National Journal LEADERSHIP COUNCIL

The future of 5G

Report on 5G deployment based on IHS economic impact analysis

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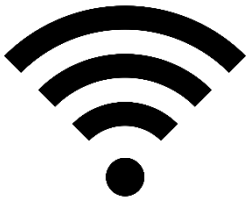
Transitioning to a 5G economy

Details on 5G and its potential

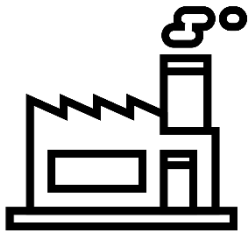


What is 5G technology?

- Fifth generation mobile networks, or **5G**, is the next stage of telecommunications standards and technology
- As a new form of wireless signal, 5G will operate in the **higher-frequency millimeter wave of the radio spectrum**. Higher frequencies bands aren't used as much and can move data more quickly
- 5G will allow users to do everything previous generations enable them to do, but at **faster speeds**, while simultaneously readying the system for **large increases in connectivity** globally

What are the advantages of 5G?

- Currently, 4G LTE transfer speeds max out at around one gigabit per second, undisrupted. 5G has the potential of increasing speeds up to 10 gigabits per second
- Additionally 5G will be robust enough to handle and encourage an increasing reliance on wireless technology, meeting the need for greater adaptability for future uses, ubiquity and lower latency



5G as a GPT

- IHS Economics and IHS Technologies have identified 5G as the next potential **GPT** (general purpose technology), characterized by "**pervasive adoption** across multiple industries," "**continual improvement** over time" and "the **ability to spawn new innovations**"
- GPTs "often are catalysts for transformative changes that **redefine work processes** and rewrite the rules of competitive economic advantage"
- Because 5G is likely to be integrated in a number of devices, services, processes and machines, IHS predicts that wireless communication using 5G technology will become what it considers a GPT

Sources: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017; Michael Nunez, "What is 5G and how will it make my life better," Gizmodo, February 24, 2016; Noun Project, 2017.

5G allows more users to do everything previous generations enabled, but faster

Generations of wireless technology

1G: The foundation of mobile, the first generation introduced **wireless analog voice communication** working in the 150 MHz frequency band. Areas were divided into cells that were served by operator deployed base stations.

However, 1G faced issues of **limited capacity** because of the limited amount of spectrum used, and **limited scalability** because of the size of analog devices, inefficiency and costs.

2G: Launched in 1991, 2G transitioned from analog voice transmission to **digital**, which allowed for compression and in turn **more users**, and introduced **SMS text messaging** as a service. Additionally, digital technology was lighter, smaller, cheaper and more secure. In many areas in the world, 2G technology is still used.

As part of the switch from analog to digital, in some cases it was more difficult for signals to reach cell towers in less crowded areas due to the difference in decay curves. This meant that in more rural areas, **calls could be dropped**.

3G: The third generation introduced data services and Internet access to mobile phones using **packet switching**, ushering in the era of the smartphone. 3G technology also includes Bluetooth, WLAN, mobile TV and video calls.

Compared to 2G technology, 3G is **much more expensive**. Additionally, because the new capabilities of 3G involved high bandwidth transmission, **battery life in devices is greatly reduced**. Cellular operators also **imposed data caps** because the data consumption could be too much for the network to handle.

4G: The most recent 4G LTE technology has bettered the functionalities available in previous generations and allows for even more capabilities, such as **downloading and uploading large video files.**

4G can experience compatibility issues, and download speed can be disrupted by many factors, such as microwaves and other WiFi signals.

5G: The newest form in development, 5G, aims to increase download speeds dramatically, decrease latency and meet the demand of the rising rates of connectivity

Sources: "The evolution of mobile technologies," Qualcomm, June 2014; Michael Nunez, "What is 5G and how will it make my life better?" Gizmodo, February 24, 2016; Vivek Sanghvi Jain, Sanchit Jain, Laskshmi Kurup & Aruna Gawade, "Overview on generations of network," Int.J. Computer Technology and Applications, Sept-Oct 2014.

5G technology has the potential to have global economic impact in a variety of ways

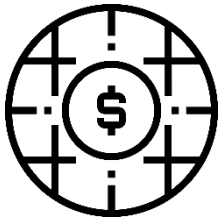
Three ways 5G can potentially contribute to the global economy

1. Potential sales of products and services

- Widespread adoption of 5G will likely enable to sales of new goods and services across a wide range of industries
- These products and services could be improved through 5G deployment, or even made possible by the technology

2. 5G value chain

- Through research and development, investments in infrastructure and application development, 5G technology will continue to evolve, and the value chain that delivers it will deepen



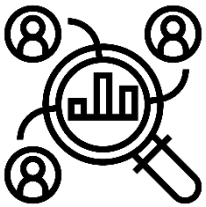
3. GDP growth

- 5G technology could potentially drive long-term sustainable GDP growth on a global scale

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

Likely stages of 5G deployment and applications

Expected progress of 5G technology adoption and types of uses



EMBB applications

- At first, 5G deployments will likely focus on enhanced mobile broadband (EMBB) applications, centering on user needs like access to multimedia content, services and data, improved performance, and better coverage
- Network improvements will likely allow for more efficient and cheaper data transmission

Industrial and governmental deployment

- As 5G deployment progresses, industry players and the government, in addition to consumers, are likely to become the main drivers
- Mission critical services (MCS), such as telemedicine and autonomous vehicles, and massive Internet of things (MIoT) applications, like smart cities, are likely to arise

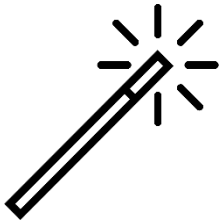
Mobile as a GPT

- As 5G implementation becomes widespread in devices, machines and processes across many industries, wireless communication will become a GPT, transforming industries and economies

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

Enhanced mobile broadband (EMBB)

Details on EMBB and use cases



Traits of EMBB

- Extended cellular coverage to a wider range of areas and structures and an improved capacity to handle a greater number of devices using larger amounts of data, resulting in better, more consistent mobile applications regardless of location
- Most likely to have a near-term impact
- Much is an extension of 4G
- Likely to see quick uptake
- Net economic impact of 5G will probably less transformative than other applications

Examples:

- Enhanced indoor wireless broadband coverage
- Enhanced outdoor wireless broadband coverage
- Fixed wireless broadband deployments
- Enterprise teamwork/collaboration
- Training and education
- Augmented and virtual reality
- Extended mobile computing
- Enhanced digital signage

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

Massive Internet of things (MIoT)

Details on MIoT and use cases

Traits of MIoT

- Built upon earlier investments in member-to-member and traditional Internet of things applications to address a larger segment of the markets
- Addresses and enables large increases in economies of scale to spread adoption and utilization in every sector
- Lower costs through improved low-power requirements, operability in licensed and unlicensed spectrum, and improved coverage
- Greater uptake of mobile technology
- Widely commercially available

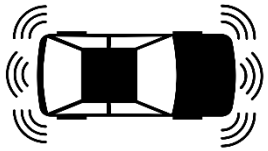
Examples:

- Asset tracking
- Smart agriculture
- Smart cities
- Energy/utility monitoring
- Physical infrastructure
- Smart homes
- Remote monitoring
- Beacons and connected shoppers

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

Mission critical services (MCS)

Details on MCS and use cases



Traits of MCS

- Requires high reliability, ultra-low latency connectivity, strong security and strong availability
- New applications for mobile technologies
- Use cases are often emerging markets
- Growth dependent on market innovation, appropriate regulation development and 5G network deployment
- Growth will likely take longer to accelerate
- Large societal impact

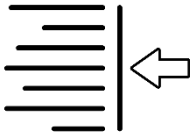
Examples:

- Autonomous vehicles
- Drones
- Industrial automation
- Remote patient monitoring/telehealth
- Smart grid

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

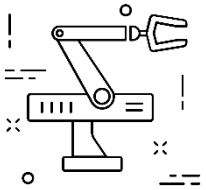
A fruitful 5G ecosystem is contingent on multiple factors

Factors that will lend to the success of 5G deployment



Development of standards

- A global standard for 5G needs to be developed, establishing an architecture for the new network
- Issues needed to be addressed: **scalable orthogonal frequency-division multiplexing-based waveforms**, a **new framework** for lower latency and forward compatibility, and **new advanced antenna techniques**

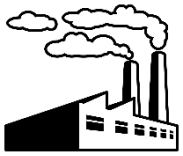


5G network deployment

- Mobile network operators and 5G stakeholders may be able to drive the pace of upgrades from LTE to 5G **by educating and engaging industries** like manufacturing, energy, healthcare and transportation
- In contrast to previous generations of wireless, which focused on the user-end experience, 5G targets the industry

Spectrum availability

- While 5G technology will more efficiently use existing spectrum, **new spectrum must also be made available for more development**
- There are already initiatives working to open up spectrum for 5G use, led by leading institutions around the globe including the FCC, the Asia Pacific Telecommunity for the Asia Pacific region and the European Commission for the EU



Adoption by industry

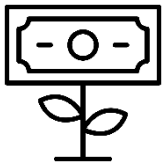
- 5G stakeholders will need to gain an understanding of the variety of industries that are potential markets, and their respective pertinent use cases
- These applications will determine network requirements
- The stronger understanding 5G players have of these applications, the more likely they are to establish traction in the market

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

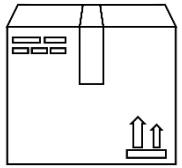
Economic projections of 5G contributions

The global impact of a 5G economy in figures

$12.3 trillion
in global sales activity enabled by 5G in 2035

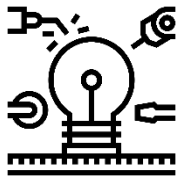


$200 billion
of expected annual investment from 2030 to 2035 for 5G development



4.6%
of global real output enabled by 5G in 2035

22 million jobs
supported by the 5G value chain by 2035



$3.5 trillion
of economic output from the 5G value chain by 2035

0.2%
contribution of 5G to global real GDP, equivalent to current GDP of India

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

Breakdown of global economic activity enabled by 5G

Expected impact level for each application type by 2035

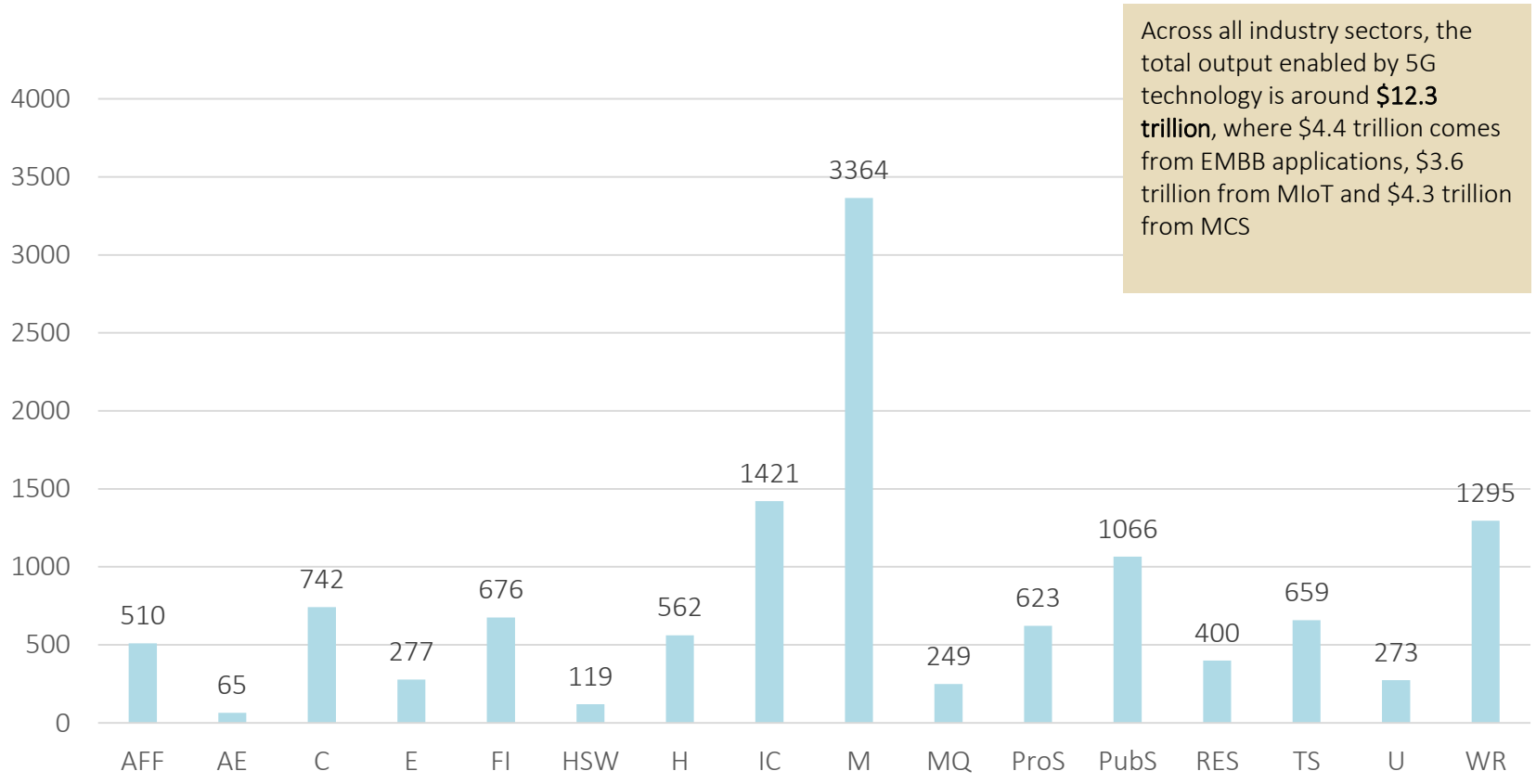
Industry	EMBB	MIoT	MCS
Agriculture, forestry & fishing (AFF)	Medium-high	Medium-high	High
Arts & entertainment (AE)	High	None	Medium
Construction (C)	Medium	Medium-high	Medium-high
Education (E)	High	None	None
Finance & insurance (FI)	Medium-high	Medium-low	High
Health & social work (HSW)	Medium-high	Medium	High
Hospitality (H)	Medium-high	Medium	None
Information & communications (IC)	High	Medium-high	Medium-high
Manufacturing (M)	High	High	Medium-high
Mining & quarrying (MQ)	Medium-high	High	Medium-high
Professional services (ProS)	High	None	None
Public service (PubS)	Medium-high	High	Medium-high
Real estate activities (RES)	Medium	Medium-high	Medium-low
Transportation & storage (TS)	Medium	High	High
Utilities (U)	Medium	Medium-high	High
Wholesale & retail (WR)	Medium-high	High	Medium

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

Manufacturing industry expected to have largest boost in output through 5G implementation

Projected industry output enabled by 5G in 2035

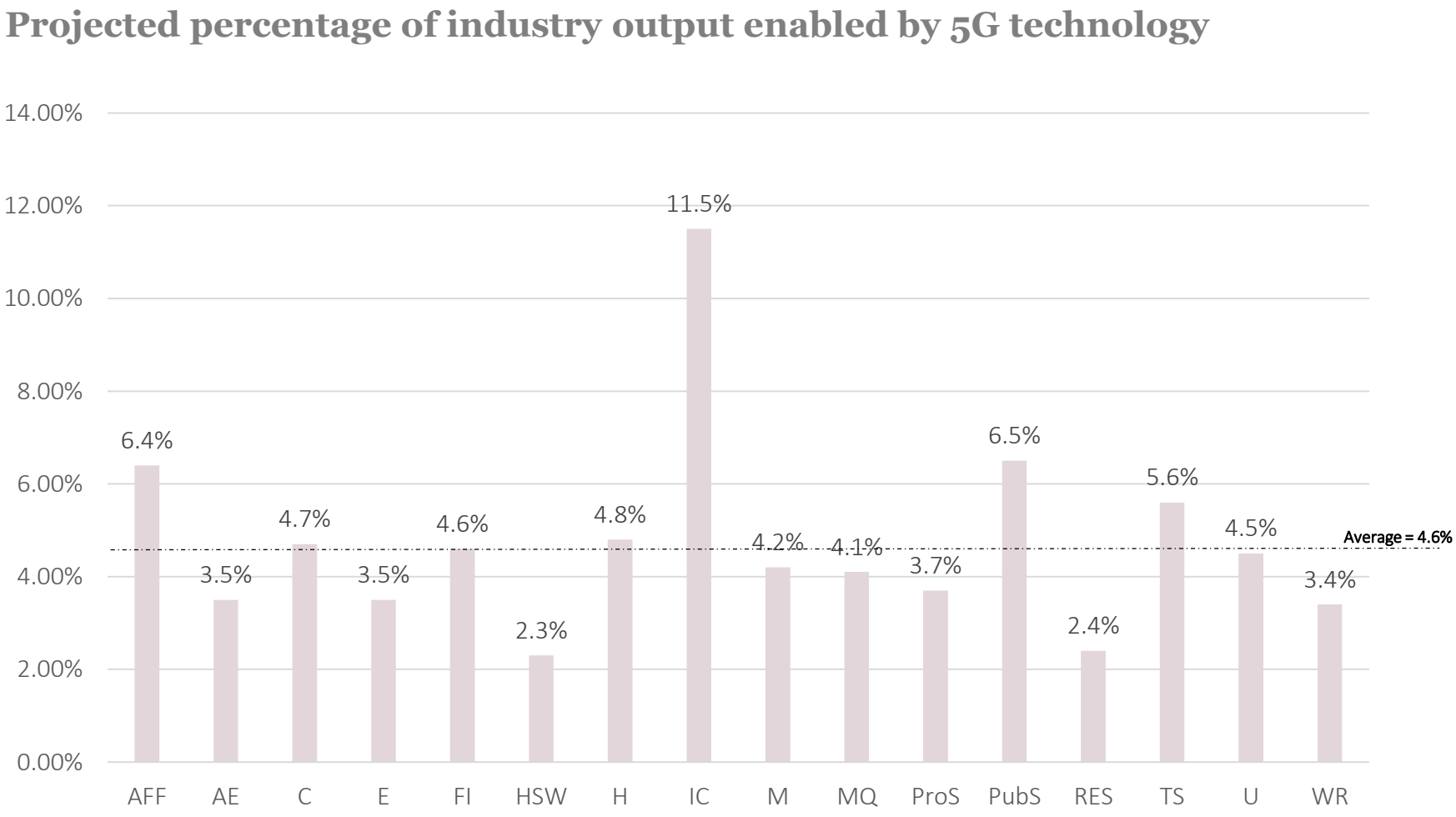
2016 US dollars, billions



Across all industry sectors, the total output enabled by 5G technology is around **$12.3 trillion**, where $4.4 trillion comes from EMBB applications, $3.6 trillion from MIoT and $4.3 trillion from MCS

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

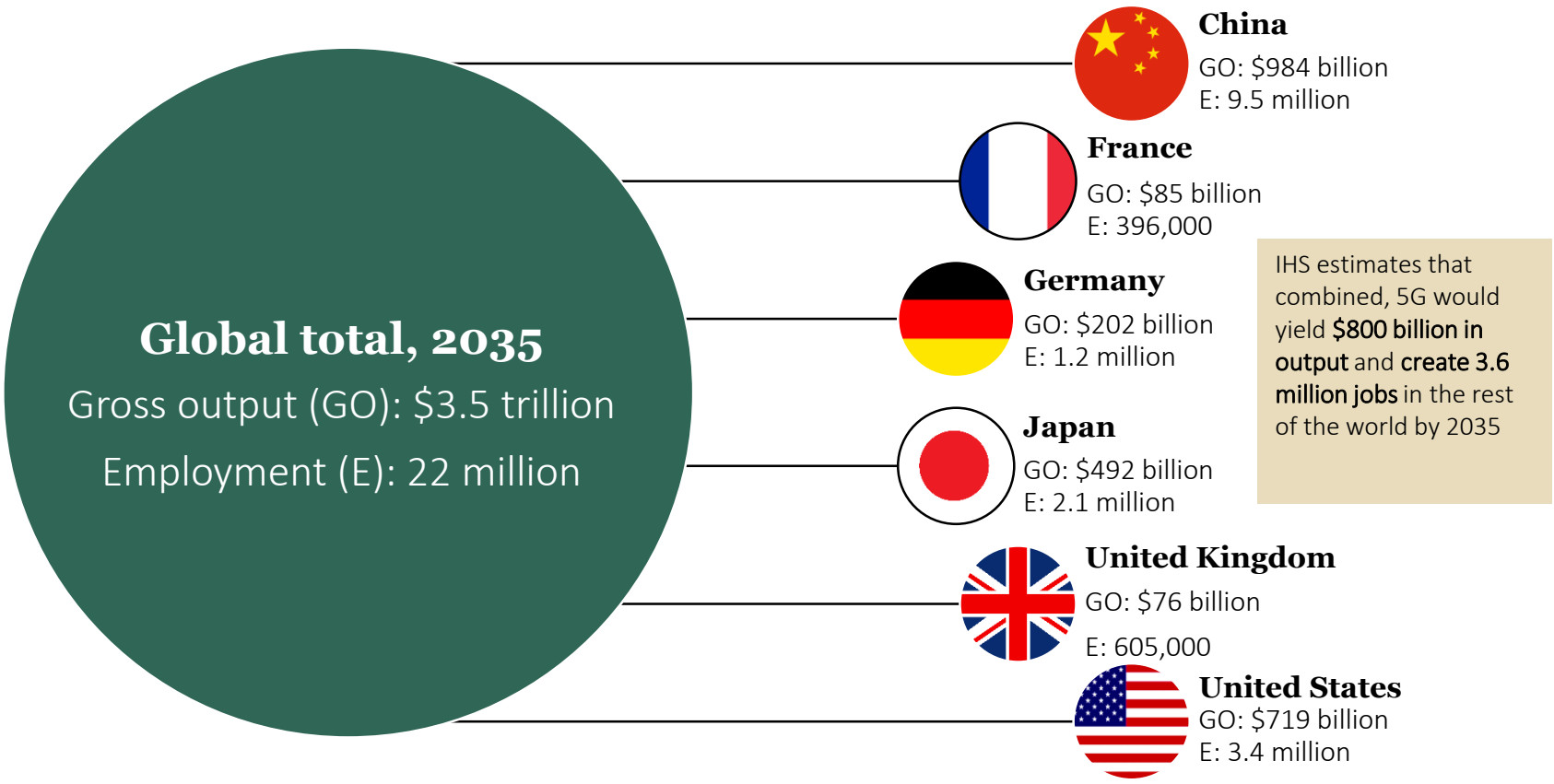
Projected percentage of industry output enabled by 5G technology



Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

5G value chain has potential global impact based on employment and investment

Projected 5G value chain output and employment by 2035



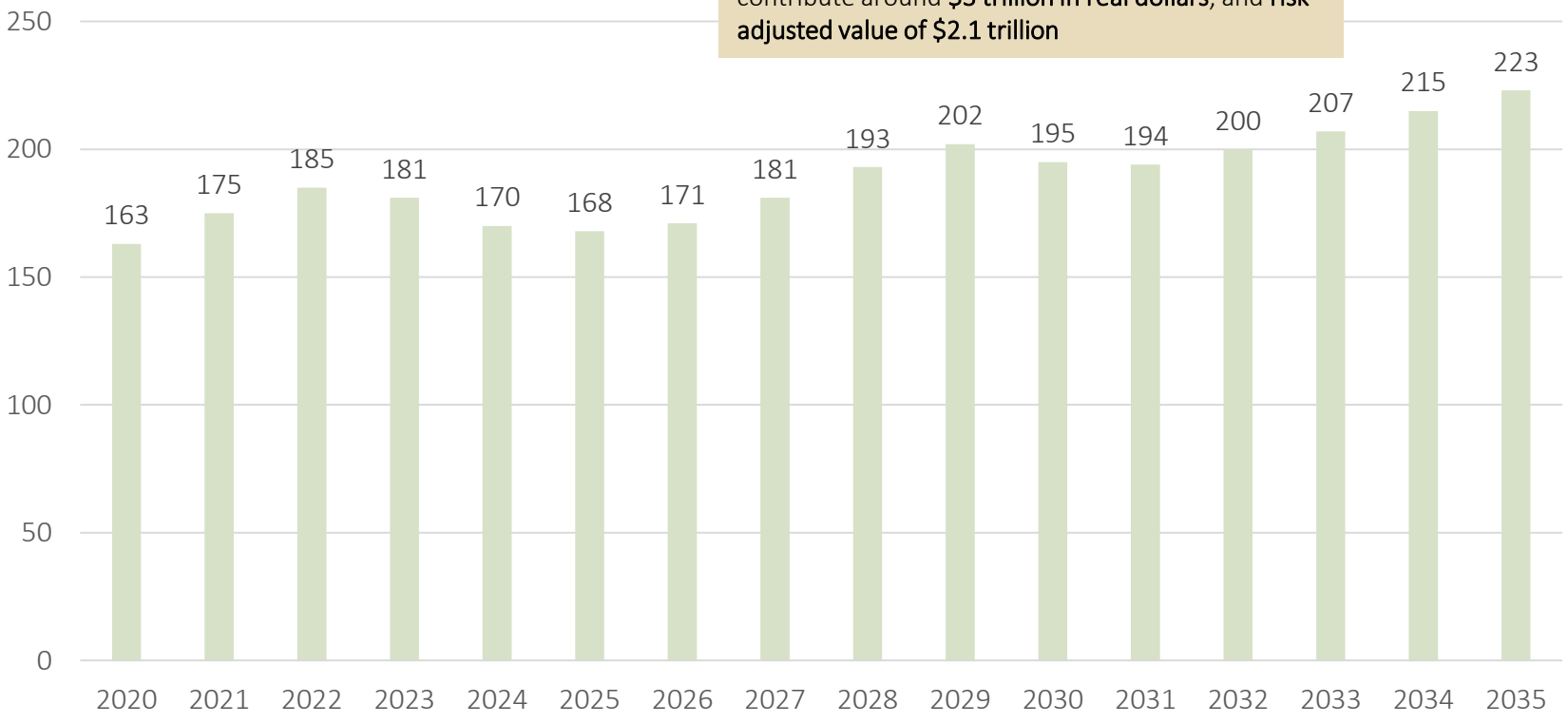
Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

5G technology expected to provide sustainable economic growth on a global scale

Projected annual net contribution of 5G to global growth

2016 US dollars, in billions

From 2020 to 2035, 5G technology is expected to contribute around **$3 trillion in real dollars**, and **risk-adjusted value of $2.1 trillion**



Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.

More than ever, policy will need to keep pace with technology when 5G is implemented

Policymaking and regulatory implications

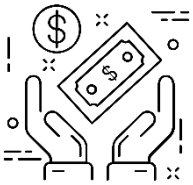
Public policy with 5G

- Because of the likely ubiquity of 5G in everyday life and every industry, the burden of government on national, state and local levels to regulate the technology and keep pace with innovation grows greater
- Additionally, 5G is likely to disrupt existing business models (ex: how 4G services such as Uber and Airbnb popularized the "sharing economy"), leaving policymakers to address these changes
- Fields policy will most likely need to address:
    - Public safety
    - Cybersecurity
    - Privacy
    - Public infrastructure
    - Healthcare
    - Spectrum licensing and permitting
    - Education, training and development

Three broader focuses for policymakers:

Encourage public and private cooperation when developing 5G standards

Ensure adequate intellectual property protection for standardized technology



Enable firms to take risks, make long-term investments, and put resources towards research and development

Source: "The 5G economy: how 5G technology will contribute to the global economy," IHS Markit, January 2017.