Electronics, Communications and Networks
A.J. Tallón-Ballesteros et al. (Eds.)

doi:10.3233/FAIA231180

ICT and Renewable Energy: A Novel Concept for Big Data Storage Centers

Ximei LIU[a], Zahid LATIF[b1], Funiu CUI[a], Xiangzhi Guo[a], Shahid LATIF[c], Daoqi XIONG[d]
[a] *School of Economics and Management, Zhejiang Sci-Tech University, Hangzhou, Zhejiang, China*
[b] *Beijing University of Posts and Telecommunications (BUPT), Hadian District, 10, Xitucheng Road, Beijing, China*
[c] *Sarhad University of Science and Information Technology Ring Road Campus, Peshawar, Khyber Pakhtunkhwa, Pakistan*
[d] *Project Manager, Hangzhou Ly'an Digital Technology Co., Ltd, Hangzhou, China*

Abstract. The tremendous growth in technology is also the cause of global warming, which is harmful greenhouse gas Emissions. The information and communication technology (ICT) sector is one of the fastest-growing industries; it has the most significant impact on almost all other technologies. Energy efficiency and reduction of global warming is now a wish and realization by all key players related to this technology. The big data is one of the modern tools of ICT. It not only has a range of energy efficiency, but it can also help other departments to become intelligent energy efficient. This research article proposes several ways to achieve the mentioned goal, like optimization of battery size, overcoming uncertainties in energy generation, and overcoming storage and consumption. In a green data warehouse, the energy supply from renewable energy sources and the user traffic load are dynamic. The big data industry is also aware of the potential benefits of renewable energy to make the future more environmentally friendly and sustainable. The research progress of big data storage solutions is reviewed in this paper.

Keywords: ICT, Renewable energy, Big data, Global warming, Ware house

1. Introduction

In the 20th century, human beings have seen unprecedented development in information and communications technology (ICT) compared to the previous centuries. In the 20th century, humanity discovered the sky, took footsteps on the moon, and launched spacecraft in the solar system. From conventional messaging, we can send pictures, videos, and texts across the globe in a few seconds. Every aspect of our lives, including health, medicine, transport, construction, aerospace, earth sciences, and psychology, has observed exponential technological advancements. This evolution of technology has been feasible due to the easy availability of electrical energy [1]. The rise of electricity escalates the technology-based growth that runs on electric power [2]. Currently, the

[1] Corresponding author: Zahid Latif, School of Management and Economics, Beijing University of Posts Telecommunications (BUPT), Hadian District, 10, Xitucheng Road, Beijing, China; E-mail: zahid25latif@yahoo.com.

system dependent on technologies is dependent further on electricity and, consequently, consumes a considerable amount of electric power. The operating system of present-day smartphones has more computing power than the computers that launched the first man on the moon. And with every coming day, the size is more innovative and cheaper according to Moore's law; it is the result of the exponential growth of technology in every aspect of life [3].

Due to the increasing demand for technology in our everyday lives, the need for energy has exponentially increased. In this regard, the global energy demand will expectedly increase by 30% from the present-day market, with an average increase of 1.4% per year [4]. Currently, the three primary fossil fuels, oil, coal, and natural gas, are used for energy production and contribute almost 80% of total energy production. In contrast, the rest of 20% are produced from hydro, nuclear, and renewable resources [5]. Hence, most technology depends on electricity, and electricity generation is the main requirement for technology to sustain growth. For example, large ICT companies such as Microsoft consume around 27 MW of electricity at any given time [6].

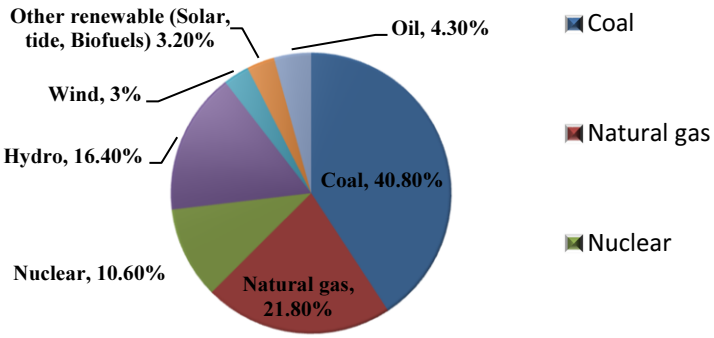

Figure 1. Global electricity production from different fuel sources.

According to International Energy Agency (IEA) statistics, the primary sources of electricity generation are fossil fuels, in a ratio shown in Figure 1. The most common power used for electricity generation is coal, which contributes around 41% of the world's electricity generation. According to the IEA, the global age of electricity was 2 TW, while the energy consumed to generate 2 TW was approximately 5 TW, having 38% efficiency of a typical power plant [7]. In renewable energy sources, the new gas-fired plants increase the efficiency by up to 55% compared to conventional sources. The quest for electricity increased day by day to advance technology and improve the living standards of people. Some authors conclude that the nexus between electricity and growth is directly related to a country's economic prosperity, urbanization ratio, and supply risks [8].

More or less, all sectors of industry and technology, including construction, aerospace, and mining, farming, and ICT sectors consumed energy generated. It is now a hot and alarming issue globally, as indicated by the famous World Energy Department. In this regard, the US Department of Energy reported in "International Energy Outlook 2007" that industrial sectors such as mining, construction, agriculture, and manufacturing consume around 37% of total energy [9].

Therefore, energy efficiency and sustainability are the core issues, and the majority of the research is going on today. The main goal is to make a world where technology becomes more efficient and sustainable and has minimum adverse effects on climate change [10]. Luckily, ICT has the capacity and could play a vital role in fulfilling both the above-recommended actions and can make the current system infrastructure energy efficient and more innovative in making sure of the utilization of renewable energy at micro and macro levels.

The paper is organized as follows: Section 2 contains a literature review. Section 3 has a renewable energy description, and section 4 elaborates on the study results. Finally, section 5 concludes the research paper.

2. ICT Smarter Initiatives

The ICT sector, like other energy sectors, has a vital role in global warming via CO_2 emissions [11]. ICT contributes to CO_2 emissions both directly and indirectly via other sectors where ICT supports businesses in different service sectors [12]. The main contributors of energy consumption in the ICT sector are data centers and wireless base stations (BS), and a report published by Gartner in 2007 depicts that the ICT sector contributes a total of 2 percent to global warming the world, which is significantly less in comparison to other service sectors [13]. ICT and its applications act as enablers for different sectors such as construction and transportation; resultantly, ICT is not only smart itself, but it also helps other service sectors become more innovative and energy-efficient [14]. It was reported various internet surveys stated that many organizations and foundations, both in public and private sectors in North America and Europe, are trying to utilize ICT to help other technologies become energy efficient and greener. Similarly, in emerging and developing countries, there are enormous prospects for the development of green ICT and its applications [15, 16].

2.1. Greener ICT Sector by Reducing Own Energy Consumption

The ICT sector consists of three sub-sectors, i.e., the telecommunication and device sector, Personal computers, laptop sector, and data centers. The usage and energy consumption of all the three sectors have increased gradually during the previous few decades due to the wide spread of computers in houses, offices and every working place and the massive increase in mobile connections and mobile broadband as well as a huge amount of data storage, resultantly, there was estimated Co_2 emission in 2007 recorded 0.83 Gt. It is estimated to be increased in 2020 to 1.43 Gt [17]. Figure 2 shows the share of all three ICTsub sectors in the emission of CO_2, which is 31% for telecom, 40% for PCs, and the rest of the 23% emitted by data centers.

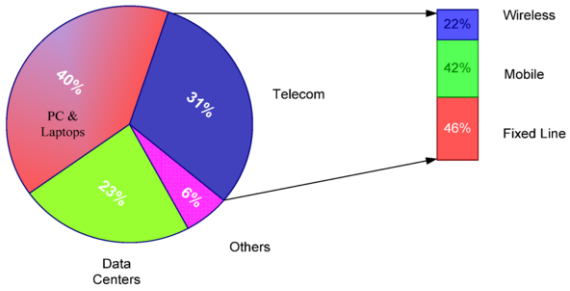

Figure 2. Green House Gases distribution among ICT elements.

The ICT sector can be energy efficient until and unless this sector is more intelligent; for this purpose, Google built a data center on Oregon's Columbia River to tap hydroelectric power; Microsoft also implemented Washington for the same reason. Moreover, HSBC is working to develop a data center near Niagara Falls. In Wyoming (United States), the US is building data centers for cheap electricity from coal [18]. The ICT sector can reduce carbon emissions by adopting innovative measures that conserve energy and mitigate carbon. The ICT sector has become more intelligent by adopting the following steps properly.

- Standardization of energy measurement approaches, which shows how much energy is being consumed.
- Monitoring of energy consumption via sensors and meters across the board.
- Accounting of energy at every small and single node where it is dissipated.
- Constant innovations for smaller and energy-efficient equipment in ICT sectors.
- The ICT sector becomes an example for other sectors regarding low carbon emissions.

The Greener ICT program was first established by the US Environmental Protection Agency (EPA) in 1992 by launching "Energy Star" to raise awareness of energy efficiency and climate change. After that, many initiatives have been taken by both public and private organizations to make ICT green. The "Green ICT Standard" is an international foundation regulating green technology standards based on professional programs. Moreover, some other projects that make ICT green include European "EARTH" called Energy Aware Radio and Network Technologies), International "Green Radio" projects, and Global e-sustainability Initiatives (GeSI).

2.2. ICT Support to Other Sectors

CO_2 emissions demand rise due to increase in global demand for services and products, with the help of smarter ICT sector these can be reduced up to 5 times less than the current status [19]. The report "SMART2020" describes that, ICT sector can reduce the global GHG emissions up to 7.8 Gt by 2020, the total estimated 51.9 Gt of CO_2 emissions contributed by all service sectors. ICT technology is directly and indirectly involved in benefiting the other technologies such as smart grid, smart homes, smart buildings and smart logistics are the sectors which are directly or indirectly benefited from ICT

technologies. Advancements in ICT give unique characteristics such as ICT protocol extension and capability to extend these protocols into other sectors. Moreover, ICT provide computational power and intelligence to other sectors in order to perform better and become energy efficient as well as provide new techniques to reduce the high carbon emissions into low carbon emissions which further optimized the process of energy efficiency [20, 21]. Besides these, ICT can help the companies in innovation process by bringing different changes in companies' strategies, and finally, with implementing the smart energy management between different sectors can promote the cooperation among them.

Further, the way ICT contributes to building smart homes, cars, grids, and smart logistics can be divided into three main parts, i.e., software, management systems, and devices. These three main parts have sub-parts like software, including:

- Real-time processing data.
- Energy accounting in grids.
- Smart billings.
- Protocols for interconnection.
- Response for load management.

ICT devices that help conserve energy include Data records, data loggers, SMART meters, chargers, Chips, alarm systems, and alert systems [22]. The third part of ICT that brings energy efficient systems in other technologies includes maintenance, operations, and repair stations, CO_2 emissions tracking platform, workflow management system, vehicle tracking system, and internal and external communications systems.

3. Renewable Energy Distribution

The distribution of renewable energy has equal importance as energy generation and utilization. So, it attracts the attention of researchers towards distribution policies and infrastructure. Smart grids are the primary tools for renewable energy distribution, and currently, they have become essential among ICT scholars with the introduction of big data and the Internet of Things. Ghorbanian [23] integrated the conventional grids with the introduction of communication technology and infrastructure to make them smart or develop them in such a way that they can fused with modern ICT applications. The concept of smart grid and energy generation is associated with the idea of distributed generation (DG); the definitions of DG are presented [24] by defining the term DG as "the generation of electric power within distributive networks on the consumer side", a layout of DG in shown in Figure 3.

The definition of smart grid in terms of ICT is as follows: "ICT-enabled distributed generation of electricity". ICT has the capability that can provide intelligence and computing power to the electricity distribution system to make it efficient.

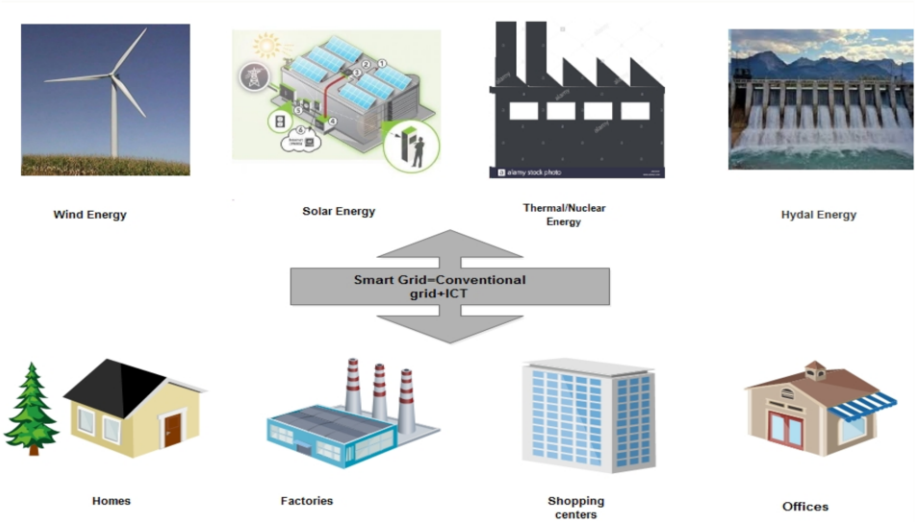

Figure 3. ICT-enabled Smart Grid

4. Incorporation into Systems and Networks

The solar and wind energy renewable resources attract researchers' intentions to integrate these RES into various ICT devices and networks. These applications include solar power wireless house and ground energy storage electric vehicle DC fast chargers. We already have practical examples working efficiently in various sectors, such as wireless data acquisition system (WDAS) and radio bas site solution for Sony Ericson. Moreover, communication systems and renewable energy are interdependent, like dynamic power allocation for maximizing the output in energy harvesting systems. A smart grid is the latest and most comprehensive example of an energy harvesting system that contains an innovative design of an intelligent Supervisory Control and Data Acquisition System (SCADA). The present communication networks containing solar and wind power reduce operational costs and are environmentally friendly.

4.1. The Case for Big Data Green Storage House

Improving energy efficiency in big data storage houses includes energy reduction of all elements in the data warehouse, including base stations, such as base stations and mobile core network elements, etc. Amongst the features mentioned above, the data warehouse is the most energy-consuming part, consuming more than 50% of the total energy in a system. Thus, the data warehouse is the prime focus of research for energy efficiency regarding the cellular communication system. Moreover, the most exciting finding of this research is that most network resources are idle. Resultantly, the energy efficiency of eMNDH (Mobile Network Data House) is low at low traffic load. The data warehouse mainly consists of Transaction Generated Data (TGD) obtained from customer calls, SMS, value-added services (VAS), recharging their prepaid connections, and internet usage. The data taken by telecom operators can be classified according to their network infrastructure management, sales and marketing, and customer care. The traffic data is measured in Erlang and is used to understand the load on a base station at any given time. Besides the infrastructure management, the utilization of any telecom services is

recorded for billing purposes, irrespective of the type of service accessed. These records are called Call Detail Records (CDR). They cover voice, SMS/MMS, VAS and internet access, etc. Generally, CDR captured the following data:

- The duration of service was used during a call
- The numbers of both origination and termination party communication.
- The type of handset used for communication
- The utilization of 3G, 4G etc.
- The data used for uploading/downloading during internet access is available.

Mobile networks capture various location data according to their network tendency. This passive data is further used for billing and network management purposes. On the other hand, the active data is generated by GPS by locating the handset or handset-based position.

5. Conclusion

The main objective of a green data warehouse is to optimize the power management of the warehouse. Big data is the only technology field with a broader impact on other technologies. This article gives big data technology can make systems more intelligent and greener by taking renewable energies. The utilization of RE is intended to reduce the expenditure cost and ensure clean energy. There can be several ways to achieve the mentioned goal, like optimization of battery size, overcoming uncertainties in energy generation, and overcoming storage and consumption. In a green data warehouse, the energy supply from RES and the user traffic load are dynamic. Resultantly, optimizing the use of green energy is a feature of energy arrival and consumption in present and future steps. Therefore, modeling a WH with RES is a function of balancing energy sources, energy storage, and optimum energy.

Funding

This work was supported by the Natural Science Foundation of Zhejiang Province, (grant number LQ21G010007) and the Transverse Project No. 23090083-J).

References

[1] Grim RG, Huang Z, Guarnieri MT, Ferrell JR, Tao L, Schaidle JA. Transforming the carbon economy: challenges and opportunities in the convergence of low-cost electricity and reductive CO_2 utilization. Energy & Environmental Science. 2020;13(2):472-94.

[2] Parmesan C, Morecroft MD, Trisurat Y. Climate change 2022: Impacts, adaptation and vulnerability: GIEC; 2022.

[3] Adha R, Hong C-Y, Agrawal S, Li L-H. ICT, carbon emissions, climate change, and energy demand nexus: The potential benefit of digitalization in Taiwan. Energy & Environment. 2023;34(5):1619-38.

[4] Santiago I, Moreno-Munoz A, Quintero-Jiménez P, Garcia-Torres F, Gonzalez-Redondo M. Electricity demand during pandemic times: The case of the COVID-19 in Spain. Energy Policy. 2021;148:111964.

[5] Kim JH, Alameri SA. Harmonizing nuclear and renewable energy: Case studies. International Journal of Energy Research. 2020;44(10):8053-61.

[6] Sermsuk M, Sukjai Y, Wiboonrat M, Kiatkittipong K. Feasibility study of a combined system of electricity generation and cooling from liquefied natural gas to reduce the electricity cost of data centres. Energy. 2022;254:124397.

[7] Cansino JM, Ordóñez M, Prieto M. Decomposition and measurement of the rebound effect: The case of energy efficiency improvements in Spain. Applied Energy. 2022;306:117961.
[8] Karanfil F, Li Y. Electricity consumption and economic growth: Exploring panel-specific differences. Energy Policy. 2015;82:264-77.
[9] Reddy BS, Ray BK. Decomposition of energy consumption and energy intensity in Indian manufacturing industries. Energy for Sustainable Development. 2010;14(1):35-47.
[10] Smit B, Pilifosova O. Adaptation to climate change in the context of sustainable development and equity. Sustainable Development. 2003;8(9):9.
[11] Belkhir L, Elmeligi A. Assessing ICT global emissions footprint: Trends to 2040 & recommendations. Journal of cleaner production. 2018;177:448-63.
[12] Zhou X, Zhou D, Wang Q, Su B. How information and communication technology drives carbon emissions: A sector-level analysis for China. Energy Economics. 2019;81:380-92.
[13] Bastida L, Cohen JJ, Kollmann A, Moya A, Reichl J. Exploring the role of ICT on household behavioral energy efficiency to mitigate global warming. Renewable and Sustainable Energy Reviews. 2019;103:455-62.
[14] Lorincz J, Capone A, Wu J. Greener, energy-efficient and sustainable networks: State-of-the-art and new trends. MDPI; 2019. p. 4864.
[15] Solanki A, Nayyar A. Green internet of things (G-IoT): ICT technologies, principles, applications, projects, and challenges. Handbook of research on big data and the IoT: IGI Global; 2019. p. 379-405.
[16] Latif Z, Yang M, Pathan ZH, Jan N. Challenges and prospects of ICT and trade development in Asia. Human Systems Management. 2017;36(3):211-9.
[17] Cheshmehzangi A. The Application of ICT and Smart Technologies in Cities and Communities: An Overview. ICT, Cities, and Reaching Positive Peace. 2022:1-16.
[18] Vermesan O, Friess P. Internet of things-global technological and societal trends from smart environments and spaces to green ICT: CRC Press; 2022.
[19] Ahmed F, Naeem M, Iqbal M. ICT and renewable energy: a way forward to the next generation telecom base stations. Telecommunication Systems. 2017;64:43-56.
[20] Liu X, Latif Z, Latif S, Mahmood N. The corruption-emissions nexus: do information and communication technologies make a difference? Utilities Policy. 2021;72:101244.
[21] Liu X, Latif K, Latif Z, Li N. Relationship between economic growth and CO 2 emissions: does governance matter? Environmental Science and Pollution Research. 2020;27:17221-8.
[22] Latif Z, Latif S, Ximei L, Pathan ZH, Salam S, Jianqiu Z. The dynamics of ICT, foreign direct investment, globalization and economic growth: Panel estimation robust to heterogeneity and cross-sectional dependence. Telematics and informatics. 2018;35(2):318-28.
[23] Ghorbanian M, Dolatabadi SH, Masjedi M, Siano P. Communication in smart grids: A comprehensive review on the existing and future communication and information infrastructures. IEEE Systems Journal. 2019;13(4):4001-14.
[24] Razavi S-E, Rahimi E, Javadi MS, Nezhad AE, Lotfi M, Shafie-khah M, et al. Impact of distributed generation on protection and voltage regulation of distribution systems: A review. Renewable and Sustainable Energy Reviews. 2019;105:157-67.