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Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda

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Towards a Green Semiconductor Industry in Malaysia

Malaysia has demonstrated a strong commitment to addressing climate change through its alignment with global initiatives such as the Paris Agreement and its Intended Nationally Determined Contributions (INDCs). Central to achieving its climate goals is the transformation of its industrial sectors, particularly the semiconductor industry, which plays a vital role in the national economy but poses significant environmental challenges. This exploratory study investigates the environmental impact of Malaysia's semiconductor sector, analyzing greenhouse gas (GHG) emissions, resource consumption, and the sustainability efforts of both multinational and local companies. While foreign semiconductor firms have made strides in environmental, social, and governance (ESG) practices, the environmental performance of local firms remains underexplored due to limited data and research. The study emphasizes the need for comprehensive assessments, enhanced policy frameworks, and better data collection to ensure the semiconductor industry's growth aligns with Malaysia's broader climate objectives.

Contents

KEYWORDS: Semiconductor, Green transition, Decarbonisation, Malaysia

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Introduction

Malaysia, as a nation, has made significant commitments to combat climate change, aligning itself with global efforts to mitigate its adverse effects. Foremost among these commitments is its participation in the Paris Agreement, a landmark accord aimed at limiting global warming to well below 2 degrees Celsius above pre-industrial levels. Malaysia has pledged to reduce its greenhouse gas emissions intensity relative to GDP by 45% by 2030, compared to 2005 levels[1], demonstrating a clear commitment to decarbonize its economy and contribute to the global effort to address climate change. In addition to its commitments under the Paris Agreement, Malaysia has submitted its Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. This requires the country to reduce emissions intensity, increase the share of renewable energy in its energy mix, enhance energy efficiency, and implement measures to combat deforestation and forest degradation.

To achieve its climate change commitments, Malaysia has implemented various policies and initiatives at the national level. The establishment of a National Climate Change Policy serves as a guiding framework for mainstreaming climate change considerations into national development planning. Malaysia has set ambitious targets to increase the share of renewable energy in its energy mix, aiming to achieve 20% renewable energy in its electricity generation mix by 2025 under its Renewable Energy Act 2011. The New Industrial Masterplan 2030 (NIMP 2030), launched in 2023, further solidified the country's aspirations to transition towards a net-zero economy. Central to achieving net zero emissions is the semiconductor industry. Being one of the country's largest industries, Malaysia holds a 13% share of the global market in packaging, assembly, and testing services for semiconductors, positioning it as the sixth-largest semiconductor exporter worldwide. This industry is a substantial contributor to the country's economic growth, accounting for approximately 25% of Malaysia's GDP[2], and employs approximately 590,000 Malaysians (MSIA, 2023). It is also the country's largest export, totaling RM387 billion in export value or 21% of Malaysia's total exports in 2022.

The electronics industry (which includes semiconductors) has a significant carbon footprint, and contributed to approximately 1.8 to 2.8% of total global emissions in 2020 (Freitag *et. al*. 2021). Although semiconductors have played a crucial role in advancing technologies aimed at reducing greenhouse gas emissions, like electric vehicles (EVs), solar panels, and smart grid technologies, the growing popularity of these technologies has also spurred a significant rise in demand for semiconductors and their production. The semiconductor sector is highly resource-intensive, requiring significant amounts of water for processes like wafer manufacturing, as well as substantial electricity consumption. Additionally, it relies on rare minerals such as tantalum, gallium, and germanium. The production of semiconductors also generates a considerable amount of waste. This means that the reduction in greenhouse gas (GHG) emissions resulting from the use of such technologies may be offset by the increased emissions generated from additional demands placed on the semiconductor industry. More so if the environmental impact of semiconductor manufacturing is not addressed.

The NIMP stated that in 2019, the Industrial Processes and Product Use (IPPU) sector (which includes semiconductors) was the second-largest emitting sector in Malaysia, contributing approximately 10 percent of the country's overall emissions. Industrial energy consumption alone accounted for an additional 10 percent of the total emissions (NIMP, 2023). Despite the significance of the semiconductor sector to the country, there is a scarcity of studies investigating

[1] https://climatepromise.undp.org/what-we-do/where-we-work/malaysia

[2] https://www.aseanbriefing.com/news/malaysias-semiconductor-sector-beckons-foreign-investors/

the environmental impact of this industry in Malaysia. This could be attributed to the intricate nature of semiconductor value chains, coupled with the prevailing focus on other growth priorities such as talent development, supply chain reorientation, and market resilience, which have overshadowed environmental concerns within the sector (MSIA, 2023)[3].

Nevertheless, foreign semiconductor multinational corporations (MNCs) in Malaysia have responded decisively to the growing expectation for an integrated approach to environmental, social, and governance (ESG) considerations across their value chains. They have been implementing measures to minimize their environmental footprint, uphold labor standards, and ensure ethical business conduct throughout their raw material sourcing, manufacturing processes, and distribution networks. In 2021*, Advanced Micro Devices* (AMD) achieved a 25% absolute reduction in greenhouse gas (GHG) emissions from its operations (Scope 1 and 2) compared to the base year of 2020, with a continued commitment to achieving a further 50% reduction by 2030 (AMD, Corporate Responsibility Report 2021-22). Semiconductor giant *Intel Corporation* in 2022 has pledged to reduce greenhouse gas emissions in its operations and across its value chain, focusing on achieving 100% renewable electricity, net-positive water, and zero waste to landfill by 2030 (Intel, Corporate Responsibility Report 2022-23). The same year *Infineon Technologies* expanded its manufacturing capacities in the field of wide bandgap semiconductors which enable the development of more efficient power electronic devices for applications in renewable energy systems and electric vehicles[4]. *Texas Instruments* improved its per-chip production efficiency to reduce 45% of energy, 32% of water consumption, and 62% of greenhouse gas emissions (GHGs) since 2010 (Texas Instruments, Corporate Responsibility Report 2022).

This is expected because the large (foreign) multinational semiconductor corporations operating in Malaysia are increasingly projected to align with global standards of corporate responsibility. However, the stance of local companies in Malaysia remains uncertain due to the absence of comprehensive studies on the semiconductor industry at a macro level. There are no official databases collecting information on the environmental impact of semiconductor companies, nor is there any trend analysis being conducted on whether Malaysian local semiconductor companies adhere to the same environmental concerns. Information is sourced from company annual reports, which often include sustainability statements mandated for listed corporations by *Bursa Malaysia Berhad* - the stock exchange of Malaysia, as part of its Sustainability Reporting Framework. This study explores the environmental impact of the semiconductor sector in Malaysia. It is an exploratory study that examines the connection between local semiconductor companies in Malaysia and their environmental priorities, as well as the methods they employ to promote environmental sustainability within the semiconductor industry.

Section 2 explores the significance of the semiconductor industry in Malaysia. Section 3 outlines the environmental impact, focusing on greenhouse gas (GHG) emissions and the policies aimed at mitigation. Section 4 analyses the practices and trends of semiconductor companies in Malaysia towards achieving sustainability. Section 5 presents the conclusions drawn from the study.

[3] In 2022, the Malaysia Semiconductors Industry Association (MSIA) conducted a survey of its 93 members, revealing that only 2% identified ESG as their primary focus area. However, by 2023, this figure had increased to 6%, indicating a marginal but growing emphasis on ESG considerations within the industry.
[4] https://www.infineon.com/cms/en/about-infineon/press/press-releases/2022/INFXX202202-053.html

Section 2: Malaysia's Semiconductor Sector

Back in the 1970s, Malaysia's semiconductor journey was motivated by the government's aim to industrialize its economy and attract foreign investments. While it is impossible to examine all available policies, this section will attempt to highlight some of the efforts made by the government to develop the E&E industry.

Policies and Initiatives Supporting Malaysia's E&E Industries.
Malaysian E&E development can be divided into two phases. The first phase in the 1970s and 1980s focused on attracting FDIs for labor-intensive assembly activities. As labor costs rose and foreign competition increased, the second phase involved policies promoting a shift to higher value-added activities.

Phase 1 (1970s and 1980s): *Push for FDIs*
In the 1970s, Malaysia intensified its push for FDIs with the Free Trade Zone (FTZ) Act of 1971 and the establishment of Export Processing Zones (EPZs) in 1972. These zones offered duty-free imports of raw materials and capital equipment, comprehensive infrastructure, and tax incentives. This attracted many MNCs, particularly US semiconductor firms, to the electronics industry within these zones. By 1990, MNCs in EPZs contributed 85% of total EPZ exports and 76% of EPZ employment (Cho, 1990). This strategy was a key step in attracting and retaining FDIs in Malaysia.

During the First Industrial Master Plan (IMP) in the late 1980s, the Reinvestment Allowance (RA) became a key incentive for the E&E industry. It provided a 60% tax allowance on capital expenditures for machine and plant upgrades and product diversification. This was crucial due to the short product cycles and rapid technological advancements in the electronics industry. Additionally, tax deductions were offered for investments in human resource training, product development, testing, and factory auditing. To support local firms in the production network, various linkage programs were introduced.

Recognizing the risks of relying on labor-intensive manufacturing, the Malaysian government founded the Malaysian Institute of Microelectronic Systems (MIMOS) in 1985 to focus on R&D, particularly in IC design and CAD for local E&E firms. The Fifth Malaysian Plan (1986–1990) allocated RM414 million specifically for R&D. In 1990, the Action Plan for Industrial Technology Development (APITD) was introduced to stimulate industrial research and technology upgrades. ew government agencies like Malaysian Industry-Government Group for High Technology (MIGHT) and Malaysian Technology Development Corporation (MTDC) to foster collaboration between government and business.

The 1985 global recession and domestic economic contraction shifted Malaysian investment strategies. The 1986 Promotion of Investments Act relaxed foreign equity guidelines, allowing up to 100% foreign ownership based on export targets. Special incentives were introduced for small and medium-sized industries with linkage-creation potential. Efforts to attract FDIs continued, complemented by industry upgrades. This led to many Japanese intermediate-input E&E firms setting up bases in Malaysia in the mid-1980s.

Phase 2 (1990 and beyond): *Push for Upgrading*
The Second IMP (IMP2, 1996-2006) focused on production fragmentation, value chain development, and supply chain deepening. It introduced "Manufacturing ++" to elevate activities from basic assembly to R&D and product development, and promoted a "cluster-based approach" for local value addition. The launch of APITD marked a shift to R&D-based industrialization,

supported by funds like Industrial Technical Assistance Fund (ITAF) and Intensification of Research in Priority Areas (IRPA). Technology parks were established for upgrading knowledge-based industries, housing major E&E players such as Intel and Hitachi. The government also privatized MIMOS and MTDC to support high-tech start-ups, establishing Malaysia as a key player in the regional E&E industry.

This led to The Third IMP (IMP3, 2006-2020), which focused on enhancing global competitiveness with trade and investment targets for various manufacturing sectors. It outlined 10 strategic thrusts aimed at making Malaysia a developed nation by 2020, including deepening the E&E value chain and integrating domestic E&E companies into global supply chains. This emphasis on global economic integration continued in the New Industrial Masterplan (NIMP 2023-2030). The plan outlines two key missions: Advance Economic Complexity and Tech Up for a Digitally Vibrant Nation. The first mission aims to expand into high value-added activities within the value chain, strengthen the R&D, commercialization, and innovation ecosystem, and boost manufacturing exports. The second mission focuses on accelerating technology adoption and driving digital transformation to ensure a vibrant, tech-driven economy.

The NIMP 2030 also features a chapter on advancing towards Net Zero - a goal of fully offsetting the greenhouse gases generated by human activities, to be accomplished by cutting emissions and employing techniques to absorb carbon dioxide from the atmosphere., underscoring the government's commitment to balancing industrialization with sustainability. The Net Zero component of NIMP 2030 drives industrial upgrading by fostering technological advancements, promoting sustainability, attracting investment, enhancing competitiveness, stimulating innovation, improving efficiency, and ensuring regulatory compliance. This approach supports the modernization and sustainable growth of Malaysia's industrialization.

Box 1: Building Malaysia's Comparative Advantage in Semiconductor

In summary, Malaysia's comparative advantage in the E&E sector was built through strategic government policies, an open trade regime, proactive FDI attraction, continuous industrial planning, and a focus on transitioning to higher value-added activities.

Government Policies and Infrastructure: The Malaysian government played a crucial role in fostering the E&E industry by implementing the Free Trade Zone (FTZ) Act of 1971 and establishing Export Processing Zones (EPZs) in 1972. These initiatives offered duty-free imports of raw materials and capital equipment, creating an attractive environment for multinational corporations (MNCs). The government's efforts included providing financial incentives such as tax holidays, tax credits, and simplifying investment approvals, which significantly reduced operational costs for foreign firms.

Foreign Direct Investments: The establishment of EPZs and favorable policies attracted numerous MNCs to Malaysia, particularly in the electronics sector. Companies like Intel, AMD, HP, Hitachi, and National Semiconductor established operations in Malaysia during the 1970s, marking a significant influx of FDI. These firms contributed substantially to the country's exports and employment, with the electronics industry becoming a major component of Malaysia's manufacturing sector. An open trade regime, extensive involvement in trade agreements, and a relatively open labor market supported the growth of the sector.

Industrial Master Plans: The government's commitment to the E&E industry was further demonstrated through a series of Industrial Master Plans (IMPs). The first Industrial Master Plan (IMP1: 1986-1995) recognized the potential of the E&E industry for economic growth and job creation. The second plan (IMP2: 1995-2005) emphasized fostering linkages between local firms and MNCs, while the third plan (IMP3: 2005-2020) focused on higher value-added activities like research and development (R&D), design, and engineering. The most recent New Industrial Masterplan (NIMP: 2023-2030) aims to increase the complexity and scope of products produced and exported while enhances industry readiness towards ESG compliance, thus reflecting a holistic effort to integrate environmental goals with economic development.

Transition to High-Value Activities: Initially, the E&E industry focused on assembly and testing operations. However, over time, there was a gradual transition to more sophisticated activities, including R&D and engineering. Efforts to stimulate functional upgrading began in earnest in the 1990s, with initiatives like the Action Plan for Technology Development (APITD) in 1991 and the establishment of local firms specializing in testing, assembly, and packaging. The government extended grants to both local and foreign firms to support high-value-added operations such as chip design and wafer fabrication. The most recent 2023 New Industrial Masterplan (NIMP – 2023 to 2030), condenses all the efforts from previous IMPs and raises the sector's value-added by broadening the scope (or increasing the complexities) of products being produced and exported.

The Semiconductor Value Chain of Malaysia

Globally, semiconductor firms fall into four categories: integrated device manufacturers (IDMs), fabless design companies, foundries, and outsourced semiconductor assembly and test companies (OSATs). In Malaysia, domestic semiconductor and semiconductor-related businesses, particularly those publicly listed, predominantly engage in the mid to lower segments of the value chain, catering to foreign semiconductor manufacturers, brand proprietors, integrated circuit (IC) developers, and fabricators. These entities can be categorized into three main groups: OSATs, manufacturers of automated test equipment (ATE), and providers of test interface solutions. It is also important to note that neither individual companies nor entire nations typically achieve full vertical integration across all value chain layers. Table 1 shows the structure and examples of semiconductor companies within the value chains.

Starting with the design phase, Integrated circuits (ICs) are developed by integrating intricate electronic components onto a single semiconductor substrate and connecting them through electrical networks. These ICs, commonly referred to as chips, are precisely crafted on flat wafers made of pure semiconductor material, typically silicon, in a process known as wafer fabrication. After fabrication, the chips undergo packaging, a critical step where they are shaped and encapsulated to meet specific design requirements. Wafers are then sliced into individual chips, with the functional ones bonded onto printed circuit boards.

To ensure the reliability and functionality of these packaged semiconductor devices, thorough testing procedures are conducted. These procedures include vision inspection, electrical functional tests, and burn-in tests, aimed at identifying defects and ensuring quality. Semiconductor automated test equipment (ATE) plays a pivotal role in this process. ATE systems are meticulously designed to streamline testing processes, reducing test time and minimizing the likelihood of defective devices reaching end-users. Notably, ATE is indispensable not only for back-end semiconductor testing but also for front-end wafer testing, ensuring comprehensive quality control throughout the manufacturing process. Finally, the process concludes with the production of final consumer products. Electronics manufacturing service (EMS) providers, predominantly contract manufacturers, oversee this stage, assembling various components to create finished electronic products ready for the market.

Table 1 shows that Malaysian publicly listed semiconductor companies primarily operate within the mid- to lower-end segments of the value chain. Most companies produce products or components that are less complex, have lower performance specifications, and are generally more affordable. This includes basic integrated circuits (ICs), simple microcontrollers, memory chips with lower capacities, and other semiconductor devices that serve relatively straightforward functions. The focus is on catering to foreign semiconductor manufacturers, brand owners, integrated circuit (IC) developers, and fabricators. There are only a few players in the front-end. Nevertheless, there are also some high-end players which produce advanced microprocessors, high-speed memory chips, specialized sensors, and other semiconductor devices designed for demanding applications such as artificial intelligence, cloud computing, automotive safety systems, and high-performance computing.

Table 1: Global and Malaysian Semiconductor Value Chain Structure.

		Design		**Manufacturing**		
GLOBAL	Integrated Device Manufacturers (IDM)			**Front end Wafer Fabrication**		**Back-end assembly and testing**
		Intel, Infineon	Samsung, Renesas	Micron, Analog Devices		Texas Instruments, SK Hynix
		Design				
	Fabless Design	Qualcomm	Broadcom	Nvidia	AMD	MediaTek
	Foundries	**Manufacturing (front-end wafer fabrication only)**				
		TSMC	Samsung	UMC	SMIC	GlobalFoundries
MALAYSIA	**Core Value Chain**					
	High Complexity			**Low Complexity**		
	Integrated circuit conceptualization and design • Oppstar Technology • Infinecs Systems • Symmid Corp • Key Asic	**Front-end wafer fabrication** • SilTerra Malaysia (Dagang NeXchange) • Infineon Technologies • X-Fab	**Back-end OSAT and volume packaging** • Inari Amerton • Malaysia Pacific Industries • Unisem • Globtronics Technology • SPF Technology • Industronic Bhd	**Burn-in** • KESM Industries		
	Sub-value chain (Supporting activities)					
		Precision cleaning and surface treatment • Frontken	**Test interface solutions** • JF Technology • FoundPac • UWC Berhad • TT Vision	**ATE and equipment** • Vitrox • Greatech Technology • Pentamaster • Mi Technovation • QES Group • Aemulus • Elsoft Research • MMS Ventures • VisDynamics • D&O Green • JHM • SiP Technology		

Source: Adapted from The Edge, March 7, 2022, with additional companies and Annual reports. https://www.mida.gov.my/mida-news/where-are-malaysian-players-in-the-semiconductor-value-chain/

Notes:

IDM: Integrated Device Manufacturers - Semiconductor companies that design, manufacture, and sell their semiconductor chips. They handle all aspects of the semiconductor production process, from designing the chips to fabricating them in their manufacturing facilities (fabs), as well as handling assembly and testing.

Fabless Design: Fabless design firms are semiconductor companies that focus solely on designing semiconductor chips without owning or operating semiconductor fabrication facilities (fabs). Instead, they outsource the manufacturing of their chip designs to third-party foundries.

Foundries: Foundries, also known as semiconductor fabrication facilities, are specialized manufacturing plants that produce semiconductor chips based on designs provided by fabless design companies or IDMs. Foundries offer semiconductor manufacturing services on a contract basis, allowing fabless design companies to bring their chip designs to market without the need for significant capital investment in manufacturing facilities.

Front-end wafer fabrication refers to the initial stages of semiconductor manufacturing, where the actual semiconductor devices are created on silicon wafers.

Back-end assembly and testing refer to the final stages of semiconductor manufacturing, where semiconductor devices, which have been fabricated on silicon wafers during the front-end process, are assembled into packages and tested for functionality and quality.

High- and Low Complexity: Also known as high-end or low-end semiconductor market. Refers to the level of sophistication or specification of the products produced.

Burn-in: A process of stressing semiconductor devices under elevated temperatures and electrical loads for an extended period before they are shipped to customers. The purpose of burn-in testing is to detect and eliminate early failures in semiconductor devices, thereby improving their reliability and longevity.

OSAT: Outsourced semiconductor assembly and test companies,

ATE: Automated test equipment

The sector contributes around a quarter of Malaysia's GDP and employs about 4% or 590,000 of the total Malaysian workforce (MSIA 2023), with approximately one in four employees is female[5]. MSIA (2023) survey shows that many jobs are high-value and high-skilled with average salaries that are approximately double the national average. It attracted the highest Foreign Direct Investment (FDI) in the manufacturing sector, amounting to RM 85.4 billion in 2023, which accounted for 56% of the total approved investment. Additionally, it is the largest contributor to manufacturing exports, comprising 27.8% of total exports in 2023. (MIDF, 2023). Figure 1 (a, b, and c) shows Malaysia's semiconductor trade from 2004 to 2023 based on HS 8541 and HS 8542[6]. An integrated circuit is the larger component of Malaysia’s semiconductor exports, amounting to USD 74 billion in 2023. Semiconductor devices, on the other hand, contribute approximately USD 10 billion. There was a surge in 2018 exports, most likely due to additional demands driven by the US-China trade war while a decline in 2023 may be due to disruptions caused by the Ukraine war on global supply chains. Figure 1(b) illustrates that semiconductor imports are lower than export values, indicating a surplus in Malaysia's semiconductor trade balance. This surplus has been consistent since 2011, as demonstrated by Figure 1(c).

Figure 2 suggests that Malaysia has a comparative advantage in the semiconductor industry, indicating that the country is relatively more competitive in producing and exporting semiconductors compared to other countries (see also *Box 1*). Semiconductor devices and integrated circuits are consistently above 1 in the RCA index, implying Malaysia specializes in the production and export of semiconductors more than would be expected based on the global average. There was a loss in market share in 2008 but it recovered significantly. The industry remained resilient during the US-China trade war (circa 2018) and persevered through the pandemic in the early 2020s. Despite a reduction in total exports and imports in Figure 1, Malaysia remained the world's seventh-largest exporter of semiconductors. Investors also maintained confidence in the country, particularly evident when semiconductor giants like Infineon announced the establishment of a third wafer fabrication module in Kulim in 2022. *Intel* followed suit with plans for a substantial investment exceeding USD 7 billion for a new factory, scheduled to commence operations in 2024. Meanwhile, *GlobalFoundries* inaugurated a hub in Penang to

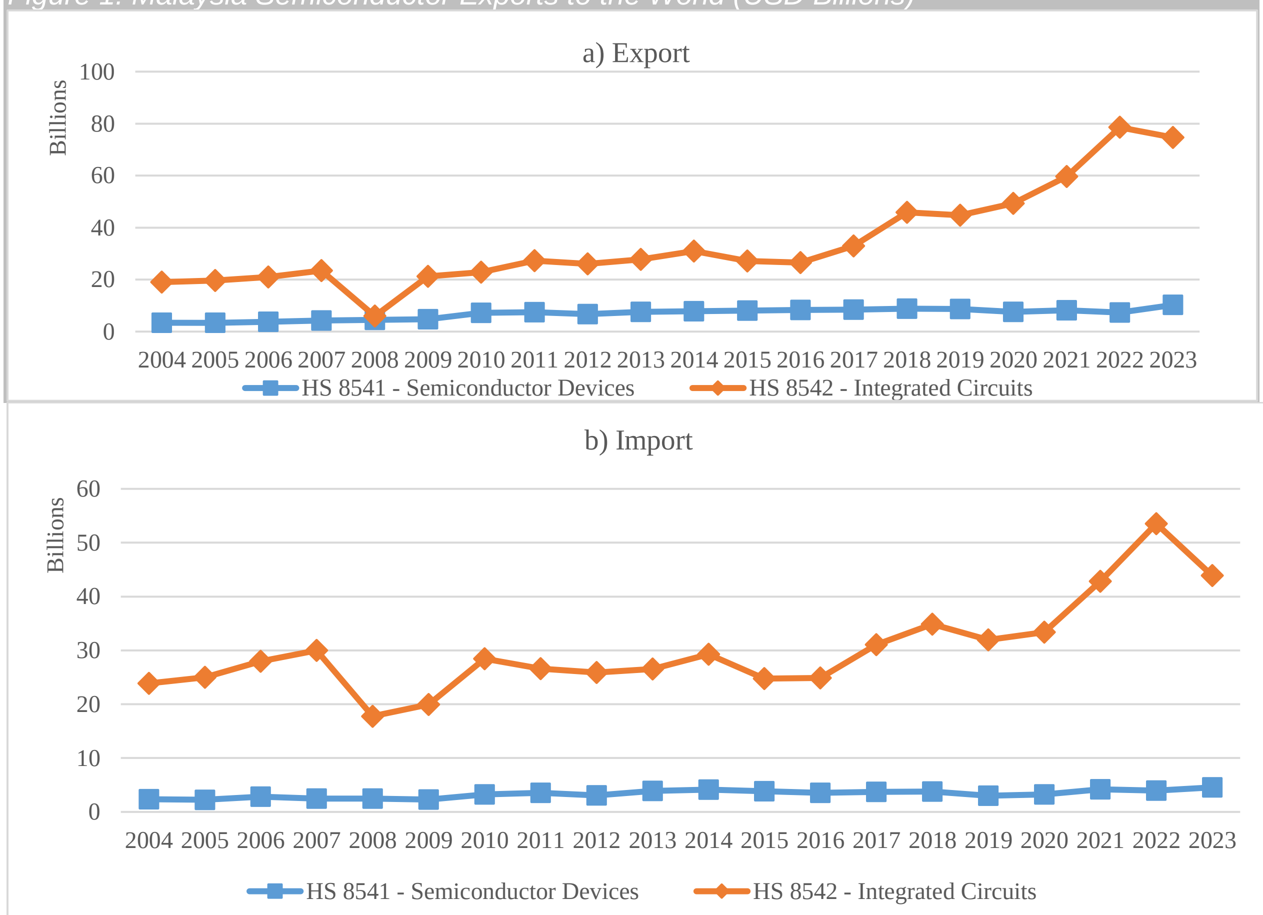
[5] https://www.channelnewsasia.com/asia/malaysia-semiconductor-industry-shortage-manpower-engineers-talent-skilled-workers-4366016

[6] These codes are endorsed by World Customs Organization (WCO) and the U.S Semiconductor Industry Association (SIA). *See* https://www.wcoomd.org/-/media/wco/public/global/pdf/events/2019/hs-conference/semiconductors-and-the-future-of-the-hs_sia-white-paper_april-2019.pdf?la=fr (accessed 18 April 2024)

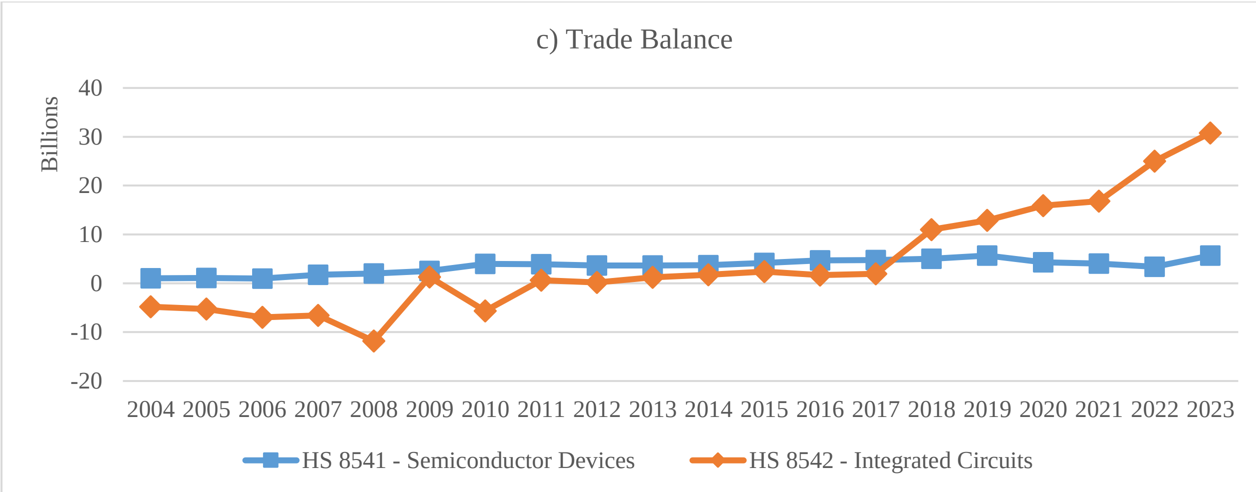
bolster global operations support, and *Neways* revealed intentions to construct a new production facility in Klang, specifically tailored for ASML[7].

The semiconductor sector heavily relies on trade, exposing it to global market fluctuations and supply chain disruptions[8]. This vulnerability is amplified by the rise of techno-nationalism, with governments worldwide acknowledging the sector's strategic significance. However, Malaysia (along with other Association of Southeast Asia (ASEAN) Member States) holds a distinct advantage as a neutral region boasting a well-established and diverse semiconductor ecosystem. While Malaysia's top trading partners consist of its traditional developed markets (US, China, Japan, Korea, and the EU), it also maintains key regional trade partnerships with countries such as Singapore, Thailand, Vietnam, and the Philippines (Table 2). This emphasizes the sector's importance in spreading risks across partners and bolstering supply chain resilience. Trade ties with multiple partners also offer competitive opportunities and market access, driving Malaysia's semiconductor industry to enhance efficiency and quality standards.

Figure 1: Malaysia Semiconductor Exports to the World (USD Billions)

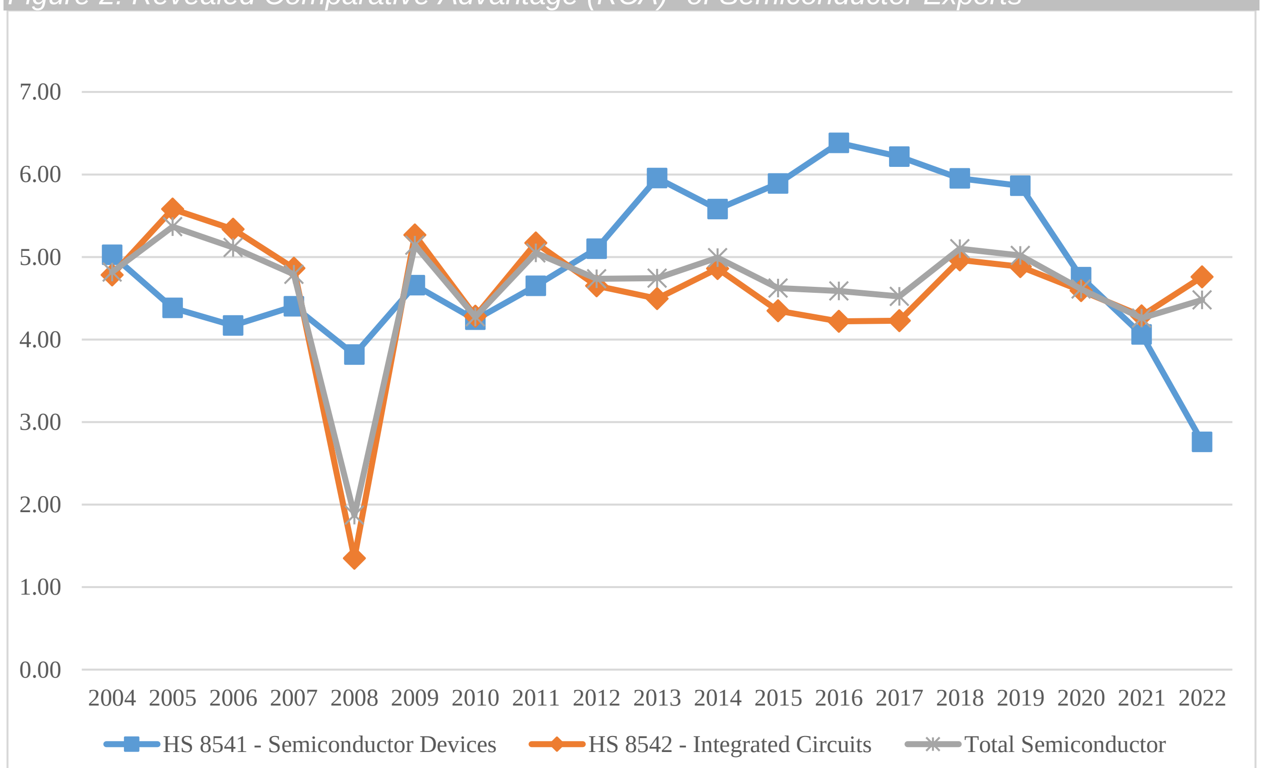


[7] https://www.msn.com/en-us/money/news/malaysia-becomes-a-focal-point-for-semiconductor-companies-amid-escalating-chip-disputes-between-the-us-and-china/ar-BB1lKVWW (accessed 18 April 2024)
[8] https://www.mida.gov.my/mida-news/semiconductors-continue-to-power-malaysia/ (accessed 18 April 2024)



Source: UNComtrade, based on WCO and SIA.

Figure 2: Revealed Comparative Advantage (RCA)[9] of Semiconductor Exports



Source: Calculated by author from UNComtrade

[9] Revealed comparative advantage, RCA = (Xik /Xi)/ (Xwk/Xw). Where, X= exports, i = exporter country, k = product, w = world, and k = commodity. BRCA above 1 indicates comparative advantage of the exported product to world. It also implies the nation specializes in the manufacture and export of that particular product compared to the world average.

Table 2: Malaysia's Top 15 Import and Exports of Semiconductor (USD Millions) Markets and Share (%).

	Semiconductor Devices			Integrated Circuits (ICs)			Total Semiconductor Devices + ICs		
Rank	Partner countries	Average[a]	Share[b]	Partner countries	Average	Share	Partner countries	Total Average	Share (%)
EXPORT									
1	United States	1403.6	18.9	China	7924.1	19.8	**Singapore**	9013.0	19.03
2	**Singapore**	1193.1	16.0	**Singapore**	7819.9	19.6	China	8559.5	18.07
3	Germany	961.4	12.9	Hong Kong	6169.7	15.4	Hong Kong	6989.7	14.76
4	Hong Kong	820.0	11.0	United States	5107.6	12.8	United States	6511.1	13.75
5	China	635.4	8.5	Mexico	2106.9	5.3	Chinese Taipei	2371.0	5.01
6	Japan	583.8	7.8	Chinese Taipei	2093.9	5.2	Mexico	2306.7	4.87
7	Chinese Taipei	277.1	3.7	Netherlands	1157.1	2.9	Germany	1953.3	4.12
8	Mexico	199.8	2.7	South Korea	1127.7	2.8	Japan	1638.4	3.46
9	South Korea	193.5	2.6	Japan	1054.5	2.6	South Korea	1321.2	2.79
10	**Vietnam**	152.3	2.0	Germany	991.9	2.5	Netherlands	1226.6	2.59
11	**Thailand**	143.4	1.9	**Thailand**	764.1	1.9	**Thailand**	907.5	1.92
12	France	116.8	1.6	France	675.3	1.7	France	792.1	1.67
13	India	82.7	1.1	**Vietnam**	558.4	1.4	**Vietnam**	710.7	1.50
14	Netherlands	69.5	0.9	**Philippines**	492.9	1.2	**Philippines**	552.3	1.17
15	**Philippines**	59.5	0.8	India	217.6	0.5	India	300.3	0.63
	IMPORT								
1	**Singapore**	743.1	23.6	**Singapore**	5086.0	20.9	**Singapore**	5829.0	21.32
2	Japan	617.8	19.6	United States	3893.3	16.0	United States	4289.4	15.69
3	United States	396.0	12.6	China	3506.6	14.4	China	3825.5	13.99
4	China	318.9	10.1	Chinese Taipei	3318.1	13.6	Chinese Taipei	3546.1	12.97
5	Germany	305.3	9.7	Japan	1781.1	7.3	Japan	2398.9	8.77
6	Chinese Taipei	228.0	7.3	Germany	1423.8	5.9	Germany	1729.2	6.32
7	Austria	154.6	4.9	South Korea	1000.4	4.1	South Korea	1055.5	3.86
8	**Philippines**	85.6	2.7	**Philippines**	830.8	3.4	**Philippines**	916.4	3.35
9	Hong Kong	68.0	2.2	Hong Kong	576.4	2.4	Hong Kong	644.3	2.36
10	South Korea	55.1	1.8	Ireland	537.0	2.2	Ireland	537.6	1.97
11	**Thailand**	47.2	1.5	**Thailand**	463.3	1.9	**Thailand**	510.5	1.87
12	United Kingdom	17.0	0.5	Israel	410.1	1.7	**Vietnam**	390.6	1.43
13	Netherlands	12.5	0.5	**Vietnam**	379.4	1.6	Israel	346.1	1.27
14	**Vietnam**	11.2	0.4	France	238.0	1.0	Austria	254.8	0.93
15	Italy	11.1	0.4	United Kingdom	140.1	0.6	France	248.2	0.91

Source: UNComtrade.
Notes: [a] Average trade from 2004 to 2022, [b] Share of in total average of all countries (%). ASEAN member states are indicated in bold.

Section 3: Environmental Impact of Semiconductor Sector

The New Industrial Masterplan Malaysia 2030 (NIMP 2030) incorporates ambitious Net Zero goals as a cornerstone of its strategy to advance Malaysia's industrialization. By prioritizing Net Zero initiatives, Malaysia aims to transition to a greener, more innovative E&E sector, aligning with global sustainability standards and driving industrial progress. Energy efficiency improvements may increase semiconductor firm's cost competitiveness by directly lowering energy expenses. Renewable energy systems tend to have lower maintenance costs due to fewer moving parts compared to traditional systems[10]. The stability and predictability of renewable energy prices[11] also provide businesses with more reliable financial planning and reduce the risk of energy price volatility.

Achieving Net Zero will enhance the semiconductor sector's readiness for ESG compliance. As global markets and investors increasingly prioritize sustainability, aligning with ESG standards will be crucial for maintaining competitiveness and access to international markets. This alignment will also attract environmentally conscious investors and consumers, driving further growth and innovation in the industry. Investing in renewable energy enhances corporate image and market position, appealing to environmentally conscious consumers and investors, which can lead to increased sales and investment opportunities. For Malaysia, this will spur the development of green infrastructure, such as eco-industrial parks, which support sustainable industrial activities and resource efficiency. This means lower operational costs in the long term for semiconductor companies, while simultaneously enhancing resilience against environmental and market disruptions. Such infrastructure will also make the industry more attractive to high-quality foreign direct investment (FDI) focused on sustainable and responsible industrial practices, thereby meeting another goal of the NIMP to create more complex industries.

Moreover, the transition to Net Zero presents economic opportunities by catalyzing new green growth areas. With a projected compounded annual growth rate (CAGR) of 7%, Malaysia's semiconductor industry is expected to reach a total output of US$46 billion (RM212.52 billion) by 2028. Major trends such as the expansion of AI technologies and the surging demand for electric vehicles are driving semiconductor manufacturers and IC designers to capitalize on these opportunities. Additionally, the increasing presence of Malaysia's OSAT players in China is expected to unlock further growth potential. However, the industry has a significant carbon footprint. According to Nagapukar et al. (2021), the expansion of the ICT sector has led to a rise in greenhouse gas (GHG) emissions by approximately 20% per decade since 2002. Projections indicate that by 2030, the ICT sector will account for nearly 7% of global energy consumption. Addressing these emissions could create new business opportunities for Malaysia's semiconductor industry and propel it towards high-technology production.

The major sources of emissions in the semiconductor sector include tool fleets, climate and humidity controls, and extensive sub-fab infrastructure for gas abatement, exhaust pumps, and

[10] For example, solar panels and wind turbines, the primary components of solar and wind energy systems, have relatively simple mechanisms. Solar panels convert sunlight directly into electricity with no moving parts involved, while wind turbines have fewer moving parts than complex fossil fuel-based power plants, which include many mechanical components like turbines, boilers, and generators. The reduced mechanical complexity of renewable energy systems means there is less wear and tear, leading to lower maintenance and repair costs over time.

[11] Traditional energy sources, such as oil, natural gas, and coal, are subject to significant price fluctuations due to geopolitical events, supply chain disruptions, and market demand shifts. These fluctuations can lead to unpredictable and often increasing energy costs.

water purification (McKinsey, 2022). The Greenhouse Protocol[12] and the Bursa Malaysia Securities Sustainable Report Guide (2022) classify GHG emissions into three scopes: Scope 1 - direct emissions from owned sources, Scope 2 - indirect emissions from purchased electricity, and Scope 3 - emissions from company activities but not owned sources. The McKinsey report (2022) revealed that 80% of semiconductor manufacturing emissions fall under Scope 1 or Scope 2, with Scope 1 emissions primarily from process gases like PFCs, HFCs, NF3, and N20, used in wafer etching, and from leaks of high GWP heat transfer fluids.

Sector-specific emissions data for Malaysia is limited. In the World Bank's Country Climate Development Report (CCDR), the semiconductor industry is aggregated under Industrial Processes and Product Use (IPPU), which includes other industries like mineral, chemical, and metal. Additionally, it is categorized under the broader electronics industry. Malaysia's Fourth Biennial Update Report (BUR4) within the UNFCCC framework provides semiconductor-specific data, but the latest available data only goes up to 2016. The semiconductor industry is also often analyzed alongside other sectors, such as the cement industry.

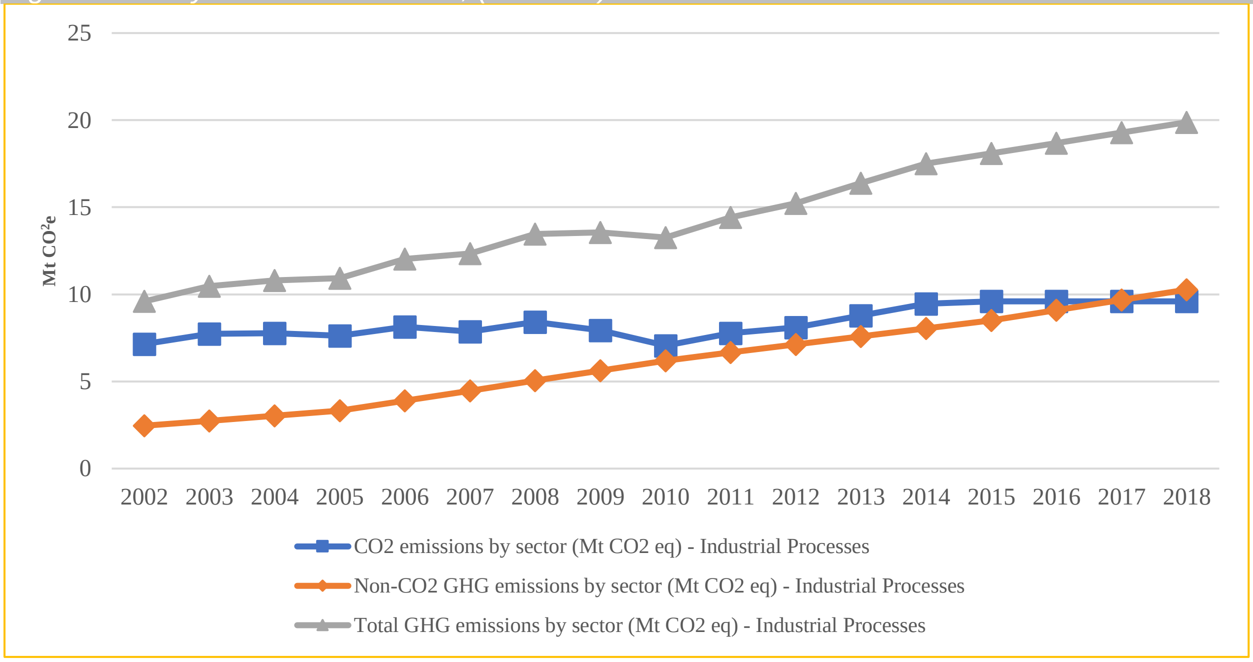
In 2021, Malaysia emitted 225.86 million metric tons of CO2 from combustible fuels, accounting for 0.7% of global CO2 emissions[13]. This marks a 96% increase since 2000, with per capita CO2 emissions rising by 34%, making Malaysia the 9th highest in carbon footprint in the Asia Pacific region. Electricity generation is primarily from coal (48%) and natural gas (32%), with renewables (hydro, solar, and biofuels) contributing about 19% in 2021 (Kam and Devadason, 2023). Despite significant fossil fuel resources, the proportion of gas in the power mix declined from 67% in 2005 to 47% in 2015, due to policies transitioning to coal amid declining domestic gas production, according to the IEA.

Since 2002, total greenhouse gas (GHG) emissions from the semiconductor industry have steadily increased, with a significant rise in non-CO2 emissions. CO2 emissions initially declined from 8.4 in 2008 to 7.0 in 2010, but then grew slowly until 2018. Non-CO2 emissions, on the other hand, rose linearly and surpassed CO2 emissions in 2017. The semiconductor sector's share of non-CO2 GHG emissions tripled from 5% to 15% of the country's total between 2002 and 2018, while its share of CO2 emissions slightly decreased from 3.9% to 3.1%. This suggests that non-CO2 gases like HFCs, PFCs, SF6, and NF3 are the primary GHG contributors from the semiconductor industry and need more focused management.

[12] Greenhouse Gas Protocol. Technical Guidance for Calculating Scope 3 Emissions. World Resources Institute. Available online: https://ghgprotocol.org/sites/default/files/standards/Scope3_Calculation_Guidance_0.pdf (accessed on 18/4/2024).

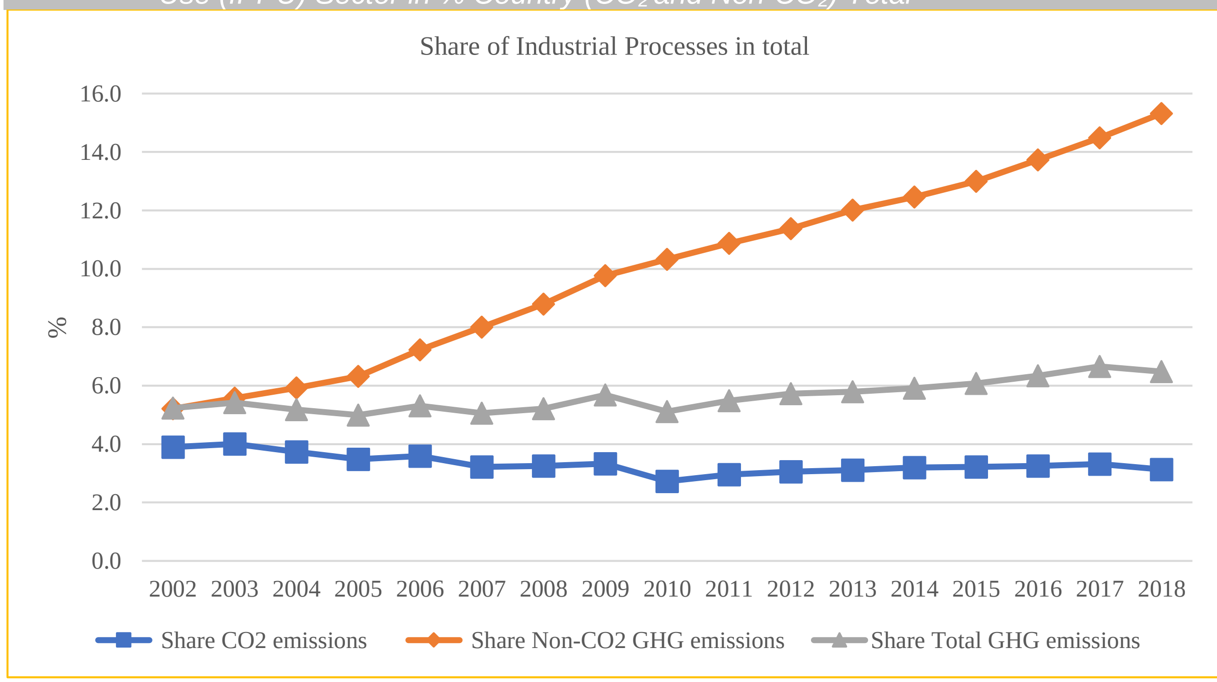
[13] https://www.iea.org/countries/malaysia/emissions

Figure 3: Malaysia GHG Emissions, (Mt CO_2e).



Source: Country Climate and Development Report (CCDR) Database https://databank.worldbank.org/source/country-climate-and-development-report-(ccdr) and

*Figure 4: Share of GHG (CO_2 and Non-CO_2) emissions by the Industrial Process and Product Use (IPPU) Sector in % Country (CO_2 and Non-CO_2) Total**



Source: Country Climate and Development Report (CCDR) Database https://databank.worldbank.org/source/country-climate-and-development-report-(ccdr) and

Note: *Emissions type in IPPU / Total emissions type in Malaysia.

Table 3 shows the composition of non-CO_2 GHG emissions in the semiconductor sector and its global warming potential (GWP). PFCs are the largest source of non-CO2 GHG emissions, followed by SF6 and HFCs. NF3, though emitted in smaller quantities, has the second highest GWP after SF6. For example, SF6 traps 22,800 times more heat than CO2 over 100 years. This indicates that non-CO2 gases, with their high GWP, significantly impact the climate, potentially more than CO2 alon3. Therefore, focusing solely on CO_2 may not fully capture the extent of the industry's climate impact. In the case of the semiconductor industry, non-CO2 greenhouse gas emissions may have a more severe impact on the environment, primarily due to their higher Global Warming Potential (GWP)

Table 3: GHG from Semiconductor / Integrated Circuits Sector 2009-2019 (CO_2 equivalents Gigagrams) & Share to Total National Emissions, and *Global Warming Potential (GWP)

	HFCs	PFCs	SF (SF_6)	Other Gases (NF_3)
2016	43.8	1425.9	337.0	50.9
2017	43.8	1425.9	337.0	50.9
2018	43.8	1425.9	337.0	50.9
2019	43.8	1425.9	337.0	50.9
GWP*	**1,430 – 14,800**	**7,390 – 12,200**	**22,800**	**17,200**

Source: Extracted from Fourth Biennial Update Report Under The United Nations Framework Convention On Climate Change (UNFCCC), 2022.

Notes:

***GWP**: Global Warming Potential. A measure of how much heat a greenhouse gas traps in the atmosphere over a specific period, usually 100 years, relative to carbon dioxide (CO_2), which is assigned a GWP of 1.

HFCs: Hydrofluorocarbon (HFC) gases are commonly used in semiconductor fabrication for processes such as etching, deposition, and cleaning

PFCs: Perfluorocarbons (PFCs) are a class of synthetic chemicals composed of carbon and fluorine atoms, often with other elements like chlorine or bromine present as well. PFC gases are used in various semiconductor fabrication processes i.e. Plasma Etching, Chemical Vapor Deposition (CVD), and cleaning.

SF: Sulphur hexafluoride is primarily used as a dielectric gas in high-voltage equipment, such as gas-insulated switchgear (GIS) and gas-insulated transmission lines (GIL). It is also used in certain plasma etching processes for semiconductor device fabrication.

NF3: Nitrogen trifluoride, is a chemical compound composed of nitrogen and fluorine. It is a colorless, odorless gas with a molecular formula of NF3. NF3 is primarily used in the electronics industry, particularly in the production of flat-panel displays, semiconductors, and photovoltaic cells (solar panels).

Green Policies Pertinent to Malaysia's Semiconductor Sector

Malaysia has pledged to reduce its Greenhouse Gas (GHG) emissions by 45 percent by 2030 compared to 2005 levels, with a 35 percent reduction unconditionally and an additional 10 percent contingent on climate finance, technology transfers, and capacity building from developed nations. The government supports this transition through international commitments, domestic initiatives, and policies (see Table 4). The *National Green Technology Policy (NGTP)*, introduced in 2009, promotes the development and use of “green technology” to conserve the environment and resources. It focuses on energy, the environment, the economy, and social aspects, with key sectors including energy, buildings, transportation, and waste management. In 2010, the *Green Technology Financing Scheme (GTFS)* was introduced to ease financing for green entrepreneurs following the 2009 *National Green Technology Policy*. Originally ending in 2015, the scheme was extended until 2017. It offers a 60% government guarantee and a 2% interest rate reduction for green projects. By October 2017, it had allocated USD 810 million to over 302 projects, attracting investments of USD 1.56 billion, creating over 5,000 jobs, and reducing emissions by 3.513 million tonnes[14] of CO2e. The scheme was further extended to GTFS 2.0, 3.0, and currently GTFS 4.0, which runs until December 2025 with support up to RM1.0 billion. GTFS 4.0 covers six key sectors and provides up to 80% government guarantee and a 1.5% annual interest rebate.

The emphasis on environmental sustainability in the nation's socio-economic strategy has only become more prominent in the past decade. The *11th Malaysian Plan (2016-2020)* targeted new renewable energy sources, aiming for 20% of the national power generation energy mix by 2025. This goal was supported by the Green Technology Master Plan (GTMP) (2017-2030), which aims to generate USD 43 billion in revenue and create 200,000 green jobs in the sector by 2030. The current 12th Malaysian Plan (2021-2025) introduces initiatives for a circular economy and Integrated Water Resources Management (IWRM). Building on this, the New Industrial Master Plan (NIMP) (2023-2030) aims to decarbonize the manufacturing sector to achieve Net Zero emissions by 2050, with a focus on the circular economy, electric vehicles, and carbon capture. Together, these plans also include measures for sustainable practices, such as carbon policies, accounting methods, taxation measures, and the launch of the iESG framework and green transition programs.

Several other national energy policies support Malaysia's adoption of energy efficiency in the public and private sectors. *The Renewable Energy Act of 2011* promotes electricity generation from sources like solar, biogas, biomass, and small hydropower through a *Feed-in Tariff (FiT)* system, allowing producers to sell surplus electricity to utilities at a premium rate and permitting up to 49% foreign equity. Similarly, the *Green Electricity Tariff (GET)* initiative, launched in 2022, offers a premium rate of 21.8 cents/kWh (effective August 1, 2023) and waives Imbalance Cost Pass-Through (ICPT) charges based on renewable energy subscribed. GET participants are also recognized with a Malaysia Renewable Energy Certificate (mREC), which is internationally acknowledged.

The National Energy Efficient Action Plan (NEEAP) (2016-2025) was introduced in 2016 to promote energy-saving measures in various sectors. The same year saw the introduction of the *Net Energy Metering (NEM)* scheme and *the Large Scale Solar (LSS)* program to encourage solar energy use. The *NEM* scheme incentivizes solar PV installations by allowing owners to offset their electricity bills with surplus power exported to the grid, credited at the retail rate. It is complemented by solar leasing programs or power purchase agreement (PPA), where consumers pay fixed monthly fees for solar PV systems installed by third-party providers. The LSS program promotes solar farm development through competitive bidding, with the government guaranteeing

[14] https://www.mida.gov.my/wp-content/uploads/2020/12/Green-technology-High-Res-Final.pdf

to purchase the generated electricity at a fixed rate. Energy produced by LSS projects is also utilized by the GET initiative.

The Malaysian government launched *MyHIJAU* to ensure compliance with environmental criteria set by the Malaysian Green Technology and Climate Change Corporation (MGTC). This certification program signifies a commitment to sustainability for labeled products and service providers. Registered green products and services are listed in the *MyHIJAU* Directory, which helps businesses access green incentives like the *Green Investment Tax Allowance (GITA)* and *Green Income Tax Exemption (GITE)*. Since 2014, businesses can apply for *GITA* for green technology assets or projects, covering 100% of qualifying capital expenditure for three years and offsetting 70% of taxable income annually. Alternatively, green technology service providers can qualify for *GITE*, enjoying a 70% income tax exemption for three years. *GITA* and *GITE* cover renewable energy projects (excluding *FiT* scheme solar projects), energy efficiency services, integrated waste management, green buildings, and electric vehicle (EV) services.

Finally, the Malaysian government encourages public listed companies to prepare Bursa Sustainability Reports to promote transparency and accountability regarding their sustainability practices and performance. *The Bursa Malaysia Sustainability Framework* provides guidelines and standards for public listed companies to report on their sustainability practices. It helps companies integrate environmental, social, and governance (ESG) considerations into their business strategies and operations, promoting transparency and accountability in sustainable development efforts. Additional discussion will be presented in the next section.

Table 4: Government Initiatives in Malaysia's Green Transition.

	Policies / Initiatives	**Category**	**Year initiated**
1.	The National Green Technology Policy (NGTP)	AP	2009
2.	The Green Technology Financing Scheme (GTFS)	FM/PT	2010
3.	The Renewable Energy Act, 2011	FM/PT	2011
4.	Feed-in Tariff (FiT) program	FM/PT	2011
5.	MyHIJAU National Green Recognition Scheme	AP	2014
6.	Green Technology Tax Incentive • Green Investment Tax Allowances (GITA) • Green Income Tax Exemption (GITE) • Green Income Tax Exemption (GITE) - Solar Leasing	FM/PT	2014
7.	Bursa Malaysia Securities Berhad "Sustainability Framework"	AP	2015
8.	11th Malaysian Plan	NP	2016 to 2020
9.	The National Energy Efficient Action Plan (NEEAP).	AP	2016 to 2025
10.	Net Energy Metering (NEM) & Solar Leasing	FM/PT	2016
11.	Large Scale Solar (LSS)	FM/PT	2016
12.	Green Technology Master Plan (GTMP)	AP	2017 to 2030
13.	12th Malaysian Plan	NP	2021 to 2025
14.	Green Energy Tariff Scheme	FM/PT	2022
15.	New Industrial Masterplan (NIMP)	NP	2023 to 2030
16.	National Energy Transition Roadmap (NETR)	AP	2023 to 2025

Notes:

National Plan (NP): A broad policy framework outlining the nation's development direction, encompassing various aspects beyond environmental issues.

Action Plan (AP): Specific policies or initiatives focused on the environment, designed to facilitate the country's transition towards a green economy.

Financing Mechanism / Policy Tool (FM/PT): Financial schemes or incentives, including government support, designed to bolster both national plans and action plans, thereby aiding in their implementation.

Section 4: Sustainability Trends and Decarbonization Strategies in Malaysian Semiconductor Companies

Semiconductor production involves highly complex procedures like photolithography, etching, doping, and deposition, which demand significant energy inputs. Specialized equipment such as furnaces, vacuum chambers, and chemical baths are crucial for achieving the necessary precision and quality but consume substantial amounts of energy. Semiconductor manufacturing facilities, or fabs, maintain stringent cleanliness standards to prevent contamination, with cleanrooms using sophisticated HVAC systems to regulate temperature, humidity, and air quality. Cooling systems, such as chillers and water-cooled heat exchangers, dissipate heat generated by equipment, preventing overheating but adding to the energy intensity. Additionally, production tools like plasma etchers, ion implanters, and laser annealers, combined with the continuous, round-the-clock operation of fabs to meet market demands, further contribute to high energy consumption levels.

The high energy consumption in semiconductor manufacturing has significant environmental implications. It contributes to increased greenhouse gas emissions from fossil fuel-based electricity and strains local water resources due to the high demand for ultra-pure water used in cooling and production. The processes generate substantial waste, including hazardous chemicals and materials, which can lead to environmental pollution and pose risks to human health and ecosystems if not properly managed. Wastewater discharge may contain pollutants like heavy metals and solvents, impacting water quality and aquatic ecosystems. Despite these challenges, there is a notable lack of data collection and research on these environmental impacts in Malaysia, which the next section aims to address.

Data Source and Analytical Framework

The study examines how Malaysian semiconductor companies are working to decarbonize and mitigate their environmental impact, focusing on 31 publicly listed companies (PLCs) classified under the *semiconductor* or *technology equipment* sectors on Bursa Malaysia. The primary data sources will be the companies' annual reports[15] and their websites. Since 2017, Bursa Malaysia has mandated sustainability reporting for all listed companies, requiring a "Sustainability Statement or Report" based on economic, social, environmental, and governance (ESG) criteria. This study will focus only on the environmental aspect of the *Sustainability Reporting Guide* (SRG), including climate change mitigation, energy consumption reduction, greenhouse gas emissions management, water conservation, efficient waste management, and biodiversity preservation.

[15] It was announced on 4th December 2023 that Bursa Malaysia is creating a platform that will act as a repository for ESG disclosures under their *Sustainability Statement* or *Report.* At the time of this writing, there have been no updates on the progress of this Bursa Malaysia's initiative.

The SRG establishes key reporting principles, requiring reports to be balanced, unbiased, and include meaningful elements such as internationally accepted metrics (e.g., kilograms, liters). Companies must also disclose their geographical boundaries and business entities. For sustainability matters, companies are required to provide information on both 'common indicators' and 'sector-specific indicators.' Common indicators include:

- i) Energy management (Total energy consumption)
- ii) Emissions management (Scope 1, 2, 3 emissions)
- iii) Water management (Total volume of water used)
- iv) Waste (Total waste generated – total waste diverted from disposal, and total waste directed to disposal).

Additional sector-specific indicators include the amount of air emissions of pollutants and particulate matter, as well as the total volume of water (effluent) discharged over the reporting period.

The dataset of 31 companies is compiled in Appendix 1. Due to variations in unit measurements across reports, all data has been standardized to ensure consistency. For instance, some companies reported electricity usage in Joules, but all measurements have been converted to kilowatt-hours (kWh) for uniformity. Data is based on availability as some companies did not disclose some indicators in their annual reports.

Findings

1. Materiality and Descriptive Analysis

Publicly listed companies conduct *materiality assessments* to gauge environmental issues' significance by comparing stakeholder and company perspectives. This is usually shown in a matrix, with the Y-axis representing stakeholder concern (e.g., emissions, waste management) and the X-axis representing company concern[16]. Figure 5 reveals varied levels of awareness and action in the industry, with environmental issues not being a top priority for stakeholders or many semiconductor companies. This suggests a misalignment between stakeholder and company views on environmental importance. Only 3 out of 19 semiconductor companies recognized environmental concerns as important to both stakeholders and themselves. This aligns with MSIA (2023) findings that semiconductor firms prioritize economic, sales, talent, and productivity issues over environmental concerns.

Figure 5: The Importance of Environmental Issues Based on Materiality Matrix.

Level of Importance to Stakeholders

N = 19

High	1 company (5.3%)	2 companies (10.5%)	3 companies (15.8%)
		2 companies (10.5%)	1 company (5.3%)
Low	7 companies (36.8%)	3 companies (15.8%)	
	Low		High

Level of importance to the company

[16] Other factors considered in a materiality assessment may include financial performance, strategic goals, regulatory requirements, social responsibility, and governance practices. However, in this study only environmental issues are observed.

Source: Analyzed based on multiple annual reports.

Note: Only 19 out of 31 companies provided the Materiality Matrix in their annual report.
Table 5 shows that Malaysian publicly listed semiconductor companies, were formed between 8 and 63 years ago, vary in sizes from 23 to over 7,600 employees, with market capitalizations ranging from RM 23 million to RM 1.2 billion. Reported energy use spans from 0.43 to 275 million kWh. Only 5 companies reported[17] renewable energy use, up to 835 thousand kWh. Given the diverse sizes and operations, absolute energy data can be misleading as larger companies typically use more energy. To standardize comparisons, energy intensity is adjusted using revenue as the denominator, with values reaching up to 339,400 kWh per RM1 million in revenue.

Table 5 indicates that companies primarily report Scope 2 emissions, followed by Scope 1 and Scope 3. On average, semiconductor companies emit about 28,000 tCO_2 or tCO_2e per year from Scope 2, with some reaching up to 194,832 tCO_2 or tCO_2e annually. Scope 2 emissions mainly come from electricity used for manufacturing and operations. Scope 1 emissions, including on-site transportation, are generally lower as they mostly involve carbon emissions. Only three companies reported Scope 3 emissions due to data challenges from varied upstream and downstream sources.

On average, companies draw more than half a million cubic meters of water per year, with some even reportedly drawing over 4.7 million cubic meters per year. The water usage data in annual reports go beyond the production component. It also includes water consumed for everyday operations, such as restroom facilities and other non-production uses. This broader scope of water usage reporting provides a comprehensive view of the factory's overall water consumption, encompassing both industrial processes and standard operational needs.

Waste in semiconductor manufacturing includes both hazardous and non-hazardous types. Hazardous waste comprises harmful materials like solvents, acids, metals, and waste gases from fabrication, as well as heavy metal contaminants. Non-hazardous waste includes general materials such as paper, cardboard, and plastic. On average, semiconductor facilities generate about 561.1 tonnes of waste annually, with 187 tonnes hazardous and 198 tonnes non-hazardous. The actual total could be higher due to incomplete reporting, and categories for e-waste or recyclables were not effectively profiled due to limited data.

[17] This does not imply that semiconductor companies do not use renewable energy sources; it merely suggests that they did not include this information in their annual reports. The same caveat applies to other indicators.

Table 5: Descriptive statistics of Annual Reports.

Variable	Obs	Mean	Std. dev.	Min	Max
Company Age	31	28.2	14.0	8.0	63.0
Employee size	31	1159.9	1874.8	23.0	7620.0
Market Capitalization (RM million)	31	2070.5	2883.2	23.0	11914.0
Company Revenue (RM million)	31	408.0	560.7	6.8	2416.0
Energy					
Total Energy Consumed mil (kWh)	22	32.2	63.8	0.43	275
Renewable Energy (kWh)	5	491084.0	429641.0	165.7	835600.0
Energy Intensity[a] ('000)	31	33.9	67.9	1.6	339.4
Emissions					
Scope 1 Emissions (tCO_2 or tCO_2e)[b]	11	867.9	1354.3	1.4	3976.2
Scope 2 Emissions (tCO_2 or tCO_2e)	17	27845.1	49577.1	60.3	194832.8
Scope 3 Emissions (tCO_2 or tCO_2e)	3	22907.7	26128.6	524.0	51619.0
Scope 1 Emissions Intensity[c]	11	1.8	3.5	0.002	11.7
Scope 2 Emissions Intensity	17	40.6	58.7	1.0	237.0
Scope 3 Emissions Intensity	3	36.4	47.3	1.9	90.4
Water					
Water withdrawal (m^3)	15	570,102.0	1,257,392.0	1,118.0	4,714,125.0
Water withdrawal intensity[d]	15	513.6	664.8	41.0	1951.2
Waste					
Hazardous waste (tonnes)	11	187.1	267.3	0.2	733.0
Non-hazardous waste (tonnes)	10	197.9	205.3	0.6	596.2
Total waste (tonnes)	14	256.1	290.3	1.1	740.5
Hazardous waste intensity[e]	11	0.1	0.5	0.0	2.7
Non-hazardous waste intensity	10	0.1	0.1	0.0	0.4
Total waste intensity	14	0.2	0.6	0.0	2.7

Source: Source: Data analyzed from annual reports of 31 semiconductor companies, latest available 2022 or 2023.

Notes:

[a] Total energy consumed per company revenue in millions. It implies the amount of energy used per 1 million revenues.

[b] Companies report emissions using these two indicators. Although tCO_2 or tCO_2e have different meanings. The SRG did not specifically indicate the preference (see SRG version 3.0, pg 64)

[c, d, e] Emissions, water withdrawal, and waste indicators per company revenue in millions. It indicates the amount of emissions, water withdrawal, and waste generated for every RM million in revenue.

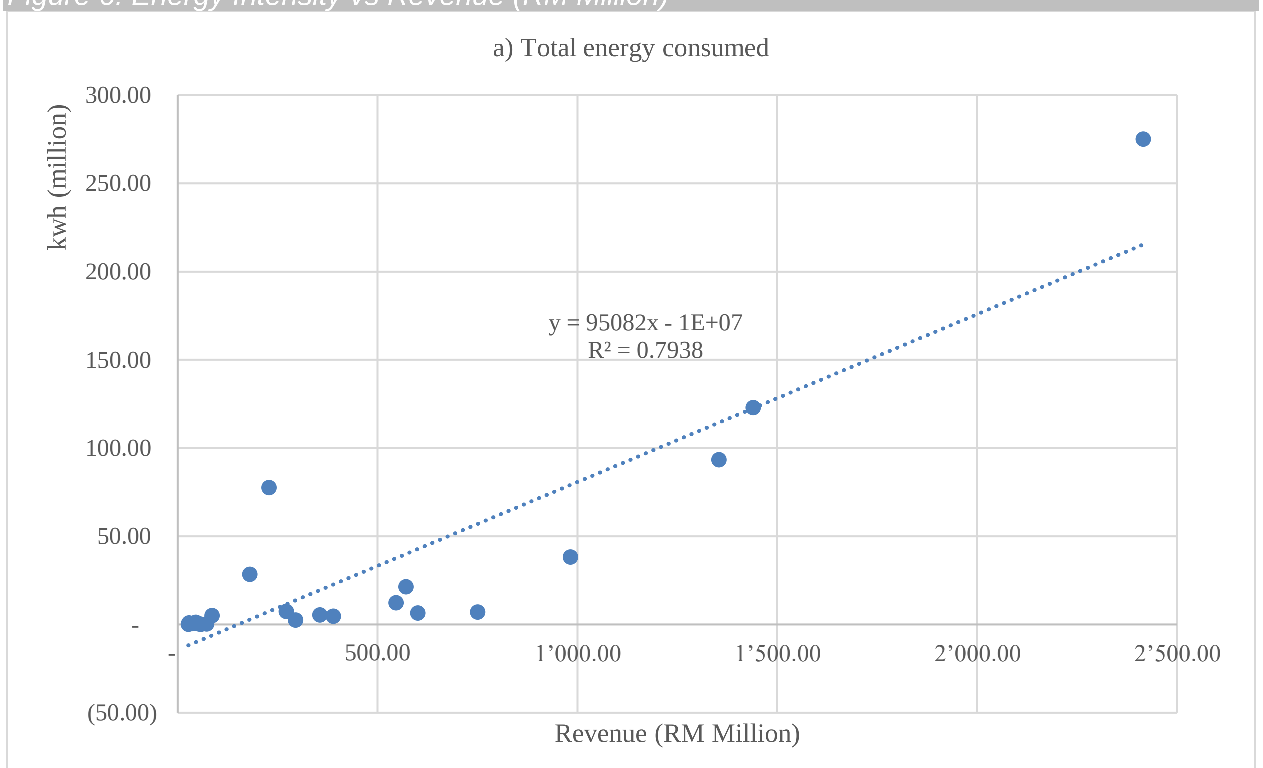
2. Environmental Indicator Trends from Semiconductor Companies

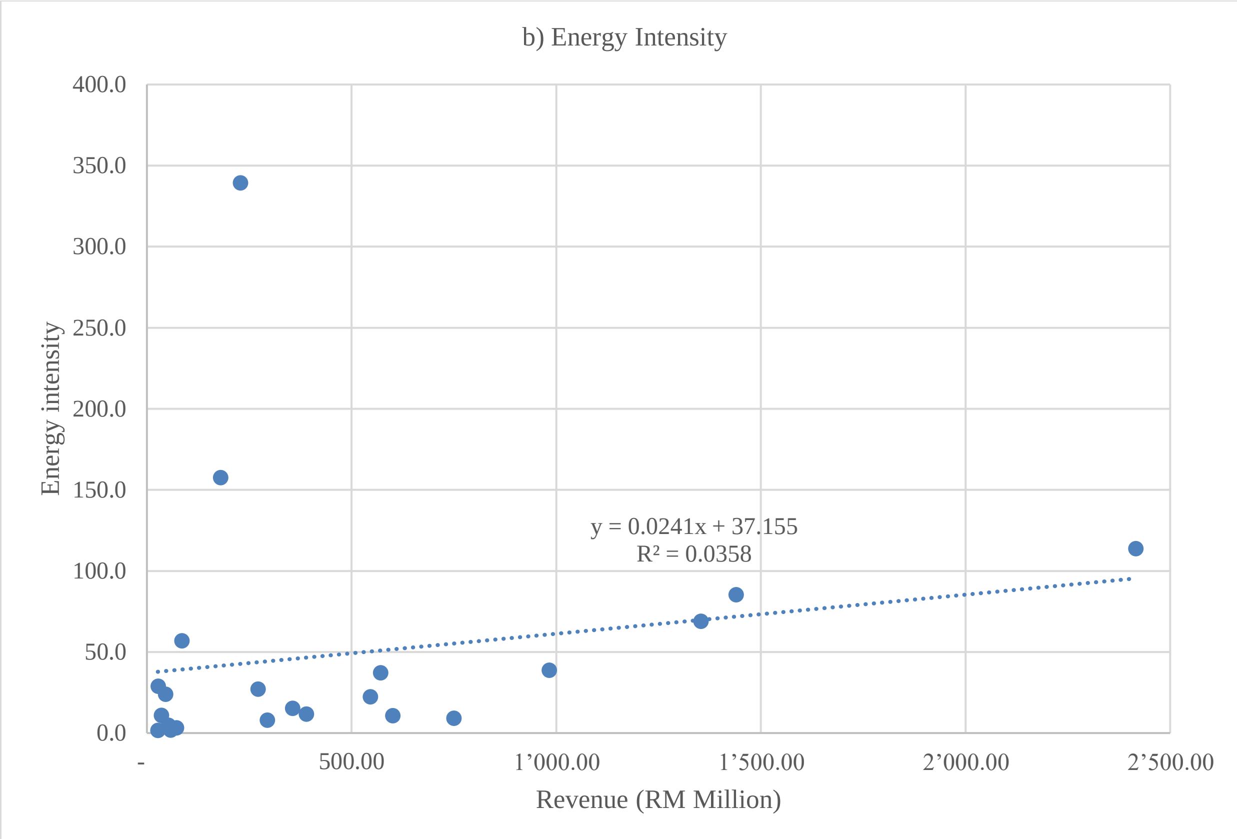
- **Energy Consumption**

Figure 6 shows a positive correlation between revenue and total energy consumption. While correlation does not imply causation, annual reports often highlight this one-sided relationship. Factors like new product introductions (NPI), increased facility usage, new locations, and expanded production contribute to higher energy consumption as revenue grows. Companies also require more energy for transportation, storage, and distribution. The analysis shows a strong linear relationship with an R-squared value of 79%.

This interpretation is further supported by the intensity indicator. Since the energy intensity ratio is calculated as the energy used divided by revenue, an increase in the denominator would necessitate a greater increase in energy consumption to maintain a positive relationship. Thus, companies with higher revenues have higher energy consumption intensity. However, external factors may also contribute to an increase in intensity. Market disruptions during the COVID-19 pandemic have led to lower production capacity or revenues for companies, thus increasing the intensity indicator. The lower revenue can also be attributed to fixed costs such as space, equipment, and utilities remaining constant, thus preventing a proportional reduction in energy usage. The resumption of business activity following the lifting of pandemic-related measures has also led to a subsequent rise in energy usage.

Figure 6: Energy Intensity vs Revenue (RM Million)





Source: Data analyzed from annual reports of 31 semiconductor companies.

- **Emissions Patterns**

Figure 7(a) shows a positive correlation between total revenue and Scope 1 emissions. This may be attributed to the increase in production, NPI, and increased capacity utilization and plant expansion. Like energy consumption, the resumption of business activities following the lifting of COVID-19 restrictions has led to a sudden surge in production and consequently, carbon emissions. However, unlike energy use, there is a negative relationship between emissions intensity and revenue (Figure 7(b)). Possible reasons for this include investments in cleaner technologies, improved operational efficiency, and better energy utilization. Additionally, some companies also decreased fuel and diesel consumption and usage of liquefied petroleum gas (LPG) in production in both operations and vehicles. These adjustments were partly influenced by lesser activity (the sluggish market) during the year.[18].

In terms of Scope 2 emissions, both emissions and intensity have positive correlations with revenue generation (Figure 7(c) and 7(d)). The differences in the findings between emissions intensity of Scope 1 and Scope 2 can be attributed to the different sources of these emissions. Scope 1 emissions encompass direct emissions from sources directly owned or controlled by the company, such as onsite combustion or vehicle fleets, making them more straightforward to manage. However, the company has limited control over emissions associated with purchased electricity (Scope 2). The effectiveness of emissions intensity reduction efforts in this category is

[18] *see* UWC Berhad Annual Report (2023)

affected by rising tariffs, a lack of funds to invest in renewable energy options, and the necessity to use electricity as a fixed cost despite lower market demands.

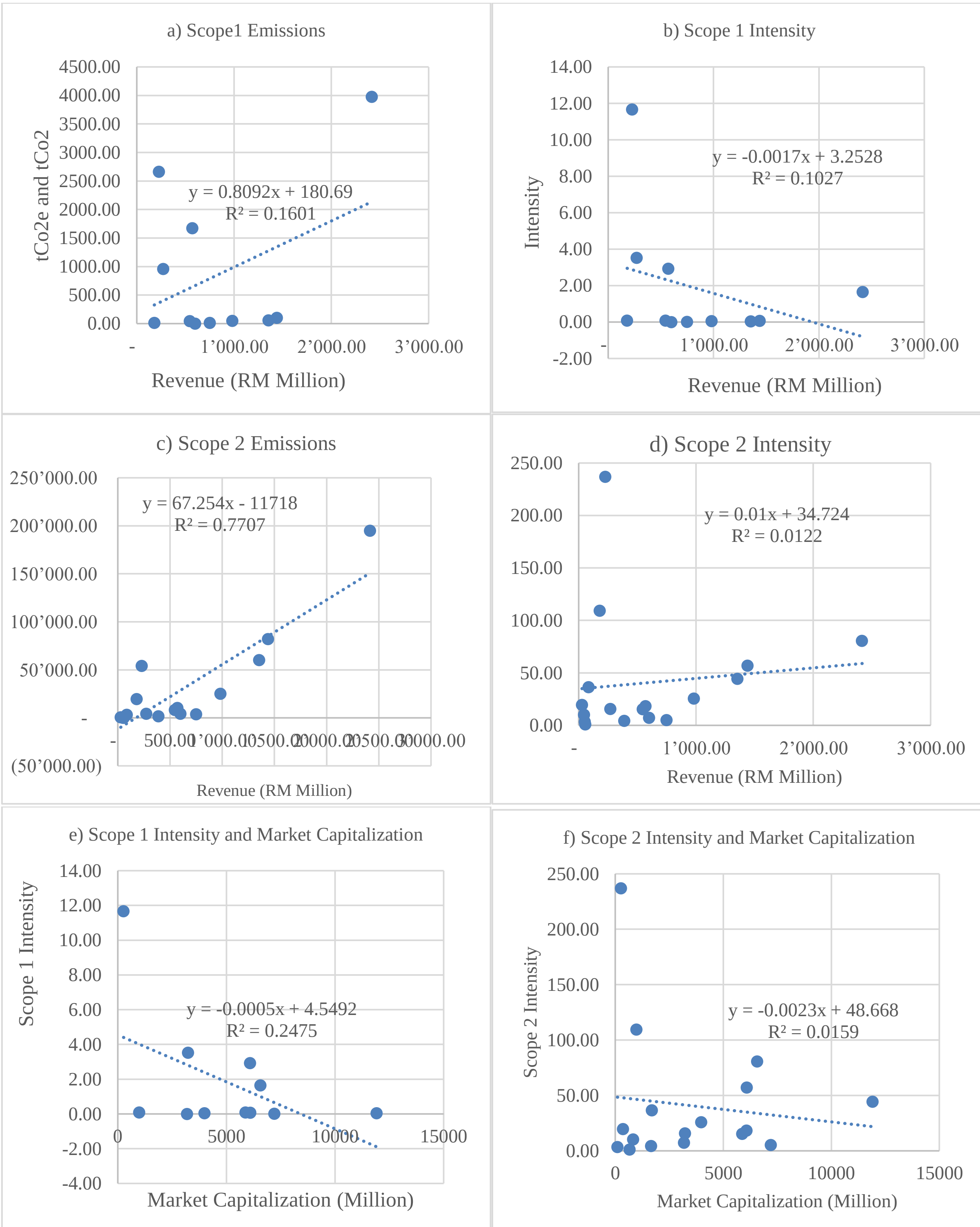
For a robustness check, revenue is substituted with market capitalization (Figures 7(e) and 7(f)). Interestingly, both Scope 1 and Scope 2 emissions intensities show a negative relationship with market capitalization. Market capitalization, reflecting a company's total stock market value, incorporates factors like investor sentiment, future growth potential, and perceived company value. Companies with higher market capitalization often face greater scrutiny regarding their environmental performance. In response to stakeholder expectations, these companies may prioritize emission reduction, leading to the negative relationship between emissions intensity and market capitalization. Additionally, companies with higher market capitalization may have more resources to invest in cleaner technologies and energy efficiency measures, further contributing to the observed negative relationship.

- **Water Management**

Water has multiple functions in the semiconductor industry. Process Chilled Water (PCW) is used for cooling, Ultra-Pure Water (UPW) for cleaning in wet-processing, and Deionized Water (DI) for cleansing and rinsing semiconductor products. Additionally, water is essential for maintenance and domestic use in offices. Due to heavy water usage, there's a positive correlation between water withdrawal intensity and revenue. The increase in water withdrawal is attributed to several factors: increased capacity and utilization, adjustments and optimizations in products and processes, and the operational activities of new infrastructure and facilities, such as surface finishing treatments, which consume more water than existing fabrication and assembly activities. Different segments of the semiconductor value chain have varying water usage intensities. Fabrication companies, which manufacture semiconductor chips, typically have higher water intensity due to processes like photolithography and chemical etching. In contrast, assembly companies, which handle packaging and testing, generally use less water. Companies utilizing advanced technologies for smaller node sizes or more complex processes also require more water for cooling and cleaning, while those using conventional technologies have lower water intensity due to simpler processes.

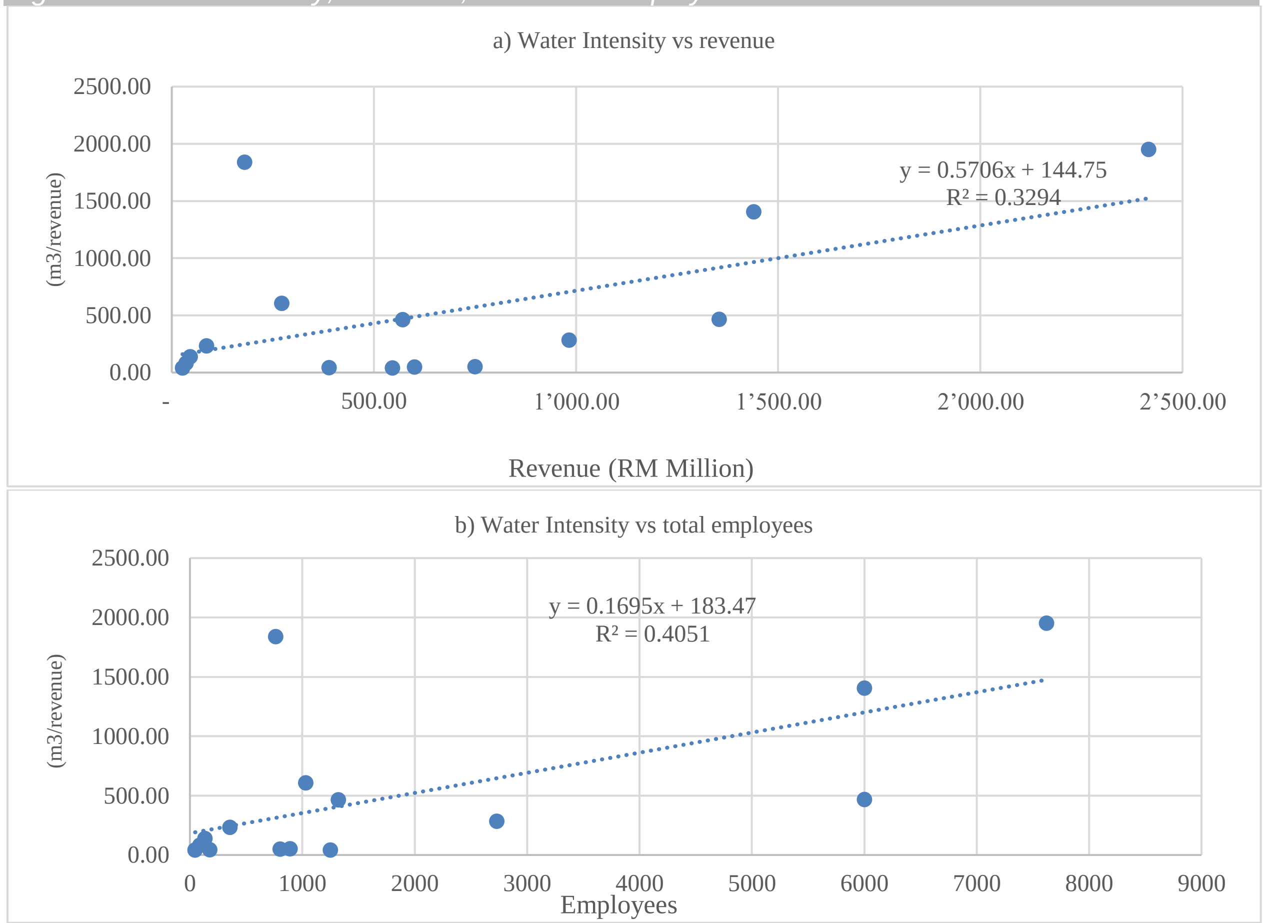
Even with lower production volumes, water intensity does not decrease due to non-production water use, such as employee consumption, sanitation, and facility maintenance. Increased employee headcount contributes to higher water intensity, especially if water conservation measures are not emphasized. Figure 8(b) shows a positive correlation between the number of employees and water intensity. Additionally, the transition from pandemic to endemic has increased water usage as employees return to work.

Figure 7: *Scope 1 and 2 Emissions (tCO_2e and tCO_2) & Intensity vs Revenue and Market Capitalization.*



Source: Data analyzed from annual reports of 31 semiconductor companies

Figure 8: Water Intensity, Revenue, and Total Employees.



Source: Data analyzed from annual reports of 31 semiconductor companies

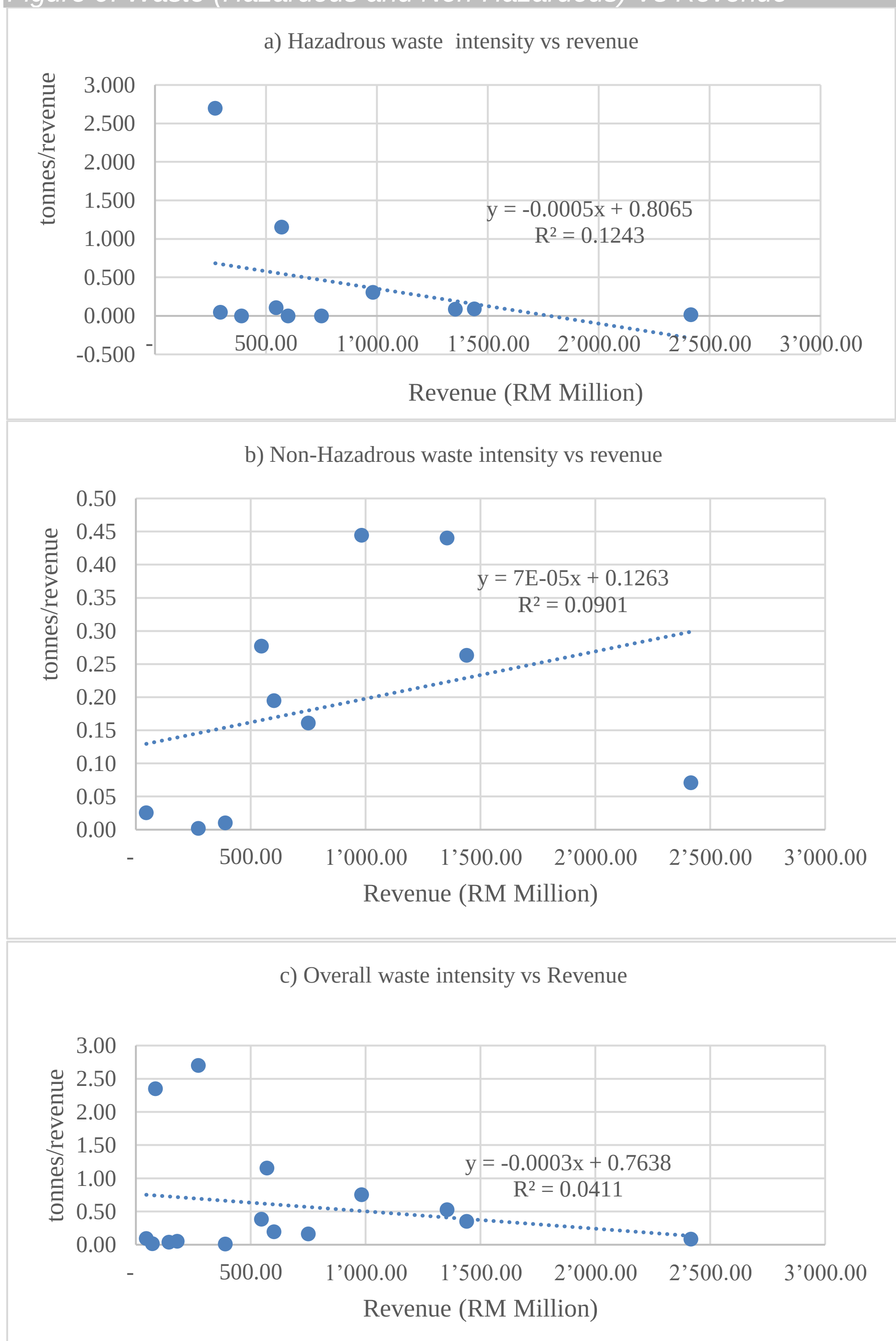
- **Waste Management**

In semiconductor manufacturing, Hazardous waste primarily stems from the extensive use of chemicals, including solvents, acids, and toxic metals such as arsenic, cadmium, and lead. Solid waste generated from discarded equipment components, contaminated gloves and rags, contaminated containers, waste coolant, electronic waste, and used chemical containers may contain hazardous materials that require special handling under the Environmental Quality Act, 1974, and Environmental Quality (Scheduled Wastes) Regulations 2005. Non-hazardous waste in the semiconductor industry encompasses materials like remainders from materials used in CNC machining (e.g SW307, SW422)[19], packaging materials (SW409, SW410), e-waste (SE110), scrap silicon wafers, and general waste. Packaging materials like cardboard, plastic, and foam, while not hazardous, contribute to solid waste and require proper recycling or disposal. Scrap silicon wafers from production defects and routine waste from cleaning, maintenance, and office operations also add to the total waste. Increased waste generation is driven by expanded business volume, new product introductions, machine replacements, and a backlog in hazardous waste disposal.

[19] Code based on Environmental Quality (Scheduled Wastes) Regulations 2005, First Schedule (Regulation 2).

Figure 9(a) shows that as revenue increases in semiconductor manufacturing, the intensity of hazardous waste decreases relative to non-hazardous waste. The prioritization of hazardous waste is driven by regulatory compliance, environmental stewardship, and worker safety. Hazardous waste is heavily regulated, and its proper management is crucial to avoid penalties and protect both health and the environment. Figure 9(c) further indicates that semiconductor companies prioritise waste management as a key component of their environmental practices.

Figure 9: Waste (Hazardous and Non-Hazardous) Vs Revenue



Source: Data analyzed from annual reports of 31 semiconductor companies

3. Environmental Measures and Strategies in Semiconductor Manufacturing

Semiconductor companies have outlined comprehensive strategies in their sustainability statements to reduce environmental impact. Their efforts, while varied, fall into five categories: i) energy efficiency and renewable energy, ii) resource conservation, iii) infrastructure and facilities improvements, iv) innovation and technology, and v) other operational sustainability measures. For more details on these environmental measures[20], see Table 6.

i) Energy Efficiency and Renewable Energy

Semiconductor companies focus on reducing energy consumption and adopting renewable sources. Notable initiative involves installing industrial-scale photovoltaic system to harness solar energy. For instance, *KESM Industries Bhd* procured 797 MWh of renewable energy through the Green Electricity Tariff program in Malaysia. Similarly, *Visdynamics Holdings Bhd* uses its car park roof for solar energy generation and benefits from the Net Energy Metering (NEM) Scheme. Despite these efforts, only 11 out of 31 companies (36%) reported using solar panels in their Annual Reports. Additionally, Genetec Technology Berhad launched Malaysia's first locally developed battery energy storage system (BESS) to store excess solar power for later use i.e during the night when solar panels are not generating electricity.

Companies upgrade lighting to high-quality LED panels, which optimize energy use by producing more light with less heat. This initiative is the most common for energy conservation, with 52% of companies implementing it. Additionally, some companies have replaced their vacuum systems with high-efficiency rotary screw systems that use Variable Frequency Drive (VFD) control, reducing energy consumption, lubricant oil use, and maintenance costs.

For air conditioning, some semiconductor companies enhance efficiency by using inverter technology, which adjusts compressor speed based on cooling needs to reduce energy waste and costs. They also install booster fan motors in Air Handling Units (AHUs) for optimal airflow. Additionally, many are transitioning from air-cooled split systems to centralized Variable Refrigerant Flow (VRF) systems and chilled water air-conditioners for better energy management and cooling. However, only about 36% of firms have adopted these strategies.

ii) Resource Conservation

Resource conserving initiatives focus on minimizing waste generation and optimizing resource utilization within semiconductor manufacturing processes. For production, about 45% of companies have implemented water conservation measures. They use "3R" practices—reduce, recycle, and reuse—to minimize environmental impact and costs. Key initiatives include water recycling, deionization, transitioning from single-spindle to dual-spindle machines to increase wafer production without extra water use, and investing in Industrial Effluent Treatment Systems (IETS) for wastewater treatment and reuse. For non-production water use, many companies employ rainwater harvesting and collection systems for lightly contaminated wastewater, reducing freshwater demand and wastewater disposal impact. They also adopt smaller measures like leak

[20] A caveat is that the number of measures is solely based on what has been reported or chosen to be reported by companies. It's possible that companies have additional initiatives that have not been included in their annual reports, potentially resulting in a downward bias in the total number of initiatives reported. Also, although the measures and strategies are not inherently mutually exclusive, they have been categorized into five themes for the purpose of facilitating the analysis.

detection, repairs, and regular maintenance. For instance, *ViTrox Campus 2.0* introduced a foot-operated, water-efficient tap to control water flow, reducing waste and enhancing hygiene.
Table 6 shows that about 87% of the 31 surveyed companies have reported waste management strategies in their Annual Reports, making it the most implemented measure. These strategies are based on the 3R principles. Facilities use recycling bins to facilitate waste segregation and raise awareness among employees. Initiatives include reusing packaging cartons and sending hazardous waste to licensed third-party disposal services for treatment according to the Environmental Quality Act and Regulations. Hazardous waste is disposed of by incineration, recovery, or chemical washing, while non-hazardous waste goes to landfills or recycling. Some companies also recycle e-waste to recover valuable materials like aluminum, gold, silver, and copper.

The second most common strategy, reported by 71% of companies, focuses on raising employee awareness. Policies encourage practices such as turning off lights, using energy-saving features, and unplugging unused equipment to reduce carbon footprints. Initiatives include going paperless, reducing plastic use, recycling, and making donations to animal conservation. Additionally, companies have installed electric vehicle (EV) charging stations and, like *ViTrox Corporation Bhd*, support sustainable transportation with carpooling parking spots through its “Green Fleet” strategy.

iii) Infrastructure and Facilities Improvements

Several companies enhance their sites with extensive tree planting and landscaping. *ViTrox Corporation Bhd* established a farm producing pesticide-free vegetables and fruits for their V-Meal program. Despite the benefits, only 13% (4 companies) reported such initiatives in their annual reports. These efforts support biodiversity and foster healthier ecosystems within company premises. About 19% of companies have implemented eco-friendly building designs. Window tinting reduces heat entry, lowering air conditioning use. Some designs utilize natural sunlight ("light wells" by *Aemulus Holdings Berhad*) and efficient wind circulation to cut electricity and air conditioning reliance. ViTrox's Interlocking Pavement Technique promotes natural water filtration and reduces heat island effects. *D&O Green Technologies Berhad* built a new hostel closer to the workplace, reducing transport emissions by approximately 68 tCO2e/year from 2023.

iv) Innovation and Technology

Sensor technology is used in rooms and washrooms to minimize energy consumption. Six companies (19%) use sensors for lighting and timers for machines to ensure efficient energy usage. Environmental considerations also extend to packaging, with a shift to recyclable materials like cardboard and certain plastics. Table 6 shows around 36% of semiconductor companies use green machinery, such as energy-saving and hydraulically driven machines, and Lithium Battery Electric Forklifts. EV buggy we also used for on-site commuting.

Other technologies include energy-efficient HVAC systems, achieved by replacing equipment with high-efficiency rotary screw systems with Variable Frequency Drive (VFD) control and installing energy-efficient chillers. VFD control optimizes system operation to match output needs, saving energy and reducing emissions. One notable technology is the Intelligent Flow Controller (IFC), which optimizes fluid flow rates, reducing energy usage from over-pumping or inefficient flow control.

D&O Green Technologies Berhad employs a dual approach: creating environmentally beneficial products for customers and improving operational processes to reduce emissions. For instance, they designed a smaller, slimmer LED, saving 200 kg of copper, 300 kg of plastic, and reducing carbon emissions by 1 tonne in 2022. Additionally, they replaced full-plated lead frames with selective-plated ones and increased lead frame density, saving 1,541 tCO_2e emissions and reducing waste by 13.9 tonnes. However, only 3 companies (10%) reported embracing this form of product stewardship, focusing on sustainability through sustainable sourcing and eco-friendly product design to mitigate Scope 3 emissions.

v) Other Sustainability Measures in Operations

While carbon emissions are a concern, they are not the main source of GHG emissions in semiconductor manufacturing. Instead, semiconductor production primarily emits potent fluorinated gases like perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). To reduce GHG emissions, companies engage certified professionals for annual air pollutant monitoring as per the Environmental Quality (Clean Air) Regulation 2014, which sets limits for pollutants like particulate matter and nitrogen oxides. Approximately 40% of companies have installed scrubber systems to filter these emissions (Table 6).

One unique strategy is the use of in-house restaurants to support sustainability. *ViTrox Corporation Bhd* implements a circular economy model with its V-meals program, offering pesticide-free produce from its V-farm, which is fertilized with campus food waste and irrigated with harvested rainwater. This initiative reduced CO_2 emissions by 479,279 kg in 2022. Similarly, *Mi Technovation Berhad's* SkyOasis restaurant addresses food waste with reusable mugs and cutlery as part of its "*Mi Anti-Food Waste*" program launched in October 2022. Only two companies reported using these strategies, making them the least common sustainability approaches in the semiconductor industry.

Table 6: Summary of Environmental Initiatives in Semiconductor Companies

	Environmental Initiatives	No. of Companies	% (N=31)
Energy Efficiency and Renewable Energy			
1.	Solar Panels	11	35.5
2.	LED lighting	16	51.6
3.	Air-conditioning management	11	35.5
Resource Conservation:			
4.	Recycle Water / Deionized/water saving	14	45.2
5.	Waste management	27	87.1
6.	Environmental Awareness/activities	22	71.0
Infrastructure and Facilities Improvements:			
7.	Landscaping (trees)	4	12.9
8.	Holistic campus/building	6	19.4
Innovation and Technology			
9.	Sensors	6	19.4
10.	Process Improvement	11	35.5
11.	Product Stewardship / Improvements	3	9.7
Other Sustainability Measures in Operations:			
12.	Air / Emissions Control	12	38.7
13.	Meals/own farm/in-house restaurant	2	6.5

Source: Source: Data analyzed from annual reports of 31 semiconductor companies

Section 5: Conclusion

Malaysia's semiconductor industry is one of the country's main engines of job creation and growth. The industry serves as a pivotal catalyst for the advancement of "green technology." In our acknowledgement for innovations like such as electric vehicles (EVs) solar panels, and smart grids, it is imperative to acknowledge that these innovations will invariably amplify the demand for semiconductors. Without control measures, the emissions resulting from the surge in semiconductor demand could negate the environmental benefits of these green technologies. This is mainly because the semiconductor industry emits gases with very high Global Warming Potentials (GWPs). Improving environmental standards in the semiconductor sector directly aligns with Malaysia's efforts to ascend the industrial ladder and fits seamlessly into the broader goals of the NIMP 2030 plan. To summarize, several key factors highlight the significance of this relationship.

Moving towards Net Zero, enhancing environmental standards can make the Malaysian semiconductor sector more attractive to international investors, particularly those who prioritize sustainability and ESG (Environmental, Social, and Governance) criteria. Global investors are increasingly focusing on sustainable practices, and companies that adhere to high environmental standards are viewed more favorably. By aligning with these expectations, Malaysia can attract higher-quality foreign direct investment (FDI), which brings not only capital but also advanced technologies and expertise. This influx of sustainable investment supports Malaysia's goal of becoming a more technologically advanced and industrialized nation. Adopting stringent environmental standards can boost the competitiveness of Malaysia's semiconductor industry on the global stage. As environmental regulations tighten worldwide, companies that already comply with high standards will have a competitive edge. This can open up new markets and maintain existing ones, ensuring that Malaysian semiconductor products meet international environmental standards, thus enhancing their marketability.

The push towards improved environmental standards necessitates innovation and the adoption of advanced technologies. This drive for cleaner, more efficient processes can spur research and development within the sector, fostering technological advancements. Such innovations not only improve environmental outcomes but also enhance productivity and efficiency, which are critical components of industrial upgrading. This aligns with the NIMP 2030's emphasis on leveraging technology to propel industrial growth. Improving environmental standards also has broader economic and social benefits. It enhances the health and well-being of the population by reducing pollution and conserving natural resources. A healthier population contributes to a more productive workforce, which is vital for industrial growth. Moreover, sustainable practices can create new job opportunities in green technologies and services, further supporting Malaysia's economic development.

Policy Suggestions

To align the greening of the semiconductor sector with Malaysia's strategic industrialization objectives outlined in its latest masterplan, the following policies can be considered:

Fostering Conducive Business Environment for Industrial Upgrading

1. **Ensure a Conducive Business Environment**: To support Malaysia's semiconductor industry, it is essential to create a favorable business environment. According to MSIA (2023), talent is the most persistent impediment to the industry's development. Immediate actions include streamlining immigration policies to attract skilled foreign talent. For the long term, investing in education and training programs tailored to semiconductor skills is crucial. Collaborations between industry stakeholders and academic institutions can develop relevant training programs and research initiatives. Workforce development programs should also be implemented to enhance the skills of existing employees and promote higher value-added activities.
2. **Diversify the Semiconductor Ecosystem**: Malaysian semiconductor players are predominantly involved in back-end OSAT, volume packaging, and ATE and equipment production, with limited presence in high-end segments. To diversify, focus on establishing clusters for IC design, fabrication facilities, and high-technology packaging. The newly announced IC Design Park in Selangor is a promising initiative that should be replicated nationwide. Supporting the development of this cluster through a conducive business environment is essential for fostering local talent and innovation.
3. **Invest in Workforce Development**: Equip the workforce with skills needed for sustainable manufacturing and green technologies. Partner with educational institutions to integrate sustainability and clean technology into curricula relevant to the semiconductor industry. Launch public awareness campaigns on the benefits of sustainable practices and foster industry collaboration to share best practices and innovations.

Promoting Sustainability and Decarbonization

4. **Promote Green Infrastructure**: Invest in eco-industrial parks that emphasize resource efficiency and low-carbon operations. Ensure new industrial developments consider

sustainability in energy, water, and waste management. This approach will support sustainable growth and competitiveness in the global market

5. **Promote Decarbonization**: Enhance the industrialization of the semiconductor sector through decarbonization. Provide incentives for renewable energy adoption, such as subsidies, tax breaks, and grants for investments in solar and wind power. Implement feed-in tariffs to encourage renewable energy production by semiconductor manufacturers. Establish strict energy efficiency standards and offer incentives for companies meeting these standards. Support R&D initiatives focused on low-carbon and energy-efficient technologies through funding and partnerships between government, academia, and industry.
6. **Implement Carbon Pricing Mechanisms**: Introduce carbon pricing mechanisms, such as taxes or cap-and-trade systems, to incentivize reductions in greenhouse gas emissions. Use the revenue from carbon pricing to fund green projects and support companies transitioning to low-carbon operations. Encourage circular economy practices by supporting infrastructure and technologies for material recovery and waste reduction.
7. **Develop Green Financing Programs**: Establish green financing programs offering low-interest loans and other financial products for companies investing in sustainable technologies. Encourage private sector investment through public-private partnerships and risk-sharing mechanisms. Develop and enforce regulatory frameworks mandating emission reductions and sustainable practices and create certification schemes for high environmental standards.
8. **Address Water Consumption**: Introduce performance-based incentives, such as tax breaks or subsidies, to encourage companies to invest in water-saving technologies and practices. These measures will support sustainable water management and drive commitment to water efficiency.
9. **Advance Waste Management**: Expand waste management initiatives to include waste-to-energy technologies, such as anaerobic digestion and waste incineration with energy recovery. Provide incentives like feed-in tariffs or renewable energy credits to support these efforts. Encourage the use of recycled materials in packaging to foster a circular economy and reduce reliance on virgin resources
10. **Enhance Reporting and Data Quality**: Improve data quality and sustainability reporting by enforcing comprehensive disclosure requirements for emissions, energy consumption, water usage, and waste management. Strengthen enforcement mechanisms to ensure compliance and establish a centralized data repository to enhance monitoring and research capabilities**.**

Appendix: Firm Data Extracted from 31 Published Annual Reports & Other Sources

Company Name	Year of the Report	Market Capitalization (RM mil)	Founded	Employee	Materiality	Revenue (RM Million)	SCOPE 1 Emissions	SCOPE 2 Emissions (in '000)	SCOPE 3 Emissions (in '000)	SCOPE 1 Intensity	SCOPE 2 Intensity	SCOPE 3 Intensity
INARI AMERTRON BERHAD	2023	11914	2006	6000	2	1,354.00	58.00	60.09		0.04	0.04	
VITROX CORPORATION BHD	2022	7204	2000	890	1	750.25	12.30	3.85		0.02	0.01	
MALAYSIAN PACIFIC INDUSTRIES	2022	6569	1962	7620	6	2,416.00	3976.18	194.83		1.65	0.08	
UNISEM (M) BHD	2023	6097	1989	6000	1	1,439.70	100.00	82.10		0.07	0.06	
FRONTKEN CORPORATION BHD	2022	6084	1996	1320		571.18	1671.00	10.43	51.62	2.93	0.02	0.09
GREATECH TECHNOLOGY BERHAD	2022	5882	1997	1250	2	546.21	45.69	8.38		0.08	0.02	
D & O GREEN TECHNOLOGIES BERHAD	2022	3987	2000	2730	8	983.0	47.00	25.25	16.58	0.05	0.03	0.02
UWC BERHAD	2023	3229	1990	1031		271.7	958.0	4.29	0.52	3.53	0.02	0.00
PENTAMASTER CORPORATION BHD	2022	3184	1991	802	1	600.6	1.4	4.31		0.002	0.01	
SFP TECH HOLDINGS BERHAD	2022	1704	2012	356	7	85.8		3.12			0.04	
MI TECHNOVATION BERHAD	2022	1665	2007	176	1	389.4		1.66			0.00	
GENETEC TECHNOLOGY BERHAD	2023	1581	1997	345	9	294.6						
DAGANG NEXCHANGE BERHAD	2022	1105	1970	2000	9	1457.4						
GLOBETRONICS TECHNOLOGY BHD	2022	986	1991	764	9	180.1	14.6	19.70		0.081	0.11	
JF TECHNOLOGY BHD	2023	834	1999	134	5	45.3		0.46			0.01	
OPPSTAR BERHAD	2023	672	2014	225.0	1	57.9		0.06			0.00	
QES GROUP BERHAD	2022	509	1991	420.0	5	264.0						
TT VISION HOLDINGS BERHAD	2022	463	2001	80.0		52.9						
ELSOFT RESEARCH BHD	2022	368	1996	68.0		28.1		0.55			0.02	
JHM CONSOLIDATION BHD	2022	336	2005	1213.0	2	355.8						
CNERGENZ BERHAD	2022	286	2004	58.0		216.9						
KESM INDUSTRIES BHD	2023	266	1972	867.0	8	228.3	2662.7	54.10		11.663	0.24	

CORAZA INTEGRATED TECHNOLOGY BERHAD	2022	262	2001	631.0		143.4						
AEMULUS HOLDINGS BERHAD	2023	245	2004	69.0		25.1						
ECA INTEGRATED SOLUTION BERHAD	2023	226	2016	89.0		35.6						
FOUNDPAC GROUP BERHAD	2023	202	2004	388.0		72.4						
MMS VENTURES BHD	2022	102	2004	81.0	1	52.9		0.18			0.00	
VISDYNAMICS HOLDINGS BHD	2023	101	2003	46.0		26.6						
KEY ASIC BHD	2023	70	2005	23.0		20.8						
INDUSTRONICS BHD	2023	35	1975	405.0		55.3						
MQ TECHNOLOGY BHD	2023	23	2003	712.0	1	6.8						

Company Name	Total Energy (kWh) ‘000	Energy intensity	Water	Water Intensity	Hazardous (H)	Non-Hazardous (NH)	Total (T)	(H) intensity	(NH) Intensity	(T) intensity
INARI AMERTRON BERHAD	93.25	68.9	633.50	467.87	116.83	596.23	713.06	0.086	0.44	0.53
VITROX CORPORATION BHD	6.89	9.2	39.50	52.65	1.20	121.00	122.00	0.002	0.16	0.16
MALAYSIAN PACIFIC INDUSTRIES	275.00	113.8	4,714.13	1951.21	39.36	171.25	210.61	0.016	0.07	0.09
UNISEM (M) BHD	122.77	85.3	2,024.00	1405.85	131.80	379.00	510.80	0.092	0.26	0.35
FRONTKEN CORPORATION BHD	21.22	37.1	265.48	464.79	659.00		659.00	1.154		1.15
GREATECH TECHNOLOGY BERHAD	12.25	22.4	22.41	41.02	58.75	151.52	210.27	0.108	0.28	0.38
D & O GREEN TECHNOLOGIES BERHAD	38.09	38.8	278.70	283.52	303.3	437.2	740.50	0.309	0.44	0.75
UWC BERHAD	7.33	27.0	164.92	606.91	733.0	0.6	733.58	2.697	0.002	2.70
PENTAMASTER CORPORATION BHD	6.46	10.8	30.29	50.44	0.2	117.1	117.30	0.000	0.19	0.20
SFP TECH HOLDINGS BERHAD	4.88	56.9	20.05	233.76			201.8	0.000	0.00	2.35
MI TECHNOVATION BERHAD	4.56	11.7	16.87	43.32	0.6	4.1	4.7	0.002	0.01	0.01
GENETEC TECHNOLOGY BERHAD	2.35	8.0	-	0.00	14.0			0.048		
DAGANG NEXCHANGE BERHAD	-	0.0	-	0.00						
GLOBETRONICS TECHNOLOGY BHD	28.39	157.6	331.36	1839.88			9.6			0.05
JF TECHNOLOGY BHD	1.09	24.0	6.28	138.44		1.2	4.2		0.03	0.09

OPPSTAR BERHAD	0.11	1.9	-	0.00						
QES GROUP BERHAD	-	0.0	-	0.00						
TT VISION HOLDINGS BERHAD	-	0.0	-	0.00						
ELSOFT RESEARCH BHD	0.81	28.90	-	0.00						
JHM CONSOLIDATION BHD	5.39	15.2	-	0.00						
CNERGENZ BERHAD	-	0.0	-	0.00						
KESM INDUSTRIES BHD	77.48	339.4	-	0.00						
CORAZA INTEGRATED TECHNOLOGY BERHAD	-	0.0	-	0.00			5.7			0.04
AEMULUS HOLDINGS BERHAD	-	0.0	-	0.00						
ECA INTEGRATED SOLUTION BERHAD	0.39	10.8	2.92	82.02						
FOUNDPAC GROUP BERHAD	0.23	3.2	-	0.00			1.1			0.02
MMS VENTURES BHD	0.25	4.8	-	0.00						
VISDYNAMICS HOLDINGS BHD	0.04	1.6	1.12	42.03						

Notes:

A caveat: The absence of data in the table does not necessarily indicate that certain companies did not collect any of these data. Similarly, the lack of certain data does not imply that companies did not take the initiative to enhance specific aspects. The table serves solely to indicate whether the data is present in the annual reports. All data extracted from the firm's Annual Reports.

Market capitalization is based on its valuation on 1st April 2024 using the website https://www.malaysiastock.biz/Listed-Companies.aspx?type=S&s1=17&s2=54

The year where the company was founded is based on https://simplywall.st/?view

Employee data is based on the Financial Times (FT) database https://www.ft.com/

Due to unstandardized reporting from the Annual reports, units for emissions are either in tCO_2 or <u>tCO_2e</u>. The ones reported in <u>tCO^2e</u> are underlined. ("tCO_2e" stands for "metric tons of carbon dioxide equivalent." This unit is used to measure the amount of greenhouse gases emitted by various sources. The "e" in tCO2e signifies that it includes not just carbon dioxide (CO2) emissions but also other greenhouse gases like methane (CH4) and nitrous oxide (N2O), which are converted into their CO2 equivalent based on their global warming potential.)

Data by MALAYSIAN PACIFIC INDUSTRIES, FRONTKEN CORPORATION BHD & MI TECHNOVATION BERHAD may include subsidiaries abroad or from other subsidiary sectors.

Waste data by UNISEM (M) BHD is divided by Diverted from Disposal and Directed to Disposal. However, only "directed to disposal" is reported here. Waste data by UWC BERHAD and SFP TECH HOLDINGS BERHAD also includes recycled waste in the mix.
MI TECHNOVATION BERHAD reported energy use based on average factory size. The annual report stated its factory size as 33278 sqm.
FOUNDPAC only reported the amount of reduction in total energy consumed. Therefore imply at least this amount is being used.

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