True north: a guide to green network evolution

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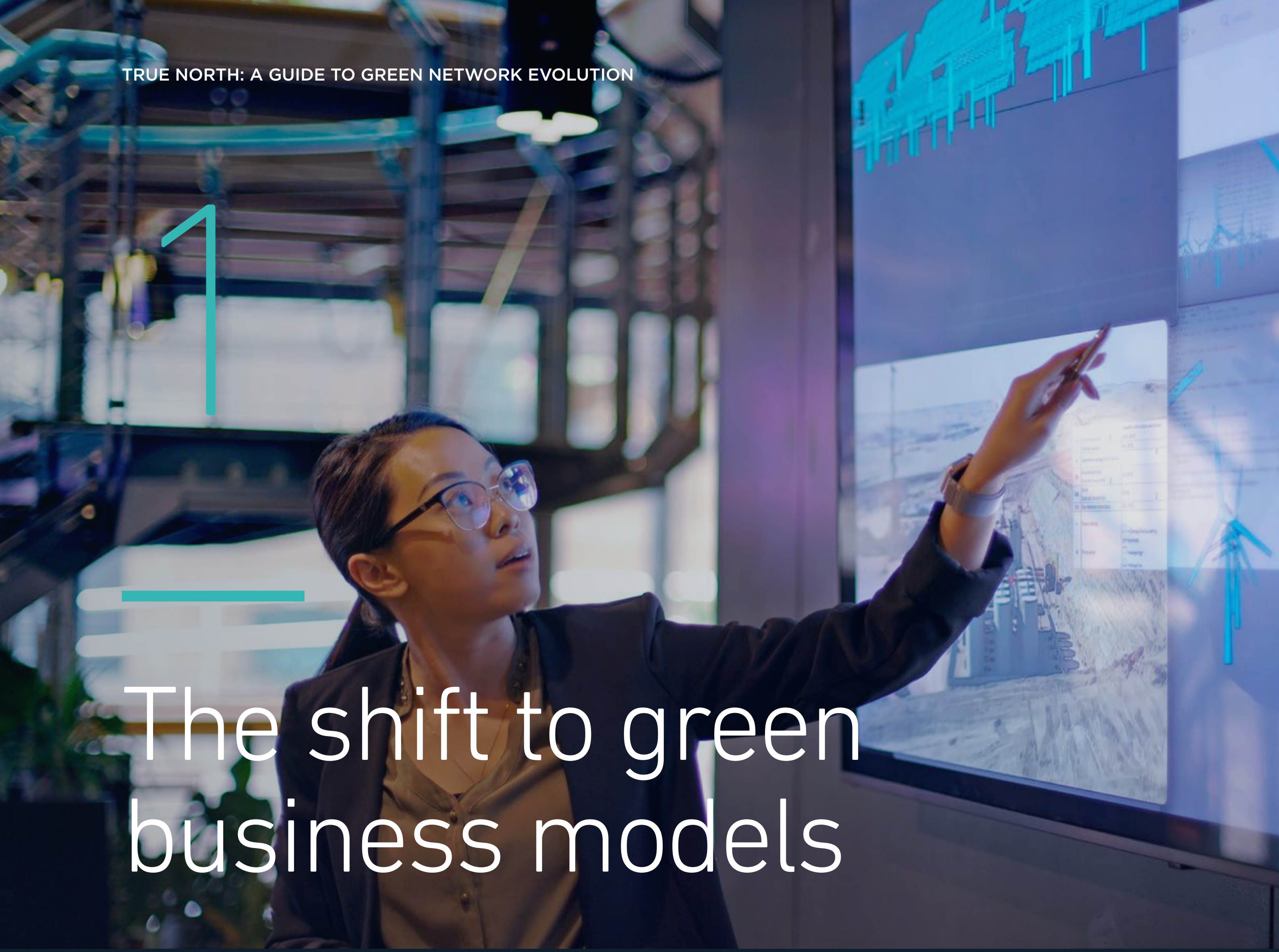


1

The shift to green business models

The complexity of reorienting network strategy around sustainability means a clear framework is key for prioritising when and where actions should be taken. This report outlines such a framework, offering telecoms operators and their suppliers a 'true north' to guide decision-making.

1.1 Environmental and business rationale

The rationale for telecoms operators to move to green business models is anchored in environmental and business logic. On the environmental side, the shift to green models supports the transition to net zero. Most nations (and therefore corporations) are targeting net zero by 2050, in line with the Paris Accord. The telecoms sector is a leader in this respect; around half of operators have publicly committed to net zero using science-based targets (SBTs). On the business side, the shift to green models helps lower energy costs through efficiencies and the use of renewables. Sustainability can also be used as a competitive selling point to appeal to consumers and enterprises. The Green is Good for Business report series provides in-depth analysis.

Net-zero commitments based on a 2050 timeline imply CO_2 reductions of 50% in each of the next three decades. The 2020s is the most difficult, as the carbon load to reduce is the largest. Looking at energy use by telecoms operators in total, GSMA Intelligence estimates that the industry accounts for around 1% of energy use worldwide. See Table 1. This equates to around 115 megatonnes of carbon, which represents a lower share of the global total (0.3%) than for energy because of the telecoms industry's greater use of renewables than other sectors such as manufacturing and aviation.

Table 1

Operators account for 1% of global energy use

	Electricity use		CO_2 footprint	
	Terawatt hours (2023)	Percentage of global total (2023)	Megatonnes of CO_2e (2023)	Percentage of global total (2023)
Mobile networks (excluding operator data centres)	168	0.6%	64	0.2%
Fixed line networks	132	0.5%	50	0.1%
Total mobile and fixed line networks	**300**	**1.1%**	**114**	**0.3%**
Operator data centres	19	0.07%	7	0.02%
Hyperscaler and other data centres	319	1.2%	120	0.3%
Total data centres	**338**	**1.3%**	**128**	**0.3%**
Global total (all industries)	**26,799**	**100%**	**37,857**	**100%**

Source: GSMA Intelligence

1.2 Renewable use: a mixed picture

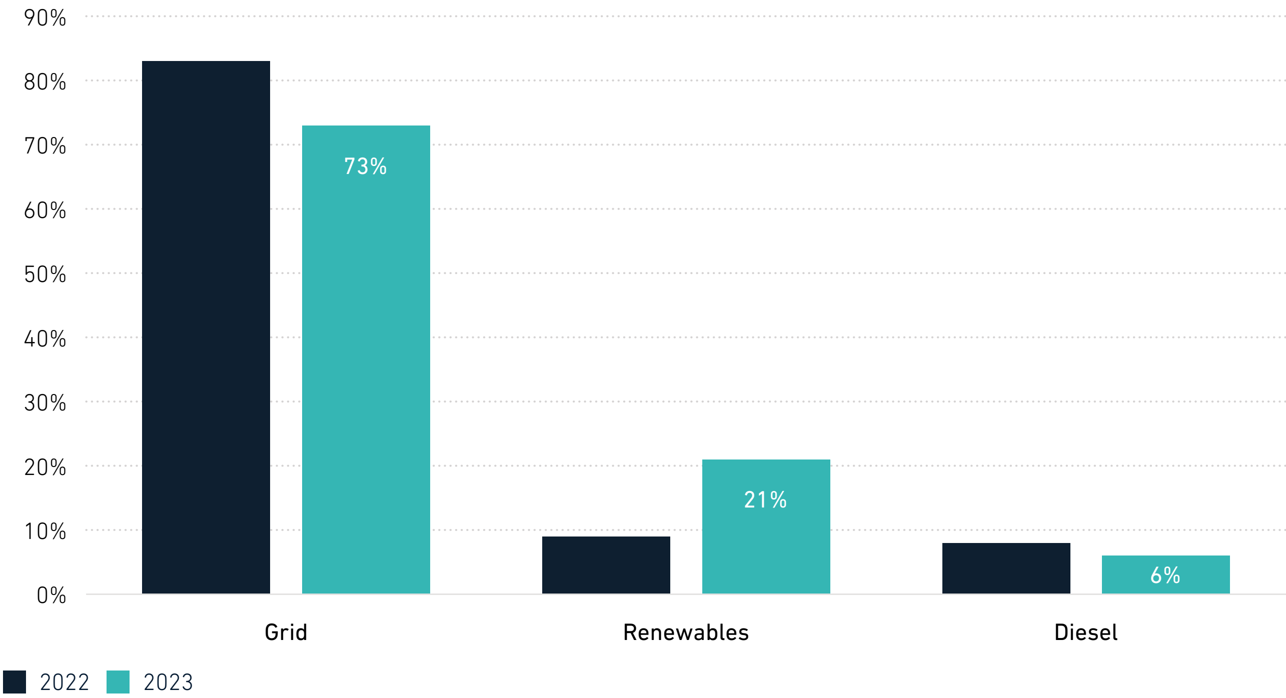
Shifting energy consumption in favour of renewables continues to be a priority for the telecoms sector, as it is for the broader economy. Figure 1 shows a mixed picture so far. Renewables still account for a minority of energy usage among operators, but it has more than doubled in a year.

The industry average of 20% is heavily driven by European operators, who often claim 80–90% of their power from solar and wind. Africa, India and large parts of Asia still rely on diesel in off-grid areas.

Figure 1

Operator use of renewables (global): increasing but still only accounting for a fifth of the power draw

Percentage of total energy used



Source: GSMA Intelligence Telco Energy Benchmark 2023

2

Sector progress so far

2.1 Efficiency slowly improving, but uneven progress

It is well recognised that holistic strategies are needed to improve energy efficiency at all levels of the telecoms network stack. Progress has generally been positive so far in terms of the sector average, but it is mixed at the regional level. This can be measured at different levels with different metrics:

- Energy efficiency
- The distribution of power in different parts of the network (radio versus core/data centre versus other layers)
- Energy splits (grid versus renewables versus diesel).

According to the GSMA Intelligence Telco Energy Benchmark study, the average power yield per unit of data traffic was around 0.15 kWh per GB in 2023 (see Figure 2). It costs a typical operator 0.15 kWh of energy to distribute 1 GB of data across the network. This has been trending downwards, from 0.17 in 2022 and 0.24 in 2021 – a drop of nearly 40% over two years. It reflects the move to more efficient equipment, the use of lithium (instead of lead) batteries and the shutting down of power-hungry 2G/3G equipment where spectrum can be repurposed for 4G/5G.

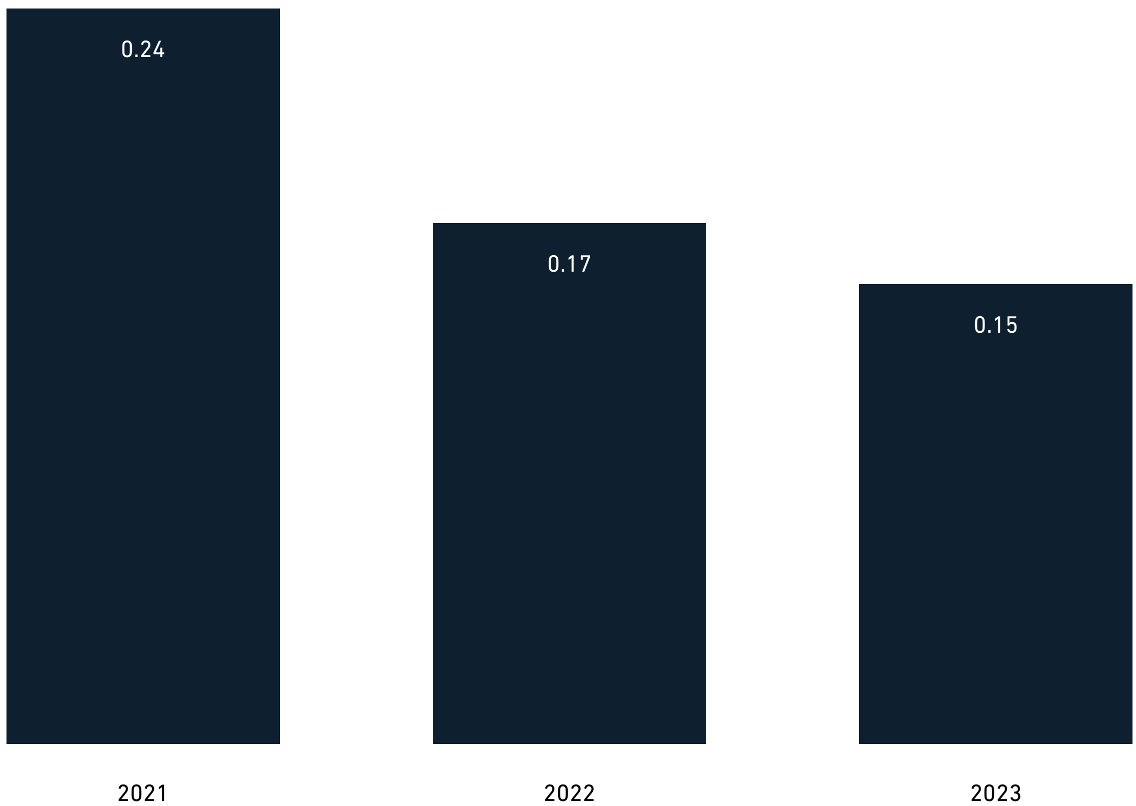
Subscribers are moving to 4G and 5G, with the latter now accounting for around 25% of the global mobile connections base. The percentage is much higher in vanguard countries such as South Korea, China and the US. The increase in data traffic (5G customers use, on average, four times more data per month than 4G users) and growing levels of digitisation underpin demand for more power in the RAN and data centres. Offsets from more efficient equipment are therefore urgent. For fixed lines, there is an energy dividend from moving from legacy copper to fibre, as the latter is around six times more power efficient.

The rate of improvement for energy efficiency is slowing. More importantly, progress is uneven across different regions. In Africa, for example, the average power yield – measured as kWh per GB – is around twice the global average, on account of the continued operation of 3G networks and the use of diesel for off-grid base stations. A similar story is seen in parts of Asia, where much of the global mobile market share is concentrated. In some cases, we do not yet have data to verify progress, but we can make reliable estimates based on the local market economy and climate.

Figure 2

Energy efficiency for operators is slowly improving but with regional gaps

kWh per GB



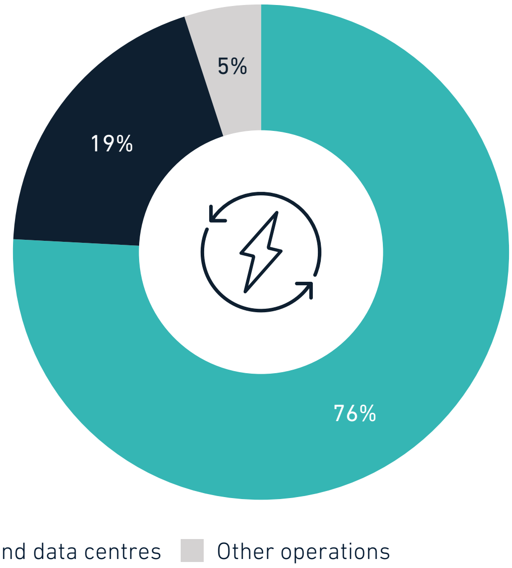
Source: GSMA Intelligence Telco Energy Benchmark 2023

There is a similar geographic pattern in the splits for energy use. On average, the 20% of telco energy use that renewables account for is heavily driven by vanguard operators in Europe and the US. The comparable figure is below 10% in much of Asia, Africa and South America, where reliance on diesel offsets much of the gains from using solar or wind in urban and suburban areas.

There is more uniformity in where energy is used in the network. Around 75% of the power draw comes from the RAN (see Figure 3), with only 5–10 pp variation by operator. Data centres that power the core account for around 10%. A group comprising anything from fleets to property account for the remainder.

Figure 3

Where energy is used across the network



Source: GSMA Intelligence Telco Energy Benchmark 2024

If renewables account for only 20% of the power draw, a huge jump (e.g. a doubling to 40%) would still necessitate a faster improvement in energy efficiency if the requisite CO_2 emission reductions are to be made by 2030 to stay on track to hit net zero by 2050. The 'lowest hanging fruit' are 2G/3G network sunsets and using the network upgrade cycle to prioritise use of AI to aid sleep states and dynamic power management.

/ultimately, KPI tracking should be part of a broader framework for implementing a green strategy across the network and energy sourcing functions of a telco. This report highlights what we believe to be a robust means of doing this – and one that is adaptable between telecoms operators of different sizes and mobile versus fixed composition.

3

A green measurement framework

3.1 Defining a green network

While the term “green” is often used for marketing purposes to describe being environmentally friendly, its precise meaning can sometimes be unclear – particularly when applied to mobile or fixed networks. This ambiguity creates challenges in defining what qualifies as a green network, making it difficult to establish consistent standards for environmental sustainability in telecoms.

Phrases such as “green”, “sustainable” and “environmentally friendly” are related but also distinct. “Green” refers solely to environmental health, focusing on minimising harm to ecosystems. “Sustainable” encompasses environmental protection and economic/social viability. This distinction is key in understanding the broader implications of environmentally responsible technologies and infrastructure. For example, a product can be green but not sustainable.

GSMA Intelligence offers a framework for defining green networks, focusing on principles such as reducing energy consumption, conserving physical resources, cutting pollution and minimising waste. This provides a useful baseline and is broad enough to be inclusive. The definitions and framework need to be usable in the diverse social, legal and geographical environments in which networks operate.

3.2 The challenges of creating a green network framework

Establishing a framework, guideline and metrics to assess the environmental friendliness of products or services is important to capture variation across companies and industries. In some industries, it is relatively simple to measure sustainability efforts. However, in areas such as telecoms, the task is much more complex.

There are two primary challenges to creating a green framework for telecoms:

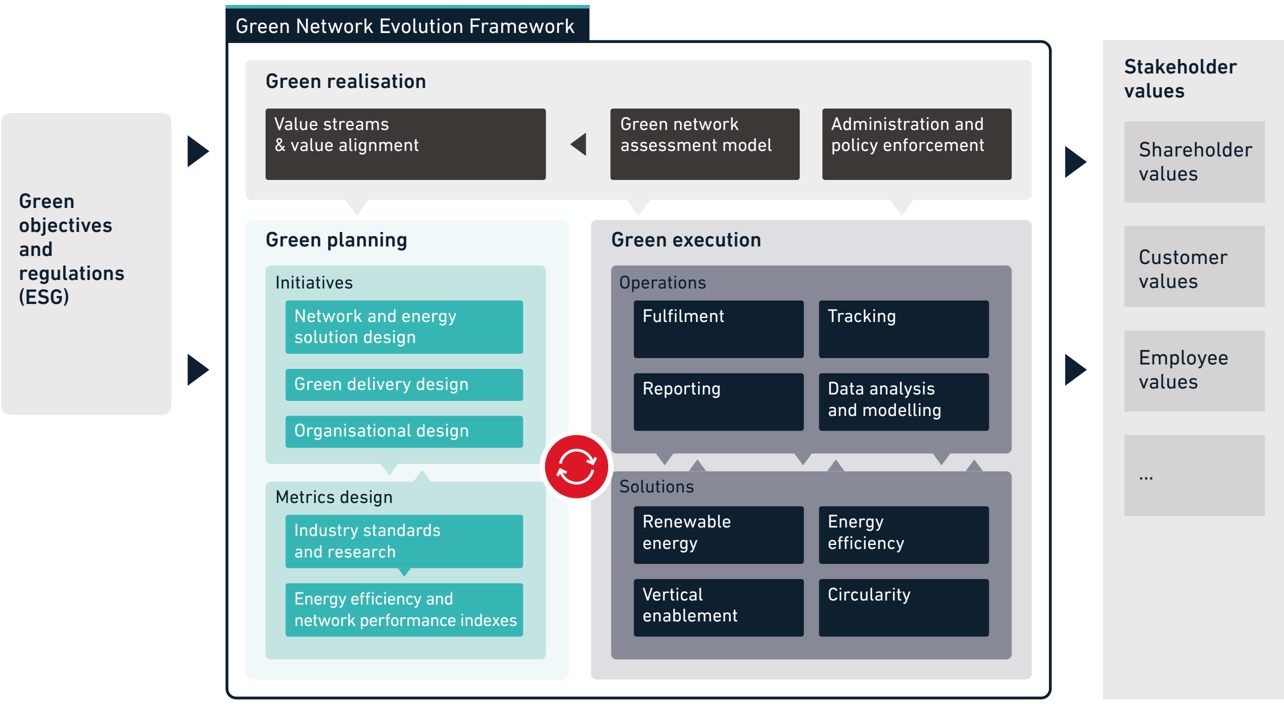
- Telecoms networks operate within highly diverse social, legal and geographical environments. This makes it difficult to apply standardised measurement techniques and to replicate best practices across different regions or markets. What works well in one country or area may not be applicable or effective in another, due to the different regulatory landscapes, infrastructure capabilities and social expectations.
- The telecoms sector is constantly evolving, with ever-changing demands and expectations among consumers and businesses. As a result, any green framework designed for the sector needs to be regularly updated and optimised to remain relevant. The dynamic nature of technology and network outputs means sustainability guidelines must be flexible enough to adapt to new developments, ensuring they continue to provide meaningful assessments and drive environmental progress.

3.3 Establishing a green network framework

Telecoms operators must develop their own detailed frameworks, regularly analysing the current situation and fine-tuning their strategies. Figure 4 outlines a systematic approach to operating a green telecoms business model, built on three key pillars: realisation, planning and execution.

Figure 4

A green network framework



Source: GSMA Intelligence

Realisation

This phase centres on maturity assessment, top-level supervision and control. These first steps and recurring analyses are crucial to drive profound and long-lasting green transformation. This phase focuses on defining the value propositions essential for the successful implementation of strategic initiatives, and constant monitoring of the process. By assessing maturity, network operators can gauge their overall readiness for and status of green transformation at different layers of the network. They can also identify gaps to be addressed to achieve their goals.

It is recommended that network operators do the following:

- Continuously run value gap analysis and evaluate the organisation's current environmental performance compared to its desired green network goals. This assessment helps highlight improvement areas.
- Map value streams to help identify improvement areas such as cutting energy consumption for data centre air conditioning or enhancing energy efficiency for 5G antennas. By pinpointing and analysing the value streams, organisations can better understand where environmental impacts arise and optimise processes for greater sustainability.

Planning

Planning involves various design approaches to create a comprehensive strategy and use of industry metrics to evaluate solution performance. Key initiatives include the following:

- **Network design** – A holistic approach is necessary to design energy-efficient solutions. This involves setting measurable goals, analysing challenges and ensuring integration into network strategy while promoting continuous improvement. This alignment helps telecoms companies achieve their environmental objectives.
- **Organisational design** – A clear structure of roles and responsibilities is crucial for effective green network evolution. This includes defining job roles for stakeholders, outlining key steps and establishing responsibilities for tasks such as energy assessments and network optimisation, promoting collaboration and accountability.
- **Delivery design** – With rising demand for ICT services, it is essential for operators and vendors to prioritise green delivery design to maximise efficiency. Initiatives include optimising logistics to reduce emissions, minimising redundant materials, leveraging remote management for site visits, and digitalising tools and documents to enhance efficiency and reduce waste.

By implementing these strategies and using intelligent digital tools (such as planning platforms and digital surveys), organisations can significantly reduce their carbon emissions and improve operational efficiency.

Execution

After the realisation and planning phases, network operators can identify, design and prepare different projects. It is recommended that each of the projects has the same high-level elements:

- **Fulfilment** – Each green project should begin with resource readiness, including network evaluations and assessments to identify strengths and weaknesses. Data preparation (including the collection and analysis of energy consumption and resource usage) provides insights into the network's environmental footprint and optimisation opportunities. Effective risk management is also crucial, as it identifies and mitigates potential risks associated with green practices.
- **Tracking** – Continuous monitoring and evaluation are essential for effective green network execution. This involves creating a dashboard that offers real-time insights on energy consumption, emissions reductions and resource usage, providing a clear visual representation of progress. Additionally, defined indexes can measure progress against specific targets and evaluate the effectiveness of green initiatives.
- **Reporting** – Transparent reporting is vital to demonstrate progress towards sustainability goals and to maintain accountability. Regular monitoring of KPIs related to energy consumption and emissions can help generate detailed reports showcasing environmental performance. These should be shared with different stakeholders with different goals.
- **Data analytics & modelling** – Analytics supports network monitoring, adjustments and planning to minimise energy consumption for a given workload.

Green solutions encompass a range of practices and technologies aimed at advancing sustainability, including the following:

- **Energy efficiency** – Increasing energy efficiency, focusing on maximising the use of energy resources without significantly impacting quality of service. Efforts can target the whole network orchestration holistically or just sites, central offices, data centres, an equipment group or operations and maintenance (O&M).
- **Renewables** – Increasing the share of renewable energy in a financially sustainable manner without risking energy security. Solution analysis, supply and storage coordination, and data extraction should be included in the projects.
- **Circularity** – Embedding circularity practices (reusing and repurposing devices and equipment), and an economic model that seeks to preserve the value of materials and products for as long as possible.
- **Vertical enablement** – Leveraging network operators' unique position and expertise to help other industries lower their own carbon footprint through connectivity and digital technology.

4

How to measure green networks

4.1 Framework metrics and reporting

Considering the complexity of green networks, one metric would not be enough and would be biased/subjective. There are several metrics for structuring a measurement framework. These include:

- different levels of energy efficiency
- operators' greenhouse gas (GHG) emissions
- circularity ratios (a nascent category).

Energy efficiency

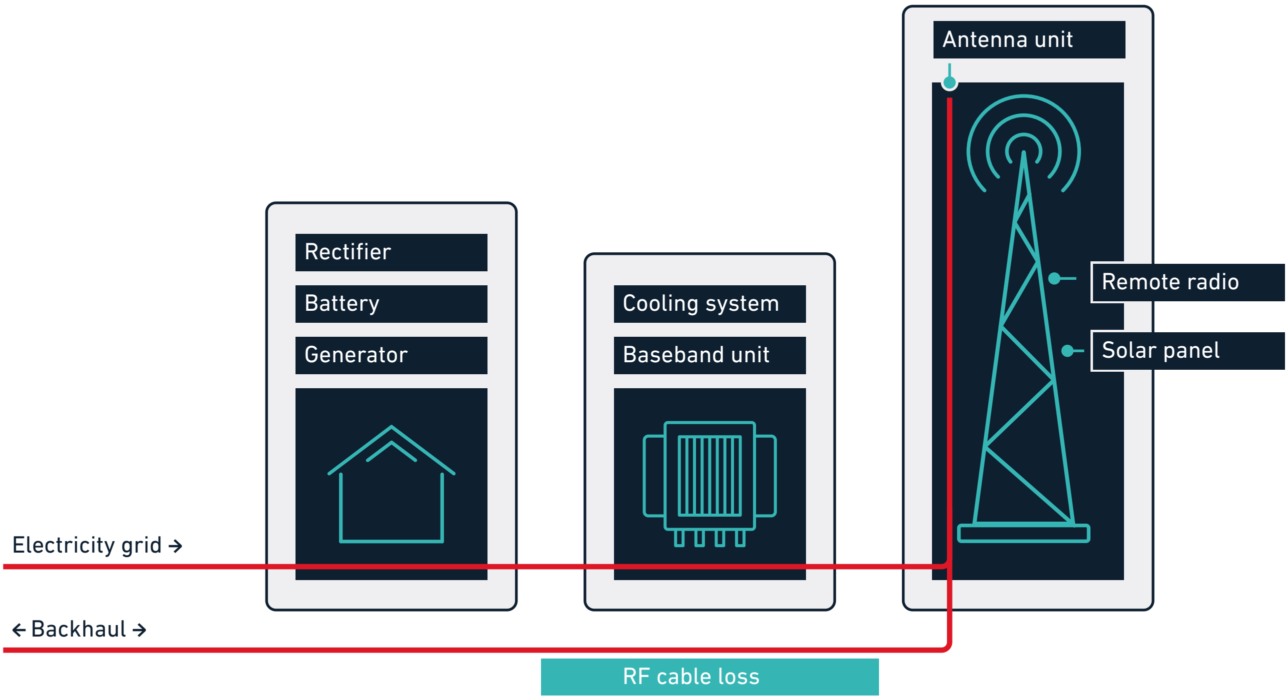
The impact of telecoms operators on the environment is driven by a range of elements, but mostly by energy-intensive network infrastructure. According to GSMA Intelligence's Telco Energy Benchmarking study in 2024, energy costs account for 20% of operators' network opex – and this is likely to rise. Energy is one of the few major operational costs expected to increase, rather than decrease, further in the future.

The majority of energy (76%) is consumed in the RAN. Providing coverage across thousands of square kilometres, transforming energy into radio waves, and receiving and processing incoming signals remain energy-intensive functions. To calculate energy efficiency in a similar way to other industries, the relationship between energy consumption and value creation would provide a straightforward method. However, in telecoms, this is problematic. Each mobile network and even each site operates under unique and constantly changing conditions, which complicates direct comparisons and makes it challenging to accurately measure and benchmark energy efficiency across different networks.

Figure 5 shows the key points of energy consumption, illustrating the complexity and challenges involved in analysing energy usage holistically. Each of the consumption points can be viewed individually, with its own energy-efficiency metrics assessed independently. Despite the challenges, energy efficiency should be constantly (in real-time) measured, analysed, reported and improved.

Figure 5

The use of energy in the RAN



Source: GSMA Intelligence

For operators, energy efficiency can be measured at different levels. Different metrics are more suitable depending on whether the focus is on one piece of equipment, a site, the whole network or the entire operation.

Each piece of network equipment has its own energy-efficiency characteristics. Although these can be affected by external factors, such as weather or data/voice traffic, they serve as a basic indicator of energy efficiency for wireless infrastructure.

Equipment-level efficiency

Equipment-level energy efficiency can be measured using a data traffic/energy metric.

Site-level energy efficiency

Power usage effectiveness – site (PUE_{site}) refers to the energy efficiency of an entire cellular base station, including a range of telecoms equipment and other passive supporting infrastructure, such as energy conversion and transmission equipment, security, cooling and power back-up.

PUE_{site} is determined by dividing the total amount of power entering the site by the total telecoms equipment energy consumption at the site. It is expressed as a ratio, with overall efficiency improving as the quotient decreases towards 1.0. PUE_{site} is a useful tool to measure and benchmark the significance of passive infrastructure per site.

Data centre energy efficiency

According to GSMA Intelligence analysis, mobile operators are using 9% of their energy in centralised data centres. The most commonly used metric for reporting the energy efficiency of data centres is the power usage effectiveness ($PUE_{data\ centre}$). This evaluates the performance of the data centre by calculating the ratio of the energy used as a whole compared to the energy used by just the telecoms or IT equipment alone.

Network-level energy efficiency

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
- connections per unit of energy consumption
- number of cell sites per unit of energy consumption
- revenue per unit of energy consumption

In an ideal situation, network energy efficiency (NEE) can also be calculated. This requires detailed coverage and network experience data from mobile operators. This comprehensive metric can bring more methodology challenges but offers the promise of a single energy-efficiency metric for networks: NEE index (total data volume / (total energy consumption × factor {coverage} × factor{experience}))

Mobile network data energy efficiency is a further indicator, expressed as the ratio between the data volume and the energy consumption during the same period, in bit/J.

The ITU-T has also completed a recommendation that defines a KPI called network carbon data intensity energy (NCIe). This represents the intensity of carbon emission relative to the level of network traffic.

Operator-level efficiency

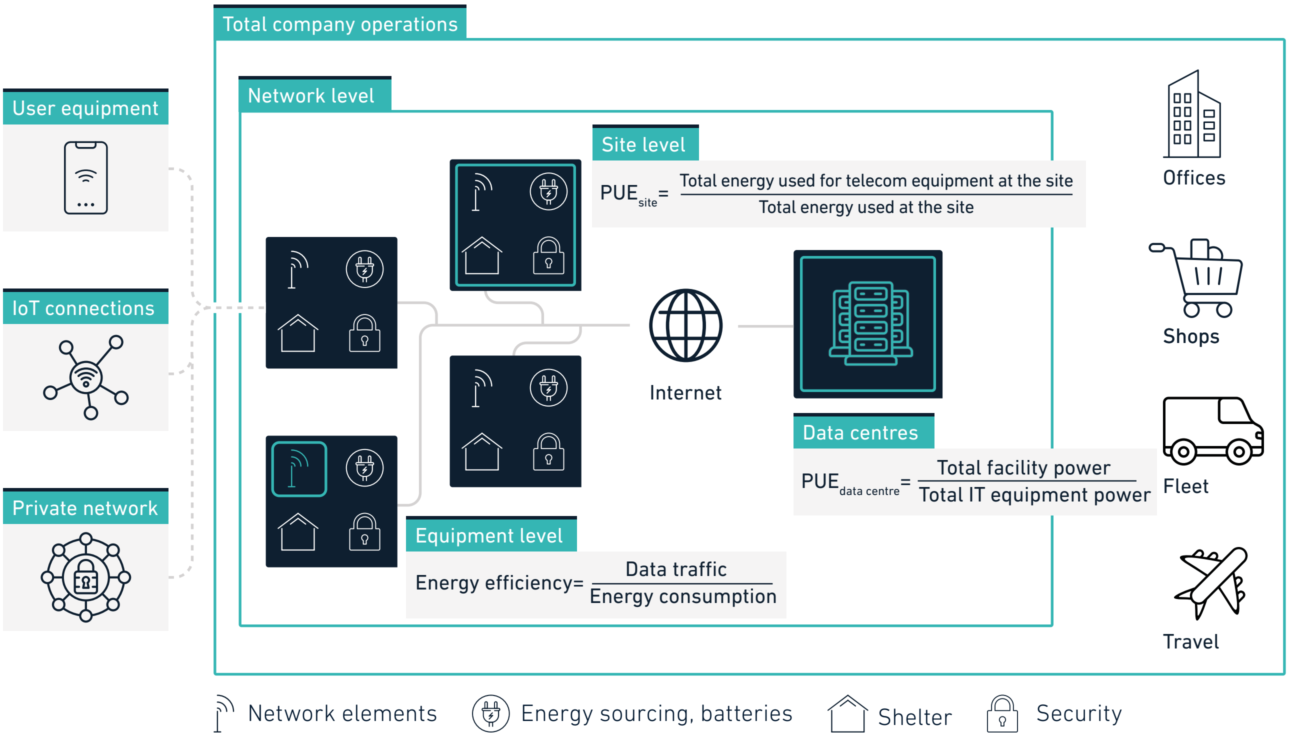
The energy-efficiency metrics mentioned above for network-level efficiency can be broadened to encompass an operator's total energy consumption. This expanded metric can account for non-network-related operations, such as fleet, buildings and other activities.

Greenhouse gas emissions

Most operators are working to improve their ability to accurately measure and track greenhouse gas emissions across their operations. Furthermore, operators can disclose whether they have set a corporate net-zero target.

Figure 6

Different levels of energy efficiency in mobile telecoms



Source: GSMA Intelligence

Energy efficiency analysis and benchmarking

Partnering with mobile operators around the world, GSMA Intelligence launched the Telco Energy Benchmarking project in 2020. The benchmark is based on anonymised, real-world data inputs, with the aim of quantifying network energy consumption, efficiency levels and fuel sources. The project offers a set of KPIs to measure overall energy efficiency: energy consumption/unit of mobile data traffic, energy consumption/connection, energy consumption/cell site and energy consumption/revenue.

4.2 The Green Network Index proposition

A long-term vision for telecoms networks would see them powered 100% by renewable energy, resources allocated where and when needed, the ideal spectrum band used and as many verticals as possible able to experience exceptional network and service quality. Based on the results of GSMA Intelligence's energy benchmarking project and other analysis, this is not going to happen in the near future. However, to achieve the vision, continuous measurement and reporting is needed on a global scale and in a standardised way.

The GSMA Intelligence Green Network Index offers a comprehensive platform based on four main groups of KPI:

- **renewable energy** – how renewable is the source of energy?
- **energy efficiency** – how effectively is the energy being used?
- **performance and availability** – how is the impact on network and service quality minimised?
- **vertical enablement** – how can connectivity enable carbon reductions for vertical enterprises?

The Green Network Index offers more than just a platform to monitor energy consumption. It is a comprehensive, global tool that provides KPI assessment and supports optimisation efforts.

However, covering the range of metrics required from participating operators can be challenging. GSMA Intelligence has identified two primary obstacles that can hinder operators fully engaging in the Index:

- **Data availability** – Most network operators struggle with accessing, gathering, organising and storing data on energy consumption and sustainability. This difficulty can stem from factors such as a reliance on third-party tower companies unwilling to share consumption data, or a lack of IoT sensors to collect real-time information.
- **Legal/organisational constraints on data sharing** – Challenges relate to data-sharing willingness, organisational bottlenecks and the absence of widely accepted metrics. Networks also operate in diverse environments, adding complexity to standardisation efforts.

GSMA Intelligence does not anticipate full participation or complete data sharing in the first year. Participation is expected to grow annually, with each additional operator enhancing the index's value for all participants. The initiative is not meant to foster competition; rather, it will create a collaborative, win–win community for sustainable progress.

5

Outlook and implications

Although networks vary, general principles are common across operators. The objective of operators is to develop standardised approaches with unified metrics that are openly accessible. This means introducing a global, green framework that is applicable universally and aids operators regardless of their size or the markets where they operate.

Form an evidence base through data harvesting

Despite the challenges, energy efficiency and circularity should be constantly (in real-time) measured, analysed, reported and improved. Operators should harvest their data to identify the critical weaknesses of their networks. Network equipment does not usually measure energy consumption, and many elements of passive infrastructure lack metering. Even if the equipment has metering capability, recording the data is labour-intensive and not in real-time. Operators should consider building comprehensive data pipelines to analyse and uncover costly anomalies. Deploying smart sensors at various points of the network will help measure equipment-level energy consumption, the status of batteries in sites, active hours of generators, fuel levels, inside/outside temperatures and air conditioning.

Gain better visibility across the organisation through data sharing

An increasing number of companies openly share or are required to disclose the size of the negative impact of their products. This can help consumers make the right decisions. A growing number of operators have started to introduce carbon-free offerings and educate consumers.

Furthermore, the comparison and benchmarking of raw energy efficiency KPIs (network energy consumed per unit of data) can be misleading given local market circumstances related to climate and demographics. Despite the diverse backgrounds of operators, data can still be cleaned and analysed, such as with the GSMA Intelligence energy efficiency analysis and benchmarking. It can also be analysed year-on-year.

Follow the standards

Establishing international standards and metrics to assess energy efficiency, emissions and circularity is essential not only to enable comparability across networks but also to foster consistency and reliability in environmental impact assessments.

Such standards provide a common framework for evaluating performance, which is critical for transparent benchmarking, regulatory compliance and informed decision-making. Rather than developing individual measurement standards, it is recommended operators align their reporting and measurement techniques with these established international guidelines.

This approach can simplify data comparison and contribute to a more unified and collaborative global effort to reduce the environmental footprint across the industry. Additionally, for GHG Scope 3, network operators are encouraged to report as many categories as possible, as a significant portion of their emissions falls under this scope. The GSMA Scope 3 Guidance for Telecommunication Operators helps to align methodologies. Its wider adoption is expected to improve future measurement.

Align operations and corporate governance

Operators do not only need to take advantage of new equipment, software and service offerings to increase energy efficiency; they also need to update their corporate governance structure and define new KPIs. As levels of data traffic and network complexity increase, the gap will only widen further and result in significant competitive disadvantages for sluggish operators. Considering the complexity of energy efficiency for an operator, no department can single-handedly and effectively take care of the entire transformation. Operators should designate a new team with an accountable, senior leader and a set of ambitious KPIs. The new team can launch cross-functional projects and help break down silos.

Take a holistic approach

The biggest challenge for operators is to maximise energy efficiency while maintaining/improving network service quality and network traffic continue to grow. A new project, the GRPE framework, aims to define a holistic approach and model, helping operators with their green initiatives and network evolution.

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