RESEARCH

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WHAT ARE KEY CONSIDERATIONS FOR 5G SITES?

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1. Executive summary

The number of cell sites rises with each generation of mobile technology to support increasing levels of data traffic. This trend will be greatly intensified by the introduction of 5G because of the wide variety of use cases and traffic patterns that will need to be supported, and some of these have demanding requirements for availability and reliability, as well as data rate. 5G use cases, in turn, will rely on a large number of spectrum bands.

The requirements for 5G will be fulfilled using new equipment such as Massive MIMO (multiple-input, multiple-output) antennas and mini-macro base stations, which deliver macro cell performance in a compact form factor that can be deployed on, or inside, a pole. Analysys Mason forecasts that by 2025 there will be 14 times more base stations deployed on poles and city furniture than in 2017.

These dense networks present significant challenges because of the number of sites that they require. The challenges fall into three main categories:

- total cost of ownership (TCO) as site numbers increase
- operations and maintenance (O&M) for large numbers of base stations
- Challenges with power consumption in dense networks with large antenna arrays.

Zhengmao Li, Executive Vice President of China Mobile, has highlighted the following differences between 5G and LTE, in terms of siting and power consumption[1]

- 5G needs 300% more base stations for the same level of coverage offered by LTE because of higher spectrum bands
- A 5G site will consume 300% more power than an LTE site and will cost four times more than an LTE one, if they are deployed in the same way.

This white paper examines how operators and other stakeholders will address these challenges in two leading regions for early 5G deployment, Western Europe (WE) and developed Asia–Pacific (DVAP). Dense 5G will only be viable in these regions if costs and power consumption can be greatly reduced, which will mean deploying and managing the sites and their power systems in a completely new way.

If 5G site planning, deployment and management are administered in the same that they were for 4G, Analysys Mason calculates that site costs will increase by 500% by 2023, and energy costs by 900%. This is all happening at a time when mobile network operators (MNOs) want to radically reduce their operating costs (which currently account for almost 70% of TCO).

However, new solutions are already starting to emerge as operators in Western Europe and DVAP start to turn on commercial 5G networks. No single solution addresses all the issues of 5G siting, but operators can meet the targets that they have set themselves for TCO reduction, capacity and coverage enhancement and power efficiency if they adopt a combination of new approaches that focus on different aspects of network deployment and operations.

[1] Source: Keynote speech at Mobile World Congress 2019

The main solutions, which are detailed in this white paper, are summarized in the table below.

Figure 1.1: Summary of 5G siting challenges and solutions

Challenge	Solution
Deployment and installation	Simplified and modular site structures that do not require skilled labour to install.
	High levels of integration to reduce space and power (for example, for active and passive antenna units).
	Standardised equipment modules that can be uniformly deployed and approved.
	Streamlined and uniform approval processes for sites and equipment.
	Equipment that can use a diversity of site options to maximise coverage while remaining unobtrusive. These include the embedding of access points within poles or pavements.
	Single RAN – moving services to 4G+5G in order to switch off inefficient legacy RATs, and to simplify the network and free up site space.
Operations and maintenance	Simplified site structures that can be easily maintained by unskilled staff.
	Automation of site operations (for example, antenna tilt adjustment (SON)).
	Predictive maintenance, using machine learning to anticipate problems and so reduce routine inspections.
Energy efficiency	Co-ordination between RAN and energy supply equipment.
	Smart lithium batteries.
	Base station automatic wake-up/sleep.
	Automatic microcell on/off.
	Cloud-based dynamic resource allocation.
	Other power saving mechanisms such as on-demand cooling.
	Smart grid techniques for BTS power, evolving towards AI-enabled intelligent energy. This allows energy levels to be raised and lowered dynamically on a per-BTS basis, using AI prediction.
	Increased use of solar power, which will be cheaper than thermal power from 2019 in many countries worldwide.

Source: Analysys Mason

MNOs should assess the options described above before they start to deploy 5G at scale. They should also adopt strategies that take a holistic, user-centric view of the network, rather than solutions that only address one aspect of siting in isolation. An effective 5G siting strategy includes key elements such as new base station and antenna form factors, streamlined site approval processes, smart power systems, and AI-enabled cloud management platforms. If they are planned in an integrated way, the effects will be greatly magnified.

Please note: where survey results are cited in this white paper, this refers to a survey of 52 mobile operators in Western Europe and developed Asia–Pacific, which was conducted by Analysys Mason in 1Q 2019.

2. Introduction: siting changes from 2G to 4G

The changes that have taken place with each successive mobile generation, from 2G to 4G, are usually assessed in terms of user experience. Higher data rates, a wider variety of applications, the introduction of new devices from wearables to connected cars are all examples of how the use of cellular connectivity has expanded.

Just as important for MNOs are the changes to how the network itself must be planned, deployed and managed in order to respond to changes in usage.

In the 4G era, the main driver of new network architectures was the explosion in the volume of data traffic, including video. This was accompanied by other trends that affected network design and operations, including:

- the extension of mobile coverage as cellular connectivity became central to many activities, and in some emerging markets, the primary high-speed internet connection
- ever-increasing data rates, including gigabit LTE
- rising customer expectations of quality of service, which related to consistency of experiences, not just peak data rates
- adoption of higher spectrum bands to meet increasing capacity needs (for example, 2.6GHz for LTE).

These changes made it impossible to continue rolling out networks in the same way that 2G and 3G networks were deployed. The main emphasis for 2G deployments was on broad coverage for services based on voice and messaging, and these networks were deployed in low-frequency spectrum. As a result, very large macro cell sites were required.

With each successive generation, more emphasis was placed on capacity as well as coverage to support rising data usage. This means that smaller cell sites were required for increased density, and this trend was also driven by the use of higher spectrum bands, which offer higher capacity but smaller cell site radius.

This has led to several changes in the architecture of cellular networks (even before the 5G era), making a profound impact on sites. These changes include:

- smaller average cell sizes, with increasing use of mid-band spectrum
- diverse base station types, from integrated macro base stations to microcells deployed on poles or street furniture, or embedded within poles
- changes in antenna design to support higher data volumes, broader coverage and better performance at the cell edge. Active antennas (with integrated radios), wideband antennas to support many spectrum bands, and increasing degrees of MIMO arrays have been deployed in recent years
- increasingly intelligent power management systems to maintain or reduce overall power consumption of a dense network.

All these trends will be intensified by the introduction of 5G, as this report will set out. One of the most-important developments has been the evolution of the outdoor micro cell. Early micro cells had considerably lower power and performance than macro base stations and were only used to fill small gaps in connectivity. However, the new generation of outdoor micro cells are ‘mini-macro’ form factors. These have equivalent power and performance to a macro base station on a tower but can be installed on poles and city furniture. This means that they are visually non-intrusive and can be deployed and maintained more simply than macrocells, while also providing seamless coverage and high targeted capacity.

The mini-macro form factor is important, especially when building networks in higher frequency bands, because it can operate at the maximum power allowed in those bands, unlike low-power designs such as picocells. That, in turn, maximises the range of the base station and reduces the number that are required to achieve full coverage of a given area, improving the total cost of ownership of that network.

Although this form factor has emerged for LTE densification, it will also play a central role in 5G deployments.

Figure 2.1: Changing data requirements and site characteristics of cellular networks from 2G to 4G

	Applications	Data rates	Average cell size	Site types	Site equipment	Typical spectrum
2G	Voice and M2M	<500kbit/s	Up to 8km	Towers	Integrated BTS	Sub-GHz, 1.8GHz
3G	Voice, some data	500bit/s-5bit/s	Up to 2km	Towers and poles	First remote radio units	2.1GHz
4G	IP, data-centric, multimedia	1–50Mbit/s	Up to 1.4km, first mini-macro cells of <500m	Towers, poles, roofs	First active antennas, 2×2 MIMO	Sub-GHz, 1.8GHz, 2.5/2.6GHz

Source: Analysys Mason

MNOs face new challenges in planning and managing their sites because of the need for more cell deployments and a greater diversity of equipment to support 5G. These challenges primarily relate to:

- total cost of ownership (TCO) as site numbers increase
- operations and maintenance (O&M) for large numbers of base stations
- challenges with power consumption in dense networks with large antenna arrays.

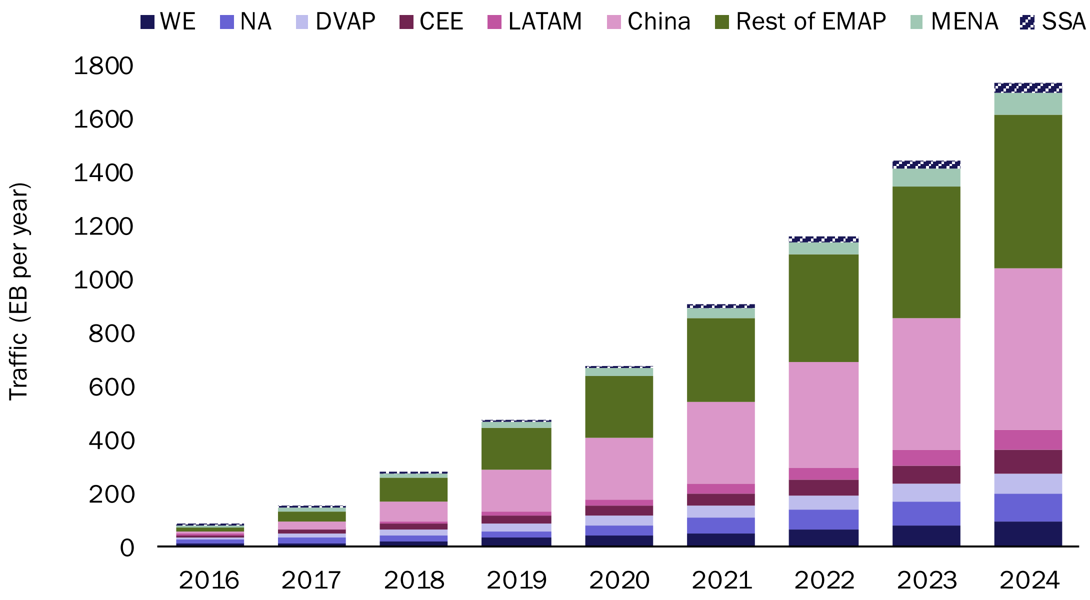
This white paper will examine these three key challenges facing MNOs, in the context of the adoption of even more dense and diverse networks to support 5G. It focuses primarily on two of the regions worldwide that are leading the deployment of 5G and of new network architectures, Western Europe and developed Asia–Pacific.

3. Why is 5G different?

In the 5G era, the trends outlined above will intensify, and there will be additional new demands on the network, which will drive new architectures, and new deployment and management challenges.

In terms of network usage, data traffic is forecast to rise to almost 1800EB per year by 2024, with 5G accounting for up to 60% of this data traffic by the end of the period. A 5G device will typically consume three to four times more data than a 4G one, and in some areas of heavy usage, such as a city centre, business park or transport hub, data traffic may increase by 100 times that for 4G devices.

Figure 3.1: Cellular data traffic, by region, 2016–2024



Source: Analysys Mason, 2019

There will also be significant coverage requirements for 5G. MNOs have often retained 2G networks to support ubiquitous coverage, especially for voice and machine-to-machine applications. 3G and 4G have therefore not had the same pressure to reach every corner of a country, including indoor and underground environments, or ultra-rural areas. In the 5G generation, a survey of 52 MNOs conducted by Analysys Mason in 2019 revealed that 75% of MNOs aim to refarm their 2G spectrum by 2025, so it will be essential to achieve the same levels of coverage in 5G when 2G no longer exists as a backup.

The need for increased coverage and capacity will be heightened by the emergence of wireless Internet of Things (IoT) because applications such as smart agriculture and smart grid require coverage everywhere. IoT, coupled with many new mobile enterprise applications including mission-critical ones, will place many demands on the cellular network. These include:

- very low latency to support virtual reality, connected vehicles and some IoT applications
- very high availability and reliability to support mission-critical applications such as public safety
- very high data rates to support rising mobile internet usage and content consumption, as well as increasingly high-quality video and immersive environments for work and leisure
- enhanced security
- a predictable quality of experience, including at the cell edge and indoors (rather than focusing only on high, but inconsistent, peak data rates).

3.1 The 5G network architecture will change to support a wide variety of use cases

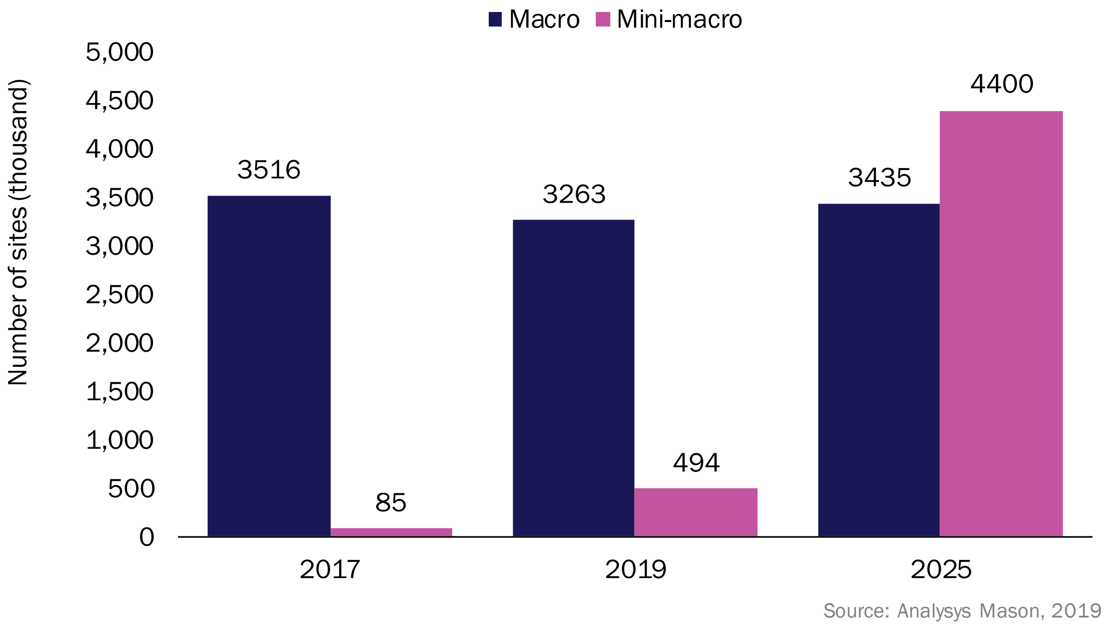
5G networks will have to handle many different types of traffic and a vast array of use cases. To do this, 5G networks will need dense capacity in usage hotspots, plus coverage in remote areas, as well as the ability to harness network resources flexibly as traffic patterns change through the day or according to the use case. The need for flexibility and an agile network will drive investment in new architectures, which will have an impact on cell site design and management.

These demands will mean that MNOs need to make significant changes to their sites. MNOs in WE and DVAP started to implement these changes – on a limited scale – in the 4G era from about 2016, and this process will gather pace from 2019 onwards.

Below we outline the main ways that sites will need to change to support the extreme levels of data traffic, as well use case diversity and quality of experience.

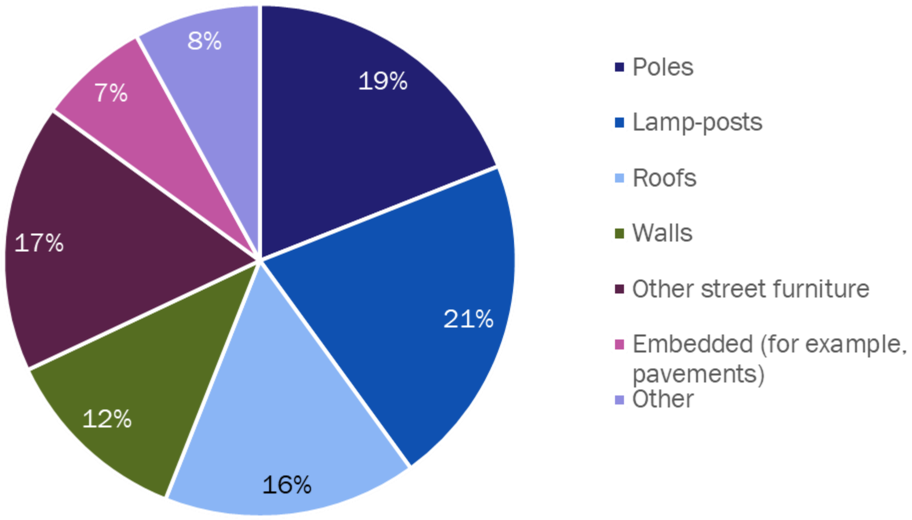
- **Densification.** This began in the 4G era but will gather pace to support 5G, both indoors and outdoors. Figure 3.2 shows the dramatic rise that is forecast in the installed base of cellular sites between 2017 and 2025 in WE and DVAP. The number of macro sites will remain fairly stable, although most of these sites will be upgraded to support 4G expansion and 5G during this period. However, there will be a 1400% growth in the number of smaller cell sites, consisting of mini-macro sites that are typically mounted on poles, roofs and street furniture. These will provide a dense capacity layer, filling coverage hotspots and supporting full coverage to supplement the macro layer.

Figure 3.2: Installed base of macro cells and mini-macro cells, Western Europe and developed Asia–Pacific. 2017–2025



- **Diversification of sites.** New site types will be essential to the process of densification. Figure 3.3 shows the expected breakdown of the siting of outdoor mini-macro cells (which are mounted on street furniture but have equivalent performance to macrocells) by 2023, based on Analysys Mason's survey of 52 MNOs in WE and DVAP.

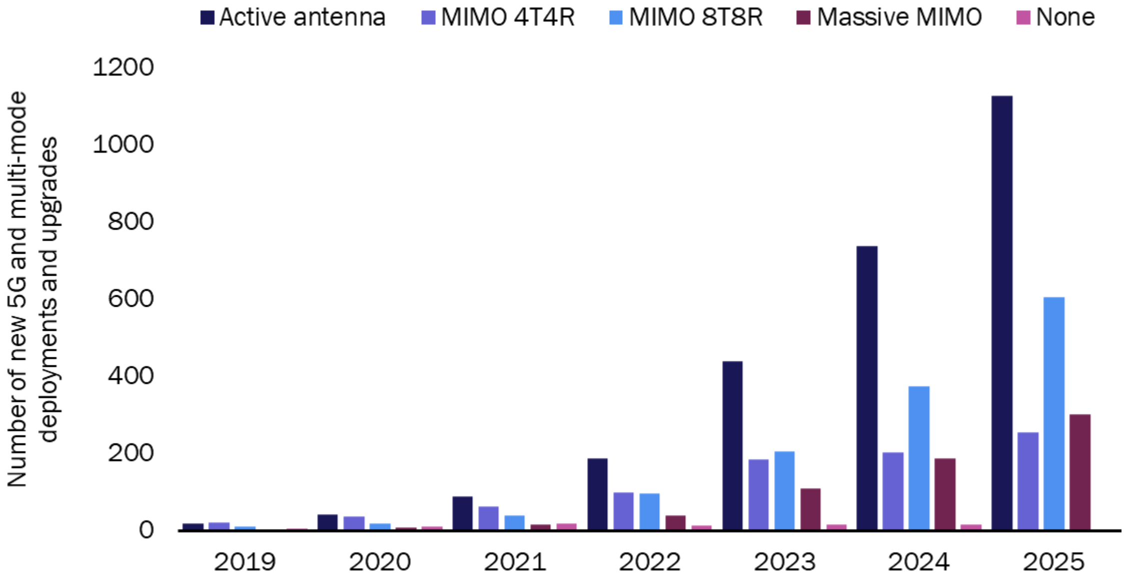
Figure 3.3: Outdoor mini-macro cell installed base, by type of site, 2023 (percentage of cells)



Source: Analysys Mason, 2019

- **The introduction of new antenna form factors will affect the cell site.** For instance, Massive MIMO technology for active antennas, combined with wideband passive antennas, could increase the amount of equipment on a tower, as well as its weight and power consumption.

Figure 3.4: Deployment of 5G and multi-mode sites by type of antenna technology, worldwide, 2019–2025



Source: Analysys Mason

- A larger number of spectrum bands than for 4G will be supported to enable 5G, plus continuing expansion of 4G and support for legacy 2G/3G provided, in most cases, until 2030 or later. This will increase the number and type of antennas on a site, especially when millimeter-wave bands come into play with their requirements for complex beamforming. These will often require fibre-to-the-antenna connectivity and may increase power consumption.

- More diverse and complex 5G use cases will require a new approach to site powering and back-up, for two key reasons. One, the large number of cells and antennas will require advanced power management techniques to ensure that overall power consumption can be maintained or reduced. And two, many 5G use cases, such as critical infrastructure monitoring or public safety, will require very high levels of reliability and zero downtime. That will require the ability to back-up base stations in case of power fluctuations or outages, on a real time basis. While macro sites will often have permanent back-up systems installed, back-up of mini-macro sites can be done dynamically with a cloud-based control system.

Figure 3.5: Data requirements and site characteristics in 5G networks

	Applications	Data rates	Average cell size	Site types	Site equipment	Typical spectrum
5G	Advanced video, VR/AR, low-latency IoT	100Mbit/s–5Gbit/s	<1km + many mini-macro cells (100–250m)	Towers, poles, city furniture, embedded microcells	Massive MIMO	Sub-GHz, 3.4–4.2GHz, mmWave

Source: Analysys Mason

4. Changes in 5G siting will create new TCO challenges

As outlined in Chapter 3, the introduction of 5G will accelerate changes to cell sites, which first started to be implemented for 4G. These changes will have a deep impact on the economics of MNOs' 4G/5G roll-outs.

Operators need to find ways to reduce the capex and opex costs of their new generation networks, but this is challenging because they are working in countries where data usage is rising rapidly but ARPU is stagnant. It is imperative, then, that they reduce the cost of delivering all that data in order to remain profitable, but this task is more challenging because far more sites need to be deployed with more complex antennas and radios.

- Zhengmao Li, Executive Vice President of China Mobile, has highlighted the following differences between 5G and LTE, in terms of siting and power consumption. 5G needs three times the number of base stations for the same level of coverage offered by LTE because of higher spectrum bands
- a 5G site will consume three times more power than an LTE site
- a 5G base station will cost four times more than an LTE one.

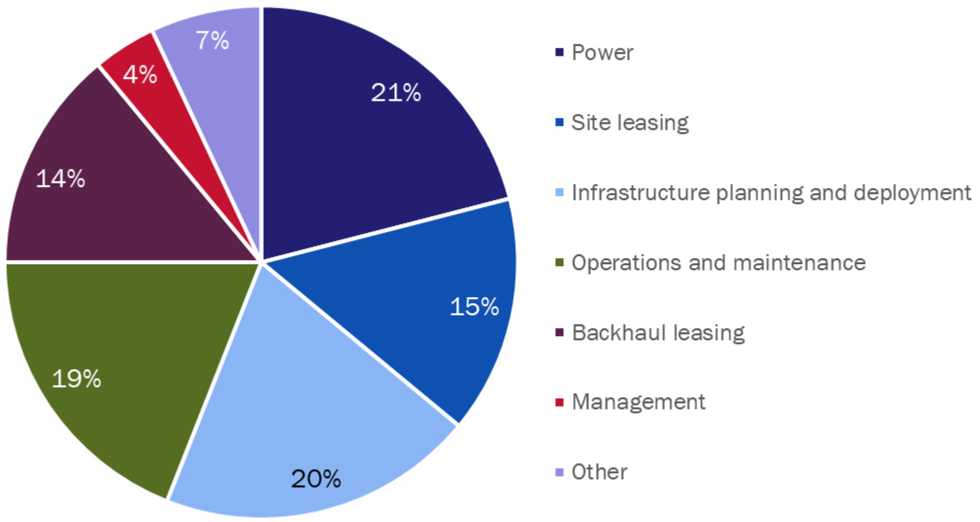
On the active equipment side, networks have become increasingly cost-effective because of a competitive vendor market and the transition to heavily software-driven architectures. However, active equipment accounts for only 10–15% of the TCO of a 5G macro site, and even less for a smaller cell site in which the base station can be highly commoditised.

In a mobile network in a developed market, capex costs are typically only around 30% of TCO, with opex accounting for the rest. For the 5G generation, the percentage spent on opex is likely to increase as more MNOs opt to reduce capex by sharing networks or by using hosted services. In taking both capex and opex into account, the most-substantial costs are associated with the following:

- site infrastructure (for example, rental, maintenance and civil works)
- energy consumption and power systems
- operations and maintenance (O&M)
- leased lines/transmission.

Figure 4.1 shows a typical estimated breakdown of opex for a 4G/5G network in 2020, based on a composite picture assembled from Analysys Mason's interviews with 22 MNOs in WE and DVAP.

Figure 4.1: Typical breakdown of operating expenditure, by category, for a 4G/5G network (excluding core and IT), Western Europe and developed Asia–Pacific, 2020



Source: Analysys Mason, 2019

If 5G site planning, deployment and management are administered in the same that they were for 4G, the operating costs would be increase significantly because of the larger number of sites and the increased capacity per site, indeed, increasing to an extent that would far outweigh capex savings, or the TCO reduction achieved through virtualisation.

Analysys Mason's modelling suggests that if no changes in approach are made, then the most-costly site requirements would increase by the following amounts, between 2017 and 2023, in a developed mobile market.

- Site infrastructure — 5 times higher in 2023 than 2017
- Energy consumption and power systems — 9 times higher in 2023 than 2017
- Operations and maintenance (O&M) — 4 times higher in 2023 than 2017
- Leased lines/transmission — 6 times higher in 2023 than 2017

These costs come at a time when MNOs in WE and DVAP are aiming to make aggressive reductions, and not just in per-site operating costs, but also absolute network opex. On average, MNOs in these markets want to reduce TCO by one-third by 2025 (see Figure 5.2).

A radical new approach will be needed if these key costs are to be reduced over the next 5 years, rather than increasing sharply. The following sections will examine these challenges in detail, and offer potential solutions in three critical areas of site TCO – site planning and deployment, power consumption, and O&M.

5. 5G density presents new challenges for site infrastructure and O&M

As discussed above, 4G expansion and the introduction of 5G will involve far more infrastructure because the number of sites required to deliver the necessary levels of capacity and coverage will increase. These numbers will increase further due to meet the rising demand for dense networks that are optimised for certain vertical industries, or to support smart city programmes.

MNOs will face some of the following challenges when planning and deploying a next-generation network

- New traditional macro sites are increasingly hard to find. Operators or neutral hosts must utilise a widening diversity of site types. New site types include lamp posts, billboards, bus stops and even access points embedded in pavements.
- These new sites, in turn, require a variety of new equipment form factors to remain unobtrusive, especially on city furniture.
- They also involve a large number of different site owners and other stakeholders, so agreements must be made with local governments, utilities, transport authorities, private landlords and many others.

A new approach must be taken to support densification, given the growing number of sites and stakeholder engagements. From an operations perspective, far more sites need to be run and maintained, which could greatly increase opex costs, as well as the risk of outages or degraded service quality if manual processes are maintained. If each site is treated individually in terms of rental, installation, maintenance and operations, the TCO will be very high and networks will not be scalable.

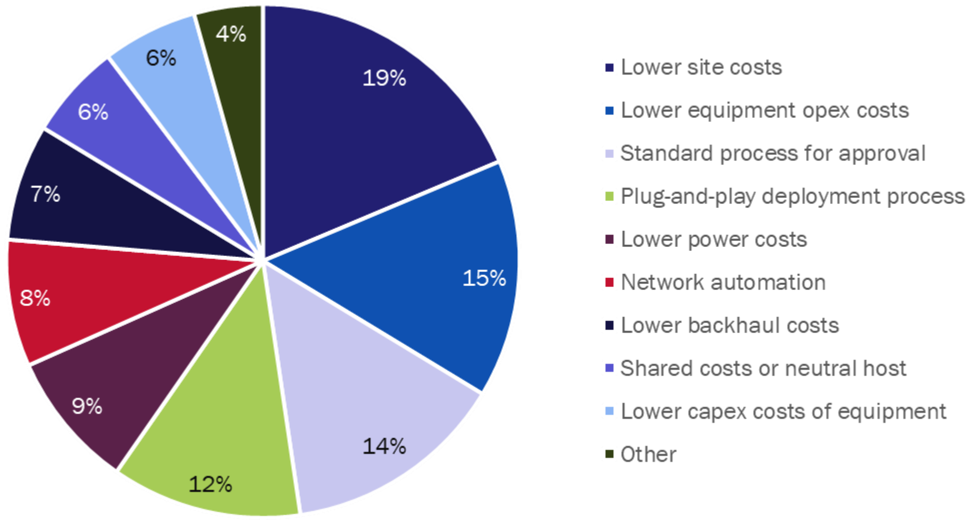
Figure 5.1 shows the main densification challenges that MNOs identified in Analysys Mason's survey of 52 operators in WE and DVAP. Operators stated that if these challenges were not addressed within 2–3 years, their current densification programmes would be delayed by up to 3 years.

The main requirements for cost-effective densification are:

- reduced site costs (rental and other contractual costs)
- lower cost of operating and maintaining equipment
- a streamlined, consistent approach to securing approvals for site deployments, especially on sites owned by local authorities or private landlords
- lower cost and shorter timescale for installing new equipment, with a simplified installation process and progress towards a plug-and-play system
- lower cost of energy
- higher degree of automation of management and optimisation of the networks
- lower backhaul and fronthaul costs, especially leased lit or dark fibre
- greater opportunity to share costs with enterprises, cities, other operators or neutral hosts.

Lower capex costs for the active equipment was one of the least-cited barriers to deployment, and only 18% of the operators surveyed reported this as was one of the top-three issues for their 5G plans.

Figure 5.1: Primary barriers to 5G densification (percentage of MNOs selecting each factor)



Source: Analysys Mason, 2019

5.1 Case study 1

This case study, based on an aggregation of three real examples, demonstrates the TCO risk if the barriers outlined above are not lowered.

An MNO in WE has 35 000 macro sites, with an average per-site annual TCO of USD26 000, totaling USD910 million a year.

By 2023, it plans to:

- upgrade 60% of cell sites to 5G and 8x8 MIMO
- introduce 20 000 mmWave sites with Massive MIMO
- deploy 180 000 microcells in urban areas.

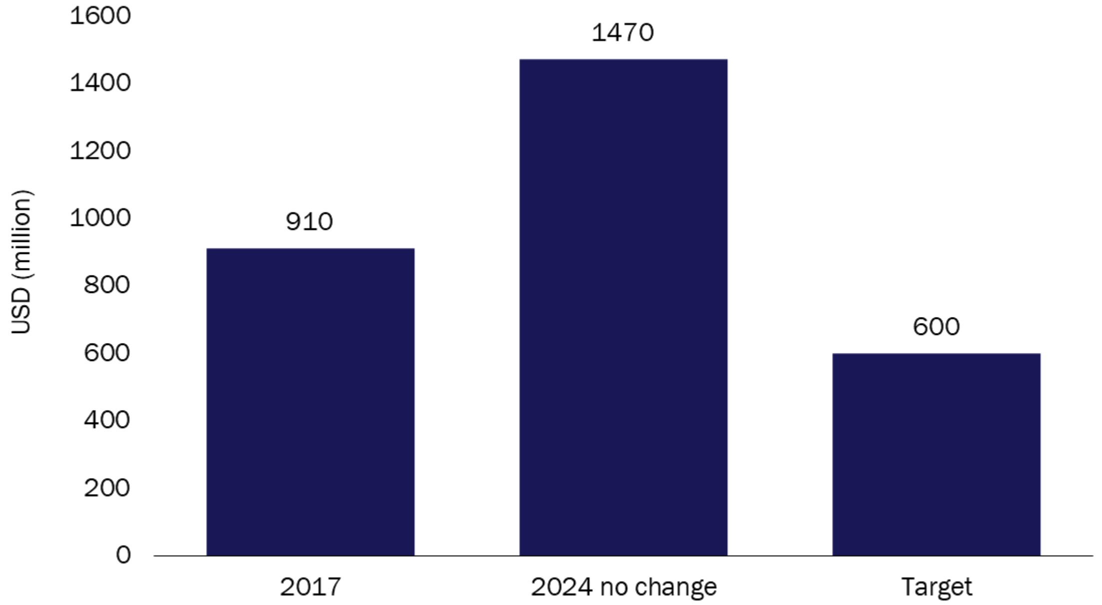
The result will be a 4G/5G network of:

- 21 000 5G macro sites (average per-site TCO down a little to USD24 000)
- 20 000 mmWave sites (per-site TCO USD25 000, the biggest increase being Massive MIMO impact on sites and power)
- 180 000 microcells (per-site TCO of USD2600).

The opex costs are split between site and transmission costs (43%), O&M (39%) and power costs (18%).

If the same approaches to siting, power and O&M are adopted for 5G as for previous network generations, the TCO for MNO's network sites will rise to USD1.47 billion by 2024, an increase of 62%, when the operator was targeting a reduction in 5G site TCO of at least 30%. In other words, as seen in Figure 5.2, the TCO of the operator's 5G network will be almost 2.5 times higher than the target in the business case (for sites and site equipment, excluding other costs such as core, IT and staff).

Figure 5.2: Projected TCO by 2024 if no changes to siting strategy are made, compared with the operator's target TCO



Source: Analysys Mason, 2019

6. Siting changes also have a profound impact on power consumption

Energy consumption in 5G is a huge issue. Operators need to deliver a massive increase in data capacity and quality, based on far larger numbers of sites, while keeping energy consumption and costs stable – or pushing them lower. As more 5G applications require absolute reliability, many sites will have requirements for far higher power availability (PAV), but site energy efficiency (SEE) targets will also be more stringent to meet cost and environmental requirements. According to a study by the ITU, almost half (49%) of macro sites in Europe and Southeast Asia have insufficient AC mains capacity to support 5G and Massive MIMO.[2]

These are challenges that cannot be achieved without a radical new approach to power.

When 5G standards were first being devised, operators around the world cited the energy efficiency of the 3GPP specifications as a key business driver to deploy the new networks. After all, energy accounts for about 15% of opex in developed markets (this percentage is far higher in emerging economies where there is less-reliable grid power).

However, this did not factor in the significant rise in density, or in the number of antennas. Each element in the 5G network may be more power-efficient, but the large number of moving parts will increase overall energy consumption if new approaches are not introduced. In addition, although the power consumption of a unit of traffic (Watt per bit) is greatly decreased with 5G, the growth in traffic will drive overall power consumption up.

The base station consumes the most energy in a mobile network, accounting for 80% of power used, so challenges and solutions are mainly seen at the cell site.

Challenges in energy efficiency, which are the result of the new density and capacity of 5G, include the following.

- High-order MIMO. The maximum power consumption of a 64T64R massive MIMO antenna array is between 1000 Watts and 1400 Watts, while that of a shared baseband unit is about 2000W. As more spectrum bands are added, the higher the power consumption will be. For example, in a site with five bands supported, total power can be as high as 10kW, while in a 10-band site, the figure will be closer to 20kW. This compares to an average of 6kW for a 4G cell site with a three-sector, 12-radio configuration.

- Networks are relatively inefficient in how they handle data, which has consequences for power efficiency. Many base stations are idle at certain times of day, yet they still consume power, even when only 10% utilised. This problem is worse in microcell networks that rely on a large number of base stations and have highly variable traffic patterns.

- Less than 20% of the energy consumed by a base station is being used for revenue-generating purposes (for example, for forwarding data and signals). Other costs are high but harder to justify in ROI terms, including cooling systems, which account for about half of the total cost of a base station.

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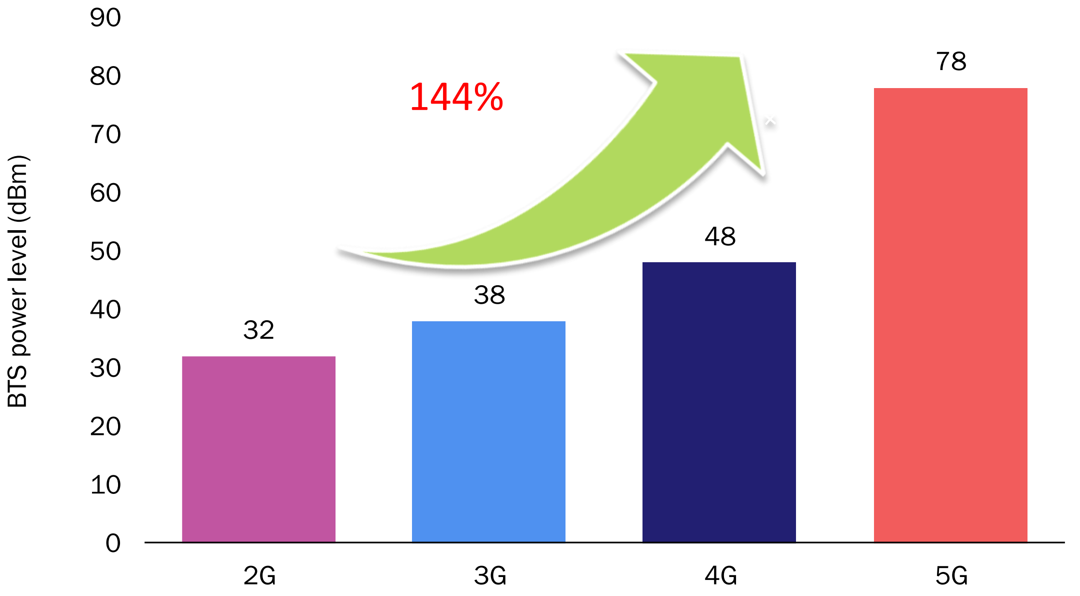
[2] ITU-T Study Group 5 (2018), *5G for smart sustainable cities*. Available at: https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2018/5G%20Greece/Session%207%20PaoloGemma-Greecerev2%20(003).pdf.

- Additional elements may be added to the network to support advanced 5G use cases, including edge micro-data centres.

- The improvements in energy efficiency of the RAN and of the power equipment are reaching their limits in early 5G. To continue to drive new enhancements, there will need to be better coordination between the two ecosystems, yet this has been limited so far.

Figure 6.1: Estimated increase in power consumption from 2G to 5G, worldwide average, if power management approaches remain the same as in 4G[3]



Source: IEEE

6.1 Case study 2

An MNO in developed APAC has 42 000 macro sites. On average, each consumes 6.5kW of power. The cost of power is USD4600 per site per year, or USD168 million in total.

It plans to deploy 5G by 2023 in the following ways.

- 28 000 macro sites with five spectrum bands and 8T8R MIMO
- 11 000 sites with 8–10 bands and Massive MIMO (64T64R)
- 90 000 microcells.

The result will be a 4G/5G network constituting:

- 28 000 sites with average power consumption of 11kW
- 11 000 sites with average power consumption of 20kW
- 90 000 microcell sites with average power consumption of 500W.

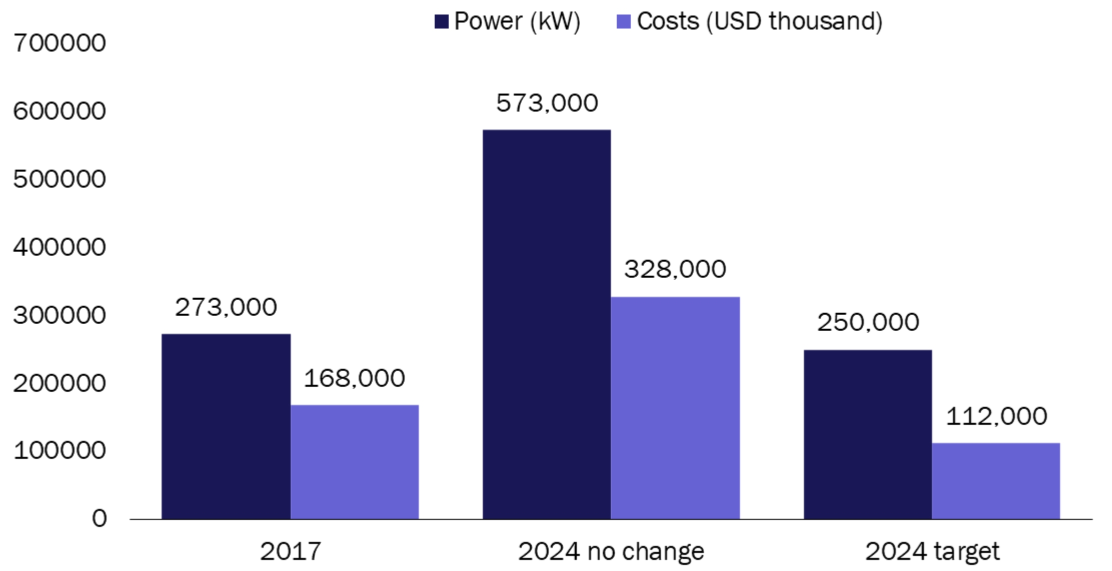
Total consumption is 573 000kW – or an increase of 110% on the 4G network – with a subsequent impact on energy costs, as well as weakening the operator ability to meet its targets for opex reduction and green progress.

[3] Source: IEEE, 'https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7448820

Even though unit costs for energy will be lower because of use of renewables will be higher, the total costs will still increase by an estimated 95%.

Figure 6.2 illustrates the gulf between this operator's targets for green efficiencies and reduced costs for power, and the reality if no changes are made to the way the network is deployed and run.

Figure 6.2: Power consumption and costs in 2024 if no change is made to power systems, compared with operators' target reductions



Source: Analysys Mason, 2019

7. Solutions – new approaches to siting and power can transform energy efficiency and TCO

5G networks present significant challenges to operators when it comes to cost, efficiency and power consumption. MNOs will have to adopt new approaches to planning, deploying and managing their new networks if they are to avoid an escalation of costs and severe damage to the 5G business case. However, new solutions are emerging as operators in Europe and DVAP start to turn on commercial 5G networks. No single solution will address all the issues of 5G siting, but if operators adopt a combination of new approaches that focus on different aspects of network deployment and operations, then they will be able to achieve their targets for TCO reduction, capacity and coverage enhancement, and power efficiency. Figure 7.1 summarises the key solutions in each of the three critical areas of 5G site economics – deployment, O&M and power.

Figure 7.1: Summary of 5G siting challenges and solutions

Challenge	Solution
Deployment and installation	Simplified and modular site structures that do not require skilled labour to install.
	High levels of integration to reduce space and power (for example, for active and passive antenna units).
	Standardised equipment modules that can be uniformly deployed and approved.
	Streamlined and uniform approval processes for sites and equipment.
	Equipment that can use a diversity of site options to maximise coverage while remaining unobtrusive. These include the embedding of access points within poles or pavements.
	Single RAN – moving services to 4G+5G in order to switch off inefficient legacy RATs, as well as to simplify the network and free up site space.
Operations and maintenance	Simplified site structures that can be easily maintained by unskilled staff.
	Automation of site operations (for example, antenna tilt adjustment (SON)).
	Predictive maintenance, using machine learning to anticipate problems and so reduce routine inspections.
Energy efficiency	Co-ordination between RAN and energy supply equipment.
	Smart lithium batteries.
	Base station automatic wake-up/sleep.
	Tightly integrated sites (one site one cabinet).
	More-efficient site utilisation through Centralized-RAN.
	Other power saving mechanisms such as on-demand cooling.
	Smart grid techniques for BTS power, evolving towards AI-enabled intelligent energy. This allows energy levels to be raised and lowered dynamically on a per-BTS basis, using AI prediction.
	Increased use of solar power, which will be cheaper than thermal power from 2019 in many countries worldwide.

Source: Analysys Mason

More details about each of these solutions can be found below.

7.1 Deployment and installation

Highly simplified site structures that can be scaled up Lego-style can make it possible to deploy new base stations quickly and without costly specialist labour. This is especially important in city environments where there will be a large number of sites to deploy, as well as ensuring that disruption to city life is minimised and equipment remains unobtrusive. Compact solutions are emerging and are sufficiently small and light to be mounted on street furniture. Some solutions also enable the base station to be completely hidden within a pole, street furniture or under a pavement.

A 5G site will typically require two poles: one for active antennas and millimetre wave, and one for passive antennas and radio heads. However, the Massive MIMO and multi-band devices add considerably to the weight – some M-MIMO products weigh 40kg, while some poles have a limit of 47kg, and installing heavy equipment requires expensive cranes. More-compact antenna arrays are also being introduced, and these can be installed using pulleys. In addition, in many cell sites, only one pole can be deployed per sector, so it is important to be able to integrate active and passive antennas in a single package in order to introduce Massive MIMO even where pole space is limited.

It is important to replace legacy networks that have these simplified structures as quickly as possible. An operator may turn off 2G/3G altogether and adopt a 4G/5G approach. This can greatly reduce power levels and O&M complexity by using only modern, efficient technologies, as well as adding to 5G spectrum and freeing up site space for new antennas and other units. If this is not practical, operators can still replace legacy equipment with an all-in-one base station that supports any combination of 2G, 3G, 4G and 5G and allows baseband and radio frequency resources to be shared flexibly between them to maximise resource efficiency. Highly integrated multi-RAT, multi-band solutions reduce power consumption and simplify O&M.

The impact of simplified site solutions will be greatly enhanced (especially in city or industrial environments) by greater co-operation between operators and other stakeholders such as municipalities, property owners and utilities.

The role of the city's administration in 5G densification will be critical. There are several ways in which local authorities will influence how quickly and efficiently 5G will be deployed in urban environments.

- A city can introduce a simplified system of approvals and regulations for equipment mounted on street furniture, sometimes in return for access to the network to support smart-city services. Deployments in the City of London, Amsterdam and Paris are good examples of the move towards a system where standardised modules can be automatically approved because they conform to set limits on features such as height, size and power output.

- A city can further accelerate densification by opening up their own street sites and by mandating standard specifications for smart poles and other urban furniture (common heat dissipation and waterproofing will make it easier to deploy all equipment in the same way). For example, Barcelona has an advanced programme of standardised pole infrastructure. Cities could work together to define and support an industry standard for smart poles which would include multiple functions such as 24-hour AC power and fibre to each pole.

A city can also introduce regulations that encourage other stakeholders to open up access to their sites at a reasonable cost. These might include highways agencies, utilities, railway operators and private commercial property owners. The result of such policies will be to make far more sites available for mini–macro cells, which can be deployed quickly and cheaply by using standard modules that are automatically qualified to work with the different site types.

7.2 Operations and maintenance

Simplified site structures are also important in lowering the cost of maintenance. They are less complex, and therefore less vulnerable to failure, and faults can be addressed without specialised skills. However, in order for the operation dense 5G networks to be effective, a high level of automation will be required to achieve acceptable TCO. Some MNOs already have roadmaps towards 'zero-touch' micro cell networks in which at least 90% of processes can be handled remotely, to avoid site visits, and at least 80% can be fully automated.

Automation involves many kinds of tools and processes, and, according to Analysys Mason's MNO survey, the most important of these in terms of the impact on 5G network TCO are as follows.

- SON (self-organising networks) to minimise interference through applications such as automatic neighbour relations, and to maximise coverage, capacity and resource efficiency by automating antenna tilt and other network features.
- Predictive maintenance, which uses machine learning (ML) to understand network behaviour, traffic patterns and other metrics, in order to know in advance when a fault is likely to occur and deal with it before an outage takes place.
- In the future, full AI-based network optimisation and O&M.

Such techniques help to shift the focus from a network-centric view of how the RAN is performing, to a user-centric one that understands the subscriber experience.

7.3 Power efficiency

The cost of renewable energy, especially solar, is falling and is expected to fall below that of conventional energy in Europe from 2019. That will help operators to achieve cost reduction and green targets, but they will need to adopt other solutions too, to improve power efficiency enough to make it cost-effective for 5G.

Many of the emerging solutions use network resources far more intelligently than previous generations of solutions. Some of the techniques apply to the RAN. For instance, macro base stations and microcells can be switched off when they are idle, in a dynamic way and, with the use of AI/ML, predictively.

Other solutions are implemented within the power supply system. For instance, base station cooling – which accounts for about half of the BTS's energy needs - can be applied only when required by a cloud-based smart grid system. Other applications include voltage boosting.

One of the most-important solutions for reducing the cost and power consumption of a 5G site is the close integration of a smart lithium battery with the main power supply. This addresses the issue of the increased power requirements of 5G and massive MIMO without the operator having to upgrade the mains power capacity to support peak requirements at every site. Instead, the smart power system can supplement mains power with the smart battery's energy only when required, while for applications, or certain times of day that require less energy, the battery will automatically power down. Implementing smart lithium batteries could avoid the capex and opex cost of upgrading mains power in 90% of 5G sites, while also making back-up more effective in sites with unreliable grid connections.

Just one solution will be insufficient on its own. 5G will require end-to-end, full-link energy design encompassing power supply, conversion, backup, power distribution, cooling and load.

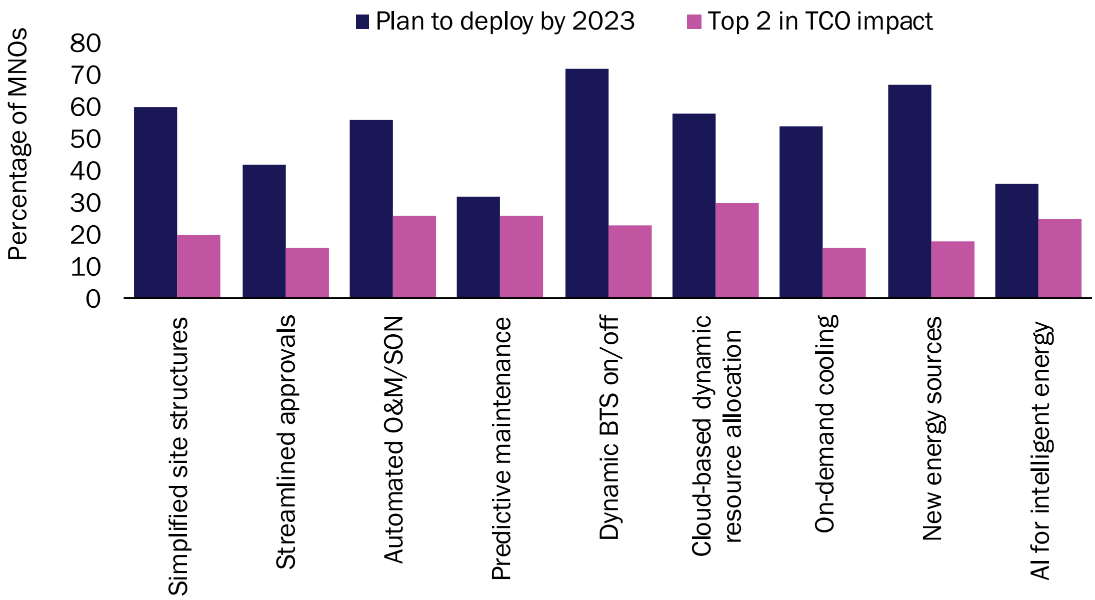
Truly intelligent power systems will require an even-more holistic view that harnesses similar cloud and AI techniques, but goes beyond the RAN. A cloud-based system can co-ordinate base stations, power supplies and other site equipment across multiple layers and domains, so that power supplies become intelligent and efficiencies are made throughout the network (the 'bit manages Watt' concept). That will evolve, in time, towards full AI-based intelligent energy, in which different levels of power are automatically made available depending on time of day or application. In this scenario, power availability (PAV) levels are identified for different applications, according to their criticality. Those with the highest levels of criticality, such as telemedicine, can be assigned the highest level of battery availability (the smart battery will have a higher threshold before it powers down).

In Analysys Mason's survey of 52 MNOs in WE and DVAP, operators were asked to name the tactics that they expected to be able to leverage before 2022, and the two that they would expect to have most impact on their 5G network TCO over the lifetime of the deployment (see Figure 7.2).

Most of the tactics that MNOs expect to adopt in the short term relate to energy efficiency, and in particular, to more dynamic ways of turning base stations off and on according to requirements, as well as the transition to new energy sources (for example, solar) as these become more cost-effective.

However, in terms of the anticipated impact on the 5G business case, operators placed greater emphasis on some of the just-emerging approaches to site efficiency, especially those driven by AI or machine learning. Predictive maintenance and AI-enabled smart power usage, and automated operations were all considered to be the most-effective approaches in the medium term, despite these being new solutions and the fact that many MNOs believe they will not be able to adopt them at scale for a few more years.

Figure 7.2: Percentage of MNOs planning to adopt each new siting approach, and percentage of MNOs placing each approach in their top -two for TCO impact



Source: Analysys Mason, 2019

8. Recommendations – operators should plan now to minimise costs and maximise power efficiency in 5G

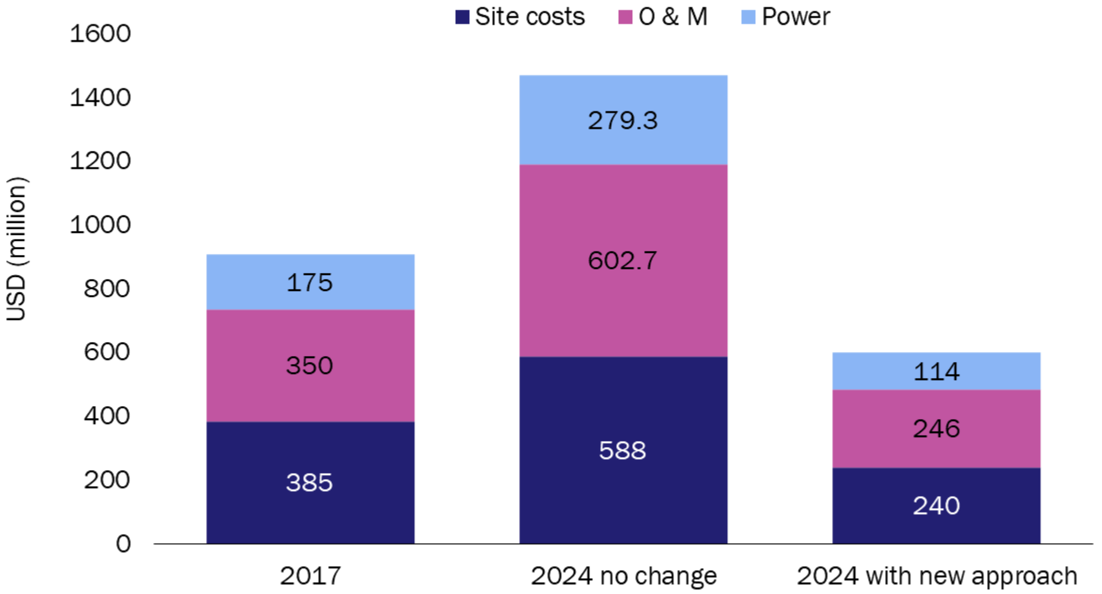
Operators in developed markets will start to deploy 5G networks from 2019 and many have plans for broad coverage and densification as early as 2020. If these deployments are to support very high data rates and an improved quality of experience for many use cases, as well as achieve cost reduction and meet power efficiency targets, operators need to lay the foundations now for a very new approach to siting.

No single solution will deliver the target cited by many MNOs of at least a 30% reduction in TCO between 2017 and 2024. A combination of solutions must be adopted in a coordinated way to address simplified site installation, automated operations and maintenance, and smart energy systems.

MNOs should assess the options described above before they start to deploy 5G at scale. They should also ensure that they adopt strategies that take a holistic, user-centric view of the network, rather than solutions that address just one aspect of siting in isolation. New base station and antenna form factors, streamlined site approval processes, smart power systems, and AI-enabled cloud management platforms are all key elements of an effective 5G siting strategy. If they are planned in an integrated way, the effects will be greatly magnified.

The potential impact is illustrated by the case study outlined in Chapter 5. If an integrated, holistic siting strategy is adopted by this operator, the effect on 5G TCO will be dramatic, as Figure 8.1 shows. Our modelling shows that if the operator adopts a holistic strategy covering site approval and installation processes, automated O&M, and smart energy, its annual TCO will be reduced by more than one-third by 2023, despite having 6000 more macro sites than for 4G, and 180 000 microcells. This figure is even more-impressive when compared with the increase in TCO that would occur if no changes were made to the deployment approach. By adopting new strategies, the operator will achieve TCO that is almost 2.5 times lower than if they were to persist with conventional methods.

Figure 8.1: Impact of a holistic strategy for 5G siting and power, in terms of TCO by 2024, compared with a 'no-change' approach



Source: Analysys Mason, 2019

The introduction of these new approaches does not only affect the TCO of a 5G network deployed over the coming 4–5 years. It will also bring additional tangible and intangible benefits to the operator's business case for 5G. These include improved quality of experience for subscribers (which can reduce churn and drive higher usage), improved green credentials (which can reflect on corporate reputation, as well as satisfying government targets), and enhanced co-operation with other industries and stakeholders, such as cities or transport authorities, to pursue common mobile connectivity goals.

This whitepaper was commissioned by Huawei. Analysys Mason does not endorse any of the vendor's products or services.

9. About the author

Caroline Gabriel (Principal Analyst) Caroline leads Analysys Mason's wireless research. She contributes to our Next-Generation Wireless Networks, Operator Investment Strategies and Spectrum research programmes and works directly with our research clients to advise them on wireless network trends and market developments. She has been engaged in technology analysis, research and consulting for 30 years, and has focused entirely on mobile and wireless since 2002. Her focus is on critical issues and trends related to mobile and wireless infrastructure, particularly operator deployment intentions for 4G, 5G, cloud-RAN and other technologies. She has led research and consulting projects with a wide range of clients, including mobile infrastructure vendors, large and start-up operators, regulators, trade bodies, government agencies and financial institutions. She holds an MA from the University of Oxford.

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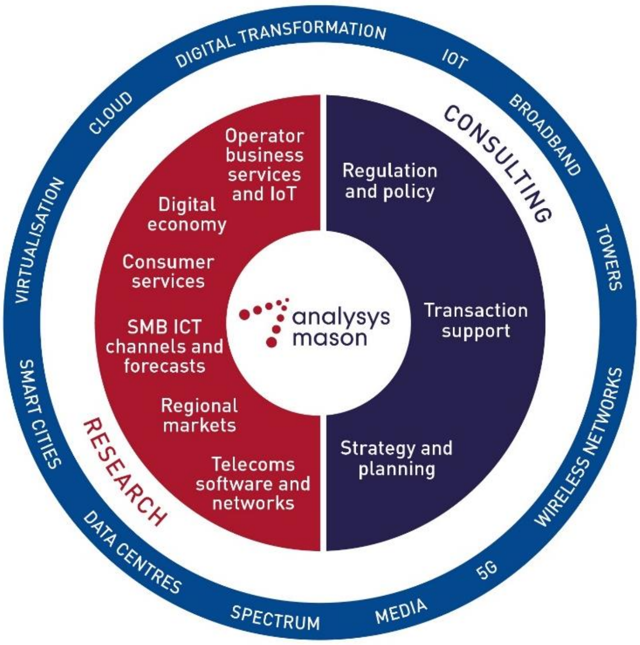

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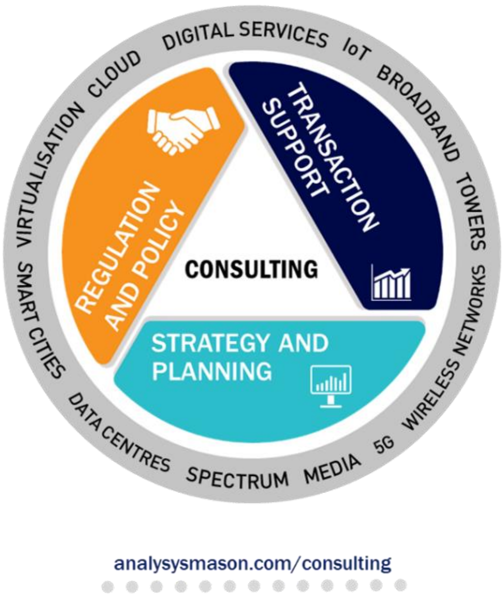

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