Tools for Calculating the ICT Footprint of Organisations: Adaptation of a European Study

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Abstract. In the face of global warming caused by greenhouse gas (GHG) emissions, the IT industry is responsible for 3–4% of global carbon dioxide emissions. Organisations aiming for a green IT strategy need to do more than just improve their environmental impact. Carbon footprinting is a valuable decision support tool that allows organisations to measure and communicate the environmental impact of their activities. To do this, they need tools that can calculate, track and report their greenhouse gas emissions and guide actions to reduce and offset these emissions. The aim of this article is to present a specific tool for calculating an organisation's digital carbon footprint, called WeNR Light. It is directly based on the WeNR2021 study.

Keywords: Sustainable Information Systems · carbon footprint calculator · individual actions · Green Computing · eco-responsible · ecological impact · sustainable development · energy consumption

1 Introduction

Firstly, one of the biggest challenges facing the world today is climate change, because of its impact on people and the environment. In the 1970s, governments around the world became aware of the need to address sustainable development. In 1983, the World Commission on Environment and Development (WCED) took on the mission of uniting nations in the pursuit of sustainable development and popularised the term "sustainable development" with the publication of the Brundtland Report [6]. Since the Rio Declaration, Agenda 21 and the United Nations Framework Convention on Climate Change, society has become more sensitive to the environment, including greenhouse gases (GHGs). Later, in 2015, the 2030 Agenda for Sustainable Development (United Nations, 2015) proposed a set of 17 Sustainable Development Goals (SDGs) to be achieved by 2030, including SDG13 (Climate Action - Acting Urgently to Combat Climate

M. Papadaki et al. (Eds.): EMCIS 2022, LNBIP 464, pp. 277–290, 2023.
https://doi.org/10.1007/978-3-031-30694-5_21

Change and its Impacts). More recently, in 2019, the European Commission (EC) proposed the European Green Deal, which includes 50 specific actions to combat climate change, with the aim of making Europe the first climate neutral continent by 2050 [3].

In addition, the main factor contributing to climate change is global warming, which is measured by the concentration of greenhouse gas (GHG) emissions released into the atmosphere. For organisations seeking to achieve their climate neutrality goals, the first step is to determine their current environmental performance in terms of their carbon footprint (CF) [19]. Then, based on an analysis of the current situation, organisations can propose action plans to reduce or even offset their GHG emissions [26]. The most important regulatory framework for accounting for greenhouse gas emissions is the Greenhouse Gas Protocol (2004), which defines the carbon footprint as the total quantity of greenhouse gas emissions, generally expressed in carbon dioxide equivalents (CO2e), resulting directly or indirectly from an organisation's activities [27].

This is why the concept of sustainable computing has gained new media visibility in recent months due to the increasing place of digital technology in our lives and activities [18], and the growing awareness of the role of human activity in global warming. On the intangible side, the IT sector (all sectors combined) now accounts for nearly 4% of global GHG emissions. Thus, climate change and sustainable development must be taken into account in all areas [29].

In summary, organisations, as the main users of digital technologies [25], must play an important role in the convergence of climate and social emergencies and technological transformation. To reach the awareness phase of the digital environment and social impact, we need to move to the next phase: the measurement phase. Indeed, as long as measurement is not at the heart of management, organisations will blindly experiment and fail to act on the critical levers. To remedy this, and as a direct legacy of the WeGreenIT work published by WWF in 2018. ISIT (Institute for Sustainable IT) in France, Switzerland and Belgium has conducted the only free study to measure the quantitative and qualitative footprint of information systems, WeNR 2021.

The WeNR method allows everyone to use a simplified process to assess the carbon footprint of their IT assets. The work of collecting and compiling the data sources and assessing the reliability of the values is carried out by a team of WeNR engineers with the aim of disseminating a common reference framework within the community. In this respect, WeNR is a big step forward [28].

However, data collection for those who wish to participate in the work can be complicated. For example, the amount of refrigerant gas injected into the chiller each year, the total power consumption of the server room, is often difficult to obtain. This difficulty should not be an obstacle to participation in the WeNR process.

To remedy this problem, the WeNR Light was born. The WeNR Light version is a much lighter version replacing the long questionnaire with a much smaller one of about ten questions to be filled in directly on the site and allowing a quick result of the equivalent number of kilograms of CO_2 that an employee produces per year for an organisation. However, there is an uncertainty rate close to 10–15%.

We will begin this article by detailing the general WeNR 2021 study that was used and its main results, drawing conclusions and strategies for recommendations. We will then show the declination of the WeNR tool into a lighter version, WeNR Light, and the conclusions that can be drawn from it, discussing them at the end of the article.

2 Study WeNR

In this chapter we present the results of the WeNR2021 study, which we will use to create our WeNR Light tool from the same database.

2.1 Presentation of the Sample

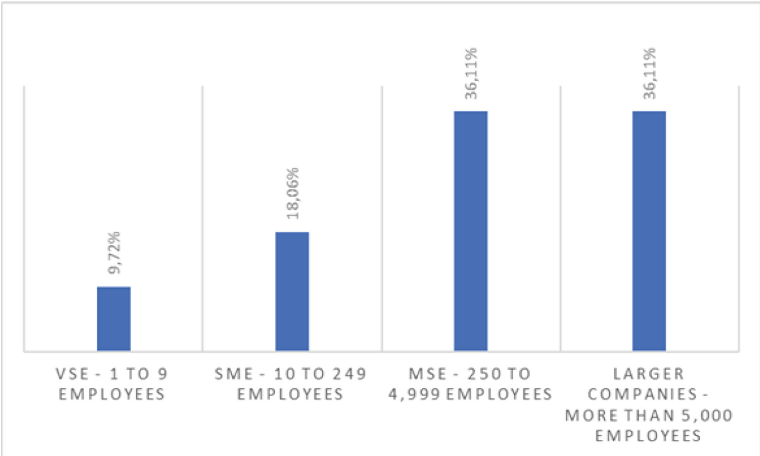

Fig. 1. Firms distribution by size.

The sample studied represents 62 French (82%), 9 Belgian (11%) and Swiss 4 (7%) companies, for a total of 1,309,604 jobs, distributed among different sizes of companies: VSEs (10%), SMEs (18%), MSEs (36%), and LMEs (36%). The companies in the sample are established in different sectors of activity (other specialized, scientific and technical activities: 26%; public administration: 23%; financial and insurance activities: 12%; production and distribution of electricity, gas, steam and water: 7%; transport and warehousing: 7%; administrative and support service activities: 6%; trade, repair of motor vehicles and motorcycles: 6%; other: 4%; legal, accounting, management, architectural, engineering, controlling, and technical analysis activities: 4%; real estate activities: 3%; and manufacture of food products, beverages, and tobacco products: 1%), either in the public domain (27%) or in the private domain (74%) (Fig. 1).

3 Interpretation

We will detail the different interpretations that can be made of the results of the study.

Facts
The main number to remember is the digital carbon footprint of a European employee which represents 265 kg CO2e per year (220 working days). It would take the planting of 66 trees per year to offset it.

Focus on Equipment
First of all, for the distribution of GHGs by equipment area, in their life cycle, the manufacturing of office equipment is responsible for 77% of the GHG emissions of the organizations participating in the study. Overall, nearly 90% of GHG emissions come from manufacturing (office equipment and data centers combined) [24].

Otherwise, 7% of the office equipment of the organizations studied is purchased reconditioned. This is a significant area of improvement for organizations wishing to reduce their environmental footprint. After use within the organization, an average of 34% of office equipment is reconditioned or given a second life. This is also a lever for improvement to reduce the environmental impact of an IT asset.

In terms of lifespan, monitors and network equipment stand out with a lifespan of 7 years. In the study, smartphones and tablets have a lifespan of 4 years (global average of 18 to 36 months depending on the country), which shows that organizations are committed to extending the lifespan of their equipment. The longevity of equipment is a very encouraging sign that needs to become more widespread. To continue their efforts, organizations that are already well on their way to a digitally responsible approach can implement key best practices such as equipment repurposing and reuse. This exercise can significantly reduce the environmental footprint of the Information System.

Focus on Maturity
Regarding maturity, the participating entities demonstrate maturity on the subject of responsible digital with an average score of 59%. Digital responsibility is expanding and moving out of the environment of expert organizations, which are already far ahead on the subject. Less mature entities are taking up the issue and are seeking to evaluate the footprint of their information systems from the very beginning of their DR approach. The democratization of the deployment of Green Procurement approaches and the ability of organizations of all sizes to work to implement good practices to reduce the social and environmental footprint of their Information System play a determining role and is very encouraging [7].

Recommendations
The recommendations that we can make are:

- Develop a Sustainable IT Strategy

Develop a responsible digital strategy based on measuring the environmental footprint of the Information System with WeNR. The deployment of the NR approach allows for a 10 to 20% reduction in the environmental impact of the information system [5].

– Extend the life of equipment

From the moment of purchase, select equipment that is easy to repair and to upgrade within the organization or outside: second life, reconditioning... It is essential to extend the life of equipment to reduce its environmental footprint.

– Eco-design of digital services

While the environmental footprint of equipment is essentially a result of manufacturing, usage will have a direct impact on its lifespan. Thus, designing digital services that are more virtuous from an environmental, social and economic point of view will have a direct impact on the quantity of equipment consumed by the organization [2].

4 WeNR Light Application

In this section, we will describe how we have adapted the WeNR 2021 study into the WeNR Light online tool:

4.1 Goal

The Carbon Footprint Estimator combines a data model with a user interface. It allows people to measure their carbon emissions and track methods to reduce them. It is called an online estimator because it exists online. Self-management is about measuring your carbon footprint or taking action to minimise it. Many estimators are available for public and private use to measure carbon footprints or emissions. This is to provide users with the ability to manage their own habits [1].

To use the information effectively, it must be relevant to the employee's daily activities. When collecting information, professionals need to consider the context - in particular, carbon footprint calculators can be useful tools for decision-makers to understand climate change and raise environmental awareness. Acquiring information in this way is particularly effective when the information comes from a professional context [4].

While there is some literature on personal carbon footprint calculators in everyday contexts as we can see in Table 1, there is no research on specific tools for professional contexts. This paper attempts to initiate and track greenhouse gas emission reductions from the WeNR2021 study by providing an open source carbon footprint calculator relevant to a professional domain to quickly measure carbon impacts within an organization and drive action. The National Climate Action Simulator (NGC) was chosen as a solid foundation for business applications. The data model is based on the WeNR2021 study and the scope is limited to ICT [8].

Table 1. Comparison of carbon footprint Calculator.

Name	Accessibility	Scalability	Broad scope of application
Carbon Footprint (CF, 2020)	●●●	●	●●●
Carbon Fund (CFund, 2021)	●●	●●	●●
Cool climate (CoolCalifornia, 2021; Simpson, 2009)	●●	●	●●
GHG Protocol Calculator (GHG Protocol, 2021)	●	●	●●●
myclimate (Foundation myclimate, 2021)	●●●	●●	●●
Simple Carbon Calculator (National Energy Foundation, 2017)	●●●	●●	●●
Simplified GHG Emissions Calculator (SGEC, 2020)	●●●	●●	●●●
Terrapass Calculator (Terrapass, 2021)	●●●	●	●●
CA-CP (CA-CP, 2020)	●●	●●	●●
SIMAP (SIMAP, 2020)	●	●●	●●

The objective of the calculator is to enable users to identify the main sources of ICT-related emissions. Special focus on user engagement and adoption. One of the issues addressed in this article is to make users feel guilty and increase positive influence by providing social comparisons and contextual suggestions.

4.2 Source Release

The French non-profit ABC has created a calculator called Nos Gestes Climat en 2020. It was inspired by a calculator created in 2010 by ADEME, a French public agency. In addition to the inspiration, Nos Gestes Climat also received input from Avenir Climatique, a French NGO dedicated to improving carbon accounting and the transition to a low-carbon society. The final product was published as an open-source application and supported by ADEME and the beta.gouv.fr incubator. NGC was created with Avenir Climatique and ADEME as advisors. They worked on a project to facilitate access to carbon footprint information, as well as on the need to transform awareness into active engagement. Many people, organisations and institutions are discussing climate change and a low carbon transition. This includes schools, businesses, governments and even families. Until recently, the public had access to climate information, including emission factors, via an online database maintained by ADEME, but it was difficult for non-specialists to use [1].

"Nos Gestes Climat" is a fork of the futur.eco project (copied from the code, then modified to serve another purpose), which is itself a fork of mon-entreprise.fr (my-company.fr), mon-entreprise.fr (my-company.fr) is produced by the French public service incubator beta.gouv.fr and URSSAF. This forked chain shows an interest in open source code for public services, where working on professional fields (social contributions) allows working on very different subjects. This success prompted the my-company team to outsource the core of the project to the TypeScript publi.codes library, which allows users to write public interest models in a new French programming language, and expose these algorithms as well as simple tables to collect. The necessary input goes directly to the web page. Models developed using public.codes can be fully documented in the web application itself. In UCS, users can easily access the account details [1].

NGC is divided into two code bases, the user interface and the data model represented by a yaml file. The model repository is where contributions are mainly made by the Datagir and ABC teams, but also includes anyone who finds bugs, has problems or wants to incorporate better local models. The use of publi.codes ensures that template updates automatically update end-user forms without any additional effort from the developer [9].

Since the first deployment of the project in June 2020, over 600 issues have been resolved or prioritised in the GitHub repository, which also includes the UCS roadmap and detailed release notes [22]. The user interface itself is coded in Javascript/Typescript and is rapidly evolving to help users understand their footprints in an interactive, mobile and graphical way, and easily share their results on social networks to engage in conversations to move away from changes in personal social debate at the level and want action at the political level. The user experience of the form follows the design principle that there should only be one question on the screen at a time (even in desktop mode), rather than the traditional collection of 10+ entries on a single page. Questions are grouped by consumer category, which also allows users to pause between sets of questions [17].

4.3 Advantages of the Organisational Design Tool

We chose the source version because it is faster than implementing and deploying from scratch. The final open source version will be made available on the GitHub platform so that future development can take place within other organisations [14].

The second advantage of WeNR light is the way users are engaged. User engagement is essential to ensure that the carbon footprint estimates via the calculator have an impact on user habits. Features such as simulation speed, interface and user-specific recommendations are carefully considered in the variants.

4.4 Designing the Declination

In order to build the declination, we chose to take the data from the WeNR study and we clustered them in order to have several possible scenarios, i.e. several homogeneous groups. Once this cluster was created, we performed a multivariate linear regression to give a weight to each question. The "our climate actions" tool enabled us to implement this method.

The image below represents the clustering into several homogeneous groups of organisations:

4.5 Implementation

The image below shows how the WeNR2021 study and its offshoot, the WeNR Light, have been implemented (Figs. 2 and 3):

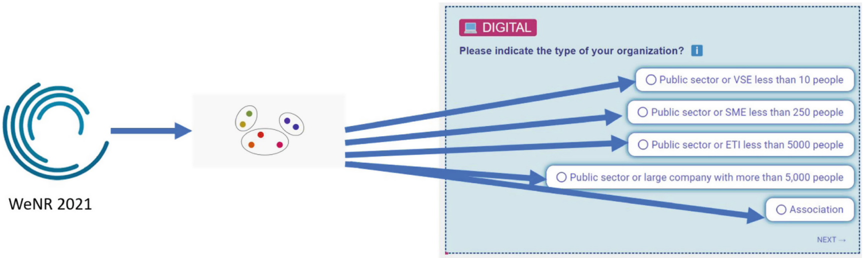

Fig. 2. Grouping of WeNR data by organisation type.

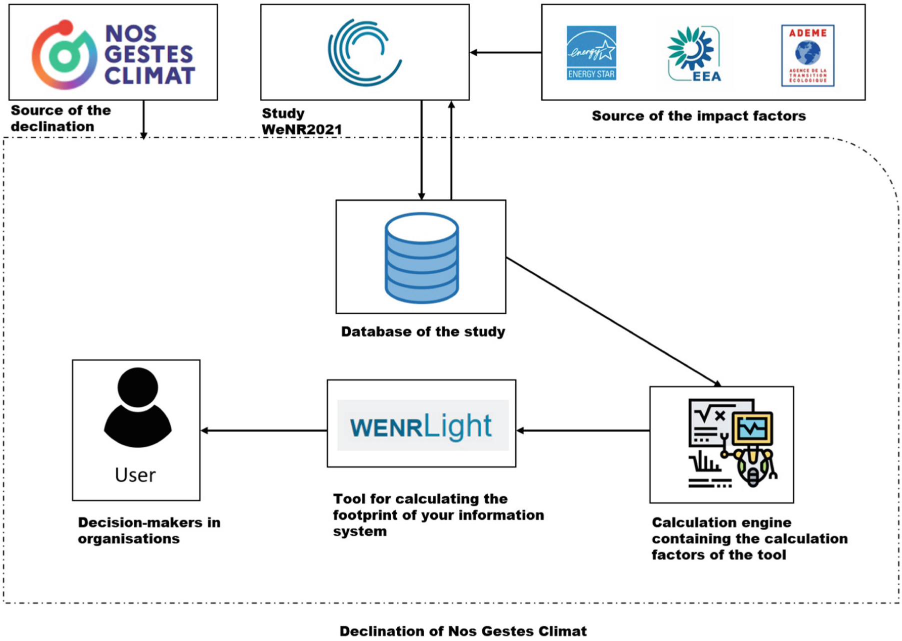

Fig. 3. Overall operation of the tool.

Unlike other calculators, WeNRLight is based on a mathematical model of the WeNR 2021 study that is a mutlivariate linear regression on multiple groups of data in order to simplify the WeNR model, allowing us to obtain the most accurate results possible by limiting the number of questions asked.

5 Achievement

We will describe the implementation of the WeNR Light, we will find the list of the 9 questions we have to answer and the information, if the decision maker does not have any values, a default one is proposed. These default answers are an average that represents the type of organisation (Fig. 4).

Fig. 4. Home page.

In order, the most relevant questions extracted from the WeNR study are

- The number of staff in your organisation,
- The number of laptops,
- The number of desktop computers,
- The number of screens,
- The number of computer accessories (mouse, keyboard, docking stations, etc.),
- The number of mobile phones,
- The number of printers (printer/copier, copier, etc.),
- The number of physical servers deployed in your organisation.

The first thing to do is to click on the START button to begin the questionnaire.

For the questions, we have to choose the corresponding answer among the six proposals. Ergonomics being very important to guide the decision-makers, the small information logo represented by an i in white on a blue background. We will then have a frame appearing in the foreground with an explanatory text on the definitions (Figs. 5 and 6).

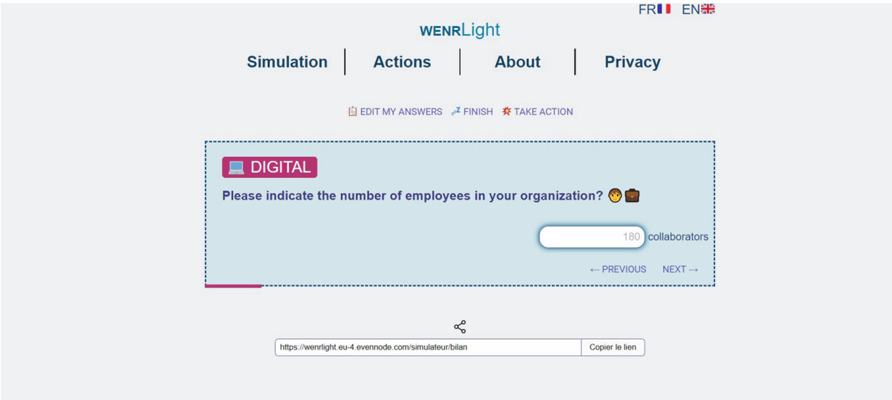

Fig. 5. Example of questions.

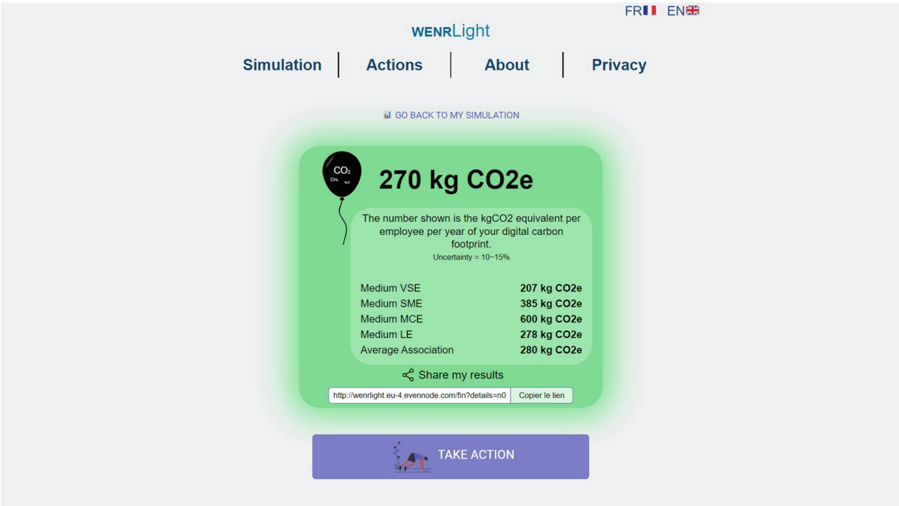

Fig. 6. End page.

The second most important page of the site, it allows us to have our equivalent consumption of kilograms of CO_2 per employee per year. A calculation will be made according to the answers to the questionnaire and the result will be written in the address bar of your browser. This result will be read out and indicated in large print to the right of the image of a balloon filled with greenhouse gases.

Here are the average values for each type of organisation:

- VSE: 207 kg CO2e,
- SME: 385 kg CO2e,
- MCE: 600 kg CO2e,
- LE: 278 kg CO2e,
- Association: 280 kg CO2e.

In an even smaller box you will see a small explanatory text followed by the uncertainty rate.

Further down you will see the average value for your type of organisation, allowing you to see where you stand (remember, however, that there is some uncertainty) [12].

As for good practices to improve your carbon score, a page has been created that allows you to know more in detail the action related and how to act well in the organisation to reduce its digital carbon footprint [30].

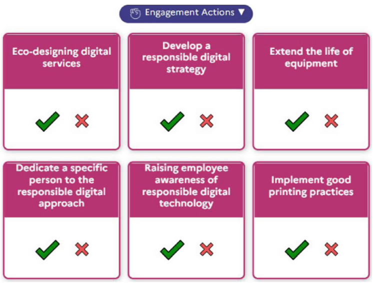

Fig. 7. Recommendations page.

Figure 7 gives an overview of the practical actions that companies can take after completing the calculator. For example, extending the lifetime of their equipment, these are all extracted from the best practices guide of the French government's interministerial digital department [30].

Regarding the collection of data, the site does not collect data, it will just monitor some small trivial information such as the pages consulted, the time spent and the address of the page at the end of the simulation containing the total digital carbon footprint [13].

6 Discussion

Firstly, it is important to have a sufficiently accurate and up-to-date inventory for the entire range covered by WeNR. The free GLPI software is so popular in the community that we recommend it. We recommend including its average power consumption or carbon footprint in the checklist when purchasing equipment. This will greatly facilitate your future WeNR evaluation [11].

For server rooms, the use of a communication PDU (Power Distribution Unit) is the best method. In the absence of these readings, theoretical values are recommended as part of the method [20].

Electricity in mainland France is particularly decarbonised. We recommend using the value from the EcoInvent database (0.119 kgCO2e), although it corresponds to peak production. This value is very low compared to the European or world average due to the high share of nuclear in the French energy mix. It is important to keep in mind that this creates other problems that do not translate into CO_2 (no decommissioning, waste storage, etc.) [21].

We also recommend publishing the data obtained in order to raise awareness of climate issues among users, who are often well-intentioned. Finally, the WeNR methods are designed to work independently, but WeNR can help you implement or interpret the results, as well as provide relevant advice.

7 Conclusion

Several conclusions can be drawn from the above results. Firstly, we found that there are few solutions for estimating an organisation's ICT carbon footprint, and the solutions that have been implemented are mainly focused on households and transport, and rarely provide accurate information. The transparency issues mentioned are partially addressed by WeNR, thanks to the thorough sharing of sources and factors used [10]. Secondly, our research related to green IT revealed that ICT needs to pay more attention to its energy consumption. While most large data centre manufacturers and service providers are aware of the need to act and adopt measures to reduce GHG emissions at various stages [15], the research shows that there are few solutions for small data centres [23].

Thus, the results of this study confirm that there is still much to be done in this area and that application services are needed to help companies reduce their costs and emissions. In carbon reduction efforts, communication is as important as the policies and actions themselves: to involve as many of the company's stakeholders as possible, public organising activities need to be carried out. These activities will increase the number of interested people [22].

It is also important to broaden and improve the data sources used. In the future, WeNR aims to become the reference tool to support the deployment of sustainable IT approaches and reduce the environmental impact of European organisations' information systems over time. ISIT announces the release of a new version in 2022 in addition to the WeNR Light, the WeNR Plus, which will provide benchmarking and actionable sustainable IT insights for participating ISIT member organisations and the WeNR 2022 and 2023 campaign.

Finally, WeNR Plus will use the WeNR models and calculations to provide a more comprehensive and detailed report in terms of quantity, quality and comparison with peer organisations, but most importantly by analysing the impact of policy decisions. In addition, the analytical tools provided will help define an action plan for developing a responsible digital strategy. Finally, as different cloud providers liberalise their carbon impact, the next version of WeNR will include the implementation of APIs to quantify the greenhouse gas emissions of cloud systems.

References

1. Auger, C., Hilloulin, B., Boisserie, B., Thomas, M., Guignard, Q., Rozière, E.: Open-source carbon footprint estimator: development and university declination. Sustainability **13**(8), 4315 (2021). https://doi.org/10.3390/su13084315
2. Foogooa, R., Dookhitram, K.: A self green ICT maturity assessment tool for SMEs. In: 2014 IST-Africa Conference Proceedings, Le Meridien Ile Maurice, Pointe Aux Piments, Mauritius, pp. 1–9 (2014). https://doi.org/10.1109/ISTAFRICA.2014.6880671
3. Belkhir, L., Elmeligi, A.: Assessing ICT global emissions footprint: trends to 2040 and recommendations. J. Clean. Prod. **177**, 448–463 (2018). https://doi.org/10.1016/j.jclepro.2017.12.239
4. Thackray, H., Kor, A., Pattinson, C., Earle, L.: Audit of an organisation's ICT systems for flexible working. Undefined (2018). Accessed 13 June 2022
5. Montbroussous, B., Berthoud, F., Feltin, G., Moreau, G., Schaeffer, J.: Calculer le bilan Carbone de votre parc informatique avec EcoDiag, un service EcoInfo, p. 10 (2019)
6. Valls-Val, K., Bovea, M.D.: Carbon footprint assessment tool for universities: CO2UNV. Sustain. Prod. Consum. **29**, 791–804 (2022). https://doi.org/10.1016/j.spc.2021.11.020
7. Pandey, D., Agrawal, M., Pandey, J.S.: Carbon footprint: current methods of estimation. Environ. Monit. Assess. **178**(1–4), 135–160 (2011). https://doi.org/10.1007/s10661-010-1678-y
8. Cheung, C.W., Berger, M., Finkbeiner, M.: Comparative life cycle assessment of re-use and replacement for video projectors. Int. J. Life Cycle Assess. **23**(1), 82–94 (2017). https://doi.org/10.1007/s11367-017-1301-3
9. Teehan, P., Kandlikar, M.: Comparing embodied greenhouse gas emissions of modern computing and electronics products. Environ. Sci. Technol. **47**(9), 3997–4003 (2013). https://doi.org/10.1021/es303012r
10. Berkhout, P.H.G., Muskens, J.C., Velthuijsen, J.W.: Defining the rebound effect. Energy Policy **28**(6), 425–432 (2000). https://doi.org/10.1016/S0301-4215(00)00022-7
11. Bourgeois, G., Courboulay, V., Duthil, B.: Deployment of a campaign to measure the ICT carbon footprint experimentation in French-speaking Europe (2021)
12. Court, V., Sorrell, S.: Digitalisation of goods: a systematic review of the determinants and magnitude of the impacts on energy consumption. Environ. Res. Lett. **15**(4), 043001 (2020). https://doi.org/10.1088/1748-9326/ab6788
13. Zhang, C., Khan, I., Dagar, V., Saeed, A., Zafar, M.W.: Environmental impact of information and communication technology: unveiling the role of education in developing countries. Technol. Forecast. Soc. Chang. **178**, 121570 (2022). https://doi.org/10.1016/j.techfore.2022.121570
14. Berthoud, F., Parry, M.: Évaluation des impacts environnementaux de l'informatique. Terminal. Technologie de l'information, culture and société, no. 106–107 (2010). https://doi.org/10.4000/terminal.1794

15. Mzabi, A.E., Khihel, F.: Green IT une solution informatique pour l'environnement. Rev. Afr. Manage. **3**(2) (2018). https://doi.org/10.48424/IMIST.PRSM/ram-v3i2.11178
16. Malmodin, J., Moberg, Å., Lundén, D., Finnveden, G., Lövehagen, N.: Greenhouse gas emissions and operational electricity use in the ICT and entertainment media sectors. J. Ind. Ecol. **14**(5), 770–790 (2010). https://doi.org/10.1111/j.1530-9290.2010.00278.x
17. Zhou, X., Zhou, D., Wang, Q., Su, B.: How information and communication technology drives carbon emissions: a sector-level analysis for China. Energy Econ. **81**, 380–392 (2019). https://doi.org/10.1016/j.eneco.2019.04.014
18. Jones, N.: How to stop data centres from gobbling up the world's electricity. Nature **561**(7722), 163–166 (2018). https://doi.org/10.1038/d41586-018-06610-y
19. Kern, E., Dick, M., Naumann, S., Hiller, T.: Impacts of software and its engineering on the carbon footprint of ICT. Environ. Impact Assess. Rev. **52**, 53–61 (2015). https://doi.org/10.1016/j.eiar.2014.07.003
20. Lean ICT: Towards Digital Sobriety: our new report. The Shift Project, 05 March 2019. https://theshiftproject.org/en/article/lean-ict-our-new-report/. Accessed 13 June 2022
21. Arushanyan, Y., Ekener-Petersen, E., Finnveden, G.: Lessons learned - review of LCAs for ICT products and services. Comput. Ind. **65**(2), 211–234 (2014). https://doi.org/10.1016/j.compind.2013.10.003
22. Malmodin, J., Lundén, D., Moberg, Å., Andersson, G., Nilsson, M.: Life cycle assessment of ICT. J. Ind. Ecol. **18**(6), 829–845 (2014). https://doi.org/10.1111/jiec.12145
23. Andrae, A.S.G., Edler, T.: On global electricity usage of communication technology: trends to 2030. Challenges **6**(1), 117–157 (2015). https://doi.org/10.3390/challe6010117
24. Grimm, D., Weiss, D., Erek, K., Zarnekow, R.: Product carbon footprint and life cycle assessment of ICT - literature review and state of the art. In: 2014 47th Hawaii International Conference on System Sciences, Waikoloa, HI, pp. 875–884 (2014). https://doi.org/10.1109/HICSS.2014.116
25. Guillaume, B., Benjamin, D., Vincent, C.: Review of the impact of IT on the environment and solution with a detailed assessment of the associated gray literature. Sustainability **14**(4), 2457 (2022). https://doi.org/10.3390/su14042457
26. Set Science-Based Emission Reduction Targets—UN Global Compact. https://www.unglobalcompact.org/take-action/action/science-based-target. Accessed 13 June 2022
27. Hu, J.-L., Chen, Y.-C., Yang, Y.-P.: The development and issues of energy-ICT: a review of literature with economic and managerial viewpoints. Energies **15**(2), 594 (2022). https://doi.org/10.3390/en15020594
28. WeNR—Information System footprint measurement tool. WeNR. https://wenr.isit-europe.org/. Accessed 13 June 2022
29. Gonzalez, A., Chase, A., Horowitz, N.: What we know and don't know about embodied energy and greenhouse gases for electronics, appliances, and light bulbs, p. 12 (2012)
30. Guide de bonnes pratiques numérique responsable pour les organisations. https://ecoresponsable.numerique.gouv.fr/publications/bonnes-pratiques/. Accessed 07 Sept 2022