ericsson.com/5g

Understanding the Economics of 5G Deployments

An in-depth look at deployment economics for mobile broadband, fixed wireless access and Internet of Things

June 2020

Contents

Perspectives on 5G economics

5G will fundamentally change mobility by delivering higher speeds and enabling more innovative use cases than past generations of wireless technology could support.

For these reasons service providers are compelled to invest in 5G, and the business case has grown even stronger as the recent pandemic highlights the critical nature of mobile networks to the global economy.

For providers to capitalize on 5G, they must optimize the economics of these investments to maximize shareholder returns. Ericsson supports providers across the globe with their move to 5G, by evaluating network economics, assessing the market opportunity and developing go-to-market strategies that optimize capital investments and drive financial value to shareholders. Through this work, we have identified three key questions about 5G that are pivotal to building a business model for future 5G deployments:

1. What are the primary economic drivers of 5G?
2. How do economics vary under different deployment conditions?
3. What are the economics of a typical next-generation network deployment?

In answering these questions, this paper provides clarity to key economic parameters surrounding investments in 5G technology and spectrum. Leveraging our experience in 5G economics, strategy and deployments, this paper considers economics for pure-play deployment scenarios—mobile broadband (MBB), fixed wireless access (FWA) and Internet of Things (IoT). Also, the economics of a triple-play scenario are evaluated as a more representative example of deployments being considered for 5G. Although these scenarios are not based on actual provider deployments, the underlying assumptions reflect real-world conditions and yield useful insights.

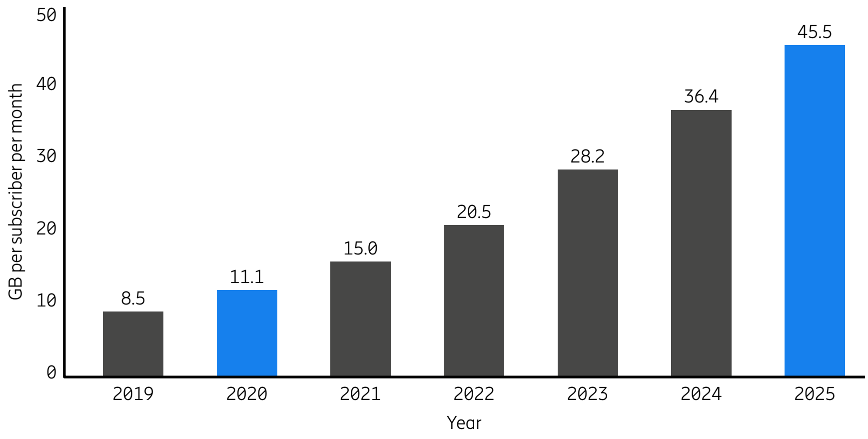
What are the primary economic drivers of 5G?

Traffic growth

Growth in mobile traffic is among the foremost economic drivers of next-generation wireless networks. As depicted in Figure 1, the **Ericsson Mobility Report**[1] projects traffic in North America will grow from 11.1 gigabytes (GB) per subscriber per month in 2020 to 45.5 GB per subscriber per month by 2025.

This trend has profound implications for providers, portending not only the need for future investments in network capacity, but with the prevalence of unlimited data plans, a continued decline in revenue per GB that makes unit economics – cost and margin per GB – increasingly important drivers of profitability.

Figure 1: Mobile traffic per subscriber, North America



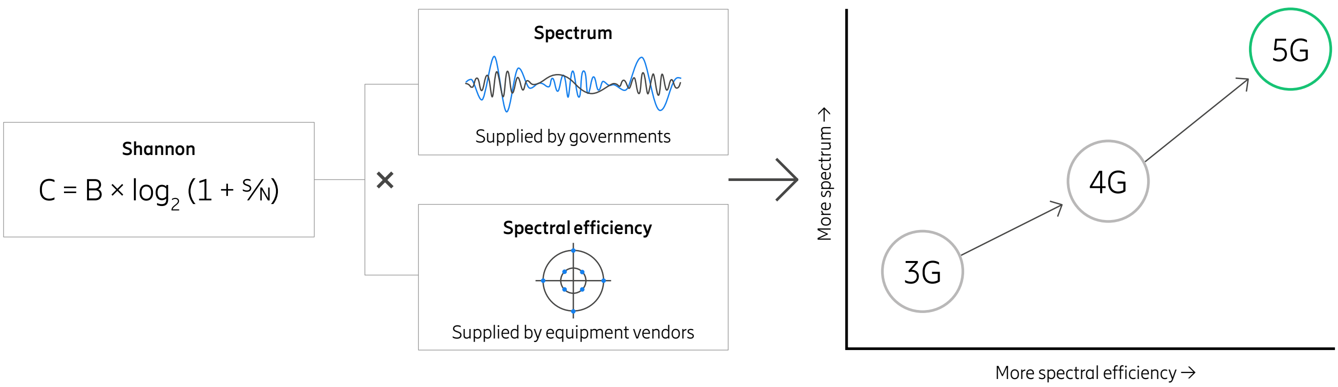
Shannon's law

Perhaps unknowingly in 1948, Claude Shannon framed the primary cost drivers for the wireless industry through his work in information theory. Shannon characterized the wireless channel as the combination of spectrum, which providers purchase from governments, and spectral efficiency, which providers purchase from companies such as Ericsson.

As shown in Figure 2, these two-factor inputs have steadily evolved with each generation of wireless technology as governments release more spectrum and as technology companies extract more capacity from each ripple of spectrum deployed.

But each has limits. Spectrum is a constrained natural resource, at least within the frequency bands considered suitable for cellular communication. Spectral efficiency is bound by a ceiling defined by Shannon, notwithstanding technical advancements such as multi-user, multiple input, multiple output (MU-MIMO). In addition to pushing the envelope on spectrum and spectral efficiency, the industry is deploying new network models such as small cells and distributed antenna systems (DAS) that are more efficient than traditional network models per unit but will drive higher unit volumes. In this context, service providers must work to understand and optimize the economics of next-generation wireless investments. The rest of this paper further develops these ideas.

Figure 2: Shannon and wireless factor inputs



[1] Released November 2019. www.ericsson.com/en/mobility-report

How do economics vary under different deployment conditions?

Economic analysis of pure-play deployments

Three pure-play scenarios (MBB, FWA and IoT) were evaluated using Ericsson's 5G economics model to demonstrate how performance varies under different deployment conditions. For the purpose of this study, each scenario assumes a greenfield deployment within a 100sq km market area over seven years. Traffic profiles were assumed for each use case, representing the speeds (Figure 3) and payloads (Figure 4) per connection during the busy hour – defined as the time during a 24-hour period where traffic consumption is highest among end users.

IoT encompasses a wide range of use cases, from lower-traffic, smart-meter applications to higher-traffic telemedicine solutions. This study assumes a "generic" IoT use case, based on the traffic profile in Figures 3 and 4.

As defined in the matrix in Figure 5, four primary sensitivities were considered for each use case:

- MIMO
- Connection density
- Spectrum band
- Channel bandwidth

Figure 3: Busy hour payload per connection

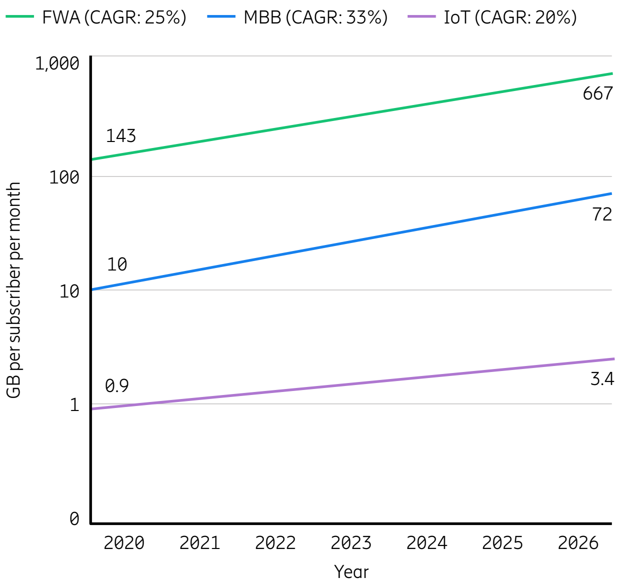


Figure 4: Busy hour traffic per connection

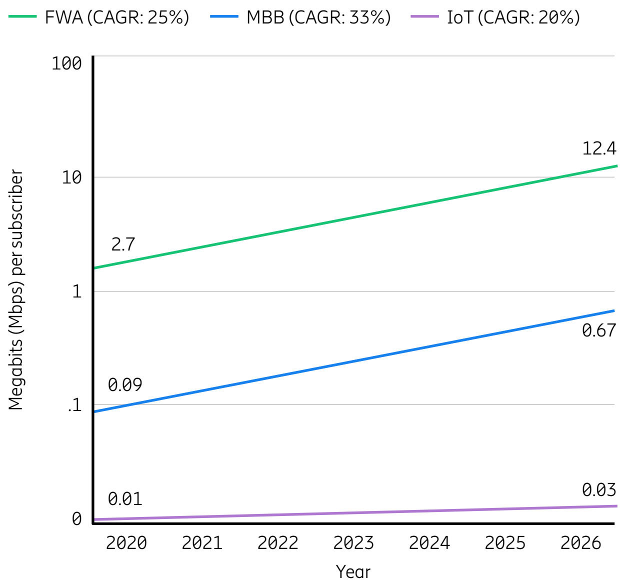


Figure 5: Sensitivities

		Low-band spectrum (700MHz, frequency division duplex)			Mid-band spectrum (3.5GHz, time division duplex)			High-band spectrum (28GHz, time division duplex)		
		Narrow bandwidth (10x10MHz)	Moderate bandwidth (15x15MHz)	Wide bandwidth (20x20MHz)	Narrow (20MHz)	Moderate (40MHz)	Wide (60MHz)	Narrow (200MHz)	Moderate (400MHz)	Wide (800MHz)
Single-user MIMO (Assumes 4x4 MIMO)	Urban connection density* (4,000 people/km²)									
	Suburban connection density* (1,000 people/km²)									
	Rural connection density* (250 people/km²)									
Multi-user MIMO (Up to 8 users)	Urban	Not applicable**								
	Suburban									
	Rural									

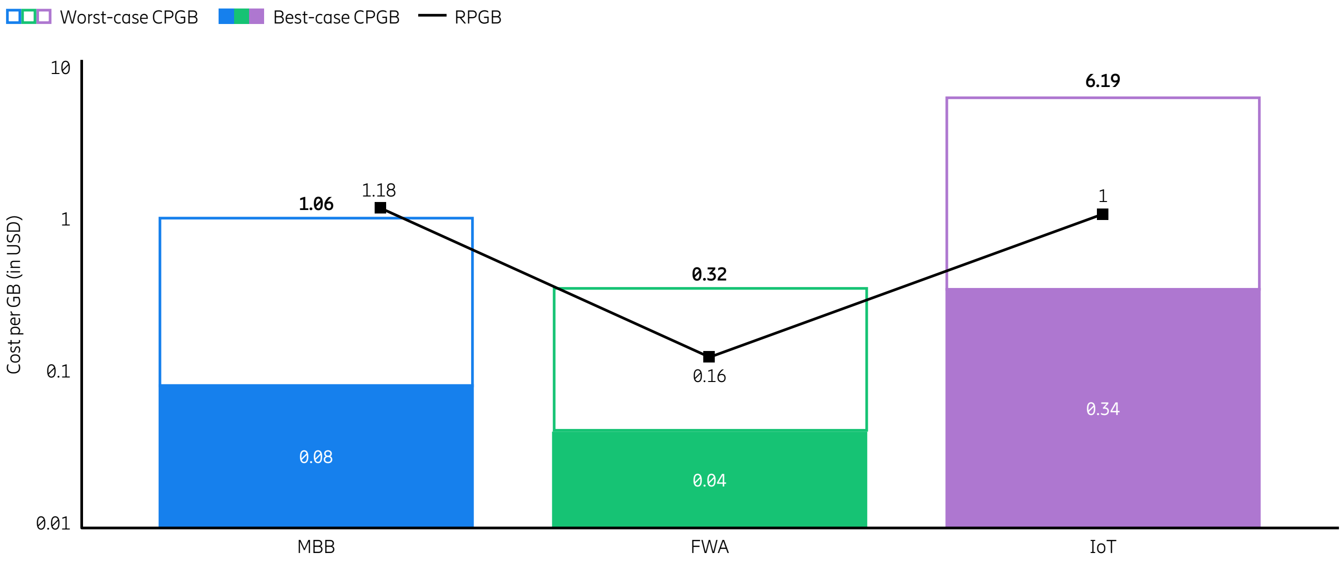
*Connection densities for FWA and IoT are multiples of those for MBB: FWA = MBB × 0.4; IoT = MBB × 2
**Low-band's large wavelengths make MU-MIMO infeasible for this spectrum at this time.

Finally, all scenarios assume a 33 percent provider market share and utilize macros for coverage and micros for capacity. Based on these and other assumptions, summary cost per gigabyte[2] (CPGB) and revenue per gigabyte[3] (RPGB) are shown in Figure 6 for each use case.

Results

- MBB is the most profitable, robust use case, with unit margins (RPGB, CPGB) positive under all conditions evaluated in this study.
- FWA performs well under some, but not all, conditions. Because FWA's traffic profile far exceeds that of MBB, its RPGB is substantially lower than MBB's, as are its unit costs.
- Like FWA, IoT performs well under some, but not all, conditions. IoT also has higher unit costs on average than those of MBB and FWA, largely due to its relatively low assumed traffic profile.

Figure 6: Summary unit costs and revenues by use case (year 7)



[2] Cost per GB is calculated by dividing cumulative network OPEX and CAPEX, including customer premise equipment (CPE) for FWA, by cumulative traffic over seven years.

[3] Revenue per GB is calculated by dividing cumulative revenue by cumulative traffic over seven years.

The heat map in Figure 7 reveals additional details behind the summary view in Figure 6, in which CPGB is reported by bandwidth, MIMO, spectrum band and channel bandwidth.

This matrix highlights the wide variability of performance under different conditions.

- MBB performs well in all but rural scenarios with high-band spectrum. It excels with mid-band spectrum, whose unique mix of coverage and capacity aligns with MBB's traffic and subscriber density profile.
- FWA performs best with wider channels of mid-band spectrum and with high-band spectrum in denser markets, and in rural markets subsidized by government funding, such as the Connect America Fund (CAF) and the Rural Digital Opportunity Fund (RFOF). It also benefits from MU-MIMO, which restores profitability in some mid-band scenarios that otherwise would be unprofitable. FWA also can be served economically with wider channels of low-band spectrum in rural markets that benefit from CAF or RDOF funding.
- IoT is best served by low- and mid-band spectrum, although more advanced, high-traffic and/or low-latency IoT use cases likely will benefit from the increased speed and capacity of high-band spectrum assets.

High band is largely immune to changes in channel bandwidth and MIMO. This can be explained in part by high band's propagation characteristics, which yield deployments that are range-limited by the uplink. To achieve full-market coverage, more sites are deployed than are needed to serve demand, resulting in a capacity surplus that reduces the impact of MU-MIMO, at least initially. This uplink limitation also makes coverage dimensioning largely insensitive to channel bandwidth.

Finally, MU-MIMO yields modest capacity gains, assuming conservatively that up to eight users can be served simultaneously.[4] For FWA, MU-MIMO gains would likely be higher than assumed because customer premise equipment (CPE) is stationary, allowing radio circuitry to optimize performance more fully than for mobile devices.

Figure 7: Cost per GB (CPGB) sensitivities

CPGB < RPGB | CPGB = RPGB | CPGB > RPGB

			Low-band spectrum			Mid-band spectrum			High-band spectrum		
			Narrow	Moderate	Wide	Narrow	Moderate	Wide	Narrow	Moderate	Wide
MBB	SU-MIMO	Urban	0.50	0.34	0.25	0.31	0.17	0.12	0.13	0.11	0.11
		Suburban	0.46	0.31	0.23	0.30	0.17	0.13	0.31	0.31	0.31
		Rural	0.75	0.51	0.38	0.67	0.38	0.29	1.06	1.06	1.06
	MU-MIMO	Urban	N/A			0.20	0.11	0.08	0.11	0.11	0.11
		Suburban				0.20	0.12	0.09	0.31	0.31	0.31
		Rural				0.46	0.28	0.22	1.06	1.06	1.06
FWA	SU-MIMO	Urban	0.32	0.22	0.17	0.20	0.11	0.08	0.06	0.05	0.04
		Suburban	0.29	0.21	0.16	0.19	0.11	0.08	0.09	0.08	0.07
		Rural*	0.25	0.17	0.13	0.14	0.09	0.07	0.13	0.12	0.12
	MU-MIMO	Urban	N/A			0.14	0.08	0.06	0.05	0.04	0.04
		Suburban				0.13	0.08	0.06	0.08	0.07	0.07
		Rural*				0.10	0.07	0.06	0.12	0.12	0.12
IoT	SU-MIMO	Urban	0.59	0.44	0.36	0.57	0.46	0.43	0.75	0.75	0.75
		Suburban	0.54	0.41	0.34	0.64	0.51	0.47	1.98	1.98	1.98
		Rural	0.80	0.59	0.48	1.34	0.93	0.76	6.19	6.19	6.19
	MU-MIMO	Urban	N/A			0.43	0.36	0.34	0.75	0.75	0.75
		Suburban				0.51	0.42	0.38	1.98	1.98	1.98
		Rural				1.11	0.80	0.66	6.19	6.19	6.19

*Capital expenditures for rural FWA deployments are assumed to be 80% subsidized by funding from Connect America Fund (CAF) or Rural Digital Opportunity Fund (RDOF).

[4] MU-MIMO allows multiple users to be served simultaneously by the same spectrum resources, effectively multiplying spectral efficiency (capacity) relative to single user (SU)-MIMO

What are the economics of a typical next-generation network deployment?

Economic analysis of a multi-play deployment

Next, a triple-play scenario is considered, serving MBB, FWA and IoT within a 100sq km suburban market area. This scenario assumes a greenfield deployment, 33 percent provider market share, the same traffic profiles as the pure-play deployment and single-user (SU) MIMO, but utilizes all three spectrum bands apportioned by site type as follows:

Macro cell
- Low-band: 15x15MHz
- Mid-band: 40MHz
- High-band: 400MHz

Micro cell[5]
- Mid-band: 40MHz
- High-band: 400MHz

By supporting multiple use cases and spectrum bands, this type of deployment can yield more attractive economics than pure-play scenarios because network and spectrum assets can be optimized for demand. Here, spectrum assets align with the traffic profiles of each use case to improve network utilization. It's important to note that the benefits of carrier aggregation (CA), in which multiple frequency bands are combined to improve network performance, are not fully reflected in this study, and would further improve the economics of deployment.

Results

MBB, FWA and IoT connections (Figure 8) are phased in over five years, growing beyond 100,000 connections collectively, of which IoT represents more than 50 percent.

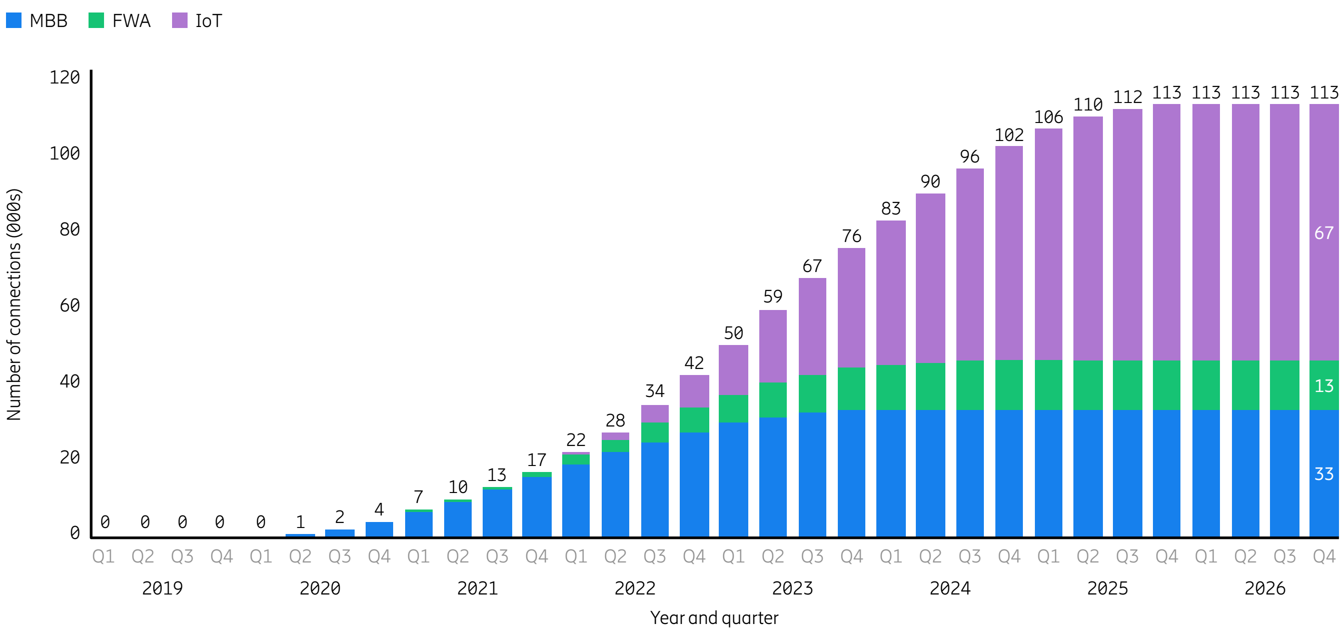
MBB delivers the most revenue as shown in Figure 9, followed by FWA and IoT, based on assumed pricing of USD 45 per subscriber per month for MBB, USD 65 per home per month for FWA, and USD 1 per GB for IoT.

Traffic approaches 12,000 terabytes (TB) per month across all use cases, or roughly 100 GB per connection per month by the end of 2026, blended across all use cases and connections. As shown in Figure 10, this study assumes the downlink carries 10 times as much traffic as the uplink, a reasonable assumption today, but one that could change as user-generated content shifts more traffic to the uplink.

As shown in Figure 11, sites grow from an initial coverage layer of 16 macros and 1 micro to a combined total of 96 macros and micros over seven years, resulting in an approximate 1km spacing between sites. Note that this growth in sites could be mitigated by the use of additional spectrum, a degree of freedom not considered in this mini-study, but one that is relevant for operators with deeper spectrum portfolios.

The coverage layer supports demand for around two years before densification ensues. The use of MU-MIMO would reduce ending site counts to roughly 70. Also, note that MU-MIMO does not affect the number of coverage sites because the coverage layer is limited by the uplink.[6]

Figure 8: Connections



[5] A typical micro may not be able to support two separate radios due to factors such as weight and wind loading, but this configuration is assumed for the purpose of this study.

[6] The current generation of MU-MIMO is assumed to benefit the downlink, not the uplink. Future generations will serve both links and drive additional performance gains.

Figure 9: Revenue

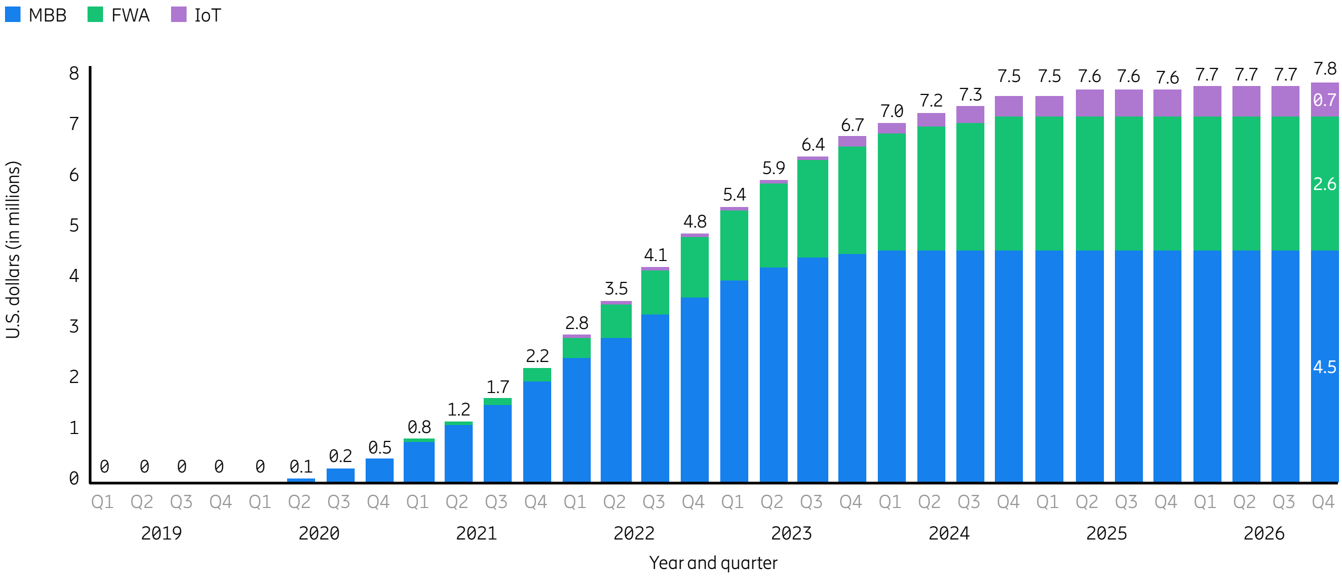


Figure 10: Traffic

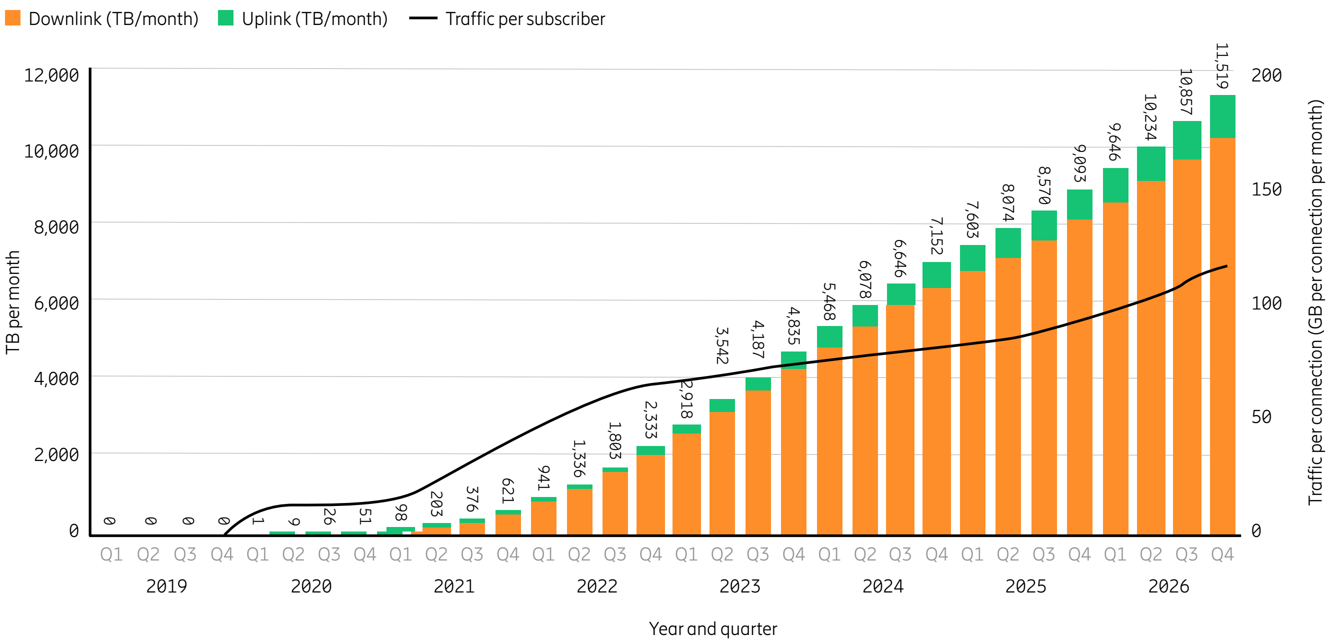
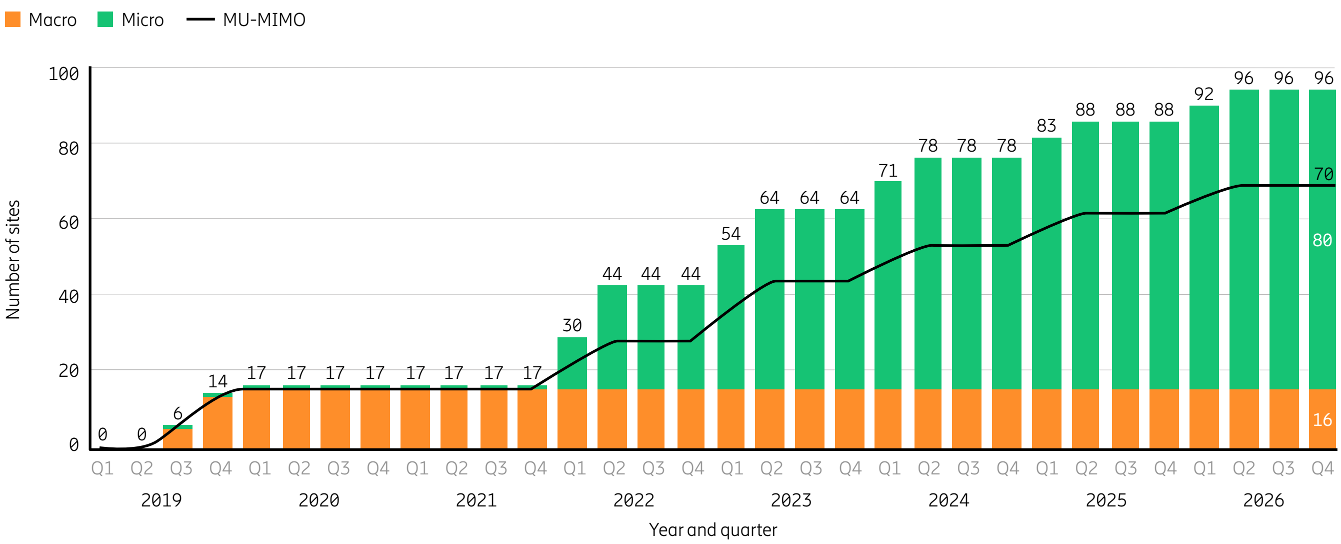


Figure 11: Sites



Loading by site type and spectrum reveals which radio link drives densification. In Figure 12, the downlink is capacity-limited, as evidenced by full loading of all spectrum bands during the busy hour, causing more sites to be deployed over time as traffic demands grow.

Conversely, the uplink runs below full capacity, as shown in Figure 13, where fluctuations in utilization are caused by densification waves that create peaks and valleys in uplink capacity. Loading is sensitive to certain radio frequency (RF) assumptions, such as the link curves used, the amount of bandwidth allocated to the uplink and downlink and the use of SU- versus MU-MIMO. Any imbalance between the uplink and downlink indicates room for optimization.

Operating expense (OPEX) includes both subscriber and network costs (see Figure 14). Because this is a greenfield deployment, subscriber acquisition costs (CPGA) grow initially with gross adds then level off as churn replacement sets in, while subscriber support costs (CCPU) scale linearly with connections.

Network OPEX trends toward USD 1.7 million annually, largely comprising lease and transport costs; however, OPEX can vary widely by provider and geography.

The investments required to deploy this network are profiled in Figure 15. The initial investment spike represents a one-time outlay for spectrum of approximately USD 5 million. The remaining spikes correspond to a macro coverage investment of around USD 5 million, followed by densification investments, which drive cumulative network CAPEX to a little more than USD 15 million over seven years, excluding spectrum and CPE. A material capital item for FWA, CPE warrants careful evaluation to optimize factors such as quality and location (indoor, window, rooftop), which can have sizable impact on network performance. This study assumes the installed cost of CPE is USD 500, of which the provider subsidizes 50 percent.

Net present value (NPV) and cumulative cash flow break even in three to four years assuming 10 percent weighted average cost of capital (WACC), pre-tax cash flows and no terminal value – yielding strong economic returns from this deployment scenario (see Figure 16).

Figure 12: Downlink loading

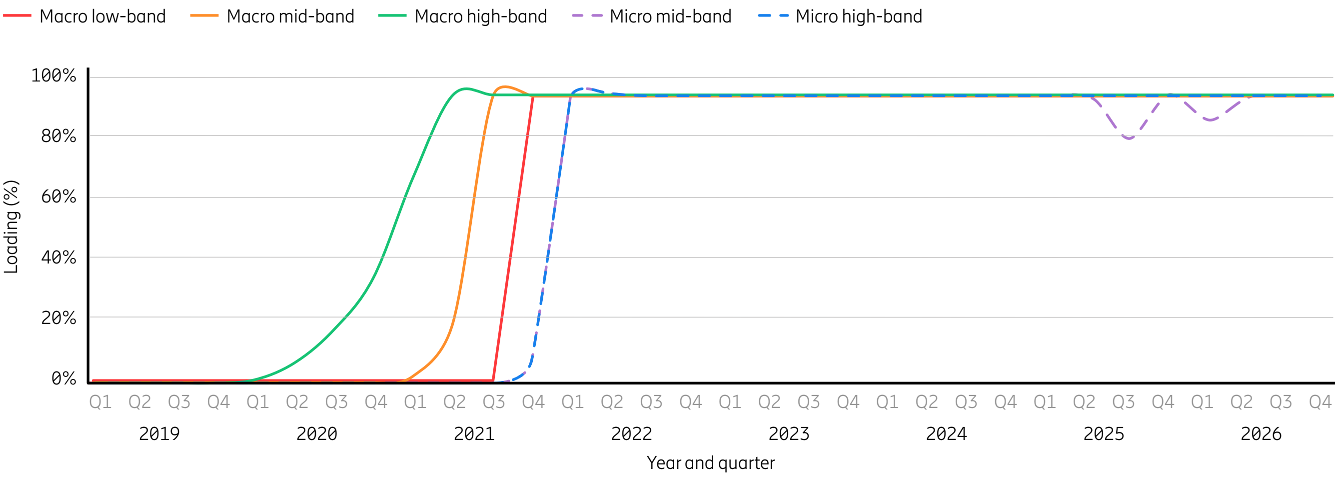


Figure 13: Uplink loading

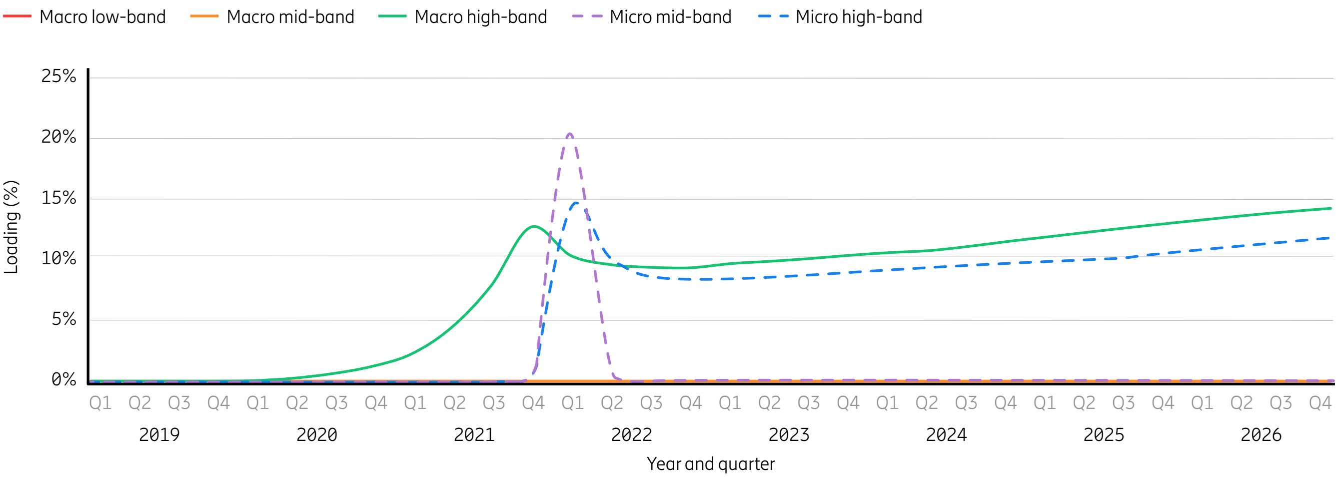


Figure 14: Operating expense (OPEX)

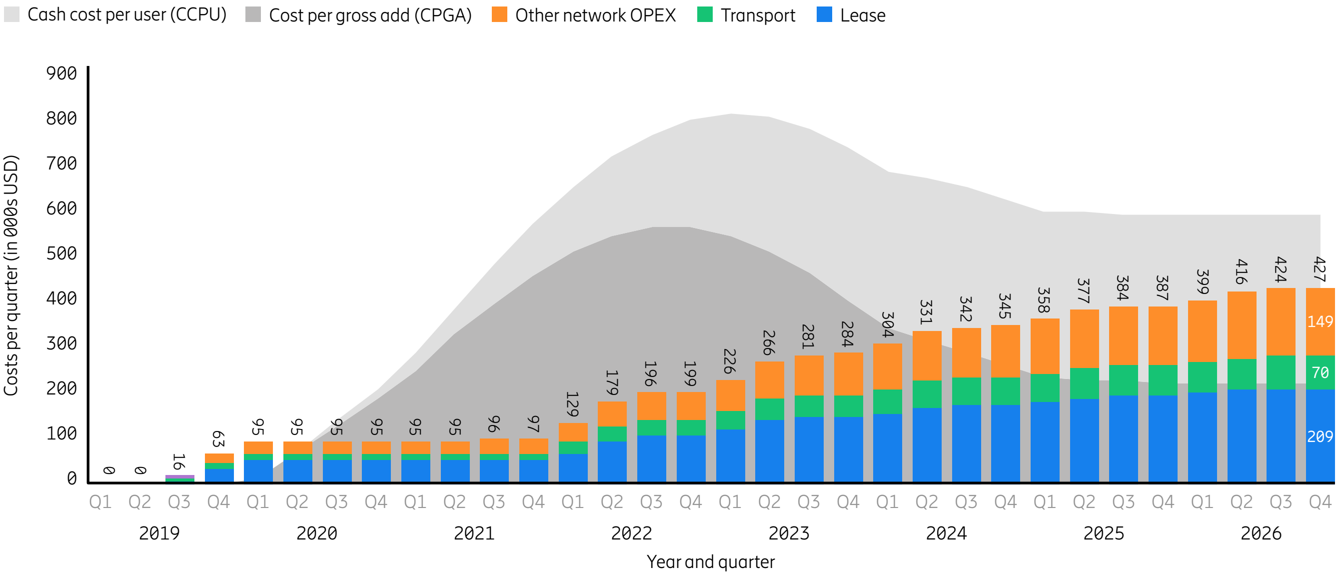


Figure 15: Capital expenditure (CAPEX)

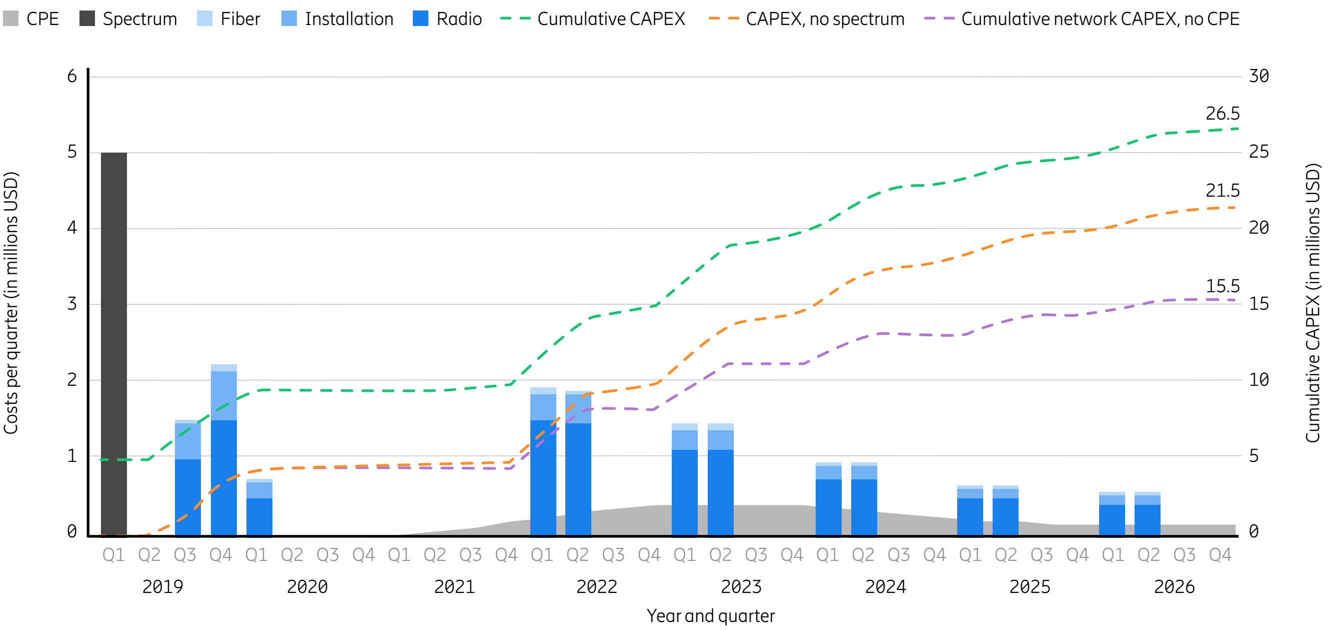
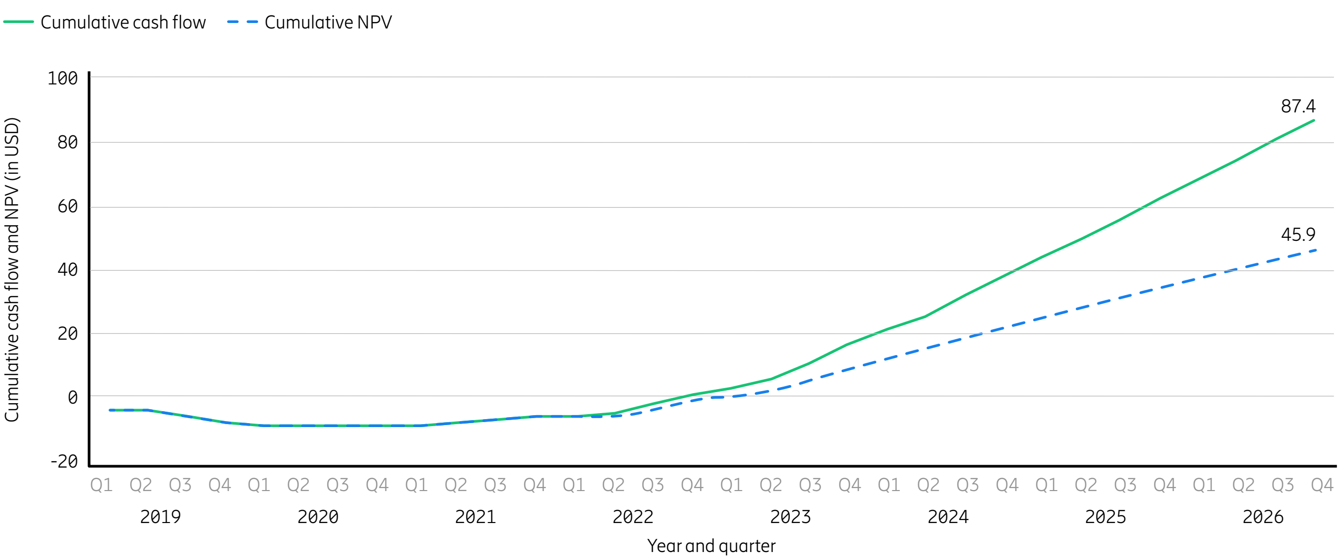


Figure 16: Cumulative cash flow and NPV



Cumulative and marginal unit economics are profiled in Figure 17. Cumulative values carry forward investments, revenues and traffic from the beginning of the deployment, and thus tie most closely to shareholder value. On this basis, RPGB reaches USD 0.38 per GB and CPGB approaches USD 0.09 per GB, yielding margin per GB of USD 0.29 or approximately 76 percent.

Marginal values treat historical investments, revenues and traffic as sunk and report only in-quarter performance. On this basis, RPGB reaches USD 0.23 per GB and CPGB approaches USD 0.03 per GB on average, yielding margin per GB of USD 0.20 or approximately 87 percent. Fluctuations in marginal CPGB are caused by periodic investments for densification.

Sensitivities

CPGB was sensitized by varying busy hour demand and connection density. As shown in Figure 18, CPGB declines as user traffic increases because traffic grows more than investment does, reducing the cost of each additional GB delivered. CPGB also improves with density because more connections per unit area beget more connections (and revenue) per site; the traffic from which can be absorbed in part by unutilized capacity, allowing more traffic to be carried with little or no additional investment.

Figure 17: Cost and revenue per GB

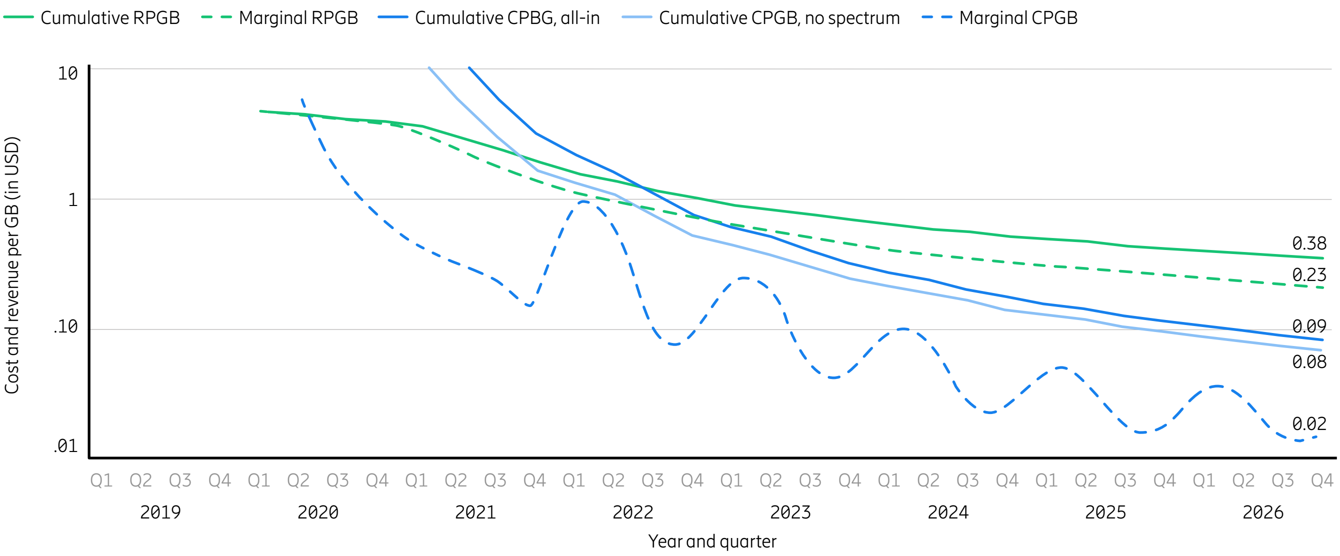
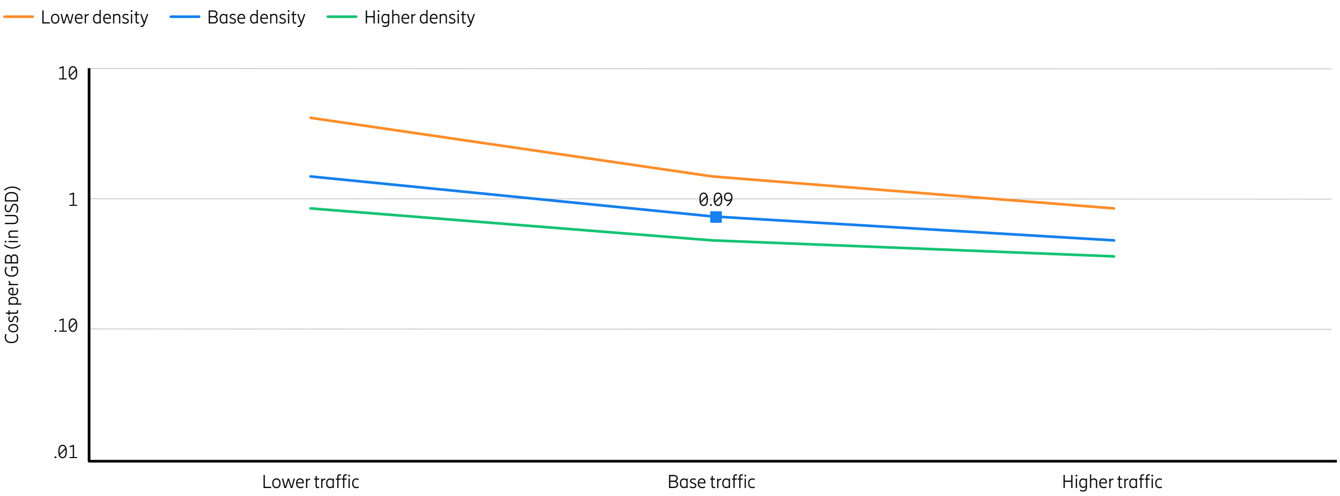


Figure 18: Cost per GB (CPGB) sensitivities



Selected insights

Based on the outcome of our study, providers should consider these selected insights as they work to build out their 5G business model and investment strategy:

The value of a gigabite (GB) is not fixed, but varies over time and by use case, spectrum, bandwidth, morphology and other factors. Optimizing this key performance indicator (KPI) requires close attention to these and other parameters to identify the conditions under which networks perform best.

With its unique coverage and capacity characteristics, mid-band can support a wide variety of use cases, in part explaining the strong interest in Citizens Broadband Radio Service (CBRS), C band, and others within the 2 to 6 GHz range.

Markets with more connections per unit area generally yield better economic performance than those with fewer connections because density drives utilization, yielding more revenue and margin per dollar of investment.

Mobile broadband (MBB) proves to be a uniquely attractive use case with its mix of higher average revenue per user (ARPU) and moderate traffic demand. These attributes yield positive economics that are resilient to a wide range of deployment conditions.

MU-MIMO can improve performance by reducing and forestalling investments needed to keep pace with market demand, even with the modest gains assumed in this study.

About Ericsson's 5G Strategy and Economics team

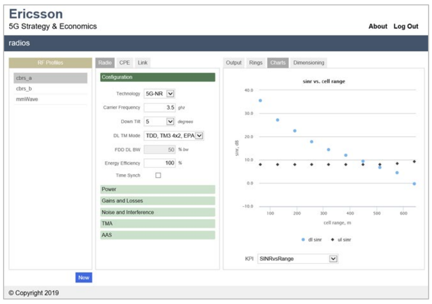
The 5G Strategy and Economics team at Ericsson has delivered more than 70 engagements globally, helping service providers and investors understand and optimize the economics and go-to-market strategies of next-generation wireless networks.

We combine depth in RF theory with expertise in commercial strategy and economics to drive actionable insights from our work.

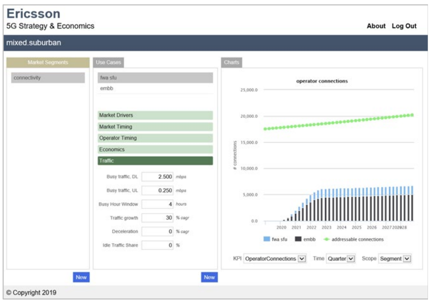
During the course of our work, we developed a 5G economics model that simulates the RF, demand-side and economic aspects of next-generation wireless deployments.

Our team works with service providers to help them reach their operational and business goals quickly and cost-effectively. Learn how Ericsson can help you at www.ericsson.com/5g.

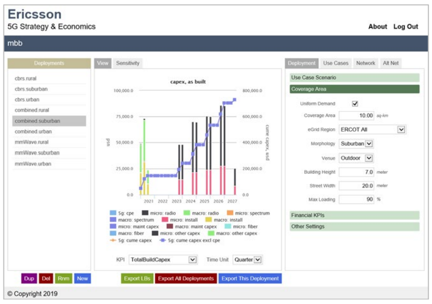
5G economics model



RF model: Applies advanced RF simulation techniques to dimension wireless networks with any combination of spectrum bands from 600 MHz to 100 GHz.



Demand model: Forecasts subscriber economics, connections and traffic for any combination of use cases, including MBB, FWA and IoT.



Economic model: Integrates the RF and demand models to evaluate the economics of tens to thousands of deployment scenarios and sensitivities to quantify and optimize network economics under a wide variety of deployment capabilities.

About the author

As Ericsson's Head of 5G Strategy and Economics, David Waite works with service providers and investors globally to define the investment case and go-to-market strategy for next-generation wireless networks. He has more than 20 years of experience in the telecommunications sector through senior-level roles in management consulting, corporate strategy and industry.

www.linkedin.com/in/david-waite-a005603
david.t.waite@ericsson.com

Glossary

ARPU: average revenue per user

Busy hour: The window of time within a 24-hour period during which traffic consumption is highest among end users

CAF: Connect America Fund

CBRS: Citizens Broadband Radio Service

CCPU: cash cost per user (recurring)

CAGR: compound annual growth rate

CPE: customer premise equipment

CPGA: cost per gross add, excluding CPE (non-recurring)

CPGB: cost per GB

DAS: distributed antenna system

Densification: deployment of additional sites, typically micros

FDD: frequency division duplex

FWA: fixed wireless access

GB: gigabyte

IoT: Internet of Things

MBB: mobile broadband

MIMO: multi-input, multi-output antenna

MNO: mobile network operator

MSO: multiple system operator

MU-MIMO: multi-user MIMO

NPV: net present value

RDOF: Rural Digital Opportunity Fund

RF: radio frequency

RPGB: revenue per GB

SU-MIMO: single-user MIMO

TB: terabyte

TDD: time division duplex

WACC: weighted average cost of capital

Ericsson enables communications service providers to capture the full value of connectivity. The company's portfolio spans Networks, Digital Services, Managed Services, and Emerging Business and is designed to help our customers go digital, increase efficiency and find new revenue streams. Ericsson's investments in innovation have delivered the benefits of telephony and mobile broadband to billions of people around the world. The Ericsson stock is listed on Nasdaq Stockholm and on Nasdaq New York.

www.ericsson.com

Ericsson
SE-164 80 Stockholm, Sweden
Telephone +46 10 719 0000
www.ericsson.com