Handbook on Sustainable Operation of the Machine Tool Industry in Response to Carbon Reduction

CIRCULAR ECONOMY

台灣工具機暨零組件工業同業公會
TMBA Taiwan Machine Tool & Accessory Builders' Association

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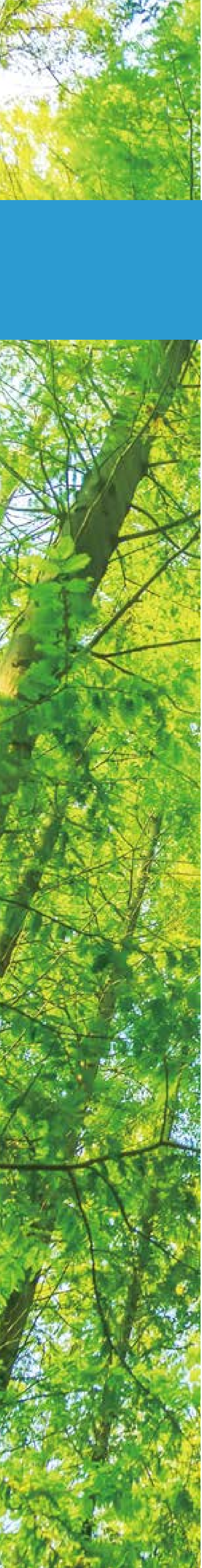

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INTRODUCTION

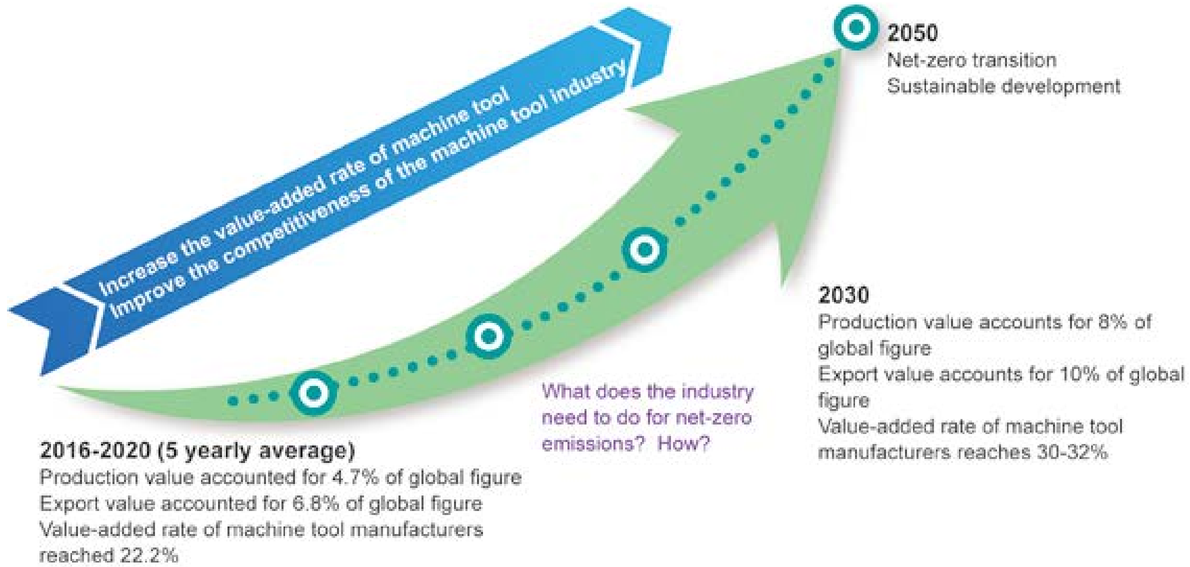
According to the "Proposal for a Regulation of the European Parliament and of the Council: establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC" issued by the European Union on March 30, 2022, the goal of achieving carbon neutrality by 2050 was set in order to reduce the global greenhouse effect; all enterprises in the nation should sequentially initiate energy conservation and reduce carbon emissions, promote the Fourth Industrial Revolution, develop smart digital products, acquire product digitization capabilities, output various digital information that serves as the basis to help end users save energy and reduce carbon emissions, and promote digital management technology in order to enhance the popularity of products in the international market and obtain a higher global market share, achieving corporate sustainable development. This Handbook provides various implementation steps that serve as a reference to strengthen the execution capability of enterprises, lay the foundation for sustainable operations, and establish a long-term lifeline for our industry to achieve a higher position and market share in the global market.

CHAPTER 1. GLOBAL CARBON REDUCTION TRENDS

Under the global net-zero emissions trend and the EU Carbon Border Adjustment Mechanism (CBAM), net-zero transition is not only an environmental issue, but also an economic issue critical to the global competitiveness of Taiwan's machine tool and accessory industry. Taiwan is an export-oriented economy, particularly for the machine tool industry. Facing the pressure of carbon reduction in the global supply chain and the challenges of stricter international carbon control, industrial transformation is urgent.

In response to changes in global situation, the machine tool industry must strengthen the R&D and application of energy-saving and carbon-reduction technologies through close international collaboration in order to seize the opportunity of net-zero transition, provide momentum for the export market, and reinforce sustainable actions. This will enable the realization of the 2030 Industrial Development Vision in the 2021 Taiwan Machine Tool Industry White Paper : increase the value-added rate and enhance industrial competitiveness, as well as medium and long-term development goals : Taiwan's machine tool production value accounts for 8% of the world's total value, its export value accounts for 10% of the world's total value, and the value-added rate of machine tool manufacturers has increased to 30-32%, as shown in Figure 1.

Figure 1. Correlation between the vision of the 2021 Taiwan Machine Tool Industry White Paper and net-zero carbon emissions



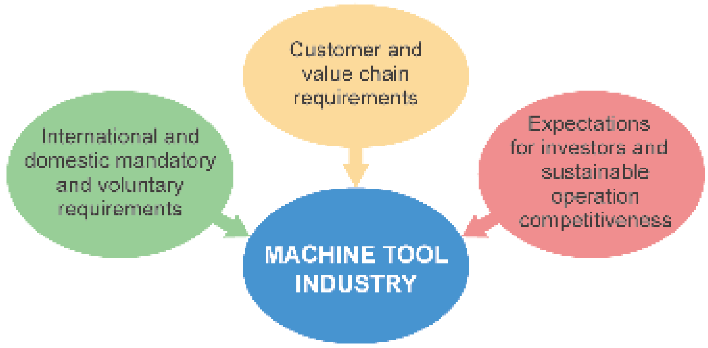
The common promotion approach on how to realize the industrial development strategy in the 2021 Taiwan Machine Tool Industry White Paper, as shown in Figure 2, reveals many specific practices and key ideas, many of which are related to net-zero emissions, energy conservation and carbon reduction, which serve as an important basis for this report to discuss how to deal with carbon management issues.

Figure 2. Key strategies for sustainable industrial development

Industrial Strategies	Promotional Approaches	Goal
- Technology and product R&D and innovation - Cross-Industry ecosystem integration and development - Strengthen corporate core competitiveness - Increase product added value - Domestic and international market expansion - Innovative business model - Maintain international market competitiveness	- Focus on creating value for customers - Explore the demand of R&D and innovation - Build a cross-industry ecosystem for software, hardware and components - Strengthen product design and innovation capability - Add new business models - Smart manufacturing - Digital transformation - Improve overall equipment effectiveness (OEE)	Net-zero emissions (Energy saving and carbon reduction)

The global driving forces for net-zero emissions basically originated from three dimensions, as shown in Figure 3. Each of the three major driving forces has its own specific requirements, specifications, purposes and timetable. Fortunately, as long as the industry focuses on its central strategy of net-zero emissions, most of the requirements from these three dimensions can be met simultaneously.

Figure 3. Three major driving forces of net-zero emissions



International and domestic mandatory and voluntary requirements:

The domestic requirements include the regulations and timetable for sustainable finance required by the Financial Supervisory Commission, the "Taiwan's Pathway to Net-Zero Emissions in 2050[1] " disclosed by the National Development Council, the increase in electricity prices, the imposition of carbon fee, and the need to approve the EIA (environmental impact assessment) of new investment and development projects through the carbon offset program. The international requirements include the implementation of EU's CBAM (Carbon Border Adjustment Mechanism)[2] that attracts global attention, the compliance of the Eco-design Directive[3] for selling products and services to Europe, the carbon emission threshold (CO_2e g/unit product) required by the EU Taxonomy Regulation, as well as the carbon neutrality and net zero declarations proposed by various countries in the world.

NOTE:

EU 2009/125/EC Eco-design Directive for sustainable products

This refers to the mandatory regulatory requirements of the European Union. The key requirements of the Directive include (a) durability, (b) reliability, (c) reusability, (d) upgradability, (e) repairability, (f) possibility of repair and refurbishment, (g) presence of concerned substances, (h) energy use or energy efficiency, (i) resource use or resource efficiency, (j) content of recycle, (k) possibility of remanufacturing and recycling, (l) possibility of material recycling, (m) environmental impact, including carbon and environmental footprint, (n) the expected waste generated, and will have more specific technical standards.

Customer and value chain requirements:

Some well-known brands in the market, such as Apple, Google, Microsoft and TSMC, have announced their goals and timetables for net-zero emissions, and required their business partners in the value chain to cooperate. These practices have caused a significant impact on Taiwan's industrial supply chain due to

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[1] Taiwan's Pathway to Net-Zero Emissions in 2050,
https://www.ndc.gov.tw/en/Content_List.aspx?n=B927D0EDB57A7A3A&upn=A2B386E427ED5689

[2] Carbon Border Adjustment Mechanism (CBAM), https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661

[3] Eco-design Directive,
https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products_en

the fact that Taiwan has an OEM- and export-oriented industrial structure. In view of this, specific responses must be made, including carbon inventory and emission reduction. In addition, from the user's point of view, customers also realize that if the purchased raw materials and equipment are not competitive in energy saving and carbon reduction, it will affect their overall operating performance and generate additional expenses such as carbon fees (taxes). Therefore, they will also require their value chain to provide energy-efficient digital smart manufacturing technologies and equipment so that they can improve the overall equipment effectiveness (OEE), reduce unnecessary production waste and unexpected downtime, thereby reducing future carbon fees or carbon taxes.

Expectations of investors and sustainable operation competitiveness:

Corporate management always considers how to improve the added value and competitiveness of a company. While creating corporate value, it is also required to take the expectations of investors into account. When necessary, appropriate investors can be combined to acquire the resources needed for the growth of the company, creating a totally new world. Internationally, several norms have been developed for net-zero emissions and sustainable operation, and they have become an important pathway for many companies to demonstrate their business performance and attract external funds. For example, the FTSE4Good of the FTSE Group and the ESG indicators of MSCI in the financial industry have been used as criteria for the selection of some ETF stocks in Taiwan; the Dow Jones Sustainability Indices (DJSI) include companies such as TSMC for raising international funds; Sustainability Accounting Standards Board[4] (SASB has established specific requirements for "industrial machinery"), Task Force on Climate-related Financial Disclosures (TCFD)[5], Carbon Disclosure Project[6] (CDP), Global Reporting Initiative[7] (GRI) and other commonly used corporate sustainability reporting standards have long been applied and cited by many industries.

NOTE:

EU Carbon Border Adjustment Mechanism (CBAM): The draft CBAM was announced on July 14, 2021, which specifies regulations and penalties associated with covered products (cement, fertilizer, steel, aluminum, imported electricity, etc.), recognition method of product's carbon content, declaration of imported products, and verification methods. After a trial period of three years starting in 2023 and the official implementation in 2027, importers must purchase certificates that serve as payment for the carbon emissions of imported products, and the price will be calculated based on the average closing price of the EU's weekly carbon credit auctions.

European Green Deal: In 2019, the European Commission announced the European Green Deal, which aims to achieve a short-term goal of 55% reduction in greenhouse gas emissions by 2030 (compared with 1990), and a medium- and long-term goal of realizing climate neutral by 2050.

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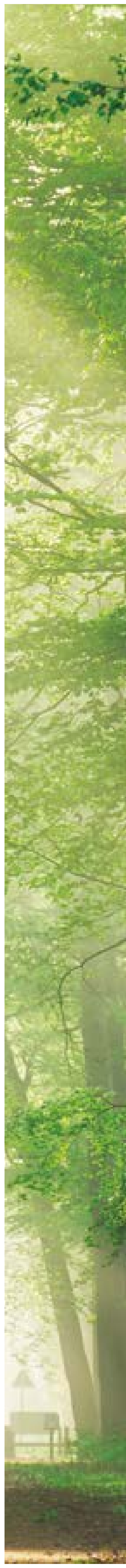
4 Sustainability Accounting Standards Board (SASB), https://www.sasb.org/standards/download/?lang=en-us

5 Task Force on Climate-related Financial Disclosures (TCFD), https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf

6 Carbon Disclosure Project (CDP), www.cdp.net

7 Global Reporting Initiative (GRI), https://www.globalreporting.org/standards/download-the-standards/

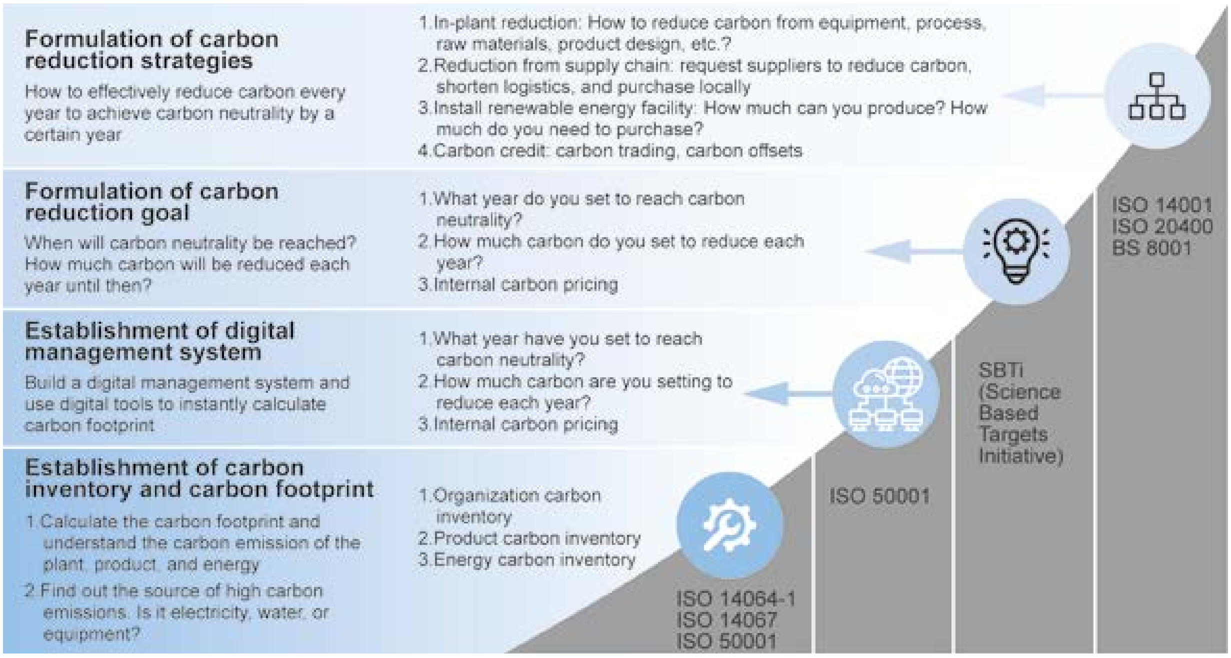
CHAPTER 2. COUNTERMEASURES FOR THE MACHINE TOOL INDUSTRY



Pathway and Strategy to Net-Zero Emissions in 2050 for Taiwan's Machine Tool Industry

To achieve a net-zero transition by 2050, it is necessary to solidly implement the transition goals for the machine tool industry, assess risks early, and propose a roadmap for net-zero emissions in a forward-looking and pragmatic way, so that the transition of the overall structure of the machine tool industry can be carried out effectively. The pathway for net-zero emissions must be reviewed on a rolling basis to meet the needs of future economic, environmental, humanistic and sustainable development. Furthermore, emphasis must be placed on intergenerational justice and cross-domain governance thinking so as to turn the impact of climate change into opportunities for green transition. The steps for achieving corporate carbon reduction are shown in Figure 4.

Figure 4. Steps for achieving corporate carbon reduction



Source: 1306th Issue, Business Today

Four strategic steps to achieve net-zero emissions for Taiwan's machine tool industry

To explore strategies for net-zero emissions, one must first analyze the sources and types of greenhouse gas emissions, and then formulate countermeasures for net-zero emissions based on the results of the analysis as well as seemingly indispensable activities.

According to the proposed countermeasures, four strategic steps were sorted out for the machine tool industry, and an overall strategy for the machine tool industry in coping with carbon issues was established to build green competitiveness.

Strategic step 1. Know yourself and your enemy: Carbon inventory
Strategic step 2. Strategy of no regrets: Energy saving and carbon reduction
Strategic step 3. Green resilience: Expand sources and reduce expenditures to explore more green competitiveness
Strategic step 4. Green opportunities: Turn crisis into opportunity, creating new green business opportunities

Strategic step 1. Know yourself and your enemy: Carbon inventory

The blue portion represents the carbon fee (tax) and costs that should be paid by companies.

Figure 5. Methods of carbon inventory

Company-wide inventory	ISO 14064-1, ETS, WRI, CDP......
Project inventory	ISO 14064-2, CDM, VCS, GS......
Product carbon footprint	ISO 14067, ETS......

At this stage, enterprises still need to pay a 100% carbon fee (tax) even if they have completed the carbon inventory, since there are no reduction measures yet.

A carbon inventory is a way of knowing yourself and your enemy. It is necessary to know the company's overall carbon emissions in order to assess the impact of the increased carbon fees or carbon taxes and internal carbon management costs on the company's operations.

The methodology of carbon inventory can be divided into three groups depending on the purpose and targets, and the commonly used methods may also vary, as shown in Figure 5.

The industry generally adopts ISO 14064-1:2018 as the tool for organizational (company-wide) carbon inventory. However, different regions and countries have their own specifications for carbon inventory verification. It is necessary to check the specifications of the intended users first, so that they will not obtain wrong data and be levied the wrong carbon fees (taxes). For example, the most common standard for the European Union is the European Union Emission Trading Scheme (EU ETS). American companies (e.g., Apple) and Japanese companies use the standard of the World Resources Institute (WRI). Other standards include the Carbon Disclosure Project (CDP), Science Based Target (STB), and so on. As shown in the figure above, during carbon inventory, carbon emissions will not substantially reduce or lower carbon fees. Only by setting specific reduction goals and achieving them through actions (such as CSR/ESG disclosure) can it be regarded as the beginning of net-zero emissions. This will be explained in the next strategic step.

According to the definition of ISO 14064-1, the most widely used standard in Taiwan, emission sources are roughly divided into "direct emissions" and "indirect emissions," among which indirect emission sources are further divided into five sub-categories as shown in Figure 6.

Figure 6. Categories of greenhouse gas emissions; ISO 14064-1: 2018

ISO 14064-1:2018

Direct greenhouse gases

Greenhouse gas sources owned or controlled by the organization within the organization's boundaries

Category 1
Direct
Major sources
Emergency generator fuel, fire extinguishers, septic tanks, refrigerants, process emissions, transformers, fire accidents

Indirect greenhouse gases

Greenhouse gases generated from the combustion of fuels associated with energy and utilities

Category 2
Energy
Major sources
Purchased electricity, steam, cold and heat sources, compressed air

Category 3
Transportation
Major sources
Employee commuting, business travel, visitor transportation, raw material and product transportation

Category 4
Use of products, materials, and services by the organization
Major sources
Supply chain manufacturing, outsourcer services, third-party repair, maintenance services, solid and liquid waste disposal

Category 5
Use of organization's products
Major sources
Use, repair, maintenance, scrap, lease to other users

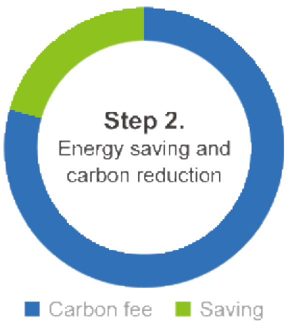
Category 6
Others
Major sources
Other activities and services

TYPICAL CASE:

In addition to announcing its "sustainable environment promotion milestone", HIWIN Technologies Corp. was the first to begin an inventory of indirect greenhouse gas emissions related to transportation in Category 3 and the purchase of raw materials in Category 4 in 2020.

Tongtai Machine & Tool Co., Ltd. has also voluntarily completed the inventory and the disclosure of greenhouse gas emissions for many years, and combined it with the company's energy saving and carbon reduction plans to carry out "carbon management" in product design, manufacturing, and daily power consumption.

Strategic Step 2. Strategy of no regrets: Energy saving and carbon reduction



The carbon fee (tax) cost that should be paid (blue portion) can be reduced

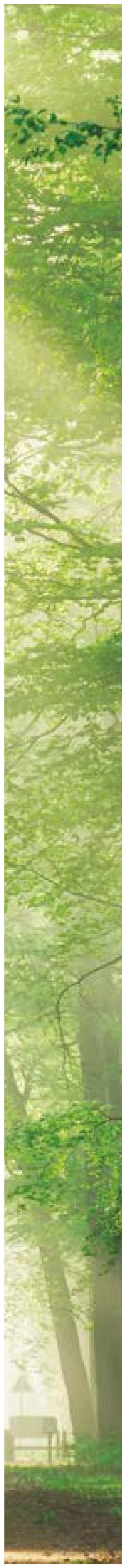
Energy saving and carbon reduction is not only a technical issue, but also a financial issue. Although the pricing of a carbon fee imposed by the Environmental Protection Administration is under study, by taking into consideration the floating price of carbon trading around the world and the current electricity rate in Taiwan, it is possible to estimate the price of the future "carbon fee." Based on Taiwan's electricity pricing, a rise of US$10 will increase the energy consumption cost by 4-5%; in other words, if Taiwan's carbon fee is in line with international standards, the energy consumption cost will be increased gradually.

At this stage, any actions for saving energy, reducing carbon costs and lowering carbon fees that can be implemented in advance and will not be regretted are worthy of being carried out first. They are referred to as the "strategy of no regrets." Daily practices of energy conservation and systematic energy management are essential to maintain energy management performance, hence, ISO 50001 is usually recommended as a beginning for energy-saving management.

The keys of energy management include: (1) energy inventory, (2) monitoring of energy consumption and carbon emissions, (3) inventory of green capacity, and (4) reducing energy consumption through energy-saving and carbon-reduction in three aspects: (a) management, (b) technologies, and (c) equipment, energy-saving designs that are in line with the plant and equipment, adoption of energy-saving technologies, optimization of operating parameters, and replacement of old equipment with new ones[8]. Taking into account the carbon fee that may be levied in 2024, if the electricity costs can be reduced, the carbon fee expenditure can be immediately reduced to lower the operating cost.

TYPICAL CASE:

Typical case: Hermle applied an energy review to incorporate new energy concepts, such as updating and retrofitting plant's electric transducers to increase efficiency, using vegetable oil instead of mineral oil to reduce carbon emissions, redesigning the plant to reduce heat loss, replacing old pumps with high-efficiency heat pumps, and incorporating LED lighting.



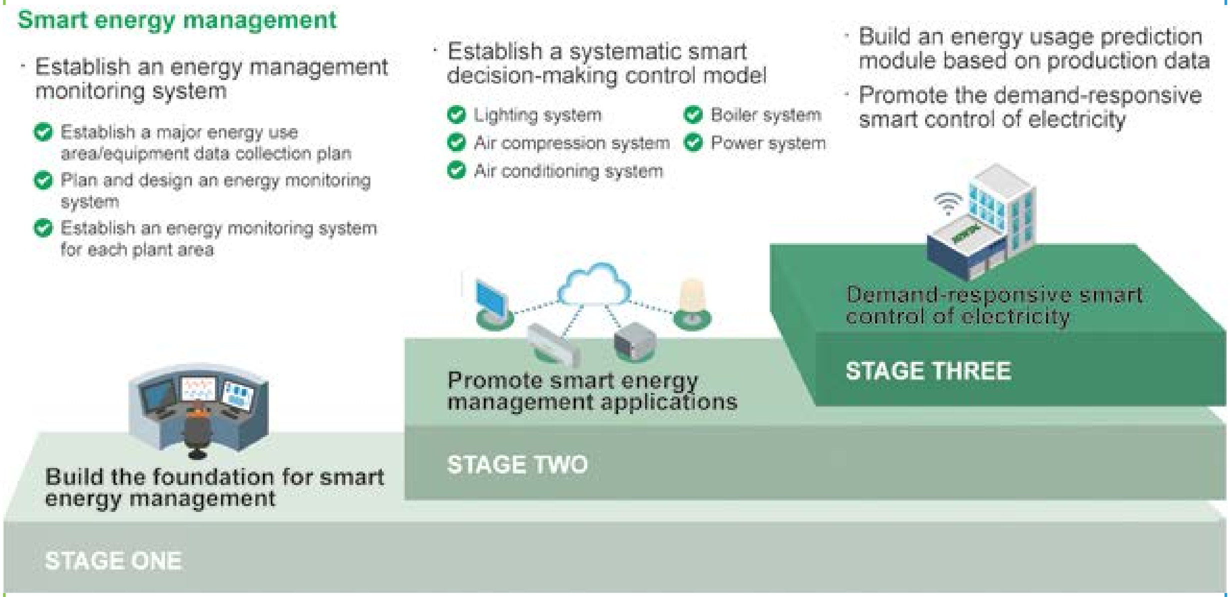
[8] Checklist of energy-saving measures for common equipment, https://emis.itri.org.tw/Home/ERL

TYPICAL CASE:

In addition to the first-stage "greenhouse gas inventory and disclosure," both HIWIN Technologies Corp. and Tongtai Machine & Tool Co., Ltd. have formulated a multi-stage "energy management strategy" in recent years.

The three-stage "Smart Energy Management" strategy adopted by HIWIN Technologies Corp., as shown in the figure below, is to promote the smart control of electricity demand response by establishing an energy management monitoring system, a systematic smart decision-making control model, and an energy usage prediction module through making use of the production data.

Figure 7. Three-stage strategy of "Smart Energy Management" adopted by HIWIN Technologies Corp.



Tongtai Machine & Tool Co., Ltd. also has remarkable experience in energy-saving and green electricity strategy, particularly in the investment and management of green electricity from solar photovoltaic power. After the launch of its solar photovoltaic system in 2019, it became the largest rooftop solar photovoltaic power plant in the Southern Taiwan Science Park, and was recognized with the "Science Park Solar Photovoltaic Best Contribution Award."

Figure 8. The rooftop solar photovoltaic system of Tongtai Machine & Tool Co., Ltd.

Lu-ke Plant I　　Lu-ke Plant II　　Hu-nei Plant I

Strategic step 3. Green resilience: Expand sources and reduce expenditures to explore more green competitiveness

The carbon fee (tax) cost that should be paid (blue portion) can be further reduced through expanding sources and reducing expenditures

The carbon management strategy at this stage is no longer a purely technical issue, but needs to simultaneously consider the choice of overall financial and investment efficiency.

After obtaining the initial energy-saving performance, one can start evaluating the investment in carbon reduction projects (such as carbon offset projects, cross-industry collaboration, reuse and recycling (3R), the circular economy, electric vehicle (EV) fleets, afforestation, etc.). Under the premise of limited green electricity, power shortage risks and carbon fees, it is also possible to evaluate and consider the investment in a green power plant to obtain carbon credits through equity, or to consider the introduction of an external energy service company (ESCO) (refer to the ESCO information website) to continuously engage in internal energy conservation and carbon reduction plans, cooperate with Taipower's incentive plans, evaluate and combine regional industrial collaboration, invest in energy storage equipment, and establish a power supply chain. Based on simulations, it is estimated that a plant with a chartered capacity of 1,000 kW (8 hours of power generation per day, 300 days per year) can be offset for about 1,200 CO_2e tons per year. If the future carbon fee and possible increases are considered, the corresponding carbon offset can shorten the return on investment (ROI) period. Enterprises can also use Figure 9 as a reference for formulating carbon reduction measures after carrying out carbon inventory via ISO 14064-1.

Figure 9. Suggested countermeasures for corporate carbon reduction; ISO 14064-1: 2018

ISO 14064-1:2018

Direct greenhouse gases

Greenhouse gas sources owned or controlled by the organization, within the organization's boundaries

Category 1

Direct

Carbon reduction strategy

Use hydrogen emergency generators, energy storage equipment, energy storage equipment to replace generators, use non-carbon dioxide fire extinguishers and refrigerants (involving replacement of system equipment), process technology changes, employee domestic sewage treatment technology changes, use SF6-free insulation switches, carbon trading, carbon sink, carbon negative technology

Indirect greenhouse gases

Greenhouse gases generated from the combustion of fuels associated with energy and utilities

Category 2

Energy

Carbon reduction strategy

Use green electricity, steam from green processes

Category 3

Transportation

Carbon reduction strategy

Encourage or provide visitors and employees to use green electric transportation, video conferencing (Metaverse, AR, VR), reduce transportation demand (automation, restructuring supply chain, local production), change transportation methods, and use biofuels

Category 4

Use of products, materials, and services by the organization

Carbon reduction strategy

Value chain: green building, selection of low-carbon sites, selection of low-carbon, zero-carbon raw materials, bio-lubricants, consumables, waste reduction, recycling, reuse, material change, use of low-carbon service technologies, carbon capture or conversion technology, carbon sink, carbon negative technology

Category 5

Use of organization's products

Carbon reduction strategy

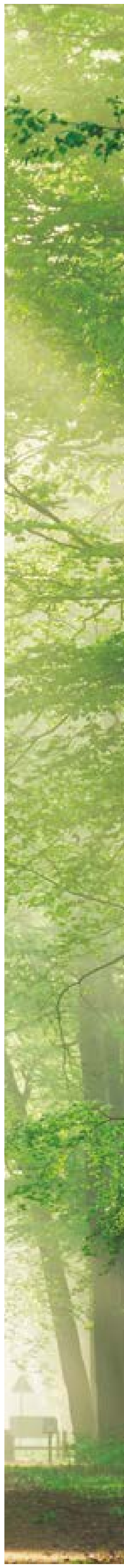
Ecological R&D and design, changing product energy use, changing equipment maintenance and repair methods as well as materials (failure prediction, automatic repair), leasing low-carbon equipment and services, green building, modular parts replacement, extending product life cycles (RAMSS)

Category 6

Others

Carbon reduction strategy

Carbon credit, carbon tax, alternative neutralization, carbon offset, carbon negative technology



TYPICAL CASE:

Hermle's fleet is equipped with the most advanced low-carbon emission technology. It uses electric stackers and electric trucks, optimizes on-site transportation routes, and installs solar photovoltaic systems to replace traditional power sources. High-performance coatings and sun control window films are applied to its buildings to insulate them from heat, effectively regulating the temperature of their buildings.

Strategic step 4. Green opportunities: Turn crisis into opportunity, creating new green business opportunities

The carbon fee (tax) cost that should be paid (blue portion) can be further reduced

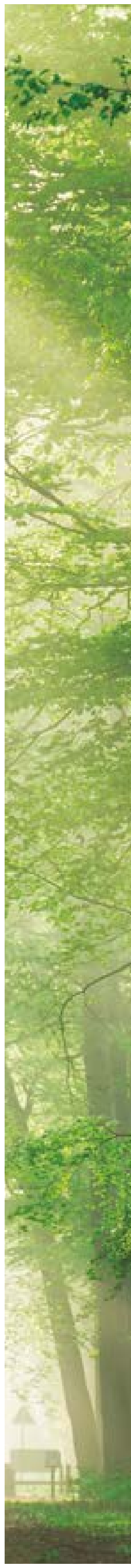
The first three steps are regarded as "passive" strategy. As the industry moves towards the goal of net-zero emissions, it adopts a "proactive" and cross-industry strategy at this stage to create a new green business model, such as the business model based on the subscription of machine tools.

Various companies or industries can establish a "net-zero emission value chain platform" through integrating their upstream and downstream value chains. After completing the first step of the carbon inventory, one can establish a carbon inventory database for the upstream, midstream, and downstream value chains so that the entire machine tool and accessory industry can "share" carbon inventory data, avoid repeated inventory, reduce management costs, and increase green competitiveness among peers. Furthermore, the successful cases of energy saving and carbon reduction in the second step can be compiled on the platform, allowing participants to jointly achieve a goal of energy saving through the mutual exchange of technology and experience.

TYPICAL CASE:

GF is committed to promoting sustainable development guidelines to suppliers, with the goal of conducting a comprehensive sustainability assessment for approximately 1,000 suppliers (80% of procurement expenditure), requiring a collective effort to achieve the goal of carbon reduction.

In the aspect of promoting international trade, net-zero emissions is a tool and a strategy. Therefore, it is necessary to continue paying attention to the policies of major international institutions as well as the trend of international standards and regulations, and to prepare ahead of schedule, striving for better responsive measures. For example, the EU CBAM and Eco-design Directive for sustainable products, EU Taxonomy Regulation, etc., require that products sold in the European market must meet the guidelines and indicators specified by the ecological requirements. For the export-oriented machine tool industry, meeting these high requirements is an indicator for demonstrating product competitiveness.



TYPICAL CASE:

In response to energy saving and carbon reduction, Hermle is equipped with a high-efficiency transmission system, energy recovery system, and low-power standby mode. Once the products are delivered to customers, they are monitored to understand potential energy waste from operation and opportunities for efficiency improvements.

In addition, it is also necessary to go further upstream to develop new low-carbon and zero-carbon products with equipment manufacturers and material suppliers, and to build a circular economy-based industrial ecosystem for the processing industry, so as to realize the possibility of remanufacturing and recycling required for eco-sustainable products, and meet the requirements for material recycling.

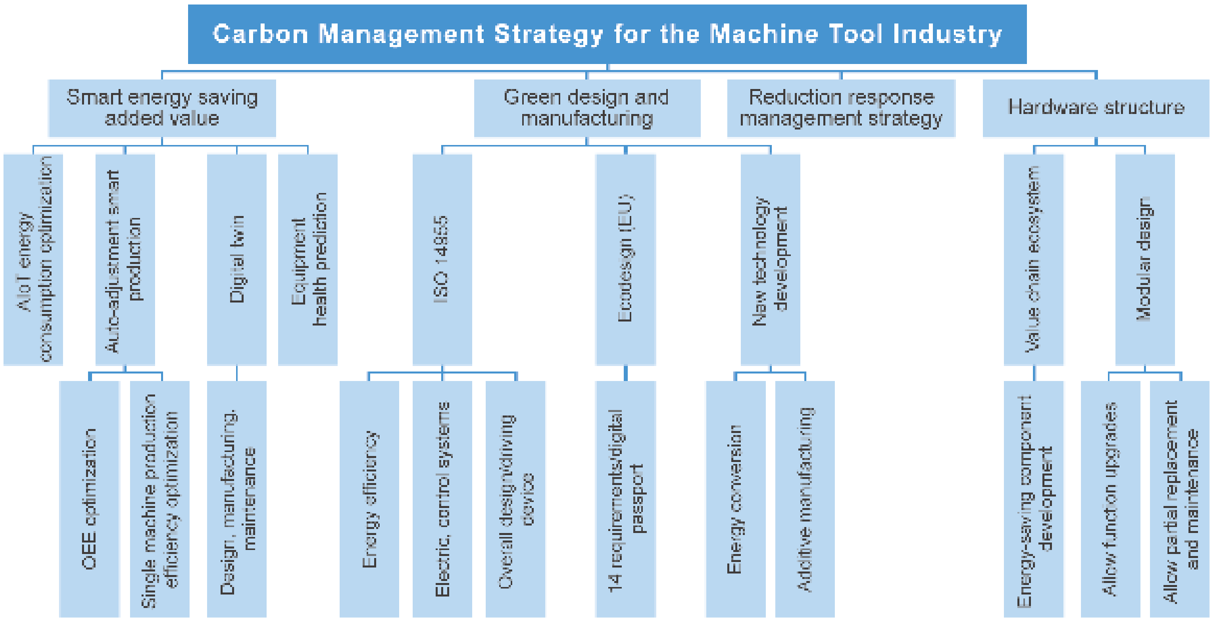
At this stage, more funds are required to activate working capital and open up new business opportunities. One may consider including green funds (such as exchange traded funds (ETF), Dow Jones Sustainability Indices (DJSI), etc.), or green energy, net-zero and low-carbon, ESG constituent stocks, on the premise that an ESG-compliant management mechanism needs to be established.

As a high-performance net-zero emissions industry, when investing in energy conservation and carbon reduction plans, it is also possible to seek subsidies, incentive plans and R&D funds from the competent authorities to support the development of new energy conservation and carbon reduction technologies. Of course, it also needs the support of green finance action plans and tax policies to promote the machine tool industry to establish a net-zero emissions ecosystem and green investment, and assist enterprises in finding new business opportunities and models to improve green competitiveness.

CHAPTER 3. CARBON MANAGEMENT STRATEGY FOR THE MACHINE TOOL INDUSTRY

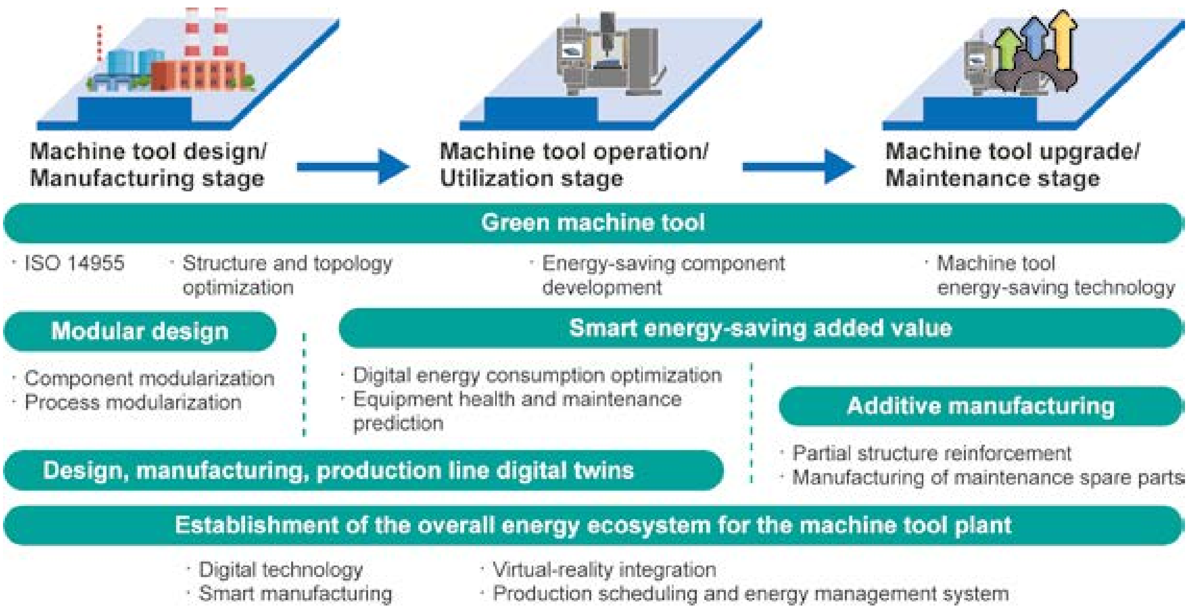
The machine tool industry can adopt the current best available technologies and technologies under development worldwide to establish a green supply chain, reduce carbon emissions from the use of raw materials as well as energy consumption of materials, and sort out a feasible "carbon management strategy for the machine tool industry," as shown in Figure 10.

Figure 10. Carbon management strategy for the machine tool industry



Under the general framework and for the three life cycle stages of machine tools: manufacturing stage, operation stage, and maintenance stage, the following carbon reduction strategies are available, including green machine tool, modular design, smart energy saving, digital twin, additive manufacturing, and establishment of the overall energy ecosystem for machine tool factories, as shown in Figure 11.

Figure 11. Carbon reduction strategy for the life cycle stages of machine tools

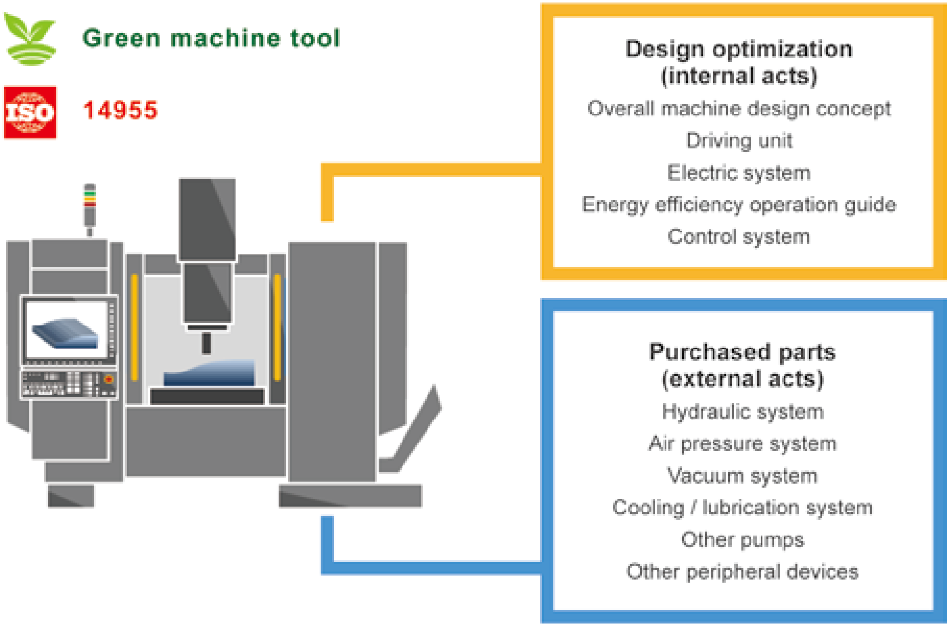


Green machine tool

- ISO 14955 design standard for the energy efficiency of machine tools

According to ISO 14955, the design principles of machine tools under energy efficiency requirements are shown in Figure 12, which include the part where machine tool manufacturers can independently carry out design optimization, and the part that covers the purchased components of external suppliers. Please refer to ISO 14955 for the details on various design principles.

Figure 12. Design principles of machine tools under energy efficiency requirements based on ISO 14955



- Machine tool design starts with structure and topology optimization

Topology optimization and parameter refinement technologies are introduced to carry out optimization simulation and analysis on the structural performance and cutting accuracy of the new machine, serving as an aid for machine parameter adjustments. The development of machine tool is trending towards lightweight structures, and goals such as design space, rigidity, and quality, which are defined to find the best design solution within the effective design space.

- Development of energy-saving components for machine tools

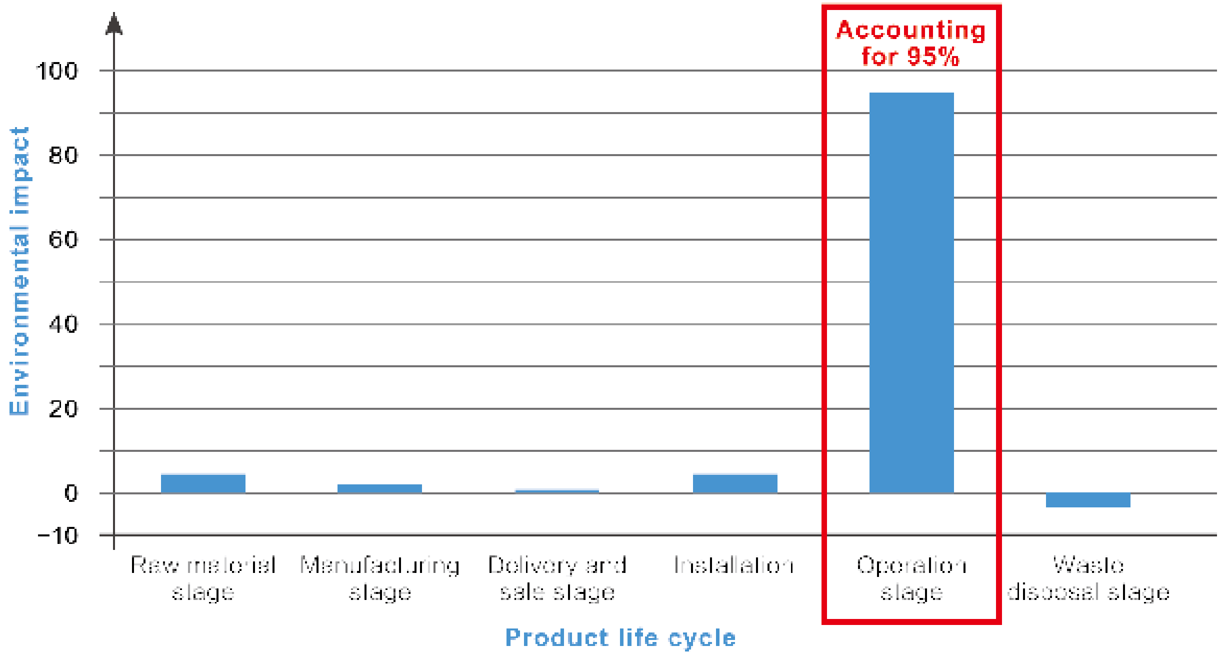
Through the changes in process technology, such as various cooling devices, defogging devices, spindle, oil and gas lubrication of linear guide, etc., the energy consumption of the machine tool is reduced, improving the energy efficiency of the machine during processing.

- Machine tool energy-saving technology

Up to 95% of the environmental impact of machine tools is in the operation stage, as shown in Figure 13. The major impact is electricity consumption. According to the statistics of the EU, the total electricity consumption

of machine tools accounts for 40% of the industrial production value, of which 70% is consumed by the electric drive system, and the electricity consumption of machine tools accounts for more than 68% of the total energy demand. Therefore, machine tool energy-saving technology has become a key to the future development of the machine tool ECO-System.

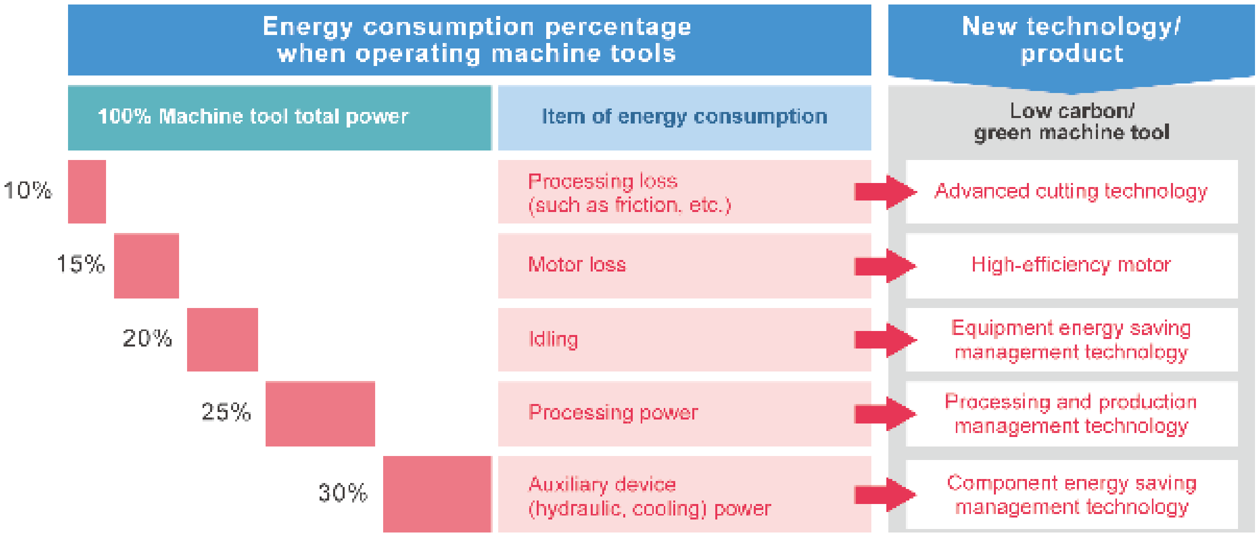
Figure 13. Percentage of environmental impact of machine tool life cycle



According to the European Machine Tool Sector and the Circular Economy report (2019)[9] published by CECIMO, a life cycle analysis (LCA) was conducted on 9 machine tools from 5 companies in Germany, France and the United Kingdom in 2009. In the scope of the overall life cycle, from cradle to grave, the operation stage of a machine tool has the greatest impact on the environment compared to other stages such as manufacturing, transportation, installation, maintenance, and decommissioning. In other words, the "total amount of greenhouse gas emissions" generated by the machine tool during its operation is the greatest, which is much higher than that in other stages such as the manufacturing of a machine tool. In addition to the energy-saving and carbon-reduction efforts for improving energy efficiency, trying to reduce the greenhouse gas emissions generated by users during the operation of machine tools can indeed make contribution to minimizing the impact of climate change on the Earth. As shown in Figure 14, the relevant low-carbon technologies and the energy consumption percentage when operating machine tools are summarized. They are valuable experiences gained from the actual operations of companies in the industry. However, it is still necessary to consider the applicability of each case in terms of their economic, technical and the engineering aspects.

[9] CECIMO, THE EUROPEAN MACHINE TOOL SECTOR AND THE CIRCULAR ECONOMY, April 2019
https://circulareconomy.europa.eu/platform/sites/default/files/circular_economy_report.pdf

Figure 14. Energy consumption percentage when operating machine tools and feasible low-carbon technologies

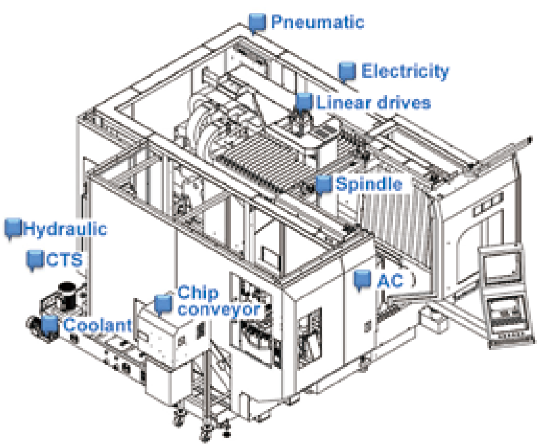


The report in the International Academy for Production Engineering (CIRP) Annals (2020)[10] analyzed and studied the energy flow of machine tools. For the power input of a machine tool, more than 50% of the power will be wasted during the operation of the equipment in the manufacturing stage. This suggests that the machine tool industry has great potential to help customers improve energy-saving efficiency, reduce carbon emission management costs, and increase market competitiveness. Considering that machine tools consist of different types, specifications, workloads and precision requirements, it is necessary to fully take into account different working environments and operation conditions to reduce the energy consumption of machine tools during operation and achieve the goal of energy saving and carbon reduction. Table 1 shows the energy-saving considerations of machine tools, and Figure 15 is a schematic diagram showing the main energy consumption of a machine tool, serving as a reference for machine tool manufacturers.

Table 1. Energy-saving considerations of machine tools

Energy-saving considerations of machine tools	
Machine tool characteristics	Parts and cutting tools used
- Machine type - Mechanical structure - Workpiece size - Degree of automation - Transmission mechanism	- Workpiece size and shape - Workpiece quality requirements - Workpiece material - Cutting tool accuracy - Cutting tool wear
Processing characteristics	Others
- Processing parameters - Cooling strategy - Overall consideration of the processing method	- Production environment - Processing time - Operation method - Operator's knowledge of the machine

Figure 15. Schematic diagram showing the main energy consumption of a machine tool



[10] Energy efficient machine tools, https://www.sciencedirect.com/science/article/pii/S0007850620301414

Modular design

Through the modular design of machine tools, the shareability of components in machine design can be improved, which in turn increases the flexibility of replacing parts during maintenance.

1.Perform partial parts replacement and maintenance; the replacement of damaged parts restores the equipment to its proper performance, reduces resource and energy consumption, and brings considerable environmental benefits in the era of limited raw materials, becoming a fundamental requirement of the circular economy.

2.Perform partial function upgrade (such as the controller, servo and spindle system) to improve machining performance and stability without purchasing a new machine, which prolongs the life cycle of machine tools, improves energy performance through high-efficiency CNC machining, and ultimately lowers overall environmental impact, as shown in Figure 16.

Figure 16. Examples of machine tool modularization under the OPC UA framework

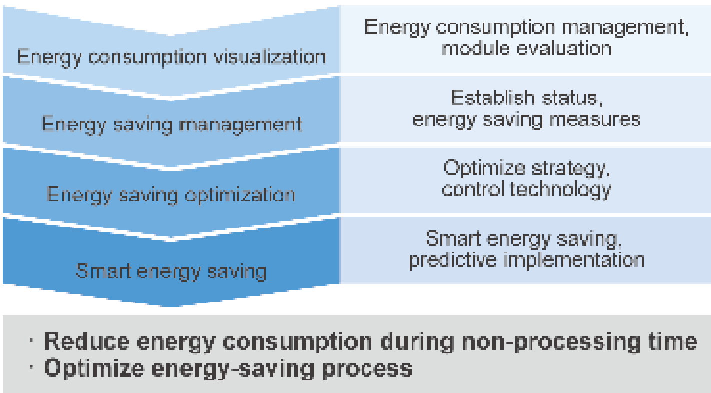
Smart energy-saving and value-added functions

Add digital technology and smart value-added functions (including AI, IoT, etc.) to existing equipment to help improve accuracy and efficiency without the need to purchase new equipment, reducing the impact on the environment.

Digital approach to optimizing energy conservation

Adding devices and instruments such as digital meters to the equipment to visualize and monitor energy consumption will be the first step in energy conservation optimization. Subsequently, through the establishment of energy conservation management measures and related optimization strategies, smart energy conservation optimization can be achieved to reduce the energy consumption of non-processing operations, obtaining the optimized energy-saving processes as shown in Figure 17.

Figure 17. Digital approach to optimize energy conservation of machine tools



Equipment health and maintenance prediction

Through information digitization and status monitoring, including AI (artificial intelligence) and IoT (Internet of Things) technology, historical and real-time data of machine operations are collected and analyzed to build a prediction model for the health of equipment. The model is used to detect potential mechanical problems early, avoid downtime for repair & maintenance, and improve product reliability and availability, thereby extending the life of the equipment and reducing the overall environmental impact.

Digital Twin

From product design, processing to decision-making control, the analysis and design of digital simulation are carried out through a digital twin to achieve the overall energy management optimization, high-efficiency energy conservation and carbon emission reduction goals.

- Digital twin of design

Combining with 3D printing, the digital model is linked with AIoT. Through the simulation analysis of software in a virtual environment, real-time comparison and corrections can be carried out to speed up product development and improve product features.

- Digital twin of manufacturing

When planning the product manufacturing process, apply simulation first to find the most efficient material preparation, procedures, and human-machine collaboration prior to the real production to improve production capacity and Order Fill Rate (OFR). Precise production procedures can also reduce product defect rates, as shown in Figure 18.

Figure 18. Digital twin of processing

Source: HEIDENHAIN

- Digital twin of production line

Select the best option from the simulation, make good use of expert experience to train the model, and find favorable decisions or resources for different production stages, which can also be applied in production management, scheduling, and equipment maintenance.

Additive manufacturing

The parts needed for the re-manufacturing and maintenance during the operation of machine tools can be produced through additive manufacturing, such as the manufacturing of lightweight and complex parts, strengthening of local structures, or maintenance spare parts that are difficult to obtain. This method reduces resource and energy consumption. Compared to traditional metal removal methods, additive manufacturing has the benefit of reducing machining waste, as shown in Figure 19.

Figure 19. Additive manufacturing

Source: TRUMPF

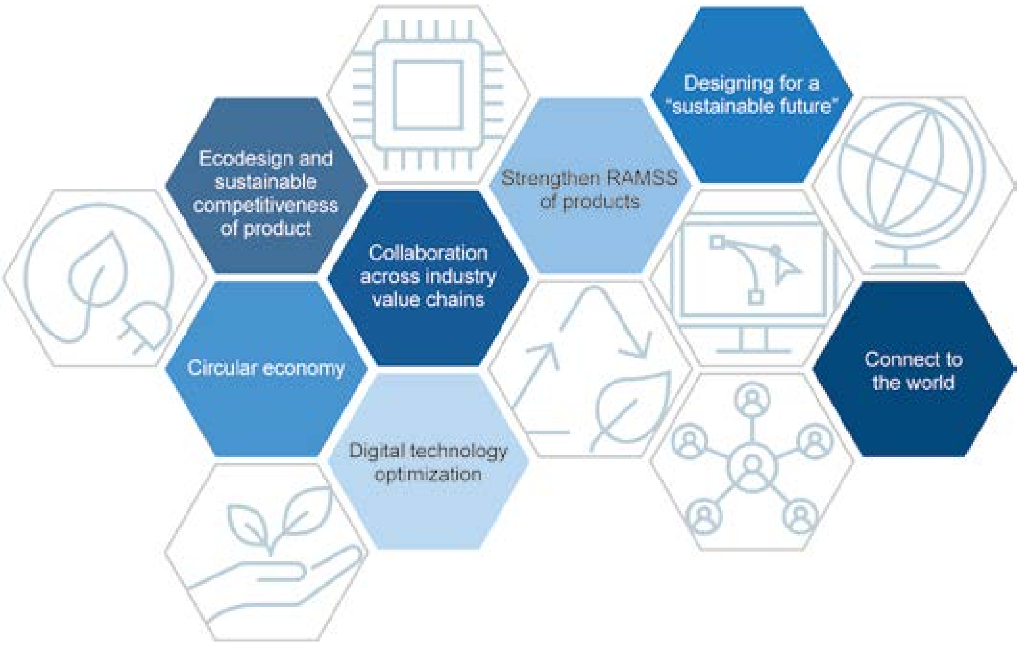
Establishment of the overall energy ecosystem for a machine tool plant

Combining smart manufacturing and virtual-real integration, the vertical division and horizontal merging of the entire plant’s manufacturing flow will be carried out comprehensively. Innovation will be brought about through digital technology, which will improve production capacity and efficiency. In the future, production scheduling can be further integrated with the energy management system to improve the energy application model and reduce indirect costs through contextualized data, achieving the goal of energy saving and carbon reduction.

CHAPTER 4. MAIN FOCUSES OF PROMOTION RECOMMENDED

Based on the content discussed in this report, the main promotion focuses recommended for the machine tool industry in response to sustainable operation and environmental protection trends are shown in Figure 20.

Figure 20. Main focuses of promotion for the machine tool industry in response to the trend of sustainable operation and environmental protection



1. Strengthen the sustainable competitiveness and ecodesign of products

(1) The proposal to revise the EU 2009/125/EC directive requirements for the ecodesign of sustainable products in 2022 was a mandatory regulation in the EU. The release of this directive also urged Apple to voluntarily announce that consumers can thereafter repair iPhones and replace their batteries. Furthermore, the specification of a common charging port (type C) will also be adopted by Apple in the future, demonstrating the importance and compulsion of this directive.

(2) International standards also play a key role, such as ISO 14955-1:2017 Machine tools — Environmental evaluation of machine tools — Part 1: Design methodology for energy-efficient machine tools, and ISO 14955-2:2018 Machine tools — Environmental evaluation of machine tools — Part 2: Methods for measuring energy supplied to machine tools and machine tool components. In addition to being in line with international standards, the introduction of international standards can save the cost and effort that Taiwan's machine tool industry needs to invest in for learning, and focus only on how to meet and improve these technical requirements. To help the plants of users establish smart production lines and realize Industry 4.0, it is very important to meet the compatibility standards of communication signals between various machine tools, such as OPC UA. These protocols and standards allow IIoT (Industrial Internet of Things) products, machines and assets from different manufacturers to interact in a transparent manner.

2. Circular economy planning for the life cycle of all products

The main focus of the circular economy in the machine tool industry is to improve the reliability, availability, and maintainability of equipment, and to reduce the loss of processing materials through machine program control optimization. Through the building of benchmarks and demonstrations over a long period of time, they will be applied gradually to the entire machine tool industry.

Machine tools are characterized by a long average service life. In a survey conducted in 2015, the average service life of CNC and non-CNC machine tools in Germany was 10.5 years and 19.7 years, respectively; therefore, extending the service life of machine tools, such as the use of digital technology, digital twin and predictive maintenance, will benefit the realization of net-zero emissions.

Predictive maintenance increases product reliability and availability, reducing total machine downtime, while extending machine life and improving overall equipment application effectiveness (OEE).

Requirements related to the circular economy in the EU Ecodesign Directive include reusability, upgradeability, repairability, possibility of repair and refurbishment, recycling content, possibility of remanufacturing and recycling, possibility of material recycling, expected waste generated, stressing the need for a circular economy in the life cycle of machine tools.

3. Win-win collaboration across industry value chains

The industry needs to rely on the supply chain to create value. Combining the “design specifications” and the “quality specifications”[11] promoted by the Industrial Development Bureau, MOEA (Ministry of Economic Affairs) and TMBA (Taiwan Machine Tool & Accessory Builders’ Association) will have the potential to create a mutual benefit opportunity.

(1) Collaborating with upstream equipment component suppliers helps to develop equipment and parts with higher energy-saving potential, which can significantly reduce the energy dependence, consumption and carbon emissions of users during the operation stage. In addition, it fulfills the modular design and assembly concept in the design specification, and achieves the long-term goal of easy disassembly and recyclability in the future.

(2) Collaborating with suppliers of raw materials and consumables to select recycled materials and use more durable composite materials, minimizing the need for exploiting raw materials, and reducing the total carbon emissions of materials in their entire life cycle. Developing alternative and environmentally friendly coolants and lubricants, reducing the generation of waste and increasing the efficiency of heat exchangers during processing can also make contributions to net-zero emissions.

(3) Collaborating with downstream customers to assist them in reducing carbon emissions and carbon emission costs during the operation stage. Energy consumption during the operation stage is a key factor affecting the environmental performance of machine tools. Applying digital technology to manage the health of equipment and predict maintenance time can effectively reduce equipment failures, minimize unexpected downtime, and improve the operation efficiency and utilization rate of machine tools for users.

This value creation thinking that combines upstream equipment manufacturers, material suppliers and downstream users complies with the design specifications as well as the quality specifications to enhance product competitiveness. It also reduces the carbon emission of products by effectively extending the service life of products.

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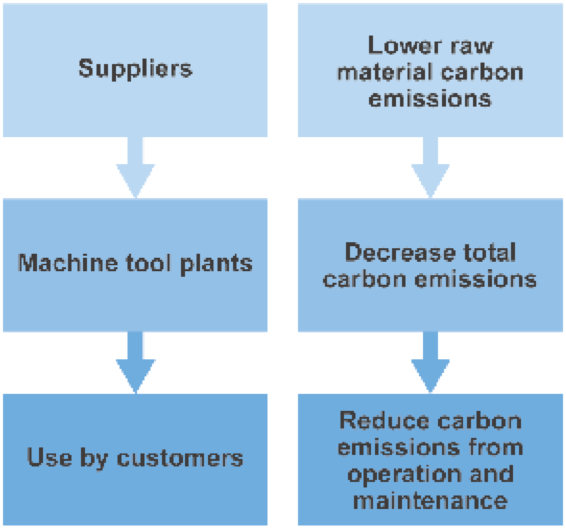
[11] The platform of design specifications and quality specifications, https://norm.pmc.org.tw/

By incorporating more precise controls and advanced IoT-related aids to machine tools, energy can be more effectively utilized in all stages of the processing operation from preparation to completion, helping to reduce standby and ineffective operation, as shown in Figure 21.

Figure 21. Carbon reduction management for the machine tool industry supply chain



NOTE:

Taiwan Machine Tool & Accessory Builders' Association (TMBA) established a technical committee in August 2020 to promote general standards for the machine tool industry. Since 2021, it has collaborated with the Industrial Development Bureau, MOEA to promote the digital transformation of the machine tool industry. It is hoped that through the introduction of the "design specifications" and the "quality specifications" for machine tools, the common design of the component interface can be improved. Furthermore, a traceability management mechanism was established to strengthen product reliability, achieve the goal of energy sustainability and build the core values for the norms of the machine tool industry.

4. Leverage digital technology to optimize management and manufacturing

Although the production and manufacturing management of machine tools have reached a certain level, with more and more successful cases of digital technology application, it is recommended that the machine tool industry can make good use of digital technology. Digital technology does not mean only AI, but also the integration of various digital technologies such as iABCDEF. By utilizing the IoT device on the machine, massive data in the manufacturing process and equipment operation is collected. Through the optimization of various digital technologies, management and manufacturing efficiencies are improved, thereby boosting the performance of machine tools. Common digital technologies that are widely used in the industry include image recognition, defect detection, production process monitoring, processing condition self-adjustment (compensation) systems, cooling and energy-saving system monitoring, remote monitoring and operating systems, equipment prognostic and health management (PHM), production scheduling, automated guided vehicle (AGV) and smart warehouse, digital twins, etc.

For manufacturers, digital technology can improve production efficiency, and minimize equipment standby or troubleshooting. The simulation of production schedule and traffic flow, plant configuration, air compressor system management, etc., prior to production line changes and adjustments can eliminate blind spots during production in advance and effectively manage the on-site process. As for the environmental control, air conditioning and cooling management of the plant, internal and external data can be used to more accurately predict and adjust the operation of energy-consuming equipment of machine tools, reducing the chance of carbon emissions.

NOTE:

Digital technology iABCDEF refers to:
i: IoT (Internet of Things), A: AI algorithm, B: Blockchain, C: Cloud computing and application, D: Big data processing, E: Edge computing, F: 5G high-speed communication and data transfer

5. Strengthen the RAMSS[12] (Reliability, Availability, Maintainability, Safety, Security) of Products

For equipment users, unexpected downtime that leads to the inability to manufacture is the biggest problem. Therefore, how to continuously improve the overall equipment efficiency (OEE), including equipment, manufacturing, energy application, time, output, manpower, utilization rates, etc., are all issues that the machine tool industry needs to pay attention to while improving competitiveness.

Equipment line/mold change, breakdown maintenance, performance drop, standby operation, and invalid handling are hidden troubles that cause equipment to waste power and increase carbon emissions. Therefore, from the design of a machine tool to its manufacture, it is necessary to carefully consider the reliability, availability, maintainability, safety and information security of the equipment during the operation stage, ensuring that the machine tool is working under the best condition during the operation stage to make good use of electricity. Overall, this can reduce electricity consumption and carbon emissions.

In addition to continuously strengthening the R&D of machine tool components and parts, the machine tool industry can also make good use of digital technology iABCDEF to effectively promote the overall performance of RAMSS. The application of digital technologies for remote diagnosis of the health status of equipment, machine performance improvement analysis and suggestions, remote equipment software automatic update (OTA function), equipment accuracy adjustments, and maintenance will greatly reduce the energy consumption in cross-border traffic and the cost of waiting for the recovery of equipment.

6. Designing for a "sustainable future": Introducing carbon-reduction materials, technologies and equipment

While the industry is constantly exploring newer and better technologies, it also needs to take into consideration the "future." The concept of designing for the future not only focuses on the protection of the environment and resources, but also takes into account the most efficient use and balance of the environment and resources. The main task of machine tools is to produce "parts." Recently, there have been many

[12] Statistics, RAMS & Quality Management, http://www.applied-statistics.org/RAMS_Standards_EN.html

pioneering applications for the circular economy of additive manufacturing, weight reduction, injection die casting, powder metallurgy, etc. Recommended designing methods for "sustainable future" include life cycle assessment[13] (LCA), bionic design, topological method, modular design of microsystems, lightweight design, mechanism design, energy conversion design (cold, heat, electricity, pressure, etc.), material alternative, reconfiguration of manufacturing systems, and smart digital technology[14].

Machine tools not only consume electricity that generate carbon emissions during production and processing, but also cause other pollutions, indirectly or directly affecting the environment and resources. Therefore, in the machine tool designing and developing stage, in addition to the consideration of energy saving and carbon reduction, the cooling and lubrication system, the discharge system, the internal and external circulation of the recycling and reuse of the processing operation should also be considered.

7. In line with the net-zero emission norms of the global machine tool industry

As countries announce their net-zero emissions goals for 2030 and 2050, various new policies, standards and norms will inevitably be introduced, which will cause a significant impact on the export-oriented machine tool industry. Instead of acting passively, it is better to respond proactively. For example, iconic machine tool manufacturers and countries in Europe are actively establishing energy-saving labels for products that are environmentally friendly, low in carbon emissions and high in energy efficiency. Representative labels include the ISO 14955 machine tool energy-saving testing and EU energy label, Blue Philosophy, and Blue Competence. In addition to the EU CBAM, other major trading countries, such as the United States, China, Japan, and South Korea are also developing similar non-tariff barriers, which are worthy of advanced planning and direct engagement.

NOTE:

Blue Philosophy is an initiative launched by UCIMU, and was incorporated into the UCIMU logo in 2011. The purpose of the initiative is to demonstrate the Italian machine tool manufacturers' responsibility and commitment to sustainability, especially with regard to energy efficiency and the environment. More than 70 companies are currently licensed to use the UCIMU logo.

Blue Competence is an initiative launched by VDMA in 2009. The initiative focuses on energy conservation and environmental sustainability, and later also covers economic and social sustainability. CECIMO has been promoting the Blue Competence initiative for the machine tool industry in Europe since 2012. As of 2018, the machine tool related associations in the United Kingdom (MTA), Germany (VDW), Spain (AFM), Switzerland (SWISSMEM) and the Czech Republic (SST) have successively joined the initiative.

[13] Review of life cycle models for enhancing machine tools sustainability: lessons, trends and future direction, https://www.sciencedirect.com/science/article/pii/S2405844021008938

[14] The Analysis of Key Technologies for Sustainable Machine Tools Design, https://www.mdpi.com/2076-3417/10/3/731/htm

CHAPTER 5. CONCLUSION

The combination of innovative thinking and digital technology serves as the power to system integration. Through cross-industry alliances, domain knowledge can be merged to strengthen and expand the R&D momentum and professional capabilities of the machine tool industry, exerting the function of linking the upstream and downstream of the industry, and developing digital transformation solutions that conform to the characteristics of the industry to create new value for industrial digital transformation. To promote the cross-domain high-value of the circular economy in the industry, one must start by thinking about the needs and opportunities of the cycle at the design and manufacturing stage, including technology integration, and the use of modular components and design standards to simplify product designs, extend product life cycles, and improve the business value of products, reducing their environmental impact.

Environmental sustainability is a responsibility and a mission; net-zero emissions are the beginning of the mission. "The Intellect Creates and the Eloquent Illustrates," this emerging model will collect the power from the upstream, midstream and downstream of the industry, give full play to their respective strengths, and write a new page in the history of the industry based on the concept of "creating links and achieving mutual benefits."

REFERENCES

1. Taiwan Machine Tool & Accessory Builders' Association (TMBA), 2021 Machine Tool Industry White Paper, 2021
2. Taiwan Renaissance Platform, Taiwania Capital, 2020 White Paper on Corporate Venturing, 2020
3. National Development Council (NDC), Taiwan's Pathway to Net-Zero Emissions in 2050
4. CECIMO, The European Machine Tool Sector and the Circular Economy, 2019
5. CIRP Annals Volume 69, Issue 2, 2020
6. European Commission, Carbon Border Adjustment Mechanism, 2021
7. European Commission, Proposal for a Regulation of the European Parliament and of the Council : establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC, 2022
8. ETMM, 10 examples of sustainability in machine tool manufacturing, 2020
9. Jean-Philippe Montfort & Pavlina Chopova-Leprêtre, EU Proposal on New Ecodesign Requirements for Sustainable Products, Mayer Brown, 2022
10. Rainer Stark, Günther Seliger, Jérémy Bonvoisin, Sustainable Manufacturing : Challenges, Solutions and Implementation Perspectives, Springer Nature, 2017
11. VDW, Energiewende bietet Potenzial für die Werkzeugmaschinenindustrie, 2022

APPENDIX

Appendix 1 : Timeline of important international events regarding net-zero emissions by 2050

International	
Time	Event
2021	● The International Energy Agency (IEA) has called on all governments to stop approving new coal or oil-gas fields and formulate plans to effectively decommission existing facilities. ● In June, the G7 pledged to jointly address the "carbon leakage" issue. ● On July 14, the EU announced the Fit for 55 Package, as well as the draft Carbon Border Adjustment Mechanism (CBAM).
2022	● The EU adopted the CBAM on June 22, which is applicable starting from January 1, 2023. The transition period will be until the end of 2026, and the official implementation time of the CBAM will be extended to 2027. ● Initially, the EU CBAM's carbon footprint inventory of products (ISO 14067) only considered direct greenhouse gases in the manufacturing stage. The CBAM adopted on June 22 added indirect greenhouse gases in the manufacturing stage. In addition to items such as cement, steel, aluminum, fertilizer, and electricity, the scope of control also includes organic chemicals, plastics, hydrogen and ammonia. ● The Clean Competition Act (CCA) of the United States is scheduled to impose carbon tariffs on regulated primary products in 2024 and 2025. Starting from 2026, carbon tariffs will be imposed on products containing more than 500 pounds (about 225 kilograms) of primary products.
2023	● CBAM transition period: carbon emission data must be declared for steel, cement, fertilizer, aluminum, electricity, chemical materials (organic, anhydrous ammonia, ammonia water, hydrogen, etc.) and polymers; however, no tax is levied.
2024	● The CCA Act of the United States imposes carbon tariffs on regulated primary products.
2025	● The Post-2030 Nationally Determined Contributions (NDCs) goals are submitted in 2025. ● The International Energy Agency (IEA) bans the installation of gas stoves in new buildings.
2026	● The CCA Act of the United States imposes carbon tariffs on products containing more than 500 pounds (about 225 kilograms) of primary products.
2027	● The EU CBAM is officially implemented.
2030	● UNFCCC COP26 declares that carbon emissions in 2030 will be reduced by 45% compared with 2010. ● The Intergovernmental Panel on Climate Change (IPCC) report suggests that the 2030 carbon reduction goal must reach 43% in order to achieve net-zero carbon emissions by 2050. ● The EU sets a goal of 55% reduction in carbon emissions by 2030 compared with 1990.
2035	● The International Energy Agency (IEA) bans the sale of new gasoline- or diesel-powered cars and quadruples the pace of building solar power plants.
2040	● The International Energy Agency (IEA) promotes the global power sector to reach net-zero carbon emissions.
2050	● Major industrialized countries around the world achieve net-zero emissions.

Source: Taiwan's Pathway to Net-Zero Emissions in 2050 for the ICT Industry

Appendix 2 : Timeline of important events in Taiwan regarding net-zero emissions by 2050

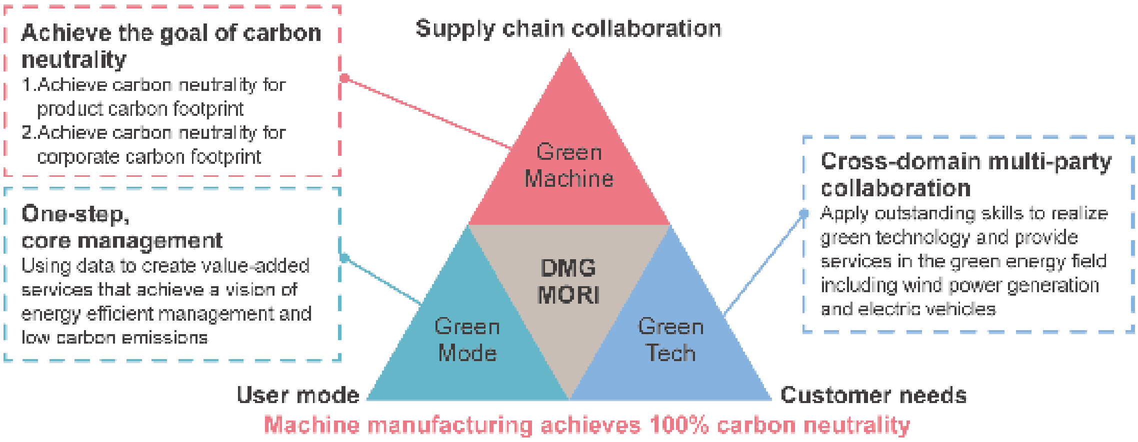
Taiwan	
Time	Event
2021	• On April 22, the Earth Day, President Tsai Ing-wen declared that 2050 net-zero transition is the goal of the world and also the goal of Taiwan.
2022	• In March, the Environmental Protection Administration tightened air pollution controls and reduced loads to lower emissions. • On March 3, the Financial Supervisory Commission released the Sustainable Development Roadmap for Listed Companies. • On March 30, the National Development Council announced Taiwan's Pathway to Net-Zero Emissions in 2050. • On April 21, the Executive Yuan passed the draft amendment to the "Greenhouse Gas Reduction and Management Act," incorporated net-zero emissions by 2050 into the Act, and renamed it the "Climate Change Response Act," which was submitted to the Legislative Yuan for examination.
2023	• The Ministry of Economic Affairs will announce the "Regulations on the Water Conservation Charge." • The Environmental Protection Administration expands the inventory of greenhouse gas emissions.
2024	• The Environmental Protection Administration imposes carbon fees in 2024-2025.
2025	• The goal of 20% electricity derived from renewable energy sources. • The penetration rate of electric buses in urban areas reaches 35%. • No new coal-fired power plants will be built.
2026	• Large electricity users with a chartered capacity of more than 5,000 KW need to install 10% renewable energy.
2030	• Total installed capacity for wind and photovoltaic systems reaches 40 GW. • The sales ratio of electric cars is 30%, the sales ratio of electric motorcycles is 35%.
2035	• The installation rate of smart meters reaches 100%.
2040	• Coal-fired and gas-fired power plants are used depending on the development of carbon capture, utilization and storage (CCUS) technologies.
2050	• Power generation from renewable energy accounts for more than 60%. • The installation rate of smart substations reaches 100%.

Source: Taiwan's Pathway to Net-Zero Emissions in 2050 for the ICT Industry

Appendix 3 : Indicative Case of International Machine Tool Manufacturers (DMG MORI)

DMG MORI launched carbon reduction solutions based on three strategies, including “building green machines,” “expanding green models,” and “promoting green technologies.” In terms of building green machines, it offers global customers with machine tool products that exhibit carbon-neutral footprints from raw materials to delivery, further increasing added value. For expanding green models, it emphasizes the creation of value-added applications based on data-driven decision-making to provide software and hardware integration solutions. As for promoting green technologies, it serves customers in the green energy sector, including wind turbines, hydropower plants, hydrogen electrolysis or electric vehicle manufacturing, with its own expertise, and further develops highly innovative technologies.

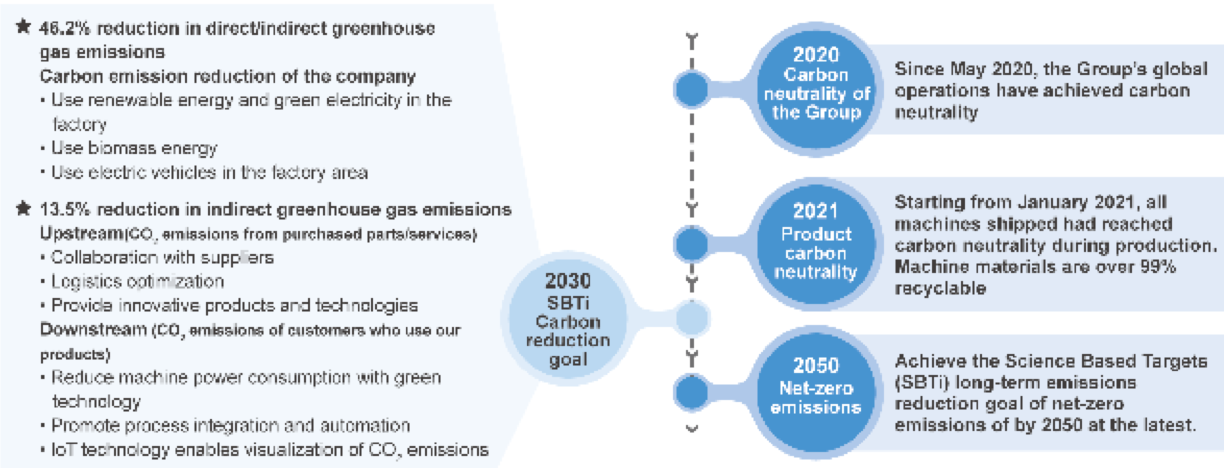
Figure 22. Carbon-neutral plan of the DMG MORI Group



Source: 2021 Annual Report of DMG MORI

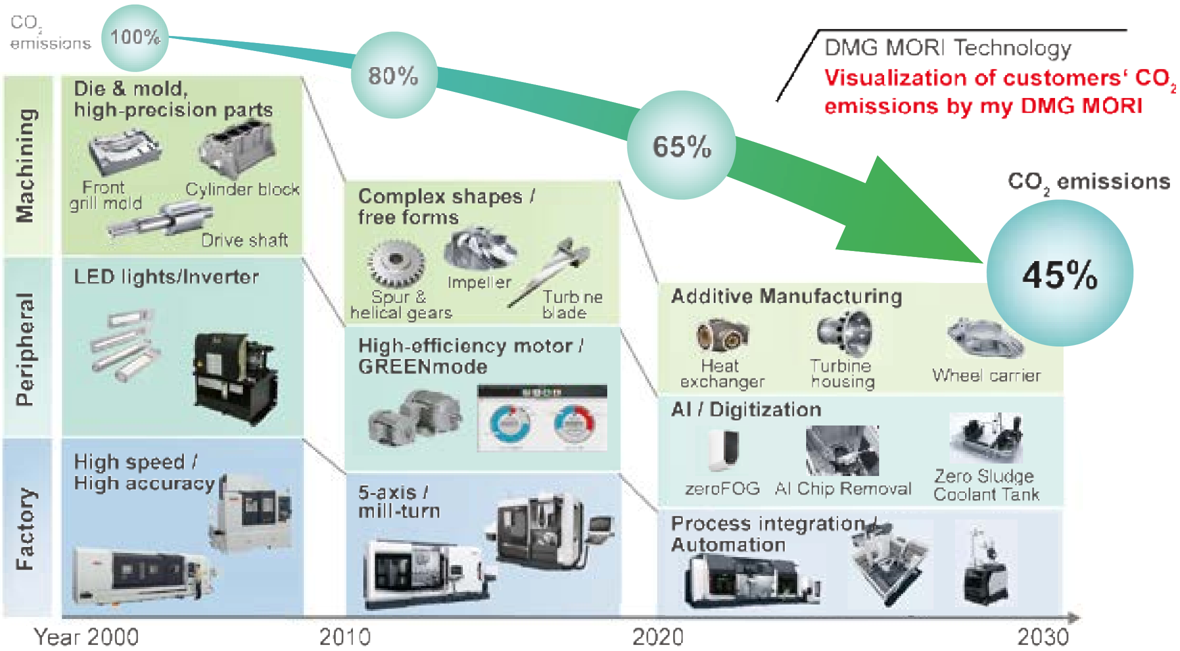
The aim of DMG MORI is to achieve the Science Based Targets (SBTi) long-term emissions reduction goal of net-zero emissions by 2050 at the latest.

Figure 23. SBTi carbon reduction verification plan of the DMG MORI Group



Source: 2021 Annual Report of DMG MORI

Figure 24. Product energy-saving technologies and achievements of the DMG MORI Group

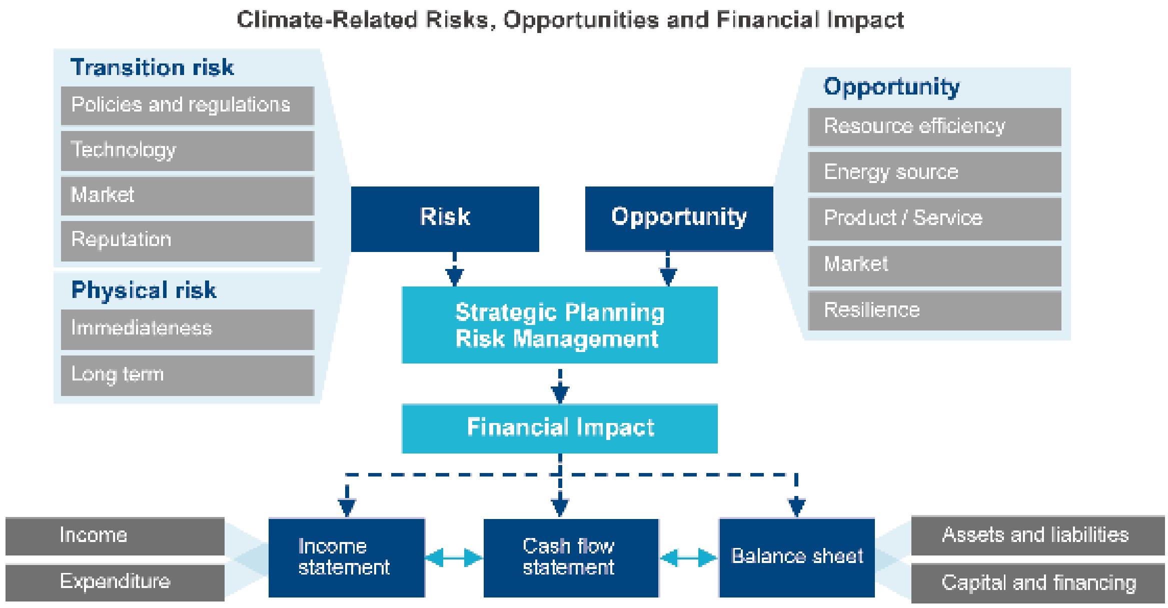


Source: DMG MORI 2021 Annual Report

Appendix 4: Using TCFD as a tool to carry out a "Business Impact Analysis" for the machine tool industry

Apply the methodology and scenario analysis of the Task Force on Climate-related Financial Disclosures (TCFD) to conduct a "Business Impact Analysis" on the machine tool industry based on climate change and net zero demands.

Figure 25. Applying the methodology and scenario analysis of the Task Force on Climate-related Financial Disclosures (TCFD)



Source: Task Force on Climate-related Financial Disclosures (TCFD) Recommendations - Summary Report

1.The impact (risk) of the consequences of climate change on the machine tool industry:

★ Transition risk: International and domestic policy and regulatory trends on energy conservation and carbon reduction have become stricter in response to climate change, and will also put pressure on the industry through economic means such as carbon fees or carbon taxes. The European Union and other countries have also clearly declared that electric vehicles will replace traditional internal combustion engine vehicles, which also has a significant impact on the transformation of the machine tool industry in terms of technology and markets. In addition, with the upsurge of net-zero emissions, if a company adopts a conservative approach, it will definitely create a negative impact on the company's image and brand, and it will in turn give customers a bad impression.

★ Physical risk: The 8% increase in electricity fees in 2022, the carbon fee that will be imposed by the Environmental Protection Administration in 2024, the collection of the EU carbon border tax in 2027, and the carbon neutrality required by brands and customers have given the industry a clear sense of the immediate financial costs and business risks.

From the perspective of long-term risks, under the premise of climate change, there are potential challenges to the energy consumption, structure, design, performance, durability, reliability and other characteristics of machine tools, such as increased energy costs, additional carbon costs, rising temperatures, water shortages, material shortages, the need for energy saving and cooling during the operation of machine tools, and the increasing demand in material consumption, particularly under a situation of lacking green electricity and uneven resource distribution.

2.The impact (opportunity) of climate change strategies on the machine tool industry:

★ At this stage, in the field of machine tool applications, the automotive, aerospace and defense, electrical and electronics engineering industry applications account for about 3/4, and other industries account for 1/4. Observing the development trend of various industries, it is estimated that in the next ten years, industries including semiconductors, energy equipment (offshore wind power and large-scale energy storage systems), and medical equipment will have significant growth opportunities, and will create a new wave of machine tool market demand.

★ In response to climate change and the realization of a sustainable energy supply, more green energy to replace fossil fuels, and supporting solutions for large-scale energy storage systems will be needed in the future. Therefore, the types and functions of machine tools required for the production of green energy-related equipment will be different and the demand will also vary. In addition to common solar power generation and wind power generation, other new types of green power equipment such as geothermal power generation, tidal power generation, hydrogen power generation, etc. also require large-scale energy storage systems. The processing tools and parts required from the new opportunities derived are different. Therefore, it also brings new types of demands and opportunities for the machine tool industry.

For the customers and market of machine tools, the cost of energy and carbon reduction is increasing. According to the research results of CECIMO's report on the European machine tool sector and the circular economy and the Annual Report of the International Academy for Production Engineering (CIRP), in the entire life cycle of a machine tool, the energy consumption and waste in the operation stage are the highest. As a result, customers and the market must have higher expectations for the energy efficiency and reliability of machine tools.

Appendix 5: List of Experts

No.	Title of Committee	Unit	Name	Title	Title of TMBA
1	General Convenor	Habor Precision Inc.	Wen-Hsien Hsu	Chairman	Chairman
	Think Tank Committee				
2	Convenor	Avex-SG Technology Inc.	Kimble J. Chen	Chairman	Vice Chairman
3	Deputy Convenor	Yeong Chin Machinery Ind. Co.,Ltd.	Patrick P. Chen	General Manager	Executive Director
4	member	Pinnacle Machine Tool Co., Ltd.	Allen Hsieh	General Manager	Director
5	member	Deta International Co., Ltd.	Alen Hwang	President	Director
6	member	Tung Pei Industrial Co., Ltd.	Cheng Chen	Chairman	Director
7	member	L & L Machinery Industry Co., Ltd.	Jeorge Lin	General Manager	Director
8	member	Shieh Yih Machinery Industry Co., Ltd.	Claire Kuo	Chairman & CEO	Director
9	member	Parkson Wu Industrial Co., Ltd.	Wenson Wu	General Manager	Director
10	member	Matech Industrial Co., Ltd.	Eugene Chen	Vice President	Director*
11	member	Winson Machinery Co., Ltd.	Eric Hsieh	General Manager	Director*
	Technical committee				
12	Convenor	Yeong Chin Machinery Ind. Co.,Ltd.	Patrick P. Chen	General Manager	Executive Director
13	Deputy Convenor	Tongtai Machine & Tool Co., Ltd.	Jui-Hsiung Yen	Chairman	Honorary Chairman
14	Deputy Convenor	Victor Taichung Machinery Works Co., Ltd.	Min-Ho Huang	Chairman	Advisor
15	Deputy Convenor	Buffalo Machinery Co., Ltd.	Paul Chang	Chairman	Advisor
16	Deputy Convenor	Awea Mechatronic Co., Ltd.	Michael Yang	General Manager	Director*
17	Deputy Convenor	Far East Machinery Co., Ltd.	David Chuang	General Manager	Director
	Advisor				
18	Advisor	Goodway Machine Corp.	Edward Yang	Chairman	Honorary Chairman
19	Advisor	Hiwin Technologies Corp.	Eric Y.T. Chuo	CEO	Honorary Chairman
20	Advisor	Taiwan Takisawa Technology Co., Ltd.	Winston Tai	Managing Director	Executive Director
21	Eexpert	Metal and Mechanical Industries Division, Industrial Development Bureau, MOEA	Lin Hua-Yu	Director	
22	Expert	Taiwan Industrial Competitiveness Association (TICA)	KP Huang	CSO	
23	Compilation unit	Precision Machinery Research & Development Center (PMC)	Tim Lai	President	
24	Compilation unit	Precision Machinery Research & Development Center (PMC)	Daniel Chen	Director	
25	Secretariat	Taiwan Machine Tool & Accessory Builders' Association (TMBA)	Carl Huang	Secretary of General	

*Alternate

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