Sustainable Energy in Telecommunications and IT Industries: Principles and Solutions

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Abstract. Sustainable energy is the solution for long-term developments. It is easy to access a clean, affordable and reliable energy. This paper provides a review on sustainable design in Information and Communication Technologies (ICTs), including the telecommunication sector, energy in data centers and end user devices underlining unsustainable design practices. This paper also explains energy saving, direct impact assumptions, greenhouse gas (GHG) emission reductions, rebound effect, direct footprint of ICTs in reducing it. Dematerialization, plays an important role in reducing GHG emissions, are proposed in this paper. A literature review deals with extant reviews through the synergic relationship between economic prospects, sustainability and the ICT design. This paper introduces an econometric example to investigate the ICT effect on energy output, descriptive statistics of ICT, industry and energy saving. European Union (EU) depends on the ICT to reach to its energy and environmental targets. An expectation that differs from 50% to 125% of the total 20% greenhouse gas reduction is needed in 2020.

1. Introduction
Sustainable energy is “Meets the present needs without undermining the generations of future desire to fulfil their own needs” [1]. Its technologies are applied to get electricity, heat and cool buildings, and power transportation models and machines. The telecommunications industry within the sector of ICT is made up of all telecommunications companies and internet service providers. Telecommunications equipment, computing hardware, office machinery, electronic goods and services activities are considered ICT.

2. Literature review
The last decade has shown greater concern for environment and sustainability. Y. Sugiyama [2] explained green and development activities for decreasing environment effect of society by decreasing the effect of ICT buildings in telecommunication places, data centers and user’s offices and houses. The research team of
ECAR [3] has a comprehensive web-based survey to analyze environmental sustainability (ESE) conducted by EDUCAUSE member organizations in the United States and Canada. Bibri [4] said that meeting energy saving, waste reduction or improved recycling goals will be harder for many organizations. The software applications consumes the ways which permit the measure and environment models. There are different system models such as climate change modelling represented by Mulder [5].

This paper provides a review on sustainable ICT design, highlighting the unsustainable design in the ICT. It examines the role of ICT in delivering energy efficient solutions through its products and services. The results demonstrate the ICT sections unsustainability according to intensive energy consumption and concomitant (GHG) pollution according to services and goods. To decease the data centers footprint and telecommunications networks, the design approaches differ from the improvements achieved in hardware technology. The ICT section is utilized to reduce its direct footprint in order to reduce energy efficient and low carbon economy.

The remainder of paper is structured as follows. Section 2 deliberates the closely related work. Section 3 explains the information and communication technology (ICT). The relation between energy and economy is introduced in Section 4. Section 5 displays and discusses the results. The conclusion with future directions are drawn in Section 6.

3. Information and communication technologies (ICTs)

ICT has recently been a central leader in making strides towards a productive and low-carbon economy. It is being extended beyond simple green product manufacturing. The scope of the analysis focused on computer facilities, data centers and communication networks that are considered part of the ICT field is explained in Figure 1, whereas TVs, top boxes and printers are beyond the scope of ICTs.

![Figure 1. Scope of the Study](image)

4. Sustainable technologies

Environmental philosophy and ecological intelligence technologies are utilized to design and improve the Sustainable ICTs. These technologies designs include adopting decarbonization technique in both the design of manufacturing and product, decreasing emissions of pollution and other GHGs and utilizing sustainable initiatives. Dematerialization is defined as moving the consumption form from product ownership to services.
5. Energy and economy

Both economies and societies have been concerned with electricity. According to International Energy Agency (IEA), the total human activity emissions in 2008 includes power sector with 34%, industry with 33%, agriculture and waste with 27%, land use with 24%, transportation with 24% and buildings with 18%. Figure 2 shows the role of ICT in reducing GHG emission, 63.5 Gt global GHG emissions in 2030 which are divided into 4% smart grid, 3% smart service, 3% smart agriculture, 2% smart work, 2% smart travel, 1% smart building and 1% smart transport.

![Figure 2. ICT role in reducing GHG emissions [6]](image)

5.1. Effective sequence based on Rebound Effect and Energy

In the sense of ICT, energy efficiency gains are strengthened by increasing rebound effect occurs. To clarify this, a greater energy efficient ICT product or service may need lower energy in order to gain an output. The rebound effect (R) is commonly defined as the gap between the potential (PES) energy savings from an energy efficiency improvement and the actual energy savings (AES) [7]:

\[
R = 1 - \frac{\text{actual energy savings}}{\text{potential energy savings}} \tag{1}
\]

The potential energy savings are expected under the assumption that there are no behavioral responses to the efficiency achievements, while actual energy savings are measured ex-post and contain one or more of the behavioral responses. So, for example, a rebound effect of 20% (R=0.2) means that one quarter of the possible energy gains have been taken down by one or more of the above replies [8].

5.2. Econometric Model

This section demonstrates the econometric model in order to study the ICT development impact on energy enrichment [9]:

\[
\text{MEPICM}_t = \beta_0 \text{MEPICM}_{t-1} + \beta_1 \ln ICT_t + \beta_2 \ln HC_t + \beta_3 \ln EI_t + \beta_4 \text{INVEST}_t + \beta_5 \text{GOV}_t + \beta_6 \text{TRADE}_t + \beta_7 \text{FDI}_t + \beta_8 \text{INDUSTRY}_t + (\sigma_t + \nu_t) \tag{2}
\]

The subscripts i and t denote, respectively, economy and the year, MEPICM describes the accumulated index of energy productivity, \(\beta_1\) describes the relationship between ICT development and energy enrichment. Specifically, HC describes human capital, considering a highly educated population. EI represents the intensity of energy, INVEST is the domestic investment level, GOV denotes the economic invention of local government, TRADE is the foreign trade level, FDI is the foreign direct investment level, INDUSTRY is the development level of industry, since a higher ratio of secondary industry may rely on more use of energy, Table 1 explains the mean, standard deviation, minimum and maximum values for previous variables. The
parameters $\beta_0$ to $\beta_8$ are the impacts of corresponding variables, $\alpha_i$ is the economy specific intercept and $\nu_{it}$ is the unobserved disturbance term, assumed to be i.i.d. Substituting from Table 1 into Eq. (2), mean, standard deviation, minimum and maximum productivity could be calculated. The knowledge stock indicator ICT can be obtained as [9]:

$$ICT_{it} = PAT_{it} + (1-\delta)ICT_{it-1}$$  \hspace{1cm} (3)

The $ICT_{it}$ represents the ICT knowledge stock in economy $i$ at year $t$ and $PAT_{it}$ describes the application number.

### Table 1. Descriptive statistics [10]

| Variables | Obs  | Mean  | Std.Dev. | Min  | Max  |
|-----------|------|-------|----------|------|------|
| MEPICM    | 950  | 1.375 | 0.713    | 0.250| 6.428|
| ICT       | 950  | 6733.420 | 24140.040 | 0.014| 203104.000|
| HC        | 950  | 2.872 | 0.523    | 1.450| 3.726|
| EI        | 950  | 3207.791 | 2159.791 | 386.471| 18178.100|
| GOV       | 950  | 0.185 | 0.059    | 0.060| 0.446|
| TRADE     | 950  | -0.024| 0.115    | -0.609| 0.397|
| FDI       | 950  | 4.312 | 9.170    | -43.463| 198.074|
| INVEST    | 950  | 23.923| 5.913    | 0.299| 47.686|
| INDUSTRY  | 950  | 31.031| 7.277    | 11.251| 66.757|

Mean, standard deviation, min and max values for productivity (MEPICM) and ICT are also calculated to develop the economic model.

6. **Results and discussion**

6.1. **Energy Saving Potential Calculation**

Figure 3 explains an example of energy saving potential which equals the electricity consumption multiplied by energy saving potential per technology. Moreover, the energy cost saving equals electricity price multiplied by previous energy saving potential and finally, market potential equals the average lifetime multiplied by energy cost saving potential.

![Figure 3](image3.png)

**Figure 3.** Example for energy saving realizable potential calculation [11].

6.2. **GHG Emission Reductions from Industrial sequences**

The climate group (2008) expects that, in 2020, China’s GHG emissions will come from motor systems alone with 10%. The development of industrial quality would deliver 200 Million ton of Carbon Dioxide Equivalent (MtCO$_2$) savings as shown in Table 2.
Table 2. GHG emission reductions from industrial processes [12].

|                      | MtCO₂e based on baseline GHG emissions 2030 | Potential GHG emission consumption 2030 MtCO₂e | Low ICT contribution to efficiency gains | Higher ICT contribution to quality gains | Potential GHG emission reduction MtCO₂e | AeA’s report (20% of baseline emissions) |
|----------------------|----------------------------------------------|-----------------------------------------------|------------------------------------------|------------------------------------------|----------------------------------------|-------------------------------------------|
| OECD countries       | 4243                                         | 470-1100                                      | 5%                                       | 30%                                      | 24-330                                  | 849                                       |
| Economies in transition | 1540                                        | 250-510                                       | 5%                                       | 30%                                      | 13-153                                  | 308                                       |
| Developing nations  | 7617                                         | 1300-3400                                     | 5%                                       | 30%                                      | 65-1020                                 | 1523                                      |
| Global               | 13400                                        | 2000-5100                                     | 5%                                       | 30%                                      | 100-1530                                | 2680                                      |

6.3. ICT direct footprint

Decarbonization strategy is performed to decrease the footprint of ICT part. Based on Forum for the Future (FF 2006) [13], the climate changes are affected by the ICT which compromises of three types: systemic, direct, and indirect. The direct ones appear on climate changing and according to the emissions of the GHG obtained by energy utilized to get the materials, to assure facilities, to transport goods, and to provide services. The indirect consequences emerge from the economy and society wide use and implementation of ICT. The effect of ICT on changing the climate results from the emissions of GHG from the resources used for powering and cooling network equipment and data centers. The systemic effects occur over the medium to long term due to the combined effects of large people numbers using groups of people or ICT.

6.4. ICT Product Life Cycle

- **Direct effects**

The footprint of the ICT section includes PCs, telecoms networks, devices and data centers, was 830 MtCO₂e. In 2002, the PC and monitors combined carbon footprint reached 200 MtCO₂e and is expected to have a greater increase up 600 MtCO₂e in 2020 (GeSI 2008). More increase is expected in the ICT industry carbon emissions, through Business-As-Usual scenario, from 0.53 Giga ton of Equivalent Carbon Dioxide (GtCO₂e) in 2002 to 1.43 GtCO₂e in 2020. The overall energy consumed by ICT in developing countries is between 5% and 10%, adding 1 percent – 3 percent to global CO2 emissions. A recent study reports that the 20% of GHG account for the immediate consequences of ICT provision emissions produced by ICT. Table 3 describe the direct impact assumptions on PCs, telecom devices, telecom networks and data centers.
Table 3. The direct impact assumptions [14].

| Drivers       | Market growth and penetration of device to 2020 | Constituting elements | Power consumption | Embodied carbon |
|---------------|-----------------------------------------------|-----------------------|-------------------|-----------------|
| PCs           | • Assuming 20% workstations of desktops       | • Desktops, laptops CRT, LCD for PCs (CRT assumed to decrease in 2020 to 0%) | • Workstations consume 2.5 times the desktop, the commercial usage: 14h/day, the consumer usage: 3h/day, desktop standby achieves 15W | • Figures assessed based on European Commission DG TREN, EuP preparatory study, TREN/D1/40-2005 |
| Telecoms devices | • Yankee user connections for broadband and mobile up to 2011, with historic trends up to year 2020 | • Mobile penetration capped to 0.92 for 2020 (US penetration) | • Mobile phones • Charging phone 0.5 kWh • Standby charging 13 kWh • IPTV rating: 25W Active 40% of rated standby 20% of rated 3 h of active TV usage, rest of the time is standby | |
| Telecoms networks | • Yankee user connection for fixed, mobile, broadband up to 2011, historic growth up to year 2020. | • Fixed-line • Mobile • Broadband • Cable operators (broadband only) | • Mobile embodied carbon from sustainable energy use in mobile communications | • Embodied carbon from sustainable energy use in mobile communications |
| Data centers  | • For each server type, IDC data up to 2011 for sales. Projected global 2002 are installed base according to sales | • 3 kinds of servers and data storage units. | • Doubled power consumption of servers for power equipment and cooling | • Assumed 4% of total data center life cycle analysis (LCA) footprint: life cycle assessment for the internet data center, NEC |

- Indirect effects

Recently, researches expect that the indirect effects may reach 80% of the GHG emissions produced by ICT. A single Google search consumes high energy. It is observed that each processor consumes actual power around 265 W for its memory and cooling overhead adds another 135 W. The microprocessor consumes a 46% of the total power. As expectation, 3% of global emissions by 2020 will depend on ICT. The initial power requirements of Internet hardware were overestimated by a factor greater than 10. Moreover, complicated ICT infrastructure is needed to mount vast networks of batteries, flywheels, magnetic superconductors, UPS and backup generators.

6.5. Energy Use of Data Center

Due to digital economy growth, energy consumption by data centers is also in increasingly growing. If economic development persists in line with demand, 122 million servers will be used worldwide in 2020, up from 18 million currently (GeSi 2008). This is predicted to rise by more than threefold to 259 MtCO2e by 2020, resulting in the speediest rising contributor of carbon footprint in the ICT industry. The volume servers exemplify greater than 50% of the footprint of the data center (174 MtCO2e) at this level, while the cooling systems only represent 4% of the overall ICT footprint. The data centers are most electricity consumers and
the largest GHG pollution producers. According to the structural defects of ICT equipment with respect to energy consumption, this is considered a mistake. Due to high electricity prices and power supply capability issues, energy usage in data centers has become a concern. A Swiss study reveals that the connection capacity is between 20 and 40 MW for data centers. The UK had a gross electricity generation capacity of some 77.4 GW in terms of national consumption in 2005-2006. Data centers in the UK are about 1500. The largest data centers will absorb 7 to 14 MW each, maybe around 10 MW on average. They cause ~25% of ICT emissions and 2 to 3% of the overall power capacity of the United Kingdom. Because of the trend of interconnecting various ICT devices and facilities, standby losses could increase drastically in the future [15].

- **Reducing the footprint of data centers**
Low energy consumption is produced according to the sustainable ICT design. Direct consideration should be paid to how to avoid greenhouse emissions at the ICT product design level. It is very possible that modern interfaces solar power or the utilization of human body movement for their energy supply could be higher energy efficient gadgets like the Apple iTouch or the RIM Blackberry. By minimizing energy usage and thereby reducing carbon emissions to minimize global warming, Green ICT is going to apply the green idea to the design of ICT and development basis, such as hard drives that could reduce up to 50% of energy consumption, choleristic, LCD displays that consume up to 80% of energy and direct methanol fuel cells. In addition, solutions are broad for the data center of green grid performance metrics. The infrastructure efficiency of data center and power consumption efficiency (PUE) are considered two of the most powerful solutions as metrics for quantifying data center changes. In order to increase performance and reduce costs, they can benefit operators.

6.6. Energy Use of Telecommunications Devices and Infrastructure
Telecommunication devices and infrastructure are a part of the ICT industry having a visible footprint. Energy requirements typically account for over 70-90% of the total energy use of a telecommunications company. The total ICT will be described by a little percentage of the telecommunication of carbon footprint in 2020. The telecommunication devices global footprint in 2002 was 18 MtCO2e, expecting to increase ~3 times in 2020 to 51 MtCO2e by 2020, driven mainly by rises in the use of broadband routers and internet protocol television (IPTV) boxes. Similarly, the telecommunication infrastructure footprint in 2002 was 133 MtCO2e, expecting in 2020 to increase to ~300 MtCO2e. Indeed in 2002 there were 1.1 billion telephone accounts, which is expected to grow to 4.8 billion by 2020 and is the main source of global pollution from telecommunications footprints. The telecommunication emissions growth is increased from 150 MtCO2e in 2002 to 300 MtCO2e in 2007 and will reach 350 MtCO2e in 2020 as shown in Fig. 5.

![Figure 5. Global telecoms footprint (devices and infrastructure) [16].](image-url)
Reducing the footprint of telecommunication devices: In order to mitigate global warming, the design of green ICT is expected to drastically decrease the consumed energy, resulting in a reduced pollution. Technological advances in a reduced power usage from smart chargers and standby modes would definitely lead to reduction footprint of cellular phones. The footprint of telecommunication devices can be reduced further if products create less emissions during development or whether the system uses greener energy during its lifespan.

Reducing the footprint of telecommunication infrastructure: The increased demand for telecommunication services leads to a more energy use and concomitant GHG emissions. Mobile infrastructure technologies that are currently available include packages for network optimization that can reduce energy consumption by ~ 44%. Operation of the night battery, which will minimize electricity usage by a 50% decrease in energy consumption. The implementation of such initiatives would encourage telecommunications companies to plan substantial changes in energy efficiency.

6.7. Energy-Efficient and Low-Carbon Economy

Solutions allowed by ICT will allow savings of 1 ton per capita in 2020.

- **Dematerialization, energy and material savings**: Dematerialization may play an important part, at several stages, in reducing energy consumption and thereby mitigating carbon emissions. The ability of dematerialization to minimize the footprint is important due to the spectrum of relevant innovations, which include global, social, public and private industries that are as complex as they are. Certain goods and services can be completely digitized and shipped over the internet, such as bills, songs, books, records, and newspapers. The new implementations of ICT in e-government, e-health, e-commerce, and other social communities are found to have a substantial effect on lowering GHG emissions [17].

- **Tele-working and Videoconferencing**: Tele-work has been rated as the greatest incentive found where there is a potential for ICT to minimize GHG emissions. The reason why teleworking technology imports are because one of the economic sections that contributes greatly to universal warming is connected to shipping. According to International Energy Agency, the transportation is a huge and the growing emission of GHG is responsible for almost 14% of global emissions. Teleconferencing and flexi-working have a positive impact on the environment. If only 10% of workforce become flexi–workers of EU, this may save 22.17 million tons of CO₂ in year. Also, up to 30 million people, in USA, work from home, in 2030, the carbon emissions will be reduced by 75 to 100 MtCO₂e. The same statement goes with teleconferencing that 63% of electricity can be minimized by substituting private meetings for teleconferences that fly. This will save 22.3 million ton of CO₂ if video conferencing replaces only 20% of travels in EU. If digital connectivity increases, without having to travel, individuals may gradually be able to feel being there. Video conferencing capabilities can help minimize GHG pollution by replacing corporate travel and everyday travel with services through the use of voice over IP (VoIP). About 20% of all miles travelled was accounted for by commuting. The value added generated by industry from 2008 to 2020 is shown in Table 4.

| Industries           | 2008   | 2010   | 2012   | 2014   | 2017   | 2019   | 2020   |
|----------------------|--------|--------|--------|--------|--------|--------|--------|
| Private Services Producing | $10380 | $10489 | $11019 | $11480 | $12384 | $13127 | $13914 |
| Private Goods-Producing | $3166  | $2979  | $3019  | $3202  | $3327  | $3526  | $3738  |
| ICT-Producing        | $835   | $913   | $985   | $1113  | $1480  | $1568  | $1745  |

Table 4. The value added produced by industry from 2008 to 2020 [18].
7. Conclusion and future directions
The principal objective of this paper is to highlight the role of ICT in the transformation and development towards a low-carbon, productive economy. Yet, bounce effects and other challenges may be tumble blocks. In order to understand the maximum potential of the estimated gains. Energy policy analysis shows that the conversion of the planet to 100% renewable energy by 2030 is both realistic and affordable, but needs a political support. It is noted that the ICT industry's overall CO₂ emissions could account for 2% of global carbon emissions. At the same time, ICT applications are known as the instrument for the global strategy for environmental conservation and offer a tremendous opportunity for enhancing efficiency across the economy and community, as the remaining 97-98% are concerned.

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