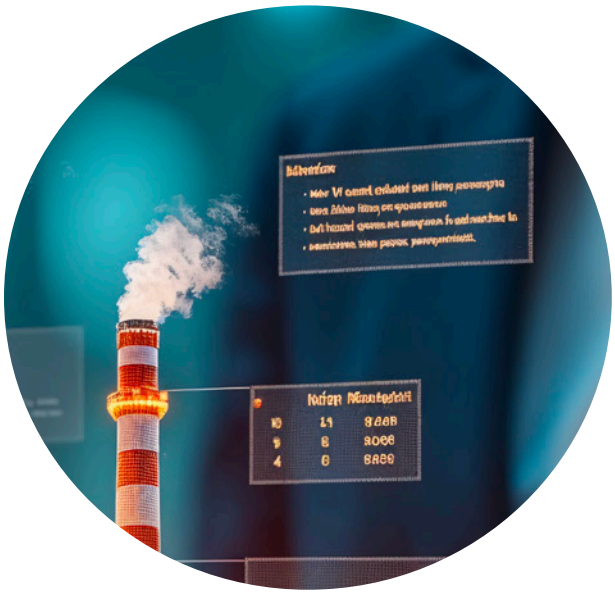
BOSCH

Rewiring Industry 4.0:
Why Private 5G is Built for Smart Factories



Software Digital Solutions

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Executive Summary

As Industry 4.0 progresses, connectivity in factories has emerged as a structural barrier to transformation. Legacy networks - wired or WI-FI cannot support the real-time, low-latency and high-density demands of modern industrial operations. Their limitations in scalability, latency, and control hinder automation, mobility, and resilience at scale.

This whitepaper outlines how private 5G overcomes these challenges. Purpose-built for industrial environments, it combines ultra-reliable low-latency communication, enhanced mobile broadband, and massive device connectivity. Unlike public networks, private 5G offers a dedicated spectrum, on-premise data security through edge computing infrastructure, and deterministic performance and ultra-reliable connectivity for mission-critical operations.

The business impact is clear. Industrial deployments have demonstrated up to a 13% improvement in gross margins and 10x–14x ROI over five years, driven by reduced downtime, increased throughput, and system adaptability.

As private 5G networks mature, enterprises and factories will unlock progressively greater value by enabling a growing portfolio of high-impact use cases tailored to their operational needs. The strategic worth of a private network is not defined solely by its infrastructure, but by the transformative applications it empowers on top of the infrastructure. These use cases are the primary drivers of business value—enhancing productivity, efficiency, and innovation across the enterprise. Clearly articulating and demonstrating this value creation is critical to justifying initial investments, accelerating adoption, and scaling the network's role as a catalyst for Industry 4.0 and industrial digital transformation.

For manufacturers seeking to scale intelligently, securely, and sustainably, Private 5G is more than a technology upgrade—it is the digital foundation for the factories of the future. With reduced infrastructure burden, it also advances sustainability targets.

Rebuilding Industrial Connectivity for the Next Era

For decades, manufacturers have refined how they move materials, assemble products, and manage labor. But today, value creation depends just as much on how reliably data moves across assets, systems, and workflows. Industry 4.0 has made the factory floor intelligent, distributed, and dynamic, but the network connecting it still remains rigid, limited, and outdated.

Wired infrastructure imposes physical constraints, increasing the cost and complexity of reconfiguration. Wi-Fi, originally built for enterprise IT, breaks down under industrial conditions, is getting congested with more devices, is prone to interference, and lacks latency guarantees. As operations grow more mobile and real-time, these limitations introduce measurable risk.

They also create a material impact. For instance, connectivity-related inefficiencies in a Tier 1 automotive facility can translate to as much as $495 million in lost output over five years. The inability to scale connectivity reliably across automated guided vehicles (AGVs), AI inspection tools, and cloud-connected production cells results in delays, downtime, and underutilized assets.

Private 5G offers a next-generation architecture to resolve these challenges. Designed for ultra-reliable, low-latency, high-density communication, manufacturers operate with deterministic control, real-time responsiveness, and secure data governance at scale. For those building the factories of the future, re-architecting connectivity is a strategic mandate to scale transformation with certainty.

Why 5G Meets the Demands of Modern Manufacturing

Modern manufacturing needs to outgrow the limits of obsolete networks. Industrial workloads now demand connectivity that delivers low latency, high throughput, and seamless scale, without compromising reliability or control. 5G meets these demands by design. Unlike traditional wired or Wi-Fi networks, which were adapted for factory use, industrial private 5G was purpose-built to serve industrial requirements from the outset. It combines three core capabilities:

Ultra-Reliable Low-Latency Communication (URLLC): Enables latency below 10 milliseconds, essential for closed-loop control, AGV coordination, and time-critical systems

Enhanced Mobile Broadband (eMBB): Supports high-bandwidth data streams like real-time video analytics and remote machine diagnostics

Massive Machine-Type Communication (mMTC): Connects over one million devices per square kilometer, enabling scale across sensor-heavy production environments

5G outperforms legacy systems on every key parameter. It eliminates the rigidity of cabling, Wi-Fi interference issues, and shared bandwidth limitations. Private 5G networks go further, offering dedicated spectrum, deterministic performance, and on-premise control over data through multi-access edge computing, infrastructure, ensuring data security.

In a direct comparison, 5G delivers faster speeds (up to 10 Gbps), lower latency (as low as 1 ms), and 99.999% uptime with full mobility support–capabilities that legacy systems cannot match. The value is already evident. Manufacturers using private 5G are improving asset reliability through predictive maintenance, reducing inspection times with AI, and accelerating workforce training via AR/VR applications.

Moreover, by 2030, manufacturing is expected to lead global 5G IoT adoption, with smart factories projected to host over 22 million connected devices, more than half of all B2B 5G deployments. 5G is not a retrofit, it is the network architecture that factories of the future will be built upon, unlocking real-time visibility, flexibility, and digital scale across every layer of industrial performance.

Public vs Private 5G in Manufacturing

Industrial transformation demands seamless, secure, and scalable connectivity, both within the factory and across the extended value chain.

Public 5G operated by Mobile Network operators (MNOs) is expanding more in consumer use cases like mobile phone, consumer goods, software defined vehicles, etc. As 5G technology evolves, a clear distinction is emerging between public and industrial private 5G deployments. Public 5G networks are designed for broad, scalable coverage and consumer mobility. In contrast, industrial 5G—deployed as private, enterprise-owned networks—is engineered for precision, performance, and control within critical operational environments. The real value of industrial 5G lies not in connectivity alone, but in its ability to serve as a secure, ultra-reliable foundation for advanced digital use cases—ranging from autonomous systems and predictive maintenance to real-time quality inspection and remote operations.

Deployed entirely within enterprise premises, it runs on dedicated spectrum, is wholly owned and managed by the organization, and supports network slicing to isolate operational traffic. This enables deterministic performance, guaranteed quality of service, and enterprise-grade security, which are critical for OT environments where delay, downtime, or data leakage are unacceptable.

In greenfield deployments, private 5G removes the need for fixed cabling, reducing infrastructure complexity and accelerating time to value. In brownfield factories, it overlays existing systems, adding wireless flexibility, often interworking with existing connectivity technologies in factories. This dual adaptability is driving adoption across sectors. In fact, the global private 5G market is projected to grow from USD 2.15 billion in 2022 to over USD 102 billion by 2032, expanding at a CAGR of nearly 50%.

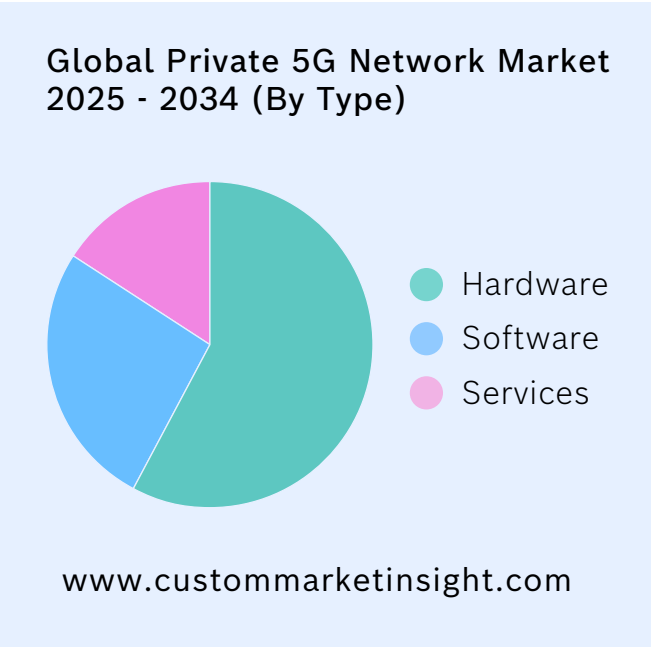


Figure 1: Global Private 5G Network Market Share by Type (2025-2034)

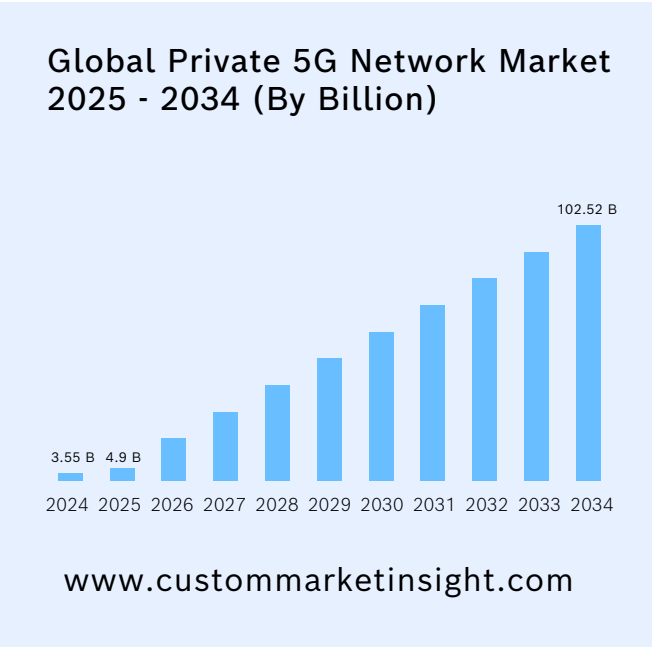


Figure 2: Global Private 5G Network Market Growth Forecast (2024-2034, USD Billion)

The Business Case for Private 5G

Private 5G delivers more than network performance; it delivers operational certainty at scale. It allows manufacturers to move from static, cable-dependent systems to intelligent, wireless infrastructures that support predictive analytics, mobile robotics, and real-time quality control. These outcomes are already being realized across Bosch-led deployments.

At Bosch's Reutlingen semiconductor plant, edge-integrated 5G networks power digital twins, AI-enhanced inspection, and dynamic reconfiguration of production lines—all while maintaining secure, on-premise control. The result: faster cycles, reduced manual intervention, and improved asset utilization. These capabilities reduce downtime, minimize manual intervention, and improve asset utilization.

The ROI is significant. Industrial deployments using private cellular networks have demonstrated up to a 13% increase in gross margins and a 10x to 14x ROI over five years. These gains stem from lower downtime, faster inspection, and reduced cabling and maintenance costs.

Private 5G is well-suited for both greenfield and brownfield deployments. In new sites, it eliminates the complexity of physical infrastructure. In existing factories, it overlays seamlessly with legacy systems, enabling wireless mobility, real-time visibility, and fast scalability without large-scale upgrades.

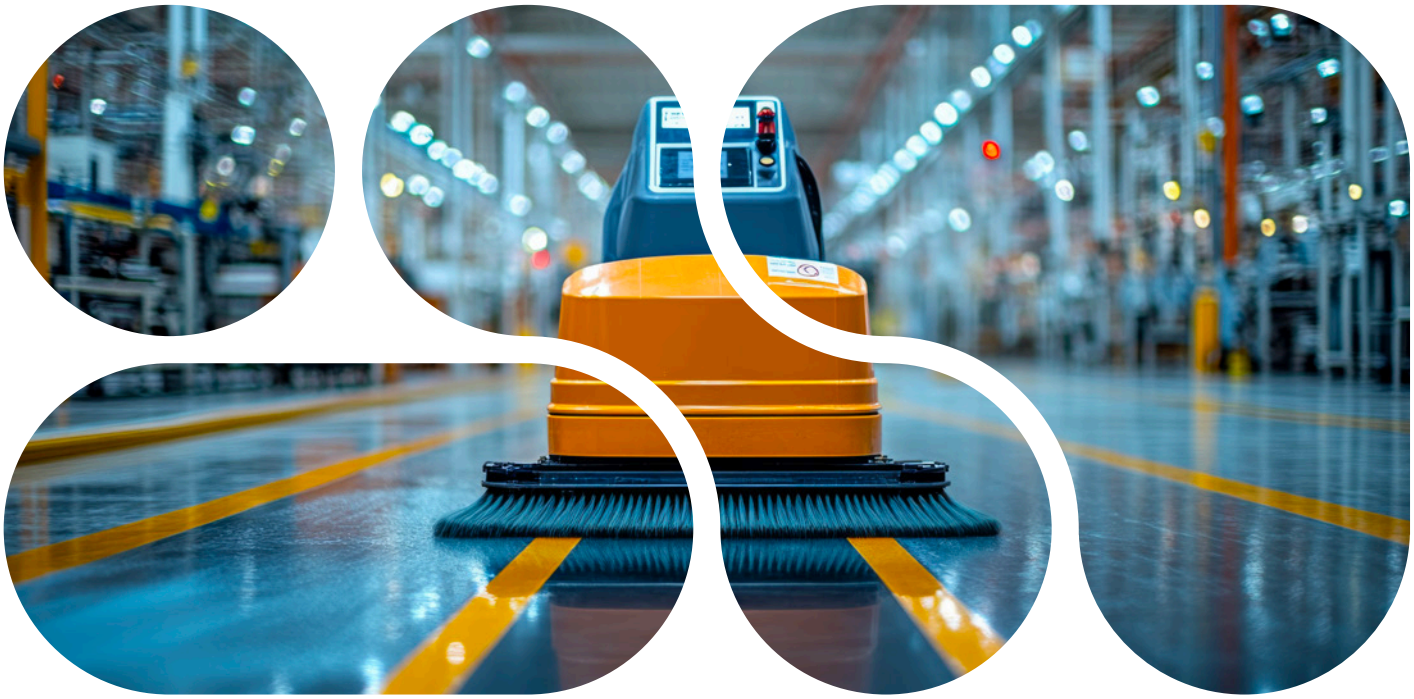
Private 5G enables a factory setup where every asset, human, machine, or system is a node in a synchronized, resilient, and future-ready network. For organizations looking to scale innovation with predictability, private 5G is a foundational requirement.

Digital Twin technology is a key enabler in Industry 4.0 and digital transformation. It creates a virtual replica of physical assets, processes, or systems, allowing real-time monitoring, simulation, and optimization. When strategically applied, Digital Twins can unlock significant value in vertical industries such as manufacturing, healthcare, energy, transportation, buildings, smart cities, etc.

5G communication infrastructure design with control plane and user plane separation (CUPS) coupled with Edge computing infrastructure uniquely supports building digital twin use cases and enterprise application integrations.

As enterprise CxOs align 5G with their broader digital transformation agendas, Bosch is uniquely positioned to drive business outcomes by enabling vertical-specific use cases through convergence of 5G and edge computing.

Through an Edge-to-Cloud infrastructure, Bosch can provide scalable and secure solutions for vertical use cases that accelerates the development and deployment of enterprise AI use cases. 5G connectivity combined with Private Edge data center, with AI compute capabilities at the edge of the network, will enable real-time AI applications that require security, ultra-low latency, and high bandwidth.



How Private 5G Supports Sustainable Manufacturing

As manufacturers re-architect operations for digital performance, sustainability has become a structural priority. Connectivity infrastructure, often overlooked, can either support or stall progress toward carbon and energy goals. Private 5G offers measurable sustainability benefits across multiple dimensions compared to traditional wired and wireless networks.

Energy efficiency:
5G networks consume significantly less energy per data unit. Advanced power management, ultra-low latency, and network slicing allow real-time load balancing and eliminate idle processing, reducing total power draw in sensor-heavy and compute-intensive environments.

Infrastructure footprint:
Fewer base stations are required for the same coverage, lowering material use, installation complexity, and operational energy. Unlike fiber and Ethernet setups, which require extensive trenching and maintenance, 5G's minimal physical layer directly reduces embedded emissions.

Lifecycle impact:
5G-enabled systems have longer operational life, reducing the need for frequent hardware replacements. This directly reduces electronic waste and lowers lifecycle carbon intensity compared to shorter-cycle Wi-Fi and cabling systems.

Cooling and operations:
5G networks optimize data transmission and compute distribution, reducing thermal loads in factory IT systems. This enables a lighter, more efficient cooling infrastructure than legacy server or fiber-heavy deployments.

Sustainability initiatives:
Private 5G supports integration with energy management systems and smart grid interfaces. At Bosch facilities, platforms like Nexeed orchestrate AGVs, HVAC, and robotic systems based on real-time demand, enabling process-level energy optimization and emission visibility.

5G does not offset sustainability; it operationalizes it. For industrial leaders embedding climate strategy into digital transformation, private 5G offers a dual advantage: high-performance connectivity with lower environmental cost.

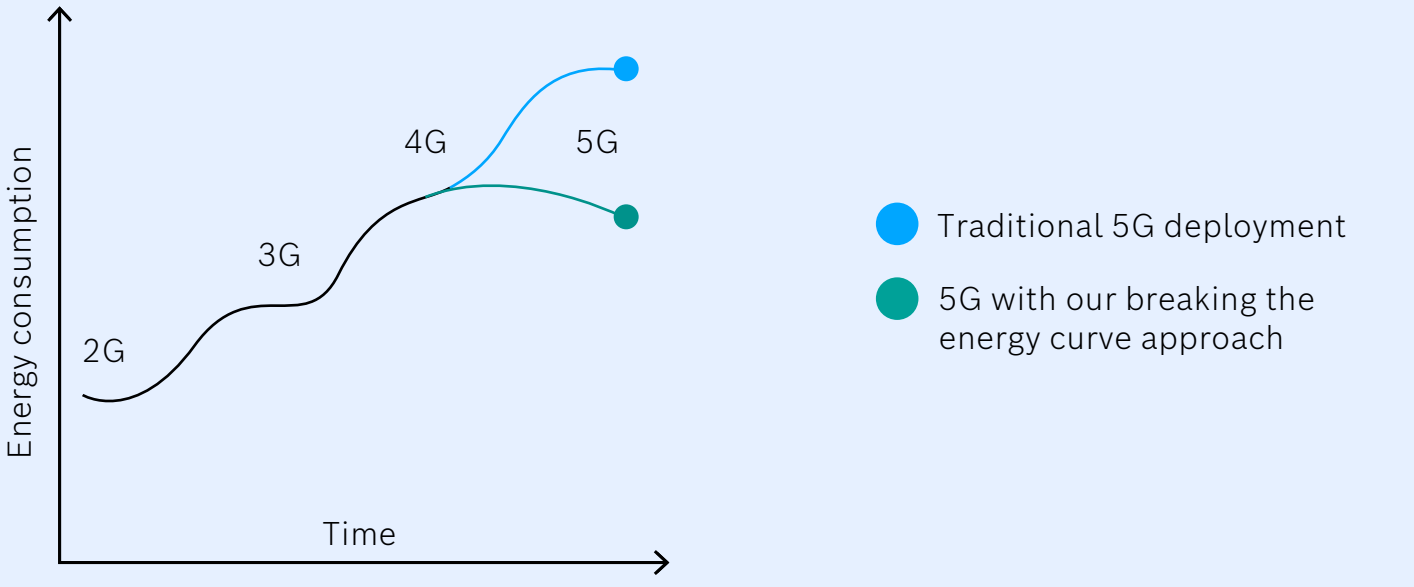
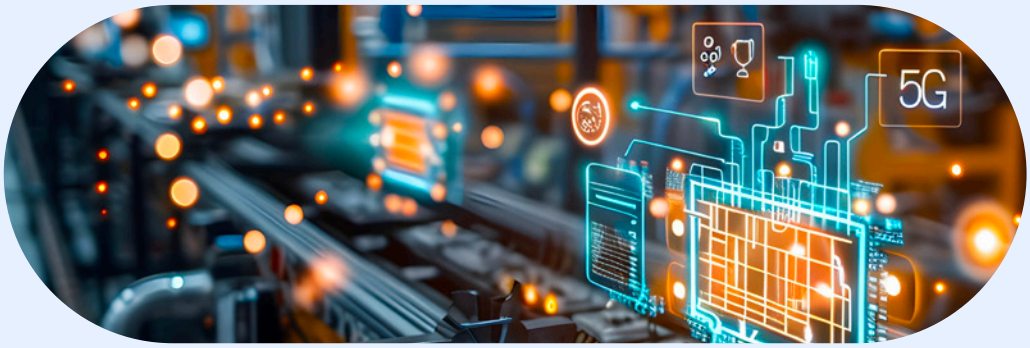


Figure 3: Reducing energy intensity through next-generation 5G deployment



Enabling the Factories of the Future with Private 5G

It marks a shift from bandwidth-constrained, interference-prone networks to infrastructure built for speed and scale. With private spectrum, ultra-low latency, and on-premise edge control, private 5G enables precise coordination across machines, assets, and edge platforms, without compromising reliability or security.

Looking ahead, the ability to orchestrate real-time, resilient operations will define the success of Industry 4.0. As manufacturing systems grow more autonomous and manufacturing facilities could scale to distributed geographic locations, industrial 5G/private 5G emerges as an essential redesign of industrial connectivity integrated with a reliable distributed computing infrastructure -Multi Access Edge Computing Infrastructure (MEC) - at distributed locations and then each edge locations further integrated to centralized cloud/data center.

This transition redefines what's possible: closed-loop robotics, predictive asset management, AI-enhanced quality, and energy-optimized operations. Crucially, it embeds adaptability into the network, empowering manufacturers to evolve continuously in response to demand, complexity, and carbon goals.

The factories of the future will not tolerate network friction. They will require seamless, software-defined performance from the ground up. And the investment case is already proven—private cellular deployments across manufacturing, logistics, mining, and oil & gas have delivered an average ROI of 28x over five years, according to global modelling across eight countries (ABI Research). These gains reflect improvements in gross margin, operational flexibility, and time-to-value across some of the world's most asset-intensive sectors.

By adopting private 5G now, manufacturers position connectivity as a competitive capability, one that drives efficiency, resilience, and long-term industrial leadership.

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Established in 1886, the Bosch Group is a leading global partner for technology and services. Bosch Software and Digital Solutions (Bosch SDS) is a global digitalization provider of consulting, engineering, and IT services. We help enterprises switch to Smarter Digital, a forward-looking approach to digitalization that is centered on the user. From creating new digital business models, enabling resilient future-proof enterprises and accelerating sustainability goals, Bosch SDS is a trusted partner for a multitude of industries across the world. As a global technology partner, Bosch SDS operates in North America, Europe, the UK, the Middle East, and Asia Pacific markets through a network of on-shore, near-shore and off-shore delivery centers.

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