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, ICTs direct footprint and role of sustainable design in reducing it. Dematerialization, plays an important role in reducing GHG emissions, are proposed in this paper. A literature review makes an advance on extant reviews by highlighting synergistic relationship between ICT design, sustainability and economy. This paper introduces an econometric model to investigate the ICT impact on energy productivity, descriptive statistics of ICT, industry and energy saving. ICT can, in fact, play a major role in initiating and enabling the European Union (EU) to reach its energy and environmental targets. Estimates vary from 50% to 125% of the total 20% greenhouse gas reduction required by 2020.

Keywords: Information and Communication Technology (ICT), Green House Gas (GHG), Low carbon economy, Rebound effect, Dematerialization.

I. Introduction
Sustainable energy is a principle in which human use of energy “meets the needs of the present without compromising the ability of future generations to meet their own needs” [1]. Its technologies are deployed to generate electricity, heat and cool buildings, and power transportation systems and machines. The telecommunications industry within the sector of ICT is made up of all telecommunications companies and internet service providers. The ICT includes telecommunications equipment, computing hardware, office machinery and electronic goods. It is a gamut of industries and services activities.

II. Literature review
The last decade has shown greater concern for environment and sustainability. Y. Sugiyama [2] described green research and development activities for reducing environment impact of society by reducing the impact of ICT installations in telecommunication centers, data centers and customer offices and homes. The ECAR research team [3], has conducted a quantitative web based survey of EDUCAUSE member institutions in the United States and Canada to examine environmental sustainability (ES). Bibri [4] declared that meeting targets for saving energy, reducing waste or increasing recycling can be tougher for many organizations. The software technology provides the tools that allow to measure and model environmental systems. There are different system models such as climate change modelling represented by Mulder [5].

This paper provides a review on sustainable design in ICT, underlining unsustainable design practices in ICT sector. It examines the role of ICT in delivering energy efficient solutions through its products and services. Findings highlight the unsustainability of ICT sector regarding energy intensive consumption and concomitant (GHG) emissions associated with its products and services. To reduce the footprint of data centers and telecommunications networks, design solutions vary from hardware technological
improvements. The ICT sector must step up its efforts in reducing its direct footprint in order to claim a leadership role in an 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.

III. **Information and communication technologies (ICTs)**

Recently, ICT has become a critical player in progress towards an efficient and low carbon economy. It is being expanded beyond mere production of green products. Figure 1 explains the scope of the study based on computing devices, data centers and communication networks which are considered a part of ICTs sector, while TVs set, top boxes and printers are out of the ICTs scope.

![Figure 1. Scope of study categorized by computing devices, data centers and communication networks](image1)

**IV. Sustainable technologies**

Sustainable ICTs are technologies that are designed and improved based on environmental philosophy and ecological intelligence. The design of such technologies involves adopting decarbonization strategy in both manufacturing processes and product design, reducing carbon and other GHG emission and using sustainable measures. Dematerialization is defined as shifting the mode of consumption from product ownership to services.

**V. Energy and economy**

Energy has been a concern for all economies and societies. According to International Energy Agency (IEA), the total emissions from human activity in 2008, 34% was from the power sector, 33% from industry, 27% from agriculture and waste management, 24% from land use, 24% from transport and 18% from buildings. 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]](image2)
5.1. Rebound Effect and Energy as an Effective Measure

In the context of ICT, when increasing energy efficiency gains rebound effect occurs. To better explain this, a more energy efficient ICT product or service would require less energy to produce. 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]:

$$R = 1 - \frac{\text{actual energy savings}}{\text{potential energy savings}}$$

(1)

The potential energy savings are estimated under the assumption that there are no behavioural responses to the efficiency improvement, while actual energy savings are measured or estimated ex-post and include one or more of the behavioural responses. So, for example, a rebound effect of 20% (R=0.2) means that one fifth of the potential energy savings have been ‘taken back’ by one or more of the above responses [8].

5.2. Econometric Model

This section constructs the econometric model to investigate the impact of ICT development on energy productivity [9]:

$$\text{MEPICM}_i = \beta_0 \text{MEPICM}_{i-1} + \beta_1 \ln \text{ICT}_i + \beta_2 \ln \text{HC}_i + \beta_3 \ln \text{EI}_i + \beta_4 \ln \text{INVEST}_i + \beta_5 \ln \text{GOV}_i + \beta_6 \ln \text{TRADE}_i + \beta_7 \ln \text{FDI}_i + \beta_8 \ln \text{INDUSTRY}_i + (\alpha_i + \nu_{it})$$

(2)

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

$$\text{ICT}_{it} = \text{PAT}_{it} + (1-\delta) \text{ICT}_{it-1}$$

(3)

where ICT$_{it}$ denotes the knowledge stock of ICT in economy i at year t and PAT$_{it}$ denotes the patent application number.

**Table 1. Descriptive statistics [10]**

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

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

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

6.2. GHG Emission Reductions from Industrial Processes

The climate group (2008) estimates that, by 2020, 10% of China’s GHG emissions will come from motor systems alone. An improvement of industrial efficiency would deliver 200 Million ton of Carbon Dioxide Equivalent (MtCO₂e) savings as shown in Table 2.

<table>
<thead>
<tr>
<th>Table.2. GHG emission reductions from industrial processes [12].</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline GHG emissions 2030 MtCO₂e</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>OECD countries</td>
</tr>
<tr>
<td>Economies in transition</td>
</tr>
<tr>
<td>Developing nations</td>
</tr>
<tr>
<td>Global</td>
</tr>
</tbody>
</table>

6.3. ICT direct footprint

Decarbonization strategy is utilized to reduce the footprint of ICT sector. According to Forum for the Future (FF 2006) [13], the effects of ICT on climate change are of three types: direct, indirect, and systemic. The direct effects of ICT impact on climate change and related to the GHG emissions that result from the energy used to produce materials, operate facilities, transport goods, provide services. The indirect effects arise from the use and application of ICT throughout the economy and society. The ICT impact on climate change derives from the GHG emissions resulting from the energy required to power and cool data centers and network devices. The systemic effects are created by the aggregated effects of large numbers or groups of people using ICT over the medium to long term.

6.4. ICT Product Life Cycle

- Direct effects

The total footprint of the ICT sector, including (PCs), telecoms networks, devices and data centers, was 830 MtCO₂e. In 2002, the combined carbon footprint of PC and monitors was 200 MtCO₂e and this is expected to triple by 2020 to 600 MtCO₂e (GeSI 2008). The ICT industry own carbon emissions are expected to
increase, under Business-As-Usual (BAU) scenario, from 0.53 Giga ton of Carbon Dioxide Equivalent (GtCo$_2$e) in 2002 to 1.43 GtCo$_2$e in 2020. In developed countries, the total electricity demand consumed by ICT is between 5% and 10% which contributes with 1%- 3% to worldwide CO$_2$ emissions. One recent report estimates that direct effects of ICT provision account for 20% of ICT generated GHG emissions. Table 3 describe the direct impact assumptions on PCs, telecom devices, telecom networks and data centers.

### Table 3. The direct impact assumptions [14].

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Market growth and penetration of device to 2020</th>
<th>Constituting elements</th>
<th>Power consumption</th>
<th>Embodied carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCs</td>
<td>• Assumed 20% of desktops are workstations</td>
<td>• Desktops, laptops, CRT, LCD for PCs (CRT assumed to decrease to 0% in 2020)</td>
<td>• Workstations consume 2.5 times desktop in all modes, commercial usage: 14 hours/day, consumer usage: three hours/day, desktop standby achieves 15W</td>
<td>• Figures assessed based on European Commission DG TREN, EuP preparatory study, TREN/D1/40-2005</td>
</tr>
<tr>
<td>Telecoms devices</td>
<td>• Yankee user connections for broadband and mobile up to 2011, historic trends up to 2020</td>
<td>• Mobile penetration capped for 2020 to 0.92 (US penetration)</td>
<td>• Mobile phones • Charging phone 0.5 kWh • Standby charging 13 kWh • IPTV rating: 25W Active 40% of rated standby 20% of rated three hours of active TV usage, rest of the time in standby</td>
<td>• Embodied carbon from sustainable energy use in mobile communications</td>
</tr>
<tr>
<td>Telecoms networks</td>
<td>• Yankee user connection for fixed, mobile, broadband up to 2011, historic growth up to 2020</td>
<td>• Fixed-line • Mobile • Broadband • Cable operators (broadband only)</td>
<td>• Mobile embodied carbon from sustainable energy use in mobile communications</td>
<td>• Embodied carbon from sustainable energy use in mobile communications</td>
</tr>
<tr>
<td>Data centers</td>
<td>• For each server type IDC data up to 2011 for sales. Projected global 2002 installed base according to sales</td>
<td>• Three kinds of servers; and data storage units.</td>
<td>• Three types of servers: 200, 500, 6000W/unit • Doubled power consumption of servers to assess cooling and power equipment</td>
<td>• Assumed 4% of total data center life cycle analysis (LCA) footprint: life cycle assessment for an internet data center, NEC</td>
</tr>
</tbody>
</table>

- **Indirect effects**
  A recent report estimated that indirect effects might account for 80% of ICT generated GHG emissions. A single Google search consumes high energy. The actual power consumed by each processor which varies with its computing power and memory is around 265 W and cooling overhead adds another 135 W. The microprocessor consumes 46% of the total power. As estimation, ICT will be responsible for 3% of global emissions by 2020. The initial power requirements of Internet hardware were overestimated by more than a factor 10. Moreover, the complex ICT infrastructure requires a reliable power supply to install huge systems 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 growth continues in line with demand, the world will be using 122 million servers in 2020, up from 18 million today (GeSI 2008). This is expected to increase more than triple by 2020 to 259 MtCo$_2$e making it the fastest growing contributor to the ICT sector carbon footprint. At this point, volume servers will represent more than 50% of the data centre footprint (174 MtCo$_2$e) and cooling systems alone will amount to 4% of the total ICT footprint. Data centers are considered to be the hungriest energy users and the great generators of GHG emissions. This is a flaw owing to the design faults of ICT equipment with regard to energy usage. The energy consumption in data centers has become an issue because of high electricity costs and problems with power supply capacity. A Swiss study shows that the connection power of data centers is between 20 and 40 MW. In terms of national consumption, UK had total electricity generating
capacity of some 77.4 GW in 2005–2006. The UK has around 1,500 data centers. The largest data centers may consume directly between 7 and 14 MW each, perhaps on average some 10 MW. They account for about a quarter of ICT emissions and 2–3% of the UK total electricity capacity. Standby losses may increase dramatically in the future due to the general trend of interconnecting different types of ICT equipment and services [15]

- **Reducing the footprint of data centers**
  Sustainable ICT design entails producing low energy consumption. Direct attention should be given to the ICT product design stage to how to avoid carbon emissions. It is quite conceivable that new interface, more energy efficient devices such as the Apple iTouch or the RIM Blackberry can be solar powered or use human body movement for their energy sources. Green ICT is about adding the green concept to ICT design and production basis by cutting energy consumption and thus reducing carbon emissions to alleviate global warming, for example, solid state hard drives which could reduce energy consumption by up to 50%, choleristic, LCD screens that reduce monitor energy consumption by up to 80% and direct methanol fuel cells that can deliver 20% savings for power supplies. Moreover, for green grid data center efficiency metrics, solutions are diverse but the data center infrastructure efficiency (DCiE) and the power usage effectiveness (PUE) are considered two of the most effective solutions as metrics to quantify improvements in the data center. They can help operators to improve efficiency and reduce costs.

6.6. **Energy Use of Telecommunications Devices and Infrastructure**

As a part of ICT industry, telecommunication devices and infrastructure have also a visible footprint. The energy demands typically account for over 70–90% of a telecommunications company total energy use. The telecommunications footprint will represent a smaller share of the total ICT carbon footprint in 2020 because efficiency measures will balance growth and data centers will rise to take a larger share of the total. The telecommunication devices global footprint was 18 MtCO\(_2\)e in 2002 and is expected to increase almost threefold to 51 MtCO\(_2\)e by 2020, driven mainly by rises in the use of broadband routers and internet protocol television (IPTV) boxes. Similarly, the telecommunication infrastructure footprint was 133 MtCO\(_2\)e in 2002 and this is expected to more than double to 299 MtCO\(_2\)e by 2020. Indeed, there were 1.1 billion mobile accounts in 2002 and this is set to increase to 4.8 billion in 2020 and is the largest source of global telecommunication footprint emissions. The growth in telecommunication emissions has grown from 150 MtCO\(_2\)e in 2002 to 300 MtCO\(_2\)e in 2007 and is expected to reach 350 MtCO\(_2\)e in 2020 as shown in figure 5.

![Figure 5. Global telecoms footprint (devices and infrastructure)](image)

- **Reducing the footprint of telecommunication devices:** The green ICT design is intended to substantially cut energy consumption and thus reduce emissions to alleviate global warming. Technological innovations in power consumption reductions from smart chargers and standby modes will certainly contribute to reduction of mobile phones footprint. The footprint of telecommunication devices can be reduced further if devices produce fewer emissions in manufacturing, or if greener electricity is used by the device during its lifetime.
Reducing the footprint of telecommunication infrastructure: The increased demand for telecommunication services which inevitably would lead to more energy use and thus concomitant GHG emissions. Mobile infrastructure technologies currently available include network optimization packages which can reduce energy consumption by 44%. Night battery operation which can reduce energy consumption by 50% reduction in energy consumption. Adoption of such measures will enable telecommunication companies to plan for significant energy efficiency improvement.

6.7. The Role of ICT in Enabling an Energy Efficient and Low Carbon Economy
The ICT enabled solutions would make possible savings of 1 ton per capita in 2020.

Dematerialization, energy and material savings: Dematerialization could play a significant role in cutting energy consumption and thus mitigating carbon emissions at many levels. The potential of dematerialization to reduce carbon footprint is substantial because of the spectrum of the associated technologies that include as diverse areas as economic, social, public, and private. Certain products and services such as bills, music, books, documents, and newspapers can be entirely digitized and transported over the internet. New ICT applications in e commerce, e government, e health, and other social e communities have been proven to significantly impact on reducing GHG emissions [17].

Tele-working and Videoconferencing: Tele-working has been ranked as the largest identified opportunity where ICT has the potential to reduce GHG emissions. The reason why teleworking technology is of import is because it is related to transportation one of the economic sectors that contribute significantly to global warming. According to IEA, transportation is a large and growing emitter of GHG, responsible for 14% of global emissions. Flexi-working and teleconferencing are positively impacting the environment, if 10% of the EU workforce were to become flexi–workers, this could save 22.17 million tons of CO\textsubscript{2} a year. Likewise, if up to 30 million people in the US could work from home, carbon emissions could be reduced by 75–100 MtCO\textsubscript{2}e in 2030. The same argument goes for teleconferencing saying that by substituting personal meetings by teleconferences travelling 63% of energy can be reduced. If 20% of business travel in the EU was replaced by video conferencing, this would save 22.3 million tons of CO\textsubscript{2}. The key way that ICT can contribute to sustainable development is that working ‘down the wire’, holds out the prospect of people moving less. As digital communications improve, people will increasingly be able to experience ‘being there’ without having to move. Through using voice over IP (VoIP), videoconferencing capabilities can help to reduce the GHG emissions by replacing business travel and daily commutes with services. Commuting accounts for around 20% of all miles travelled. Table 4 shows the value added produced by industry from 2008 to 2020.

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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Services Producing</td>
<td>$10380</td>
<td>$10489</td>
<td>$11019</td>
<td>$11480</td>
<td>$12384</td>
<td>$13127</td>
<td>$13914</td>
</tr>
<tr>
<td>Private Goods-Producing</td>
<td>$3166</td>
<td>$2979</td>
<td>$3019</td>
<td>$3202</td>
<td>$3327</td>
<td>$3526</td>
<td>$3738</td>
</tr>
<tr>
<td>ICT-Producing</td>
<td>$835</td>
<td>$913</td>
<td>$985</td>
<td>$1113</td>
<td>$1480</td>
<td>$1568</td>
<td>$1745</td>
</tr>
</tbody>
</table>

VII. Conclusion and future directions
The principal aim of this paper is to highlight the role ICT sector in the transition and progress towards an efficient, low carbon economy. But, rebound effects and other hurdles might be stumbling blocks to the realization of the full potential of the projected gains. The research that has been published in energy policy suggests that converting the entire world to 100% sustainable energy by 2030 are both possible and affordable, but requires a political support. It is observed that the total amount of CO\textsubscript{2} emissions from the ICT industry could amount to 2% of global carbon emissions. At the same time, ICT applications are acknowledged to be the tool for the global environmental protection strategy and they present a huge potential to improve performance across the economy and society, as it concerns the remaining 97- 98%.

References