6GStart

The potential of Future Connectivity systems for Vertical Industries: A Trend Analysis of 5G PPP use cases through the Verticals Cartography

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Executive summary

The widespread implementation of 5G and 6G technologies is poised to revolutionise a broad spectrum of sectors, including automotive, smart cities, Industry 4.0, and media. These advancements, driven by the potential for ground-breaking real-life applications such as autonomous vehicles, sophisticated urban management systems, and smart manufacturing, provide transformative practical solutions for industries.

Through the 5G PPP programme (2014-2023), Europe has been at the forefront of integrating these technologies, viewing the transition as not just technological but as a broad societal transformation. In this context, significant investments have been channelled into research and innovation, standardisation, and the development of practical applications across various sectors. This has included extensive trial and pilot projects to test and refine 5G applications, contributing to the development of an online tool, the Verticals Cartography. This tool maps 5G use cases sponsored by 5G PPP and assesses readiness across different sectors, identifying gaps and trends for future development.

This white paper examines the functionality and impact of the Verticals Cartography tool, detailing its role in tracking 5G advancements. In particular, it showcases key datasets on emerging trends to understand industry-specific applications, guide future policy, and devise effective industry standards.

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Introduction

The emergence of 5G and the impending arrival of 6G technologies are poised to revolutionise various vertical sectors, from automotive and smart cities to Industry 4.0 and extended reality (XR) in media. Far from being isolated enhancements, these advancements are intricately woven together, potentially reshaping the global societal and economic landscape. In this transformative wave, different vertical sectors participate, anticipating a new epoch of game-changing real-life applications. These include connected and autonomous vehicles, sophisticated integrated urban management systems, smart manufacturing and logistic applications driven by the Internet of Things, real-time data analytics, and extended reality for innovative content creation, delivery, and consumption. However, the influence of 5G applications potentially extends beyond these use cases, envisioning a future where every domain harnesses these technologies to boost productivity, sustainability, and living standards.

As Europe advances, the integration of 5G and the anticipation of 6G signifies more than a technological evolution; they mark a societal metamorphosis. This digital transformation era is set to be one where innovation harmonises with core values, benefiting all sectors and steering the continent towards a more interconnected, efficient, and sustainable future. So far, Europe's 5G strategy, orchestrated by the European Commission (EC), has aimed to forge a unified digital platform characterised by high-speed connectivity, minimal latency, and robust data-handling capabilities. This platform is expected to spur widespread innovation and efficiency in the ecosystem, including the vertical sectors. Such an approach is driven by strategic policies, investments, and regulatory frameworks to ensure a secure, fair, and sustainable deployment of these technologies.

GSMA has estimated the mobile sector's contribution to the European economy in 2022 to amount to 910B€, representing 4,3% of the total GDP, as shown in Figure 1.

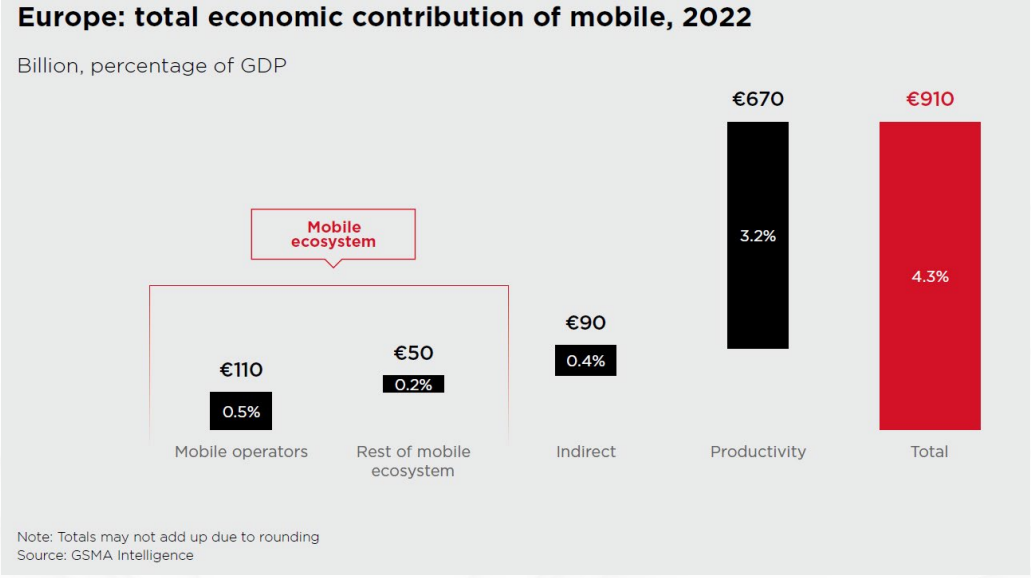

Figure 1. Mobile Economy Europe (GSMA)

The Mobile Economy will reach approximately €1 trillion in Europe by 2030. By the time 6G is commercially deployed, 5G is projected to generate revenues of 153 B€ thanks to productivity gains in vertical sectors, as depicted in Figure 2.

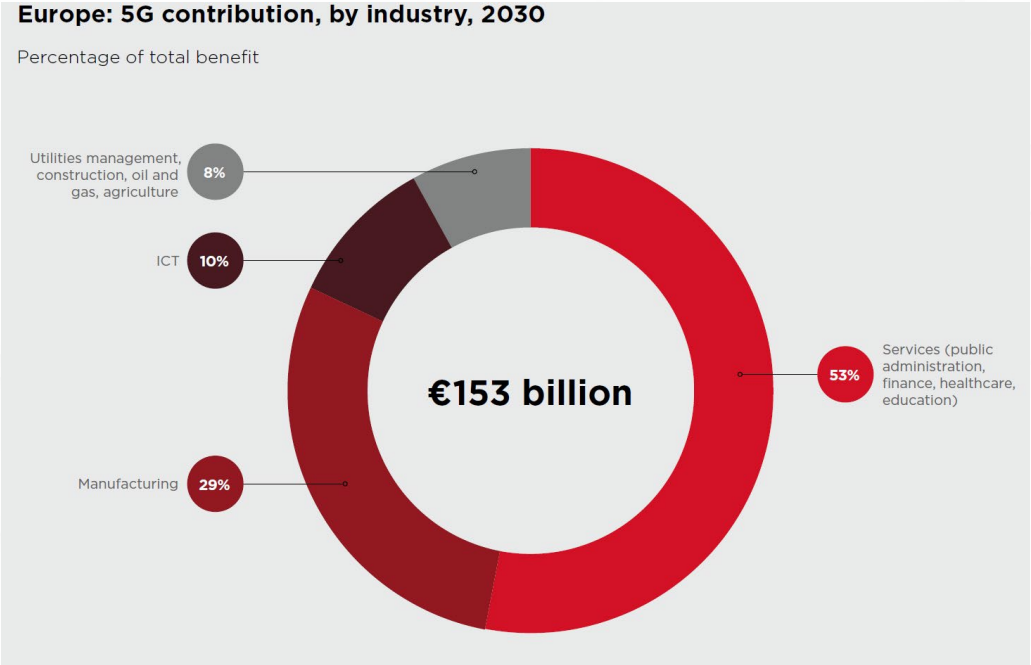

Figure 2. 5G Contribution by Industry

In this context, initiatives like the 5G Action Plan[1] and the Digital Single Market Strategy[2] are central to fostering an environment where technological progress translates into broad societal and economic benefits through the creation of revolutionary use cases spanning across different vertical sectors. In practical terms, the EC's agenda to develop and test 5G applications across different vertical sectors has been one of the pillars of the 5G Public-Private Partnership (5G PPP).[1] Initiated in 2014, 5G PPP has supported 93 research and innovation projects through three distinct phases, engaging over 700 participants. This endeavour has significantly contributed to over 800 standardisation activities, yielded over 2000 scholarly articles, and produced 40 whitepapers while fostering 445 innovations. Each phase has strategically focused on various technologies, infrastructures, devices, and industry sectors:

- **Phase 1**, starting in 2015, encompassed 19 projects that propelled key 5G technologies forward. These projects addressed spectrum requirements and evaluation, identified candidate bands, and made strides in flexible Radio Access Networks (RAN), network management, and security.
- **Phase 2**, commencing in 2017, introduced 21 additional projects concentrating on 5G flexible RAN, innovative radio systems, multi-tenant control planes, slicing control, and vertical experimentation, including trials and pilots.
- **Phase 3**, which began in 2018 and is progressing, has achieved milestones in various domains such as cellular systems, architecture, network management and orchestration, software networks, and security and privacy. It also includes trials and pilots across ten diverse sectors, notably Industry 4.0, Agriculture and Agrifood, Automotive, Smart Cities and Utilities, and eHealth and Wellness.

1. Learn more at **5g-ppp.eu**

All the 5G-related use cases from different vertical sectors, developed during 5G PPP's above-mentioned three phases, were mapped into an online tool to keep track of these evolving technological enablers at an industrial level across different segments. This tool, entitled **Verticals Cartography**[2], also measures readiness levels across European innovation landscapes, understanding emerging gaps and trends.

This white paper provides the background, scope, functionality, insights gained and impact of the Verticals Cartography tool and paves the way for the development of an even more advanced framework to keep track of the relevant developments in the 5G/6G EU research community concerning the various vertical sectors, and linking them to appropriate vertical associations and relevant standards.

2. verticals-cartography.5g-ppp.eu

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Presentation of the Verticals Cartography

2.1 Purpose and origins

The online Verticals Cartography was developed in a normative and policy scenario focused on advancing 5G technologies. A vertical, vertical sector or industry vertical is a term used for industries such as energy, media, and manufacturing. Sometimes, the terms used are aligned with statistical reports on industries; other times, they have emerged as terms signalling a concept or new ambition for a sector, such as Industry 4.0 or Smart City. Within verticals, more specific use cases are defined.

The inception of the verticals cartography was a response to the growing need for systematic tracking and analysis of 5G vertical-specific use-case experiments in a context shaped by the European Union's ambition to lead in 5G innovation and deployment to integrate innovative solutions in its industrialisation strategy. The 2021 European Union's industrial strategy tackles the challenges and opportunities presented by the twin transitions to a green and digital economy. The strategy is a roadmap for enhancing the EU's global competitiveness and ensuring its open strategic autonomy in a rapidly changing world. At its core, the strategy is about adapting to and leveraging the digital transformation, for which 5G technology is critical.[3]

In this context, 5G is seen as a primary innovation vehicle, enabling more efficient and sustainable industrial processes, enhancing remote working capabilities, and supporting innovative digital services that can lead to a more resilient and adaptable economy, including low carbon targets. High-speed connectivity and low latency are, in fact, crucial for strategic industrial areas such as smart manufacturing, autonomous vehicles, and advanced healthcare systems — all of which are part of the EU's envisioned vertical ecosystems. These ecosystems, 14 in total, range from aerospace and defence to health, digital, and energy, each potentially revolutionised by the integration of 5G technology[4].

5G is also crucial to address the need for open strategic autonomy and sovereignty, reflecting a desire to reduce dependencies on non-EU countries for critical technologies and components, given the global nature of the telecommunications supply chain and the strategic importance of the technology. By fostering diversified international partnerships and monitoring strategic dependencies, the EU aims to secure its supply chain for 5G and other critical technologies, ensuring its industries remain competitive and secure.

This environment, therefore, was (and still is) characterised by policies aimed at facilitating the widespread adoption of 5G technologies across various vertical sectors. In this sense, cartography ultimately serves as an instrument to inform policy decisions by providing a comprehensive overview of 5G applications and their impact across different industry verticals, thereby supporting EU policies related to digital innovation and infrastructure development.

The tool was initially conceived and developed within the Global5G[3] Coordination and Support Action (July 2017-December 2019) in close cooperation with a Technical Board of experts to track the progress of 5G vertical use-case experiments within 5G PPP phase 2 projects[4], starting with ICT-08-2017 and then incorporating projects funded under phase 3 ICT-17-18-19. The cartography draws on a dedicated blueprint with data points on industry vertical(s), experiment type, country and city location and the target ITU 5G functionalities, as well as overviews of the use cases or facilities supporting them as relevant.

The cartography was then handed over to the Full5G[5] project, which sustained and expanded on the previous efforts, targeting updates from the above projects alongside the integration and analysis of experiments and facilities from ICT-20, ICT-41, ICT-42, ICT-52 and ICT-53 and ICT-08. The cartography is designed to allow for continuous updates and adaptations to mirror the evolving landscape of 5G technology and its applications in various sectors. Indeed, it has lately further evolved under the 6GStart[6] project.

For 6GStart, in particular, a rebranded version of the cartography has been produced with new use cases, published on a dedicated page linked to 5G-PPP.eu's website[7].

3. global5g.org
4. 5g-ppp.eu/5g-ppp-phase-2-projects
5. 5g-ppp.eu/full-5g
6. 5g-ppp.eu/6gstart
7. verticals-cartography.5g-ppp.eu

2.2 Purpose and origins

Concretely, the Vertical Cartography is a spreadsheet that collects data on 5G PPP projects and their use cases and analyses:

- **Targeted industry verticals**: The targeted industry vertical is mentioned when possible. References are harmonised as much as possible with terminology at both the programme level and 5G standardisation.
- **Targeted ITU 5G functionality**: Enhanced Mobile Broadband (eMBB); massive machine-type communications (mMTC); ultra-reliable low latency communications (URLLC).
- **Type of Experiment**: Proof of Concept; Prototype, Demonstration; Trial; Pilot, assessing maturity and rollout readiness levels following the EU official metrics measuring the potential impact of the use cases following market readiness principles.
- **Main use case locations** at the country level (optionally city level).
- **Date of the experiment**, expressed as "Quarter (Q)-Year".

The analysis aimed to get a bird's eye view of the vertical distribution, including use cases targeting more than one vertical and new scenarios emerging outside the core set of verticals. The results emerged from mapping 92 projects funded under the 5G PPP programme.

In the cartography, industry verticals were associated with one or more icons representing the targeted vertical sector. Figure 3 displays the visual mapping of each vertical with the icon used on the online Cartography as the baseline to cluster different use cases across vertical sectors. More details about the contents of the cartography and the trends resulting from the analysis are provided in the next chapter.

Figure 3. Vertical sectors icons

8. For further information, see
HORIZON 2020 – WORK PROGRAMME 2014-2015 - General Annexes

3

Use case analysis

This Section analyses the metrics linked to the main use cases described in the verticals cartography. As of December 2023, a total of 353 use cases were collected, engaging 66 5G PPP projects targeting vertical sectors. This allowed a comprehensive view of the 5G-enabled use cases, encompassing targeted vertical sectors, testbed sites and readiness levels.

3.1 Analysis by sector

As shown in Figure 4, most use cases concern key sectors within the European industrial strategy, with peaks in Industry 4.0, broadcasting and media, transport & logistics, automotive and public safety.

Overall, the transport & logistics use case is the most addressed, with 58 use cases. The automotive sector is in second position, with 54 total use cases, of which 16 are across the border. Manufacturing is the third most addressed vertical sector, with 53 total use cases targeting smart industrial solutions and industry 4.0. This is followed by broadcasting and media, with 47 use cases linked to augmented reality, communications, and several applications in the entertainment sector. Security is the fifth most addressed vertical, with 36 public safety use cases, most linked with public protection and disaster relief (PPDR) situations.

5G applications linked to Smart cities follow, with 34 use cases divided between smart cities in general (26), smart cities containing multiple vertical applications (5) and indoor spaces (3). The remaining use cases concern the energy sector (22), healthcare applications (18), agriculture (5), satellite (4), and 22, which deal with complex technological applications whose vertical applications are still not explicit. Key topics include network innovation and service management, data security and compliance, infrastructure management, advanced technologies for enhanced connectivity and smart connectivity.

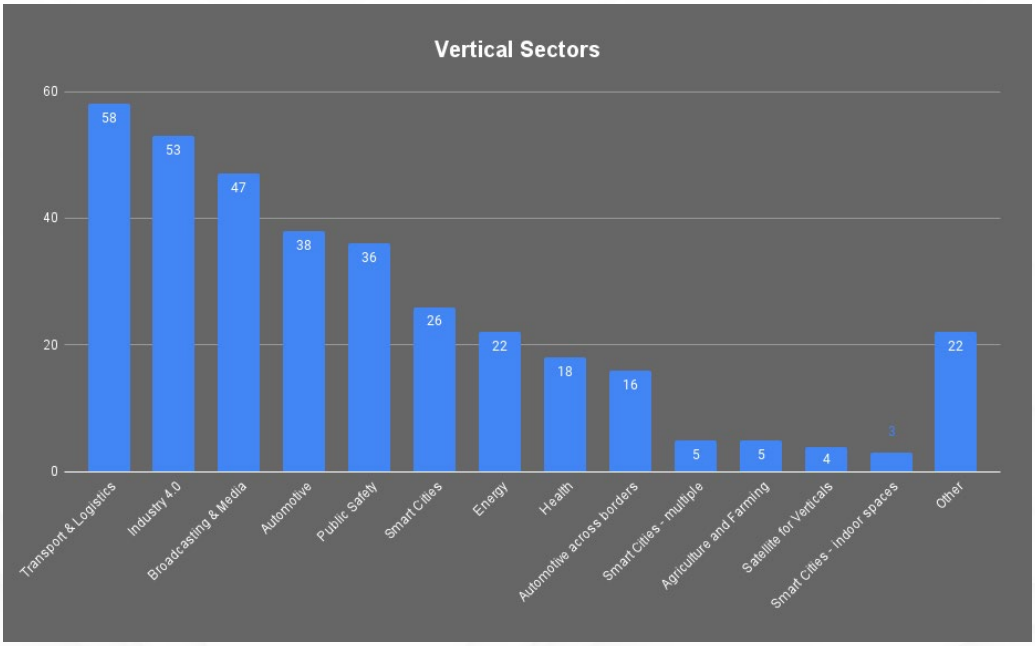

Figure 4. 5G PPP targeted use cases.

As depicted in Figure 5, the composition of experiment types within 5G projects reveals a clear preference for Proof of Concepts (TRL 3) and Demonstrations (TRL 4), constituting over 22% and 21%, respectively. Overall, these formats are favoured for their ability to showcase the practical applications and effectiveness of new 5G technologies in real-world scenarios. Demonstrations provide tangible, visual examples of how 5G can be utilised, while Proof of Concepts further verifies the feasibility and performance of 5G solutions.

Conversely, more industrially mature use cases such as Trials (TRLs 5/6) and Pilots (TRL 7) account for over 35% of total use cases – 21% and 16%, respectively. Trials are critical for testing 5G under specific conditions and parameters, often preceding broader rollouts. They provide valuable data on performance, challenges, and potential improvements under realistic conditions. Pilots offer a more comprehensive approach, implementing 5G solutions in limited areas or capacities to assess their impact and functionality before a wider launch.

Although less prevalent at 10%, Prototypes are instrumental in the early stages of 5G technology development. They represent initial versions used to demonstrate concepts or test components, serving as a foundational step toward more advanced experiment types. In 8% of the instances, the projects could not specify the exact type of experiment conducted, as they did not fit into any of these categories. This might indicate a blend of methods or a deviation from standard classifications, reflecting the innovative and evolving nature of 5G experimentation.

While the diversity in experiment types ostensibly illustrates a multifaceted approach to developing, testing and implementing 5G technologies, heterogeneous market readiness levels suggest that the industry can still make significant advances to fulfil the commercial potential of 5G solutions. With many experiments focused on Demonstrations and Proof of Concepts, there is remaining potential for many 5G applications still in the conceptual or early testing stages.

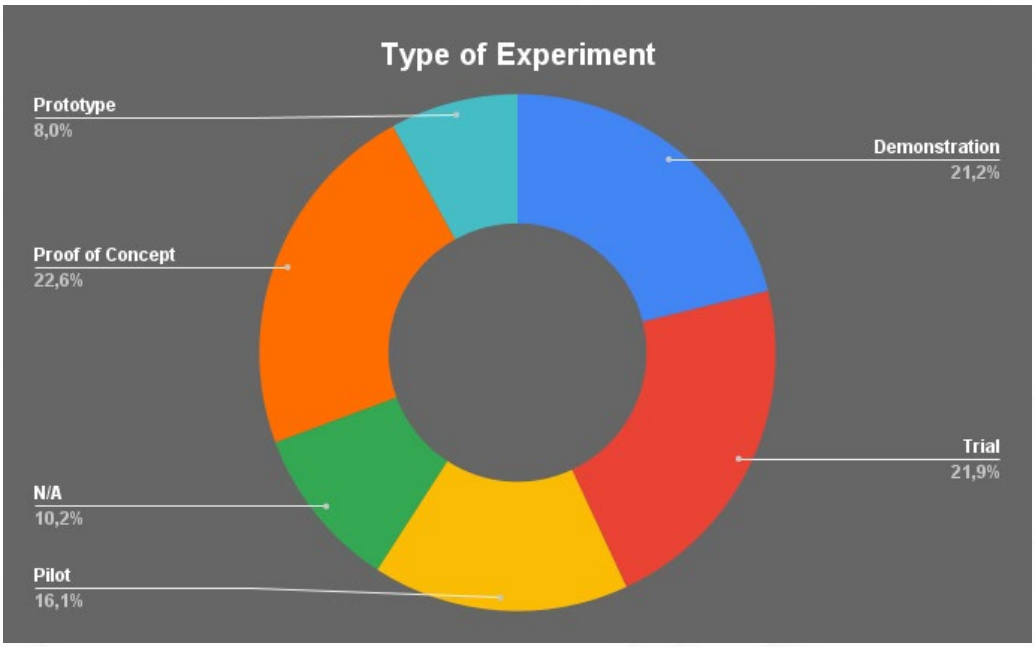

Figure 5. 5G PPP use cases experiment types and market readiness

3.2 Geographical analysis

The location within the EU, where experimentation took place on the above mentioned use case is another insight gained by the Vertical Cartography tool, allowing to outline a thorough mapping of its geographical reach (Figure 6).

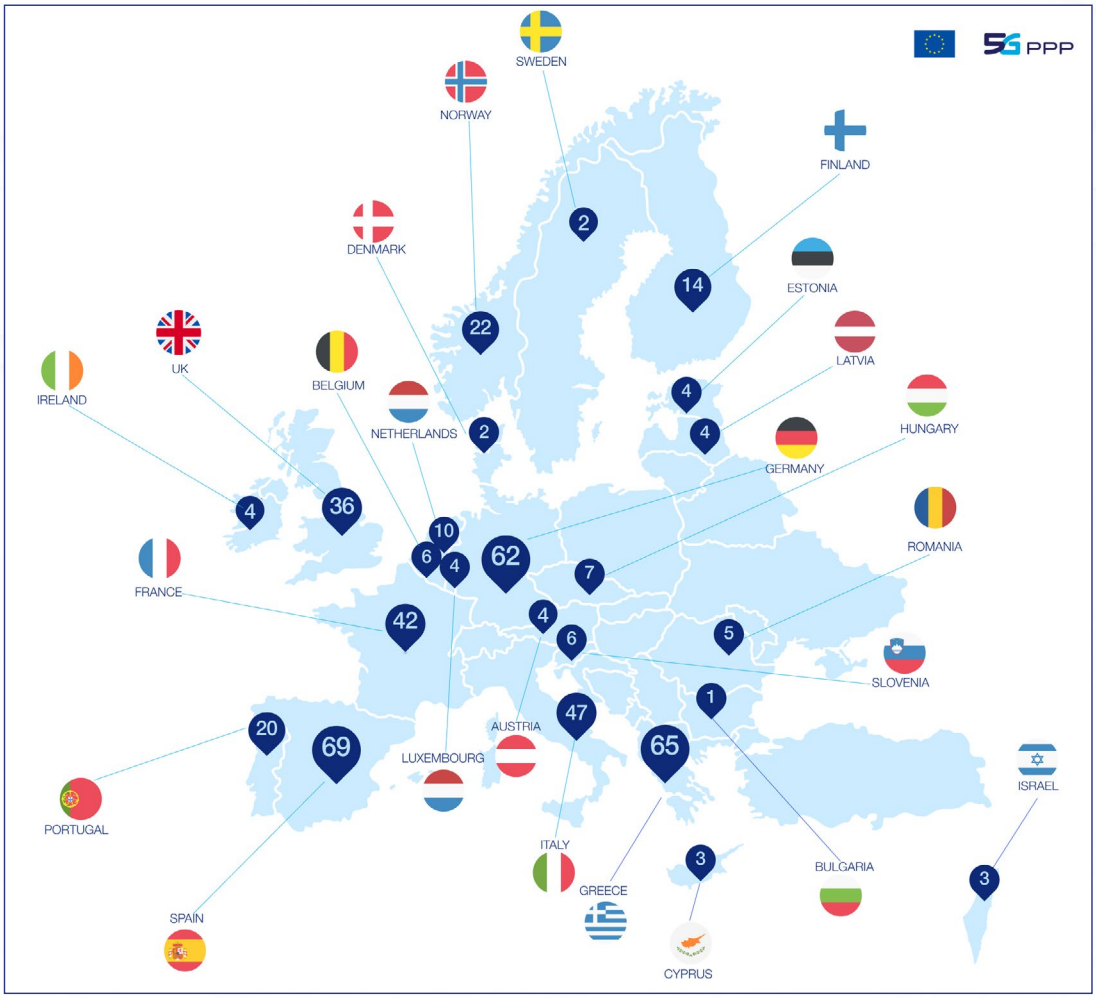

Figure 6. Use cases map

Given the geographical distribution of use cases across different projects, a four-tier classification criteria can be adopted.

Tier #1: Spain, Greece and Germany stand out as the frontrunners in Europe's 5G landscape, boasting 69, 65 and 62 use cases, respectively. These countries represent present the most use cases in Europe's 5G development.

Tier #2: The second tier sees Italy, France and the UK as prominent players in this domain, hosting 47, 42 and 36 use cases, respectively, reflecting its strategic approach to integrating 5G across various sectors.

Tier #3: Norway, with 22 use cases; Portugal, with 20; Finland, with 15; the Netherlands, with 10, compose the third tier, leveraging 5G to enhance their digital infrastructure and services.

Tier #4: Beyond these countries, the fourth and final tier sees other European and affiliated countries active on a smaller scale, with less than ten use cases hosted.

This widespread engagement reflects a collective European effort to explore and realise the potential of 5G technology. These efforts are not just about enhancing telecommunications but are also critical to driving future economic growth, supporting smart city initiatives, and enabling advancements in healthcare, transportation, and entertainment.

As 5G continues to evolve, the landscape of testbeds and use cases across Europe is expected to expand, further solidifying the continent's position as a global leader in 5G innovation and deployment.

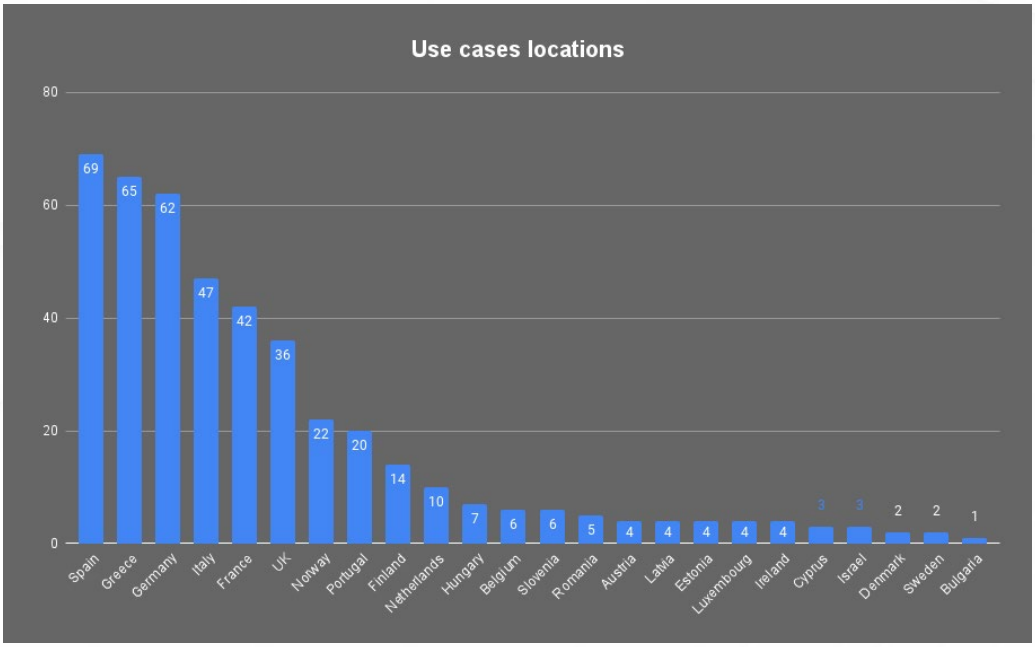

Figure 7. 5G PPP use case locations

4

Experiment types and replicability

Most of the projects have developed and experimented with use cases/solutions addressing a number of verticals. The cartography is providing a very good overview of what has been developed. In order to avoid the loss of all this work, the objective of replicability is to identify the use cases developed and to use an assessment tool to define the replicability level. This replicability level indicates the ease of replicating a use case/solution in another location.

The vertical cartography provides a large list of use cases/solutions developed and experimented with by 5G PPP projects that we have questioned to understand their willingness to make them replicable. The subset of replicable use cases will populate the replicability catalogue that the digital innovation hubs could use to develop applications for end users in the context of the Digitalisation of the European Industry.

Today, the replicability catalogue encompasses 63 replicable use cases from 15 5GPP projects. This large number of use cases covering most of the verticals will be a very useful catalogue of solutions that could be used by DIHs and contribute to the acceleration of the transfer to the market.[9]

Project	#R eplicable Usec ases	All Verticals	Industry 4.0	AutomotiveA	griculture	Media	Public Safety	Energy	Smart Cities	Transport &L ogistics	Health
MonB5G	22										
5GZORRO	31		1		1						
5G-EPICENTRE	8						8				
HEXA-X	55										
5G-HEART	16			2						68	
Smart5Grid	1						1				
DEDICAT6 G	1		1								
AI@EDGE	4		4								
EVOLVED-5G	12	1	2								
Int5Gent	2						1		1		
VITAL-5G	1								1		
5GRecord	2				2						
6GBRAINS	22										
5GInduce	21		1								
5GSMART	2		2								

Table 1. Replicability Catalogue

9. The catalogue's latest version

5

Implications and impacts of the verticals cartography

The vertical cartography tool extensively mapped the development and implementation of 5G technologies and tracked the interest/impact on each sector. This initiative was designed to map and analyse the specific needs and use cases of different industry verticals, aiming to guide and optimise the deployment of 5G solutions tailored to these sectors.

Here are some key impacts of the 5G PPP verticals cartography:

- **Mapping technology development and customised solutions for industries**. By collecting information on a large set of unique use cases, the 5G PPP vertical cartography has enabled a focused mapping of 5G use cases, contributing to a better understanding of market readiness.
- **Highlighted the value proposition of 5G**. By highlighting the concrete applicability of different use cases, companies are more inclined to invest in and adopt new technologies when there is evidence of applicability and value.
- **Informed policy and regulatory decisions**. The insights gained from the vertical cartography can help shape policy and regulatory decisions regarding 5G deployment.
- **Economic growth and competitiveness**. By driving the adoption of 5G in key sectors, the tool contributes to overall economic growth and enhances the competitiveness of European industries.
- **Consumer and societal benefits**. Ultimately, vertical-specific development translates to direct consumer benefits, such as improved services, enhanced experiences, and new products.

Future steps

6

The Verticals Cartography tool has provided significant insights into the volume, type, focus, geographical distribution and replicability of the use cases addressed within the EU Research and Innovation ecosystem. Moreover, it provides a clear indication of the views of the EU scientific community regarding the applicability of 5G-enabled solutions in the various vertical sectors, as well as the expectations of several prominent vertical stakeholders regarding the impact expected of future network technologies in their respective domains.

As the 5G PPP programme draws to an end, its successor, the Smart Networks and Services Joint Undertaking (SNS-JU)[10], has already highlighted the importance of the engagement of the vertical communities from the very early stages of the development of 6G networks. This approach is evident from funding several vertical-oriented collaborative projects through the SNS JU Work Programme and attracting even more vertical experimenters via open calls from existing SNS-JU projects[11].

The above developments signify the ever-increasing importance of the role of vertical industries within the telecoms ecosystem, which will lead to the practical co-design of future networks and services. In such an environment, the aggregated views, implementation details and insights offered by tools such as the Verticals Cartography will provide significant added value to the research and vertical communities, as well as the funding authorities, and may play a pivotal role in the further engagement of vertical stakeholders and the proper matching of available experimentation facilities, with relevant communities and related standards.

To that end, the SNS ICE Coordination and Support Action (CSA) project[12] is already working on the evolution of the Vertical Cartography tool towards a more comprehensive Vertical Engagement Tracker, which will not only keep track of the various vertical sectors and Use Cases addressed within the EU R&I community but will also link them to the respective vertical associations and relevant standards, thus providing a complete taxonomy of the engaged vertical sectors. The ambition of the SNS JU is to use such an advanced tracker to maintain a constantly updated mapping of all the relevant vertical activities within the B5G/6G scientific domain and to assist the relevant stakeholders in finding each other as well as all relevant information, communities and standards.

10. smart-networks.europa.eu
11. smart-networks.europa.eu/open-calls-from-sns-projects
12. smart-networks.europa.eu/csa-s/#SNS-ICE

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5G PPP

The 5G Infrastructure Public Private Partnership