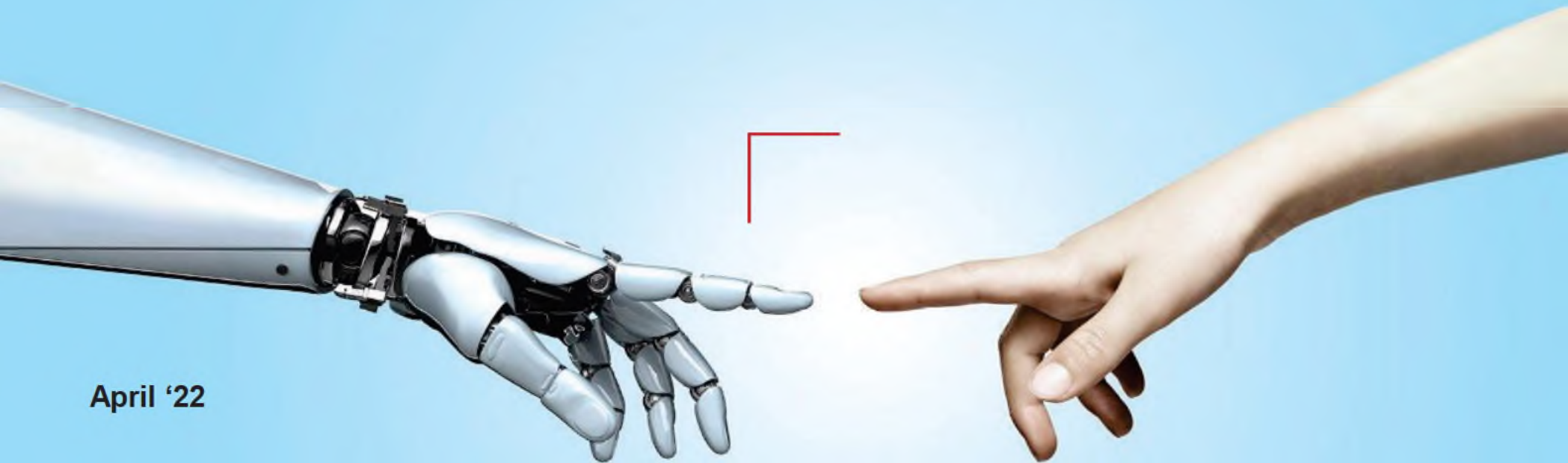


# 5G Evolution: European spectrum roadmap



April '22

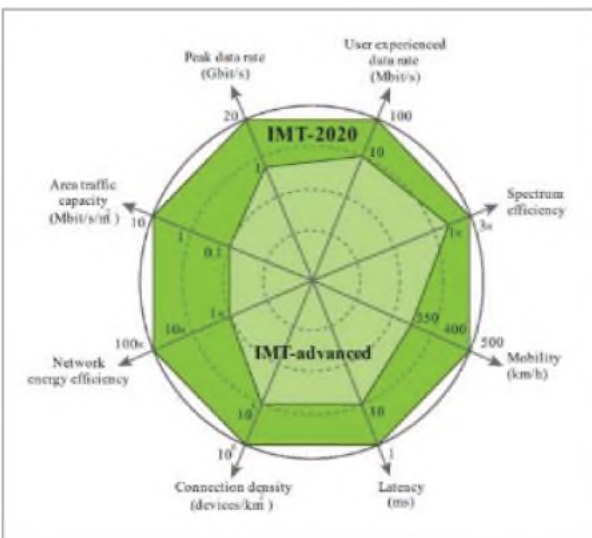
## Content

- **Key opportunities and challenges**
- **The previous decade: Europe great spectrum policy leadership**
- **This decade: great opportunity to keep the European leadership**
- **5G spectrum policy approaches globally**
- **Key issue for the new European spectrum roadmap**
- **Key takeaways**

# Key opportunity: From IMT-2020 (5G) to IMT-2030 (6G): Internet of everything to intelligent connection of everything

## IMT-2020: 5G

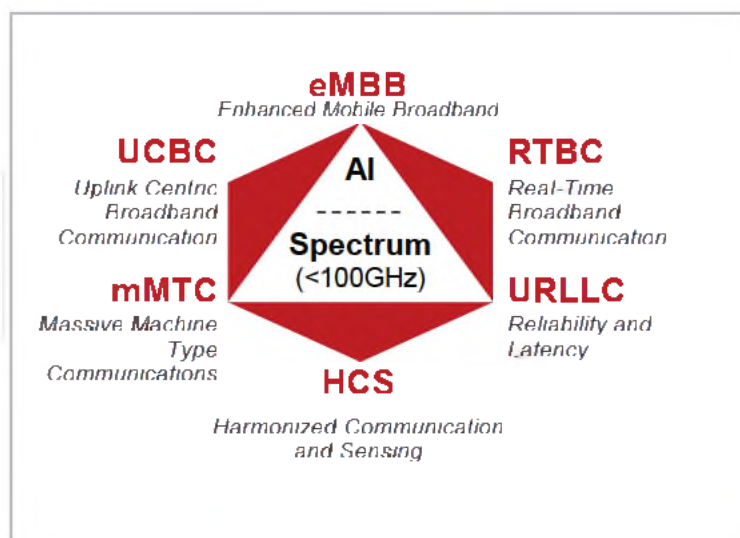
100 Mbit/s any time, anywhere



Spectrum: WRC-15, WRC-19

## 5G-Advanced

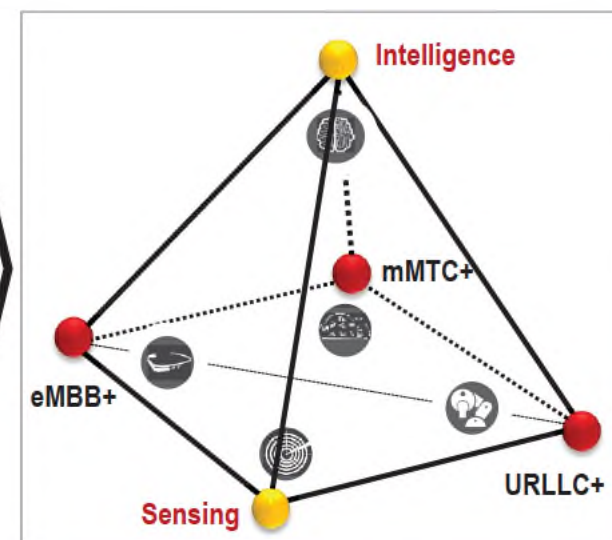
Ongoing evolution



Spectrum: WRC-23

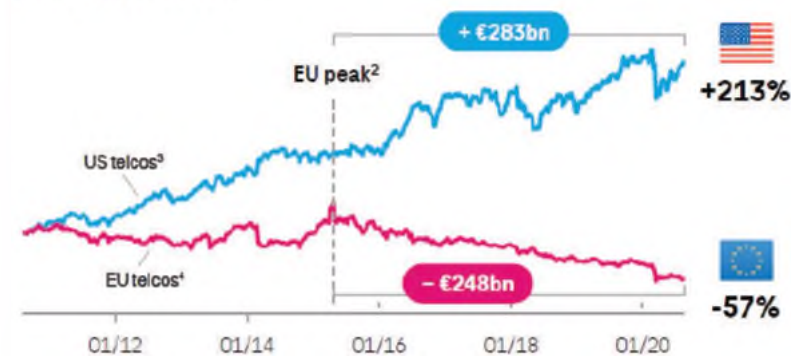
## IMT-2030: 6G

Connected Intelligence



Spectrum: WRC-27 ?

## Digitization targets vs. European investment challenge

Market cap, 2010-2020<sup>1</sup>

More investment-friendly regulatory environment in the US – no access and price regulation for mobile in the US

Less fragmented market: 3 network operators for >300m people in US vs. >100 MNOs for >400m people in the EU

Source: Credit Q 3, 2006, Cambridge Analytica, Inc.

Nome: 1) WIR-2015-00005 05.08.2015 2) IS-2015-00000 (indagato) 3) EU-2015-00000 23.04.2015 4) US-2015-THUS-5a-111-A87-VanderVZ, Charm-Akka USA, Corriere di EU Trigger-British Telecom, L'Espresso, Global Change, Telenor, Telenor Italia, Vodafone 5) McKim,

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HUAWEI TECHNOLOGIES CO., LTD.

## 6 GHz - A Key Resource for 5G Mobile Broadband

NOTICE: CONFIDENTIAL

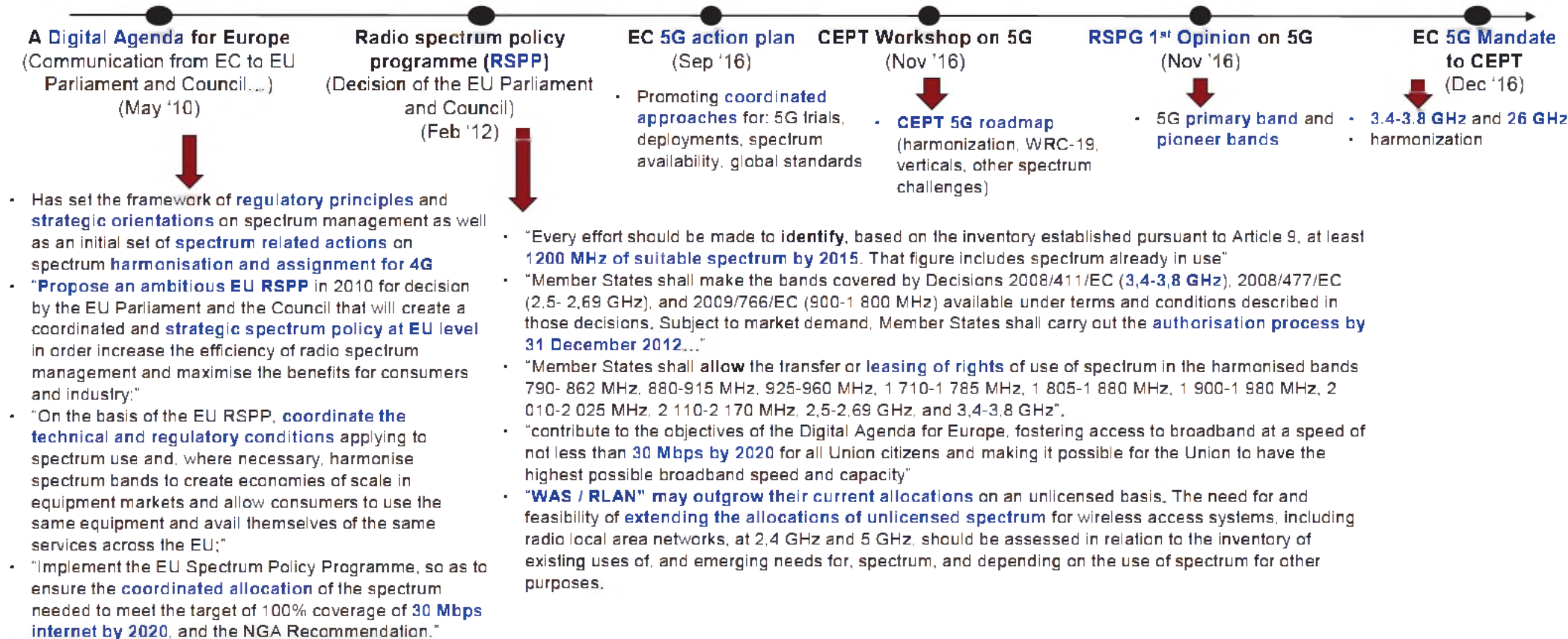
**2024**

Region	Percentage
European Union	25%
North America	45%
China, Japan and South Korea	43%

## Content

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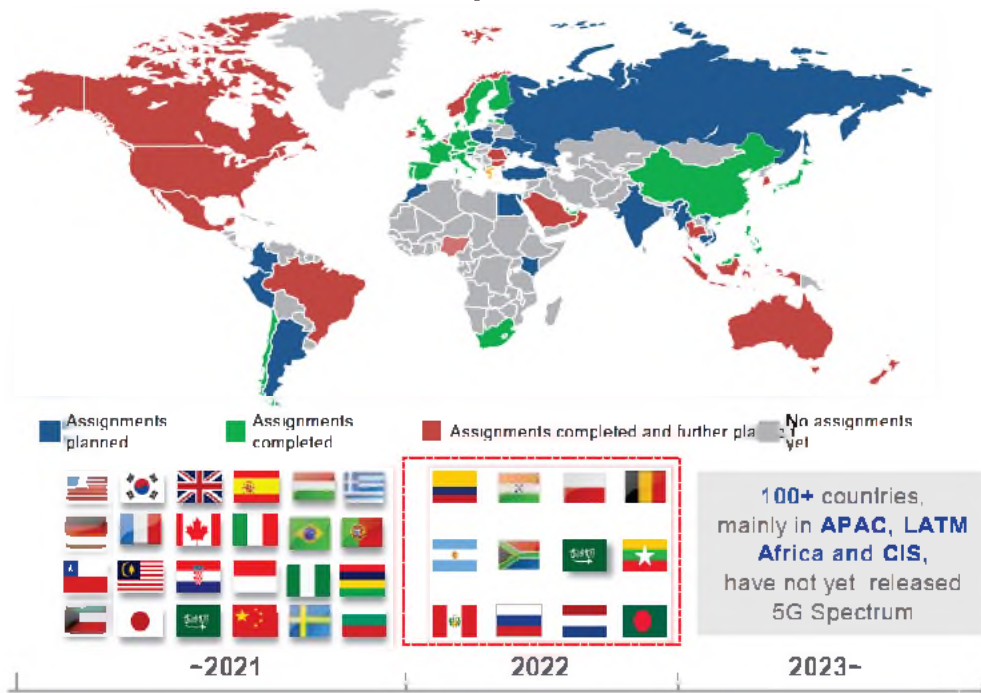
## The previous decade – great spectrum policy leadership





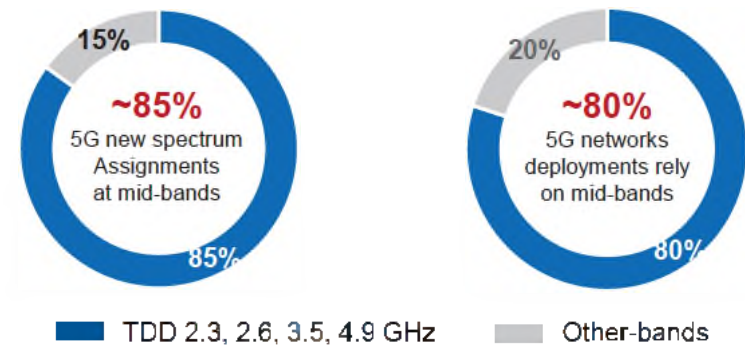
# Spectrum assignments globally

~70 countries will release 5G spectrum by the end of 2022, while 100+ countries still needs to accelerate 5G spectrum allocation



\*Source: GSA & Huawei MI

80-100 MHz @ 2.3, 2.6, 3.5, 4.9 GHz has become the main stream



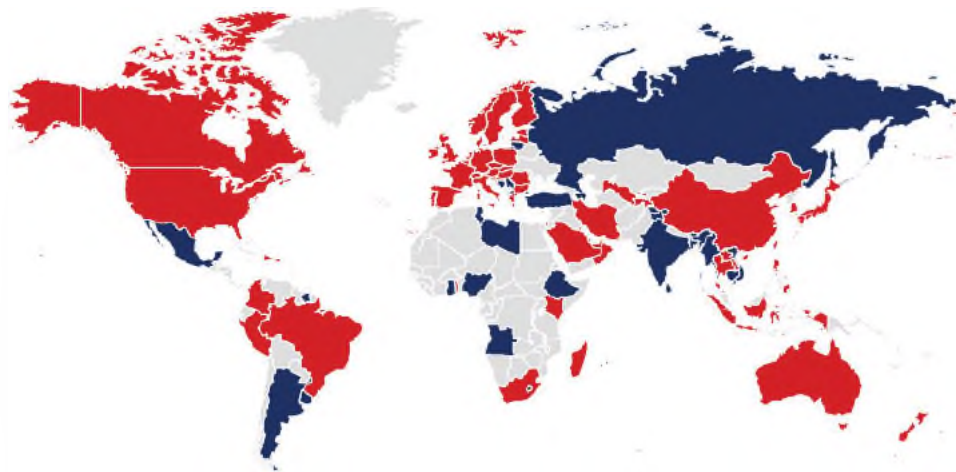
Mid band is the **primary** 5G spectrum. Europe has lead the trend.

**Unclear plans** for future mid-bands assignments in Europe.

# 5G Deployment is Accelerating Globally

70+ countries have launched 5G service

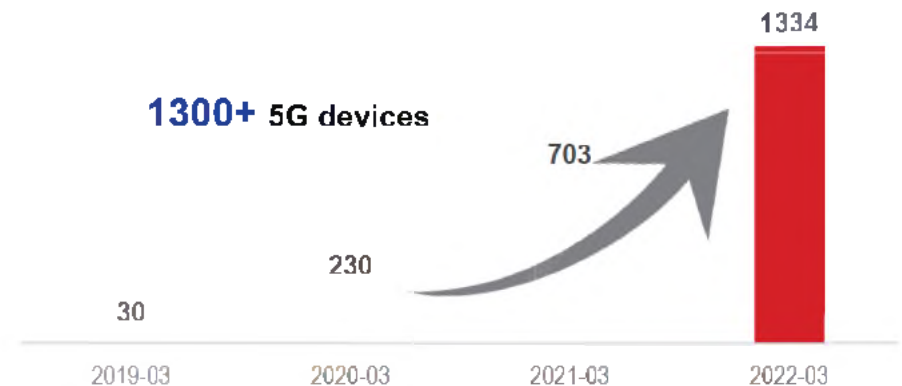
● Live commercial 5G Networks    ● Planned commercial 5G networks



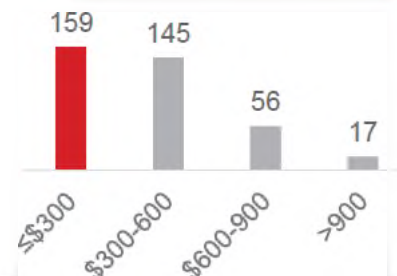
Source: GSMA & Huawei MI

Mature E2E ecosystem supports the rapid development of 5G

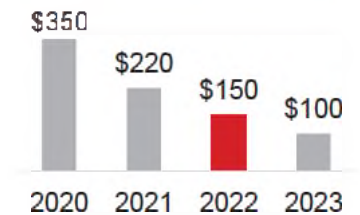
1300+ 5G devices



~160 models of smartphones at below \$300



5G CPE average price drop to \$150



Source: GSA & Huawei MI



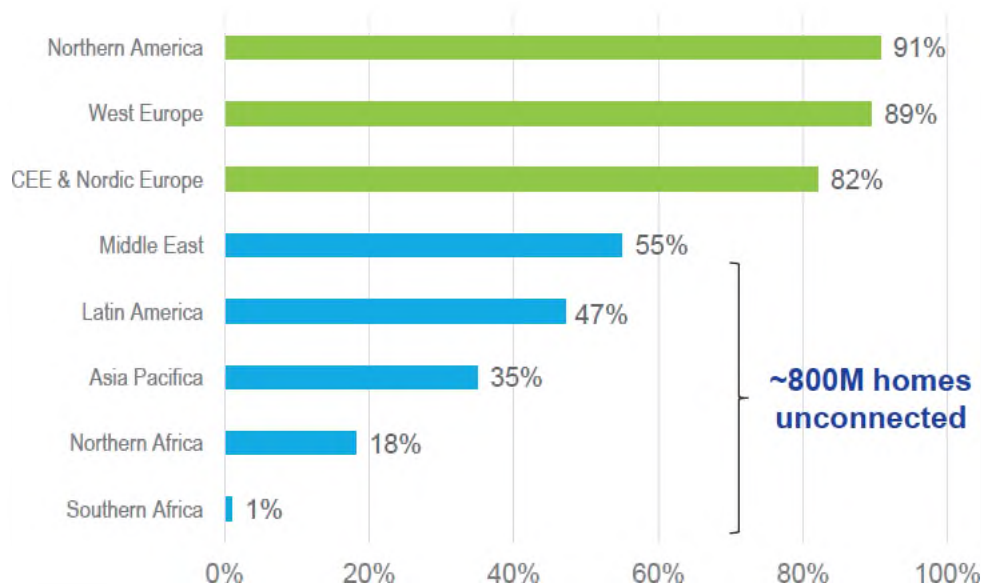
## Commercial Interest



# ToH: 5G FWA boosts home broadband connections for unconnected households

Huge fixed BB connection gap remains in developing countries

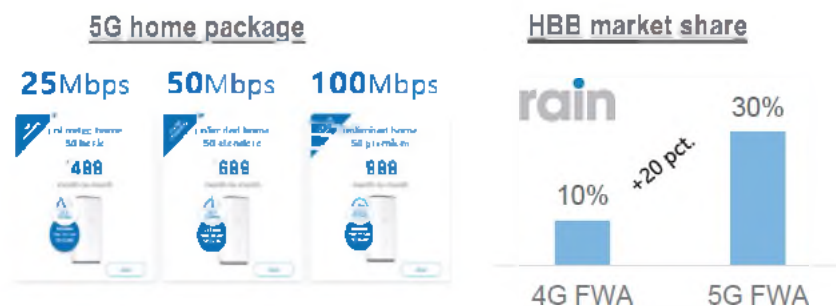
*HBB penetration rate in each region*



40%+ 5G operators have launched FWA services



SA Rain: Connected 200K homes rapidly with 5G FWA in 2 years



## Commercial interests



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## 6 GHz to support the EU policy objectives

### European Digital Compass cardinal point:



“ 2) **Secure, performant and sustainable digital infrastructures**; By 2030, **all EU households should have gigabit connectivity and all populated areas should be covered by 5G**; the production of cutting-edge and sustainable semiconductors in Europe should be 20% of world production; 10,000 climate neutral highly secure edge nodes should be deployed in the EU; and Europe should have its first quantum computer; ...”

### The European partnership on Smart Networks and Services (SNS)

Joint Undertaking co-led by industry and the Commission with close involvement of Member States, sets the strategic **R&I roadmap for Europe**. The initiative builds on an EU contribution of **€900 million over the next 7 years** to be matched by the private sector with the same amount. The aim is to enable European players to build the R&I capacities for 6G systems and develop lead markets for 5G infrastructure as a basis for the digital and green transformation

**5G** Evolution

**6G**

**Stream A (RIA):** 5G mid-term evolution

**Stream B (RIA):** 6G Research

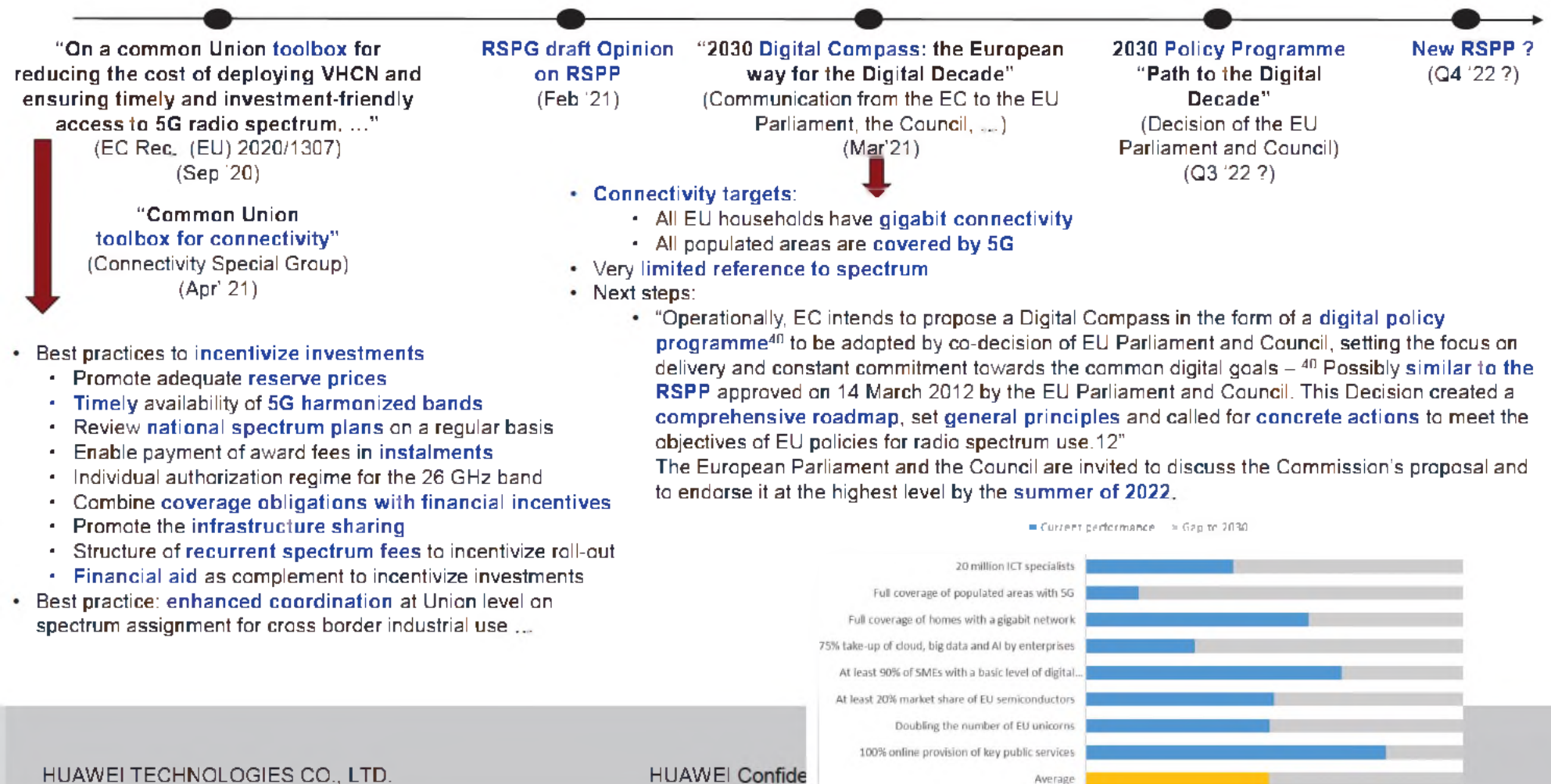
**Stream D (IA):** Large Scale Trials and Pilots with Verticals

**Stream C (RIA):** SNS Experimental Infrastructures

RIA: Research and Innovation Actions  
IA: Innovation Actions

The important efforts in R&D should be supported with the development of an ambitious and forward looking **European spectrum roadmap for the evolution of 5G.**

# This decade – great opportunity to keep leadership





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**Commercial Interest**

**Personal Data**



## Commercial Interest



## Commercial Interest



**Commercial Interest**

**Personal Data**



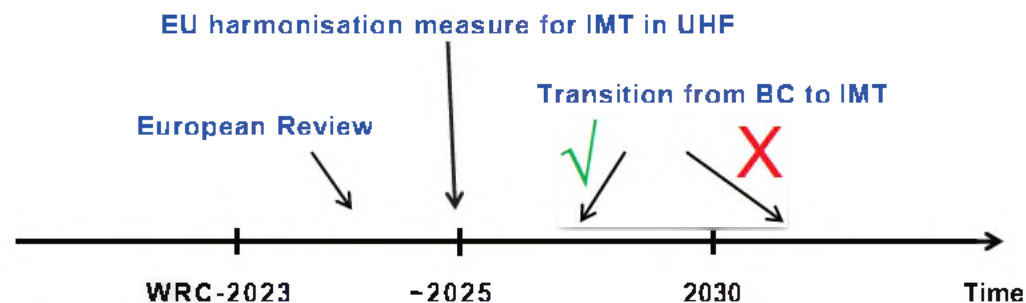
## Content

- Key challenges and opportunities
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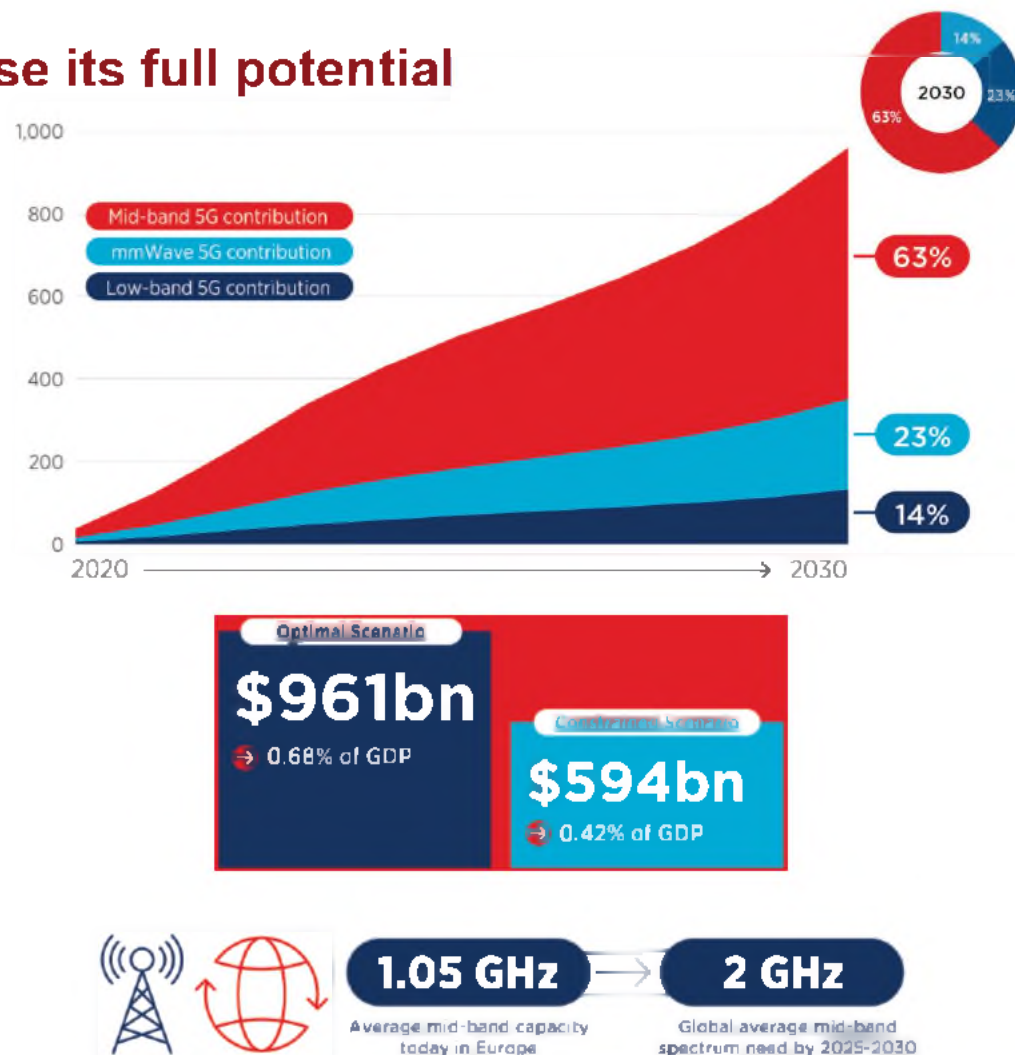
## Europe strategy for UHF

- In Europe, **DTT consumption is constantly decreasing** while MNOs need both DL and UL additional spectrum in lower bands:
  - **DL capacity in rural areas** to meet demand for delivering AV data & coverage obligations;
  - **Enhanced UL connectivity**, not least to achieve **balanced coverage** when using higher bands for DL
- 
- Most promising use cases in low bands are among **mMTC and eMBB** types of services requiring **wide and deep coverage** while **certain URLLC** services could be also efficiently implemented
- The alternative DTT/IMT co-existence scenario would require severe power and geographical restrictions on IMT, both within countries and along the borders with neighboring countries, and would thus lead to a low spectrum efficiency.



## 5G relies on mid-band spectrum to realise its full potential

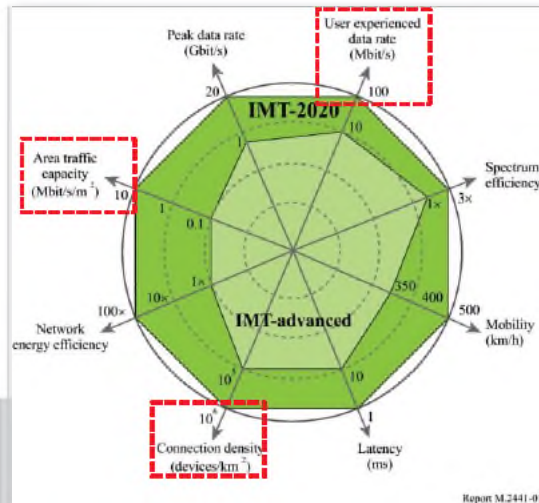
- In 2030, 5G is expected to generate \$960 billion in GDP on a global basis;
- Mid-band spectrum will drive an increase of more than \$610 billion in global GDP in 2030, producing almost 65% of the overall socio-economic value generated by 5G;
- However, up to 40% of the expected benefits of mid-band 5G could be lost if no additional mid-band spectrum is assigned to mobile services;
- To realise the potential benefits, countries must fulfil mid-band needs in harmonised ranges including 3.5 GHz, 4.8 GHz, and 6 GHz to deliver economies of scale and lower broadband costs.



## Need for additional mid-bands spectrum

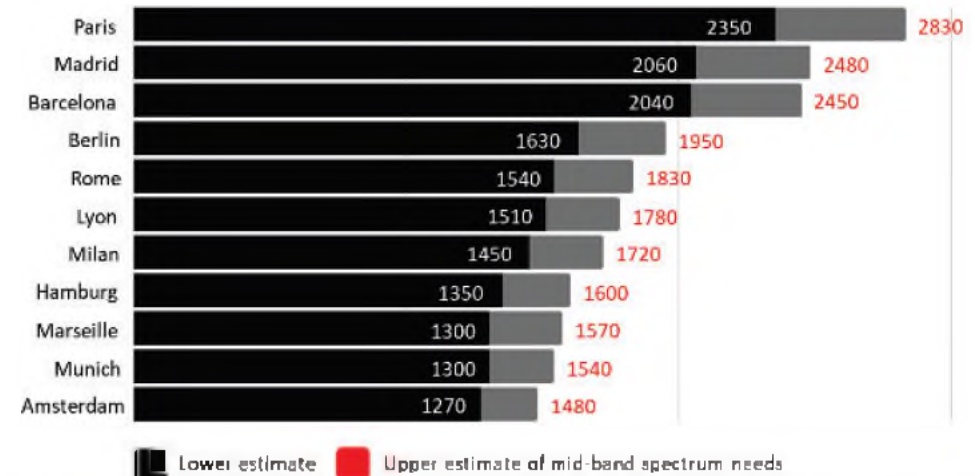
The GSMA recommends governments and regulators to:

- Plan to make 2 GHz of mid-band spectrum available in the 2025-2030 time frame. This is the average value needed to guarantee the IMT2020 requirements for 5G;
- Carefully consider 5G spectrum demands when 5G usage will be reaching its peak, and advanced use cases will carry additional needs;
- Base spectrum decisions on real-world factors including population density and extent of fibre rollout; and
- Support harmonised mid-band 5G spectrum (e.g., within the 3.5 GHz, 4.8 GHz and 6 GHz ranges) and facilitate technology upgrades in existing bands.



- 1) 36 studied cities
- 2) Population density
- 3) Available spectrum
- 4) Inter-site distance
- 5) 5G technology, massive MIMO upgrades
- 6) High bands, indoor small cells and Wi-Fi offload
- 7) End users' activity factor

Total mid-band spectrum needed for 5G in the 2025-2030 time frame [MHz]



Source: "Estimating the mid band spectrum needs in the 2025-2030 time frame" — July '21



See GSMA vision [here](#).  
See report key highlights [here](#).  
See full report [here](#).

## Additional mid-band spectrum and network densification

- MNOs' sustainable business needs to **minimize the cost per transmitted bit** since revenues are flat / slightly growing
- While network **densification** plays an important role, there is clearly an **upper limit** to it
- **Two main scenarios** for MNOs' networks coverage expansion in medium/long term:

A. Add new radios (to existing macro sites) using **new mid-band** spectrum, in combination **with small cells densification**



**Balance between macro and small cells** coverage minimizing cost/transmitted bit

B. Enhance coverage through **small cells densification only**



### **Extreme densification**

- Unsustainable radio network **deployment costs** (x4.1 in Paris, source Coleago)
- Increases overall **power consumption** (x2.2 in Paris, source Coleago)
- May not even be feasible due to interference or site availability.

**"Densification in the urban areas in Europe is a myth, small cells are not economically viable. That is the reality; if small cells were viable we would have deployed them by now instead of investing in 3.5 GHz spectrum. We are seeing a significant growth in traffic rate, nearly doubling every year when you count fixed and mobile. That growth can be accelerated by other applications such as AR/VR and metaverse. We think the 3.5 GHz will be congested before the end of the decade."**

Source: Santiago Tenorio, Fellow and Network Architecture Director – Vodafone at the 6 GHz 5G/IMT Spectrum Forum (March '22)

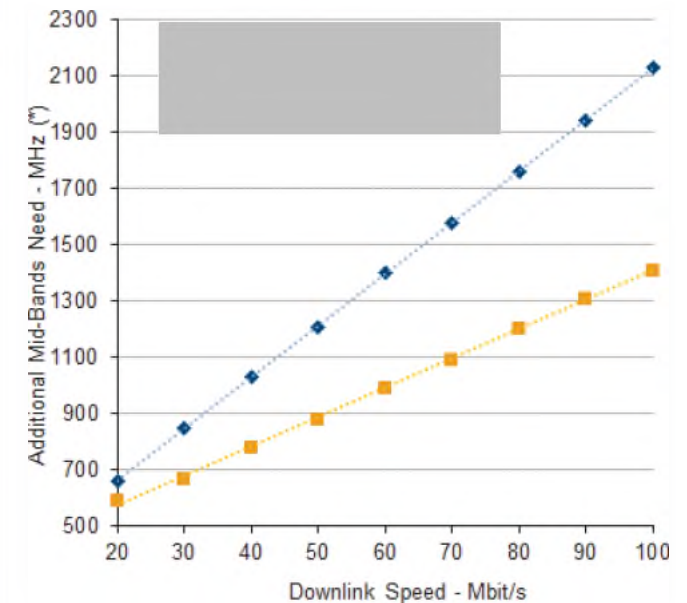


**Spectrum policy is important to minimize the cost/transmitted bit.  
For sustainable deployments for 5G and its evolution.**

# Commercial Interest

DL and UL total (including baseline) mid-bands spectrum need [MHz] (city average)															
	World Bank income group	Popn density per km <sup>2</sup>	Dense area km <sup>2</sup>	Mbit/s											Mid-band baseline spectrum
				100 DL	80 DL	60 DL	50 DL	40 DL	30 DL	20 DL	10 DL	50 UL	45 UL	40 UL	
				MHz											
		81386	117	1230	1140	1050	960	880	790	700	630	560	540	935	
		81836	92	1280	1180	1090	1000	920	830	720	640	570	540	835	
		91035	43	1300	1200	1110	1020	940	850	720	640	570	540	935	
		91289	69	1320	1220	1130	1040	960	870	730	650	580	540	835	
		101162	141	1410	1310	1220	1130	1040	960	820	720	590	540	935	
		101595	73	1460	1360	1270	1180	1090	960	790	680	590	540	935	
		101655	174	1500	1380	1270	1160	1050	920	810	700	600	540	935	
		111859	163	1590	1470	1340	1220	1090	970	840	720	610	540	835	
		151576	179	1980	1830	1660	1490	1330	1170	1000	840	680	550	935	
		151773	303	2000	1840	1670	1500	1340	1180	1010	840	680	550	935	
		171439	515	2130	1940	1760	1580	1400	1210	1030	850	660	500	850	
		181400	243	2280	2090	1890	1700	1500	1310	1120	920	730	570	935	

Source: Coleago



(\*) Additional mid bands spectrum need to meet the DL speed from "X" axis as well as 50% UL (see table)

Source: Coleago

## Commercial Interest



## Large contiguous bandwidth in mid-bands mitigates climate change

- Climate change KPI: impact in terms of **Kg of CO<sub>2</sub>**
- **Stage 1: equipment manufacturing distribution and installation**
  - BSs, application servers and UE
  - Including site construction (new spectrum vs. densification)
- **Stage 2: use**
  - Minimize power consumption (new spectrum vs. densification)
- **Stage 3: end of life**
- In order to minimize impacts on climate, spectrum policy should aim at limiting the number of sites and large contiguous channels
- Interesting study by ARCEP in France

**Power consumption** dependence on mid-band spectrum availability

	Paris	Hamburg	Mexico City	Mumbai
Reference macro site power consumption	6kW	6kW	6kW	6kW
Reference small cell power consumption	0.5kW	0.5kW	0.5kW	0.5kW
<b>With additional mid band spectrum</b>				
# of macro sites	1,752	170	6,236	6,812
# of outdoor small cells (including the baseline)	5,256	510	18,708	20,436
Consumption reduction due to power saving features	20%	20%	20%	20%
Uplift in power assumed due to additional spectrum	20%	20%	20%	20%
Reference power consumption (MW)	12.6	1.2	44.9	49.1
<b>Without additional mid band spectrum</b>				
# of macro sites	1,752	170	6,236	6,812
# of outdoor small cells (including the baseline)	48,234	2,739	238,967	234,321
Consumption reduction due to saving features	20%	20%	20%	20%
Reference power consumption (MW)	27.7	1.9	125.5	126.4
<b>Relative increase in power consumption:</b>	<b>2.2x</b>	<b>1.6x</b>	<b>2.8x</b>	<b>2.6x</b>



**Extreme densification**  
= **2.3x** Mid-band

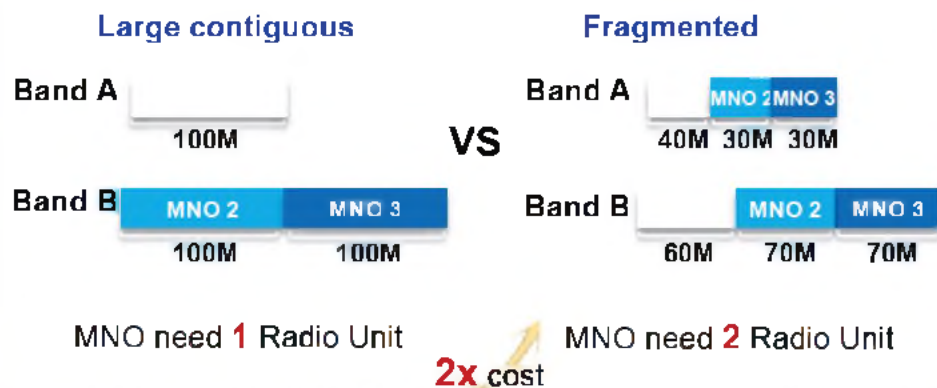
The **extreme radio network densification** required to deliver the 5G requirements, in the absence of additional mid-band spectrum would lead to a significant relative increase in terms of the **energy consumption and radio network complexity and cost**.

## Large contiguous bandwidth in mid-bands improves business sustainability

Contiguous 100 MHz + M-MIMO enable 10 Gbit/s capacity



Contiguous 80-100MHz save Operator cost



Radio network cost dependence on mid-band spectrum availability

	Paris	Hamburg	Mexico City	Mumbai
<b>With additional mid band spectrum</b>				
Additional mid band spectrum assumed (MHz)	1,250	500	900	1,200
# of macro sites	1,752	170	6,236	6,812
# of outdoor small cells (including the baseline)	5,256	510	18,708	20,436
Reference radio network capex cost over 10 yrs. (USD m)	140	14	499	545
Reference radio network opex cost over 10 yrs. (USD m)	259	25	920	1,005
Reference total radio network cost over 10 yrs. (USD m)	399	39	1,419	1,550
<b>Without additional mid band spectrum</b>				
# of macro sites	1,752	170	6,236	6,812
# of outdoor small cells (including the baseline)	48,234	2,739	238,967	234,321
Reference radio network capex cost over 10 yrs. (USD m)	570	36	2,702	2,684
Reference radio network opex cost over 10 yrs. (USD m)	1,051	66	4,983	4,951
Reference total radio network cost over 10 yrs. (USD m)	1,621	102	7,685	7,635
<b>Relative increase in radio network cost:</b>	<b>4.1x</b>	<b>2.6x</b>	<b>5.4</b>	<b>4.9x</b>

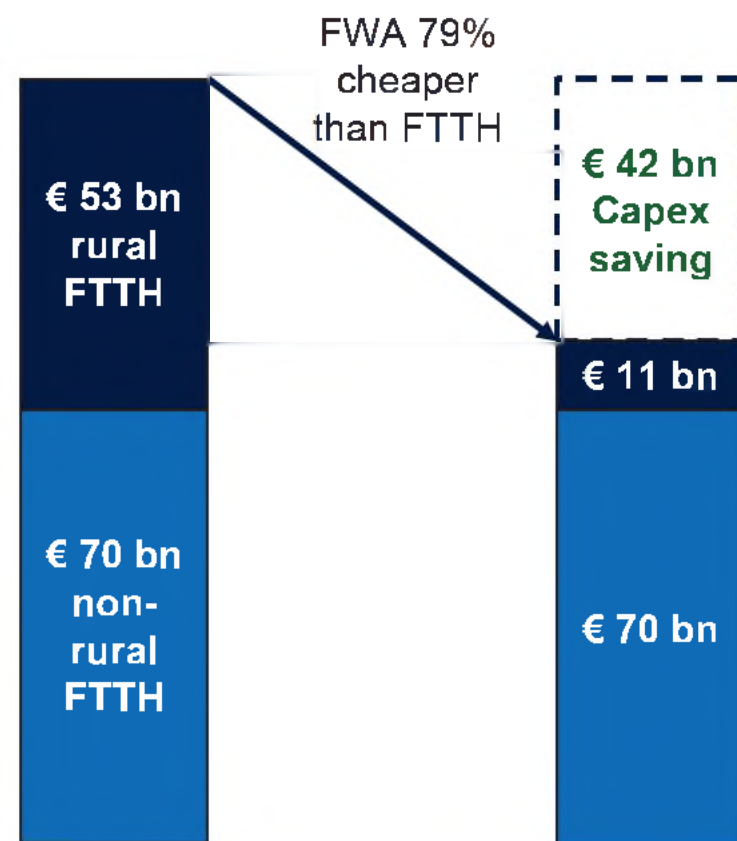
Source: Coleago 2021



Other band  
= **4.2x** Mid-band

## Using additional mid-bands spectrum for FWA would reduce the cost to deliver the EU 100 Mbit/s connectivity target by €42 billion

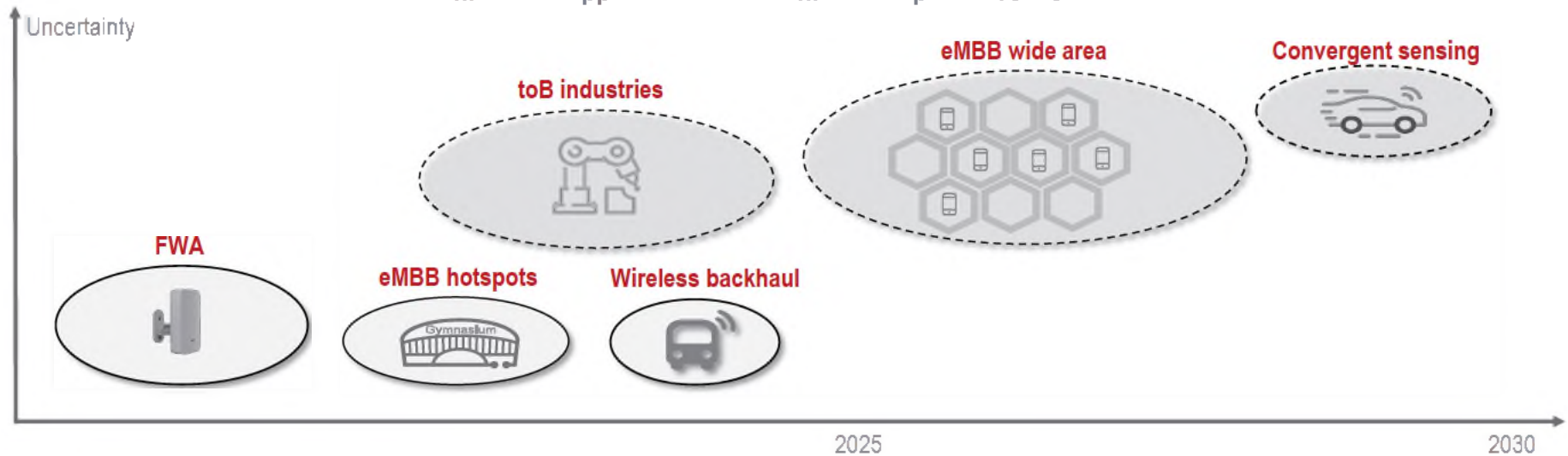
- The **total investment** required to cover 100% of households in the EU with **FTTH** is estimated at **€123 bn**, **€53 bn** investment needs to be made in **rural areas**.
- With **rural FWA**, an additional **2 GHz** of spectrum, leads to an investment saving of 79% (from €53 bn to **€11 bn**).
- 5G IMT has a capital expenditure avoidance value of €42 bn, for FWA alone, i.e. not counting the capex avoidance value for mobile 5G.
- If only **1 GHz** of additional mid-bands spectrum is made available, the **saving is €40 bn**.



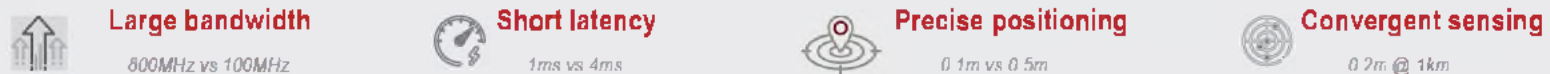
Source: Coleago Consulting 2021

## Millimeter Wave 5G will be commercial in a large scale in 2025-2030

mmWave applications and commercial pace forecast



mmWave advantages





## Need for balance between mid-bands spectrum for macro cellular (wide area) networks and low/medium power (local area) deployments

- Low/medium power deployments – using licensed or unlicensed spectrum – should not be assigned as much spectrum as wider area mobile networks.
- Cells with smaller radius:
  - Capture less users and traffic (per cell);
  - Geographic reuse across local networks with sufficient isolation.
- High bands also play a role for low/medium power networks.

The amount of mid-band spectrum for low/medium-power deployments is **currently 1.6 times larger** than for macro cellular networks.

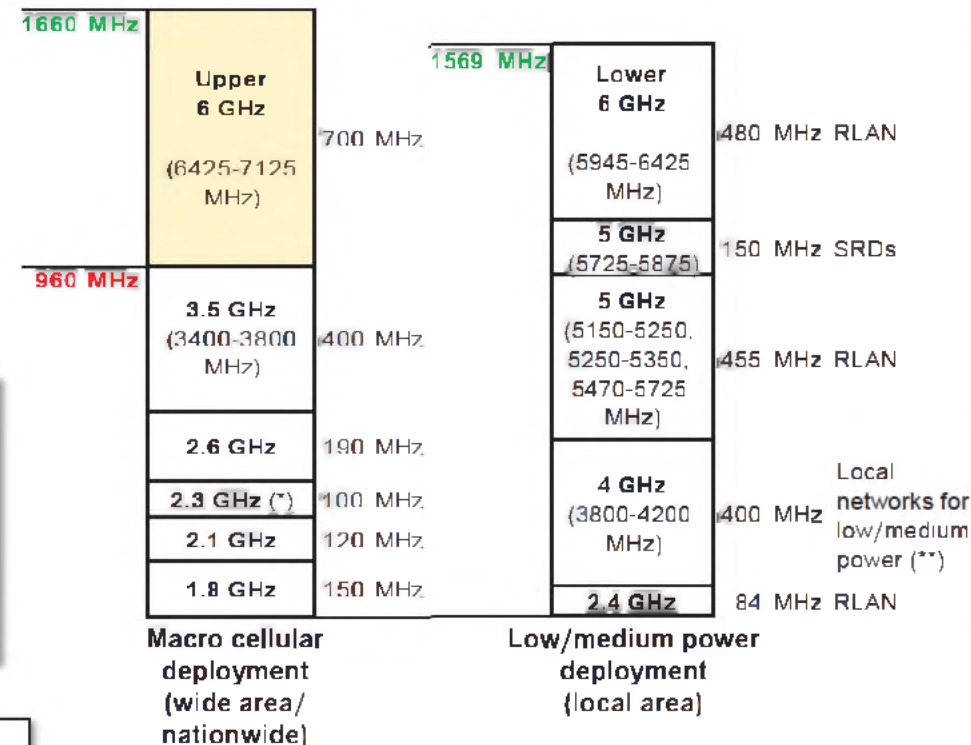
The imbalance would grow **up to 2.4 times** if the upper 6 GHz band will be used for low/medium-power.

A **more reasonable balance, 0.9 times**, can be achieved if the upper 6 GHz band is made available for macro cellular networks.

There is a need for

**European roadmap for wide-area / nationally licensed mid-band spectrum** to address the needs of macro-cellular **5G evolution and 6G**.

It is apparent that the upper **6 GHz band** represents the only remaining mid-band opportunity in Europe.



NOTE: the diagram shows the harmonized frequency bands in the EU

(\*) the band might not become widely available for macro in all Member States

(\*\*) based on EC Mandate (Dec. '21)

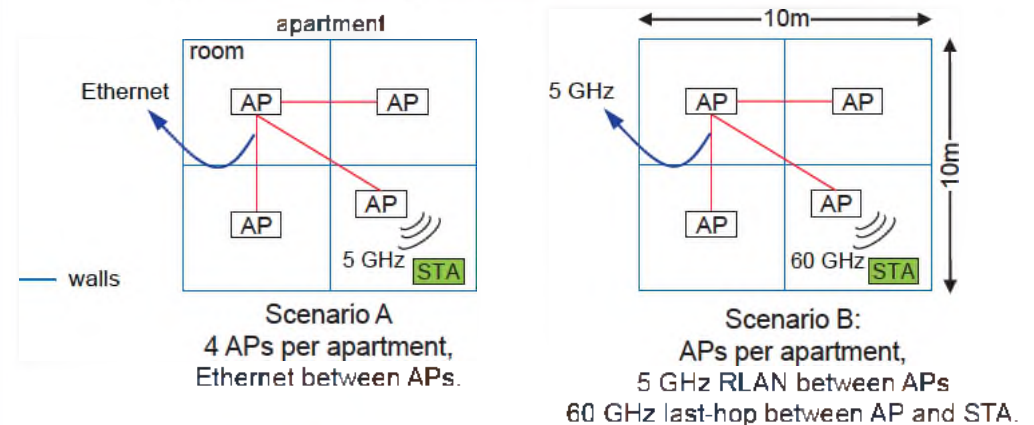


## RLAN spectrum and FBB evolution

Home Wi-Fi will require < 500 Mbit/s  
in the next 5-10 years



	Target DL throughput = 1 Gbit/s	Bandwidth (*)
Scenario A	4 ant. per AP, 2 ant. per STA	480 MHz
	4 ant. per AP, 4 ant. per STA	320 MHz
Scenario B	4 ant. per AP	480 MHz
	8 ant. per AP	480 MHz



Source: Qualcomm [whitepaper](#) "A quantification of 5 GHz Unlicensed Band Spectrum Need" – 2016

(\*) Based on simulations. Key assumptions: 802.11ax (Wi-Fi 6), maximum channel bandwidths of 160 MHz, 70% MAC efficiency, dense residential setting (3 story apartment building with 10 apartments on each floor, wall loss of 11 dB (both for inner and outer walls), 18 dB loss for floors.

**Currently available spectrum will be sufficient to address home Wi-Fi demand.**

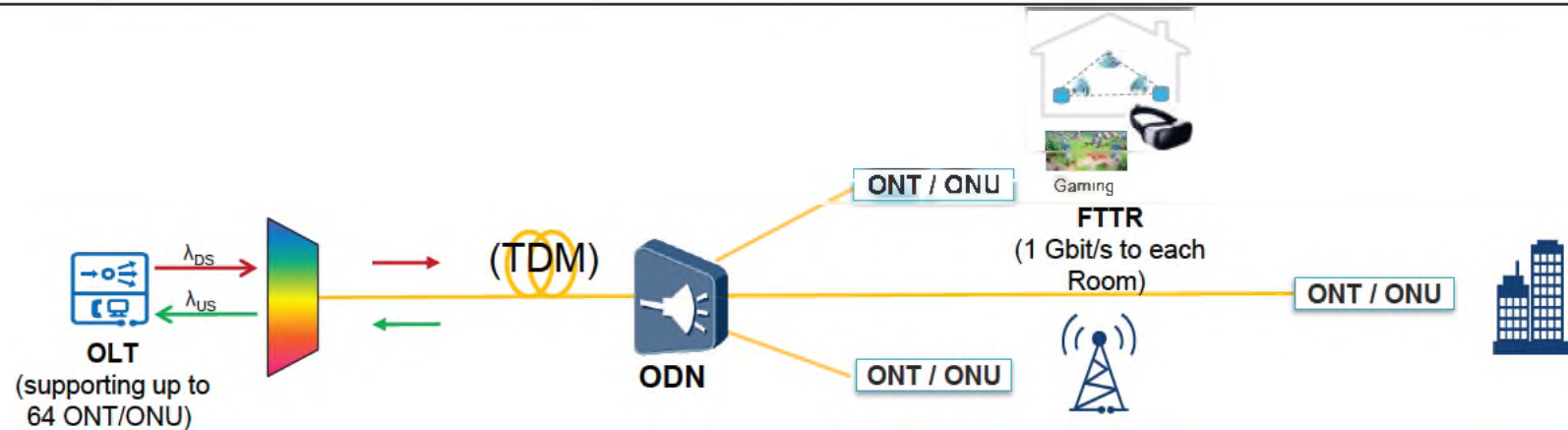
The 14 GHz of bandwidth at **60 GHz** can also play an important role for short-range communications.

**Other high bands** can also be considered for Wi-Fi use in the coming years, for example, the **Q-band (42-48 GHz)** is already supported by the IEEE standard (802.11aj-2018) together with the **60 GHz** band.



## RLAN spectrum and FBB evolution

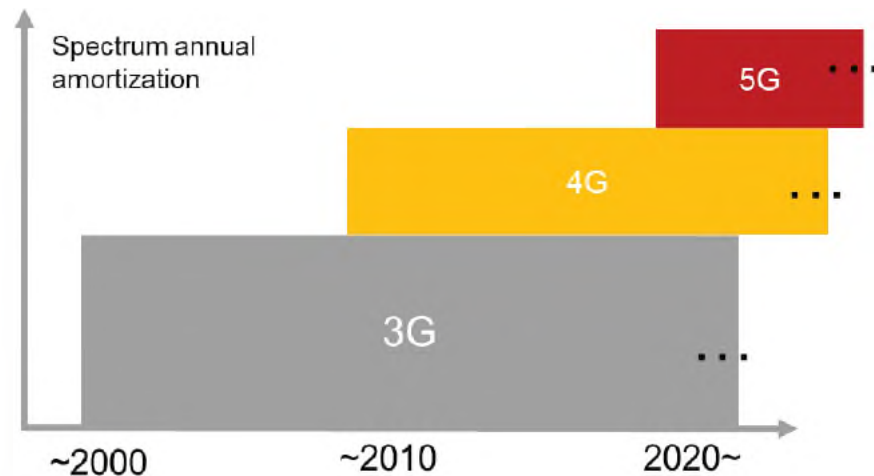
FBB Technology	Market introduction	Large scale	Average speed delivered to household
10G PON	2019	By 2026	1.3 Gbit/s
50G PON	By 2023 (standards available in 2021)	By 2029	6.6 Gbit/s
Next generation PON	Preliminary research ongoing	Not in this decade	> 10 Gbit/s



**New FTTx technology generation every 8 – 10 years delivering ca. four-times faster speeds to end users compared to the previous generation**

# Affordable annual spectrum cost to incentivize network investments

Accumulated spectrum cost will reach the highest level in 5G era



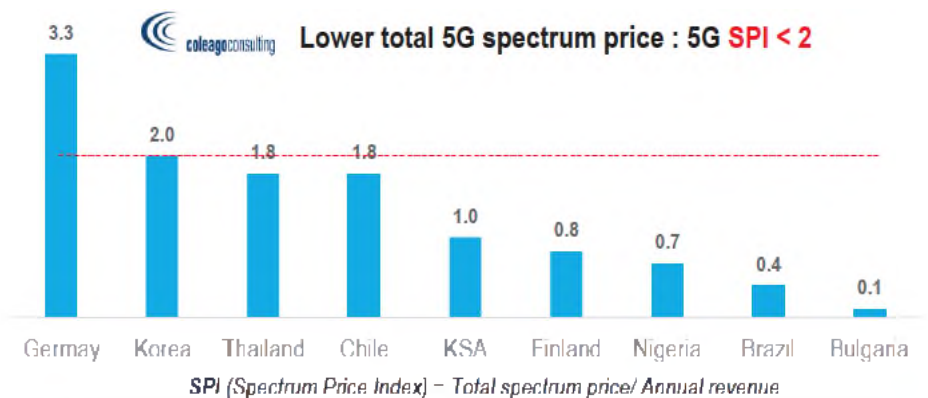
Germany

- Annual amortization: € 3.3Bn
- ~10% of annual revenue

UK

- Annual amortization: £1.3Bn
- ~8% of annual revenue

Lower spectrum price with flexible payment relieves MNOs' burden



Instalment payment



Instalment payment in 20 years



Instalment payment in 10 years

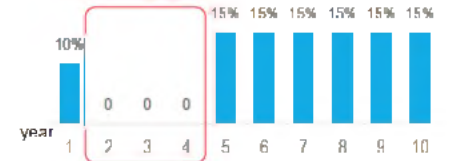


Instalment payment in 15 years

Deferred payment

3 years

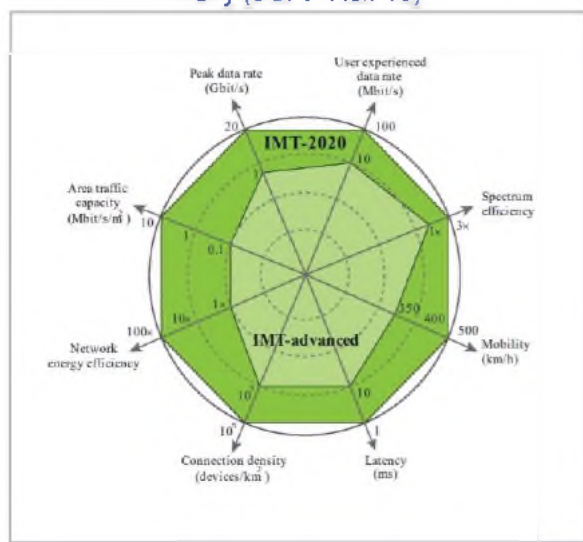
deferred payment



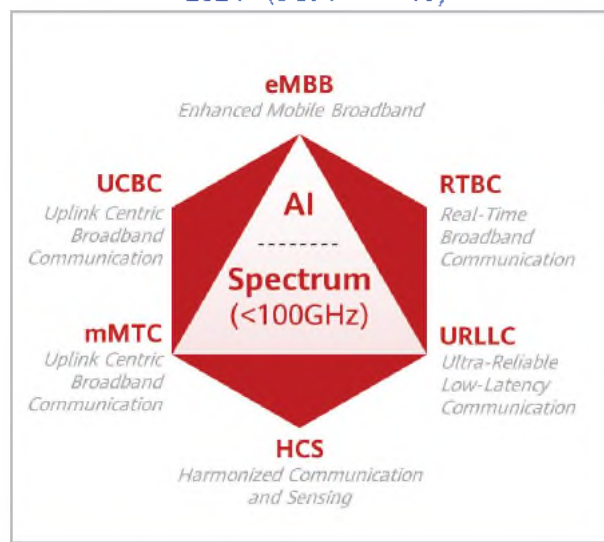
# 5G Advanced: Internet of Everything to Intelligent Connection of Everything



**IMT-2020: 5G**  
 100 Mbit/s any time, anywhere  
 Today (3GPP Rel. 16)



**5G Advanced**  
 Ongoing evolution  
 2024+ (3GPP Rel. 18)



**5G Advanced key technologies**

**E2E Affordable in 6GHz/mmWave**

For DOU and user experience increase  
**Uplink Gbps**  
 For HD video uplink and machine vision

**FDD Massive MIMO**

For 10x Capacity

**5GtoB+V2X**

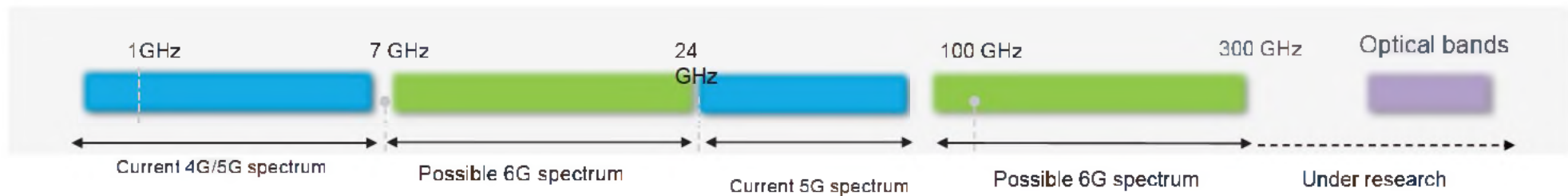
REDCAP, accurate positioning and sensing

**SUL (Super Uplink)**

For uplink capacity and coverage improvement

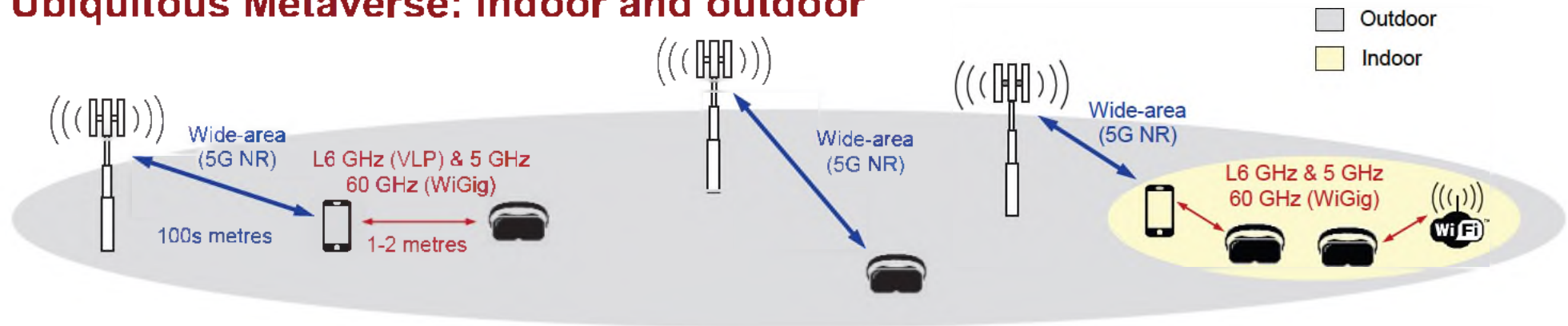
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## New spectrum for 6G



- **Low, mid and high bands already used or identified for IMT should be allowed for 6G usage in the future.**
- **To secure enough spectrum for 6G to accommodate future use-cases, additional new spectrum is needed:**
  - The **7-24 GHz** range should be studied for 6G targeting large contiguous bandwidth (e.g. 500 MHz to 1 GHz)
    - spectrum of 7-15 GHz may be prioritized; possibilities of global or regional harmonization should be considered
  - For the **24-100 GHz** range, taking into account that 66-71 GHz has a global IMT identification, additional new spectrum (71-76 GHz) can be considered to form a wider contiguous bandwidth, in order to also support various new 6G applications
  - For the **sub-THz/THz bands** (100 GHz and beyond), the bands of 100-300 GHz with wider contiguous blocks can be explored, e.g. W-band and D-band

## Ubiquitous Metaverse: indoor and outdoor



- The Metaverse will involve AR/VR/XR in indoor and outdoor scenarios
- **Wide-area outdoor mobility** will be an important element of the Metaverse
- The **smartphone** must connect to the 5G macro-cellular mobile network with sufficient bandwidth. XR headsets might also directly connect to the mobile network. These can be supported by 5G NR @ upper 6 GHz.
- **Short-range personal area connections** (e.g., between smartphone and XR headsets) can be addressed with:
  - Wi-Fi/WiGig/IMT sidelink @ 60 GHz
  - Wi-Fi @ 5 GHz and lower 6 GHz (VLP)
- Various chipset suppliers have been developing 60 GHz products targeting AR/VR headsets, there are already WiGig XR headsets on the market.



High data-rate (Gbit/s)  
**mobile communications anytime, anywhere,**  
 It will be an **important element of the Metaverse,**  
 enabled by **macro-cellular networks** at the upper 6 GHz.

## Content

- **Key challenges and opportunities**
- **The previous decade: Europe great spectrum policy leadership**
- **This decade: great opportunity to keep the European leadership**
- **5G spectrum policy approaches globally**
- **Key issue for the new European spectrum roadmap**
- **Key takeaways**

## Key takeaways (1/3)

- **Key opportunity to exploit: Internet of everything to intelligent connection of everything facilitated by 5G and its evolution**
- **Key challenge to manage: investments sustainability**
- **The previous decade: great spectrum policy leadership**
  - **Digital agenda for Europe**
  - **RSPP**
  - **5G Action Plan**
  - CEPT Workshop on 5G
  - RSPG Opinion on 5G
  - **EC 5G Mandates**
- **This decade: great opportunity to keep leadership**
  - **2030 Digital Compass**
  - **Connectivity toolbox**
  - **2030 Policy Programme**
  - **New RSPP – towards a European spectrum roadmap to support the evolution of 5G ?**



## Key takeaways (2/3)

### Key issue for the new European spectrum roadmap

#### Spectrum policies and roadmap to support 5G evolution

- **5G Advanced**
- **6G**
- **Indoor and outdoor Metaverse** (enhanced, real-time interactive experience across physical and digital worlds)

A **single, visionary, holistic view** is needed to drive the spectrum strategy and its execution at European level.

#### Spectrum policy for sustainable investments

- **Low, mid- and high bands spectrum is key**
  - **UHF** spectrum policy to support the transition from legacy TV to modern multimedia communications
  - Need for 2 GHz **mid-bands in 2025-2030**
  - **Large scale mmW** in 2025-2030
- **Large contiguous bandwidth** for business sustainability
- **FWA** role within VHCNs
- **Enhanced uplink** connectivity to address new use cases
- **Balance:**
  - Between additional spectrum availability and **densification**
  - Between mid-bands spectrum for **macro cellular** (wide area) networks and **low/medium power** (local area) deployments
  - Between **licensed and unlicensed**
- **RLAN** spectrum and **FBB** evolution
- **Spectrum sharing**
- **Mitigate climate change**
- **Sustainable spectrum fees, investment obligations**



## Key takeaways (3/3)

- Europe needs to be **united** in its spectrum policy, **coordination** at European level is important
- There is a need to keep a balance between **European wide strategy and harmonization** and the **individual national interests and agendas** of Member States
- The European Commission has been **essential in keeping the balance** during last decade
- The European Commission **should continue** to play its role in driving a future proof unified strategy and roadmap across all Member States to **support the 5G evolution and maintain the policy leadership globally**
- **Tight cooperation with industry is important**, Huawei remains committed to sharing its technical expertise on the 5G business and technology evolution

# Thank you.

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每个组织，构建万物互联的智能世界。

Bring digital to every person, home, and  
organization for a fully connected,  
intelligent world.

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