The next generation of operator sustainability: greener edge and open RAN

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Executive summary

Decarbonisation has for some years been anchored in the global climate objectives that were enshrined in the Paris Agreement of 2015. The compact relies on individual countries and their industries setting and delivering on national roadmaps. UN Climate Change Conferences (COPs) have come and gone since then, with mixed success in the incremental rate of national commitments and timelines stipulated. Nevertheless, nearly 85% of telecoms operators worldwide have made net-zero commitments – a stellar figure. Furthermore, two thirds have committed to do so by 2040, well in advance of the generally accepted guidance of 2050.

Tackling the glass half empty

The question for operators is how to navigate the sustainability pivot on a business level. The ongoing enterprise digitisation across the economy is a massive shift, on a scale akin to industrialisation and the advent of the web. As power usage rises from an increasing share of enterprise 5G and other compute workloads being hosted on edge servers or shifted to the cloud, improving energy efficiency is no longer a 'nice to have'; it is a 'must have'.

Positively, there is an abundance of technology developed by major equipment vendors to harvest power efficiencies and generally be longer lasting. Energy efficiencies in the network now come from a range of sources, including vendors making RAN equipment with AI-enabled sleep states; lower air conditioning usage in edge and core data centres that deploy liquid cooling (or natural cooling); smarter site selection; and lithium-ion batteries.

Despite the strategic value of energy growing in importance, moves at the product and competitive levels are not as well developed. This became clear when GSMA Intelligence asked operators whether they see energy efficiency as a competitive advantage or weakness for their own businesses. Only 20–25% see it as an advantage. Some 60–70% regard it as a weakness, seeing themselves as behind the curve.

Understanding the energy dividend from greener edge

The energy implications of rising enterprise data traffic, and the role of edge in digital transformation, are an underappreciated element of the sustainability discussion. Questions include the following:

- How will rising enterprise data traffic and workloads affect overall energy usage and efficiency?
- How should we think about the differences between processing data at the edge versus the cloud?
- What can operators, vendors and others in the infrastructure value chain do to mitigate energy consumption?

To help answer these questions, GSMA Intelligence surveyed 100 operators and developed a model to simulate the impact of changing enterprise traffic flows across a range of industries.

Looking ahead, operators expect both far edge (on premises) and the cloud to soak up rising enterprise data traffic. By 2030, on-premises and cloud processing are expected to account for 70% of total enterprise traffic processing. In contrast, on-device processing is expected to fall as a share of the total, perhaps reflecting the associated technical challenges and improvements to edge and cloud infrastructure.

Factoring in backhaul-related energy and the energy associated with datacentre cooling and running high compute workloads, there is a potential energy-saving impact by retaining more data at the edge versus the cloud. For example, by retaining 20% of edge traffic at the edge (instead of sending it to central datacentres), a potential overall reduction in energy usage of 15% is possible. Similarly, at a higher scale, if 40% of edge data is retained, this would translate into energy savings of just over 30%. The savings come from requiring less energy associated with backhaul transport, datacentre compute processing and cooling.

These are projections; actual figures for individual enterprise deployments will vary. It is also key to note innovations to improve datacentre energy efficiency such as dynamic workload sharing, more efficient compute, and the use of natural cooling in colder climates where possible. Regardless, the underlying point of an energy 'dividend' by making more use of efficient processing at the edge is important for operators and enterprise IT partners.

Assessing the attraction of vRAN and open RAN

Besides the edge and cloud portion of the computing value chain, sustainability efforts are also heavily targeting the radio access network (RAN). Within this arena, the issue of virtualisation is an important consideration when it comes to energy. Virtualisation of the RAN encompasses a broad set of solutions including open RAN, which generally looks to combine the virtualisation/cloudification of RAN elements with open interfaces, allowing for mixing and matching of vendors. The attraction of vRAN is an alignment of the radio network with a broader move towards use of IT infrastructure and the performance and operations innovations this can enable. The attraction of open RAN, in turn, is the potential for a more diversified supply chain, vendor choice, and flexibility in how networks are deployed.

The question of whether vRAN will be more or less energy efficient than fixed-function appliances has been hotly debated. There is no clear answer, as only a minority of operators have launched open RAN, and those that have done so are often at a low scale.

When operators were asked about their energy-related expectations for open RAN, 40% claimed it will be more energy efficient than other networks, with only 6% believing the opposite. Some 30% regard it as being energy neutral and just over 20% believe it is too early to tell. Around 75% of the operators who believe open RAN networks will be more energy efficient ascribe it to better baseband processing, with around half citing automation and more efficient radios.

Looking ahead

The purpose of this research is to understand how operators can optimise energy usage as enterprise digitisation grows in size and scope. Digitisation is a multi-year process, with network virtualisation intertwined.

The remaining questions will be explored through further research outputs in Q4 2023. Continuing the industry debate is most important, so GSMA Intelligence welcomes all comments on this work.

1 Sustainability in telecoms: gathering pace

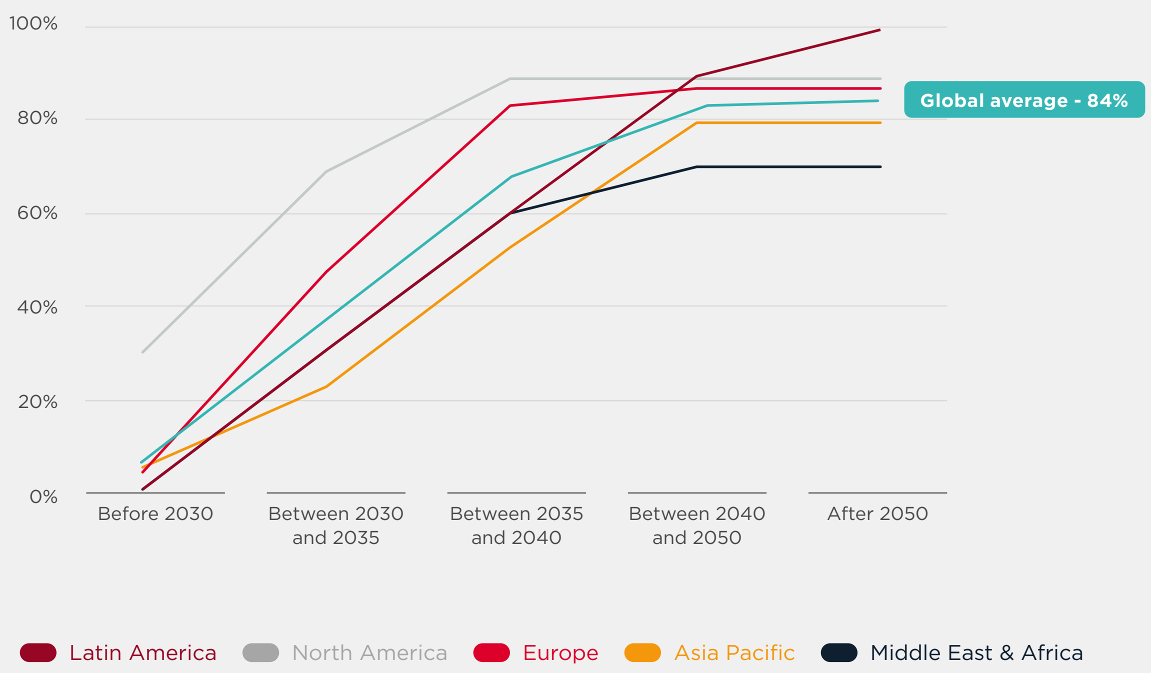
1.1 The environmental case and the business case

Momentum continues to build behind reorienting business practices to a sustainable-first approach. This spans all industries (particularly in higher income regions), but telecoms and parts of the tech sector are among the leaders. Decarbonisation has for some years been anchored in the global climate objectives that were enshrined in the Paris Agreement of 2015. The compact relies on individual countries and their industries setting and delivering on national roadmaps. UN Climate Change Conferences (COPs) have come and gone since then, with mixed success in the incremental rate of national commitments and timelines stipulated.

GSMA Intelligence survey responses indicate nearly 85% of telecoms operators worldwide have made net-zero commitments. This becomes a stellar 97% if including those with plans to. Furthermore, two thirds have committed to do so by 2040, well in advance of the generally accepted guidance of 2050. See Figure 1.

Figure 1 Cumulative share of operators committed to net zero by given date

Percentage of operators (N=100)

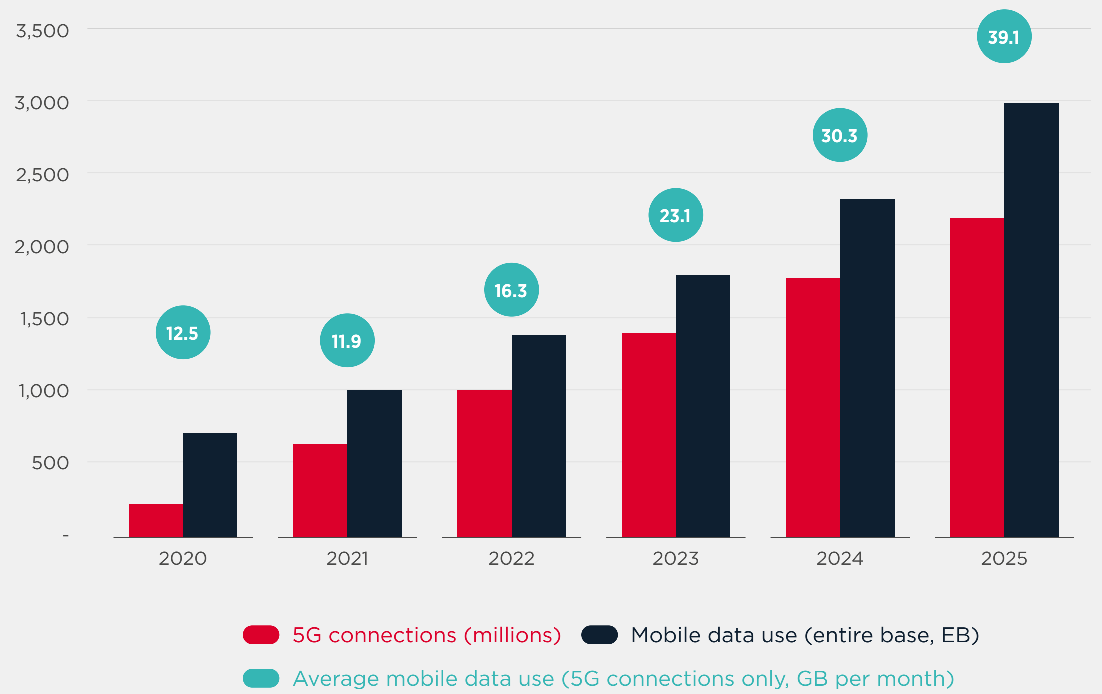


Source: GSMA Intelligence based on survey of telecoms operators, June/July 2023

The business rationale for going green is as strong as the environmental case. For the telecoms sector, the main motivation for energy-related cost savings is to mitigate the outlay and ongoing expenditure on 5G networks. 5G infrastructure continues to expand as operators in countries beyond the early adopters invest in new builds, primarily on non-standalone (NSA) architectures. This is expensive; 5G will account for 85–90% of operator capex to 2025.

For the industry as a whole, this equates to around $1 trillion (20–25% of revenue). GSMA Intelligence estimates that 5G will account for just over 25% of total mobile connections by 2025 and 55% by the end of the decade. This will have a direct impact on data traffic (which will rise sixfold over the decade) as the average 5G customer uses 4–5× the level of data per month of a 4G user.

Figure 2 **As 5G rises in the customer base, so too does traffic**



Source: GSMA Intelligence, Ericsson

1.2 Energy efficiency: no longer a nice to have

The effect illustrated in Figure 2 is also true for enterprise customer segments, as an increasing share of 5G and other compute workloads are hosted on edge servers or shifted to the cloud. For this reason, improving energy efficiency is no longer a 'nice to have', but a 'must have'.

Glass half full

The positive comes from an abundance of technology developed by major equipment vendors to harvest power efficiencies and generally be longer lasting. Energy efficiencies in the network now come from a range of sources, including RAN equipment with AI-enabled sleep states; lower air conditioning usage in edge and core data centres that deploy liquid cooling (or natural cooling); smarter site selection; and lithium-ion batteries. There have also been improvements to network planning and the standards for mobile technology overall. While 6G is still at the planning stage (commercial deployments will not take place until 2028), 20% of operators rate energy efficiency as the No.1 attribute to prioritise in 6G networks from a business standpoint (behind security at 31% and support for enterprise verticals at 28%). All of this is a positive reflection of the importance operators place on energy efficiency in their own network transformation plans.

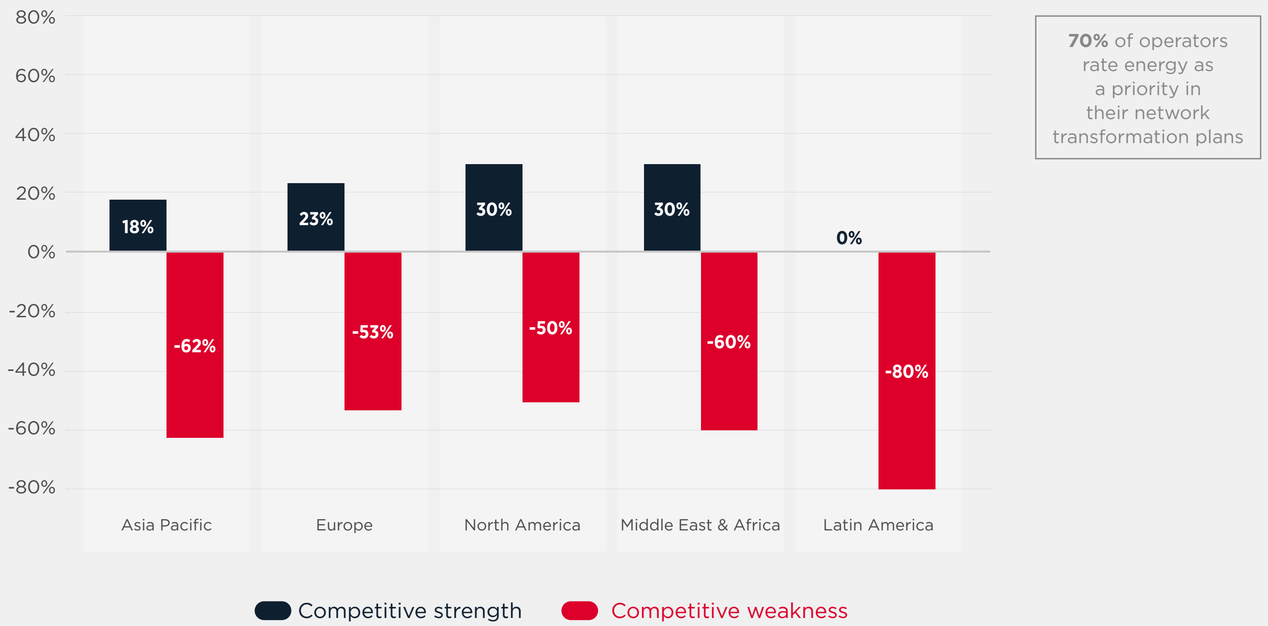
Glass half empty

Despite the growing strategic value of energy, moves at the product and competitive levels are not as well developed. This became clear when we asked operators whether they see energy efficiency as a competitive advantage or weakness for their own businesses. On average, only 20–25% see it as an advantage, while 60–70% regard it as a weakness (see Figure 3). The weakness rating is high, likely reflecting operators seeing themselves as still translating corporate-level climate commitments into product-level selling features – in short, being behind the curve. There is surprisingly little variation by region. A gap therefore exists – if only temporary – for consumer and enterprise mobility products that trade on sustainability as a key selling attribute.

The focus of this report is on the enterprise side, given the pace of digitisation. However, the insights are equally valid to network vendors whose equipment and solutions are ultimately the drivers of the efficiencies their clients (operators) are pushing to customers.

Figure 3 Despite operators rating energy as a priority in network plans, they see themselves behind on energy as a competitive selling point

How would you assess the effectiveness of energy efficiency and sustainability in your product marketing? Percentage of operators surveyed (N=100)



Source: GSMA Intelligence based on survey of telecoms operators, June/July 2023

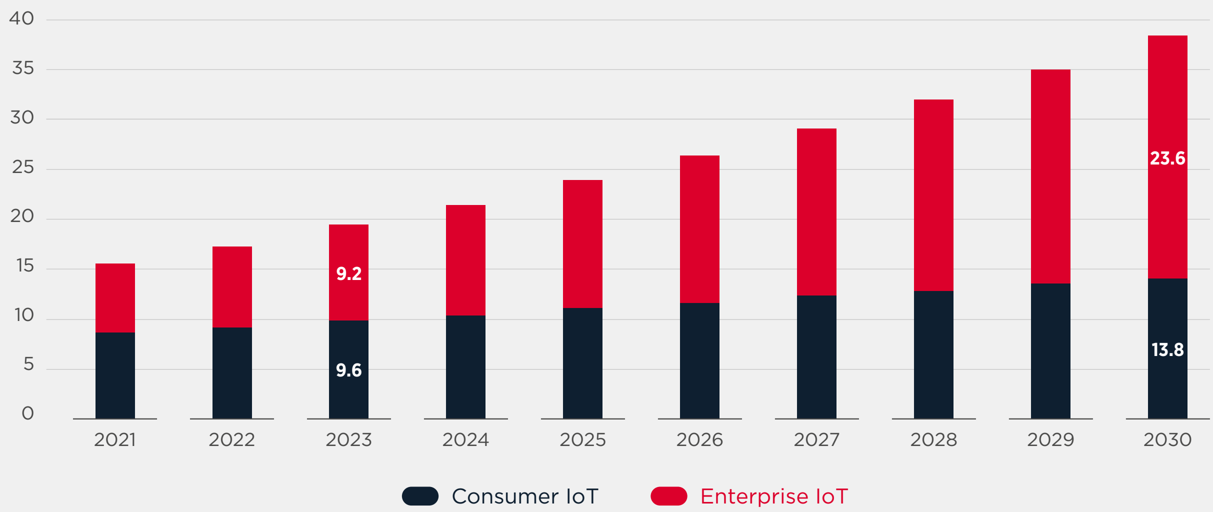
2 Edge compute: a new era?

2.1 Business light turns green for edge compute

The movement towards enterprise digitisation across the economy is a shift on a scale akin to transformations such as industrialisation and the advent of the web. IoT is an enabler of this shift. It is a broad term referring to objects embedded with connectivity to make their use smarter. The consumer portion of IoT (excluding mobile phones and cellular dongles) spans smart TVs, home security, vehicle infotainment systems and other applications. The enterprise segment stretches across a range of industries including manufacturing, transportation, utilities, buildings and logistics. The scale of IoT growth is large; GSMA Intelligence forecasts that the total connections base will increase from 20 billion in 2023 to around 37 billion by 2030 – a near doubling in less than a decade, with growth of 10% per year.

Figure 4 The growth of IoT, powered by enterprise digitisation

IoT connections (billion)



Source: GSMA Intelligence

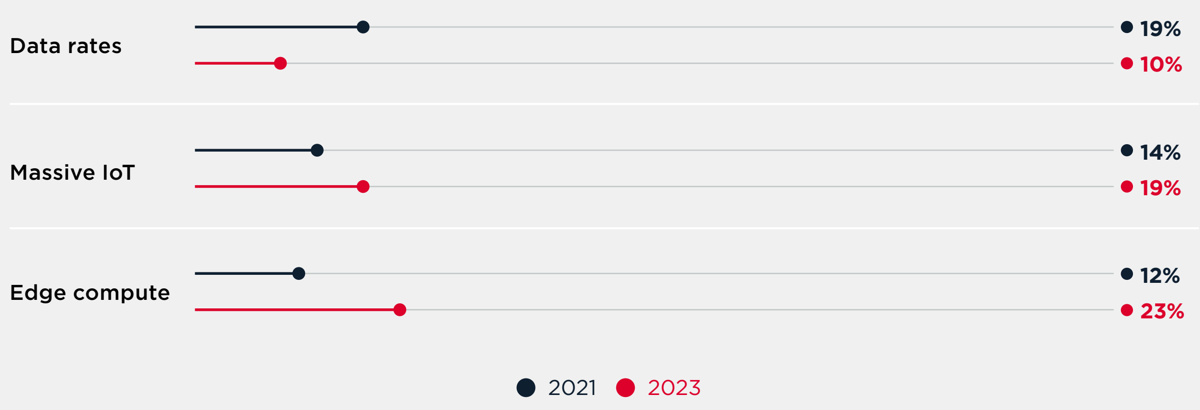
The enterprise segment is the key driver of the rise, growing 2.5× over the period. The infrastructure requirements to support this growth increasingly rely on distributed architectures to enable low latencies, which has brought 5G, cloud computing, edge computing and AI into play – often in combination rather than working in isolation. Edge computing, in particular, has experienced something of a renaissance, meeting the requirements of companies seeking to process more of their workloads on the premises, or between premises and the central cloud servers of the hyperscalers.

This renaissance is evident in the improving sentiment of mobile operators. Many have deployed edge infrastructure to complement private network deployments of greenfield 5G coverage to enterprise clients. GSMA Intelligence asked operators to rate their prized assets in selling 5G into enterprise verticals. Edge computing is now the No.1 proposition for around 25% of operators, up from 12% just two years ago (see Figure 5).

It is striking that the edge response has doubled over a two-year period. However, more important is the recognition that 5G cannot simply be seen as a speed upgrade (data rates are the top enterprise selling point for only 10% of operators); rather, it is something that needs IoT and edge infrastructure for it to be sold as a service package to enterprise buyers.

Figure 5 The case for edge compute is growing across industries

What do you [operators] see as the No.1 selling proposition as part of your 5G enterprise strategy?



Source: GSMA Intelligence Network Transformation Survey

2.2 The energy dividend of edge compute

Modelling the impact of changing enterprise traffic flows

The energy implications of rising enterprise data traffic,[1] and the role of edge in digital transformation, are an underappreciated element of the sustainability discussion. Relevant questions include the following:

- How will rising enterprise data traffic and workloads affect overall energy usage and efficiency?
- How should we think about the differences between processing data at the edge versus the cloud?
- What can operators, vendors and others in the infrastructure value chain do to mitigate energy consumption?

To help answer these questions, GSMA Intelligence developed a model to simulate the impact of changing enterprise traffic flows across a range of industries. This was built using three main layers:

- projections for data traffic carried by fixed and mobile access networks (consumer and enterprise)
- split of data processing between the edge and cloud
    - device edge
    - on premises (far edge)
    - between premises and central cloud (near edge)
    - central cloud datacentres
- the energy consumption and CO_2 footprints of different traffic scenarios, based on the network requirements of each (compute and connectivity).

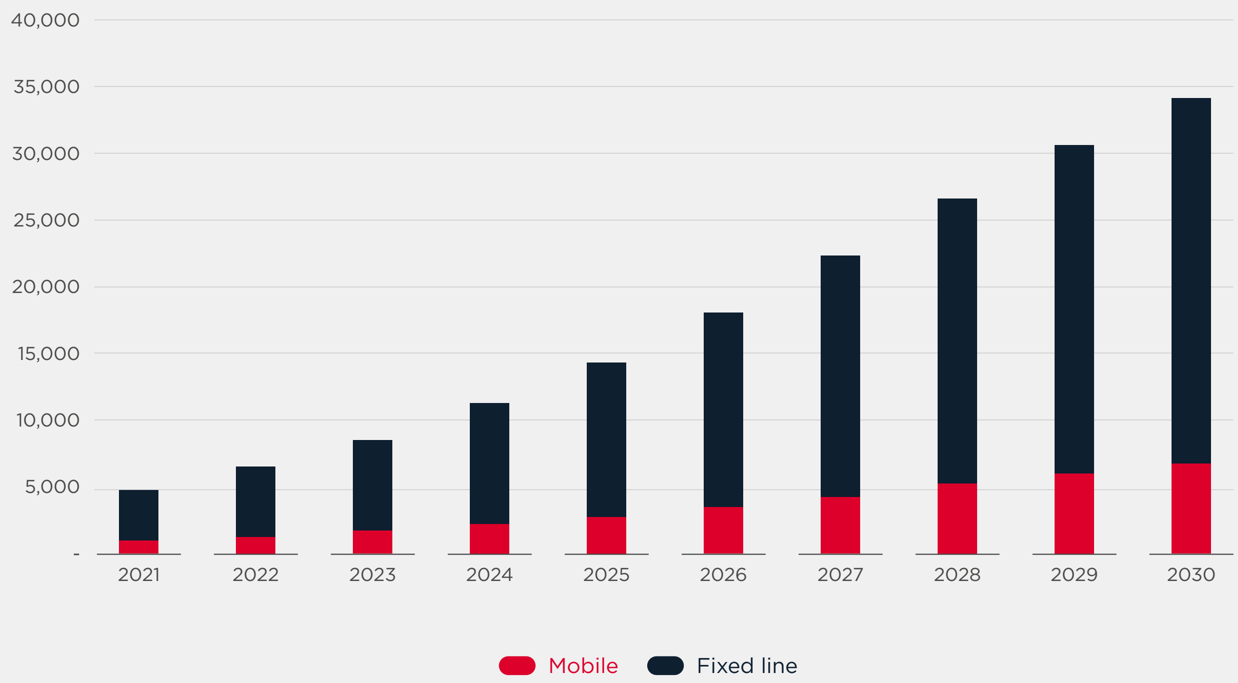
1 GSMA Intelligence also asked operators about their consumer-based edge traffic (e.g. for gaming). This report focuses on the enterprise dimension.

As well as global-level projections, splits were made for different industries, with each taking up a meaningful share of enterprise data traffic. See the Appendix for assumptions.

Traffic projections are shown in Figure 6. By the end of the decade, both mobile traffic (cellular and FWA) and fixed-line traffic (fibre, ADSL, copper, ethernet and some satellite variants) will have risen sixfold on 2022 levels. This totals around 35,000 exabytes, or 35 zetabytes, per year by 2030. The reasons for the rise are well understood, resulting from the interplay between rising take-up of high-speed access tiers (fibre and 5G) and higher monthly data consumption rates. 5G subscribers already use 4–5× the amount of data per month of 4G customers. As this feeds through the subscriber base, the effect on traffic will follow. The same ratios broadly hold for fibre versus ADSL.

Figure 6 Traffic over mobile and fixed access networks will rise sixfold between 2022 and 2030

Exabytes per year



Source: GSMA Intelligence, Ericsson

It is easy to lose a sense of perspective at these scales, given that the data traffic projections encompass nearly all global internet activity. This analysis on sustainability only uses a subset: mobile data traffic from enterprises.

Where traffic is handled matters

More important than the actual volumes is where the traffic is handled. To get a detailed view of this, GSMA Intelligence surveyed operators across the world on where they expect their enterprise traffic to be processed:

- device edge
- on premises (far edge, such as a factory or hospital)
- between premises and central cloud (near edge)
- central cloud datacentres.

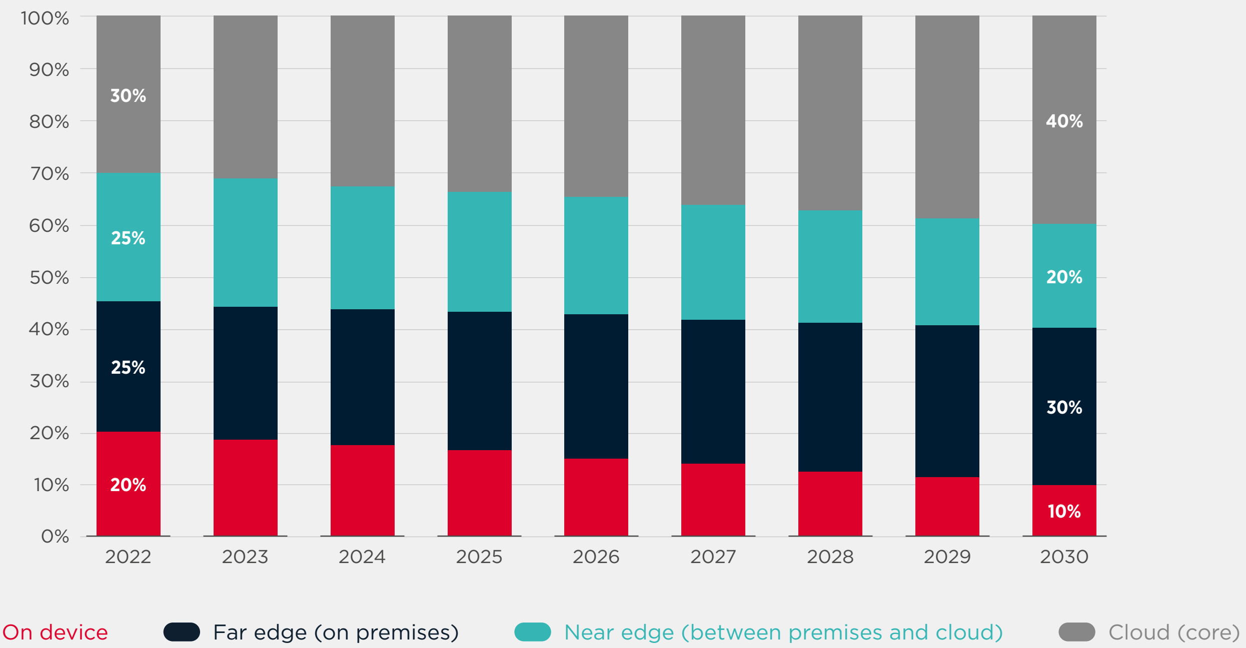
The first three collectively make up the edge. The reason for the split is that the edge is not one place; rather, it is a continuum of compute power being driven closer to where it is being used.

According to survey responses, sense checked with GSMA Intelligence's own data and industry conversations, enterprise volumes today are at around 20% on the device (such as an automated guided vehicle in a manufacturing plant), 25% on premises, 25% at the near edge and 30% in the cloud. See Figure 7.

Looking ahead, operators anticipate both far edge (on premises) and cloud to soak up the additional enterprise data traffic. By 2030, on premises and cloud processing are expected to account for 70% of total enterprise traffic processing. By contrast, on-device processing is expected to fall as a share of the total, perhaps reflecting the associated technical challenges and improvements to edge and cloud infrastructure.

Figure 7 Operators anticipate far edge and cloud to soak up additional enterprise data traffic

Share of enterprise data processing, according to operators (N=100)



Source: GSMA Intelligence based on survey of telecoms operators, June/July 2023

The fact that operators see both edge and cloud as part of the enterprise solution has implications from a sustainability point of view, given the inherent power requirements involved. The difference in energy use between the edge and cloud comes down to energy consumption associated with:

- backhaul/transport between enterprise premises (or near edge, i.e. off premises) and the cloud
- processing and cooling in central datacentres and edge nodes.

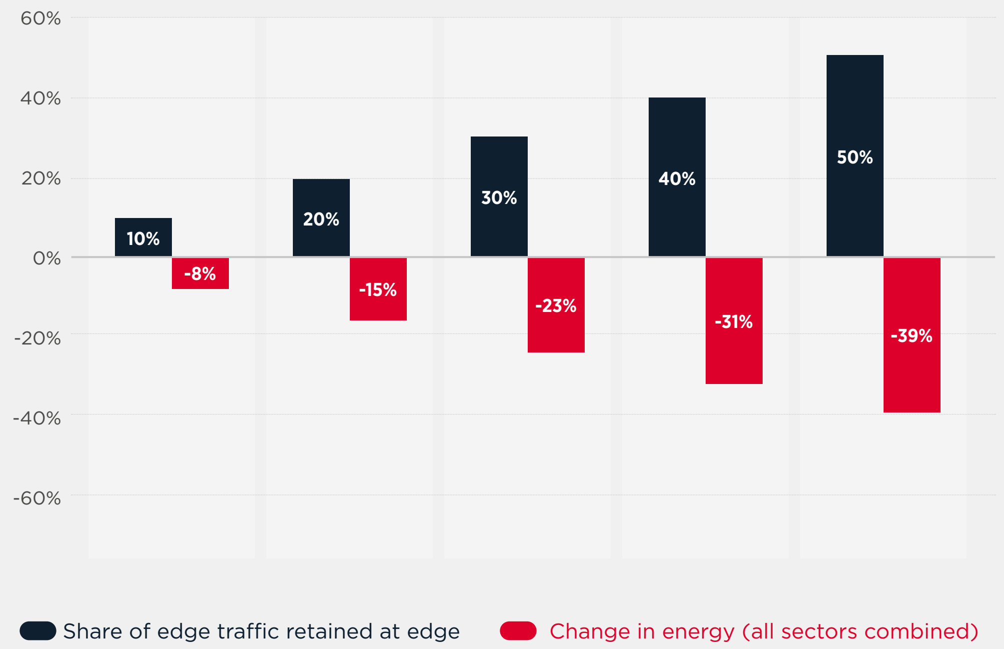
More than 50% of backhaul links still use microwave or mmWave (wireless) technologies, either for lack of necessity, higher cost of fibre or lack of fibre availability (mostly in emerging markets). Fibre is at 30% growing, and more common in metro links. But it is ultimately constrained by the high cost of laying it. The energy footprint of the wireless links is unfortunately considerably higher than fibre, which feeds through to the energy cost of transporting data to cloud datacentres, particularly over distances running into hundreds of kilometres.

The potential energy saving impact

Factoring in the energy associated with datacentre cooling and running the high compute workloads, there is a potential energy saving impact by retaining more data at the edge versus the cloud. For example, by retaining 20% of edge traffic at the edge (instead of sending it to central datacentres), there is a potential overall reduction in energy use of 15% (see Figure 8). Similarly, at a higher scale, if 40% of edge data were retained, this would translate into an energy saving of just over 30%.

These are projections; actual figures for individual enterprise deployments will vary. It is also key to note the innovations that can improve datacentre energy efficiency, such as dynamic workload sharing, more efficient compute, and the use of natural cooling in colder climates where possible. Regardless, the underlying point of an energy 'dividend' by making more use of efficient processing at the edge is important for operators and enterprise IT partners.

Figure 8 Retaining data at the edge can save energy at meaningful scale



Source: GSMA Intelligence

To illustrate the potential impacts on energy use over time and how this may change as traffic patterns shift, GSMA Intelligence extended the analysis to cover a series of key industries. Five are shown in Table 1. These collectively account for almost 50% of IoT connections/devices and 60% of enterprise workloads.

The energy cost from edge processing for enterprise mobile traffic is around 26 terawatt hours per year, compared to 10 terawatt hours for cloud. Individual sector splits are roughly in line with their share of data traffic (e.g. manufacturing accounts for 15% of traffic and 15% of edge processing, or 3.9 terawatt hours per year). However, the edge-related energy savings could translate into 4–5 terawatt hours per year if even 20% of traffic were retained at the edge (this excludes on-device processing).

Table 1: Breakdown for five industries that account for around 50% of IoT connections and 60% of edge processing workloads (2022)

				Energy consumption (terawatt hours)	
	IoT connections	**Enterprise mobile data traffic**	**Edge processing**	**Edge**	**Cloud**
Manufacturing	10%	15%	15%	3.90	1.62
Healthcare	5%	10%	10%	2.61	1.08
Power and energy	23%	10%	11%	2.79	0.90
Retail	6%	10%	10%	2.61	1.08
Financial services	2%	15%	15%	3.90	1.62
Other*	54%	40%	40%	10.38	4.32
Total	**100%**	**100%**	**100%**	**26.20**	**10.60**

*Industries included in the IoT forecasts beyond the five shown. This is a wide group including industries such as transportation, heavy industry (oil & gas and mining), agriculture, logistics and buildings.

Source: GSMA Intelligence

3 Open RAN and open questions

3.1 Sustainability and the industry as a whole

While we have focused primarily on the enterprise side of the telecoms business in this analysis, the sustainability issue has become central to thinking about the industry as a whole. Both telecoms and cloud are among the leading industries driving energy efficiency and renewables in their operations. On a global level, each accounted for around 1% of worldwide electricity consumption as of 2022, which is about 300 terawatt hours each (see Table 2). Projected out to 2030, these should both fall slightly as energy efficiencies and renewables feed through, helping operators stay on track with net-zero timelines. The CO_2 footprints are also lower than energy consumption would imply because each industry uses a higher-than-average share of renewables (even if still below 50%).

Significant work is ongoing at all levels of the value chain to drive sustainability. At the hardware level, major telecoms equipment vendors have positioned energy efficiency as a key competitive differentiator, often making it front and centre of product marketing for 5G radios, core equipment and IT product lines. Progress is slow but steady. According to the Telco Energy Benchmark study, which measures progress across the industry, the headline mobile network efficiency indicator improved to 0.17 kWh per GB of data in 2022, from 0.24 in 2021. This positioning on energy efficiency is equally true of vendors, such as Dell and Intel, focused on enterprise connectivity, cloud, edge and broader server solutions. These are playing to the potential energy savings outlined in the previous chapter, and the steady march of cloudification and virtualisation in the telecoms network.

Table 2: Telecoms networks and the cloud each account for around 1% of global energy use

2022	Electricity usage		CO_2 footprint	
	Terawatt hours	Percentage of global total	Megatonnes CO_2e	Percentage of global total
Total mobile and fixed line networks	**300**	**1.1%**	**114**	**0.3%**
Mobile networks (excl. operator datacentres)	168	0.6%	64	0.2%
Fixed line networks	132	0.5%	50	0.1%
Total datacentres	**338**	**1.3%**	**128**	**0.3%**
Hyperscaler and other	319	1.2%	120	0.3%
Operator	19	0.07%	7	0.02%
Global total (all industries)	**26,799**	**100%**	**37,857**	**100%**

3.2 The impact of virtual RAN and open RAN

Virtual RAN (vRAN) deployments are another key front – and open question – in the energy discussion. Virtualisation of the RAN encompasses a broad set of solutions including open RAN, which generally looks to combine the virtualisation/cloudification of RAN elements with open interfaces, allowing for mixing and matching of vendors. The attraction of vRAN is an alignment of the radio network with a broader move towards use of IT infrastructure and the performance and operations innovations that this can enable. The attraction of open RAN, in turn, is the potential for a more diversified supply chain, vendor choice, and flexibility in how networks are deployed.

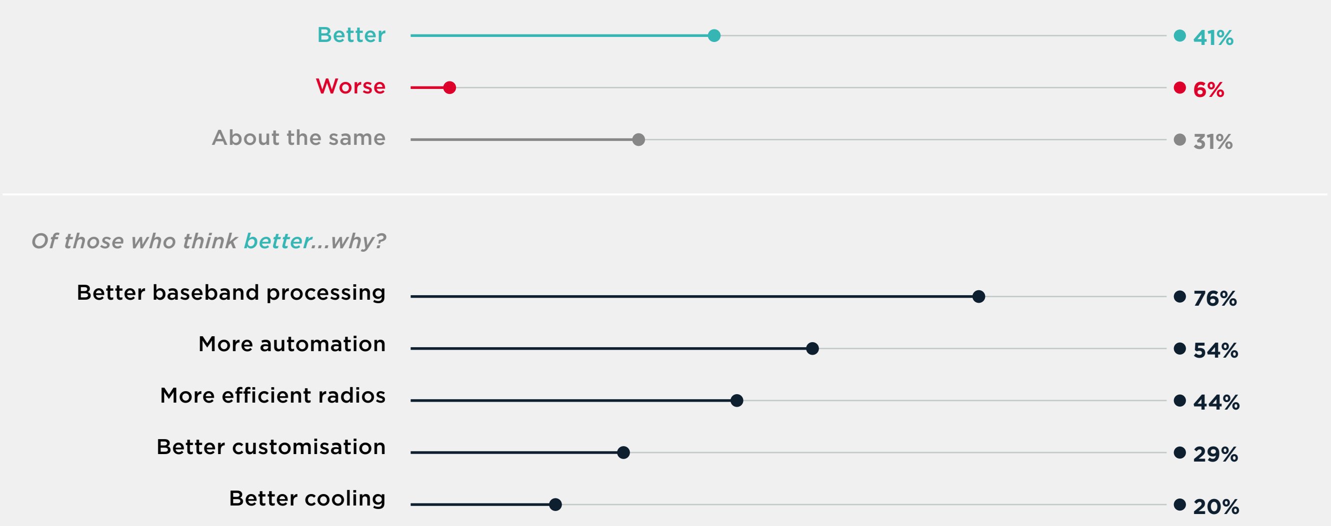
Deployment rates for open RAN globally are at around 20% of operators according to the GSMA Intelligence Network Transformation Survey (June 2023), with 40% of operators claiming to be actively testing it and a further 35% in the planning phase. However, this ignores how expansive open RAN is likely to become, as integration costs are added into the equation, potentially leading to single-vendor, or pre-integrated, solutions adhering to open RAN specifications. Regardless of how open RAN plays out, a broader focus on virtualisation is undeniable and a component of vendor and operator strategies across the globe.

The question of whether open RAN will be more or less energy efficient than fixed-function appliances has been hotly debated. There is no clear, empirical answer as only a minority of operators have launched open RAN, and those that have done so are often initially at a low scale (e.g. Vodafone started with around 2,500 sites in the UK, or 10–20% of its country total, and a smaller fraction still of its European footprint).[2]

GSMA Intelligence asked operators about their energy-related expectations for open RAN. Some 40% think it will be more energy efficient than other networks. Only 6% believed the opposite. Around 30% regard it as energy neutral, and just over 20% believe it is too early to tell. Around 75% of the operators who believe open RAN networks will be more energy efficient ascribe this to better baseband processing, with approximately half citing automation and more efficient radios. While this cannot be taken as a clear conclusion, at least some of these findings will have been drawn from operators that have conducted open RAN trials or been part of lab tests.

Figure 9 **Will open RAN be better or worse on energy than traditional networks?**

Percentage of operators (N=100)



Source: GSMA Intelligence based on survey of telecoms operators, June/July 2023

2 "Vodafone begins volume deployment of OpenRAN for 2,500 sites across Wales and south west England", Vodafone, August 2023

Table 3 details a range of features and technology upgrades associated with, or catalysed by, open RAN.

Table 3: The energy credentials of vRAN and open RAN

RAN intelligent controller (RIC) use cases	Although the RIC is most commonly associated with open RAN innovation, it can also be used outside of full open RAN solutions, making it applicable to vRAN deployments too. It has the potential to deliver myriad benefits, including energy efficiency gains. RIC coordinates RAN functions by using open interfaces, third-party apps and AI toolsets. For example, the RIC could be used to orchestrate power-saving mechanisms across RAN components by hosting third-party control applications, known as xApps and rApps, developed by specialist software providers. Examples include direct power saving through the activation of advanced sleep-mode functions (whereby different network elements can be switched off using predictive analysis) and indirect power reductions through energy-aware traffic steering (particular cells can be switched off by offloading traffic to specific bands).
Future chipset innovation	Disaggregating RAN infrastructure elements enables companies to focus more clearly on specific components. For example, chipset providers can focus on delivering energy-efficient processors to support virtualised distributed unit (vDU) functions – a key objective of companies including ARM, Qualcomm, Intel and AMD, and applicable within open RAN and vRAN strategies. Progress with energy-efficient processors should accelerate as RAN virtualisation moves forward, attracting further investment from a wider set of chipset providers for devices and enterprise-grade workloads at the edge and in datacentres.
Vendor interoperability and commercial off-the-shelf (COTS) hardware	By maintaining a focus on openness and solution diversity, RAN virtualisation can ensure software and hardware components enjoy a longer lifecycle. This applies whether talking about a full-blown open RAN solution with vendor interoperability or vRAN offers where one vendor's RAN software lives on COTS silicon and server platforms. Consequently, software upgrades do not necessarily mean hardware components need to be replaced. Moreover, common equipment can be used to ensure that future upgrades can utilise the base components again without the need for new supply, avoiding the need to send hardware to landfill.

3.3 The changing outlook for circularity

Circularity refers to a paradigm shift in how manufactured materials are designed, used and repurposed, rather than being consigned to waste. It is fundamental in addressing scope 3 emissions, which come from the supply chain and consumer/business use of products. These are estimated to represent 65–70% of total CO_2.

Device recycling rates are woefully low at only 10–15% of smartphones even in western Europe (the highest rate in the world), but this will change as more manufacturers partner with operators on handset-recycling schemes and scrappage schemes with metal recycling groups. IT and network equipment has not really been in play but this is also changing; this would extend the life of 4G and 5G radios and, potentially, see schemes for the shipment of equipment for reuse in other parts of the world.

GSMA Intelligence will cover circularity further in a series of short analysis pieces in Q4 2023.

4 Looking ahead

The purpose of this research is to understand how operators can optimise energy usage as enterprise digitisation grows in size and scope. Digitisation is a multi-year process, with network virtualisation intertwined. The modelling suggests interesting findings on power savings from working at the edge, helped by savings from backhaul and compute volumes. However, these are only projections. The proof will come from reporting on actual deployments. GSMA Intelligence will follow the space closely. The same is true for open networks – a debated topic but as yet without clear, firm conclusions until more data becomes available, as open RAN comprises only a minority of sites from a minority of operators (15–20%).

The remaining questions will be explored through further research outputs during Q4 2023. This includes:

— a Spotlight (short-form) report
— a three-part blog series on the practical impact of this research, and how it can be used by companies in the enterprise compute and telecoms industries.

Furthering industry debate is most important, so GSMA Intelligence welcomes all comments on this work.

Appendix

Table 4: Assumptions used in model

	Source	Value (2022)	Notes
Energy efficiency of data transport (kWh per GB)			
Mobile	GSMA Intelligence Energy Benchmark	0.17	Derived from Energy Benchmark study (of operators accounting for approximately 25–30% of global market share)
Fixed	Aalto University (Finland)	0.03	Weighted average based on efficiency of different fixed options (copper, ADSL, VDSL, FTTx)
Datacentres	Calculated	0.164	
Percentage of mobile network energy use			
RAN	GSMA Intelligence Energy Benchmark	85%	Some geographic variation
Core and operator datacentres		10%	
Other		5%	
Share of data traffic (operators)			
Consumer	GSMA Intelligence	80%	
Enterprise		20%	
Fixed line		75%	
Mobile		25%	
Share of data processing (operators)			
On device	GSMA Intelligence Telco Edge Survey (June/July 2023)	Consumer: 20% Enterprise: 20%	
Far edge (on premises)		Consumer: 20% Enterprise: 25%	
Near edge (between premises and cloud)		Consumer: 30% Enterprise: 25%	
Cloud (core)		Consumer: 30% Enterprise: 30%	
Backhaul energy efficiency (kWh per GB)			
Microwave and mmWave	GSMA	0.136	Global average. Energy value consistent, but there will be variation in backhaul depending on link (e.g. far edge to cloud versus near edge to cloud) and country
Fibre		0.024	
Satellite		0.272	
Copper		0.1	

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*See [E1] at intel.com/processorclaims: 4th Gen Intel® Xeon® Scalable processors. Results may vary.