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Digitalisation with decarbonisation

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Contents

Summary

Depending on the form it takes, digitalisation has the potential to either help or hinder the fight against climate change. Reconciling these two trends or transitions to ensure they complement each other is one of the great challenges of our time, more so given that both are essential parts of the economic and social recovery and transformation following the crisis caused by COVID-19. Technology –including digitalisation (of which artificial intelligence is just one example)– has become an indispensable tool for achieving the objectives of a green economy without pollution. Yet technology itself is also responsible for a significant amount of pollution. While the exact figures are up for debate, studies have found that between 2018 and 2020 the digital sector was responsible for around 3% of global primary energy consumption and 7% of electricity consumption, generating 5% of global CO_2 emissions.[1] The electricity consumed by the digital sector is increasing rapidly (9% a year), although its effects on the climate are closely linked to the source of the energy used (whether it comes from fossil fuels that emit greenhouse gases or from clean sources). This is a key aspect and an area in which both business and national, European and international institutions are finally starting to make progress. This Working Paper analyses the overall contribution of information and communications technology (ICT) to the fight against climate change, as well as its direct and indirect impact on the emissions of CO_2 and other greenhouse gases and the public-private policies being implemented to ensure the two transitions complement each other. It proposes improving metrics and creating national and European barometers to monitor good practices in this area in both the public and private sectors.

(1) Introduction[2]

We often think of the digital world as something lightweight, far removed from the physical bulk and energy consumption of traditional industry. However, this is not the case. We live in a world full of computers, of all shapes and sizes, with thousands of miles of copper and fibre-optic cables to facilitate the circulation of information, enormous data centres, antennas (outside and inside our homes and offices), constellations of satellites and myriad user terminals whose manufacturing and use consume large amounts of energy. All this means that, as we stand at the dawn of the Fourth Industrial Revolution, advanced artificial intelligence (AI) systems have a considerable carbon footprint. Failing to check the CO_2 emissions caused by the exponential growth of digitalisation will jeopardise the decarbonisation objectives for both 2030 and 2050.

[1] IEA (2020), 'Energy end-use data collection methodologies and the emerging role of digital technologies', October, https://www.iea.org/reports/energy-end-use-data-collection-methodologies-and-the-emerging-role-of-digital-technologies.

[2] We would like to express our gratitude to Gonzalo Escribano and Lara Lázaro at the Elcano Royal Institute for their valuable feedback on various drafts of this document and to the participants of the Working Group on Climate Change and Technology Transformations on 13/IV/2021. We are also grateful to Borja Adsuara (Consultant), Gloria Álvarez (UC3), Eloy Álvarez (Fundación Deusto), Carlos Arruego (Naturgy), Txetxu Ausín (CSIC), Enrique Herrera (University of Granada), Pablo Martín (Elewit), Laka Mugartza (Tecnalia), Miguel Muñoz (Iberdrola), Maya Ormazábal (Telefónica) and Peter Sweatman (Climate Strategy). However, all opinions expressed here are the sole responsibility of the authors.

One of the biggest challenges of our time is reconciling the inexorable progress of a necessary digitalisation with efforts to deliver a green economy.[3] But is this possible? This is a key issue and one that is all too absent from public debate, despite now featuring prominently in the strategies of a number of large companies and the digitalisation proposals of European governments and institutions over the last two years.

Digitalisation –in its multiple dimensions– is an essential part of the fight against climate change and of managing clean technologies. Yet if this process does not take place correctly, it has the potential to exacerbate existing problems and create new ones. Big data and AI have played a key role in modelling climate change and its causes. Digitalisation has the potential to make existing products and activities more efficient or replace them altogether. As the European Commission's 2030 Digital Compass[4] (its updated digital strategy,[5] published just before the pandemic), notes: 'digital technologies can significantly contribute to achieving the European Green Deal objectives'. In fact, they are essential, since the two transitions are inseparable.

The adoption of digital solutions and the use of data for the transition towards a climate-neutral, circular and more resilient economy, the replacement of business travel by videoconferencing and the use of digital technology to reduce greenhouse gas emissions in agriculture, energy, buildings, industry, urban planning and services can all contribute to the EU objective of reducing greenhouse gas emissions by at least 55% by 2030 and achieving climate neutrality by 2050, making it the world's first climate-neutral bloc. Digital technologies play a key role in generating energy efficiency measures across all sectors. For example, smart power grids are 90% digital technology and, as the last decade has shown, the incorporation of renewable energies is simply not feasible without them.

Both these trends –digitalisation and the green economy– must achieve a tight-knit and complex coupling. The digital and ecological transitions must go hand in hand.[6] The COVID-19 recovery and transformation plans initially treated them as two separate transitions. However, they have gradually come to incorporate this coupling, both in terms of using digital technology to achieve environmental objectives and the need for digitalisation to control energy consumption and reduce greenhouse gas emissions.

[3] For an overview, see Gregorio Martín Quetglas (2019), '¿Qué es la digitalización?', ARI, nr 64/2019, Elcano Royal Institute, http://www.realinstitutoelcano.org/wps/portal/rielcano_es/contenido?WCM_GLOBAL_CONTEXT=/elcano/elcano_es/zonas_es/ari64-2019-martinquetglas-que-es-la-digitalizacion#:~:text=Con%20la%20digitalizaci%C3%B3n%2C%20electrones%20que,de%20profundidad%20en%20la%20litosfera.

[4] European Commission (2021), '2030 digital compass: the European way for the digital decade', https://ec.europa.eu/info/sites/info/files/communication-digital-compass-2030_en.pdf.

[5] European Commission (2020), *Shaping Europe's digital future*, 19/II/2020, https://ec.europa.eu/info/publications/communication-shaping-europes-digital-future_en.

[6] Lluís Torrent (2020), "Ecological transition and digitalisation, an essential alliance in the climate decade", https://www.telefonica.com/en/web/public-policy/blog/article/-/blogs/ecological-transition-and-digitalisation-an-essential-alliance-in-the-climate-decade.

Figure 1. Evolution of key indicators for ICT, 2000-19

	2000	2019	% change
Population (a)	6.1 billion	7.7 billion	+26
GDP (b)	US$34 trillion	US$87 trillion	+155
Electricity consumption (c)	14 PWh	23 PWh	+62
Sustainable energy consumption (d)	4 exajoules	28.98 exajoules	+724
Internet users (e)	300 million	4.1 billion	+1,260
Internet traffic (f)	0.9 exabytes	1,992 exabytes	+28,900

Sources: (a) United Nations, 2019; (b) International Monetary Fund, 2020; (c) International Energy Agency, 2020; (d) BP; (e) International Telecommunication Union 2020; (f) CISCO 2018; IEA Presentation, November 2020 https://spark.adobe.com/page/dey6WTCZ5JKPu/, although COVID-19 has resulted in a major change in Internet usage.

(2) The ICT/digitalisation ecosystem

As the French engineer Luc Julia notes, taking a selfie can be harmless.[7] However, when posted on a social media site like Facebook or Instagram, the data travels tens of thousands of miles to these companies' data centres over waves and fibre-optic cables before setting out on its return journey to reach the devices of the users of these networks. All this means that this simple photograph can end up consuming as much electricity as three or four energy-saving light bulbs in an hour.

As we have noted, ICT (which includes AI) is playing an increasingly important role in measures to mitigate climate change. It has the potential to deliver almost half (46%) of the emissions savings required by 2030.[8] A study produced by GSMA and the Carbon Trust, has found that mobile technology has enabled a global reduction in greenhouse gas emissions of over 2 billion tonnes of CO_2 in 2018, a saving ten times higher than the global carbon footprint of the mobile industry itself.[9] Digitalisation is based on electricity. This means its overall impact on greenhouse gases and on CO_2 emissions in particular depends on the mix of energy sources used, which varies considerably depending on location and circumstances.

The different greenhouse gases have different global warming potentials. Since CO_2 makes up the bulk of these gases, the concept of CO_2 equivalent (CO_2e) is used as a

[7] Luc Julia (2019), *L'Intelligence Artificielle n'existe pas*; and Laia Ros (2019) "Subir un selfie a Instagram contamina", *La Vanguardia*, 3/XII/2019, https://www.lavanguardia.com/vida/junior-report/20191203/471919095671/internet-contamina.html.

[8] Bitkom (2021), *The digital economy's impact on the climate*, https://www.bitkom.org/climate-protection; and "Digitization can save one in five tons of CO_2", https://www.bitkom.org/EN/List-and-detailpages/Press/Digitization-can-save-one-in-five-tons-of-CO2.

[9] GSMA (2020), "The enablement effect. The impact of mobile communication technologies on carbon emission reduction", https://www.gsma.com/betterfuture/wp-content/uploads/2019/12/GSMA_Enablement_Effect.pdf.

proxy to express the impact of all greenhouse gases that are emitted on climate change.[10] These emissions include the extraction of the required raw materials, manufacturing processes and the transport and distribution of products. We can distinguish between direct and indirect emissions in companies' value chains. The latter can be divided into upstream direct emissions, such as goods and services sourced from external suppliers, their transport to the company, the use of assets like offices and data centres, and business trips and employee travel, and downstream indirect emissions, which include the transport, distribution, use and end-of-life processing of products, in addition to investments and leased assets. The direct effects associated with the life cycle and use of ICT devices are known as their environmental footprint, a concept that encompasses their carbon footprint.[11] The Greenhouse Gas Protocol[12] classifies these emissions as scope one (direct), scope two (indirect related to energy consumption) and scope three (other indirect).

However, while reliable statistics are available on energy production, it is much harder to find accurate data on consumption by key sectors and harder still to find figures on the energy consumption associated with the production of specific goods.[13] In the case of digitalisation, the energy incorporated into products is part of the environmental price we pay for everything we own and use, and plays a part in reducing emissions derived from the associated production of electricity and manufacture of peripherals. The lack of metrics to monitor the evolution of greenhouse gas emissions that take into account both changes in the electricity mix and the role of the carbon incorporated into the equipment associated with devices in the various sectors of ICT (data centres, networks and user devices) is a major issue.

The carbon footprint of the ICT sector in 2018 was 730 million tonnes of CO_2, almost equivalent to the 800 million tonnes of CO_2 produced by the fuel burnt by the aviation industry (80% of which is associated with travel).[14] However, there is a huge difference in the number of users: approximately 70% of the world's population use ICT, while just 10% use aviation services. The emissions from the fuel used by one person on a return transatlantic flight are estimated to be equivalent to 50 years of use of a smartphone (including the use of networks and data centres).[15] Holding international meetings online clearly has significant potential to reduce emissions.

Will renewable energies decarbonise ICT? As we shall see further on, the ICT sector is striving to increase its use of renewable energy, which has helped it to reduce its emissions. This change is a necessary one, together with increased renewable energy

[10] CO_2e expresses the impact on climate change of all greenhouse gas emissions associated with an activity in terms of the amount of CO_2 that would have the same impact.

[11] IEA (2017), *Digitalisation and Energy*, Paris, https://www.iea.org/reports/digitalisation-and-energy.

[12] Greenhouse Gas Protocol, https://ghgprotocol.org/.

[13] Vaclav Smit (2021), *Numbers Don't Lie: 71 Stories to Help Us Understand the Modern World*, Penguin Books, London.

[14] BBC (2020), "Should we give up flying for the sake of the climate?", https://www.bbc.com/future/article/20200218-climate-change-how-to-cut-your-carbon-emissions-when-flying.

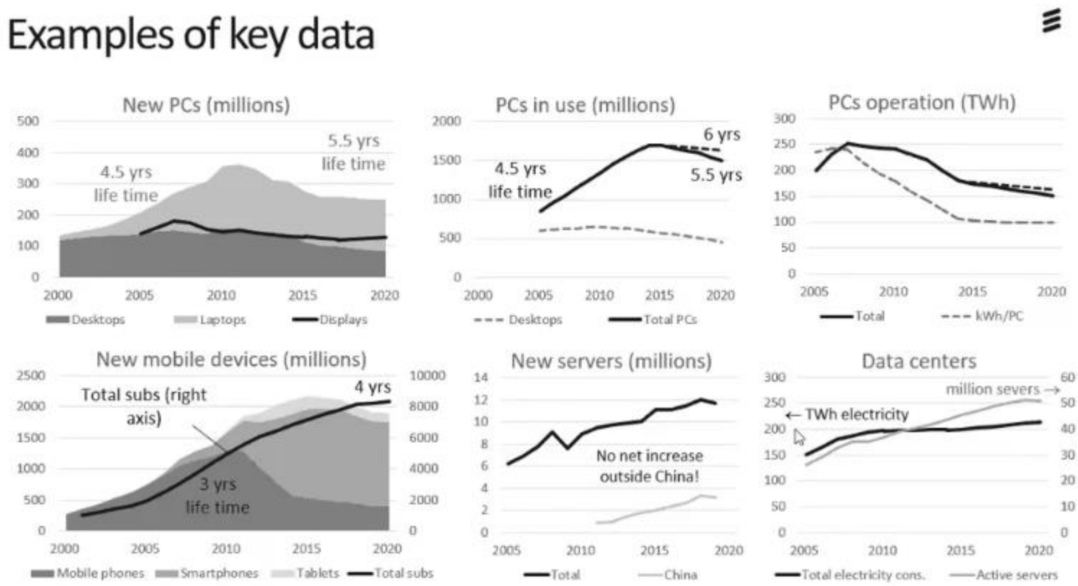
[15] Nina Lövehagen (2020), "What's the real climate impact of digital technology?", https://www.ericsson.com/en/blog/2020/2/climate-impact-of-digital-technology.

capacity, since all sectors will need to replace fossil fuels with renewable sources. However, renewable energy itself has a significant carbon footprint embedded in its infrastructure and supply chains, albeit much less than that of fossil fuels. According to the recent commitment by the European Commission,[16] achieving the ambitions of carbon neutrality for data centres by 2030 will require an absolute cap on absolute energy consumption, in addition to a higher proportion of renewable energy.[17]

(3) Direct and indirect effects

We must distinguish between the direct and indirect effects of digitalisation when it comes to greenhouse gases. Direct effects encompass the manufacture of products, the corresponding facilities and their use. All these aspects have their own electricity consumption, although new developments in technology, which have run in parallel to the rise of digitalisation, are helping reduce this consumption.

Figure 2. Evolution of the most representative devices and their demand for electricity: the number of personal computers manufactured every year has fallen with the appearance of new mobile devices, the average useful life of these devices has increased, and the electricity consumption of data centres has risen



Presentation by Ericsson https://www.youtube.com/watch?v=o2f9ms9Ynhk.

[16] "Euro data center & cloud providers commit to climate neutrality by 2030", https://datacentrenews.eu/story/euro-data-center-cloud-providers-commit-to-climate-neutrality-by-2030.

[17] European Commission (2020), *Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market*, https://ec.europa.eu/digital-single-market/en/news/energy-efficient-cloud-computing-technologies-and-policies-eco-friendly-cloud-market.

The current results are promising for the three main components:

(a) Data centres can accommodate the rise in Internet traffic without increasing the demand for energy.
(b) Networks as a whole have maintained low levels of greenhouse gas emissions.
(c) The various user devices.[18]

In terms of the absolute figures for these emissions, the German institute Bitkom[19] has published a study with data for 2018:

- Data centres use 160 ± 25 millions of tonnes of CO_2e
- Mobile networks use 54 ± 13 millions of tonnes of CO_2e
- Optical networks use 83 ± 20 millions of tonnes of CO_2e
- Devices use 460 ± 110 millions of tonnes of CO_2e

The estimates published by Bitkom, which are backed by other studies cited in the report, show that user devices as a whole have a higher carbon footprint than data centres and networks, with the particular feature that the impact of the manufacture of these devices is higher than their use. Apple estimates the carbon footprint of each new iPhone to be 70-85 kg of CO_2e.[20]

The main conclusion that can be drawn from all of this is that, despite our fears, current trends show there is significant potential for the infrastructure that is currently installed – or that may be installed in the future– to meet the rising demand for data traffic without increasing the carbon footprint of ICT. The effects of improvements in efficiency must be able to outpace or at least cancel out growth. Indirect effects come from the environmental impact of the production and consumption of digital devices and may be harmful, depending on how they are manufactured. In this respect, the growing programmed obsolescence of many of these devices undermines their sustainability, meaning lifespans and recycling must be increased.

Digitalisation alone will not have a sufficient impact on consumption patterns to address climate change. The fact is that changes in these patterns are often produced solely in response to price. In the case of ICT, this cost is relatively low.

One example of an indirect reduction in greenhouse gas emissions is the aforementioned use of videoconferencing systems to replace in-person meetings, with Forbes estimating that the pandemic could permanently reduce business travel by 10%.[21] Another example

[18] Tech UK (2020), "Decarbonising Data - Jen Malmodin", 29/IX/2020, https://www.youtube.com/watch?v=o2f9ms9Ynhk.

[19] Bitkom (2020), *Klimaschutz durch digitale Technologien–Chancen und Risiken*, https://www.bitkom.org/sites/default/files/2020-05/2020-05_bitkom_klimastudie_digitalisierung.pdf.

[20] Apple (2020), "Product Environmental Report", 13/X/2020, https://www.apple.com/environment/pdf/products/iphone/iPhone_12_PER_Oct2020.pdf.

[21] Oliver Wyman (2020), 'How videoconferencing and Covid-19 may permanently shrink the business travel market", *Forbes*, 11/XI/2020, https://www.forbes.com/sites/oliverwyman/2020/11/11/how-covid-19-may-permanently-shrink-the-business-travel-market/.

is teleworking, which was already growing but experienced a boom during the pandemic. In principle, as many studies have confirmed, avoiding travel saves greenhouse gas emissions, although this claim has also been disputed by other studies.[22]

(4) The impact of certain technologies

One of the indirect impacts of digital technology –a positive for climate change mitigation– is its potential to reduce the emissions of other activities (eg, transport, manufacturing, agriculture, buildings, construction and energy), with the European Commission estimating savings of up to 12.1%.[23]

New data from Bitkom in partnership with the consultancy firm Accenture,[24] shows that for the four groups examined so far (industrialisation, mobility, building and teleworking), accelerating digitalisation could deliver almost half (46%) of the CO_2e savings required by 2030. Moreover, this figure could increase to over 50% with the incorporation of the energy, agriculture and public services sectors, whose digitalisation also has the potential to reduce the corresponding carbon footprint. The report notes that not only will an acceleration in digitalisation help protect the environment and the climate, it will make the German economy –and, by extension, the EU as a whole– more competitive. Digitalisation has the potential to square the circle of economic growth and environmental and climate protection. The study found that digitalisation could save one in five tonnes of CO_2.

Clearly, as noted, the carbon footprint of digitalisation can be significantly reduced by increasing the use of renewable energy for ICT equipment. Various studies[25] corroborate the contribution digital technology can make to sustainability in areas such as electricity and heating (efficient buildings controlled by AI and using smart meters to change consumption), industrial production, agriculture and media and publishing.

It should be stressed that these digital technologies play a crucial role in the ecological transition. In line with the Paris Agreement, the European Commission envisages the

[22] See Andrew Hook, Victor Court, Benjamin K. Sovacool & Steve Sorrell (2020), 'A systematic review of the energy and climate impacts of teleworking', *Environmental Research*, https://iopscience.iop.org/article/10.1088/1748-9326/ab8a84. Out of 39 studies reviewed, 24 suggest that teleworking reduces energy consumption, while eight suggest it causes an increase or has no impact. See also Tech UK (2020), 'Decarbonising data – how tech is going for net zero', 18/XI/2020.

[23] European Commission (2020), 'Energy-efficient cloud computing technologies and policies for an eco-friendly cloud market final report', Directorate-General for Communications Networks, Content and Technology, https://op.europa.eu/en/publication-detail/-/publication/bf276684-32bd-11eb-b27b-01aa75ed71a1.

[24] Bitkom (2021), *The Digital Economy's Impact on the Climate*, https://www.bitkom.org/climate-protection; and 'Digitization can save one in five tons of CO_2', https://www.bitkom.org/EN/List-and-detailpages/Press/Digitization-can-save-one-in-five-tons-of-CO2.

[25] In addition to the aforementioned study by Bitkom, see, for example, 'Exponential Roadmap Initiative', https://exponentialroadmap.org/.

use of these technologies for these purposes.[26] The Digital Spain 2025 agenda[27] states that digitalisation 'will also be a driver of the other major transition that must be addressed by our society: the ecological transition to a new economic and social model based on sustainability'. One of the goals is to accelerate the digitalisation of the productive model through projects to bring about sectoral transformations with structural effects (aiming for a 10% reduction in CO_2 emissions as a result of digitalisation). According to the World Economic Forum, digital services have the potential to reduce energy and materials throughout the economy and could directly facilitate a significant reduction (15%) in emissions by 2030.[28]

For example, last year Google began using AI to make wind energy more predictable –and thus more valuable– in a number of its renewable energy projects. The initial results have shown that AI has increased the value of its wind energy by 20%. The company has also used machine learning to help people decide whether to fit solar panels on their roofs, after mapping over 107 million roofs in over 21,000 cities.[29] Companies like Google are also studying dynamically distributing their computational capacity across data processing centres where the supply of energy comes from a higher percentage of renewable sources.

The remainder of this section will focus on three digital technologies with the potential to contribute to carbonisation or decarbonisation, if designed and used correctly: (a) big data, data science and AI; (b) the Internet of Things (highly dependent on 5G networks); and (c) blockchain. While developments in the transport sector (which makes up 21% of global emissions, 73% of which come from short journeys)[30] has shown how technology can have positive effects in different areas (virtual, shared and smart mobility), this is slightly different to the concept of digitalisation being discussed here. Another example is streaming services, such as video and music, which have a significant environmental impact.[31]

[26] For example, Technology Executive Committee (2020), 'United Nations framework convention on climate change', TEC Brief #10; 'Technological innovation for the Paris Agreement implementing nationally determined contributions, national adaptation plans and mid-century strategies', https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf; and European Commission (*op. cit*), *2030 Digital Compass*.

[27] Ministry of Economic Affairs and Digital Transformation (2020), *España Digital 2025*, https://portal.mineco.gob.es/RecursosArticulo/mineco/prensa/ficheros/noticias/2018/Agenda_Digital_2025.pdf.

[28] World Economic Forum (2019), 'Digital technology can cut global emissions by 15%. Here's how', https://www.weforum.org/agenda/2019/01/why-digitalization-is-the-key-to-exponential-climate-action/.

[29] Carl Elkin & Sims Witherspoon (2019), 'Machine learning can boost the value of wind energy', *DeepMind*, https://deepmind.com/blog/article/machine-learning-can-boost-value-wind-energy.

[30] World Economic Forum (2019), 'Digital technology can cut global emissions by 15%. Here's how', https://www.weforum.org/agenda/2019/01/why-digitalization-is-the-key-to-exponential-climate-action/.

[31] Rolling Stone (2019), 'Is streaming music dangerous to the environment? One researcher is sounding the alarm', https://www.rollingstone.com/music/music-features/environmental-impact-streaming-music-835220/.

Big data and AI

Big data is made possible by the gathering and storing of data from multiple sources and the powerful computational resources of the cloud (which, despite the name's celestial connotations is based on the data processing centres of an all too earthly world). There is significant interest in interpreting these large and complex datasets through data science and AI, which play a central role in the vision of a 'smart future' with less carbon[32] and smart networks, cities, logistics, agriculture and homes. Sometimes referred to as the 'new oil',[33] big data has already had a commercial impact. However, the carbon footprint of the growing energy consumption of storage and data centres makes big data prohibitive if its electricity does not come from clean sources. This has led many companies to opt for renewable forms of energy and the European Commission to include it as an aspect of its data strategies.

It has been shown that AI and its computationally complex algorithms operating on big data (especially with machine and deep learning) can emit 284 tonnes of CO_2 to train just one machine learning algorithm for natural language processing, an impact five times higher than the lifetime emissions of running a car.[34] Neural networks significantly increase the carbon footprint of AI: without them, it has a carbon footprint of just 650kg, compared with 285 tonnes with them.[35] As Fernando Mateo notes, neural networks improve the performance of AI but at the high environmental cost from operating the supercomputers needed for the calculations. This order of magnitude means that unless all energy comes from clean sources, this growth (an exponential doubling every four months) will not be compatible with addressing the climate crisis.[36]

This increase in computation underlines the need for 'green' AI, with a focus on increasing the energy efficiency of calculations, in contrast to the current 'brown' AI. Unfortunately, sustainability is one of the most under-represented issues in AI ethics guidelines.[37] For example, it was absent from the OECD guidelines[38] and the G20's 2019 guidelines.[39] Nonetheless, as we have noted, companies, governments and organisations like the EU are insisting more and more on this dimension, even if –in the case of the latter two– only in a general manner and without specific proposals.

[32] Y. Saleem *et al.* (2019), 'Internet of things-aided smart grid: technologies, architectures, applications, prototypes, and future research directions', IEEE Access, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8701687.

[33] J. James (2019), 'Data as the new oil: the danger behind the mantra', The Enterprises Project, https://enterprisersproject.com/article/2019/7/data-science-data-can-be-tox.

[34] E. Strubell *et al.* (2019), 'Energy and policy considerations for deep learning in NLP', Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics, https://arxiv.org/abs/1906.02243.

[35] Joaquín Fernández Mateo (2021), '¿Cuarta Revolución Industrial? El reto de la digitalización y sus consecuencias ambientales y antropológicas', *Revista DIECISIETE*, nº 4, Madrid.

[36] L. Biewald (2019), 'Deep learning and carbon emissions', *Towards Data Science*, https://towardsdatascience.com/deep-learning-and-carbon-emissions-79723d5bc86e.

[37] A. Jobin, M. Ienca & E. Vayena (2019), 'The global landscape of AI ethics guidelines', *Nature Machine Intelligence*, vol. 1, nº 9, http://ecocritique.free.fr/jobin2019.pdf.

[38] https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0449.

[39] https://www.mofa.go.jp/files/000486596.pdf.

Internet of Things and 5G

The Internet of Things (IoT) refers to everyday and other objects that are connected to the Internet via mobile terminals that control domestic appliances, vehicles (autonomous or otherwise) and industries and is one of the fastest developing areas. Its applications are classed as 'smart technology', especially when combined with data science and AI to optimise the use of energy. For example, IoT services based on the location and analysis of data from smart cities can reduce pollution from transport through more efficient routes[40] and improve logistics by reducing energy requirements. There are expected to be over 75 billion devices connected to the Internet by 2025, compared to 15 billion in 2015.[41]

The impact of IoT is closely linked to the development of 5G networks, which offer lower latency and faster speeds. There are many examples of potential synergies between the two technologies to reduce greenhouse gas emissions, provided IoT applications replace and do not supplement more traditional carbon-intensive activities. However, the growing dependency on 5G networks is set to increase total energy consumption by between 150% and 170% by 2026, a figure that represents between 5% and 13% of annual electricity consumption.[42]

These emissions are already covered by the EU Emissions Trading System (EU ETS). According to a report produced by the French Senate,[43] this market-based mechanism theoretically guarantees that the 5G rollout will fit the negotiated quotas. However, it does not guarantee compliance, a significant source of concern in the country.

Blockchain, digital currencies and cryptocurrencies

Blockchain technology is based on decentralised databases designed to prevent centralised authority or a central point that can fail or be tampered with, using a range of cryptographic techniques. Blockchain algorithms are dependent on high levels of replication and redundancy, which means their energy consumption is extremely high.

Cryptocurrencies like Bitcoin, which are based on this technology, consume large amounts of electricity. For example, according to Digiconomist, which has created a Bitcoin Energy Consumption Index, one Bitcoin transaction is equivalent to 735,121 Visa transactions or 55,280 hours spent watching YouTube.[44] This makes the type of energy

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[40] S.E. Bibri (2018), 'The IoT for smart sustainable cities of the future: an analytical framework for sensor-based big data applications for environmental sustainability', *Sustainable cities and society*, https://www.sciencedirect.com/science/article/abs/pii/S2210670717313677.

[41] Statista Research Department (2020), 'Internet of Things (IoT) connected devices installed base worldwide from 2015 to 2025', https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/; Cisco (2020), 'Cisco Annual Internet Report (2018-2023)', https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.pdf.

[42] https://www.information-age.com/energy-consumption-and-iot-technologies-what-to-know-123485884/.

[43] Haut Conseil pour le Climat (2020), 'Maitriser l'impact carbone de la 5G. Rapport du Haut Conseil pour le Climat', December, https://www.hautconseilclimat.fr/wp-content/uploads/2020/12/haut-conseil-pour-le-climat_rapport-5g.pdf.

[44] https://digiconomist.net/bictoin-energy-consumption/.

consumed key. Assuming that other cryptocurrencies have the same carbon intensity as Bitcoin, the carbon footprint of all these currencies would be 69 $MtCO_2$, the equivalent of 0.1% of global emissions. The vast majority of Bitcoin miners are located in China. For example, it has been calculated that blockchain mining operations in the country could consume as much energy and produce the same amount of carbon emissions as certain European countries like the Czech Republic,[45] while a British study found Bitcoin consumes more energy than Argentina.[46]

If unchecked, these trends could drive growth that is unlikely to be offset by reductions in greenhouse gas emissions enabled by ICT in other sectors,[47] including blockchain itself, which is finding an increasing number of applications, including the traceability of "green" hydrogen. There is also the future development of official digital currencies, such as the euro, the yuan, the yen and the dollar, which will use part of these technologies but whose effects on the climate have not been widely discussed.

(5) Business initiatives

Large technology companies are increasingly aware of the need and their responsibility to reconcile the ecological and digital transitions,[48] not only as a consequence of pressure from public policy, changes in the price of clean energy and internal developments in the companies themselves but also in response to public opinion. Indeed, the *Financial Times* has published an analysis of this trend titled 'How tech went big on green energy'.[49] Yet despite these advances, the measures already taken and the good intentions of reaching 100% of renewable energy (without specifying how), a significant gap remains. Changing the source of the energy consumed lies at the heart of this approach. This section gives an overview of some representative examples of initiatives in the business sector. In 2021, European businesses have joined forces to form a European Green Digital Coalition[50] and at the global level, there is also the World Business Council for Sustainable Development, which includes the participation of major technology companies.[51]

[45] Shangrong Jiang *et al.* (2021), 'Policy assessments for the carbon emission flows and sustainability of Bitcoin blockchain operation in China', *Nature*, https://www.nature.com/articles/s41467-021-22256-3.

[46] Cambridge Bitcoin Electricity Consumption Index (CBECI), https://cbeci.org/.

[47] Charlotte Freitag *et al.* (2020), 'The climate impact of ICT: a review of estimates, trends and regulations', https://arxiv.org/pdf/2102.02622.pdf.

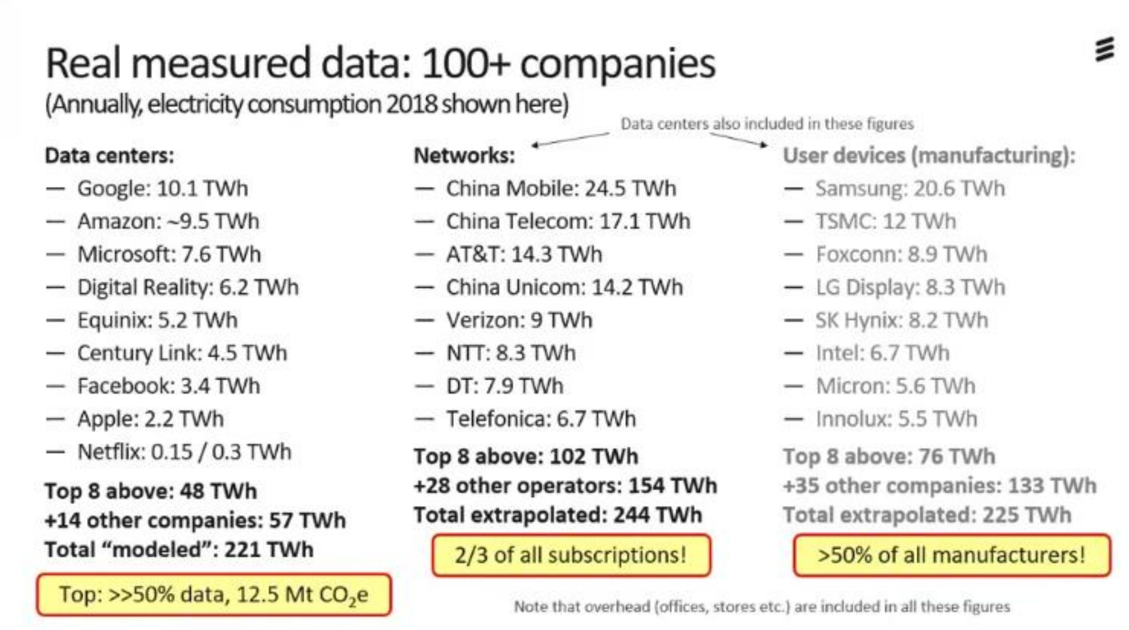
[48] For an overview, see Enrique Pérez (2020), 'Los planes para reducir el impacto medioambiental de Apple, Google, Microsoft y las grandes compañías de tecnología', *Xataka*, 16/IX/2020, https://www.xataka.com/energia/planes-para-reducir-impacto-medioambiental-apple-google-microsoft-grandes-companias-tecnologia.

[49] Leslie Hook & Dave Lee (2021), 'How tech went big on green energy', *Financial Times*, 10/II/2021, https://www.ft.com/content/0c69d4a4-2626-418d-813c-7337b8d5110d?shareType=nongift.

[50] https://www.digitalsme.eu/digital/uploads/European-Green-Digital-Coaliton-Declaration-FINAL-Digital-Day-2021.pdf.

[51] https://www.wbcsd.org/.

Figure 3. Estimates by Ericsson of the energy consumption recorded for the top 100 digital companies in 2018



Source: Jan Malmodin (2020), 'Decarbonising Data', London, https://www.youtube.com/watch?v=o2f9ms9Ynhk.

Google

Google reports that since 2017, 100% of the electricity consumption of its global operations has been sourced from purchases of renewable energy, making it the world's largest corporate buyer of renewable energy.[52] It has made its data centres more energy efficient, with a 30% saving in the energy used for cooling through the use of AI and has also joined forces with another 300 companies to launch the Renewable Energy Buyers Alliance, the largest group of corporate renewable energy purchasers in the US. Its goal is for all its operations to run on carbon-free energy by 2030.

Amazon

The day before a protest arranged by the organisation Amazon Employees for Climate Justice in 2019, Amazon adopted its Climate Pledge[53] undertaking to reach net-zero carbon emissions by 2040 across all its industries and setting a number of milestones along the way: 100% renewable electricity by 2025 (currently at 42%); the procurement of 100,000 electric transport vehicles and reaching 50% of shipping with zero emissions by 2030; and shipping with zero carbon emissions by 2040. Its data centres (Amazon Web Services) are included in the general objective and the company's Climate Pledge entails an investment of US$2 billion. Yet at the same time, Amazon CEO and founder,

[52] Data provided by the company.

[53] Amazon (2020), 'All in: staying the course on our commitment to sustainability', https://sustainability.aboutamazon.com/pdfBuilderDownload?name=sustainability-all-in-september-2020.

Jeff Bezos, acknowledges that the company's environmental footprint continues to grow, with CO_2 emissions for 2019 up 15% on the previous year.[54]

Telefónica

Telefónica has reduced its emissions by 61% over the last five years. Its Digital Deal[55] notes that 100% of the energy it uses in Europe and Brazil is renewable and that the Spanish multinational is helping its customers to reduce their CO_2 footprint. In 2020 Telefónica reaffirmed its commitment to the climate and has pledged to reach net-zero emissions in its primary markets by 2025 and by 2040 across the world. According to the company's calculations, its services prevent the emission of 9.5 million tonnes of CO_2.[56] It has proposed classifying advanced communications networks as green infrastructure that meets climate change objectives as Sustainable Finance and has already issued €2.5 billion of bonds linked to sustainability.

Other companies

The year 2030 is a key milestone for many technology companies for reducing their CO_2 emissions to zero, despite the exponential growth in the generation and consumption of data. Apple, for example, has announced a series of measures covering its activities, suppliers, assembly chains and product life cycles.[57] Similarly, Microsoft has set a target of 100% of obtaining the energy it uses from renewable sources by 2025 and has pledged to be 'carbon negative' within a further five years. Facebook aims to reduce its greenhouse gas emissions by 75% and reach 100% renewable energy by 2020. Samsung has already reached 92% renewable energy and is targeting 100% by the end of 2021. Intel claims to have reduced its emissions by 39% in 2020 and its greenhouse gas emissions by 10% and has reached 71% renewable energy, also targeting 100% by 2030. The path of Sony is slower –or more realistic– given the energy-intensive nature of the production of semiconductors. The company plans to eliminate its carbon footprint by 2050 and obtain 100% of its energy from renewable sources by 2040. ZTE is supporting the circular economy through green development.[58] Netflix has announced its intention to reduce the carbon footprint of its streaming service to zero by 2022.[59] Finally, the European Green Coalition, whose members include Telefónica, was launched in March 2021 by 26 CEOs in the sector to show the commitment of companies that have signed the declaration to link the digital and green transformations.[60]

[54] Justine Calma (2020), 'Amazon boosts climate commitments and greenhouse gas emissions', *The Verge*, 23/VI/2020, https://www.theverge.com/2020/6/23/21300427/amazon-climate-change-commitments-greenhouse-gas-emissions-jeff-bezos.

[55] https://www.telefonica.com/es/web/public-policy/pacto-digital-de-telefonica.

[56] Telefónica (2020), 'Consolidated Management Report', https://www.telefonica.com/documents/162467/141705152/Consolidated-Annual-Accounts-2020.pdf/fc0a1436-9d93-5268-8dda-096dc663611e.

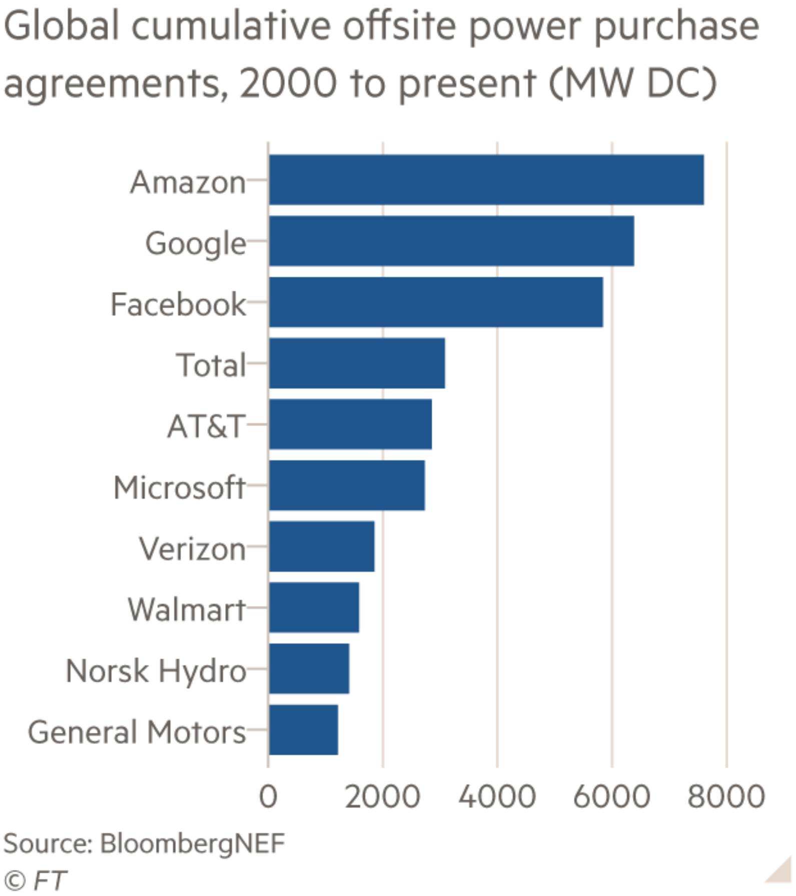
[57] https://www.applesfera.com/apple-1/apple-anuncia-medidas-para-ser-compania-cero-impacto-medioambiente-2030.

[58] https://res-www.zte.com.cn/mediares/zte/Files/PDF/white_book/202007021439EN.pdf.

[59] https://www.theverge.com/2021/3/30/22353098/netflix-greenhouse-gas-emissions-climate-change-goals.

[60] https://ec.europa.eu/digital-single-market/en/news/companies-take-action-support-green-and-digital-transformation-eu.

Figure 4. Technology companies in the US are the largest corporate buyers of green energy



Source: 'How tech went big on green energy', *Financial Times*, February 2021, https://www.ft.com/content/0c69d4a4-2626-418d-813c-7337b8d5110d.

In terms of investing in the green economy, the European Commission has presented a series of proposals on a 'sustainable finance' taxonomy[61] as the first global attempt at distinguishing between 'green' and 'brown' investment. While the proposal does not mention nuclear power (Brussels is preparing a specific proposal on this issue), environmental defence groups are firmly against classifying investment in gas and nuclear energy as green. The proposal has been criticised, with a raft of suggested amendments and additions. The European Telecommunications Networks Operators insists on the contributions of networks and other aspects to delivering a green economy, citing the principle that 'climate targets will not be achieved without the crucial role of ICT as enablers'.[62] A group of 123 scientists from 27 countries have signed an open letter expressing their 'deep concern' at the proposal's failure to note that businesses must

[61] Technical Expert Group (TEG) on Sustainable Finance (2020), *TEG final report on the EU taxonomy*, https://knowledge4policy.ec.europa.eu/publication/sustainable-finance-teg-final-report-eu-taxonomy_en.

[62] European Telecommunications Networks Operators (ETNO) (2020), 'Comments to the draft delegated regulation on criteria defining environmentally sustainable activities', https://etno.eu/downloads/positionpapers/etno%20comments_%20draft%20delegated%20act%20on%20environmentally%20sustainable%20activities_final%20for%20submission.pdf.

reduce their carbon emissions to zero by 2050.[63] Faced with an avalanche of comments and suggestions, the European Commission has decided to postpone the presentation of the final version of the document.

However, it is not enough for the additional electricity to come from sources that do not emit greenhouse gases, since additional sources will be required. Any corporate publicity based on the commitment to decarbonisation and renewable energy must effectively result in decarbonisation or additional renewable energy in the system, with a contribution that is substantially above the collective effort.[64]

(6) Public-private policies

Generating complementarity –and not conflict– between the digital and ecological transitions requires public, private (examples of which we have seen above) and public-private policies. The digital industry must form part of the Green Deal in general, although, as we have seen, it has already adopted a number of measures.

The main problem is that, partly for conceptual reasons and partly for bureaucratic ones, these issues are often seen as independent and are handled by separate departments of the European Commission and national administrations. Sustainability departments often make reference to using digitalisation to reduce greenhouse gas emissions and address climate change, with less focus on the contribution digitalisation makes to these emissions. Digitalisation departments increasingly emphasise the green dimension of their strategies, albeit in general terms.

The Paris Agreement,[65] for example, insists on the use of technology to increase resilience to climate change and reduce greenhouse gas emissions. It establishes a technology framework, giving general direction to the technological mechanism to accelerate technology development and transfer but does not address the negative impacts of its development on climate change.

The European Commission's Green Deal commits the EU to carbon neutrality by 2050 and climate neutrality by the end of the century.[66] ICT plays a prominent role in this policy: firstly, due to recent efforts to show international leadership as part of an approach based on sustainable, human-centred innovation and, secondly, to reduce greenhouse gas emissions across all sectors of the economy.

[63] 'Scientists warn of "disconnect" between EU climate goals and finance rules', *Financial Times*, 6/XII/2020, https://www.ft.com/content/3b017b2b-e8a5-4ea0-b7d0-c96337e33e5f.

[64] In this respect, see European Commission in partnership with COWI and CEPS for DG ENER (2020), 'Competitiveness of the renewable energy sector', https://op.europa.eu/en/publication-detail/-/publication/618d5369-c48f-11e9-9d01-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=37085&WT.ria_f=3608&WT.ria_ev=search.

[65] https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

[66] European Commission (2018), 'A clean planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy', https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=E.

The official figures from the European Commission estimated the current share of global greenhouse gas emissions from ICT to be over 2%[67] and a study commissioned by the European Commission anticipates that 'the energy consumption of data centres and telecommunications networks will grow at an alarming rate (35% and 150%, respectively) over nine years' (from 2018).[68] Instead of trying to address this trend in consumption directly, the political approach involves mitigating the associated impacts, specifically through increased efficiency and renewable energy. The wording of the European Commission report is ambiguous, stating that ICT 'probably' saves more energy than it consumes. However, the Green Deal is unequivocal: 'Digital technologies are a critical enabler for attaining the sustainability goals of the Green Deal in many different sectors'.[69] One of the most notable contributions of digital technology is the reliable incorporation of a higher percentage of renewable energy into power grids as a result of improved predictability and optimisation. This includes numerous initiatives and major funding schemes to promote innovation and the adoption of AI, IoT and blockchain. However, the Green Deal does not give a detailed roadmap of how these technologies will achieve these objectives or estimates of the expected savings.

Digitalisation and sustainability –the main priorities of the recovery fund, making up 20% and 37%, respectively– have not been correctly linked at the level of the European Commission or the European Council. In both Next Generation EU and the conditions published by the European Commission to allow national plans to benefit from these funds, they are treated as separate issues. However, subsequent guidance from the European Commission,[70] establishes a link between them, with a reference to 'greening' the digital sector through 'policies to reduce waste and energy consumption and to increase the use of renewable energy for digitalization and the use of waste heat from data centres'. For example, it states that 'Member States investing in digital infrastructures should be encouraged to prioritise the most energy efficient and greenest technologies'.

In the United States, the Democrat platform for the November 2020 elections[71] addressed climate change and technology successively, without establishing any relationship between them and the first Executive Orders by President Biden to implement his green agenda do not mention the relationship between the two transitions.

[67] European Commission (2020), 'Supporting the green transition', https://ec.europa.eu/commission/presscorner/detail/en/fs_20_281.

[68] Pan-European Data Centre Academy (PEDCA) (2015), 'Final Report Summary', European Commission, https://cordis.europa.eu/project/id/320013/reporting.

[69] European Commission (2019), 'The European Green Deal', https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.

[70] https://ec.europa.eu/info/sites/info/files/document_travail_service_part1_v2_en.pdf.

[71] https://democrats.org/es/lo-que-representamos/plataforma-del-partido-democrata/.

(7) Spain: strengths and weaknesses

Spain has already taken steps towards a sustainable digitalisation. The country is well above the European average for all indicators in the EU Digital Economy and Society Index for 2020,[72] with its score increasing from 80.9 points in 2019 to 87 points in 2020. The report ranks Spain fourth in the EU in terms of progress on digitalisation, with just Malta, the Netherlands and Ireland ahead. In addition to the strong results in digital public services, the country has also scored well for connectivity (especially fibre-optic networks), although there is still room for improvement, above all in rural areas, and the challenge of providing general 5G coverage.

However, for the purposes of this study, the most important aspect is the weighting of renewable energies in total electricity production, which in Spain reached a record high of 43.6% in 2020.[73]

Spain's Integrated National Energy and Climate Plan 2021-30,[74] published by the Ministry for the Ecological Transition and the Demographic Challenge, addresses technology and digitalisation as part of building a green economy but makes no mention of any negative effects. The Digital Spain 2025 plan produced by the Ministry of Economic Affairs and Digital Transformation also touches on this issue, albeit not in depth.

In the Climate Change and Energy Transition Law,[75] article 5 bis (new) contains not just measures 'to promote the digitalisation of the economy that contribute to achieving the objectives of decarbonisation in the context of the Digital Spain 2025 strategy' but also (of greater relevance to this study) to 'inform and disseminate new proposals to reduce the greenhouse gas emissions of the digital economy and new business models' and 'harness the potential of new technologies like AI to transition to a green economy, for example, through algorithms that are energy efficient by design'. However, there remains a gap to be bridged between the legal text and specific programmes. The Spanish administration has started to talk about 'green algorithms',[76] not as a scientific or technical term but as a communications term that seeks to encompass the efficient consumption of energy as a key aspect, over and above the consumption of time and memory or space. The National AI Strategy[77] contains a reference to promoting 'the energy efficiency of data storage and computation systems'.

[72] https://ec.europa.eu/digital-single-market/en/digital-economy-and-society-index-desi.

[73] https://www.ree.es/es/sala-de-prensa/actualidad/nota-de-prensa/2020/12/las-renovables-alcanzan-el-43-6-por-ciento-de-la-generacion-de-2020-su-mayor-cuota-desde-existen-registros#:~:text=As%C3%AD%2C%20Espa%C3%B1a%20gener%C3%B3%20109.269%20GWh,hasta%20alcanzar%20los%20250.387%20GWh.

[74] https://www.miteco.gob.es/images/es/pnieccompleto_tcm30-508410.pdf.

[75] https://www.congreso.es/backoffice_doc/prensa/notas_prensa/81345_1617867418184.pdf.

[76] https://www.ree.es/es/sala-de-prensa/actualidad/nota-de-prensa/2020/12/el-nuevo-programa-nacional-de-algoritmos-verdes-nos-permitira-disenar-algoritmos-eficientes-energeticamente.

[77] National Artificial Intelligence Strategy (2020), https://www.lamoncloa.gob.es/presidente/actividades/Documents/2020/ENIA2B.pdf.

The Spanish Government's Recovery, Transformation and Resilience Plan states that its measures fully meet the regulatory requirements of the do no significant harm principle and aim to maximise synergies from the dual green and digital transition through a range of projects that use digital tools to make progress in areas such as energy efficiency, green algorithms, smart networks and the efficient use of water and land.[78] However, this needs to be measured in practice.

As part of these objectives, it is necessary to include the indicators in the EU directive, as well as ensure their transposition into Spanish law on non-financial information for companies. The law already addresses the issue of indicators, albeit to an insufficient extent.[79]

In terms of teleworking, Spain had one of the lowest rates in the EU in 2018, at around 7%, according to a study by the Bank of Spain,[80] although COVID-19 has changed this. During the pandemic, 30.5% of people stated they had done more teleworking, according to a study by the Centre for Sociological Research (compared to 60% in some Nordic countries).[81] Another survey by Eurofound states that this proportion may have risen to 51.5%.[82]

The cooling of data centres due to the need to maintain low temperatures makes up almost 50% of their energy consumption. This explains why most of the continent's data centres are situated in the north, since this helps minimise the energy needed for cooling. These regions were responsible for 82% of energy consumption by data centres in 2018, a figure that is set to increase to 87% by 2025. The energy consumption of data centres in the north of Europe is forecast to increase by 48% between 2018 and 2025. There is a wide range of potential future developments in Europe. However, taking advantage of all this potential will allow the energy consumption of data centres to be reduced to 2010 levels.[83] While it represents a business model and reasons that go against the interests of Spain, a number of large data centres are being installed in the country. For example, Amazon will open its first three data centres in Spain in 2022 and the country is increasing its role in the rollout of data centres that leverage subsea cable infrastructures and the national technology sector. However, Spain should request compensation from companies in the form of R&D or other measures.

[78] Recovery, Transformation and Resilience Plan (2021), https://www.lamoncloa.gob.es/presidente/actividades/Paginas/2021/130421-sanchez_recuperacion.aspx.

[79] https://www.boe.es/boe/dias/2018/12/29/pdfs/BOE-A-2018-17989.pdf.

[80] Brindusa Anghel, Marianela Cozzolino & Aitor Lacuesta (2020), 'El teletrabajo en España', Bank of Spain, https://www.bde.es/bde/es/utiles/Canal_RSS/Publicaciones/el-teletrabajo-en-espana.html.

[81] Centro de Investigaciones Sociológicas (2020), 'Efectos y consecuencias del coronavirus (i)', http://www.cis.es/cis/export/sites/default/-Archivos/Marginales/3280_3299/3298/es3298mar.pdf.

[82] Eurofound (2021), 'Working during COVID-19', https://www.eurofound.europa.eu/data/covid-19/working-teleworking.

[83] Jens Malmodin & Dag Lundén (2018), 'The energy and carbon footprint of the global ICT and E&M sectors 2010-2015', *Sustainability 10*, nr 9, p. 3027, https://doi.org/10.3390/su10093027.

(8) Conclusions and proposals: measurement, supervision and a barometer

The two transitions are inseparable. Digitalisation and the green economy must form a decisive alliance. The growing digitalisation of our societies is driving an increase in electricity consumption. Failure to ensure this is met from sources that do not emit greenhouse gases will lead to an increase in emissions, especially for certain technologies such as AI backed by big data, blockchain and new connectivity. It is essential to analyse the full cycle of digitalisation, considering the environmental and ecological dimension.

This means analysing the potential of digital and other technologies to reduce their footprint. It means identifying, gauging the maturity of and prioritising decarbonisation technologies, over and above the contributions of ICT. For example, a comprehensive study is needed of the impact of digital technologies on the energy sector.

In light of digitalisation and its applications in a range of sectors, including health, transport, agriculture, manufacturing and smart cities, it will become increasingly necessary to ensure the integration of ICT and decarbonisation technologies. Public-private policies play an important role and will require public and private financing, in addition to research for technology to minimise energy use (eg, reducing the heat produced by components to reduce consumption from cooling, which is extremely important in hot countries like Spain). The promotion of a 'European cloud' –an EU data policy– must incorporate sustainability and social responsibility criteria.

Public awareness of this problem has shifted over the last few years, with consequences for companies, which have begun to take major steps, and public administrations, which have started to address the issue in recent months, albeit as part of an approach that remains much too general. The slow reaction of public administrations at the national, European and international levels is partly due to bureaucratic divisions, the compartmentalisation of knowledge and the lack of connections between the departments responsible for addressing each of the problems. All this requires a change of culture and governance.

The imperative of aligning the digital and ecological transitions means expanding the ethical focus from human-centred AI and digitalisation to an eco-centric approach as part of a reference framework for public policy on digitalisation and sustainability, both in Europe and also at the global level. This means promoting a culture of 'digital responsibility' among users and creating digital services and devices; integrating environmental issues into the decision-making parameters of users; and incentivising the rational use of digital content that takes sustainability criteria into account.

The capacity of authorities to manage the environmental footprint of digital technology can only be improved by developing instruments to more accurately measure progress in this area. Rigorous metrics for emissions in this area must be developed.

An objective and independent evaluation of public-private policies in this area, analysing their costs and results, would be useful. We propose developing an environmental barometer to promote best practices throughout the digital ecosystem at the national and

European levels. In Spain this could be developed by the National Telecommunications and Information Society Observatory (ONTSI).