# The New Normal: The Semiconductor Access Singularity and What It Means to You

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**Keywords: supply shortage, global trade, supply resilience**

## Introduction

The COVID-19 pandemic has been a catalyst that significantly accelerated the penetration of technology in how society connects, communicates, and collaborates. We are witnessing the pervasive deployment of semiconductors as the underlying intelligence that enables these new experiences and human interfaces.

This acceleration, coupled with new technology introductions, geo-political tensions and global trade disruptions have fueled an insatiable appetite for semiconductors. The confluence of these factors has created a supply singularity with demand far outpacing supply. This is a singularity the semiconductor industry and the society it serves were unprepared for. Semiconductor scarcity is impeding society's access to cars, appliances, and computers, generating an important toll on local and global economies. The scarcity has also raised important questions on how semiconductor access should formulate in national security and autonomy conversations.

This work will review cyclical and secular demand acceleration drivers, the traditional semiconductor supply model, and its breakdown, and describe a new model being applied to create higher resilience, scale, and sustainability in the semiconductor supply chain.

## Demand Acceleration Drivers

From the eve of the new decade, the year 2020 was expected to be a critical year for technology and semiconductors. Even before 5G, the mobility end market was already the largest demand driver for semiconductors manufacturers[1]. The 5G cellular rollout was launching and seen as a once-in-a-generation super-cycle that would fuel broad deployment in semiconductor solutions to support new mobile phones, wireless infrastructure, and data center scale.

With the arrival of 5G, the semiconductor industry was bracing to address increased demands breaking from the traditionally saturated growth in mobile handsets. In addition to the new 5G wireless and compute-centric smartphone components, pervasive deployment of semiconductors powering novel functionality and use cases translated to a far higher degree of semiconductor components per phone over the 4G generation. As shown in Figure 1, there was a remarkable 39% year over year increase in non-memory semiconductor area for high-end Android phones into 2020[2].

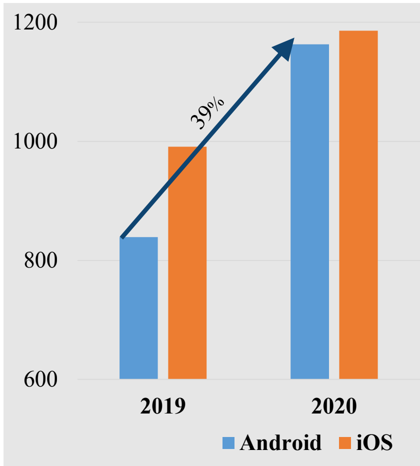


Fig. 1. Total silicon area in $mm^2$ of high-end smartphones, excluding memory

Beyond the 5G roll out, by 2020 the IoT revolution was starting to hit its stride. IoT had long been a buzzword attached to the unrealized potential of smart connectivity enabling a multitude of products in and around the home, office, factory, etc. However, in the later years of the 2010s, IoT made measurable progress in fulfilling that potential. A great example of this realized potential is the story of the smart speaker. According to S&P Global Market Intelligence[2], unit shipments for these devices grew from 6.5Mu in 2016 to a staggering 146Mu in 2019. By way of comparison, applications such as personal computers and smartphones took decades from launch to reach similar per year shipment levels[3]. Figure 2 showcases a CAGR above 20% across 2022-2025 for the number of IoT connected devices[4] which easily beats the industry's single digit growth. New applications are entering the IoT ecosystems with similar potential, supporting the thesis of pervasive semiconductor deployment.

Geo-politics have also played a fundamental role in contemporary semiconductor supply and demand dynamics. In 2019, the US government introduced export restrictions on Huawei Technology Co.

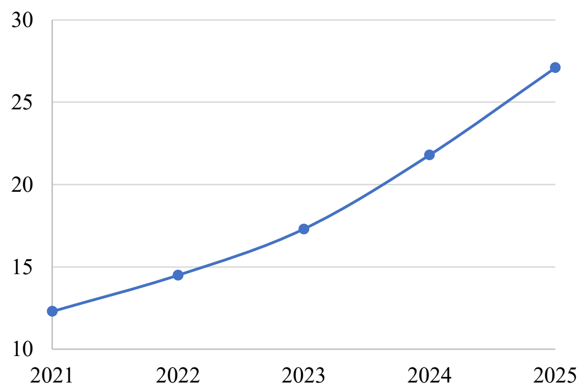

Fig. 2. IoT Market growth forecast in billions of connected devices

The United States Export Administration Regulations ("EAR") action triggered a set of restrictions that crippled Huawei's ability to design, produce, and sell products from consumer to infrastructure end markets in China and across the globe. Table 1 showcases the massive scale of mobile handset share redistribution byproduct of the export restrictions. Huawei's market share from the second quarter of 2020 to the first quarter of 2021 reduced by a staggering 75%[5]. As Counterpoint research pointed out in their 2021 report, the market share reduction is in part due to Huawei separating Honor as a standalone brand; nevertheless, the impact on Huawei is enormous. Due the sheer mega scale of the pre–EAR Huawei semiconductor consumption, this event triggered a sudden reconstitution of the global semiconductor demand base which increased volatility and yielded dramatic increases in demand for companies that competed with Huawei or manufactured for Huawei's competitors. While the net effect of this redistribution to smartphone demand was near neutral, it left the semiconductor industry rattled, adapting to material changes and thirsty for a stabilization that would never come.

| | Q2 2020 | Q3 2020 | Q4 2020 | Q1 2021 |
|---|---|---|---|---|
| Samsung | 20% | 22% | 16% | 22% |
| Apple | 14% | 11% | 21% | 17% |
| Xiaomi | 10% | 13% | 11% | 14% |
| OPPO | 9% | 8% | 9% | 11% |
| vivo | 8% | 8% | 8% | 10% |
| **Huawei** | **20%** | **14%** | **8%** | **4%** |
| realme | 2% | 4% | 4% | 4% |
| Others | 16% | 20% | 23% | 18% |

Table 1. Global smartphone market share by quarter[5]

## THE ARRIVAL OF COVID-19

With the arrival of the COVID-19 pandemic in March 2020, the very fabric of day-to-day life was deeply impacted and transformed. The pandemic brought human tragedy, uncertainty, and isolation. Over the course of the first months, the world stayed at home, catalyzing what for many service industries felt like years of transformation in a few short months. Work and study from home, telemedicine, e-commerce, and contactless interactions became daily household realities across the globe. Figure 3 shows a McKinsey and Company study that suggests digital adoption has taken a significant leap forward with an effective 7-year global acceleration of the percent of products and services that have are partially or fully digitized[6].

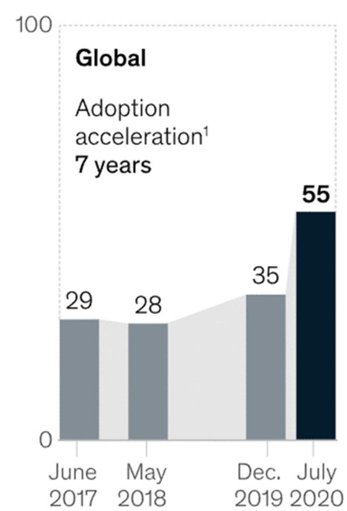

Fig. 3. Average share of products and services that are partially of fully digitized

Survival in this new reality literally required adaptability and flexibility. Much of this real-time evolution was enabled by technology solutions that had semiconductors at its core. Demand skyrocketed. The acceleration and upscaling in semiconductor long-term demand forecasts is shown in Figure 4. The new growth rates are far higher than the historical CAGR[7]. Further, Figure 4 shows how industry analyst predictions have been revised higher over the last quarters as the full impact of the acceleration is comprehended.

These cyclical and secular factors all came together to create an environment that challenged the traditional semiconductor supply model to its core.

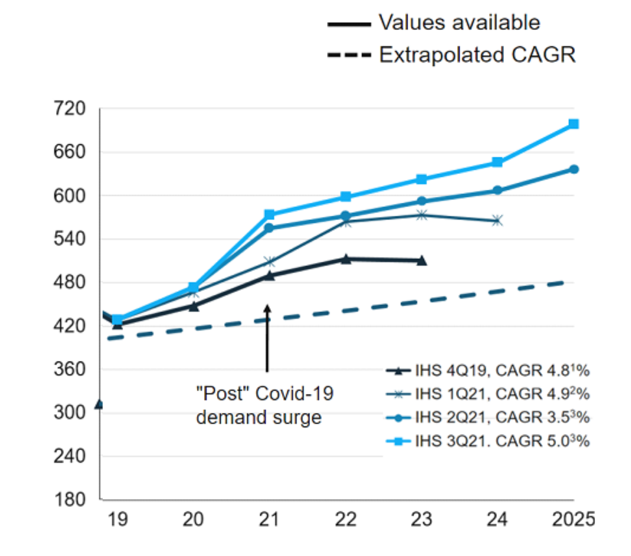


Fig. 4. Semiconductor industry sales projections in $Bn

THE TRADITIONAL SUPPLY MODEL AND ITS BREAKDOWN

The 1990s marked the raise of the foundry contract manufacturing model, providing open access to semiconductor production to design entities who had the design expertise but not the desire, capital, nor expertise to manufacture their own chips. The rise of the foundry model created significant momentum in the growth and diversification of design-centric semiconductor innovation. The model was simple: foundries would develop platform technologies and invest large amounts of capital to create capacity accessible to their customers.

Semiconductor growth across the 1990s and 2000s was largely driven by PCs, laptops, and later by the mobile technology revolution. In both cases there were large dependencies on digital scaling as the primary form to create next generation compute-centric value. As the platform technology lifetime progressed, specialized foundries and Integrated Device Manufacturers ("IDM") innovated to add analog, power, RF, and embedded memory features. The design intent of many of these semiconductors relied upon these features as primary value drivers that in most cases did not benefit from raw digital scaling. These technologies became the lifeblood of solutions that enable today's fastest growing end markets including automotive, IoT, mobility, to name a few. As such, the definition of 'leading edge' technology is being redefined, from a Moore's Law centric definition to one that recognizes the power of these features and the value they create. Before the acceleration, the capacity needs for these feature-rich technologies were similar in scale to the opportunity made available from the migration of digital-centric products to the next Moore's law node. This approach offered the opportunity to repurpose pre-existing digital semiconductor manufacturing equipment and supported a lower cost point to enable feature-rich technology capacity. As a request these feature rich platforms were built largely on existing, and highly depreciated assets.

As Figure 2 illustrated, the growth projections for devices outside the traditional compute-centric end markets is witnessing disruptive growth. So, while tremendous growth in semiconductors gravitated to feature-rich solutions, the investment levels and resulting capacity scale were not matched. For example, an S&P Global Market Intelligence report showcased that only 12% of the 2020-2021 capacity investments were on 40nm or larger nodes, yet these nodes represent 90% of the chips inside of representative car[8]. Figure 5 shows that this overarching focus on Moore's Law node investment towered over all other investments. This imbalance and chronic underinvestment in existing nodes added high risk to the expansion of supply of these pervasively deployed semiconductors.

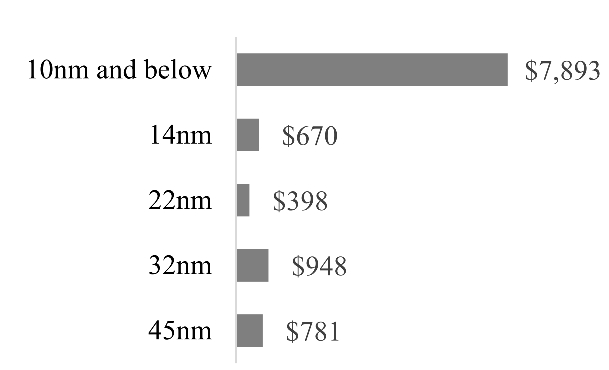


Fig. 5. Wafer fab equipment shipped revenue in $M by node generation, excluding memory

Within the traditional foundry model, foundry customers designed with confidence as the industry added what seemed to be abundant capacity. It remained uncommon to see a binding interlock of investment or demand and supply between the foundry and its customers. It is hard to find another industry with $100B+ scale that operated in this unbalanced, tactical manner.

Particularly significant is the rise of automotive semiconductor content. Electrification and digitization of cars are expected to drive the growth in the number of analog chips in cars by 26% from 2021 to 2023[8]. Figure 6 shows the high growth forecasted for electric vehicles[9] that will be powered by semiconductor technology including electrification through compound semiconductors. But this growth is not well coupled with complimentary scaling in auto-centric semiconductor manufacturing. Despite this growing reliance on semiconductors, parts of the automaker ecosystem have exhibited a limited understanding of the end-to-end semiconductor supply chain and its strong influence on automotive roadmaps. As the early days of the pandemic drove the stay-at-home culture, the key players from car makers to rental car providers braced for the worse and took measures to ensure business resilience and continuity - an effective full stop. As the early signs of the acceleration were seen, markets such as mobility reacted faster than others, locking up supply and capacity at the higher levels required to support the acceleration. This resulted in additional stress on the end markets that did not react as quickly, including automotive. It added challenge to secure supply at pre-pandemic levels, let alone at higher levels to capitalize on the acceleration. Few if any of these large players had secured binding certainty of supply, leaving them and their ecosystem highly exposed. The confluence of these factors led to a crippling automotive chip shortage. The major shortage gaps were reported to be on these same, feature-rich semiconductors, with S&P Global Market Intelligence suggesting the primary component shortage to be on microcontrollers and analog chips[9] above 40nm and not their Moore's Law counterparts. As the supply shortage continued, sources suggested that the auto industry would produce 4 million fewer cars than planned with an impact of over $100B[12]. The impact was broad-based, with tens of thousands of workers furloughed or laid off, significant increases in prices for old and new cars alike, and a clear social and governmental awakening of the strategic role of semiconductors.

It became clear that this traditional semiconductor supply model would need to be quickly overhauled.

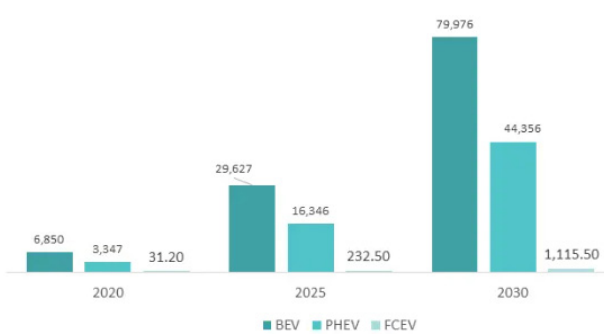


Fig. 6. Forecasted estimated stock of electric vehicles

THE NEW MODEL AND A 'BETTER' NORMAL

The year 2021 will go down as a year of significant transformation for the semiconductor industry. The industry and its end customers appear to recognize a need to change the approach to solutioning semiconductor manufacturing capacity and growth. A new economic model is being developed that includes public-private partnerships, shared investment, decentralization of manufacturing locations, and a far more robust end-to-end supply chain interlock.

As a result of the shortage, several governments worldwide initiated actions to support a strengthening of the local semiconductor manufacturing ecosystem. Announcements have been made, first from GlobalFoundries in June of 2020[13] followed by TSMC and UMC, that outlined new construction across multiple geographies with governmental economic support towards the construction of green-field semiconductor manufacturing sites[14,15]. These announcements included committed investments in the tens of billions of dollars. A material portion of the additional capacity is serving the pervasive semiconductor technologies that power applications in automotive, IoT, power, and cellular communications whose features do not rely on Moore's Law technology. Unlike prior precedent, many of the new construction announcements were outside of Taiwan, which is home to the largest semiconductor foundry and other smaller makers generating 65% of the outsourced chip production revenue[10]. Unlike prior precedent, the aggressive government support came from nations outside of China. Figure 7 shows the overall footprint with the broader APAC region accounting for 85% of the total worldwide capacity.

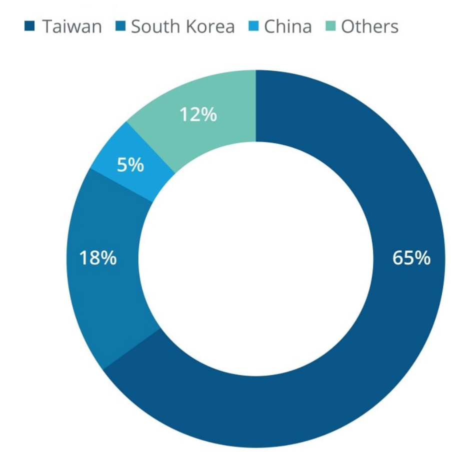


Fig. 7. 2021 Global foundry capacity share by region

To the semiconductor industry and these stakeholder nations it became increasingly important to apply a degree of decentralization away from APAC as a core requirement of the new model. This decentralization offered opportunity for resilience against possible geo-political and natural disaster challenges. It also offered a more direct path towards increased national technology autonomy. This decentralization has been far-reaching. Even TSMC announced that it would be building manufacturing sites in the USA[15] and Japan[16], their first outside of Greater China.

A global semiconductor manufacturing footprint which would have been deemed a competitive weakness or cost efficiency hurdle not long ago, was now seen as a strategic imperative to business scaling and continuity. The industry has reacted boldly. Table 2 offers a selection of the new semiconductor site announcements for nodes above 10nm coming online and ramp to serve the market.

| Vendor | Location | Node | Capacity | Ramp |
|---|---|---|---|---|
| UMC | Taiwan | 28nm | 336 | 2022 |
| TSMC | China | 28nm | 360 | 2022 |
| GF | Germany | 22-45nm | 279 | 2022 |
| GF | USA | 14-45nm | 162 | 2022 |
| SMIC | China | 28nm | 1200 | 2022 |
| SMIC | China | 40nm | 480 | 2022 |
| TSMC | Taiwan | 28nm | 480 | 2023 |
| GF | Singapore | 40-130nm | 450 | 2023 |
| UMC | Singapore | 22nm | 360 | 2024 |
| TSMC | Japan | 28nm | 540 | 2024 |
| TSMC | Germany | 28-16nm | 360 | 2024 |
| SMIC | China | 28nm | 1200 | 2024 |
| GF | USA | 12-28nm | 590 | 2025 |
| SMIC | China | 28nm | 420 | 2025 |
| UMC | Taiwan | 14nm | 360 | 2026 |

Table 2. Selection of new semiconductor construction for nodes above 10nm

An important hallmark of several of these manufacturing expansion announcements is the visible levels of partnership between the manufacturer and the users of the technology. Not only is there alignment of scale and breadth but also direct co-investment into these new sites[13]. Maybe the most remarkable aspect of this new model is in many cases the end market downstream player, a level removed from the semiconductor manufacturing is taking stake in the new manufacturing capacity. A great example is the announcement from Denso, a tier 1 automotive component manufacturer, with participating equity in a new semiconductor manufacturing factory in Japan[16]. As additional announcements surface, a clear common thread is observed highlighting that the industry is going to follow a much more disciplined, connected, and binding supply and demand interlock model.

## Conclusions

The COVID-19 pandemic brought a dramatic acceleration in the consumption of technology powered by semiconductors and came at a time when major themes including the 5G rollout, explosive IoT growth and geo-political tensions were already adding pressure to semiconductor sourcing and growth models. The pandemic also exposed significant longstanding structural gaps in the way that the semiconductor industry set itself up for growth. This gap was particularly acute for high-growth end markets that leveraged feature-rich semiconductor solutions that historically had suffered from long-term chronic underinvestment. These factors led to this singularity, with a deep impact on society and heightened visibility of semiconductors as a strategic national asset. The industry is adapting by changing its foundational economic model and how the ecosystem collaborates and partners with the markets they serve and the nations that host them. Important changes have been implemented to add strength and resilience to the semiconductor manufacturing footprint and the supply chains they serve. Improved emphasis exists on the semiconductor technologies that are deployed pervasively that do not rely on digital scaling as its primary method of creating value. This new model offers a stronger approach that will ensure that semiconductor technology will continue to play a fundamental role in human advancement.

## Acknowledgements

The author would like to thank Dr. Ciby Thuruthiyil and Dr. Martin Kuball for the kind invitation to participate in this conference.

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## ACRONYMS

APAC: Asia Pacific
CAGR: Compound Annual Growth Rate
EAR: Export Administration Regulation
IDM: Integrated Device Manufacturer
IoT: Internet of Things