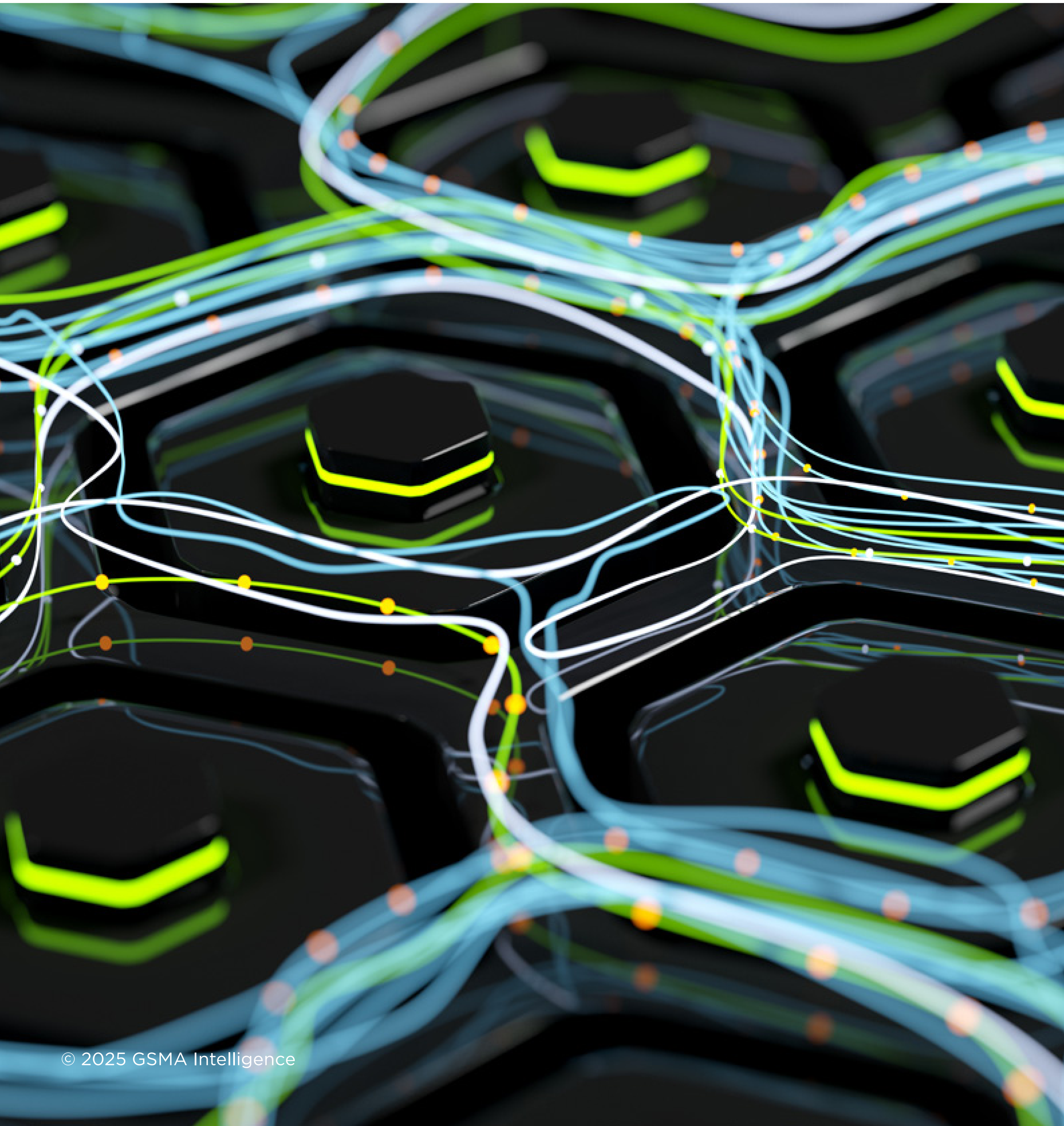
GSMA Intelligence

Going green: measuring the energy efficiency of mobile networks

(Fourth edition)



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GSMA Intelligence is the definitive source of global mobile operator data, analysis and forecasts, and publisher of authoritative industry reports and research. Our data covers every operator group, network and MVNO in every country worldwide — from Afghanistan to Zimbabwe. It is the most accurate and complete set of industry metrics available, comprising tens of millions of individual data points, updated daily.

GSMA Intelligence is relied on by leading operators, vendors, regulators, financial institutions and third-party industry players, to support strategic decision-making and long-term investment planning. The data is used as an industry reference point and is frequently cited by the media and by the industry itself.

Our team of analysts and experts produce regular thought-leading research reports across a range of industry topics.

www.gsmaintelligence.com

info@gsmaintelligence.com

Authors
Emanuel Kolta, Lead Analyst
Tim Hatt, Head of Research and Consulting

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Executive summary

Background

Sustained cost pressures and commitments to net zero have made energy efficiency a strategic priority for telecoms operators; sustainability registered as a top network transformation priority for operators around the world in 2024. Partnering with a global set of mobile operators, GSMA Intelligence leveraged its independent position and analytical capabilities to launch its Energy Efficiency Analysis and Benchmarking project in 2020. The benchmark is based on fully anonymised, real-world data inputs, with a goal of quantifying network energy consumption, efficiency levels and fuel sources.

With each successive year, operator participation in the benchmarking project has grown. The result is a unique, increasingly salient, network-level global data set on energy efficiency, alongside insights into sustainability trends, technologies and best practices. GSMA Intelligence is grateful for the 16 operator groups that participated in the project: A1, Airtel Africa, Axian, Deutsche Telekom, Elisa, Ethio Telecom, Globe, Jio, M1, MTN, Orange, Safaricom, Telecom Argentina, Telefónica, Vodacom and Vodafone. The 16 operator groups not only provided data about 95 networks in 73 countries but also actively participated in workshops and provided useful insights for this report. Overall, these operators serve more than 1.7 billion connections globally, representing 21% of total cellular connections.

Highlights

Our modelling and analysis resulted in a number of findings at a global level:

- On average, 82% of the mobile network–related energy of the participating operators is consumed in the radio access network (RAN). The network core and owned data centres (15%) and other operations (3%) account for the rest.
- In the markets covered, the average primary energy efficiency ratio indicates that operators used on average 0.1 kWh of energy to transfer 1 GB of data across their RAN. Over 80% of network operators peformed in the 0.1–0.5 kWh/GB range.
- In terms of other RAN efficiency ratios, one mobile connection required an average of 14 kWh of energy during the 12-month period, while one cell network site used on average 24 MWh during the same period.
- On average, 66% of operators' energy came from non-renewables via the electricity grid, 29% came from renewables and the remaining 5% came from diesel (which is more concentrated in developing regions, where grid and renewables access is less prevalent).
- Participating operators stated in the workshops that they used 75% of their total energy in the active infrastructure and only 25% was consumed in the passive infrastructure, to support, defend and supply the active network elements.
- On average, 14% of the total operational expenditure was attributed to energy costs, highlighting energy as one of the most significant operating expenses.

These figures are averages from a specific subset of operators. Even within the sample group, there is significant variation – and this would apply to the industry overall too. The results should therefore be interpreted at a high level rather than be predictive for any one country or operator.

Next steps

2024 was the fourth year of tracking energy efficiency by GSMA intelligence, with the highest number of participants so far. We intend to extend this further with a wider group of industry participants to increase the representativeness and direct applicability of the research.

GSMA Intelligence hopes that the project will aid best-practice guidance on the rationale and means of becoming more energy efficient, given this is an industry-wide rather than company-specific challenge.

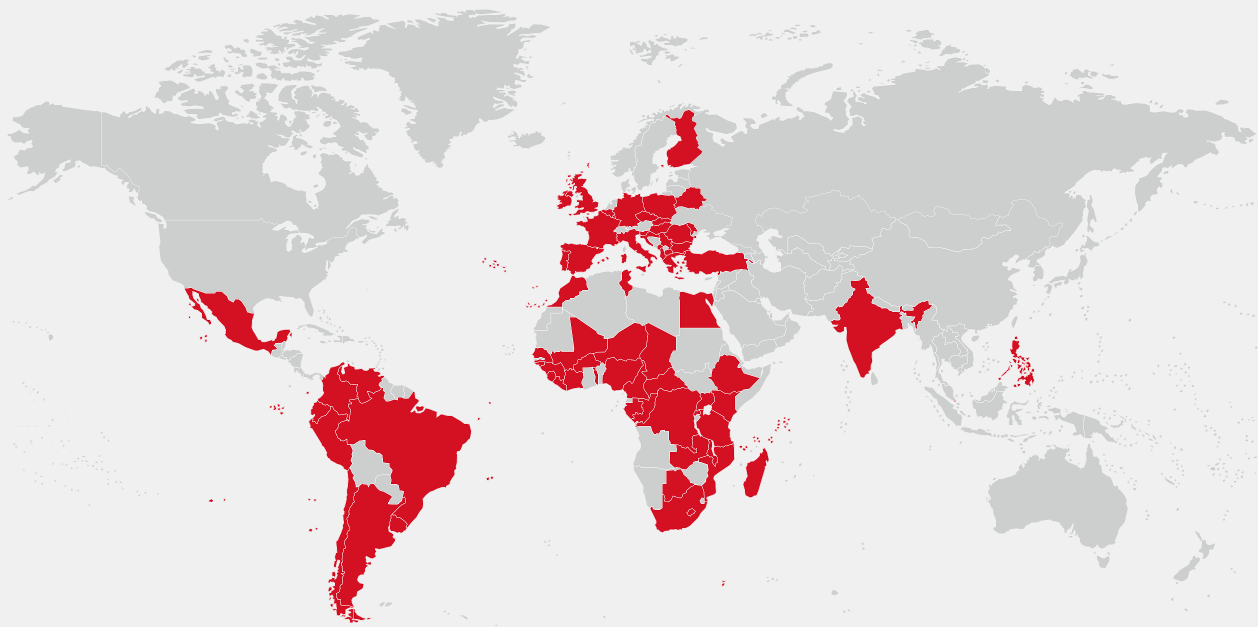
1.
Project rationale and scope

Sustained cost pressures and commitments to net zero have made energy efficiency a strategic priority for telecoms operators; sustainability registered as a top network transformation for operators around the world in 2024. Partnering with a global set of mobile operators, GSMA Intelligence leveraged its independent position and analytical capabilities to launch its Energy Efficiency Analysis and Benchmarking project in 2020. The benchmark is based on fully anonymised, real-world data inputs, with a goal of quantifying network energy consumption, efficiency levels and fuel sources.

The research is set against a context of broader efforts to help tackle climate change and embed sustainable business practices into the telecoms industry and its supply chain.

16 operators participated in this project: A1, Airtel Africa, Axian, Deutsche Telekom, Elisa, Ethio Telecom, Globe, Jio, M1, MTN, Orange, Safaricom, Telecom Argentina, Telefónica, Vodacom and Vodafone. The data provided by these groups spans 95 networks in 73 countries.

Figure 1 Countries included in the Energy Efficiency Analysis and Benchmarking 2024 project



Source. GSMA Intelligence

Based on a range of energy-related metrics and more than 5,500 data points gathered, we derived insights on:

- energy use and energy efficiency
- diesel versus renewable energy usage
- consumption distribution across different parts of an operator network (RAN, core network and data centres, and operations related to mobile networks)
- 5G's energy efficiency
- active and passive infrastructure.

2. Methodology

Selection of a comparable KPI

The goal of the Energy Efficiency Analysis and Benchmarking project is to help operators measure the relative efficiency of their networks. The basic principle of efficiency is simple: how much energy is needed to deliver one unit of output. In the context of mobile networks, this means the amount of energy needed to transmit 1 GB of data (voice also requires energy but its load is negligible compared to data). However, measuring energy efficiency can be carried out in various ways.

Based on the standard of ITU-T and the European Telecommunications Standards Institute (ETSI), mobile network data energy efficiency is the ratio between the data volume and the energy consumption during the same period. Thus, the metric for energy efficiency is useful output over energy consumption.[1] A mix of KPIs can help operators measure the relative efficiency of their networks in the era of multi-generational networks, including 2G, 3G, 4G and 5G. Four KPIs combined can provide a comprehensive evaluation of network-level energy efficiency:

- data traffic per unit of energy consumption
- number of connections per unit of energy consumption
- number of cell sites per unit of energy consumption
- revenue per unit of energy consumption.

Each measure has its pros and cons, so the exercise of selection becomes a question of balance. We have primarily chosen the first method – data traffic per unit of energy consumption – as it is the most easily comparable and meaningful KPI to monitor over time.

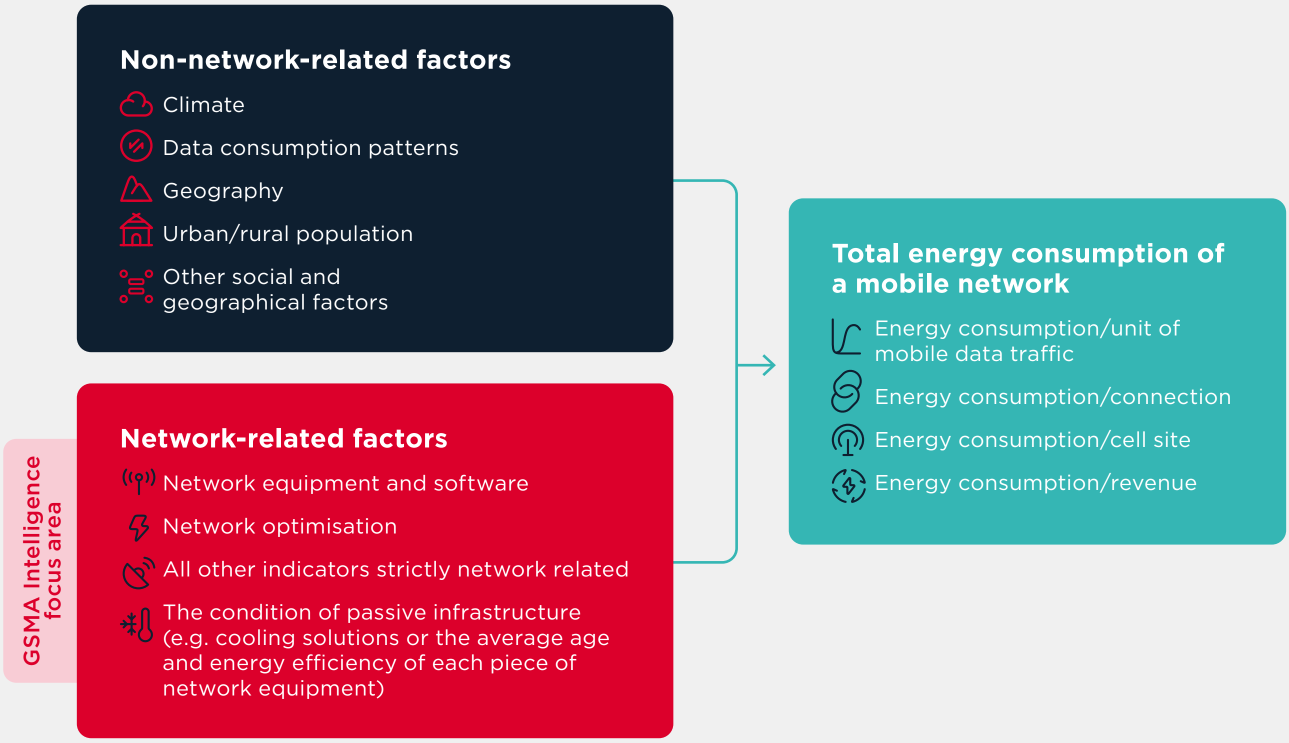
1 The ITU defines energy efficiency and explains the recommended methods to measure energy efficiency in more detail in Energy efficiency measurement and metrics for telecommunication networks.

How to compare telecoms networks

Comparing multiple networks in different countries with different characteristics – such as climate, population density and data consumption levels – is a complex task. To normalise the results and allow like-for-like comparisons, we divided the explanatory variables into:

- non-network-related variables (those outside the operator's control e.g. population distribution and climate)
- network-related factors (those within the sphere of control of the operator).

Figure 2 **Factors affecting energy usage**



Source: GSMA Intelligence

See the Appendix for more details on our methodology for the benchmarking activity.

3.
The results

Categorising energy consumption

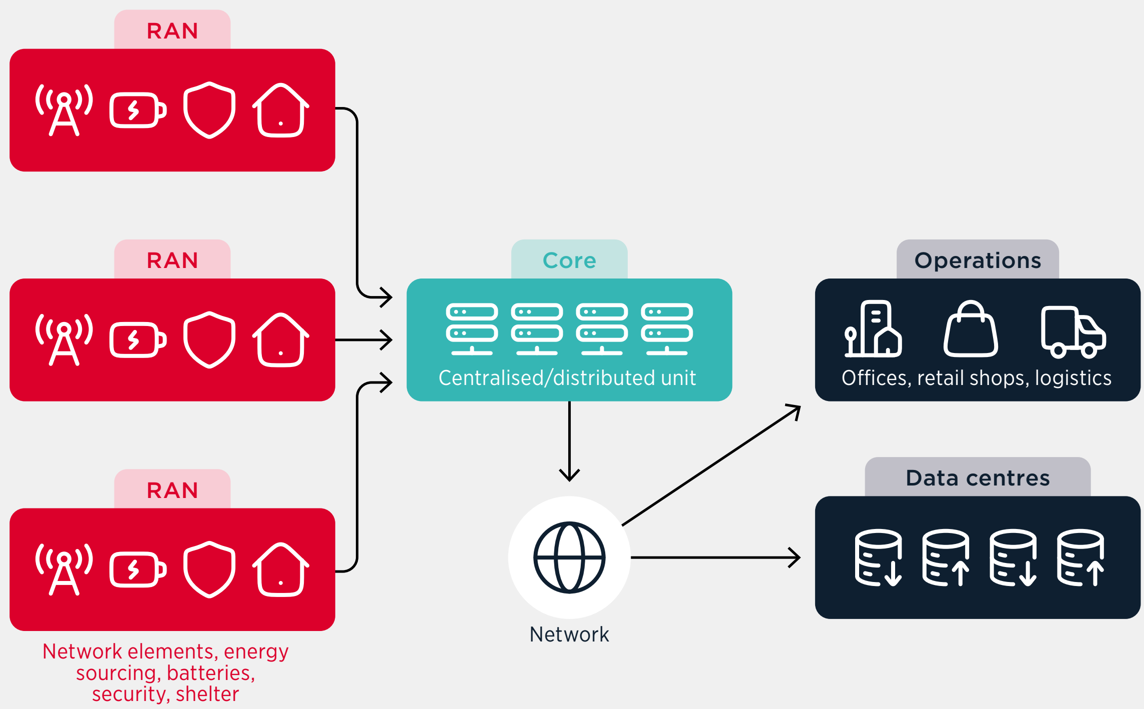
The direct energy consumption of the operators can be categorised into three groups:

— **RAN energy consumption:**[2] This comprises energy consumed by the RAN, which includes BTS, Node B, eNodeB and gNodeB energy usage and all associated infrastructure energy usage such as from air-conditioning, inverters and rectifiers. It includes energy usage from repeaters and all energy consumption associated with backhaul transport. It excludes picocell, femtocell and core network energy usage, as well as mobile radio services.

— **Core and data centre energy consumption:** This comprises energy consumed by the core network and data centres related to the mobile network, which are the physical sites that host operators' IT, including OSS and BSS and intranet infrastructure. Our analysis only includes energy consumption for data centres owned by an operator; it does not include energy consumption related to leased or outsourced capacity from web-scale providers such as AWS, Microsoft and Google. It also includes all energy consumption associated with backhaul transport.

— **Other operations:** This comprises energy consumed by the mobile operator for its own operations. This includes offices, shops, retail activity and logistics.

Figure 3 **Where mobile operators use energy in their network operations**



Source: GSMA Intelligence

2 After the first year of this study, we decided to combine the core network and data centre energy consumption categories. Driven by digital transformation, especially virtualisation, many operators cannot separate their core and data centre energy consumption as they previously could. These functions have been collocated together and electricity consumption metering can no longer be separated.

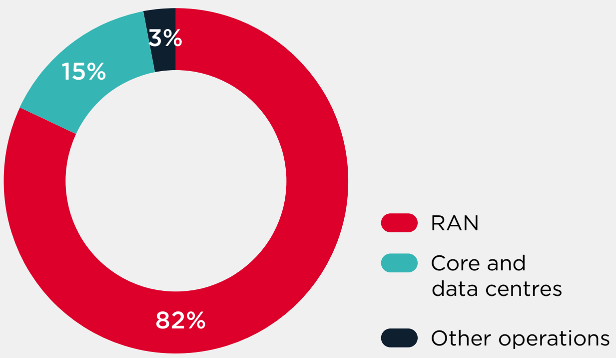
Findings

Consumption

— The majority of mobile network energy use (82%) is consumed in the RAN. Providing coverage across thousands of square kilometres, transforming energy into radio waves, and receiving and processing incoming signals are still energy-intensive functions.

— The remaining distribution of consumption comprises data centres and core network (15%) and operations (3%) supporting mobile networks.

Figure 4 Where mobile operators use energy in their mobile network operations



Note: Data based on GSMA Intelligence Energy Efficiency Analysis and Benchmarking project in 2025 with 95 mobile networks.
Source: GSMA Intelligence

Efficiency

— According to our dataset, this indicates that operators used on average 0.1 kWh of energy to transfer 1 GB of data in their RAN network and 0.12 kWh for the full network, including core and data centres and other operations. GSMA Intelligence also used three secondary efficiency ratios, which aimed to measure energy efficiency from different angles:

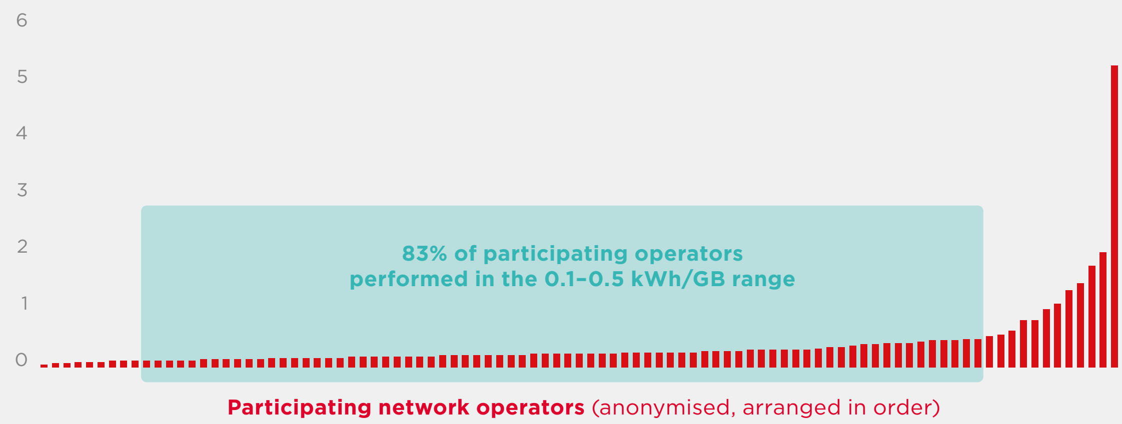
- For the 95 network operators covered, one mobile connection required on average 14 kWh of energy in the RAN during the 12-month period.
- One network site used on average 24 MWh for the same 12-month period.
- From an energy-intensity point of view, one network operator used on average 226 MWh of energy to generate €1 million in revenue.

— It is worth noting that the above values are averages and the standard deviation is high, sometimes as much as 20×. Furthermore, as the list of the participating operators changed significantly, we could not present any scientifically evaluable result in terms of year-on-year change. The number of networks that participated in the first three years of this project was too low for the results to be representative.

— Of the participating operators, 83% performed in the 0.1–0.5 kWh/GB range (see Figure 5), meaning that most of the included networks used 0.1–0.5 kWh to transfer 1 GB of data. Values outside of this range can be explained by inefficient networks, consumer habits or low data traffic per connection.

Figure 5 **Overall energy efficiency of participating operators**

kWh/GB

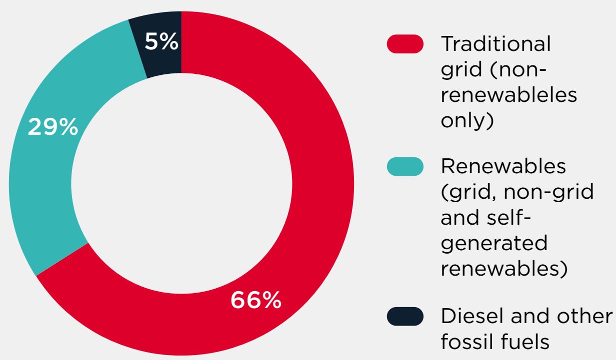


Source: GSMA Intelligence

Fuel sources: renewables versus fossil fuels

- On average, 66% of the total energy consumption came from non-renewable sources via the conventional grid supply, 29% came from renewables (on-site renewables, purchased renewables and renewable energy on the grid) and 5% came from diesel generators.
- Fossil fuels usage is more concentrated in developing regions, where grid and renewable electricity access is less prevalent. Despite operators being at the forefront of the use of renewables, they need an immediately available energy source in bad-grid, off-grid and hard-to-reach areas to provide critical infrastructure in developing regions and bridge the digital divide for underserved communities.
- The use of fossil fuels such as diesel is most common in South Asia and Sub-Saharan Africa. In Europe, diesel usage has decreased further over the past year. There are a few countries in Europe where diesel accounts for 1–4% of consumption, but the overall trend in Europe is a rapid decline in the use of diesel among operators. No network operator prefers to use diesel; it is typically used as a last resort for hard-to-reach sites and locations with unreliable electricity grid conditions.
- Renewables are mostly purchased via certified energy suppliers. While solar is becoming more price competitive, self-generated renewable electricity is still outside of operators' comfort zone. Directly produced solar accounts for less than 1% of total energy consumption.
- European operators are at the forefront of renewables usage. European operators can access renewable energy more easily via the grid and many have set ambitious goals. Some already have network operations powered 100% by electricity from renewable sources.

Figure 6 **Source of used energy for mobile operators**



Note: Data based on the GSMA Intelligence Energy Efficiency Analysis and Benchmarking project in 2025, with 95 mobile networks.
Source: GSMA Intelligence

4.
Outlook and implications

GSMA Intelligence collaborated with 95 network operators to conduct this analysis. Each of these network operators operate under different conditions, with the 73 included countries providing a variety of social, political and geographical environments. While individual assessments and priorities are needed for each case, there are some cross-regional trends and globally applicable best practices, as outlined below.

How to build and operate an energy-efficient cellular network

In general, an energy-efficient wireless network is built on site simplicity and advanced passive cooling technologies, frequently harvesting data from almost every part of the network and turning them into actionable insights. An energy-efficient network takes advantage of the improved characteristics of the purpose-built network elements and uses about as much energy as needed at the moment without impacting user experience. The separate equipment on site and the number of site visits are also limited to a minimum. Further, network elements improve their energy efficiency day by day through frequent software updates. The combination of these factors can help operators to build a future-proof, energy-efficient and sustainable network that improves their overall competitiveness and satisfies their customers.

GSMA Intelligence identified five main areas where operators can improve their energy efficiency (see Figure 7).

Figure 7 Five main areas to improve energy efficiency

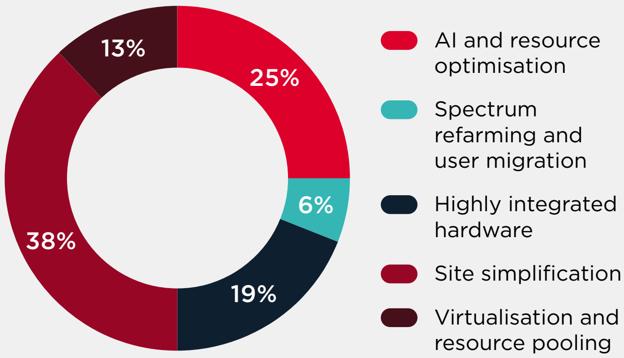
Site simplification and physical modernisation	Using lean site designs, simplified sites with pooled baseband units and multi-generational equipment, as well as avoiding shelter or cabinets, can all help to improve overall energy efficiency.
Spectrum refarming and user migration	As legacy wireless technologies approach the end of their lifecycle, refarming valuable spectrum and migrating users to newer technologies can significantly improve energy efficiency.
Highly integrated hardware	The use of highly integrated radio devices and ultra-wideband active antenna units can help operators to use shared power modules and decrease cable loss.
Advanced cooling solutions	Prioritising outdoor equipment placement and passive thermal management, and reducing site complexity and cable loss can improve overall energy efficiency.
AI and resource optimisation	Symbol, channel and carrier shutdown, real-time analysis and cross-cell optimisation can all help operators to use their energy resources in a more efficient manner.

Source: GSMA Intelligence

Figure 8 The best methods to improve energy efficiency

What is the most effective method to improve energy efficiency in the active infrastructure? (Percentage of operators)

Percentage of operators



N=17
Source: GSMA Intelligence Workshop Operator Survey 2025

Passive infrastructure

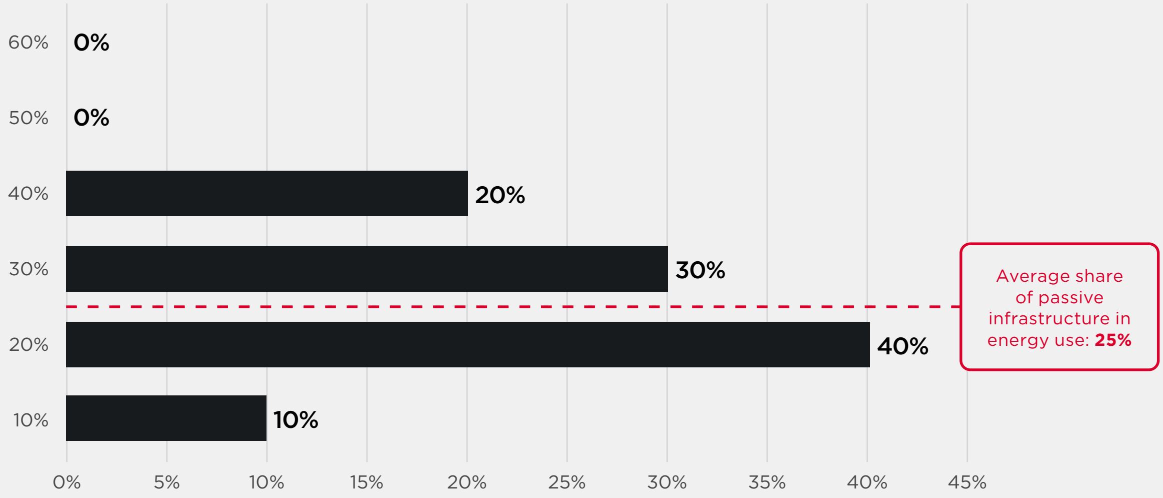
The role of passive infrastructure is to support, defend and supply the active network elements. There are significant variations between mobile sites, the regulatory and physical environments they operate in and the traffic load experienced, based on country or location, so improving the energy efficiency of passive infrastructure can be a complex and labour-intensive task. Also, depending on the climate and the quality of the electricity grid, passive infrastructure (especially air-conditioning) can be responsible for a significant part of operators' energy use, meaning the stakes can be high.

During the fourth edition of the Energy Efficiency Analysis and Benchmarking project, GSMA intelligence asked participating operators what proportion of their energy consumption is related to passive infrastructure. Based on this, on average, 25% of the total energy is spent on passive infrastructure and the remaining 75% is consumed in the active infrastructure.

Figure 9 The role of passive infrastructure

What percentage of your total energy consumption is related to the passive infrastructure?

Percentage of operators

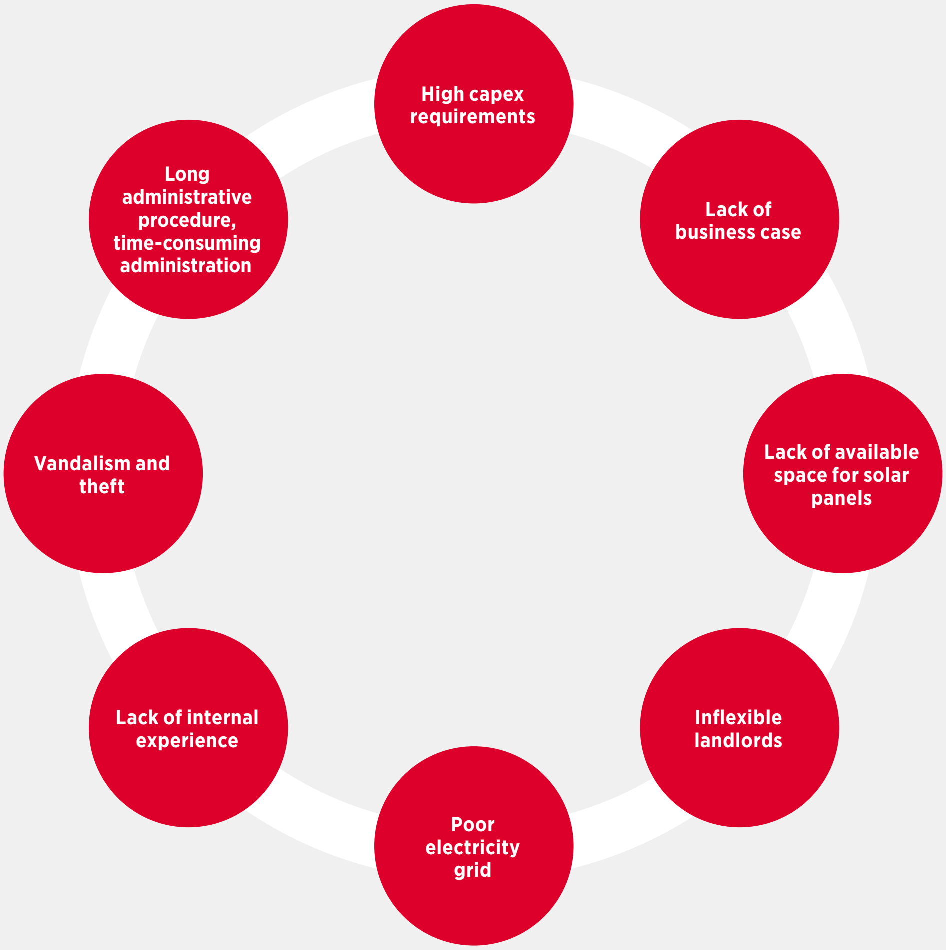


N=17
Source: GSMA Intelligence Workshop Operator Survey 2025

We also asked the participating operators about the biggest bottlenecks to improving energy efficiency in the passive infrastructure. The majority of operators were in agreement on the top three bottlenecks: capex intensity, available space on site and vandalism.

During the workshops, network operators also pointed to the inflexibility of landlords, the poor condition of the electricity grid, lack of internal experience and administrative permits as bottlenecks.

Figure 10 The bottlenecks of passive infrastructure



Source: GSMA Intelligence Workshop Operator Survey 2025

Back in the 2G and 3G eras, when many operators used general-purpose passive network elements (batteries, air-conditioning, rectifiers etc.), equipment vendors introduced purpose-built products. General-purpose equipment is less efficient and also needs more maintenance. Such equipment may also simply not be feasible because mobile operators have unique needs, including:

— special insulation to avoid dust, heavy rain and exterior temperature effects

— features to prevent theft and vandalism

— high-capacity fuel tanks, automatic oil and fuel refilling, and sensors for the generator to avoid frequent refill and maintenance site visits

— special lightning protection systems because mobile sites are taller than their surroundings.

Sustainable 5G

As 5G becomes more pervasive, the energy consumption demand on mobile networks will rise. Energy-saving measures built into the 5G new radio (NR) standard may be offset by rising data traffic, resulting in overall higher levels of energy consumption and emissions. However, the energy strategies of operators take a holistic perspective that includes retiring legacy networks, using more renewables and buying power-efficient equipment.

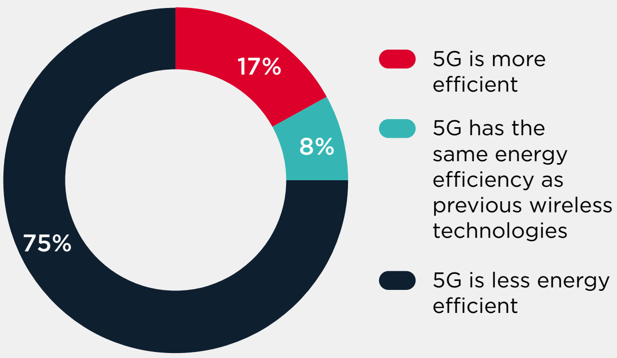
Each wireless technology generation is more energy efficient than its predecessor – but 5G is the first cellular technology designed to be more energy efficient and sustainable. Energy efficiency improved by severalfold from 3G to 4G and it improved even more from 4G to 5G. Thus, encouraging users to migrate from 2G/3G to 4G/5G will significantly improve efficiency and reduce both energy consumption and carbon emissions.

During the workshops, GSMA Intelligence asked operators about their experience with 5G deployments (see Figures 11 and 12). Despite 5G's theoretical energy efficiency being well known, we wanted to have a deeper understanding of the real-life experiences of the operators in the short and long terms, too.

Figure 11 5G's energy efficiency in the short term

What is the impact of 5G on overall energy efficiency in the short term?

Percentage of operators



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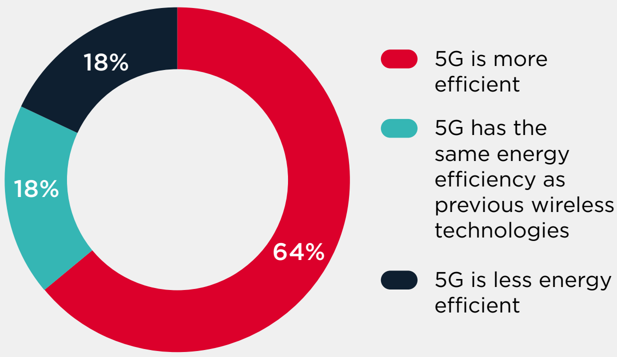
Source: GSMA Intelligence Workshop Operator Survey 2025

Figure 12 5G's energy efficiency in the long term

What is the impact of 5G on overall energy efficiency in the long term?

Percentage of operators



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Source: GSMA Intelligence Workshop Operator Survey 2025

The results indicate that operators' real-life experiences support the statement that 5G is more energy efficient in the long run. However, this energy efficiency is not necessarily perceptible immediately. This temporary inconsistency can be caused by mainly two factors:

— A whole new 5G layer is introduced and a relatively small number of connections are using the layer in the beginning. After 5G penetration increases and the number of connections reaches the critical mass, 5G's superior energy efficiency becomes palpable.

— After operators introduce a new network layer, there is a transitional period while the engineers optimise the network performance and gain enough knowledge to operate the new 5G layer efficiently.

An earlier GSMA Intelligence report[3] provided an overview of efficiency strategies. The benchmark analysis presented in the current report is complementary and will need to be updated over time to account for the mixed effect in the mobile customer base that will gradually increase in favour of 5G.

3 A blueprint for green networks, GSMA Intelligence, 2022

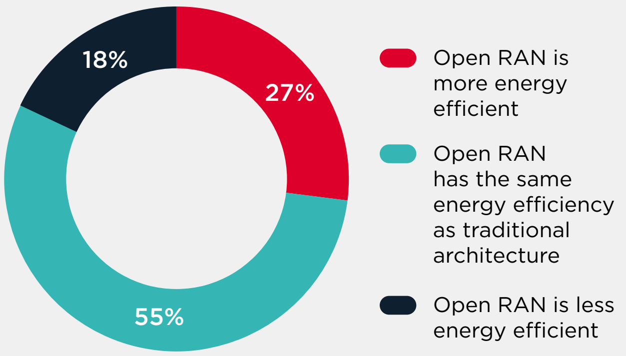
Open RAN and energy efficiency

The energy-efficiency implications of open RAN are not yet certain. While many operators claimed that they could improve some of their energy-efficiency metrics after open RAN deployments, others reported the opposite.

Figure 13 Open RAN and energy efficiency

What is the impact of open RAN deployments on energy efficiency (used energy/data traffic)?

Percentage of operators



N=17
Source: GSMA Intelligence Workshop Operator Survey 2025

While a few operators and vendors could 'mix and match' their latest open RAN deployment and achieve significant energy-efficiency gains, most of the early experiences show similar or less energy-efficient output. In the case of open RAN, the technology itself is less mature and the deployment experience of operators and system integrators is lower than that of traditional vendors. Also, x86-based architecture is less energy efficient than tailor-made, telco proprietary solutions. Currently, most of the open RAN equipment is less compact, weighs more and has more wind load.

Measuring and reporting energy efficiency in the 5G era

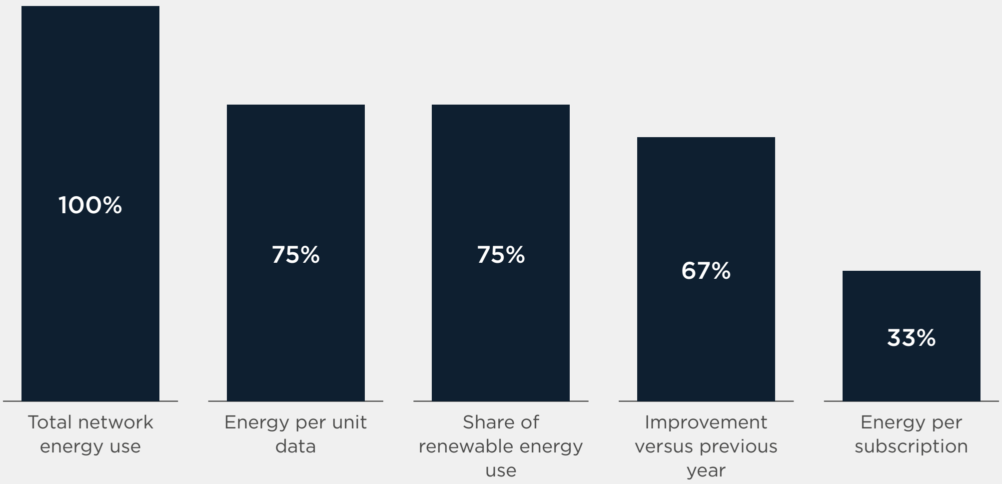
In the process of exploring energy-efficiency improvements for mobile operators, one of the greatest challenges is figuring out how to effectively and scientifically implement network energy-efficiency index management. The first step is to fully understand the requirements of 'metric metering', which comprises a set of mechanisms and methods that include the whole process of measurement, reporting, analysis, presentation, policy formulation and optimisation suggestions. This can help operators build a standardised, intelligent and visual management system of energy efficiency.

In terms of indicator measurement and reporting standardisation, standard sampling points and sampling frequencies can be defined for the hierarchical architecture of mobile and fixed networks. In terms of indicator visualisation, the operator's energy-efficiency management system can display not only indicators at the site and network and operation layers, but also the available resources of the domain-based network, such as the RAN, backhaul and core, to support the formulation and delivery of energy-efficiency optimisation policies.

Figure 14 Most important energy-efficiency indicators

Which of the following energy indicators do you track?

Percentage of operators



N=17
Source: GSMA Intelligence Workshop Operator Survey 2025

The basic principle of measuring cross-sectoral energy efficiency is simple: how much energy is needed to deliver one unit of output. Measuring energy efficiency for cellular networks, however, is more complex, as the output of the industry is continuously changing: in the 2G era, the output was mainly voice and SMS; in the 3G and 4G eras, it was voice, data traffic and SMS; and in the 5G era, the range of offered services has branched out even more. Because of this variety in cellular and digital services, there is no one way to measure energy efficiency with just a single KPI, especially because operators are running multi-generational networks, often 2G, 3G and/or 4G in combination with 5G.

In the case of a mobile operator, energy efficiency can also be interpreted at different levels. Different metrics can be more suitable, depending on if the focus is on one piece of equipment, a site, the whole network or even the entire operation of a mobile operator.

Overall, measuring, comparing and benchmarking energy efficiency in the 5G era is a complex task. Multi-generational (2G, 3G, 4G and 5G) mobile networks are operating in different social and geographical environments, and separating energy from 2G, 3G, 4G, 5G and fixed services can be challenging without an all-encompassing, real-time metering system. GSMA Intelligence published a report[4] that further elaborates on this issue and the different levels of energy efficiency.

The value of partnerships

Building partnerships is essential for operators to improve their energy efficiency. While partnerships between mobile operators are valuable, cross-industry partnerships are also vital for a number of different reasons. Cross-industry partnerships and collaborations can help operators to share the latest, most advanced technologies and processes while also providing access to know-how. Teaming up with startups can help to boost innovation and test new, more energy-efficient technologies. Partnerships can also help to exploit synergies, such as some industries' waste being a resource somewhere else. A good example is the heat generated by telecoms equipment: while mobile operators are keen to get rid of the heat generated by their equipment, many other industries would like to produce or purchase heat more efficiently. Thus, partnerships can help to connect the demand for heat and the excess heat, and to form new collaborations, such as a utility provider buying the extra heat generated from an operator's data centre and using this for commercial or industrial facilities.

4 A blueprint for green networks, GSMA Intelligence, 2022

Energy sourcing, transportation and optimisation can all fall outside of an operator's comfort zone. Operating advanced energy management tools requires specific expertise and the use of cutting-edge optimisation methods demands a unique skill set. Even larger operators may not have the required talent, knowledge and/or capacity to execute the necessary transformation, which would endanger their long-term competitiveness. Partnering with utility or energy management companies, tech startups or governments can therefore be essential for acquiring knowledge, buying resources or having smooth capex cycles with energy-saving-as-a-service business models.

The addressable market is significant for green solutions in the telecoms sector and this includes opportunities for smaller vendors. Companies from the energy sector should tailor their offerings to the unique needs of operators. Network vendors can also benefit from working with energy suppliers and energy management companies or building their own energy-efficiency product portfolio. Partnerships across the ecosystem will be key to achieving improved energy efficiency.

Increasing importance of tower companies

The rising significance of tower companies is mainly influenced by financial and economic factors. Network operators can create a separate entity to manage all tower assets, continuing to serve the operator through this new organisation. This can increase shareholder value quickly since tower companies typically have higher valuations than network operators. The other factor is that tower companies can leverage economies of scale more effectively by consolidating equipment from different operators. Although tower companies benefit from local knowledge and economies of scale, it may also lead to network operators losing control over their key assets, such as their RAN.

A lack of data visibility

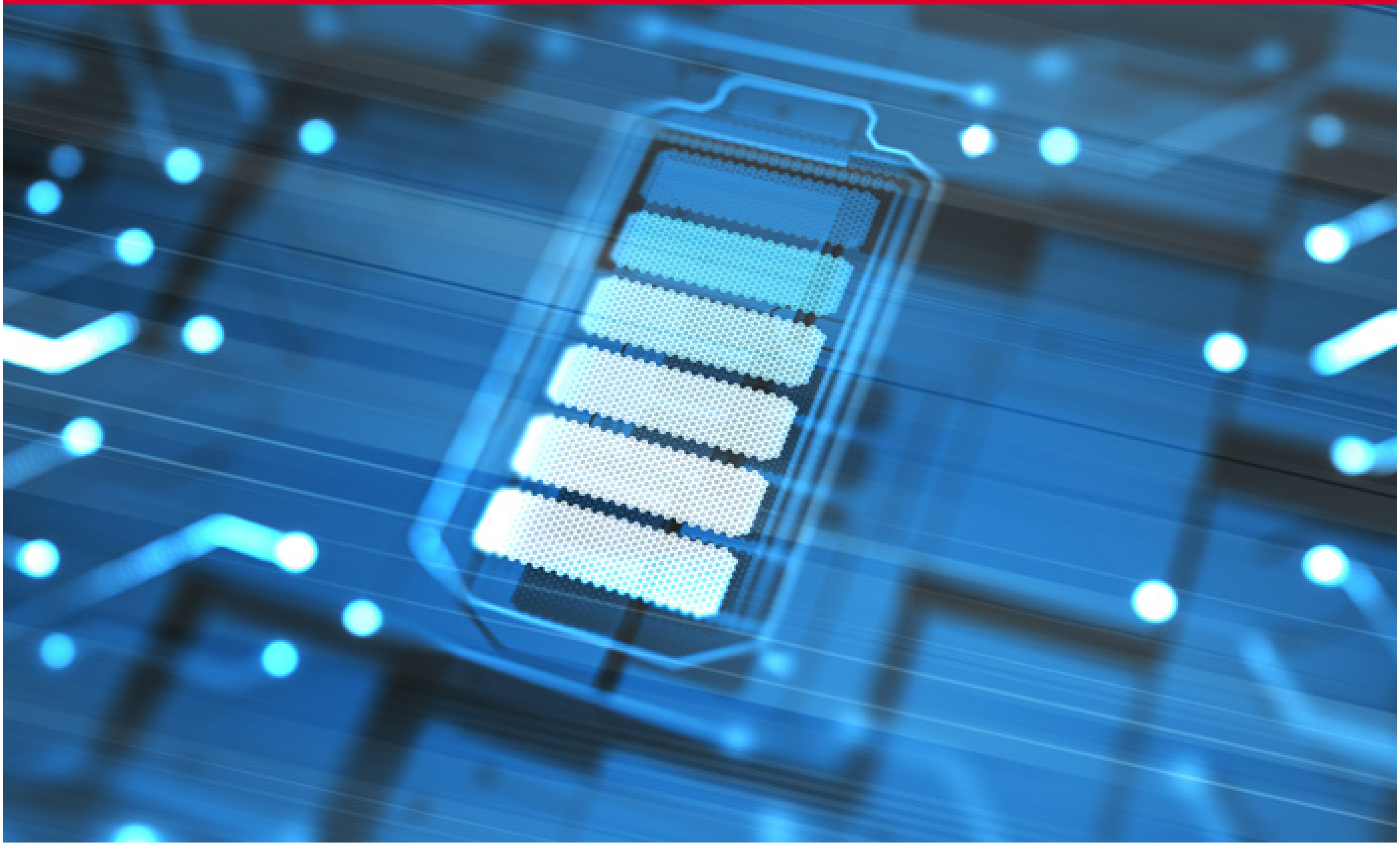
Energy efficiency is a highly data-intensive topic. Millions of energy-related decisions are made each day: which equipment should enter sleep mode and which depth of sleep mode? Where should the next solar panel be deployed and which region should be prioritised for the next deployment? Which sites are overperforming or underperforming and why? When should an operators refill the diesel tank and run maintenance?

These decisions are traditionally made by highly skilled and expensive network engineers and not in real time. Quicker reactions and data-driven decision-making can be key differentiators. Improvements around AI can help network operators make decisions almost in real time, thereby saving on both energy and labour costs.

In 2025, with the decrease in computing costs and the advent of advanced AI systems, the lack of data availability and visibility has become the biggest bottleneck. This is caused by technological barriers such as the lack of metering, unconnected data pipelines, silo-like legacy networks and operational, institutional or legal barriers, such as tower companies not providing data to the network operators or non-interconnected legacy systems working in isolated environments using different systems.

A number of operators highlighted examples of visibility of energy-related data being surprisingly low. Some operators could not track or harvest any data due to a lack of metering or because the necessary data was not provided to them by a third party. While data availability was a noticeable obstacle in previous years of the study, it became an even more prominent issue during the fourth year of the Energy Efficiency Analysis and Benchmarking project. This may be due to the increase in the number of included operators from Africa: tower companies are more prevalent in Africa and local operators have limited ownership over network data.

In the 5G era and beyond, real-time data gathering, standardised metrics, full visibility and efficient data pipelines are essential to further increase energy efficiency and competitiveness, especially since 14% of operational costs are related to energy, making it a key factor.



5.
How to get involved

Decarbonisation and sustainability will continue to be a key strategic priority area for the telecoms sector over the next decade as operators play their part in the global response to climate change. A sustainable approach also helps to foster innovation and engender enthusiasm and loyalty from employees, customers and suppliers. Mobile operators are increasingly placing a green agenda at the heart of their business strategies, driving the wider industry's contribution to the UN Sustainable Development Goals. To support these aspirations, GSMA Intelligence will continue to run an extended version of a similar energy efficiency benchmarking activity later in 2025, based on new 2024 data.

However, to make the results as representative and impactful as possible across all regions, we would like to increase the range of participating operators. In addition to public-facing research and best-practice guidelines, participating operators will receive customised reports on their own network energy efficiency compared to industry averages on an anonymised basis.

For more information on the next round of the Energy Efficiency Analysis and Benchmarking project or to be involved directly, please contact any of the following individuals:

Emanuel Kolta
Project Lead, GSMA Intelligence
ekolta@gsma.com

Tim Hatt
Head of Research and Consulting, GSMA Intelligence
thatt@gsma.com

Steven Moore
Head of Climate Action, GSMA
smoore@gsma.com

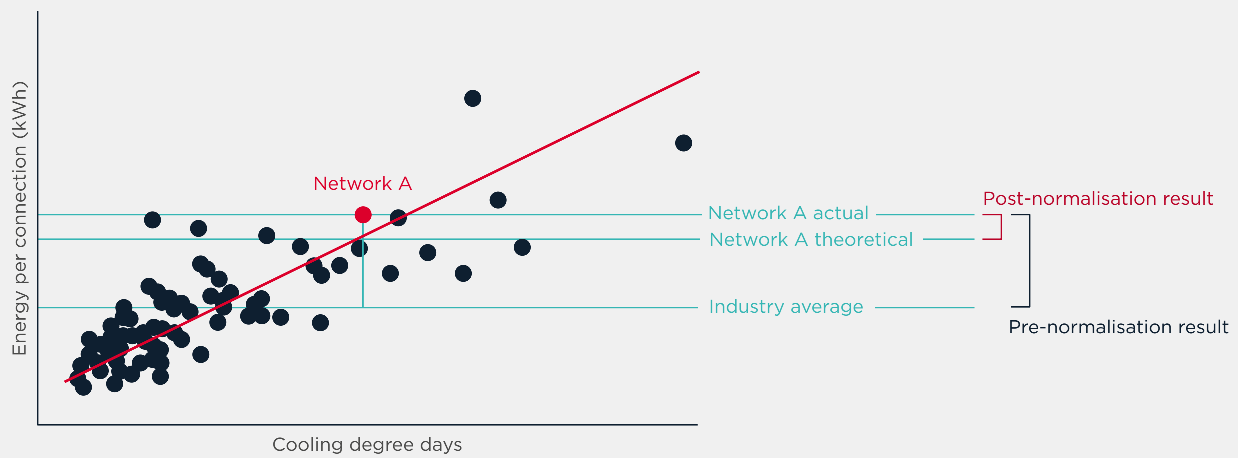
Appendix

Normalisation

Regression analysis produces a set of results that enable a mathematic equation to be written to explain the relationship. With this equation, we can calculate the theoretical energy per connection for a network, using the network's values for each of the independent variables. Subtracting the network's actual value from the theoretical value gives a measure of whether the network is overperforming or underperforming. This approach can be extended to multiple networks.

Without the normalisation process, the efficiency ratios would be compared to an industry average. This could be misleading since many other impacts would be included that are not the responsibility of the mobile network operators. For example, just because a network is located in a warm climate with a consequent high demand for air-conditioning does not necessarily translate to a poor energy-efficiency reading.

Figure A1 **Actual versus theoretical energy consumption**



Source: GSMA Intelligence

Regression analysis

Data inputs from the participating operators include energy usage, data traffic, number of cell sites and fuel consumption split between diesel and renewables. To avoid seasonality and outlier periods, the data covers the full-year period of 2023.

After normalisation, we ran a regression analysis of variables against energy consumption to understand which have the highest correlations. Conclusions were then drawn on benchmark levels for energy consumption, fuel sourcing and efficiency ratios.

Key factors influencing energy efficiency

After testing several potential explanatory variables, three non-network factors were identified to normalise the data. GSMA Intelligence aimed to extract those factors outside an operator's control from the original energy per unit of traffic value. These variables enable us to normalise the result from three different angles:

- **Network traffic:** The average monthly mobile data traffic per mobile subscriber during 2023.
- **Climate:** A cooling degree day (CDD) is a measurement designed to quantify the demand for energy needed to cool buildings.
- **Network density:** The number of connections per cell site. The average size of the area that the cell site covers has an impact on energy efficiency/ consumption. This measure accounts for population density, market share and topology.

Thanks to the subtraction of these different variables, the real network-related attributes come to the forefront in the benchmarking.

The result of the benchmarking gives us a diverse picture: top performers can be found in different regions; network efficiency does not directly correlate with how developed a market is; and there is a difference of 20× between the worst and best performers.

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