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Bridging 5G and 6G

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Executive summary

This report is the second in a two-part series from GSMA Intelligence, in partnership with Microsoft, on the sustainable design and operation of telecoms networks in the 5G era. The first report examined the wider picture of climate commitments made across the telecoms sector, and equipment upgrades designed to improve the energy efficiency of RAN and core networks. This report extends this to the 'avant-garde' of telecoms network change – specifically, cloud-native models involving two key technology areas: open RAN and edge computing.

Open RAN: a role to play in future efficiency gains

The emergence of open RAN coincides with the increased focus of the mobile industry on improving network energy efficiency. Efforts to develop more energy-efficient RAN solutions are integral to telecoms operators' decarbonisation efforts, considering RAN's role in energy consumption across mobile networks.

While it is too early to claim open RAN will be more energy efficient than traditional RAN solutions, initial open RAN lab tests highlight the potential for energy efficiency gains. Energy savings can be enhanced by combining open interfaces with RAN virtualisation, enabled by cloud partnerships. Virtualisation can offer better economics and energy efficiency through capacity aggregation, cloudification and the use of refurbished equipment. Cloud-native RAN equipment can also be upgraded, set up and authenticated remotely, saving on truck roll and associated staff.

Both incumbent and greenfield operators are interested in open RAN. Vodafone and Telefónica have made two of the largest commitments to date. Meanwhile, greenfield operators such as Rakuten, Dish Wireless and 1&1 have demonstrated their open RAN intent with large deployments, unencumbered by the challenge of fitting new technologies around existing IT platforms.

While just 20% of operators have live open RAN deployments in place today, commitments (e.g. from Orange) to deploy only open RAN mean this will change as network contracts are renewed – particularly where tenders are pan-regional rather than for a single country.

Edge computing: the next part of 5G enterprise networks

The simplest way to think about edge computing is pushing network and computing power closer to the end user – whether a person, device or type of machine. It is not a new technology, but it is being renewed. Commercial deployments have not always kept pace with expectations. While 20% of operators currently have their own edge infrastructure in place, 40% of operators are in the testing phase and a further 30% are planning to roll out edge.

The power implications of shifting computing power to the edge depend on factors such as where workloads are processed, fuel sources of local datacentres, and amount of energy for transporting data off-premises where required. Retaining processing on-premises – either on device or localised datacentres – for manufacturing, healthcare, transport and other vertical sector applications will save on electricity from transport. This could be further helped to the extent that power for local ICT infrastructure is sourced from renewables (approximately 45% of telecoms sector end electricity consumption comes from renewables). However, the interdependencies in edge computing are complex, as operators often interface with hyperscalers and a raft of systems integrators in-between. This places the emphasis on joint systems design to ensure the energy efficiency of a telco-cloud hybrid network is maximised. This coordinated 5G network in the cloud is the future of 5G enterprise networks.

Implications for industry players

Telecoms operators

A primary financial objective for operators is to grow enterprise revenues, which still account for only 20–30% of the base for even the largest operators. Disclosure on enterprise uplifts from 5G connectivity and other services such as private networks has so far been minimal, suggesting it is early days – even if deployments are rising. This will change as energy efficiency and energy savings from industrial clients using 5G connectivity become a competitive advantage for operators.

From an energy standpoint, there are three key priorities: embedding energy efficiency across the network lifecycle; accelerating the shift to renewables; and increasing the transparency of targets and reporting. The last is key. One of the erstwhile barriers to understanding industry progress on energy and emissions reductions is the lack of consensus on what to actually track. In 2021, GSMA Intelligence sought, through a benchmark study, to introduce metrics to measure and track operators' network energy efficiency in three categories: electricity consumption, fuel sourcing split, and distribution of energy use across the network. To give one example, the average energy consumption per GB of data was 0.24 kWh, based on full-year 2020 data. GSMA Intelligence will track and report on this and other metrics in 2022 to understand the extent of progress and how much is driven by efficiency gains versus renewables.

Equipment vendors

Vendors are the next level down in the stack from operators, so most of the implications are intertwined. There is also a competitive dimension in how much energy efficiency continues to be a purchasing criteria, or even procurement requirement, for the larger operators. The key areas to pay attention to will be the increased competitive pressure from newer entrants pushing open RAN; embedding energy efficiency in 6G standards; and coordinating with operator (and other) partners on emissions reporting.

The 6G question is interesting. What is 6G? While some applications are clear, some are not. Which 6G services eventually materialise will be determined by physical capabilities. If we assume throughputs rise a further 10× multiple on 5G, and latency gains in the opposite direction, extended reality and the metaverse are firmly in play, as are holographics, robotics and distributed sensing capabilities. Networks will be automated, or near-automated, in a virtual environment, with relatively little hardware differentiation. Energy-saving techniques (such as AI-driven sleep states and lithium-ion batteries) will need to be ported over as a baseline requirement. While the renewables shift is likely to get the overall sector to renewables at above 60% of total electricity consumption by 2030, uneven regional distribution means equipment suppliers will need to boost efficiency efforts in their 6G products to mitigate power demands from the higher intensity use cases.

Hyperscalers

Cloud groups with global scale – particularly AWS, Google and Microsoft – control much of the compute power in the modern age. The shift of 5G workloads will continue to move to the cloud, meaning hyperscalers have a major role to play in facilitating IT convergence with mobility and the benefits of that, including energy efficiencies. Datacentre operations are a major power consumer, accounting for around 300 megatonnes of CO_2 worldwide, which is equivalent to approximately 0.5–1.0% of global CO_2 emissions. This includes crypto mining; removing this element would put consumption at around 220–320 TWh in 2021 – a rise of 30% on 2015 levels, driven by the huge growth in data traffic over that period (according to IEA data). The expansive datacentre footprint makes efficiency opportunities all the more important.

The hyperscaler role is therefore central in driving efficiencies as a lot of the digitisation workloads, including those over some 5G networks, are processed through their infrastructure. Better workload management, more efficient datacentre operations, and coordination with operator (and other) partners on emissions reporting are key.

Server utilisation is still only 20–25% globally, presenting further potential for more processing per unit of server space. Introducing energy parameters to determine when and how datacentres process mobile workloads can, for example, move non-urgent processing to off-peak hours or to datacentres with spare capacity, avoiding excessive demand in peak areas. There is also a growing trend of inserting AI algorithms to intelligently route workloads between multiple datacentres that are part of an overall 'network' based on the supply of renewable energy. Shifting to renewables for datacentre power, along with complementary changes to battery use, air conditioning and siting locations in cold weather climates to enable natural cooling should also be prioritised.

1

Context: the sustainability imperative

This report is the second in a two-part series from GSMA Intelligence in partnership with Microsoft on the sustainable design and operation of telecoms networks in the 5G era.

The first report examined the wider picture of climate commitments made across the telecoms sector, and the equipment upgrades designed to improve the energy efficiency of RAN and core networks.

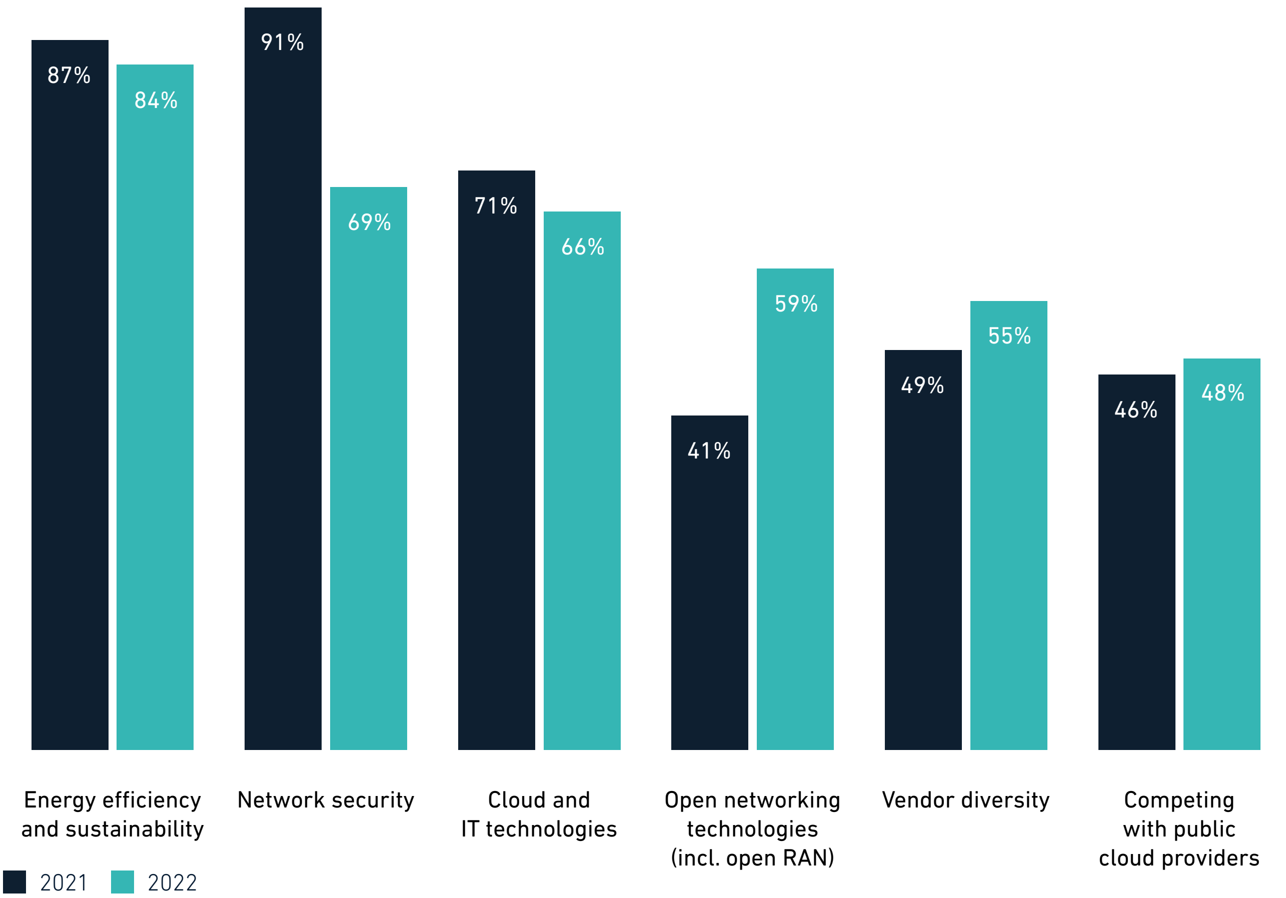
This report extends this to the 'avant-garde' of telecoms network change – specifically, cloud-native models involving two key technology areas: open RAN and edge computing. It explores the energy implications of a broad shift in computing workloads to the cloud and, in the context of enterprise digitisation, edge computing using both 5G and localised datacentres. The report also casts light on the importance of energy efficiency being incorporated into the standards governing 5G-Advanced and 6G networks.

Operator network investment priorities now feature sustainability as a core tenet. GSMA Intelligence survey data, which polled 100 operators worldwide in mid-2022, indicates it is now top of the agenda, ahead of must-haves such as security (see Figure 1). In parallel with the shift to renewables, energy efficiency at all levels of the stack is now foundational in financial decision making (capex and opex) and the orchestration of partnerships between operators and other companies in the networks and ICT networking value chain.

Figure 1

Sustainability is now top of the network agenda, while open tech is rising

How important are the following priorities as part of your current network transformation strategy?



Percentage of operators rating the priority as very or extremely important (N=100)
Source: GSMA Intelligence Operators in Focus: Network Transformation Survey

2

Open RAN

Open interfaces and virtualisation lie at the heart of future RAN design

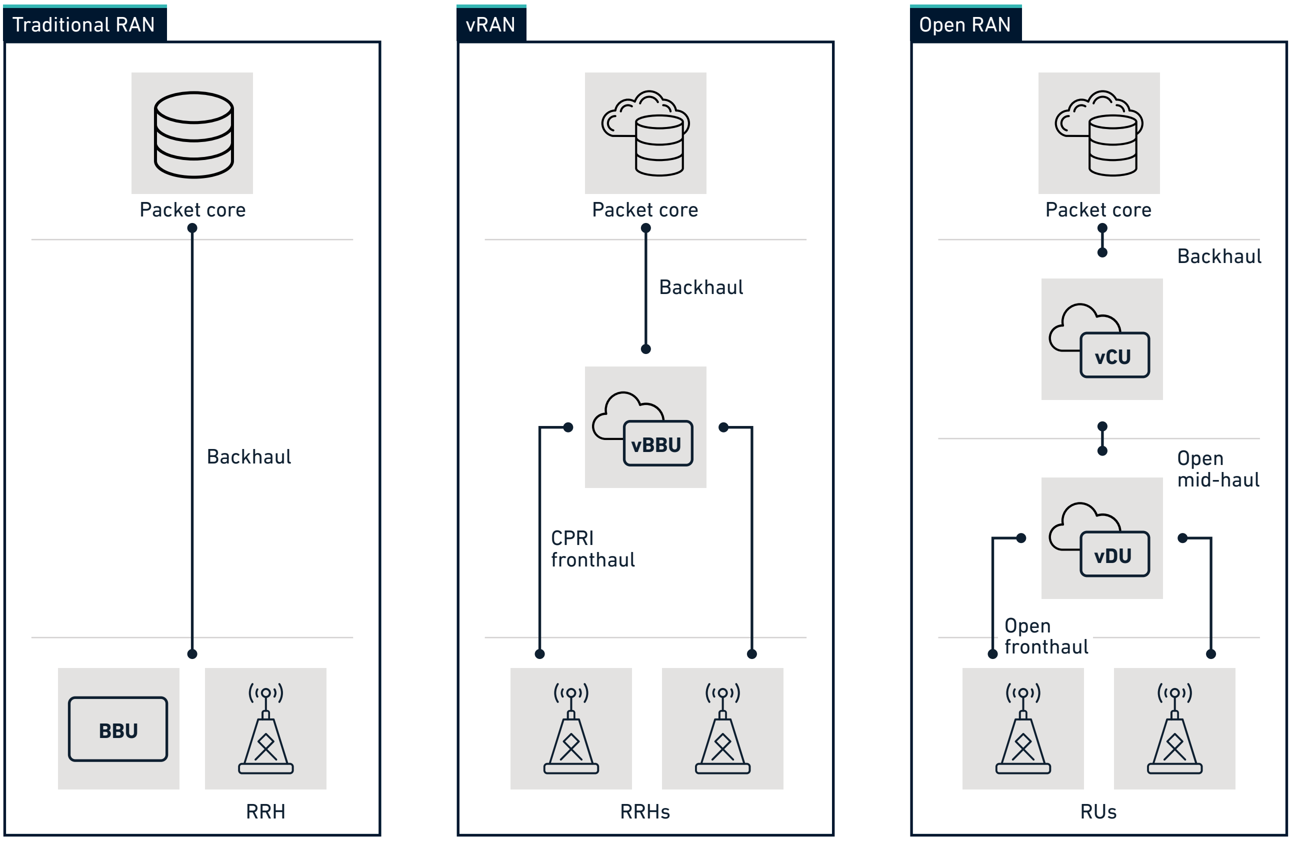
Discussions on the future of the RAN often conflate open RAN and virtualised RAN (vRAN). Both technologies represent a major rethink of RAN architecture, and many open RAN upstarts are vRAN proponents

However, whereas vRAN focuses on decoupling software features from the hardware platform, open RAN is about disaggregating the digital and radio components by moving to standardised interfaces. This enables operators to broaden their number of network infrastructure partners. Open RAN and vRAN are therefore different things, and an operator can deploy one without the other.

That said, virtualising digital components of the RAN is a logical complement to open RAN initiatives. There is also a clear trend towards deploying the technologies in tandem. For these reasons, in this report, the term open RAN refers to a virtualised RAN architecture that uses open interfaces for a multi-vendor deployment of hardware and software components.

Figure 2

Traditional RAN, vRAN and open RAN



Note: BBU – baseband unit, CPRI – common public radio interface, RRH – remote radio head, RU – radio unit, vCU – virtualised central unit, vDU – virtualised distributed unit
Source: GSMA Intelligence

Open RAN is about more than saving money

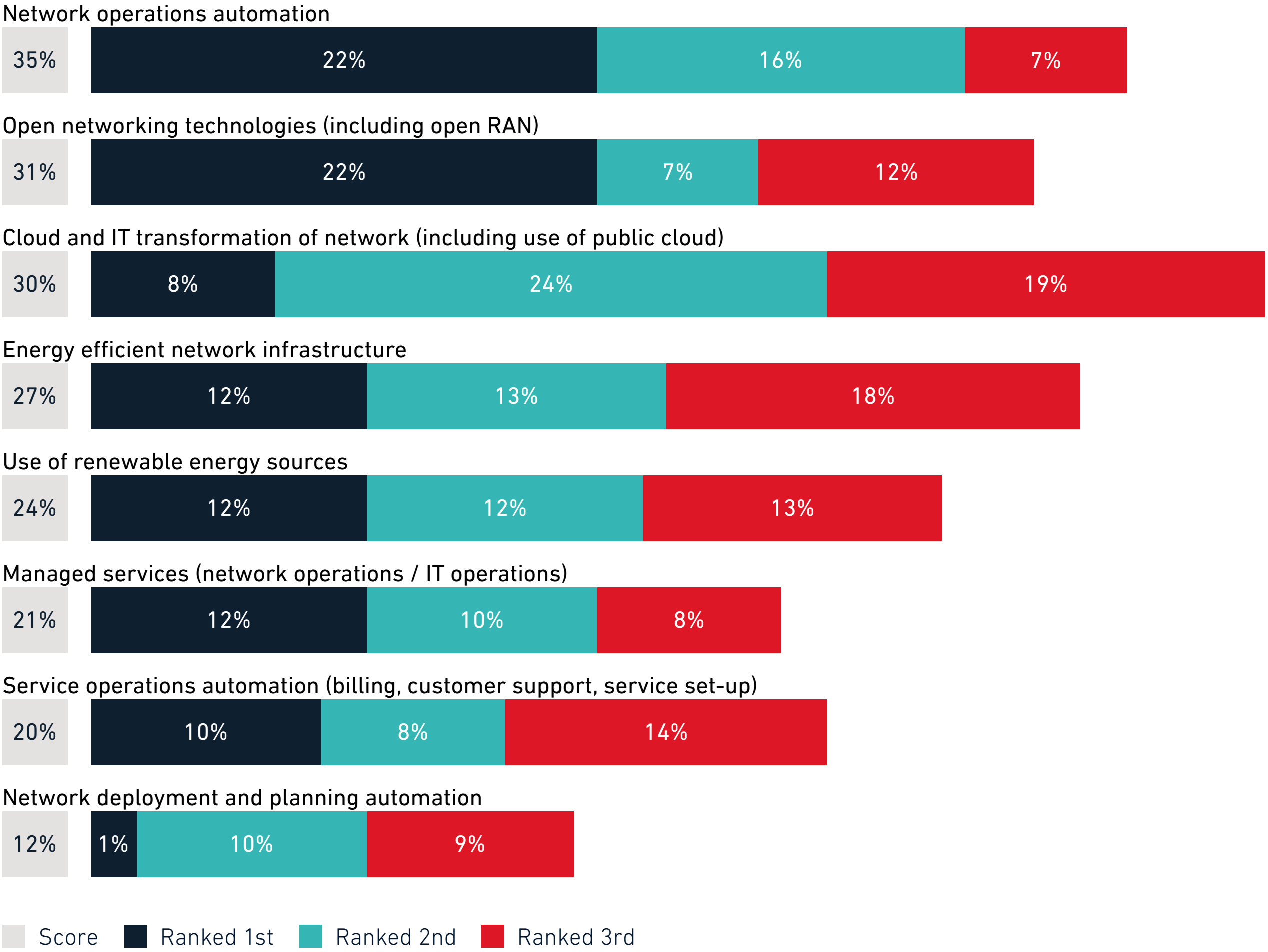
Cost savings are frequently touted early on as the main value proposition for new technologies. The supplier diversity and use of lower-cost, standardised hardware (e.g. commercial off-the-shelf servers and general-purpose CPUs) promised by open RAN fit into this narrative. Open RAN vendors have an interest in promoting this message considering the 5G capex burdens that operators face, which are compounded by 'rip and replace' requirements in certain markets.

Open RAN can also deliver opex savings by enabling operators to add a layer of network automation on top of their existing network management systems. This is something operators appear to be optimistic about; open RAN ranked second (behind network operations automation) in terms of favoured technologies for opex reduction, according to a GSMA Intelligence global survey of operators. See Figure 3.

Figure 3

Open RAN's standardised solution can simplify operations and deliver opex savings

Which technologies, in your company's view, hold the most promise of driving opex savings over the next 12 months in your network operations? (Rank importance)



Score calculated as (Ranked 1st * 1.00) + (Ranked 2nd * 0.66) + (Ranked 3rd * 0.33)
Source: GSMA Intelligence Operators in Focus: Network Transformation Survey 2022

While cost savings are important, the GSMA Intelligence survey highlights that growth and revenue generation matter much more to operators. In 2022, 75% of operators selected generating new revenues or improving customer experience as the primary network transformation goal, compared to 25% for cost savings. Open RAN supports the revenue and customer focus in several ways. For example, the decoupling of hardware and software enables increased agility, leading to faster network and service deployment. Open RAN could also create a more diverse vendor ecosystem, allowing operators to access a wider range of solutions at different price points and form factors for an array of use cases.

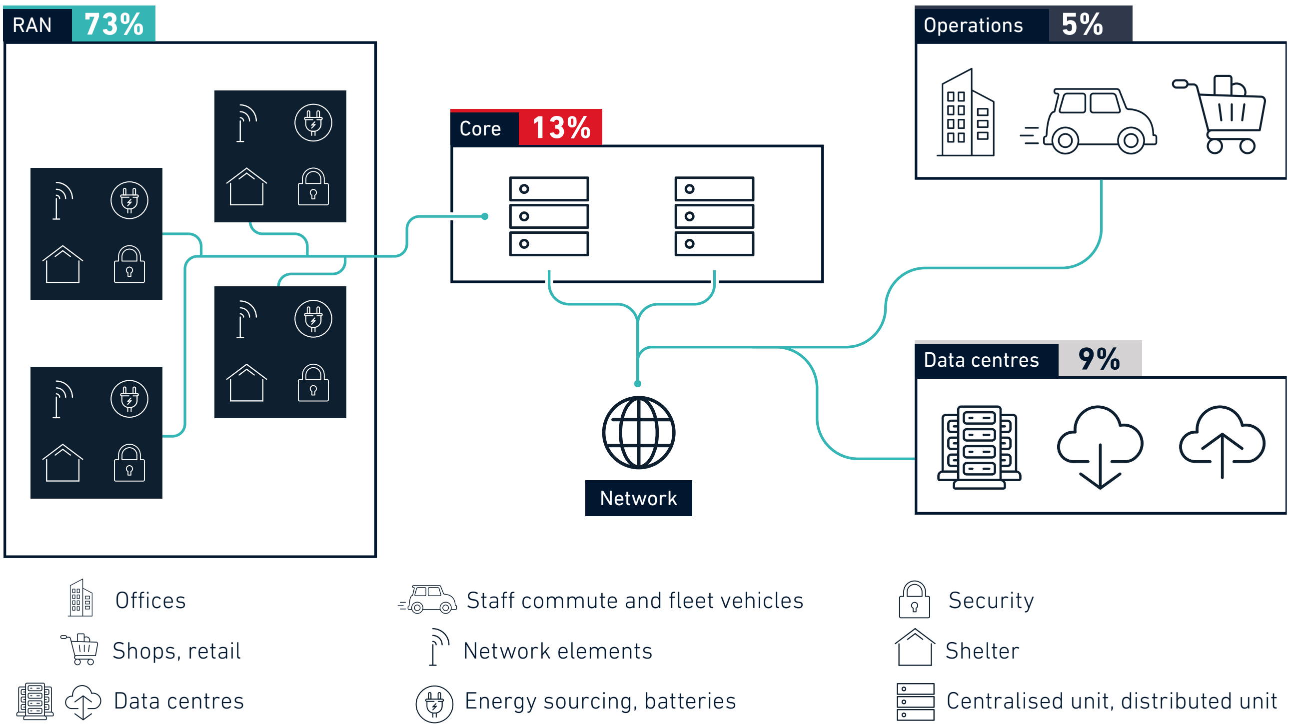
This is evidenced by recent RAN Intelligent Controller (RIC) developments in the open RAN space. As a software hosting platform, the RIC gives third-party vendors a way to insert their own innovation and value into open RAN solutions. This is why we have seen RIC marketing from large vendors (e.g. Nokia and Ericsson), open RAN specialists (e.g. Parallel Wireless and Mavenir) and players that sit outside the RAN but have aspirations to tap into 5G growth (e.g. Juniper and Cisco). The growing focus on RIC offers and RIC-based applications indicates that open RAN is increasingly positioned as a tool for driving business innovation, reflecting operator priorities.

Energy efficiency is often overlooked as a strategic driver for adopting open RAN

The emergence of open RAN coincides with an increased focus from the mobile industry on improving network energy efficiency. Efforts to develop more energy-efficient RAN solutions are integral to operators' decarbonisation efforts, considering RAN's role in energy consumption across mobile networks (see Figure 4). As a result, open RAN proponents are focussed on ensuring the technology is more energy efficient than traditional RAN solutions.

Figure 4

Distribution of electricity usage across a typical mobile network



Percentages reflect electricity consumption as a share of total. Based on analysis of data from seven telco groups across 31 operating business in 2020.
Source: Going green: benchmarking the energy efficiency of mobile, GSMA Intelligence, 2021

While it is too early to say whether open RAN will be more energy efficient than traditional RAN solutions, initial open RAN lab tests highlight the potential for energy efficiency gains. For example, Vodafone recently completed lab tests of open RAN power-saving techniques. These showed that open RAN infrastructure lowers power consumption by 9–12% compared to traditional infrastructure.[1] The tests mimicked real-world mobile traffic patterns and were conducted alongside Wind River, Intel, Keysight Technologies and Radisys in a laboratory at the University of Utah. While further tests are needed to ensure the energy efficiency gains from the lab could be replicated across multiple sites running actual customer traffic, the test results indicate the potential size of the energy savings that open RAN could generate.

Energy savings can be enhanced by combining open interfaces with RAN virtualisation, enabled by cloud partnerships. Virtualisation can offer better economics and energy efficiency through capacity aggregation, cloudification and the use of refurbished kit. Cloud-native RAN equipment can also be upgraded, set up and authenticated remotely, saving on truck roll and associated staff. Moreover, open interfaces can offer more choice and vendors, with the hope of further innovation in the supply chain. See Table 1.

1 "Vodafone tests open RAN power usage", Mobile World Live, July 2022

Table 1

Open RAN's energy credentials

New RIC use cases	The RIC will be a key enabler of open RAN innovation across multiple areas, including energy efficiency. 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). While it is possible to incorporate similar innovations in closed network architectures, adopting open interfaces and automating control functions in software is likely to accelerate the adoption of energy optimisation techniques in the access network.
Future chipset innovation	Disaggregating RAN infrastructure elements enables companies to focus more acutely on the energy efficiency of specific RAN components. For example, chipset providers can focus on delivering energy-efficient processors to support vDU functions. Progress with energy-efficient processors should accelerate as open RAN adoption grows, attracting further investment from a wider set of chipset providers. There are also opportunities to leverage chipset innovations from the datacentre world to optimise open RAN power consumption.
Vendor interoperability and commercial off-the-shelf (COTS) hardware	By maintaining a focus on openness and solution diversity, open RAN can ensure software and hardware components are vendor agnostic and interoperable. 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 hardware being sent to landfill.

Source: GSMA Intelligence

Most RAN energy-saving techniques to date are not able to be deployed very quickly, and the energy-saving algorithms are typically operated at a diurnal timescale, following people's daily movements. Even during peak hours, the network is rarely operated at full capacity due to the nature of internet traffic, which is lumpy. A further large energy gain is possible if the traffic demand burstiness could be explored at faster timescales.

5G RAN is carefully engineered real-time software. If a part of the system is in hibernation for energy savings, any instant traffic burst requires an immediate, sub-millisecond reaction to wake up more CPU cores. Otherwise, RAN performance could be seriously impacted, potentially leading to a crash. This is why any further innovation in RAN energy saving is hard to implement through external apps that do not have the full visibility and telemetry from RAN that allow operators and their equipment suppliers to predict, and react to, bursts according to fast timescales. Developers with new ideas cannot really innovate in one of the most important areas of open RAN design.

Fortunately, dynamic service models can come to the rescue here within an open RAN environment. These allow fine-grained access to different metrics across different layers of the RAN stack. With a dynamic service model, a developer can collect only the data needed for its novel energy prediction algorithm (for example, number of active users or changes in different queue sizes). Microsoft's RAN analytics, built on top of Capgemini 5G RAN and Intel FlexRAN, can achieve energy savings of up to 30% during the short periods of time a base station could be idle.

A standardised approach to measurement

To achieve open RAN's energy efficiency ambitions, a standardised approach to evaluating, testing, measuring and monitoring the energy consumption of open RAN deployments is required. The five European operators that signed an open RAN memorandum of understanding (MoU) in early 2021 have taken a step towards this by issuing a technical paper detailing a set of principles for open RAN energy efficiency KPIs.[2,3] Examples include the following:

- open RAN software should be able to collect measurement data at the hardware component level, workload level and for the software components themselves
- KPI reporting should be supported across all open RAN interfaces
- KPIs should be provided by real-time metering
- KPIs should be able to monitor the power consumption per frequency band in multi-band open RAN radio units.

2 The European Open RAN MoU was signed by Deutsche Telekom, Orange, TIM (Telecom Italia), Telefónica and Vodafone
3 Open RAN Technical Priorities: Focus on Energy Efficiencies, Open RAN MoU, 2022

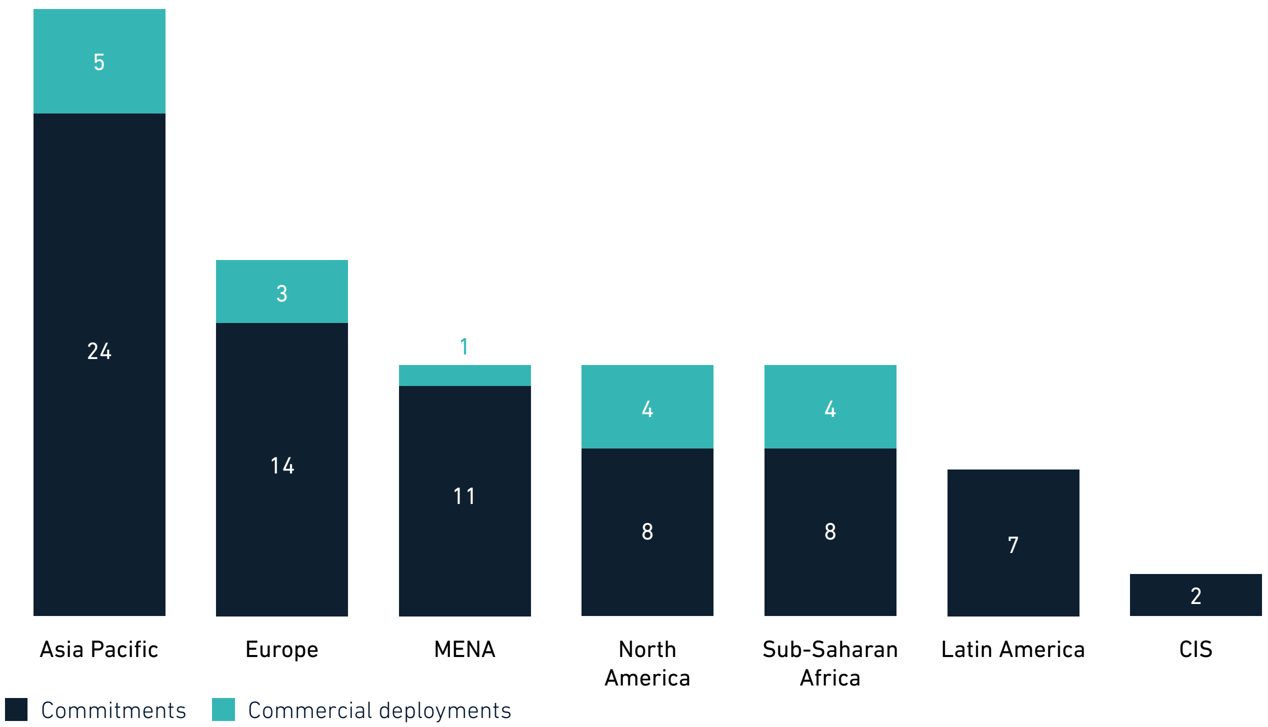
Open RAN is gaining traction globally

With the benefits of open RAN becoming clearer, at least 91 operators from 47 countries have active open RAN trials, deployments or commitments. The expansion of open RAN should not be seen as just a European or US project. Several operators in less mature markets within Asia and Africa are also deploying open infrastructure – a real sign of a paradigm shift.

Figure 5

Open RAN is not just for high-income markets

Commitments and deployments as of August 2022



Source: GSMA Intelligence

Open RAN interest is coming from both incumbent and greenfield operators. Vodafone and Telefónica have made two of the largest commitments to date. Vodafone is aiming for open RAN to account for up to 50% of its 4G and 5G RAN growth between 2022 and 2025, while Telefónica wants to deploy open RAN in 30% of its masts across Europe by 2030. Orange has indicated it intends to begin open RAN equipment build-outs in 2025. Greenfield operators (e.g. Rakuten, Dish Wireless and 1&1) have also demonstrated their open RAN intent, shown by large open RAN deployments, unencumbered by the challenge of fitting new technologies around existing IT platforms. Open network architectures have also garnered political interest (e.g. in the UK and US), primarily on the basis of diversifying the network equipment supplier base.

However, there remains a gap between intentions and actions, with 20% of operators having live open RAN deployments in place. This will change as network contracts are renewed, particularly where tenders are pan-regional rather than for a single country. In the meantime, further large tenders are needed to build the open RAN supplier ecosystem and develop the industry proof points required to quantify open RAN's financial and environmental merits.

3

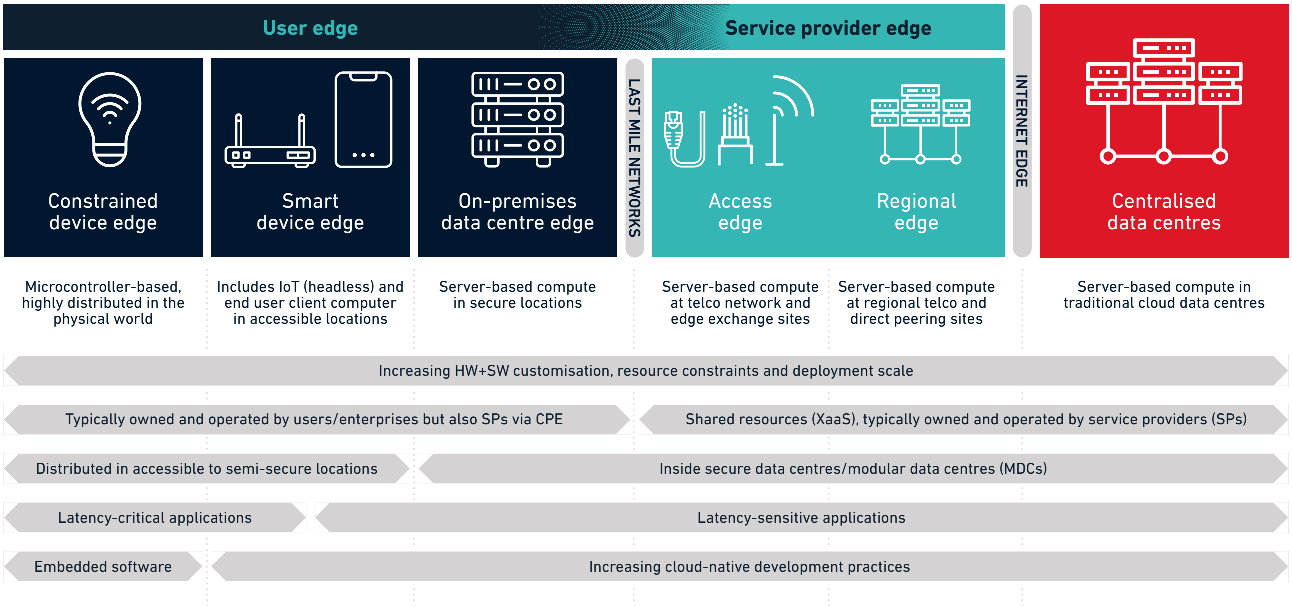
Edge computing and networking

Edge computing gains traction in the 5G era

The shift of computing workloads from centralised to decentralised architectures has been a cyclical process over the last 30 years, alternating from one to the other. The current focus on pushing out to the edge pre-dates 5G launches as part of the smartphone era in the mid-2010s. However, it has gained traction as different sectors of the economy digitise using IoT and analytics capabilities. While edge computing can mean different things to different people (and depends on the context), the simplest way to think about it is pushing network and computing power closer to the end user – whether a person, device or type of machine. Figure 6 illustrates the edge spectrum based on proximity to datacentres.

Figure 6

Pushing out the edge



Source: The Linux Foundation

The rationale for telecoms operator edge deployments (whether their own infrastructure or through partnerships with datacentre operators) focuses on three main areas:

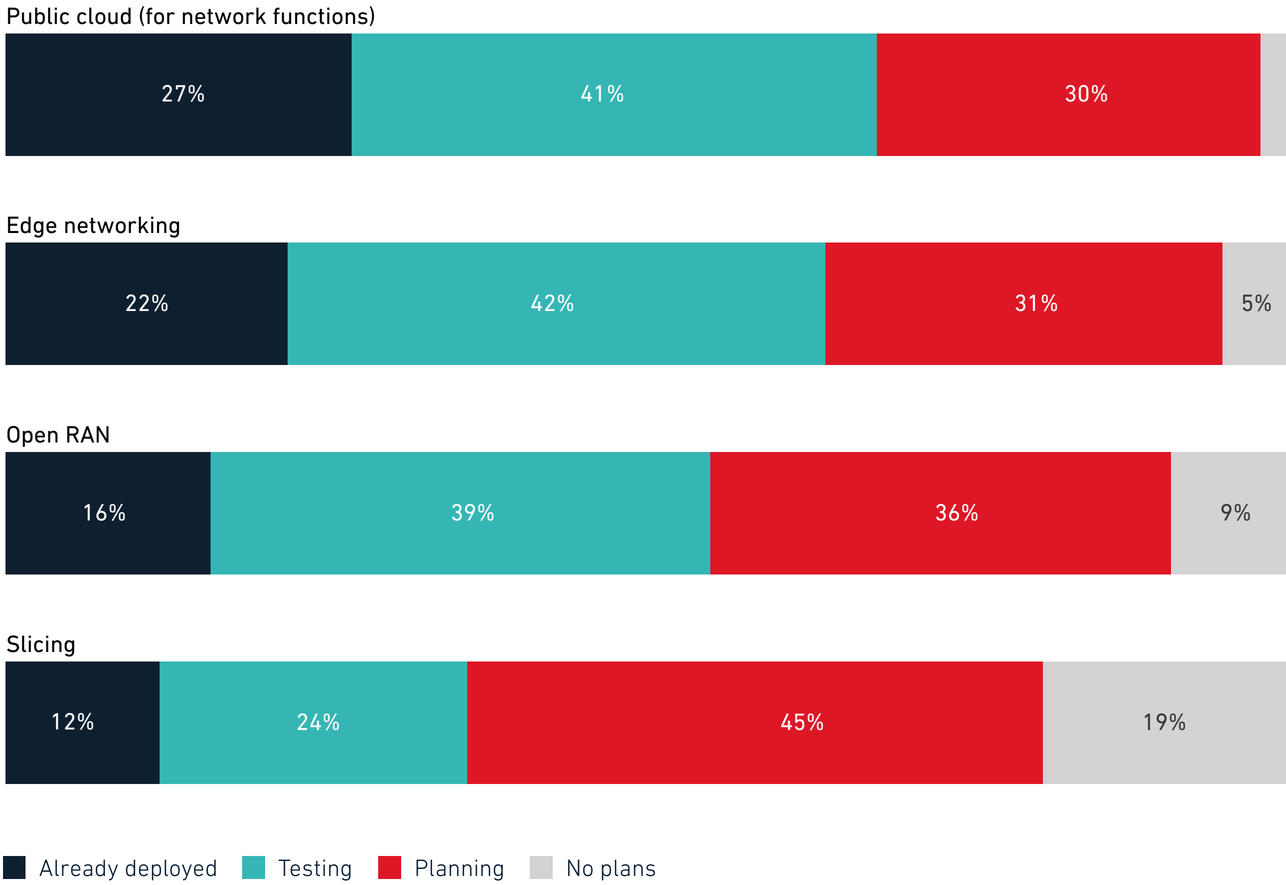
- **Enterprise sell-in.** Over 80% of operators view enterprise sectors as the main source of incremental revenue from 5G deployments. A big part of the value proposition for selling 5G services into enterprise customers is low latency. This is key for robotics in manufacturing plants, precision agriculture and (eventually) remote surgery, for example. Edge infrastructure enables computing and analytics to be completed closer to where it is needed and more quickly, rather than being sent to centralised datacentres or nodes of a mobile network.
- **Security.** The data harvested by IoT sensors/connectivity nodes needs to be secure. The more that processing can be done on-premises (rather than at offsite locations), the less risk there is of breaches during the transfer process.
- **Costs.** The local processing capabilities of edge infrastructure, including micro datacentres in a mobile RAN, reduce or obviate the need for backhaul links to central cloud servers. This is an often forgotten part of the network cost structure but one that can be mitigated through on-premises processing, supplemented by use of the public cloud, particularly in scaled environments such as a manufacturing plant or shipping port.

Despite the rationale, commercial deployments have lagged expectations; only around a fifth of mobile operators currently have edge networking infrastructure in place (see Figure 7). These tend to be concentrated in the US, Europe, South Korea and Japan, where consumer adoption of 4G and 5G smartphones is higher and the enterprise pivot is more advanced. However, intention sentiments are healthy; 40% of operators are in the testing phase, with a further 30% planning to roll out edge. This would suggest the lag effect is more a result of the economic challenges from the pandemic (and now inflation) and the pragmatic need to prioritise capex for 5G network rollout. The same pattern is seen with open networking technologies (including open RAN), though this movement is much more recent than edge.

Figure 7

Virtualisation is a when, not if, scenario

Where are you in the process of deploying the following technologies?



Percentage of operators (N=100)
Source: GSMA Intelligence Operators in Focus: Network Transformation Survey 2022

Joint systems design key to environmental impact

The power implications of shifting computing power to the edge depend on several factors. These include where workloads are processed, fuel sources of local datacentres, and amount of energy for transporting data off-premises where required. Retaining processing on-premises – either on the device or localised datacentres – for manufacturing, healthcare, transport and other vertical sector applications will save on electricity from transport. This could be further helped to the extent that power for local ICT infrastructure is sourced from renewables (approximately 45% of telecoms sector end electricity consumption comes from renewables). However, the interdependencies in edge computing are complex as operators often interface with hyperscalers and a raft of systems integrators in-between. This places the emphasis on joint systems design to ensure the energy efficiency of a telco-cloud hybrid network is maximised. This coordinated 5G network in the cloud is the future of 5G enterprise networks.

Competitive battleground gives way to more co-opetition

Most of the competitive implications, paradoxically, centre on partnerships rather than competition. Edge used to be thought of as a competitive battleground between operators and hyperscalers. While this is true in some settings, it has become something of a misnomer, as Amazon, Microsoft, Google and other cloud majors have more strategic interest in working with operators on joint 5G enterprise contracts than in direct competition. If, for example, a 5G private network was put in place for a car manufacturing plant, the rationale for building or utilising localised datacentres is high – and here comparative advantage favours cloud groups, which can push out datacentre capacity. Recent activity reflects this – see AWS's expansion of its Local Zones product, Google's acquisition of MobiledgeX, and Microsoft's vast push of Azure edge services. GSMA Intelligence survey data provides further evidence; in rating motivations for upcoming network transformations, less than 50% of operators cite competition with cloud providers – the lowest of any motivator.

Co-opetition movement will likely continue as it is a pragmatic and cost-effective means of servicing enterprise clients at various stages of digitisation overhauls. AT&T's partnership with Microsoft to effectively merge edge and cloud provides a good example. This now includes Azure handling AT&T's 5G core workloads. The applications are driven by latency and compute workload requirements, covering areas including automotive manufacturing, healthcare, gaming and city infrastructure (including emergency services).

4 Implications and outlook for key players

Operators

A primary financial objective for operators is to grow enterprise revenues, which still account for only 20–30% of the base for even the largest operators. Consumer ARPU premiums from 5G tariffs are likely to be competed away, meaning enterprise clients offer a more realistic incremental revenue source, helping to monetise 5G network and spectrum investments. Disclosure on enterprise uplifts from 5G connectivity and other services such as private networks has so far been minimal, suggesting it remains early days – even if deployments are rising. As cited in *Radar: Digital transformation in a post-pandemic future*, automotive, logistics, healthcare and manufacturing are verticals with strong potential.

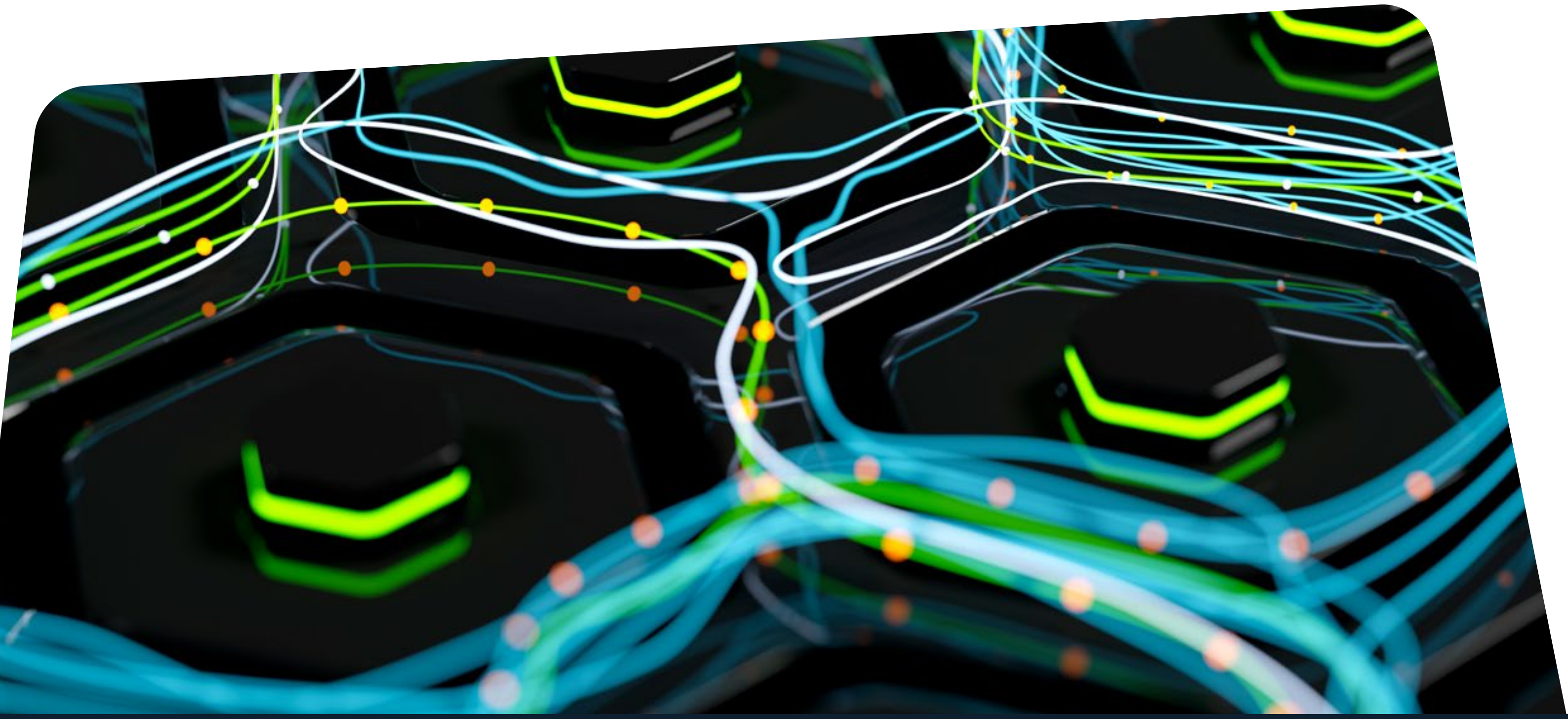
The energy and sustainability objectives in future network strategy fall into three broad groups:

- **Embedding energy efficiency across the network lifecycle.** The paradigm shift to green networks implies the need to architect network design with energy efficiency as a primary objective and key performance indicator (KPI). This was not the case in the 3G and 4G eras, but the data traffic rises projected with 5G (a fourfold rise on average, per smartphone customer) necessitate it. GSMA Intelligence views this holistically to include design, procurement, operations and end of life (or transition). For example, network procurement criteria will increasingly require energy efficiency performance standards of RAN and core equipment suppliers. This is also likely to be the case for cloud partnerships as 5G workloads are migrated to, and processed in, the cloud.

Hyperscalers are at the forefront of efficiency gains from cloud workload management and moving to renewable-powered datacentres. Operator influence in 3GPP and other standards forums will also be a key determinant of energy efficiency becoming enshrined in 5G-Advanced (the next version of 5G) and 6G in the 2027/2028 timeframe.

- **The shift to renewables.** This is the end game for all industries on a decarbonisation trajectory to net zero by 2050. Telecoms operators vary in their progress, which correlates with renewable energy supply on the grid. European and US groups are most advanced. For example, Vodafone, Telefónica, BT and Orange are all on committed targets of 100% renewable energy consumption by 2030 or earlier (sometimes much earlier). GSMA Intelligence data from Going green: benchmarking the energy efficiency of mobile indicates a mixed picture in fuel sourcing splits. Globally, around 45% of telco end energy consumption is derived from renewables, 40–45% from traditional grid, and the rest from diesel. There is, however, significant regional variation, with diesel still highly relied upon in Africa, India and parts of Asia where sites are off-grid, renewable supply is weak, and where (in some cases) political environments sustain hydrocarbon energy production as a strategic national asset.
- **Targets and reporting.** The oft-quoted maxim that 'you can't manage what you can't measure' is a prescient reminder of the need for transparent reporting measures. Around 35–40% of market share sits with operators committed to science-based targets (SBTs) – a strong, if geographically imbalanced, figure. The pace at which SBT commitments spread to a larger portion of the industry will be instructive as a proxy for commitments to net zero and the organisational culture shift required to achieve that goal. This is the high level; reporting is also crucial at the operational level. One of the erstwhile barriers to understanding industry progress on energy and emissions reductions is the lack of consensus on what to actually track. Again, drawing on a benchmarking study, GSMA Intelligence has sought to introduce metrics to measure and track operator network energy efficiency in three categories:
  - electricity consumption (kWh per GB data transferred, per cell site etc)
  - fuel sourcing splits
  - distribution of energy use across the network (RAN, core, edge and other operations).

To give one example, the average energy consumption per GB of data was 0.24 kWh, based on full-year 2020 data. GSMA Intelligence will track and report on this and other metrics in 2022 to understand the extent of progress and how much of that is driven by efficiency gains versus renewables. Vodafone's reporting on its FY 2021 is one encouraging barometer; total energy usage was flat, despite costs rising 11%



Equipment vendors

Vendors are the next level down in the stack from operators, so most of the implications are directly intertwined. There is also a competitive dimension in how much energy efficiency continues to be a purchasing criteria, or even procurement requirement, for the larger operators.

- **Increased competitive pressure from newer entrants pushing open RAN.** Energy efficiency has now become a competitive differentiator for Nokia, Ericsson, Huawei and other equipment suppliers to mobile operators. In countries and regions where demand for open architecture networks (including open RAN) is growing, so too will energy performance demands from the buying operators, on cost and environmental grounds. It is too early to draw conclusions on whether open is more efficient than proprietary networks, but this will be a key measurement focus for the next two years as more open builds are switched on.
- **Implications for 6G.** What is 6G? While some applications are clear, some are not. The basis of what 6G services eventually materialise will, of course, be determined by its physical capabilities. If we assume throughputs rising a further 10× multiple on 5G, and latency gains in the opposite direction, XR (i.e. virtual and augmented reality) and the metaverse are firmly in play, as are holographics (think of a virtual personal trainer), robotics, and distributed sensing capabilities. Networks will be automated, or near-automated, in a virtual environment, with relatively little hardware differentiation. Energy-saving techniques (such as AI-driven sleep states and lithium-ion batteries) will need to be ported over as a baseline requirement. While the renewables shift is likely to get the overall sector to renewables accounting for above 60% of total electricity consumption by 2030, uneven regional distribution means equipment suppliers will need to boost efficiency efforts in their 6G products to mitigate power demands from the higher intensity use cases.
- **Coordination with operator (and other) partners on emissions reporting.** Emissions reporting alignment is a key step in terms of checks and balances. Vendors and operators have different SBT methodologies (they operate different businesses) but can align on common metrics such as network energy efficiency, total energy consumption and splits for different parts of the network (e.g. RAN, core, datacentres), and CO_2 emissions. Alignment also extends to the supply chain in an effort to measure and track Scope 3 emissions, which are currently poorly quantified but widely estimated to be 70–75% of the global CO_2 footprint. Emissions here relate to the sourcing and manufacture of products (sometimes called 'embedded carbon'), transport and recycling at the end of usable life. The latter is a key part of the circular economy, which has mostly focussed on smartphones and other consumer electronics devices and is now moving to encompass certain types of network equipment that can, for example, be shipped to another operator in another country, rather than being consigned to landfill.

Hyperscalers/cloud players

- **Better workload management.** This concerns how efficiently 5G workloads are handled in the cloud, and the dynamic shifting of those based on energy parameters. Server utilisation is still only 20–25% globally, presenting further potential for more processing per unit of server space. Introducing energy parameters to determine when and how datacentres process mobile workloads can, for example, move non-urgent processing to off-peak hours or to datacentres with spare capacity, avoiding excessive demand in peak areas. There is also a growing trend of inserting AI algorithms to intelligently route workloads between multiple datacentres that are part of an overall 'network' based on the supply of renewable energy. For example, if the workload for a hospital was being handled between datacentres in Kansas City, Denver and Little Rock (hypothetically), traffic could by dynamically shifted based on which of the locations had the highest availability of renewables (or should an outage happen at one).
- **Efficiency improvements for datacentre operations.** Datacentre operations are a major power consumer, accounting for around 300 megatonnes of CO_2 worldwide, equivalent to 0.5–1.0% of global CO_2 emissions. This includes crypto mining; removing this element would put consumption at 220–320 TWh in 2021 – a rise of 30% on 2015 levels, driven by the huge growth in data traffic over that period (according to IEA data). The expansive datacentre footprint makes efficiency opportunities all the more important. The top level is the shift to renewable energy to power datacentres, along with complementary changes to battery use, air conditioning, and siting locations in cold weather climates to enable natural cooling. Microsoft's objective of being carbon negative by 2030 is a marker on these targets.
- **Coordination with operator (and other) partners on emissions reporting.** As networks increasingly move to be cloud-native, and eventually zero-touch, there is a joint responsibility for operators and their hyperscaler partners to drive at energy efficiency and renewable sourcing. This hold true for emissions reporting. Although a mobile operator and cloud partner operate on different SBTi methodologies, it is important that energy and CO_2 emissions are viewed as part of joined up systems rather than isolated silos of mobile radios (and the companies that operate those) versus cloud infrastructure (and the companies that operate the major data centres). It is most feasible for this first to happen on a small scale – for example, starting with energy savings or other emissions KPIs reported on an individual deployment basis for a private 5G network in a manufacturing plant. However, to the extent that operators can quantify and split out their Scope 3 emissions in more detail to include different levels of the infrastructure supply chain, this will be a major contributor to understanding progress on the journey to energy sustainability in future networks.

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