RESONANCE
ASSET MANAGEMENT

The Semiconductor Industry
Sustainability Challenges and Opportunities

Summary

- **The global context**
    - Geopolitics and disruptive global events are reshaping the semiconductor industry. Governments recognise semiconductor supply chain security as a key component of international competition and national security.
    - The US is proactively pursuing domestic capacity expansion with a $260bn and the CHIPs and Science Act allocation of $54bn.[1]
    - The European Commission is also enacting its own €43bn European Chips Act to remain competitive.
- **Challenges of reshoring policies**
    - Nationalising a supply chain comes with sustainability challenges of sourcing water and energy - a key issue in new production geographies.
    - Reshoring is costly given relative costs of production are higher in the US and Europe than in Southeast Asia.
- **Securing reliable inputs**
    - Certainty of securing water and energy inputs is a top priority as downtime can reduce margins - downtime at some of TSMC's largest sites could cost up to $1.5m /hour.[2]
    - Ultrapure water is required for cleaning the wafers, cooling the systems, cooling, scrubbing and point-of-use abatement. Input resources must meet stringent quality standards.
- **A focus on sustainability**
    - Sustainability has gained prominence as companies set ambitious water and energy use targets, necessitating on-site infrastructure solutions.
    - Pressure to adapt sites to have lower environmental footprints comes from national legislation and local political pressure, the threat of physical climate risks, end users and supply chain transparency, and reputational factors.
- **Investing in co-located, sustainable infrastructure achieves effective resource management** – the following solutions present an opportunity to reduce the environmental footprint of production and improve the operational efficiency of semiconductor manufacturing:
    - **Water reuse and management**– onsite infrastructure reduces procurement costs, conserves water as a resource, achieves regulatory discharge compliance, and reduces local competition over water.
    - **Waste management and recycling** – sustainable practices generate less onsite waste and lower disposal fees; circular economy solutions reduce the need for further resource extraction.
    - **On-site renewable energy** reduces the carbon footprint of the site, improves energy cost stability, and demonstrates accountability and a visible commitment to green energy, enhancing the producer's reputation.
    - **Alternative, green fuels** – biofuels and hydrogen solutions have the potential to substitute polluting fossil fuels reducing the sites dependency on traditional sources of energy and accelerating the clean energy transition.

[1] Bartlett, et al. McKinsey & Company, Article, 27 January 2023

[2] J Choi, Business Korea, 25th July, 2023

One chip → 2,200 gallons of ultra-pure water (UPW) → 3,520 gallons of tap water → a day's worth of water for 25 average US households[3]

The Global Context

Global macroeconomic, geopolitical, and climate factors are shaping the semiconductor industry. A series of national self-sufficiency strategies have emerged due to the essential role of semiconductors in economic development and national security.

Since 2020, the industry has endured several unforeseen supply chain issues in an increasingly volatile political environment. The fallout of the COVID-19 pandemic saw end-users of advanced chips facing sustained shortages due to a sudden jump in demand for IT equipment. New political challenges developed over this same period with the Huawei scandal resulting in tense US-Sino relations and restrictive US export policies legislated in October 2022. Market capitalization for the top 10 global chip companies dropped by 34% in 2022, reflecting economic difficulties.[4]

However, 2023 witnessed industry growth, with strong performance expected in semiconductor stocks. Notable IPOs like British chip designer Arm and KKR's listing of Hitachi Kokusai indicate this positive trend.[5] Increased M&A activity and investment in the industry around the world signifies an uptick in activity outside the typical regions - a visible symptom of a decentralising industry.

A Disrupted Supply Chain

Global policymakers are pursuing three main supply chain strategies: **onshoring,** nationalising the value chain, **nearshoring,** working within close geographies, and **friendshoring,** working with geopolitical allies despite geography. Corporations favour these for reduced insurance costs, climate metrics transparency, quality assurance, faster response times and customisation potential. New regional clusters reduce dependence on politically fraught supply chain nodes.

However, shoring up supply chains poses challenges:

1. **Timing** – construction of large semiconductor fabs takes approximately 3 – 5 years.[6] Delays are common due to scale, equipment, and skilled labour shortages.
2. **Lack of experienced personnel** –the Southeast Asian semiconductor ecosystem was refined over decades in Taiwan, Korea, and China.[7] Bridging the talent gap in the US and Europe will require long-term investment in higher education facilities and specialised training schemes.
3. **Higher construction, production, and end-product costs** – Relocating value chain segments is costly. With manufacturing growing in complexity, full onshoring is extremely costly due to the increased relative cost of producing chips in Europe/US vs. Asia and the added cost of re-locating sections of the value chain.

A Global Pipeline of Projects

The US Onshoring Opportunity

The US is proactively diversifying all parts of the semiconductor supply chain away from the typical Asian-Pacific stronghold. The aim is to increase its domestic manufacturing share from 11% in 2020 to 30% by 2030 with a $260bn investment pipeline.[8] The main federal incentive is the CHIPS and Science Act which allocates $54bn to manufacturing capability development. State-level partnerships are also influencing incentives, with State officials and chip companies joining forces to influence the CHIPS and Science Act in Washington.

The three leading states for investment in chip fabrication plants are Arizona, Texas, and Ohio, closely followed by New York, Indiana, New Mexico, Utah, and Virginia.

US Project Developments

Private investment and state subsidies have flowed to specific geographic clusters.

Arizona – Arizona is leading in pipeline share due to Senator Kelly negotiating $13bn in R&D grants along with a four-year, 25% investment tax credit in the bill.[9] Key developments include a $60bn investment in two new fabs and TSMC's $40bn investment in a Phoenix site for six fabs.

Texas - Second in new fab investments, offers a low-tax environment and a $1.4bn Texas CHIPS Act allocation.[10] Investments include Samsung's $17bn fab near Austin and

[3] American Bar Association, 1st Feb 2023
[4] Deloitte, Outlook Report, May 2023
[5] Financial Times, 6th September, 2023
[6] Intel, What does it take to build a fab, 2022
[7] EE Times Europe, January 2023
[8] Bartlett, et al. McKinsey & Company, Article, 27 January 2023
[9] C. Kang, The New York Times, Feb 2023
[10] K. Tarasov, J. Pettitt, CNBC News, 20th July 2023

Texas Instruments' $30bn project. Industry players like Infineon, Global Wafers, NXP, X-FAB, Applied Materials, Apple, and Amazon have announced plans for expansion.[11]

Ohio – $700mn to infrastructure improvements and providing over $1bn in corporate tax breaks.[12] Intel will invest $20bn in two Columbus sites. An additional $100mn supports higher education and research programs.[13]

New York - Offers $10bn in incentives for sustainable "Green CHIPS" projects, backed by advanced R&D facilities, available sites, and a highly skilled workforce.[14]

The European Opportunity

In 2022, the European Commission introduced a €43bn European Chips Act to boost digital sovereignty. Europe has key players like Arm, ASML, and Carl Zeiss SMT in its value chain.[15] While it encourages mid-market players and hopes to create open foundries for smaller designers, the EU aims to enhance advanced chip production, targeting a market share increase from 10% to 20% by 2030 to rival the US and Southeast Asia.

Limiting factors include manufacturing scale, skilled labour, and higher relative costs of production of up to 40 – 50% due to labour and environmental compliance costs.[16]

Producing advanced microchips <7nm requires twice as much water and three times the electricity of 28nm chips for automotive and less advanced applications.[17] Building out advanced manufacturing has potential trade-offs for public spending efficiency and may conflict with Europe's green agenda.[18]

European Project Developments

Out of the 81 new chip facilities planned to be built between 2021 – 2025, 10 of them are in Europe.[19] Key regions include:

Germany - Silicon Saxony and Intel are investing €33bn in Magdeburg site (largest FDI to date) coming online in 2027.[20] Infineon invests €5bn in Dresden, while Global Foundries commits €1bn in the same area. Bosch is planning a €250mn site extension.

France - A GlobalFoundries-STMicro consortium plant to invest €5.7bn in the French Alps, making France Intel's R&D HQ. · France has made €355mn available in state-level funding for research and innovation.[21]

Sustainability Challenges and Opportunities

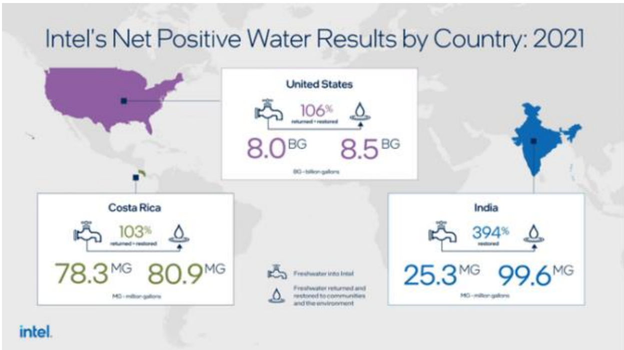
Several drivers have required the semiconductor industry to place more emphasis on sustainability.

Political – Overallocation of local resources can pose a political problem. For example, water in Arizona is carefully managed with 80% of the state population being covered by the 1980 Arizona Water Management Act which guarantees municipal water supplied for 100 years. The state has had to restrict building homes around Phoenix to avoid breaching this allocation. Without the appropriate infrastructure, construction of large semiconductor projects will increase local competition over water resources.

Environmental – Many semiconductor manufacturers are need to achieve environmental resilience to climate events and uphold climate-focused legislation by reducing GHG emissions and improving resource efficiency.

The largest companies have set ambitious internal sustainability targets for water and energy use.

- **Water** - TSMC achieved an 86.7% water recycling rate in 2019. They aim to cut water usage by 30% by 2030 and give back water to local communities. Intel has achieved net positive water through reclamation and desalination. However, as production increases, their water footprint will grow putting pressure on sustainability commitments.[22]



(Fig. 1 Intel Water Strategy, Intel Press Release)

- **Energy** - Large semiconductor fabs operate 24/7, consuming up to 100 MWh of power surpassing many automotive plants and refineries.[23] Off-grid power comes from fossil fuel power plants with renewable sources seen as complementary to this. However, many industry players such as Intel, STMicroelectronics, NXP, and UMC, have committed to science-based climate targets. Greening energy

[11] Katie Tarasov, CNBC Tech, 20th July 2020
[12] G. Bervejillo PhD, Policy Matters Ohio, 5th January 2023
[13] Intel Press, 21 January 2021
[14] Empire State Development, ny,gov, 2022
[15] L Li, Financial Times, December 2022
[16] SEMI, Semiconductor Industry Association 2023
[17] L Bertuzzi, Euractiv, February 2022
[18] L Bertuzzi, Euractiv, February 2022
[19] SEMI, US Semiconductor Research Platform, 2022
[20] Politico.EU European Union Inc Report, Oct 2022
[21] Intel, European Report, March 2022
[22] Intel, Press Release, July 2022
[23] S. Chen, A. Gautam, F Weig, McKinsey & Company, 2022

inputs for production has become a more urgent matter to achieve these internal targets.

Intel recently committed to net zero by 2040 and targeted 100% use of renewable electricity as an interim milestone in 2030[24]

- **Resource Recovery** - There is an opportunity to recover heavy metals and inorganic compounds from semiconductor wastewater.[25] The need for these solutions is more pressing in resource-scarce regions like the EU, where rare earth metal access is a supply chain risk. Circular economy projects are vital, with EU Horizon-funded pilot projects focusing on sustainable heavy metal recovery.

Reputational - End customers are focused on reducing emissions in their supply chain.[26] Big tech buyers of chips like Apple, Microsoft, and Google, are cutting supply chain emissions due to internal targets and pressure from their climate-conscious customer base.

Investing in Sustainable Water

Water resources must be secured by the sites and quality guaranteed, via reliable infrastructure solutions. Outsourced financing and operations benefit industrial producers as they can focus capital expenditure on core business activity and secure more efficient and sustainable master inputs from experienced operators.

Ultrapure Water Assets – UPW Assets are core plant infrastructure, vital for cleaning semiconductor wafers in manufacturing. Contaminated water risks damaging chips; hence, supply must be constant and reliable.

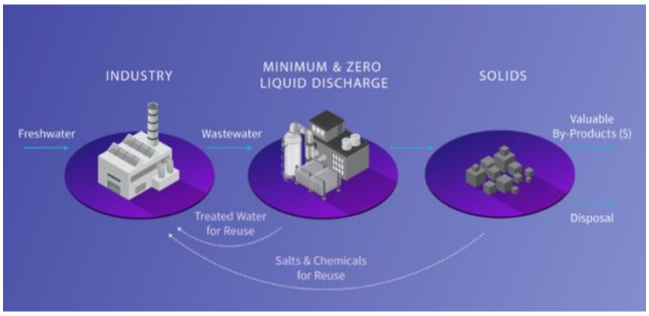
It takes 1.4 – 1.6 gallons of municipal water to make 1 gallon of UPW

While UPW Assets historically weren't often outsourced, increasing sustainability and efficiency concerns may offer opportunities to upgrade technology by integrating circular UPW solutions with improved recycling and resource recovery methods.

Water Reuse - Environmental regulations, water allocation, and climate awareness drive water efficiency improvements in semiconductor fabs. Gradiant reports a 43% average recycling rate in 2022, while new fabs are targetting near-zero discharge or over 90% recycling.[27]

Semiconductor firms are keen to invest in water reuse solutions. For example, Intel's Ocotillo campus houses a large water reuse site that recycles 90% of water, serving planned fabs without altering Chandler's local water plan.

This presents investment potential for enhancing existing fabs and integrating sustainable assets at new facilities.[28] .



(Fig. 2 Gradiant, Minimum and Zero Liquid Discharge Solution with Resource Recycling)

Resource Recovery – Semiconductor sludge contains valuable chemical compounds with potential industrial applications.

Studies indicate semiconductor sludge can replace cement in mortar, mitigating chemical disposal hazards and benefiting the construction industry.[29]

Emew Clean Technologies' copper recovery from sludge, at 30 tonnes annually, generated $190,000 in copper revenue. The use of hydrogen peroxides reduced disposal costs by $2mn annually, creating a circular solution for water sourcing, precious metal recovery, and lower operation costs.[30]

Investing in Sustainable Energy

Two main issues arise with regard to onsite use of energy – reliability of supply and the environmental footprint.

Large fabs run 24/7, needing substantial margins to cover the initial investment. TSMC's $40bn site produces around 50,000 wafers daily, costing roughly $20,000 per advanced 3nm wafer. An hour of downtime equals approximately $1.5m in lost wafer sales, not counting maintenance and recovery costs.[31]

[24] McKinsey & Company, Article, 17th May 2022
[25] Bayon et al, Journal of Cleaner Production, Nov 2019dd
[26] McKinsey & Company, Article, 17th May 2022
[27] Gradient, website, accessed 2023
[28] James Teeple, Business Journalism, 17th May 2022
[29] Qudoos, A.; Jeon, I.K.; Kim, S.S.; Lee, J.B.; Kim, H.G., Utilization of Waste Polysilicon Sludge in Concrete, Materials 2020
[30] Emew Clean Technologies, S Wollschlaeger, 2018
[31] J Choi, Business Korea, 25th July, 2023

An hour of downtime at a large semiconductor fab can cost the firm approx. $1.5m in wafer sales

Semiconductors are crucial to renewable energy infrastructure like wind and solar PV. However, the chip industry's carbon footprint and its sudden ramp-up in scale, threaten overall progress towards net zero targets. To reduce their impact, producers can take several approaches:

Procuring renewable energy - Industry leaders have joined RE100, opting for renewable energy power purchase agreements (PPAs) and on-site renewable assets.[32]

Green fuels - Biofuels and green hydrogen can substitute fossil fuels for production. Linde, a renewable energy provider, contracted with Infineon to supply green hydrogen to its Villach site in Austria. Linde operates an air separation unit to ensure a steady gas supply, showcasing a path to net-zero fabs.[33]

Onsite solar / wind - Renewables suffer from intermittency, but combined with onsite battery storage, semiconductor sites can deploy dispatchable renewable energy.

Reduction of GHG in production processes - New plants can alter their operations to reduce emissions. Scope 1 and Scope 2 emissions can be curbed via gas recycling and abatement methods, involving capturing, and refining unused gases and detoxifying by-product gases. This might necessitate additional industrial infrastructure or process adjustments.

Conclusion

Securing advanced semiconductors has become a national security issue in an age where tech is indispensable to economic growth and innovation. Governments have had to reassess their supply chains considering recent global events. As of 2023, the sector faces more geopolitical turbulence and trade restrictions, a volatile environment for market capitalisation of top chip companies, rising costs of production, a lack of experienced personnel in new geographies, and continued supply chain bottlenecks due to international conflicts and export regulations. Policymakers and corporations are committing to onshoring and friendshoring to bolster industry resilience.

The current US administration is diversifying the semiconductor supply chain away from the traditional Asian-Pacific stronghold. Europe has also devised a strategy to remain competitive and reduce reliance on Asian imports. Private and public investments to expand domestic semiconductor production are taking shape. Sustainability is gaining prominence in the industry, with a focus on enhancing water and energy efficiency, and resource recovery.

There is an opportunity for investing in sustainable assets onsite to improve water reuse and management, lower waste disposal fees and potentially recover precious metals. Water solutions operators are developing increasingly efficient methods for recycling and reuse onsite to reduce discharge metrics and replenish local basins. On-site renewable energy solutions present themselves as an opportunity to reduce the carbon footprint of an energy-intensive industry. Green fuels, biogas and green hydrogen have the potential to substitute traditional fossil fuel-based energy resources.

Overall, the industry is growing quickly in tandem with mounting sustainability concerns. Given that semiconductors are indispensable for the clean energy transition and digital economy, market growth will accelerate, and producers must find sustainability solutions to remain competitive in a resource-intensive industry.

Get In Touch

Daniel Vizard-Williams, Investment Analyst
dwilliams@resonance.fund

Ekaterina Barker-Privalova, Investment Analyst
ebarker-privalova@resonance.fund

Disclaimer

[32] MRL, 22nd May 2023

[33] Linde Website, 2022