



5G Spectrum and Economic Challenges

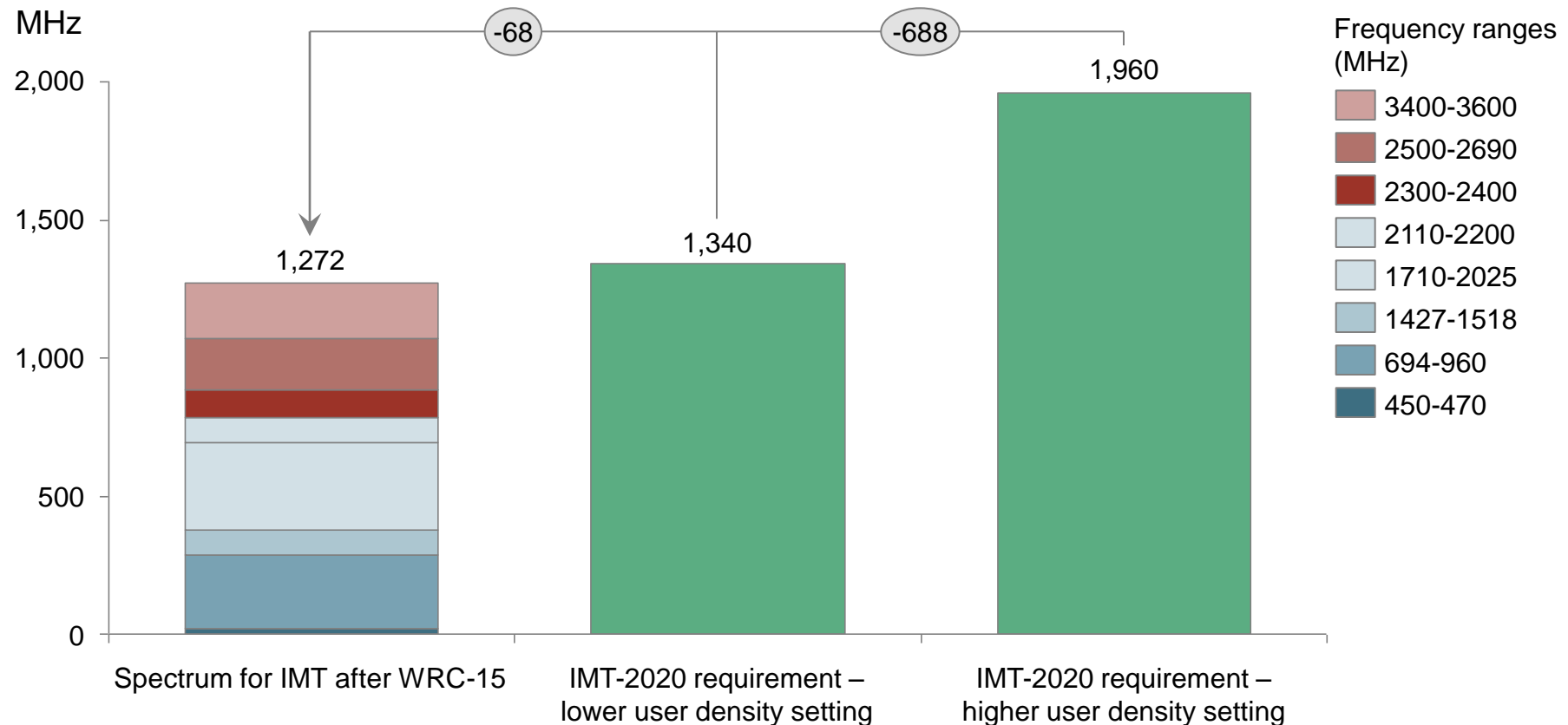
IEEE 5G Summit in Lisbon

January 19th, 2017

THE BOSTON CONSULTING GROUP

New spectrum required for IMT-2020 and 5G

Spectrum available and required for IMT-2020



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Nearly 700 MHz additional spectrum required until 2020 in higher user density setting

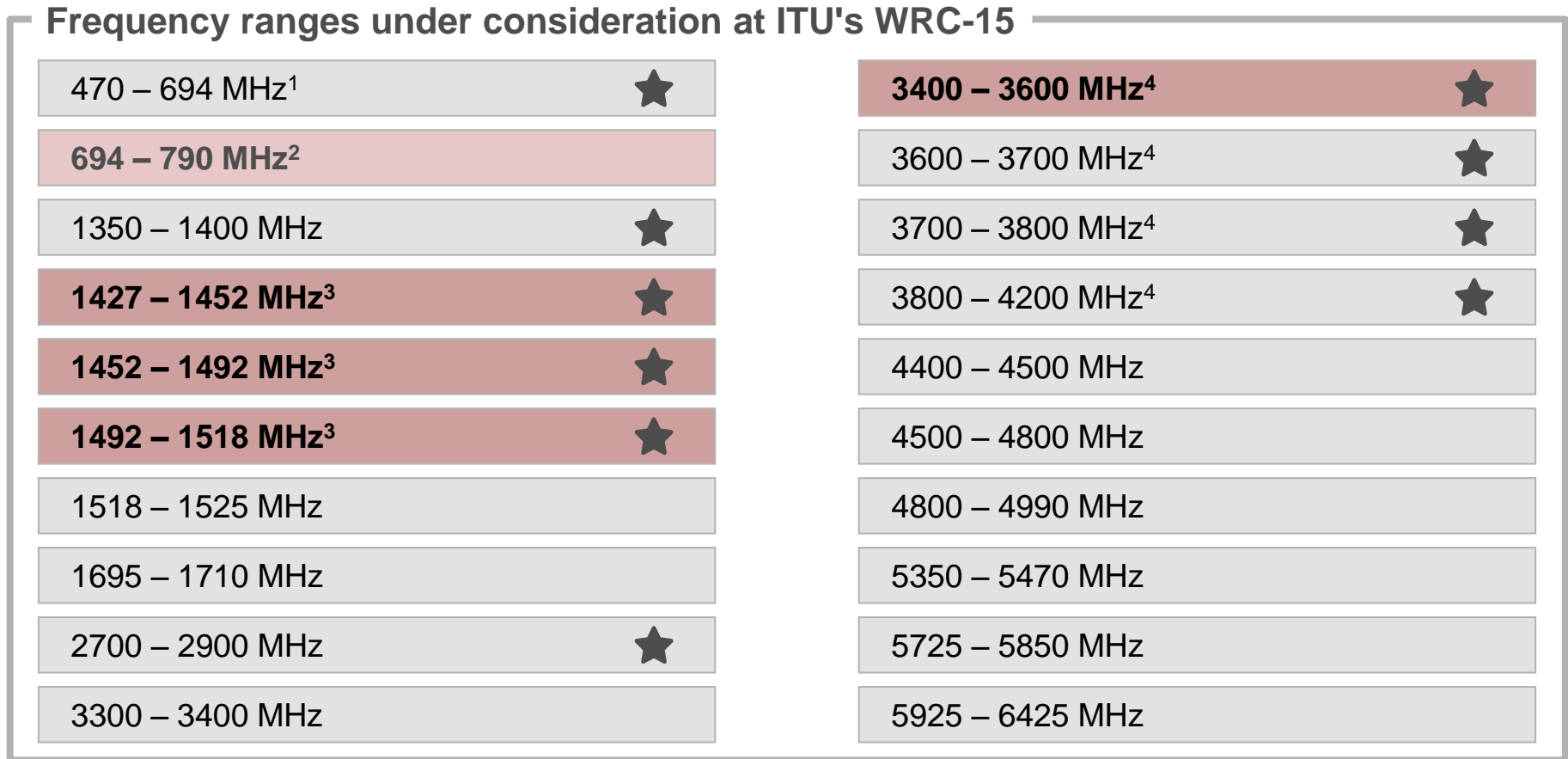
Note: IMT = International mobile telecommunications

Source: ITU-R (M.2290-0; 12/2013), BCG

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Consensus on new frequency ranges for IMT is difficult

Overview of bands under consideration and allocated at ITU's WRC-15



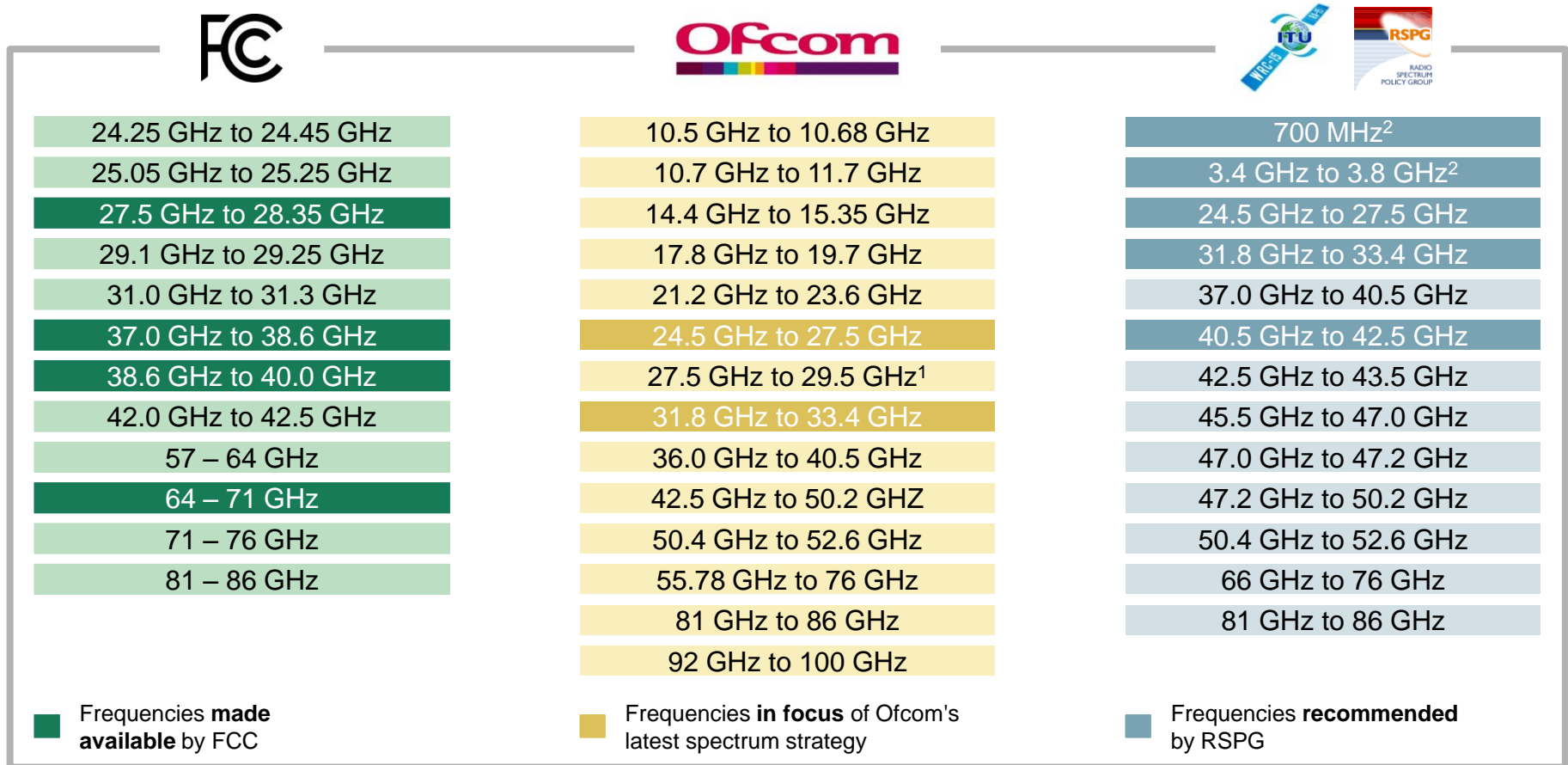
★ Frequency ranges recommended by GSMA

■ New frequency ranges allocated for IMT

Relatively little additional spectrum allocated to IMT

1. IMT in ITU regions 2 (Americas) and 3 (Asia-Pacific); 2. ITU region 1 (Europe, Africa, the Middle East and Central Asia); 3. Allocated to IMT worldwide except parts of Africa and Asia; 4. 3500 – 4200 MHz already allocated to IMT in ITU regions 2 and 3; Note: IMT = International mobile telecommunications; Source: ITU (2016), GSMA (2015), BCG analysis

Various frequency ranges are being considered for IMT-2020 and 5G



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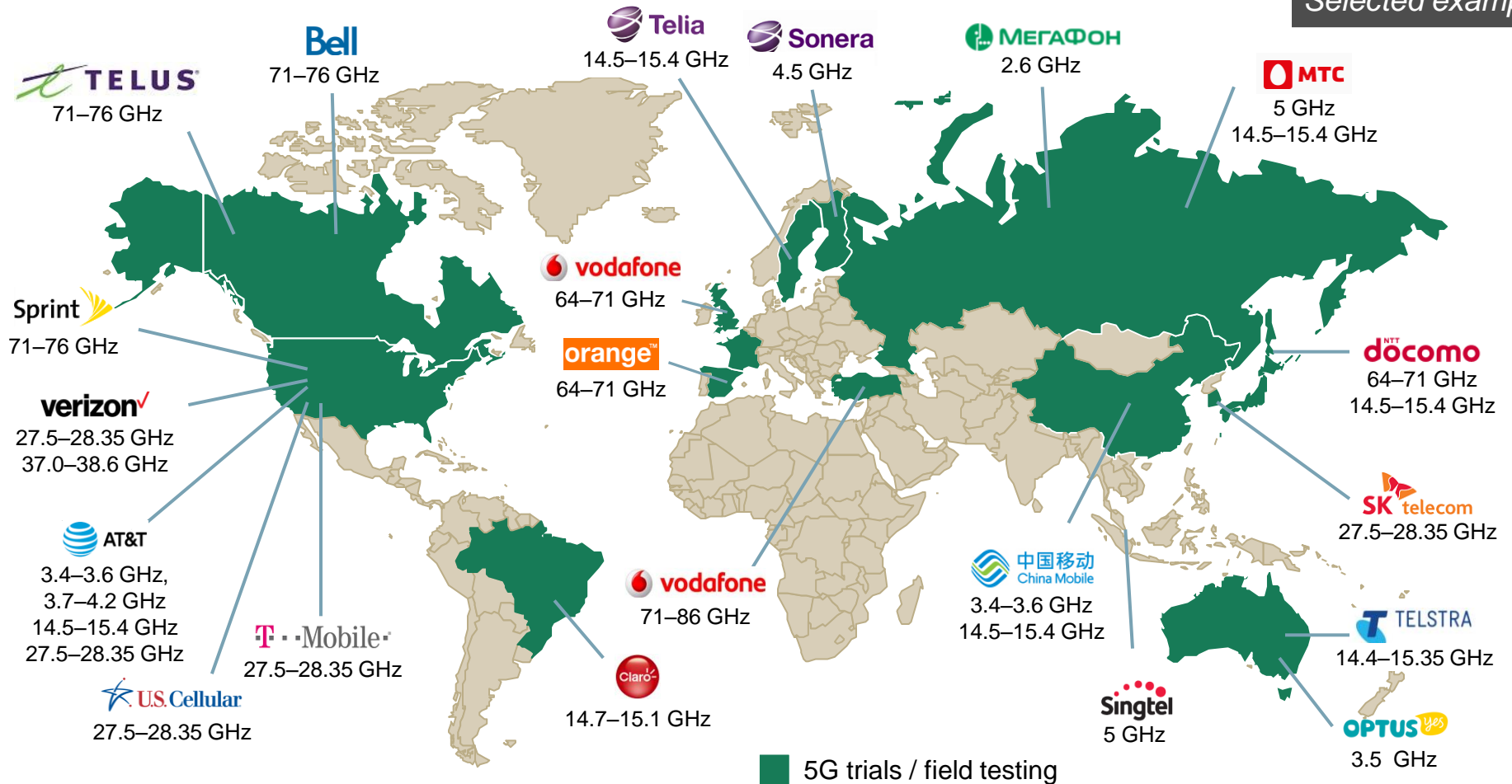
Global harmonization of 5G spectrum will be challenging

1. Previous frequency range recommended was 25.25-29.5 GHz; 2. 700 MHz and 3.4 to 3.8 GHz considered by ITU in addition to WRC-19 studies; Note: IMT = International mobile telecommunications; Source: FCC (Notice of Inquire, 2014; Notice of Proposed Ruling, 2015; Notice of New Rules, 2016), Ofcom, (2015/2016), ITU (2016), RSPG (2016), GSA (2016), BCG analysis

Operators are trialing 5G on numerous spectrum bands

Overview 5G trials and used spectrum bands¹

Selected examples

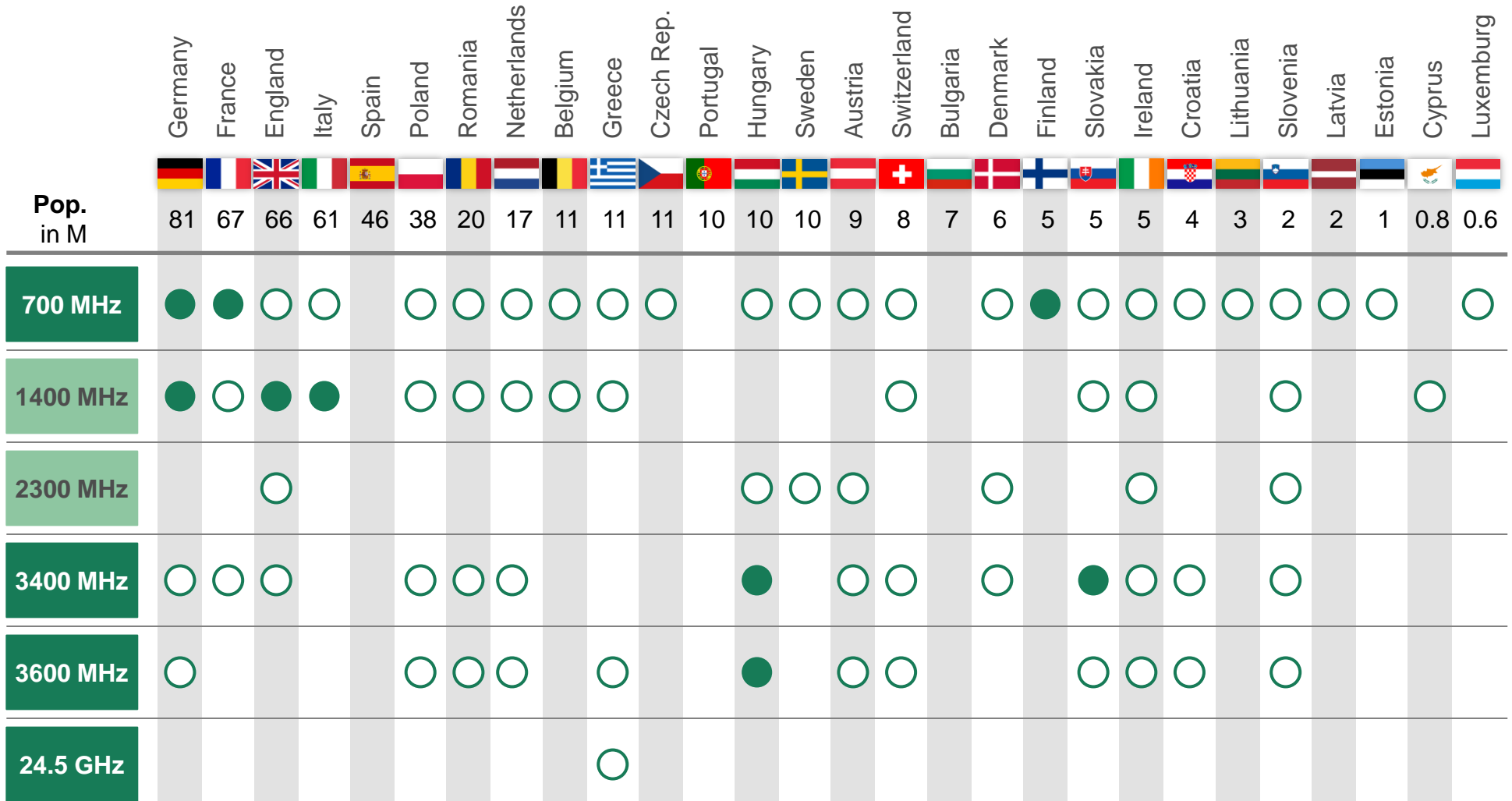


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Preferred 5G spectrum bands start to crystallize, e.g. around 3 GHz and 28 GHz

1. Bandwidths of several 100 MHz typically used in 5G trials
Source: Company press releases, BCG press research, GSA (2016)

European telecoms regulators currently focusing on allocating low and mid frequency bands for 4G – and 5G



● 2015-16 ○ 2017+

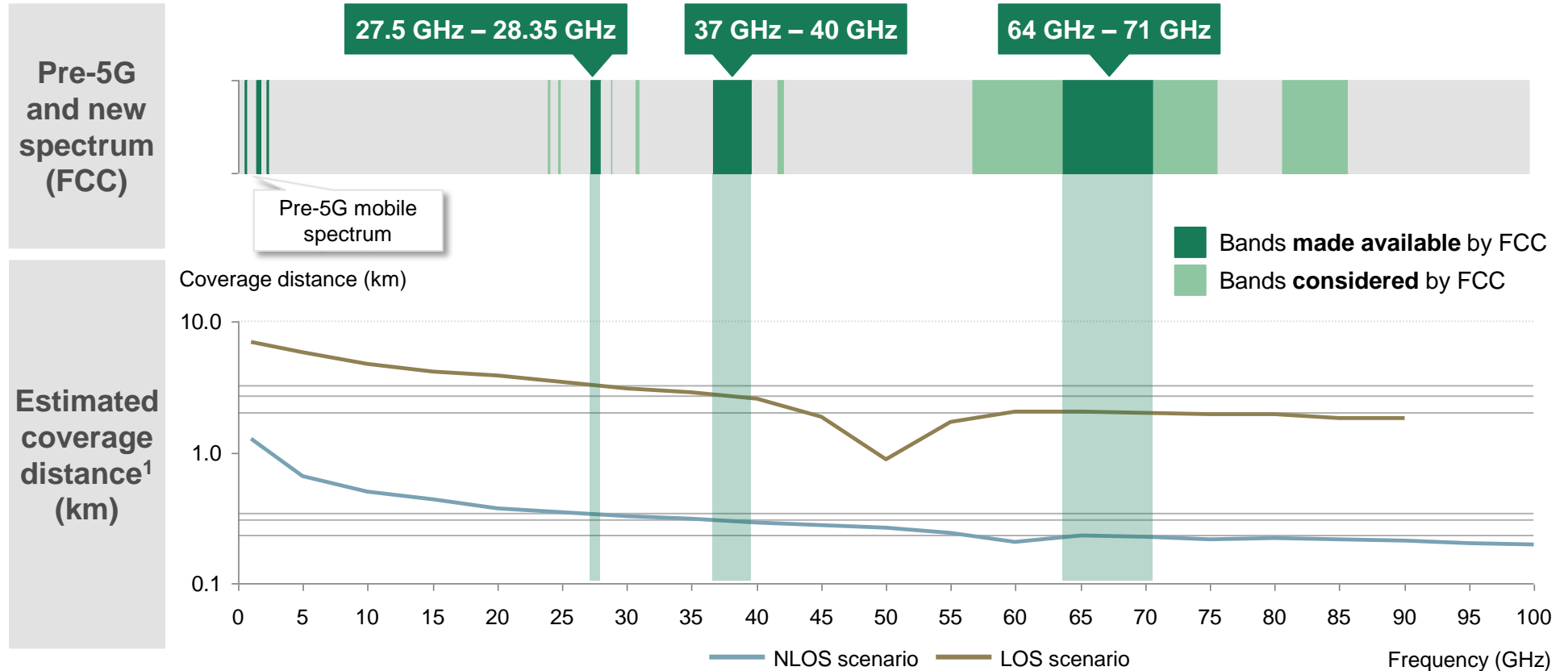
Source: News reports, NRAs, BCG Note: EU and Switzerland

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Large amount of 5G spectrum available above 20 GHz

Example



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No significant difference of spectrum bands in mmWave

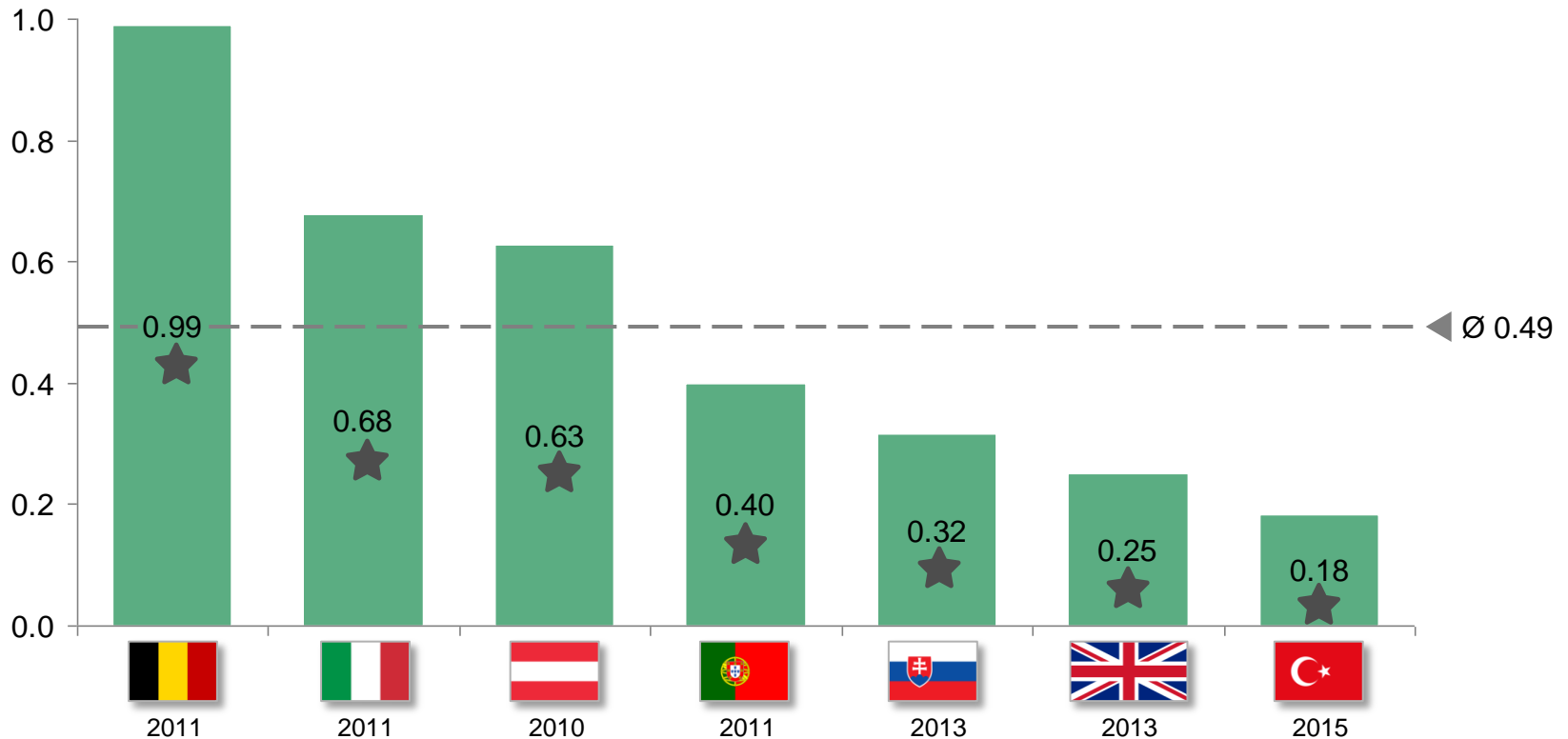
1. Max. coverage distance with 70 dB max. path loss dynamic range and 10 dB SNR, as a function of transmitter and receiver distance; loss model assumes path loss with exponent 3.5 or 5 (LOS or NLOS measurements in urban setting for 28 GHz) and atmospheric attenuation; source: Rappaport et al. "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!", BCG analysis

Ecosystem uncertainty is a big challenge for operators

Price comparison of 2600 MHz FDD vs. 2600 MHz TDD

Example

2.6GHz TDD price index (2.6GHz FDD=1.00)



★ Spectrum acquired for free or (close to) minimum reserve price

High frequency and TDD spectrum could be acquired at substantial discounts

Note: Comparison of price of 1 MHz of TDD spectrum vs. 2x0.5 MHz of FDD spectrum

Source: BCG spectrum benchmark database and analysis

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Draft—for discussion only

5G faces high requirements to take use cases to mass market

Requirements needed by use case



Use Case	Peak throughput (1+ Gbps)	Mean throughput (100+ Mbps)	Connection density (10k+ devices per km ²)	Coverage (Deep indoor & rural)	Reliability (<0.01% error ¹)	Latency (<10 ms)	Energy efficiency (10y+ battery life)
A Enhanced mobile broadband	Mobile broadband	✓ ²	✓				
	Fixed wireless access	✓	✓				
B Massive Internet of Things	Smart wearable		✓	✓			✓
	Sensor networks		✓	✓			✓
	Logistics and tracking		✓	✓			✓
C Mission-critical IoT	Industrial automation			✓	✓	✓	
	Remote medical care				✓	✓	✓
	Connected vehicles		✓		✓	✓	✓

 Major requirement
 Increase
 Decrease

1. E.g.: Less than 1 connection loss in 10k connections; 2. Mean throughput sufficient for most use cases; peak speeds on demand and for flash downloads as additional service

Source: BCG analysis, NGMN Alliance

Enhanced mobile broadband requires dense broadband radio access and investments in fiber connectivity

Example: eMBB

Massive densification with **small cells** (dense urban, urban and business) – fiberized if fiber fronthaul within short range of existing fiber network

Central offices are upgraded to proximity data centers

Macro site ramp-up increases availability of 100 Mbps average throughput

Existing access network is upgraded from 4G to 5G

Fiber and mmWave provide scalable x-haul

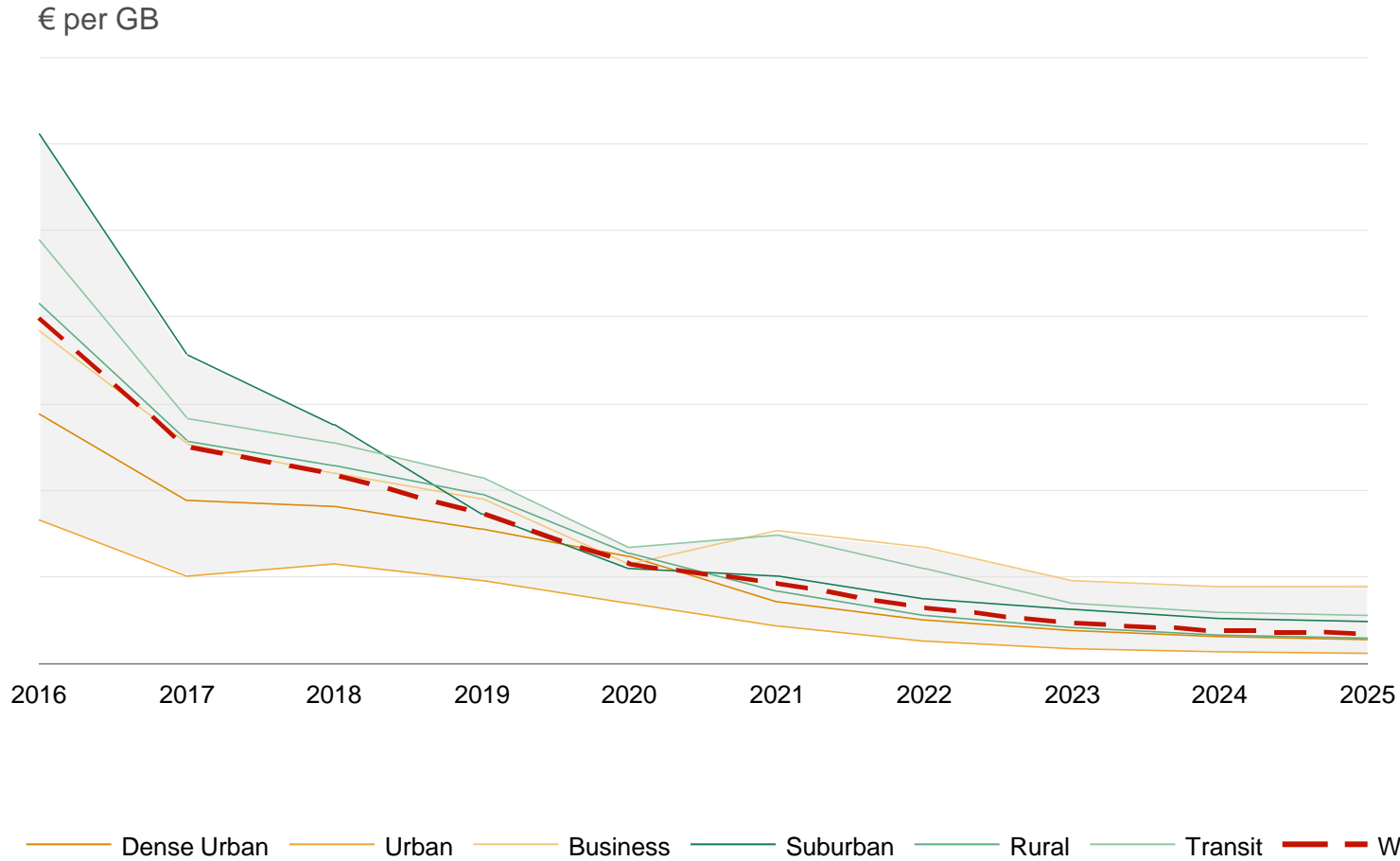
Map profile: eMBB
 Berlin | 2025
 Dense Urban, Urban, Business

Type	#	
	New	Total
Macro sites	X	X
Small cells	X	X
Proximity data centers	X	X

Note: Requires defined set of data
 Source: BCG
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- (•) New 5G small cell
- (•) Small cell (black=newer)
- (•) IBS (black=newer)
- (•) New 5G macro site
- (•) Proximity data center
- (•) Existing macro site
- Fiber

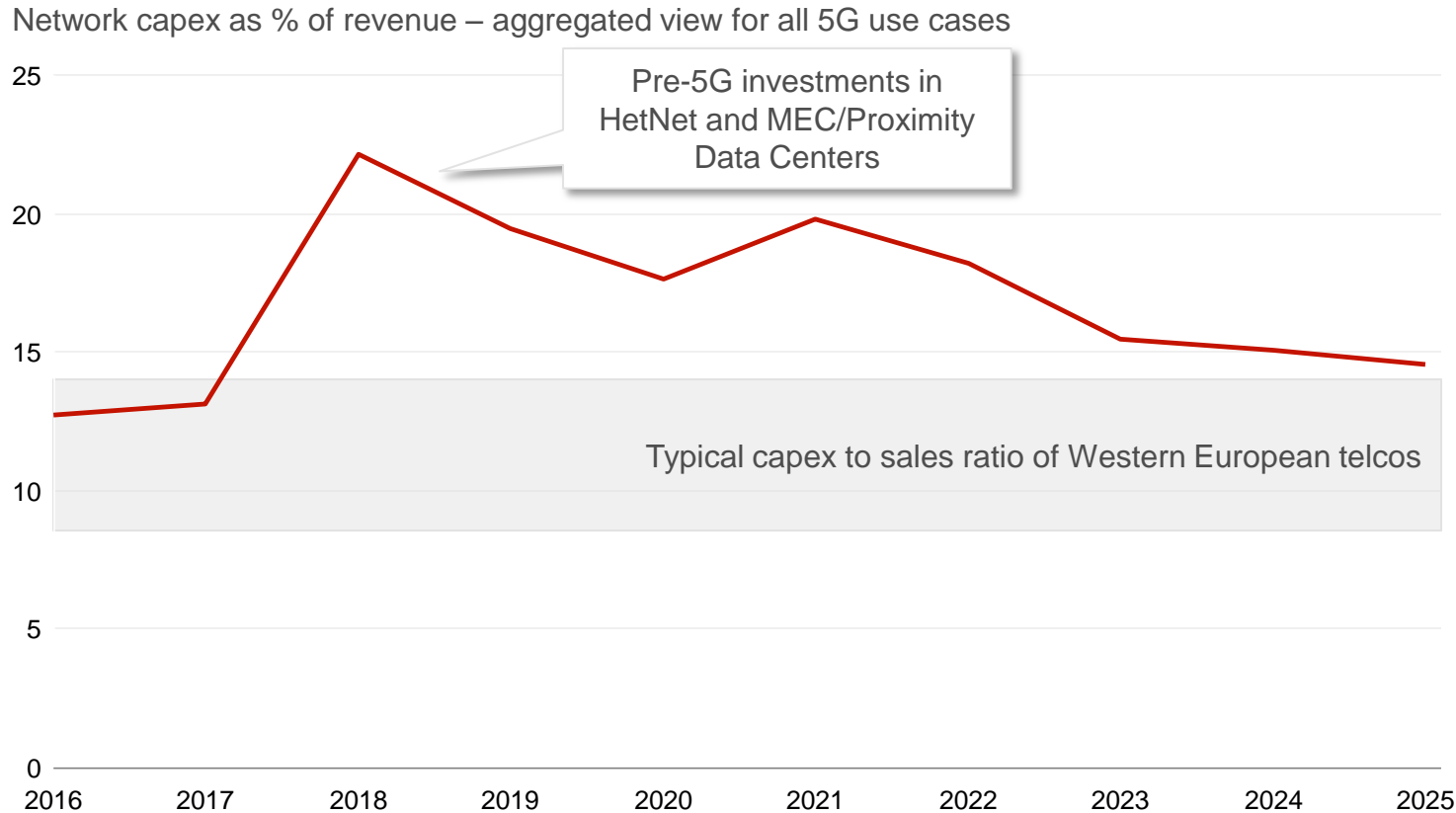
Cost per GB – including opex and capex – decreases significantly in all area types



Cost per GB
until 2025

90+%

However, capex to sales ratio expected to increase to 20%+ to prepare networks for 5G



Capex to sales ratio could increase well above

20%

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Operators need a business case for each 5G use case and the respective investments



Thank you