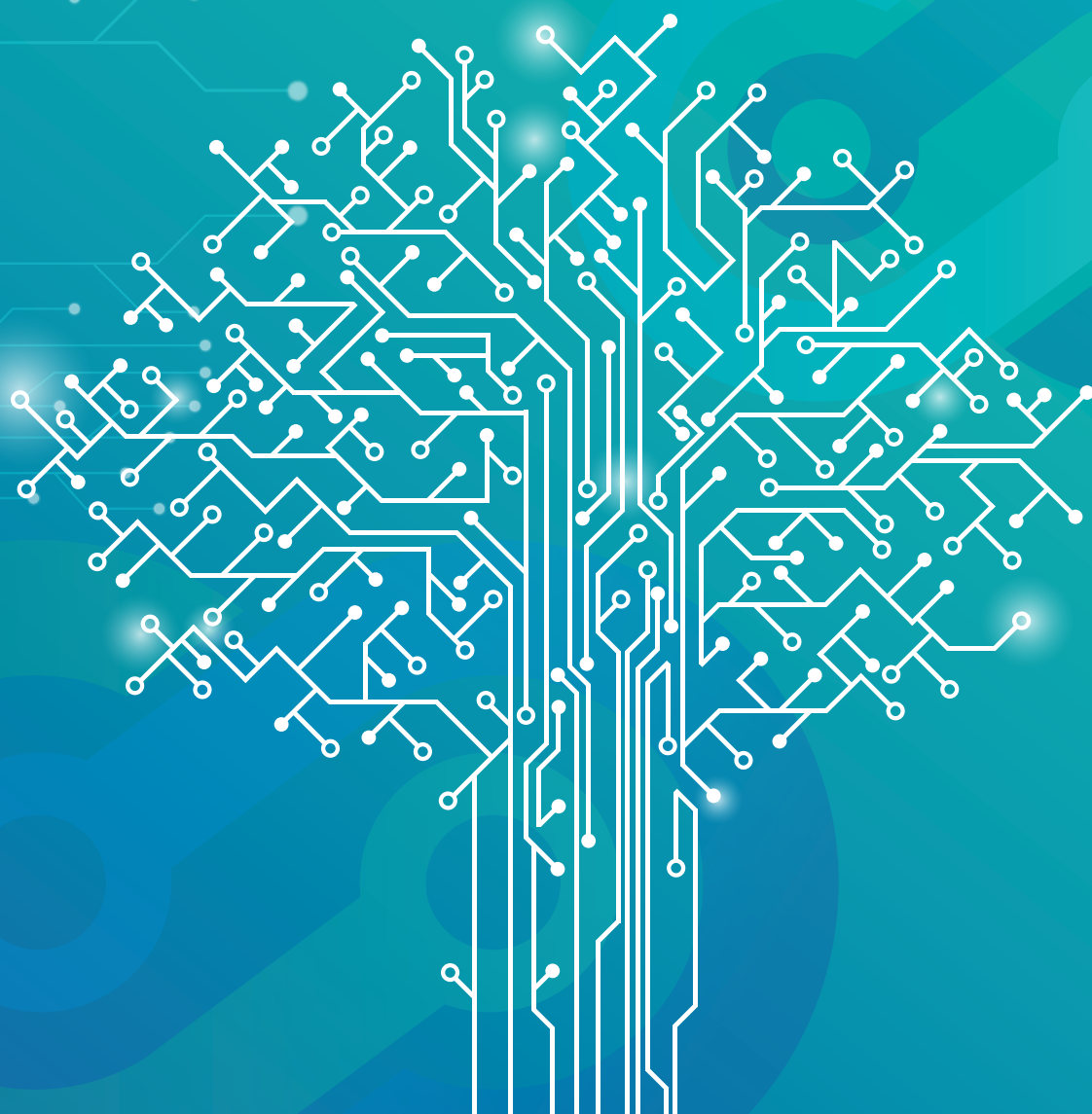


# Taiwan PCB Sustainable Carbon Reduction Strategy

2023



# Taiwan PCB Sustainable Carbon Reduction Strategy 2023

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## Chairman's Message

### Transformation Creates the Future

The PCB industry chain, which is deeply rooted in Taiwan for over half a century, has, with perseverance, weathered the changes of times and ups and downs, such as the financial crisis, the rise of Mainland China, the COVID-19 crisis, the launch of 5G networks and global geopolitical developments, etc. The PCB industry chain has transformed and advanced through each challenge, and in 2011, Taiwanese companies dominated the global PCB manufacturing industry. Since its establishment in 1998, the Taiwan Printed Circuit Association (TPCA) has grown together with the industry for more than 20 years. Through two white papers, TPCA has forged a consensus on the strategic development of the industry and has formulated a vision to build a highly competitive PCB industry in Taiwan with high value-added, green, and intelligent manufacturing. Major promotion projects, such as the blueprint for advanced technology, the blueprint for smart manufacturing, and the blueprint for a circular economy, have been launched, and through these initiatives, we aim to converge momentum to lead the transformation and upgrade of the PCB industry chain in Taiwan to expand the overall scale of the PCB industry chain in Taiwan to reach NT\$1 trillion by 2020.

In the face of extreme climate risks caused by global warming, may we translate rising awareness of net-zero sustainability into concrete actions. In the face of extreme climate risks caused by global warming, governments and major brand companies have been advocating carbon-neutral targets in recent years, making low-carbon transition a pivotal issue in national strategies and corporate restructuring. Taiwan's PCB industry, the world's leading PCB industry, with visionary ambition, independently initiated the "Taiwan PCB Sustainable Carbon Reduction Strategy" research project, supported by the Industrial Development Bureau, MOEA, and commissioned the Industrial Economics & Knowledge Center of the Industrial Technology Research Institute to conduct a year of rigorous research, inventory of the current status of Taiwan PCB greenhouse gas emissions, power consumption hot spots, carbon emissions reduction roadmap and target setting, culminating in the Taiwan PCB industry's low carbon transition strategy. The three main axes of promotion will be independent energy conservation, renewable energy and negative carbon/carbon trading, and the nine promotion directions will be extended to 39 industrial action guidelines and 27 government recommendations, which are expected to serve as a booster for the transformation of Taiwan's PCB industry once again, so that Taiwan's PCB industry can be at the forefront of net-zero transition.

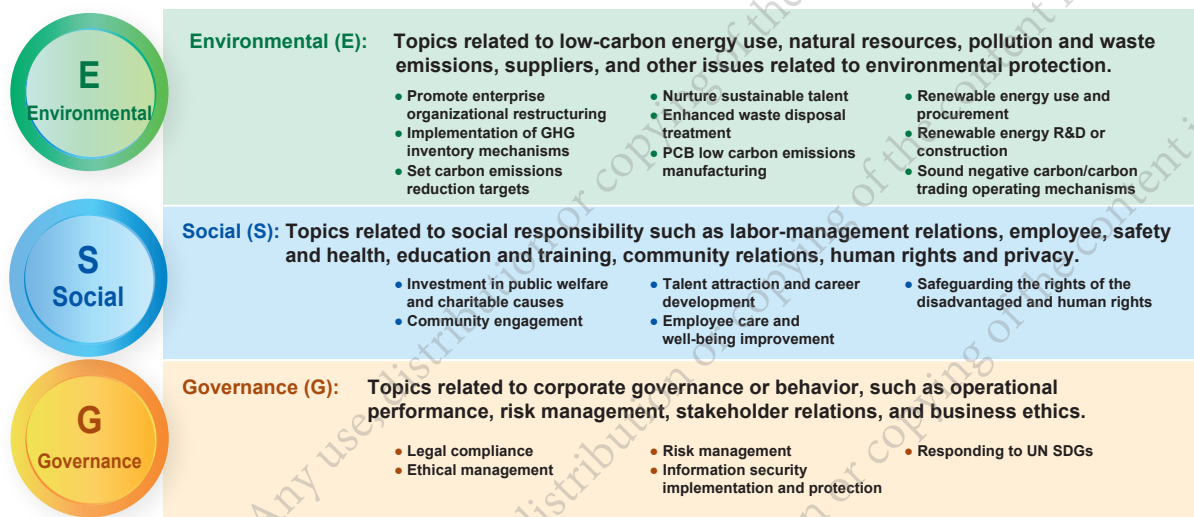
We would like to express our sincere gratitude to all contributors from the industry, government and academia, and research who participated in the "Taiwan PCB Sustainable Carbon Reduction Strategy". After nearly a year of research and discussion, the "Taiwan PCB Sustainable Carbon Reduction Strategy" was finally completed and proposed the main resources for promoting the development of the three main axes. It is imperative for industry, government, academia and research to jointly work together to implement the low-carbon roadmap one by one. We hope that the release of the "Taiwan PCB Sustainable Carbon Reduction Strategy" report symbolizes that Taiwan's PCB industry has embarked on a new milestone towards sustainability because actions are much more valuable than words!

*Maurice Lee.*

Chairman, Taiwan Printed Circuit Association  
Chairman of the Sustainable Development Committee

## I. Foreword

While sustainability remains an unchanging goal of corporate governance, net zero carbon emissions has reinterpreted the definition of "sustainability" and the implementation of related measures is no longer just a matter of ethics or corporate social responsibility to create a good corporate image. To stay ahead of the curve, ESG (Environmental; Social; Governance) will be the new playing field for companies facing global competition. Among them are global warming and extreme climate issues, and governments have made carbon emissions reduction an important policy objective. This trend will further affect the operational strategies of end customers and upstream and downstream supply chains and can even be considered a necessary condition for business operations. As a global leader, although Taiwan's PCB industry has achieved stellar results in the transition to higher value production, but in order to remain competitive in the net-zero trend, the industry must adopt an active carbon emissions reduction mindset and take immediate action.



Source: TPCA; IEK Consulting, ITRI

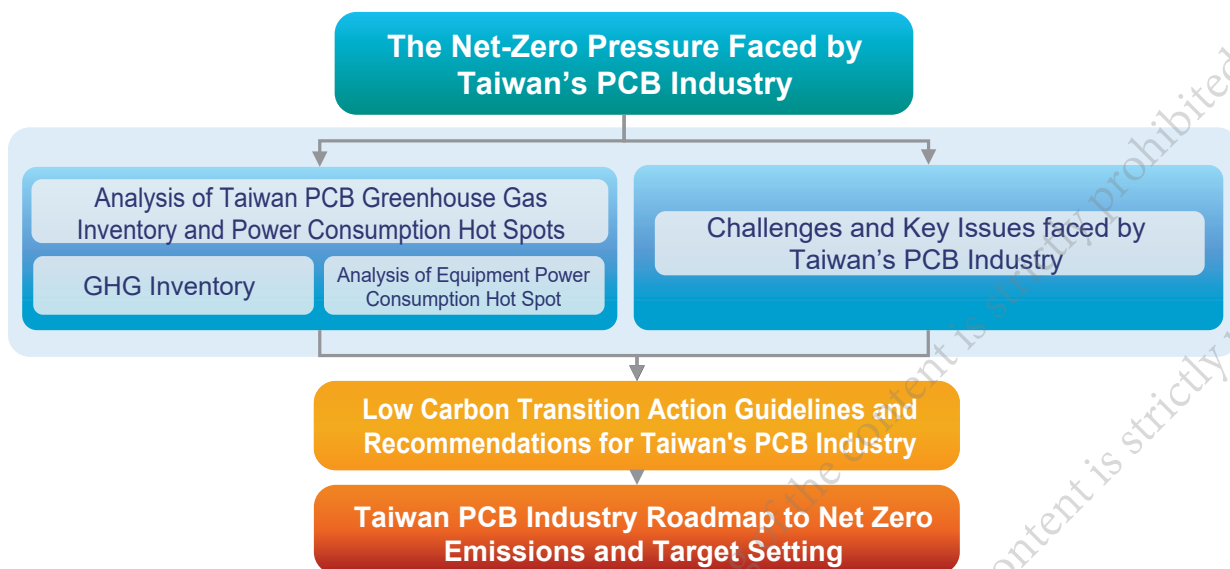
Figure 1: ESG framework and related issues

When facing various difficulties in energy saving and carbon emissions reduction, TPCA is ready to assist the industry in its development role by initiating the Taiwan PCB Industry Net-Zero Sustainable Development Strategy Proposal Project in 2022, titled "Taiwan PCB Sustainable Carbon Reduction Strategy", in the hope that this will bring together the strengths of all parties and consensus among industry players to jointly promote Taiwan's low-carbon, high-value PCB industry. The "Taiwan PCB Sustainable Carbon Reduction Strategy" focuses on environmental sustainability, in addition to the ESG indicators of Social and Governance, which companies must continue to work on to achieve sustainable management.

## II. "Taiwan PCB Sustainable Carbon Reduction Strategy" Framework and Description

The "Taiwan PCB Sustainable Carbon Reduction Strategy" was conducted after several months of rigorous research and due diligence including data collection, vendor visits and questionnaire analysis. The state of Taiwan's PCB industry and future scenarios is taken from an overall perspective, as the survey results cannot fully express or reflect the uniqueness of individual manufacturers due to the differences among them.

The main body of this paper is divided into six units in chapter order: the net-zero pressure faced by Taiwan's PCB industry, greenhouse gas inventory and power consumption hotspot analysis of Taiwan's PCB industry, the three major stages of low-carbon transition to promote the axis, the challenges and key issues facing the Taiwan's PCB industry, industry low-carbon transition strategy guidelines and recommendations



Source: IEK Consulting, ITRI

**Figure 2: "Taiwan PCB Sustainable Carbon Reduction Strategy" framework**

for Taiwan's PCB industry and Taiwan PCB industry's net-zero emissions roadmap and goal setting. The six main sections are organized in accordance with the current state of the industry and the inventory of problems, solutions and goals set in the context.

Taiwan PCB greenhouse gas inventory and hot spot analysis takes 2020 as the base year of the GHG inventory, and the production of PCB manufacturing in Taiwan as the scope of the GHG inventory exercise, excluding upstream raw materials and equipment manufacturers.

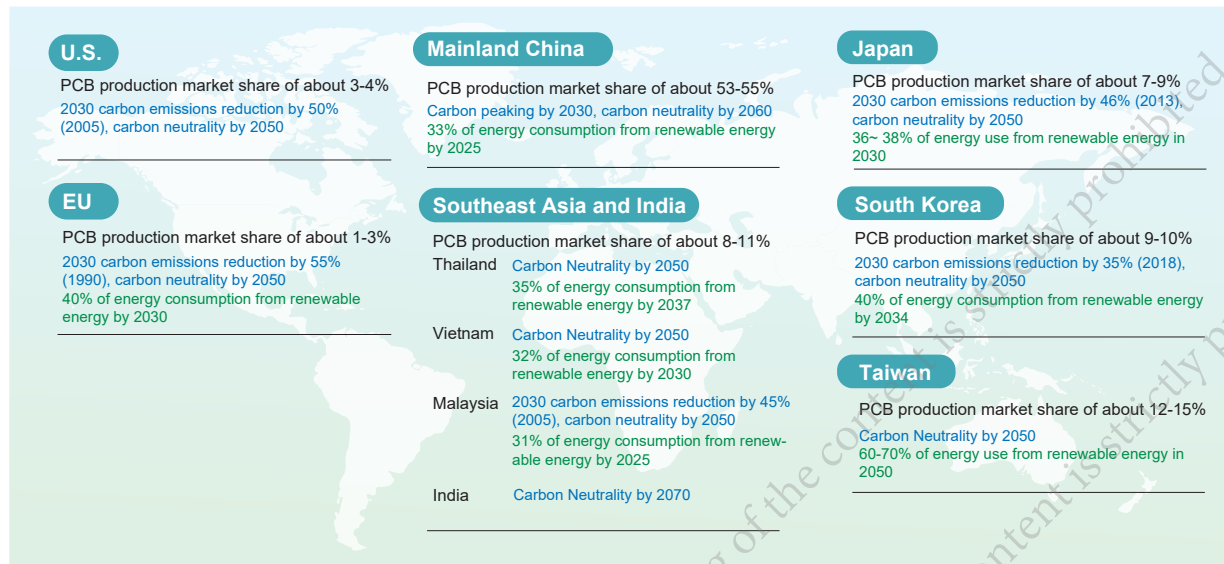
### III. Net-Zero Pressure Faced by Taiwan's PCB Industry

#### (1) Pressure from international and local governments

##### Carbon emissions reduction milestones for major global PCB production sites or regions

On the governmental level, in addition to helping enterprises to reduce carbon emissions to achieve net-zero strategy, the policies formulated to require enterprises to comply with will also be an important governance goal in the future. In other words, enterprises will face increasing international and government pressure. In terms of PCB production value, this includes China, Taiwan, South Korea, Japan, Southeast Asia and India, all have set the goal of carbon neutral or renewable energy proportional goals. In the EU, for example, according to the target set by the "European Climate Law", carbon emissions to be reduced by 2030 will be increased from 40% to 55% (compared to 1990). Furthermore, the "Fit for 55" release will also increase the proportion of renewable energy from 32% to 40% in 2030. In Korea, the "Carbon Neutral Green Growth in Response to the Climate Crisis Act" explicitly sets the greenhouse gas reduction target at 35% by 2030, while the energy policy of "Energy Plan for the Conversion of Fossil Fuels and Nuclear Energy to Renewable Energy" estimates that the proportion of renewable energy will be increased to 40% by 2034. In the United States, President Biden has publicly pledged to reduce carbon by 50% by 2030 (compared to 2005), setting a very aggressive target.



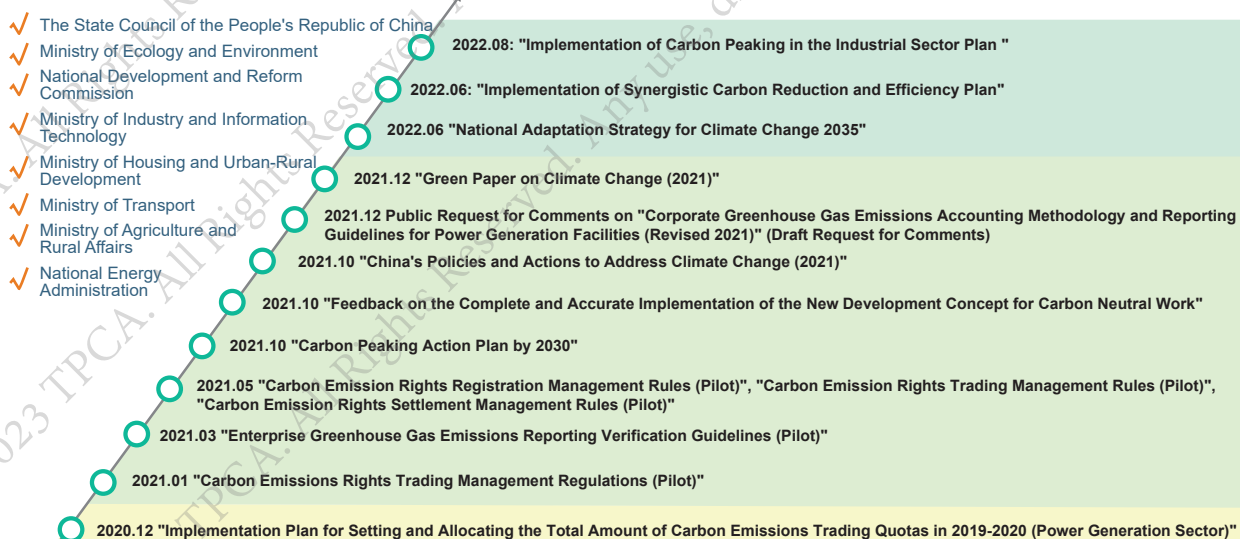


Source: IEK Consulting, ITRI

**Figure 3: Global major PCB production regions of the carbon emissions reduction phase target planning**

### China announced carbon emissions reduction related rules starting from the end of 2020

As the key PCB production center of the world, China, since the end of 2020, announced carbon emissions reduction-related rules which include: carbon trading, carbon rights, carbon emissions reduction guidelines and strategies. In addition to setting forth the general direction of development, these rules will also affect how relevant enterprises operate as more than 60% of Taiwan's PCB production value is produced in mainland China, hence companies that have set up factories in the region or are still evaluating the situation should pay special attention. The objectives mentioned in the "Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy" include: based on 2020, energy consumption per unit of GDP will drop by 13.5%, CO<sub>2</sub> emissions per unit of GDP will drop by 18%, and the proportion of non-petrochemical energy consumption



Source: IEK Consulting, ITRI

**Figure 4: Mainland China announces carbon emissions reduction related rules and regulations**



will reach 20% in 2025; by 2030, energy consumption per unit of GDP will drop by more than 65% compared to 2005, the proportion of non-petrochemical energy consumption will reach 25%, and the total installed capacity of wind power and photovoltaic energy will reach more than 1.2 billion kWh. By 2060, the proportion of non-petrochemical energy consumption will reach more than 80%, in order to achieve carbon neutrality. In addition, the initial operation framework of carbon trading in mainland China originated from the "Interim Measures for Carbon Emissions Trading Management" in 2014, and the related preparatory work officially commenced after the announcement of the "National Carbon Emissions Trading Market Construction Plan (Power Generation Industry)" in 2017. The formal implementation will be at the end of the year after the announcement in 2021 of the 3 regulations "Carbon Emission Rights Registration Management Rules (Trial)", "Carbon Emission Rights Trading Management Rules (Trial)" and "Carbon Emission Rights Settlement Management Rules (Trial)", in which the subject of the national carbon emission rights trading only includes the key emission units as well as the organizations and individuals that comply with the relevant national trading rules. Initial eligibility is still primarily for power producers, with institutions and individuals not yet defined.

### Korea is promoting 10 core technologies and is the first country in the world to enact a hydrogen energy law

Under President Moon Jae-in's administration, Korea launched a series of carbon emissions reduction policies, including the "Carbon Neutral Scenario 2050", the "Carbon Neutral Advancement Strategy 2050", and the "Carbon Neutral Technology Innovation Advancement Strategy", in addition to the above-mentioned "Carbon Neutral Green Growth in Response to the Climate Crisis Act" and the "Energy Plan for the Conversion of Fossil Fuels and Nuclear Energy to Renewable Energy". The "Carbon Neutral Innovation and Advancement Strategy" further announces 10 core technologies for energy conversion (solar and wind energy, hydrogen energy, bioenergy), industrial decarbonization (steel and cement, petrochemicals, high value industrial processes, CCUS), and energy efficiency (transportation efficiency, building efficiency, digitization). In addition to the overall framework, the Korean government is also active in the development of hydrogen energy. In addition to promoting the popularization of hydrogen fuel cells from 2019, the enactment of the Hydrogen Economy Promotion and Hydrogen Safety Management Act makes South Korea the first country in the world to legislate on hydrogen energy policies.

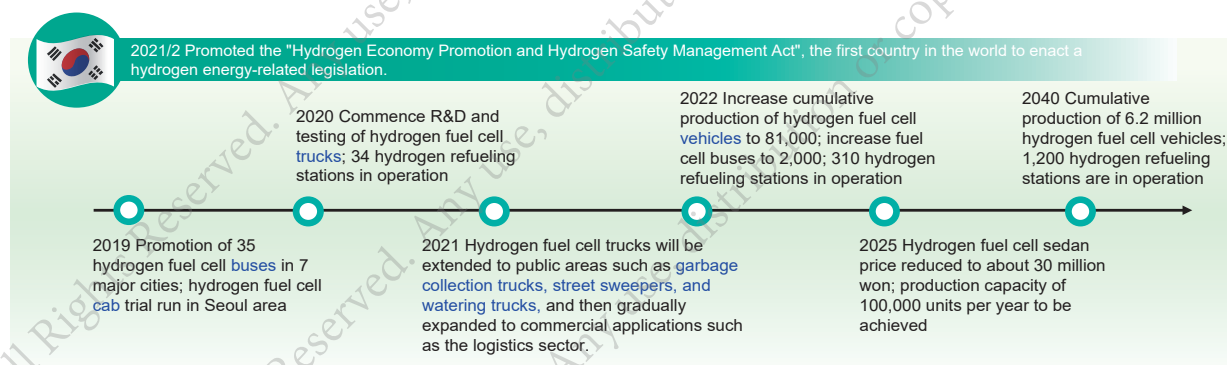


Figure 5: Hydrogen energy development history and planning in South Korea

### Japan adopts "2050 Net-Zero Carbon Emissions Green Growth Strategy" as a framework

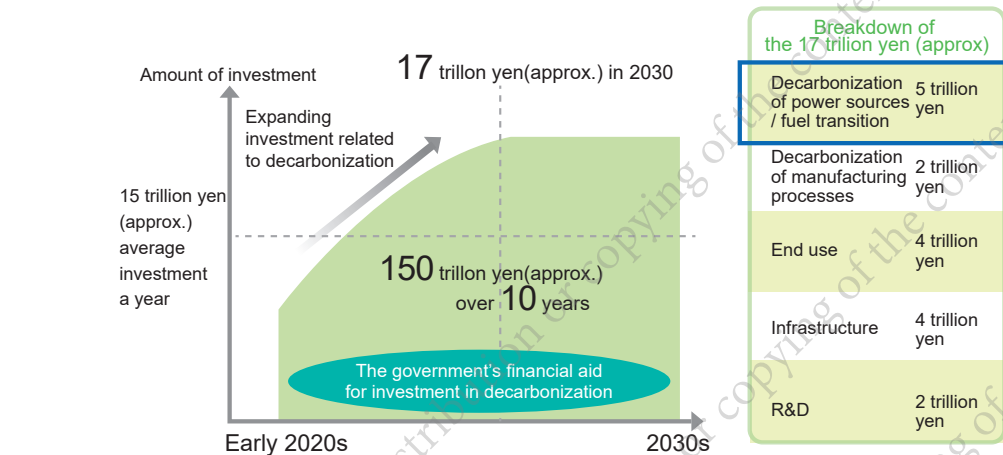
In October 2020, Japan's former prime minister, Yoshihide Suga, declared "Net Zero Carbon Emissions by 2050" as Japan's goal to combat global warming. In April 2021, he further set a new target of 46% or even 50% carbon emissions reduction by 2030 at the United Nations COP26 climate conference and proposed the "2050 Net Zero Carbon Emissions Green Growth Strategy". In the area of technology development, a 2 trillion yen Green Venture Fund has been established to support research and development in 14 carbon emissions reduction-related fields (next-generation renewable energy such as wind/geothermal/solar energy, ammonia fuel industry, hydrogen energy, nuclear energy, electric vehicles/batteries, semiconductors/communications, shipping, logistics/people flow/civil engineering infrastructure, food/agriculture, forestry and aquaculture, aviation, carbon recovery, building/next-generation power

management, resource recycling, and lifestyle). For clean energy, the Ministry of Economy, Trade and Industry commenced the "Clean Energy Strategy" study in December 2021, with the mid-2022 edition of the report estimating that investment related to carbon neutrality in 2050 will reach 17 trillion JPY in 2030, and will accumulate to 150 trillion JPY in the next decade. The Japanese government has also established a Joint Crediting Mechanism (JCM) with 17 governments, including Mongolia, Bangladesh, Ethiopia, Kenya, Maldives, Vietnam, Laos, Indonesia, Costa Rica, Palau, Cambodia, Mexico, Saudi Arabia, Chile, Myanmar, Thailand, and the Philippines.



2022/5 Release of "Clean Energy Strategy" Interim Report

### Scale & Timeframe of Investment Related to Decarbonization



Source: JAPANGOV

Figure 6: Japan's strategic investment amount in clean energy

## (2) Pressure from customers and competitors

**Most of the major brands have set goals to reach carbon neutrality or net-zero emissions between 2030 and 2040.**

Differences in the supply chain and resources available to different manufacturers will affect the timeline laid out. If we look at the representative brands highly relevant to Taiwan's electronic components industry, the timeline for achieving carbon neutrality, net zero emissions, or 100% renewable energy use is mainly between 2030 and 2040. Although the upstream component industry is generally slower to achieve its goals than brand-name manufacturers due to the high energy consumption and relative complexity of the manufacturing process, and perhaps the requirements from customers vary from company to company at this stage, customers are compelled to increase the pressure on their supply chains in the future in order to fulfill their ESG commitments, and PCB manufacturers must be consciously prepared in advance.



Source: IEK Consulting, ITRI

Figure 7: Timeline of 100% renewable energy/carbon neutral/net-zero emission targets for major branded plants

**Table 1: Carbon emissions reduction targets for major EMS and semiconductor plants**

Enterprise	Phased Targets
Hon Hai Precision	<ul style="list-style-type: none"> <li>With 2020 as the base year, carbon emissions will be reduced by 21% in 2025, 42% in 2030 and 63% in 2035.</li> <li>50% share of renewable energy in 2030</li> </ul>
Pegatron	<ul style="list-style-type: none"> <li>With 2019 as the base year, 25% reduction in GHG emissions and 25% reduction in electricity consumption per unit of revenue in 2030,</li> </ul>
Compal	<ul style="list-style-type: none"> <li>With 2019 as the base year, reduce carbon emissions by 4.2% per year to reach 50% reduction by 2030</li> </ul>
Jabil	<ul style="list-style-type: none"> <li>With 2019 as the base year, 25% GHG reduction by 2025</li> </ul>
Flextronics	<ul style="list-style-type: none"> <li>With 2019 as the base year, 50% GHG reduction by 2030</li> <li>50% of suppliers are required to set carbon emissions reduction targets by 2025; 100% of suppliers are required to set carbon emissions reduction targets by 2030</li> </ul>
Qualcomm	<ul style="list-style-type: none"> <li>Achieving net zero carbon emissions in 2040 itself and in the supply chain</li> </ul>
Intel	<ul style="list-style-type: none"> <li>Achieve 100% renewable energy in 2030; achieve net zero carbon emissions in 2040</li> </ul>
ARM	<ul style="list-style-type: none"> <li>Achieve net zero carbon emissions by 2030</li> </ul>
Mediatek	<ul style="list-style-type: none"> <li>100% renewable energy by 2030</li> </ul>
Infineon	<ul style="list-style-type: none"> <li>Achieve carbon neutrality by 2030</li> </ul>

Source: Companies; compiled by IEK Consulting, ITRI

### Among PCB companies, Japan has the largest number of companies that have made public their carbon emissions reduction targets

In terms of the PCB industry, at the current stage, the public commitment to carbon emissions reduction targets are mostly concentrated in large enterprises with generous resources. In the public commitment to carbon emissions reduction targets among PCB manufacturers, Japan has seen more companies making public commitments and the vast majority of them disclosed their phased target setting in 2021. If we look at the planning of Japanese companies, although the targets set by individual companies are different, if we cut the base year to 2020, the reduction in carbon emissions by 2030 will range from 20% to 45%, with the average falling between 28% and 33%.

**Table 2: Carbon emissions reduction targets publicly committed by PCB companies**

Enterprise	Phased Targets
Zheng Ding Tech	Taiwan • 40% reduction in greenhouse gas emissions by 2025, using 2013 as the base year
Unimicron	Taiwan • With 2020 as the base year, 25% carbon emissions reduction in 2030
Unitech PCB	Taiwan • With 2020 as the base year, 30% carbon emissions reduction in 2030
FLEXium	Taiwan • 100% renewable energy by 2040
Ibiden	Japan • With 2017 as the base year, carbon emissions reduction of 16% by 2030
Shinko	Japan • With 2020 as the base year, carbon emissions reduction of 42% by 2030
Sumitomo	Japan • With 2019 as the base year, carbon emissions reduction of 50% by 2035
Meiko	Japan • With 2013 as the base year, carbon emissions reduction of 50% by 2030
Fujikura	Japan • With 2018 as the base year, 20% carbon emissions reduction in 2025 and 45% renewable energy in 2030
Nitto	Japan • With 2013 as the base year, 40% CO <sub>2</sub> reduction by 2030
LG-Innotek	South Korea • 2030: 100% renewable energy; 2040: reduce net CO <sub>2</sub> emissions to zero
SEMCO	South Korea • With 2014 as the base year, target 7% reduction in carbon emissions by 2025 100% share of renewable energy in 2050
AT&S	Austria • 2025: Renewable energy reaches 80%; 2030: Factory Scope 1 direct emissions reduced to zero

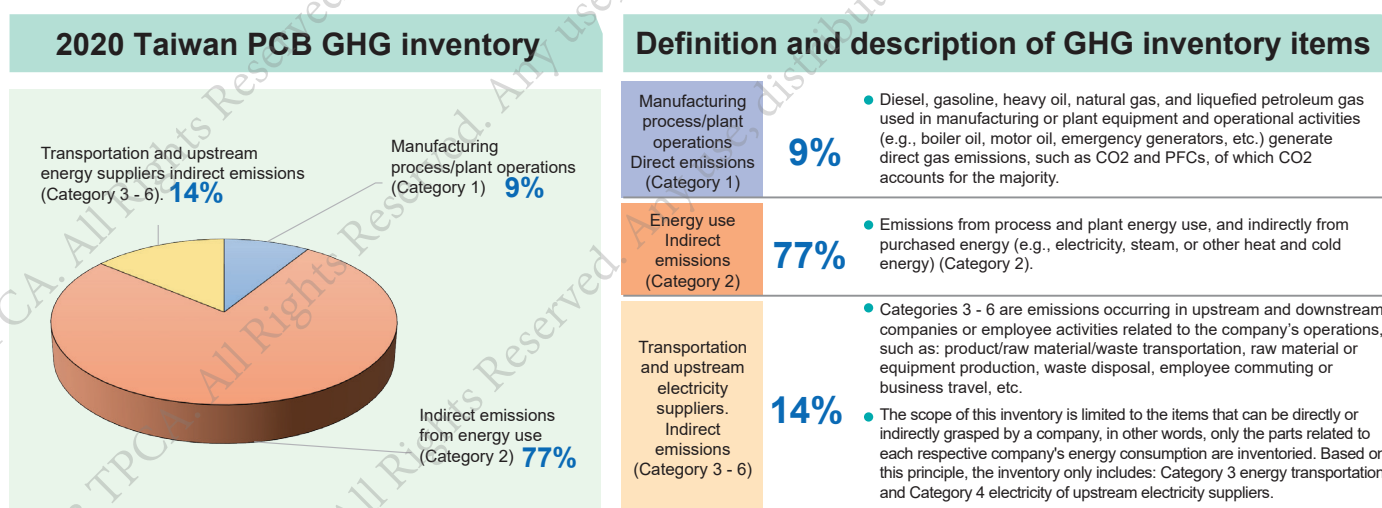
Source: IEK Consulting, ITRI

## IV. Taiwan PCB Greenhouse Gas Inventory and Power Consumption Hot Spot Analysis

### (1) Taiwan PCB industry greenhouse gas inventory definition and scope description

Taiwan's PCB industry greenhouse gas inventory and terminology expression adopts the definition of ISO 14064-1 (2018), based on the inventory data of individual manufacturers, and considers the product structure, the proportion of production value, the proportion of energy consumption and other relevant parameters and weights to estimate the overall industry. In considering that most of the PCB enterprises have not yet conducted a complete GHG inventory at this stage, from the perspective of the industry as a whole, for this report, only the items with higher correlation of energy consumption within the enterprise are subject to limited GHG inventory, including: Category 1 direct emissions from processes/plants, Category 2 indirect emissions from energy use, Category 3 indirect emissions from energy transportation, and Category 4 indirect emissions from upstream electricity, which will be adjusted in the future depending on the improvement of the enterprises' GHG inventory capacity.

Overall, in 2020, Taiwan's PCB industry's (PCBs produced in Taiwan) had total GHG emissions of 3,471,728 tCO<sub>2</sub>e (hereinafter referred to as about 3.47 million tons of CO<sub>2</sub>e), the proportion of distribution in order of category 9% (Category 1), 77% (Category 2) and 14% (Category 3 ~ 6), of which category 3 ~ 6 only had a limited GHG inventory. The above data is based on manufacturers' announcements or feedback data results for industry projections. However, due to the differences in GHG inventory capability and experience, items recognized, data collection capability, degree of automation, product structure and process conditions, the GHG inventory results vary greatly among manufacturers or plants, with a margin of error of plus or minus 10% in 2020. In addition, with 2020 was the initial phase of GHG inventory, most PCB manufacturers were still in the stage of exploration and learning, and this margin of error will be reduced year by year with the accumulation of experience in GHG inventory exercises, the establishment of GHG inventory standards, and the increase of data acquisition and data retention integrity.



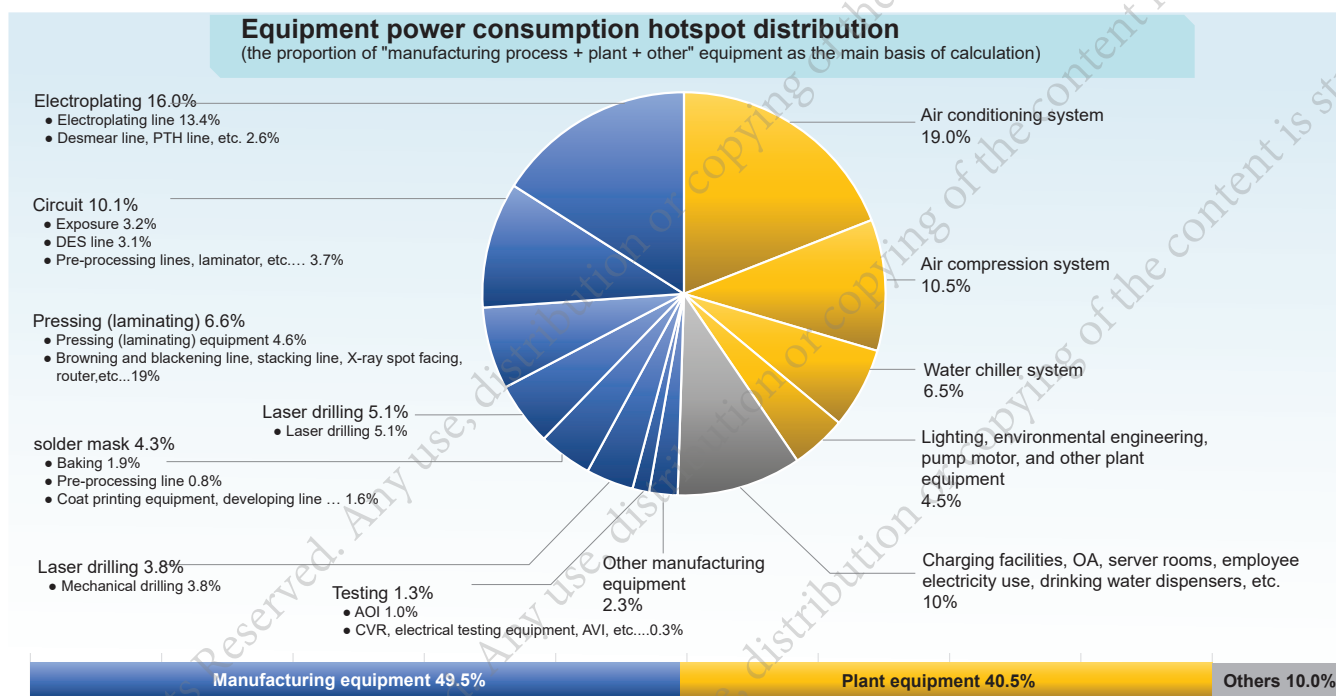
Source: TPCA; IEK Consulting, ITRI

Figure 8: 2020 Taiwan PCB greenhouse gas inventory

## (2) PCB equipment power consumption hot spot analysis

In 2020, the total energy consumption of Taiwan's PCB industry (PCBs produced in Taiwan) stood at about 17,664,562 gigajoules (GJ), which is equivalent to about 4.9 billion kWh of electricity; if compared to the results of the greenhouse gas inventory, the use of electricity from Category 2 accounts for the majority, so the following is a hot spot analysis according to electricity consumption.

Electricity-consuming equipment can be divided into process equipment, plant equipment and other equipment by type of application, accounting for 49.5%, 40.5% and 10% of the total electricity consumption respectively. The process equipment covers PCB production-related equipment, classified by major process stations and in order of power consumption: electroplating (16.0%), wiring (10.1%), lamination (6.6%), laser drilling (5.1%), solder mask (4.3%), machine drilling (3.8%), and inspection (1.3%). The percentage of plant equipment and power consumption for non-specific process stations are: air conditioning system (19.0%), air pressure system (10.5%), water cooling system (6.5%), and others (4.5%), in respective order. Other equipment is used for process or plant equipment, such as: charging facilities, OA, computers, machine rooms, staff electricity, water dispensers, etc.



Source: TPCA; IEK Consulting

**Figure 9: Analysis of PCB industry power consumption hotspots in Taiwan**

## V. PCB Low-Carbon Transition: Three Major Phases to Promote the Main Axes

### (1) Three main driving axis: independent energy saving, renewable energy, and negative carbon/carbon trading

In general, Taiwan's PCB industry will adopt a dual model of independent energy saving and renewable energy introduction until 2030, and a multi-pronged approach of expanding renewable energy and supplementing with independent energy saving and negative carbon/carbon trading in the middle and late stages, gradually moving towards the goal of net zero emissions by 2050.

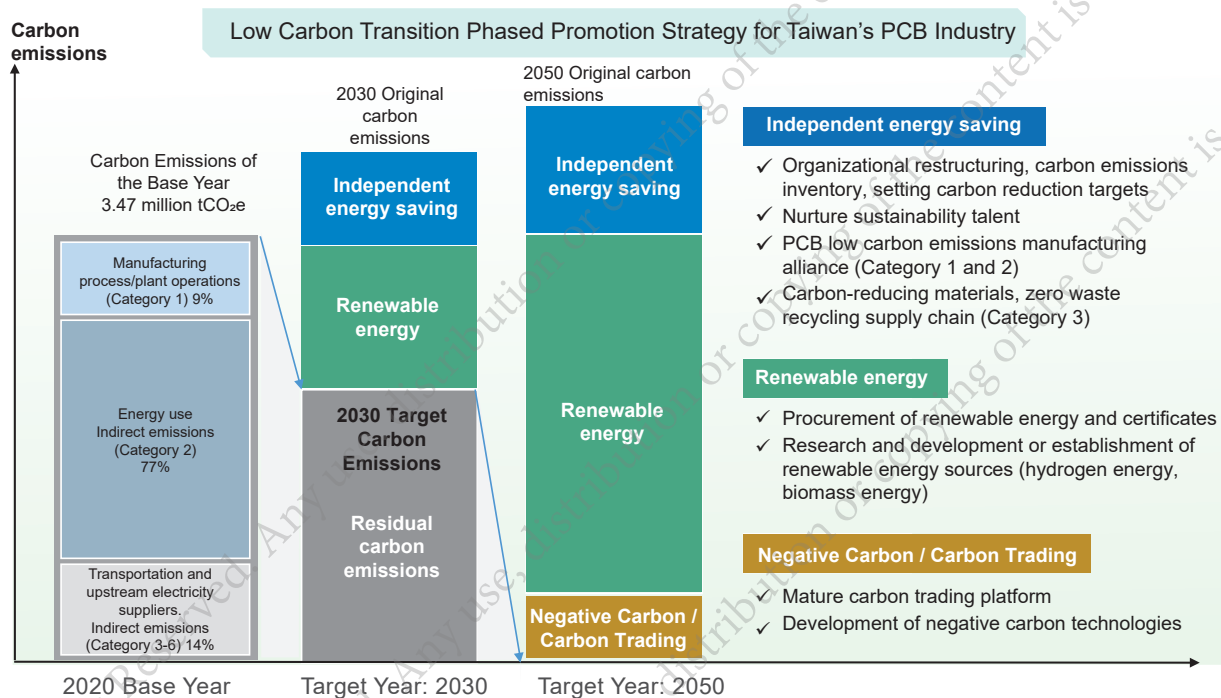
**Main Axis I (Independent Energy Saving):** Reduce greenhouse gas emissions, such



as reducing the use of high-carbon emission fuels, developing next-generation carbon-reducing materials, reducing VOC emissions, etc.; enhance energy use efficiency, such as improving energy consumption of processes and plant equipment, next-generation low energy consumption processes or equipment, intelligent energy monitoring and management systems, etc.; promote supply chain and waste reduction, such as low-carbon supply chain management, recycling efficiency improvement, waste reduction, etc.

**Axis 2 (Renewable Energy):** Construction of new type of power generation facilities, such as the development of new type of power generation equipment and energy storage technology such as hydrogen and biomass, to reduce the use of old diesel generators; the use of renewable energy and certificates as the basis for calculation of greenhouse gas inventory Category 2.

**Axis 3 (Negative Carbon/Carbon Trading):** Implement carbon offsets to offset remaining carbon emissions through natural carbon sinks, negative carbon technologies or carbon trading.

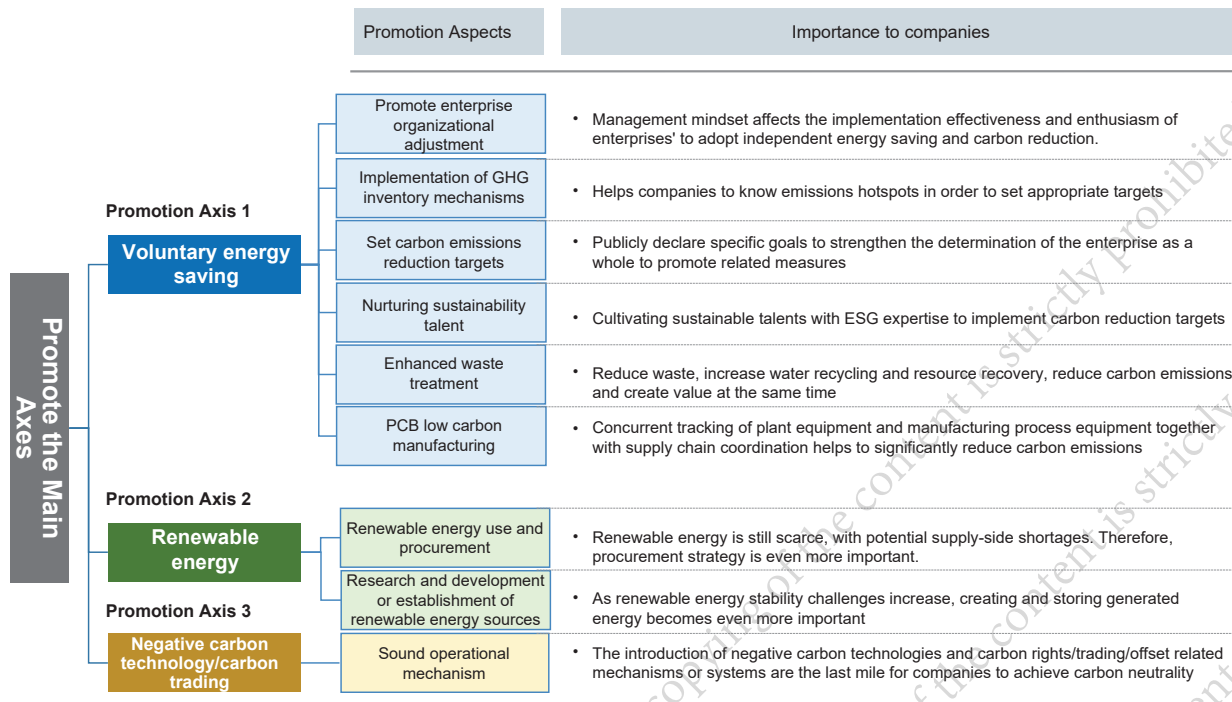


**Figure 10: Low Carbon Transition Phased Promotion Strategy for Taiwan's PCB Industry**

## (2) 9 major promotion aspects

For most companies, past efforts in energy saving and carbon emissions reduction is mainly built on the framework of savings in expenditure, in the absence of external mandatory requirements, the implementation of the force or scale are limited, in other words, the Taiwan PCB industry or individual companies face greater intensity of carbon neutral or net-zero emissions trend and is bound to go through the process of transition and adjustment. The following are the three main axes of promoting energy conservation, renewable energy, and negative carbon/carbon trading to nine major aspects of promotion: promoting organizational adjustment of enterprises, implementing GHG inventory mechanism, setting carbon emissions reduction targets, cultivating sustainable talents, strengthening waste treatment, PCB low-carbon manufacturing, renewable energy use and procurement, renewable energy research and development or construction, and sound operation mechanism.





Source: TPCA; IEK Consulting, ITRI

**Figure 11: PCB industry low carbon transition - 9 major aspects of promotion**

## VI. Challenges and Key Issues Faced by Taiwan's PCB Industry

Carbon emissions reduction is a cross-disciplinary issue, and enterprises still face many challenges in the process of promoting it. In addition to their own level of enthusiasm, the soundness of the external environment will also affect the effectiveness of implementation. The following is a list of 21 challenges and key issues faced by the industry in three main axes and nine major directions.

### (A) Voluntary energy saving

**Table 3: Challenges and key issues in promoting Axis 1 (autonomous energy saving) (15 items in total)**

Promotion Aspects	Challenges and Key Issue Descriptions	
Promote enterprise organizational adjustment	Although companies are aware that net-zero emissions will profoundly change the way they operate, only a few have set up dedicated units to deal with integration issues, and ESG-related knowledge and capabilities are generally lacking.	
	Challenges and Key Issues	<ol style="list-style-type: none"> <li>1. The existing organizational division of labor can not respond to change management associated with net-zero transition</li> <li>2. Insufficient ESG knowledge and grasp of data, not easy to assess the benefits</li> <li>3. Sustainability ratings are multi-faceted and not easy for companies to integrate across departments</li> </ol>
Implementation of GHG inventory mechanisms	At present, only a few companies have carried out GHG inventory and product carbon footprint experience, and the overall PCB industry is relatively new to GHG inventory. PCB products are diversified, due to cost constraints, it is also not easy to expand the GHG inventory on product carbon footprint.	
	Challenges and Key Issues	<ol style="list-style-type: none"> <li>4. Companies generally lack the experience of organizing type and product carbon footprint inventory</li> <li>5. Third-party GHG inventory organizations applicable to PCB industry is lacking, and due to cost constraints, unable to expand GHG inventory</li> </ol>
Set carbon emissions reduction targets	At this stage, Taiwan's renewable energy market still has many challenges to overcome, and the inability of companies to obtain sufficient information for assessment will affect the setting of carbon emissions reduction targets.	
	Challenges and Key Issues	<ol style="list-style-type: none"> <li>6. It is not yet possible to evaluate how to implement the planning environment after the initiative</li> <li>7. Renewable energy industry market expansion speed is limited, affecting assessment decisions</li> </ol>

Promotion Aspects	Challenges and Key Issue Descriptions	
Nurturing sustainability talent	The long-standing corporate culture or mindset overly focused on efficiency has affected the development focus of environmental talents as a whole, which in turn has led to an obvious shortage of carbon emissions reduction-related talents.	
	Challenges and Key Issues	8. Management still lacks complete ESG and sustainability knowledge 9. Low-carbon process and energy-related technology talents are insufficient
Enhanced waste treatment	Waste recycling requires investment of resources, and in the past it was difficult to generate sufficient incentives from the perspective of economic benefits, including: there is much room for strengthening the recycling industry, recycling programs and regulations.	
	Challenges and Key Issues	10. Business waste recycling circular ecosystem is not yet mature 11. Renewable resources-related certification and regulations have not been reconciled
PCB low carbon manufacturing	Although smart manufacturing, process improvement, low energy consumption equipment or raw materials are the directions that companies need to actively invest in, there are still many factors or problems to be considered or overcome in terms of actual implementation, and the development of low carbon manufacturing is challenging to a certain extent.	
	Challenges and Key Issues	12. Limited energy saving effect of plant equipment retirement 13. Carbon reducing material verification and high-level equipment technology threshold 14. High difficulty in linking upstream and downstream supply chains 15. Smart manufacturing is not yet in full swing, and energy efficiency optimization technology is not yet mature

Source: TPCA; IEK Consulting, ITRI

## (2) Renewable Energy

**Table 4: Challenges and key issues in promoting Axis II (Renewable Energy)**  
(4 items in total)

Promotion Aspects	Challenges and Key Issue Descriptions	
Procurement of renewable energy	The purchase of renewable energy is the most direct way to achieve net-zero emissions and is the main option in the long term, but the liberalization of the green power market is just at its nascent stage and the market mechanism is not yet complete.	
	Challenges and Key Issues	16. Only a few companies have experience in green power procurement 17. The reasonable price and procurement cost for green power or certificate is not easy to grasp
Building autonomous energy sources	The establishment of autonomous energy sources is an option considered by companies. However, at this stage, due to capital investment and site and space constraints, coupled with the lack of maturity of alternative renewable energy technologies, the scale and willingness to invest is limited.	
	Challenges and Key Issues	18. Insufficient conditions and incentives for the establishment of autonomous energy, and the willingness to develop 19. Independent research and development costs for renewable energy are high, the benefits are difficult to assess

Source: TPCA; IEK Consulting, ITRI

## (3) Negative Carbon / Carbon Trading

**Table 5: Challenges and key issues in promoting Axis 3 (Negative Carbon / Carbon Trading)** (2 items)

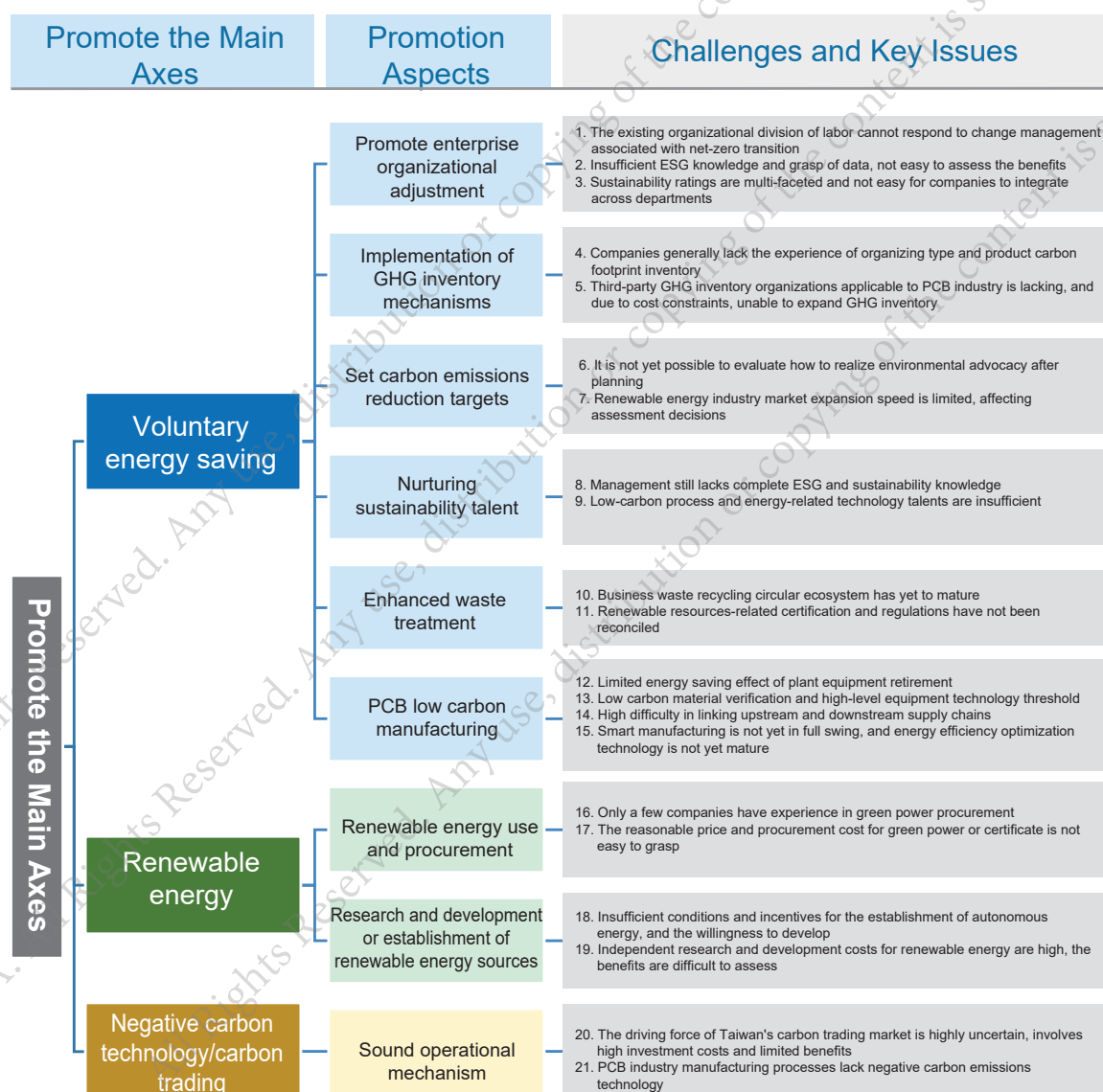
Promotion Aspects	Challenges and Key Issue Descriptions	
Sound operational mechanism	Taiwan's carbon rights and carbon trading system has not yet seen a concrete implementation schedule, and enterprises still have some degree of difficulty in obtaining relevant resources or collecting information.	
	Challenges and Key Issues	20. Taiwan's carbon trading market is driven by uncertainty, high investment costs and limited benefits 21. PCB industry process emissions lack of negative carbon technology

Source: TPCA; IEK Consulting, ITRI

## VII. Low Carbon Transition Action Guidelines and Recommendations for Taiwan's PCB Industry

### (1) Action guidelines and suggestions overview

In response to the different challenges and key issues, and concepts in addressing the problems, Figure 12 compiles 39 action guidelines and 27 recommendations for the PCB industry and the government in the short term (2022-2025) and long term (2026-2030), respectively, as the basis for subsequent promotion.



Source: TPCA; IEK Consulting, ITRI

Figure 12: Overview of low carbon transition strategies for Taiwan's PCB Industry

### Action Guidelines and Recommendations (2022-2025)

#### Industry

#### Government

Internal resource integration and organizational restructuring

Improve the guidelines for manufacturers

Inventory of corporate carbon emission hotspots, introduction of low carbon management system

Strengthen the capacity of industry GHG inventories

Strengthen corporate ESG structure, public declaration of goals

Provide ESG-related information for industry, carbon fee collections, improve supporting measures, and improve the green finance platform

Take stock of sustainable talent needs

Promote sustainable industry-academia cooperation projects

Inventory of resources and waste, reduction of non-recyclable waste types, improvement of water recycling, promotion of waste reduction at source by design, and expansion of waste resource recycling

Development of new waste treatment technologies, create a digital platform for recycling resources, adaptation of waste regulations

Improvement of energy consumption of plant and equipment systems, reduction of high-carbon emissions fuel use, R&D and upgrading of low-carbon emissions equipment, implementation of low-carbon supply chain management, digitalized real-time monitoring and control system

Implement low-carbon related incentives and subsidies

Targeted renewable energy procurement plan

Construction of diversified renewable energy infrastructure, sound renewable energy industry and business model

Feasibility assessment of autonomous energy

Strengthen the incentive mechanism for renewable energy development and encourage enterprises to invest in renewable energy industry

Raise awareness of domestic and international climate trends and negative carbon technology development

Establish an international low carbon information platform, establish a carbon certification mechanism

### Action Guidelines and Recommendations (2026-2030)

#### Industry

#### Government

Adjust business models and disclosure of sustainability information

Provide guidance to enterprises to connect to the sustainability system

Expand supply chain carbon emissions coefficient database, establish product carbon footprint inventory capability, develop carbon inventory smart systems

Promote digital transformation

Achieve goals and develop strategies to strengthen corporate sustainability image and influence

Foster low carbon transition of industries

Talent retention and expand recruitment

International talent

Develop a supply chain resource recycling cooperation platform, develop new technologies for low energy consumption and recycling, develop VOC emissions reduction technology

Assist in entering the international market, establish a waste recycling circular ecosystem or a specific industry park for the PCB industry

Invest in smart low-carbon plant equipment, develop next-generation low-carbon materials, develop next-generation low energy consumption processes, improve capability to calculate GHG emissions of equipment, promote low carbon supply chain ecosystem

Support forward-looking research and development resources and expand its benefits

Timely green power procurement strategy

Expand the supply of renewable energy

Independent energy technology innovation at PCB plants, Expand renewable energy investment pipeline

Create low-carbon demonstration parks

Evaluation and introduction of negative carbon solutions

Development of negative carbon technology, establish and improve the system and regulations

## (2) PCB industry action plan and promotion

This chapter further illustrates the 39 action guidelines for the PCB industry as shown in Figure 12, based on the three main axes of independent energy saving, renewable energy and negative carbon/carbon trading, and provides a reference for industry implementation direction through specific implementable projects.

### Voluntary energy saving

**Table 6: Summary and description of industry action guidelines for promoting Axis I (independent energy saving)**

Promotion Aspects	Industry Action Guidelines (2022~2025)	Industry Action Guidelines (2026~2030)
Promote enterprise organizational adjustment	<p>In the short term, companies reshape sustainability and ESG through internal resource integration and restructuring, while in the long term, they take a proactive approach to the implementation of relevant regulations.</p> <p><b>Internal resource integration and organizational restructuring</b></p> <ul style="list-style-type: none"> <li>Establish a dedicated sustainability or ESG unit</li> <li>Organizational restructuring, awareness and goal setting</li> </ul>	<p>Adjustment of business models</p> <ul style="list-style-type: none"> <li>Adjustment of product development strategy (according to lifespan, resource consumption, waste, type, ...)</li> </ul> <p>Continuous information disclosure</p> <ul style="list-style-type: none"> <li>Disclosure of information related to GHG inventory and verification by listed companies</li> </ul>
Implementation of GHG inventory mechanisms	<p>In the short term, focus on the establishment of standard SOPs and systems or databases, and in the long term, enhance the depth and breadth of GHG inventory through smart approaches.</p> <p><b>Inventory of GHG hotspots</b></p> <ul style="list-style-type: none"> <li>Inventory of carbon emission hotspots of companies and establishment of a database</li> <li>Listed companies complete carbon inventories and compile ESG reports</li> </ul> <p><b>Introduction of low carbon management system</b></p> <ul style="list-style-type: none"> <li>Establish the capability and mechanism of independent GHG inventory by companies</li> <li>Phased introduction of ISO14064:2018-, 14067- and ISO50001- related international standards</li> </ul>	<p><b>Expansion of supply chain carbon emissions coefficient database</b></p> <ul style="list-style-type: none"> <li>PCB material and equipment carbon coefficients and inventory database</li> </ul> <p><b>Establish product carbon footprint inventory capability</b></p> <ul style="list-style-type: none"> <li>Establish standard product carbon footprint PCR</li> </ul> <p><b>Develop carbon inventory smart systems</b></p> <ul style="list-style-type: none"> <li>Develop supply chain product carbon footprint calculation system</li> <li>Develop PCB product carbon footprint inventory smart integration system</li> </ul>
Set carbon emissions reduction targets	<p>In the short term, strengthen the collection of information and the development of knowledge in order to cultivate the ability to set carbon emissions reduction targets, and in the long term, adjust according to each respective company's development and simultaneously enhance corporate image.</p> <p><b>Strengthen corporate ESG structure</b></p> <ul style="list-style-type: none"> <li>Large enterprises assess and make decisions to advocate benefits and plan group carbon emissions reduction targets and strategies</li> <li>Planning carbon emissions reduction goals and strategies for small and medium-sized enterprises</li> <li>Training and collection of initiatives, green credentials, transfer mechanisms and other related knowledge building</li> </ul> <p><b>Public declaration of goals</b></p> <ul style="list-style-type: none"> <li>Develop a carbon emissions reduction plan and publicly announce targets</li> </ul>	<p><b>Implement targets and develop strategies</b></p> <ul style="list-style-type: none"> <li>Timely adjustment of phased carbon emissions reduction strategies</li> <li>Adapt to the development resources of the renewable energy industry at home and abroad, and introduce them according to regional attributes</li> </ul> <p><b>Reinforce corporate sustainability image and influence</b></p> <ul style="list-style-type: none"> <li>Promote corporate ESG sustainability</li> </ul>
Nurturing sustainability talent	<p>Companies conduct talent inventories in response to organizational restructuring and leverage industry-academia cooperation to strengthen their talent pools and guide the direction of talent development through performance assessment adjustments.</p> <p><b>Take stock of sustainable talent needs</b></p> <ul style="list-style-type: none"> <li>Cultivate talent for organizational carbon inventory and product carbon footprint seeding</li> <li>Cultivate mid- and senior-level executives to enhance sustainable ESG governance capabilities</li> <li>Industry-academia cooperation to create dual-track talents for R&amp;D and carbon emissions reduction</li> <li>Linking performance assessment to motivate organizations to transform to low carbon</li> </ul>	<p><b>Talent retention and expand recruitment</b></p> <ul style="list-style-type: none"> <li>Promote ESG talent</li> <li>Deepen industry-academia cooperation to improve corporate ESG systems, strengthen corporate image, and increase employment incentives</li> </ul>

Promotion Aspects	Industry Action Guidelines (2022~2025)	Industry Action Guidelines (2026~2030)
Enhanced waste treatment	<p>Waste treatment is carried out step by step according to the stages of re-inventory, reduction of non-recyclable types, improvement of recycling efficiency, and resource recovery, while research and development is planned to be carried out simultaneously from the perspective of design at source or development of recyclable raw materials.</p> <p>Resource and waste inventory</p> <ul style="list-style-type: none"> <li>Re-inventory and refine waste classification</li> <li>Set reduction targets for waste and wastewater</li> <li>Improve yield rate and reduce scrap</li> </ul> <p>Reduce the types of non-recyclable waste</p> <ul style="list-style-type: none"> <li>Develop recyclable substrate materials such as FPCs, glass fiber, resin, etc. to increase the proportion of PCB solid waste recycling.</li> <li>Develop special PCB products that are recyclable, such as printing ink, dry film and desmear, and increase the proportion of PCB liquid waste to be recycled.</li> </ul> <p>Improve water recycling</p> <ul style="list-style-type: none"> <li>Increase the ratio of water reuse</li> </ul> <p>Promote waste reduction at the source of design</p> <ul style="list-style-type: none"> <li>Modular design of parts and equipment to extend equipment life cycle and reduce idle time</li> <li>Production flow and layout redesign to reduce waste trimmings</li> </ul> <p>Expand waste recycling</p> <ul style="list-style-type: none"> <li>Promote the commercialization of waste materials (e.g. fiber glass yarn, waste film scraps, waste pads)</li> </ul>	<p>Develop a supply chain resource recycling cooperation platform</p> <ul style="list-style-type: none"> <li>Cooperate with suppliers to increase resource reuse ratio</li> <li>Tie up with suppliers to enhance the economic benefits of resource recycling</li> </ul> <p>Develop new technologies for low energy consumption and recycling</p> <ul style="list-style-type: none"> <li>Develop low energy consumption metal purification technology</li> </ul> <p>Develop VOC emission reduction technology</p> <ul style="list-style-type: none"> <li>Development of CO<sub>2</sub>, PFCs and other gas concentration and recovery technologies</li> </ul>
PCB low carbon manufacturing	<p>In the short term, gradually improve or replace the existing solution options, while also establishing a cooperation mechanism between supplier management standards and low-carbon equipment research and development. In the long term, realize low-carbon PCB manufacturing through technological innovation.</p> <p>Energy consumption improvement of factory equipment system</p> <ul style="list-style-type: none"> <li>Lighting system: High efficiency flat panel LED lighting</li> <li>Motor system: High efficiency IE3, IE4 motors</li> <li>Air conditioning system: Fan filter, low noise, intelligent energy efficiency monitoring</li> <li>Water cooled chiller: Heat recovery and energy saving, centrifugal chiller</li> <li>High efficiency energy saving improvements: Air compressor, water pump, blower, elevator, dust collection inverter...</li> </ul> <p>Reduce use of high carbon emissions fuels</p> <ul style="list-style-type: none"> <li>Gradually replace fuel oil equipment with low carbon emission fuels (e.g. natural gas) in the pressurization process</li> <li>Gradually reduce the use of diesel fuel for boilers and switch to low-carbon fuels</li> </ul> <p>R&amp;D and upgrade of low carbon equipment</p> <ul style="list-style-type: none"> <li>Set up PCB next generation low carbon equipment alliance (electroplating, wiring, pressing, laser drilling, solder mask, etc.)</li> <li>Upgrade existing energy-consuming equipment or components</li> <li>Introduce AI technology to improve equipment preventive maintenance and energy efficiency optimization</li> </ul> <p>Implement low carbon supply chain management</p> <ul style="list-style-type: none"> <li>Establish green supply chain management system and team</li> <li>Organize supplier conferences to establish communication channels</li> <li>Provide supply chain carbon inventory education and training</li> </ul> <p>Real-time digital information monitoring and control system</p> <ul style="list-style-type: none"> <li>Process: Develop PCBECI standard communication protocol information module</li> <li>Factory: Set up industrial IoT facilities such as electricity meters, real-time data monitoring, and energy management</li> </ul>	<p>Invest in smart low-carbon plant equipment</p> <ul style="list-style-type: none"> <li>Smart power grid and energy management system</li> <li>Introduction of smart production line control systems</li> </ul> <p>Development of next-generation carbon-reducing materials</p> <ul style="list-style-type: none"> <li>Development of local low-carbon raw materials (e.g., copper foil or glass fiber, resin, solder paste, dry film, chemicals, etc.)</li> </ul> <p>Development of next-generation low energy consumption processes</p> <ul style="list-style-type: none"> <li>Development of low temperature pressing and low temperature drying process equipment and components</li> <li>Develop new electroplating process technology, such as high-speed plating, porous metallization technology</li> </ul> <p>Improve capability to calculate GHG emissions of equipment</p> <ul style="list-style-type: none"> <li>Automatically calculate carbon emission based on raw material usage.</li> </ul> <p>Promote low carbon supply chain ecosystem</p> <ul style="list-style-type: none"> <li>Develop technologies, components and systems with suppliers</li> <li>Include localized procurement and carbon emissions reduction assessment in procurement specifications</li> <li>Assist supply chain to reduce carbon emissions</li> </ul>



## Renewable energy

**Table 7: Summary and description of industry action guidelines for promoting Axis 2 (renewable energy)**

Promotion Aspects	Industry Action Guidelines (2022~2025)	Industry Action Guidelines (2026~2030)
Renewable energy use and procurement	<p>The procurement of renewable energy is the key to net-zero emissions. In the short term, companies need to initiate assessment and planning operations to grasp the relevant procurement process and information to prepare for large-scale procurement, and in the long term, to develop procurement strategies according to the development needs of the industry.</p> <p>Targeted renewable energy procurement plan</p> <ul style="list-style-type: none"> <li>Establish a procurement evaluation team</li> <li>Grasp domestic and overseas green power procurement platforms and planning local procurement plans based on factory locations</li> <li>Establish a group procurement mechanism for green power in the PCB industry through TPCA integration</li> </ul>	<p>Timely green power procurement strategy</p> <ul style="list-style-type: none"> <li>Observe international trends and customer requirements to adjust and plan diversified green power procurement channels in a timely manner</li> </ul>
Research and development or establishment of renewable energy sources	<p>For autonomous energy source development (including: power generation and energy storage), feasibility assessment can be the short-term focus, and energy generation and energy storage equipment solutions as the long-term goal.</p> <p>Feasibility assessment of autonomous energy</p> <ul style="list-style-type: none"> <li>Photovoltaic power generation and development of new power generation equipment (hydrogen, biomass, etc.)</li> <li>Evaluation of energy storage and autonomous power generation technology solutions</li> </ul>	<p>Innovation of autonomous energy technology in plants</p> <ul style="list-style-type: none"> <li>Installing new power generation equipment (hydrogen, biomass, etc.) and energy storage technologies to replace legacy power generation equipment</li> </ul> <p>Expansion of renewable energy investment pipeline</p> <ul style="list-style-type: none"> <li>Jointly invest in renewable energy industry with industry resources</li> <li>Financial industry collaboration to create renewable energy sources to supply the PCB industry</li> </ul>

Source: TPCA; IEK Consulting, ITRI

## Negative carbon technology/carbon trading

**Table 8: Summary and description of industry action guidelines for promoting Axis 3 (negative carbon/carbon trading)**

Promotion Aspects	Industry Action Guidelines (2022~2025)	Industry Action Guidelines (2026~2030)
Sound Operational Mechanisms	<p>Carbon tax, carbon rights, carbon trading, and negative carbon technologies are still under development, and companies need to view information collection and evaluation a continuous task and undertaking.</p> <p>Raise awareness of domestic and international climate trends and negative carbon technology development</p> <ul style="list-style-type: none"> <li>Explore and grasp the carbon border adjustment mechanism, environmental sustainability classification standards, and international carbon pricing</li> <li>Develop internal carbon pricing</li> <li>Collect information on negative carbon technologies</li> </ul>	<p>Evaluation and introduction of negative carbon solutions</p> <ul style="list-style-type: none"> <li>Evaluate natural carbon sinks at home and abroad</li> <li>Investing in the development of negative carbon technologies</li> <li>Active participation in carbon trading, green power and certificate procurement at overseas plants</li> <li>Introduce reduction projects/apply for carbon credit registration</li> </ul>

Source: TPCA; IEK Consulting, ITRI

## Summary: PCB manufacturing carbon emissions reduction plan

In order to foster a better understanding among PCB-related enterprises on the specific effect of various carbon emissions reduction actions, Figure 13 regroups 39 action guidelines for the PCB industry according to ISO 14064 (2018). In addition to the original 2022-2025 and 2026-2030 phased approaches, the 2031-2050 vision includes the goals of zero VOC emissions, zero emissions from power generation equipment, zero waste manufacturing centers, and zero carbon material development. Furthermore, with the maturity of renewable energy in the overall market environment and the expansion of procurement by enterprises, the industry will also implement 100% renewable energy introduction by 2050, which is also the key direction to promote the overall industry to achieve net zero emissions.

Manufacturing process/plant operations (Category 1)	Indirect emissions from energy use (Category 2)	Upstream and downstream indirect emissions in the value chain (Category 3-6)
<ul style="list-style-type: none"> <li>✓ Reduce use of high carbon emissions fuels <b>2022-2025</b></li> <li>✓ Reduce VOC emissions <b>2026-2030</b></li> <li>✓ Implementing zero VOC emissions <b>2031-2050</b></li> </ul>	<ul style="list-style-type: none"> <li>✓ Energy consumption improvement of factory equipment system <b>2022-2025</b></li> <li>✓ R&amp;D and upgrade of low carbon equipment</li> <li>✓ Real-time digital information monitoring and control system</li> <li>✓ Targeted renewable energy procurement plan</li> <li>✓ Feasibility assessment of autonomous energy</li> <li>✓ Invest in smart low-carbon plant equipment <b>2026-2030</b></li> <li>✓ Development of next-generation low energy consumption processes</li> <li>✓ Improve capability to calculate GHG emissions of equipment</li> <li>✓ Timely green power procurement strategy</li> <li>✓ Innovation of autonomous energy technology in plants</li> <li>✓ Expansion of renewable energy investment pipeline</li> <li>✓ Achieve 100% renewable energy <b>2031-2050</b></li> <li>✓ Construct zero-emissions power generation equipment</li> </ul>	<ul style="list-style-type: none"> <li>✓ Resource and waste inventory <b>2022-2025</b></li> <li>✓ Reduce the types of non-recyclable waste</li> <li>✓ Improve water recycling</li> <li>✓ Promote waste reduction at the source of design</li> <li>✓ Expand waste recycling</li> <li>✓ Implement low carbon supply chain management</li> <li>✓ Enhance the recycling and circular efficiency of renewable resources <b>2026-2030</b></li> <li>✓ Develop a supply chain resource recycling cooperation platform</li> <li>✓ Expansion of supply chain carbon emissions coefficient database</li> <li>✓ Promote low carbon supply chain ecosystem</li> <li>✓ Development of next-generation low-carbon materials</li> <li>✓ Establish zero waste manufacturing center <b>2031-2050</b></li> <li>✓ Development of net-zero carbon emissions materials</li> </ul>

Source: TPCA; IEK Consulting, ITRI

**Figure 13: PCB manufacturing carbon emissions reduction plan for Categories 1 to 6**

### (3) Government recommendations and promotion

In this section, the 27 recommendations listed in Figure 12 are developed in accordance with the three main axes of independent energy saving, renewable energy, and negative carbon/carbon trading, and provides a reference for the government in setting its related policies.

#### Independent energy saving

**Table 9: Summary and description of recommendations to government to promote Axis 1 (independent energy saving)**

Promotion Aspects	Government suggestions (2022~2025)	Government suggestions (2026~2030)
Promote enterprise organizational adjustment	<p>In the short term, the government plays an integral role in guiding enterprises to establish carbon emissions reduction-related systems from scratch, and in the long term, it assists enterprises to align with relevant norms and standards through policy tools.</p> <p>Improve the guidelines for manufacturers</p> <ul style="list-style-type: none"> <li>• Set guidelines and milestones for carbon emissions reduction measures in the PCB industry</li> <li>• Provide a brief description of international initiatives and guidelines for their promotion</li> <li>• Support the benchmark enterprises with carbon emissions reduction or SBTi capability by having large companies set an example for smaller companies, and to demonstrate the expansion and counsel small and medium-sized companies</li> <li>• Provide financial institutions with guidance to the industry and provide preferential financing channels for low-carbon transition</li> </ul>	<p>Provide guidance to enterprises to connect to the sustainability system</p> <ul style="list-style-type: none"> <li>• Evaluate and reward enterprises' carbon emissions reduction performance</li> <li>• Counsel listed companies to meet verification and financial disclosure requirements</li> <li>• Assist in the international marketing of successful industry or enterprise cases</li> </ul>
Implementation of GHG inventory mechanisms	<p>In the short term, the government will strengthen the external resources required by enterprises to conduct carbon inventories in order to lower the entry barrier for enterprises, while in the long term, digital transformation will enhance the efficiency of industry GHG inventories.</p> <p>Strengthen the capacity of industry GHG inventories</p> <ul style="list-style-type: none"> <li>• Increase the number of GHG inventory and sustainability report verification organizations</li> <li>• Provide guidance to companies on carbon inventories and promote the practical experience of verification units in PCBs</li> <li>• Develop a platform for calculating carbon emission coefficients for the PCB industry chain</li> <li>• Expand promotion through public associations</li> </ul>	<p>Promote digital transformation</p> <ul style="list-style-type: none"> <li>• Assist PCB industry to build a digital carbon footprint verification platform</li> <li>• Assist PCB industry to build carbon coefficient and inventory database</li> </ul>

Promotion Aspects	Government suggestions (2022~2025)	Government suggestions (2026~2030)
Set carbon emissions reduction targets	<p>Assist companies in obtaining the necessary information for setting carbon emissions reduction targets (e.g., renewable energy supply and demand and prices, carbon fee collection mechanisms, etc.), and provide them with relevant resources through policies and incentives.</p> <p>Provide ESG-related information to industry</p> <ul style="list-style-type: none"> <li>• Provide guidance to companies in building international initiative assessment and ESG capabilities</li> <li>• Provide planning and timeline of renewable energy solutions for the industry</li> <li>• Provide energy supply and demand and price forecasting trends</li> </ul> <p>Carbon fee reduction and improvement of supporting measures</p> <ul style="list-style-type: none"> <li>• Aligning carbon fee pricing with international standards</li> <li>• Carbon fee is used to subsidize carbon emissions reduction investment offsets and R&amp;D</li> </ul> <p>Mature green finance platform</p> <ul style="list-style-type: none"> <li>• Provide financial institutions with guidance to the industry and provide preferential financing channels for low-carbon transition</li> <li>• Counseling enterprises with carbon pricing capability</li> </ul>	<p>Foster low carbon transition of industries</p> <ul style="list-style-type: none"> <li>• Execute energy structural transition to ensure a stable supply of electricity</li> <li>• Reward and promote successful cases of carbon emissions reduction in industry</li> </ul>
Nurturing sustainability talent	<p>In the short term, the government supports the sustainable talents needed by the industry through specific projects, while in the long term, the government implants a sustainable mindset into the talent cultivation system and connects it with international standards.</p> <p>Promote sustainable industry-academia cooperation projects</p> <ul style="list-style-type: none"> <li>• Promote schools or corporations to jointly plan PCB industry-academia cooperation projects with public associations</li> <li>• Promote the certification mechanism for sustainable talents in the PCB industry</li> <li>• Support net-zero themed master's and doctoral students' adoption and internship programs</li> </ul>	<p>International talent</p> <ul style="list-style-type: none"> <li>• Promote cooperation between academic and research institutions and public associations to promote international exchange of talents and connect with international resources</li> </ul>
Enhanced waste treatment	<p>The government invests resources to assist the industry in developing innovative waste treatment technologies and attracts outside capital or technology investment through regulatory amendments to revitalize the waste recycling ecosystem.</p> <p>Development of new waste treatment technologies</p> <ul style="list-style-type: none"> <li>• Develop biomass power generation technology</li> <li>• Develop waste decomposition technology</li> <li>• Develop wastewater treatment and water recycling technologies</li> </ul> <p>Create a digital platform for recycling resources</p> <ul style="list-style-type: none"> <li>• Establish a digital platform for recycling information</li> </ul> <p>Adaptation of waste regulations</p> <ul style="list-style-type: none"> <li>• Establish a certification mechanism for recycling resources and amending waste regulations</li> </ul>	<p>Assist in entering the international market</p> <ul style="list-style-type: none"> <li>• Establish an international certification platform for recycled materials or products to meet international supply chain requirements</li> </ul> <p>Establish a waste recycling circular ecosystem or a specific park for the PCB industry</p> <ul style="list-style-type: none"> <li>• Assist in the integration of industrial resources to promote waste resource centers</li> </ul>
PCB low-carbon manufacturing	<p>Provide the industry with the necessary resources to develop low carbon manufacturing through policy tools, such as: R&amp;D investment, investment tax credits, project guidance, aging equipment retirement and replacement, and validation sites, etc.</p> <p>Implement low-carbon related incentives and subsidies</p> <ul style="list-style-type: none"> <li>• Set up thematic PCB low-carbon R&amp;D technology programs and assist in establishing next-generation PCB low-carbon equipment alliances</li> <li>• Establish low-carbon investment tax credit programs: encourage the retirement of high energy-consuming equipment or components</li> <li>• Encourage energy-saving renovation of aging factories</li> <li>• Counseling and subsidies for SMEs</li> <li>• Collaborate with public associations to accelerate the low-carbon transformation of the industry</li> </ul>	<p>Support forward-looking research and development resources and expand its benefits</p> <ul style="list-style-type: none"> <li>• Incentivize the construction of energy storage facilities</li> <li>• Provide subsidies to industries to develop low-carbon processes and materials innovation-related R&amp;D and validation sites</li> <li>• Assist upstream and downstream alliances to build supply chain smart system development and carbon data platform applications</li> <li>• Promote the effectiveness of the policy through public associations</li> </ul>

Source: TPCA; IEK Consulting, ITRI

## Renewable energy

**Table 10: Summary and description of recommendations to government to promote Axis 2 (renewable energy)**

Promotion Aspects	Government suggestions (2022~2025)	Government suggestions (2026~2030)
Renewable energy use and procurement	<p>Building a diversified renewable energy infrastructure and a sound business model will help companies assess and strengthen their confidence in renewable energy and move further toward expanding supply to meet their carbon emissions reduction needs.</p> <p>Build a diverse renewable energy infrastructure</p> <ul style="list-style-type: none"> <li>Provide diversified renewable energy sources for the industry (e.g. wind, solar, hydrogen, geothermal, biomass, nuclear, etc.)</li> </ul> <p>Sound renewable energy industry and business model</p> <ul style="list-style-type: none"> <li>Rationalize the length of renewable energy procurement contracts</li> <li>Develop tariff stabilization mechanism</li> <li>Ensure the transparency of renewable energy supply</li> <li>Establish a fair trade or quota protection mechanism</li> <li>Cooperate with public associations to help the industry establish a renewable energy procurement platform</li> </ul>	<p>Expand the supply of renewable energy</p> <ul style="list-style-type: none"> <li>Expand the supply of large renewable energy sources (e.g., wind, solar, hydrogen, geothermal, biomass, small-scale and advanced nuclear energy) to achieve energy restructuring goals.</li> <li>Set and announce the target of Taiwan's power emission coefficient for the period of 2025~2030 in line with international standards.</li> </ul>
Research and development or establishment of renewable energy sources	<p>In the short term, the goal is to lower the threshold and restrictions for enterprises to build renewable energy, and in the long term, to create demonstration parks to synergize related resources.</p> <p>Reinforce the incentive mechanism for renewable energy construction</p> <ul style="list-style-type: none"> <li>Encourage enterprises to build power generation and energy storage facilities at their plants</li> <li>Raise the Feed-in Tariff (FIT) to encourage enterprises to build renewable energy facilities</li> <li>Establish a green power and energy storage certification system</li> </ul> <p>Encourage enterprises to invest in renewable energy industry</p> <ul style="list-style-type: none"> <li>Provide diversified channels and relax regulatory restrictions</li> </ul>	<p>Create low-carbon demonstration parks</p> <ul style="list-style-type: none"> <li>Build low-carbon demonstration parks to provide diversified demonstration sites for renewable energy, recycled water, energy storage technology, and smart grid applications.</li> </ul>

Source: TPCA; IEK Consulting, ITRI

## Negative Carbon / Carbon Trading

**Table 11: Summary and description of recommendations to government to promote Axis 3 (negative carbon/carbon trading)**

Promotion Aspects	Government suggestions (2022~2025)	Government suggestions (2026~2030)
Sound Operational Mechanisms	<p>Short-term focus is to develop a low-carbon information platform to help enterprises grasp international related information, while the long-term focus is on the development of regulations and systems and the development of negative carbon technologies</p> <p>Establish an international low carbon information platform</p> <ul style="list-style-type: none"> <li>Collect industry needs for carbon tax, carbon fee, carbon trading, carbon certification and other related systems</li> <li>Counseling enterprises with carbon pricing capability</li> </ul> <p>Establishment of carbon certification mechanism</p> <ul style="list-style-type: none"> <li>Establish a carbon rights certification system for overseas plants</li> <li>Establish a system for recognizing overseas carbon rights for Taiwanese plants of multinational operations.</li> </ul>	<p>Development of negative carbon technology</p> <ul style="list-style-type: none"> <li>Develop negative carbon and carbon capture technologies</li> </ul> <p>Establish and improve the system and regulations</p> <ul style="list-style-type: none"> <li>Improve carbon trading/pricing system</li> <li>Promote the recognition of renewable energy certificate system for biomass technology</li> </ul>

Source: TPCA; IEK Consulting, ITRI

## Summary: The government plays a pivotal role

The effectiveness of the low-carbon transformation of industries depends not only on the proactive and voluntary actions of PCB manufacturers in the industry, but also on the participation of the government, which is no less important than that of companies or the supply chain. In particular, the supply and dispatch of external environmental resources are beyond the control of enterprises. In other words, the government must consider how to provide sufficient low-carbon resources and allocate them appropriately to meet the needs of most enterprises. Although the 27 government proposals listed in this chapter are based on the

perspective of Taiwan's PCB industry, many of them are discussed from the environmental aspect. If these proposals are implemented in a realistic and qualitative manner, it will benefit more than the PCB industry in Taiwan. In summary, stable and sufficient renewable energy, development of carbon-reducing materials and equipment, circular economy mechanism and platform, cultivation of sustainable talents, and assistance in low-carbon resources at home and abroad are all issues of primary concern to companies.

## 8. Taiwan PCB Industry Roadmap to Net Zero Emissions and Target Setting

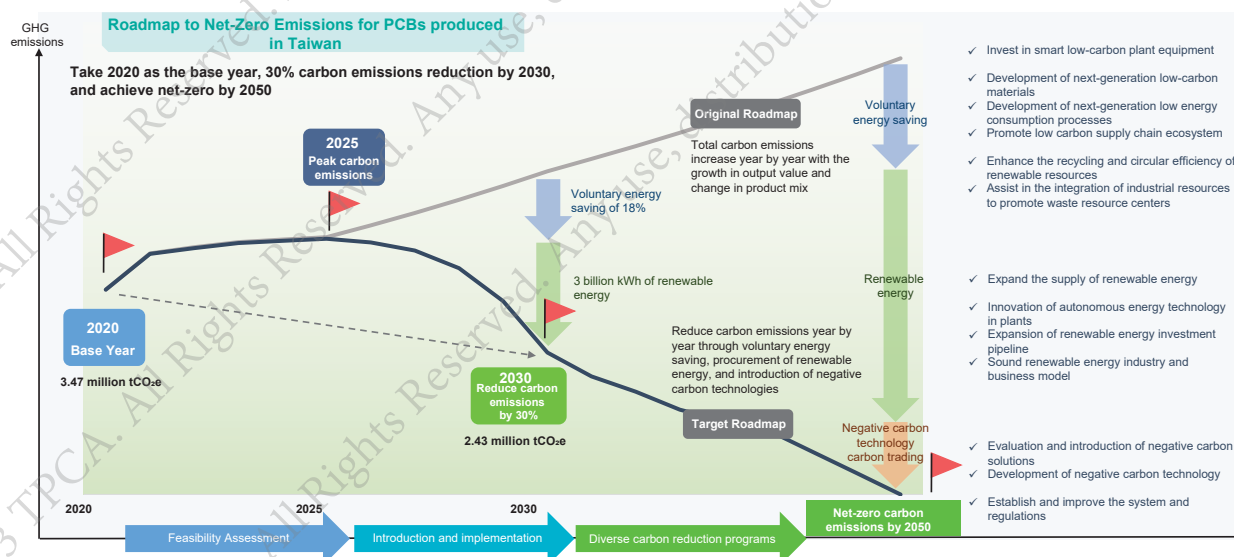
### (1) Taiwan PCB Industry Roadmap to Net-Zero Emissions

The Taiwan PCB Industry Roadmap to Net-Zero Emissions follows the three main axes of independent energy saving, renewable energy and negative carbon / carbon trading, and is gradually implemented in three stages to 2025 carbon peak, 2030 milestone and 2050 net-zero emissions.

**2021 to 2025 (Feasibility Assessment Phase):** Focuses on internal feasibility assessment and external collaboration, including technology research and development and renewable energy procurement planning, carbon emissions reduction in this phase mainly comes from the enhancement of existing energy saving programs and minimal renewable energy sources. As output grows, carbon emissions will increase more than the sum of independent energy savings and renewable energy use, and carbon emissions will continue to increase until 2025, when they peak.

**2026 to 2030 (Introduction and Implementation Phase):** Focuses on the introduction of carbon emissions reduction solutions and the procurement of renewable energy, as innovations in low-carbon processes, materials, equipment, and smart manufacturing, coupled with the expansion of renewable energy supply. The emission reduction effects of independent energy conservation and renewable energy use emerge, and overall GHG emissions begin to decline.

#### Taiwan PCB Industry Roadmap to Net-Zero Emissions - Description



Source: TPCA; IEK Consulting, ITRI

Note: The net-zero emissions roadmap shown above are only the average values for the industry as a whole; some companies may reach the net-zero emission or phased target earlier depending on their own situation.

Figure 14: Taiwan PCB Industry Roadmap to Net-Zero Emissions



**2031 to 2050 (Diverse Carbon Emissions Reduction or Offsetting Stage):** It is expected that negative carbon technologies will mature, carbon trading mechanisms will be developed, renewable energy markets will become more robust, companies will expand renewable energy procurement and begin using diverse carbon emissions reduction or offsetting programs, and follow global and government trends to reach net-zero emissions by 2050.

## (2) Promote Target Settings for 2030 and Description

According to the carbon emissions reduction plans of major countries or companies around the world, in addition to declaring the timeline for net zero emissions, the setting of milestones can demonstrate the proactiveness and ambition of the country or company in the face of the net-zero trends. Taiwan's PCB industry chain (PCB manufacturing plus equipment and material suppliers) has achieved a total domestic and international output of NT\$1 trillion, of which PCB manufacturing ranks first in terms of global market share. Considering the dynamics of competitors and customer expectations, Taiwan will actively build a low-carbon, high-value PCB industry to maintain its competitiveness in the next 30 years. Table 12 takes 2020 as the base year, assumes a 55% growth in production value, and further illustrates the milestone of a 30% reduction in carbon emissions from PCB production in Taiwan by 2030, based on the premise of independent energy saving of 18% and renewable energy use of 3 billion kWh.

**Table 12: 2030 Scenario and Goal Setting and Description**

2020 as the base year, 30% carbon emissions reduction by 2030	
Output 55%	<ul style="list-style-type: none"> <li>Based on the evolution of every decade, it is estimated that in 2030, we will enter the era of 6G communication and combine Terahertz (THz), AI, non-terrestrial networks and other emerging technologies on the basis of 5G, with the advantage of more than 10 times increase in computing power and bandwidth, with new technologies. Fully autonomous driving, hologram communication, immersive experience, telemedicine surgery, and other applications where 5G cannot be fully utilized at this stage will all have the opportunity to be realized, leading to a change in the end product type and then lead to another wave of technology upgrade and rapid growth in production value.</li> <li>According to the "Taiwan's Pathway to Net-Zero Emissions in 2050 and Strategy Master Plan", Taiwan's electricity demand will grow at a rate of 2.6% from 2021 to 2030, which is a positive view of the overall industrial environment development. Taiwan's PCB industry occupies a leading position in terms of production scale and technology development. It is estimated that the domestic and overseas production value of PCB manufacturing will exceed NT\$1 trillion by 2030, and the production scale of PCBs in Taiwan is estimated to reach NT\$401.3 billion, seeing a 55% increase from 2020.</li> </ul>
Independent Energy Savings of 18%	<ul style="list-style-type: none"> <li>Including electricity and other forms of energy, the total energy consumption for the production of PCBs in Taiwan in 2020 will be about 17,664,562 gigajoules (GJ) (equivalent to about 4.9 billion kWh), with an energy intensity of about 70.5 (GJ/NT\$ million).</li> <li>The industry will promote industry process improvement, smart manufacturing, equipment retirement and replacement, carbon-reducing materials and low energy consumption equipment solutions to implement independent energy saving.</li> <li>The PCB industry will also actively link up the upstream and downstream of the industry chain and government R&amp;D units to invest resources in the form of R&amp;D of innovative technologies or disruptive innovations to help the industry expand the effectiveness of energy saving.</li> <li>With this as the driving force of promotion, the industry aims to reduce energy intensity to 57.4 (GJ/NT\$ million) by 2030, which is equivalent to a reduction in electricity consumption of 1.4 billion kWh, or a reduction of 18%.</li> </ul>
Renewable energy use up to 3 billion kWh	<ul style="list-style-type: none"> <li>In 2020, the total energy consumption of PCBs produced in Taiwan is equivalent to about 4.9 billion kWh. Without any independent energy saving, if calculated based on the baseline value in 2020, 55% growth in production value and changes in product structure, it is estimated that the total energy consumption will grow to the equivalent of 7.8 billion kWh by 2030.</li> <li>The total energy consumption of the industry is estimated to drop to 6.4 billion kWh by 2030 through independent energy saving of 18%, and the further target of 30% carbon emissions reduction will require the use of 3 billion kWh of renewable energy.</li> <li>According to the Ministry of Economic Affairs' June 2021 "Green Power Trading Market Promotion" data, if we take into account the bidding of offshore wind power, the supply of renewable energy will reach 61.6 billion kWh in 2030. In other words, it is still quite challenging to meet the needs of the industry.</li> <li>Since renewable energy is crucial for Taiwan's PCB industry to achieve net-zero emissions, in order to achieve the 2030 milestone, in addition to recommending the government to expand the supply of photovoltaic and wind power, the development of diversified renewable energy solutions is also the recommended direction of promotion.</li> <li>Overall, the majority of the PCB industry's renewable energy will be sourced from external purchases, and a small portion will be acquired through independent construction.</li> </ul>

Source: TPCA; IEK Consulting, ITRI

Note: Energy consumption intensity = total energy consumption / total output value



## IX. Conclusion

### 1. Low-carbon transition elimination will kick off soon

An overview of past development history suggests there are always key issues or events that have a far-reaching impact on the industry every now and then. Each event is like a race for an industry or a company, and whether or not it can persevere and stand out depends not only on luck, but also on foresights and how well the company grasps and prepares for emerging trends. The global wave of net-zero carbon emissions is coming, and the industry will face an unprecedented test. A "carbon-dated" report released by Standard Chartered also points out that 67% of multinational companies regard reducing suppliers' GHG emissions as the first step of net-zero strategy, and 78% of multinational companies will start phasing out low-performing suppliers (in terms of GHG reduction) by 2025, which is the beginning of the global race to low-carbon transition.

### 2. Net-zero transition is not an easy task, enterprises should start as soon as possible

In terms of Taiwan's PCB industry, although most companies still have many doubts and worries about how to achieve net-zero carbon emissions, but from a global market perspective, except for a few PCB manufacturers who take a relatively positive attitude due to customer demands for GHG emissions reduction, the vast majority of manufacturers still do not disclose clear milestones or plans, indicating that net-zero emissions is not an easy undertaking, and sufficient assessment and planning is required. Every crisis is also an opportunity; because GHG reduction is difficult, enterprises should start as soon as possible and take positive action, and may have the opportunity to open up the gap with competitors and seize more business opportunities.

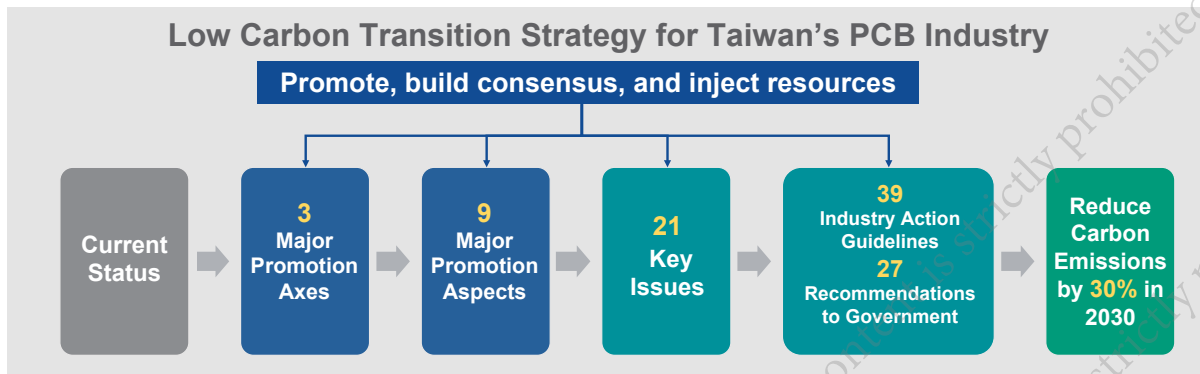
### 3. Setting 2030 goals with a proactive mindset

In addition to the carbon emissions reduction measures that are being implemented by the industry itself at this stage, this plan is used to strengthen and expand the effectiveness of carbon emissions reduction in the industry by promoting from the sidelines. In addition to the positive target setting (18% independent energy saving, 3 billion kWh of renewable energy use, 30% carbon emissions reduction) to strengthen the awareness of carbon emissions reduction among PCB manufacturers, we expect to issue public declaration and showcase the determination of low carbon transition in the PCB industry, and then converge the power and resources from all walks of life, so that innovative low carbon technology and a larger amount of renewable energy can be realized. This way, all partners shall jointly work together for the next golden decade of the PCB industry in Taiwan.

### 4. 39 industry action guidelines and 27 government recommendations lead Taiwan's PCB industry to low carbon transition

The "Low Carbon Transition Strategy for the Taiwan's PCB Industry" brings together and integrates the views of the industry and explains them in a hierarchical structure based on the main axis of promotion, the direction of promotion, the key issues and action guidelines for the industry, and the recommendations to the government. The content clearly outlines the challenges faced by the PCB industry and the areas in need of assistance, so that companies can adopt or adjust the corresponding measures according to their own situation and needs, and the government can use it as a reference basis to rethink the priority of resource allocation and governance.

Figure 15: Taiwan PCB Industry Carbon Reduction Promotion Framework



Source: TPCA; IEK Consulting, ITRI

## 5. Joint collaboration to maximize the effectiveness of the multi-pronged approach

Low-carbon transition is a cross-disciplinary issue, involving a wide range of layers and complexities, and most of the measures cannot achieve immediate results and require long-term investment and dedication, so for enterprises, although there is pressure to initiate action, but relying on the investment of only a few manufacturers not only has limited effect, but also has considerable investment risks. If we can bring together the efforts of upstream and downstream companies, as well as the policies or R&D resources of the government and organizations, we can work together in a group mode to converge our strengths, which will not only help achieve breakthroughs in key areas such as low-carbon processes, carbon-reducing materials, waste recycling, renewable energy, and negative carbon technologies, but also integrate resources from all sectors to maximize effectiveness.



**Enhancing industry competitiveness**

**Jointly creating new value in sustainability**

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<b>Tel</b>	+886-3-3815659
<b>Fax</b>	+886-3-3815150
<b>Website</b>	<a href="https://www.tpca.org.tw/">https://www.tpca.org.tw/</a>
<b>Address</b>	No. 147, Sec. 2, Gaotie North Road, Dayuan District, Taoyuan City 337002, Taiwan (R.O.C.)
<b>E-mail</b>	<a href="mailto:service@tpca.org.tw">service@tpca.org.tw</a>
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**TPCA** 台灣電路板協會  
Taiwan Printed Circuit Association

337002桃園市大園區高鐵北路二段147號  
No.147, Sec. 2, Gaotie N. Rd., Dayuan Dist.,  
Taoyuan City 337, Taiwan  
TEL : 886-3-3815659 FAX : 886-3-3815150  
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