# Taiwan's Chemical Industry: Looking Back and Looking Ahead

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Since World War II, Taiwan's chemical industry and economy have escalated dramatically. Self-sufficient in many areas, today Taiwan still faces the challenges imposed by government technical initiatives, international trade policies and regulations, and competition from China and other emerging economies.

Taiwan's chemical industry originated in the 19th century, after the Qing Dynasty ceded Taiwan to Japan. In the era of Japanese occupation, which lasted from 1895 until 1945, Taiwan served as a base for the export of agricultural and industrial materials to Japan. After World War II, the Republic of China became the governing body of Taiwan and initiated an era of rapid industrialization. In line with this rapid economic growth, Taiwan's chemical industries expanded and thrived in the ensuing decades.

By 1991, the gross domestic product (GDP) of Taiwan's chemical industries totaled approximately $37 billion* and accounted for a quarter of Taiwan's total manufacturing industry. In particular, $24.2 billion was attributable to a growing market for consumer goods and basic chemical products. In 2010, the total revenue from Taiwan's chemical industries reached $135 billion, accounting for 29.3% of Taiwan's overall GDP in the manufacturing sector (approximately $461 billion).

One noteworthy feature of Taiwan's chemical industry is its backward integration — growing demand from downstream processing drives the development of upstream petrochemical industries. In 2010, approximately 80 major chemical companies and the 42 member companies of the Taiwan Petrochemical Association produced the upstream, midstream, and downstream products of the petrochemical industry. (Many of the key companies and their products are listed in Table 1.) Taiwan's production capacity for ethylene now exceeds 4 million m.t./yr, making Taiwan the eighth largest ethylene producer in the world *(1)*. Overall, Taiwan exports 50% of its petrochemical products, with about 70% of its plastic, synthetic resin, and synthetic rubber raw materials (*e.g.*, polyethylene, styrene butadiene rubber) going to China.

This article charts Taiwan's progress as a chemical industry leader over the past century. It details the rapid growth in key industry sectors since World War II, and addresses some of the challenges the nation's industries face today.

## The foundations of an industry (1895–1945)

During the Qing era of the 19th century, Taiwan had small-scale plants for such industries as brewing, papermaking, dyeing, and grease processing. These sectors

* All monetary quantities are in U.S. dollars; when this article was written, the exchange rate was 1 U.S. dollar = 30 New Taiwan dollars.

| Table 1. Major petrochemical producers and their products. |
|---|
| **China Petroleum Corp. (CPC)** |
| *Aromatics:* benzene, toluene, p-xylene |
| **China Petrochemical Development Co.** |
| *Monomers:* caprolactam; acrylonitrile<br>*Industrial Chemicals:* acetic acid |
| **China Man-Made Fiber Corp. (CMFC)** |
| *Monomers:* ethylene glycol; ethylene oxide |
| **Chang Chun Plastics Co. (CCP)** |
| *Monomers:* acrylamide<br>*Plastics:* polyvinyl alcohol; epoxy resin<br>*Solvents:* acetone<br>*Industrial Chemicals:* acetic acid; phenol; biphenyl A (BPA) |
| **Chi Mei** |
| *Synthetic Rubber:* styrene-butadiene rubber; thermoplastic elastomer<br>*Plastics:* polystyrene; acrylonitrile butadiene styrene (ABS); polymethylmethacrylate; polycarbonate |
| **Darien Chemical Corp.** |
| *Monomers:* vinyl acetate monomer; 1, 4-butanediol; polytetramethylene ether glycol<br>*Solvents:* ethyl acetate<br>*Industrial Chemicals:* ethylene vinyl acetate (EVA) emulsion powder; 2-methyl-1,3-propanediol; allyl alcohol |
| **Formosa Chemical and Fiber Corp.** |
| *Aromatics:* benzene, toluene, p-xylene<br>*Monomers:* purified terephthalic acid; styrene monomer<br>*Plastics:* ABS; polypropylene; polycarbonate<br>*Solvents:* acetone<br>*Industrial Chemicals:* phenol |
| **Formosa Plastics Corp. (FPC)** |
| *Monomers:* vinyl chloride monomer, acrylonitrile; acrylic acid; methyl methacrylate<br>*Plastics:* polyethylene (low density, high density); EVA; polyvinyl chloride (PVC); polypropylene; polyacetals |
| **Grand Pacific Petrochemical Corp.** |
| *Monomers:* styrene monomer<br>*Plastics:* ABS |
| **LCY Chemical Corp.** |
| *Monomers:* acetaldehyde<br>*Synthetic Rubber:* thermoplastic elastomer<br>*Plastics:* polypropylene<br>*Solvents:* acetone; ethyl acetate; isopropyl alcohol; methyl ethyl ketone |
| **Nanya** |
| *Monomers:* ethylene glycol; 1, 4-butanediol<br>*Plastics:* epoxy resin<br>*Industrial Chemicals:* BPA |
| **Taiwan Prosperity Chemical Corp.** |
| *Solvents:* acetone<br>*Industrial Chemicals:* BPA |

remained important after Japan took over Taiwan in 1895. Increasing demand and production capacity entailed the use of more machinery, thereby modernizing Taiwan's chemical industry. Taiwan's abundance of agricultural raw materials spurred Japan's government and enterprises to invest significant capital to build plants and develop technologies in Taiwan, and most of the resulting products were exported to Japan.

One important raw material was sugarcane, whose ample supply laid the foundation for several industries. Molasses, the byproduct of sugar production, was exploited for fermentation, stimulating the brewing industry. Molasses was also employed in the production of ethanol, which was used in industry and tested as an alternative fuel. Yet another byproduct of sugar production, bagasse, was recycled for papermaking. This burgeoning agricultural sector led to the establishment of a chemical fertilizer industry, albeit at a small scale.

Taiwan's oil refining industry was also launched during this period, when in 1937 the Japanese government constructed a refinery in the southwestern port city of Kaohsiung to provide fuel for the Japanese Navy.

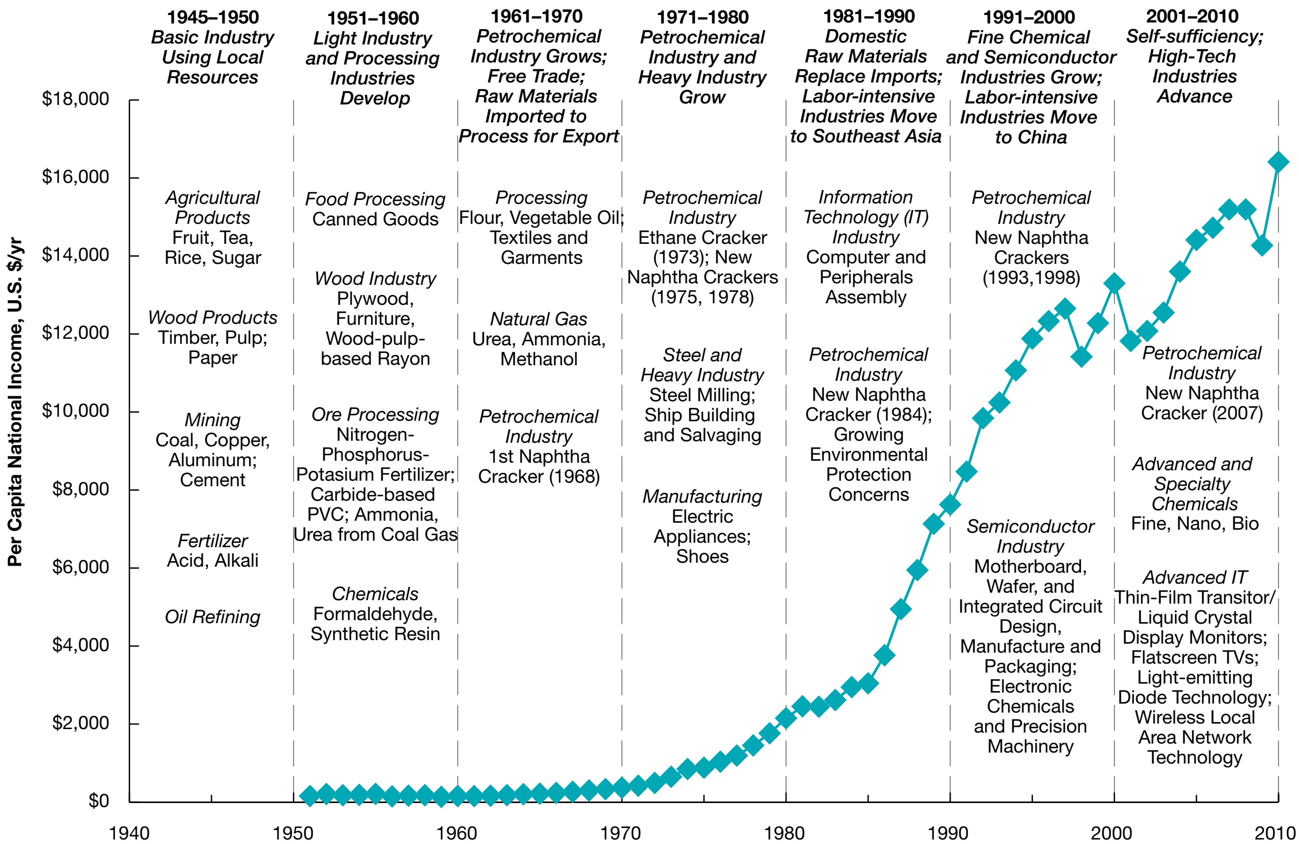
## Revival to rapid growth (1945–1990)

The majority of Taiwan's industrial equipment was devastated during World War II, after which all industrial infrastructure was transferred by Japan to the Taiwan government. From 1945 to 1950, Taiwan's remaining industries survived by making practical use of locally available resources, such as wood and sugar. This period of basic-resource exploitation was the first step in Taiwan's postwar industrial re-emergence and progress (Figure 1).

Despite a shortage of equipment and technology, Taiwan's government managed to build plants to produce alkali (NaOH) and acid ($H_2SO_4$) for agricultural fertilizers. The state-run China Petroleum Corp. (CPC) was founded in 1946, and began producing fuels and petrochemicals in 1947 when it took over the Japanese Navy fuel refinery at Kaohsiung, with its capacity of 6,000 bbl/d. In the years that followed, CPC built more plants, upgraded equipment, and upgraded refinery processes to meet downstream demand — increasing its refinery capacity to nearly 60,000 bbl/d by the late 1960s.

Another impetus to Taiwan's emerging chemical industry was the production of bakelite at Chang Chun Plastics Co. (CCP), beginning in 1949.

In the early 1950s, Taiwan's government initiated a series of economic development plans, assisted by some $100 million per year in U.S. aid from 1951 to 1965 to build industrial parks and strengthen electricity supply and transportation infrastructures. These investments bolstered Taiwan's inorganic acid- and fertilizer-based light indus-




▲ **Figure 1.** The progress of Taiwan's chemical industry accelerated from 1950 to 2000. In parallel with the maturing petrochemical industry was a skyrocketing of per capita income.

tries, including paper, sugar, camphor oil, textile, leather, and pesticide manufacturing — although Taiwan still relied on imported raw materials for the processing of downstream end products such as fertilizers and plastics.

The foundation of Taiwan's plastics and synthetic-fibers industries was cemented in 1957, when Formosa Plastics Corp. (FPC) and China Man-Made Fiber Corp. (CMFC) launched the production, respectively, of polyvinyl chloride (PVC) and rayon.

Beginning in the 1960s, Taiwan established free-trade zones, encouraging companies to import and process raw materials to make products such as PVC for export. To keep up with the pace of agriculture development and industrialization, in 1961 CPC co-founded a company with Mobil and Allied Chemical — Mobil China Allied Chemical Co., in Miaoli — to produce urea and ammonia from natural gas.

The economic development plans in this period helped Taiwan to become a leading exporter of textiles, garments, leather goods, umbrellas, toys, and shoes.

The country's booming economy and expanding exports drove new domestic demand for fuel, lubricants, and chemical materials such as PVC and nylon. In response, CPC built Taiwan's first naphtha cracker at Kaohsiung, with an ethylene capacity of 54,000 m.t./yr, in 1968. This fueled even more growth in the petrochemical industries, and necessitated CPC's launch of a second naphtha cracker. By 1975, CPC was supplying ethylene (230,000 m.t./yr), propylene (110,000 m.t./yr), and butadiene (35,000 m.t./yr), as well as benzene, toluene, and xylene, to plants in the nearby industry clusters.

CPC completed three additional naphtha crackers in the next decade, and by 1984 Taiwan's total ethylene capacity had reached 953,000 m.t./yr — the 12th largest capacity in the world at the time. Meanwhile, Taiwan's capacity for such chemical products as PVC and acrylonitrile butadiene styrene (ABS) was the largest in the world.

In parallel with this rapid industrial growth was Taiwan's skyrocketing per capita national income (Figure 1). The rising cost of domestic labor coincided with a move by Taiwan-based companies to relocate labor-intensive industries, such as plastic processing and textiles, to Thailand, Indonesia, the Philippines, and Vietnam. Rising costs and nascent environmental protectionism prompted Taiwan's chemical industry to produce higher-value-added products, such as those used in the assembly of computers and other electronic devices. Taiwan's first semiconductor plant — United Microelectronics Corp., in Hsinchu — was established in 1980, heralding the arrival of information technology (IT)-related industries.

In the 1990s, Taiwan lifted policies banning visitation to and investment in China. This new openness, coupled with soaring domestic labor costs and lower wages in China, triggered another wave of relocations of labor-intensive and low-end industries to China. This restructuring allowed Taiwan's chemical industry to diversify into new manufacturing industries, such as semiconductors, motherboards, electronic chemicals, fine chemicals, and precision machinery.

Meanwhile, the petrochemical industry continued to build momentum as Formosa Plastic Corp. (FPC), a subsidiary of Formosa Plastic Group (FPG), constructed a $19.1-billion petrochemical complex at Mailiao, Taiwan. The mega-scale complex — consisting of 61 plants and a port — covered Taiwan's upstream (*e.g.*, oil refining) and downstream (*e.g.*, phenol, polycarbonate, etc.) needs, and marked the start of a new era for the petrochemical industry. Taiwan was now able to produce a full spectrum of chemicals and downstream products that not only met domestic demand but also satisfied export needs to overseas markets.

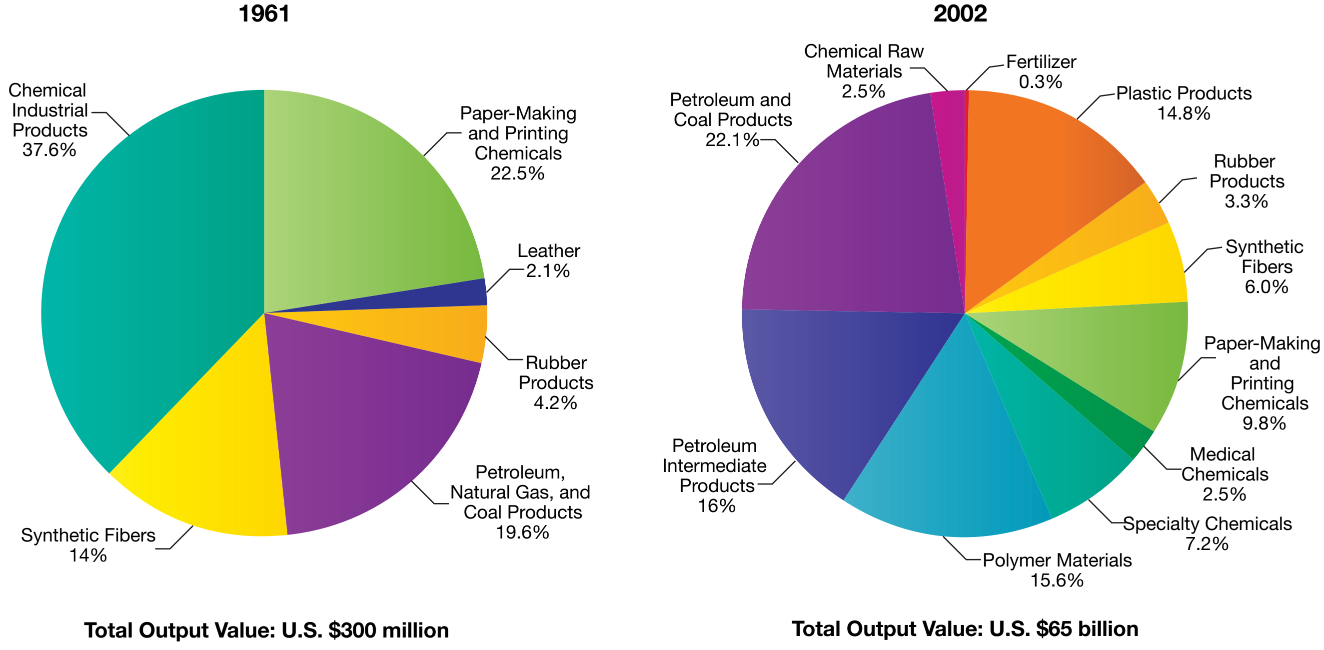
The diagrams in Figure 2 illustrate the evolution of Taiwan's chemical industry between 1961 and the start of the 21st century.

## Self-sufficiency and new opportunities (2001–2011)

In 2011, the naphtha-cracking capacity at FPG's refineries had reached some 540,000 bbl/d, further solidifying Taiwan's self-sufficiency in raw materials. The FPG complex is expected to increase its capacity by another 150,000 bbl/d by 2013.

After a series of equipment upgrades and technology improvements, CPC's three refineries, in 2010, had a total capacity of 770,000 bbl/d — providing 9.1 billion L/yr of gasoline (57.2 million bbl/yr) and 6.6 billion L/yr of diesel (41.5 million bbl/yr), as well as liquefied petroleum gas, lubricants, jet fuel, and other fuels. Also by 2010, CPC's five naphtha crackers had increased the company's capacity for ethylene (1.08 million m.t./yr), propylene (725,000 m.t./yr), and butadiene (173,000 m.t./yr).

Into the 21st century, factors such as rising wages, increasing environmental awareness, and keen competition from the Middle East and China have pushed many of Taiwan's large manufacturers into producing key chemical materials (*e.g.*, polybutylene terephthalate, epoxy resin), and high-value-added specialty chemicals such as electronics-grade chemicals. In particular, Taiwan is focusing on high-tech products and industries, including silicon wafers,




▲ **Figure 2.** Taiwan's chemical industry has diversified over the past four decades. Source: *(2)*.

| Table 2. Production capacity of Taiwan's petrochemical industry in 2010. | |
|---|---|
| Product | Production, m.t./yr |
| Purified terephthalic acid (PTA) | 5,162,706 |
| Ethylene | 3,929,135 |
| Propylene | 2,976,013 |
| Xylene | 2,731,197 |
| Ethylene glycol | 2,138,585 |
| Styrene monomer | 1,921,722 |
| Vinyl chloride monomer | 1,758,189 |
| Benzene | 1,708,346 |
| Polyvinyl chloride (PVC) | 1,432,356 |
| Acrylonitrile butadiene styrene (ABS) | 1,364,772 |
| Polypropylene | 1,215,354 |
| Polystyrene | 844,988 |
| Ethylene vinyl acetate (EVA) | 690,508 |
| Butadiene | 576,593 |
| High-density polyethylene (HDPE) | 544,142 |
| Vinyl acetate monomer | 472,089 |
| Acrylonitrile | 458,361 |
| EVA resin | 345,000 |
| Polycarbonate | 340,000 |
| Caprolactam | 290,359 |
| 1,4-butanediol | 260,000 |
| Phthalic anhydride | 244,263 |
| Allyl alcohol | 217,326 |
| Methyl methacrylate | 194,517 |
| Toluene | 166,973 |
| Polybutylene terephthalate | 160,000 |
| Polytetraethylene ether glycol | 160,000 |
| Dioctyl phthalate | 122,459 |
| Styrene-butadiene rubber | 100,828 |
| Polyvinyl alcohol | 99,509 |
| Carbon black | 96,821 |
| Alkyl benzene | 90,659 |
| EVA emulsion | 74,667 |
| Butadiene rubber | 58,852 |
| Polyoxymethylene | 52,000 |
| EVA powder | 16,283 |
| Melamine | 10,796 |

thin-film transistors (TFT), liquid crystal displays (LCD), flat-panel televisions, solar energy, nanotechnology, and biotechnology — opening a wider range of opportunities for the country's chemical industries. As a result, pharmaceutical chemicals, specialty chemicals, high-performance synthetic materials, optoelectronic materials, and petroleum-based products have seen enormous growth.

In addition to expanding production capacity and increasing sales, Taiwan's companies have globalized, with the establishment of production or trading bases in China, the U.S., and Southeast Asia.

Today, Taiwan's chemical industry constitutes a complete supply chain, providing products needed in the upstream, midstream, and downstream sectors. The industry's basic upstream feedstocks (ethylene, propylene, butadiene) are produced by CPC and FPC, and middle stream products (including PVC and polypropylene), intermediates, and monomers/polymers are produced by a range of companies. Table 2 lists the production capacity for major petrochemicals in 2010, with the total exceeding 31 million m.t./yr.

## The path forward

Taiwan's chemical industry faces challenges on several fronts — among them the economic rise of China and other competitive Asian countries, the mergers and alliances

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## Textiles and Synthetics

A significant proportion of Taiwan's midstream resources are consumed by the synthetic-fiber industry, which plays a pivotal role in the country's textile trade. Except for caprolactam, Taiwan's current domestic capacity for raw materials used in fiber manufacturing — including purified terephthalic acid, ethylene glycol, and acrylonitrile — is sufficient to meet the demands of the domestic textile industry.

In 2009, the total revenue of Taiwan's textile industry reached $12.2 billion, to which the synthetic-fibers industry contributed $3.4 billion; in 2010, its contribution surged to $4.7 billion. Taiwan's current synthetic-fiber capacity — between 2.5 and 2.9 million m.t./yr — is the third largest in the world, with end products that include polyester filament, polyester staple, polyester processed filament, polyester membrane, polyamine fiber, polyamide filament, polyamide staple, and polyacrylonitrile staple.

Taiwan's synthetic-fiber industry has long been committed to developing high-tech products such as functional fibers, environmentally friendly fibers, composite processed fibers, and industrial fibers. This thrust aims to improve product properties and increase added value, as well as to expand into new applications such as home furnishings and electronics. The high quality and wide range of specifications of its synthetic fibers have made Taiwan a major global supplier.

Taiwan's synthetic resins industry began in the 1950s, in response to the need for adhesives and coatings. In the 1970s, synthetic resins became widely used in textiles and synthetic leather, and since the 1990s they have been used in printed circuit boards, integrated-circuit packaging, and electronics.

**Table 3. Production capacity of synthetic resins in 2009.**

| Product | Production, m.t./yr |
|---|---|
| Polycarbonate | 340,000 |
| Epoxy resin | 272,688 |
| Polyacrylate resin | 261,200 |
| Polyurethane resin | 164,039 |
| Polybutylene terephthalate | 160,000 |
| Unsaturated polyester resin | 114,197 |
| Phenolic resin | 100,230 |
| Polyvinyl alcohol resin | 92,252 |
| Alkyd resin | 53,000 |
| Petroleum resin | 52,500 |
| Polyacetal | 52,000 |
| Polyvinyl acetate resin | 40,880 |
| Saturated polyester resin | 39,940 |
| Melamine resin | 18,930 |
| Urea formaldehyde resin | 16,380 |
| Polyamide resin | 11,670 |

Today, Taiwan's synthetic resins are derived from upstream raw materials (*e.g.*, ethylene, propylene and benzene) and are used in a variety of categories — from printing ink, adhesives and sealants, to semiconductors and information technology applications. In 2009, sales of Taiwan's synthetic resins (Table 3) reached $2.6 billion.

of multinational chemical companies, as well as trade barriers, tariffs (*e.g.*, anti-dumping taxes), and the European Union's Registration, Evaluation, Authorization and Restriction of Chemical Substances (REACH) regulation on chemicals and their safe use. To deal with these challenges, the industry must modernize and restructure its core technologies and its products.

In 2009, the Taiwan government selected biotechnology, green energy, agriculture, tourism, medical care, and innovative cultural business as six strategic emerging industries. The focus on these initiatives is prompting chemical manufacturers to upgrade production technology and to develop materials for new applications in optoelectronics, communications, medical devices, pharmaceutical intermediate ingredients, and more. "Green" production processes and products (*e.g.*, hydrogen energy, biofuels, biodegradable plastics) are also emerging from this strategy.

Industry sectors that can create high-value-added products (*e.g.*, new engineering plastics, coatings, pharmaceutical chemicals, and nanomaterials) while reducing resource consumption and carbon emissions will likely play increasingly important roles in warding off competition from countries with lower-wage workforces. One example is the recent construction of plants that use $CO_2$ as a raw material for making acetic acid, offsetting carbon emissions and reducing dependence on oil.

Finally, to promote the internationalization of trade, Taiwan's production and sales systems should be consolidated and globalized to better seize new business opportunities. CEP

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