Patchy coverage: New CREDS study finds a number of ‘blackspots’ in the publicly available evidence base on the energy use impacts of 5G

Laurence Williams

Introduction

The fifth and latest generation of mobile network (5G) has been widely heralded as a green technology with the capacity to drastically improve the energy efficiency of mobile networks and enable energy and emissions savings across other areas of economic and social life. However, according to a new paper from CREDS researchers, *The energy use implications of 5G: reviewing whole network operational energy, embodied energy, and indirect effects*, the evidence base on the energy use implications of 5G is lacking in four key respects.

1. Whilst there are a large number of studies that assess the energy saving potential of single technologies associated with 5G, there is a lack of studies that assess the implications of 5G for energy consumption at the whole-network level.
2. The majority of studies focus only on operational energy use, without taking embodied energy use into account.
3. The scope for direct rebound effects is rarely explicitly acknowledged, and insufficient attention is paid to encouraging less energy-intensive user behaviours and designing less energy-intensive mobile services.
4. The scope for 5G to enable energy savings in other sectors of the economy has not yet been comprehensively assessed, nor has whether such enablement effects will be sufficient to offset the direct energy use and rebound effects of 5G.

These issues prompt seven recommendations aimed at policy-makers, researchers and funding bodies, and various industry actors. This briefing summarises the paper’s findings and highlights the recommendations that stem from them.

Can 5G render the 'data avalanche' sustainable?

The energy efficiency of mobile networks has increased with each new generation. This trend will continue with 5G, which stands to significantly improve the energy efficiency of networks. However, at the same time, the amount of data traffic across mobile networks has dramatically increased, and is forecast to continue increasing well into the future. For instance, Ericsson recently estimated that global monthly mobile data traffic stood at 80EB by the end of 2021 (with a monthly average usage per smartphone of 11.4GB), and forecasted that this would increase to 370EB by the end of 2027 (with a monthly average usage per smartphone of 41GB) (Ericcson, 2021). The question therefore becomes whether sufficient energy efficiency improvements can be achieved in order to render data traffic growth sustainable and ensure that traffic increases don't lead to overall increases in network energy consumption.

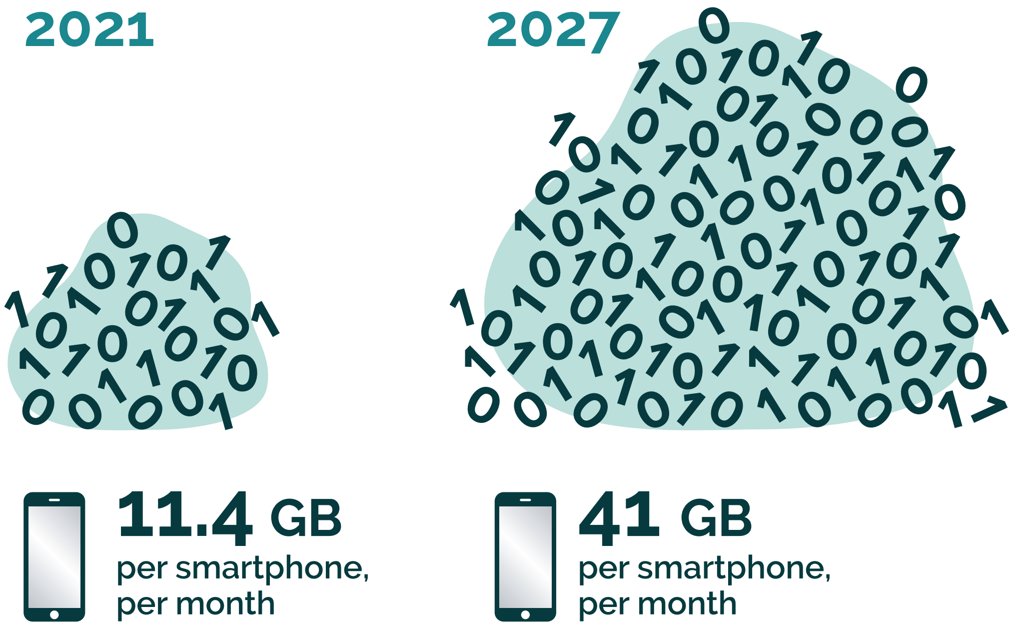

Figure 1: Graphic shows the estimated increase in data traffic per smartphone, per month from 11.4 GB in 2021 to 41 GB in 2027. Source: Ericsson, 2021.

Growing mobile data traffic and the need for networks to serve it in environmentally and economically sustainable ways have led to a strong focus on improving the energy efficiency of mobile networks from both industry and academia. In particular, a good deal of attention has been paid to the energy use of radio access networks (RANs), because historical estimates have suggested that the RAN consumes the majority of the operational energy use of mobile networks. One oft-quoted estimate suggests that the RAN accounts for nearly 60% of the operational energy use of a mobile network (not including user device operational energy use) (Han et al., 2011), whereas another estimates that the RAN is responsible for 80% of the operational energy use of a mobile network including user device operational energy use (Auer et al., 2011).

Alongside efforts focusing on the energy consumption of networks themselves, the industry has also pointed to the scope for 5G to enable energy savings in other areas of economic and social life by, for example, enabling the monitoring, analysis and optimisation of various processes and systems or enabling virtual interactions and so avoiding the need for travel. In spite of these efforts and high hopes, however, the current, publicly available evidence base on the energy use implications of 5G is lacking in a number of potentially significant ways.

How will 5G affect mobile network energy consumption?

Whilst a large number of studies have focused on the energy saving potential of particular technologies associated with 5G, surprisingly few studies have assessed the overall impact of 5G on the energy consumption of mobile networks. Those studies that are available generally find that efficiency improvements will enable network energy consumption to remain flat or fall in spite of projected traffic growth. For example, Nokia estimate that in a European network scenario where traffic increases by 58% per year between 2015 and 2025, energy consumption could fall by 30% over the same period (Nokia, 2016). Nonetheless, there is a lack of peer-reviewed, publicly available, whole network level assessments of the impact of 5G on the energy consumption of mobile networks. Furthermore, the assessments that do exist often fail to disclose key detail about the data and assumptions that they are based on. As such, on the basis of the publicly available evidence base, it is not currently possible to draw firm and clear conclusions about the impact of 5G on the energy consumption of mobile networks.

- **Recommendation 1: There is a need for more peer-reviewed assessments of the implications of 5G for the energy consumption of mobile networks with fuller disclosure of the key data and assumptions used. Research funding bodies should support such work as a priority.**

The hidden costs of embodied energy

Future assessments should include the embodied energy use associated with 5G, because this form of energy use has been largely overlooked in the literature so far. Embodied energy refers to the energy required to manufacture, install and maintain network infrastructure, as opposed to the operational energy required to power networks. Assessments of the energy use implications of 5G have almost exclusively focused on the latter form of energy use.

The embodied energy associated with user devices has long been considered a bigger issue than the embodied energy associated with network infrastructure. For instance, a historical estimate suggested that embodied energy accounted for 36% of the total energy consumption of a base station over a 10 year lifetime (Humar et al., 2011), whereas a more recent estimate has suggested that the embodied emissions associated with a base station amount to 10-15% of its operational emissions (assuming a 10 year lifetime and global electricity mix) (NGMN, 2021).

On the other hand, the extraction and manufacturing phases account for the majority of the carbon footprint of smartphones, around 75% on average according to one review (Suckling and Lee, 2015). Finally, according to one historical estimate, by 2020 mobile device manufacturing was expected to be responsible for the largest share of the global carbon footprint of mobile communications (30%), just edging out RAN operation (29%) (Fehske et al., 2011).

Overlooking embodied energy is a potentially significant oversight for two reasons. First, because 5G-enabled operational energy savings require large amounts of new equipment to be added to (or replace) existing infrastructure, current assessments that ignore embodied energy necessarily overstate the total energy savings that are possible. This is because the embodied energy costs of rolling out 5G will, to some extent, counteract the operational energy saved by more efficient 5G networks. Second, taking embodied energy into account may change the relative merits of various energy saving strategies. At the very least, decision-makers should be sceptical about claims of the energy saving potential of strategies based on the large-scale introduction of new infrastructure that are based on assessments that fail to consider the embodied energy costs of that infrastructure.

- **Recommendation 2: Embodied energy use should be included in assessments of the energy use implications of 5G and factored into comparisons between different energy saving strategies. Network infrastructure providers and network operators should make up-to-date figures for the embodied energy use associated with mobile network equipment publicly available.**
- **Recommendation 3: Industry and policy-makers should take steps to reduce the embodied energy associated with 5G and future mobile network generations. Network infrastructure manufacturers and providers and mobile device manufacturers should improve the upgradeability, repairability, reusability and recyclability of network equipment and user devices (e.g. through modular design approaches). Policy-makers should ban the practice of planned obsolescence and enshrine a 'right to repair' in law in order to prolong the average lifespan of mobile devices.[1]**

Unlimited 5G and the response of users

Another issue requiring greater attention is that of direct rebound effects and 5G-driven changes in mobile device user behaviour. 5G will improve the energy efficiency of networks and so make data cheaper on a per-bit basis, allowing unlimited data plans to become more common. This abundance of data and 5G's low latency and fast download speeds will enable more data-intensive services. As such, there is clear scope for 5G to lead to direct rebound effects.

Direct rebound effects occur when the efficiency of a good or service is improved, leading to that good or service becoming cheaper or more convenient, which in turn increases demand for that good or service.

1 Planned obsolescence has been banned in both France and Italy (see House of Commons Environmental Audit Committee, 2020), whilst the EU is expected to legislate to further establish the 'right to repair' in legislation in 2022 (see European Parliament, 2022).

The significance of direct rebound effects for the energy use implications of 5G is that the energy saving potential of improving the energy efficiency of data transmission could be counteracted to some extent (or even exceeded) by increases in data traffic due to the lower cost of data. In other words, improving the energy efficiency of mobile networks does not guarantee that their energy consumption will fall, and, in fact, it is perfectly possible for the energy consumption of mobile networks to rise *because of improvements to their energy efficiency*.

Whilst rebound effects are rarely explicitly factored into assessments of the energy use implications of 5G, such effects are often implicitly accounted for in this literature to the extent that assumed increases in data traffic are the result of 5G-driven efficiency improvements. Generally, however, this literature presents traffic growth as occurring independently from 5G, and 5G associated efficiency improvements as being the solution to rendering this growth sustainable.

Rebound effects depend on how users respond to per-bit data price reductions. As such, the energy use implications of 5G are to some extent dependant on user behaviour, how 5G changes it, and whether, if at all, policy-makers, network operators and service providers seek to shape it.

- **Recommendation 4: The scope for 5G to produce direct rebound effects should be more explicitly acknowledged and factored into assessments of the energy use implications of 5G. More 'user-centric' research is required in order to improve our understanding of practices and patterns of mobile device use, their implications for network energy use, and the ways in which 5G might change them.**
- **Recommendation 5: Network operators, service providers and device manufacturers should take steps to increase user awareness of the device and network energy use implications of different user practices and pursue strategies aimed at encouraging less energy-intensive user practices. Such strategies might include displaying accurate, real-time estimates of user energy use or offering prompts to switch to more efficient access networks when available (e.g. WiFi).**
- **Recommendation 6: Application developers should factor sustainability considerations into the earliest design stages and aim to ensure that their apps are an efficient way to deliver a particular service. Energy-intensive features that add little to the quality of the user experience should be identified and turned off as default (e.g. the hint message function of instant messaging apps). Service and content providers should also carefully consider the default quality settings for media content, especially video; and features such as auto-play and infinite scrolling should be disabled as default.**

CREDS

The enablement effect

As with ICTs in general, there are hopes that 5G-enabled energy or emissions savings in other areas of economic and social life – so-called 'enablement effects' – will offset and perhaps justify the direct energy use and rebound effects of 5G. The potential size of 5G-driven enablement effects has not yet been comprehensively assessed, nor has whether such effects will exceed the direct energy use of networks and any rebound effects produced by 5G. It should be pointed out that in order for enablement effects to allow lower reductions in the energy use or emissions of ICTs in a way that is consistent with climate policy, such effects would have to be accurately measured or estimated and clear accounting principles and mechanisms would have to be established.

- **Recommendation 7: Further research is required to comprehensively assess the scope for 5G to produce enablement effects, and the size of such effects relative to the direct energy use and rebound effects of 5G.**

Understanding and realising 5G's energy saving potential

The publicly available evidence base on the energy use implications of 5G is lacking in four key respects, and it is crucial that these gaps are addressed through future research and the transparent sharing of information. Whilst the energy efficiency improvements associated with 5G are both impressive and important, energy efficiency and operational energy use are only part of the picture. Much more attention needs to be paid to understanding and limiting embodied energy use and direct rebound effects, and maximising and exploiting enablement effects in ways that are consistent with climate policy. It is crucial that these issues receive greater attention from researchers, policy-makers and industry actors, not only to improve our understanding of the energy use implications of 5G, but also to actively shape 5G and how it's used to realise its energy saving potential.

References

Auer, G., Giannini, V., Desset, C., Godor, I., Skillermark, P., Olsson, M., Ali Imran, M., Sabella, D., Gonzalez, M.J., Blume, O. and Fehske, A. 2011. How much energy is required to run a wireless network. *IEEE Wireless Communications*, **18** (5): 40–49. doi: 10.1109/MWC.2011.6056691

Ericsson, 2021. Ericsson mobility report. Stockholm: Ericsson.

European Parliament, 2022. Briefing: Right to repair. Strasbourg: European Parliamentary Research Service.

Fehske, A., Fettweis, G., Malmodin, J. and Biczok, G. 2011. The global footprint of mobile communications: The ecological and economic perspective. *IEEE Communications Magazine*. **49** (8): 55–62. doi: 10.1109/MCOM.2011.5978416

Han, C., Harrold, T., Armour, S., Krikidis, I., Videv, S., Grant, P.M., Haas, H., Thompson, J.S., Ku, I., Wang, C.X., Le, T.A., Nakhai, M.R., Zhang, J., Hanzo, L., 2011. Green radio: Radio techniques to enable energy-efficient wireless networks. *IEEE Communications Magazine*. **49** (8): 46–54. doi: 10.1109/MCOM.2011.5783984

House of Commons Environmental Audit Committee, 2020. Electronic waste and the Circular Economy - First report of session 2019–21. London: House of Commons.

Humar, I., Ge, X., Xiang, L., Jo, M., Chen, M. and Zhang, J. 2011. Rethinking energy efficiency models of cellular networks with embodied energy. *IEEE Network*, **25** (2): 40–49. doi: 10.1109/MNET.2011.5730527

NGMN, 2021. Green future networks: Network equipment eco-design and end to end service footprint. Frankfurt am Main: Next Generation Mobile Networks e.V.

Nokia, 2016. 5G network energy efficiency.

Suckling, J. and Lee, J., 2015. Redefining scope: the true environmental impact of smartphones? *International Journal of Life Cycle Assessment*, **20**: 1181–1196 doi: 10.1007/s11367-015-0909-4

Contact details

Laurence Williams: Laurence.Williams@sussex.ac.uk

This briefing should be referenced as:

> Williams, L. 2022. Patchy coverage: New CREDS study finds a number of 'blackspots' in the publicly available evidence base on the energy use impacts of 5G. CREDS Briefing 021. Oxford, UK: Centre for Research into Energy Demand Solutions.

This briefing is based on the following paper:

> Williams, L., Sovacool, B.K. and Foxon, T.J. 2022. The energy use implications of 5G: Reviewing whole network operational energy, embodied energy, and indirect effects. *Renewable and Sustainable Energy Reviews*, **157**: 112033. 21. doi: 10.1016/j.rser.2021.112033

About CREDS

The Centre for Research in Energy Demand Solutions (CREDS) was established as part of the UK Research and Innovation's Energy Programme in April 2018, with funding of £19.5M over five years. Its mission is to make the UK a leader in understanding the changes in energy demand needed for the transition to a secure and affordable, net-zero society. CREDS has a team of over 140 people based at 26 UK universities

CREDS is funded by UK Research and Innovation, Grant agreement number EP/R035288/1

www.creds.ac.uk @CREDS_UK

www.linkedin.com/company/credsuk/