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Is the semiconductor industry at a turning point?

Schedule

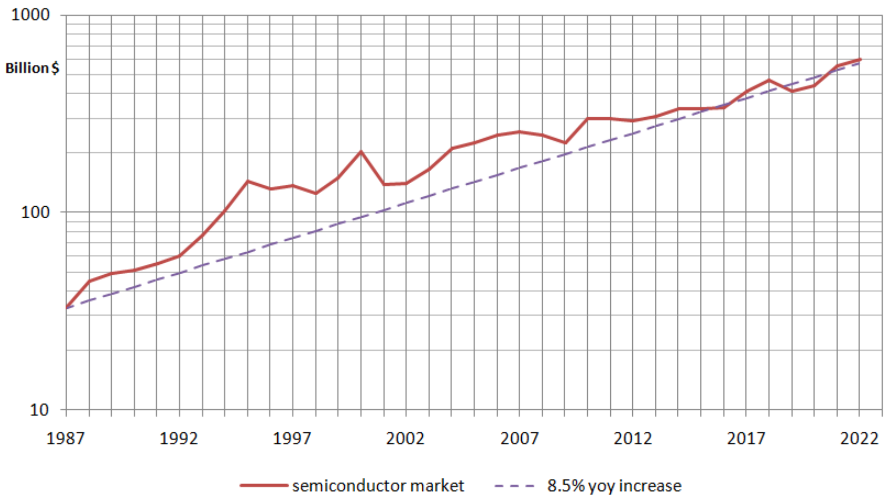
- ❑ The Semiconductor Industry
- ❑ Analysis and Perspectives
- ❑ Conclusions
- ❑ Q&A

The Semiconductor Industry

PREVIOUS SCENARIO

The semiconductor industry has **grown** over the past three decades, at an average of **8.5% per year**, fundamentally because **the industry's extraordinary efforts have been based on strong and open scientific, technological, and commercial cooperation** within both the global market and the supply chain **to maximize effciency**.

Log scale



In the semiconductor ecosystem, the **capital-intensive segment of the fabs** (especially for the extreme technology nodes) was **separated and specialized** from that of the IC design, so that fabless and fab-light houses could potentially generate a greater revenue.

The **packaging** step—once responsible for only a few percent of the final chip cost—became more and more sophisticated, especially for systems in a package (SIP), and for advanced RF chips, and was also **separated and specialized** to **outsourced assembly and test** companies.

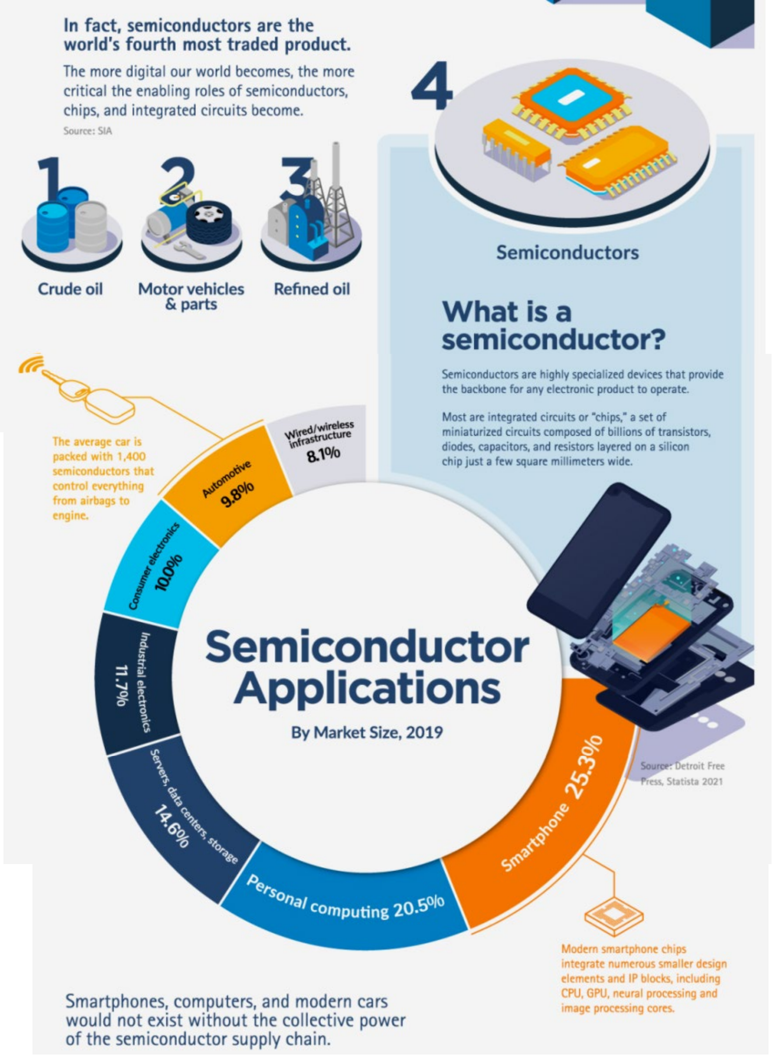
Semiconductors have a huge role to play as part of the digital economy, with massive growth for the industry on the horizon.

Source: UNCTAD, Gartner

Semic. Devices market

2021	2035E
$0.6 trillion	$1.0 trillion

Chips empower the technology of the present and the future. From advances in **5G** and **AI to smart factories** and advances in **automotive** and **quantum** computing, the companies in **the semiconductor supply chain make it all possible**.

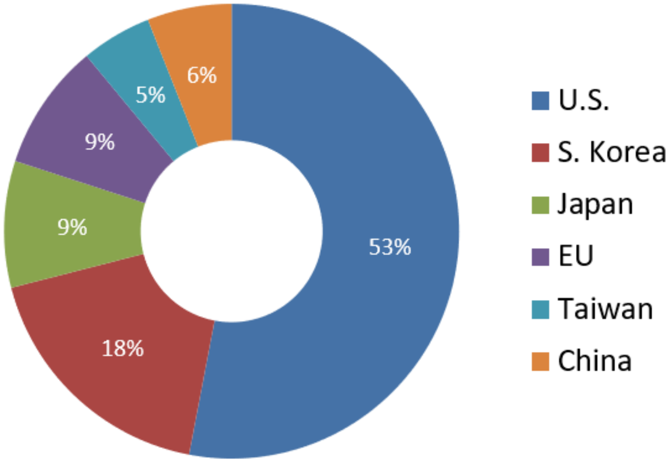


https://www.bnnbloomberg.ca/the-global-fight-over-chips-is-only-going-to-get-worse-1.1738270

The global semiconductor device market increased from $555 billion in 2021 to $573 billion in 2022

- The **U.S**. grew its market share from 51% to 53%
- **Korea** decreased from 22% to 18%
- **Japan** increased from 8% to 9%
- **Taiwan** and **Europe** remained constant, 5% and 9% respectively
- **China** increased from 5% to 6%

Global chip sales in 2022



However, today, the entire industry relies for the **most advanced nodes on a sole player (TSMC)** in Taiwan which is a disputed Chinese territory that could be cut off from the rest of the world if Taiwan-China tensions escalate.

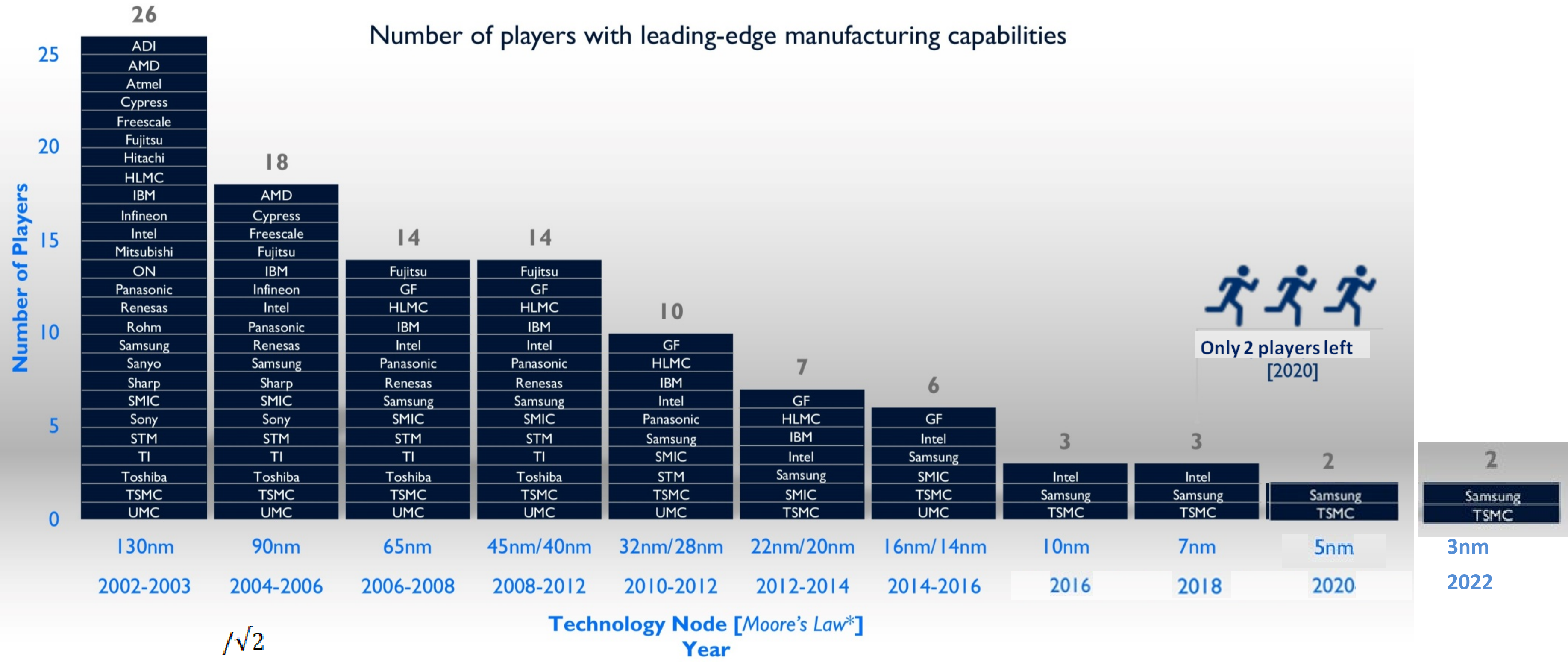
	<10 nm	10–22 nm	28–45 nm	>45nm
Europe		12%	4%	6%
Americas		43%	6%	9%
Japan			5%	13%
China		3%	19%	23%
Taiwan	92%	28%	47%	31%
South Korea	8%	5%	6%	10%
Other		9%	13%	8%

Global percentage IC capacity by technology node in 2021

2021 State of the U.S. Semiconductor Industry; SIA Report; 2021. Available online: https://www.semiconductors.org/wp-content/uploads/2021/09/2021-SIA-State-of-the-Industry-Report.pdf

Semiconductor industry evolution

(Source: High-End Performance Packaging: 3D/2.5D Integration report, Yole Développement, 2020)



* Moore's law states that the number of transistors in an integrated circuit chips doubles every 2 years
Data referenced from Intel and WikiChip

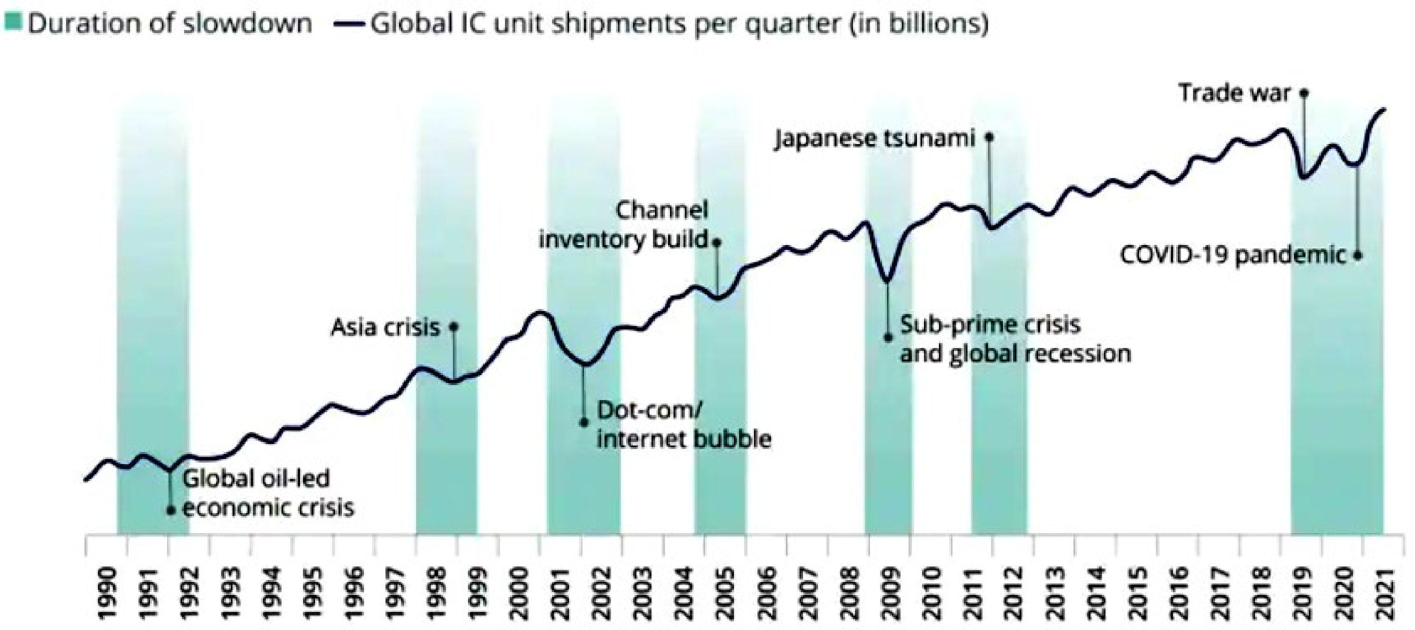
YOLE Développement

This ecosystem, highly dependent on business cooperation among nations, produced a **relatively stable market**, where most of the demand came from consecutive **killer applications** such as computers, laptop, smartphones, and now automotive, industrial IoT, and AI.

Because of this stability, the **supervision of supply chain** inventory, production, sales, and even R&D was quite **predictable**, and the **scalability of technology** nodes was ‘only’ a matter of reducing optical size (**shrinking**) while keeping the transistor structure almost unchanged.

Within this framework, **semiconductor shortages** have occurred cyclically, sometimes due to the **emergence of a new killer application** or exacerbated by **external shocks**, such as the 2000 dot.com bubble or the 2009 recession or the 2020 COVID pandemic.
In general, however, cycles from **underproduction to overproduction** have been repeatedly observed in leading-edge ICs and memory ICs. In the alternation of these semiconductor cycles, **large fabless companies did not take on real financial risks** and stresses. **Even the risks were outsourced to foundries and, ultimately, to TSMC**.

Global Integrated Circuit (IC) unit shipments across various downturns, quarterly, 1990 to Q2, 2021 (log scale)



Source: Deloitte analysis based on secondary research and data gathered from publicly available articles and reports.

Deloitte Insights | deloitte.com/insights

Schedule

- ❑ The semiconductor industry
- ❑ **Analysis and Perspectives**
- ❑ Conclusions
- ❑ Q&A

Analysis and Perspectives

The semiconductor ecosystem is undergoing **a radical change** in its structure **for a number of important concomitant reasons that will be discussed** in the following:

1. Unprecedented Market Growth and Profitability
2. A New Class of Competitors
3. Technological Breakpoints
4. New Foundry-Customers Agreement
5. Trade War
6. Talent Shortage/War
7. Human Resources /Branding
8. The Ukraine Conflict
9. Reshoring

These open up **new scenarios** in terms of **market growth and opportunities**, but also of **potential dangers**, and require the development of new policies and business models.

1. Unprecedented Market Growth and Profitability

We see an **unprecedented level of demand for ICs**, driven by 5G, IoT, health, automotive applications and AI.
2017 and 2021 were record years for the semiconductor industry, with 22% and 25% year-on-year improvement.

2018 was identified as the year when the amount of **data** generated by humans was equaled and surpassed by that **generated by machines**, which has since grown exponentially.

The **high demand will require, much greater capacity from the manufacturing industry**. The scenario is radically **different from the usual alternating inventory cycles** seen above.

In addition, the advent of AI, IoT, and autonomous vehicles requires the IC industry to be more flexible, more focused on R&D, and with shorter production times.

2. A New Class of Competitors

Increased IC demand is leading to a **resurgence of IC design start-ups**, and perhaps more importantly, **many big technology and automotive companies have begun to design chips in-house**. The semiconductor industry has been faced with **new type of competitors**.

For example, **Apple** develops custom chips for the iPhone and iPad, **Facebook** (now Meta) designs chips optimized for the types of content it stores and processes on its servers, **Amazon**'s Graviton and Inferentia and **Google**'s (now Alphabet) Tensor Processing Unit (TPU) are AI-based IC accelerators for cloud computing, and **Tesla** has developed the D1 Dojo Chip to train AI models. It may sound surprising, but **Apple can be considered the third largest fabless player in the world**, behind Broadcom and Qualcomm.

Besides Tesla, many automakers are collocating semiconductor engineers to develop new chips. They are understood to be part of the semiconductor industry, as the average **IC content per vehicle will exceed $1000 by 2026**.

As we approach the **atomic scale**, optical shrinking techniques no longer work. In other words, **the scaling road map is no longer marked**. For each new nanoscale generation, new paths have to be worked out in terms of *materials, processes,* and *transistor architecture*. Every technological advance requires exponentially increasing expenditures in R&D, plant, machinery, and tools, which explains why there are only a few state-of-the-art foundries in the world today.

Another remark is about the **breaking of the link between leading nodes**.
The state-of-the-art in lithography has moved to 7, 5, and 3 nm, while microcontrollers, analog, IoT, and automotive, because of the functionality and reliability needed, are still implemented at 40–180 nm. As a result, **when the next node is released, the previous one does not find suitable applications**, contributing to **increased foundry risks**.

High-risk expenditures can no longer be borne by foundries alone.
Because large fabless companies have a vital need for new technology nodes, **fabless must share these risks with foundries, by entering** into **long-term agreements** (LTAs) or **non-cancelable, non-refundable orders** (NCNRs).

Just as ASML required strong co-investment from its customers to realize EUVL machines, foundries require co-investment and capacity risk-sharing with their customers, to manage the semiconductor cycles. This is an indicator of the changing structure of the industry, which also explains TSMC's present investment of $100 billion over three years, based on consultation with customers in anticipation of their needs.
2023-Apple secured 100% TSMC production of 3-nm components for one year (!).

Chen, M.; Shen, J. *TSMC Secures 3nm Order Commitments from Chip Vendors*; Digitimes: August 2022. Available online: https://www.digitimes.com/news/a20220818PD208/3nm-ic-manufacturing-mediatek-qualcomm-samsung-tsmc.html

The chip shortage showed that **even mature technologies can be in short supply**, and revealed the **new power and privileged position of the foundries**, which can now take advantage of NCNRs (no longer accepting the usual just-in-time order policy) with customers who want to ensure constant supply. Automakers are an example of such customers.

An **agreement between chipmakers and automakers** (and also with other industries) is also necessary for another reason:
The majority of automotive and industrial chips are realized in 40 nm or above, utilizing 200-mm wafers, with 200-mm fabs today fully depreciated. The manufacturing cost of a chip made in one of these depreciated fabs is very low, and the final price is (or can be) very low too. However, increasing fabrication capacity means that companies are building **new non-depreciated 200-mm fabs** and have to buy new machines and tools to produce chips whose market price is a fraction of what they would really cost. The investment in foundry is justified if customers sign LTA and NCNR, or if the foundry is supported by **strong government subsidies** (many of the 20 new 200-mm fabs are in fact in China), or if **several companies join forces**.

•200mm Semiconductor Fab Capacity Set to Surge 21% to Mitigate Supply-Demand Imbalance. *SEMI Reports*, April 2022. Available online: https://www.semi.org/en/news-media-press-releases/semi-press-releases/200mm-fab-capacity-set-to-surge-21%25-to-mitigate-supply-demand-imbalance-semi-reports.
•Merritt, R. Fab Joint Venture Seen for 200 mm. *EETimes*, May 2019. Available online: https://www.eetimes.com/fab-joint-venture-seen-for-200-mm.

New Foundry-Customer Agreements

REUTERS® World ∨ Business ∨ Markets ∨ Sustainability ∨ Legal ∨ Breakingviews Technology ∨ Investigat

Autos & Transportation | ADAS, AV & Safety | Products

Volkswagen strikes direct supply deals for chips to avoid global shortage

Reuters

August 23, 2023 6:53 PM GMT+2 · Updated 7 days ago

Aa

Previously observed (commercial) **cooperation between nations is now blocked by the U.S.–China trade war**.
China is currently the main importer of semiconductors (35% of the global demand for semiconductors) and **plans to reach 70% onshore chip manufacturing by 2025** by supporting its industry with large sums of money.

In reply, the **U.S. government** not only is replicating this **funding policy** with the Chips and Science Act but is also attempting to **set barriers** in China's way to developing advanced semiconductors. Companies receiving subsidies from the U.S. cannot build advanced (<28 nm) chip fabs in China.
The U.S. Chip Act tries also to **push foreign companies to take sides in the trade war**, in order to obtain U.S. subsidies, surely affecting small and medium-sized businesses.

But the effect of the U.S. bans, as **SMIC and its 7-nm** technology has shown, has been **to push Chinese companies to do even more massive research**. China also choose to block deals with large U.S. tech companies such as Micron, cutting more than 50% of their revenues, and further reducing the U.S. market share.
As another countermeasure, China could limit or ban Rare Earth Elements exports to the U.S. and its allies.

In fact, U.S.–China tensions are accelerating the decoupling of the two supply chains and markets, raising concerns that **Western semiconductor capacity could be oversized** if the Chinese market is cut off.

Research for new lithography nodes and **IC design** require an increasing number of **well-educated engineers**, possibly with a Ph.D., as these activities are *talent-intensive*. Moreover, we have seen that **chip designers are** recently being **competed for** also by big tech companies and carmakers.

However, the **number of semiconductor engineers is decreasing**. The continuing global **shortage of young talent** is of great concern, and a **talent war** is already underway.

Whereas all types of industrial and information engineers are in demand, those that work on enabling technology should be prioritized.

Deloitte. Services Industries Insights Careers Search

Perspectives

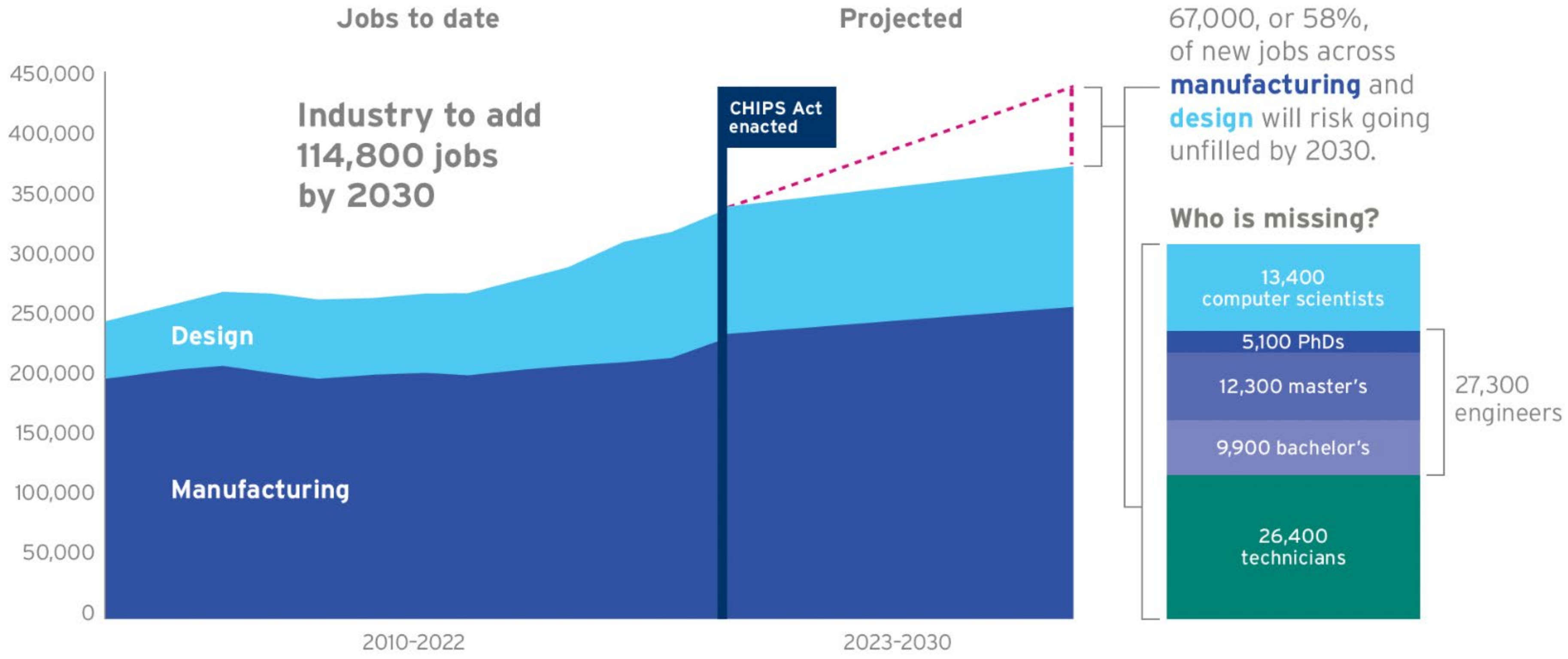
The global semiconductor talent shortage

How to solve semiconductor workforce challenges

By 2030, more than one million additional skilled workers will be needed to meet demand in the semiconductor industry. As the competition for talent gets tighter, how can companies address the semiconductor worker shortage? In this report, learn what's ahead for the semiconductor supply chain and three actions the industry can take to identify, recruit, and develop the necessary workforce.

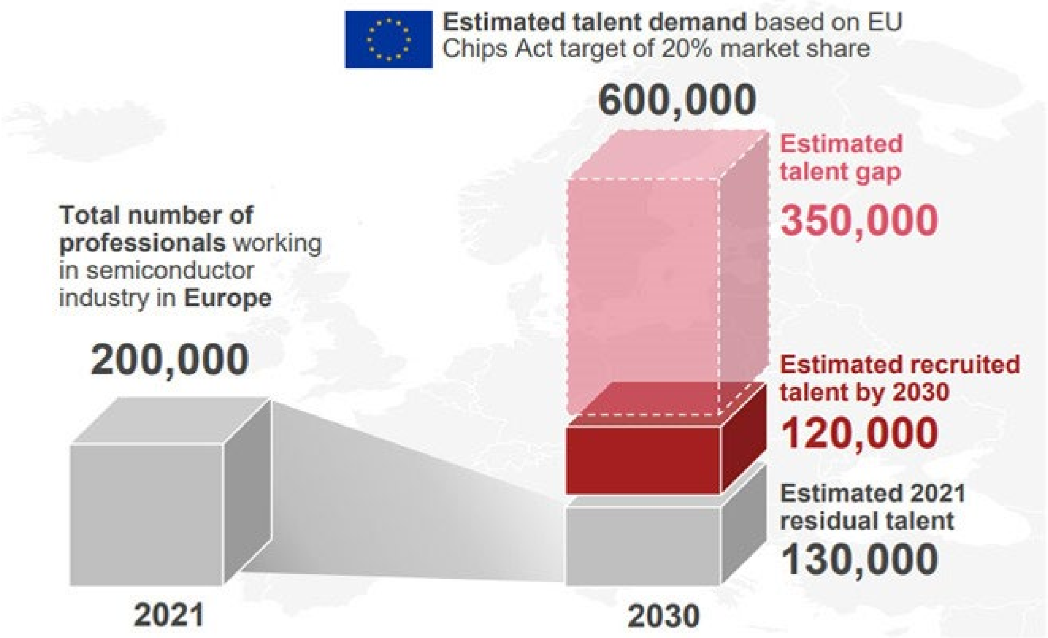
https://www2.deloitte.com/us/en/pages/technology/articles/global-semiconductor-talent-shortage.html

FIG. 1: Historical semiconductor workforce and projected 2023-2030 gap U.S. (study by SIA)



https://www.semiconductors.org/chipping-away-assessing-and-addressing-the-labor-market-gap-facing-the-u-s-semiconductor-industry/

Forecast: Estimated talent gap in Europe's semiconductor landscape in 2030 (indicative)



missing

Talent Gap in semiconductor market
Strategy&

nn Stiftung (2023); Destatis (2023) European Centre for the Development of Vocational Training (2023); PwC Global Workforce –
is (2023); European Chips Act (2022); Eurostat (2022); Strategy& analysis

https://www.elettronicaemercati.it/dove-trovera-leuropa-gli-ingegneri-che-serviranno-allindustria-dei-semiconduttori-entro-la-fine-di-questo-decennio/

Underestimating EE professional roles is reflected in the **total absence of the keywords ‘electronics’ and ‘semiconductors’** (either micro- or nano-) in the various analyses and reports on the **professions of the future***.

*“**The future of jobs report 2020**,” World Economic Forum, Oct. 20, 2020. https://www.weforum.org/reports/the-future-of-jobs-report-2020

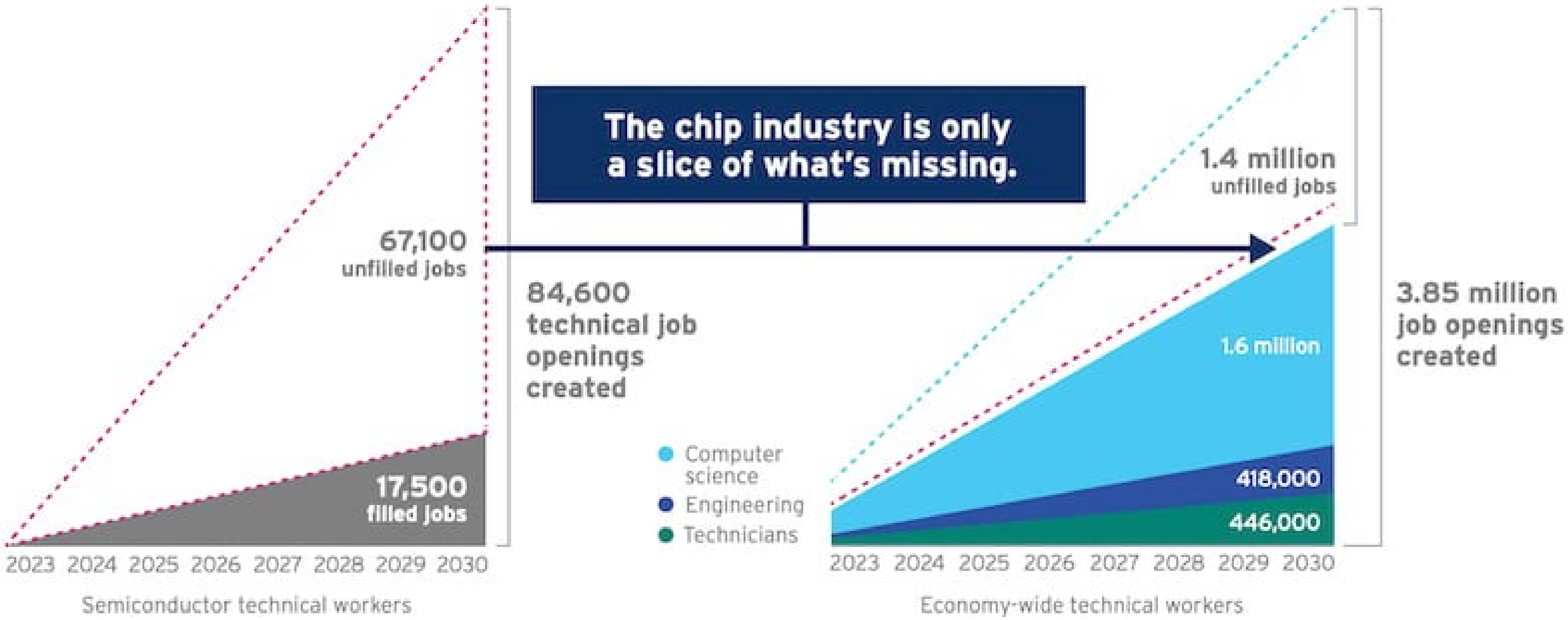
Something is changing but much still needs to be done!

word “electronics” occurrencies: 38

“semiconductors” occurrencies: 0

“digital” occurrencies: 314

https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf



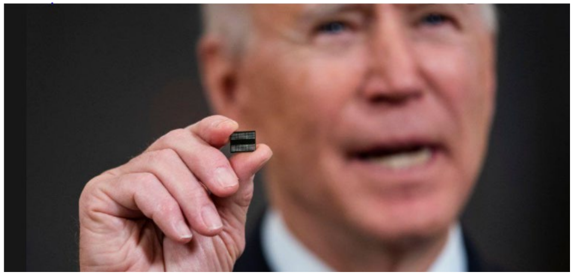
America Faces Significant Shortage of Tech Workers in Semiconductor Industry and Throughout U.S. Economy
Tuesday, Jul 25, 2023, by **Semiconductor Industry Association**

Semiconductor Skills Shortage May Escalate to 'Crisis' by 2030, August 14, 2023 by **Jake Hertz**

Talent shortage ca be counteracted only through structural policies with joint effort of Governments, Academy and Companies.

- Manufacturing
- Research
- Design
- **Workforce development**

U.S. and EU Chips Acts GOALS



Example of Partnerships Industry-Academic institutions

Arm and industry leaders launch Semiconductor Education Alliance to address the skills shortage

July 26, 2023

Gary Campbell, EVP Central Engineering, Arm

The semiconductor industry's global strategic importance is more widely understood than ever before, and this increased recognition is unlocking tens of billions of dollars of investment in all aspects of the semiconductor space: from design to fabrication and deployment. The opportunity for growth and innovation is clear – but the availability of the right skills in the workforce could be a significant barrier to progress. In my role leading the central engineering organization at Arm, this is a hot topic for myself and my peers and colleagues across the business – and we believe the answer lies in stronger cross-industry/academia collaboration.

Arduino, Cadence, STMicroelectronics, Synopsys, Semiconductor Research Corporation, Cornell University in New York, Taiwan Semiconductor Research Institute, the All-India Council for Technical Education, and the University of Southampton in the UK

Academies risk to be bypassed by private players

POLYMATH ANALOG

Polymath Analog   ASIC Development   Consulting   Workshops and Seminars

We currently offer workshops and seminars on the following topics:

- Design of Mixed-Signal Chips (basics)
- Design of Mixed-Signal Chips (advanced)
- Nanometer CMOS Analog Design
- Electrochemical impedance spectroscopy: theory - techniques - applications
- Fully integrated waveform generators
- Data converters: theory - design - state of the art
- Chip Design Management: Specification - Development - Planning
- Organic electronics: fundamentals, applications and future
- Implantable electronics: development and challenges
- Smart Implants: State of the art and emerging trends

Example of Summer Camp School NXP-UniCT (July 2023)

Lunedì 3 luglio

- 10:00 Accoglienza e check in presso 4SPA Resort Hotel****
- 11:30 Briefing e istruzioni
- 12:00 - 12:30 Trasferimento UNICT
- 12:30 Light Lunch
- 13:45 Inizio attività di formazione presso UNICT
- 17:00 Trasferimento presso Campus
- 18:30 Incontro motivazionale NXP "Inspire Your Future"
- 20:30 Cena conviviale
- 23:00 Rientro in stanza

Martedì 4 luglio

- 7:30 Sveglia
- 8:00 Colazione
- 9:00 Trasferimento presso UNICT
- 9:30 Inizio attività di formazione presso UNICT
- 13:00 Light Lunch
- 14:00 Ripresa attività di formazione presso UNICT
- 17:00 Trasferimento presso Campus
- 18:30 Incontro motivazionale NXP "Inspire Your Future"
- 20:30 Cena Conviviale
- 23:00 Rientro in stanza

Mercoledì 5 luglio

- 7:30 Sveglia
- 8:00 Colazione
- 9:00 Trasferimento presso UNICT
- 9:30 Inizio attività di formazione presso UNICT
- 13:00 Light Lunch
- 14:00 Ripresa attività di formazione presso UNICT
- 17:00 Trasferimento presso Campus
- 18:30 Incontro motivazionale NXP "Inspire Your Future"
- 20:30 Cena Conviviale
- 23:00 Rientro in stanza

Giovedì 6 luglio

- 7:30 Sveglia
- 8:00 Colazione
- 9:00 Trasferimento presso UNICT
- 9:30 Inizio attività di formazione presso UNICT
- 13:00 Light Lunch
- 14:00 Ripresa attività di formazione presso UNICT
- 17:00 Trasferimento presso Campus
- 18:30 Incontro motivazionale NXP "Inspire Your Future"
- 20:30 Cena Conviviale
- 23:00 Rientro in stanza

Venerdì 7 luglio

- 7:30 Sveglia
- 8:00 Colazione
- 9:00 Trasferimento presso UNICT
- 9:30 Inizio attività di formazione presso UNICT
- 13:00 Light Lunch
- 14:00 Ripresa attività di formazione presso UNICT
- 17:00 Trasferimento presso Campus
- 18:30 Incontro motivazionale NXP "Inspire Your Future"
- 20:30 Cena Conviviale con finale a sorpresa
- 23:00 Rientro in stanza

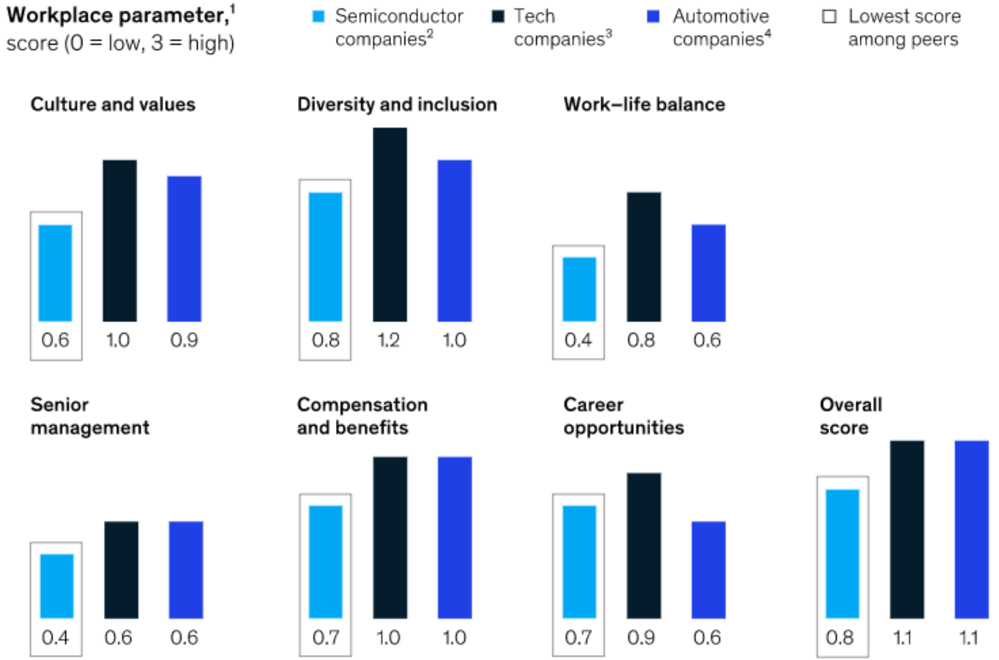
Sabato 8 luglio

- 7:30 Sveglia
- 8:00 Colazione
- 9:00 Check out: riconsegna ai genitori e trasferimento in privato presso UNICT
- 10:00 Cerimonia di chiusura presso Aula Magna del DIEEI UNICT
- 12:30 Fine delle attività

Talent shortage requires **industry players to change their hiring and staffing policies**.

Currently, salaries for **chip-related hardware research and design are low, compared to Internet companies. Better wages** are needed to make this profession more attractive, together with better **work-life balance**, **compensation benefits** and **career opportunities**.

Semiconductor companies rank lower than businesses in other sectors on dimensions of workplace attractiveness.



[1]Normalized score, showing difference to value of 3.
[2]Including integrated device manufacturers, fabless, and foundry.
[3]Customer-facing tech companies preferred by graduates in science, technology, engineering, and mathematics; in detail: Amazon, Apple, Google, IBM, Microsoft, Samsung.
[4]Main competing automotive companies preferred by graduates in science, technology, engineering, and mathematics; in detail: BMW Group, Ferrari, Ford Motor Company, Lamborghini, Tesla, Volkswagen.
Source: Glassdoor

McKinsey & Company

The **IC industry** now exhibits a structure with high barriers to entry, and **significant pricing power**.
Selling an IC for the price of a few cents, even if it comes from a depreciated fab, seems rather unbelievable, if we think of the expensive technology and the knowledge necessary to produce it.
Chip manufacturers should use value-based pricing, and avoid downward quotations if they want to increase revenues, draw investors, and offer better salaries.
This could happen more easily if they do not operate in a stagnant market, but instead move into emerging and more profitable ones. Working in new markets improves the company's reputation and attracts more customers and talent.

Semiconductor companies **may need to build their brand**. Typically, **semiconductor products receive less attention than end products, and prospective employees may have little knowledge of the many strong and innovative companies within the sector**.

https://www.mckinsey.com/industries/semiconductors/our-insights/strategies-to-lead-in-the-semiconductor-world

Effects of the war on **commodity prices** and **supply chain constraints**:
Ukraine is the world's largest supplier of **neon gas** (70% of global supply)—critical for lasers used in lithography—and of **xenon and krypton gas**, also critical for chip production.
Russia holds 40% of the market for **palladium**, 15% for **titanium**, 12% for **platinum**, and 10% for **copper**, all of which are important for printed circuit boards, and for sensors and plating processes in chip production. **Sanctions on Russia make the latter an uncertain source for such supplies**.

Instability in world energy markets, raising energy costs, and driving oil and gas prices to their highest levels. **Large fabs consume up to 100-MWh of energy per hour**.

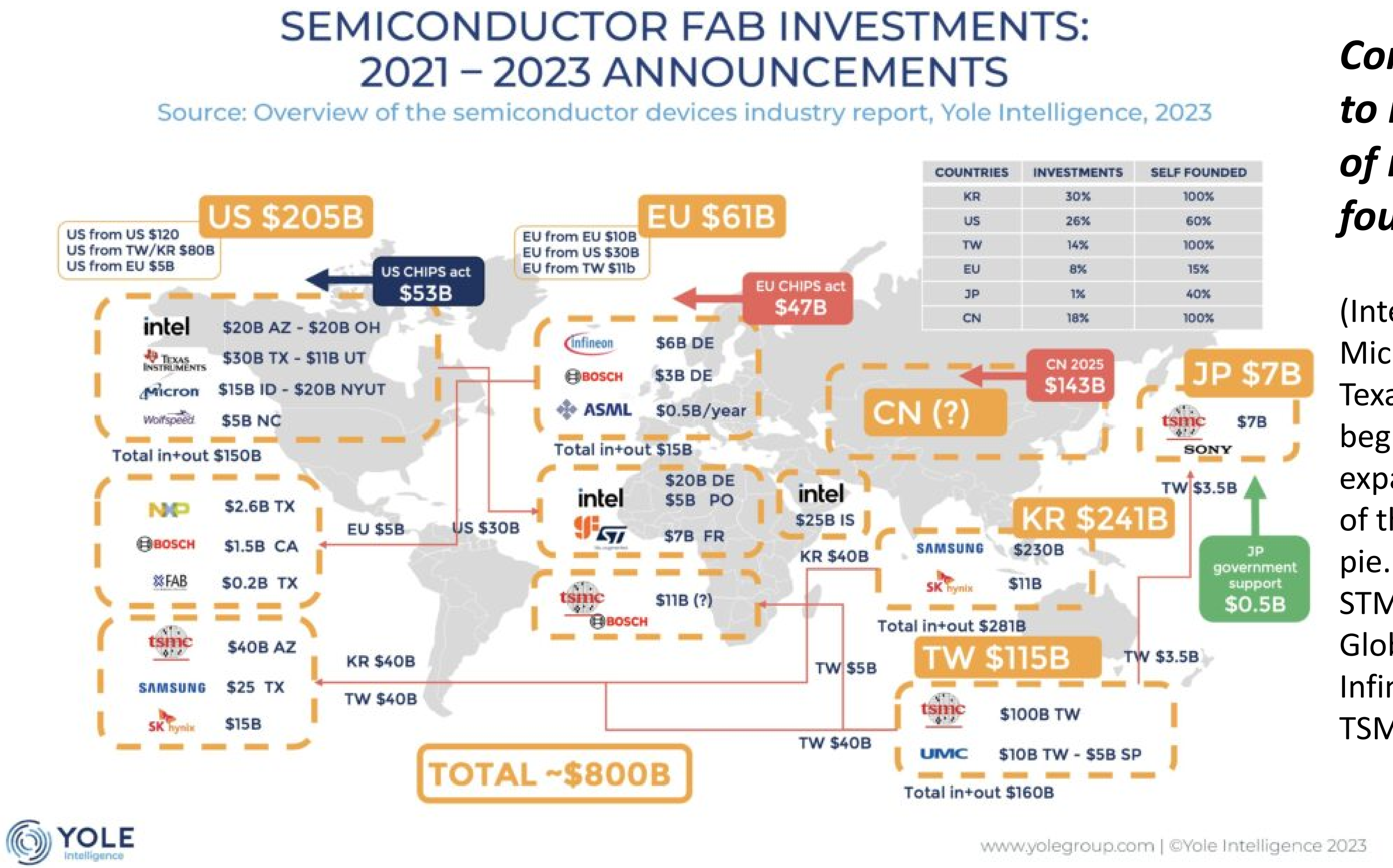
Rising energy and fuel costs, combined with rising inflation, taxes, and interest rates, are putting pressure on **consumers' disposable income**. We are already seeing weakness in semiconductor end markets, particularly those exposed to consumer spending.

The Ukraine Conflict has also further **highlighted that chips are strategic components**:
The country that has the best chips also owns the best defense and attack weapons.

The disruption of the supply chain is reversing the trend of recent years to relocate, even far away, in view of significant savings on labor costs.
Bringing the production of components closer (reshoring) is a new trend to shorten the supply chain.

In response to trade tensions, many Japanese, South Korean, and Taiwanese manufacturers plan to move some or all of their operations out of China. TSMC is building two fabs in the U.S. and one in Germany.

Reshoring *could* also happen for outsourced assembly and testing (**OSAT**) **services**, now in countries with cheap labor.
OSAT services will require less and less manpower (but highly specialized) in the new automated fabs.



Companies will need to invest about 20% of revenue into new foundries every year.

(Intel, TSMC, IBM, Samsung, Micron Technology, and Texas Instruments have also begun aggressive fab expansions to claim a share of the U.S. CHIPS Act funding pie. Similarly, STMicroelectronics + Globalfoundries, Infineon + TSMC+Bosch+NXP,...in EU)

https://www.yolegroup.com/strategy-insights/global-semiconductor-players-prepare-to-cash-in-the-chips-and-invest-to-secure-supply-atreg-yole-group/

CORRIERE DELLA SERA

Reindustrializzare l'Occidente è difficile: Taiwan ci spiega perché

Federico Rampini | 29 agosto 2023

Viaggio all'Itri, nel cuore della Silicon Valley taiwanese per capire la genesi dei "miracoli asiatici" (che non sono affatto miracoli). Gli ostacoli per il ritorno della produzione di micro-chip in America: costi elevati, burocrazia, tempi dilatati «e manca l'etica del lavoro»

Penuria di manodopera specializzata, agenda ambientalista

TSMC is postponing the inauguration of the first of its two new factories in Arizona by one year (from 2024 to 2025).

CORRIERE DELLA SERA

Taiwanese are even more skeptical about Europe

«You don't have a **truly unique market** and therefore **comparable in size to the American one**. Industrial **policies** are still **decided at the national level**, country by country. Taiwanese companies will try to meet the wishes of European customers, for example in the automotive industry. But each European country goes ahead on its own, in no particular order, and this means that you lack the dimensional economies offered by the Americans».

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Conclusions

- **Demand for integrated circuits is steadily rising**, in **both advanced and mature technology nodes**.
- A general **boost in chip production capacity is being prepared**, which requires a new kind of **strong commercial agreement between manufacturers and customers**, made possible by the **new power position of foundries** and the general consensus that chips are not commodities, but key and strategic elements.
- If new fabs are built by prior agreement with customers, then **labor should also be secured in advance**. New **workers and engineers are already in short supply**; not to mention that **other types of industries** are developing in-house chip design capabilities, and **will compete in the talent war**.
- Governments, companies, universities, and associations, must work jointly on actions such as **orientation and communication** for young people, **promotion of STEM studies for girls, grants to universities to create new degree programs, new positions and new laboratories, and study exchanges with foreign countries**.

Conclusions

- **Raising salaries, improving career opportunities, compensation, benefits and company branding** are also necessary actions to reverse the trend of young people interested in engineering who now massively prefer software to the lab.

- The **major unknown** that will affect the future of the IC industry concerns the **trade war between the U.S. and China** and, to a lesser extent, the **Ukrainian crisis**. Developments in these tensions are leading to **partial or even full supply chain decoupling from markets that are no longer global**, **causing major concerns for the profitability of foundries (especially those at the forefront) facing such severe constraints and market limitation**. The effects of the Ukrainian war are on commodity and energy prices, supply chain constraints, and overall uncertainty.

The future of the semiconductor ecosystem, however potentially disruptive it may continue to be, is closely tied to these critical issues, whose effects will need to be carefully considered. It will be necessary to comprehend the extent to which the costs of this commercial and technological decoupling can be absorbed and legitimized.

Thank you for your attention

chips

MDPI

Perspective

The Integrated Circuit Industry at a Crossroads: Threats and Opportunities

Salvatore Pennisi

*“Sometimes the **smallest thing** can bring an entire ecosystem to its knees.”*

Whether it's a microscopic virus or a common microchip,
we are learning the hard lessons of underestimating risk.

If we are to avoid a catastrophe in the future,
we should reconsider some of the fundamental systems and processes
that we have taken for granted.

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