

Singapore's Chemicals Industry: Engineering an Island

KEITH CARPENTER
WAI KIONG NG
INSTITUTE OF CHEMICAL AND
ENGINEERING SCIENCES (ICES)

The chemicals industry is a pillar of Singapore's economic success. The island city-state's emergence as a chemical industry leader has been boosted by investment in infrastructure and the creation of an industrial island complex.

The Republic of Singapore is a small city-state, probably better known as one of the world's leading financial centers, busiest ports, favorite airlines, or popular tourist destinations than as a global chemical hub. This is hardly surprising, since Singapore does not enjoy any of the normally accepted prerequisites for a successful major chemical industry. It has no natural resources for feedstocks; no mineral deposits, no crude oil, no natural gas. It does not have a major domestic market. Even land is in short supply; Singapore comprises a small mainland island and 62 much smaller islands, all totaling only 778 km² (274 mi²) of land area, off the southern tip of Malaysia (Figure 1).

In spite of this, Singapore is home to some of the world's largest chemical plants, with ongoing major investments on a global scale driving a successful chemicals industry that continues to grow. A major contributor to this success is a new island reclaimed from the sea — Jurong Island — which is home to one of the world's largest and most modern fully integrated chemical parks.

A major pillar of the economy

Singapore is among the most developed economies in Asia. However, unlike many of its economically developed neighbors, manufacturing remains a key component of Singapore's gross domestic product (GDP), accounting for 27% of its GDP. This is a pillar of the government's strategy to promote stability and growth through a diversified economy of trade, manufacturing, and services.

Today, the chemicals industry is a key driver of Singapore's economy. In 2010, the chemicals industry, including pharmaceuticals, produced the largest share — 37% — of Singapore's manufacturing output, with a value of US\$81 billion (1). The most recent financial figures indicate that in 2011, the chemicals industry's share grew to 42% of total manufacturing output.

Singapore's chemicals sector is also a major employer, and its employees have the highest skills profile among all manufacturing industries. Furthermore, the remuneration per worker for the sector is almost twice that of the manufacturing industry's average (2, 3). Over the past decade, the



▲ **Figure 1.** Singapore occupies the southern tip of Malaysia, surrounded by the Indonesian archipelago, some 85 miles north of the equator. Jurong Island, site of Singapore's chemical park complex, is shown in green.

chemicals sector has enjoyed strong growth in production and sales (Figure 2), as well as significant investment opportunities. Employment in the sector between 2000 and 2010 has also remained steady, at around 40,000 workers.

Creating a chemicals industry: 1960s–1980s

Aside from establishing itself in the 1890s as a regional distribution center for kerosene, Singapore had no chemicals industry until the 1960s. This stemmed from Singapore's having neither petroleum feedstocks nor a large enough domestic market to support and develop a chemicals industry. Ironically, this became viewed as an advantage by international oil companies seeking to invest globally, as it also meant that, unlike many other countries, Singapore had no national oil company and so could allow 100% foreign ownership of chemical investments.

Between 1961 and 1973, four major refineries were built and commissioned, one each by Royal Dutch Shell, Mobil, Esso, and the Singapore Refining Company (SRC; a BP-Caltex joint venture). Because of the shortage of land in Singapore, three refineries — Shell, Esso, and SRC — were built on offshore islands southwest of Singapore's mainland,

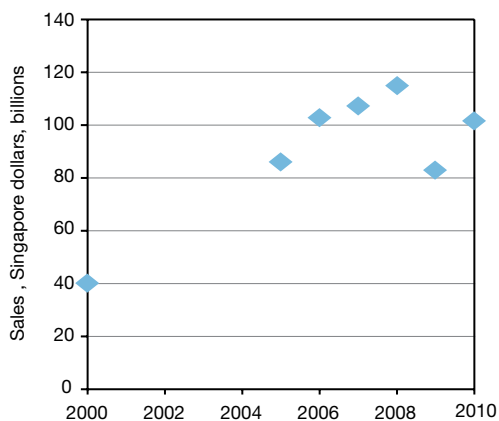
while the Mobil refinery was sited on Singapore's mainland coast, facing the offshore islands. The subsequent merger of Esso and Mobil led to the integration of their two refineries, now operating as one across a narrow sea channel.

By the late 1970s, Singapore became one of the largest refining centers in the world, with a capacity of more than 1.2 million bbl/d. With such an enormous output of refined products (*e.g.*, naphtha, gasoline, oils, paraffins, etc.), Singapore saw a new opportunity to use refinery products as feedstock to develop a downstream petrochemicals and specialty chemicals industry.

A major product of Singapore's refineries is naphtha, an intermediate product that cannot be directly utilized without secondary processing. By converting naphtha to basic building blocks like ethylene, propylene, C_4 s, and aromatics, a wide variety of higher-value finished products, such as polymers, fibers, plastics, personal and home care products, and additives, can be manufactured.

To turn this concept into reality, the Singapore government took a major financial stake in building the first integrated petrochemical complex in Southeast Asia, in partnership with a consortium of Japanese, American, and European companies led by Sumitomo Chemical Ltd. The Singapore Petrochemical Complex was commissioned in 1984. To this day, the complex, consisting of a naphtha cracker and downstream plants, produces a suite of petrochemical products — including polyethylene, polypropylene, alkene oxides and glycols, acetylene black, methyl *tert*-butyl ether, and aromatics. The ready availability of naphtha and products from the refineries has improved supply chain economics, and has ensured feedstock security (4, 5).

Article continues on next page



▲ **Figure 2.** Sales for Singapore's chemicals industry showed impressive growth over the past decade (7). (Sales figures are shown in Singapore dollars, with approximately US\$0.8 = 1 Singapore dollar.)



▲ **Figure 3.** The Jurong Island industrial park complex comprises 30 km² (3,000 ha) and more than 100 companies. To date, industry investments in the complex have exceeded the equivalent of US\$30 billion.

Creating Jurong Island

Singapore, with its dense population of over 5 million people (on 778 km² of land area), did not have the land needed to develop a sizeable chemical industry infrastructure. To overcome this hurdle, Singapore started a gigantic land-reclamation project in 1995 to amalgamate seven small offshore islands, including some of the islands housing refineries and emerging chemicals industries, into a single 30-km² land mass called Jurong Island (Figure 3). Some of the world’s largest companies — including DuPont, Exxon Mobil, Eastman, Mitsui Chemicals, Sumitomo, and Vopak — each invested millions of dollars on this new island complex, even though at that time it was still very much under the sea (2, 3).

Driven by ongoing commitments from companies that wanted to have a presence on Jurong Island, as well as the rise of Asian nations in the global chemicals industry, the government-funded land reclamation project was completed in 2009 — decades ahead of its initial 2030 target date. To supplement its original naphtha cracker that existed prior to the construction of Jurong Island, Singapore Petrochemical Complex commissioned a second naphtha cracker in 1997, and Exxon Mobil launched another in 2000. Together, they raised Singapore’s ethylene capacity to 1.8 million m.t./yr. In 2010, Shell opened its largest petrochemicals facility to date on an adjacent offshore island, adding 800 million m.t./yr of ethylene cracker capacity. Another million m.t./yr of capacity is coming online this year with the startup of Singapore’s fifth cracker, the new Exxon Mobil parallel train.

Another advance supporting the complex was made in 2001, when a 640-km submarine pipeline from West Natuna, Indonesia, was completed to supply Jurong Island with natural gas.

From 2000 to 2009, the number of chemical companies on Jurong Island increased from 61 to 95, and the total fixed

assets grew from US\$17 billion to US\$25 billion (2, 3).

Table 1 shows a selection of the international companies that have established a presence on Jurong Island. Table 2 lists the major chemical-related consumer products companies in Singapore.

The real success story of Jurong Island is not so much about land, which is more abundant and less costly in many neighboring countries, but rather about integration and cost effectiveness. Similar to the German Verbundstandort, or self-contained industrial park concept (see *CEP*, Oct. 2011, pp. 44–47), Jurong Island is a model of industry integration. Companies share common facilities and infrastructure, and can buy and sell feedstocks and products literally “over the fence.”

By leveraging the large base of manufacturers present, companies on Jurong Island are able to reduce capital and operating costs by outsourcing their nonmanufacturing needs to specialized third-party providers on the Island, who supply utilities and services like steam, hydrogen, cooling water, demineralized water, effluent treatment, industrial gases, storage, port and terminal facilities, and even emergency services — with all parties benefiting from economies of scale.

As part of the government’s “plug-and-play” strategy for chemical investors, a causeway linking the Singapore mainland to Jurong Island was completed in 1999, and a 10-km four-lane highway was constructed to facilitate transport between the port facilities and border crossings on the Singapore mainland and the manufacturing plants on Jurong

Table 1. A roster of some of the multinational companies operating on Jurong Island (6).		
United States	Europe	Japan
Air Products	Akzo Nobel	Asahi Kasei
Celanese	BASF (partner in Ellba)	Dainippon Ink & Chemicals
Chemical Specialties	Ciba	Denka
Chevron (partner in Singapore Refining Co.)	Coim	Mitsui Chemicals
Chevron Oronite	Croda	Mitsubishi Gas (partner in Polyxlenol)
Chevron Phillips	Evonik RohMax	Kuraray
DuPont	Faci	Sumitomo Chemical
Eastman Chemical	Infineum	Sumitomo Seika
Exxon Mobil	Katoen Natie	Teijin
Huntsman	Linde	Toagosei
Invista	Lucite	Stella Chemifa
Rohm & Haas	Oiltanking	Unimatec
Tate & Lyle	Perstrop	
	Shell	
	SOXAL	
	Stolt-Nielson	
	Vopak	

Table 2. Key chemical-related consumer products companies operating in Singapore (7).

Household and Personal Care	Food and Nutrition	Flavors and Fragrances
Unilever	Nestle	Givaudan
L'Oreal	Kraft	International Flavors & Fragrances
Johnson & Johnson	Coca-Cola	Takasago
Kimberly Clark	Danone	Firmenich
Estee Lauder	Suntory	Symrise
Reckitt-Benckiser		

Island. To protect the highly valued investments, a biometric security system was put in place for all employees and visitors entering the island. Two fire stations with capabilities to tackle major fires and hazardous materials incidents have been set up, so that emergency responders can reach any part of Jurong Island in less than eight minutes.

To further optimize land resources, plans were developed in 2005 to construct an underground storage facility, called Jurong Rock Cavern, to expand storage capacity and free up valuable land for other purposes. The land savings is about 60 ha, roughly the size of 130 football fields. Large oil-storage

companies, including Horizon, Vopak, Oiltanking, and Hin Leong, will collectively add 26% to Singapore's total storage capacity (currently 18 million m³), which will make Singapore one of the largest oil storage centers in Asia when Jurong Rock Cavern is commissioned in 2014 (6). Singapore is also evaluating the feasibility of building a very large floating platform (VLFP) in the sea to further increase storage capacity.

Human capacity

In addition to building a manufacturing base, Singapore is placing an equal emphasis on developing the skilled labor force required to run the expanded chemical park. In 2004, the Chemical Process Technology Center was established on Jurong Island as the first training center in the world that also houses an industry-scale petrochemical plant. This facility provides technologists with the opportunity to learn and practice plant operations under real-time conditions.

Also in 2004, a new university chemical engineering department — Singapore's second — was opened at Nanyang Technological Univ. There was already a highly successful and globally recognized chemical engineering department at the National Univ. of Singapore, which had been graduating chemical engineers at a rate of about 250 BEng and 30 PhD chemical engineers per year since the mid-1970s. Today, around 400 BEng-level chemical engineers graduate in Singapore every year.

To move beyond chemical manufacturing and to foster

KEITH CARPENTER (keith_carpenter@ices.a-star.edu.sg) is the Executive Director of the Institute of Chemical and Engineering Sciences (ICES) in Singapore, a government funded national research institute located on Jurong Island. Prior to joining ICES when it was founded in 2002, he was a senior fellow in the Global Specialist Technology Group, and Global Process Engineering Competence Manager, at Syngenta. There, he was responsible for strategic technology development and technical support for Syngenta's global supply in process engineering, particle and colloid technology, and process measurement and analysis, as well as for Syngenta's career development programs for its chemical engineers worldwide. He is an adjunct professor at the National Univ. of Singapore, was formerly a visiting professor at several universities in the U.K, and has served on many government and professional committees. He earned a PhD in chemical engineering at the Univ. of Leeds, in the U.K. He is a member of several editorial boards, including those for the journals *Chemical Engineering Science* and *Advanced Powder Technology*. He was a member of the Executive Board of the European Federation of Chemical Engineers, is a Fellow of the Royal Academy of Engineering, a Fellow of the Institution of Chemical Engineers, Chairman of IChemE in Singapore, a Fellow of the Royal Society of Chemistry, a member of the American Chemical Society, and Chairman of the Singapore Chemical Standards Committee.

WAI KIONG NG (ng_wai_kiong@ices.a-star.edu.sg) is Program Manager for Sustainable Processes for Specialty Chemical Products in the Institute of Chemical and Engineering Sciences (ICES). He is concurrently Team Leader and Senior Scientist for Formulation Sciences in ICES's Div. of Crystallization and Particle Science. He received his PhD in chemical engineering from the National Univ. of Singapore and a Dipl.-Ingénieur in chemical engineering from the Technical Univ. of Clausthal in Germany, where he was supported by a GlaxoSmithKline-Economic Development Board (EDB) scholarship. Upon graduation, he joined the Chemicals Group of the EDB Industry Development Div. During the formative years of ICES, he headed its Industrial Programme Development Group. Previously, he managed the Applied Process Technology Group at Sulzer Chemtech. His research interests lie in the areas of novel formulations and processes, particle technology, preformulation characterization, and process analytical technologies.

LITERATURE CITED

1. **Dept. of Statistics Singapore**, "Yearbook of Statistics Singapore, 2011," www.singstat.gov.sg (2011).
2. **Lim, H. K.**, Address by the Minister of Trade and Industry at the Jurong Island Reclamation Completion Ceremony (Sept. 25, 2009).
3. **Foo, C.**, Welcome remarks presented by the Jurong Town Corporation Chairman at the Jurong Island Reclamation Completion Ceremony (Sep. 25, 2009).
4. **Ng, W. H., and K. Ang**, "Guide to Petrochemical and Chemical Industry in Singapore 1997," Future Print and Stationery, Singapore (1997).
5. **Ching, C. B., and W. K. Ng**, "Singapore Chemical Industry: Past, Present and Future," Proceedings of the Regional Symposium on Chemical Engineering 1999, Thailand, pp. 4.1–4.5 (1999).
6. **Economic Development Board**, "Jurong Island Factsheet 2011," www.edb.gov.sg/edb/sg.
7. "Singapore Shines as Consumer Business Hub," *The Straits Times*, p. B24 (Aug. 1, 2011).
8. **National Climate Change Secretariat**, "Climate Change and Singapore: Challenges. Opportunities. Partnerships." <http://app.nccs.gov.sg/nccs-2012/faqs.html> (2012).
9. **Lim, H. K.**, Speech by the Minister of Trade and Industry at the opening of Mitsui Chemicals' second TAFMER plant in Singapore (Jul. 13, 2010).

Global Outlook

research and development in new products and processes, a national research institute called the Institute of Chemical and Engineering Sciences (ICES) was established in 2002 and opened custom-designed facilities on Jurong Island in 2004. Since then, ICES has hosted numerous corporate laboratories, *e.g.*, Mitsui Chemicals, Dystar, Syngenta, and Ciba Specialties (now BASF), and has allowed them to share laboratory facilities, state-of-the-art analytical equipment, and research expertise to jumpstart their R&D activities. These collaborations paid off, as almost all of the companies have since established their own research presence in Singapore. In Nov. 2011, the largest experimental power grid facility in the world was commissioned and is being used to develop future energy and smart-grid options, including renewable energy integration.

Future prospects

Recognizing the importance of achieving sustainable growth, Singapore has started drawing up blueprints for Jurong Island, Version 2.0 — the next phase of expansion for

its chemicals industry. Plans are in place to secure diversified sources of raw materials, such as liquefied natural gas and biomass, as well as natural oils for a Neste Oil biodiesel plant commissioned in 2010. Singapore is also developing leadership in specialty chemicals; for example, in 2011, a new Procter & Gamble Innovation Center broke ground. And, the industry is aiming to move to higher-value chemical chains while raising energy efficiency and minimizing environmental impact. Toward that end, Singapore is striving to reduce its projected CO₂ emissions by 16% by 2020 (8).

Singapore's Trade and Industry Minister Hng Kiang Lim revealed a glimpse of the future in a 2010 speech, when he described the Jurong Island v2.0 initiative as a government-wide effort being undertaken in close cooperation with the chemicals industry. "We intend to achieve new levels of competitiveness and sustainability for operations on Jurong Island," said Lim. "We are also looking at enhancing the sustainability of our chemicals industry through R&D in emerging areas such as biomass-to-chemicals conversion as well as carbon capture" (9).

CEP

Spread the Word: The 5th CCPS Latin American Conference on Process Safety Meets

August 12-14, 2013 • Cartagena, Colombia

HIGHLIGHTS

FEATURED SPEAKERS INCLUDE:	SESSION TOPICS INCLUDE:
<ul style="list-style-type: none">• Javier Gutiérrez Pemberthy Ecopetrol• Scott Berger CCPS• Mauricio Jaramillo Equion Energy• David Kamrath Air Liquide• Mike Broadribb BakerRisk	<ul style="list-style-type: none">• Process Safety for Senior Management – What They Need to Know• Case Histories and Lessons Learned• Hazard Identification and Risk Management• Prevention of Fires and Explosions via Inherently Safer Design• Process Safety Culture

Register now at www.aiche.org/lacps

5th CCPS
LATIN AMERICAN
CONFERENCE
ON PROCESS SAFETY™

© 2013 AIChE. 0409 • 03.13