Perspective

China's semiconductor ecosystem: opportunities and challenges

April 2021

Caroline Gabriel and Michela Venturelli

RESEARCH

Contents

List of figures

1. Executive summary

The Chinese government laid out its Made in China 2025 strategy in 2015, setting a target of achieving 70% self-sufficiency in semiconductor production within a decade. In 2020, trade tensions and restrictions on access to key US technology redoubled that desire to be self-sufficient. More than that, China aspires to technology leadership in the chips that power platforms, such as those for 5G and artificial intelligence (AI), that are central to the country's economic and hi-tech goals.

These two goals, for greater self-reliance and for technology leadership or global parity, are driving an increase in investment and innovation, which will transform China's hi-tech sector and affect the global ecosystem. A significant number of start-ups and large companies are contributing to the effort, and in the second quarter of 2020, investment in the semiconductor industry was 10 times the figure in the same quarter in 2019.

Progress is not only driven by the current geopolitical situation, but by China's broader ambitions to be at the cutting edge of technologies that will transform society and the economy, such as 5G, AI, robotics and green energy. Analysys Mason carried out an assessment, based on extensive stakeholder interviews, of China's progress in these strategic technology areas. We judged that memory technology and AI were the areas where Chinese companies had made the most significant progress, by 2020, in closing the gap with international suppliers in terms of technology and production scale.

In some areas, China is close to equalling international market leaders in terms of advanced capabilities. It has the most advanced semiconductor capabilities in the world in some applications, such as chips with unique performance levels for advanced video transcoding and crypto mining; and in some broader technology categories, including some types of memory, it is levelling with the global giants in terms of implementing next-generation designs with advanced capacity and power efficiency.

However, the challenge for China's ambitions lies not in a lack of hi-tech capabilities, but in the time it will take to scale up its innovations and its processes, to support huge levels of demand. In 2019, Chinese companies purchased chips worth a total of USD304 billion, so the goal of self-sufficiency is a challenging one.

Individual vendors can rely on in-house teams or key partners to develop the semiconductor technology they require quickly, on a proprietary basis, but to achieve the bigger goals of Made in China, and deliver affordable chips for the hi-tech industry as a whole, open ecosystems with massive scale are needed. Only these will be able to support the extremely high demands of vendors in sectors such as telecoms or cloud, at price points that are comparable to those paid by hi-tech suppliers in other countries.

This is a multi-year journey, so it is important that efforts are prioritised effectively. In reality, China does not need to achieve self-sufficiency and technology parity across the whole vast range of semiconductors. The biggest impact on its economy will be felt if it focuses on developing chips that power the most critical advanced technologies. In our view, the top-five technologies are 5G system-on-chip (SoC), AI (including robotics), cloud processors and accelerators, automotive, and ultra-low-power chips for mass-scale Internet of Things (IoT) use cases. We have also considered memory chips and the new generation of foundry processes, because these underpin success in all five categories.

All of these are the focus of many Chinese developments involving hi-tech giants and start-ups, as well as major technology buyers such as cloud providers. This report summarises our detailed assessment of the timeframe in which China can achieve self-sufficiency in these key areas, with the main opportunities and risks.

Individual semiconductor design is important, but it is just as important that the chips can be manufactured using the most advanced, scalable processes and enable technologies to deliver the best performance at the lowest cost and power consumption.

The main Chinese foundries, Semiconductor Manufacturing International Corporation (SMIC) and Hua Hong Semiconductor, are expected to achieve domestic self-sufficiency in the 28nm process within a year. The most advanced categories of chips, in terms of performance and power efficiency, require smaller geometries, so the eyes of the global chip industry are on SMIC’s finFET N+1 process, which was unveiled in summer 2020. This delivers 57% lower power consumption and 55% smaller chip size than 28nm, which makes those metrics similar to those enabled by a 7nm process. The success of this process at scale will be critical to achieving China’s semiconductor ambitions in the next 1–2 years.

The acceleration of Chinese investment in, and development of, semiconductors will deliver benefits for its own technology vendors and consumers, and for national socioeconomic objectives. It will also have international impact. For instance, China may adopt a new approach to a semiconductor design challenge, in order to leapfrog existing technologies, and that would affect the whole industry. Strong support for the open RISC-V processor architecture is an example.

However, the maximum impact will be felt only with a return to international co-operation, enabling the global hi-tech industry to take advantage of China’s innovations, and allowing Chinese companies to access markets and hi-tech developments on a global basis.

2. Introduction

The Chinese government laid out its Made in China 2025 strategy in 2015, setting a target of achieving 70% self-sufficiency in semiconductor production within a decade. Objectives included:

- helping the Chinese electronics industry to find new growth opportunities and improve its control of access to strategic components
- supporting China’s broader ambition to transition to a more knowledge-based economy with the development of valued-added manufacturing and services
- reducing China’s trade deficit in semiconductors – the largest element of its total trade deficit because of its industries’ very high usage of chips
- reducing reliance on foreign vendors for the supply or manufacture of chips with strategic purposes such as defence.

In 2020, trade tensions and restrictions on access to key US technology redoubled China’s desire to be self-sufficient, and the benefits of controlling the full supply chain in key industries such as telecoms and automotive were highlighted by the COVID-19 pandemic-driven worldwide shortage of some automotive chips in early 2021.

In the second quarter of 2020, investment in China's semiconductor industry was 10 times the figure in the same quarter in 2019.

So China's latest 5-year plan (2021–2026) introduced in March 2021, is ambitious in terms of the country becoming self-sufficient in the production of semiconductors.

More than self-sufficiency, China aspires to technology leadership in the chips that power platforms, such as those for 5G and AI, which are central to the country's economic and hi-tech goals. Semiconductors are one of seven hi-tech industries for which detailed strategic plans will be published during 2021 as part of the 5-year plan and building on Made in China 2025, as well as the Dual Circulation strategy, announced in 2020.

So far, China has fallen short of its ambitious objective to address 40% of its domestic semiconductor needs by 2020. However, Chinese semiconductor companies have generally outperformed global competition in terms of sales growth in recent years, and this growth is often particularly strong in the most strategic semiconductor sectors, such as 5G chips. In a sample of 25 leading listed Chinese semiconductor companies, in the period from 2010 to 2020, their revenue growth averaged about 18% a year, compared to about 4% for the industry worldwide. Restrictions on some Chinese organisations accessing US components have only accelerated efforts to reduce reliance on external suppliers and intellectual property.

An important factor behind the growth of Chinese semiconductor companies is the size of the home market, which can support a strong business even without exports. In 2019, Chinese companies purchased chips worth a total of USD304 billion, and the Chinese market for semiconductors and chip manufacturing equipment will generate opportunities close to USD1 trillion by 2025. This makes it challenging to become self-reliant, but the further the country progresses towards self-sufficiency, the more of that huge sum will go to domestic suppliers.

In the period to 2025, the most important goals are greater self-sufficiency, and the building-up of technology leadership and intellectual property in strategic technology areas such as 5G and AI. The latter will provide the foundations of an increasing export business, especially when geopolitical conditions improve, but in the short term, global market share is not the primary objective.

This can create confusion when assessing the progress of China's semiconductor ecosystem, as reports often focus on market share rather than growth within the home market. Chinese companies remain small on the global stage. Among listed companies, only the largest Chinese foundry, SMIC, is in the global top five in its segment, but such assessments exclude major state-backed groups such as Tsinghua Unigroup, or divisions within diversified companies, such as HiSilicon. In addition, a large number of start-ups, and a supportive investment environment for them, will help to stimulate innovation. Over 20 000 new semiconductor companies were listed in China in 2020. Of course, many will fail or amalgamate, but the figure highlights the levels of innovation and funding that are now being pumped into the industry.

The twin goals of greater self-reliance and of technology leadership or global parity are driving a significant increase in investment and innovation, which will transform China's hi-tech sector and affect the global ecosystem. These investments will also help Chinese semiconductor providers to increase market share and influence in external markets. The global semiconductor market was worth USD430 billion in 2020, up 10% on the previous year, and several trends are expected to drive growth throughout the 2020s, opening up new opportunities for Chinese firms to establish technology leadership. In the short term, individual companies can address new requirements with proprietary developments, but the national goal is an open ecosystem with a common technology and intellectual property base, which can deliver massive scale and have an impact on global trends and standards.

3. Key categories for self-sufficiency and leadership

As noted above, an assessment of the success of the semiconductor industry in China should be measured not according to the entire chip industry, but rather in the context of how strategic the chips are to key industries. Analysys Mason carried out an assessment of the most important categories of semiconductor by which to assess China's status and progress. This assessment identified the most important industries or technologies for China's economic plan, and the chips that would be essential to them; and assessed the scale of the domestic market, in terms of potential revenue for semiconductor providers. We assumed that, if the country's chip providers perform well domestically, based on the drive for self-sufficiency in strategic components, that would in future translate into a global revenue and intellectual property rights opportunity too.

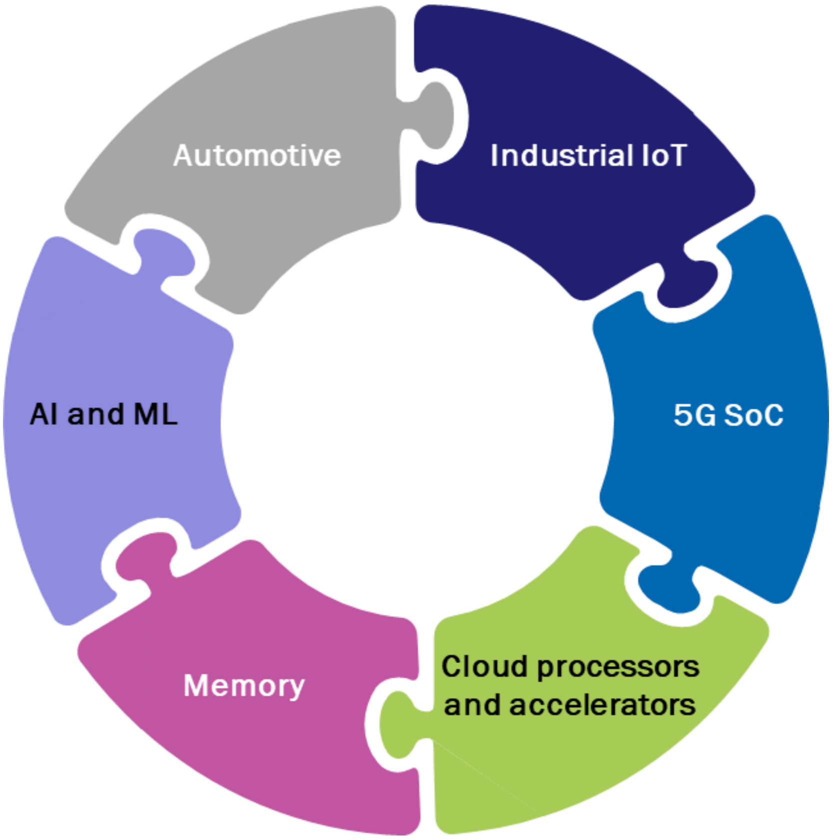
Our assessment was based on a rich set of stakeholder interviews with Chinese companies and international players with significant Chinese activities. It included a survey of:

- 22 supply-chain participants (processor designers, other components providers, foundries, start-ups)
- 20 semiconductor customers, including suppliers of 5G devices and infrastructure, servers, enterprise networks, vehicles and IoT systems
- 6 other stakeholders including investors in semiconductor start-ups, large users (for example, webscalers).

These interviews were used to understand the key drivers of semiconductor demand and development, which were then mapped against national objectives and our knowledge of the global industries. They were also critical to understanding customer requirements and adoption plans (Chapter 4).

Based on this assessment, we identified the five main technologies that are driving semiconductor demand and performance, in China and worldwide, which will form the basis of the ecosystem assessment in this report (see Figure 1). All of these technologies require increasing numbers of chips, and/or more advanced processors. In addition, we have considered China's progress in memory chips, which are essential enablers for all of the five technologies.

Figure 1: Semiconductor categories considered by our study to be most critical to China's strategic objectives



Source: Analysys Mason

- **5G SoC.** As 5G becomes a ubiquitous technology for supporting consumer and industrial connectivity, chips will be required for billions of devices. In addition, 5G network infrastructure will require increasingly powerful chips for network processing, signal and radio frequency processing and high-performance accelerators to enable cloud servers to support the demanding processes of a virtualised RAN. Mobile phone chips are the most important semiconductor category in the Made in China plan because they support the important local handset industry, which ships about 300 million units a year worldwide.

- **AI and machine learning (ML).** AI and ML will be increasingly embedded into a wide range of processes and activities, and these functions will be carried out in local devices as well as centrally, driving the need for a large number and variety of advanced processors. Particularly important applications of AI include robotics and autonomous vehicles, which require their own specialist chips too.

- **Cloud.** Data and applications will continue to move to the cloud, which will require increasing volumes of high-performance supporting processors, as well as specialist accelerator chips for particularly demanding functions such as neural networking or real-time network processing.

- **Automotive.** The progress towards increasingly advanced connected and autonomous vehicles (CAV) and V2X connectivity applications will ensure that the automotive sector will continue to consume huge volumes of chips and require increasingly sophisticated processors.

- **Industrial IoT.** The increasing adoption of machine-to-machine (M2M) and IoT connectivity in many industries will require huge volumes of chips for endpoint devices, and will drive the take-up of high-performance semiconductors for key IoT enablers such as 5G, cloud and AI/ML. Some IoT platforms will be developed for high-value segments and applications such as critical infrastructure management or smart grid systems. These will be strategic in industries, such as green energy, in which China aims to take a global lead.

These five technologies are important elements of the Made in China semiconductor plan but they also have broader significance because they will underpin industries, such as automotive, energy and 5G, which will transform society and the economy and in which the country aims to take a lead. Therefore, these technologies are important targets for self-sufficiency, to secure the supply chain in key target industries, as well as potential global markets in future.

These technologies also drive demand for, and reliance on, enabling chips, notably general purpose processors and memory chips, so these more generic categories are also considered strategic for self-sufficiency.

It is also vital that China becomes self-sufficient in the chip manufacturing process, particularly in light of restrictions on access for some Chinese companies to international foundries using US technology. Achieving cutting-edge foundry capacity is a strategic goal, mainly centred on China's largest foundry, SMIC.

4. Status of, and opportunity in, each category

This section will examine each of the selected categories in terms of the status of China's ecosystem and the size and timing of the opportunity. Analysys Mason has estimated the time it is likely to take for China to reach the goal of 75% self-sufficiency, and to reach a top three position in terms of technology leadership, or at least parity with global technology leaders. In this study, we equate leadership to processing performance, power efficiency and unique or innovative capabilities. Note that these assessments are of open or merchant chip platforms that are available to multiple customers – individual device or equipment vendors may reach the goals more rapidly through proprietary developments that are only for internal use.

4.1 5G chips

Revenue from chipsets to power 5G devices and infrastructure (excluding cloud) is expected to increase at a compound annual growth rate of over 44% worldwide between 2019 and 2026 to reach USD21 billion. From 2020, China was the world's largest 5G market in terms of device production and network deployment, and a significant share of the global demand will come from China during the first half of the 2020s.

This means that Chinese chip providers have a large and growing market available from day one, provided they can meet the demanding requirements of 5G operators and device makers. Large vendors such as Huawei, major semiconductor groups such as Tshinghua, and public and private investors have invested large sums in developing 5G chipsets. These investments, and the rapid adoption of 5G in China, have driven the development of a broad and robust local ecosystem, a process that accelerated in 2019–2021 because many of the trade restrictions introduced by the USA and some other countries have related directly to 5G. This has resulted in a particularly urgent need to build self-reliance quickly in this strategic segment.

All this means that Chinese chip providers are becoming well-placed to meet the requirements of the customer base in the 5G market. In fact, international chip majors such as Intel and Qualcomm still have active investments and ventures in China, and local partners have drawn upon their experience to accelerate the evolution of a local platform.

The level of effort and investment that has gone into building that platform, the presence of huge customers such as Huawei to drive the ecosystem, and the urgency of the national need to control the supply chain, will make 5G one of the areas where China achieves about 75% self-sufficiency most rapidly, within 2–3 years. Its chip vendors already leaders in key areas of 5G technology, although some of the most advanced aspects of Chinese 5G infrastructure, such as massive MIMO antennas, are largely using vendor-specific application-specific integrated circuits (ASICs), which are designed for a single company and purpose rather than being available to any vendor. These advances are significant for China's overall knowhow and the progress of its 5G platform, but are not included in the chip ecosystem ratings for this report.

The biggest uncertainty, which offsets the advances on the technology side, surrounds access to the most cutting-edge process technology to manufacture the chips (see Chapter 5). This is particularly critical for smartphone SoC products, to maximise performance while keeping cost, size and power consumption low.

Figure 2: Rating of China's semiconductor ecosystem for 5G in early 2021

Critical success factor	Rating
Timescale to mass market in China	Immediate – large-scale roll-out and take-up of 5G began in 2020
Chip revenue opportunity worldwide by 2026	USD21 billion, up from USD1.6 billion in 2019
Size of the existing ecosystem in China	Large and relatively mature thanks to increasing demand for local suppliers from China's broad base of mobile technology vendors
Examples of Chinese 5G chipset vendors	HiSilicon, Picocom, Spreadtrum and Unisoc
Criticality to national economic strategies	Very high
Self-sufficiency timing	2–3 years
Technology leadership/parity rating	2 years in RF, network infrastructure; 4+ years in smartphone SoC products (because of the need to access 7nm geometries)

Source: Analysys Mason

4.2 AI/ML chips

The AI/ML chip category is a broad one, including general accelerators to add advanced AI or deep learning capabilities to cloud infrastructure, as well as specialised chips to enable applications of AI such as robotics or machine vision. AI/ML chip revenue worldwide is expected to increase from USD11 billion in 2019 to USD72 billion in 2026.

China has made development of AI systems, from chips to software, a central point of its technology strategy; in 2017, the State Council published a policy blueprint that set out a goal of making the country into "the world's primary AI innovation centre" by 2030.

China is already a significant adopter of AI/ML. The technology is being developed and applied extensively by Alibaba and Baidu for consumer and enterprise cloud-based services. China's rapid progress in smart cities and robotics are driving demand for AI/ML chips. Beijing and Shanghai each has over 600 AI companies, indicating the rapid scaling-up of the ecosystem and innovation base.

All this drives immediate demand for semiconductors, and as with 5G, the strategic nature of AI/ML for the whole economy provides a strong incentive to protect the supply chain and be as self-reliant as possible.

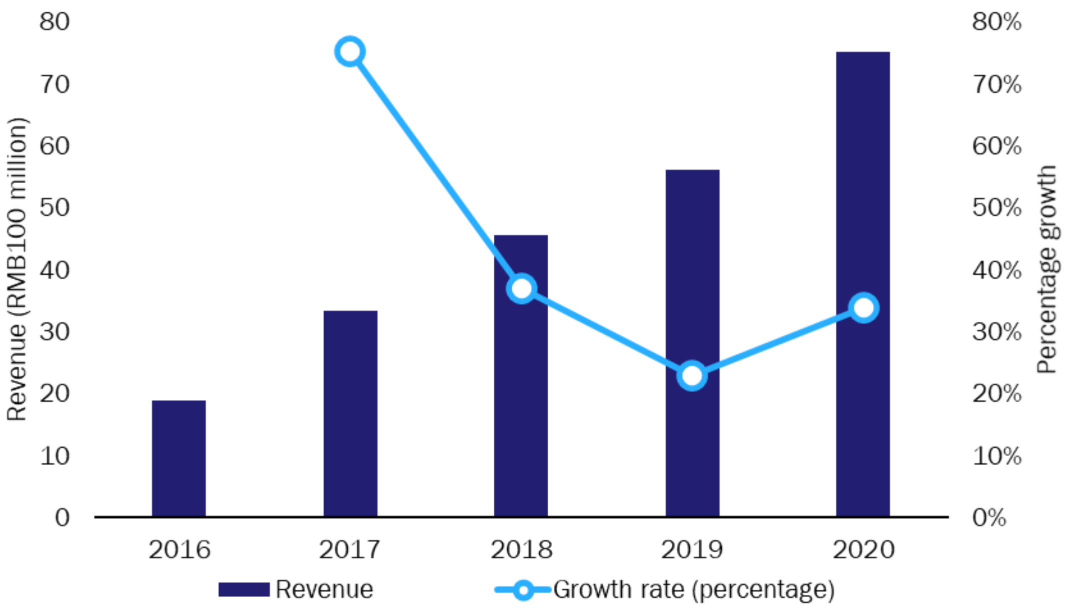
Cambricon, the leading Chinese AI/ML chip specialist is going to great lengths to rival Nvidia, the world's leading AI chip manufacturer; Cambricon filed four times as many patents as Nvidia in 2018–2020. Cambricon, founded by Yunhi and Tianshi Chen, raised USD368 million in its initial public offering in 2020 and was valued at USD2.5 billion at the end of that year. Its Cambricon-1H and Cambricon-1M chips already power about 100 million mobile devices and servers.

Large equipment vendors such as Huawei, and webscalers like Alibaba, Baidu, JDcom and Tencent, have also invested large amounts in AI chip designs, but these are primarily for their own internal use. This does not directly drive the growth of an open Chinese semiconductor ecosystem, but the knowledge, skills and intellectual property that these large companies build up feeds into broader national or international efforts. In addition, these huge companies are also investors in start-ups.

Start-ups are innovating in the AI/ML market, often supported by the USD150 billion fund set aside under the 2017–2030 New Generation Artificial Intelligence Development Plan. Some are broad-based AI/ML developers like Bitmain, while others focus on a particular aspect of AI technology, as Horizon Robotics or Hikvision do, for example.

The intense focus on AI has driven both demand, and local supplier growth, in the past 3 years, and the Chinese AI chip market almost quadrupled in value between 2016 and 2020 (see Figure 3).

Figure 3: AI chip vendor revenue, 2016–2020, and CAGR 2017–2020, China[1]



[1] Source: Qianzhan Industry Research Institute, Deloitte

The rapid development of an ecosystem to meet this burgeoning local demand means that China will achieve its self-sufficiency goal more quickly in AI/ML than in any other of the semiconductor segments covered in this report. However, the pace is expected to vary according to the application. In deep learning and smartphone AI, for instance, the R&D and ecosystem investments of major players such as Baidu and Huawei will drive both self-sufficiency and technology leadership. In other areas, however, such as robotics, China is leading the world in adoption of the technology, but relies on external suppliers for the enabling semiconductors.

Figure 4: Rating of China's semiconductor ecosystem for AI/ML

Critical success factor	Rating
Timescale to mass market in China	Immediate, driven by smart cities, smart factories, webscalers, mobile applications and other growth areas
Global chip revenue opportunity by 2026	USD72 billion, up from USD11 billion in 2019
Existing ecosystem size in China	Large and relatively mature thanks to multi-layered investment programmes from the public and private sector since 2017 and the influence of major AI users such as Alibaba and Baidu
Examples of Chinese AI/ML chipset vendors	Bitmain, Cambricon, Hikvision and Horizon Robotics
Criticality to national economic strategies	Very high
Self-sufficiency timing	0–3 years depending on the application (for example, mobile and vision chips are advanced, robotics less so)
Technology leadership/parity rating	1–2 years in some applications where China has achieved a lead such as vision recognition

Source: Analysys Mason

4.3 Cloud infrastructure chips

The transition of consumer and enterprise data and applications to the cloud is well underway in China. Spending on cloud infrastructure services in China grew by more than 60% in the last quarter of 2020, to reach USD5.8 billion, according to data from Canalys.

The build-out of the infrastructure to support such growth in usage requires high volumes of processors, as well as memory and connectivity chips. The processors also have to continually improve in terms of performance and power efficiency in order to enable the scale that lies at the heart of the cloud model. But as clouds support increasingly complex functions such as real-time 5G connectivity or deep learning, the processors must also be surrounded by various kinds of accelerators, which use different types of chips (such as graphics processing units or field programmable gate arrays) to offload demanding tasks from the central processor. Those tasks might include 5G signal processing or cryptography functions.

This is a diverse category, but success relies on scale, and that requires common architecture for the main processors. To date, most cloud processors have been based on Intel's x86 architecture, but manufacturers of server chips, such as Huawei, are increasingly using designs created by Japan-owned ARM (which has a separate company called ARM China). There is also interest in designs based on an open-source platform called RISC-V, and the development of this fledgling ecosystem has been heavily driven by China, as a potential alternative to the dominant platforms.

ARM and RISC-V provide non-US alternatives to Intel x86, but both have a small share of the cloud infrastructure market, and so China will need to invest in or encourage new players in order to create a broad ecosystem and innovation base. That, in turn, will help to drive economies of scale into the emerging platforms, making them more competitive with Intel. Some progress has already been made, driven by start-ups but also by the major cloud players. Huawei unveiled its first high-end server based on ARM processors in early 2019 and has also worked with RISC-V, while Baidu has worked on its own processor designs using both these architectures. Huawei has been particularly active in opening up its compilers and source code to encourage an ecosystem around its designs.

However, China lacks a large-scale supplier of general-purpose processors, or of field programmable gate arrays (FPGAs) or graphical processing units (GPUs). These three categories are foundational to many new generation cloud platforms because they each support different processes and functions. Jingjia Micro and Zhaoxin are among the companies that have developed GPUs, but these are relatively low-performance, well-suited to PC applications but not high-end cloud servers. China has several general FPGA makers, such as Anlogic and Gowin, but as yet, their products are not equal to those of international leaders like Xilinx in performance. Meanwhile, the habit of server makers to develop their own processors can limit the opportunity for merchant suppliers and fragment the market. Server vendor Sugon, for instance, has set up its own chip division for in-house purposes and is working with multiple architectures including the MIPS platform.

China's semiconductor industry has, so far, made better progress in addressing specific cloud and acceleration requirements through ASICs or specialised processors. Perhaps the leading example is server accelerators to support cryptocurrency mining, as well as advanced security and blockchain applications. Two local firms, Bitmain and Canaan, are the world's leading vendors of crypto-mining chips.

Figure 5: Rating of China's semiconductor ecosystem for cloud

Critical success factor	Rating
Timescale to mass market in China	Build-out of cloud infrastructure has already achieved critical mass and continues to grow, but much of this is not based on merchant chips
Global chip revenue opportunity by 2026	USD16.8 billion, up from USD9.2 billion in 2019
Existing ecosystem size in China	Limited in general-purpose merchant CPUs, GPUs and FPGAs but growing rapidly in terms of innovation and skills for specialist processors and accelerators for applications such as cryptocurrency mining
Examples of Chinese cloud chipset vendors	Anlogic, Bitmain, Canaan and Zhaoxin
Criticality to national economic strategies	High
Self-sufficiency timing	3–4 years for generic processors, 2 years for some specialist accelerators, 0 years for some applications
Technology leadership/parity rating	0–3 years depending on the application, longer for generic cloud CPU because of the global dominance of x86

Source: Analysys Mason

4.4 Automotive and V2X connectivity chips

The global market for automotive chips has grown steadily for two decades as vehicles have included more and more electronics, and more recently, as connected, electric and even automated technologies have gained scale. A modern electric or hybrid car or industrial vehicle with high levels of automation plus 5G connectivity has more than 20 times more semiconductors, of different kinds, than an unconnected petrol car of the turn of the century. These are increasingly advanced and high value too, with 5G modems and AI processors for vision recognition joining the traditional array of microcontrollers.

These trends will drive the value of the automotive semiconductor market from USD41 billion in 2019 to about USD68 billion in 2026[2], and an increasing percentage of that value will be associated with V2X and automation functionality, and connectivity. Take-up of these technologies in new cars, as well as fully unattended vehicles such as drones, is growing more rapidly in China than in any other major economy.

The demand exists to drive a major ecosystem of semiconductors for connected and automated vehicles, V2X connectivity and drones. However, Chinese automotive firms have had fewer international restrictions on accessing international components than telecoms or AI firms. Therefore, the urgency to develop self-sufficiency is less intense than in those sectors, and many large Chinese car makers continue to buy semiconductors mainly from international vendors. The dynamics may be changed by the global shortage of automotive components, sparked since late 2020 by foundry constraints associated with the COVID-19 pandemic. This could encourage Chinese automotive companies to rely more heavily on local suppliers if there is greater availability from homegrown partners.

Until 2018, Chinese firms had a very small share of the worldwide market, but this has been changing in the past few years. By contrast with some of the sectors examined in this report, this has come about partly through acquisition of non-Chinese firms rather than purely through internal investment.

This is seen clearly in the field of power electronics, which is central to the connected and automated vehicles market; China's Wingtech Technology acquired Nexperia, a spin-off from NXP in the Netherlands, which focused on MOSFET a technology that is heavily used in modern power electronics.

Nexperia will be boosted by the high growth in the adoption of connected vehicles in China, but it also has global reach. It is ranked second in the world in automotive-grade MOSFET behind Infineon of Germany. Other local firms are also active in this area – Huawei invested in a specialist called Oriental Semiconductor, for example.

Another chip technology that is key to the automotive industry is image recognition and sensing, and here, China also acquired a strategic player, Omnivision. It was acquired by a consortium of Chinese investors in 2015 and then by China's Will Semiconductor in late 2018. In 2019, Omnivision accounted for about 10% of the revenue worldwide for CMOS[3] imaging sensors, which put it in third in the world behind Sony and Samsung in this segment. For CMOS imaging sensors specifically for automotive, Omnivision is second in the world by revenue as of the end of 2020, with 22% market share, outdone only by US-based ONSemi.

Processors to support autonomous driving by handling the data from the image sensors are also an important growth area in the connected and automated vehicles market. Huawei has its own chip, called MDC, while there are also many start-ups, such as Black Sesame and Horizon Robotics (which has a deal with Audi as well as local vendors).

[2] Source: IHS Markit

[3] Complementary metal oxide semiconductor.

Figure 6: Rating of China's semiconductor ecosystem for automotive and V2X connectivity

Critical success factor	Rating
Timescale to mass market in China	The number of electric and connected vehicles is expected to grow rapidly in the 2020s and Chinese vehicle makers are developing models for the international and home markets. Domestic take-up will be encouraged by investment in V2X infrastructure and in 5G. However, players in this industry are more willing to buy from international suppliers than are players in the telecoms or cloud industries.
Global chip revenue opportunity by 2026	USD68 billion, up from USD41 billion in 2019 (total automotive)
Existing ecosystem size in China	Several large players are now Chinese-owned and anchor large ecosystems. There are also many start-ups
Examples of Chinese CAV/V2X chipset vendors	Black Sesame, Horizon Robotics, Huawei, Nexperia and Omnivision
Criticality to national economic strategies	High
Self-sufficiency timing	1–2 years for power electronics and image sensors; 3–4 years for some other components; 4+ years for general microcontroller platforms because of massive volume requirements
Technology leadership/parity rating	0–3 years depending on application

Source: Analysys Mason

4.5 Industrial IoT chips

Semiconductor provider revenue from chips to support IoT is projected to grow from USD8.7 billion worldwide in 2019, to USD17.9 billion[4], representing CAGR of 11%, but the fastest growing sub-segment will relate to the industrial IoT, which will experience 28% CAGR in the same period. China is the world's largest IoT market in terms of device connections, accounting for 22% of the world's connections, and will account for almost one-third of the world's industrial IoT connections by 2025, according to GSMA Intelligence. The Annual IoT Industry Development Report of China, published by the China Economic Information Service, says the IoT market in the country is worth more than RMB1.19 trillion (USD176 billion) as of June 2020.

This represents a significant market for IoT chips, and while Chinese consumers are driving adoption of many connected devices, the strategic focus in the national investment plans is on the industrial IoT, which underpins smart manufacturing and Industry 4.0.

It is hard to assess the level of self-sufficiency that China has in such a fragmented landscape. The IoT encompasses a huge diversity of devices, from sensors to robots; of applications; and of industries and each has specialised processors.

Chinese companies are significant suppliers of sensors, microchips and other IoT components. Indeed, GSMA Intelligence claims that 95% of IoT devices and components are made in Greater China. And as most IoT semiconductors, even for high value applications, do not require the most advanced foundry processes, China does not suffer from that disadvantage, as it does with products such as smartphones that are highly reliant on

[4] Source: Valuates Research 2020

those new processes. The scaling-up of SMIC's 28nm process is expected to create significantly more capacity for IoT components and increase the percentage that can be sourced locally.

Some Chinese semiconductor suppliers have achieved strong national or even international positions in specific components of the industrial IoT. Important ones include GigaDevice, which has developed flash memory chips that are optimised for industrial IoT applications; Goodix, which specialises in fingerprint sensors; Unigroup Guoxin, which makes modules to support factory and edge compute controllers; and Jingjia, which has designed GPUs specifically for industrial vision applications. China's growing robotics industry, which IDC China estimates will grow threefold between 2019 and 2024 to reach USD120 billion, is driving a strong ecosystem of component suppliers such as Horizon Robotics.

However, China is not a significant player in mass-scale industrial microcontrollers, and leadership and self-reliance in the technologies that enable the IIoT will depend on controlling a full platform that integrates AI processing and connectivity for vast numbers of endpoints. Achieving a world-class position in the complex industrial IoT value chain will depend on success in some of the other areas analysed in this report, such as 5G, AI/ML and robotics.

Figure 7: Rating of China's semiconductor ecosystem for IIoT and Industry 4.0

Critical success factor	Rating
Timescale to mass market in China	The industrial IoT and Industry 4.0 are central to national industrial plans and there is already significant adoption, with threefold growth in deployments of robotics and IIoT systems expected by 2024.
Global chip revenue opportunity by 2026	USD17.9 billion, up from USD8.7 billion in 2019 (total IoT)
Existing ecosystem size in China	Large but fragmented. Strong in sensors and many mass-market IoT device components, and in key strategic areas such as robotics; weaker in microcontrollers and platforms.
Examples of Chinese IIoT chipset vendors	GigaDevice, Goodix, Horizon Robotics, Jingjia and Unigroup Guoxin
Criticality to national economic strategies	Very high
Self-sufficiency timing	0–1 years for device components and IoT connectivity (for example, NB-IoT); 2–3 years for robotics and edge control; 5+ for microcontroller or integrated platforms
Technology leadership/parity rating	0–3 years depending on application, longer for a full IoT platform because of the influence of international players on the broad ecosystem

Source: Analysys Mason

4.6 Memory chips

This is one of the largest categories of semiconductors because it is essential to nearly every branch of electronics, and the steady rise of data usage and intelligence from mobile devices to the cloud leads to a limitless appetite for more memory and storage. It is also one of the most volatile markets; capacity fluctuates as new generations of technology emerge and companies that consume huge volumes of memory chips, such as Apple, speculate on supplies. In times of periodic memory shortage, Tier-2 providers have an opportunity to step into the breach and gain market share at the expense of the global giants, led by Samsung – but any major provider of memory chips must have huge scale in order to cope with the fluctuations.

The memory chip market was worth USD100 billion in manufacturer revenue worldwide in 2019 spread across the main categories of DRAM, NAND flash and NOR. It is forecast to grow at almost 14% CAGR until 2026, when it will reach USD250 billion. Drivers of growth will include data centres, 5G and automotive. China is the largest consumer of memory chips in the world, and that consumption will grow at a rate higher than anywhere else in the world during 2019–2026, amid growing demands for solid-state devices for consumer electronics and various kinds of memory chips for vehicles.

China has several significant memory chip providers and all of them are under pressure to increase production and accelerate development of advanced designs, in order to reduce the reliance of Chinese industries on the giant suppliers of Japan, South Korea and the USA. The local market leader by revenue is Yangtze Memory Technologies, founded in 2016, which plans to double its production in 2021 to over 100 000 wafers a month, or about 7% of total global output (by contrast, world leader Samsung produces 480 000 wafers a month).

Just as importantly, Yangtze is poised to overtake leaders like Kioxia, Samsung and SK Hynix with some technology advances. In mid-2021, it aims to trial its first 192-layer 3D NAND flash memory chips, to add to its current 64- and 128-layer chips. It is challenging to design more layers, but they result in lower-cost and more power-efficient chips. Samsung and Micron are working to develop 176-layer 3D NAND flash chips. Yangtze also produced its first solid-state drive for consumer electronics last year. Its memory chips are found in Lenovo products, Huawei base stations and many other local applications.

Yangtze's key advantage is that it has developed its own Xtacking technology for building 3D NAND flash, and so is shielded from restrictions on access to US technology and tools. However, its parent, Tshinghua Unigroup, has debt challenges, and Yangtze has yet to achieve major sales in the mass consumer devices market, which will be important to its scale and cashflow.

Chips in the NOR market are easier to develop and China has several players such as Gigadevice, which is also a majority shareholder in Changxin Memory Technologies (CXMT), a foundry specialising in DRAM chips. Another important DRAM supplier is ISSI, a US maker of DRAM, SRAM and NOR flash, which was acquired by Chinese investment vehicle Uphill Investment in 2015. In 2019, ISSI was sold to Chinese fabless chip maker Ingenic. However, Tsinghua Unigroup's ambitious attempt to acquire US memory giant Micron in 2015 was blocked by US competition regulators.

Figure 8: Rating of China's ecosystem for memory chip technologies (DRAM, NAND flash and NOR Flash)

Critical success factor	Rating
Timescale to mass market in China	China is the world's largest market for memory chips and this is a key driver of self-sufficiency because of the volatility in the global supply
Global chip revenue opportunity by 2026	USD250 billion, up from USD100 billion in 2019
Existing ecosystem size in China	Local ecosystem is growing quickly and is anchored by several major players with international as well as domestic reach. Some are homegrown such as Yangtze and others have been acquired like ISSI
Examples of Chinese memory chipset vendors	Changxin, Innotron, ISSI, JHICC and Yangtze
Criticality to national economic strategies	High
Self-sufficiency timing	1–2 years in NOR, 2–3 years in DRAM and NAND flash. Unlike in other semiconductor segments, manufacturing processes in China are at the cutting edge with Yangtze's Xtacking technology due to support large-scale production in 2022

Critical success factor	Rating
Technology leadership/parity rating	1 year in NAND and NOR 2–3 years in DRAM

Source: Analysys Mason

5. China has advantages, but also significant challenges to address

The analysis in Chapter 4 highlights the significant investment and progress that China has made in recent years to lay the foundations for high levels of self-sufficiency and for technology parity and, in some applications, leadership. In 2020, production of semiconductors rose by 16.2%, a far sharper increase than the 7.2% of 2019.

However, the country and its industries need to build on those foundations rapidly if 2025 goals are to be met. There is a big leap to be made from the estimated 20% self-sufficiency rating of 2020 to the goal of 70% or more, and domestic demand for advanced chips will only continue to rise. China’s huge success as a global manufacturing hub for industries such as consumer electronics has created a semiconductor deficit worth about USD200 billion in 2019.

There are significant efforts to reduce that deficit rapidly, especially in the most strategic semiconductor categories, as outlined above. But there are challenges that will need to be addressed to reach the national objectives. These are less about advanced semiconductor design than about processes and scale. China has a strong and growing skills base in innovative chip design and with the high levels of available funding and support, this will translate, over the coming 4–5 years, into technology parity with companies in other regions. In some areas, such as cryptography and automotive, this is already starting to be visible.

Chinese companies have two main obstacles to self-sufficiency and leadership. One is that the technologies that drive the semiconductor industry are still largely driven by US-based players, notably Intel. It will be important for Chinese companies not only to design innovative products, but to invest in alternatives to US or Japanese architecture.

The other obstacle is more immediately serious for the self-sufficiency goals. This relates to China’s ability to catch up with global leaders in process technology, so that the most advanced and strategic chip designs can be manufactured at scale at home. Although China’s Yangtze Memory Technologies has caught up with global leaders in memory chip processes, the same is not yet true for the production of processors and other key semiconductors.

5.1 The biggest challenges relate to foundry technology

Restrictions on Chinese foundries accessing US process technology in some scenarios have placed this issue in the spotlight. US-based companies have a near-monopoly on electronic design automation (EDA) tools, while silicon wafers are monopolised by Japanese players, and manufacturing equipment by players from both these countries, plus the Netherlands’ ASML (which recently increased its investment in China). The control of the chip manufacturing supply chain by the USA and Japan further complicates Chinese foundries’ efforts to catch up with their global peers.

The biggest challenge is to support foundry processes below 10nm. Categories such as SoC devices for smartphones are starting to be made in 7nm or 5nm processes by Taiwan's TSMC, which drives down cost, size and power consumption of the SoC and the end device. TSMC and Samsung are implementing 5nm and Intel and TSMC is investing in developing 3nm and 2nm processes.

To date, China's largest foundry, SMIC, has not implemented a process below 10nm, and it is in these new geometries that the need for international EDA tools and manufacturing equipment is most significant.

However, considerable progress is being made in response to the challenges. Only a year ago, SMIC's most advanced process was 28nm planar technology. This is now implemented at mass scale and China is poised to be self-sufficient in 28nm and 45nm by the end of 2021 because it will activate its first homegrown 28nm lithography machine this year, a key step to independence from external suppliers. It is important to note that 28nm and 40nm processes still account for the majority of advanced chips used worldwide, and some of the key growth areas in China that rely on 28nm include NB-IoT, industrial IoT, edge computing processors with AI, consumer electronics, robots, automotive and satellite navigation. Most of these categories require cutting edge design, which is an increasingly important Chinese capability, rather than cutting edge fabrication. In addition, SMIC is to build a USD7.6 billion plant in Beijing in 2021, which will help to address the shortage of 28nm capacity.

The smaller geometries are important for mobile devices, and while they may not have the same volume as 28nm, they are required by developers of the most cutting-edge applications and so are important to China's overall bid for technology leadership. SMIC has made rapid progress in the past year. It is now shipping 14nm finFET chips, and said in March 2021 that it had achieved 95% yield. SMIC, Huawei and Qualcomm's Chinese affiliate recently entered into an agreement to form an R&D organisation, SMIC Advanced Technology Research & Development (Shanghai) Corporation, to research the 14nm node.

SMIC looks set to skip the 10nm node and go straight to developing 7nm but it has much to do to catch up in full 7nm, so SMIC has devised a new version of its 14nm process, called N+1, which went into limited production in late 2020, and claims performance comparable to other foundries' true 7nm. SMIC says N+1 improves on the existing 14nm process by 20% in performance, 57% in power efficiency, 63% in logic area, and 55% in the area for the whole SoC.

The next generation is called N+2 and has been developed in the laboratory, but requires next-generation lithography technology called EUV to implement it. China is working on its own lithography system to reduce its dependence on its supplier ASML of the Netherlands. When Chinese lithography machines are available from this year, it will enable other local foundries to start manufacturing 28nm, 14nm and eventually 7nm processors.

The Suzhou Institute of Nano-tech and Nano-Bionics, working with the National Centre for Nano-science and Technology, recently announced a breakthrough in a new type of 5nm laser lithography, which overcomes the traditional limitations of laser direct writing because it processes at the nano level to improve precision, yield and resolution. This is an example of the Chinese projects that are well underway to leapfrog, not just catch up with, international technologies and so enable a new generation chipmaking industry from the mid-2020s.

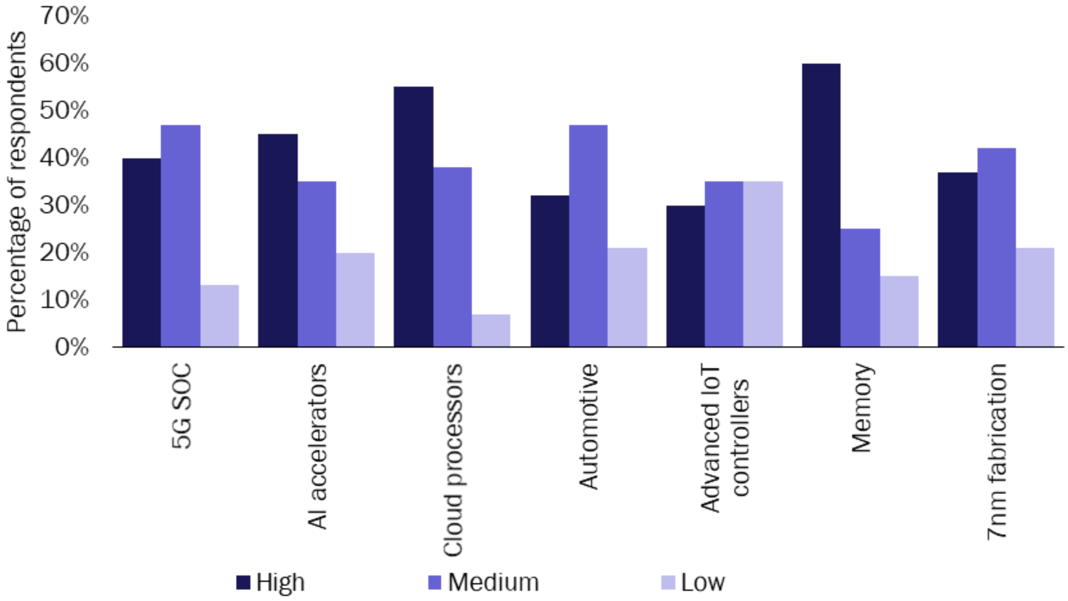
5.2 Stakeholders have the most confidence in progress in the memory and cloud chip markets

Projects such as those mentioned above are critical to China achieving its self-sufficiency goals, but they will inevitably take some years to reach full-scale deployment. In the meantime, it will be important to reduce the time between designing an innovative chip and achieving mass scale. This will be achieved more rapidly in some semiconductor segments than others, as the analysis in this report has demonstrated. In our survey, it was clear that the 48 stakeholders were more confident about short-term success in some of the strategic sectors than in others (see Figure 9).

They were asked about their level of confidence that China would achieve its self-sufficiency goal of over 70% by 2025, in the five strategic categories, plus in memory chips and in the sub-10nm foundry processes.

The survey respondents were most confident about the memory chip market, followed by cloud processors and AI accelerators (see Figure 9). China already has strong design capabilities in these areas and is moving towards large scale, and none of these categories requires the sub-10nm process. The level of confidence was rather lower when it comes to 5G SoC, because these chipsets will increasingly require 7nm nodes. Overall, 40% of the survey respondents express high levels of confidence that China will achieve its goal of 70% self-sufficiency in the 5G SoC market, and 37% in the 7nm process in general. However, in both these categories, less than 20% of respondents have low levels of confidence – they just believe it will take more time to catch up in 5G and 7nm than in other areas such as AI. The only categories in which more than 30% have low confidence are advanced microcontrollers, reflecting China's relatively limited position in this space.

Figure 9: Level of confidence that China will be 70% self-sufficient in semiconductor production by 2025, by category[5]



Source: Analysys Mason

5 Note: Question = "What is your level of confidence that China will achieve its goal of being 70% self-sufficient in semiconductor production by 2025, in the following technology categories?"; n = 48.

6. Conclusion

In general, the stakeholder survey summarised in Chapter 5, and our broader analysis, indicate a growing degree of optimism about the development of China's semiconductor platforms, despite the acknowledged challenges in terms of scale and the process.

This reflects Analysys Mason's assessment that there is visible progress in many areas, and the foundations have been laid to expand capabilities and production more quickly in the years until 2025. In our view, memory technology and AI platforms are the areas where Chinese companies have made the most progress so far, significantly closing the gap with international suppliers in terms of technology and production scale.

In some areas, China is close to equalling international market leaders in terms of advanced capabilities. It is ahead of the world in some applications, such as chips for advanced video transcoding and crypto mining; and in some broader categories, including certain memory processes.

Figure 10: Estimated time to achieve 75% self-sufficiency and technical parity in five key semiconductor segments

Technology	Time to 75% self-sufficiency	Time to technology parity/lead (in open ecosystem – proprietary systems may be quicker)	Opportunities	Risks
Memory	1 year	1.5 years	Well-established sector and processes	Fluctuating demand and pricing
5G SoC	2–3 years	4 years	High level of investment, influence of HiSilicon	Reliant on most advanced processes
AI including V2X and robotics	0–3 years depending on application	1 year in some applications	Rich ecosystem, open platforms (Alibaba)	Fragmentation
Advanced cloud processors and accelerators	3–4 years	3–4 years	Breakthroughs in some advanced applications (for example, crypto mining)	Potential acquisition of ARM by Nvidia
IoT	3 years	1 year	Accelerated by open initiatives (for example, RISC-V)	Diversity of requirements

Source: Analysys Mason

Individual hi-tech vendors may achieve technology leadership and self-sufficiency more quickly than indicated in this report, but their advances will remain proprietary and so will have a limited impact on the creation of a broad, open ecosystem to drive maximum self-reliance across all industries.

In the broader industry, the pace of innovation and investment will increase in China in the next few years, resulting in a huge wave of progress in key semiconductor capabilities. This will lead to China driving global adoption of some emerging technologies, and leapfrogging other countries in certain semiconductor segments.

However, challenges will remain to drive these technologies and surrounding ecosystem to the scale required to support China's primary industries. Semiconductors, and the industries that rely on them, are global in scope. Renewed international co-operation is the key to driving maximum scale and growth for all players, including Chinese ones, and to help international organisations to access Chinese innovations, and vice versa. Hi-tech industries worldwide are willing to restart co-operation and global ecosystems, and it is hoped that political organisations will want to do the same.

7. About the authors

Caroline Gabriel (Research Director) leads Analysys Mason’s Networks research practice, as well as leading many 5G-related research activities across multiple programmes. She is responsible for building and running Analysys Mason's unique research base of mobile and converged operators worldwide.

She works directly with Analysys Mason’s research clients to advise them on wireless network trends and market developments. She has been engaged in technology analysis, research and consulting for 30 years, and has focused entirely on mobile and wireless since 2002. Her focus is on critical issues and trends related to mobile and wireless infrastructure, particularly operator deployment intentions for 4G, 5G, cloud-RAN and other technologies. She has led research and consulting projects with a wide range of clients, including mobile infrastructure vendors, large and start-up operators, regulators, trade bodies, government agencies and financial institutions.

Michela Venturelli (Analyst) is a member of the *Infrastructure Investments* research team in London, and contributes to various research programmes, focusing on *Operator Investment Strategies* and *Wireless Infrastructure*. She previously worked with the Telecoms Software and Networks research team. Michela holds a PhD and an MSc in Physics from University College London and Statale di Milano university, respectively.

This perspective was commissioned by Huawei. Analysys Mason does not endorse any of the vendor’s products or services.