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Allianz Research

More emissions than meet the eye: Decarbonizing the ICT sector

Executive summary

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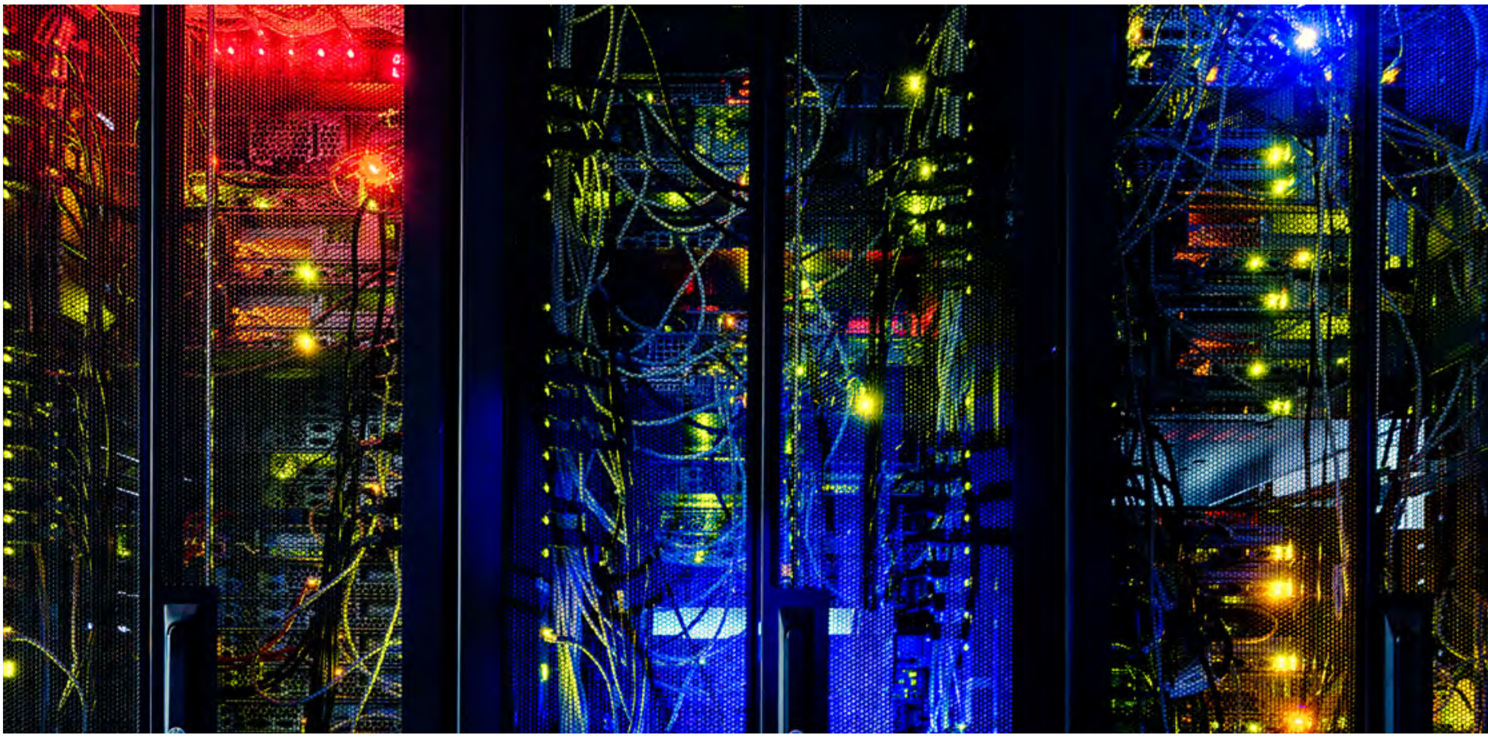
- **More emissions than meet the eye: Even without taking into account the cryptocurrency boom, the global ICT sector emits as much greenhouse gases as the aviation sector.** The information and communications technologies (ICT) sector drives economic growth, enables digital transformation, fosters innovation and promotes global collaboration and connectivity. But these benefits come at a cost: ICT's share of global greenhouse-gas emissions ranged between 1.8 to 2.8% in 2020. In a business-as-usual scenario, assuming the emission-intensity of electricity used remains unchanged, the ICT sector would be responsible for 830 MT of CO2 emissions by 2030. And this is before taking into account the boom in cryptocurrencies, such as Bitcoin and Ethereum, which consume up to 240 terawatt-hours of electricity annually, more than the yearly electricity consumption of Australia.

- **The good news is that decarbonization prospects are better in the ICT sector.** Its carbon footprint heavily depends on the electricity mix, so emissions are likely to decline steadily with the increasing share of renewable electricity and the improving energy-efficiency of appliances. Many mobile operators and other ICT industries have also set carbon-neutrality and net-zero targets that are aligned with the 1.5°C decarbonisation pathway, which will also contribute to keep electricity consumption and carbon emissions in check.[1] The remaining emissions could be brought down by optimizing the product life cycle, i.e., assessing material selection, design choices, manufacturing and transportation.

1. GSM Association (2022). Mobile Net Zero: State of the Industry on Climate Action 2022

- **Decarbonizing cryptocurrency should be top of the agenda, but blockchain can also play a key role in climate action**. Bitcoin mining is diverting electricity from other priorities such as the electrification of buildings, transportation and manufacturing. Moreover, even though switching to renewables has the potential to slash GHG emissions, this cannot be done quickly enough if energy demand keeps rising, which could slow the phase-out of fossil-fuel power plants. Some countries, such as China, have taken drastic measures and banned Bitcoin but this seems to have only driven miners underground: China is still the world's second-largest Bitcoin miner after the US.[2,3] Less drastic measures could also foster emission reductions through technological advancements. At the same time, blockchain can be used to help to build trust and ambition in climate negotiations by providing an interoperable and open-source digital infrastructure that could enable transparent measurement, reporting and tracking of Nationally Determined Contributions (NDCs[4]). Moreover, given its transparency and accessibility, blockchain can also help build a framework for a trustworthy and scalable Voluntary Carbon Market (VCM) to trade carbon credits.
- **Policymakers will have to spur changes in consumer behaviour to decarbonize the ICT sector further.** The majority of emissions come from user devices and it is unlikely that consumer behaviour will change drastically towards using fewer devices in the future. In fact, quite the opposite is likely. This means these changes would have to be mandated top-down through regulations or incentives.



2. The White House (2022). Climate and Energy Implications of Crypto-Assets in the United States
3. Forkast (2022). China banned Bitcoin mining and became world's No.2 Bitcoin miner
4. NDCs is the term for the climate policy and emission reduction commitments of countries within the United Nations climate negotiations.

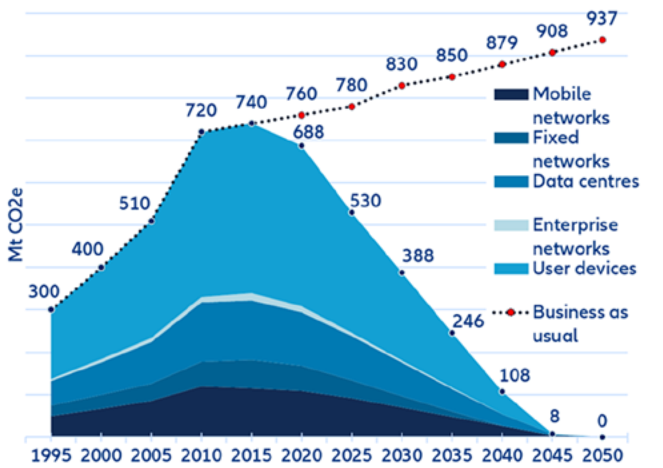
More emissions than meet the eye

Even without taking into account the cryptocurrency and artificial intelligence boom, the global ICT sector is responsible for as much greenhouse-gas emissions as aviation. The Information and Communication Technology (ICT) industry has seen tremendous growth in recent decades, driven by trends such as the Internet of Things (IoT), cryptocurrency mining, cloud computing and an overall increasing reliance on the internet and electronic devices. But this growth has raised concerns about the environmental impact, and in particular the carbon footprint. Current estimates indicate that ICT's share of global greenhouse-gas (GHG) emissions ranged from 1.8% to 2.8% in 2020,[5] equivalent to that of the aviation sector.

Figure 1 shows the International Telecommunication Union's (ITU) projections for the sector's emissions in a "business-as-usual" scenario (BAU) as well as a scenario that is compatible with limiting global warming to 1.5°C, both of which have been extended for this report.[6]
In the business-as-usual scenario, assuming the emission-intensity of electricity used remains unchanged, the ICT sector would be responsible for 830 MT of CO2 emissions by 2030.

The data represented here includes emissions from users i.e., Scope 3 emissions, which explains the large values. The ICT sector's carbon footprint comprises two components – embodied emissions and operational emissions. Embodied emissions[7] cover the emissions originating from the manufacturing and installation of equipment and appliances. Operational emissions stem from the use-phase of these networks and devices, primarily based on the level of electricity consumption and the related emissions from the global electricity mix during that time period. The embodied emissions account for roughly 30% of the total carbon footprint while the operational emissions take a majority share with ca. 70% of the total emissions.[8]

Figure 1: Global GHG emission trajectories of the ICT sector for 1.5°C scenario

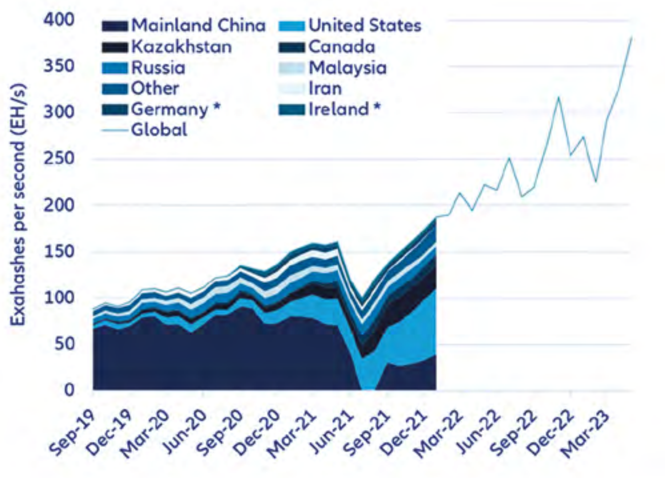


Sources: ITU-T, Malmodin. J (2020), Freitag et.al (2021), Allianz Research. Note: As the 1.5°C scenario projections by the ITU are presented as a recommendation, ICT industries are not bound to comply with this voluntary standard and a realistic trajectory will lie between the BAU and 1.5°C scenario.

5. Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G. S., & Friday, A. (2021). The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. Patterns, 2(9), 100340.
6. ITU provides data until 2030 starting from the baseline year 2015. To paint a holistic picture of the emissions development, the historical data for the total sectoral emissions were sourced from periodically conducted studies employing similar methodologies, which were downscaled to a sub-sector level based on the assumption that the proportional contribution to the total emissions remain consistent over time, by using Malmodin, J. (2020) (The ICT Sector's Carbon Footprint. Presentation at the techUK Conference in London Tech Week on 'decarbonising Data'). The data for the years from 2030 were generated using linear extrapolation, with the assumption that the entire sector will achieve net-zero targets at the latest by 2050.
7. Several scholars argue that the embodied emissions should also take into consideration trade emissions since globalization has made it easy to import ICT equipment or outsource production, thus making it possible to shirk responsibility for emissions.
8. Freitag, C., Berners-Lee, M., Widdicks, K., Knowles, B., Blair, G. S., & Friday, A. (2021). The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations. Patterns, 2(9), 100340.

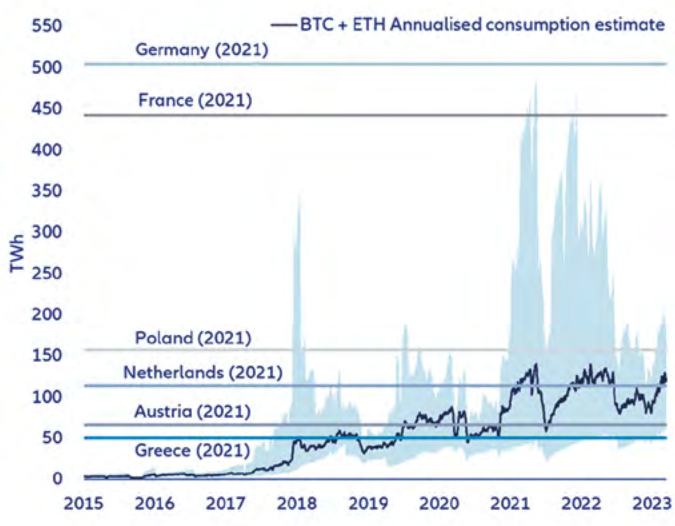
This worrying trajectory does not take into account the boom in cryptocurrency and artificial intelligence, which are contributing their own sizable carbon footprint. Bitcoin, for instance, popularized proof-of-work (PoW)[9] for validating transactions on the blockchain and many others followed suit. But this mechanism has so far proven to be an energy guzzler owing to its high demand for processing power. Bitcoin and Ether alone consume as much electricity as the Netherlands or Austria (Figure 2). Higher electricity prices only allow new-generation energy-efficient computers to stay competitive over time as the production costs for mining each Bitcoin could prove to be too high otherwise. Seeking higher profit margins, crypto miners tend to set up their operations in countries with lower electricity prices, usually developing economies (Figure 3), which tend to have a higher share of fossil fuels in their energy mix. As a result, crypto mining contributes heavily to emissions (Figure 4).

Figure 3: Development of the global Bitcoin hashrate[12] (monthly averages)



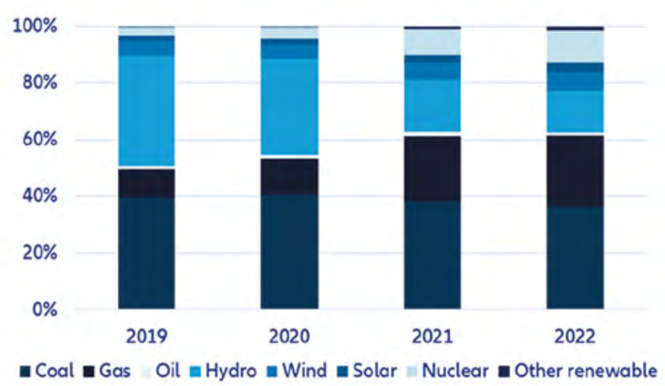
Source: NASDAQ[13], Cambridge Centre for Alternate Finance, Allianz Research

Figure 2: Combined annualized electricity consumption of Bitcoin and Ethereum vs. that of certain EU member states



Source: ECB[10], Eurostat, Cambridge Centre for Alternate Finance[11], Allianz Research

Figure 4: Bitcoin electricity consumption (yearly)



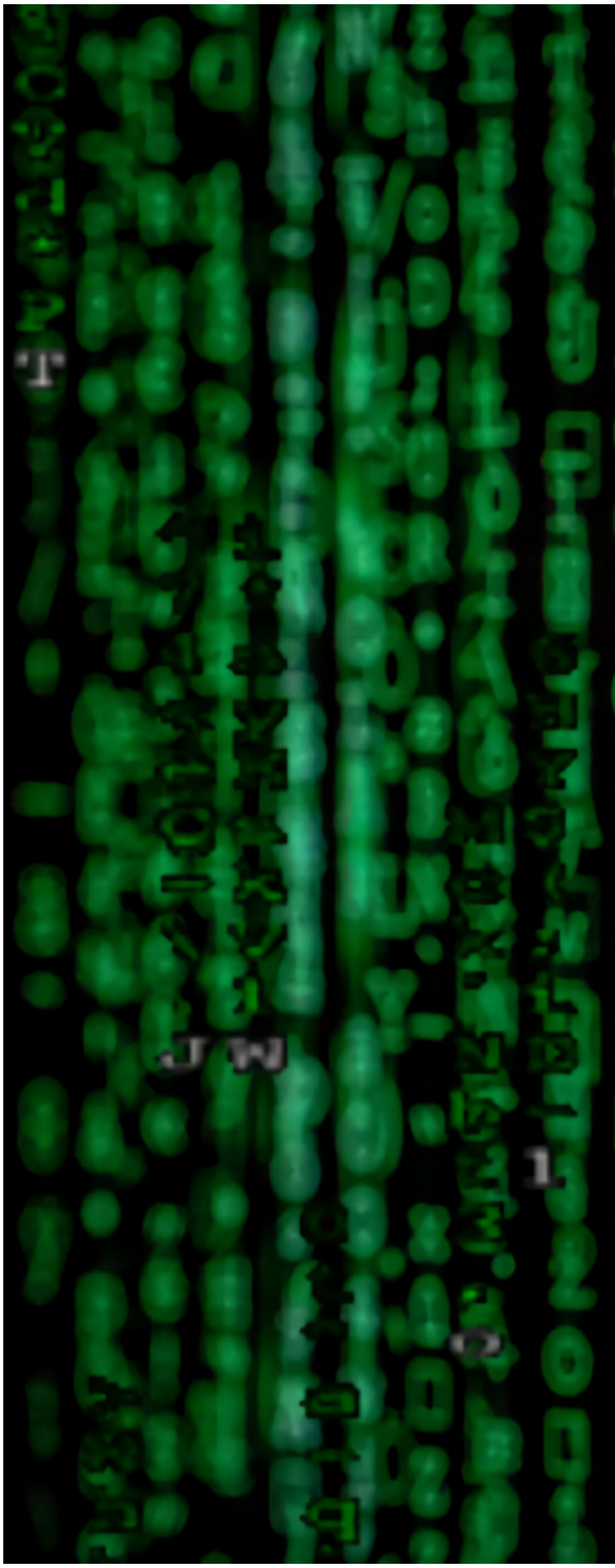
Source: Cambridge Centre for Alternate Finance, Allianz Research

9. Proof-of-work (PoW) is a consensus mechanism that rewards network members for spending computational power to solve a complex mathematical puzzle. It is used to validate transactions and open new blocks.
10. ECB (2022). Mining the environment – is climate risk priced into crypto-assets?
11. Cambridge Centre for Alternative Finance (2022). Bitcoin Electricity Consumption Index
12. Hash rate refers to the amount of computational power demanded by a blockchain network
13. Nasdaq Data Link (2023). Bitcoin Hash Rate

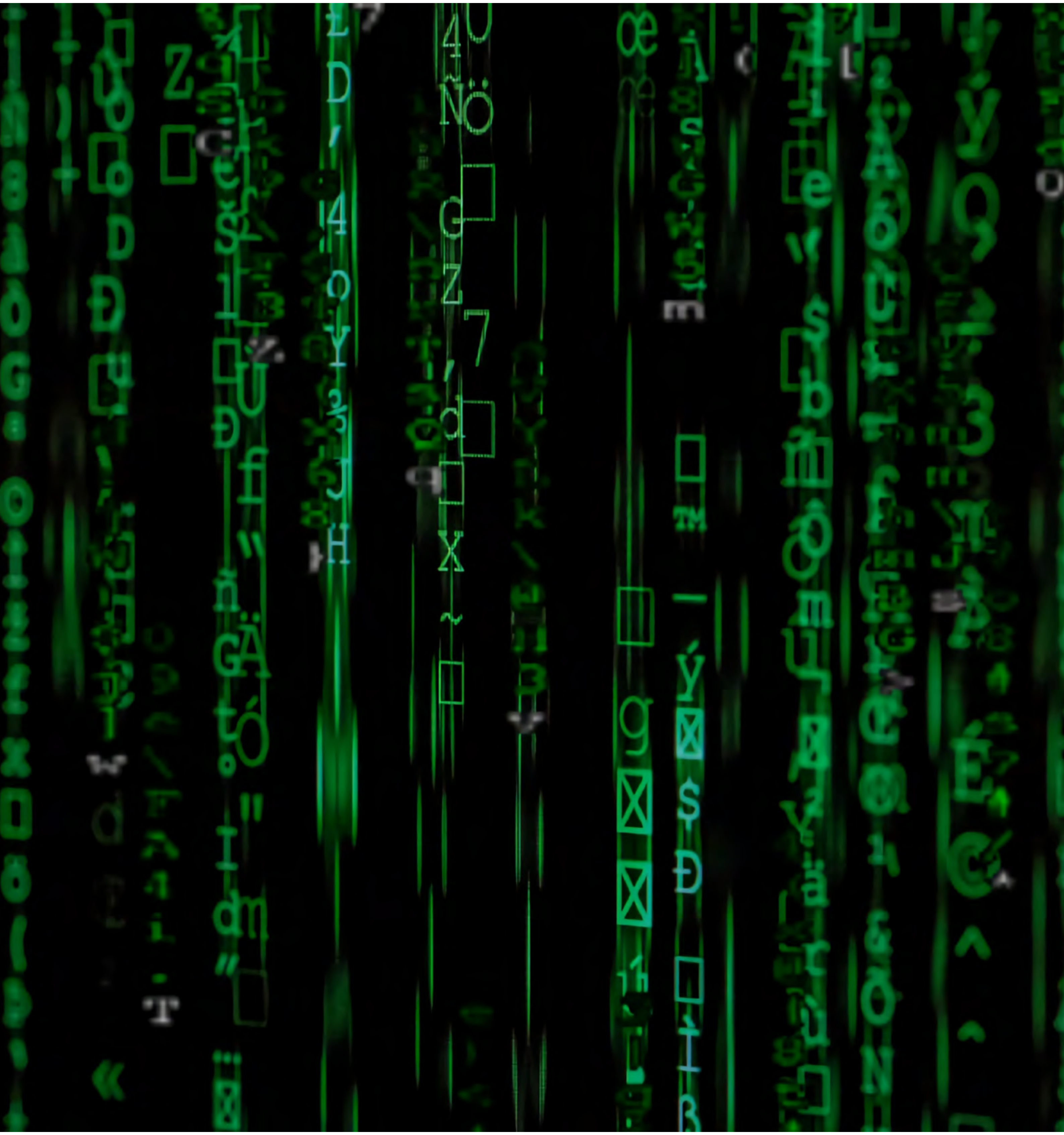
As of end-April 2023, the global bitcoin hashrate, which represents the amount of mining activity, was double the level in January 2022. If this trend continues unchecked, the energy demand and consequently any associated emissions could prove to be fatal to climate goals.

The cautionary tale of Bitcoin's hunger for energy suggests that other emerging and trending technologies should be examined for their environmental impacts. Several researchers at Google, UC Berkeley and Meta, among others, have been studying emissions linked to Machine Learning workloads (training AI models being one such workload). Focusing on operational energy-related emissions, the training phase for AI is found to be highly energy-demanding and consequently emission-intensive. Their studies compare the energy consumption of various models, one of which is OpenAI's third Generative Pre-trained Transformers (GPT-3), which recorded the highest energy consumption and emissions among the group. For the training phase, the measured energy consumption was 1287MWh and the associated operational emissions (location-dependent owing to the energy mix) were calculated to be 552.1 $tCO2e$[14].

The operational emissions (from research and development of AI and chips) are localized primarily in the US, given its high research output on AI and AI chips. But the embodied emissions (from manufacturing the chips) are to be found elsewhere. For instance, NVIDIA is emerging as a leader in developing AI chips, but it still relies on Taiwan Semiconductor Manufacturing Co Ltd to produce the chips, which means that the energy mix of the production site and the emissions from transportation should also be considered.



14. Patterson, D; et al. (2021). Carbon Emissions and Large Neural Network



How to decarbonize the ICT sector?

The good news is that decarbonization prospects are better in the ICT sector. Its carbon footprint heavily depends on the electricity mix, so emissions are likely to decline steadily with the increasing share of renewable electricity and the improving energy-efficiency of appliances. Many mobile operators and other ICT industries have also set carbon-neutrality and net-zero targets that are aligned with the 1.5°C decarbonisation pathway, which will also contribute to keep electricity consumption and carbon emissions in check.[15] The remaining emissions could be brought down by optimizing the product life cycle, i.e., assessing material selection, design choices, manufacturing and transportation.

However, it will take developing nations longer to reach net-zero in the ICT sector. Developing nations would lie on the far end of the timeline for the decarbonization pathway, due to the challenges of greening a fast-growing electricity sector. Probably even beyond 2050, with a delayed net-zero transition. In contrast, the ICT sector in Europe, for instance, could achieve the same target relatively earlier, being an ambitious forerunner in the net-zero transition.[16]

Decarbonizing cryptocurrency is top of the agenda. Bitcoin mining is diverting electricity from other priorities such as the electrification of buildings, transportation and manufacturing. Moreover, even though switching to renewables has the potential to slash GHG emissions, this cannot be done quickly enough if energy demand keeps rising, which could slow the phase-out of fossil-fuel power plants. Governments are taking note: Calls for action in Europe come from the Swedish financial institution and the ECB since the yearly emissions from crypto mining could threaten targeted GHG emission-savings for many Eurozone countries.[17,18] Members of parliament have asked the European Commission to present a legislative proposal to include any crypto-asset mining activities that contribute substantially to climate change in the EU taxonomy for sustainable activities by January 2025[19].

At the same time, to deter crypto mining from moving to locations with cheaper electricity prices and reduce energy demand, some countries have issued outright bans. China, for instance, issued a ban on all crypto transactions and mining in 2021. However, the effectiveness of this ban is debatable since it simply drove the miners underground: China is still the world's second-largest Bitcoin miner after the US.[20,21] Less drastic measures could also foster emission reductions through technological advancements. Ethereum set such an example by switching to a different consensus mechanism called proof-of-stake (PoS)[22] in 2022. The merging of the Ethereum Mainnet with a separate PoS blockchain called Beacon Chain has slashed Ethereum's energy demand by 99.95%.[23]

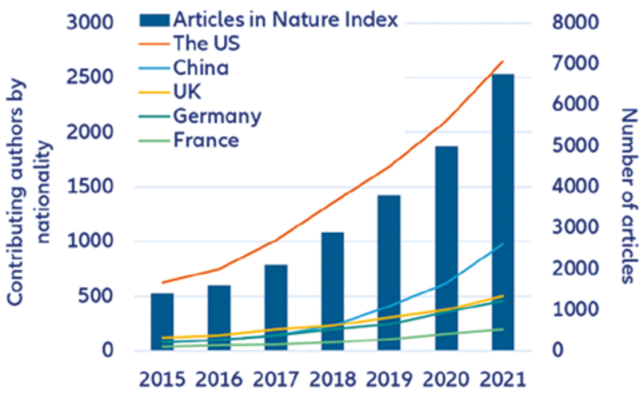
15. GSM Association (2022). Mobile Net Zero: State of the Industry on Climate Action 2022
16. European Commission (2022). EU's renewable energy targets
17. ECB (2022). Mining the environment – is climate risk priced into crypto-assets?
18. Swedish Financial Supervisory Authority (2021). Crypto-assets are a threat to the climate transition – energy-intensive mining should be banned
19. European Parliament (2022). Cryptocurrencies in the EU: new rules to boost benefits and curb threats
20. The White House (2022). Climate and Energy Implications of Crypto-Assets in the United States
21. Forkast (2022). China banned Bitcoin mining and became world's No.2 Bitcoin miner
22. Proof-of-stake (PoS) was developed as an alternative to the original proof-of-work consensus mechanism. It is less computationally demanding and consequently less energy intensive.
23. Ethereum (2023). Ethereum's energy expenditure

Blockchain does have a role to play in decarbonization and climate action.[24] It can help to build trust and ambition in climate negotiations by providing an interoperable and open-source digital infrastructure that could enable transparent measurement, reporting and tracking of Nationally Determined Contributions. Moreover, given its transparency and accessibility, blockchain can also help build a framework for a trustworthy and scalable Voluntary Carbon Market (VCM) to trade carbon credits. Participants can navigate through carbon registries on blockchains, ensuring global price and supply coordination. Digital measurement, reporting and verification tools, such as smart meters and sensors, could also help buyers gauge the effectiveness of carbon-sequestration efforts. Such markets would foster a streamlined discovery and purchase of carbon credits, reducing reliance on intermediaries, which in turn would lower transaction costs, ensuring that a larger chunk of the finances actually make it to the project developers. Digitizing carbon credits would improve accessibility to conventional carbon finance markets. By allowing fractional ownership of credits, individuals and smaller organizations can also participate. Tokenization also makes high-value credits such as tech-based carbon-dioxide removal credits, accessible to small buyers. The broader access to carbon offsetting would foster climate action.

Similarly, AI could help reduce global GHG emissions by around 1.5-4.0% by 2030 via productivity and efficiency gains. The biggest absolute emissions-reduction potential (or up to -2.2% in relative terms) would be realised in the energy sector from improvements such as better planned grid infrastructure. The transport sector is up next, with a promising emissions-reduction potential of up to -1.7% owing to smart navigation and automated-driving technologies. The agriculture and water sectors would benefit from an environmental conservation perspective as using AI for agricultural applications would help slash emissions while bolstering food and water security by means of optimized resource allocation and utilization.[25,26]

If AI and robotics research output is used as metric to gauge the development of AI, the US, China and the UK come out on top (Figure 5). If solely the publications on AI are considered, China and the US lead the research followed by India supposing the trends from the latest comparable estimate are assumed to stay true till date.[27]

Figure 5: Trends in AI and robotics research output



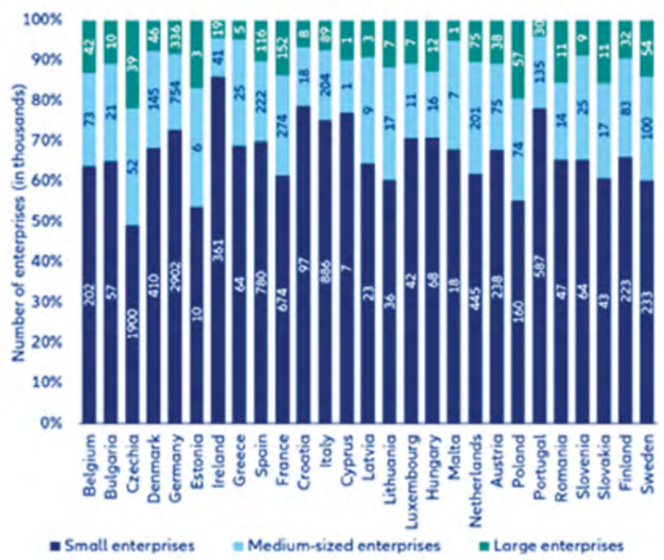
Source: Nature,[28] Allianz Research

Note: The data only refers to the articles published in 82 high-quality science journals. The chart shows the total number of articles on AI and robotics published, in these journals, globally while the share of contributing authors/ institutions reflects the top 5 countries leading the research on these themes.

AI is already improved efficiency in the European industrial sector, with Germany leading the pack in terms of the number of companies that have adopted AI in operations (Figure 5). This has resulted in increased production quantity & quality, with reduced demand for energy and raw materials, and further translates to reduced generation of GHG emissions and industrial waste. AI is also helping to achieve better energy demand-and-supply synergy.

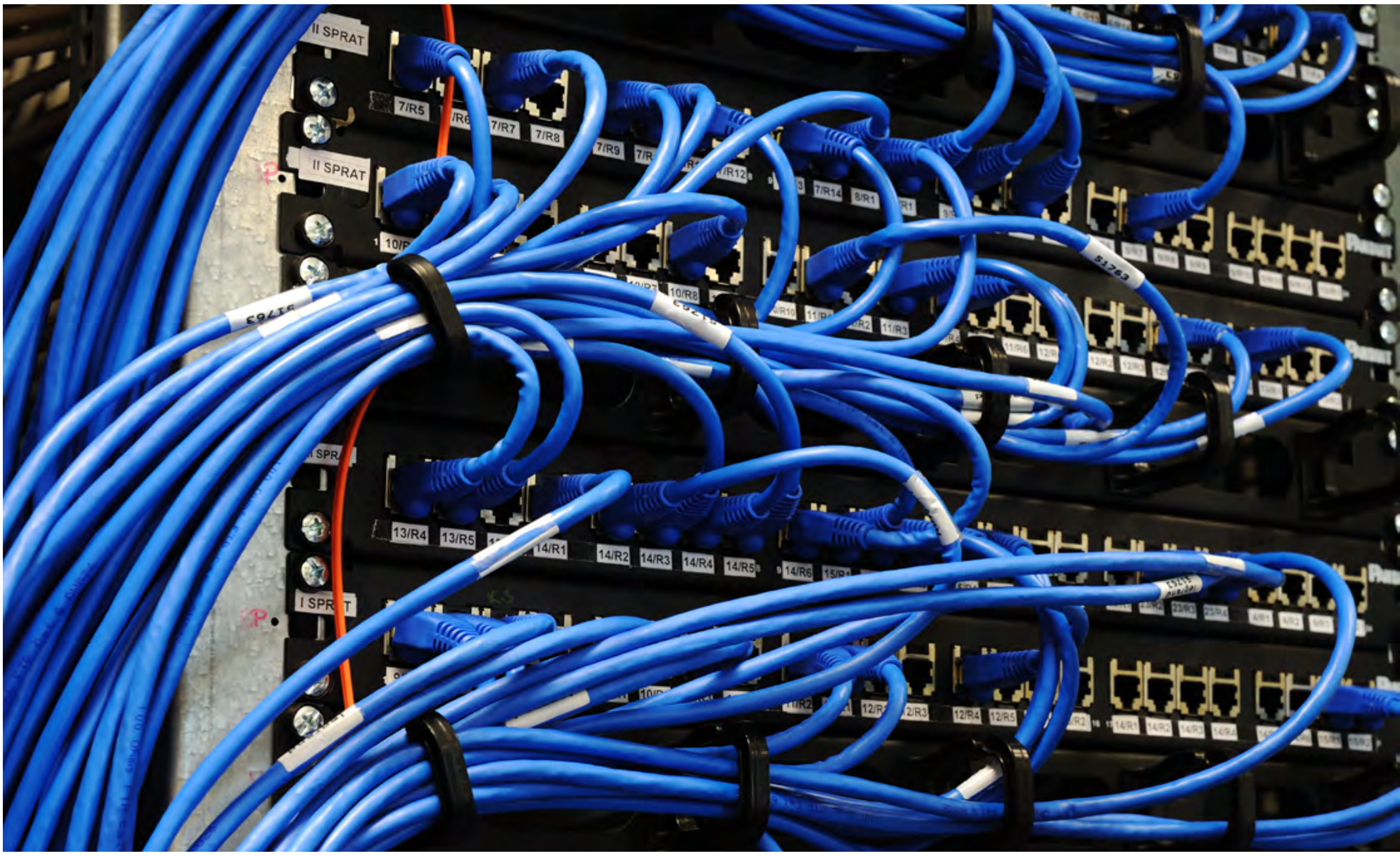
24. World Economic Forum (2023). Blockchain for Scaling Climate Action
25. Microsoft & PwC (2019). How AI can enable a Sustainable Future
26. IEA (2017). Digitalization and Energy
27. The race to the top among the world's leaders in artificial intelligence (nature.com)
28. Growth in AI and robotics research accelerates (nature.com)

Figure 6: Enterprises in EU member states using at least one AI technology in 2021, figures in columns refer to number of enterprises in thousands



Source: Eurostat, Allianz Research. Note: Micro enterprises (less than 10 employees) are excluded from this data representation.

Policymakers will have to spur changes in consumer behaviour to decarbonize the ICT sector further. The majority of emissions come from user devices and it is unlikely that consumer behaviour will change drastically towards using fewer devices in the future. In fact, quite the opposite is likely. This means these changes would have to be mandated top-down through regulations or incentives.



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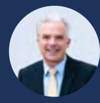

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