Financing 5G and Broadband Infrastructure

Stirling Infrastructure
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REPORT

M&A and Financing

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Stirling Infrastructure Partners provides corporate finance and M&A advisory to listed corporations, institutional investors, and private companies. The firm arranges debt and raises equity capital, and provides M&A advisory services to companies across 5G and broadband infrastructure segments internationally, including all infrastructure in the backhaul, fronthaul, and the last mile (inclusive of data centres, deep sea cabling, street infrastructure, radio access networks, etc). This also includes advisory on strategic investment decisions, origination of strategic national and international joint ventures and co-investments, and acquisition and disposals of telecom infrastructure assets and companies.

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FINANCING 5G AND BROADBAND INFRASTRUCTURE

This paper is our investor's primer on how the globe will switch to 5G, in the context of the wider internet and broadband landscape. This document provides insight into the opportunities and factors that our investment banking team considers necessary for our clients to make effective capital allocations in the global 5G and broadband sector.

EXECUTIVE SUMMARY: THE GLOBAL 5G LANDSCAPE

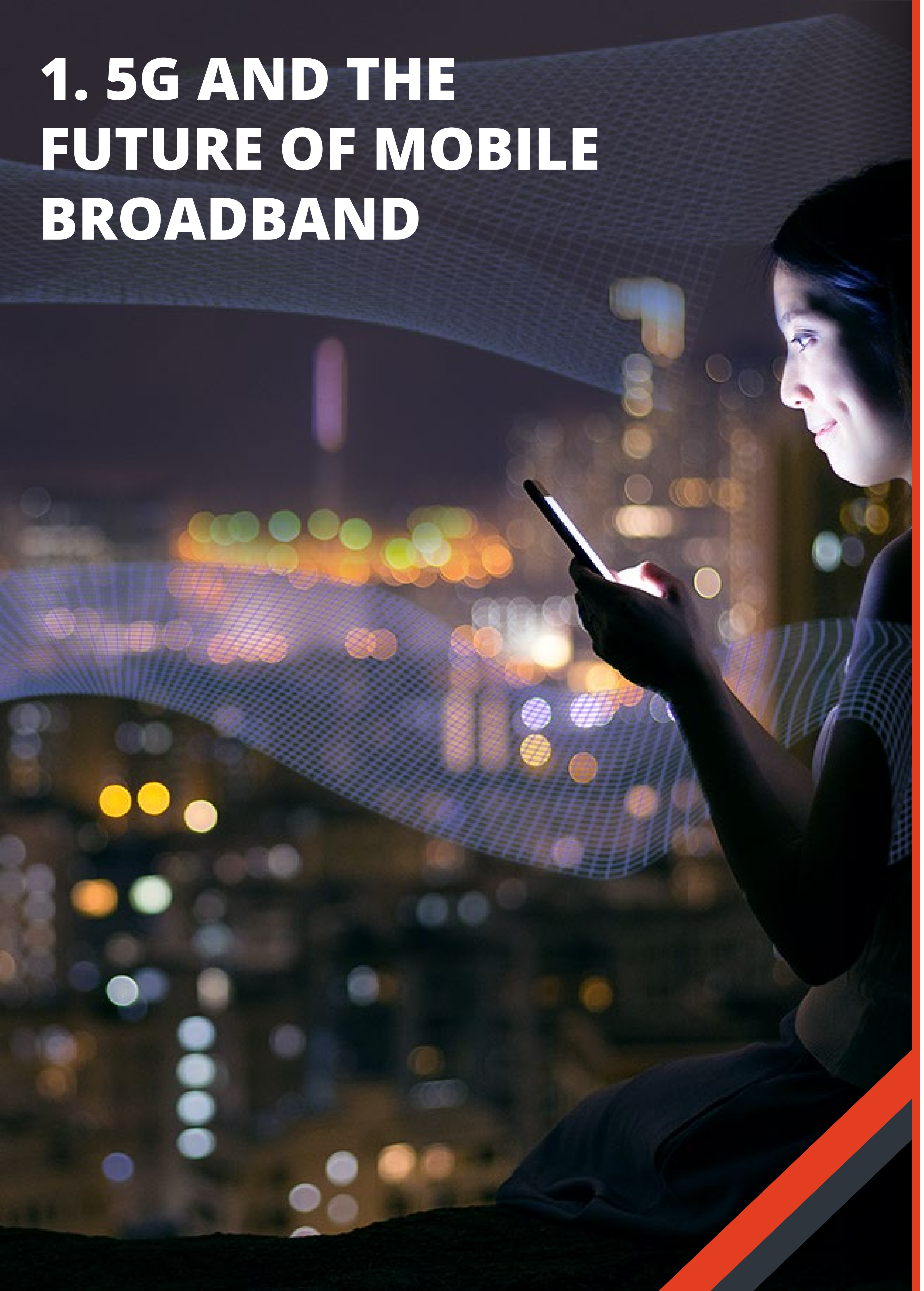
The internet has been around since the 1970s. Since then, from sending simple text messages to downloading HD movies in a few seconds, we now stand to witness the deployment of 5G, a new global wireless technology designed to connect virtually everyone and everything. Independent market research conveys that 5G is expected to enable more than $13 trillion in global economic output in 2035[1], suggesting significant scope for value creation within the 5G networks and technology sectors. However, as countries begin to roll out 5G commercially, Stirling Infrastructure believes that a sober and easy-to-understand assessment of progress based on facts and current data is much needed for our clients to make informed capital allocation decisions. This report highlights our expertise in understanding telecommunications, and particularly the 5G and broadband sectors. We have developed the following insights which we consider crucial considerations for investment decisions in 5G:

1. In addition to improving mobile internet users' experience, 5G is expected to usher in significant socio-economic benefits and realise the promise of innovations such as automatic vehicles, precision surgery robots, and the Internet of Things (IoT). However, barriers across different economic sectors and jurisdictions will determine the uptake of 5G. A select few Asian and European economies followed by the US will reap the most value from 5G, while less developed economies will lag behind.
2. A 5G network employs new technologies including small cells, massive multiple-input and multiple-output (massive MIMO) antennae and high-band spectrum, as well as building on extensive existing infrastructure. Evolution from non-standalone 5G to 5G core technologies will be a costly but necessary investment by Mobile Network Operators (MNOs).
3. Strategy-wise, most MNOs prefer a measured, capacity-backfilling deployment over a costly, full-scale 5G rollout. Infrastructure sharing will play an important role in the initial roll-out stage, while open radio access network (open RAN) solutions that unbundle software and hardware providers have been gaining traction recently as a cost-reducing strategy.
4. Spectrum licensing is highly regulated, and allocation via auctions leads to fierce competition between MNOs. We observe that the nature of the allocation process, the type of auction, and the associated costs, discounts, and incentives can significantly affect the long-term profitability of investments in 5G.
5. Public and private sectors both affect spectrum prices, which may significantly affect the speed of 5G deployment. In developed countries, high spectrum costs significantly slowed down the rollout of both 3G and 4G networks, negatively impacted consumer uptake, and drove long-term reductions in overall network quality. Stirling Infrastructure expects countries with high spectrum prices to suffer a similar impact for their 5G expansion.
6. Regulatory and socio-political risks vary by country, but effect on the success of 5G expansion is not always straightforward. Regulatory risks can be mitigated by engaging competent legal advice and by adopting robust compliance measures. Against that background, other macro-economic factors have a stronger impact on the attractiveness of 5G markets.
7. Globally, spectrum is being allocated fast, with low, mid and high-bands being already allocated in some countries with the most ambitious 5G rollout schemes. Countries which have fully allocated all of the 5G spectrum will have a head start in a rollout process. Going forward, from a regulatory standpoint, we see progress in spectrum allocations as critical for continued success in 5G deployment.

8. COVID-19 will stall network rollout, derivative industry growth, and consumer uptake, but impact will be more severe for some countries than others. COVID-19 has impacted 5G by causing delays in the rollout and postponing the release of key regulations and technology standards. The economic shock is expected to have a stronger hit to GDP on advanced economies due to the pandemic, while emerging and developing economies in Asia are expected to perform better. Economies are also expected to see increased levels of fiscal deficit into 2020 and 2021, and in our view, governments must take a key role in supporting and incentivising modernisation and 5G deployment to boost economic growth, productivity and technological advancements.
9. Asian countries dominate the 5G value chain across the globe, from chipsets to handsets to infrastructure equipment. The 5G value chain is the most crucial enabler of a 5G-driven economy. In 2021, Stirling Infrastructure expects competition among 5G chipset and handset manufacturers to intensify. Samsung is presently leading the pack in handsets but its dominance will be challenged by the introduction of Apple's 5G handset. Another big player is Huawei, which holds the largest market share in China and has a strong presence in Europe, South Africa and Latin America. Huawei is expected to continue expansion in its stronghold markets and not focus on the US and its allied nations due to the geo-political situation. The infrastructure equipment market is dominated by Asian and European companies such as Huawei, Ericsson, Nokia, ZTE and Samsung, which have already deployed infrastructure in advanced economies. We note that that Asian companies do not fully disclose information regarding 5G infrastructure deployment.
10. At comparable speeds, users who prioritise mobility will prefer 5G, while those that place a premium on data security and privacy will prefer fixed broadband. Moreover, rather than capturing traditional internet usage, 5G will manifest its full potential through non-consumer technologies and new uses cases such as AI, IoT, and Machine Learning. Stirling Infrastructure expects that the global internet landscape and associated investment opportunities will continue to develop with strong influences from both technologies.

Disclaimer: this report was written before September 1, 2020 and contains running figures up to that date. Please direct any question about updated numbers to Stirling Infrastructure Partners.

1. 5G AND THE FUTURE OF MOBILE BROADBAND



1. 5G AND THE FUTURE OF MOBILE BROADBAND

1.1. AN INTRODUCTION TO 5G

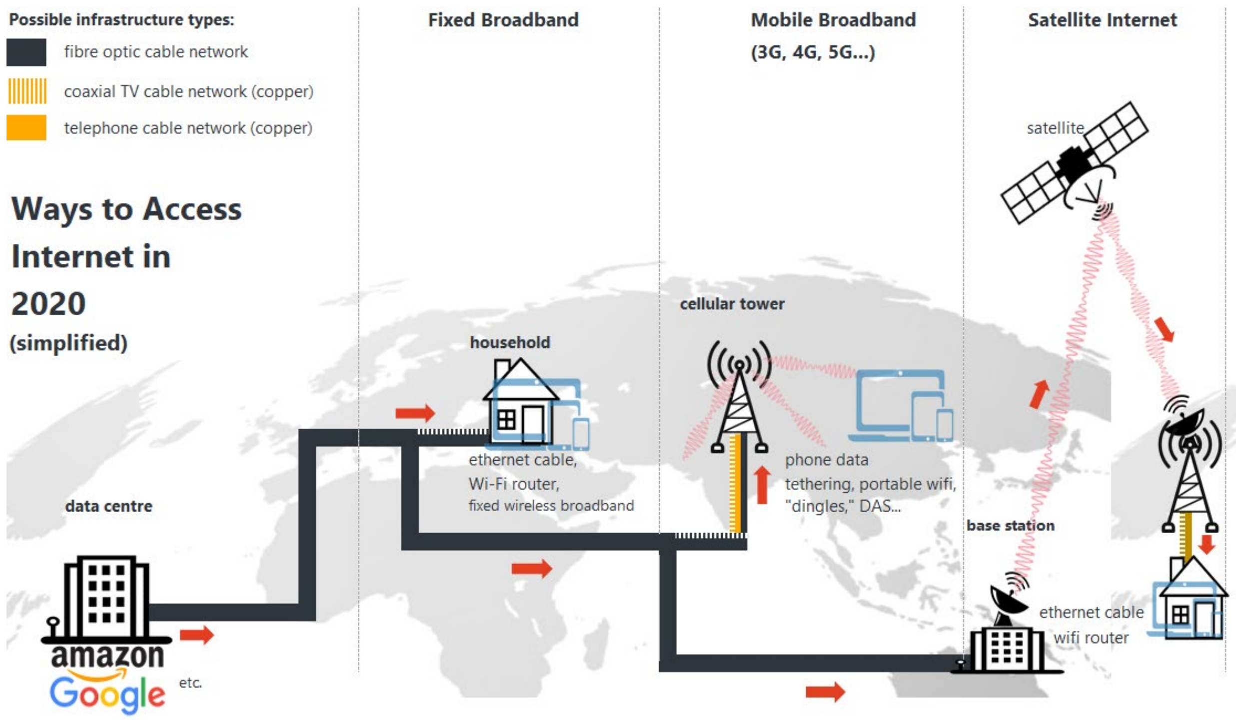
5G connects everyone and everything, anywhere, anytime

Imagine the simple everyday act of opening a webpage, whether on a desktop computer, a laptop, a cell phone or a tablet. How does the data get to a user's device? The digital information from one of the world's large data centres travel hundreds of kilometres across the bottom of the sea inside fibre optic cables. These fibre cables reach the land, splitting off into smaller branches into towns, cities and neighbourhoods, running underground and over utility poles.

Some cables will reach all the way into individual houses via TV and telephone lines, providing the end user with fixed broadband access (Exhibit 1). Other cables will eventually reach a cell tower, which beams the signals at an end device as electromagnetic (EM) waves.

The way of accessing internet on the move—called mobile broadband—has revolutionised how internet is consumed globally since the birth of 3G ("third generation" mobile broadband) in the mid-2000s. Google Maps, Instagram, TikTok, Twitter, and other user platforms demand the access and sharing of information anywhere and anytime. 4G has stepped in to fill this ever-rising hunger for faster and more data since the 2010s, but as a new decade approaches, a new set of technologies and protocols, 5G, promises to expand the possibilities of wireless broadband internet in ways unprecedented and even unforeseeable.

Exhibit 1: The global internet infrastructure, simplified



5G is a new global wireless standard designed to connect virtually everyone and everything, including objects, devices and machines. With extremely high data transfer volume and low latency on the move, 5G will significantly change the way people interact or do business.

Besides a significantly improved consumer experience for the average mobile user, 5G will drive socio-economic improvements across a number of sectors via innovative use cases such as safe and autonomous transportation, precision agriculture, remote healthcare, and smart cities. To quantify, independent research shows that 5G is expected to enable more than $13 trillion in global economic output in 2035 across all sectors, while generating $3.6 trillion in economic output and supporting 22.3 million jobs across the 5G value chain itself.[2] However, the global impact of 5G will be unequal: while the US, Europe and a select few Asian economies will reap the most value from 5G, less developed economies will lag behind.

1.2. INDUSTRIES ENABLED BY DIFFERENT 5G USE CASES

Derivative industries will benefit from 5G adoption via three different use case categories: Enhanced Mobile Broadband (eMBB), Massive Internet of Things (MIoT), and Mission Critical Services (MCS)

The global 5G network and value chain will enable use cases across sectors in three distinct categories: Enhanced Mobile Broadband (eMBB), Massive Internet of Things (MIoT, also called Massive Machine-Type Communications, or MMTC), and Mission Critical Services (MCS, also called Ultra-Reliable and Low Latency Communication, or URLLC).

The earliest use cases for 5G will be eMBB, which improves the user experience of the average consumer who owns a mobile device. eMBB will improve on the 4G through greater bandwidth, lower latency, and better coverage, making things like augmented reality (AR), virtual reality (VR) and cloud computing-supported apps possible.

MIoT is envisioned to realise concepts like smart city and smart agriculture by providing connectivity to a large number of devices (or "the Internet of Things") such as sensors and smart meters that intermittently transmit small amounts of traffic.

MCS is another futuristic use case which takes advantage of 5G's ultra-low response time (1-5 milliseconds) between devices to transform, making no-fail, mission-critical operations like autonomous vehicles, remote surgery and automated manufacturing into a foreseeable reality.

Transportation, agriculture, manufacturing, medicine, entertainment, and utilities are several sectors predicted to benefit from adopting these three 5G-enabled use cases. Some such examples are listed in Exhibit 2. We note that 5G adoption by these sectors—and subsequently the economic value generated—will depend on a number of factors, including the technological readiness for the new use cases, regulatory barriers, competing technologies (such as Wi-Fi), scalability, and consumer acceptance. Under specific favourable conditions, 5G adoption is expected to create disruption across markets and industries.

Exhibit 2: Industries adoption of 5G technology: some proposed and in-trial use cases

Use Cases Industries	"Enhanced mobile broadband (eMBB)"	"Massive Internet of Things (MIoT)"	"Mission Critical Service (MCS)"
Transportation			Autonomous driving with information exchange between vehicles, and infrastructure improves safety and manages fuel consumption.
Agriculture	Uploading sensor and farm vehicle data	Smart sensors measuring factors such as soil conditions and humidity for crops; locating animals and monitoring for diseases.	Remotely controlled farm vehicles and monitoring drones increases efficiency for farm owners.
Manufacturing	"Interconnected supply chain management will be more efficient, via the sharing of locations and key business information; Product customization becomes more feasible."		Manufacturing robots equipped with sensors coupled with automated systems allows greater coordination between machines, leading to greater production flexibility and efficiency.
Medicine	"Consultation, treatment and health monitoring, can be conducted remotely, shortening the time for appointments and queuing. Medical equipment management and tracking becomes more convenient"		Home care automation and remote surgery reduces need for mobility and increases hospital capacity.
Entertainment	Streaming of live sports events, concerts and panoramic and 360-degree video sharing; VR and AR supported gaming and cloud-gaming will enhance user experience.		
Utilities		5G supports smart metering that use private networks, licensed or unlicensed spectrums, and reduces power requirements.	Smart grid manages supply and demand, efficiently manages fragmented and irregular supply of solar and wind energy renewable energy.

2. BUILDING A 5G NETWORK: TECHNOLOGY, COSTS, LICENSES AND RISKS

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2.1. SPECTRUM REQUIREMENTS

A 5G network employs a wide range of spectrum to deliver faster and more data.

To fulfil the promises set forth by various 5G use cases, EM waves will need to transmit data to devices at a significantly higher speed than the previous generation of mobile internet standards, both in terms of transmission rate and latency (Exhibit 3). Simply put, all EM waves used in wireless communication can be divided into low band, mid band, and high band according to their wavelengths and corresponding frequency (Exhibit 4). However, for any given wavelength, speed and coverage are inversely related. For example, waves in the low-band region (long wavelength, low frequency) travel far from the cell towers, but carry less information per second. Conversely, waves in the high-band region (short millimetre waves, high frequency) carry thousands of times more information per second, but are easily blocked by physical objects.

Exhibit 3: Speed, latency, capacity, data volume specifications of 4G vs 5G for mobile devices in the UK

	4G	5G
Download Transmission Rate (Mbps)	20-30	150-250
Upload Transmission Rate (Mbps)	8	65-120
Theoretical Download Speed (Gbps)	0.3	10-50
Latency (ms)	20-30	<5
Capacity of connected devices per km2	4,000	1,000,000
Mobile Data Volume (Gbps/km2)	10	10,000
Battery Life implications		10% energy usage reduction

Source: 5G.co.uk

To counteract this trade-off, 5G employs a combination of wavelengths to increases the speed of wireless signals in two main ways:

1. By dedicating more airwaves in the low-band (long wavelength) and mid-band (medium wavelength) part of the spectrum for 5G use (making a wider "road," to offset slower speed)
2. By exploiting the high-band (short wavelengths in the millimetre range) part of the spectrum through a host of innovative wireless technologies (making data travel faster)

Exhibit 4: Different parts of the RF spectrum used for 5G

0.003 MHz (3 KHz) · 1000 MHz (1 GHz) · 10,000 MHz (10 GHz) · 20,000 MHz (20 GHz) · 300,000 MHz (300 GHz)

	Low band	Mid band	High band
Definition	<1GHz	1GHz - 10GHz	24GHz - 300GHz
Characteristics	Low data transfer per second	Godd balance between data transfer and coverage Considered "golden real estate" for 5G spectrum auctions	**Super fast, high-volume** data transfer Limited coverage
Usage for 5G	Blanket coverage	Making more of the mid-band waves available will provide **increased capacity** (high volume of data transfer/s) AND **mobility** fills in the coverage "gaps" for high band waves	Requires small cells **If signal is unencumbered**, can get speeds between 1 Gb/s to 3 Gb/3 or higher

While low band and mid band waves have historically been used by mobile carriers (low band for the oldest analogue cell phones of the 1980s, and mid band currently used for 4G), high-band waves have not been successfully exploited until recent 5G technologies such as small cells and beam-forming made their deployment feasible and reliable. Since air waves need to be free from signal interference, spectrum has become an increasingly scarce resource with rising data demands, as seen in recent spectrum auctions for 5G (see section 2.4).

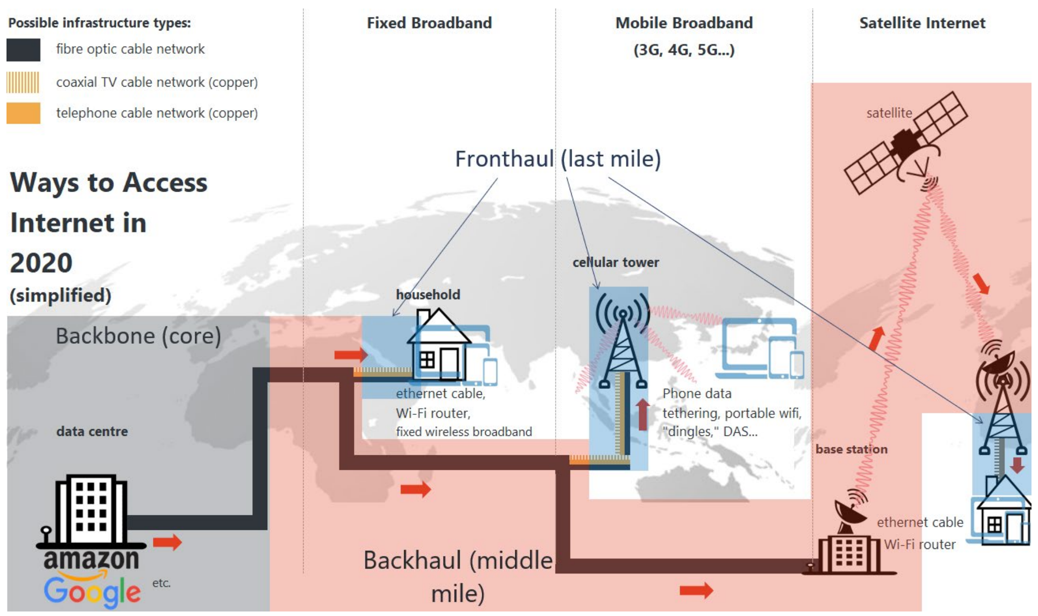
2.2. INFRASTRUCTURE AND TECHNOLOGICAL UPGRADE REQUIREMENTS

Building a 5G network requires maintenance and upgrades in the backbone and backhaul, and innovations in the fronthaul of the network infrastructure

Despite the futuristic vision of 5G use-cases, 5G shares infrastructure with other ways of accessing the internet (see Exhibit 1) and builds upon the technology of previous generations of mobile broadband. For investors, this fundamental understanding is crucial to appreciating the scale and cost of rolling out a global 5G network.

To provide a simplified illustration, Exhibit 5 divides the global internet infrastructure into three parts: backbone (internet core), backhaul (middle mile), and fronthaul (last mile). If one imagines internet infrastructure as roads, for the majority of the journey, the information leaving the data centre for a user's mobile device would be travelling on an "expressway" of fibre-optic cables called the backbone of the internet. The backbone eventually branches off to a "busy city road" made of mostly fibre wires, called the backhaul, before making a turn into the neighbourhood on a "side alley" called the fronthaul, completing the last mile of its journey to the user. The fronthaul and backhaul of a mobile network that connect the user's device to the backbone is called the radio access network (RAN), and contain all the cell towers (or "base stations").

Exhibit 5: Backbone, backhaul, and front haul of an internet network



Unsurprisingly, inadequate backbone and backhaul infrastructure can become a major bottleneck to the extremely high-speed requirements of 5G. Therefore, laying new fibre optic cables under the sea, and replacing old copper cables with faster fibre optic ones on land, are crucial investments being made by telecommunication companies and owners of large data centres such as Google and Amazon (mostly for backbone), and by mobile network operators (MNOs) and national governments (mostly for backhaul). These investments will not only benefit 5G deployment, but also improve other forms of internet access such as fixed broadband (Exhibit 5).

However, for MNOs building a 5G network, it is at the fronthaul that the majority of infrastructure upgrades and technological innovations will be incurring costs (Exhibit 5). MNOs have the choice between a) building 5G as an overlay upon existing 4G networks (non-standalone 5G), which focuses on opening up the low- and mid-band spectrum for an immediate speed boost for existing mobile consumers, and b) diving into investments into equipment making millimetre waves deployable and system upgrades that have to be built separate from the 4G infrastructure (5G core, or stand-alone 5G) (Exhibit 6). In fact, it is expected that the first successful deployments of millimetre waves to be in crowded places with a limited, defined area, such as airports, malls, and university campuses. Due to the prohibitive cost of building a 5G network, most MNOs are focusing on deploying non-standalone 5G (see section 2.3). However, the eventual transition to 5G core is necessary to unleash the full potential of new use cases for businesses and consumers.

Exhibit 6: Some fronthaul technological innovations in 5G

- **Small cells** (femtocells, picocells, microcells) around existing 4G base stations – on buildings, trees, in the ground, or on a small pole – to beam and receive high frequency/ mm waves
- **Massive MIMO antennas** (Multiple-Input Multiple-Output) on existing 4G base stations, with beam forming abilities/equipment
- **Outdoors DAS** (distributed antenna system): Upgrading old utility poles by adding new antennas, turning them into a series of makeshift cell towers to serve locations underserved by existing base stations
- **Indoors DAS** (distributed antenna system): Installing a series of antennas inside buildings
- **C-RAN technology:** Removing baseband units and routers on existing base stations to centralized hubs; building new base stations without baseband units and routers, which are cheaper and easier to deploy.

2.3. ROLLOUT STRATEGIES AND ASSOCIATED COSTS

Strategy-wise, most mobile network operators (MNOs) now prefer a measured, capacity-backfilling deployment over a costly, full-scale 5G rollout

5G networks can be deployed using a range of strategies, depending on the suitability of the strategy to the location and the structure of its economy (Exhibit 7). Below we present a high-level summary of the potential deployment strategies and their associated costs. In Exhibit 8, the cost breakdown for each case focuses on the average annual total cost of ownership (TCO) for the 2021-2025 period for a European MNO with 5G network in the 3.4-3.6 GHz band (mid-band), while 4G reference case refers to the 2013-2018 period.

Exhibit 7: Rollout strategy

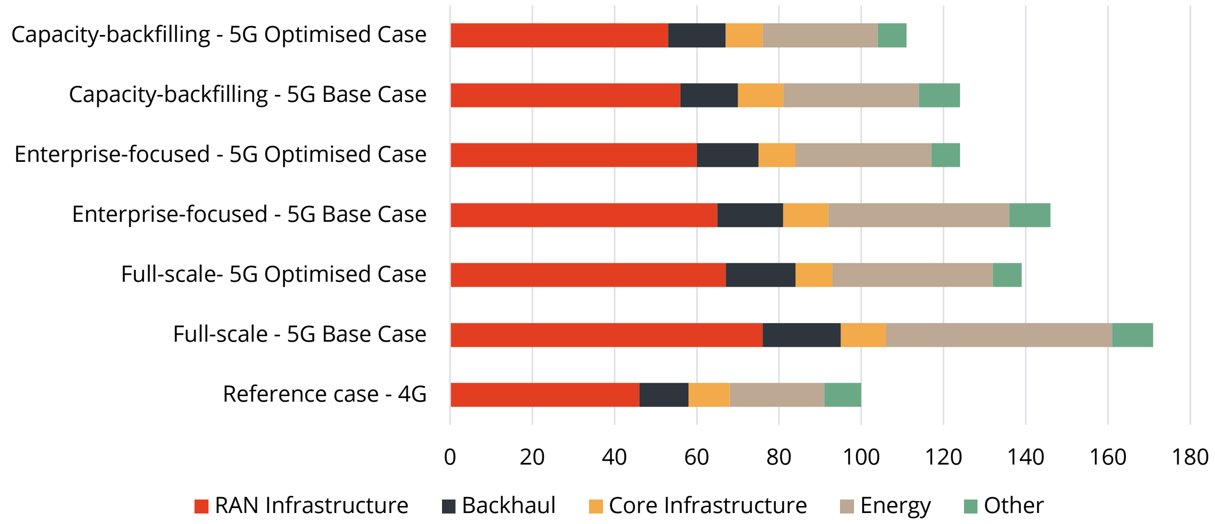
	Rapid, full-scale 5G deployment	Enterprise-focused 5G deployment	Capacity-backfilling 5G deployment
2018-2025 data traffic CAGR	40%	30%	20%
2025 vs 2018 data traffic multiple	10x	6x	3x
Strategy description	Rapid rollout covering 80% of the population with a high-capacity 5G network by 2025.	Fast-paced rollout covering 65% of the population with a high-capacity 5G network in enterprise hubs by 2025.	Measured rollout covering 50% of the population with additional 5G capacity by 2025. Currently the most common approach among operators.
Use cases in focus	Targets new 5G use cases for both Consumer and Enterprise segments	Targets existing and select new Enterprise use cases	Targets existing use cases, capacity backfill of current networks and eMBB services

Source: GSMA

An aggressive 5G rollout can come with risks. For example, in China, the high number of base stations required (6 million) and high electricity consumption has forced MNOs to strategically shut down some base stations. Reluctant consumer uptake further drove the challenge to recover costs, as the 5G ecosystem (e.g. apps and related technologies) is still immature.

It is important to note that technological advances may allow significant cost reductions, as demonstrated in the optimised cases (Exhibit 8). Countries where MNOs introduce cost optimisations using new technologies will set new standards for highly efficient and cost-effective 5G networks. For example, Rakuten is a Japanese company which plans to rollout 5G with ambitions to revolutionise telecom networks. The company envisions its 5G network as heavily software-focused with the concept of open radio access networks, or "Open RAN". Hardware and software traditionally come bundled together from single providers such as Ericsson and Huawei, making inter-operability and switching providers difficult and costly. The Open RAN paradigm un-bundles hardware and software and supports inter-operable interfaces between different equipment, effectively "opening up" the market to more software developers and hardware vendors and resulting in cost-optimisation.

Exhibit 8: 5G Rollout strategies - cost breakdown (in percent vs reference case)



Source: GSMA

Among other sources of cost optimisation, we want to highlight infrastructure sharing. Infrastructure sharing refers to MNOs sharing elements such as towers, cell sites, RAN, core elements, etc. We see infrastructure sharing as an important factor that will determine how fast countries will be able to develop 5G networks, since this source of cost optimisation can allow companies to rollout 5G with less capital and operating expenditure. Independent tower companies, managed-service providers and joint-venture agreements between MNOs have been gaining commercial traction in recent years, and we see infrastructure sharing taking even more importance as 5G is deployed across the world.

2.4. MECHANISMS FOR SPECTRUM LICENSE ALLOCATIONS AND AUCTIONS

Spectrum licensing is highly regulated, and allocation via auctions leads to fierce competition between mobile network operators (MNOs)

The telecommunications sector is heavily regulated, and market players, especially mobile network operators and infrastructure providers need permissions and licenses from their concerned regulator to build, operate, and offer services on 5G networks. Of these permissions, radio-frequency/spectrum licenses are particularly important and especially costly. This is because spectrum is a scarce resource and competition for it is fierce. The main way of obtaining these licenses is through participating in an auction, which is organised by the concerned regulator.

Spectrum auctions are employed by governments to make more air-space available to MNOs for telecommunication services, and these auctions are designed to generate revenue for the public sector. The format and substance of any spectrum action depends on the jurisdiction. For instance, recently, the US and UK governments have started auctioning spectrum for 5G usage. While the most recent UK auction has focused on the mid-band (2.3GHz and 3.4GHz) frequencies, the US auctions have instead sought to re-assign millimetre-wave frequencies above 28GHz, specifically in the 28GHz, 37GHz, and 47GHz ranges.

In the latest 2020 US auction, the Federal Communications Commission (FCC) used an incentive-based model which employed an initial reverse auction to establish an incentive price to re-allocate spectrum that had incumbent license owners. In the next stage, MNOs bid in a reiterative "clock phase" auction for license blocks over multiple rounds. If this stage was not successful (i.e. if MNO bids did not meet the necessary incentive prices demanded by incumbent owners), the initial reverse auction was repeated with less spectrum being made available for a lower price. If the clock phase auction was successful, the auction proceeded to the optional assignment stage. In this stage, MNOs could bid for specific frequencies in a single-rounded sealed-bid process. If an MNO was successful in the auction, they acquired a license allowing wave transmission in a specific frequency band (for example 27.5GHz-27.925 GHz) for a duration of 10 years.

Similarly, the UK held an auction for the 2.3GHz and 3.4GHz spectrum in 2020. The auction, which did not involve buying back from incumbent license holders, had a similar format to the US 2020 auction without the initial reverse auction stage.

We observe that the type of auction and the associated costs, discounts, and incentives can significantly affect the long-term profitability of investments in 5G. Thus, the nature of auction process in any country can be an important factor to consider. For example, in the US auction, coverage obligations are built into each spectrum license by county, whereas in the UK auction, coverage obligations are determined separately and spectrum rights are nationwide. Moreover, not all countries allocate spectrum through an auction process. For example, in 2019, Japan required MNOs to apply to a public procurement process and awarded 5G spectrum based on the merits of each proposal, such as the extent of the planned coverage.

2.5. FACTORS AFFECTING SPECTRUM PRICES

Public and private sectors both affect spectrum prices, which may significantly affect the speed of 5G deployment.

Independent study shows that historically, four factors have been particularly important in affecting spectrum prices at auctions:[3]

First, the government or the regulator's spectrum management decisions. Decisions to set high reserve prices and limit the supply of spectrum could drive spectrum prices higher. Similarly, unclear spectrum roadmaps and/or poor auction formats can result in spectrum price instability.

Second, the level of public debt. Spectrum prices in developing countries tend to be more expensive than developed countries because governments in developing countries, which are often experiencing financial distress, lack the ability to provide subsidies. They may therefore set higher spectrum prices to finance public debt.

Third, the degree of competition. Strong competition between incumbent and aspiring service providers during an auction drives up prices.

Fourth, the economic value attached to the spectrum offered for sales perceived by bidders. The amount of money spent by each mobile customer in a country as well as the extent of the coverage/performance requirements that are attached to the license can impact the perceived economic value of spectrum.

In developed countries, high spectrum costs significantly slowed down the rollout of both 3G and 4G networks, negatively impacted consumer uptake, and drove long-term reductions in overall network quality. We expect countries with high spectrum prices to suffer a similar impact for their 5G expansion. Investors seeking opportunities in the 5G landscape need to carefully consider the above four factors and their long-term impact on 5G rollout and uptake in their jurisdiction of interest.

2.6. RISKS OF BUILDING A 5G NETWORK

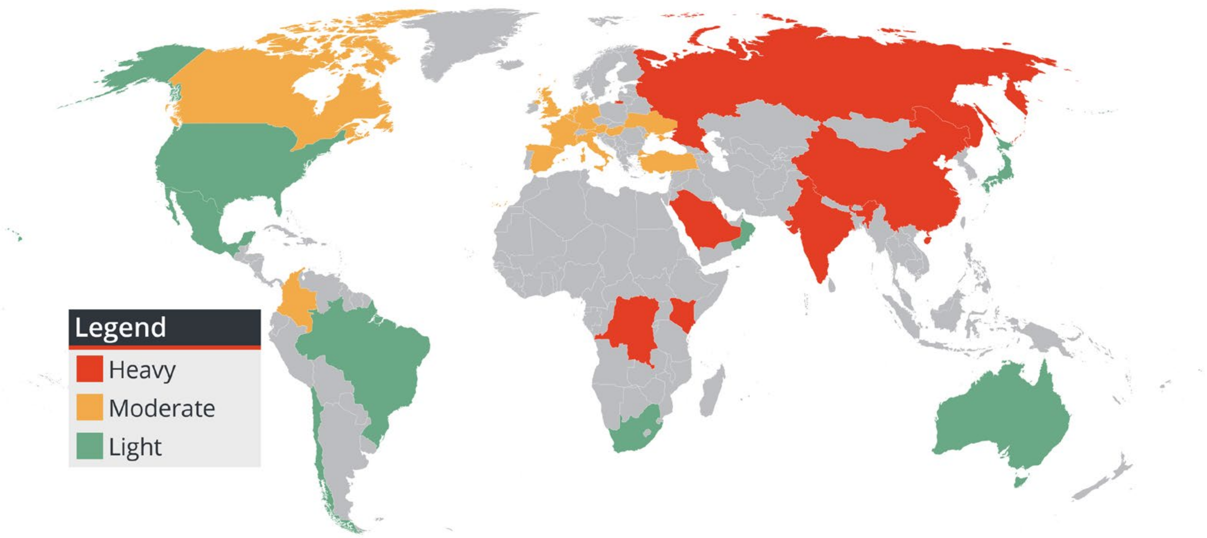
Regulatory and socio-political risks vary by country, but effect on the success of 5G expansion is not always straightforward

Apart from high spectrum prices, we observe that a number of jurisdiction-specific risks also negatively impact the amenability of a market to 5G deployment and expansion. These are briefly summarised as follows:

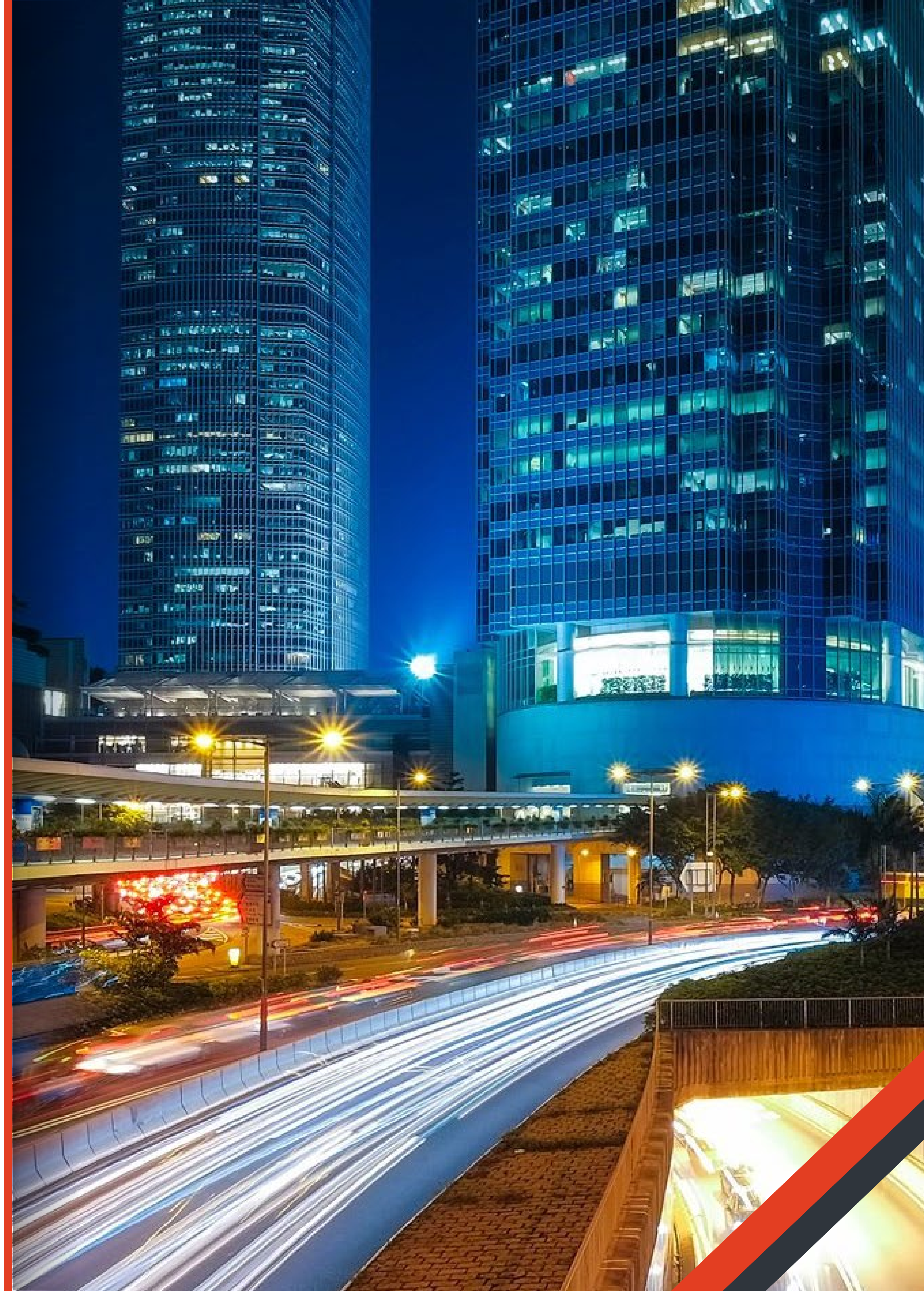
Environmental	Socio-Political	Regulatory and Legal
Health - thermal damage to humans, animals, and the biosphere if over established standards	Aesthetic - oppositions to 5G equipment	Jurisdiction specific - numerous regulatory requirements which change rapidly and slow local bureaucracy delay deployment
Conservation and Landscape - restrictions on areas of natural beauty, scientific interest, and conservation importance	Public health - arguments against 5G radiation exposure	Licenses - buying licenses from existing operators subject to risks of fraud and misrepresentation
Cultural - restrictions on areas of historical, cultural, and archaeological value	Corruption - governments favouring local competitors and bribery	Inter-operator/builder disputes - disputes over spectrum, competition law, and access and interconnectivity
Vulnerable areas - prior approvals for areas prone to natural disasters	Political - oppositions on national security grounds and practical difficulties due to political conflicts	Government litigation - risk of aggressive state litigation over regulatory non-compliance, competition law, and tax issues

These jurisdiction-specific risks are impacted by the severity of the regulatory framework in the country or region concerned. For example, in the UK, MNOs do not need a license to operate, whereas in China they must apply for national and provincial level permissions. The map in Exhibit 9 depicts the level of telecommunications regulation and enforcement in some major economies:

Exhibit 9: Level of telecommunications regulation and enforcement in major economies



However, we would like to point out that there is no strict direct relationship between regulation and the potential of an economy to significantly benefit from 5G. For instance, China and India have heavy regulation, however other factors such as government incentives, high population, and low market saturation nonetheless make them attractive economies for 5G expansion. Conversely, South Africa has a light regulatory regime, but that factor alone does not guarantee its success as a 5G market.[4] This is because regulatory risks can be mitigated by engaging competent legal advice and by adopting robust compliance measures, and because other macro-economic factors have an arguably stronger impact on the attractiveness of 5G markets. Thus, an economic analysis (section 3.1-3.3) is a crucial indicator of the winners and laggards of the 5G opportunity around the world.



3. THE 5G LANDSCAPE: PATTERNS OF 5G EXPANSION AROUND THE GLOBE

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3.1. SPECTRUM ALLOCATIONS AROUND THE WORLD

Globally, spectra are being allocated fast, with low, mid and high-bands being already allocated in countries with the most ambitious 5G rollout schemes

5G relies on spectrum across low, mid-band and high band ranges to unlock its maximum capacity. Low band spectrum (<1GHz) enables greater coverage. Mid/C-band spectrum (3.3-4.2GHz) offers good balance between coverage and capacity aspects. High band spectrum (>24GHz) is responsible for supporting the ultra-high speeds of 5G.

We notice that it is common for countries to roll out mid and low band spectrum first for 5G usage. This is in line with the approach to rolling out 5G networks which build upon existing 4G infrastructure. Under this capacity-backfilling/non-standalone 5G rollout approach, the 4G equipment built for low- and mid-band spectrum usage can be shared for overlapping 5G deployment before full migration into standalone 5G, which will then require more high-band spectrum.

As high band spectrum waves travel at a shorter distance, they require more cell towers to be built to achieve greater connectivity, which translates to higher infrastructure investment cost (see section 2.3). Hence, Stirling Infrastructure predicts that high band spectrum will usually be rolled out last for 5G (as compared to the low and mid band spectra).

This is supported by countries' patterns of spectrum allocation. Since 2015, 46 countries/regions have completed allocations of 5G-suitable spectrum (defined as spectrum either dedicated to 5G use, or technology-neutral license that could be used for 5G for some or all the possible 5G spectrum bands). More countries/regions have finished allocation for the low band (24) and mid band (33) spectrum, outnumbering the countries/regions that have completed high band spectrum (11) (Exhibits 10-12).

Exhibit 10: Countries that have completed low band spectrum (<1GHz) allocations

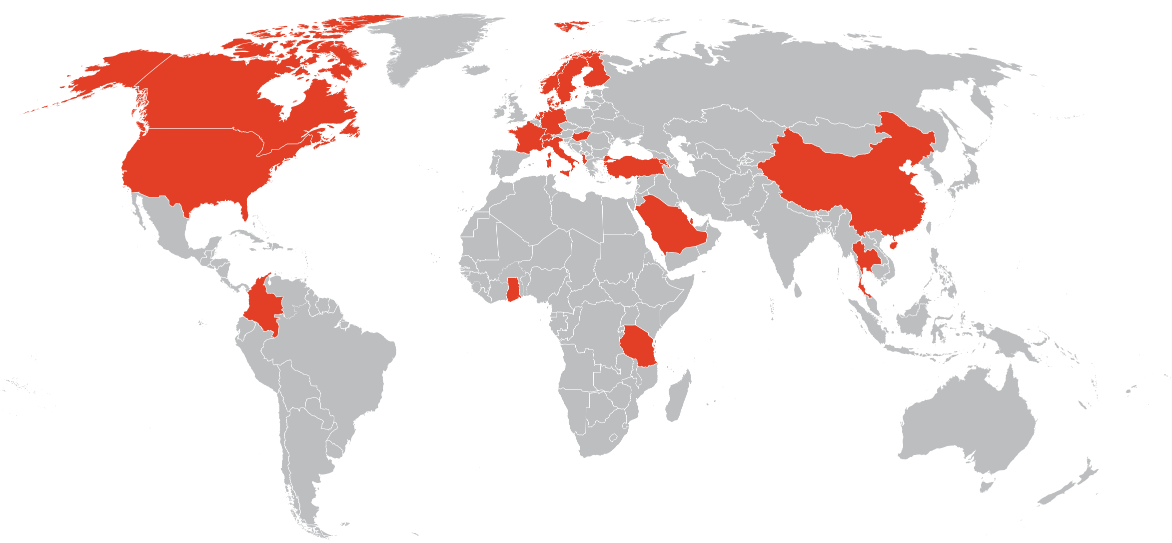


Exhibit 11: Countries that have completed mid band (C-band) spectrum (3.3-4.2GHz) allocations

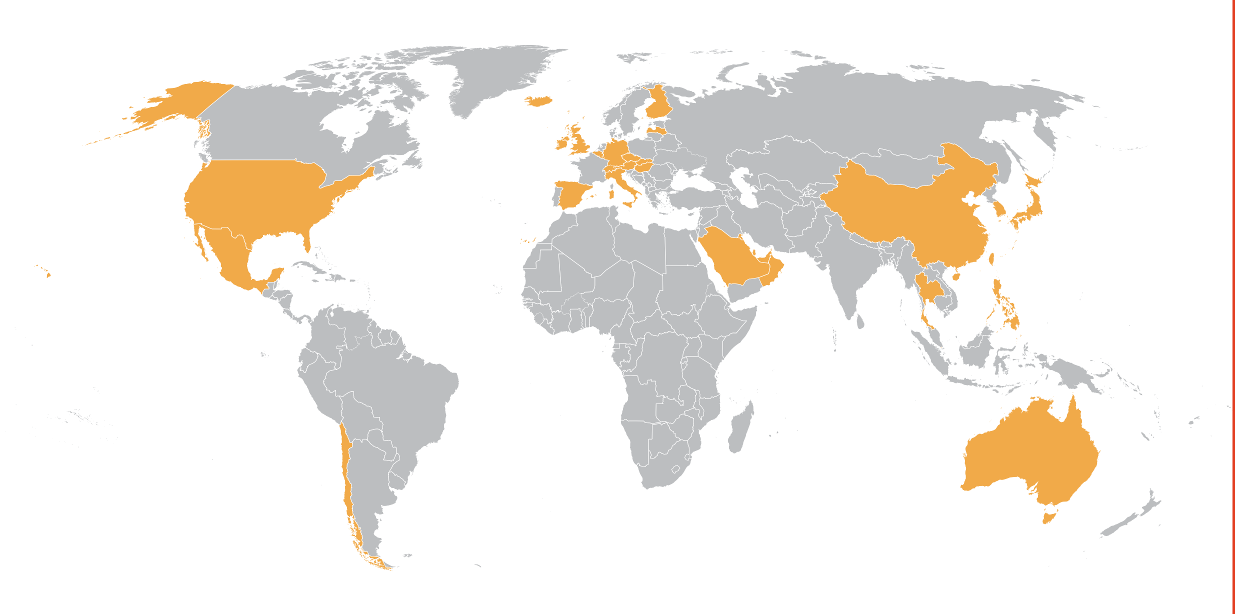
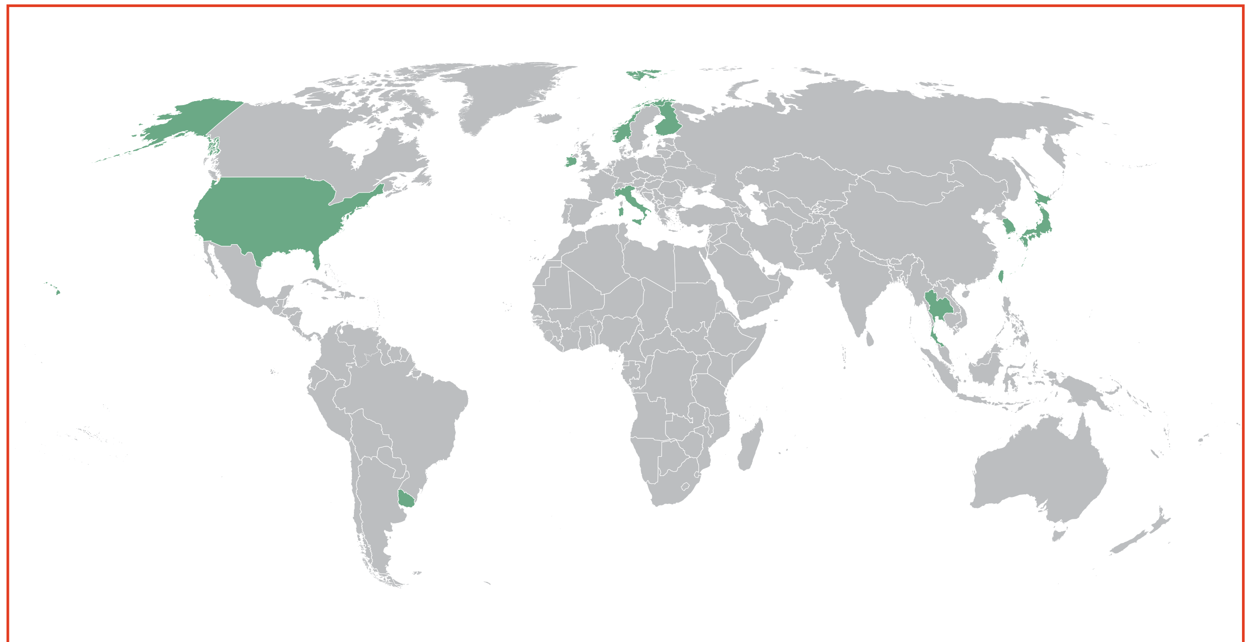


Exhibit 12: Countries that have completed high band spectrum (>24GHz) allocations



Europe

In Europe, 21 countries have already completed auctions for some and/or all the possible 5G suitable spectrum. Of these, 12 countries have auctioned low band spectrum (<1GHz), 15 countries for C-band spectrum (3.3-4.2GHz) and 4 countries for mm Waves spectrum (>24GHz).

- **Low Band –** Albania, Denmark, France, Finland, Germany, Hungary, Italy, Luxembourg, Netherland, Norway, Sweden, Switzerland
- **C-Band –** Austria, Belgium, Czech Republic, Finland, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Luxembourg, Slovakia, Spain, UK, Switzerland
- **mm Waves Band –** Finland, Ireland, Italy, Norway

Asia-Pacific

Ten countries/ regions have completed 5G spectrum allocations for some and/or all the possible 5G spectrum. Of these, Armenia, China, Hong Kong and Thailand have completed allocation for low band spectrum. As for C-Band spectrum allocation, nine countries/ regions including Australia, China, Hong Kong, Japan, Philippines, South Korea, Singapore, Taiwan and Thailand have completed the allocation process. For the mm Waves band spectrum, five countries/regions have completed the allocation (Hong Kong, Japan, South Korea, Taiwan and Thailand.)

Americas

Six countries have completed 5G spectrum allocation for some and/or all the possible 5G spectrum. The USA has already allocated low and high band spectrum whereas the C-Band allocation is ongoing and expected to be concluded soon. Other than the US, countries within the Americas that have completed allocation for 5G spectrum are Canada and Colombia (low band), Mexico and Chile (C-Band) and Uruguay (mm Waves band).

Middle East and Africa

Nine countries in the Middle East and Africa region have completed 5G spectrum allocation for some of the possible 5G spectrum. Countries with low band spectrum allocation already completed include Bahrain, Ghana, Saudi Arabia, Tanzania and Turkey. As for C-Band allocations, countries which have completed allocation include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE. No countries within this region have allocated high band 5G spectrum yet. Upcoming 5G spectrum auctions are planned in Israel and South Africa as well as in the territories of Mayotte and Réunion.

A number of countries have already deployed 5G. Below, we highlight five "early adopters", defined as countries with the most cities where 5G is available, including South Korea, China, Saudi Arabia, the US and the UK (Exhibit 13).

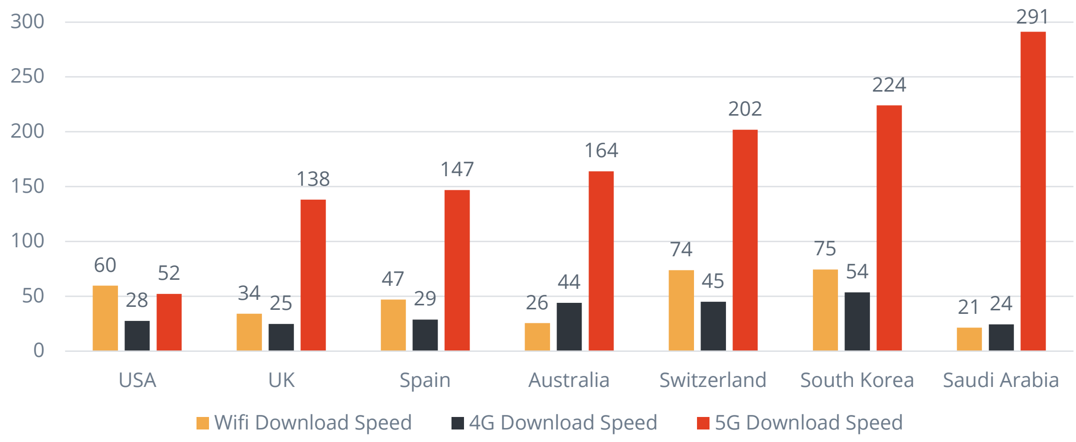
Exhibit 13: 5G – early adopters, listed by number of cities with 5G coverage

Country	Operators	First Launch Date	Cities Covered (as of Jan 2020)
South Korea	KT, LG Uplus, SK Telecom	Dec 18	85
China	China Mobile, China Tele-com, China Unicom	Oct 19	57
United States	Verizon, AT&T, T-Mobile, US Cellular, GCI	Oct 18	50
United Kingdom	Three, EE, O2, Vodafone	May 19	31
Saudi Arabia	STC, Zain	Jun 19	24

Source: GSMA, Viavi Solutions

Exhibit 14 further shows a number of countries that have already rolled out 5G commercially. 5G download speeds are considerably higher than 4G and Wi-Fi in a majority of locations, yet, some countries, such as the US, are behind on speed, which is said to be due to a shortage in mid-band spectrum. Going forward, from a regulatory standpoint, Stirling Infrastructure sees progress in spectrum auctions and allocations as critical for continued success in 5G deployment.

Exhibit 14: Average (Mbps) between Jan 22 - Apr 21, 2020 period



Source: OpenSignal

3.2. THE ECONOMIC IMPACT OF COVID-19 ON 5G EXPANSION

COVID-19 will stall network rollout, derivative industry growth, and consumer uptake, but impact will be more severe for some countries than others

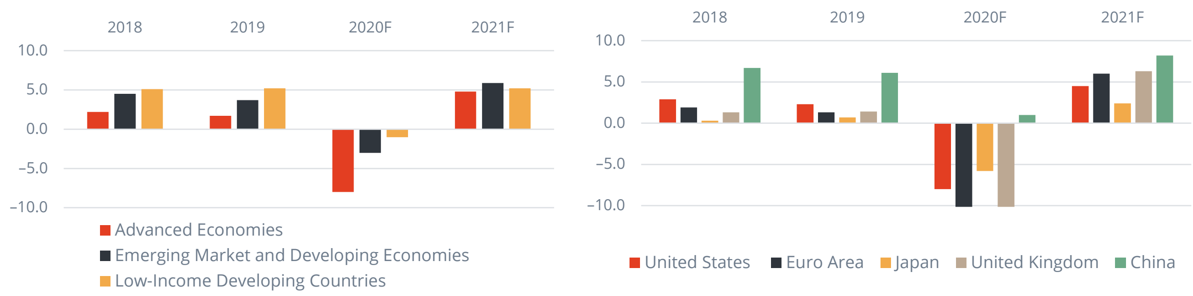
COVID-19 has impacted 5G by causing delays in the rollout and postponing the release of key regulations and technology standards. With respect to enterprises, 5G spending plans are expected to be delayed due to the economic slump, as warned by Nokia, Ericsson, Samsung and Huawei. Moreover, many countries, mainly in Europe, postponed 5G spectrum auctions to 2021. On the other hand, a number of countries are being more aggressive, such as China and US, who are more or less on track in terms of 5G investment and rollout. For example, GSMA expects the impact of COVID-19 on migration to 5G to be less pronounced in Asia Pacific region versus the rest. Overall, the speed of economic recovery is certainly an important factor, and it is useful to watch how quickly countries bounce back from the pandemic.

The economic shock is expected to have a stronger hit to GDP on advanced economies due to the pandemic (Exhibit 15a), while emerging and developing economies in Asia are expected to perform better (Exhibit 15b). A number of Asian economies (e.g. China, South Korea, Japan) have strong 5G ambitions and a quicker recovery from the pandemic may allow them to get ahead of western economies in terms of 5G deployment.

Exhibit 15: YoY real GDP growth rate (%)

a) Advanced, emerging and low-income economies

b) Five leading economies

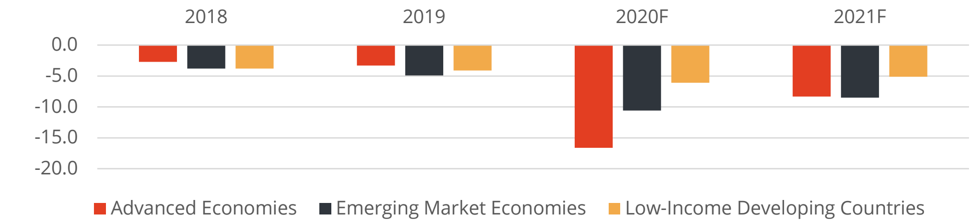


Source: International Monetary Fund

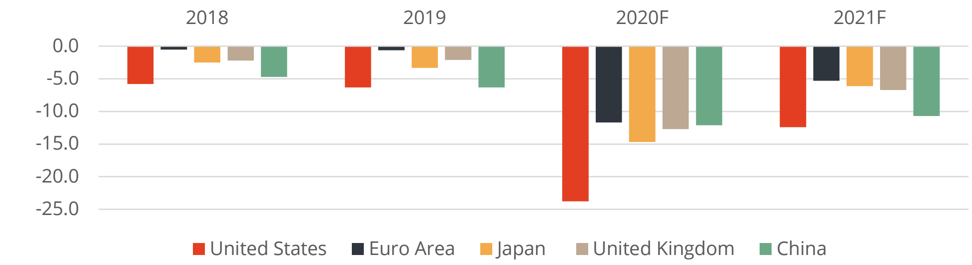
Economies are also expected to see increased levels of fiscal deficit into 2020 and 2021 (Exhibit 16). Targeted fiscal stimulus with infrastructure and digitalisation as important agendas could create strong tailwinds for 5G. However, many countries see their private debt levels elevated and private sector deleveraging could remain on the agenda. Private indebtedness is an important consideration, since enterprises may not rush in with investment in new IoT-based business models and applications, especially if economic growth remaining sluggish and debt overhang become serious headwinds. In our view, governments must take a key role in supporting and incentivising modernisation and 5G deployment to boost economic growth, productivity and technological advancements.

Exhibit 16: Fiscal balance (% of GDP)

a) Advanced, emerging, and low-income economies



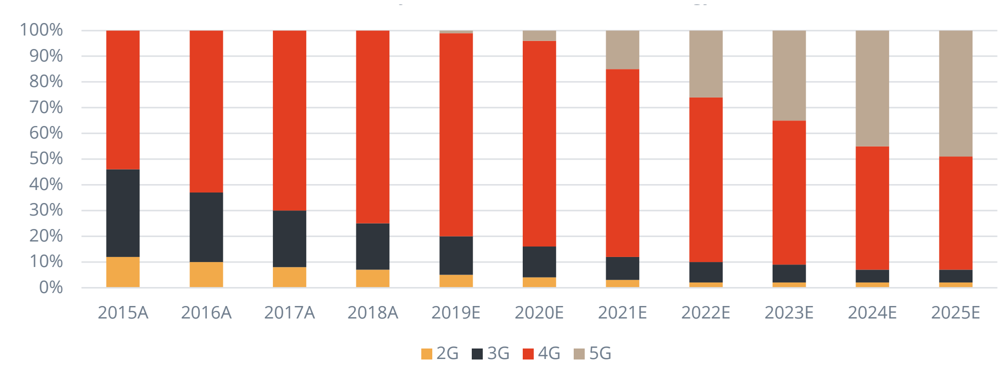
b) Five leading economies



Source: International Monetary Fund

Finally, a critical factor for consumer uptake of 5G is availability and affordability of 5G handsets. Currently, Apple is expected to launch its 5G iPhone device in Q1 2021. Apple smartphones tend to have higher market shares in developed economies, such as United States, Western Europe, Japan, and Singapore. Uptake of Apple's new 5G device will play an important role in migration to 5G in developed countries. Apple's Q3 results show that iPhone sales were relatively flat year on year even after the release of the 5G iPhones (iPhone 12, 12 mini, 12 Pro and 12 Pro Max) in October 2020, but it is important to watch iPhone sales going forward as the economy recovers. Prior to the pandemic, in North America, 5G's share of mobile connections was expected to reach 50% by 2025 (Exhibit 17). However, in a scenario where consumers in developed economies reduce spending in response to the economic shock, migration to 5G may be slower than what could have been in a pandemic-free environment.

Exhibit 17: Share of connections (%) by mobile broadband technology in North America



Projections made in 2018. Source: GSMA Intelligence

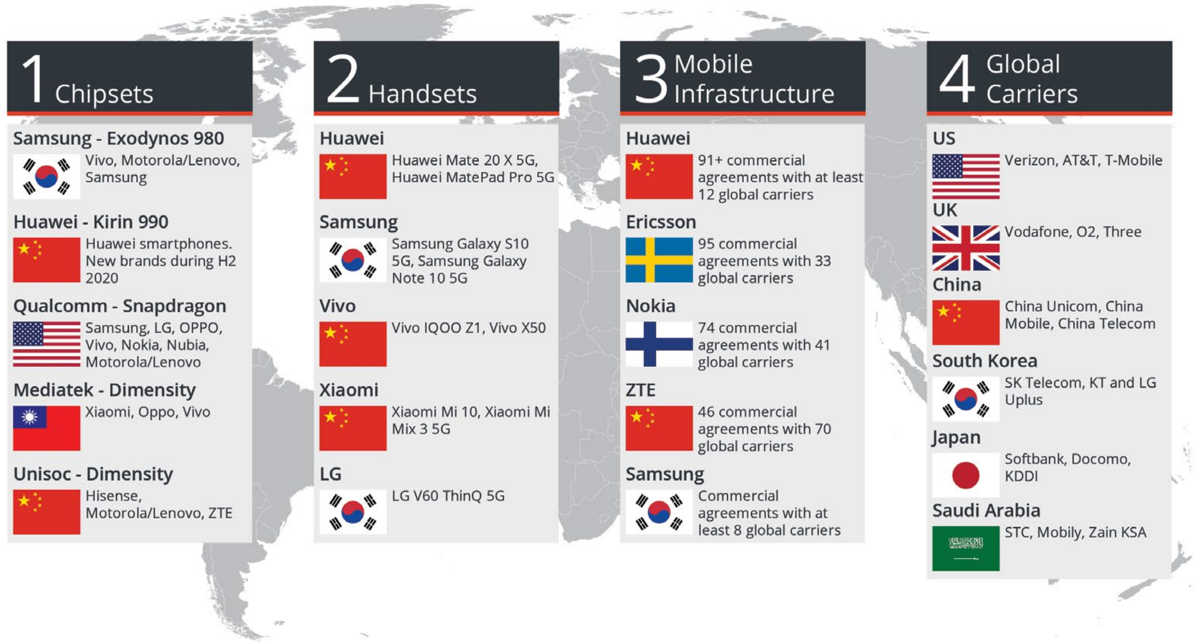
On the other hand, consumers in South Korea and China (two leading countries in 5G deployment) are subscribing to 5G at rapid rates. South Korea ended May 2020 with almost 7 million 5G subscribers (representing approximately 10% of total mobile subscriptions). Whereas China saw 5G subscriptions reach 65 million among two largest national carriers as of April 2020 (representing approximately 5% of total subscriptions). These positive developments are being facilitated by a quicker economic recovery, cheaper 5G smartphones, consumers seeking faster mobile internet and MNOs providing the service just in time.

3.3. GLOBAL LEADERS OF THE 5G VALUE CHAIN

Asian countries dominate the 5G value chain across the globe, from chipsets to handsets to infrastructure equipment

The 5G value chain will be the most crucial enabler of a 5G-driven economy (apart from regulations and incentives), paving the foundation for a variety of use cases across industries (see section 1.2). The 5G equipment value chain that serves global carriers can be divided in three sectors: chipsets, handsets and mobile infrastructure (Exhibit 18).

Exhibit 18: Global leaders across the 5G value chain



Source: Forbes, Strategy Analytics, Statista, 2019.

The 5G chipsets market

Chipsets are electronic components (semiconductors) that include 5G technology, which can then be incorporated in handsets such as smartphones and tablets. The 5G chipsets market has a strong presence of Asian companies (Samsung, Huawei, MediaTek and Unisoc), with Qualcomm being the only western company among the top players. Huawei and Samsung have traditionally developed chipsets to be incorporated exclusively in their smartphones, while Qualcomm is the main chipset supplier for almost all other smartphone manufacturers, including LG, OPPO, Vivo, HMD Global (Nokia), Nubia, Motorola/Lenovo, etc.

MediaTek and Unisoc are smaller players who serve Chinese smartphone manufacturers such as Xiaomi, Vivo, Hisense, and ZTE. However, in late 2019 Vivo and Motorola/Lenovo started using Samsung's chipsets for some of its new handsets, while Huawei announced it was open to sell its chipsets to third parties. Consequently, we expect competition among 5G chipset manufacturers to intensify during 2021.

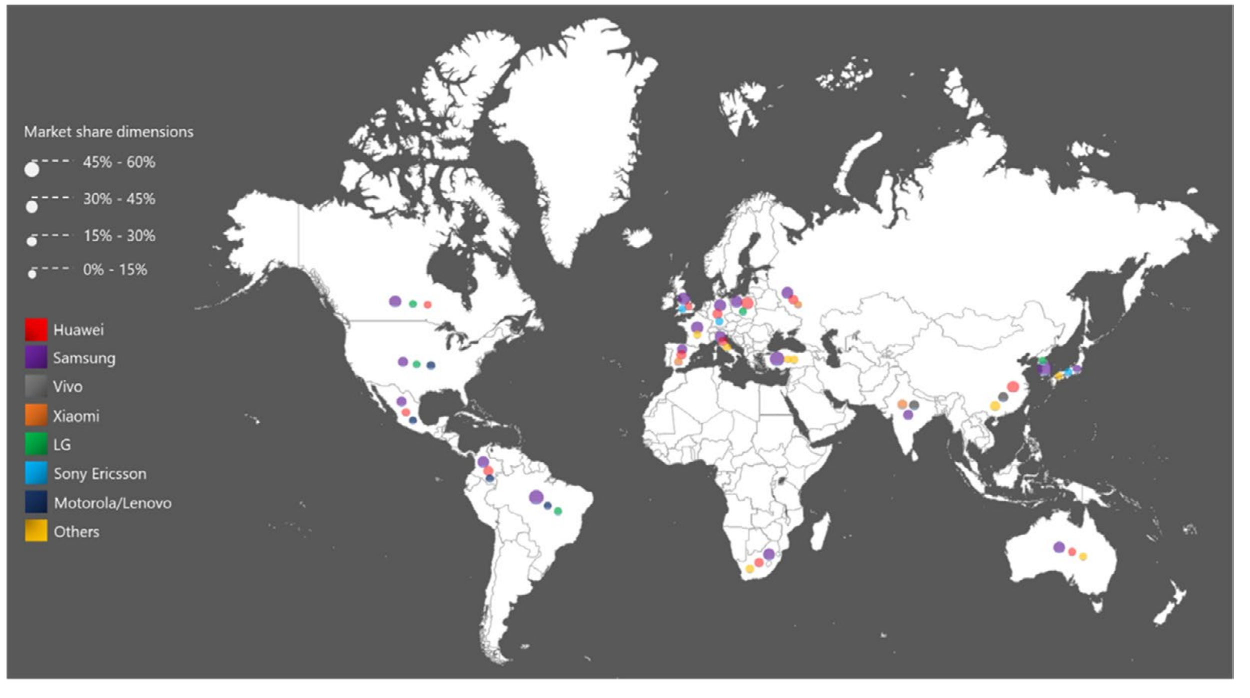
The 5G handsets market

Handsets refer to smartphones and other mobile devices. The global 5G handset market is dominated by Asian companies Huawei and Samsung, whose combined market share reached 73% in 2019. Samsung was the first company to release a 5G smartphone in April 2019. Since then, it has released 7 additional 5G smartphones. Huawei released its first 5G smartphone in June 2019 and it was the first company to release a second generation 5G smartphone in September 2019. Despite Covid-19, Huawei released 15 new 5G smartphones during H1 2020. The smaller Chinese competitors Xiaomi and Vivo released 5G smartphones in May and September 2019, respectively. American competitors Apple and Google are expected to release 5G smartphones in late 2020.

Samsung is the leader in terms of 5G handsets geographic coverage (Exhibit 19), holding the largest market share in several countries including the US, Brazil, the UK, South Korea, Australia, and South Africa. However, Samsung's in the 5G handsets space could be compromised, as Apple released its 5G smartphones in October 2020. The impact of Apple's 5G iPhone release globally is still unknown at the time of writing this paper, because adoption will still depend on the underlying infrastructure and the development of a 5G ecosystem. On the other hand, Huawei holds the largest market share in China and has a strong presence in Europe, South Africa and some Latin American countries.

Due to current geopolitical frictions between the US and China, Stirling Infrastructure expects Huawei to maintain the focus in the regions mentioned, without including the US and other Five Eyes nations as a priority in its expansion agenda. Xiaomi and Vivo hold a strong presence in India and China, whereas Motorola/Lenovo is one of the top 3 players in the US, Mexico, Colombia and Brazil.

Exhibit 19: Market share of smartphone manufacturers who have launched 5G handsets



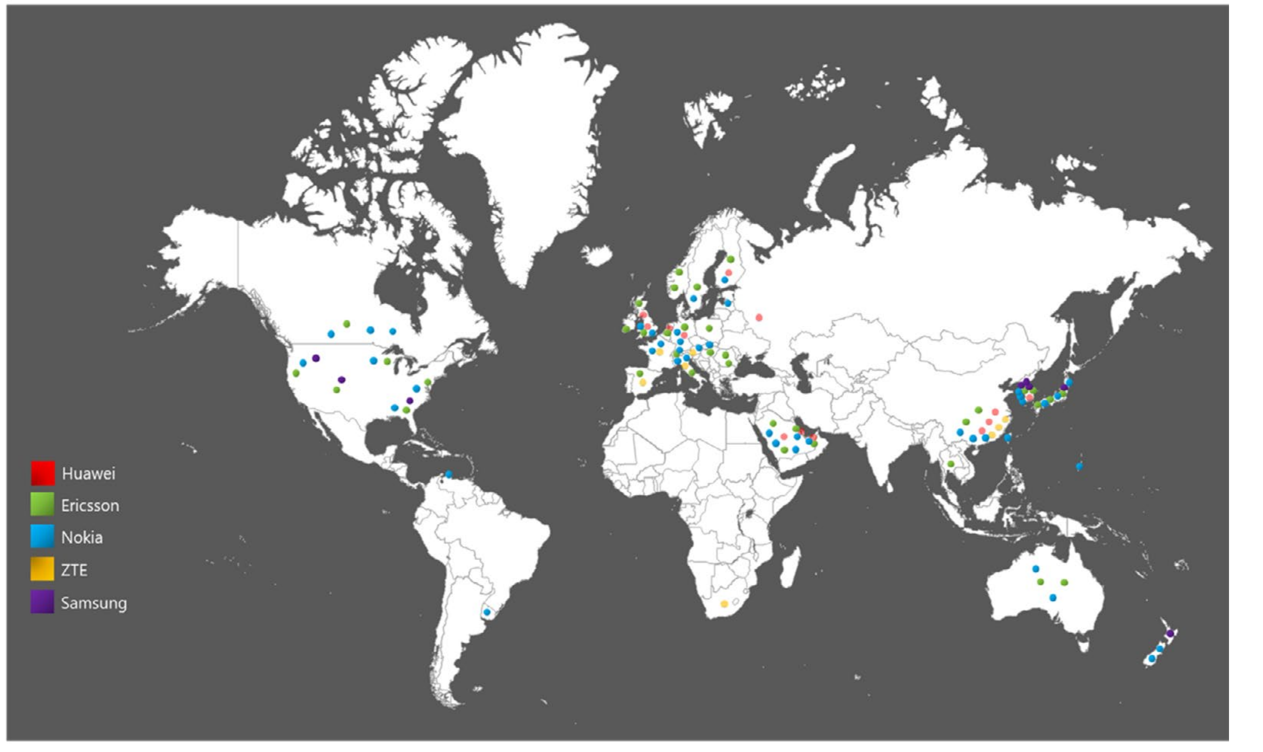
Source: Statista. (Information displayed as of December 2019 except France, Italy and Brazil, whose cut-off dates correspond to 2015, 2016 and 2018, respectively.)

The 5G mobile infrastructure equipment market

Mobile infrastructure equipment refers to the portion of infrastructure equipment that includes radio access network components, such as base stations (i.e. cell towers) and antenna arrays, which allow handsets to communicate with the network.

The mobile infrastructure equipment market is dominated by Asian and European companies such as Huawei, Ericsson, Nokia, ZTE and Samsung (Exhibit 20). Global carriers usually sign commercial agreements with several network providers in any given country, with the number of commercial agreements being a proxy for market share power in the 5G infrastructure space. The top 2 leaders, Huawei and Ericsson, hold over 90 5G contracts, followed by Nokia and ZTE with 74 and 46 contracts, respectively. (We note that Asian companies including Huawei, ZTE and Samsung do not fully disclose information regarding the number of contracts and locations of 5G infrastructure deployment.)

Exhibit 20: Mobile infrastructure providers geographic coverage



Source: Ericsson, Nokia, Forbes, Strategy Analytics.

The largest mobile infrastructure providers have deployed 5G mostly across advanced economies, covering territories in North America, Europe, the Middle East and Asia-Pacific (Exhibit 20). Western mobile infrastructure providers Ericsson and Nokia have signed commercial agreements with several global carriers, keeping a strong focus in the US, Europe, the Middle East, Australia and Japan. According to the incomplete information disclosed by Samsung, Huawei, and ZTE, Samsung has signed commercial agreements with global carriers in South Korea and the 3 largest carriers in the US; Huawei has signed commercial agreements in China, the Middle East and Europe, whereas ZTE is deploying 5G infrastructure in South Africa, China and some European countries.

An interesting trend to watch for in the infrastructure equipment market is Open RAN (see section 2.3). Following the recent Huawei fallout with the US and the UK from 2019 to 2020, we see the new Open RAN paradigm posing potential future disruption to the existing pattern of dominance by major infrastructure providers, as governments have awoken to the risks and costs of relying on single providers. We predict that the entrance of smaller software and hardware vendors focusing on inter-operable equipment interfaces will intensify competition in the market, especially for standalone 5G infrastructure.

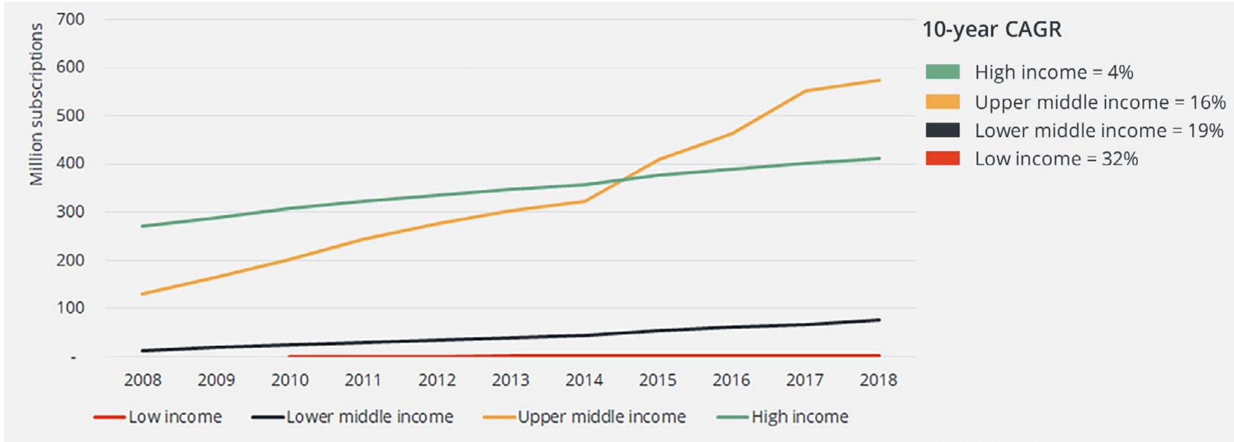
4. 5G'S PLACE WITHIN THE INTERNET SERVICE PROVISION CONSUMER MARKET

4.1. WILL 5G DISRUPT TRADITIONAL FIXED BROADBAND ACCESS?

5G will be a disruptor, but not a replacement, to fixed broadband

Although 5G promises higher data speed, lower latency and improved coverage, MNOs in both advanced and developing economies across the world continue to roll out fibre-to-the-premise (FTTP) fixed broadband access, seeking to improve last-mile connection to users with high-speed fibre (as opposed to copper lines).[9] From a consumer point of view, fixed broadband subscription has seen dramatic mean annual growth in China (17%) and India (13%) from 2008 to 2018 (10-year CAGR), and have high subscription rates in non-high-income countries (Exhibit 21). Considering the often-large gap between theoretical speeds and real network quality, connection speeds for FTTP fixed broadband can easily rival, even outperform, 5G speeds in certain circumstances (Exhibit 22). In addition, factors such as prohibitive spectrum prices (section 2.5) and regulatory hurdles (section 2.6) can slow down 5G rollout and prevent long-term improvement in overall network quality.

Exhibit 21: Fixed broadband subscriptions by country income group



Source: World Bank, 2018

Exhibit 22: Speed and latency comparison between FTTP broadband and 5G

Broadband

- Current global average download speed: 76.94 Mbps
- Current average latency: 24 ms
- Theoretical speed: 100 Gbps (which could be expanded to 10 terabits/s by solely relying on fibre)

5G

- Current global average download speed: 50 Mbps (expected to increase to 200 Mbps
- Current average latency: 10 ms
- Theoretical (practical) speed: 10 Gbps

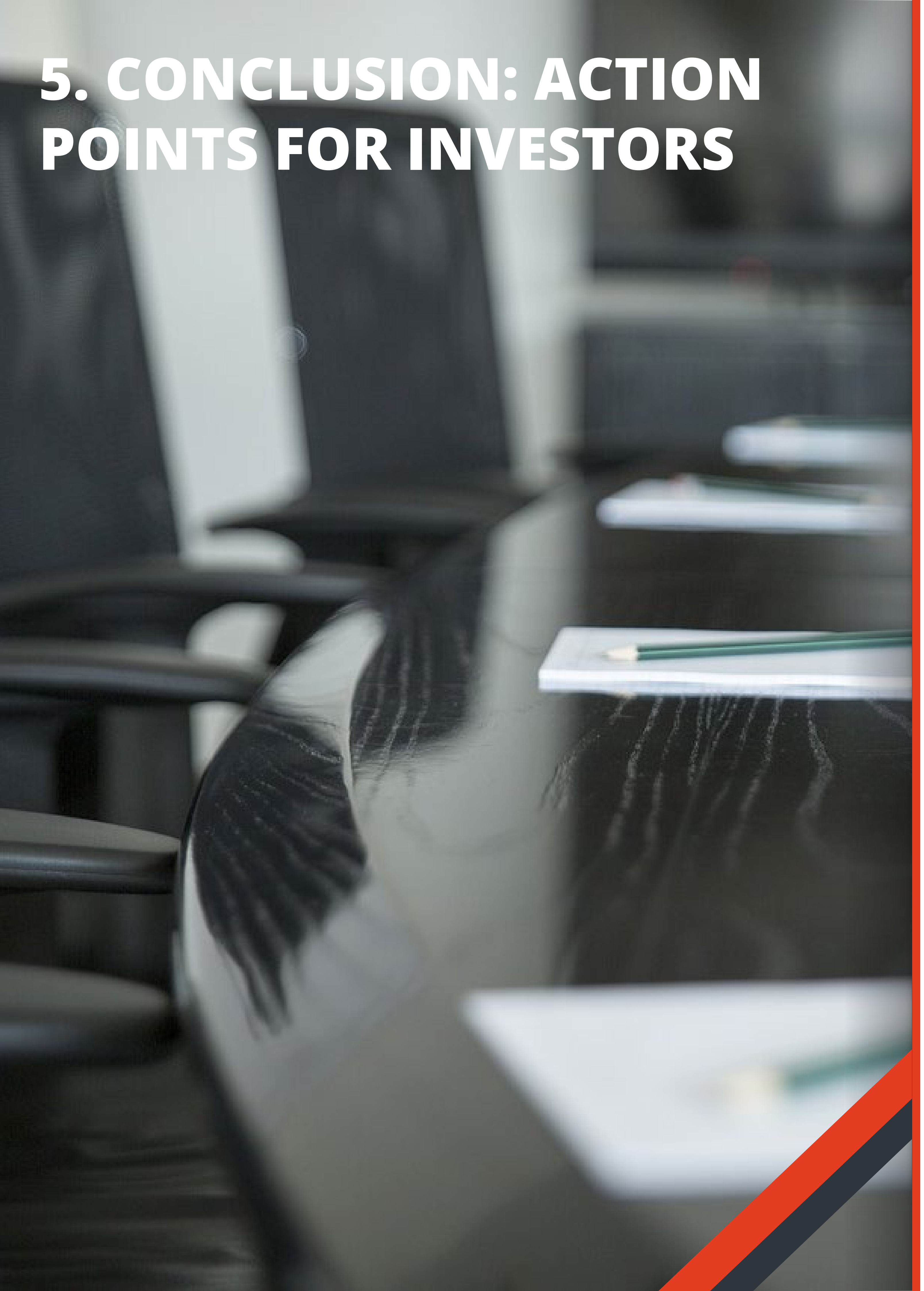
From the point of view of telecommunication providers, Stirling Infrastructure considers it unlikely that 5G will replace fixed broadband entirely, and any potential for disruption exists only in the last-mile of connectivity. This is because 5G and fixed broadband share the same backhaul in the form of high-speed low-latency fibre optic infrastructure. Governments and telecommunication companies have been heavily investing in fibre optic backhaul (see section 2.2), which facilitates the uptake of both broadband and 5G. The last-mile potential for disruption is further diluted by the fact that 5G and fixed broadband cater to very different preferences and uses. Users that prioritise data security and privacy over mobility will prefer fixed broadband over 5G (Exhibit 22). Indeed, rather than capturing traditional internet usage, it is through typically non-consumer technologies and new uses cases such as AI, IoT, and Machine Learning, that 5G will manifest its full potential (see section 1.2).

Exhibit 23: Critical factors for choosing fixed broadband providers

Residential	Business
1 Price of internet subscription	1 Download speed and allowance
2 Download speed and allowance	2 Technical support
3 Technical support	3 Security
4 Bundled internet subscription	4 Static IP
5 Equipment cost	5 Contention Ratio
6 Contract Length	6 VPN
	7 Offsite backup
	8 Equipment

Admittedly, it is possible to populate certain geographies with 5G infrastructure and eliminate the need for fixed broadband. This may even be desirable given the fact that there are significant challenges in connecting homes and businesses to FTTP fixed broadband in places that have extensive legacy copper lines and in remote regions. These challenges include massive installation costs and high CAPEX and OPEX which reduce the profitability of fixed broadband, and regulatory hurdles such as licensing and legal permissions which can cause deployment lags. However, as we noted earlier, setting up, maintaining, and running 5G infrastructure is similarly and often even more costly. For instance, in the UK, the cost of setting up a single small cell site is £16,000, and MNOs have paid as much £317,720,000 for 40MHz of 3.4GHz spectrum. Against these costs, operating a 5G connection in areas without dense demand is unlikely to provide an adequate return on investment. Furthermore, as of 2018, 59% of rural areas in the UK still did not have reliable 4G coverage, while 677,000 UK homes and offices (mostly rural) did not have reliable fixed broadband connection, illustrating the general challenge of extending rural coverage for both mobile broadband and fixed broadband.[5] Whether 5G provides a viable solution to a lack of high-speed home broadband coverage remains to be seen.

In our view, 5G and fixed broadband are both costly enterprises, and there will invariably remain geographies and clusters more uniquely suited to either 5G or fixed broadband connectivity. Thus, while we expect that 5G certainly will disrupt the way in which we access the internet, it will not replace and obviate the need for fixed broadband, and the global internet landscape, derivative industries, technologies and associated investment opportunities will continue to develop with strong influences from both technologies.



5. CONCLUSION: ACTION POINTS FOR INVESTORS

Whether it be virtual and augmented reality, factory automation, or self-driving cars, the successful commercialisation of these cutting-edge technologies predicate upon having a reliable underlying network infrastructure. In this investor's primer into the 5G sector by Stirling Infrastructure, we have introduced the spectrum and technology requirements of a 5G network, which incur high costs that need to be carefully considered as part of the roll-out strategy. We have discussed how a regulator's way of allocating spectrum, spectrum prices, and environmental, regulatory, and social/political risks can impact the rollout and expansion of a 5G network in different jurisdictions. We also examined the global patterns of 5G spectrum allocation, the impact of COVID19, and the leading manufacturers in the 5G value chain (handsets, chipsets, and network equipment). Based on our global overview, we have identified that a select few Asian and European economies followed by the US will reap the most value from 5G, while less developed economies will lag behind.

It is apparent that for advanced economies, deploying 5G presents a sound business case: 5G network with a significant degree of coverage will enable those countries willing to make the investment to create jobs, support new industries, and gain a competitive advantage over other economies. However, the current 5G ecosystem for both consumers and businesses is still at its early stages. Countries that are early adopters of 5G, as well as investors interested in 5G-enabled technologies and services, are subject to many risks and uncertainties.

We also note that there are situations where 5G does not make a sound case for investment, and that aggressive deployment regardless of the geographical realities of a location and the structure of its economy can present significant risks to cost recovery by MNOs. To illustrate this point, we analysed the major competitor to 5G in the consumer market: fixed fibre broadband. Additionally, while 4G is expected to stay well after 2035, other competitors to 5G not discussed in this paper, such as private licensed networks and Wi-Fi, can all compete with 5G in important non-consumer use cases such as manufacturing and R&D. Ultimately, knowing which technologies and use cases will truly benefit from 5G, and how the global internet landscape, derivative industries, technologies and associated investment opportunities will evolve, remains a challenge for investors.

Stirling Infrastructure as a firm supports clients in identifying the risks and opportunities in the 5G and broadband infrastructure sector, as well as 5G-enabled and broadband-enabled technologies and services. In doing so, we advise and execute on behalf of our clients on the selection of tangible, bankable investments. Stirling Infrastructure is experienced in project finance and raising capital for direct investment and infrastructure funds. With a global network of over 1500 institutional investors and market participants, the firm is well placed to advise on fund manager selection, asset valuations and M&A transactions.

ENDNOTES

1. IHS Markit. (2019). The 5G Economy: How 5G will contribute to the global economy. <https://www.qualcomm.com/media/documents/files/ihs-5g-economic-impact-study-2019.pdf>
2. The 5G value chain refers to: mobile network operators (MNOs), providers of core technologies and components, original equipment manufacturers (OEMs), infrastructure equipment manufacturers, and content and application developers. See IHS Markit. (2019). The 5G Economy: How 5G will contribute to the global economy. <https://www.qualcomm.com/media/documents/files/ihs-5g-economic-impact-study-2019.pdf>
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APPENDIX

LIST OF ABBREVIATIONS

Term	Definition
AI	Artificial Intelligence
AR	Augmented Reality
VR	Virtual Reality
C-RAN	Cloud Radio Access Network
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
DAS	Distributed Antenna System
EM Waves	Electro-Magnetic Waves
eMBB	enhanced Mobile Broadband
FCC	Federal Communications Commission
FTTC	Fibre to the Cabinet
FTTP/H	Fibre to the Premise/Home
GDP	Gross Domestic Product
GHz	Giga-Hertz
GSMA	Global System for Mobile Communications
HD	High Definition
IoT	Internet of Things
M&A	Mergers and Acquisitions
MCS	Mission Critical Services
MIMO	Multiple-input and Multiple-output
MIoT	Massive Internet of Things
MMTC	Massive Machine Type Communications
MNO	Mobile Network Operator
OPEX	Operating Expenditure
Q1/Q2/Q2/Q4	Financial Quarters
RAN	Radio Access Network
TCO	Total Cost of Ownership
URLLC	Ultra-Reliable Low Latency Communications
YoY	Year over Year

APPENDIX

LIST OF ADDITIONAL DEFINITIONS FOR TECHNICAL TERMS

Simple, non-technical definitions for industry-specific terms not extensively explained in the main text.

5G value chain: for the purpose of this report, refers to mobile network operators (MNOs), providers of core technologies and components, original equipment manufacturers (OEMs), infrastructure equipment manufacturers, and content and application developers.

5G ecosystem: for the purpose of this report, refers to the policies, strategies, processes, information, technologies, applications and stakeholders that together make up the technology environment for 5G in a country.

Wi-Fi: technology whereby wireless signals are typically accessed through a router connected to a local network, i.e. fixed broadband. Coverage is limited ranging from 20 metres indoors to 150 metres outdoors.

RAN (radio access network): all of the equipment in a network that connects a mobile device to the core network (backbone); called the “radio access network” because cell signals are transmitted via radio frequency EM waves.

Base station: commonly referred to as cell towers; contains equipment that houses radio transmitters and receivers that carry cell signals. Part of RAN.

Small cells: small cell towers that are designed to transmit and receive 5G millimetre wave signals; typically cover a smaller area than regular cell towers. Part of RAN. See “Base station”.

DAS (distributed antenna system): an interconnected system of antennas that transmit and receive cell signals just like base stations and small cells; if installed throughout a building, users can walk around without losing signal and having to reconnect (unlike Wi-Fi). Part of RAN. See “Wi-Fi”.

Massive MIMO (multiple-input, multiple-output): “massive” refers to the large number of smaller antennas that can be installed on a 5G cell tower, compared to previous generations of mobile broadband which use larger antennas. These antennas can communicate with multiple spatially separated user devices using the same frequency without interference, with a technology called “beam forming”. This maximizes the efficient use of limited spectrum resource. Part of RAN. See “Beam forming”.

Beam forming: a technology that allows signals to be steered directly to specific users, reducing signal interference in the air and enabling the same frequency to be used at the same time for different users, resulting in efficient spectrum use. Part of RAN. See “Massive MIMO”.

C-RAN (centralised/cloud-RAN): abbreviation means two related concepts: centralised RAN and cloud RAN. In a centralised RAN, the baseband processing unit (BBU) is moved from a base station to a central location. This approach reduces the cost of deploying new base stations, as one centralised equipment room can process cell signals from multiple remote base stations. Cloud RAN has the same architecture as centralised RAN, but instead of the MNO directly owning the baseband processing equipment, the baseband processing is handled in software run on a server owned by a third-party service provider. In a C-RAN, base stations are connected to the centralised equipment room via fibre optic cables. See “RAN,” “Base station”.

FOR FURTHER INFORMATION

This report is a primer that sets out some of the key themes and data sets that our analysts have assessed to be relevant for listed companies, institutional investors and companies in the telecommunications industry. If the report is of interest in relation to any M&A transaction services or for debt or equity capital raises for projects globally, please contact Stirling Infrastructure.

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