Digital Sufficiency: One Step Closer to Sustainable Computing

Nicolas Tirel
Universite de Pau et des Pays de l'Adour, E2S UPPA, LIUPPA
Anglet, France
I3A, Universidad de Zaragoza
Zaragoza, Spain
nicolas.tirel@univ-pau.fr, 922295@unizar.es

Philippe Roose
Universite de Pau et des Pays de l'Adour, E2S UPPA, LIUPPA
Anglet, France
philippe.roose@iutbayonne.univ-pau.fr

Ilarri Sergio
I3A, Universidad de Zaragoza
Zaragoza, Spain
silarri@unizar.es

Adel Noureddine
Universite de Pau et des Pays de l'Adour, E2S UPPA, LIUPPA
Pau, France
adel.noureddine@univ-pau.fr

Olivier Le Goaër
Universite de Pau et des Pays de l'Adour, E2S UPPA, LIUPPA
Pau, France
olivier.legoaer@univ-pau.fr

***Abstract*—The ICT sector has seen many improvements in productivity and efficiency in the past decades. However, its total energy consumed, as well as its carbon emissions, has never decreased. This is mostly due to a systemic phenomenon called the rebound effect: although each process consumes less energy, the global increase in process usage results in an unexpected growth in carbon emissions. In this paper, we present energy-efficient techniques and we argue why it is necessary to combine efficiency with a new approach. This novel approach is digital sufficiency, involving users and developers to reduce the demand in addition to efficiency improvements.**

***Index Terms*—Digital Sufficiency, Climate Change, Sustainable Computing**

I. Introduction

Anthropogenic climate change fueled by the emissions of greenhouse gases such as carbon dioxide is a threat to human well-being and planetary health [5]. A recent report shared that there is a 50% likelihood to reach a 1.5°C increase above the 1850–1900 average if we emit at least 200 Gigatonnes of CO_2 (Gt CO_2) after 2024 [2]. It will be achieved by 2029 at the current emission level.

The Information and Communication Technology (ICT) sector plays a major role in carbon emission, as we burn fossil fuels and emit carbon dioxide throughout the whole lifecycle of digital equipment and services. New digital services (Artificial Intelligence, blockchain, IoT, etc.) are likely to boost demand and increase carbon emissions in the next few years. In this paper, we argue in favor of sufficiency techniques, which aim to reduce this demand. Our purpose is to provide an overview of the following points:

- Limitations of energy efficiency techniques to reduce carbon emissions.
- Challenges to apply digital sufficiency.
- Examples of digital sufficiency.

The concept of sufficiency was introduced in the latest Intergovernmental Panel on Climate Change (IPCC) reports [5], and then adapted by Santarius et al. in the ICT sector as digital sufficiency [10]. Santarius et al. defined digital sufficiency as 'any strategy aimed at directly or indirectly decreasing the absolute level of resource and energy demand from the production or application of ICT'.

II. Limitations in energy efficiency improvements

Many improvements in energy efficiency have been achieved in the past decades [1], [6]. At the software level, we can mention the use of virtualization, workload balancing through virtual machine placement and consolidation, data management strategies to optimize data placement. At the hardware level, we can consider the use of low-power processors, dedicated energy-saving architectures such as Field-programmable Gate Arrays (FPGA), and accelerators such as Graphic Process Units (GPU). At the data center level, we can consider improvements in cooling methods to reduce the heat generated by devices with air-conditioning, free cooling, and liquid cooling.

These combined techniques have certainly helped to limit the increase in electricity consumption. However, according to Freitag et al. [3], carbon emissions from the ICT sector have always increased to reach 1.8%-3.9% of global carbon emissions in 2021. This increase is explained by phenomenons called rebound effects. Rebound effects are different that appear when the efficiency of devices is improved, but the demand is increasing faster in number of users and the variety of usages [7]. For instance, data centers are more efficient, and the energy used to compute a workload is lower, but as the Internet traffic has grown faster, the overall energy consumption has increased. Eventually, the best evaluation of

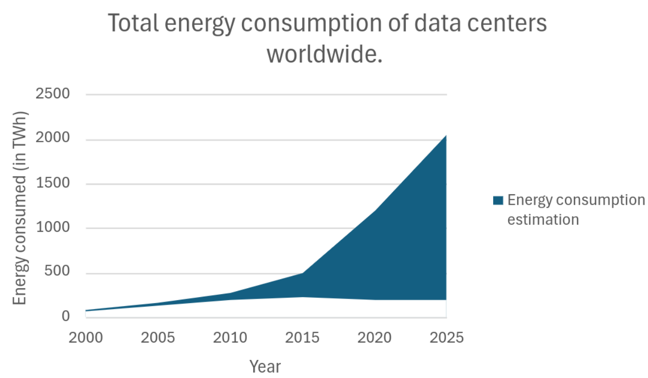

Fig. 1. Trends in the energy consumed by data centers worldwide.

the energy consumed by data centers in 2025 is estimated around 200 TWh, in the worst evaluation it is estimated at 2040 TWh [8]. Trends in energy efficiency of data centers in this century are illustrated in Figure 1.

III. Challenges

We identified three main challenges to reducing demand. Systematic assessments of the coming demand by researchers and companies are necessary. In addition, a common method to assess carbon emissions is also a necessity to provide good information to users. Finally, sufficiency techniques need to involve users by sharing understandable metrics.

A. Assess the demand

Santarius et al. identified in [10] that current studies on sustainability do not include a proposal to reduce direct or indirect rebound effects. In addition, improving the efficiency of the services solutions share a narrative that technology improvements will be sufficient to reduce carbon emissions, without the need to reduce the demand [3]. Given the lack of consideration for assessing coming demand [12], reducing demand is one of the main challenges for sufficiency techniques.

B. Assess carbon emissions

To assess carbon emissions of the ICT sector, it is possible to use life cycle assessments (LCA), protocols (e.g., the Greenhouse Gas protocol), and measurement tools (like Intel RAPL, or power meters). Freitag et al. used an example to describe this complexity with the example of 'truncation error' [3]: the partial exclusion of supply chain pathways leads to underestimation of the carbon footprint of ICT. There is currently no obligation for companies to use a common assessment method, nor is there an obligation to share information on carbon emissions resulting from the use of IT equipment.

C. Involve the user

Current limitation to raise awareness of good behavior is sharing good information with users and suggest alternatives. Most users are unaware of carbon emissions from their digital services. Feedbacks to users must be systematic, accompanied by alternative solutions to compute their workloads. Noureddine et al. found that users may be discouraged if they cannot change their behavior knowing it is wrong [9].

IV. Examples

There are various ways to implement sufficiency techniques. An example is space and time workload shifting. These concepts include a set of solutions to deploy workloads where and when renewable energy is available, with a negligible impact on the quality of service provided to the users [13]. Another example is the development of a toolkit to guide sufficiency for edge computing proposed by Toczé and Nadjm [11]. The toolkit includes the identification and analyze of the resources involved in a project, and questioning and challenging demand and the level of a satisfying service. To address rebound effects, Widdicks et al. proposed to keep constraints on emissions for ICT environmental savings in digital innovation [12]. Within constraints in total emissions, every resources saving cannot be used to compute other workloads.

To involve users in changing their behavior, Noureddine et al. proposed three techniques inspired by the building sector [9]: social interactions (comparing users' energy consumption), gamification (involving people emotionally with interactive games), and eco-feedback (providing energy consumption indicators to users). Labels like energy scores are good ways to influence users' choices towards energy-efficient products. Guyon et al. proposed their own ecolabel 'GLENDA' (Green Label towards Energy proportioNality for IaaS DAta centers), combining Power Usage Effectiveness (PUE) and Green Energy Coefficient (GEC) to push cloud providers to do more for greener data centers and helping energy-conscious users to choose among cloud providers [4].

V. Conclusion

We reviewed some energy efficiency solutions implemented over the last few decades and their limitations to reduce carbon emissions. In particular, we identified the need to implement sufficiency techniques aiming at reducing demand and limiting rebound effects. Implementing digital sufficiency techniques faces several challenges: the complexity of assessing the IT demand and the carbon footprint of digital services, the lack of consideration for rebound effects in current literature, and an absence of coordinated action to push people to apply sufficiency. To enable the use of sufficiency techniques, we support the need to develop and use monitoring tools with understandable metrics to raise awareness of end-users and developers, and to involve users with positive feedback. Suitable data management techniques are needed to help people to make decisions. As this decade is crucial for tackling climate change, we argue the urgency to adopt a 'sufficiency' approach with appropriate actions and policies.

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