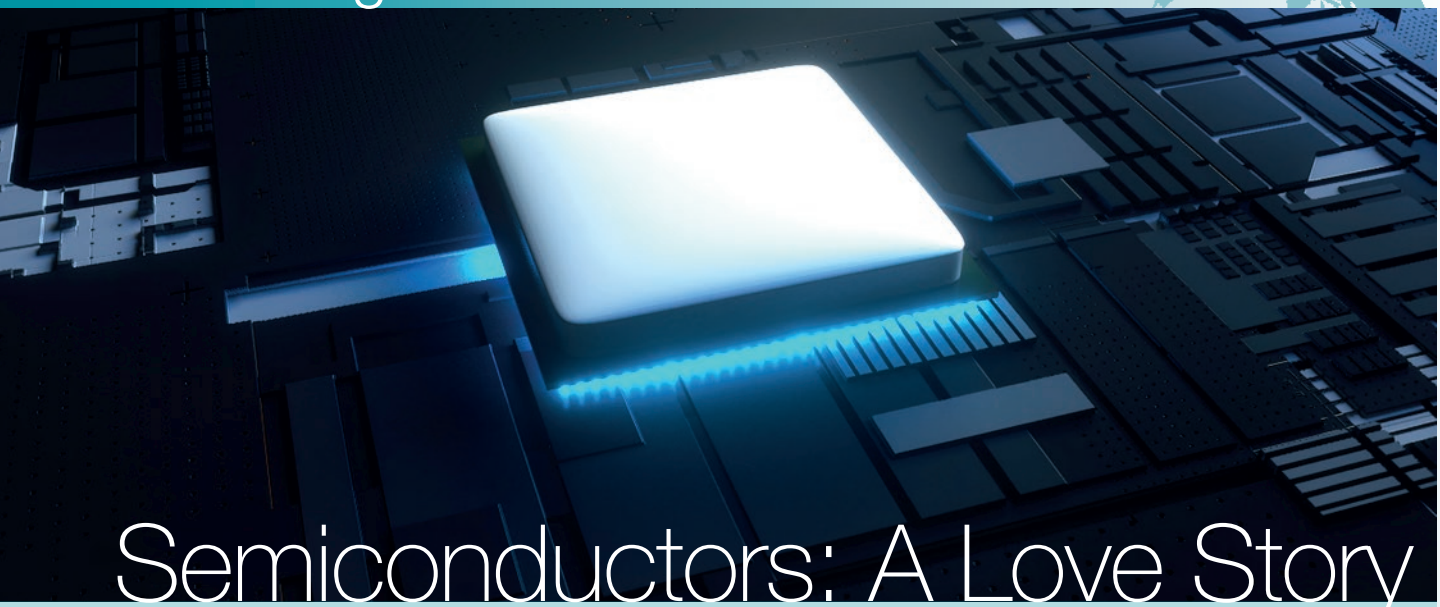


Semiconductors: A Love Story

By Melissa Cogavin, Managing Editor, SCTE

The global development, manufacture and distribution of semiconductors was severely disrupted by Covid-19, but not for the reasons you might think. We're over the worst of it but it's still affecting supply chains now. Will it happen again? What have we learned?

"Semiconductors may be to the twenty-first century what oil was to the twentieth. If so, the history of semiconductors will be the history of the twenty-first century."

Financial Times

The pandemic of 2020 saw the acceleration of a number of trends that in March were only in their infancy; in the panic of lockdown worldwide they were adopted so fast, so unthinkingly by so many millions that is it difficult to even remember back to a world without Zoom, for example, or antibacterial gel. Ordering food via QR code in a restaurant is now normal, as is table service in pubs. (Queuing up in pubs is a rather unwelcome hangover from lockdown, however, and the sooner normal service is resumed, the better, SCTE feels).

Disney+ brought forward its launch date by months, seeing the sizable opportunity of a captive audience of millions of people on furlough; it transformed the streaming market, sending complacent Netflix executives, deep in the red for years by then, into a tailspin after only a few weeks. Disney+, with 220m subscribers, is now the favoured service amongst consumers (which includes ESPN and Hulu) and in August, usurped Netflix's number one position after only two years.

Working from home is perhaps the biggest change, and according to some, the most stubborn stain to shift of all. The mental health benefits it has heralded have forced companies to change their approach completely, having resisted it for years, and you will see they now proudly announce hybrid working in job ads, support for mental health as part of their ESG commitments and cosy up to charities that would have been difficult to justify a few years previously. Admitting to a mental health problem in the 2000s would have been career suicide; things really have moved on apace. Another positive outcome.

It wasn't all great though was it. Bored, furloughed staff might have been gazing at the Star Wars franchise on televisions with glassy eyes, their thoughts straying only as far as the next meal and daily walk outside, but deep in lockdown the telecoms industry was becoming increasingly twitchy and at a loss, seeing its supply chain in disarray, gossip replacing facts wherever information failed. The semiconductor, so integral to the manufacture of broadband components and mobile phones, was suddenly unavailable. Lead times for component parts were suddenly weeks, if not months, and production schedules were thrown completely off course.

It is overly simplistic to look back on the dearth of semiconductors and blame early lockdowns in Asia for creating an unholy bottleneck; it is a great deal more complex than that.

The semiconductor market has grown exponentially over the last three years, after a fairly stable decade from 2006

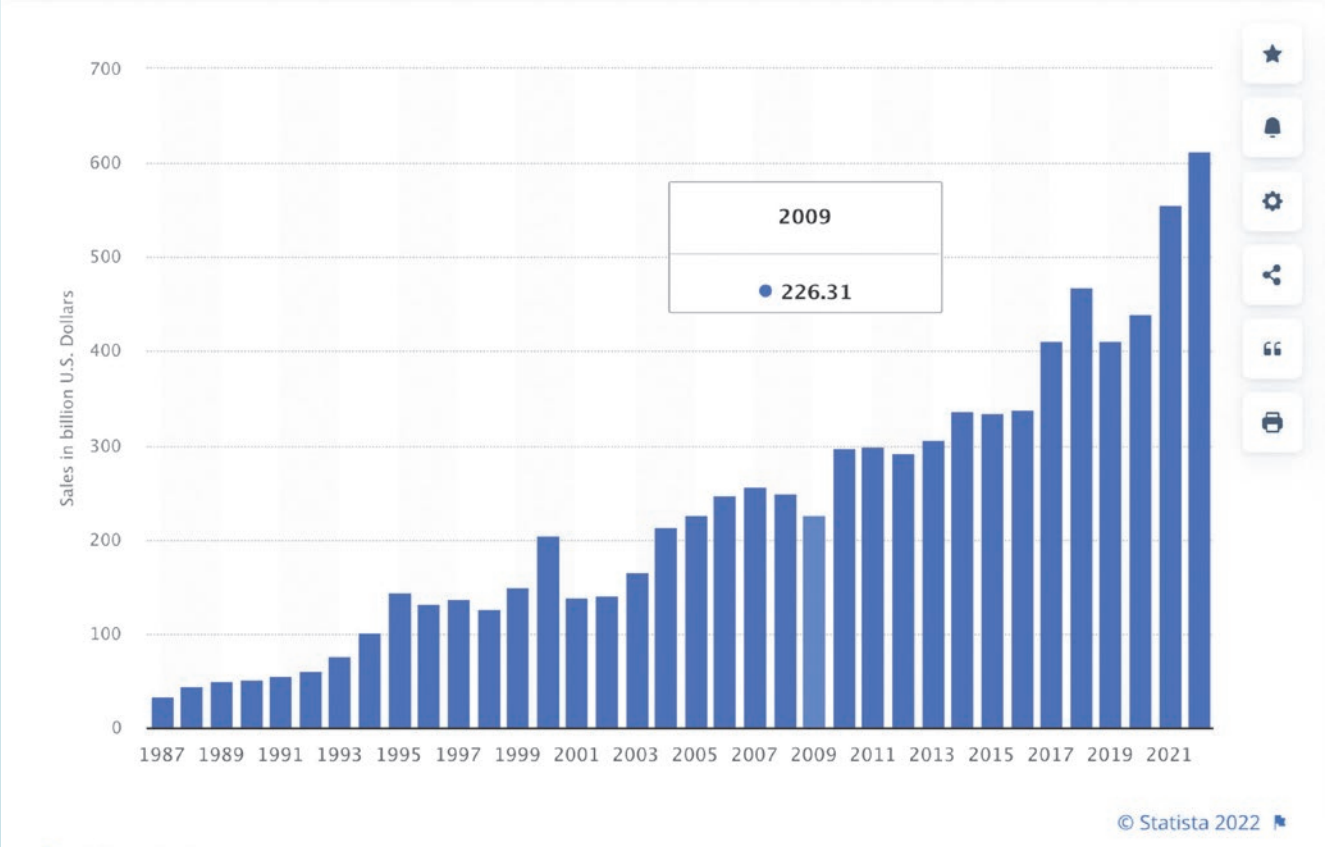
to 2016. Reasons for the jump include the increased adoption of smart devices, most obviously the iPhone and its Android competitors, but semiconductors are now present in cars, e-bikes, electric scooters, tvs, radios, home heating systems, doorbells, fitness trackers, laptops, gaming consoles, microwaves and even fridges. Anything falling into the category Internet of Things will contain hundreds of semiconductors each. The average car contains over 1000 semiconductors, and the average electric vehicle contains twice that.

Like Disney+ and Zoom, we have fallen on these devices hungrily and can't get enough of logging our temperatures, steps, calories, sleep, PBs and opinions on a daily basis, often hourly. We are addicted to connectivity. Just as our hunger for connected devices was peaking, Covid appeared around the corner, throwing a digital spanner in the works. The result was a well-documented, unprecedented rise in demand coupled with an unexpected decrease in supply. For example, in the last quarter of 2020, computer sales saw a 25% rise compared with the last quarter of 2019 at 90.3 million units (source: Canalys). As lockdown was in place it was obvious that to meet that need that a number of chip manufacturers were depleting existing inventories.

Adding to the hunger for gadgets while lockdown rolled on, in recent years consumer demand for electric vehicles and solar panels also put pressure on supply chains, while the increasing calls for renewable energy - turbines, panels and so on - caused demand to rise at a point where supply was already stretched.

According to the Semi-Conductor Association, (there truly is an association for absolutely anything if you look hard enough), "A single semiconductor chip has as many transistors as all of the stones in the Great Pyramid in Giza, and today there are more than 100 billion integrated circuits in daily use around the world—that's equal to the number of stars in our corner of the Milky Way galaxy." Worldwide revenue produced from semiconductor sales hit $470bn in 2020. A year later, in the middle of a global pandemic, they reached $595bn. In 2022 that figure was $676bn. That's a 43% increase in 2 years.

The SCA tells us that semiconductors are generally produced from pure elements such as silicon or germanium, or compounds such as gallium arsenide. These elements are produced into semiconductors almost exclusively in Asia; 60% in China, 19% in Korea and 21% in Taiwan. Contrary to popular opinion, it wasn't the mining of precious metals found in semiconductors that caused the bottlenecks. It was



Semiconductor sales worldwide in billions $. Credit: Semi-Conductor Association

however, the early lockdowns in February 2020 and strict measures subsequently employed by the authorities in this region had a knock-on effect on manufacturing from bicycles to automotives and that, in addition to a multitude of other, often quite random factors, drastically affected the supply of semiconductors to electronics manufacturers worldwide, just as the appetite for devices was going through the roof.

Globalisation

Globalisation is certainly in large part responsible for the growth of the semiconductor market, since the development and production is spread throughout the world in a masterclass of supply chain economics and distribution. However, globalisation is also responsible for the semiconductor shortage, since R&D happens largely in the US (fabless production, or 'fabs'), and manufacture in Asia. Fabless producers include Qualcomm, Broadcom, NVIDIA and AMD. Manufacturers include Taiwanese market leader TSMC, which stands for the rather obviously named Taiwan Semiconductor Manufacturing Company, as well as Samsung and SMIC, standing for the equally playful Semiconductor Manufacturing International Corporation..

The exception to this rule includes companies like Intel, Infineon and Samsung who also develop and manufacture their own semiconductors. They are known as integrated device manufacturers, or IDMs. More on that in a moment.

Partnerships like this work well in a stable market when there are no extenuating circumstances, but as we have seen - the boom in demand for electronic devices, coupled with a global pandemic and associated lockdowns worldwide for two years, plus the instability provided by Mr Putin have led companies like Intel to bring the work in-house; in fact, Intel recently announced their intention to invest $95bn in manufacturing plants in Europe, specifically to reduce its dependency on plants in the Asia.

A new "mega factory" in Germany, a new R&D hub in France, planned investments in R&D, manufacturing and foundry services in Ireland, Italy, Poland and Spain are all part of this strategy to minimise risk and protect the company's long term prospects. This is being echoed by fabless companies on both sides of the Atlantic but will be dependent on government subsidy to be successful, and is unlikely to diminish dependence on semiconductors produced in Asia, again for a host of complex, historical reasons; some obvious, others less so.

Such moves have led to chin-stroking from academics and economists worldwide, many speculating that globalisation is now in retreat and we are entering a new age of manufacturing and production and consumption at home. Certainly geo-politics and the recent rise of populism in Europe as well as the America First movement in the Trump era suggested a possible shift. However, if nothing else, Covid reminded us how dependent we are on our neighbours overseas as we waited patiently for Amazon deliveries of products produced in China, doing COVID tests… produced in China.

Geo-political tension

Rather disappointingly for Mr Putin, the war in Ukraine has had the inverse effect of strengthening relationships across the EU, not dividing them. The threat of Russia's aggression has resulted in NATO and the EU receiving applications for membership from several potential new members in Central Europe and Scandinavia; clearly neither are about to be disbanded as some critics have predicted.

However, Intel's CEO Pat Gelsinger urged us not to be complacent. Russia's war with Ukraine, he said, was "further increasing supply chain risk and contributing to inflationary pressures", exacerbating the shortage. He went on, "In the supply chain, lockdowns in Shanghai and the war have demonstrated more than ever that the world needs more resilient and more geographically balanced semiconductor manufacturing."

He should know. On the ground in Ukraine the invasion severely impacted the mining of neon krypton and xenon, two noble gases essential for semiconductor production. Ukraine is responsible for 70% of the world's production of both, and just as we emerged out of the pandemic with all its associated problems, Russia invaded its neighbour. Prices have soared as availability decreased. Additionally the supply of palladium metal, found in a host of electronics from semiconductors to dentistry, has been affected since 40% of it is mined in Russia; sanctions have hit Russians hard, but equally they have badly affected semiconductor manufacturers beyond Russia. According to the Centre for Strategic and International Studies, stockpiling had been underway since the annexation of Crimea in 2014 and prior to the invasion of Ukraine this year, US chip firms had been advised to up their supplies by the Biden administration directly. However, the shortage of supply and the effect on the industry of panicky stockpiling has badly affected the manufacturing process.

The interconnections between the chip industries in the U.S., China, and Taiwan are dizzyingly complex. There's no better illustration of this than the individual who founded TSMC, a company that until 2020 counted America's Apple and China's Huawei as its two biggest customers. Morris Chang was born in mainland China; grew up in World War II–era Hong Kong; was educated at Harvard, MIT, and Stanford; helped build America's early chip industry while working for Texas Instruments in Dallas; held a top secret U.S. security clearance to develop electronics for the American military; and made Taiwan the epicenter of world semiconductor manufacturing. Some foreign policy strategists in Beijing and Washington dream of decoupling the two countries' tech sectors, but the ultra-efficient international network of chip designers, chemical suppliers, and machine-tool makers that people like Chang helped build can't be easily unwound.

Unless, of course, something explodes. Beijing has pointedly refused to rule out the prospect that it might invade Taiwan to "reunify" it with the mainland. But it wouldn't take anything as dramatic as an amphibious assault to send semiconductor-induced shock waves careening through the global economy. Even a partial blockade by Chinese forces would trigger devastating disruptions. A single missile strike on TSMC's most advanced chip fabrication facility could easily cause hundreds of billions of dollars of damage once delays to the production of phones, data centers, autos, telecom networks, and other technology are added up.

Holding the global economy hostage to one of the world's most dangerous political disputes might seem like an error of historic proportions. However, the concentration of advanced chip manufacturing in Taiwan, South Korea, and elsewhere in East Asia isn't an accident. A series of deliberate decisions by government officials and corporate executives created the far-flung supply chains we rely on today. Asia's vast pool of cheap labor attracted chipmakers looking for low-cost factory workers. The region's governments and corporations used offshored chip assembly facilities to learn about, and eventually domesticate, more advanced technologies. Washington's foreign policy strategists embraced complex semiconductor supply chains as a tool to bind Asia to an American-led world.

Credit: Chris Miller, Chip War: The Fight for the World's Most Critical Technology' (Simon & Schuster, 2021)

China/Taiwan and the US

Chris Miller is Assistant Professor of International History at the Fletcher School at Tufts University in Massachussetts, as well as Eurasia Director at the Foreign Policy Research Insititute in Philadelphia. His recent book, 'Chip War: The Fight for the World's Most Critical Technology' (Simon & Schuster, 2021) has been critically acclaimed and described variously as 'an eye-popping work', 'a riveting history' and 'a tour de force'; he explains that the various business interests of China, Taiwan and the US created a complex network of mutually beneficial relationships in the late 80s, that had the benefit of protecting national security for all three concerned, as well as being highly lucrative. 'Keep your friends close and your enemies closer' would be a crude way of describing this arrangement, and is chronicled in some detail in the excerpt above.

It has worked well over the years but is far from secure, and the tension and uncertainty brought on by the pandemic has raised tensions to an unprecedented level in recent months.

The impact of US sanctions on the Chinese semiconductor market was significant, and hit supply chains at the worst possible time; production was already at capacity in other territories. Amid worsening relations the Biden administration has gradually tightened its restrictions to control the rise of China's technological power beyond its own shores.

JIT Supply Chain Production

Miller also asserts that globalisation, while an easy target and an obvious one, has been wrongly blamed for the shortages during the pandemic. "Everyone thinks Covid and lockdowns were the reason for the chip shortage," he said. "The real issue is the nature of purchasing and the just-in-time supply chain strategy," he explained, adding that there is little in the way of wriggle room when unanticipated global events occur. "Purchasing is really to blame." Likewise, complacency. Gelsinger was right.

Developed after the Second World War in Japan out of necessity, and in response to high unemployment, scant natural resources, low capital investment and little room to build large manufacturing plants, just-in-time production dazzled executives in the American automotive industry in the 1970s, by then in serious, long term decline. Further to a presentation in Detroit by Toyota executives whose competition was a serious threat, its methods of ordering only what was needed and storing the bare minimum were quickly and widely adopted across the US. It kept cashflow tight and productivity high and saved whatever industry was left in Detroit during that period.

JIT strategy works well when orders are coming in regularly and quantities of component parts for assembly can be anticipated. It is efficient and saves money on warehousing parts. JIT has been the dominant and most successful production strategy worldwide for decades but as we have seen, the slightest hiccup can cause absolute panic. Severe lockdowns in Asia, combined with news changing on the hour made it impossible to predict demand. We all remember that uncertainty in early 2020 and nobody knew when the pandemic would end: end of the month? By June? August, surely? All bets were off. As it turned out, we were wrong by more than a year.

Coupled with this was the surge in demand during the pandemic. Billions of us doing nothing at home were responsible for an 8% rise in the demand for semiconductors. That rose again in 2021 to 12%, Miller explained.

As mentioned already, some large tech companies had been quietly stockpiling prior to Covid and, grasping the seriousness of what was happening in Asia, upped their game; another reason why semiconductors were suddenly unavailable to those who weren't paying attention. Anthony Basham, CSO at DKT in Copenhagen told Broadband, "We had to stockpile, and we did it as soon as we could. It was a matter of survival for our FTTx portfolio, and we were glad we thought to do it. We would do it again in a heartbeat, it has allowed us to support our customers and their projects."

Cryptocurrency

As if things weren't bad enough, the rise of crypto currency mining in recent years has also put pressure on the supply chain. Part of the allure of bitcoin is its limited number; only 21 million bitcoins exist (created by design in 2008, the effect being enormous, unsustainable hype and a digital gold-rush of sorts), and mining the remaining 1.8m bitcoins takes powerful, specialist computers requiring large numbers of semiconductors to produce the mathematical algorithms that comprise a single bitcoin.

A once-in-a-millenia gold rush combined with a once-in-a-century pandemic added further pressure to an already combustible situation.

Climate Change

Droughts in Taiwan during the pandemic and the water-saving measures implemented by the government added considerably to the manufacturers' problems. Emanuela Barbiroglio of Forbes Magazine painted a sorry picture in a report published in May 2021, pointing out that while domestic water supply had been cut off altogether for two days a week in some cities in Taiwan, some manufacturers were literally unable to produce anything at all.

In the city of Taichung on the north of the island, supply was deliberately, completely cut off. Barbiroglio explained that TSMC consumes '150,000 tons of water a day, approximately 80 standard swimming pools' in its output of semiconductors, so while that demand was put on hold temporarily, it did little to quash the worldwide demand for chips.

Freak events

Beginning to take on biblical proportions by Spring 2021 (plague and drought having already been covered here), the semiconductor shortage worldwide was also badly affected by a series of unrelated fires breaking out in two manufacturing plants in Japan, and one in Germany. Fortunately no actual casualties were reported, and the causes of the fires are still unclear, but they impacted on the already strangled supply of semiconductors as the plants variously had to be shut down, cleared, assessed and rebuilt.

Manpower

Many of us, including this writer, found ourselves facing an unplanned career change during the pandemic, causing reverberations in the manpower available in semiconductor plants in Asia and elsewhere. Staff shortages are now a common theme in daily life in the UK, and this can be attributed partly to Brexit of course, but there are specific staff shortages across all industries. Hospitality, aviation, logistics, manufacturing and retail all suffered precisely because furloughed workers took a look around for the first time in years and realised there were other, better paid jobs available that didn't require shift work and offered substantially better benefits. Others took on work in new areas during lockdown and just didn't go back. The knock-on effect of an exodus from any industry would be therefore considerable, and combined with stockpiling, just-in-time supply chain problems, geopolitical tension, bitcoin mining, climate change and random fires as well as inherent issues with globalised production, it is a wonder the semiconductor got produced at all during the final years of the 2010s.

The consequences of all of this have been considerable. Competitors like Intel and Qualcomm are delighted that President Joe Biden finally approved the passing in the US of the Chips Act in August (Creating Helpful Incentives to Produce Semiconductors), drafted in the wake of Covid, which enabled $52bn to boost semiconductor research and production in the US for the first time. This is a direct result of the pandemic and designed to safeguard supply chains in future. With 10% of the world's global semiconductor market, the same act was passed by the EU back in February, with the intention that Europe will account for 30% of the market by 2030, according to the European Commission.

Arguably this is an anti-globalist initiative, but few are describing it as such. In an uncertain world, this shores up

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production, safeguards supply chains and protects industries from the unexpected.

Where are we now?

Depending where you are on the supply chain you are either still very much affected by the shortage, or hardly at all. The semiconductor shortage has given everybody pause for thought, and while we are on our way out of this mess, the industry has been forced to take stock. Human nature makes us good at problem solving and we have emerged vaccinated, wiser, warier. There are mountains to climb in terms of sustainability, something hardly touched on in this piece, worthy of another one altogether, and our hunger for semiconductors will have to be aligned with aggressive net-zero ESG commitments we touched on earlier if we are to survive as a species.

It will take massive quantities of semiconductors to achieve net-zero by 2050 anyway, consuming millions of gallons of water and producing outrageous quantities of waste. Equally, the increasing threat to Taiwan by China is pushing the US and Europe to establish manufacturing plants locally to ease reliance on an unstable region, which is not in the least bit aligned to anyone's sustainability targets. And then there is Russia.

Chris Miller explained that conversely, the economic downturn that followed the pandemic (as the world recovered from two years of lockdowns) has seen demand for semiconductors in gadgets and devices fall for the first time in years. Inflation is rising and the cost of living is biting as we enter another worrying winter. Consumers are hanging onto their phones for longer, waiting another year before getting that new car, living with that TV while it still works. This pattern, replicated at scale has lifted the pressure on semiconductor demand, so superficially it appears the shortage is no longer as critical.

He feels lessons have been learned. "The problems we saw with purchasing hurt the automotive industry in particular," he said, explaining that during lockdown they were not considered as much of a priority by semiconductor producers as Apple, plus a lot of brands had not thought to stockpile either; the industry suffered greatly because of it and they are still experiencing problems now, as anyone in the market for a new car lately will tell you. "Have lessons been learned by the rest of the industry? That's not so obvious," he admitted. Chris also feels that the current instability of the world's economic, political and ecological climate means that another world event is only ever around the corner. "Chip shortages might not ever be truly over," he said.

Intel's Gelsinger reported gloomily in May that "The chip shortage cost the US economy $240bn last year, and we expect the industry will continue to see challenges until at least 2024 in areas like foundry capacity and tool availability." By contrast, his competitor Cristiano Amon, CEO and President of Qualcomm was bullish, telling reporters in May at the World Economic Forum in Davos, Switzerland he was glad he had foreseen capacity issues and invested in multi-sourcing early on, mitigating the damage to Qualcomm's bottom line. He is therefore optimistic that by March 2023 the shortages will be a thing of the past.

Whether Amon's statements are the stuff of chest-beating hyperbole or not, it is encouraging that measures on both sides of the Atlantic have been taken at government level to ensure shortages like this do not occur again. Free markets drive business, but they do not protect it; intervention by the EU and Washington was essential to protect the interests of consumers as well as multinationals. President Trump's vision of America First may have actually become a reality, though it took a global pandemic to initiate it.

It is worth revisiting this landscape to learn how the semiconductor industry plans on reaching net-zero by 2050, further to a pledge by TSMC, amid the current tensions and further, inevitable disrupters.