficient use of the hardware.

B.   Smart autonomous sensor systems for the so-called Internet of things (IoT) scenario. IoT foresees that an ever-increasing number of intelligent, mobile, sensing, and communicating devices will be dispersed into ordinary appliances and tools of common use. However, most applications require an IoT device to be miniaturized, energy-efficient, and autonomous so that it is portable and self-sustaining. To achieve this, the amount of energy required by such devices needs to be significantly reduced and conventional power management needs to be replaced with energy-saving devices and other methods to regulate power supply and demand. Emerging autonomous sensors need to maintain ultra-low power (ULP) duty cycles and incorporate an energy-harvesting source, an energy storage device, and electronic circuits for power management, sensing, and communication into sub-cm scale systems.

C.   Chargers and charging of portable ICT devices

The growing pile of unused chargers causes a great amount of unnecessary electronic waste and inconvenience to users. As part of its work on ICT and climate change, the International Telecommunication Union's telecommunication standardization sector (ITU-T) is progressing in the approval process for a technical standard describing an energy-efficient one-charger-fits-all new mobile phone solution. "Universal power adapter and charger solution for mobile terminals and other ICT devices" provides high-level requirements for a universal power adapter and charger solution that will reduce the number of power adapters and chargers to be produced and recycled by widening their application to more devices and increasing their lifetime [16]. This solution also aims to reduce the energy consumption and to increase energy efficiency. The introduction of the new standard is estimated to lead to a 50 per cent reduction in standby energy consumption, an elimination of up to 82,000 tons of redundant chargers, and a subsequent reduction of 13.6 million tons in greenhouse gas emissions each year. Moreover, the use of the power adapter and charging solution is not limited to mobile phones and addresses a great number of ICT devices (Gallagher, 2017).

D.   New energy sources for mobile devices
The constant need to recharge batteries compromises the mobility and autonomy of the devices they power. Aware of this, many manufacturers are involved in the research for advanced or alternative energy sources

that should also be safe, clean and cheap. Promising technologies exist, although a leader has not yet emerged.

Research on mobile power supplies can be generally grouped in three categories:
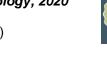
- Application of known alternative power supplies (such as photovoltaics, fuel cells, thermoelectricity, piezoelectricity, (human) movement) to mobile devices;
- Incremental advances to current solutions, mainly in the field of Li-ion batteries;
- Breakthrough developments by applying nanotechnology: cell-sized batteries, nanoscale fuel cells, nanoscale capacitors, electroactive polymers, dielectric elastomers, new semiconductor compounds and the use of organic materials.

E.   Data centres have become a critical ICT infrastructure owing to software as a service, mobile cloud applications, digital media streaming, and the expected growth of IoT. Data centre energy consumption is currently growing at a compound annual rate of over 10%. Power and thermal monitoring and control as well as recovery of waste heat play a key role in reducing consumption and economic costs. However, ever more opportunities exist towards a comprehensive integrated energy management system to enhance the energy and power management of data centres in conjunction with renewable energy generation and integration with their surrounding infrastructure.

Within the second category, an exploratory focus has been laid on photovoltaics and fuel cells. If these technologies could be miniaturized and incorporated into portable electronic devices, they would represent a step forward in extending the autonomy between recharges.

Solar photovoltaics have been used in some applications for about three decades (e.g., in pocket calculators), and recent progress has encouraged some ICT manufacturers to experiment with thin-film solar cell powered portable devices. However, as solar radiation is highly variable, photovoltaics can at best extend battery lifetimes at the current state of development. Other obstacles for mobile use of solar cells include efficiency, size and cost [17].

Nanotechnologies are being spoken of as the driving force behind a new industrial revolution. Both private- and public-sector spending are constantly increasing. Spending on public research has reached levels of well over EUR3 billion world-wide, but private sector

spending is even faster – the private sector has already exceeded the government spending. Nanotechnologies will be a major technological force for change in shaping Allianz's business environment across all industrial sectors in the foreseeable future and are likely to deliver substantial growth opportunities.

Nanotechnology – the branch of engineering that deals with things smaller than 100 nanometers (especially with the manipulation of individual molecules) can be applied to most current technologies with a multitude of benefits, among them miniaturization, flexibility in scaling, and increased energy density for energy storage systems. One field of nanotechnology research is addressing the storage of energy in carbon nanotubes, for instance with the help of electric fields. In addition, the properties of nanomaterials can be beneficial to the development of high-performance Li-ion batteries. Nevertheless, before being ready for use in consumer goods, further research is required to better understand the mechanisms of lithium storage in nanomaterials, and to achieve controlled, large-scale synthesis of nanostructures and kinetic transport on the interface between electrode and electrolyte

An even more recent field of research focuses on cell-sized batteries. These are tiny microbatteries about half the size of a human cell, which might one day power a range of miniature devices by stamping them onto a variety of surfaces. One of the potential benefits of nanotechnology and cell-sized battery technology is that they could open the way for new features and start a new era for mobility [18]. Wireless recharging is an area of research aimed towards address replacing chargers and cables and powering mobile devices on the fly and over distances up to several meters using non-radiative electromagnetic coupling [19]. The technology has shown to be able to wirelessly power devices, such as DECT handsets or vacuum cleaners, in the range of a few milliwatts up to kilowatts (Gallagher, 2017).

VII.   CONCLUSIONS

Energy consumption is critical on use of ICT's today due to advancement of modern technology in computing and other related devices several ways have been suggested on how to reduce energy. Batteries play a critical role in the usefulness of mobile ICT devices, and with an increasing number of users going mobile; the importance of reliable and efficient mobile energy supply will increase. Studies also differ with respect to the life cycle phases of ICT equipment they cover. While most studies consider only the energy consumption in the use phase (which reduces to

electricity), some pursue a life-cycle approaches. To foster development of batteries or devices that do not solely depend on electric power grids for recharging, and to gradually improve and expand the energy infrastructure are therefore essential to connecting any user, anywhere, and to bridging the digital divide. Programs and projects to find ways to provide sustainable electrical energy supply at minimum cost and to enable access to ICTs for these regions are being spearheaded by different international organizations. Wireless recharging is an area of research aimed towards address replacing chargers and cables and powering mobile devices on the fly and over distances up to several meters using non-radiative electromagnetic coupling. The technology has shown to be able to wirelessly power devices, such as DECT handsets or vacuum cleaners, in the range of a few milliwatts up to kilowatts.

VI.   REFERENCES

[1]   M. a. A. K. Salahuddin, "ICT , Electricity Consumption and Economic Growth in OECD Countries: A Panel Data Analysis.," Int. J. Electr. Power Energy Syst. 2016, 76, 185–193, p. 185.193, 2016.

[2]   R. S. a. Z. Y. Zheming Yan, "ICT Development and Sustainable Energy Consumption:A Perspective of Energy Productivity," Creative Commons Attribution (CC BY) license , 2018.

[3]   a. V. Hanumaiah Vrudhula., "Energy-efficient Operation of Multicore Processors by DVFS,Task Migration and Active Cooling," IEEE Transactions on Computers 63(2), pp. 349–360, (2012), pp. 349-360, 2012.

[4]   A. B. a. H. Lorenz, "The energy demand of ICT: a historical perspective and current methodological challenges," ICT Innovations for Sustainability. Cham: Springer, 71-103. DOI: https://doi.org/10.1007/978-3-319-09228-7_4, pp. 71-103, 2015.

[5]   Gartner, "Gartner Press Release : Gartner Estimates ICT industry acconts for 2 percnt of global co2 emissions 26 April 2007,Http://www.Gartner.com.It/page.jsp?id=503867 ," Gartner Inc, USA, 2007.

[6]   L. G. J. P. G. a. D. P. Giorgos Fagas, ICT - Energy Concepts for Energy Efficiency and Sustainability, Croatia: IntecOpen, 2017.

[7]   E. G. a. y. Caseau, "The impact of IT on energy consumption and carbon emissions," ubiquity (2015) issue June , pages1-15 ,volume June 2015, pp. 1-15, 2015.

[8]   L. a. A. Elmeligi, "Assessing ICT global emissions footprint: Trends to 2040 and recommendations," Journal of Cleaner Production

(177   448-463),journal homepage:www.elsevier.com/locate/jclepro, pp. 448-463, 2018.

[9]   E. Commission, "AdAdressing the Challenge of Energy Efficiency through Information and Communication Technologies.," Communication from the Commission to the European Economic and Social Committee and the Committee of the Regions on Mobilising Information and Communication Technologies to facilitate the transition to an energy efficient, low carbon economy -, 2009.

[10]   K. a. B. S. Fichter, "Green IT: Energieeffiziente Rechenzentren.," est-PracticeBeispiele aus Europa,, 2010.

[11]   DEFRA, "Policy Brief: Improving the energy performance of information and communication technology products," London, UK, Department for Environment, Food and Rural Affairs. , 2008.

[12]   V. C. a. L. M. Hilty, "Energy Consumed vs. Energy Saved by ICT – A Closer Look," Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and ToolsCopyright © Shaker Verlag 2009. ISBN: 978-3-8322-8397-1, 2009.

[13]   O. Willum, "Residential ICT related energy consumption which is not registered at the electric meters in the residences.," WiTricity Corporation: "Wireless Electricity Delivered Over Distance," http://www.witricity.com/ITU: "The World in 2009: ICT Facts and Figures," October 2009. http://www.itu.int/ITU-D/ict/material/Telecom09_flyer.pdf Appfrica blog: "Do Cellphones Outnumbe, 2010.

[14]   L. M. a. C. Hilty, "The Role of ICT in Energy Consumption and Energy Efficiency.," EMPA Switzerland, Technology and Society Lab, Switzerland, 2009.

[15]   J. P. G. L. G. a. D. J. P. Giorgos Fagas, "Fundamentals on Energy in ICT," Submitted: February 23rd 2016Reviewed: November 17th 2016Published: March 22nd 2017, 2017.

[16]   G. F. a. J. P. Gallagher, "Energy Challenges for ICT, ICT - Energy Concepts for Energy Efficiency and Sustainability," DOI: 10.5772/66678. Available from: https://www.intechopen.com/books/ict-energy-concepts-for-energy-efficiency-and-sustainability/energy-challenges-for-ict, 2017.

[17]   H. L. Tuller, "Solar to fuels conversion technologies: a perspective," Mater Renew Sustain Energy. 2017; 6(1): 3.Published online 2017 Jan 30. doi: 10.1007/s40243-017-0088-2, 2017.

[18]   S. Y. Hui, "Planar Wireless Charging Technology for Portable Electronic Products and Qi,," Proceedings of the IEEE, vol. 101, no. 6,pp. 1290-1301, June 2013, pp. 1290-1301, 23 June 2013.

[19]   R. Z. a. C. K. Ho, "MIMO broadcasting for simultaneous wireless information and power transfer," IEEE Transactions on WirelessCommunications, vol. 12 , no. 5, pp. 1989-2001, May 2013., pp. 189-2001, 26 May 2013.

[20]   J. Houghton, "ICT and the Environment in Developing Countries: A Review of Opportunities and Developments," In What Kind of Information Society? Governance, Virtuality, Surveillance, Sustainability, Resilience; Berleur, J., Hercheui, M.D., Hilty, L.M., Eds.; Springer: Berlin/Heidelberg, Germany, 2010; pp. 236–247., pp. 236-247, 2010.