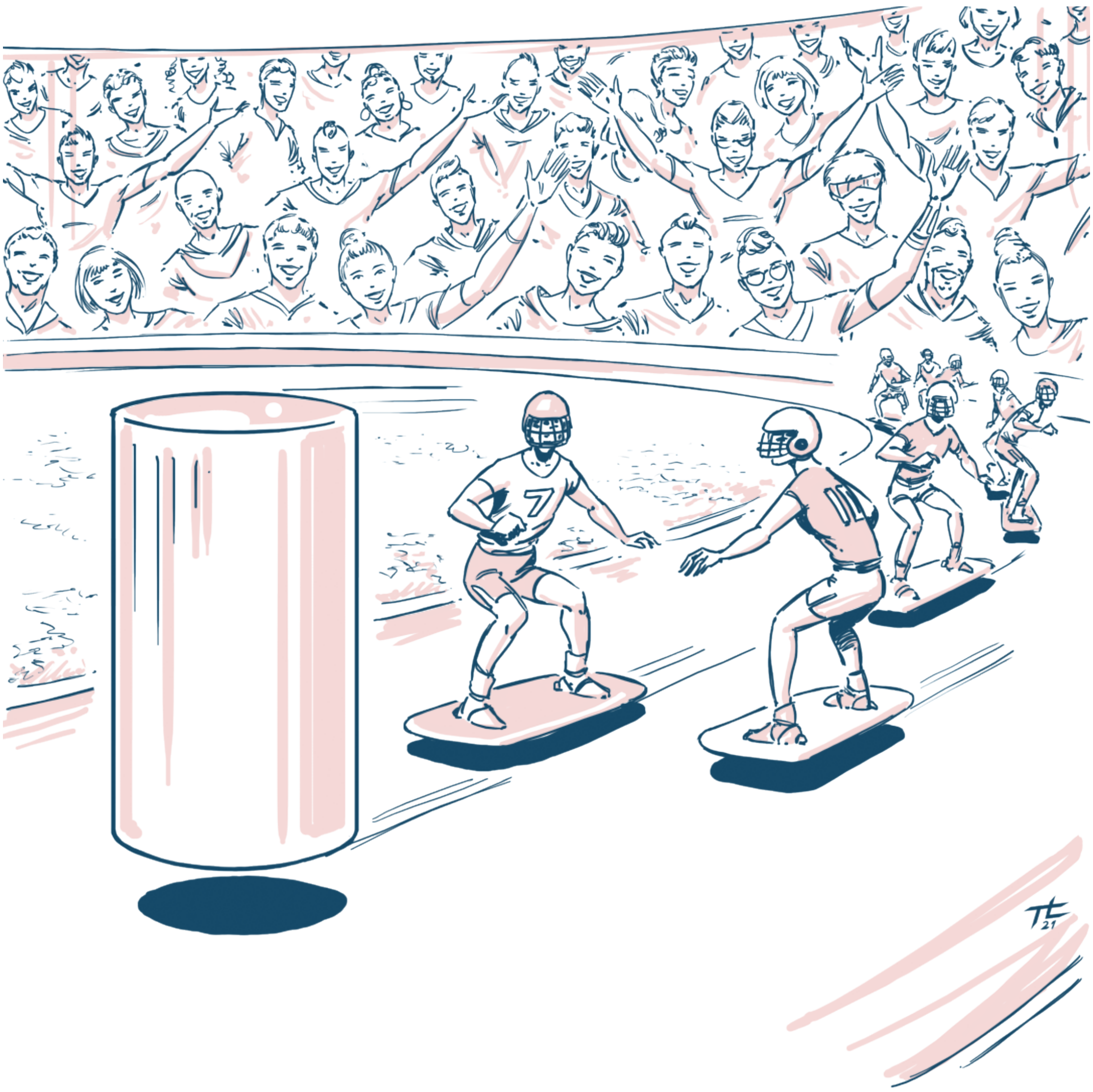
SEMICONDUCTORS

GREATER SELF-SUFFICIENCY AND INCREASING COSTS?



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In recent years, there has been significant disruption in the global semiconductor supply chain, affecting the automotive and electronics industries. However, by now, chip levels have more or less returned to normal. According to the SIA, global semiconductor industry sales reached a record high of $573.5 billion in 2022, but sales slowed down in the second half of the year.

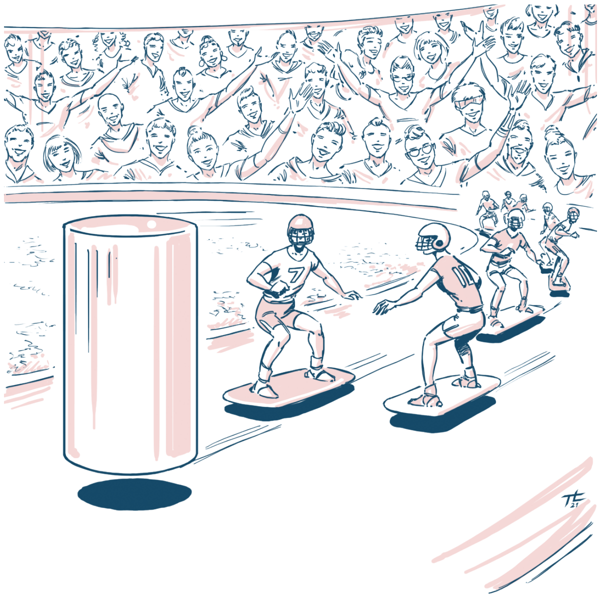
Asian countries, particularly Taiwan, play a vital role in chip production, with over 70% of chips being manufactured in Asia. Taiwan alone produces around 90% of the world's most advanced chips.

Chips are essential components in our lives, used in work, education, entertainment, transportation, healthcare, and more. Apple's game-changing products caused a „mobile tsunami" that reshaped the semiconductor industry and shifted the volume towards mobile devices, significantly impacting the market. They are crucial for technologies like artificial intelligence, 5G/6G communications, and the Internet of Things. Industries driving the top trends of this era, such as 5G, predictive healthcare, automation, and artificial intelligence, heavily rely on semiconductors.

In the past decade, the semiconductor industry has undergone significant changes. Rising factory costs, increased device volumes, fabless chip companies, and the Chinese presence have reshaped the industry's power structure. The shift to no-fab chip companies, driven by models like Arm, has had a notable impact on volume manufacturing.

The industry is currently facing challenges related to the semiconductor shortage, innovation, the end of Moore's law, and the development of new processes. Companies like AWS, Alibaba, Apple, and Facebook are even venturing into chip manufacturing themselves. The imbalance between supply and demand is a pressing issue being addressed worldwide.

Sanctions imposed by the US in 2020 prevented China from accessing the equipment necessary for advanced semiconductor development. China, in turn, has recently introduced export restrictions on rare earths, including germanium and gallium, further escalating the „chip war" between China and the Western world.



IS MOORE'S LAW DEAD?
IS IT ALIVE AND WELL?

WHAT ABOUT THE LOOMING CHINA THREAT IN SEMICONDUCTORS?

WHO STANDS TO LOSE IN THIS CLASH? THE WESTERN WORLD OR CHINA?

WHAT ARE THE NEWEST TECHNOLOGICAL TRENDS IN INTEGRATED CIRCUITS?

IS GREATER SELF-SUFFICIENCY INCREASING LONG-TERM SECURITY OR SIMPLY INCREASING COSTS?

SHIFTING MARKET STRUCTURE

The broken supply chains caused by the chip shortage have **practically rewired again**.

Changing Competitive Landscape

Tech giants such as **Apple, Tesla, Google, and Amazon are now making their own ASIC chips** designed specifically for their products. This gives them more control over the integration of software and hardware while differentiating themselves from their competition.

Silicon Nationalism and Investments

U.S. CHIPS Act In 2023, the US began disbursing the funding (~ $52 bn) for new or expanded semiconductor and chip-making facilities. Companies, including Micron Technology, Intel, Samsung, and TSMC, have announced plans to invest billions to build new semiconductor factories across different states.

The European Chips Act Almost 80% of suppliers to European semiconductor firms are based outside the EU, while the EU's share in global production capacity is less than 10%. The European Chips Act aims to boost semiconductor production in Europe and raise Europe's share to 20%. Intel and TSMC announced plans to build new production and engineering capacities in Europe. While Intel's factories in Germany and in Ireland will produce „wafers", the new Polish plant worth €4.6 billion will cut those wafers into individual chips and assemble and test them before they're shipped off to customers.

China China's „Made in China 2025" initiative aims for 70% self-sufficiency by 2025, with significant investment in domestic semiconductor manufacturing. Taiwan plans to manufacture and supply all its semiconductor equipment.

Volume shifts to Arm

Volume remains a determining factor that impacts cost, speed, and efficiency, making it crucial in the industry. Estimations suggest that Arm's wafer volumes are 10 times greater than those of x86 (Intel).

Outsourced foundries led to major changes in chip manufacturing, with most companies separating design from manufacturing. This shift has resulted in faster turnaround times, with some firms going **from design to tape out in just 12 months instead of the previous 3-year timeline**. Tesla's deal with Arm and Samsung is an excellent illustration of this trend.

Intel, once dominant in the foundry industry in terms of clock speed, wafer density, volume, low cost, and high margin, is now facing challenges, falling behind TSMC, Samsung, Nvidia, and Arm in the race for supremacy.

US corporations have been adjusting their supply chains by **moving production away from China to countries like India, Vietnam and Cambodia**. The Biden administration's sanctions on China's semiconductor manufacturing industry have accelerated this trend.

TECHNOLOGY RACE

RISC-V

The semiconductor supply chain issues have sped up the adoption of RISC-V architectures. RISC-V is an open-source instruction set architecture (ISA) designed for flexible and customizable chip-building. It has gained popularity due to its open-source nature and the ability to create custom chips at a lower cost. Companies are turning to RISC-V as a scalable and cost-effective alternative to traditional ISAs, allowing them to reduce reliance on proprietary ISAs.

Technology nodes

Over 70% of semiconductor revenue and 90% of chips globally are based on 7nm or older process tech, which China has access to. 7nm is just one generation behind 5nm, which is used in advanced smartphones, while 7nm or older is common in midrange or lower-end devices.

The next step in semiconductor manufacturing is the 3nm process, targeted for production by TSMC, Intel, and Samsung in 2023. It offers increased transistor density, speed, and reduced power consumption, but faces challenges with EUV lithography. Apple has secured the initial supply of TSMC's first-generation 3nm process. AMD, Intel, and Qualcomm plan to adopt the 3nm process in the next version, N3E.

The 2nm process is the further shrink after 3nm, with TSMC planning to begin risk production in late 2024 and mass production in 2025. Intel forecasts production in 2024, and Samsung in 2025.

Nanosheets transistors

Industry leaders — Samsung, Intel, TSMC, and IBM — announced they are transitioning to nanosheet transistor architectures, a type of transistor that uses extremely thin sheets of material, known as nanosheets, to control the flow of electrical current. These nanosheets are typically only a few atoms thick, and are smaller, faster, and consume less power. Nanosheet transistors are expected to play a key role in the development of next-generation electronics, including high-performance computing, IoT devices, and 5G communications systems.

Chiplets

The concept of chiplets involves dismantling a system-on-a-chip into functional components: computational processors, graphics units, AI accelerators, and more. This approach allows for building systems with interoperable chiplet components from various sources, potentially revolutionising computing paradigms, improving energy efficiency, shortening development cycles, and reducing costs.

CHALLENGES

Systemic and scale complexity

Engineers strive to meet the progressively challenging task of optimising power, performance, and area (PPA) in chips with as many as trillions of transistors.

The nationalisation of semiconductor technology is the biggest geopolitical concern.

The growing impact of **energy consumption** on our planet.

Supply chain Microchip manufacturing depends on an intricate worldwide supply chain, involving numerous nations. A large semiconductor firm could lean on up to 16,000 specialised suppliers globally.
This interconnectedness renders the chain susceptible to global challenges (geopolitical, pandemics or natural disasters).

Demand, supply, and availability of raw materials are major factors affecting the prices of semiconductors. Semiconductors are composed of raw materials such as tin, silicon, gold, and tungsten. These are physically sourced from various parts of the world. While there are thousands of suppliers, the prices of the material aren't stable.

There are **no sufficient fabs for the growing demand**. Massive investments or technological progress might help in the longer-term.

Cyclical swings in product demand

Escalating effects of **climate change** like extreme weather and ongoing **water scarcities** could further disrupt the semiconductors industry.

The lack of chips is already fueling **changes in the design of future products**, delaying the next generations of devices, and forcing engineers to come up with all manner of Plan Bs.

The demand for **substantial capital** is a hurdle, and chip suppliers caution.

Deficiency of **skilled labour** to sustain efficient factory operations.

TRENDS

Current changes that could significantly affect the future of semiconductors

- Growth of semiconductors' **nationalism**
- Further **geographical shifts in supply chain**
- **Disruptions in rare raw materials** availability
- **Enhancing sustainability** thanks to energy conservation and larger water efficiency
- Appearance of **new markets** due to further digitalisation, new technologies and its applications
- Further progress in **room-temperature ambient-pressure superconductors**
- **Focus on computing power, energy and thermal efficiencies** driving the semiconductors tech development
  - **Nanosheet or GAA transistors** will maintain the relevance of Moore's Law
  - Further shift in the dominance of x86 **architecture towards ARM and RISC-V**
  - **Next-gen chips powered from under the surface of the silicon**, linking them to a power-delivery network built on the backside of the chip
  - Exploration of **complementary new materials** to diversify beyond silicon, approaching its limits due to demands for smaller and faster circuits (**geranium, tin oxide, high-power gallium nitride, antimonide-based and bismuthide-based materials, graphene, pyrite**)
  - Achieving **significantly higher efficiency of edge AI chips** to realise IoT's potential
  - **Improve heterogeneous integration** with further enhancement of 3D tech
  - Growth of fresh techniques for storage enhancement (**MRAM**)
  - Increasing logic performance with **low-resistance materials** like ruthenium and cobalt-based alloys for chip interconnects
  - CMOS technologies to be increasingly supplemented with **MEMS** in the future

ANTI TRENDS

Factors of change that may disrupt currently observed trends.

- Escalation of the **U.S. / E.U. - China conflict**
- **Rebirth of the China's chip industry** as a result of U.S. sanctions
- Climate change hindering current production and further development of investments due to **water scarcity or natural disasters**
- Limited **access to rare metals** needed for production due to the geopolitical situation
- Another **pandemic** and breaking supply chains
- **Global economic downturn** or disruptions in a few key economies (China, Taiwan, South Korea, U.S., Japan) destabilising the world-wide supply of semiconductors and quickly propagating to numerous downstream sectors
- The **economic / institutional crisis of the European Union and/or U.S.** resulting in lacking public funds and commercial financing for the development of a semiconductor eco-system in these regions
- **Changes in energy policy** and a slowdown in green energy development due to armed conflicts and social unrest
- The pace of growth depends on **disruptive innovation. Slowdown in international collaboration** in R&D due to geopolitics might harms the pace of progress and transformation to the green and digital economy.
- Lack of **skilled labour**
- Advances in new technological developments in **quantum and/or optical computing** to have a revolutionary impact on the entire semiconductors sector

CONCLUSIONS

The semiconductor industry is grappling with a complex landscape marked by technological innovations, geopolitical shifts, and supply chain vulnerabilities. The industry's adaptability to these challenges while advancing in design, production processes, and sustainability will be pivotal in shaping its future. This shift has been influenced by trade wars, national defence concerns, and the recognition of semiconductors' strategic importance. Relocalization of the industry, particularly spurred by the Ukraine crisis, has accelerated, with new fabs being established in North America and Europe. Furthermore, the industry is reshaping due to new players and innovative technologies. The adoption of RISC-V architectures and nanosheet transistors showcases advancements that challenge traditional paradigms.

Europe is striving to catch up in the global microchip race, facing strengths like advanced equipment but grappling with chip design capabilities and material supplier investments. Initiatives such as the European Chips Act and significant investments aim to boost chip manufacturing within the region. However, challenges encompass building advanced supply chains and addressing issues like electronic waste and skills shortages. The persistent semiconductor supply crisis, influenced by geopolitical tensions and rising costs, threatens industries globally, impacting product delivery and costs.

Addressing the remaining issues, we find that Moore's Law remains vibrant and is poised to exert its influence for at least another decade. As for the ramifications of the American-Chinese standoff, the primary casualties appear to be none other than the progress of humanity and the global economy at large. The pursuit of heightened long-term security via self-reliance emerges as a costly endeavour, standing in contrast to the more economically viable option of multifaceted international cooperation. However, the crux of the matter rests in assessing the feasibility and desirability of collaboration between democratic and authoritarian governments to address these intricate issues.

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4CF is a strategic foresight and long-term strategy building consultancy. For almost two decades, 4CF has been helping its clients prepare for an uncertain tomorrow.
The company has completed hundreds of projects for private companies, public and international institutions, including UNESCO, UNDP and WHO.

Using foresight, 4CF supports clients in uncovering future opportunities so that they can make important strategic decisions today and implement solutions to ensure a better future for their stakeholders. We care that our clients are always one step ahead of the competition. The company is the only Polish member of the Association of Professional Futurists, Foresight Educational and Research Network and founder of the Polish node of The Millennium Project.

4CF is at the forefront of global innovation and actively contributes to the development of cutting-edge foresight tools. The company's foresight experts have extensive interdisciplinary knowledge and experience.
They are constantly refining the 4CF methodology and actively collaborate with leading international foresight centres.

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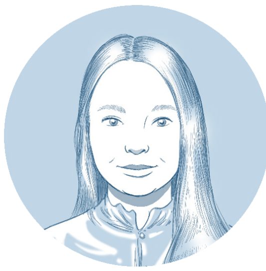

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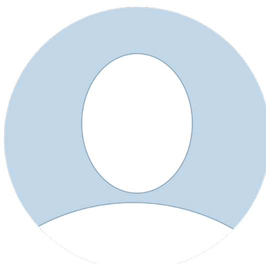

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