

Chlorine and Building Materials

A Global Inventory of Production Technologies and Markets

Phase 2: Asia • Including Worldwide Findings



BY HEALTHY BUILDING NETWORK
MARCH 2019



Chlorine and Building Materials: A Global Inventory of Production Technologies and Markets

Phase 2: Asia



© March 2019 Healthy Building Network

AUTHORS

Author: Jim Vallette

Lead Researcher: Connie Murtagh

Editors: Michael Dedeo, Teresa McGrath,
Rebecca Stamm, Biftu Takele, Bill Walsh

Copy Editor: Kate Brubeck

Report Design: Amie Walter

Cover photo: Google Map of this report

SUBSCRIBERS

Carnegie
Designtex
Humanscale
Interface
Metroflor
Tarkett



Contents

Executive Summary & Introduction	1
Executive Summary	2
About HBN & HBN Subscription Research	4
Introduction	5
Methodology.....	5
Phase 2 (Asia) and Global Findings	6
The Inventory	17
China.....	18
India	39
Indonesia.....	45
Iran	47
Japan	48
Pakistan	53
Qatar	54
Saudi Arabia.....	55
South Korea	57
Taiwan	60
Thailand	62
Turkey	63
The Appendices	64
Appendix A. Global Inventory of Chlor-Alkali Plants	65
Appendix B. Global Inventory of PVC Plants	76



EXECUTIVE SUMMARY & INTRODUCTION

Executive Summary

This Healthy Building Network (HBN) report is the second of a two-part project, *Chlorine and Building Materials: A Global Inventory of Production Technologies and Markets*. It is a landmark effort: a globe-trotting, plant-by-plant accounting of the production and use of chlorine, a key feedstock for a wide range of chemicals and consumer products. **Phase 1**, completed in July, 2018, included Africa, the Americas, and Europe. Phase 2, covered in this report, examines Asia.

Demand from manufacturers of building and construction products drives the production of chlorine, especially in the region covered by this report: Asia. Chlorine is the key ingredient of polyvinyl chloride (PVC) used in pipes, siding, flooring, roofing membranes, and more.

This report focuses on chlorine production and PVC production. Chlorine is produced in chlor-alkali plants where sodium chloride (brine) is split into chlorine and sodium hydroxide in an energy intensive process. Four different technologies are used in chlor-alkali plants:

- mercury cell;
- asbestos diaphragm;
- per- and polyfluoroalkyl substances (PFAS) diaphragm; and
- PFAS-coated membrane

The chlorine can then be used to make the vinyl chloride monomer (VCM) which is in turn used to generate PVC. Two different technologies are used in VCM production:

- acetylene route (uses coal and a mercury-based catalyst); and
- ethylene route (uses ethylene from natural gas or oil)

Phase 2 of this project provides details about 60 chlor-alkali plants and 52 PVC plants in Asia. This review resulted in three types of resources that can help manufacturers make informed decisions about their supply chain and have productive conversations with their suppliers.

These resources include:

This report containing:

- The key findings both in Asia and globally.
- An inventory of plants that produce chlorine and PVC in Asia.

HBN Chlor-Alkali Inventory Maps

HBN Chlor-Alkali Inventory Spreadsheets

These resources are accessible on HBN's Chlorine and Building Materials project page, <https://healthybuilding.net/reports/20-chlorine-building-materials-project-phase-2-asia-including-worldwide-findings>.

Asia Production

Cheap coal, labor, and technology allowed China to become Asia's biggest producer for both the chlorine market and the PVC market, generating half of Asia's chlorine and one-third of the world's PVC. Production of PVC continues to grow in Asia, driven largely by India's growing population that has demanded a sixfold increase in supply over the past 20 years. The rate of increase in production in China has slowed due to a slower rate of building and construction in that country. PVC production in East Asia is contracting. For example, production in Japan declined 14% in the past decade (see Japan Overview for further details).

Asia Chlor-Alkali Production Technology

In Asia, almost all chlorine (we estimate 94%) produced in the 60 plants covered in this report comes from PFAS-coated membrane technology. Our preliminary research on over 500 plants in Asia did not identify any facilities with at least 100,000-ton-per-year chlorine production capacity that still use mercury cells to produce chlorine. This is due to the Minamata Convention and the collapse of site-specific end uses — such as chlorinated pesticides and chlorine pulp bleaching — for chlorine plants that previously used mercury cells.

Asia VCM/PVC Production Technology

The PVC industry in Asia has traded reliance on one form of mercury for another. As stated above, mercury cell use in chlorine production is declining. However, due to the low cost of coal, the acetylene route of PVC production (which uses coal and mercury) is growing. This is especially true in China, where we found that 83% of PVC capacity uses the acetylene route. In Asia as a whole, we estimate that 63% of PVC capacity uses the acetylene route.

Global Production

We estimate that PVC production consumes about 48% of the chlorine produced worldwide. The largest producers of PVC are China (we estimate 34% of the global PVC production capacity) and the United States (we estimate 20%).

PVC and chlor-alkali production in most of the world is plateauing or even declining. Even China has struggled with overcapacity in the face of a slowing economy, and has become increasingly export-oriented, as has the United States. (See China overview in this report's Inventory, and the findings in our [Phase 1 report](#)).

Global Technology

Mercury, asbestos, or PFAS is used in 100% of PVC production.

The following figures add up to over 100% because some PVC produced using the acetylene route contains chlorine from non-mercury chlor-alkali technologies and so is counted in two categories.

- 12% of PVC contains chlorine produced using diaphragms coated in asbestos.
- 29% of PVC contains chlorine produced using mercury cells or VCM produced using mercury catalyst in its production.
- 87% of PVC contains chlorine produced using PFAS-coated membranes or diaphragms.

Moving Forward

While environmentalists, building owners, architects and designers, and building-product manufacturers differ in their opinions on avoiding PVC, there is widespread and growing support for the elimination of pollution from the supply chain of PVC and of other chlorine-based products. A public global inventory of chlorine and PVC producers is a necessary first step for taking action.

HBN is providing this report, and accompanying online materials, spreadsheets, and map, as full open-access content. This data can help manufacturers to avoid chemicals derived from toxic technologies, and scientists to fill gaps in understanding the material flow of pollutants like mercury, PFAS, and carbon tetrachloride.

When we know better, we can do better.

About HBN

Healthy Building Network (HBN) envisions a future in which all people and the planet itself thrive in an environment that is free of hazardous chemicals. HBN's mission is to advance human and environmental health by improving transparency about hazardous chemicals and by inspiring product innovation. As a non-profit organization, our work broadly benefits the public, especially children and the most marginalized communities, who suffer disproportionate health impacts from exposure to toxic chemicals.

Since 2000, HBN has defined the leading edge of healthy building practices that increase transparency in the building-products industry, reduce human exposure to hazardous chemicals, and create market incentives for healthier innovations in manufacturing. We are a team of researchers, engineers, scientists, building experts, and educators, and pursue our mission on three fronts:

- 1) Research and policy — uncovering cutting-edge information about healthier products and health impacts;
- 2) Data tools — producing innovative software platforms that ensure product transparency and that catalog chemical hazards; and
- 3) Education and capacity building — fostering others' capabilities to make informed decisions.

We work to reduce toxic-chemical use, minimize hazards, and eliminate exposure, especially to those chemicals of concern which fail to improve product performance. We promote the development of affordable green chemistry solutions that support a healthy, successful, circular economy.

About HBN Subscription Research

Healthy Building Network prides itself on independent and unbiased research. Our partners and stakeholders rank our independence and impartiality as a key value proposition in their decision to work with us. Our analysis of chemical hazards, industry trends, supply chains, and market structures, and of the health, social, and environmental impacts of product manufacture is widely respected for its depth and rigor.

HBN has launched a “crowd-funded” research model to allow several interested parties to jointly participate in funding support for select research projects. HBN develops the goals, conducts the research, and publishes the results. Subscribers receive research updates and have pre-publication access to research findings.

Eligibility: There are no restrictions on the types of organizations eligible to apply for the subscription research services. HBN reserves the right to accept or decline subscribers on a case-by-case basis. Subscription rates and limits, if any, are determined project by project, at the sole discretion of HBN.

Transparency: The names of all subscribers will be listed in research products to which their subscription fees contributed.

Introduction

This report is the second of a two-part plant-by-plant accounting of the production and use of chlorine, a key feedstock for a wide range of chemicals and consumer products. Phase 1, completed in July, 2018, covered Africa, The Americas and Europe. Phase 2, in this report, covers Asia.

The production of three plastics — PVC, epoxies, and polyurethane — consumes most of the world's chlorine. This report focuses on chlorine production and PVC production. Chlorine is produced in chlor-alkali plants, where sodium chloride (brine) is split into chlorine and sodium hydroxide. This energy intensive process relies upon asbestos, mercury, or PFAS to separate chlorine and sodium hydroxide. To make PVC, chlorine is combined with a carbon source. Coal and mercury are used in the acetylene method of PVC production. Natural gas or oil is the basis for the ethylene route.

This Healthy Building Network report establishes basic facts concerning chlorine production: Who is producing chlorine? Who is producing PVC? Where? How much? And with what technologies? What products use the chlorine made in each plant?

PVC products, especially those used in building and construction, are dominant end uses of chlorine. But other chlorine derivatives, especially chemicals key to epoxy and polyurethane production, are of increasing importance. This project identifies which of these industries each plant serves and, plant by plant, examines the markets, capacities, and technological evolution of chlor-alkali and PVC production in Asia. It includes details about 60 chlor-alkali and 52 PVC plants.

Worldwide, between the two phases of this project, HBN provides vital information about 146 chlor-alkali plants and 113 PVC plants, including their capacities, owners, technologies, and markets.

The Findings section synthesizes key data, mostly from this Phase 2 report. It also summarizes our findings from both phases of our research for a global view of production technologies. In addition to this report's long-form Inventory and detailed Appendices, essential data also is available in online companion resources, including the HBN Chlor-Alkali Inventory Maps and the HBN Chlor-Alkali Inventory Spreadsheets. "The maps and spreadsheets are available on the homepage for HBN's Chlorine and Building Materials project, <https://healthybuilding.net/reports/20-chlorine-building-materials-project-phase-2-asia-including-worldwide-findings>.

Chlorine and Building Materials: A Global Inventory of Production Technologies, Markets, and Pollution is a prerequisite to understanding the origins and life-cycle impacts of high-volume building materials such as polyvinyl chloride, polyurethane, and epoxies. This is open-access content, available online at www.healthybuilding.net, free of charge. All text, charts, graphs, tables, spreadsheets, and maps, may be re-used without restriction except for required attribution to Healthy Building Network as the source.

Methodology

This project establishes a baseline understanding of the global chlorine industry. *Chlorine and Building Materials: A Global Inventory of Production Technologies, Markets, and Pollution* is not an insider's view of the industry, but rather an outsider's accounting of the industry as revealed by its own data.

To complete this project, HBN scoured many thousands of sources, spanning over a century, to establish facts and draw conclusions. Our research is derived from resources on hand or available online during the time this report was researched (August 2018 to February 2019). For each source, we provide full citations, including links where available. Sources include annual corporate reports, technical literature, trade databases, industry news and press releases, reports, directories, news articles, and government and chemical industry archives. Google's automated translation service was used for many sources from countries where the government owns most of the industry and has published very little information in English; this is particularly true for sources written in Chinese.

There are many more smaller chlor-alkali plants in operation than those detailed in this report. We conducted preliminary research on over 500 locations in Asia, many of which have closed.



THE FINDINGS

Phase 2 (Asia) and Global Findings

This is Phase 2 of a global inventory of chemical plants that produce chlorine and PVC. It is intended to establish a public domain accounting of the technologies used to make chlorine and related products.

Phase 2 of this project provides details about 60 chlor-alkali plants and 52 PVC plants in Asia. (Chlor-alkali plants produce chlorine and caustic soda.) The plants in this report represent an estimated 56% of Asia's chlorine capacity and 67% of its PVC production capacity in 2017.¹

The Phase 1 report provides details for 86 chlor-alkali plants and 61 polyvinyl chloride (PVC) in the rest of the world. Combined, these two phases of HBN's Chlorine & Building Materials project researched 146 chlor-alkali and 113 PVC plants. These represent an estimated 73% of the world's chlorine production capacity², and 72% of global PVC production capacity.³

Findings are summarized below, beginning with a look at Asia's chlorine markets and production technologies, followed by global findings. Additional data and analysis are found elsewhere in this report, and in online companion spreadsheets and maps.⁴

Asia Findings

Markets

- Since 2000, chlor-alkali production in the Middle East, China, and Southeast Asia has increased sharply as domestic and regional demand for PVC products has risen. PVC is by far the leading consumer of chlorine from the chlor-alkali industry in Asia, especially China. "Spurred by rapid economic growth and fast urbanization in the People's Republic of China (PRC), demand for PVC more than doubled between 2001 and 2007 and grew by 54.4% more between 2007 and 2013 to reach a total of 15.5 million metric tons⁵ in 2013. Capacity growth outpaced demand growth from 2001 to 2013," reported the Asian Development Bank.⁶
- PVC resin manufacturing consumes an estimated 64% of all the chlorine produced by the plants in the scope of our Phase 2 study (Asia). The production of a kilogram of PVC requires an estimated 0.61 kilograms of chlorine. This is based on the chemical composition of PVC (which is 57% chlorine by weight) plus releases of chlorine that occur through the production chain.⁷ The installed capacity of chlor-alkali plants in Asia that we researched is an estimated 21.6 million tons. The 52 PVC plants that receive chlorine from these facilities have an estimated combined capacity of 22.8 million tons, which requires an estimated 13.9 million tons of chlorine, or 64% of Asia's chlorine capacity.
- All but one of the 27 largest chlor-alkali plants in China produce PVC or vinyl chloride monomer (VCM, the monomer used to produce PVC) on-site. We estimate that nearly three-quarters (74%) of the chlorine produced at these plants in China is used to make PVC.⁸ The PRC's PVC production now accounts for more than one-third of global production.⁹
- Three of the world's four largest PVC plants are located in inner China. Each uses the acetylene route of VCM production.
- In other Asian countries, chlor-alkali production is more frequently tied to non-PVC supply chains. In India, four of the seven largest chlorine producers do not appear to supply PVC plants. In Japan, chlorine from four of nine plants support industries other than PVC. The chlor-alkali plants covered in our Phase 2 report supply chlorine feedstocks for non-PVC products such as isocyanates, chlorinated paraffins, carbon tetrachloride, chloroform, methylene chloride, epichlorohydrin, and hydrochlorofluorocarbons.

- In East Asia, where the pace of industrialization, building, and construction has subsided, PVC production has become export-oriented. South Korea produces more than twice the PVC it consumes, exporting over one-third of its production to India.¹⁰ Taiwan, with the capacity to produce 1.93 million tons of PVC, has a domestic demand of just 700,000 tons, resulting in the world's highest overcapacity of PVC. A reported 43% of Taiwan's PVC is sold in India.¹¹ In Japan, PVC production is 20% below peak values and is not expected to recover. Producers from Japan are shifting and expanding capacity to less expensive overseas locations such as Indonesia and Vietnam.
- As building and construction take off, India is the main destination of PVC exports from other Asian countries. PVC demand in India increased sixfold in the past 20 years.¹² Net consumption of PVC (factoring in imports and exports) increased 79% between 2009-10 and 2016-17, from 1.82 million tons to 3.25 million tons.¹³ The Indian chemical industry anticipates PVC demand to exceed 5 million tons by 2020.¹⁴

US IMPORTS FROM CHINA

In 2017, about 85% of all PVC floor, wall, and ceiling coverings entering the United States came from China. The rate of flooring shipments accelerated in 2018. Despite an escalating trade war, the United States remained a major market for PVC building materials, especially floor coverings, made in China. According to shipping records, in just one recent month (December 2018) over 2,000 shipping containers arrived in the US from China containing PVC building materials, including:

- 119,026 tons of PVC floors;
- 1,096 tons of PVC moulding;
- 927 tons of PVC window blinds and shades;
- 782 tons of PVC windows;
- 706 tons of PVC fence;
- 162 tons of PVC slat walls;
- 125 tons of PVC pipes, valves, and fittings;
- 119 tons of PVC ceiling tiles; And,
- 88 tons of PVC rails.¹⁵

If all the PVC flooring products shipped to the United States from China in December 2018 were luxury vinyl tile (LVT), there would be enough to cover about 139,000 homes with 2,000-sq-ft floor plans.¹⁶

On September 24, 2018, the US government imposed 10% tariffs on imported PVC floor coverings from China. LVT flooring shipments spiked in anticipation of tariffs that were due to increase to 25% on January 1, 2019. This increase was delayed 90 days and reduced to an incremental 15% tariff; however, Floor Daily reported in January 2019, this still had LVT importers "nervous."¹⁷

Chlor-Alkali Production Technology

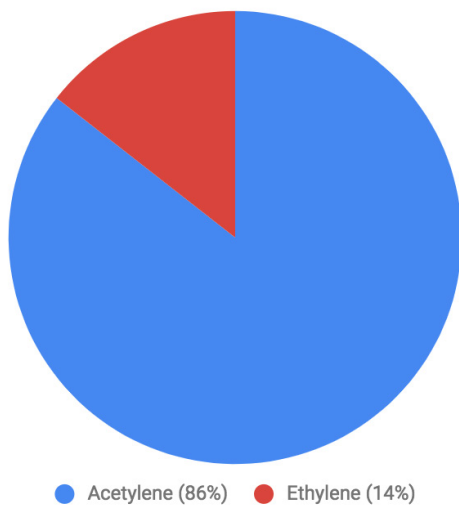
- The 60 chlor-alkali plants in Asia researched for this report, combined, can produce an estimated 21.6 million tons of chlorine per year. About half of Asia's chlor-alkali capacity is in China.
- Four industrial processes create chlorine gas. The oldest technologies use either mercury or asbestos. Two newer technologies (introduced in the 1970s) use diaphragms or membranes coated with per- and polyfluoroalkyl substances (PFAS). In Asia, almost all chlorine (an estimated 94%) produced in plants listed in this report comes from PFAS-coated membrane technology.
- Five of the 60 plants in our Phase 2 study use asbestos diaphragm technology along with PFAS membrane cells to produce chlorine. One of these five is in Saudi Arabia. The other four operate in China, where asbestos diaphragms were the most common chlor-alkali technology until the 2000s.¹⁸
- Our preliminary research on over 500 plants in Asia did not identify any facilities with at least 100,000 tons per year of chlorine production capacity that still use mercury cells to produce chlorine. Scores of smaller mercury cell chlor-alkali plants have closed (but not all) in recent years due to the implementation of the Minamata Convention (see Phase 1 report for further details) and due to the collapse of site-specific end uses, such as chlorinated pesticides and chlorine pulp bleaching.
- The coal-mining region of inner China provides Asia's least expensive source of energy. Coal also serves as chemical feedstock for PVC production through the acetylene process. Through the 1990s, much of the chlor-alkali and PVC industry in China was concentrated in the east coast, where ethylene was the primary fossil fuel used to make VCM. Production shifted north and west in the last 15 years, as chlorine-to-PVC plants proliferated in the vast and remote coal regions, especially the Xinjiang Uyghur and Inner Mongolia Autonomous Regions. The continent's capacity is heavily concentrated in China's coal-mining regions.¹⁹

VCM/PVC Production Technology

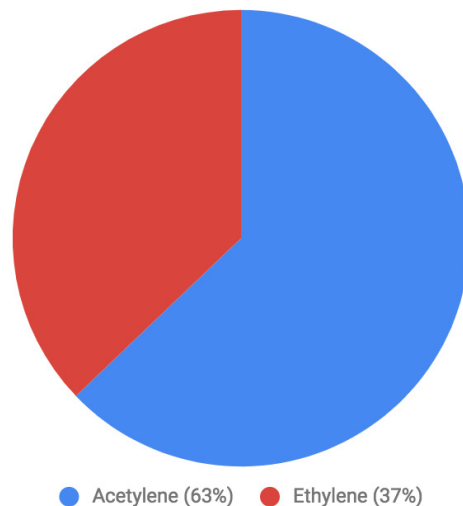
- The 52 PVC plants in Asia reviewed in this report have a combined capacity to produce about 22.8 million tons of PVC per year.
- Half of the plants documented in Phase 2 are in China; these 26 plants have an estimated combined capacity of 14.3 million tons per year or 63% of Asia's PVC production reviewed in this report. Recent estimates of China's total PVC capacity range from 16.3 million tons to 23.9 million tons.²⁰ Based on these estimates, this report covers plants that account for about 60-88% of China's PVC capacity.
- The PVC industry has traded reliance on one form of mercury for another. The use of liquid mercury in chlor-alkali production is dwindling; however, the use of mercury is rising rapidly in the acetylene route of production of VCM in China. VCM is the precursor to PVC. The Royal Society of Chemistry explains that the industry is exploiting China's "vast coal resources, turning coal into calcium carbide and from there acetylene. Producers then get VCM by reacting acetylene and hydrogen chloride gas using a mercury (II) chloride catalyst supported on activated carbon."²¹
- 83% of China's PVC production chain uses the acetylene route. This estimate is based on our research into the 21 largest PVC producers in China (11.8 million out of the 14.3 million tons of capacity). The result is similar to a United Nations estimate for the whole of China. In 2016, the United Nations Industrial Development Organization estimated that the acetylene method accounted for 14 million out of 16.3 million tons of VCM production.²²
- Three of the world's four largest PVC plants are located in inner China. Each uses the acetylene route of VCM production.
- The use of mercury in the production of VCM by the acetylene route is growing rapidly. The United Nations Environment Programme estimates that the global VCM industry (mainly China) consumed around 1,200 tons of mercury in 2015. This is roughly double what it consumed in 2005.

- VCM production may consume more mercury than the other primary remaining use, the artisanal and small-scale gold-mining industry (ASGM). UNEP estimates that the ASGM industry consumes between 872 and 2,598 tons of mercury worldwide.²³
- Some PVC resin factories using the acetylene route produce building materials that are directly exported to North America. For example, Yibin Tianyuan Group Co. (Inventory Code: ASIACHN22) shipped over 2,291 tons of PVC floors to the United States and Canada in 2018.
- In Asia, 37% of PVC is made using the ethylene route. In this method, ethylene made from natural gas or crude oil is the carbon source for PVC. Ethylene is reacted with chlorine to create ethylene dichloride (EDC). In the next step, EDC is “cracked” at high temperatures and broken down into the simpler molecule, VCM.
- Many ethylene-route PVC resin producers in Asia depend upon imported feedstocks — ethane, ethylene dichloride (EDC) and/or vinyl chloride monomer (VCM) — from the Middle East, Indonesia, or, increasingly, the United States. Reliance Industries of India imports ethane from the United States to make EDC. It also owns the world’s first fleet of Very Large Ethane Carriers (VLECs). These ships started delivering ethane in 2016. India quickly became the leading destination for ethane exported from the United States.²⁴ Other PVC producers in Asia, import EDC from the US Gulf Coast. China, South Korea, Japan, India, and Taiwan are the top five destinations for EDC exported from the United States.²⁵ Within Asia, the Middle East and Indonesia are the cheapest sources of ethylene; there, export-oriented EDC and VCM factories supply PVC producers in other countries.

PVC Production Routes (China)



PVC Production Routes (Asia)



XINGJIANG ZHONGTAI IN URUMQI, XINJIANG UYGHUR AUTONOMOUS REGION, CHINA: THE PROTOTYPICAL PRODUCER IN ASIA



Photo © J. Carl Ganter / Circle of Blue

In many ways, the largest PVC plant in Asia — and in the world — is the industry’s prototypical operation. The Xingjiang Zhongtai chemical plant in Urumqi (ASIACHN26) has a PVC production capacity of at least 1,530,000 tons per year, higher even than Shin-Etsu’s Shintech plant in Freeport, Texas, USA (by far the largest PVC plant identified in Phase 1 of our research).

Energy is a major factor in the industrial geography of chlorine and PVC production. Chlor-alkali plants consume vast quantities of fossil fuels. These fuels power the chlor-alkali process and are a carbon-based feedstock necessary to turn chlorine into PVC. In the United States, that cheap energy comes from fracking for natural gas. In China, it comes from coal. In the last two decades, the Chinese government and related companies have built several of the world’s largest chlorine-to-PVC plants in the heart of the country’s coal-mining region. Of the four plants in the world that can produce more than one million tons of PVC per year, three are located in China’s coal belt.

Most of these plants have some degree of government ownership and are integrated with coal-mining operations. In this case, two of the four leading shareholders in 2016 were state-owned: Xinjiang Zhongtai (Group) and Urumqi Huan Peng Co., Ltd., which is a coal-mining operation.²⁶

Some of the coal is burned to power the chlor-alkali plant. The Urumqi complex, for example, obtains its energy from an on-site 900 megawatt (MW) coal-fired plant. The rest of the coal is heated and, from coke, begins the acetylene route of VCM and PVC production. The plant is new (built since 2004) and uses PFAS membrane technology for the chlor-alkali process.

Xinjiang Zhongtai has directly shipped PVC resin to North America for use in building materials. There is not much direct resin export to the United States, but there is a significant rise in the export of PVC building materials, especially flooring, to the United States.



Photo © BILL WORD, 2018

Reliance Industries, India's largest private company, now owns fracking sites in the US and the world's first fleet of Very Large Ethane Carriers, including the Ethane Crystal pictured here, to deliver feedstock from the US to its PVC plants in India.

Global Findings

Summary Results of the Global Inventory of Chlor-Alkali Plants

This Healthy Building Network research project began with some basic questions: Where does the chlorine used in the production of PVC (and other plastics) come from? Which of those plants use mercury, asbestos, or other potentially toxic technologies?

This Inventory provides the answers to those questions for 146 chlor-alkali plants around the world, with a combined estimated capacity of 51.2 million tons of chlorine per year. We believe this includes all of the world's operating chlor-alkali plants with at least a 300,000-ton-per-year capacity.

Our research project identifies the chlorine sources for 112 PVC plants worldwide, with a combined estimated capacity of 41.8 million tons per year of resin. We believe this includes all of the world's operating PVC plants with at least a 250,000-ton-per-year capacity, of which there are 74.

Summary tables of all 146 chlor-alkali plants and 113 PVC plants are available in the Appendices to this report. Further details are found in on-line spreadsheets, maps, and the Phase 1 report available at <https://healthy-building.net/reports/20-chlorine-building-materials-project-phase-2-asia-including-worldwide-findings>.

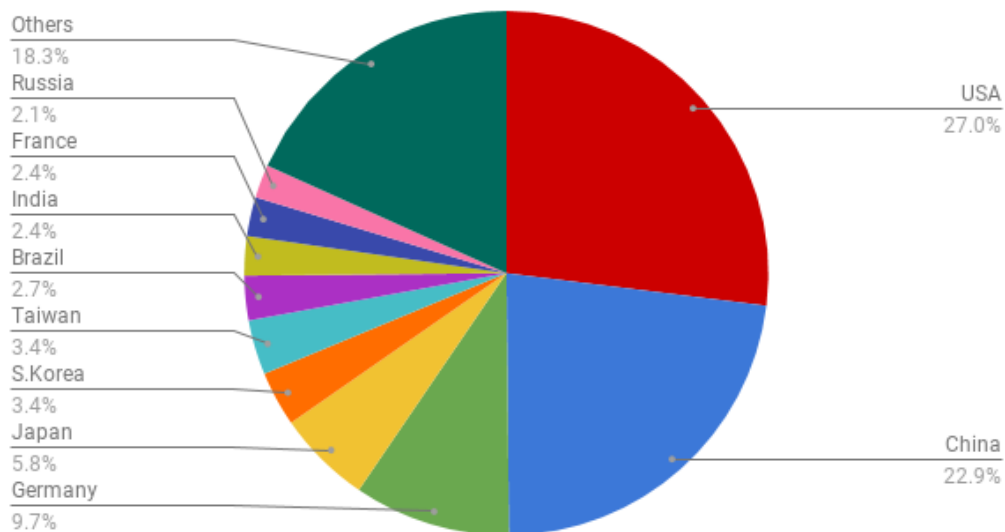
Our reports document important shifts in the industrial geography of chlor-alkali and PVC production since the 1990s. Large-scale mercury cell production of chlorine has been nearly fully replaced by PFAS technology (with several notable exceptions). However, the use of mercury in the next step of the PVC supply chain – VCM production – is rising alongside the development of massive chlorine-to-PVC plants in the coal-mining regions of China. The chlor-alkali industry is fading in older industrialized regions, especially where production was dependent upon obsolete markets or is burdened with high energy costs. Production is surging where fossil fuels and brine abound, especially the US Gulf Coast and inner China. And, more than ever, PVC demand is driving these trends.

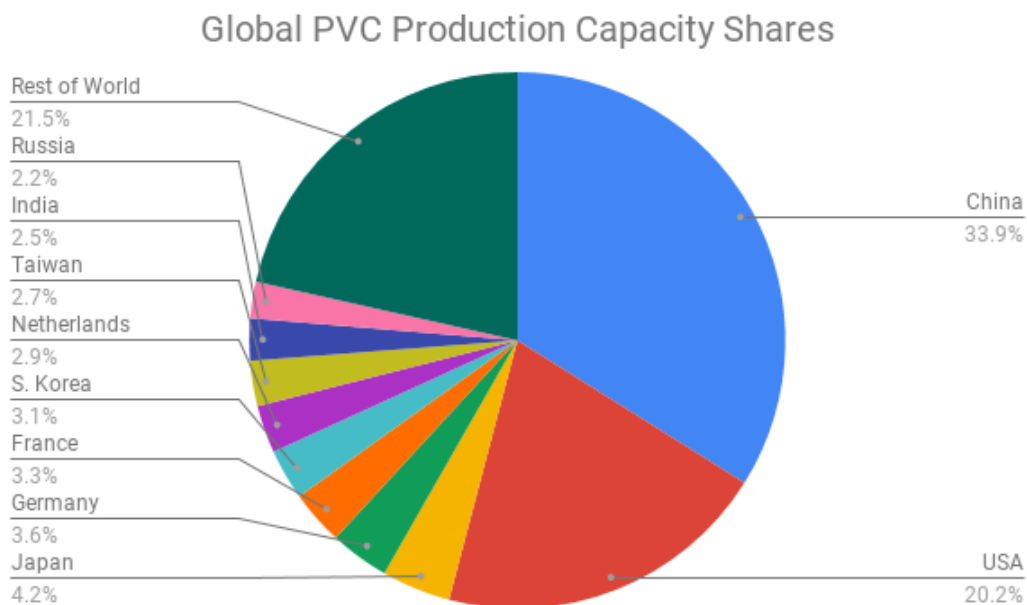
These are the main findings of our report:

Markets

- We estimate that PVC production consumes about 50% of the chlorine produced worldwide. The 113 PVC plants in this study have a combined estimated capacity of 41.8 million tons per year. This requires the consumption of 25.5 million tons per year of chlorine, which is 50% of the estimated capacity of this study's 146 chlor-alkali plants.
- Global chlorine and PVC production is increasingly concentrated in low-cost energy regions. The relationship of chlor-alkali and PVC production is closest in China (where we estimate 74% of chlorine is used to make PVC) and the United States (54%). China accounts for over a third of the PVC produced worldwide, according to the Asian Development Bank.²⁷ Our study arrived at a similar result: China accounts for 34% of the global PVC production capacity. We found that the United States accounts for 20% of the capacity, leaving a balance of 46% in the rest of the world.
- The chlorine and PVC resin production chain is increasingly global. The United States is the largest exporter of PVC resins, and all the feedstocks that go into their production, including ethane, ethylene dichloride, and VCM. Production within the United States is also globalizing: Mexichem (Mexico), Formosa Plastics (Taiwan), and Shin-Etsu (Japan) are major players in the US chlorine/PVC chain. India's Reliance Industries invests in fracking sites in Pennsylvania and Texas, and owns a fleet of ships to deliver ethane to its PVC plants in India. The globalization of the PVC production chain extends to Europe, where companies from the Americas and China are supplying and buying chemical plants, and companies from Belgium and China are investing in Russian producers. There is one area where globalization has taken little hold: China's coal-mining region, where the government and related companies control all of the production.

Global Chlorine Production Capacity Shares





Chlor-Alkali Technology

Among the plants in our report:

- An estimated 79% of the world's chlor-alkali capacity is based on PFAS membranes or diaphragms, 18% on asbestos diaphragms, and 3% on mercury cells.
- The mercury percentage likely would be revealed to be higher if we researched more plants under a 100,000-ton-per-year capacity.
- Production by asbestos diaphragm is heavily concentrated in the United States, where 11 plants use this technology. We estimate that 67% of the world's chlor-alkali production by asbestos diaphragm occurs in the United States (6.1 million of 9 million tons per year of capacity).

PVC/VCM Technology

Worldwide, we estimate that:

- 100% of PVC uses mercury, asbestos, or PFAS in its production. (The following figures add up to over 100% because some PVC is produced using the acetylene route with chlorine from non-mercury chlor-alkali technologies and so is counted in two categories.)
 - 12% of PVC has asbestos diaphragm technology origins.
 - 29% of PVC has mercury cell or acetylene origins.
 - 87% of PVC has PFAS origins.
- Larger plants are more likely than smaller ones to produce PVC with origins in either the acetylene route of VCM production or the asbestos diaphragm method of chlorine production.
 - Seven of the 10 largest PVC plants in the world rely upon feedstocks produced with either asbestos or mercury.

- Among the top 50 PVC plants, 15% of the production capacity is tied to asbestos diaphragm-based chlorine and 37% comes from acetylene-based VCM. They account for 85% of the asbestos diaphragm-based chlorine production and 91% of the acetylene-based VCM capacity of plants in our global inventory.
- Among the 63 smaller PVC plants we researched, 6% of the capacity comes from asbestos-based chlorine, and 8% from acetylene based-VCM.
- PVC and chlor-alkali production in most of Europe and East Asia is declining as export-oriented production surges in the United States and China. *Combined, China and the United States control half of the world's chlorine production capacity, and 54% of global PVC production capacity.* In 2018, the chemical industry news site, ICIS, predicted a growing US influence on world chlor-alkali markets. “As the US becomes a larger global supplier, prices are likely to continue upward as US plants churn at near capacity, and any production upset will ripple through markets around the world.”²⁸

Ten Largest PVC Producers in the World

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/YR)	CHLORINE TECH.	VCM TECH.
1	Xinjiang Zhongtai Chemical	Urumqi, XUAR, China	1,530	PFAS	Acetylene
2	Shin-Etsu	Freeport, Texas, USA	1,450	PFAS	Ethylene
3	Tianye Group	Shihezi Development Zone, XUAR, China	1,200	PFAS	Acetylene
4	Shaanxi Coal and Chemical Industry Group	Shenmu County, Shaanxi, China	1,100	PFAS	Acetylene
5	Occidental	Pasadena, Texas, USA	898	Asb/PFAS	Ethylene
6	Mexichem	Altamira, Tamaulipas, Mexico	876	Asbestos	Ethylene
7	Westlake	Plaquemine, Louisiana, USA	861	Asbestos	Ethylene
8	Formosa	Point Comfort, Texas, USA	816	PFAS	Ethylene
9	Inner Mongolia Junzheng Energy & Chemical Group	Wuhai City, Inner Mongolia, China	800	PFAS	Acetylene
10	LG Chemical	Yeosu City, South Korea	750	PFAS	Ethylene

Note: Chlorine and VCM technologies are based upon either on-site or suppliers' production methods.

PVC Production Chain Technologies Worldwide

CHLOR-ALKALI TECHNOLOGY			VCM ROUTE		GLOBAL CAPACITY	
Asbestos	Mercury	PFAS	Acetylene	Ethylene	100,000 per year (est.)	Share
–	–	☑	–	☑	25,846	60%
–	–	☑	☑	–	11,324	26%
☑	–	–	–	☑	4,548	11%
☑	–	–	☑	–	633	1.5%
–	☑	–	–	☑	348	0.8%
–	☑	–	☑	–	63	0.1%

Note: This table summarizes the technologies used to produce the chlorine and VCM used by 113 PVC plants worldwide. Total is less than 100% due to rounding.

PVC Production Chain Technologies (by plant size)

PVC PLANTS - SOURCE TECHNOLOGIES	CHLORINE SOURCE TECHNOLOGY			VCM SOURCE TECHNOLOGY		PVC Resin Capacity (total)
	Asbestos Diaphragm	Mercury Cell	PFAS Membrane or Diaphragm	Acetylene	Ethylene	
World's 50 Largest PVC Plants						
1,000 tons per year	4,417	0	25,171	10,950	18,638	29,588
No. of PVC plants	11	0	46	17	33	50
% of production capacity	15%	0%	85%	37%	63%	–
All PVC Plants in the HBN Inventory (Phase 1 and Phase 2)						
1,000 tons per year	5,181	410	37,170	12,020	30,741	42,761
No. of PVC plants	18	5	102	23	90	113
% of production capacity	12%	1%	87%	28%	72%	–

Note: This table summarizes the technologies used to produce the chlorine and VCM used by 113 PVC plants worldwide, including the 50 largest ones. Some PVC plants obtain feedstocks from multiple chlorine sources. These have been apportioned as follows: When chlorine comes from both on-site and off-site sources, it is assumed that all the on-site chlorine is used for PVC production on-site and the remainder PVC production is covered by the off-site chlorine. When chlorine comes from multiple off-site sources, it is assumed that the chlorine is evenly distributed amongst the sources.



THE INVENTORY

COUNTRY: CHINA

OVERVIEW

In the 2000s, as China's booming building and construction sector demanded more and more PVC, the country became the world's largest chlorine producer. China also became the world's largest PVC producer in 2006, and has kept growing since then. The industry has grown so large that "Chinese production and consumption dominates (the) global market structure," reported Ana Lopez, an industry analyst at IHS Markit.²⁹

Chlorine-to-PVC plants have proliferated in the coal belt of China, especially in the Xinjiang Uyghur Autonomous Region (XUAR), where an estimated 40% of the country's PVC capacity is located.³⁰ Three of the four largest PVC plants in the world are located in the heart of China's coal mining region (see ASIACHN15, ASIACHN24 and ASIACHN26 below).

Cheap coal, labor, and technology created the perfect conditions for the industry's rapid expansion in the 2000s. In 2005, coal cost as little as \$10 per ton at the mine, reported ICIS. "The acetylene route seemed destined to disappear entirely, but it has had a remarkable renaissance in China in the last few years. The reason is the extreme cheapness of coal, as low as RMB70-100 per ton [roughly US\$10-15] at the minehead in some of the remote provinces of the country, such as Nei Mongol [Inner Mongolia] or Ningxia, where labour costs are low. This in turn allows production of electricity as cheaply as Rmb120-150 [\$18-23] per MWh. The calcium carbide is made near to the coal mines and can be used locally to make acetylene, which is then combined with HCl from a local chlor-alkali plant to make VCM and then PVC." Furthermore, "the production chain from calcium carbide to VCM requires much less capital investment than the ethylene route."³¹

For this report, we concentrated on plants with greater than 250,000-ton capacity. The 27 Chinese PVC plants that we researched have a combined capacity of 16.4 million tons per year.

The plants in this inventory account for between 67% and 80% of what industry analysts say is the country's total estimated capacity.

Market research estimates of its total PVC capacity range between 20 and 24.3 million tons. At the end of 2017, according to researchandmarkets.com, China had the capacity to produce "over 20 million tons." The China National Chemical Information Center (CNCIC) reported that China's PVC production capacity was 22.8 million tons in 2017, from 62 plants.³² The Federation of Indian Chambers of Commerce and Industry (FICCI) said China had another estimate placing capacity at 24.3 million tons in 2016.³³ Some of these estimates may include inflated plant capacity sizes or plants that are not currently operating. Plants have closed in eastern China as the government shifts some heavily polluting industries away from coastal population centers.³⁴ Others have closed due to explosions. In November 2018, for example, VCM leaked and exploded at ChemChina's Hebei Shenghua chlorine-to-PVC plant in Zhangjiakou, Hebei Province. The accident killed 24 people and injured 21.³⁵ This was an acetylene-based unit.

The PVC industry's pace of expansion in China correlated with the growth of building and construction. This pace slackened in recent years. In 2016, FICCI said China's PVC capacity exceeded domestic demand by 9,500,000 tons. "Growth of Chinese capacity addition has decreased [dramatically] and capacity is expected to be at 25,200,000 tons in 2020," the FICCI report predicted.³⁶

Still, there are expansions underway in the coal-mining regions as the industry becomes more export-oriented. PVC resin production that exceeds domestic demand is shipped mainly to India, Russia, Malaysia, and other countries on mainland Asia.

Excess production, and exports, may decline. After the past 15 years of rapid growth, "the risk of Chinese capacity coming down is very real," adds the FICCI report. The Indian industry federation (FICCI) is concerned about how this could impact India, which relies upon imported PVC. The risk comes from China's dependence upon the acetylene method of VCM manufacturing, it said. "This process has come under pressure on account of air pollution, mercury pollution, international conventions on mercury and depletion of mercury resources in China."

These factors “bring into doubt not only the exportable surplus of PVC that would be available in China but also the ability of the local manufacturers to meet domestic demand, thereby providing manufacturers based in Taiwan and Korea a market closer than India to offload their surplus.”³⁷

INVENTORY CODE: ASIACHN01

- **Plant Name:** *Anhui Huasu (also spelled Anhui Hwasu)*
- **Owner:** Government of China. Five state-owned enterprises own shares of Anhui Huasu Co., Ltd.: Huaibei Mining (Group) Co., Ltd. (58% share); China Chengda Engineering Co., Ltd. (12%); Ma Steel (Group) Holding Company (holding 10%); Anhui Investment Group Co., Ltd. (10%) and Zhongyan Dongxing Salt Chemical Co., Ltd. (10%).³⁸
- **Location:** Luquiaozen, Dingyuan County, Chuzhou, Anhui Province, China.
- **Process:**
 - Chlor-alkali: membrane.³⁹
 - PVC: acetylene.
- **Year Opened:** 2013.⁴⁰
- **Capacities** (tons per year):
 - 290,000 tons of chlorine (2013).
 - 560,000 tons of calcium carbide (2013).
 - 460,000 tons of PVC (2017, acetylene route).⁴¹
 - 600 MW coal-fired power plant (2013).⁴²
- **Capacity Rankings:** Not among the largest 33 chlor-alkali plants in Asia. 18th largest PVC plant in Asia. 29th largest PVC plant in the world.
- **Technology Conversions:**
 - According to the company’s website, the plant reduced its consumption of calcium carbide, per ton of PVC, from 1.42 tons to 1.38 tons.⁴³
 - In March 2018, Anhui Huasu announced it planned to raise 920 million yuan (about \$133 million) to build phase two of the plant. This expansion, according to Platts, “will increase production capacities to 1 million mt/year of PVC, 1.4 million mt/year of calcium carbide and 760,000 mt/year of caustic soda.”⁴⁴
 - A test run of the expanded capacity is planned in 2019.⁴⁵
- **Markets:**
 - The plant’s PVC resins are sold domestically and worldwide.⁴⁶

INVENTORY CODE: ASIACHN02

- **Plant Name:** *Tangshan Sanyou Chlor-alkali Co.*
- **Owner:** Tangshan Sanyou Chlor-Alkali / Tangshan Chlor-Alkali.
- **Location:** NanPu Development Zone, Tangshan, Hebei Province, China.
- **Process:**
 - Chlor-alkali: membrane.⁴⁷
 - PVC: acetylene
- **Year Opened:** 2005.⁴⁸
- **Capacities** (tons per year):
 - 455,000 tons of chlorine (2016).
 - 400,000 tons of PVC (acetylene route, 2017).⁴⁹
- **Capacity Rankings:** Tied as the 14th largest chlor-alkali plant in Asia and 27th largest chlor-alkali plant in the world. Tied as 20th largest PVC plant in Asia and 37th largest PVC plant in the world.

- **Technology Conversions:**
 - In 2002, the plant had the capacity to produce 100,000 tons of PVC, which is planned to double. Existing and planned capacities were acetylene-based.⁵⁰
 - It installed a membrane-based 91,000-ton-per-year chlorine capacity chlor-alkali plant in 2005.⁵¹
 - In 2012, Tangshan Sanyou increased its PVC and caustic soda capacities by 100,000 tons, to 400,000 tons each.⁵²
 - In 2016, the company planned to increase the plant's production capacities from 500,000 tons per year of caustic soda to 530,000 tons, and from 400,000 tons per year of PVC to 435,000 tons.⁵³
- **Markets:**
 - It exports a reported 50,000 tons of PVC resin (brand name: Sanyou) per year.⁵⁴ The company says its "products sell well all over the country and are exported to more than 20 countries and regions such as Asia, Europe and America."⁵⁵
 - Tangshan Sanyou Chemical sells other chlorinated products, including liquid chlorine, hydrochloric acid, calcium chloride, and sodium chloride.⁵⁶
 - In 2002, it entered into a joint venture with General Chemical (Canada) to "produce, market and sell calcium chloride for the Asian market and for export to Europe, Africa, and the Middle East. Under the agreement, which would give 60% of the ownership to General Chemical and 40% to Tangshan Sanyou, the plant will be located at the existing Tangshan Sanyou soda ash facility in Tangshan, Hebei province," according to the Journal of the Electrochemical Society.⁵⁷

INVENTORY CODE: ASIACHN03

- **Plant Name:** *Heilongjiang Haohua Chemical*
- **Owner:** ChemChina (China National Chemical Corporation), via China Haohua Chemical (Group). According to a 2016 *ChemWeek* article, "ChemChina ranks among the top three producers of PVC in China, but the company's production is coal-based."
- **Location:** Ang'angxi Industrial Park of the Harbin-Daqing-Qiqihar Industrial Corridor, Heilongjiang Province, China.
- **Process:**
 - Chlor-alkali: membrane.⁵⁸
 - PVC: acetylene.
- **Year Opened:** 2008.⁵⁹
- **Capacities** (tons per year):
 - 300,000 tons of chlorine (2012).
 - 300,000 tons of PVC (2012).⁶⁰ PVC production is by acetylene-VCM route.⁶¹
- **Capacity Rankings:** Tied as the 32nd largest chlor-alkali plant in Asia and 62nd largest chlor-alkali plant in the world. Tied as 33rd largest PVC plant in Asia and 57th largest PVC plant in the world.
- **Technology Conversions:**
 - In 2005, ChemChina bought Qiqihar Chemical Group and shut down its plant (45,000 tons per year of chlorine, 80,000 tons per year of PVC capacities) in the industrial park three years later. It replaced it with a new plant in the same vicinity, although the old devices remained onsite in 2012.⁶²
- **Markets:**
 - In addition to PVC, the plant's chlorinated products include chlorine and hydrochloric acid.⁶³

INVENTORY CODE: ASIACHN04

- **Plant Name:** *Haohua Yuhang*
- **Owner:** ChemChina, via China Haohua Chemical Corporation subsidiary.⁶⁴

- **Location:** Qinyang Chemical Industrial Park, Xinyang, Henan, China. (Haohua Chemical also operates a 91,000-ton-per-year chlorine and 100,000-ton-per-year PVC plant in Jiaozuo, Henan province.⁶⁵)
- **Process:**
 - Chlor-alkali: asbestos diaphragm and Membrane.⁶⁶
 - PVC: acetylene.
- **Year Opened:** 1969.⁶⁷
- **Capacities** (tons per year):
 - 400,000 tons of chlorine (82,000 tons by asbestos diaphragm and 318,000 tons by membrane).⁶⁸
 - 400,000 tons of PVC per year (acetylene process, 2014).⁶⁹
 - 115 MW coal-fired power plant.⁷⁰
- **Capacity Rankings:** Tied as 21st largest chlor-alkali plant in Asia and 39th largest chlor-alkali plant in the world. Tied as 20th largest PVC plant in Asia and 44th largest PVC plant in the world.
- **Technology Conversions:**
 - In 2008, Haohua Yuhang expanded PVC production capacity (acetylene route) from 180,000 tons to 200,000 tons per year.⁷¹
 - In 2009, the plant had the capacity to produce 82,000 tons of chlorine per year using asbestos diaphragm and 100,000 tons by membrane technology, with an expansion of capacity by membrane underway.⁷²
- **Markets:**
 - Chlorinated products include chlorine, barium chloride, PVC calendered film and sheet, PVC artificial leather, and hydrochloric acid.⁷³
 - Carbide slag from the operation is used in cement sold by Beijing Building Materials Group.⁷⁴

INVENTORY CODE: ASIACHN05

- **Plant Name:** *Jilantai Salt Chemical (Group) Co., Ltd.*
- **Owner:** China National Salt Industry Corporation (CNSIC).⁷⁵
- **Location:** Wusital, Alashan Economic Development Area, Alxa Zuoqi, Alxa Left Banner, Inner Mongolia China.
- **Process:**
 - Chlor-alkali: membrane.⁷⁶
 - PVC: acetylene.⁷⁷
- **Year Opened:** 2008.
- **Capacities** (tons per year):
 - 273,000 tons of chlorine.⁷⁸
 - 400,000 tons of PVC (2018).⁷⁹
 - 270 MW coal-fired power plant.⁸⁰
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia. Tied as 20th largest PVC plant in Asia and 37th largest PVC plant in the world.
- **Technology Conversions:**
 - In September 2007, the Jilantai Salt plant, with PVC production capacity (acetylene route) of 200,000 tons, was completed.⁸¹ It was the first phase of a planned 400,000-ton-per-year complex.⁸²
 - From 2008 to 2010, the company expanded membrane-based chlorine production by 182,000 tons in 2009 and 2010, to feed its growing PVC unit.⁸³
 - On December 2, 2010, an acetylene converter explosion at the plant killed three workers. According to *ICIS News*, the explosion “caused a feedstock snag” and a PVC plant shutdown until the end of the month.⁸⁴

- Chlorine production capacity in 2012 was 273,000 tons.⁸⁵
- The company plans to reach a PVC production capacity of 1,000,000 tons per year.⁸⁶
- **Markets:**
 - Most of the “company’s PVC cargoes are sold... on the spot market,” according to *ICIS News*.⁸⁷ According to the company’s website, PVC and other products are exported around the world.⁸⁸
 - A 2011 survey of 13 plants in China found that China Salt Jilantai offered the lowest price for PVC.⁸⁹
 - Additional chlorinated products include liquid chlorine, hydrochloric acid, calcium chloride, perchlorate, and tetrachloroethylene.⁹⁰
 - In 2017, the National Development and Reform Commission, a Chinese government authority, accused China Salt Jilantai Salinization Group Co., Ltd. of price-fixing practices.⁹¹

INVENTORY CODE: ASIACHN06

- **Plant Name:** *Baotou Haipingmian (alternatively Baotou Haiping) Polymer Industry Co., Ltd.* Also called *Baotou Haipingmian Macromolecule Industry Company*
- **Owner:** East Hope Group.⁹²
- **Location:** Hope Industrial Park, Baotou Rare Earth High-tech, Baotou, Inner Mongolia, China.
- **Process:**
 - Chlor-alkali: membrane.⁹³
 - PVC: acetylene.⁹⁴
- **Year Opened:** 2010.⁹⁵
- **Capacities** (tons per year):
 - 291,000 tons of chlorine.
 - 400,000 tons of PVC.
 - 600,000 tons of calcium carbide.⁹⁶
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia. Tied as 20th largest PVC plant in Asia and 37th largest in the world.
- **Technology Conversions:**
 - The Baotou Haipingmian project, planned since 2002, opened in 2010 with the capacity to produce up to 400,000 tons per year of PVC.⁹⁷
 - In December 2018, Baotou Haipingmian reported that control measures reduced mercury emissions by half, on a per-unit PVC resin basis, as compared to 2010.⁹⁸
- **Markets:**
 - PVC resin produced at this plant is sold on the spot market.⁹⁹
 - In 2017, the National Development and Reform Commission fined the company for establishing a PVC price monopoly agreement with Dezhou Shihua Chemical.¹⁰⁰

INVENTORY CODE: ASIACHN07

- **Plant Name:** *Inner Mongolia Yili Chemical Industries Inc.*
- **Owner:** Elion Resources Group, via Inner Mongolia Yili Energy, of which it was the controlling shareholder in 2013. Inner Mongolia Yili Energy was named Inner Mongolia Yili Science & Technology Industry Co. until 2008.¹⁰¹ Elion Resources and Shanghai Huayi Group launched this 52:48 joint venture in 2005.¹⁰²
- **Location:** Dalat Banner Industrial Park, Erdos City, Inner Mongolia, China.
- **Process:**
 - Chlor-alkali: membrane.¹⁰³
 - PVC: acetylene.¹⁰⁴

- **Year Opened:** 2006.
- **Capacities** (tons per year):
 - 364,000 tons of chlorine (2013).¹⁰⁵
 - 500,000 tons of PVC (2017, acetylene-based).¹⁰⁶
 - 640,000 tons of calcium carbide (2013).
 - 800 MW coal gangue-fired power plant (Shenhua Yili).¹⁰⁷ Coal gangue is mainly waste rock from mining operations.¹⁰⁸
- **Capacity Rankings:** Tied as the 23rd largest chlor-alkali plant in Asia and 44th largest in the world. Tied as 15th largest PVC plant in Asia and 24th largest in the world.
- **Technology Conversions:**
 - Started up in 2006 with a 159,400-ton-per-year chlorine production capacity by membrane electrolysis.¹⁰⁹
 - Expanded in 2007 to 328,000 tons per year of chlorine capacity.¹¹⁰
- **Markets:**
 - Sells PVC resin on the spot market. In 2017, the National Development and Reform Commission fined the Elion Resources Group and 17 other PVC producers for price fixing. “The 18 companies involved in the case have increased the price of PVC sales and actual sales in accordance with the agreed price or price increase of the monopoly agreement,” reported the NDRC.¹¹¹
 - PVC pipe manufacturing in China consumes a significant amount of resin made at this plant.¹¹²

INVENTORY CODE: ASIACHN08

- **Plant Name:** *Inner Mongolia Yidong Group Dongxing Chemical Co., Ltd.*
- **Owner:** Inner Mongolia Yidong Resources Group Co., Ltd.
- **Subsidiaries -** Inner Mongolia Yidong Dongxing Chemical Co., Ltd. / Inner Mongolia Dong Xing International Trade Co., Ltd. Largest shareholder is Xie Dongsheng.¹¹³
- **Location:** Qixiaying Industrial Park, Ulan Qab City, Inner Mongolia, China.
- **Process:**
 - Chlor-alkali: membrane.¹¹⁴
 - PVC: acetylene.
- **Year Opened:** The company was founded in 2006.¹¹⁵
- **Capacities** (tons per year):
 - 291,000 tons of chlorine.
 - 400,000 tons of PVC (including 100,000 tons of emulsion PVC), by acetylene route.¹¹⁶
 - 600,000 tons of calcium carbide.
 - 30,000 tons of trichloroethylene.¹¹⁷
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia. Tied as 20th largest PVC plant in Asia and 37th largest in the world.
- **Technology Conversions:**
 - In 2014, the plant’s PVC production capacity was 300,000 tons.¹¹⁸
- **Markets:**
 - In addition to PVC, the plant exports other chlorinated products, including calcium chloride and magnesium chloride.¹¹⁹
 - The company also runs a 100,000 ton-per-year capacity emulsion PVC plant in Erdos, Inner Mongolia, China. It opened the plant in 2013.¹²⁰

INVENTORY CODE: ASIACHN09

- **Plant Name:** *Inner Mongolia Junzheng Chemical Co., Ltd.*
- **Owner:** Inner Mongolia Junzheng Energy & Chemical Group (also referred to as Junzheng Group).¹²¹ In 2016, *Forbes* magazine listed its owner, Du Jiangtao, as China's 76th richest person.¹²² He fell to #208 in 2018. Du ranked #965 on *Forbes'* worldwide Billionaires 2018 list.¹²³
- **Location:** Wudai Industrial Park, Wuda District, Wuhai City, Inner Mongolia, China.
- **Process:**
 - Chlor-alkali: membrane.¹²⁴
 - PVC: acetylene.
- **Year Opened:** 2008.¹²⁵
- **Capacities** (tons per year):
 - 500,000 tons of chlorine.
 - 800,000 tons of PVC.¹²⁶ The company also is developing a large-scale (planned 600,000-ton capacity) integrated chlor-alkali/PVC plant in Erdos (Erdos Junzheng).¹²⁷
 - 200 MW coal-fired power plant (Junzheng Chemical Power Plant).¹²⁸
- **Capacity Rankings:** The 13th largest chlor-alkali plant in Asia and 24th largest in the world. 4th largest PVC plant in Asia and 9th largest in the world.
- **Technology Conversions:**
 - Construction on the first phase of the PVC plant began in 2007.¹²⁹
 - PVC production capacity reached 400,000 tons in 2012 after a 300,000-ton overhaul.¹³⁰ Actual production for the year was 314,000 tons.¹³¹
 - In 2012, the company shut down an old 55,000-ton PVC unit and two original calcium carbide furnaces.¹³²
- **Markets:**
 - The largest customers for the plant's PVC resin in 2012 were state trading companies.¹³³
 - In addition to PVC, chlorine, and caustic soda, the plant sells hydrochloric acid, ferrosilicon, calcium carbide, limestone, and cement clinker.¹³⁴

INVENTORY CODE: ASIACHN10

- **Plant Name:** *Inner Mongolia Wuhai Chemical Plant*
- **Owner:** Hongda Xingye Co., Ltd., via its subsidiary, Inner Mongolia Wuhai Chemical Co., Ltd.;¹³⁵ Hongda Xingye acquired this plant — then called Wuhai Temple Chemical Plant — in 2004.¹³⁶
- **Location:** Haihua Industrial Park, Wuda District, Wuhai City, Inner Mongolia, China.
- **Process:**
 - Chlor-alkali: membrane.¹³⁷
 - PVC: acetylene.¹³⁸
- **Year Opened:** 2007.
- **Capacities** (tons per year):
 - 267,000 tons of chlorine (2013).¹³⁹
 - 500,000 tons of calcium carbide (undated).¹⁴⁰
 - 600,000 tons of PVC (2017).¹⁴¹
 - 400 MW coal-fired power plant.
- **Capacity Rankings:** Not among the largest 33 chlor-alkali plants in Asia. Tied as 8th largest PVC plant in Asia and 16th largest in the world.
- **Technology Conversions:**

- In 2007, Wuhai Chemical said it was partnering with Asahi Kasei (Japan) to install a new membrane chlor-alkali plant (109,000-ton-per-year chlorine capacity). “Wuhai Chemical has said it would start up its 300,000 tonnes/year polyvinyl chloride (PVC) plant at the same time as the membrane caustic soda plant this year,” reported ICIS.¹⁴²
- PVC production began on April 28, 2007.¹⁴³
- Wuhai Chemical acquired Inner Mongolia Menghua Haibowan Power Generation Co., Ltd. in 2013. This company has a 400 MW coal-fired power plant, which is integrated with the site’s chlor-alkali and PVC production.¹⁴⁴
- In 2015, the plant’s PVC capacity was reported as 300,000 tons per year.¹⁴⁵
- **Markets:**
 - In addition to PVC (“Tianhu” brand), the company sells other chlorinated products, including liquid chlorine and hydrochloric acid.
 - The company says its products are sold domestically and “are exported to South Africa, Russia, Canada, Bangladesh, Sudan, Korea, Vietnam, Mongolia, and other countries.”¹⁴⁶
 - In addition to chlorinated products, it sells soda ash, caustic soda, cement, slag, and other raw materials.¹⁴⁷

INVENTORY CODE: ASIACHN11

- **Plant Name:** *Shingpu Chemicals Ltd.*
- **Owner:** SP Chemical Holdings (Cayman Islands/Singapore), via SP Taixing subsidiary.¹⁴⁸
- **Location:** Taixing, Jiangsu Province, China.
- **Process:**
 - Chlor-alkali: membrane.¹⁴⁹
 - PVC: ethylene.
- **Year Opened:** 1998.¹⁵⁰
- **Capacities** (tons per year):
 - 660,000 tons of chlorine
 - 500,000 tons of VCM (2018).¹⁵¹
 - 160 MW coal-fired power plant.¹⁵²
- **Capacity Rankings:** The 7th largest chlor-alkali plant in Asia and 14th largest in the world.
- **Technology Conversions:**
 - The first chlor-alkali operations began in 1998 with the capacity to produce 36,000 tons of chlorine per year.¹⁵³
 - In 2006, it embarked upon an expansion plan.
 - It added a VCM production line (200,000 tons per year) in 2007.
 - In 2008, SP Chemical expanded the plant’s chlorine production capacity from 264,000 to 396,000 tons and its aniline capacity from 90,000 tons to 135,000 tons.¹⁵⁴
 - In June 2008, SP Chemicals imported EDC from the United States (10,500 tons), Saudi Arabia (4,998 tons), and Taiwan (5,065 tons).¹⁵⁵
 - SP Chemical is located on the Yangtze River, where it operates a shipping terminal. In 2019, SP Chemicals and partner INEOS plan to launch the largest ethane carrier in the world. The ship will deliver shale gas ethane from the United States to the Taixing plant.¹⁵⁶ The ethane will be used as feedstock for the production of EDC and VCM.
- **Markets:**
 - “SP Chemicals’ customer base in the PRC [People’s Republic of China] spans the Jiangsu, Zhejiang and Shandong provinces, as well as Shanghai. In 2004, the Company also started exporting its products to the US, Japan, Korea and Taiwan,” read a company press release in 2004.

Its customers included Akzo Nobel Basic Chemical Solutions, BASF, Dow Chemical, Tomen, and Yantai Wanhua.¹⁵⁷

- In 2008, SP Chemical noted that it sells VCM “on a spot basis.”¹⁵⁸
- Other products include aniline, chlorobenzene, and nitrochlorobenzene.¹⁵⁹ Aniline is a feedstock for isocyanate production. Chlorobenzene is a solvent used in pesticides, paints, and other products. Nitrochlorobenzene is a chemical intermediate used in the production of dyestuffs, insecticides, rubber chemicals, and oil additives.¹⁶⁰
- Local customers of this plant’s chlorine and VCM included:
 - Taiwan UPC Group, which has the capacity to produce 450,000 tons of PVC per year¹⁶¹;
 - Solvay (100,000 tons per year epichlorohydrin capacity)¹⁶²; and,
 - Akzo Nobel (60,000 tons per year of monochloroacetic acid).¹⁶³

INVENTORY CODE: ASIACHN12

- **Plant Name:** *Jiangsu Meilan*. Formerly known as *Taizhou Electrolysis Chemical Factory*¹⁶⁴
- **Owner:** Jiangsu Meilan Chemical (established 1996).¹⁶⁵
- **Location:** Taizhou, Jiangsu Province, China.
- **Process:**
 - Chlor-alkali: asbestos diaphragm¹⁶⁶ and membrane¹⁶⁷.
 - PVC: ethylene.
- **Year Opened:** By 1969.¹⁶⁸
- **Capacities** (tons per year):
 - 293,000 tons of chlorine (2013); of which, an estimated 232,000 tons are from membrane cell production and an estimated 61,000 tons are by asbestos diaphragm.¹⁶⁹
 - 400,000 tons of PVC (2004, ethylene route).¹⁷⁰
 - 240,000 tons of methylene chloride (2016).¹⁷¹
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia. Tied as 20th largest PVC plant in Asia and 37th largest in the world.
- **Technology Conversions:**
 - In 2002, the plant stopped producing CFC-113, a potent ozone-depleting substance.¹⁷²
 - In 2003, the plant produced 3,395 metric tons of carbon tetrachloride. It consumed 76,348 tons of chlorine, according to a United Nations Environment Programme report.¹⁷³
 - In 2004, the plant installed 133,000 tons per year of chlorine production capacity by membrane cell technology.
 - In 2005 and 2006, the plant added 99,000 tons per year of chlorine production capacity by membrane cell technology.¹⁷⁴
- **Markets:**
 - In addition to PVC and methylene chloride, the plant produces HCFC-22, carbon tetrachloride, and chloroform, all of which are ozone-depleting substances.¹⁷⁵
 - In 2005, the World Bank agreed to purchase Carbon Finance Emissions Reduction credits from the plant and provide technical assistance in exchange for the installation of an HFC-23 incinerator. The World Bank reported, “At this site, Jiangsu Meilan produces a variety of chemical products (e.g. caustic soda, aniline, organic silicon, polytetrafluoroethylene, KFM, and PVC) and chemical intermediates (such as chlorine, hydrochloric acid, hydrofluoric acid, anhydrous hydrogen fluoride, methylene chloride, chloroform, HCFC-22, tetrafluoroethylene, perfluoropropene, chloroethylene).”¹⁷⁶
 - According to a list of registered pesticides in Pakistan, Jiangsu Meilan produces the pesticide, trichlorfon, which targets mango and melon fruit flies.¹⁷⁷ Trichlorfon also is used in veterinary medicine and a lawn-grub pesticide product.¹⁷⁸

- A 2017 company report suggested that “both the sale of large EDC [ethylene dichloride] and hydrochloric acid should be done.”¹⁷⁹

INVENTORY CODE: ASIACHN13

- **Plant Name:** *Hangjin - Huludao*
- **Owner:** Hangjin Technology Co., Ltd. The company was named Fangda Jinhua Chemical until April 2018. The Shenzhen Stock Exchange-listed corporation also produces military electronics.¹⁸⁰
- **Location:** Huludao, Liaoning Province, China. Huludao was known as Jinxi until 1994.
- **Process:**
 - Chlor-alkali: membrane
 - PVC: acetylene
- **Year Opened:** 1941.¹⁸¹ Originally named Jinhua [or Jin Hua] Chlor-Alkali.
- **Capacities** (tons per year):
 - 354,000 tons of chlorine (2018).¹⁸²
 - 40,000 tons of PVC (by acetylene method).¹⁸³
 - 200,000 tons of propylene oxide (2014).¹⁸⁴
 - 100,000 tons of polyether polyols.¹⁸⁵
- **Capacity Rankings:** The 27th largest chlor-alkali plant in Asia and 52nd largest in the world.
- **Technology Conversions:**
 - In 1989, the plant added a nonylphenol production plant. It also had the capacity to produce 114,000 tons per year of chlorine, 20,000 tons of propylene oxide, 20,000 tons of polyether polyols, and 20,000 tons of chlorobenzene.¹⁸⁶
 - In 1998, the plant (then called Jinhua Chemical) replaced “obsolete and highly polluting mercury and diaphragm cells for caustic soda production with ion exchange membrane cells, according to the ADB, which financed the conversion (73,000 tons per year chlorine capacity).¹⁸⁷
 - In 2003, the company built another chlor-alkali unit with membrane technology (109,000 tons per year of chlorine capacity). The Japan Bank for International Cooperation supported this project with supplier’s credit.¹⁸⁸
 - In 2009, it reported, the Huludao plant produced 168,000 tons of chlorine, 45,084 tons of propylene oxide, 10,318 tons of polyether polyols, and 17,205 tons of chlorobenzene.¹⁸⁹
 - In 2012, according to industry analysts at ICIS, “the company’s 2012 production output more than doubled year on year.” It reported producing 309,000 tons of chlorine, 119,550 tons of propylene oxide, and 55,793 tons of polyether polyols.¹⁹⁰
- **Markets:**
 - According to a Reuters Company Profile, the company “distributes its products in the domestic and overseas markets.”¹⁹¹
 - Hanjin Technology’s PVC resins are used to produce “cable sheaths, various types of films, sheets, profiles, pipes, pipe fittings, transparent sheets, etc. in the fields of industry, agriculture, military and health medicine.”¹⁹²
 - Hanjin’s website says it serves “China’s major military industrial groups and subordinate units, private military enterprises and other domestic key weapons and equipment manufacturing enterprises, especially in the high-end fields such as military industry and aerospace.”¹⁹³
 - Propylene oxide and polyether polyols produced by this plant are used in the production of polyurethane.¹⁹⁴
 - It also supplies chlorine to a phosgene plant, Liaoning Hongshan Chemical Co., in Kazuo County, Liaoning Province.¹⁹⁵ Phosgene, the leading nerve gas used in the First World War, is used in the manufacture of pesticides and polyurethane. It is made from the reaction of chlorine with carbon monoxide.

- According to Hanjin Technology, the plant's chlorobenzene "is mainly used in the production of sulfur dyes and azo dyes, as well as in the synthesis of DDT, nitrochlorinated benzene, phenol, aniline, pyrochloric acid and organic solvents."¹⁹⁶

INVENTORY CODE: ASIACHN14

- **Plant Name:** *Ningxia Jinyuyuan Chemical Group Co, Ltd.*; also called *Ningxia Jinhaoyuan Chemical Group, Ltd.*; formerly called *Qingtongxia Resin Factory*
- **Owner:** Ningxia Jinyuyuan Chemical Group Co. Ltd. Also called Ningxia Jinyuyuan Chlor-Alkali Co, Ltd.¹⁹⁷
- **Location:** Qingtongxia Town, Wuzhong City, Ningxia, China.
- **Process:**
 - Chlor-alkali: membrane.¹⁹⁸
 - PVC: acetylene.¹⁹⁹
- **Year Opened:** 1991.²⁰⁰
- **Capacities** (tons per year):
 - 455,000 tons of chlorine.
 - 700,000 tons of PVC.
 - 1.6 million tons of calcium carbide slag.
 - 600 MW coal-fired power plant.²⁰¹
- **Capacity Rankings:** Tied as the 14th largest chlor-alkali plant in Asia and 27th largest in the world. 7th largest PVC plant in Asia and 12th largest in the world.
- **Technology Conversions:**
 - In 2001, Ningxia Jinyuyuan completed a renovation that increased its production capacity to 91,000 tons of chlorine, 100,000 tons of PVC, and 100,000 tons of calcium carbide. This collaboration with Shanghai Chlor-Alkali Chemical (SCAC) was, at the time, the largest chlor-alkali operation in Northwest China.²⁰² The government of China (through the Huayi Group) is the largest shareholder of SCAC.²⁰³
 - From 2005 through 2007, the plant added a 71,000-ton-per-year chlorine production capacity.²⁰⁴
 - In 2010, ICIS News reported that a project to add 400,000 tons of carbide-based PVC production capacity was delayed.²⁰⁵ In 2011, this project was envisioned as an additional output of 291,000 tons of chlorine, 400,000 tons of PVC, 600,000 tons of calcium carbide, and 8000,000 tons of cement, to be constructed in two phases²⁰⁶
 - In 2011 it reported capacities of 120,000 tons of caustic soda, 150,000 tons of PVC resin, 200,000 tons of calcium carbide, 40,000 tons of hydrochloric acid, and 5,000 tons of liquid chlorine.²⁰⁷
 - In 2016, a 240,000-ton expansion in PVC capacity was planned to start.²⁰⁸
 - The project to add 400,000 tons of carbide-based PVC production capacity was completed in 2018. The company reported expanding its resin production production to 700,000 tons of PVC, or "more than 70 times" the plant's opening capacity in 1991.²⁰⁹
- **Markets:**
 - According to the company's website, its leading products are general purpose suspension PVC resins used in electrical insulating materials, membranes, agricultural films, pipes, pipe fittings, and profiles.²¹⁰
 - It sells PVC resin on the spot market. In 2017, the National Development and Reform Commission fined Ningxi Jinyuyuan and 17 other PVC producers for price fixing. "The 18 companies involved in the case have increased the price of PVC sales and actual sales in accordance with the agreed price or price increase of the monopoly agreement," reported the NDRC.²¹¹

INVENTORY CODE: ASIACHN15

- **Plant Name:** *Shaanxi Beiyuan Chemical Industry Group Co.*
- **Owner:** Shaanxi Coal and Chemical Industry Group (state owned), via Beiyuan Group subsidiary.²¹²
- **Location:** Jinjie Industrial Park, Yulin, Shenmu County, Shaanxi Province, China.
- **Process:**
 - Chlor-alkali: membrane.²¹³
 - PVC: acetylene.²¹⁴
- **Year Opened:** 2010.²¹⁵
- **Capacities** (tons per year):
 - 800,000 tons of chlorine.
 - 1.1 million tons of PVC (acetylene route).
 - 500,000 tons of calcium carbide.
 - 500 MW coal-fired power plant.²¹⁶
- **Capacity Rankings:** The 5th largest chlor-alkali plant in Asia and 11th largest in the world. 3rd largest PVC plant in Asia and 4th largest in the world.
- **Technology Conversions:**
 - Construction was started in 2008 and the first phase was completed in 2010, with the capacity to produce 82,000 tons per year of chlorine and 100,000 tons of PVC.²¹⁷
 - By 2011, the plant's capacity expanded by 364,000 tons of chlorine and 500,000 tons of PVC.²¹⁸
 - In 2014, the plant produced 801,000 tons of chlorine. At the time, it ranked as the third largest chlorine producer in China and planned further expansion.²¹⁹
 - In the first half of 2018, according to the company's website, "the company produced 558,800 tons of PVC, 387,700 tons of caustic soda, 784,300 tons of cement, 219,900 tons of calcium carbide, and 1.782 billion kWh of electricity."²²⁰ By the end of the year, it achieved its goal of producing 1.1 million tons of PVC resins per year.²²¹
- **Markets:**
 - The main customers of the PVC produced here are domestic.²²² The company says that "it can convert 1.35 million tons of raw salt and 8 million tons of raw coal directly and indirectly, which will drive the rapid development of local chemical, building materials, transportation, service and other related industries, which is of great significance to boost local industrial economic growth and catch up with development."²²³

INVENTORY CODE: ASIACHN16

- **Plant Name:** *Dezhou Shihua Chemical Co. Ltd.. (DSC), formerly Shandong Dezhou Petrochemical General Factory*
- **Owner:** ChemChina, via its China Hoahua Chemical Group subsidiary. ChemChina acquired the plant in 2007.²²⁴
- **Location:** Tianqu Industrial Park, north of Dezhou City, Shandong Province, China.
- **Process:**
 - Chlorine: membrane.²²⁵
 - PVC: acetylene.
- **Year Opened:** 1971. Moved from the city to 8 kilometers north of the city in 2011.²²⁶
- **Capacities** (tons per year):
 - 364,000 tons of chlorine (2015).
 - 360,000 tons of PVC resin (2015).
 - 182 MW coal-fired power plant (2015).²²⁷
- **Capacity Rank:** Tied as 23rd largest chlor-alkali plant in Asia and 44th largest in the world. Tied as 27th largest PVC plant in Asia and 46th largest in the world.

- **Technology Conversions:**

- The chlor-alkali and PVC plant moved to its current location in 2010 and restarted in 2011 with a capacity to produce 218,000 tons of chlorine and 300,000 tons of PVC resin.²²⁸ A report by the Asian Development Bank (ADB) explains, “Before 2011, the DSC manufacturing facility was located in Dezhou City. However, as a result of a government policy to relocate heavy industries out of [the] city boundary, DSC moved its facility to the current location, which is [on the] outskirts of Dezhou City, 8 kilometers (km) north of the city center. The construction of the DSC facility started in 2011 and since December 2012, the DSC has been operating the current facilities.”²²⁹
- In 2015, the Asian Development Bank approved a loan to demonstrate a new way of producing VCM using calcium carbide. The method intends to reduce energy consumption and replace the use of mercury catalysts with barium chloride. According to an ADB environmental impact assessment, in this new process, “acetylene and EDC are reacted in a fixed bed reactor and produce VCM. In this reaction, barium chloride is used as a catalyst and nitrogen-doped coal-based activated carbon is used as a carrier of the catalyst.”²³⁰ This technology is called the Jiang-Zhong process.²³¹ It “passed expert review” in 2014, according to ChemChina.²³²
- In 2017, the ADB noted that “with this demonstration project, ChemChina and the government intend to pave the way for a complete elimination of mercury in the PRC’s PVC industry.”²³³
- ChemChina is installing up to 400,000 tons of PVC production capacity using the process backed by the ADB.²³⁴ The first mercury-free VCM production units financed by the ADB loan were under construction in 2018.²³⁵
- According to a 2018 industry survey, in addition to the new production using the Jiang-Zhong process, DSC is also planning to install another 100,000 tons of PVC capacity using the conventional calcium carbide route.²³⁶

- **Markets:**

- In 2017, China’s National Development and Reform Commission accused Dezhou Shihua Chemical of establishing a PVC price monopoly agreement with Baotou Haipingmian.²³⁷
- In addition to PVC, the plant produces hydrochloric acid (100,000-ton capacity per year), liquid chlorine (120,000 tons), trichloroethylene (40,000 tons) and hydrogen peroxide (100,000 tons).²³⁸

INVENTORY CODE: ASIACHN17

- **Plant Name:** *Shandong Yangmei Hengtong Chemical Co., formerly Shandong Hengtong / Hengtong Chemical*
- **Owner:** Yangmei Group.
- **Location:** Linyi City Tancheng, Shandong, China.
- **Process:**
 - Chlor-alkali: membrane.²³⁹
 - PVC: ethylene.²⁴⁰
- **Year Opened:** 2011.
- **Capacities** (tons per year):
 - 364,000 tons of chlorine.
 - 300,000 tons of PVC.²⁴¹
 - 200 MW coal-fired power plant.²⁴²
- **Capacity Ranks:** Tied as 23rd largest chlor-alkali plant in Asia and 44th largest in the world. Tied as 33rd largest PVC plant in Asia and 46th largest in the world.
- **Technology Conversions:**
 - The Shandong Yangmei Hengtong Chemical plant opened in 2011 with the capacity to produce 182,000 tons of chlorine per year via membrane cells, which it doubled in 2012.²⁴³
 - In February 2015, the company started up a methanol-to-olefins (MTO) plant, with capacities

to produce 120,000 tons of ethylene and 180,000 tons of propylene per year.²⁴⁴ A company source informed ICIS that “the plant’s ethylene output will be fed into the company’s downstream 300,000 tonne/year PVC unit at Tanchen in the same province, while the propylene produced will be for commercial sales.”²⁴⁵

- The methanol is derived from coal. As of June 2016, Shandong Yangmei Hengtong Chemical’s complex was one of 9 active coal-to-chemicals projects in China, and the only one directly connected to PVC production.²⁴⁶ Honeywell, which supplied the technology for this project, said, “The two most widely used components to make plastics are ethylene and propylene, and both have traditionally been derived from crude oil. Regions such as China that lack domestic sources of crude oil have turned to MTO [methane-to-olefin] technology to take advantage of alternative feedstocks such as coal and natural gas.”²⁴⁷
- **Markets:**
 - In addition to PVC, caustic soda, propylene, and ethylene, Shandong Yangmei Hengtong Chemical can produce 200,000 tons of hydrogen peroxide, 80,000 tons of phosphorus trichloride (which is mainly used in pesticides manufacturing), 20,000 tons of bleaching powder, and 80,000 tons of hydrochloric acid.²⁴⁸

INVENTORY CODE: ASIACHN18

- **Plant Name:** *Qilu Petrochemical*
- **Owner:** China Petroleum & Chemical Corporation (Sinopec), via its subsidiary, Sinopec Qilu Petrochemical Corporation.²⁴⁹
- **Location:** Zibo, Shandong Province, China.
- **Process:**
 - Chlor-alkali: diaphragm and membrane.²⁵⁰
 - PVC: Ethylene.²⁵¹
- **Year Opened:** 1966.²⁵²
- **Capacities** (tons per year):
 - 410,000 tons of chlorine (2012).²⁵³ Estimated 230,000 tons by asbestos diaphragm and 180,000 tons by membrane technology (see below).
 - 600,000 tons of VCM (2004).
 - 600,000 tons of PVC (2017).²⁵⁴
 - 800,000 tons of ethylene (2012).²⁵⁵
- **Capacity Rank:** 20th largest in Asia and 37th largest in the world. Tied as the 8th largest PVC plant in Asia and 16th largest in the world.
- **Technology Conversions:**
 - In 2000, Qilu Petrochemical’s chlorine production capacity in Zibo increased to 230,000 tons per year.²⁵⁶
 - In 2004, a plant expansion increased chlorine, VCM, and PVC production capacities to their current (2018) tonnages. The expansion incorporated membrane cell technology.²⁵⁷
 - In 2005, its PVC production capacity of 600,000 tons per year was the largest of four plants in China that produced PVC from on-site chlorine and ethylene.²⁵⁸
- **Markets:**
 - In addition to PVC (including chlorinated PVC) resins, the plant produces epichlorohydrin and epoxy resins.²⁵⁹

INVENTORY CODE: ASIACHN19

- **Plant Name:** *Shandong Xinfra Chemical Co. Ltd.*
Also called *Shandong Xinfra Huayu and Chiping Xinfra PVC Co. Ltd.*

- **Owner:** Xinfra Group.
- **Location:** Liaocheng, Shandong Province, China.
- **Process:**
 - Chlor-alkali: membrane.²⁶⁰
 - PVC: acetylene.²⁶¹
- **Year Opened:** 2007.
- **Capacities** (tons per year):
 - 510,000 tons of chlorine (2014).²⁶²
 - 600,000 tons of PVC (2017).²⁶³
- **Capacity Rank:** 12th largest chlor-alkali plant in Asia and 23rd largest in the world. Tied as the 9th largest PVC plant in Asia and 16th largest in the world.
- **Technology Conversions:**
 - The first chlor-alkali plant - using membrane cells with the capacity to produce 182,000 tons of chlorine per year - was completed in 2007.
 - By 2013, after a series of expansions starting in 2009, the plant's PVC production capacity reached 600,000 tons.²⁶⁴ It added more chlor-alkali capacity in 2013 (273,000 tons of chlorine).²⁶⁵
- **Markets:**
 - The company's website markets PVC resins to "countries in South Asia (which) have an urgent need to build infrastructure."²⁶⁶ Its exports are handled by Ningbo Grand International Trading Company Limited, upon which the Indian government has imposed anti-dumping duties.²⁶⁷

INVENTORY CODE: ASIACHN20

- **Plant Name:** *Shanghai caustic soda and PVC project*;²⁶⁸ also called *Tianyuan Chemical Plant*²⁶⁹
- **Owner:** Joint venture of Shanghai Tianyuan (Group) Corporation, through its subsidiary, Shanghai Tianyuan Huasheng Chemical Co Ltd.; Shanghai Chlor-Alkali Chemical Co. (SCAC); and, Shanghai Coking Co.²⁷⁰ The government of China (through the Huayi Group) is the largest shareholder of SCAC.²⁷¹
- **Location:** Shanghai Chemical Industry Park, Caojing, Shanghai Province, China
- **Process:**
 - Chlor-alkali: membrane.
 - PVC: ethylene.²⁷²
- **Year Opened:** 2005.²⁷³
- **Capacities** (tons per year):
 - 655,000 tons of chlorine.
 - 720,000 tons of PVC.²⁷⁴
- **Capacity Rank:** 8th largest chlor-alkali plant in Asia and tied as 15th largest in the world. 6th largest PVC plant in Asia and 11th largest in the world.
- **Technology Conversions:**
 - In the first phase of this project, the owners built a chlor-alkali plant (328,000-ton-per-year chlorine production capacity) and a 280,000-ton-per-year EDC plant, followed by a 300,000-ton VCM/PVC plant. The EDC unit startup coincided with the Shanghai Secco cracker project started by BP in the same complex. Construction of the 1.2-million-ton-per-year ethylene cracker began in 2002, was completed in 2005, and expanded in 2009.²⁷⁵ Ethylene from Shanghai Secco is combined with byproduct hydrogen chloride from the nearby isocyanate consortium to make EDC.
 - In 2012, the company increased its chlorine production capacity from 491,000 tons to 655,000 tons per year, and doubled the capacity of the EDC unit to 720,000 tons.²⁷⁶

- In 2016, SCAC closed its chlor-alkali and PVC units in the Wujing Zone and “transferred the production center of gravity to Caojing Chemical Zone,” according to its annual report.²⁷⁷
- **Markets:**
 - In addition to PVC production, the chlor-alkali plant supplies chlorine to Shanghai Lianheng Isocyanate Co. Ltd., (SLIC), a US\$1.12 billion isocyanates production complex that opened in 2006. The operation was launched as a joint venture of SCAC, BASF, Huntsman, Shanghai Huayi (Group) Company, and Sinopec Shanghai Gao Qiao Petrochemical Corporation. Its initial capacities were 240,000 tons per year of methyl diisocyanate (MDI) and 160,000 tons per year of toluene diisocyanate (TDI). At the time, China’s demand for isocyanates was an estimated 1 million tons per year.²⁷⁸ In 2014, Huntsman and SCAC announced plans to double their joint venture’s MDI production capacity to 480,000 tons by 2017.²⁷⁹ As of 2017, the MDI plant’s capacity was 370,000 tons, with full scale expansion expected by early 2018.²⁸⁰ Huntsman (US) owned 70% of the joint venture, and SCAC owned the remaining 30%.²⁸¹
 - Chlorine from the plant is feedstock for a bisphenol A (BPA) plant run by a joint venture of Mitsui (Japan) and Sinopec (or China Petroleum & Chemical Corporation).²⁸² The plant has the capacity to produce 120,000 tons of BPA per year.²⁸³
 - Covestro is another chlorine consumer located in the Shanghai Industry Chemical Park. It produces polycarbonate plastics and isocyanates. The plant opened in 2006 as a partnership between Bayer (Germany) and SCAC. In 2013, Bayer and SCAC planned to increase the plant’s polycarbonate capacity to 400,000 tons, and reached this target in 2016. By 2016, the Covestro plant in Caojing had capacities to produce up to 500,000 tons of MDI, 300,000 tons of TDI, and 500,000 tons of hexamethylene diisocyanates (HDI), according to an ICIS report. In 2018, it planned to add, by 2022, up to 140,000 tons of MDI and 200,000 tons of polycarbonate capacity in Caojing.²⁸⁴

INVENTORY CODE: ASIACHN21

- **Plant Name:** *Sichuan Jinlu Resin*
- **Owner:** Sichuan Jinlu Group (also called Jinlu Group).
- **Location:** Deyang City, Sichuan, China.
- **Process:**
 - Chlor-alkali: membrane.
 - PVC: acetylene.
- **Year Opened:** 2004.
- **Capacities** (tons per year):
 - Chlor-alkali: 200,000 tons.
 - PVC: 300,000 tons.²⁸⁵
- **Capacity Rank:** Not among 33 largest chlor-alkali plants in Asia. Tied as 33rd largest PVC plant in Asia and 57th largest in the world.
- **Technology Conversions:**
 - In March 2018, the Sichuan provincial government announced that it would close nine chemical plants and move others - including Sichuan Jinlu - away from cities. It gave the Jinlu Group until the end of 2025 to relocate.²⁸⁶
- **Markets:**
 - The plant produces general purpose suspension PVC resins and PVC paste.²⁸⁷
 - In 2017, the National Development and Reform Commission, a Chinese government authority, accused Sichuan Jinlu Group of price-fixing practices.²⁸⁸
 - Sichuan Jinlu High-tech Materials Co., Ltd., a subsidiary of the Jinlu Group, produces PVC artificial leather used in interior finishes, toys, gloves, and other consumer products. It sells PVC “wall leather” that it claims to be “environmentally friendly, moisture-proof, flame-retardant, flexible,

sound- absorbing, easy to clean, and resistant to aging.” The factory has the capacity to produce 8 million yards of artificial leather per year.²⁸⁹

INVENTORY CODE: ASIACHN22

- **Plant Name:** *Yibin Haifeng Herui Co., Ltd.*
- **Owner:** Yibin Tianyuan Group Co., Ltd. (Tianyuan Group, state owned), via its Yibin Haifeng Herui Co. subsidiary which operates the chlor-alkali plant.²⁹⁰ The Shanghai municipal government formed the Tianyuan Group in 1996.²⁹¹
- **Location:** Yibin, Sichuan Province, China.
- **Process:**
 - Chlor-alkali: asbestos diaphragm and membrane.
 - PVC: acetylene.²⁹²
- **Year Opened:** 1944. This is “one of the earliest chlor-alkali manufacturers in China,” according to a Tianyuan Group website.²⁹³ It was originally called the Yibin Branch of Tianyuan Electrochemical Plant.²⁹⁴
- **Capacities** (tons per year):
 - 437,000 tons of chlorine (estimated 146,000 tons from asbestos diaphragm and 291,000 tons from membrane).
 - 500,000 tons of PVC (2014).²⁹⁵
- **Capacity Rank:** 19th largest chlor-alkali plant and 33rd largest in the world. Tied as 15th largest PVC plant in Asia and 24th largest in the world.
- **Technology Conversions:**
 - Installed membrane cell technology with 11,000-ton-per-year capacity in 1991.²⁹⁶
 - In 2005, the plant produced 252,000 tons of PVC from 320,000 tons of capacity.²⁹⁷ In 2008, the plant had 320,000 tons of PVC production capacity, with a 180,000-ton expansion underway.²⁹⁸
 - In 2009, the plant had 273,000 tons of chlorine production capacity (half asbestos diaphragm and half membrane technology) and a 137,000-ton expansion underway (membrane).²⁹⁹
 - The plant’s PVC production capacity reached 500,000 tons in 2009, at which time it ranked as China’s 4th largest PVC plant.³⁰⁰
- **Markets:**
 - The Tianyuan Group sells PVC resin under the “Jiangshui” brand name. It also sells plastic pipes under the “Tianyuan” brand name.³⁰¹
 - The Tianyuan Group produces vinyl floors in this same location, through its recently formed subsidiary, Yibin Tianyi New Material Technology Co., Ltd. Flooring types include luxury vinyl tile (LVT), stone plastic composite (SPC), and wood plastic composite (WPC).³⁰² From May to December 2018, this factory shipped over 2,291 tons of SPC and PVC floors to the US and Canada.³⁰³
 - Other PVC building and construction materials made by the Tianyuan Group include water supply pipe, drain pipe, and wire and cable sheathing.³⁰⁴
 - The Tianyuan complex also can produce 30,000 tons per year of trichloroethylene and 1.2 million tons of 600,000 tons per year of cement.³⁰⁵
 - It also sells tetrachloroethylene, liquid chlorine, and hydrochloric acid.³⁰⁶

INVENTORY CODE: ASIACHN23

- **Plant Name:** *Tianjin LG Bohai Chemical Co., Ltd.*
- **Owner:** LG Chem (Korea).³⁰⁷
- **Location:** Lingang Industrial Area, Tanggu, Tianjin Province, China.

- **Process:**
 - Chlor-alkali: membrane.³⁰⁸
 - PVC: ethylene.
- **Year Opened:** 2007.
- **Capacities** (tons per year):
 - 218,000 tons of chlorine (2007)
 - 350,000 tons of VCM (2007).³⁰⁹
- **Capacity Rank:** Not among 33 largest chlor-alkali plants in Asia.
- **Technology Conversions:**
 - In 2005, LG Chem, Ltd., broke ground on a new chlor-alkali and VCM/EDC plant in the Lingang Industrial District. The new plant had planned capacities of 218,000 tons of chlorine, 300,000 tons of EDC, and 350,000 tons of VCM.³¹⁰
 - The plant opened in 2007.³¹¹
 - According to an ICIS report, the LG Bohai EDC plant consumed “a significant proportion” of the ethylene produced in LG Chem’s naphtha cracker in Daesan, South Korea.³¹²
- **Markets:**
 - In 2005, LG said it selected the Lingang Industrial District site in Tianjin due to the proximity to its LG Dagu PVC plant located 10 kilometers away.³¹³ The Dagu plant became one of the world’s largest PVC producers, with a capacity of 800,000 tons per year. It also produced doors and windows.³¹⁴ However, in 2016, *Business Korea* reported, the Dagu plant was closed, and its production “absorbed” by the Tianjin LG Bohai plant. The article attributed the closure to “an expanding worldwide PVC glut.”³¹⁵ LG reported that its LG Dagu and LG Bohai subsidiaries merged in 2015. It reported that the two subsidiaries, combined, lost over 105 billion Korean won that year, or the equivalent of over US\$100 million.³¹⁶ The 800,000-ton-per-year Dagu plant is in the process of being relocated next to the LG Tianjin chlor-alkali plant, in part in response to a city government initiative to move chemical plants from the urban center to the Nanning Industrial Zone along the coast.³¹⁷ It has been located in the Tianjin Bohai Chemical Group complex, which is the site of China’s first chlor-alkali plant. In 2015, a chemical warehouse explosion in Tianjin killed at least 179 people.³¹⁸ In 2017, Morimatsu of Japan was awarded the contract to relocate the 800,000-ton-capacity plant.³¹⁹
 - According to a government of Pakistan National Tariff Commission analysis in 2018, LG Bohai sells PVC grades TL 700, TL 800, and TL 1000, some of which it exports to Pakistan through Bohai Chemical (HK) Ltd. The analysis found that “100 percent of domestic sales were below cost to make and sell.” The commission imposed 20% anti-dumping duties.³²⁰

INVENTORY CODE: ASIACHN24

- **Plant Name:** Xinjiang Tianye Co. Ltd.
- **Owner:** Tianye Group, through its subsidiary, Xinjiang Shihezi Zhongfa Chemical Co.
- **Location:** Shihezi Development Zone, Xinjiang Uyghur Autonomous Region (XUAR), China.
- **Process:**
 - Chlor-alkali: membrane.³²¹
 - PVC: acetylene.³²²
- **Year Opened:** 1995.³²³
- **Capacities** (tons per year):
 - 910,000 tons of chlorine (2016).³²⁴
 - 1.2 million tons of PVC (2017).³²⁵ Xinjiang Tianye had the world’s 8th largest reported PVC production capacity in 2016.³²⁶

- 40% of China's PVC capacity is in XUAR.³²⁷
- 1,800 MW coal-fired power plant.³²⁸
- **Capacity Rank:** 4th largest chlor-alkali plant in Asia and tied as 9th largest in the world. 2nd largest PVC plant in Asia and 3rd largest in the world.
- **Technology Conversions:**
 - The plant opened in 1995 with the capacity to produce 3,000 tons per year of chlorine and 6,000 tons per year of PVC.³²⁹
 - By 2002, the plant's capacities reached 41,000 tons of chlorine and 60,000 tons of PVC.³³⁰
 - In 2008, the plant's PVC production capacity was 320,000 tons per year, and the company was adding another 200,000 tons of capacity.³³¹
 - By 2010, the Xinjiang Tianye plant's production capacity reached 546,000 tons of chlorine and 720,000 tons of PVC, with another 273,000 tons of chlorine and 400,000 tons of PVC capacity under construction.³³²
 - In 2013, *ICIS News* reported that the plant's production levels were far below its reported capacities. "In 2013, Xinjiang Tianye produced 293,200 tonnes of PVC resin and 213,700 tonnes of liquid membrane caustic soda, up from 3.1% and 2.5% respectively from 2012," it said. "Xinjiang Tianye posted a net loss of yuan (CNY) 216m (\$34.8m) for 2013 because of softer caustic soda and polyvinyl chloride (PVC) prices amid oversupply in the domestic chlor-alkali market, the producer said."³³³
- **Markets:**
 - Much of the plant's PVC is consumed on-site in the production of agricultural irrigation pipes.³³⁴ The company also exports PVC resins to neighboring countries. It was the largest exporter of suspension grade PVC to Russia in 2007.³³⁵
 - In 2017, the National Development and Reform Commission, a Chinese government authority, accused Xinjiang Tianye of price-fixing practices.³³⁶
 - In 2018, Xinjiang Tianye and four other companies sought anti-dumping measures against imported PVC resin imports from the United States, Japan, South Korea, and Taiwan.³³⁷

INVENTORY CODE: ASIACHN25

- **Plant Name:** *Xinjiang Shengxiong Energy Co.*³³⁸
- **Owner:** Xinjiang Zhongtai Chemical (often abbreviated to Zhongtai Chemical).³³⁹ Two of the four leading shareholders in 2016 were state-owned: Xinjiang Zhongtai (Group) and Urumqi Huan Peng Co., Ltd., which is a coal-mining operation.³⁴⁰ Xinjiang Zhongtai ranked as the world's 7th largest PVC producer in 2016, according to a Mexichem report.³⁴¹
- **Location:** Shengxiong Industrial Park, Alehui Town, Toksun County, Turpan Prefecture, Xinjiang Uyghur Autonomous Region (XUAR), China.
- **Process:**
 - Chlor-alkali: technology not found, but assumed to be membrane.
 - PVC: acetylene.³⁴²
- **Year Opened:** 2016.³⁴³
- **Capacities** (tons per year):
 - 200,000 tons of chlorine (2016).
 - 250,000 tons of PVC (2016).
 - 600 MW coal-fired power plant (2016).³⁴⁴
- **Capacity Rank:** Not one of the 33 largest chlor-alkali plants in Asia. 41st largest PVC plant in Asia and tied for 73rd largest in the world.

- **Technology Conversions:**
 - In 2006, Xinjiang Shengxiong Energy Co. said it planned to build a 3,000,000-ton PVC plant on this site.³⁴⁵
 - Upon opening the first phase of the plant in 2016, the company said it plans to increase production capacities to 637,000 tons of chlorine and 900,000 tons of PVC.³⁴⁶
 - The company also plans to double its coal-fired power production capacity to 1200 MW. However, according to the Center for Media and Democracy, “Due to new restrictions announced during 2016 by the National Energy Administration and the National Development and Reform Commission, further [coal-fired power plant] capacity expansions at this location appear to be on hold or cancelled.”³⁴⁷
- **Markets:**
 - See Xinjiang Huatai Heavy Chemical below.

INVENTORY CODE: ASIACHN26

- **Plant Name:** *Xinjiang Huatai Heavy Chemical*
- **Owner:** Xinjiang Zhongtai Chemical (often abbreviated to Zhongtai Chemical). Two of the four leading shareholders in 2016 were state-owned: Xinjiang Zhongtai (Group) and Urumqi Huan Peng Co., Ltd., which is a coal-mining operation.³⁴⁸
- **Location:** Urumqi, XUAR, China.
- **Process:**
 - Chlor-alkali: membrane.³⁴⁹
 - PVC: acetylene.³⁵⁰
- **Year Opened:** 2006.
- **Capacities** (tons per year):
 - 1,000,000 tons of chlorine (2016).
 - 1,530,000 tons of PVC (2016) (see below)
 - 900 MW coal-fired power plant.³⁵¹
- **Capacity Rank:** 3rd largest chlor-alkali plant in Asia and 7th largest in the world. Largest PVC plant in Asia and the world.
- **Technology Conversions:**
 - The VCM plant started up in early 2006 with the capacity to produce 120,000 tons per year of PVC.³⁵²
 - In 2010, the plant had capacities to produce 218,000 tons of chlorine and 300,000 tons of PVC.³⁵³
 - The site’s production capacities in 2011 reached 582,000 tons of chlorine and 740,000 tons of PVC after Xinjiang Zhongtai completed the installation of 273,000 tons of chlorine and 360,000 tons of new PVC production capacities.³⁵⁴
 - According to a 2014 MRCPlast report, “In 2012, Xinjiang Zhongtai began a trial run of the third plant for suspension PVC production with the capacity of 900,000 tonnes per year in Fukang (China). The launch of the third unit of Xinjiang Zhongtai will allow to increase the total production capacity of acetylene PVC up to 1,600 thous. tonnes and, thus, become a major producer in Northern China and surpass the company Xinjiang Tianye, the total annual capacity of which makes 1,300 thous. tonnes.”³⁵⁵
 - In its 2016 annual report, Xinjiang Zhongtai Chemical said its production capacities reached 1,000,000 tons of chlorine and 1,530,000 tons of PVC.³⁵⁶
 - Also of note: In 2018, Xinjiang Zhongtai and Jinhui Zhaofeng Energy announced a partnership “to build a million-ton polyvinyl chloride plant in Baicheng county, Xinjiang [Uighur] Autonomous Region,” reported the Chinese news service, Yicai Global.³⁵⁷

- **Markets:**

- In 2003, Xinjiang Zhongtai sold about 30% of its PVC to markets in eastern China.³⁵⁸
- A 2010 Russian PVC market report describes Xinjiang Zhongtai as a “major supplier of imported PVC.”³⁵⁹
- In 2015, it exported 17 tons of PVC resin to Emballage Sefaco Inc., a manufacturer of fences, ramps, garden accessories, and lattice, in Quebec, Canada.³⁶⁰
- In 2017, the National Development and Reform Commission (NDRC), a Chinese government authority, accused Xinjiang Zhongtai of price-fixing practices.³⁶¹ The NDRC fined the company 71 million yuan (about US\$10 million).³⁶²
- In 2018, Xinjiang Zhongtai and four other companies sought anti-dumping measures against imported PVC resin imports from the United States, Japan, South Korea, and Taiwan.³⁶³

INVENTORY CODE: ASIACHN27

- **Plant Name:** *Ningbo Wanhua*
- **Owner:** Wanhua Chemical Group Co., Ltd.³⁶⁴
- **Location:** Wanhua Industrial Park, Ningbo Daxie Development Zone, Ningbo, Zhejiang Province, China.
- **Process:**
 - Chlor-alkali: membrane.
- **Year Opened:** 2010.
- **Capacities** (tons per year):
 - 455,000 tons of chlorine (2015)³⁶⁵
 - 1,200,000 tons of methylene diisocyanate (MDI, 2018).
 - 250 MW coal-fired power plant.³⁶⁶
- **Capacity Rank:** Tied as 14th largest chlor-alkali plant in Asia and 27th largest in the world.
- **Technology Conversions:**
 - In 2003, Wanhua Chemical began construction of the project in Ningbo.³⁶⁷
 - In 2010, the Wanhua Chemical (then called Yantai Wanhua Polyurethanes) opened a new chlor-alkali and MDI plant. According to an ICIS news report, “The new complex houses a 300,000 tonne/year MDI plant, a 240,000 tonne/year formaldehyde unit, a 360,000 tonne/year aniline facility and a 150,000 tonne/year caustic soda plant.”³⁶⁸
 - By 2017, Wanhua Chemical was operating two MDI plants at Ningbo. One had 400,000 tons per year capacity; the other, 800,000 tons.³⁶⁹
 - In 2018, Wanhua said it would increase total MDI capacity to 1.5 million tons by 2021.³⁷⁰
- **Markets:**
 - Wanhua’s Ningbo chemical complex is the largest MDI plant in the world.³⁷¹
 - Overall, “Wanhua Chemical (WHC) is the biggest global methylene diphenyl diisocyanate (MDI) producer with a 24% market share,” according to a 2017 market analysis by Deutsche Bank.³⁷² Wanhua Chemical also produces MDI in Yantai, China (600,000 tons per year of MDI capacity), and Kazincbarcika, Borsod-Abaúj-Zemplén, Hungary (240,000 tons see Inventory Code EU-RHU01 in Phase One report). The plant in Yantai dates to 1980. It is also building a polycarbonate (70,000-ton-per-year capacity) plant in Yantai, and considering starting an isocyanates plant in the U.S. Gulf Coast.³⁷³
 - According to a *Chemical & Engineering News* report in 2016, “About two-thirds of Wanhua’s sales are to customers in China.” The US also is a major market.³⁷⁴

COUNTRY: INDIA

OVERVIEW

The Indian chlorine industry has almost eliminated the use of mercury cell technology. In 1991, 80% of India's chlorine production capacity used mercury cell technology. PFAS-coated membrane and PFAS diaphragm technology both held 10% shares.³⁷⁵ By 2008, 23 out of 32 plants in India were using only PFAS-coated membrane technology.³⁷⁶ The largest plants have since converted to PFAS-coated membrane and expanded capacity, while many of the smaller mercury cell plants have closed.

India has ratified the Minamata Convention, which prohibits the use of mercury cell technology by 2025.³⁷⁷ However, this treaty does not yet ban the use of mercuric catalysts in VCM production.³⁷⁸ The DCM Shriram plant in Kota, Rajasthan (ASIAIND04) uses the acetylene route of VCM/PVC production and its owners have not announced any plans to convert to ethylene-based production.

India's building and construction sector is in the midst of long-term growth, and PVC materials – especially pipes – are a big part of that growth. According to a 2016 report published by the Federation of Indian Chambers of Commerce and Industry (FICCI), 73% of the PVC consumed in the country was used in pipes and fittings, which compares to a global rate of 43%. It also uses more PVC in flooring than reflected in global averages (8% versus 3%).³⁷⁹

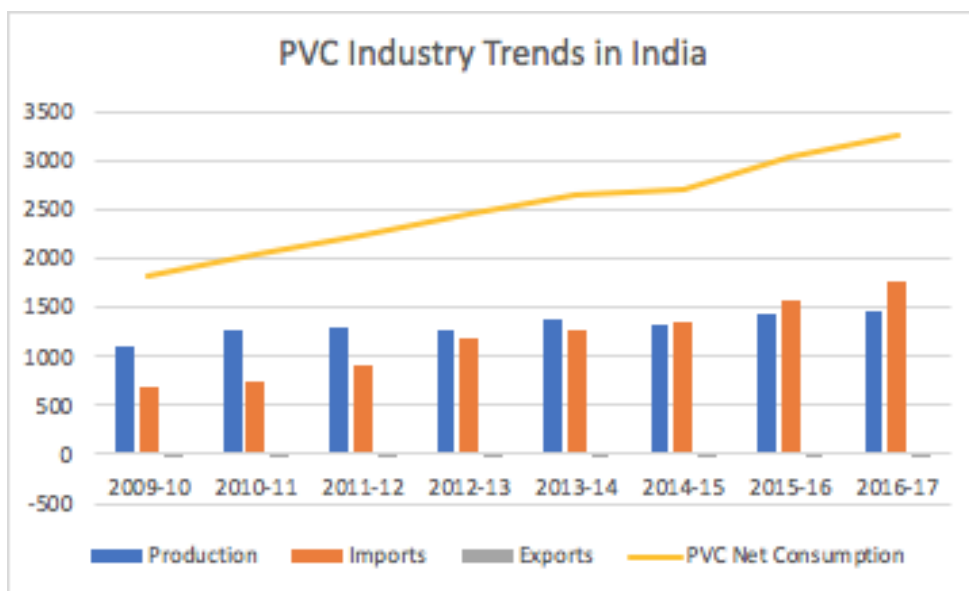
In the 2016-17 fiscal year (which runs from July to June), India produced 1.46 million tons of PVC, up from 1.11 million tons in 2009-10. It is producing PVC at near full capacity (97.9% in 2016-17). Almost all of the PVC was consumed domestically.³⁸⁰ Net consumption of PVC (factoring in imports and exports) increased 79% between 2009-10 and 2016-17, from 1.82 million tons to 3.25 million tons.³⁸¹ PVC demand in India increased sixfold from 1996 to 2016.³⁸²

The Indian business community expects demand to accelerate. In 2016, FICCI “estimated that annual demand growth for PVC will be at least 13% in the next five years. Demand is expected to cross 5 million tons in 2020.”³⁸³

Since the 2014-15 fiscal year, India imported more PVC resin than it produced domestically (see chart).

According to FICCI, the leading sources of imported PVC resin are Taiwan, South Korea, Japan, China, and Iran. The industry group worried that these countries might not be “able to meet the demand in India in the future, thereby making capacity addition in the domestic industry an absolute must.”³⁸⁴

Most PVC supply-chain imports have been in the form of PVC resins; however, India's largest producer has installed multi-billion-dollar ethane crackers at three locations to provide feedstock for EDC/VCM/PVC production. The producer, Reliance Industries, is in three joint ventures in the US to produce shale gas from fracking. It also owns a fleet of ships dedicated to delivering ethane from the US to its PVC plants in India.



HBN Chart based on Government of India 2017 petrochemical statistics.³⁸⁵

In addition to the chlor-alkali producers listed below, India's third and fourth largest producers of PVC resins rely upon imported feedstocks. Chemplast Sanmar (Cuddalore, Tamil Nadu, 270,000-ton-per-year PVC resin capacity) imports 200,000 tons per year of VCM that it manufactures in Port Said, Egypt.³⁸⁶ Finolex Industries (Ratnagiri, Maharashtra, 260,000-ton-per-year PVC resin capacity), imports EDC from Southeast Asia and Middle Eastern producers.³⁸⁷

INVENTORY CODE: ASIIND01

- **Plant Name:** *Grasim Industries - Vilayat*
- **Owner:** Aditya Birla Chemicals. Aditya Birla acquired Grasim in 2015.³⁸⁸
- **Location:** Vilayat, Gujarat, India.
- **Process:**
 - Chlor-alkali: PFAS membrane.
 - PVC: Ethylene.
- **Year Opened:** 2013.
- **Capacities** (tons per year):
 - 150,000 tons of chlorine (2013). Aditya Birla owns five chlor-alkali plants in India. In addition to the new Vilayat operation, it owns plants in Nagda (Madhya Pradesh, listed below), Renukoot (Uttar Pradesh, listed below), Rehla (Jharkhand, 90,000-ton chlorine capacity), Veraval (Gujarat, 84,000 tons), and Karwar (Karnataka, 60,000 tons).³⁸⁹
- **Capacity Rank:** 4th largest chlor-alkali plant in India. Not among the largest 50 plants in Asia. Largest epoxy producer in India.
- **Technology Conversions:** None.
- **Markets:**
 - Alongside the new chlor-alkali plant in Vilayat, Grasim (now owned by Aditya Birla) opened a 123,000-ton-per-year-capacity epoxy production unit in Vilayat in 2014. The epoxy resins are sold worldwide under the brand name Epotec.³⁹⁰
 - The US imported over 14,000 tons of Epotec from Aditya Birla, mainly from Thailand, in a recent one-year period (October 25, 2017 to October 24, 2018).³⁹¹ Aditya Birla produces epoxy resins at its chlor-alkali complex (71,500 tons per year chlorine capacity) in Map Ta Phut, Thailand.³⁹²

INVENTORY CODE: ASIIND02

- **Plant Name:** Grasim Industries - Nagda
- **Owner:** Aditya Birla Chemicals. Aditya Birla acquired Grasim in 2015.³⁹³
- **Location:** Nagda, Madhya Pradesh, India
- **Process:** PFAS membrane.³⁹⁴ Converted from mercury.³⁹⁵
- **Year Opened:** 1972.³⁹⁶
- **Capacities** (tons per year):
 - 245,000 tons of chlorine.³⁹⁷
- **Capacity Rankings:** 2nd largest chlor-alkali plant in India. Not among largest 33 plants in Asia.
- **Technology Conversions:**
 - In 1989, the plant's chlorine production capacity was 74,000 tons per year.³⁹⁸
 - In 1993, the capacity was 82,000 tons of chlorine per year. The company announced it would convert to membrane technology.³⁹⁹
 - By 1995, the plant had converted from mercury cell to membrane technology. The new capacity totalled 91,100 tons of chlorine per year.⁴⁰⁰

- **Markets:**

- In 2016, Aditya Birla reported that 55% of its chlorine was sold on the open market (merchant chlorine).⁴⁰¹
- According to Aditya Birla, “Grasim set up a rayon grade caustic soda unit at Nagda in 1972 with the intention of achieving a reliable and economical supply of rayon grade caustic soda, an important raw material in VSF [viscose staple fibre] production.”⁴⁰² Grasim produces VSF in Nagda and at two other sites.⁴⁰³ Oceana reported in 2007 that Grasim was the world’s leading source of rayon (23% of the global market share), and that India supplied 20% of the United States’ imports of rayon.⁴⁰⁴
- Grasim’s chlorinated products include hydrochloric acid, bleaching powder, poly aluminum chloride, aluminum chloride, and chlorinated paraffins. From July 2015 to June 2016, Aditya Birla, over all of its plants, produced over 157,000 tons of PAC, 47,000 tons of chlorinated paraffins, 36,000 tons of aluminum chloride, and 94,000 tons of bleaching powder.⁴⁰⁵
- “It also supplies chlorine to Gwalior Chemical Industries Limited’s chemical complex at Nagda,” reported ICIS in 2007.⁴⁰⁶ Lanxess AG of Germany purchased Gwalior in 2009.⁴⁰⁷ The Lanxess Gwalior complex in Nagda produces specialty chemicals, including benzyl chloride, benzotrithloride, thionyl chloride, sulfur chloride, and sulfur dichloride.⁴⁰⁸

INVENTORY CODE: ASIAND03

- **Plant Name:** *Renukoot Chemical Division (RCD)*
- **Owner:** Aditya Birla Chemicals, which acquired the plant from Kanoria Chemicals & Industries (KCIL) in 2011.⁴⁰⁹
- **Location:** Renukoot, Uttar Pradesh, India.
- **Process:** PFAS membrane.⁴¹⁰ Converted from mercury cell.
- **Year Opened:** 1965.⁴¹¹
- **Capacities** (tons per year):
 - 117,000 tons of chlorine.⁴¹²
 - 50 MW coal-fired power plant.⁴¹³
- **Capacity Rankings:** 6th largest chlor-alkali plant in India. Not among largest 33 plants in Asia.
- **Technology Conversions:**
 - In 1995, Kanoria Chemicals converted part of its capacity (9,000 tons of chlorine per year) from mercury to PFAS membrane technology and increased its overall capacity from 30,000 tons of chlorine to 44,000 tons.⁴¹⁴
 - In 2004, KCIL announced plans to expand its chlorine production capacity by 35,000 tons, to a total of 75,560 tons per year.⁴¹⁵ The International Finance Corporation supported this expansion with a \$20 million loan.⁴¹⁶ The new PFAS membrane based unit was built adjacent to its existing mercury cell-based plant; the company planned to continue operating the mercury cell unit until 2012.⁴¹⁷
 - In September 2011, the mercury cell operations “permanently stopped,” according to a company filing.⁴¹⁸
 - In 2013, the company reported that it expanded chlor-alkali production in Renukoot by 43,000 tons per year. It said it accomplished this “despite the pressure of increasing input costs for power, coal and other raw materials and the unstable supply of power from the grid.”⁴¹⁹
- **Markets:**
 - The Renukoot complex makes a variety of chlorinated products, including bleaching powder, chlorinated paraffins, poly aluminum chloride, and aluminum chloride.⁴²⁰

INVENTORY CODE: ASIIND04

- **Plant Name:** *Shriram Vinyl & Chemical Industries (SVCI), Kota*
- **Owner:** DSCL (DCM Shriram) / Shriram Fertilizers & Chemicals / Shriram Chem. The related PVC compounding business, Shriram Axiall, is a 50:50 joint venture with Westlake (formerly Axiall Corporation) of the USA.⁴²¹
- **Location:** Kota, Rajasthan, India.
- **Process:**
 - Chlor-alkali: PFAS membrane.⁴²² Converted from mercury cell.
 - PVC: Acetylene. It is the only plant in India to use the acetylene route of PVC production.⁴²³
- **Year Opened:** 1964.⁴²⁴
- **Capacities** (tons per year):
 - 103,000 tons of chlorine (2016).⁴²⁵ Expansion planned (see below).
 - 70,000 tons of PVC resin (2016).
 - The Shriram Axiall PVC compounding operation has a capacity of 32,564 tons per year.⁴²⁶
 - 133 MW coal-fired power plant.⁴²⁷ Expansion planned.
- **Capacity Ranking:** 7th largest chlor-alkali plant in India. Not among largest 33 plants in Asia.
- **Technology Conversions:**
 - In 2003, the Kota complex had the capacity to produce 34,000 tons per year of PVC resins.⁴²⁸
 - In 2005, DCSL expanded its calcium carbide capacity from 62,700 to 112,200 tons per year, and its PVC capacity from 37,950 to 57,750 tons per year.⁴²⁹
 - Also in 2005, it announced it had converted from mercury cell to membrane technology for producing chlorine, and that it would expand this chlorine production capacity from 75,000 to 93,000 tons per year.⁴³⁰
 - In 2016, the company proposed increasing the plant's chlorine capacity from 103,000 tons per year to 173,000 tons.⁴³¹
- **Markets:**
 - DSCL's subsidiary, Fenesta, manufactures UPVC (unplasticized PVC) windows and doors. The products are extruded in the Kota complex.⁴³²
 - In 2014, Shriram entered into a joint venture, with Axiall (now Westlake) Corporation. Shriram Axiall operates in the Kota complex. It makes PVC polymers used in medical and healthcare products such as IV tubing and blood bags.⁴³³ Compounded PVC made by the Shriram Axiall is sold worldwide. It also is used in wire and cable sheathing, pipes, and other applications.⁴³⁴
 - The company also sells calcium carbide to other industrial users in India.⁴³⁵ In addition to its primary use in acetylene-route PVC production, calcium carbide is a feedstock for acetylene used in oxyacetylene welding. It also is a feedstock for manufacturing calcium cyanamide, organic solvents, and, in the steel industry, desulfurization blends.⁴³⁶

INVENTORY CODE: ASIIND05

- **Plant Name:** *Shriram Alkali & Chemicals, Bharuch*
- **Owner:** DSCL (DCM Shriram).
- **Location:** Jhagadia, Bharuch District, Gujarat, India.
- **Process:** PFAS membrane.
- **Year Opened:** 1996.⁴³⁷
- **Capacities** (tons per year):
 - 284,000 tons of chlorine (2017).⁴³⁸
 - 110 MW coal-fired power (2017), from imported coal.⁴³⁹

- **Capacity Rankings:** Largest chlor-alkali plant in India. Not among largest 33 plants in Asia.
- **Technology Conversions:**
 - In 2005, the plant's reported chlorine production capacity was 57,000 tons per year.⁴⁴⁰
 - In 2016-2017, DCM Shriram expanded its chlorine production capacity in Bharuch to 284,000 tons per year. It also added a 60 MW captive power plant.⁴⁴¹
- **Markets:**
 - In 2017, DCM Shriram reported that the major use of chlorine from the plant is in the production of PVC.⁴⁴²
 - DCM Shriram planned to start a 19,800-ton-per-year unit to produce anhydrous aluminum chloride by June 2018.⁴⁴³

INVENTORY CODE: ASIIND06

- **Plant Name:** *Dahej Complex*
- **Owner:** Reliance Industries Limited (RIL). Formerly Indian Petrochemicals Corp. Ltd., which merged with RIL in 2007.⁴⁴⁴ Reliance is the largest private company in India.⁴⁴⁵
- **Location:** Dahej, Bharuch District, Gujarat, India.
- **Process:** PFAS membrane.
- **Year Opened:** 1996.⁴⁴⁶
- **Capacities** (tons per year):
 - Chlorine: 141,200 tons (2016)
 - EDC: 498,960 tons
 - VCM and PVC: 315,000 tons each.⁴⁴⁷ A major expansion is under way (target is 1.2 million tons per year of PVC).
 - Reliance also has the capacity to import and store 650,000 tons of ethane and produce 500,000 tons per year of ethylene.
 - 270 MW coal-fired power plant and 195 MW gas-fired power plant.⁴⁴⁸
- **Capacity Rank:** 5th largest chlor-alkali plant in India. Not among the largest 33 chlor-alkali plants in Asia. 34th largest PVC plant in Asia.
- **Technology Conversions:**
 - This salt-to-PVC production complex opened in 1996 with capacities to produce 115,000 tons per year of chlorine, 170,000 tons of VCM, 150,000 tons of PVC. It was powered by a 65-MW captive power plant.⁴⁴⁹
 - In 2000, a second phase of development added a 300,000-ton-per-year ethylene cracker.⁴⁵⁰
 - By 2003, the plant's PVC capacity expanded to 180,000 tons per year.⁴⁵¹
 - In 2014, Reliance planned to replace its existing 142.5 MW gas-fired power plant with a 270 MW coal-fired power plant.⁴⁵²
 - In 2016, Reliance proposed expanding the Dahej complex's capacities to 187,000 tons per year of chlorine, 700,000 tons ethylene, 588,000 tons of ethylene dichloride, 360,000 tons of VCM, and 360,000 tons of PVC. It also envisioned a new 1.2-million-ton VCM/PVC plant using mostly using imported EDC.⁴⁵³
 - This major expansion is relying upon ethane shipments from the USA. RIL is building six "Very Large Ethane Carriers" (VLECs). The first two — Ethane Crystal and Ethane Emerald — launched in 2016.⁴⁵⁴
 - In December 2016, Reliance Industries began importing ethane from the USA. In 2017, according to the U.S. Energy Information Agency, it imported 20.8 million barrels of ethane. India became the leading destination for US ethane exports.
 - Reliance has invested heavily in replacing naphtha with ethane from the USA. These investments

- include stakes in gas fracking joint ventures, including two in Pennsylvania (with Chevron and Carrizo Oil & Gas) and one in Texas (Pioneer Natural Resources Co.).⁴⁵⁵
- In April 2017, Reliance announced the completion of its project to receive ethane from the USA. This project included “securing ethane refrigeration capacity in the US Gulf Coast; delivery of dedicated Very Large Ethane Carriers (VLECs) to carry ethane from the US Gulf Coast to the West Coast of India; construction of ethane receipt and handling facilities; laying pipelines and upgrading crackers (to receive ethane) at Dahej, Hazira and Nagothane Manufacturing Facilities,” according to a company press release.⁴⁵⁶
- Also in April 2017, Reliance secured government approval for its planned expansion of PVC production capacity.⁴⁵⁷ According to a plastics industry website, Plastemart, the company’s plans are influenced by erratic feedstock supplies, and the “adequate supply of shale gas ethane from the US.”⁴⁵⁸
- **Markets:**
 - Reliance sells several grades of PVC resins under the Reon brand name. Typical applications for these resins include pipes, bottles, flooring, wire and cable sheathing, shoe compounds, and medical blood bags.⁴⁵⁹

INVENTORY CODE: ASIIND07

- **Plant Name:** *Hazira Complex*
- **Owner:** Reliance Industries (RIL).
- **Location:** Hazira, Gujarat, India.
- **Process:**
 - Chlor-alkali: PFAS membrane.
 - PVC: Ethylene.⁴⁶⁰
- **Year Opened:** 1993.⁴⁶¹
- **Capacities** (tons per year):
 - 198,000 tons of chlorine.⁴⁶²
 - 360,000 tons of PVC.⁴⁶³
 - 372 MW of coal-fired power.⁴⁶⁴
- **Capacity Rankings:** 3rd largest chlor-alkali plant in India. Not among the largest 33 chlor-alkali plants in Asia. Tied for 33rd largest PVC plant in Asia.
- **Technology Conversions:**
 - From 1991 to 1995, Reliance built a \$2.5 billion petrochemical complex in Hazira, including chlor-alkali and PVC units. It features a cracker that converts naphtha from its Jamnagar Complex to ethylene, propylene, and butene.⁴⁶⁵ ICIS reported “the PVC plant will rely on ethylene dichloride imports halving the amount of ethylene that would normally be required.”⁴⁶⁶ Other products include polyethylene, polypropylene, polyester, and polyethylene terephthalate (PET).
 - By 1996, the plant’s PVC capacity reached 270,000 tons. Reliance planned to further expand capacity to 300,000 tons per year, representing nearly half of India’s PVC production capacity in 1998.⁴⁶⁷
 - In 2014, the steam cracker at Hazira had the capacity to produce 790,000 tons per year ethylene.⁴⁶⁸
 - By 2016, the plant’s PVC capacity reached 360,000 tons.⁴⁶⁹
 - In April 2017, Reliance announced the completion of its project to receive ethane from the USA. This project included “securing ethane refrigeration capacity in the US Gulf coast; delivery of dedicated Very Large Ethane Carriers (VLECs) to carry ethane from the US Gulf Coast to the West Coast of India; construction of ethane receipt and handling facilities; laying pipelines and upgrading crackers (to receive ethane) at Dahej, Hazira and Nagothane Manufacturing Facilities,”

according to a company press release.⁴⁷⁰ The move to import 1.5 million tons of ethane per year from the US was projected to save Reliance \$450 million per year.⁴⁷¹

- In 2018, Reliance proposed installing several new pipelines to feed production at Hazira, including lines to deliver ethylene (at a rate of 2,500 tons per hour) and EDC (125 tons per hour) from the port of Adani to the chemical complex. It plans to begin operating the pipelines in 2019.⁴⁷²
- **Markets:**
 - Reliance sells several grades of PVC resins under the Reon brand name. Typical applications for these resins include pipes, bottles, flooring, wire and cable sheathing, shoe compounds, and medical blood bags.⁴⁷³

COUNTRY: INDONESIA

INVENTORY CODE: ASIAIDN01

- **Plant Name:** *PT Asahimas Chemical (PT ASC)*
- **Owners:** AGC Inc. (formerly named Asahi Glass Corporation) owns 52.5% shares of P.T. Asahimas Chemical. Additional major shareholders are PT Rodamas (Indonesia, 18%), Benny Suherman or Ableman Finance (Indonesia, 18%), and Mitsubishi Corporation (Japan, 11.5%).⁴⁷⁴
- **Location:** Cilegon, Banten province, Indonesia.⁴⁷⁵
- **Process:** PFAS membrane.⁴⁷⁶
- **Year Opened:** 1989.⁴⁷⁷
- **Capacities** (tons per year):
 - 636,000 tons of chlorine, 800,000 tons of VCM, and 550,000 tons of PVC (2016).⁴⁷⁸
 - 300 MW on-site coal-fired power plant planned for 2018 opening.
 - Receives ethylene from the nearby Chandra Asri Petrochemical Complex.⁴⁷⁹
- **Capacity Rankings:** 10th largest chlor-alkali plant in Asia. 29th largest chlor-alkali plant in the world. 11th largest PVC plant in Asia. 20th largest PVC plant in the world. This is the “biggest integrated chemical production site in Southeast Asia,” according to the *Jakarta Post*.⁴⁸⁰
- **Technology Conversions:**
 - Opened in 1989 with a 118,000-ton-per-year chlorine production capacity.⁴⁸¹
 - In 1996, the plant expanded capacity to 281,000 tons of chlorine per year and planned to increase it further to 409,000 tons.⁴⁸²
 - In 2015, Asahimas Chemical announced it planned to add on-site power plants and further expand its manufacturing capacity.⁴⁸³
 - In 2016, Kawasaki Heavy Industry announced it was selected to install two 150- MW coal-fired power plants at the Cilegon chemical complex.⁴⁸⁴
 - The company planned to increase VCM capacity from 800,000 to 900,000 tons in 2018.⁴⁸⁵
- **Markets:**
 - VCM feedstocks are used in PVC production on-site and in AGC’s Phu My Plastics and Chemicals PVC plant in Vietnam (150,000 tons per year of PVC capacity).⁴⁸⁶
 - An estimated 80% of Asahimas’ products are consumed domestically, with the balance exported.⁴⁸⁷
 - In addition to the AGC PVC resin plant (run by its Phu My Plastic and Chemicals subsidiary) in Vietnam, Asahimas exports VCM and PVC resins to Australia, Malaysia, Singapore, Saudi Arabia, and Turkey.⁴⁸⁸

INVENTORY CODE: ASIAIDN02

- **Plant Name:** *PT Sulfindo Adiusaha*
- **Owner:** According to Moody's Investors Service, Sulfindo Adiusaha "is owned by entities controlled by Debora Wahjutirto Tanoyo. The company has been owned and controlled by Ms. Tanoyo's family since 2001."⁴⁸⁹ Previously owned by the Salim Group.⁴⁹⁰ Known as PT Indo Chlor Prakarsa Industries before 1995.
- **Location:** Merak, Banten Province, Indonesia.
- **Process:** PFAS membrane.
- **Year Opened:** 1987.⁴⁹¹
- **Capacities** (tons per year):
 - 300,000 tons of chlorine, 320,000 tons of EDC, 130,000 tons of VCM, and 95,000 tons of PVC (since 2012).⁴⁹²
 - The plant receives its ethylene by pipeline from Chandra Asri Petrochemical.⁴⁹³
 - Sulfindo operates two 60-MW coal-fired power plants on-site.⁴⁹⁴
- **Capacity Rankings:** 33rd largest chlor-alkali plant in Asia. 50th largest PVC plant in Asia.
- **Technology Conversions:**
 - In 1998, converted from mercury cell to membrane technology.⁴⁹⁵
 - In 1998, completed expansion to a 193,000-ton chlorine capacity.⁴⁹⁶ At the same time, Sulfindo Adiusaha shut down its 82,000-ton-per-year mercury cell plant.⁴⁹⁷
 - In 2004, ICIS reported the complex had the capacity to produce 195,000 tons of chlorine, 265,000 tons of EDC, 100,000 tons of VCM (through Satomo Indovyl Monomer, SIM), and 80,000 tons of PVC (through Satomo Indovyl Polymer, SIP).⁴⁹⁸ The PVC plant restarted after being idle since 2002.⁴⁹⁹
 - In 2008, Sulfindo reported its production capacities were 238,000 tons of chlorine per year, 295,000 tons of EDC, 100,000 tons of VCM, and 80,000 tons of PVC.⁵⁰⁰
 - In 2012, Sulfindo reported these capacities as 300,000 tons per year of chlorine, 320,000 tons of EDC, 130,000 tons of VCM, and 95,000 tons of PVC. These figures remained unchanged in 2018.⁵⁰¹
 - In September 2018, Sulfindo signed a Memorandum of Understanding with Hyundai Engineering to expand the plant's VCM- and PVC-production capacity. The expansion would be supported by loans from the Korean Export-Import Bank.⁵⁰²
- **Markets:**
 - According to PT Sulfindo Adiusaha, infrastructure developments "in the region has led to a growing demand for PVC products such as pipes and cables. The changing lifestyles of consumers also demand high quality of PVC products such as leather for furniture, film for food packaging, PVC doors, profile for housing and others."⁵⁰³
 - "Sulfindo is a commodity-chemical producer and distributor of caustic soda, ethylene dichloride (EDC) and PVC, which accounted for approximately 45%, 25% and 29% of revenue during the nine months ended 30 September 2017. The balance of sales are from hydrochloric acid and sodium hypochloride," reports Moody's Investors Service.⁵⁰⁴
 - According to a 2012 *ICIS* report, "Sulfindo is the sole exporter of EDC in Southeast Asia."⁵⁰⁵

COUNTRY: IRAN

OVERVIEW

In 2014, the Iranian government reported a national PVC production capacity of 745,000 tons per year. In addition to the Arvand Petrochemical Company plant listed below, major Iranian PVC producers include:

- Abadan Petrochemical Company (110,000 tons of PVC per year, some of which is exported to Iraq, Afghanistan, Pakistan, Azerbaijan, Turkey, and Armenia⁵⁰⁶);
- Ghadeer Petrochemical Company (150,000 tons of VCM and 120,000 tons of PVC);
- Hamedan Petrochemical Industry Company (48,000 tons of medical grade PVC); and
- Qadir Petrochemical Company (Khuzestan Province, in 2018 planned to increase production from 120,000 to 160,000 tons of PVC).⁵⁰⁷

INVENTORY CODE: ASIARN01

- **Plant Name:** *M/s Arvand Petrochemical Co. (APC Complex)*
- **Owner:** Islamic Republic of Iran, via Iranian Petroleum Ministry and the National Petroleum Company.⁵⁰⁸
- **Location:** Special Economic Zone, Bandar Emam, Iran.
- **Process:** PFAS membrane.⁵⁰⁹
- **Year Opened:** 2009.⁵¹⁰
- **Capacities** (tons per year):
 - 585,000 tons of chlorine.
 - 890,000 tons of EDC.
 - 343,000 tons of VCM.
 - 340,000 tons of PVC (2016).⁵¹¹
- **Capacity Rankings:** 11th largest chlorine plant in Asia. 20th largest chlorine plant in the world. 30th largest PVC plant in Asia. 50th largest PVC plant in the world.
- **Technology Conversions:**
 - In 2002, the Iranian National Petrochemical Company contracted with Uhde of Germany to build the integrated chlor-alkali-to-PVC plant.⁵¹²
 - In 2006, the plant was producing 175,000 tons per year of PVC.⁵¹³
 - In 2014, the Iranian government was considering a second-phase expansion of its PVC capacity.⁵¹⁴
 - In 2015, the plant reached its planned initial capacity of 340,000 tons per year of PVC.⁵¹⁵
- **Markets:**
 - Arvand Petrochemical produces PVC for domestic and overseas markets, particularly China and India.⁵¹⁶ Destinations include Afghanistan, Azerbaijan, Iraq, Italy, India, Iraq, Kuwait, Pakistan, Turkey, and the United Arab Emirates.⁵¹⁷
 - The plant opened with the intention of supplying 186,700 tons of chlorine gas and 339,300 tons of EDC to other plants in the area.⁵¹⁸
 - Some of this plant's outputs feed production at the 110,000-ton-per-year Abadan Petrochemical Company PVC plant.⁵¹⁹

COUNTRY: JAPAN

OVERVIEW

The chlor-alkali industry in Japan was the first to fully convert from mercury cell to PFAS membrane cell technology. The first PFAS membrane cells producing chlorine and caustic soda were introduced in Japan in 1975. The country, reacting to the mercury-poisoning tragedy of Minamata Bay, quickly converted and closed all mercury cell plants. Japan completed its conversion to ion-exchange processes by the late 1980s.⁵²⁰

Chlor-alkali and PVC production in Japan is contracting. In 2017, there were 30 chlor-alkali plants in Japan with a combined production capacity of 3.7 million tons of chlorine, down from 31 plants and 4.3 million tons capacity in 2008.⁵²¹

For decades, Japan has been “haunted” by oversupply of PVC, as *ICIS* described the situation in 2000.⁵²² In announcing that it would close its Osaka plant by 2020, Taiyo Vinyl, recently said, “The domestic PVC business environment continues to be plagued by oversupply. And given other market factors such as Japan’s declining population and the forecast for a decrease in new housing, the market is expected to remain sluggish.”⁵²³ AGC (formerly Asahi Glass) is focused on “expansion of production capacity in overseas markets, which show potential for growth in the Chlor-Alkali business.”⁵²⁴

According to a 2016 report published by the Federation of Indian Chambers of Commerce and Industry (FICCI), Japan’s 2,090,000 tons of PVC capacity exceeded domestic demand (1,450,000 tons) by 640,000 tons.⁵²⁵

INVENTORY CODE: ASIAJPN01

- **Plant Name:** *Chiba Plant*
- **Owner:** AGC Inc. (formerly Asahi Glass).
- **Location:** Ichihara City, Chiba, Japan.
- **Process:** PFAS membrane. Formerly mercury cell and asbestos diaphragm.
- **Year Opened:** 1959.⁵²⁶
- **Capacities** (tons per year):
 - 182,000 tons of chlorine (2017).⁵²⁷
- **Capacity Rankings:** Not among top 33 chlor-alkali plants in Asia.
- **Technology Conversions:**
 - In 1975, AGC’s Chiba plant converted from mercury cell to asbestos diaphragm technology.⁵²⁸
 - In 1986, it converted from asbestos diaphragm to ion exchange PFAS membrane technology.⁵²⁹
 - In 2004, AGC announced the “world’s first” “practical application” of chlorofluorocarbon resin recycling.⁵³⁰
- **Markets:**
 - The Chiba plant produces carbon tetrachloride, chloroform, and methylene chloride (also called dichloromethane).⁵³¹ “Volatile organic compounds (such as dichloromethane) produced by Asahi Glass are widely used as raw materials for the making of chemical products, cleaning solvents, reaction solvents and so forth,” states a 2001 company report.⁵³²
 - It also produces fluorinated resins, and intermediates for pesticides and pharmaceuticals.⁵³³

INVENTORY CODE: ASIAJPN02

- **Plant Name:** *Kashima Plant (AGC)*
- **Owner:** AGC Inc. (formerly Asahi Glass).

- **Location:** Kamisu Town, Kashima, Ibaraki, Japan.
- **Process:** PFAS membrane.
- **Year Opened:** 1975.⁵³⁴
- **Capacities** (tons per year):
 - 318,000 tons of chlorine (2017).⁵³⁵
- **Capacity Rankings:** 30th largest chlor-alkali plant in Asia. 59th largest chlor-alkali plant in the world.
- **Technology Conversions:**
 - In 1975, AGC converted the Kashima plant from mercury cell to asbestos diaphragm technology (146,000 tons per year of chlorine capacity).⁵³⁶
 - In 1989, AGC converted the Kashima plant from asbestos diaphragm to ion exchange PFAS membrane technology.⁵³⁷
 - In 1994, the plant's chlorine production capacity was 251,000 tons per year.⁵³⁸
 - On March 11, 2011, the Kashima industrial complex “suffered major earthquake and tsunami damage (although for the most part buildings remained intact),” according to an *Environmental Health Perspectives* journal article by Elizabeth Grossman and Winifred Bird. “As cleanup continues in the disaster area, questions remain about the fate of chemical contaminants released by these damaged industrial facilities and other sources, and the environmental health hazards they might pose to the hundreds of thousands of people living and working in this area.”⁵³⁹
- **Markets:**
 - AGC's Kashima plant has the capacity to produce 110,000 tons of propylene oxide per year.⁵⁴⁰ Propylene oxide is manufactured in two primary ways: the chlorohydrin and hydroperoxidation processes. The chlorohydrin route is typically integrated with chlor-alkali plants such as this. Nexant, a global consultant to the energy and chemical industries, says the chlorohydrin process “suffers from environmental liabilities and large capital investment requirements. Also, inexpensive electric power must be available for the integrated chlor-alkali facility.”⁵⁴¹
 - The plant also sells epichlorohydrin.⁵⁴²

INVENTORY CODE: ASIAJPN03

- **Plant Name:** *Kashima Plant (Shin-Etsu)*
- **Owner:** Shin-Etsu Chemical Co. Ltd., via Kashima Chlorine & Alkali Ltd. (including Kashima VCM. Shin-Etsu is the majority shareholder. Mitsubishi Chemical holds a minority stake.⁵⁴³ Asahi Glass, Adeka, and Kaneka were shareholders until 2012.⁵⁴⁴
- **Location:** Kashima, Ibaraki, Japan.
- **Process:** PFAS membrane. Converted from mercury cell.
- **Year Opened:** 1968.⁵⁴⁵
- **Capacities** (tons per year):
 - 364,000 tons of chlorine.
 - 600,000 tons of VCM (2012).⁵⁴⁶
 - 550,000 tons of PVC (2011).⁵⁴⁷
- **Capacity Rankings:** 26th largest chlor-alkali plant in Asia. 47th largest chlor-alkali plant in the world. 13th largest PVC plant in Asia. 22nd largest PVC plant in the world.
- **Technology Conversions:**
 - The plant converted chlorine production technology in July 1983 from mercury cell to PFAS membrane technology.⁵⁴⁸
 - In 1987, the plant's PVC production capacity was 200,000 tons per year.⁵⁴⁹
 - In 1994, the plant's chlorine production capacity was 281,000 tons per year.⁵⁵⁰

The March 11, 2011, Great East Japan Earthquake halted plant operations for several weeks.⁵⁵¹ The company reported “some damage” to its chemical production facilities and “heavy damage” to electrical and water supplies in the Kashima industrial complex.⁵⁵²

- **Markets:**
 - PVC is the main product of this factory, Shin-Etsu’s largest in Japan;. Shin-Etsu is also the world’s largest PVC producer.⁵⁵³

INVENTORY CODE: ASIAJPN04

- **Plant Name:** *Miyazaki Chemical Center*
- **Owner:** Asahi Kasei Corporation, via subsidiary, Asahi Kasei Chemicals Corporation (AKCC).
- **Location:** Nobeoka City, Miyazaki, Japan.
- **Process:** PFAS membrane.⁵⁵⁴ Converted from mercury cell.
- **Year Opened:** 1923.⁵⁵⁵
- **Capacities** (tons per year):
 - 141,000 tons of chlorine (1994).⁵⁵⁶
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia.
- **Technology Conversions:**
 - A 1949 US Army chemical industry inspector found that the Asahi “Nobeoka Plant... at the southern part of Kyushu, has a small mercury cell caustic plant, part of a large chemical plant – as a unit practically useless to anyone else. To move that for reparations would, [the inspector was] informed, throw eight hundred men out of work. In that case the caustic and chlorine to be used in the main plant must be brought in from plants located at a distance.”⁵⁵⁷
 - In 1975, the Asahi Kasei began producing chlor-alkali using perfluorocarboxylic acid (PFAS) membranes, with chlorine production capacity of 80,000 tons per year.⁵⁵⁸ According to the 1976 report of the electrolytic industries, “initially, commercial testing was done with DuPont’s Nafion membranes but more recently a perfluorocarboxylic acid membrane developed by Asahi Chemical is being substituted for the DuPont membranes.”⁵⁵⁹ The Asahi Kasei PFAS membrane technology has since become “employed in plants with a total production capacity of over 25 million tons of caustic soda per year,” according to Asahi Kasei.⁵⁶⁰ It was the first plant in the world to convert directly from mercury to PFAS membrane technology (most of the 1970s conversions were to asbestos diaphragm technology).⁵⁶¹
 - In 1982, the *Journal of the Electrolytic Industries* reported that the company “plans to replace the remaining mercury cells at Nobeoka with ion exchange membrane technology.”⁵⁶²
 - In 2012, Asahi Kasei opened a wood biomass power plant in the Nobeoka complex.⁵⁶³
- **Markets:**
 - This chemical complex produces polyvinylidene chloride (PVDC) resin and latexes. Applications include: Saran Wrap (PVDC) film; paper coating; polyurethane coating; binder for PVDC or PVC fiber; and flame retardant fabric, paper, and leather.⁵⁶⁴ In 2012, Asahi Kasei said it held a 20% share of the global PVDC market.⁵⁶⁵ This equals 40,000 tons of a worldwide PVDC production capacity of 200,000 tons.⁵⁶⁶
 - Other chlorinated products include sodium hypochlorite and PAC (poly aluminum chloride).⁵⁶⁷
 - The Nobeoka plant also produces toluene diisocyanate, which uses chlorine as a feedstock.⁵⁶⁸

INVENTORY CODE: ASIAJPN05

- **Plant Name:** *Takasago Plant Kanevinyl*
- **Owner:** Kaneka Corporation (previously Kanegafuchi Company⁵⁶⁹), through its subsidiary Toagosei Corporation.
- **Location:** Takasago, Hyōgo, Japan.

- **Process:** PFAS membrane.⁵⁷⁰
- **Year Opened:** 1960.⁵⁷¹
- **Capacities** (tons per year):
 - 270,000 tons of chlorine (1998).⁵⁷²
 - 400,000 tons of VCM (2012).⁵⁷³
 - 290,000 tons of PVC (2012).⁵⁷⁴
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia. 39th largest PVC plant in Asia. 67th largest PVC plant in the world.
- **Technology Conversions:**
 - In 1971, the Takasago plant's vinyl chloride production capacity was 115,000 tons per year.⁵⁷⁵
 - In 1974, the plant's owners converted its production technology from mercury cell to asbestos diaphragm.⁵⁷⁶
 - In 1989, it converted the plant to PFAS membrane technology.⁵⁷⁷
 - In 1994, the plant's chlorine capacity was 181,000 tons per year.⁵⁷⁸
 - By 1998, its chlorine production capacity grew to 270,000 tons per year.⁵⁷⁹
 - In 2008, Kaneka stated that it had "appointed a consultant and uncovered issues at our Takasago Plant, which has high energy consumption compared to our other plants."⁵⁸⁰
 - In 2010, Kaneka's total PVC capacity in Japan (including Takasago and another plant, at Kashima, Ibaraki) was 430,000 tons per year.
- **Markets:**
 - In 1960, Takasago was "the exclusive producer of vinyl chloride in Japan."⁵⁸¹
 - The primary chlorinated products of the Takasago plant are VCM, PVC, and sodium hypochlorite.⁵⁸²

INVENTORY CODE: ASIAJPN06

- **Plant Name:** *Mizushima Plant*
- **Owner:** Osaka Soda, through its Daiso Co. subsidiary, and in turn, Daiso's Okayama Chemical subsidiary.⁵⁸³
- **Location:** Mizushima, Kurashiki, Okayama, Japan.
- **Process:** PFAS membrane. Converted from mercury.
- **Year Opened:** 1968.⁵⁸⁴
- **Capacities** (tons per year):
 - 126,000 tons of chlorine (1994).⁵⁸⁵
 - 60,000 tons of epichlorohydrin (2015).
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia.
- **Technology Conversions:**
 - In 1986, the plant's production technology was converted from mercury cell to PFAS membrane.⁵⁸⁶
 - "In 1971, we expanded into the Mizushima chemical complex and built a system for integrated production of AC [allyl chloride] and EP [epichlorohydrin]," reported Osaka Soda.⁵⁸⁷ Allyl chloride is a feedstock for epichlorohydrin production.
 - In 2003, the plant's epichlorohydrin production capacity was 33,000 tons per year.⁵⁸⁸
 - In 2015, Osaka Soda said, "In Epichlorohydrin, we expanded [the] production capacity of Mizushima Plant to pursue market share expansion aggressively, making [the] AC/EP chain more competitive globally by enhancing [its] low-cost position."⁵⁸⁹

- **Markets:**
 - Osaka Soda is Japan's largest producer of epichlorohydrin.⁵⁹⁰

INVENTORY CODE: ASIAJPN07

- **Plant Name:** *Tokuyama Soda*
- **Owner:** Tokuyama Corporation. Formerly known as Nihon Soda Kogyo Co.
- **Location:** Tokuyama, Yamaguchi, Japan.
- **Process:** PFAS membrane. Converted from mercury cell and asbestos diaphragm.
- **Year Opened:** 1952.⁵⁹¹
- **Capacities** (tons per year):
 - 445,000 tons of chlorine (2018).⁵⁹²
 - 330,000 tons of VCM (2012).⁵⁹³
- **Capacity Rankings:** 18th largest chlor-alkali plant in Asia. 31st largest chlor-alkali plant in the world.
- **Technology Conversions:**
 - In 1975, the plant converted from mercury cell to asbestos diaphragm technology.
 - In 1983, the plant converted from asbestos diaphragm to PFAS membrane technology.⁵⁹⁴
- **Markets:**
 - Tokuyama Group's subsidiary, Shin Dai-ichi Vinyl Corporation, uses VCM produced at this plant.⁵⁹⁵ It uses the PVC mostly for "building materials such as pipes, wallpaper, and flooring tiles; film sheets."⁵⁹⁶ In 2011, the Shin Dai-ichi Vinyl Corporation plant in Tokuyama had the capacity to produce 145,000 tons per year of PVC.⁵⁹⁷
 - Tokuyama Group uses chlorine from this plant to produce propylene oxide, which is a feedstock for isocyanate and then polyurethane production.⁵⁹⁸
 - The company also produces the solvent methyl chloride.⁵⁹⁹

INVENTORY CODE: ASIAJPN08

- **Plant Name:** *Nanyo Complex*
- **Owner:** Tosoh Corporation. Formerly named Toyo Soda.
- **Location:** Shin-Nanyo, Yamaguchi, Japan.
- **Process:** PFAS membrane.
- **Year Opened:** 1936.⁶⁰⁰
- **Capacities** (tons per year):
 - 1,022,000 tons of chlorine (2017).⁶⁰¹
 - 850,000 tons of VCM (2015).⁶⁰²
 - 400,000 tons of methylene diisocyanate (MDI) (2016).⁶⁰³
- **Capacity Rankings:** 2nd largest chlor-alkali plant in Asia. 6th largest chlor-alkali plant in the world.
- **Technology Conversions:**
 - In 1975, the plant converted from mercury cell to diaphragm technology.⁶⁰⁴
 - In 1998, the plant's chlorine production capacities were 148,000 tons by diaphragm technology, and 384,000 tons by PFAS membrane.⁶⁰⁵
 - In 1999, according to Tosoh, the plant replaced its remaining asbestos diaphragm production units with ion exchange PFAS membranes.⁶⁰⁶
- **Markets:**
 - Tosoh is the largest producer of VCM in Japan and uses it to produce PVC in Japan and overseas.⁶⁰⁷ In Japan, Tosoh operates PVC factories in Takaishi (Osaka, 158,000 tons), Ichihara

(Chiba, 102,000 tons), and Yokkaichi (Mie, see below).⁶⁰⁸ Overseas operations include Tosoh Guangzhou Chemical Industries (Guangdong Province, China),⁶⁰⁹ P.T. Standard Toyo Polymer (Indonesia),⁶¹⁰ and Philippines Resins Industries (Makati City, Bataan, Philippines).⁶¹¹

- The MDI produced in Nanyo is used in a wide range of products, including artificial leather, spandex, shoe soles, coatings, adhesives, spray foam, integral skin foams, elastomers, flexible foam, and automobile parts.⁶¹²
- The plant also produces calcium hypochlorite for water disinfection and sterilization.⁶¹³

INVENTORY CODE: ASIAJPN09

- **Plant Name:** *Yokkaichi Complex*
- **Owner:** Tosoh Corporation. Formerly named Toyo Soda.
- **Location:** Yokkaichi, Mie, Japan.
- **Process:** PFAS membrane
- **Year Opened:** 1971.⁶¹⁴
- **Capacities** (tons per year):
 - 115,000 tons of chlorine (2017).⁶¹⁵
 - 260,000 tons of VCM (2015).⁶¹⁶
 - 310,000 tons of PVC (2018).⁶¹⁷
 - 527,000 tons of naphtha cracker (2016). Ethylene produced by the cracker feeds ethylene dichloride/VCM production, as well as on-site lines to produce polyethylene and ethylene-vinyl acetate.⁶¹⁸
- **Capacity Rankings:** Not among the 33 largest chlor-alkali plants in Asia. 32nd largest PVC plant in Asia. 56th largest PVC plant in the world.
- **Technology Conversions:**
 - In 1976, the plant had 64,000 tons per year of chlorine production capacity using asbestos diaphragm technology.⁶¹⁹
 - The plant converted to PFAS membrane technology in 1983.⁶²⁰
 - In 2017, Tosoh announced a project to expand its naphtha-cracking furnace, which it expected to complete by mid-2019.⁶²¹
- **Markets:**
 - Tosoh PVC resins are used in rigid plates, extruded sheets, injection molding, pipes, window frames, food films, wire and cable sheathing, agricultural films, and other applications.⁶²²

COUNTRY: PAKISTAN

INVENTORY CODE: ASIAPAK01

- **Plant Name:** *Engro Polymer and Chemicals (EPCL)*
- **Owner:** Engro Corporation. EPCL was formerly Engro Asahi Polymer and Chemical, established in 1997 as a joint venture between Engro Chemical (50%, Pakistan), Asahi Glass Company (30%, Japan) and Mitsubishi Corporation (20%, Japan).⁶²³
- **Location:** Port Qasim, Baluchistan, Pakistan.
- **Process:** PFAS membrane.⁶²⁴
- **Year Opened:** 1999 (PVC), 2007 (chlor-alkali, EDC, VCM).⁶²⁵
- **Capacities** (tons per year):

- 96,000 tons of chlorine (2015)
- 195,000 tons of VCM and PVC (2018).⁶²⁶ The VCM plant uses imported ethylene, 90-95% of which comes from Qatar Vinyl (ASIAQAT01 below).⁶²⁷
- 65 MW gas-fired power plant.
- **Capacity Rankings:** Largest chlor-alkali and PVC plant in Pakistan. Not among largest chlor-alkali or PVC plants in Asia.
- **Technology Conversions:**
 - Opened in 1999 with a 100,000-ton-capacity PVC plant.⁶²⁸
 - In 2009, EPCL expanded PVC capacity to 150,000 tons per year, and added chlor-alkali, EDC, and VCM production units to the complex.⁶²⁹
 - In 2010, EPCL added a 65 MW natural-gas-fired power plant.⁶³⁰
 - In 2013, a debottlenecking process increased the Port Qasim complex's PVC capacity to 178,000 tons.⁶³¹
 - In 2016, ICIS reported that EPCL "will conduct debottlenecking works at its polyvinyl chloride (PVC) plants in 2018."⁶³²
 - In December 2017, *The Express Tribune* reported that EPCL was going to "add a new PVC plant with a capacity of 100,000 tons (taking total capacity to 295,000 ton per annum) and increase production of VCM (the raw material) by 50,000 tons through debottlenecking of the existing plant by the third quarter of 2020."⁶³³
 - According to a 2018 environmental impact assessment, an EDC import pipeline will supply the new VCM and PVC plant.⁶³⁴ At an October 25, 2018, hearing on the assessment, residents and environmentalists raised concerns about contaminated groundwater, air pollution, the destruction of mangrove swamps, and discharges into the ocean.⁶³⁵
 - In August 2018, EPCL stated that it is partnering with Tianchen Corp China on the plant expansion.⁶³⁶ Tianchen will supply the plant and machinery.⁶³⁷
 - In November 2018, EPCL announced that it obtained \$35 million in financing from the International Finance Corporation (part of the World Bank Group) in support of its planned expansion.⁶³⁸
- **Markets:**
 - EPCL sells four grades of PVC, with the brand name Sabz.⁶³⁹ It says 55% of its resin is used to make PVC pipes; other consumers include artificial leather, shoes, hoses, windows, and doors.⁶⁴⁰
 - In 2016, ICIS reported that "PVC demand in Pakistan currently stands at around 200,000 tonnes/year and is growing at an annual rate of 16%."⁶⁴¹
 - The *Express Tribune* reported that EPCL produced 73% of the PVC consumed in Pakistan in 2017.⁶⁴²

COUNTRY: QATAR

INVENTORY CODE: ASIAQAT01

- **Plant Name:** *Qatar Vinyl Company Ltd. (QVC)*
- **Owner:** Government of Qatar through shareholders.⁶⁴³ Shareholders in 2015 were Mesaieed Petrochemical Holding Company (55.2%), Qatar Petrochemical Company (Qapco, 31.9%) and Qatar Petroleum (12.9%).⁶⁴⁴ Total (France) owns 20% of Qapco.⁶⁴⁵
- **Location:** Mesaieed Industrial City, Al Wakrah Municipality, Qatar.
- **Process:** PFAS membrane.⁶⁴⁶
- **Year Opened:** 2001.⁶⁴⁷

- **Capacities** (tons per year):
 - 336,000 tons of chlorine, 470,000 tons of EDC (of which 180,000 tons is sold overseas), and 360,000 tons of VCM (2017).⁶⁴⁸
 - An ethane cracker located in the Mesaieed petrochemical complex provides 220,000 tons of ethylene to QVC (2017, ICIS).⁶⁴⁹
 - 110 MW gas-fired power plant.
- **Capacity Rankings:** 28th largest chlor-alkali plant in Asia. 56th largest chlor-alkali plant in the world.
- **Technology Conversions:**
 - Qatar Vinyl Co. was launched in 1999 as a joint venture of the government of Qatar, Norsk Hydro (Norway, which divested its petrochemical business in 2007⁶⁵⁰), and Elf Atochem (France, now Arkema, which sold its shares in QVC in 2013⁶⁵¹). The venture planned to have the capacity to produce 290,000 tons of chlorine, 175,000 tons of EDC, and 230,000 tons of VCM.⁶⁵² According to Qatar Petroleum, “QVC was established to produce intermediates in the PVC industry.”⁶⁵³
 - In 2003, the plant’s capacities were 260,000 tons per year of chlorine, 368,000 tons of EDC (175,000 tons for sales, 193,000 tons for VCM unit), and 230,000 tons of VCM.⁶⁵⁴
 - In 2006, QVC postponed plans to double chlorine and EDC production.⁶⁵⁵
- **Markets:**
 - QVC exports EDC and VCM to PVC manufacturers.⁶⁵⁶ In 2004, the *Gulf Industry* newsletter reported that “the entire production of both EDC and VCM is exported while some 10,000 tonnes of caustic soda is consumed within Qatar itself. Among the export markets for caustic soda are GCC states UAE and Oman. QVC’s major market is South-east Asia, the Far East, Australia and the Indian Subcontinent. Small quantities are sold in Europe and the US as well as South Africa. The company works through the marketing network of its European shareholders in various countries.”⁶⁵⁷
 - It supplies Engro Polymer & Chemical in Pakistan with 90-95% of its imported VCM.⁶⁵⁸

COUNTRY: SAUDI ARABIA

INVENTORY CODE: ASIASAU01

- **Plant Name:** *Saudi Petrochemical Co. (SADAF) Complex/SABIC*
- **Owner:** Saudi Basic Industries Corporation. (SABIC), via its SADAF subsidiary. SABIC is “owned 70% by the Saudi government and 30% by private investors from the six GCC countries,” according to a 2018 *ICIS* report.⁶⁵⁹ SADAF had been a 50/50 joint venture with Shell since its inception, but Shell sold its stake to SABIC in 2017.⁶⁶⁰
- **Location:** Jubail Industrial City, Al-Jubail, Saudi Arabia.
- **Process:** Asbestos diaphragm and PFAS membrane.⁶⁶¹
- **Year Opened:** 1987.⁶⁶²
- **Capacities** (tons per year):
 - 645,000 tons of chlorine (2016).⁶⁶³ Estimated 342,000 tons by asbestos diaphragm and 303,000 by membrane technology.
 - 840,000 tons of EDC.
 - 500,000 tons of VCM.
 - 400,000 tons of PVC (2008).⁶⁶⁴
 - The Sadaf complex also includes an ethylene cracker, a salt plant, styrene and MTBE plants, and a power plant.⁶⁶⁵ The ethylene is produced from ethane, a co-product of Saudi Aramco’s crude oil production.⁶⁶⁶

- **Capacity Rankings:** 9th largest chlor-alkali plant in Asia. 23rd largest PVC plant in Asia. 17th largest chlor-alkali plant in the world.
- **Technology Conversions:**
 - In 1985, the Shell/SABIC joint venture began production. It used asbestos diaphragm cell technology capable of producing 342,000 tons per year of chlorine.⁶⁶⁷ It also opened with the capacity to produce 454,000 tons of EDC.⁶⁶⁸
 - In 1996, SADAF installed a PFAS membrane chlor-alkali plant with a 221,600-ton-per-year chlorine capacity.⁶⁶⁹
 - In 2000 and 2004, the plant's chlorine production capacity was reported as 609,000 tons per year.⁶⁷⁰
 - In 2006, ICIS reported that "Sabic is looking to increase PVC capacity by 450,000 tonnes/year to 850,000 tonnes/year and VCM feedstock capacity by 500,000 tonnes/year to 950,000 tonnes/year."⁶⁷¹ However, as of 2018, this does not appear to have been implemented.
 - In 2017, SABIC's board planned to replace the chlor-alkali plant's asbestos diaphragms with membrane cell technology by the end of 2018. The board reported in 2017 on the "SADAF project in Al-Jubail Industrial City to convert the DIVRAM cell lines, which contains the banned asbestos material to membrane cell technology to eliminate environmental problems and problems related to industrial health." The conversion was schedule for completion by Q4 2018.⁶⁷² No confirmation of this conversion had been announced on SABIC's website through the end of 2018.
- **Markets:**
 - When the plant opened in 1987, the Saudi government planned to export chlorine to Japan and Taiwan. "Saudi chlorine appears to be replacing 10,000 tons per year of market that had been exported to the Far East by U.S. producers," reported the *1987 Report of the Electrolytic Industries*.⁶⁷³ In 2004, *Oil and Gas News Worldwide* reported, "The main customers for Sadaf's products are in Asia, Australia, Europe and the US. Hence, basically, the Sadaf Business Unit markets its products in four continents. The main market for caustic soda is in Australia, where it is an important ingredient in the bauxite refining process to produce alumina - the raw material used to make aluminum. Caustic soda is also being sold in other markets in Asia and the Americas.... EDC is supplied to major customers in Asia, who manufacture VCM and PVC, mainly in Taiwan, Japan, Malaysia and China." A major customer, it said, is the Taiwan VCM (TVCM) Corporation, part of the USI Group. The Taiwan VCM (TVCM) plant in Kaohsiung, Taiwan, had a capacity of 330,000 tons VCM production in 2006.⁶⁷⁴
 - According to TVCM, "major clients in Taiwan are China General Plastics Corporation, CGPC Polymer Corporation, and Ocean Plastics Corporation. We also export VCM to mainland China, South East Asia and India etc."⁶⁷⁵

INVENTORY CODE: ASIASAU02

- **Plant Name:** Sahara & Ma'aden Petrochemicals (SAMAPCO)
- **Owner:** SAMAPO is a 50/50 joint venture between Sahara Petrochemicals and Saudi Arabian Mining Co (Ma'aden) and Sahara Petrochemicals.⁶⁷⁶ The Saudi government owns 50% of Ma'aden.⁶⁷⁷ In October 2018, the Saudi International Petrochemical Company (Sipchem) agreed to purchase Sahara Petrochemicals.⁶⁷⁸
- **Location:** Jubail Industrial Complex, Al-Jubail, Saudi Arabia.
- **Process:** PFAS membrane.⁶⁷⁹
- **Year Opened:** 2014.⁶⁸⁰
- **Capacities** (tons per year): 227,000 tons of chlorine, 300,000 tons of EDC (2014).⁶⁸¹
- **Capacity Rankings:** 2nd largest chlor-alkali plant in Saudi Arabia. Not among the largest 33 chlor-alkali plants in Asia.
- **Technology Conversions:** None.
- **Markets:**

- All of the caustic soda from this plant supplies an alumina refinery owned by Ma'aden, in Ras Alkair.
- EDC produced by this plant is consumed domestically and exported, on the wholesale and retail markets.⁶⁸²
- SABIC is the “prime marketer” for this plant’s EDC.⁶⁸³

COUNTRY: SOUTH KOREA

There is an excess amount of caustic soda in South Korea, leading at least one plant to convert to a technology to produce caustic potash, instead, as a co-product of chlorine production.⁶⁸⁴

High electricity costs, and overseas competition, also are constraining production of chlorine. For example, in 2018, Hanwha, a leading producer, “reduced operating rates for 3 chlor-alkali lines out of the 5 lines owing to poor export prices and high electricity cost during peak hours.”⁶⁸⁵

Supply also exceeds domestic demand for PVC, and much of the country’s industry has become export-oriented, especially to India. In 2017, *Sisa Journal* reported, “PVC, which makes pipes, is classified as an oversupply item in Korea and is subject to restructuring, but exports to India are steadily increasing. PVC exports to India amounted to 500,000 tons by November last year. Exports to India account for more than one-third of the total PVC production of 1.5 million tons in Korea and more than half of PVC exports in Korea. LG Chem and Hanwha Chemical are in charge of PVC production in Korea and the market is also divided. LG Chem and Hanwha Chemical produce 900,000 tons and 600,000 tons respectively.”⁶⁸⁶

According to a 2016 report published by the Federation of Indian Chambers of Commerce and Industry (FICCI), South Korea’s capacity of 1,470,000 tons of PVC exceeded domestic demand (700,000 tons) by 770,000 tons. FICCI said that 52% of South Korea’s 575,000 tons of exports were shipped to India.⁶⁸⁷

INVENTORY CODE: ASIAKOR01

- **Plant Name:** *Ulsan CA Plant*.
- **Owner:** Unid Co. Hanwha Chemical sold the chlor-alkali unit to Unid in 2016.⁶⁸⁸ Formerly known as Daehan Plastic Industry.⁶⁸⁹
- **Location:** Ulsan, South Korea.
- **Process:** PFAS membrane.⁶⁹⁰
- **Year Opened:** 1966.⁶⁹¹
- **Capacities** (tons per year):
 - 182,000 tons of chlorine.⁶⁹²
 - 300,000 tons of PVC.⁶⁹³
 - The EDC plant receives its ethylene from Yeochun NCC (YNCC), a naphtha cracker in which Hanwha holds a 50% stake. YNCC has a capacity of 1.9 million tons of ethylene per year.⁶⁹⁴
- **Capacity Rankings:** Not among the largest 33 chlor-alkali plants in Asia. 36th largest PVC plant in Asia.
- **Technology Conversions:**
 - The first VCM plant was set up in 1972.⁶⁹⁵
 - A PVC paste-resin plant was added in 1977.⁶⁹⁶
 - In 2011, Hanwha listed plant capacities as 176,000 tons of chlorine, 385,000 tons of EDC, 247,000 tons of VCM, and 305,000 tons of PVC.
 - In 2016, Hanwha sold the chlor-alkali production unit in its Ulsan complex to Und Co. Unid planned to convert the plant to produce caustic potash rather than caustic soda. According to the

business news site, *Pulse*, Hanwha will continue to receive chlorine from the plant to produce PVC.⁶⁹⁷

- In 2016, Hanwha began building a new chlorinated polyvinyl chloride (CPVC) plant in Ulsan, with a planned 30,000-ton capacity.⁶⁹⁸
- In January 2018, Unid began production at the new chlor-alkali unit.⁶⁹⁹
- **Markets:**
 - CPVC produced in Ulsan is used in fire sprinkler systems, hot-water and specialty industrial pipes.⁷⁰⁰
 - Hanwha's subsidiary, Hanwha L&C, processes PVC resins into flooring, tiles, and automotive parts.⁷⁰¹
 - Hanwha exports PVC resins made in Ulsan, including to India.⁷⁰²

INVENTORY CODE: ASIAKOR02

- **Plant Name:** *Yeosu Plant - Hanwha*
- **Owner:** Hanwha Chemical (formerly Hanyang Chemical).
- **Location:** Yeosu City (formerly Yeochon), South Korea.
- **Process:** PFAS membrane.
- **Year Opened:** 1980.⁷⁰³
- **Capacities** (tons per year):
 - 782,000 tons of chlorine ⁷⁰⁴
 - 430,000 tons of EDC (2012).⁷⁰⁵
 - 360,000 tons of VCM (2014),⁷⁰⁶
 - 290,000 tons of PVC (2015).⁷⁰⁷
 - The EDC plant receives ethylene from the nearby Yeochun NCC (YNCC) naphtha cracker. Hanwha holds a 50% stake in this cracker. YNCC has a capacity of 1.9 million tons of ethylene per year.⁷⁰⁸
- **Capacity Rankings:** 6th largest chlor-alkali plant in Asia. 12th largest chlor-alkali plant in the world. 38th largest PVC plant in Asia. 68th largest PVC plant in the world.
- **Technology Conversions:**
 - In 1992, the naphtha cracker began operating at the Yeosu chemical complex.⁷⁰⁹
 - In 2008, the plant's chlorine production capacity was 500,000 tons per year.⁷¹⁰
 - In 2017, the plant's chlorine production capacity expanded by 118,000 tons.⁷¹¹
- **Markets:**
 - Hanwha Chemical is South Korea's second-largest epichlorohydrin producer, according to *ICIS*.⁷¹² In 2009, it had the capacity to produce 25,000 tons of epichlorohydrin per year.⁷¹³
 - Hanwha's subsidiary, Hanwha L&C, processes PVC resins into flooring, tiles, and automotive parts.⁷¹⁴
 - Chlorine also is consumed on-site in the KPX Fine Chemical isocyanates plant, which can produce 150,000 tons per year of toluene diisocyanate (TDI).⁷¹⁵ Hanwha Chemical acquired KPX Fine Chemical in 2014. KPX is one of three isocyanates producers in South Korea (the others are BASF and OCI).⁷¹⁶

INVENTORY CODE: ASIAKOR03

- **Plant Name:** *Yeosu Plant - LG*; originally called "*Lucky Vinyl Ltd.*"⁷¹⁷
- **Owner:** LG Chemical.
- **Location:** Yeosu City (formerly Yeochon), South Korea.

- **Process:** PFAS membrane.
- **Year Opened:** 1962.
- **Capacities** (tons per year):
 - 454,000 tons of chlorine, 575,000 tons of EDC, and 750,000 tons of VCM and PVC (2012).⁷¹⁸
 - The EDC plant receives ethylene from LG's on-site Yeosu naphtha cracker. This cracker expanded in 2010. It can produce 1.15 million tons of ethylene per year. In 2018, LG announced that it will invest over \$2.4 billion to expand cracker and polyolefin capacity.⁷¹⁹ LG, like other cracker operators in Asia, purchases naphtha from the global market.⁷²⁰
- **Capacity Rankings:** 17th largest chlor-alkali plant in Asia. 30th largest chlor-alkali plant in the world. 5th largest PVC plant in Asia. 10th largest PVC plant in the world.
- **Technology Conversions:**
 - In 1976, the first PVC paste-resin plant was opened; it was expanded in 1982.⁷²¹
 - In 1997, LG complete expansion of the chlor-alkali, EDC, and VCM operations.
 - In 2012, LG added 245,000 tons of chlorine capacity and 300,000 tons of EDC capacity. It expanded the EDC plant to 575,000 tons per year.⁷²²
- **Markets:**
 - LG exports PVC resins made in Yeosu, including to India.⁷²³
 - LG is a vertically integrated producer of PVC products. In Cheongju, South Korea, its LG Hausys subsidiary produces PVC profiles, windows, tile flooring, carpet, wood polymer composites, and coated fabric.⁷²⁴
 - The USA is a major importer of PVC products made by LG Hausys in South Korea.⁷²⁵

INVENTORY CODE: ASIAKOR04

- **Plant Name:** *Lotte Fine Chemical*
- **Owner:** Lotte Group. Originally Korea Fertilizer Industries, which was founded in 1964 and nationalized in 1967. It was later privatized, then became Samsung Fine Chemical, part of the Samsung Group, in 1994. Samsung sold the plant to the Lotte Group in 2016.⁷²⁶
- **Location:** Ulsan, South Korea.
- **Process:** PFAS membrane.
- **Year Opened:** 1994.⁷²⁷
- **Capacities** (tons per year): 318,000 tons of chlorine (2015).⁷²⁸
- **Capacity Rankings:** 31st largest chlor-alkali plant in Asia. 60th largest chlor-alkali plant in the world.
- **Technology Conversions:**
 - Korea Fertilizer industries added a methyl chloride plant to the Ulsan complex in 1991.⁷²⁹
 - Samsung added a chlor-alkali plant in 1994.
 - In 1998, Samsung installed a waste incinerator.⁷³⁰
 - In 1999, it built an epichlorohydrin plant.⁷³¹
- **Markets:**
 - The plant produces, for domestic and global customers, numerous chemicals including epichlorohydrin, chloroform, tetramethylammonium chloride (TMAC), methylene chloride, and methyl chloride.⁷³²
 - The plant's epichlorohydrin production capacity is 120,000 tons per year.⁷³³
 - TMAC, according to Lotte, is "a core chemical material used in semiconductors for electronic devices and LCD circuit boards for TVs, smartphones and similar devices. Fueled by the continuing growth of semiconductor, LCD, OLED and other display-related industries, the product has maintained a solid growth trend, and the area of applications has been broader."⁷³⁴

COUNTRY: TAIWAN

According to a 2016 report published by the Federation of Indian Chambers of Commerce and Industry (FICCI), Taiwan has the world's highest proportion of excess PVC capacity. It estimated that Taiwan's 1,930,000 tons of PVC capacity exceeded domestic demand (700,000 tons) by 1,230,000 tons per year.⁷³⁵ FICCI reported that 43% of Taiwan's 751,000 tons of exports are shipped to India.⁷³⁶

INVENTORY CODE: ASIATW01

- **Plant Name:** *Jen-Wu (or Kaohsiung) Plant*
- **Owner:** Formosa Plastics Corporation.
- **Location:** Jen-Wu (or Jenwu or Renwu) District, Kaohsiung City, Taiwan.
- **Process:**
 - Chlor-alkali: PFAS membrane. Converted from mercury cell in 1988.
 - PVC: Ethylene. Formosa phased-out acetylene process in 1977.⁷³⁷
- **Year Opened:** 1957
- **Capacities** (tons per year):
 - 400,000 tons of chlorine (2007)
 - 540,000 tons of VCM (2015). Formosa imports EDC from its US Gulf Coast plants.
 - 550,000 tons of PVC (2007).⁷³⁸
- **Capacity Rankings:** 22nd largest chlor-alkali plant in Asia. 40th largest chlor-alkali plant in the world. 12th largest PVC plant in Asia. 21st largest PVC plant in the world.
- **Technology Conversions:**
 - Formosa Plastics Corporation started producing plastics in 1957, with the opening of a PVC plant in Kaohsiung City with a capacity of just four tons per day, the world's smallest. It delivered PVC resins to outgoing ships by ox-towed carts.⁷³⁹
 - In 1972, a larger PVC plant opened with a 28,800-ton-per-year capacity.⁷⁴⁰
 - In 1975, a chlor-alkali plant opened using mercury cell technology, with a 175,000- ton-per-year capacity. It also began producing VCM, with a 240,000- ton-per-year capacity.⁷⁴¹
 - In 1988 the Jenwu (Renwu) plant converted to ion-exchange membrane technology.⁷⁴²
- **Markets:**
 - The plant's chlorinated products include VCM, PVC resin, chloroethylene, chloromethanes, and hydrochlorofluorocarbons (HCFCs).⁷⁴³
 - According to ICIS, "Most of the VCM produced by FPC is for captive uses in producing polyvinyl chloride (PVC)."⁷⁴⁴
 - It supplies PVC resins to the global market, mostly India and China.⁷⁴⁵
 - Formosa's plants in Kaohsiung and Mialiao, Taiwan, supply VCM to the company's 300,000-ton-per-year PVC plant in Ningbo, Zhejiang Province, China.⁷⁴⁶
 - In 2010, after authorities discovered VCM pollution in groundwater, manufacturers feared the plant would be shut down, and thus increase PVC prices in India. "FPC is a major PVC exporter to India. A shutdown of its Jenwu plant would have definitely sent PVC prices rocketing," an Indian PVC buyer told ICIS.⁷⁴⁷ Hundreds of villagers marched on the site and demanded a shutdown of the plant.⁷⁴⁸

INVENTORY CODE: ASIATW02

- **Plant Name:** *Mailiao Chlor-Alkali Plant*

- **Owner:** Formosa Plastics Co.
- **Location:** Mailiao, Taiwan.
- **Process:** PFAS membrane.
- **Year Opened:** 1998 (PVC plant) and 1999 (chlor-alkali and VCM plant).⁷⁴⁹
- **Capacities** (tons per year):
 - 1,209,000 tons of chlorine (2014).⁷⁵⁰
 - 1,650,000 tons of EDC.
 - 800,000 tons of VCM (2018).⁷⁵¹
 - 500,000 tons of PVC (2011).⁷⁵²
- **Capacity Rankings:** Largest chlor-alkali plant in Asia. 4th largest chlor-alkali plant in the world. 11th largest PVC plant in Asia. 26th largest PVC plant in the world.
- **Technology Conversions:**
 - The Mailiao PVC plant opened in 1998 with a capacity of 420,000 tons.⁷⁵³
 - Added chlor-alkali plant (300,000-ton chlorine production capacity) and VCM plant (600,000 tons per year) in 1999.⁷⁵⁴
 - Expanded from 600,000 tons to 750,000 tons of chlorine production capacity in 2003.
- **Markets:**
 - In addition to the VCM and PVC products, Formosa Plastics produces 100,000 tons of epichlorohydrin in Mailiao. One of Formosa's subsidiaries, Nan Ya Plastics Corp., produces 160,000 tons of epoxy resins. Another subsidiary, called Formosa Chemicals and Fibre Corp., produces 200,000 tons of polycarbonate resins, which are also dependent upon chlorine feedstocks.⁷⁵⁵
 - Formosa's Mailiao plant exports PVC resin to the USA and other countries.⁷⁵⁶

INVENTORY CODE: ASIATW03

- **Plant Name:** *TCI*
- **Owner:** Taiwan Chlorine Industries (TCI), a joint venture between Westlake Chemical (60%) and PPG (40%). PPG acquired its share from China Petrochemical Development Corporation (CPDC of Taiwan) in 2016.⁷⁵⁷
- **Location:** Lin Hai industrial area, Kaohsiung City, Taiwan.
- **Process:** PFAS membrane.⁷⁵⁸ Replaced CPDC mercury cell plant in 1988.
- **Year Opened:** 1988⁷⁵⁹
- **Capacities** (tons per year): 120,000 tons of chlorine.⁷⁶⁰
- **Capacity Rankings:** Not among largest 33 chlor-alkali plants in Asia.
- **Technology Conversions:**
 - In 1988, the plant converted from mercury cell to membrane technology.⁷⁶¹ The new plant opened with the capacity to produce 103,000 tons of chlorine per year.⁷⁶²
- **Markets:**
 - TCI's only chlorinated products are chlorine and hydrochloric acid (hydrogen chloride). It also provides sodium hydroxide and liquid caustic soda to China Petrochemical Development Corporation.⁷⁶³
 - It markets these products "within the country... for the development of chlorine derivatives with high added-value."⁷⁶⁴

COUNTRY: THAILAND

INVENTORY CODE: ASIATH01

- **Plant Name:** *ACTH Rayong Plant*; previously called *Thasco (Thailand Asahi Chemical Company)*
- **Owner:** AGC Group (formerly named Asahi Glass) through its subsidiary, AGC Chemicals Thailand (ACTH), since 2007.
- **Location:** Map Ta Phut (also translated as Mab Ta Phut), Rayong, Thailand.⁷⁶⁵
- **Process:** PFAS membrane.⁷⁶⁶
- **Year Opened:** 1997.⁷⁶⁷
- **Capacities (tons per year):** 146,000 tons (2003).⁷⁶⁸
- **Capacity Rankings:** Not among largest 33 chlor-alkali plants in Asia.
- **Technology Conversions:**
 - In 1997, Asahi Glass provided membrane technology with the capacity to produce 115,000 tons of caustic soda per year.⁷⁶⁹
 - In 1999, the plant added 40,000 tons of caustic soda capacity.⁷⁷⁰
 - In October 2018, AGC announced plans to build a pipeline between its two chlor-alkali plants (ACTH and Vinythai) in Map Ta Phut.⁷⁷¹
- **Markets:**
 - Chlorine from the plant is sold to nearby chemical producers in Map Ta Phut.
 - Customers include polycarbonate producers (Bayer [now Covestro] and Thai Polycarbonate).⁷⁷²
 - PVC producer Thai Plastic and Chemicals Public Company Limited (TPC, 450,000-ton-per-year capacity) is another major customer.⁷⁷³ Asahi sold TPC to the CPB Equity Company and the Siam Cement Public Company, Limited, in 2004.⁷⁷⁴ The PVC plant opened in 1990.⁷⁷⁵

INVENTORY CODE: ASIATH02

- **Plant Name:** *Vinythai*
- **Owner:** AGC Group (formerly named Asahi Glass Co., Japan), through its Vinythai Public Company Ltd. subsidiary. AGC holds a 58.8% share of Vinythai; PTT Global Chemical of Thailand owns 25%. AGC acquired its stake from Solvay in 2017.⁷⁷⁶
- **Location:** Map Ta Phut, Rayong, Thailand.
- **Process:** PFAS membrane.
- **Year Opened:** 1992.⁷⁷⁷
- **Capacities (tons per year):**
 - 336,000 tons of chlorine, 320,000 tons of EDC, 560,000 tons of VCM, and 280,000 tons of PVC (2016).⁷⁷⁸
 - Vinythai imports EDC and VCM as needed.⁷⁷⁹
 - It receives ethylene from Thai Olefins.⁷⁸⁰
- **Capacity Rankings:** 29th largest chlor-alkali plant in Asia. 57th largest chlor-alkali plant in the world. 40th largest PVC plant in Asia. 69th largest PVC plant in the world.
- **Technology Conversions:**
 - Solvay opened the PVC plant in 1992, using VCM imported from the global market.⁷⁸¹
 - In April 1996, Solvay added chlor-alkali and VCM production. It used ethylene from the new NCP 2 cracker, and salt from a joint venture - Pimai Salt Company - that it shared with two Thai companies.⁷⁸²

- In 2012, the company began producing epichlorohydrin in the Vinythai Map Ta Phut complex.⁷⁸³
- In October 2018, AGC announced plans to increase PVC production at the Vinythai plant to 860,000 tons per year, VCM to 830,000 tons, and chlorine to 536,000 tons. It also plans to connect its two chlor-alkali plants (ACTH and Vinythai) in Map Ta Phut by pipeline.⁷⁸⁴
- **Markets:**
 - Vinythai markets VCM and PVC resins, the latter under the trademark “SIAMVIC®.”⁷⁸⁵ In 2017, it exported over 1,400 tons of PVC resins to the USA.⁷⁸⁶
 - A Vinythai division, Advanced Biochemical (Thailand) Co. Ltd, makes epichlorohydrin on-site. ABT markets its Epicerol® epichlorohydrin as “bio-based.”⁷⁸⁷

COUNTRY: TURKEY

INVENTORY CODE: ASIATUR01

- **Plant Name:** *Petkim Aliaga*
- **Owner:** Petkim Petrokimya Holding AS/ SOCAR Turkey Enerji A.Ş.
- **Location:** Aliaga, Izmir Province.
- **Process:** PFAS membrane.⁷⁸⁸ Converted from mercury cell in 2000.⁷⁸⁹
- **Year Opened:** 1985.⁷⁹⁰
- **Capacities** (tons per year):
 - 100,000 tons of chlorine.
 - 152,000 tons of VCM.
 - 150,000 tons of PVC.⁷⁹¹
 - This complex includes an ethane cracker with the capacity to produce 585,000 tons of ethylene per year.⁷⁹²
- **Capacity Rankings:** Not among the largest chlor-alkali or PVC plants in Asia.
- **Technology Conversions:**
 - The chlor-alkali plant opened in 1985 using De Nora mercury cell technology.
 - In 1995, the company added ethylene, VCM, and PVC production units; by 2003, production capacity had reached 520,000 tons of ethylene, 152,000 tons of VCM, and 150,000 tons of PVC.⁷⁹³
 - In 2000, all mercury cells in the chlor-alkali plant were replaced with PFAS membranes.⁷⁹⁴
- **Markets:**
 - Markets for the plant’s PVC include “pipe, window shades, cable, bottles, building materials, packaging film, floor tiles, serum bags,” according to the company’s 4Q 2017 financial report.⁷⁹⁵



THE APPENDICES

APPENDIX A

GLOBAL INVENTORY OF CHLOR-ALKALI PLANTS

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
1	AMUSA16	Olin	Freeport, Texas, USA	3,030	1450	1580		Chlorinated solvents and epoxy resins (on-site); PVC (Shintech, adjacent); Isocyanates (Dow, adjacent).
2	EURDE09	DowDuPont	Stade, Lower Saxony, Germany	1,580	550	1030		PVC (through EDC sales); polycarbonates, chlorinated polyethylene, epoxies, perchloroethylene, trichloroethylene, and carbon tetrachloride (on-site).
3	AMUSA22	Westlake	Lake Charles / Westlake, Louisiana, USA	1,270	1270			PVC (off-site: Westlake, Aberdeen, Mississippi, and Certainteed, Lake Charles).
4	ASIATW02	Formosa Plastics	Mailiao, Taiwan	1,209	1209			PVC (on-site and through VCM sales), epichlorohydrin (on-site).
5	AMUSA19	Shin-Etsu	Plaquemine, Louisiana, USA	1,055	1055			PVC (on-site and Addis, Louisiana).
6	ASIAJPN08	Tosoh Corp. (formerly Toyo Soda)	Shin-Nanyo, Yamaguchi, Japan	1,022	1022			PVC (on-site and overseas through VCM exports).
7	ASIACHN26	Xinjiang Zhongtai Chemical	Urumqi, Xinjiang, China	1,000	1000			Merchant PVC (on-site).
8	AMUSA18	Olin	Plaquemine, Louisiana, USA	971		971		Carbon tetrachloride, epoxies, perchloroethylene (on-site); Merchant EDC; PVC (Shintech, off-site).
9 (tie)	AMUSA03	Formosa Plastics	Point Comfort, Texas, USA	910	910			PVC (on-site).
9 (tie)	ASIACHN24	Tianye Group	Shihezi Development Zone, Xinjiang, China	910	910			PVC (on-site).
11	ASIACHN15	Shaanxi Coal and Chemical Industry Group	Shenmu County, Xinjiang, China	800	800			PVC (on-site).
12	ASIAKOR02	Hanwha Chemical	Yeosu City, South Korea	782	782			Epichlorohydrin, isocyanates and PVC (on-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
13	AMUSA14	Olin	McIntosh, Alabama, USA	685	320	365		PVC (off-site).
14	ASIACHN11	SP Chemical Holdings	Taixing, Jiangsu, China	660	660			On-site: chlorobenzene, nitrochlorobenzene. Off-site, nearby: PVC (Taiwan UPC Group); epichlorohydrin (Solvay), monochloroacetic acid (AkzoNobel).
15 (tie)	AMUSA10	Occidental Petroleum	Hahnville/Taft, Louisiana, USA	655	217	438		PVC (off-site).
15 (tie)	ASIACHN20	Government of China	Caojing, Shanghai, China	655	655			PVC (on-site). Off-site (in chemical park): isocyanates (Shanghai Lianheng Isocyanate Co.); bisphenol A (Mitsui/Sinopec); polycarbonate and isocyanates (Covestro).
17	ASIASAU01	Government of Saudi Arabia via Saudi Basic Industries Corp. (SABIC)	Jubail Industrial City, Saudi Arabia	645	303	342		PVC (on-site and through EDC and VCM exports).
18	EURNE01	AkzoNobel	Botlek-Rotterdam, Netherlands	637	637			PVC, isocyanates, epichlorohydrin (other plants in complex).
19	ASIAIDN01	AGC	Cilegon, Banten, Indonesia	636	636			PVC (on-site and in Vietnam).
20	ASIAIRN01	Government of Iran	Special Economic Zone, Bandar Emam, Iran	585	585			PVC (on-site and nearby Abadan Petrochemical Company).
21	AMUSA07	Occidental Petroleum	Gregory, Texas, USA	570		570		PVC (Mexichem plants in Mexico, Colombia, and USA).
22	AMUSA06	Occidental Petroleum	La Porte, Texas, USA	525		525		PVC (OxyChem, Pasadena, Texas).
23	ASIACHN19	Xinfa Group	Liaocheng, Shandong, China	510	510			PVC (on-site).
24	ASIACHN09	Inner Mongolia Junzheng Energy & Chemical Group	Wuhai City, Inner Mongolia, China	500	500			PVC (on-site).
25	EURDE05	Covestro	Dormagen, North Rhine-Westphalia, Germany	480	480			Isocyanates (on-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
26	EURBE02	Ineos	Port of Antwerp, Belgium	458	368		90	PVC (on-site and in In-ovyn's plant in Jemeppe).
27 (tie)	ASIACHN02	Tangshan Sanyou Chlor-alkali Co.	Tangshan, Hebei, China	455	455			PVC (on-site).
27 (tie)	ASIACHN14	Ningxia Jinyuyuan Chemical Group	Wuzhong City, Ningxia, China	455	455			PVC (on-site).
27 (tie)	ASIACHN27	Wanhua Chemical Group Co. Ltd.	Ningbo, Zhejiang, China	455	455			Isocyanates (on-site).
27 (tie)	ASIAKOR03	LG Chemical	Yeosu City, South Korea	455	455			PVC (on-site).
31	ASIAJPN07	Tokuyama Corp.	Tokuyama, Yamaguchi, Japan	445	445			PVC (off-site in nearby plant owned by subsidiary).
32	AMUSA08	Occidental Petroleum	Geismar, Louisiana, USA	438	438			Blowing agents, carbon tetrachloride, chlorinated solvents (on-site); PVC (off-site).
33	ASIACHN22	Yibin Tianyuan Group	Yibin, Sichuan, China	437	291	146		PVC, tetrachlorethylene, liquid chlorine, hydrochloric acid (on-site).
34	EURUK01	International Chemical Investors Group	Runcorn, Cheshire, UK	430	430			Carbon tetrachloride, chloroform, methylene chloride, and perchloroethylene (on-site); merchant chlorine.
35	AMUSA20	Westlake	Plaquemine, Louisiana, USA	426		426		PVC (on-site).
36	AMBRA05	DowDuPont Inc.	Candeias, Bahia, Brazil	415		415		Propylene dichloride for isocyanates used in polyurethane.
37	ASIACHN18	Sinopec	Zibo, Shandong, China	410	180	230		PVC, epichlorohydrin, epoxy resins (on-site).
38	AMBRA01	Braskem	Maceió, Alagoas, Brazil	409	409			PVC (on-site).
39 (tie)	ASIACHN04	ChemChina	Xinyang, Henan, China	400	318	82		PVC, barium chloride (on-site).
39 (tie)	ASIATW01	Formosa Plastics	Kaohsiung City, Taiwan	400	400			PVC, chloroethylene, chloromethanes, and HCFCs (on-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
41	EURDE06	Covestro	Leverkusen, North Rhine-Westphalia, Germany	390	390			Isocyanates (on-site). Also supplies chlorine for nearby producers of benzyl chloride, chlorobenzene, chlorotoluene mixtures, methyl chloride, chloroaniline, chloronitrobenzene, dichlorobenzene, and titanium dioxide.
42 (tie)	EURDE03	BASF	Ludwigshafen, Rheinland-Palantine, Germany	385	215		170	Isocyanates, trichlorethylene, alcoholates (on-site).
42 (tie)	EURBE03	International Chemical Investors Group	Tessenderlo, Limburg, Belgium	365	365			PVC (through VCM supplied to subsidiaries in France and the Netherlands).
44 (tie)	ASIACHN07	Elion Resources Group	Erdos City, Inner Mongolia, China	364	364			PVC (on-site).
44 (tie)	ASIACHN16	ChemChina	Dezhou City, Shandong, China	364	364			PVC, hydrochloric acid, merchant chlorine, trichloroethylene (on-site).
44 (tie)	ASIACHN17	Yangmei Group	Tancheng, Shandong, China	364	364			PVC, phosphorus trichloride on-site).
44 (tie)	ASIAJPN03	Shin-Etsu	Kashima, Ibaraki, Japan	364	364			PVC (on-site).
48 (tie)	AMUSA02	Covestro	Baytown, Texas, USA	363	363			Isocyanates and polycarbonate (on-site).
48 (tie)	EURFR03	Kem One	Lavéra, France	363	363			PVC (through VCM supplies to related plants in France and Spain); ferric chloride (on-site).
50	EURFR01	Ineos	Tavaux, France	360	360			PVC (on-site and through EDC sales); epichlorohydrin, caustic soda, chloromethanes, and allyl chloride (on-site).
51	AMBRA03	Unipar Carbocloro	Cubatão, São Paulo, Brazil	355	248		107	EDC for nearby PVC plant (Santo Andre).
52	ASIACHN13	Hangin Technology Co.	Huludao, Liaoning, China	354	354			PVC, propylene oxide, chlorobenzene (on-site), phosgene (off-site, Liaoning Hongshan).
53	AMUSA09	Occidental Petroleum	Convent, Louisiana, USA	353		353		EDC sold to off-site PVC manufacturers.

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
54	EURFR02	Kem One	Fos-sur-Mer, Bouches-du-Rhône, France	340	340			PVC (on-site and nearby related plants).
55 (tie)	AMUSA04	Occidental Petroleum	Niagara Falls, New York, USA	336		336		Merchant chlorine.
55 (tie)	ASIAQAT01	Government of Qatar	Mesaieed Industrial City, Qatar	336	336			PVC (on-site and through merchant VCM exports).
55 (tie)	ASIATH02	AGC Group	Map Tha Phut, Rayong, Thailand	336	336			PVC (on-site and through VCM sales); epichlorohydrin (on-site).
58	EURHU01	Wanhua Industrial Group	Kazincbarcika, Borsod-Abaúj-Zemplén, Hungary	323	192		131	PVC and isocyanates (on-site).
59 (tie)	ASIAJPN02	AGC	Kashima, Ibaraki, Japan	318	318			Propylene oxide; epichlorohydrin.
59 (tie)	ASIAKOR04	Lotte Group	Ulsan, South Korea	318	318			Epichlorohydrin, chloroform, tetramethylammonium chloride, methylene chloride, and methyl chloride (on-site).
61	AMUSA21	Westlake Chemical Corp	Geismar, Louisiana, USA	317	317			PVC (on-site).
62 (tie)	ASIACHN03	ChemChina	Ang'angxi Industrial Park of the Harbin-Daqing-Qiqihar Industrial Corridor, Heilongjiang, China	300	300			PVC (on-site).
62 (tie)	ASIAIDN02	P.T. Sulfindo Adiusaha	Merak, West Java, Indonesia	300	300			PVC (on-site and overseas through EDC exports).
	AMUSA05	Occidental Petroleum	Deer Park, Texas, USA	295		295		PVC, hydrogen cyanide, chlorinated paraffins (on-site).
	ASIACHN12	Jiangsu Meilan Chemical	Taizhou, Jiangsu, China	293	232	61		PVC, methylene chloride, HCFC-22, carbon tetrachloride, chloroform, chlorinated pesticides (on-site).
	ASIACHN06	East Hope Group	Baotou, Inner Mongolia, China	291	291			PVC (on-site).
	ASIACHN08	Inner Mongolia Yidong Resources Group	Ulan Oab City, Inner Mongolia, China	291	291			PVC, trichloroethylene, calcium chloride, magnesium chloride (on-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
	ASIACHN01	Government of China	Cangzhou City, Anhui, China	290	290			PVC (on-site).
	ASIAIND05	DCM Shiram Consolidated	Jhagadia, Bharuch District, Gujarat, India	284	284			Aluminum chloride (on-site); Merchant chlorine.
	EURDE07	Covestro	Uerdingen-Krefeld, North Rhine- Westphalia, Germany	280	280			Isocyanates and polycarbonate (on-site).
	EURNO01	Ineos	Stathelle, Norway	280	280			PVC (nearby related plant and through exports).
	ASIACHN05	China National Salt Industry Corporation	Alxa Left Banner, Inner Mongolia, China	272	272			PVC, perchlorate, tetrachloroethylene (on-site).
	ASIAJPN05	Kaneka	Takasago, Hyōgo, Japan	270	270			PVC (on-site and off-site through VCM sales).
	ASIACHN10	Hongda Xingye	Wuhai City, Inner Mongolia, China	267	267			PVC (on-site).
	EURDE12	Mexichem	Marl, North Rhine-Westphalia, Germany	265	265			PVC (on-site).
	AMMEX01	Mexichem and PEMEX	Coatzacoalcos, Veracruz, Mexico	260		260		PVC (off-site).
	AFEGY03	Sanmar Holdings	Port Said, Egypt	250	250			PVC (on-site and Tamil Nadu, India).
	AMUSA23	Westlake Chemical Corp	Calvert City, Kentucky, USA	250	250			PVC (on-site).
	EURDE01	AkzoNobel	Frankfurt, Germany	250	250			Merchant chlorine; isocyanates (on-site).
	EURDE08	DowDuPont	Schkopau, Saxony-Anhalt, Germany	250	250			Merchant chlorine.
	EURDE14	Westlake	Hürth-Knapsack, North Rhine-Westphalia, Germany	250	250			PVC (on-site and in related plants in Germany).
	AMUSA11	Occidental Petroleum	Wichita, Kansas, USA	248	83	165		Carbon tetrachloride, chlorinated solvents.
	AMUSA17	Olin	St. Gabriel, Louisiana, USA	246	246			Isocyanates and PVC (off-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

				<i>Technology, Estimated Capacity (1000 tpy, est.)</i>				
RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	TOTAL	PFAS	ASBES	MERC	CHLORINE USES
	ASIAIND02	Aditya Birla Chemicals	Nagda, Madhya Pradesh, India	245	245			Merchant chlorine, poly aluminum chloride, chlori- nated paraffins (on-site); benzyl chloride, benzotri- chloride, thionyl chloride, sulfuryl chloride, and sulfur dichloride (off-site, Gwalior in Nagda).
	AMUSA15	Olin	Niagara Falls, New York, USA	240	240			Merchant chlorine.
	AMCAN01	Chemtrade Logistics Income Fund	North Vancouver, B.C., Canada	231	231			Merchant chlorine.
	AMUSA24	Westlake (ex PPG, Axiall)	Natrium (New Martinsville), West Virginia, USA	227	227			Merchant chlorine.
	ASIASAU02	50:50 joint ven- ture between Sahara Petro- chemicals and Saudi Arabian Mining Co.	Jubail Industrial City, Saudi Arabia	227	227			PVC (through EDC sales).
	EURDE11	Ineos	Rheinberg, North Rhine-Westphalia, Germany	220	220			PVC, epichlorohydrin, allyl chloride (on-site).
	EURRU05	Nikochem	Volgograd, Russia	220		95	125	PVC, HCFCs, trichloroeth- ylene (on-site).
	ASIACHN23	LG Chem	Tanggu, Tianjin, China	218	218			PVC (nearby, being moved) .
	EURRU04	JSC Bash- kirskaia Khimiya	Steritamak, Bashkortostan, Russia	218		84	134	PVC (on-site and through EDC exports).
	EURPO02	PKN Orlen	Wloclawek, Wlo- clawskie, Poland	214	214			PVC (on-site).
	EURDE04	Covestro	Brunsbüttel, Germany	210	210			Isocyanates (on-site).
	EURRU03	Sibur and Solvay (JV)	Kstovo, Nizhny Novgorod, Russia	205	205			PVC (on-site).
	AMUSA13	Olin	Charleston, Tennessee, USA	200	200			Merchant chlorine.
	ASIACHN21	Sichuan Jinlu Group	Deyang City, Sichuan, China	200	200			PVC (on-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
	ASIACHN25	Xinjiang Zhongtai Chemical	Toksun County, Xinjiang, China	200	200			Merchant PVC (on-site).
	ASIAIND07	Reliance Industries / Reliance Petrochemicals Ltd.	Hazira, Gujarat, India	198	198			PVC (on-site).
	ASIAKOR01	Unid Co.	Ulsan, South Korea	185	185			PVC (on-site).
	ASIAJPN01	AGC	Ichihara City, Chiba, Japan	182	182			Carbon tetrachloride, chloroform, and methylene chloride (on-site).
	EURRU01	JSC Halo-Polymer	Kirovo-Chepetsk, Kirov region, Russia	182			182	Chloroform, HCFCs (on-site).
	EURDE13	Westlake	Gendorf, Burgkirchen an der Alz, Germany	180	180			PVC (on-site).
	EURUR01	Xedrian Holding	Kalush City, Ivano-Frankivsk, Ukraine	180	180			PVC (on-site).
	AMCAN03	Olin	Bécancour, Quebec, Canada	175	65	110		Merchant chlorine.
	EURBE01	Ineos	Jemeppe-sur-Sambre, Belgium	174	174			PVC (on-site and through EDC sales).
	EURFR04	PTT Global Chemical and Perstorp Group (JV)	Le Pont-de-Claix, France	171	171			Isocyanates (on-site) and merchant chlorine.
	AMUSA12	Occidental Petroleum	New Johnsonville, Tenn, USA	165	165			Titanium dioxide (DuPont, adjacent).
	AMARG01	Unipar Carbocloro	Bahia Blanca, Buenos Aires, Argentina	163			163	PVC (on-site).
	AMBRA04	Unipar Carbocloro	Santo André, São Paulo, Brazil	155	155			PVC (on-site).
	ASIAIND01	Aditya Birla Chemicals	Vilayat, Gujarat, India	150	150			Epoxy resins (on-site).
	EURIT01	Ineos	Rosignano Solvay, Tuscany, Italy	150	150			Chloromethanes, including methylene chloride (on-site).
	EURPO01	PCC Rokita	Brzeg Dolny, Poland	150	150			Hydrochloric acid, chlorobenzene, and trichloroethylene.

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
	ASIATH01	AGC Group	Map Tha Phut, Rayong, Thailand	146	146			Local chlorine consumers: polycarbonate (Covestro and Thai Polycarbonate), PVC (Thai Plastic and Chemicals).
	ASIAIND06	Reliance Industries Ltd.	Dahej, Bharuch District, Gujarat, India	141	141			PVC (on-site).
	ASIAJPN04	Asahi Kasei	Nobeoka, Miyazaki, Japan	141	141			Polyvinylidene chloride (PVDC), poly aluminum chloride, isocyanates.
	EURDE10	Evoniik	Lülsdorf, North Rhine-Westphalia, Germany	137			137	Alcoholates (on-site); Cyanuric chloride (nearby related plant).
	EURRU06	Renova Group	Sayansk city, Irkutsk region, Russia	135	135			PVC (on-site).
	ASIAJPN06	Osaka Soda	Mizushima, Okayama, Japan	126	126			Epichlorohydrin.
	EURNE02	AkzoNobel	Delfzijl, Netherlands	121	121			Local producers of ethylene amine, chlorinated PVC, and monochloroacetic acid.
	AMVEN01	Pequiven	Los Puertos de Altigracia, Zulia, Venezuela	120	120			PVC (on-site); water sanitation.
	ASIATW03	Taiwan Chlorine Industry (JV between Westlake and PPG)	Kaohsiung City, Taiwan	120	120			Merchant chlorine.
	EURES01	Ercros Industria	Vila-seca, Tarragona, Spain	120	120			PVC (on-site).
	EURSV01	Ineos	Stenungsund, Västra Götaland County, Sweden	120	120			PVC (on-site and through EDC sales).
	ASIAIND03	Aditya Birla Chemicals (formerly Kanoria Chemicals & Industries)	Renukoot, Uttar Pradesh, India	117	117			Bleaching powder, chlorinated paraffins, poly aluminum chloride, and aluminum chloride (on-site).
	ASIAJPN09	Tosoh Corp. (formerly Toyo Soda)	Yokkaichi, Mie, Japan	115	115			PVC (on-site).

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	Technology, Estimated Capacity (1000 tpy, est.)				CHLORINE USES
				TOTAL	PFAS	ASBES	MERC	
	AFSAF02	Sasol	Midland, Sasolburg, South Africa	112	20	92		PVC (on-site).
	AFEGY02	Egyptian Petrochemicals Company	Alexandria, Egypt	109	109			PVC (on-site).
	AMPER01	Quimpac	Callao, Callao, Peru	107	58		49	Merchant chlorine.
	EURRO01	Oltchim S.A.	Râmnicu Vâlcea, Romania	105	105			Propylene oxide, sodium hypochlorite, hydrochloric acid and merchant chlorine.
	ASIAIND04	DCM Shiram Consolidated	Kota, Rajasthan, India	103	103			PVC (on-site).
	AFSAF01	SynChem	Cloorkop, Gauteng, South Africa	101	101			Merchant chlorine.
	ASIATUR01	Petkim Petrokimya Holding AS/ SOCAR Turkey Enerji A.Ş.	Aliaga, Izmir, Turkey	100	100			PVC (on-site).
	AMMEX02	Cydsa	Allende, Veracruz, Mexico	98			98	Merchant chlorine.
	ASIAPAK01	Engro Corporation	Port Qasim, Baluchistan, Pakistan	96	96			PVC (on-site).
	EURRU02	EuroChem Group	Novomoskovsk, Tula region, Russia	91	91			PVC, sodium hypochlorite, hydrochloric acid, calcium chloride (on-site).
	AMCAN02	Westlake Chemical	Beauharnois, Quebec, Canada	88	88			Merchant chlorine.
	EURDE02	AkzoNobel	Ibbenbüren, North Rhine-Westphalia, Germany	75	75			Chloromethanes (on-site).
	AMBRA02	Braskem	Camaçari, Bahia, Brazil	70			70	PVC (on-site).
	AFEGY01	Misr Chemical Industries	Alexandria, Egypt	68	68			Merchant chlorine.
	AFMOR01	Ynna Holding	Mohammedia, Morocco	68	68			PVC (on-site).
	AMMEX03	Cydsa	Monterrey, Nuevo Leon, Mexico	60	60			Merchant chlorine.

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms. Merc = Mercury cells.

Continued on next page

				<i>Technology, Estimated Capacity (1000 tpy, est.)</i>				
RANK (SIZE)	INVENTORY CODE	PARENT COMPANY	LOCATION	TOTAL	PFAS	ASBES	MERC	CHLORINE USES
	AMUSA01	ASHTA	Ashtabula, Ohio, USA	47			47	Titanium dioxide (Cristal, adjacent).
	AMMEX05	Mexichem	El Salto, Jalisco, Mexico	40		40		Merchant chlorine.
	AMMEX04	Cydsa	Ecatepec de Mo- relos, Estado de México, Mexico	39	39			Merchant chlorine.
	AMPER02	Quimpac	Paramonga, Lima, Peru	27			27	Merchant chlorine.
				51,218	40677	9011	1530	
			No. of Plants	146	127	24	14	
			Shares of capacity		79%	18%	3%	

Notes

PFAS = Per- and polyfluoroalkyl substances that coat membranes or diaphragms used in chlor-alkali production.

Asbes = Asbestos diaphragms.

Merc = Mercury cells.

Rankings are not included for chlor-alkali plants under 300,000 tons per year capacity because this Inventory does not include some operating plants with capacities in this range.

This Phase 2 report contains additional details about chlor-alkali plants in Asia. Details about plants in the rest of the world are available in the Phase 1 report. These reports provide sources for data in this Appendix.

Phase 1 and Phase 2 reports, and related spreadsheets and maps, are available on the homepage for HBN's Chlorine and Building Materials project, <https://healthybuilding.net/reports/20-chlorine-building-materials-project-phase-2-asia-including-worldwide-findings>.

APPENDIX B

GLOBAL INVENTORY OF PVC PLANTS

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/ YR.)	CHLORINE SOURCE	CHLORINE SOURCE TECHNOLOGIES	VCM SOURCE TECHNOLOGY
1	Xinjiang Zhong-tai Chemical	Urumqi, Xinjiang, China	1,530	ASIACHN26 (on-site)	PFAS PFAS membrane	Acetylene
2	Shin-Etsu	Freeport, Texas, USA	1,450	from AMUSA16	PFAS membrane	Ethylene
3	Tianye Group	Shihezi Development Zone, Xinjiang, China	1,200	ASIACHN24 (on-site)	PFAS membrane	Acetylene
4	Shaanxi Coal and Chemical Industry Group	Shenmu County, Shaanxi, China	1,100	ASIACHN15 (on-site)	PFAS membrane	Acetylene
5	Occidental	Pasadena, Texas, USA	898	from AMUSA06 and AMUSA14	Asbestos diaphragm and PFAS membrane	Ethylene
6	Mexichem	Altamira, Tamaulipas, Mexico	876	from AMUSA07 and AMMEX01	Asbestos diaphragm	Ethylene
7	Westlake	Plaquemine, Louisiana, USA	861	AMUSA20 (on-site)	Asbestos diaphragm	Ethylene
8	Formosa	Point Comfort, Texas, USA	816	AMUSA03 (on-site)	PFAS membrane	Ethylene
9	Inner Mongo- lia Junzheng Energy	Wuhai City, Inner Mon- golia, China	800	ASIACHN09 (on-site)	PFAS membrane	Acetylene
10	LG Chemical	Yeosu City, South Korea	750	ASIAKOR03 (on-site)	PFAS membrane	Ethylene
11	Government of China	Caojing, Shanghai, China	720	ASIACHN20 (on-site)	PFAS membrane	Ethylene
12	Ningxia Jinyuyuan Chemical	Wuzhong City, Ningxia, China	700	ASIACHN14 (on-site)	PFAS membrane	Acetylene
13	Westlake	Calvert City, Kentucky, USA	680	AMUSA23 (on-site) and AMUSA09	Asbestos dia- phragm and PFAS membrane	Ethylene
14	Shin-Etsu	Plaquemine, Louisiana, USA	635	AMUSA19 (on-site)	PFAS membrane	Ethylene
15	Shin-Etsu	Botlek-Rotterdam, Netherlands	620	from EURNE01	PFAS membrane	Ethylene
16 (tie)	Shin-Etsu	Addis, Louisiana, USA	600	from AMUSA19	PFAS membrane	Ethylene
16 (tie)	Xinfa Group	Liaocheng, Shandong, China	600	ASIACHN19 (on-site)	PFAS membrane	Acetylene
16 (tie)	Hongda Xingye	Wuhai City, Inner Mongolia, China	600	ASIACHN10 (on-site)	PFAS membrane	Acetylene

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/ YR.)	CHLORINE SOURCE	CHLORINE SOURCE TECHNOLOGIES	VCM SOURCE TECHNOLOGY
16 (tie)	Sinopec	Zibo, Shandong, China	600	ASIACHN18 (on-site)	Asbestos diaphragm and PFAS membrane	Acetylene
20 (tie)	AGC Group	Cilegon, Banten, Indonesia	550	ASIAIDN01 (on-site)	PFAS membrane	Ethylene
20 (tie)	Formosa Plastics	Jen-Wu District, Kaohsi- ung City, Taiwan	550	ASIATW01 (on-site)	PFAS membrane	Ethylene
20 (tie)	Shin-Etsu	Kashima, Ibaraki, Japan	550	ASIAJPN03 (on-site)	PFAS membrane	Ethylene
23	Thai Plastic & Chemicals	Rayong, Thailand	530	from ASIATH01	PFAS membrane	Ethylene
24 (tie)	Mexichem	Cartagena, Bolivar Region, Colombia	500	from AMUSA07 and AMMEX01	Asbestos diaphragm	Ethylene
24 (tie)	Elion Resources Group	Erdos City, Inner Mongolia, China	500	ASIACHN07 (on-site)	PFAS membrane	Acetylene
24 (tie)	Formosa Plastics	Mailiao, Taiwan	500	ASIATW02 (on-site)	PFAS membrane	Ethylene
24 (tie)	Yibin Tianyuan Group	Yibin, Sichuan, China	500	ASIACHN22 (on-site)	Asbestos diaphragm and PFAS membrane	Acetylene
28	Formosa	Baton Rouge, Louisiana, USA	470	from AMUSA03	PFAS membrane	Ethylene
29 (tie)	Government of China	Cangzhou City, Anhui, China	460	ASIACHN01 (on-site)	PFAS membrane	Acetylene
29 (tie)	Braskem	Maceió, Alagoas, Brazil	460	AMBRA01 (on-site)	PFAS diaphragm	Ethylene
31	Westlake	Aberdeen, Mississippi, USA	455	from AMUSA22	PFAS membrane and PFAS diaphragm	Ethylene
32 (tie)	Ineos	Jemeppe-sur-Sambre, Belgium	450	EURBE01 (on-site)	PFAS membrane	Ethylene
32 (tie)	Shin-Etsu	Pernis, Netherlands	450	from EURNE01	PFAS membrane	Ethylene
32 (tie)	Taiwan UPC Group	Taixing, Jiangsu, China	450	from ASIACHN11	PFAS membrane	Ethylene
35	Ineos	Newton-Aycliffe, UK	440	from EURNO01	PFAS membrane	Ethylene
36	Mexichem	Marl, Germany	416	EURDE12 (on-site)	PFAS membrane	Ethylene
37 (tie)	China National Salt Industry Corporation	Alxa Left Banner, Inner Mongolia, China	400	ASIACHN05 (on-site)	PFAS membrane	Acetylene
37 (tie)	East Hope Group	Baotou, Inner Mongolia, China	400	ASIACHN06 (on-site)	PFAS membrane	Acetylene

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/YR.)	CHLORINE SOURCE	CHLORINE SOURCE TECHNOLOGIES	VCM SOURCE TECHNOLOGY
37 (tie)	Government of Saudi Arabia	Jubail Industrial City, Al-Jubail, Saudi Arabia	400	ASIASAU01 (on-site)	Asbestos diaphragm and PFAS membrane	Ethylene
37 (tie)	Wanhua Industrial Group	Kazincbarcika, Hungary	400	EURHU01 (on-site)	PFAS membrane	Ethylene
37 (tie)	Jiangsu Meilan Chemical	Taizhou, Jiangsu, China	400	ASIACHN12 (on-site)	Asbestos diaphragm and PFAS membrane	Ethylene
37 (tie)	Tangshan San-you Chlor-alkali	Tangshan, Hebei, China	400	ASIACHN02 (on-site)	PFAS membrane	Acetylene
37 (tie)	Inner Mongolia Yidong Resources	Ulan Oab City, Inner Mongolia, China	400	ASIACHN08 (on-site)	PFAS membrane	Acetylene
37 (tie)	ChemChina	Xinyang, Henan, China	400	ASIACHN04 (on-site)	Asbestos diaphragm and PFAS membrane	Acetylene
45	International Chemical Investors Group	Wilhelmshaven, Netherlands	370	from EURUK01 and EURBE03	PFAS membrane	Ethylene
46 (tie)	ChemChina	Dezhou City, Shandong, China	360	ASIACHN16 (on-site)	PFAS membrane	Acetylene
46 (tie)	Reliance Industries	Hazira, Gujarat, India	360	ASIAIND07 (on-site)	PFAS membrane	Ethylene
48	Occidental	Niagara Falls, Ontario, Canada	341	from AMUSA05 and AMUSA14	Asbestos diaphragm	Ethylene
49 (tie)	Islamic Republic of Iran	Special Economic Zone, Bandar Emam, Iran	340	ASIAIRN01 (on-site)	PFAS membrane	Ethylene
49 (tie)	PKN Orlen	Wloclawek, Poland	340	EURPO02 (on-site)	PFAS membrane	Ethylene
51	Westlake	Geismar, Louisiana, USA	331	AMUSA21 (on-site)	PFAS membrane	Ethylene
52	Sibur and Solvay (JV)	Kstovo, Russia	330	EURRU03 (on-site)	PFAS membrane	Ethylene
53	Ineos	Rheinberg, Germany	320	EURDE11 (on-site)	PFAS diaphragm and PFAS membrane	Ethylene
54	Reliance Industries Ltd.	Dahej, Bharuch District, Gujarat, India	315	ASIAIND06 (on-site)	PFAS membrane	Ethylene
55	Tosoh Corp. (formerly Toyo Soda)	Yokkaichi, Mie, Japan	310	ASIAJPN09 (on-site)	PFAS membrane	Ethylene
56 (tie)	ChemChina	Heilongjiang, China	300	ASIACHN03 (on-site)	PFAS membrane	Acetylene
56 (tie)	Kem One	Balan, France	300	from EURFR02 and EURFR03	PFAS diaphragm and PFAS membrane	Ethylene

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/ YR.)	CHLORINE SOURCE	CHLORINE SOURCE TECHNOLOGIES	VCM SOURCE TECHNOLOGY
56 (tie)	Sanmar Holdings	Cuddalore, Tamil Nadu, India	300	from AFEY03	PFAS membrane	Ethylene
56 (tie)	Sichuan Jinlu Group	Deyang City, Sichuan, China	300	ASIACHN21 (on-site)	PFAS membrane	Acetylene
56 (tie)	Xedrian Holding	Kalush City, Ukraine	300	EURUR01 (on-site)	PFAS membrane	Ethylene
56 (tie)	Unipar Carbocloro	Santo André, São Paulo, Brazil	300	AMBRA04 and from AMBRA03	Mercury cell and PFAS membrane	Ethylene
56 (tie)	Renova Group	Sayansk, Russia	300	EURRU06 (on-site)	PFAS membrane	Ethylene
56 (tie)	Yangmei Group	Tancheng, Shandong, China	300	ASIACHN17 (on-site)	PFAS membrane	Ethylene
56 (tie)	Unid Co.	Ulsan, South Korea	300	ASIAKOR01 (on-site)	PFAS membrane	Ethylene
65 (tie)	Kem One	Berre-L'Etang, France	290	from EURFR02	PFAS diaphragm and PFAS membrane	Ethylene
65 (tie)	Kaneka	Takasago, Hyōgo, Japan	290	ASIAJPN05 (on-site)	PFAS membrane	Ethylene
65 (tie)	Hanwha Chemical	Yeosu City, South Korea	290	ASIAKOR02 (on-site)	PFAS membrane	Ethylene
68	AGC Group	Map Tha Phut, Rayong, Thailand	280	ASIATH02 (on-site)	PFAS membrane	Ethylene
69	Occidental	Deer Park, Texas, USA	275	AMUSA05 (on-site)	Asbestos diaphragm	Ethylene
70	Ineos	Tavaux, France	260	EURFR01 (on-site)	PFAS membrane	Ethylene
71	International Chemical Investors Group	Mazingarbe, France	255	from EURBE03 (b)	PFAS membrane	Ethylene
72 (tie)	Sanmar Holdings	Port Said, Egypt	250	AFEY03 (on-site)	PFAS membrane	Ethylene
72 (tie)	Xinjiang Zhongtai Chemical	Toksun County, Xinjiang, China	250	ASIACHN25 (on-site)	PFAS membrane	Acetylene
	International Chemical Investors Group	Beek Geleen, Netherlands	225	from EURBE03	PFAS membrane	Ethylene
	Unipar Carbocloro	Bahia Blanca, Buenos Aires Province, Argentina	220	AMARG01 (on-site)	Mercury cell	Ethylene
	Tosoh Guangzhou Chemical Industries	Huangge Town, Nansha District, Guangzhou, China	220	from ASIA-JPN08	PFAS membrane	Ethylene

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/YR.)	CHLORINE SOURCE	CHLORINE SOURCE TECHNOLOGIES	VCM SOURCE TECHNOLOGY
	Certainteed	Lake Charles, Louisiana, USA	215	from AMUSA22	PFAS Membrane and PFAS diaphragm	Ethylene
	Ineos	Stenungsund, Sweden	215	EURSV01 (on-site)	PFAS membrane	Ethylene
	Westlake	Burghausen, Germany	210	from EURDE13	PFAS membrane	Ethylene
	Kem One	Saint-Fons, France	205	from EURFR02, EURFR03 and EURFR04	PFAS diaphragm and PFAS membrane	Ethylene
	Shin-Etsu	Estarreja, Portugal	200	from EURNE01 via Shin-Etsu-Rotterdam	PFAS membrane	Ethylene
	Ineos	Porsgrunn, Norway	200	from EURNO01	PFAS membrane	Ethylene
	Engro Corporation	Port Qasim, Baluchistan, Pakistan	195	ASIAPAK01 (on-site)	PFAS membrane	Ethylene
	Taiyo Vinyl - Takaishi	Takaishi, Osaka, Japan	180	from ASIA-JPN08	PFAS membrane	Ethylene
	Westlake	Hürth-Knapsack, Germany	160	EURDE14 (on-site)	PFAS membrane	Ethylene
	Westlake	Köln-Merkenich, Germany	160	from EURDE13	PFAS membrane	Ethylene
	Occidental	Pedricktown, NJ, USA	160	from AMUSA05 and AMUSA14	Asbestos diaphragm and PFAS membrane	Ethylene
	JSC Bashkirskaya Khimiya	Steritamak, Russia	160	EURRU04 (on-site)	Mercury cell and Asbestos diaphragm	Ethylene
	Westlake	Gendorf, Germany	155	EURDE13 (on-site)	PFAS membrane	Ethylene
	Petkim Petrokimya Holding AS/ SOCAR Turkey Enerji A.Ş.	Aliaga, Izmir, Turkey	150	ASIATUR01 (on-site)	PFAS membrane	Ethylene
	AGC Group	Ba Ria-Vung Tao, Vietnam	150	from ASIAIDN02	PFAS membrane	Ethylene
	Shin Dai-Ichi Vinyl	Tokuyama, Japan	145	from ASIAJPN07	PFAS membrane	Ethylene
	Formosa	Delaware City, Delaware, USA	144	from AMUSA03	PFAS membrane	Ethylene
	Spolana	Neratovice, Czech Republic	135	from EURPO02	PFAS membrane	Ethylene
	Mexichem	Pedricktown, NJ, USA	123	from AMUSA07	Asbestos diaphragm	Ethylene
	Mexichem	Henry, Illinois, USA	122	from AMUSA06	Asbestos diaphragm	Ethylene

RANK	OWNER	LOCATION	PVC CAPACITY (1,000 TONS/YR.)	CHLORINE SOURCE	CHLORINE SOURCE TECHNOLOGIES	VCM SOURCE TECHNOLOGY
	Taiyo Vinyl - Ichihara	Ichihara, Chiba, Japan	120	from ASIA-JPN08	PFAS membrane	Ethylene
	Pequiven	Maracaibo, Venezuela	120	AMVEN01 (on-site)	PFAS membrane	Ethylene
	Ercros Industria	Vila-seca, Spain	120	EURES01 (on-site)	PFAS membrane	Ethylene
	Sasol	Midland, South Africa	112	AFSAF02 (on-site)	PFAS diaphragm and PFAS membrane	Ethylene
	Nikochem	Volgograd, Russia	110	EURRU05 (on-site)	Mercury cell and Asbestos diaphragm	Acetylene
	Egyptian Petrochemicals Company	Alexandria, Egypt	109	AFEGY02 (on-site)	PFAS membrane	Ethylene
	Phillippines Resins (Tosoh)	Mariveles, Bataan, Philippines	100	from ASIA-JPN08	PFAS membrane	Ethylene
	Westlake	Schkopau, Germany	100	from EURDE08	PFAS membrane	Ethylene
	P.T. Sulfindo Adiusaha	Merak, West Java, Indonesia	95	ASIAIDN02 (on-site)	PFAS membrane	Ethylene
	P.T. Standard Toyo Polymer (Statomer)	Kodya Cilegon, Banten, Indonesia	82	from ASIA-JPN08	PFAS membrane	Ethylene
	Kem One	Chateau-Arnoux-Saint-Auban, France	70	from EURFR03	PFAS diaphragm and PFAS membrane	Ethylene
	DCM Shiram Consolidated	Kota, Rajasthan, India	70	ASIAIND04 (on-site)	PFAS membrane	Acetylene
	Ynna Holding	Mohammedia, Morocco	68	AFMOR01 (on-site)	PFAS membrane	Ethylene
	Kem One	Hernani, Spain	45	from EURFR02 and EURFR04	PFAS diaphragm and PFAS membrane	Ethylene
	Hangin Technology Co.	Huludao, Liaoning, China	40	ASIACHN13 (on-site)	PFAS membrane	Acetylene
	Khimprom	Volgograd, Russia	27	from EURRU05	Mercury cell and Asbestos diaphragm	Ethylene
		Total all PVC plants	41761			

Notes:

Rankings are not included for chlor-alkali plants under 250,000 tons per year capacity because this Inventory does not include some operating plants with capacities in this range.

This Phase 2 report contains additional details about PVC plants in Asia. Details about plants in the rest of the world are available in our Phase 1 report. These reports provide sources for the data in this Appendix.

See also the spreadsheets and map on HBN's Chlorine and Building Materials project page, <https://healthybuilding.net/reports/20-chlorine-building-materials-project-phase-2-asia-including-worldwide-findings>.

Endnotes

- 1 A 2019 industry estimate placed Asia's share as 55% of global production. (Merchant Research & Consulting Ltd. "Caustic Soda: 2019 World Market Outlook and Forecast up to 2028," January 2019. <https://mcgroup.co.uk/researches/caustic-soda>.) This is the equivalent to 38.6 million tons using 2017 estimates of global production (see footnote below). The chlor-alkali plants in our Phase 2 report have a combined estimated capacity of 21.6 million tons. The PVC plants in this report have a combined estimated capacity of 22.8 million tons per year. Eddie Kok, executive director of IHS Markit, estimated Asia's PVC capacity in 2017 to be 34.2 million tons. (Kok, Eddie. "Global PVC Market Tightening?" presented at the PVC Australia 2018, March 2018. https://www.vinyl.org.au/images/vinyl/Events/PVCAUS2018-presentations/Eddie_Kok_IHS.pdf.)
- 2 The two phases of this project identified 51.2 million tons of chlorine capacity in 146 chlor-alkali plants. The World Chlorine Council estimated global production in 2017 to be 70 million tons. (World Chlorine Council. "Sustainable Progress," 2017. https://worldchlorine.org/wp-content/uploads/2017/10/WCC_Sustainable-Progress_Version-3-2017_web.pdf.)
- 3 Our global inventory identifies 41.8 million tons of capacity in 112 PVC plants. Kok, cited above, estimated global capacity in 2017 to be 54 million tons. A Formosa Plastics presentation in 2016 placed the global PVC capacity at 61.5 million tons. (Jian, Sunny. "Caustic Soda Market Information." Formosa Plastics Corporation, October 2016. [http://www.kcaia.or.kr/upload/info04/007%20TAAIA\[3\].pdf](http://www.kcaia.or.kr/upload/info04/007%20TAAIA[3].pdf).)
Our estimated percentage of coverage is based on an average of these two industry estimates.
- 4 Healthy Building Network. "Chlorine & Building Materials Project," 2019. <https://healthybuilding.net/reports/18-chlorine-building-materials-project>.
- 5 Where the term "tons" appears, it refers to metric tons, into which reported weights have been converted for consistency. See the Glossary of Notes in our Phase 1 report for further details of this and other technical terms.
- 6 "Innovative Energy Efficiency and Emission Reduction Technologies." Asian Development Bank, October 2015. <https://www.adb.org/sites/default/files/linked-documents/47051-002-sd-01.pdf>. (ADB 2015)
- 7 As discussed in the Phase 1 report's Glossary of Notes, "To calculate how much chlorine is lost in these reactions, we have taken the amount of chlorine that is required for the overall reaction (0.61 kg Cl / kg PVC) and subtracted the amount of chlorine that ends up in the PVC (0.5672 kg Cl / kg PVC) to arrive at 0.04 kg Cl lost / kg PVC produced. In other words, 7% of the chlorine used by this method is released into the environment or subsumed by by-products, and 93% ends up in PVC."
- 8 We estimate that the PVC plants that are associated with chlor-alkali plants we researched in China have a combined capacity of 14.1 million tons per year. This requires the consumption of 8.6 million tons of chlorine. This is 74% of the estimated chlorine capacity (11.7 million tons) of the 27 chlor-alkali plants in China that we researched for this report.
- 9 ADB 2015.
- 10 "Petrochemical Industry, Land of Opportunity to Advance into India" (Google Translation)." Sisa Journal, March 3, 2017. <https://www.sisapress.com/journal/articleb/165519>. (Sisa).
- 11 Federation of Indian Chambers of Commerce and Industry. "White Paper on Enhancing Competitiveness of Indian PVC & Caustic Soda Industries," n.d. <http://ficci.in/spdocument/20684/PVC-Report-new.pdf>. (Ficci).
- 12 According to Reliance Industries, domestic demand for PVC was 503,000 tons in 1996-97. http://www.ril.com/getattachment/d356257d-19ee-4bbf-b254-61ee614ada3d/AnnualReport_1996-97.aspx
- 13 Shyama, Ghan, and Dinesh Kumarb. "Chemical and Petrochemical Statistics at a Glance - 2017," November 9, 2017. http://chemicals.nic.in/sites/default/files/Chemical%20and%20Petrochemical%20Statistics%20at%20a%20Glance%20-2017_0.pdf.
- 14 Ficci.
- 15 Panjiva, Inc. "Panjiva Trade Database," n.d. <http://www.panjiva.com>. (Panjiva).
- 16 Using the median weight per area based on sources in: Healthy Building Network. "Common Product: Luxury Vinyl Tile (LVT)." Pharos Project, n.d. <https://www.pharosproject.net/material/show/2077801>.
- 17 "Floorcovering Retail Sales Slowed in Q4, Says Stifel." Floor Daily, January 25, 2019. <https://www.floordaily.net/flooring-news/retail-sales-slowed-in-q4-says-stifel>. See also: "Stifel Offers Industry Outlook for 2019." Floor Daily, January 9, 2019. <https://www.floordaily.net/floorfocus/stifel-offers-industry-outlook-for-2019>.
And, FCNews staff. "Trump's Tariffs Force Manufacturers to Take Action." Floor Covering News, September 20, 2018. <https://fcnews.net/2018/09/trumps-tariffs-force-manufacturers-to-take-action/>. FCNews staff. "Trump's Tariffs Force Manufacturers to Take Action." Floor Covering News, September 20, 2018. <https://fcnews.net/2018/09/trumps-tariffs-force-manufacturers-to-take-action/>.
- 18 Tse, Pui-Kwan. "The Mineral Industry of China." U.S. Geological Survey, 1998. <https://minerals.usgs.gov/minerals/pubs/country/1998/9308098.pdf>.
- 19 Wang, Shiyao. "Strategy of China's Players Amidst PVC Overcapacity." presented at the PVC Session at APIC 2018, September 21, 2018. http://cpmaindia.com/pdf/apic_country_papers_2018-presentations/APIC%20CNCIC%20SHI-YAO%20WANG.pdf. (Wang)
- 20 Wang; and UN Environment. "Global Mercury Supply, Trade and Demand." United Nations Environment Programme, Chemicals and Health Branch, 2017. https://wedocs.unep.org/bitstream/handle/20.500.11822/21725/global_mercury.pdf?sequence=1&. (UNEP 2017)
- 21 Exrance, Andy. "New Vinyl Catalyst Will Reduce Mercury Emissions." Chemistry World, January 11, 2016. <https://www.chemistryworld.com/news/new-vinyl-catalyst-will-reduce-mercury-emissions/9326.article>
- 22 UNEP 2017.

- 23 UNEP 2017.
- 24 “Ethane Exports by Destination.” Accessed December 5, 2018. https://www.eia.gov/dnav/pet/PET_MOVE_EXPC_A_EPLLEA_EEX_MBBL_M.htm. (EIA).
- 25 HTS Codes 280110, 290315, 290321, 390410, 394021 and 390422, 2012 to 2016 data, from “Interactive Tariff and Trade DataWeb.” United States International Trade Commission, n.d. <https://dataweb.usitc.gov/>.
- 26 Xinjiang Zhongtai Chemical Co., Ltd. “新疆中泰化学股份有限公司, Xinjiang Zhongtai Chemical Co., Ltd. 2016 年年度报告摘要.” cninfo (Shenzhen Securities Information Co.), March 2017. http://finance04.com/sbdm/pg/acc/CN_DISC/STOCK_TIME/2017/03/21/002092_nb_1203180941.PDF. (Xinjiang Zhongtai 3-17).
- 27 ADB 2015.
- 28 ICIS News. “China Chemical Closures Send Ripples around the World.” ICIS, January 11, 2018. <https://www.icis.com/explore/resources/news/2018/01/11/10182086/china-chemical-closures-send-ripples-around-the-world/>.
- 29 Lopez, Ana. “Global Chlor-Alkali Market Outlook.” November 15, 2018. <http://www.clorosur.org/seminar2018/presentations/15-10.pdf>.
- 30 Xinjiang Tianye (Group). “Xinjiang Tianye: PVC Faucet Re-Starts a New Journey - Xinjiang Tianye,” June 5, 2018. <http://www.xj-tianye.com/xwz/1278.jhtml>.
- 31 Fryer, Charles. “VCM and PVC in China.” presented at the APIC Meeting, Bangkok, Thailand, July 2006. See also, “Carbide Economics Still Work.” ICIS, October 23, 2005. <https://www.icis.com/explore/resources/news/2005/10/24/2010631/carbide-economics-still-work>.
- 32 “PVC Sector Accelerates the Elimination of Outdated Capacities-Chemical Information.” China National Chemical Information Centre Co., Ltd, September 1, 2018. <https://web.archive.org/web/20181217140857/http://www.chemconsulting.com.cn/en/en/industrynews/283.html>. (CNCIC).
- 33 FICCI and CNCIC
- 34 Trembley, Jean-Francois. “China’s Jiangsu Province Will Close 1,000 Chemical Plants.” *Chemical & Engineering News*, September 18, 2018. <https://cen.acs.org/environment/Chinas-Jiangsu-province-close-1000/96/i37>. O’Melveny & Myers LLP. “China Broadens Environmental Enforcement Plant Closures.” *Lexology*, April 3, 2018. See also: <https://www.lexology.com/library/detail.aspx?g=f93848a8-eb9c-4c54-a79c-d56e85386c3e>.
- And, John, Woodside. “Too Fast, Too Soon: How China’s Growth Led to the Tianjin Disaster.” *The Guardian (U.K.)*, May 23, 2017. <https://www.theguardian.com/cities/2017/may/23/city-exploded-china-growth-tianjin-disaster-inevitable>.
- 35 Baiyu, Gao. “Investigators Allege Cover-Up in Deadly Hebei Chemical Explosion.” *CX Live*, February 4, 2019. <https://www.caixinglobal.com/2019-02-04/investigators-allege-cover-up-in-deadly-hebei-chemical-explosion-101377826.html>. And Toloken, Steve. “ChemChina Says It Caused Deadly PVC Plant Explosion.” *Rubber & Plastics News*, December 5, 2018. <https://www.rubbernews.com/article/20181205/NEWS/181209970/chemchina-says-it-caused-deadly-pvc-plant-explosion>.
- 36 FICCI.
- 37 FICCI.
- 38 “Company Profile - About Us - Hwasu.” Hwasu Corporation. Accessed February 13, 2019. http://www.hwasu.com/category.php?class_id=101.
- 39 Baiinfo. “Aluminum Weekly,” August 14, 2014. <http://file.baiinfo.com/FileManage/Download.ashx?FileName=VXBsb-2FkRmlsZXNcRU5cQkFJSU5GTyBBbHVtaW51bSBXZWVrbHkucGRm&GUID=79900a39-e5a3-4459-9215-699706f65d02>.
- 40 “Anhui Hwasu: Arkema Process for China PVC Plant,” January 7, 2010. https://www.k-online.com/cgi-bin/md_k/lib/pub/tt.cgi/Anhui_Hwasu_Arkema_process_for_China_PVC_plant.html?oid=18362&lang=2&ticket=g_u_e_s_t. See also: “Hwasu Shares the First Batch of PVC Products on the Market.” China Energy Network, March 6, 2013. http://www.cnenergy.org/yq/lh/201303/t20130306_58421.html.
- 41 “China’s Anhui Hwasu Starts up 460,000 Mt/Year PVC Plant in Huabei.” S&P Global Platts, October 18, 2011. <https://www.platts.cn/latest-news/petrochemicals/singapore/chinas-anhui-hwasu-starts-up-460000-mtyear-pvc-7559347>. See also: CNCIC.
- 42 “Anhui Hwasu Power Station.” SourceWatch, December 20, 2018. https://www.sourcewatch.org/index.php/Anhui_Hwasu_power_station.
- 43 “‘China Building Materials News’ on the Headline of the First Edition on December 6th: The Road to Transformation of the Mighty, the High-End Look and the Long-Term.” Hwasu Corporation, December 6, 2018. <http://www.hwasu.com/display.php?id=6195>.
- 44 “Hwasu Intends to Raise 920 Million Yuan to Build Two Phase PVC Project.” CCAON, July 18, 2018. <http://world.ccaon.com/content.asp?table=News&id=795>. Also: “China’s Anhui Hwasu Starts up 460,000 Mt/Year PVC Plant in Huabei.” S&P Global Platts, October 18, 2011. <https://www.platts.cn/latest-news/petrochemicals/singapore/chinas-anhui-hwasu-starts-up-460000-mtyear-pvc-7559347>.
- 45 CNCIC 2018.
- 46 “Company Overview of Anhui Hwasu Co., Ltd.” EMIS. Accessed February 13, 2019. https://www.emis.com/php/company-profile/CN/Anhui_Hwasu_Co_Ltd_%E5%AE%89%E5%BE%BD%E5%8D%8E%E5%A1%91%E8%82%A1%E4%B-B%BD%E6%9C%89%E9%99%90%E5%85%AC%E5%8F%B8__en_5427310.html.
- 47 “Production News - China Chlor-Alkali.” CCAON Beijing, July 8, 2008. http://www.ccaon.com/baogao/upload/Production%20News%20Issue_12.pdf. Also: CCAON. “Chlor Alkali Monthly Report,” June 8, 2009. <http://world.ccaon.com/edit/uploadfile/20090609131002886.pdf>.

- 48 “Tangshan SanYou Chlor-Alkali Co.,Ltd.” EC21, 2019. <https://hellohappyjenny.en.ec21.com>. (EC21.) Also: “Chlor-Alkali Company.” Tangshan Sanyou. Accessed February 13, 2019. <http://www.sanyou-group.com.cn/jtwebx/contents/1853/52908.html>
- 49 “Domestic PVC Enterprises Factory Price Summary for May 17.” Haohua East China Chemical Corporation, May 18, 2012. <http://www.hhhd.chemchina.com/hhhdn/xwymt/cpxw/webinfo/2012/05/1344232103888349.htm>. Also: “China’s Tangshan Chlor-Alkali to Restart Caustic Soda Unit on 26 May.” ICIS, May 24, 2013. <https://www.icis.com/explore/resources/news/2013/05/24/9672011/china-s-tangshan-chlor-alkali-to-restart-caustic-soda-unit-on-26-may>. And, “Tangshan Sanyou Will Expand the Existing Capacities of the PVC & Caustic Soda Plants.” CCAON, February 26, 2016. <http://world.ccaon.com/content.asp?table=News&id=345>. (CCAON 2016). And, “Welcome to Sanyou Group-Product.” TangShan SanYou Chemical Industries Co., Ltd., October 3, 2014. <https://web.archive.org/web/20141003165915/http://www.sanyou-group.com.cn/jtweb/contents/736/9433.html>. And, CNCIC 2018.
- 50 Zhang, Allen, Lily Wang, Kevin Lv, and Nancy Hao. “Polyvinyl Chloride Monthly.” CCAON, August 8, 2008.
- 51 “Chemical - Caustic Soda.” China Chemical Engineering Co., Ltd., May 28, 2014. <http://www.cncec.com.cn/html/gcyj/251.html>.
- 52 ICIS News. “China’s Tangshan Sanyou Trial Runs New PVC, Caustic Soda Lines.” ICIS, June 14, 2012. <https://www.icis.com/explore/resources/news/2012/06/14/9569303/china-s-tangshan-sanyou-trial-runs-new-pvc-caustic-soda-lines/>.
- 53 CCAON 2016.
- 54 EC21.
- 55 “Chlor-Alkali Company.” Tangshan Sanyou. Accessed February 13, 2019. <http://www.sanyou-group.com.cn/jtwebx/contents/1853/52908.html>.
- 56 “TANGSHAN SANYOU CHEMICAL INDUSTRIES CO (600409).” MarketScreener, 2019. <https://www.marketscreener.com/TANGSHAN-SANYOU-CHEMICAL-6498003/company/>.
- 57 Pankaj, and Venkat Srinivasan. “Report on the Electrolytic Industries for the Year 2001.” Journal of the Electrochemical Society 149, no. 11 (October 2002): K1–29.
- 58 “Heilongjiang Haohua Chemical Co., Ltd.” Heilongjiang Haohua Chemical Co., Ltd., 2019. <http://www.hhhlj.chemchina.com/hljhhen/index.htm>.
- 59 Ibid.
- 60 “Company Profile.” ChemChina, 2012. <http://www.hhhlj.chemchina.com/hljhhen/gywm/gsjj/webinfo/2012/06/1339396734432358.htm>. (ChemChina 2012). See also: “Vice Governor Hu Yafeng Visits Heilongjiang Haohua.” ChemChina, April 8, 2015. <http://www.chemchina.com.cn/en/xwymt/qyxw/webinfo/2015/04/1429233459285329.htm>.
- 61 IPEN, and Green Beagle. “China Chemical Safety Case Study: Qihua PVC Plant in Qiqihar, Heilongjiang Province.” IPEN: a toxics-free future, January 2015. <http://ipen.org/sites/default/files/documents/Case%20Study%20Report%20Qihua%202015r.pdf>. See also: “Acetylene Section of PVC Workshop to Carry out Emergency Plan Drill.” ChemChina, November 23, 2018. <http://www.hhhlj.chemchina.com/hljhh/xwymt/hhxw/webinfo/2018/11/1542193763316951.htm>.
- 62 “‘Every Case of Pollution Is a Case of Corruption’: Farmer Turned Eco-Warrior Takes on China’s Largest Chemical Firm.” Hong Kong Free Press HKFP (blog), November 19, 2017. <https://www.hongkongfp.com/2017/11/19/every-case-pollution-case-corruption-farmer-turned-eco-warrior-takes-chinas-largest-chemical-firm/>. See also: ChemChina 2012.
- 63 “Product Description.” ChemChina. Accessed February 14, 2019. http://www.hhhlj.chemchina.com/hljhh/cpyfw/ppysb/A430302web_1.htm. See also: “Polyvinyl Chloride Resin.” ChemChina, 2019. http://www.hhhlj.chemchina.com/hljhh/cpyfw/ppysb/jlyxs/A43030204web_1.htm.
- 64 “China Haohua Chemical Group Co.,Ltd.” China Haohua Chemical Group Co.,Ltd. Accessed February 14, 2019. <http://www.chinahaohua.com.cn/hhchem/index.htm>.
- 65 “Introduction.” Haohua Yuhang Chemical Co., Ltd. n.d. http://www.hhyh.chemchina.com/hhyhen/gywm/gsjj/A640101web_1.htm. (Haohua).
- 66 Ibid.
- 67 Beijing Zeefer Consulting Ltd. “Directory: Major Chinese Industrial Companies.” AllChinaReports.com, April 2012.
- 68 “Chlor Alkali Monthly Report.” CCAON, June 8, 2009. <http://world.ccaon.com/edit/uploadfile/20090609131002886.pdf>. (CCAON 6/8/09).
- 69 Haohua. See also: “China’s Haohua Yuhang to Restart Henan Caustic Soda Unit on 12 May.” ICIS, May 10, 2013. <https://www.icis.com/explore/resources/news/2013/05/10/9666995/china-s-haohua-yuhang-to-restart-henan-caustic-soda-unit-on-12-may>. And, CNCIC 2018.
- 70 “Qinyang Changhuai Power Station.” SourceWatch, October 12, 2018. https://www.sourcewatch.org/index.php/Qinyang_Changhuai_power_station.
- 71 Zhang, Allen, Lily Wang, Kevin Lv, and Nancy Hao. “Chlor Alkali Monthly Report.” CCAON, August 8, 2006. <http://world.ccaon.com/edit/uploadfile/20080811161656670.pdf>. (CCAON 8/6/06).
- 72 CCAON 6/8/09.
- 73 “Yuhua Yuhang Chemical Co., Ltd.” Haohua Aerospace Chemical Co., Ltd, February 1, 2009. <https://web.archive.org/web/20090201101548/http://www.haohuayuhang.com:80/products.asp>.
- 74 Haohua.

- 75 “China’s Jilantai Salt Chemical Restarts Caustic Soda Plant.” ICIS, May 30, 2012. <https://www.icis.com/explore/resources/news/2012/05/30/9565225/china-s-jilantai-salt-chemical-restarts-caustic-soda-plant>. (ICIS 5/30/12).
- 76 “Ionic Membrane Base.” Zhongyan Jilantai Salt Chemical Group Co., Ltd, March 3, 2017. <http://jilantai.chinasalt.com.cn/jitcpzx/jlthgcp/ff8080815a93015e015a936da6a60108.html>.
- 77 ICIS 5/30/12.
- 78 Ibid.
- 79 “Polyvinyl Chloride Resin.” Zhongyan Jilantai Salt Chemical Group Co., Ltd, March 3, 2017. <http://jilantai.chinasalt.com.cn/jitcpzx/jlthgcp/ff8080815a93015e015a936bd5520101.html>.
- 80 “Company Profile.” Zhongyan Jilantai Salt Chemical Group Co., Ltd, 2016. <http://jilantai.chinasalt.com.cn/jltgywm/jltqyjj/>. (Zhongyan Jilantai)
- 81 CCAON 8/6/06.
- 82 Business Monitor International. “China Petrochemicals Report. Q2 2011.” Business Monitor International Ltd., 2011. (China Petrochemicals).
- 83 CCAON 6/8/09. See also: Knak.jp. “China-19.” Accessed February 14, 2019. <http://www.knak.jp/china/china-19.htm>.
- 84 ICIS News. “China’s Jilantai Chlor-Alkali Sets End Dec Restart for PVC Unit.” ICIS, December 23, 2010. <https://www.icis.com/explore/resources/news/2010/12/23/9421960/china-s-jilantai-chlor-alkali-sets-end-dec-restart-for-pvc-unit/>. (ICIS 12/23/10)
- 85 “China’s Jilantai Salt Chemical Restarts Caustic Soda Plant.” ICIS, May 30, 2012. <https://www.icis.com/explore/resources/news/2012/05/30/9565225/china-s-jilantai-salt-chemical-restarts-caustic-soda-plant>.
- 86 CCAON Beijing China. “China Chlor Views,” September 2008. <http://www.ccaon.com/baogao/upload/CCV%20Issue%20009.pdf>.
- 87 ICIS 12/23/10.
- 88 Zhongyan Jilantai.
- 89 Ma, Michael. “Polyvinyl Chloride Weekly Report.” CCAON, October 17, 2011.
- 90 “Company Overview of Jilantai Salt Chemical (Group) Co., Ltd.” Bloomberg, 2019. <https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=46988056>. See also: “HSDB: TETRACHLOROETHYLENE.” Toxnet, November 9, 2016. <https://www.nrc.gov/docs/ML1706/ML17060A915.pdf>.
- 91 “Identification of Price-Fixing Behavior through Electronic Evidence.” October 19, 2017. <http://www.euchinacomp.org/attachments/article/525/03%20-%20NDRC%20and%20SAIC%20-%20Session%201%20Zeng-EN.pdf>. (NDRC 2017).
- 92 Baotou Haiping Polymer Industry Co. “Baotou Haiping Polymer Industry Co., Ltd. Emergency Plan for Sudden Environmental Incidents” (Google translation), September 2015. <https://www.easthope.cn/newspaper/2015090205.pdf>. See also: “Chemical.” East Hope Group, 2016. https://www.easthope.cn/ehw/vm/index_huag. (East Hope 2016)
- 93 “Baotou Haiping Polymer Industry Co., Ltd. Recruitment.” Sohu, June 16, 2017. http://www.sohu.com/a/149393237_694999.
- 94 Zhang, Allen, Lily Wang, Kevin Lv, and Nancy Hao. “Polyvinyl Chloride Monthly Report.” CCAON, August 8, 2008. (CCAON 8/8/08).
- 95 Focus on Polyvinyl Chloride, June 2002. (Focus on PVC).
- 96 East Hope 2016. See also: “PVC Market Monthly Report.” SCI99, October 2013. And, MEXICHEM, S.A.B. de C.V. “REPORTE ANUAL 2016,” 2016. <https://img.gruporeforma.com/Libre/Offlines/Reporte-Empresarial/img/Reportes/PDF/610.pdf>. (Mexichem 2016). And, “Project Name: Baotou Haiping Polymer Industry Co., Ltd. Jiuyuan Branch 600,000 Tons / Year Calcium Carbide Project Safety Status Assessment Report.” Inner Mongolia Hengruian Technology Service Co., Ltd., 2017. <http://www.nmgghrags.com/a/?thread-4-1.html>.
- 97 Focus on PVC.
- 98 “Baotou City Environmental Protection Bureau Checks the Mercury Intensity Reduction Work of Calcium Carbide Production Enterprises in Calcium Carbide.” Baotou Environmental Protection Bureau, December 14, 2018. http://hbj.baotou.gov.cn/hbdt_6280/gzdt/201812/t20181214_1585506.html. See also: “Baotou Municipal Solid Waste Supervision Center Launched a Report on the Verification of the Halving of Mercury Intensity in Calcium Carbide Production Enterprises.” Xuehua, December 7, 2018. <https://www.xuehua.us/2018/12/07/%e5%8c%85%e5%a4%b4%e5%b8%82%e5%9b%ba%e4%bd%93%e5%ba%9f%e7%89%a9%e7%9b%91%e7%ae%a1%e4%b8%ad%e5%bf%83%e5%b-c%80%e5%b1%95%e5%af%b9%e7%94%b5%e7%9f%b3%e6%b3%95%e8%81%9a%e6%b0%af%e4%b9%99%e7%83%af%e7%94%9f>.
- 99 “On February 3, Inner Mongolia Baotou Sea Level PVC Price Stability.” 浙ICP备, February 3, 2016. <http://www.100ppi.com/news/detail-20160203-745763.html>.
- 100 “National Development and Reform Commission Administrative Punishment Decision [2017] No. 9.” National Development and Reform Commission, October 16, 2017. http://www.ndrc.gov.cn/xzcf/201710/t20171016_863699.html. (NDRC 2017).
- 101 CCAON, “China Chlor Views,” October 2008. <http://world.ccaon.com/upfile/CCV%20Issue%20011.pdf>.
- 102 “China’s Huayi to Start up Inner Mongolia PVC JV in 2007.” ICIS, February 24, 2005. <https://www.icis.com/explore/resources/news/2005/02/24/654724/china-s-huayi-to-start-up-inner-mongolia-pvc-jv-in-2007>.
- 103 “Yili Chemical: Full Production of Full-Selling PVC Purchase and Sales Two Wang - Yili Jie Can.” Elion, September 4, 2017. http://www.elion.cn/newsdetail_21074.

- 104 CNCIC.
- 105 “Inner Mongolia Yili Energy Co., Ltd. 2013 Annual Report Summary.” Inner Mongolia Yili Energy Co., 2013. http://finance04.com/sbdrm/pg/acc/CN_DISC/STOCK_TIME/2014/04/02/122143_nb_63773639.PDF. (Yili 2013)
- 106 CNCIC.
- 107 “Shenhua Yili Power Station.” SourceWatch, February 6, 2019. https://www.sourcewatch.org/index.php/Shenhua_Yili_power_station.
- 108 Pan, Rongkun, Ligang Zheng, Hailin Jia¹, and Gang Ma. “The Environmental Pollution and Control of Coal Gangue Spontaneous Combustion In Mining.” *Electronic Journal of Geotechnical Engineering* 20 (2015). <http://www.ejge.com/2015/Ppr2015.0303mplr.pdf>.
- 109 “Uhde & Uhdenora Reference List,” March 2006. https://www.valveclosures.com/pdf/reference_list_single_elements.pdf. (Uhde).
- 110 Ibid.
- 111 NRDC 2017. See also Huan, Zhang. “Chinese Enterprises Fined Nearly 100 Million Yuan for Suspicion of Price Fixing.” *People’s Daily Online*, September 12, 2017. <http://en.people.cn/n3/2017/0912/c90000-9268010.html>.
- 112 Yili 2013. See also: “Yili Jie Can: Strong Environmental Protection to Promote the Transformation of the PVC Industry, ‘Leading’ Focuses on Improving the Quality of the Industry Chain.” *Elion*, November 13, 2018. http://www.elion.cn/news-detail_21189.
- 113 “INNER MONGOLIA DONG XING INTERNATIONAL TRADE CO., LTD.” *JCtrans*. Accessed February 15, 2019. http://www.jctrans.net/ShopComProfile/Details_67437.html. (JCtrans).
- 114 (Aluminum Weekly)
- 115 JCtrans.
- 116 “Introduction of Acetylene Branch.” Inner Mongolia Yidong Group Dongxing Chemical Co., Ltd. Accessed February 15, 2019. http://www.yddxhg.com/about_Introduction_show.aspx?cid=1223&nid=1754.
- 117 “Introduction to Trichloroethylene Branch.” Inner Mongolia Yidong Group Dongxing Chemical Co., Ltd. Accessed February 15, 2019. http://www.yddxhg.com/about_Introduction_show.aspx?cid=1223&nid=1751. See also JCtrans. And, “Inner Mongolia Dongxing Chemical Co., Ltd.” *Made-in-China*, 2019. <https://www.made-in-china.com/show-room/122568>.
- And, “PVC Plant Introduction.” Inner Mongolia Yidong Group Dongxing Chemical Co., Ltd. Accessed February 15, 2019. http://www.yddxhg.com/about_Introduction_show.aspx?cid=1223&nid=1750.
- 118 “China’s Yidong Group Dongxing Chem Shuts PVC Unit for Maintenance.” *ICIS*, May 12, 2014. <https://www.icis.com/explore/resources/news/2014/05/12/9779841/china-s-yidong-group-dongxing-chem-shuts-pvc-unit-for-maintenance>.
- 119 JCtrans.
- 120 “China’s Dongxing Chemical Starts up Its New E-PVC Unit on 23 Dec.” *ICIS*, December 23, 2013. <https://www.icis.com/explore/resources/news/2013/12/23/9738335/china-s-dongxing-chemical-starts-up-its-new-e-pvc-unit-on-23-dec>.
- 121 “Company Profile.” Junzheng Group, September 3, 2018. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=1>. See also: “Junzheng Group (601216) Company Information_F10_同花顺金融服务网.” Accessed February 15, 2019. <http://basic.10jqka.com.cn/601216/company.html>.
- 122 Flannery, Russell. “2016 Forbes China Rich List (Full List).” *Forbes*, October 29, 2016. <https://www.forbes.com/sites/russellflannery/2016/10/29/2016-forbes-china-rich-list-full-list/#4985f3b92bae>.
- 123 “Du Jiangtao & Family.” *Forbes*, 2019. <https://www.forbes.com/profile/du-jiangtao/#d36f9d355c4f>.
- 124 “A New Chlor-Alkali Plant in the Chemical Industry” Junzheng Group, October 26, 2011. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=837>. See also: “Wuda Chemical Chlorine and Alkali Branch.” Junzheng Group, February 6, 2015. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=3275>.
- 125 “Inner Mongolia Junzheng Energy Chemical Co., Ltd.” Junzheng Group, September 10, 2008. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=554>.
- 126 “Company Profile.” Junzheng Group, September 3, 2018. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=1>.
- 127 Inner Mongolia Junzheng Energy Chemical Co., Ltd. “Annual Report 2012,” April 23, 2013. http://webcache.googleusercontent.com/search?q=cache:DYenRWkpabAJ:file.finance.sina.com.cn/211.154.219.97:9494/MRGG/CNSESH_STOCK/2013/2013-4/2013-04-23/1106413.PDF+&cd=4&hl=en&ct=clnk&gl=us. (Junzheng 2012).
- 128 “The Preliminary Review Meeting for the Expansion.” Junzheng Group, July 19, 2012. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=1190>. See also: “The Company’s 1×200MW Unit Project.” Junzheng Group, July 23, 2013. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=1969>.
- 129 “400,000 Tons of PVC Foundation Laying Ceremony.” Junzheng Group, February 8, 2007. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=485>.
- 130 “Junzheng Chemical Co., Ltd. Held the Integral...” Junzheng Group, October 26, 2011. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=839>.
- 131 Junzheng 2012.
- 132 Ibid.
- 133 Ibid.
- 134 “Junzheng Group Product Distribution.” Junzheng Group, July 15, 2014. <http://www.junzhenggroup.com/index.php?m=Home&c=List&a=detail&id=4585>.

- 135 “WUHAI XINYE CHEMICAL INDUSTRY CO.,LTD.” Wuhai Xinye Chemical Co., Ltd., 2013. <http://en.nmgxyhg.net/>. See also: “INNER MONGOLIA WUHAI CHEMICAL INDUSTRY CO., LTD - CHINAPLAS 2018 Exhibitor List.” CHINAPLAS. Accessed February 15, 2019. <https://www.chinaplasonline.com/ExhibitorList18/lang-eng/cid-237989/src-12/ExhibitorInfo.aspx>.
- 136 “Group Profile.” Hongdaxingye Group Co., Ltd. Accessed February 15, 2019. <http://www.hdxy.cn/nav/about/group.html>.
- 137 “Wuhai Chem, Asahi Kasei Partner on Caustic Soda.” ICIS, January 16, 2007. <https://www.icis.com/explore/resources/news/2007/01/16/1120693/wuhai-chem-asahi-kasei-partner-on-caustic-soda>. (ICIS 1/16/07).
- 138 CNCIC.
- 139 “China’s Inner Mongolia Wuhai Chemical to Shut Caustic Soda Plant.” ICIS, March 19, 2013. <https://www.icis.com/explore/resources/news/2013/03/19/9650949/china-s-inner-mongolia-wuhai-chemical-to-shut-caustic-soda-plant>.
- 140 “Inner Mongolia Wuhai Chemical Industry Co., Ltd.” Accessed February 18, 2019. <https://www.chinaplasonline.com/ExhibitorList18/lang-eng/cid-237989/src-31/ExhibitorInfo.aspx>.
- 141 CNCIC.
- 142 CIS 1/16/07.
- 143 “Hainan District Accelerates the Pace of Chlor-Alkali Chemical and Coal Chemical Construction.” Inner Mongolia Yidong Group Dongxing Chemical Co., Ltd., August 20, 2014. http://www.yddxhg.com/news_show.aspx?cid=1228&nid=1720.
- 144 <http://www.hdxy.cn/product/service/resourceenergy.html>. See also: “Hongda Industrial Group.” Accessed February 15, 2019. <http://www.hdxy.cn/nav/about/group.html>.
- 145 “Resource Energy.” Hongdaxingye Group Co., Ltd. Accessed February 15, 2019. <http://www.hdxy.cn/product/service/resourceenergy.html>. See also: “Domestic PVC Enterprises Factory Price Summary for May 17.” Haohua East China Chemical Corporation, May 18, 2012. <http://www.hhhd.chemchina.com/hhhdn/xwymt/cpxw/webinfo/2012/05/1344232103888349.htm>.
- 146 “Home.” Inner Mongolia Wuhai Chemical Industry Co.,Ltd. Accessed February 18, 2019. <http://www.whqu.com>.
- 147 Ibid.
- 148 “Company Corporate Structure | SP Chemicals.” SP Chemicals, 2018. <https://www.spchemicals.com/company-corporate-structure/>. See also: SP Chemicals. “CIRCULAR TO SHAREHOLDERS IN RELATION TO THE PROPOSED VOLUNTARY DELISTING OF SP CHEMICALS LTD. PURSUANT TO RULES 1307 AND 1309 OF THE SGX-ST LISTING MANUAL,” December 24, 2008. <http://infopub.sgx.com/FileOpen/SP%20Chemicals%20Cir.ashx?App=Prospectus&FileID=5219>. (SGX).
- 149 “Company Profile and History.” SP Chemicals, 2018. <https://www.spchemicals.com/company-profile-and-history/>. (SP).
- 150 Ibid.
- 151 Ibid. See also: “China’s SP Chemicals (Taixing) Sets Late-Nov Turnaround at SM Unit.” ICIS, September 29, 2016. <https://www.icis.com/explore/resources/news/2016/09/29/10038883/china-s-sp-chemicals-taixing-sets-late-nov-turn-around-at-sm-unit>.
- 152 “Singpu Chemicals Taixing Power Station.” SourceWatch, June 10, 2017. https://www.sourcewatch.org/index.php/Singpu_Chemicals_Taixing_power_station.
- 153 SP.
- 154 SGX.
- 155 CCAON 8/8/08.
- 156 “INEOS to Deliver the First Ever US Ethane from Shale Gas to China in 2019 Using the World’s Largest Ethane Carrier.” INEOS, November 20, 2017. <https://www.ineos.com/news/ineos-to-deliver-the-first-ever-us-ethane-from-shale-gas-to-china-in-2019-using-the-worlds-largest-ethane-carrier/>.
- 157 NRA Capital Pte Ltd. “SP Chemicals Ltd,” September 8, 2008. https://www.nracapital.com/sgxmas/sp%20chemicals%20report_8sep08.pdf. See also: “Sp-Chemicals.” Asia Chemical Weekly, October 9, 2007. <http://www.knak.jp/china/sp-chem.htm>.
- 158 SGX.
- 159 “SP Chemicals Starts Turnaround at SM Plant in China | Market Report Company - Analytics, Prices, Polyethylene, Polypropylene, Polyvinylchloride, Polystyrene, Russia, Ukraine, Europe, Asia, Reports.” Market Report Company, November 9, 2017. http://www.mrcplast.com/news-news_open-333129.html. See also: “Products.” SP Chemicals, 2018. <https://www.spchemicals.com/products/>.
And “Products - Plasticizers - Producers Chemical Company.” Producers Chemical Company, 2019. <https://www.producerschemical.com/products-plasticizers.php>.
- 160 “Chemical Hazard Data Commons | Healthy Building Network.” Chemical Hazard Data Commons. Accessed February 15, 2019. <https://commons.healthymaterials.net>.
- 161 CNCIC.
- 162 “Solvay Is to Settle Its Subsidiary in Taizhou.” Everychina, May 20, 2011. http://news.everychina.com/wz409b1a/solvay_is_to_settle_its_subsidiary_in_taizhou.html
- 163 Ondrey, Gerald. “AkzoNobel Doubles MCA Production in China - Chemical Engineering | Page 1.” Chemical Engineering, November 13, 2008. <https://www.chemengonline.com/akzonobel-doubles-mca-production-in-china/>.
- 164 Yiu, Enoch. “Meilan’s Cool Rise to the Top in Refrigerants.” South China Morning Post, August 14, 2012. <https://www.scmp.com/business/article/1013861/meilans-cool-rise-top-refrigerants>. (Yiu).
- 165 “Corporate Profile.” Jiangsu Meilan Chemical Co., Ltd, 2013. <http://www.meilanchem.com/gsjj-en.html>. (Jiangsu Profile).

- 166 “Diaphragm Caustic Soda (30%).” Jiangsu Meilan Chemical Co., Ltd, 2013. http://www.meilanchem.com/product3e_detail/id/19.html.
- 167 “Caustic Soda of Ion Exchange Membrane (32%).” Jiangsu Meilan Chemical Co., Ltd, 2013. http://www.meilanchem.com/product3e_detail/id/18.html.
- 168 Yiu.
- 169 “China’s Jiangsu Meilan to Restart Caustic Soda Unit on 29 July.” ICIS, July 25, 2012. <https://www.icis.com/explore/resources/news/2012/07/25/9580737/china-s-jiangsu-meilan-to-restart-caustic-soda-unit-on-29-july>.
- 170 “References of Tank Field.” China National Chemical Engineering Group Corporation, May 28, 2014. <http://www.cncec.com.cn/html/Projectperformance/328.html>. See also: “The Price of Caustic Soda Has Risen by 19 Times.” Jiangsu Meilan Chemical Co., Ltd, September 6, 2017. http://www.meilanchem.com/news1_detail/id/173.html. (Jiangsu Meilan 2017).
- 171 “China’s Jiangsu Meilan Runs Chloromethane Unit at 80%.” ICIS, May 18, 2016. <https://www.icis.com/explore/resources/news/2016/05/18/9999221/china-s-jiangsu-meilan-runs-chloromethane-unit-at-80->.
- 172 United Nations Environmental Programme. “Project Proposal: China. UNEP/OzL.Pro/ExCom/43/30. Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol. Forty-Third Meeting. Geneva, 5-09 July 2004.” United Nations, June 11, 2003. (UNEP 2003).
- 173 Ibid.
- 174 Uhde.
- 175 Jiangsu Profile. See also: “Jiangsu Meilan Chemical Co Ltd.” Bloomberg, 2019. <https://www.bloomberg.com/profiles/companies/0180663D:CH-jiangsu-meilan-chemical-co-ltd>. And UNEP 2003.
- 176 World Bank. “ISDS: China HFC-23 Emission Reductions Project,” October 28, 2005. <http://documents.worldbank.org/curated/en/152041468238761916/pdf/340561a1CN1HFC1230ISDS0Updated010128105.pdf>.
- 177 “PESTICIDE REGISTERED LIST,” n.d. <http://www.agripunjab.gov.pk/system/files/PESTICIDE%20REGISTERED%20LIST%20-%20Form%2016.pdf>.
- 178 “TRICHLORFON.” Chemical Hazard Data Commons. Accessed February 15, 2019. <https://commons.healthymaterials.net>.
- 179 Jiangsu Meilan 2017.
- 180 “Company Overview of Hangjin Technology Co., Ltd.” Bloomberg, 2019. <https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=5607188>. See also: “Fangda Chemical Renamed ‘Hangjin Technology’ New East Bank and ‘Fangda Department’ Draw a Clear Line |.” Oriental Wealth Network, April 5, 2018. <http://westdollar.com/sbdrm/finance/news/1354,20180405853516562.html>. And, “Fangda Chemical: 2015 Semi-Annual Report.” finance04.com, August 20, 2015. http://finance04.com/sbdrm/stock/share_disc,2015-08-20,000818,00000000000000by6bd.shtml. And, Fangda Jinhua Chemical Technology Co., Ltd. “Fangda Jinhua Chemical Technology Co., Ltd. 2015 Semi-Annual Report,” 2015. http://finance04.com/sbdrm/pg/acc/CN_DISC/STOCK_TIME/2015/08/20/000818_nb_1201460689.PDF.
- 181 “Petrochemical Industry Projects Look for Co-Operation.” China Daily, December 24, 1997. http://www.chinadaily.com.cn/epaper/html/cd/1997/199712/19971224/19971224014_2.html. (China Daily).
- 182 “Chlor-Alkali Series Products.” Hangjin Technology Co., Ltd, 2019. http://www.hangjintech.com/product_category/ljxlcp.html.
- 183 “Polyvinyl Chloride Series Products (Suspension Method).” Hangjin Technology Co., Ltd, 2019. http://www.hangjintech.com/product_category/jlyxlcpxff.html.
- 184 “China’s Fangda Jinhua to Ramp up Liaoning PO Plant to Full Rate.” ICIS, June 6, 2016. <https://www.icis.com/explore/resources/news/2016/06/06/10004950/china-s-fangda-jinhua-to-ramp-up-liaoning-po-plant-to-full-rate>. (ICIS 6-6-16).
- 185 “China’s Fangda Chemical Posts Lower 2012 Net Profit at \$2.9m.” ICIS, March 21, 2013. <https://www.icis.com/explore/resources/news/2013/03/21/9651890/china-s-fangda-chemical-posts-lower-2012-net-profit-at-2-9m>.
- 186 China Daily.
- 187 “Second Industrial Energy Efficiency and Environment Improvement Project in the People’s Republic of China.” Operations Evaluation Department Asian Development Bank, June 2005. <https://www.adb.org/sites/default/files/evaluation-document/35146/files/ppar-prc-25252.pdf>.
- 188 Ibid.
- 189 “FANGDA JINHUA CHEMICAL TECHNOLOGY CO.,LTD(000818.SZ).” ResearchInChina, 2011. <http://www.researchinchina.com/Htmls/Company/566.html>.
- 190 ICIS 6-6-16.
- 191 “Hangjin Technology Co Ltd (000818.SZ) Company Profile.” Reuters, 2019. <https://www.reuters.com/finance/stocks/company-profile/000818.SZ>.
- 192 “Polyvinyl Chloride Series Products (Suspension Method).” Hangjin Technology Co., Ltd, 2019. http://www.hangjintech.com/product_category/jlyxlcpxff.html.
- 193 “About Hangjin.” Hangjin Technology Co., Ltd, 2019. <http://www.hangjintech.com/aboutus.html>.
- 194 “China Polyurethane Monthly Report.” PU Daily, no. 201407 (July 2014). (PU Daily).
- 195 “Attract Investment.” Liaoning Hongshan Chemical Co., Ltd. Accessed February 15, 2019. <http://en.inhschem.com/zsy.html>.
- 196 “Industrial Chlorobenzene.” Hangjin Technology Co., Ltd, 2019. <http://www.hangjintech.com/product/gylb.html>.

- 197 “Chlor-Alkali Chemical Industry.” HYEC, 2014. http://www.hyec.com/en/project/list.asp?class_fatherid=7&class_id=8&page=4.
- 198 Uhde. See also: “Group Profile.” Ningxia Jinyu Yuan Chemical Group Co.,Ltd, 2018. <http://www.nx-jyy.com/pro.asp?classid=11>.
- 199 “New Projects: April 1-7, 2009.” ICIS, April 12, 2009. <https://www.icis.com/explore/resources/news/2009/04/13/9207595/new-projects-april-1-7-2009/>.
- 200 “Group Profile.” Ningxia Jinyu Yuan Chemical Group Co.,Ltd, 2018. <http://www.nx-jyy.com/pro.asp?classid=11>.
- 201 “Ningxia Jinhaoyuan Chemical Group Co., Ltd.” Ningxia University College of Chemistry and Chemical Engineering, May 20, 2016. <https://chem.nxu.edu.cn/info/1073/3643.htm>.
- 202 “Chlor-Alkali Renovation Project in Ningxia Completed.” Focus on Polyvinyl Chloride, March 2002.
- 203 <https://utech-polyurethane.com/news/shanghai-chlor-alkali-chemical-moves-profit-2017/>)
- 204 Uhde.
- 205 Ho, Jane. “Shanghai Chlor-Alkali Chemical Moves into Profit in 2017.” Urethanes Technology International, February 28, 2018. <https://utech-polyurethane.com/news/shanghai-chlor-alkali-chemical-moves-profit-2017/>.
- 206 “Jinhaoyuan Chemical Group’s Annual Production of 400,000 Tons of Calcium Carbide Method PVC Project.” China City and County Merchants Network, September 19, 2011. <http://www.zgsxzs.com/c/p/21071>.
- 207 “Ningxia Jinhaoyuan Chemical Group Co., Ltd.” Investment Promotion Bureau of Qingtongxia City, Ningxia Hui Autonomous Region, March 14, 2011. <https://web.archive.org/web/20161103175340/http://www.qtxinvest.com/index.php?m=content&c=index&a=show&catid=56&id=250>.
- 208 “VALUE CHAIN CHLORINE.” ICIS Chemical Business, July 4, 2016. <https://www.icis.com/assets/getasset.aspx?itemID=813238>.
- 209 “Group Profile.” Ningxia Jinyu Yuan Chemical Group Co.,Ltd, 2018. <http://www.nx-jyy.com/pro.asp?classid=11>.
- 210 “Polyvinyl Chloride.” Ningxia Jinyu Yuan Chemical Group Co.,Ltd, February 28, 2018. http://www.nx-jyy.com/photo_view.asp?id=854. See also: “Polyvinyl Chloride Resin.” Ningxia Jinyu Yuan Chemical Group Co.,Ltd, 2010. http://200600.nx.cn.hg.customer.hi2000.net/cgi/search-en.cgi?f=product_en+product_en_1_&t=product_en_1_&id=14811.
- 211 NRDC 2017.
- 212 “Company Profile.” Shaanxi Beiyuan Chemical Group Co., Ltd. Accessed February 15, 2019. http://www.shccig.com/all.php?cat_id=1. See also: And “Company Profile.” Shaanxi Beiyuan Chemical Group Co., Ltd., 2018. http://www.sxbychem.com/about.php?cat_id=2036. (Shaanxi Beiyuan).
- 213 Shaanxi Coal and Chemical Industry Group. “Chemical Products.” 6/4/2015. Accessed February 18, 2019. <http://web-cache.googleusercontent.com/search?q=cache:NEvIXyUkDVUJ:www.shccig.com/en/proshow.php%3Fid%3D203+%&c-d=1&hl=en&ct=clink&gl=us>.
- 214 “Domestic PVC Enterprises Factory Price Summary for May 17.” Haohua East China Chemical Corporation, May 18, 2012. <http://www.hhhd.chemchina.com/hhhdn/xwymt/cpxw/webinfo/2012/05/1344232103888349.htm>.
- 215 “China’s Shaanxi Beiyuan Chem Starts up PVC, Caustic Soda Units.” ICIS, November 11, 2010. <https://www.icis.com/explore/resources/news/2010/11/11/9409271/china-s-shaanxi-beiyuan-chem-starts-up-pvc-caustic-soda-units>. (ICIS 11-11-10).
- 216 “Company Profile.” Shaanxi Beiyuan Chemical Group Co., Ltd., 2018. http://www.sxbychem.com/about.php?cat_id=2036. See also: “Affiliated Companies.” Shaanxi Beiyuan Chemical Group Co., Ltd., 2018. http://www.sxbychem.com/all.php?cat_id=2040. And, CNCIC.
- 217 ICIS 11-10-10. See also: ChinaCoalChem. “Monthly Report,” November 2010. <http://www.chinacoalchem.com/en/Sample.pdf>.
- 218 Ibid.
- 219 Wright, Janet. “Global Chlor-Alkali Markets: Have You Heard the News About...” presented at the Abiclor Meeting, Sao Paulo, November 12, 2014.
- 220 “Information Center-Shaanxi Beiyuan Chemical Group Co., Ltd.” Shaanxi Beiyuan Chemical Group Co., Ltd., July 31, 2018. <http://www.sxbychem.com/view.php?id=24252>.
- 221 “Shaanxi Beiyuan Launches 1.0 Million t/a PVC Project.” EBSCO Host Connection, May 26, 2008. <http://connection.ebscohost.com/c/articles/32203743/shaanxi-beiyuan-launches-1-0-million-t-pvc-project>. See also: “Beiyuan Chemical: Innovation Drives Accelerate Running on the Road of High Quality Development.” Shaanxi Beiyuan Chemical Group Co., Ltd., December 25, 2018. <http://www.shccig.com/newshow.php?id=1396644>.
- 222 ICIS 11-11-10.
- 223 Shaanxi Beiyuan.
- 224 “Dezhou Shihua Chemical Co, Ltd - Introduction.” Introduction, n.d. <http://www.hhdz.chemchina.com/dzshen/gywm/gsjj/webinfo/2012/06/1339396704214069.htm>.
- 225 Ibid.
- 226 “PRC: Chemical Industry Energy Efficiency and Emissions Reduction Project.” Environmental Impact Assessment and Due Diligence Report (DRAFT). ChemChina and CHC for the Asian Development Bank, May 2015. <https://www.adb.org/sites/default/files/project-document/159820/47051-002-eia.pdf>. (ADB 2015).
- 227 Ibid. See also: “ChemChina - About Us,” n.d. http://www.hhdz.chemchina.com/dzsh/gywm/gsjj/A440101web_1.htm.

- 228 “Dezhou Shihua Chemical Co, Ltd - Introduction.” Introduction, n.d. <http://www.hhdz.chemchina.com/dzshen/gywm/gsjj/webinfo/2012/06/1339396704214069.htm>.
- 229 ADB 2015.
- 230 Ibid.
- 231 Shen, Zhaobing, Hong Zhao, Yue Liu, Zeyuan Kan, Ping Xing, Jinguang Zhong, and Biao Jiang. “Mercury-Free Nitrogen-Doped Activated Carbon Catalyst: An Efficient Catalyst for the Catalytic Coupling Reaction of Acetylene and Ethylene Dichloride to Synthesize the Vinyl Chloride Monomer.” *Reaction Chemistry & Engineering*. Royal Society of Chemistry, 2018. <https://pubs.rsc.org/en/content/articlelanding/2018/re/c7re00201g/unauth#!divAbstract>.
- 232 “Dezhou Shihua’s Mercury-Free Chloroethylene Synthesis Process Passes Review.” *ChemChina*, August 18, 2014. <https://www.chemchina.com/en/xwymt/jtxw/webinfo/2014/08/1409874233563679.htm>
- 233 ADB 2015.
- 234 Ibid.
- 235 “PRC: Chemical Industry Energy Efficiency and Emission Reduction Project.” Environmental Monitoring Report. Asian Development Bank, 2018. https://www.adb.org/sites/default/files/project-documents/47051/47051-002-emr-en_1.pdf.
- 236 CNCIC.
- 237 NDRC 2017.
- 238 ADB 2015.
- 239 “China’s Hengtong Chem Achieves on-Spec Caustic Soda at New Unit.” *ICIS*, May 3, 2012. <https://www.icis.com/explore/resources/news/2012/05/03/9556032/china-s-hengtong-chem-achieves-on-spec-caustic-soda-at-new-unit/>.
- 240 “Shandong Yangmei Hengtong Chemical Co., Ltd.,” n.d. <https://sdym.dlzb.com/introduce/>.
- 241 “Shandong Yangmeihengtong Chemical Co.,” n.d. <http://www.hengtongchemical.com/>.
- 242 “Wison Engineering Services Co. Ltd. Voluntary Announcement Entering into of Procurement and Construction Contracts with Shandong Yangmei Hengtong Chemicals Company Limited, Shanxi Lu’An Mining (Group) Company Limited.” Wison Engineering Services Co. Ltd., June 10, 2013. <http://doc.irasia.com/listco/hk/wison/announcement/a130625.pdf>.
- 243 “China’s Hengtong Chemical to Start up Caustic Soda Unit in April.” *ICIS*, February 7, 2012. <https://www.icis.com/explore/resources/news/2012/02/07/9529918/china-s-hengtong-chemical-to-start-up-caustic-soda-unit-in-april/>.
- 244 “Wison Engineering Successfully Completes Delivery of Yangmei Hengtong 300kta MTO Plant Project,” February 15, 2015. http://www.wison-engineering.com/en/press/press_each.php?id=p150215.
- 245 “China’s Shandong Yangmei Hengtong Starts up MTO Plant in End-Sept.” *ICIS News*, March 26, 2014. <https://www.icis.com/explore/resources/news/2014/03/26/9766349/china-s-shandong-yangmei-hengtong-starts-up-mto-plant-in-end-sept/>.
- 246 U.S. Department of Energy, Office of Fossil Energy, and National Energy Technology Laboratory. “Proposed Worldwide (Non-U.S.) Gasification Projects Having Commercial Potential.” U.S. Department of Energy, June 2016. (Spreadsheet)
- 247 “Jiangsu Sailboat Accepts World’s Largest Single-Train Coal-To-Chemicals Plant from Honeywell UOP,” March 1, 2018. https://www.uop.com/?press_release=jiangsu-sailboat-accepts-worlds-largest-single-train-coal-to-chemicals-plant-from-honeywell-uop.
- 248 “Shandong Yangmeihengtong Chemical Co - About Us,” n.d. <http://www.hengtongchemical.com/a/gywm/>.
- 249 “Sinopec Qilu Petrochemical Company,” n.d. <http://qlsh.sinopec.com/qlsh/>.
- 250 “Zibo Yongjia Chemical Co., Ltd - Product.” Welcome to Zibo Yongjia Chemical Co., Ltd Website, 2016. <http://www.shuguang-china.com/English/Product/1892651938.html>. See also: “Zibo Yongjia Chemical Co., Ltd - About,” 2016. <http://www.shuguang-china.com/English/About/>.
- 251 CNCIC.
- 252 “About Sinopec.” Sinopec Qilu Company, November 9, 2016. http://www.sinopec.com/listco/en/about_sinopec/subsidiaries/refinery_petrochemical/20161109/news_20161109_378488319963.shtml (Sinopec 11-9-16). See also: Jing, Li. “Toll of Cancer Misery Rises in Shandong’s Petrochemical Villages.” *South China Morning Post*, April 4, 2013. <https://www.scmp.com/news/china/article/1206722/toll-cancer-misery-rises-shandong-s-petrochemical-villages>.
- 253 Sinopec 11-9-16.
- 254 Chemorbis. “Production News,” 2013. (Chemorbis). See also: China Petrochemicals and CNCIC.
- 255 Sinopec 11-9-16. See also: “China’s Qilu PC Expands Refinery, Maintains Cracker Capacity.” *ICIS News*, April 8, 2010. <https://www.icis.com/explore/resources/news/2010/04/08/9348881/china-s-qilu-pc-expands-refinery-maintains-cracker-capacity/>.
- 256 “Caustic Concentration.” *ICIS News*, September 24, 2000. <https://www.icis.com/explore/resources/news/2000/09/25/122607/caustic-concentration/>.
- 257 “Chlor-Alkali Report: VCM Prices on the Rise.” *ICIS News*, December 23, 2002. <https://www.icis.com/explore/resources/news/2003/03/14/187066/chlor-alkali-report-vcm-prices-on-the-rise/>.
And “The Relevant Technology Ionic Membrane Caustic Soda Is Introduced.” Alibaba.com, December 9, 2010. https://resources.alibaba.com/topic/800003915/The_relevant_technology_ionic_membrane_caustic_soda_is_introduced.htm.
- 258 Fryer, Charles. “VCM and PVC in China.” presented at the APIC Meeting, Bangkok, Thailand, July 2006.
- 259 “Qilu Chlor-Alkali Plant Uses Its Marginal Product Advantages to Create Benefits.” *New Technology In Manufacturing Industry*, Computer Manufacturing Industry, Engineering Industries Blog - Ihpindustrial.com, May 23, 2018. <http://www.ihpindustrial.com/2018-05-23-qilu-chlor-alkali-plant-uses-232.html>.

See also:

"Sinopec (China Petroleum & Chemical Corporation) - Intermediate Chemical Products," November 14, 2016. http://www.sinopec.com/listco/products_services/for_business/chemical_products/organic_chemicals/20161114/news_20161114_583232798289.shtml.

And, "Chlor Alkali Monthly Report." CCAON, June 8, 2009. <http://world.ccaon.com/edit/uploadfile/20090609131002886.pdf>.

And, "Qilu Petrochemical chlor-alkali plant actively develops new PVC products." *Polymer.cn*, August 27, 2014. http://www.polymer.cn/polymernews/2014-8-27/_201482794425118.htm.

260 Homepage, Xinfu Group, n.d., <http://www.xinfugroup.com.cn>. Accessed February 19, 2019. (Xinfu Group).

261 "Domestic PVC Enterprises Factory Price Summary for May 17." Haohua East China Chemical Corporation, May 18, 2012. <http://www.hhhd.chemchina.com/hhhdn/xwymt/cpxw/webinfo/2012/05/1344232103888349.htm>.
And, CNCIC.

262 Wright, Janet. "Global Chlor-Alkali Markets: Have You Heard the News About..." presented at the Abiclor Meeting, Sao Paulo, November 12, 2002. <http://clorosur.org/technicalseminar/wp-content/uploads/3-Janet-Wright-Tecnon-Orbichem.pdf>.

263 "China's Shandong Xinfu Chemical Restarts Two PVC Lines." ICIS News, June 19, 2013. <https://www.icis.com/explore/resources/news/2013/06/19/9679754/china-s-shandong-xinfu-chemical-restarts-two-pvc-lines/> (ICIS 6-19-13). See also Xinfu Group, and, CNCIC.

264 "Sinopec (China Petroleum & Chemical Corporation) - Intermediate Chemical Products," November 14, 2016. http://www.sinopec.com/listco/products_services/for_business/chemical_products/organic_chemicals/20161114/news_20161114_583232798289.shtml.

And "Chlor Alkali Monthly Report." CCAON, June 8, 2009. <http://world.ccaon.com/edit/uploadfile/20090609131002886.pdf>.

And, ICIS 6-19-13.

265 "China's Xinfu Huayu Runs New Shandong Caustic Soda Unit at 40%." ICIS News, December 10, 2013. <https://www.icis.com/explore/resources/news/2013/12/10/9734269/china-s-xinfu-huayu-runs-new-shandong-caustic-soda-unit-at-40->

266 "Xingfa Group - PVC," n.d. <http://www.xinfugroup.com.cn/ChanPinJieShao/PVC.aspx>

267 "Government of India Ministry of Commerce & Industry Department of Commerce Directorate General of Anti-Dumping & Allied Duties Udyog Bhawan, New Delhi Final Finding," April 4, 2014. http://www.dgtr.gov.in/sites/default/files/adfin_SSR_Polyvinyl_Chloride_Taiwan_ChinaPR_Indonesia_Japan_KoreaRP_Malaysia_Thailand_USA.pdf. See also: Trade Relief Information Network. "India Finalizes Anti-Dumping Sunset Review of Suspension-Grade PVC in China." China Trade Remedies Information, May 16, 2014. <http://www.cacs.mofcom.gov.cn/cacscms/article/ckys?articleId=123675&type=1>.

268 "Shanghai Chemical Industrial Park - Shanghai Caustic Soda and Polyvinyl Chloride Project," n.d. <http://www.scip.com.cn/xmjs-7.htm>.

269 "Shanghai Chlor-Alkali Chemical Co., Ltd. 2016 Annual Report." Annual. SCAC, March 30, 2017. http://file.finance.sina.com.cn/211.154.219.97:9494/MRGG/CNSESH_STOCK/2017/2017-8/2017-08-28/3694716.PDF.

270 "Company Overview of Shanghai Tianyuan Huasheng Chemical Co Ltd." Bloomberg, n.d. <https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapid=30350124>. (Bloomberg Shanghai Tianyuan). See also: "Shanghai Chemical Industrial Park - Shanghai Caustic Soda and Polyvinyl Chloride Project," n.d. <http://www.scip.com.cn/xmjs-7.htm>. (Shanghai Chemical Industrial Park).

271 Ho, Jane. "Shanghai Chlor-Alkali Chemical Moves into Profit in 2017." Urethanes Technology International, February 28, 2018. <https://utech-polyurethane.com/news/shanghai-chlor-alkali-chemical-moves-profit-2017/>.

272 Bloomberg Shanghai Tianyuan.

273 "150000t/Year Ionic Membrane Caustic Soda DCS System." Shanghai Tianyuan Group Huasheng Chemical Co.,Ltd, January 30, 2012. <http://www.hite.com.cn/en/2012-01-30/142045656.html>. (Hite)

274 Shanghai Chemical Industrial Park.

275 "Shanghai Secco 1.2 Million Tons/Year Ethylene Project." Shanghai Chemical Industry Park, n.d. <http://www.scip.com.cn/xmjs-1.htm>. See also: "Shanghai Chlor-Alkali Chemical Co., Ltd." Chemical Industry Topics (database), n.d. <http://www.knak.jp/munikai/pvc/pvc-china-2n.htm>.

And, "Tianyuan Pre-Commissions Shanghai EDC Plant." *ICIS News*, August 25, 2006. <https://www.icis.com/explore/resources/news/2006/08/25/1087719/tianyuan-pre-commissions-shanghai-edc-plant/>.

And, "New Projects

And Permanent Plant Shutdowns March 19-26, 2012." *ICIS Chemical Business*, 2012. <https://www.icis.com/assets/getasset.aspx?ItemID=791286>.

276 Hite. See also: "Shanghai Chlor-Alkali Eyes Completion of Caojing Complex by April." *ICIS News*, March 21, 2012. <https://www.icis.com/explore/resources/news/2012/03/21/9543500/shanghai-chlor-alkali-eyes-completion-of-caojing-complex-by-april/>.

277 "Shanghai Chlor-Alkali Chemical Co., Ltd. 2016 Annual Report." Annual. SCAC, March 30, 2017. http://file.finance.sina.com.cn/211.154.219.97:9494/MRGG/CNSESH_STOCK/2017/2017-8/2017-08-28/3694716.PDF.

278 "Opening Ceremony Marks Successful Start-up of China's Largest Isocyanates Project in SCIP Aug.18,2006." Shanghai Chemical, August 18, 2006. <http://www.scip.com.cn/en/2.asp?id=161>.

279 "Huntsman and Shanghai Chlor-Alkali Chemical to Double MDI Splitting Capacity at Shanghai Plant." PR Newswire, July 2, 2014. <https://www.prnewswire.com/news-releases/huntsman-and-shanghai-chlor-alkali-chemical-to-double-mdi-splitting-capacity-at-shanghai-plant-265518001.html>.

- 280 Huntsman Corporation. "Form 10-K (2017)," December 31, 2017.
- 281 PU Daily.
- 282 Shanghai Sinopec Mitsui Chemicals, Co., Ltd. "About Sinopec Mitsui." Sinopec & Mitsui. Accessed February 18, 2019. <http://www.ssm-chem.com/english/aboutus.aspx>.
- 283 "China's Shanghai Sinopec Mitsui Chemicals Restarts BPA Unit." *ICIS News*, August 23, 2012. <https://www.icis.com/explore/resources/news/2012/08/23/9589299/china-s-shanghai-sinopec-mitsui-chemicals-restarts-bpa-unit/>. See also: Volkova, Margaret. "BPA Plant Shuts by Sinopec Mitsui." *MRC*, August 20, 2018. http://www.mrcplast.com/news-news_open-342151.html.
- 284 "Polycarbonate (PC)." *Kunststoffe International: Magazine for Plastics*, October 2013. See also: Kurtenbach, Elaine. "Bayer Expands Shanghai Chemicals Plant." *Washington Post*, September 5, 2006. <http://www.washingtonpost.com/wp-dyn/content/article/2006/09/05/AR2006090500168.html>. And, "Covestro Moves from Expansion to Consolidation Mode." *ICIS News*, February 8, 2016. <https://www.icis.com/explore/resources/news/2016/02/08/9967604/covestro-moves-from-expansion-to-consolidation-mode/>. See also: Covestro. "Covestro Roadshow Presentation 2018." 2018. <https://investor.covestro.com/secured/14423>.
- 285 "Introduction to the subsidiary introduction of Golden Road resin," 2019. http://www.jinlgroup.cn/Category/zgsjj_33.html. See also: "August 31, Sichuan Jinlu PVC Temporarily Stabilized." *Westdollar.com*, August 31, 2018. <http://westdollar.com/sbdm/futures/news/2193,20180831938068850.html>.
- 286 "China's Sichuan Province to Close Nine Chemical Plants, Relocate 37." *ICIS News*, March 7, 2018. <https://www.icis.com/explore/resources/news/2018/03/07/10200090/china-s-sichuan-province-to-close-nine-chemical-plants-relocate-37/>.
- 287 "Jinlu Group Co., Ltd - Overview of Business & product Products PVC resin," Jinlu Group. 2019. http://www.jinlgroup.cn/Category/cpgy_11.html. See also: "Jinlu Group Co. Ltd - Business & Product Overview Mix Polyvinyl Chloride Resin," 2019. http://www.jinlgroup.cn/Category/chjlyxs_42.html.
- 288 Zeng, Chuan. "Identification of Price-Fixing Behavior through Electronic Evidence Introduction of PVC Price-Fixing Case." Xiamen: National Development Reform Commission, October 17, 2017.
- 289 "Introduction to the subsidiary introduction of Golden Road resin." Jinlu Group. 2019. http://www.jinlgroup.cn/Category/zgsjj_33.html.
- 290 "Tianyuan Group's Subsidiary Plans to Set up a New Company with 200 Million Yuan." *Westdollar.com*, July 12, 2018. <http://westdollar.com/sbdm/finance/news/1354,20180712905868664.html>.
- 291 Sutherland, Dylan. "List and Description of Trial Groups: Table 3.4." In *China's Large Enterprises and the Challenge of Late Industrialisation*, 200. pg 79: Routledge, 2013.
- 292 "Company Profile : Yibin Tianyuan Group Co., Ltd." *Global Manufacturers*, n.d. <https://www.gmdu.net/corp-866958.html>.
- 293 "Tianyuan Group." Yibin Tianyi New Material Technology Co., LTD., 2018. <https://ty-flooring.com/tianyuan-group/>.
- 294 "Tianyuan Group Historical evolution." Tianyuan Group, n.d. <http://www.ybty.com/01/History.aspx?ModuleCode=0102>.
- 295 "Yibin Tianyuan Group Co. Ltd. Intends to Invest to Launch a 10,000t/a High-Quality Synthetic Rutile Project." *CCM Data & Business Intelligence*, n.d. http://www.cnchemicals.com/Product/Release/7082-yibin_tianyuan_group_co_ltd_intends_to_invest_to_launch_a_10_000t_a_high_quality_synthetic_rutile_project.html.
- 296 Yarime, Masaru. "From End-of-Pipe Technology to Clean Technology: Effects of Environmental Regulation on Technological Change in the Chlor-Alkali Industry in Japan and Western Europe." Universiteit Maastricht, 2003. (Yarime)
- 297 "Shanghai Chlor-Alkali Chemical Co., Ltd." *Chemical Industry Topics (database)*, n.d. <http://www.knak.jp/pvc/pvc-china-2.htm>. (Knak Shanghai).
- 298 Zhang, Allen, Lily Wang, Kevin Lv, and Nancy Hao. "Chlor Alkali Monthly Report." CCAON, August 8, 2006. <http://world.ccaon.com/edit/uploadfile/20080811161656670.pdf>. (CCAON 08-08-06).
- 299 CCAON. "Chlor Alkali Monthly Report," June 8, 2009. <http://world.ccaon.com/edit/uploadfile/20090609131002886.pdf>.
- 300 China Petrochemicals. See also Knak Shanghai.
- 301 "Tianyuan Group - Company Profile." Yibin Tianyuan Group Co. Ltd, n.d. <http://www.ybty.com/01/Main.aspx>.
- 302 "A summary of the 2017 annual report of Yibin Tianyuan Group Co., Ltd." Tianyi Group, 2018. <http://q.stock.sohu.com/newpdf/201831030505.pdf>. See also: "Tianyi - SPC Flooring." Yibin Tianyi New Material Technology Co., LTD., n.d. <https://ty-flooring.com/spc-flooring-2/>.
- 303 Panjiva.
- 304 "Tianyuan Group - Product Center." Yibin Tianyuan Group Co. Ltd, n.d. <http://www.ybty.com/03/Product.aspx>.
- 305 "Yibin Tianyuan Group Co. Ltd. Intends to Invest to Launch a 10,000t/a High-Quality Synthetic Rutile Project." *CCM Data & Business Intelligence*, March 23, 2014. http://www.cnchemicals.com/Product/Release/7082-yibin_tianyuan_group_co_ltd_intends_to_invest_to_launch_a_10_000t_a_high_quality_synthetic_rutile_project.html.
- 306 "Tianyuan - Tetrachloroethylene." Yibin Tianyuan Group Co., Ltd., n.d. <http://www.ybty.com/03/ProtForm.aspx?ModuleCode=0301&id=27>.
- 307 "LG Chem - Subsidiaries." *LG Chem Associates and Joint Ventures*, n.d. <http://www.lgchem.com/global/investment-information/management-information/subsidiaries>.
- 308 "Tianjin LG Bohai Chemical Caustic Dynamics." *info.chem.hc360*, April 22, 2008. <http://info.chem.hc360.com/2008/04/22162831498.shtml>. [See also: Baiinfo. "Aluminum Weekly," August 14, 2014. <http://file.baiinfo.com/File-Managedownload.ashx?FileName=VXBsb2FkRmlsZXNcRU5cQkFJSU5GTyBBbHVtaW51bSBXZWVrbHkucGRm&GUID=79900a39-e5a3-4459-9215-699706f65d02>.

- 309 “LG Bohai Runs Tianjin PVC and Vinyl Chloride Monomer Plants at 70% Due to G20 Meetings.” MRC, June 29, 2016. http://www.mrcplast.com/news-news_open-319291.html.
- 310 Untitled press release. LG Chem Holds Groundbreaking for VCM/EDC Plant in Tianjin, China). LG Chem Ltd., n.d. <http://www.lgchem.com/global/lg-chem-company/information-center/press-release/popup/news-detail-120>.
- 311 “LG Chem Builds Plant for PVC Raw Materials in China.” The Korea Times, September 7, 2007. http://m.koreatimes.co.kr/phone/news/view.jsp?req_newsidx=9754.
- 312 “LG Chem’s Expanded Daesan Cracker Runs at 100%.” *ICIS News*, April 27, 2007. <https://www.icis.com/explore/resources/news/2007/04/27/9024356/lg-chem-s-expanded-daesan-cracker-runs-at-100/>.
- 313 Untitled press release (LG Chem Holds Groundbreaking for VCM/EDC Plant in Tianjin, China). LG Chem Ltd., 2004. <http://www.lgchem.com/global/lg-chem-company/information-center/press-release/popup/news-detail-120>.
- 314 “Tianjin Dagu Chemical Co., Ltd. - Company Introduction.” Tianjin Dagu Chemical Co., Ltd., n.d. https://daguhua.en.ec21.com/company_info.html.
- 315 Herh, Michael. “LG Chem Accelerates Self-Restructuring by Integrating Plants in China.” *Business Korea*, August 5, 2016. <http://www.businesskorea.co.kr/news/articleView.html?idxno=15467>.
- 316 “LG Chem Annual Report 2015.” Annual Report, 2016. [http://www.lgchem.com/upload/file/annual-report/2015_LGChem_AR\[0\].pdf](http://www.lgchem.com/upload/file/annual-report/2015_LGChem_AR[0].pdf).
- 317 “Tianjin Starts Relocating Isocyanates Storage.” *Urethanes Technology*, April 20, 2016. <https://utech-polyurethane.com/news/tianjin-starts-relocating-isocyanates-storage/>.
- 318 Bodeen, Christopher. “22 Dead in Blast Outside Northern China Chemical Plant.” *The Spokesman - Review*, November 27, 2018. <http://www.spokesman.com/stories/2018/nov/27/22-dead-in-blast-outside-northern-china-chemical-p/>.
- 319 “Procurement of 0615-174017030093 ‘Two Chemical’ Relocation Project, 800 Thousand Tons / Year PVC Unit of Tianjin Bohua Chemical Industry Development Co., Ltd.(2).” *www.chinabidding.com*, November 17, 2017. <http://www.chinabidding.com/en/detail/232340384-BidResult.html>.
- 320 “Final Determination and Levy of Anti-Dumping Duties in Anti-Dumping Investigation Against Dumped Imports of Polyvinyl Chloride Resin Into Pakistan Originating In and / Or Exporting From China, Chinese Taipei, South Korea, and Thailand.” Government of Pakistan National Tariff Commission, April 24, 2018. <https://ntc.gov.pk/wp-content/uploads/2018/05/FD-Report-of-PVC-Non-Confidential50.pdf>.
- 321 “Home.” Xinjiang Tianye, n.d. <https://web.archive.org/web/20181108002527/http://en.xj-tianye.com/>. (Xinjiang Tianye Homepage). See also: “Xinjiang Tianye - Chemical Products.” Xinjiang Tianye, n.d. <https://web.archive.org/web/20180629170323/http://en.xj-tianye.com/enHgc/870.jhtml>.
- 322 “China’s Xinjiang Tianye Raises Capacity of PVC Project.” *ICIS News*, November 19, 2004.
- 323 “Xinjiang Tianye: PVC Faucet Re-Starts a New Journey - Xinjiang Tianye.” 2018-06-05, June 5, 2018. <http://www.xj-tianye.com/xwzl/1278.jhtml>. (Xinjiang Tianye 06-05-18).
- 324 Xinjiang Tianye (Group). “Company Overview.” Accessed February 18, 2019. <https://web.archive.org/web/20180707113048/http://www.xj-tianye.com/qyjj.jhtml>.
- 325 Ibid. See also: CNCIC.
- 326 Mexichem 2016.
- 327 Xinjiang Tianye 06-05-18.
- 328 https://www.sourcewatch.org/index.php/Tianye_power_station
- 329 Xinjiang Tianye 06-05-18.
- 330 Huisheng, Zhuang. “Study on the Circular Economic Development Mode of the Xinjiang Tianye Chlor-Alkali Chemical Industrial Park to Reduce Carbon [E]mission in China.” Shanghai Jiao Tong University, 2009.
- 331 CCAON 08-08-06.
- 332 Tianye Chemicals. “Company Profile,” April 14, 2010. <https://tianyechemicals.wordpress.com/2010/04/14/hello-world/>.
- 333 *ICIS News*. “China’s Xinjiang Tianye Suffers Net Loss of CNY216m in 2013.” *ICIS*, March 28, 2014. <https://www.icis.com/explore/resources/news/2014/03/28/9767028/china-s-xinjiang-tianye-suffers-net-loss-of-cny216m-in-2013/>.
- 334 Xinjiang Tianye Homepage.
- 335 Directorate General of Anti-Dumping & Allied Duties, Department of Commerce, and Government of India Ministry of Commerce & Industry. “Final Finding Subject: Final Findings in the Antidumping Investigation Involving Import of Poly Vinyl Chloride (PVC) Suspension Grade from Taiwan, China PR, Indonesia, Japan, Korea RP, Malaysia, Thailand and USA.” *Gazette of India Extraordinary Part 1 Section 1*, December 26, 2007. (Gazette). See also: Yaremenko, Sergey. “Caustic & Chlorine Outlook in Russia / Eastern Europe.” presented at the 4th Russia / CEE ChlorVinyls, Kiev, Ukraine, June 3, 2008.
- 336 NDRC 2017.
- 337 Xu, Wei. “China’s MOFCOM to Conduct Final PVC Dumping Review.” *YiCai Global*, September 28, 2018. <https://www.yicai.com/news/china%E2%80%99s-mofcom-conduct-final-pvc-dumping-review>. (Xu).
- 338 “Company Profile.” Xinjiang Shengxiong Energy Co., Ltd., n.d. <https://hr.bjx.com.cn/vip/shengxiong/>. (Xinjiang Shengxiong Profile).
- 339 “Zhongtai Chemical Merger and Acquisition Integration of Shengxiong Energy.” *China Management Case-sharing Center*, September 2017. <http://www.cmcc-dut.cn/Cases/Detail/2853>.
- 340 Xinjiang Zhongtai 3-17.
- 341 Mexichem 2016.

- 342 Minsheng Securities. "Zhongtai Chemical's... Largest Shareholder." China Chlor-alkali Network (CCAON), August 7, 2015. http://www.ccaon.com/content.asp?id=65898&aim_id_field_true=ecrp_id&inner_table=new_notprod_mrjd.
- 343 Nina Ying Sun. "PVC giant launches PVC capacity, starts new project," *Plastics News China*, December 9, 2016.
- 344 "Toksun Mahatma Power Station." *SourceWatch*, July 10, 2018. https://www.sourcewatch.org/index.php/Toksun_Mahatma_power_station. (SourceWatch Toksun).
- 345 "Introduction to the Shengxiong Group Chlor-Alkali Project." CCAON. Accessed February 18, 2019. <http://www.ccaon.com/advertise/shengxiong/>.
- 346 Xinjiang Shengxiong Profile.
- 347 SourceWatch Toksun.
- 348 Xinjiang Zhongtai 3-17.
- 349 "Shenzhen Stock Exchange: Xinjiang Zhongtai Chemical Co Ltd (002092)." *MarketScreener*, n.d. <https://www.market-screener.com/XINJIANG-ZHONGTAI-CHEMICA-6499313/company/>.
- 350 Knak Shanghai.
- 351 "Xinjiang Zhongtai Fukang Power Station." *SourceWatch*, July 24, 2017. https://www.sourcewatch.org/index.php/Xinjiang_Zhongtai_Fukang_power_station.
- 352 ACN. "Carbide Economics Still Work." *ICIS*, October 23, 2005. <https://www.icis.com/explore/resources/news/2005/10/23/2010631/carbide-economics-still-work>.
- 353 *ICIS News*. "China's Xinjiang Huatai Runs New PVC, Caustic Soda Plants at 65%." *ICIS*, December 1, 2010. <https://www.icis.com/explore/resources/news/2010/12/01/9415420/china-s-xinjiang-huatai-runs-new-pvc-caustic-soda-plants-at-65-/>.
- 354 *Ibid*. See also: *ICIS News*. "China's Xinjiang Zhongtai Chemical Expects 68% Rise in 2011 Profit." *ICIS*, February 27, 2012. <https://www.icis.com/explore/resources/news/2012/02/27/9535921/china-s-xinjiang-zhongtai-chemical-expects-68-rise-in-2011-profit/>.
- 355 MRC Company. "Xinjiang Zhongtai to Shut Two PVC Plant[s] for Maintenance in China." *MRC Plast*, June 23, 2014. http://www.mrcplast.com/news-news_open-292991.html.
- 356 Xinjiang Zhongtai 3-17. Note: The figures in the 2016 annual report are contradicted / exceeded by a since removed company website claim that it had the capacities "by the end of 2016" to produce 2.2 million tons PVC and 1.5 million tons caustic soda. (<http://webcache.googleusercontent.com/search?q=cache:CWFxgWYHMCKJ:www.zthx.com/en/aboutus/index.do?action=content+&cd=3&hl=en&ct=clnk&gl=us>) The China National Chemical Information Center Co. repeats the 2.2 million ton per year figure in a PVC market analysis published in 2018. (CNCIC)
- 357 Tang, Shihua. "Zhongtai Chemical, Jinhui Zhaofeng Energy Team Up to Make a Million Tons of PVC Each Year." *YiCai Global*, September 6, 2018. <https://www.yicaiglobal.com/news/zhongtai-chemical-jinhui-zhaofeng-energy-team-make-million-tons-pvc-each-year>.
- 358 Knak Shanghai.
- 359 MRC Company. "PVC in Russia: 2010 Annual Report." *ICIS*, 2010.
- 360 Panjiva. See also: Sefaco inc. "Home." Accessed February 18, 2019. <http://www.sefaco.com/en/>.
- 361 NDRC 2017.
- 362 *Beijing Business Daily*. "Suspected to Implement Price Monopoly Zhongtai Chemical Was Administratively Punished..." <http://westdollar.com/sbdm/finance/news/1354,20170929782059228.html>.
- 363 Xu.
- 364 Wanhua Chemical. "Wanhua Chemical Group Co., Ltd. 2017 Semi-Annual Report," July 31, 2017. <http://www.whchem.com/uploadfile/2017/1020/20171020045550873.pdf>.
- 365 *ICIS News*. "China's Ningbo Wanhua Chemical to Shut Caustic Soda Units." *ICIS*, November 20, 2015. <https://www.icis.com/explore/resources/news/2015/11/20/9945775/china-s-ningbo-wanhua-chemical-to-shut-caustic-soda-units/>.
- 366 Flue Gas Desulfurization Task Force Report. "Analysis of the Illinois Coal Industry and Electrical Generation in Illinois," December 2018. https://www.eenews.net/assets/2018/12/21/document_ew_01.pdf.
- 367 Wanhua Chemical. "About Us: 2003-2008," 2008. <http://www.whchem.com/en/aboutus/history/2003.shtml>.
- 368 *ICIS News*. "China's Yantai Wanhua Begins Commercial Ops at Ningbo Complex." *ICIS*, December 23, 2010. <https://www.icis.com/explore/resources/news/2010/12/23/9421956/china-s-yantai-wanhua-begins-commercial-ops-at-ningbo-complex/>.
- 369 *ICIS News*. "China's Wanhua Runs Smaller Ningbo MDI Unit at 80%." *ICIS*, January 24, 2017. <https://www.icis.com/explore/resources/news/2017/01/24/10072343/china-s-wanhua-runs-smaller-ningbo-mdi-unit-at-80-/>. (ICIS 1-24-17).
- 370 Robinson, Simon. "Wanhua to up MDI Capacity with New Breakthrough," March 26, 2018. <https://utech-polyurethane.com/news/wanhua-to-up-mdi-capacity-with-new-breakthrough/>.
- 371 Trembley, Jean-Francois. "C&EN Profiles Wanhua Chemical, a Chinese Firm That Made It Big in Urethanes." *C&EN*, May 23, 2016. <https://cen.acs.org/articles/94/i21/CEN-profiles-Wanhua-Chemical-Chinese.html>. (Trembley Wanhua).
- 372 Deutsche Bank. "Wanhua Chemical: A Crown Jewel in Fine Chemicals; Initiating Buy with TP RMB42.0," August 11, 2017. [http://www.hysec.com/f/tsnr/\[D2017\]/2017-08/TSNR100/14/RR_3003768457.pdf](http://www.hysec.com/f/tsnr/[D2017]/2017-08/TSNR100/14/RR_3003768457.pdf). See also Covestro. "Covestro Investor Presentation," September 4, 2015.
- 373 Trembley Wanhua and ICIS 1-24-17.
- 374 Trembley Wanhua.

- 375 Talbot, Jan B., and Sharon D. Fritts. "Report of the Electrolytic Industries for the Year 1991." *Journal of the Electrochemical Society* 139, no. 10 (October 1992): 2981–3018.
- 376 Bhattacharya, Prosun. "Mercury Emissions from Industrial Sources in India and Its Effects in the Environment." In *Mercury Fate and Transport in the Global Atmosphere*, 81–112, 2009. <https://www.researchgate.net/publication/227153535>.
- 377 United Nations Environmental Programme. "Minamata Convention on Mercury. Text and Annexes.," September 2017. <http://www.mercuryconvention.org/Portals/11/documents/Booklets/COP1%20version/Minamata-Convention-booklet-eng-full.pdf>.
- 378 Instead, it requires that manufacturers reduce the use of mercuric catalysts by 50%, from 2010 to 2020, on a per-unit basis. This means that if VCM production by acetylene more than doubles by 2020, a country may still use more mercury than it did in 2010.
- 379 FICCI.
- 380 Shyama, Ghan, and Dinesh Kumarb. "Chemical and Petrochemical Statistics at a Glance - 2017," November 9, 2017. http://chemicals.nic.in/sites/default/files/Chemical%20and%20Petrochemical%20Statistics%20at%20a%20Glance%20-2017_0.pdf.
- 381 Shyama.
- 382 According to Reliance Industries, domestic demand for PVC was 503,000 tons in 1996-97. Reliance Industries Limited. "Creating World-Class Assets for India." Annual Report, 1996-97. http://www.ril.com/getattachment/d356257d-19ee-4bbf-b254-61ee614ada3d/AnnualReport_1996-97.aspx (Reliance 1996-97).
- 383 <http://ficci.in/spdocument/20684/PVC-Report-new.pdf>
- 384 <http://ficci.in/spdocument/20684/PVC-Report-new.pdf>
- 385 Ibid.
- 386 "Chlorine and Building Materials. A Global Inventory of Production Technologies, Markets, and Pollution. Phase 1: Africa, The Americas, and Europe." Healthy Building Network, July 2018. <https://healthybuilding.net/reports/18-chlorine-building-materials-project>.
- 387 "India's Finolex to Expand PVC Pipe Capacity by 40,000 Tonnes." ICIS. Accessed November 27, 2018. <https://www.icis.com/explore/resources/news/2012/02/06/9529542/india-s-finolex-to-expand-pvc-pipe-capacity-by-40-000-tonnes>. See also: "Vinyls Growth on a Roll." ICIS. Accessed November 27, 2018. <https://www.icis.com/explore/resources/news/2004/12/17/638695/vinyls-growth-on-a-roll>. And, Vinythai. "Vinythai Annual Report 2017," 2017. And, FICCI. And, ICIS News. "India's Finolex Resumes 100% Production at VCM-Based PVC Plant." ICIS, September 25, 2012. <https://www.icis.com/explore/resources/news/2012/09/25/9598232/india-s-finolex-resumes-100-production-at-vcm-based-pvc-plant/>. And, "INSIGHT: The Indian PVC Market – the Need for a Benchmark." Icis. Accessed November 27, 2018. <https://www.icis.com/explore/resources/news/2016/08/26/10029281/insight-the-indian-pvc-market-the-need-for-a-benchmark>.
- 388 "Aditya Birla Chemicals to Merge with Grasim Industries - The Economic Times." Accessed November 27, 2018. <https://economictimes.indiatimes.com/industry/indl-goods/svs/cement/aditya-birla-chemicals-to-merge-with-grasim-industries/articleshow/46201139.cms>. (Economic Times)
- 389 "SBP_Factsheet.Pdf." Accessed November 3, 2018. http://www.adityabirlachemicalsindia.com/products/factsheet/SBP_Factsheet.pdf. See also: "Aditya Birla Chemicals Acquires Solaris Chemtech's Chlor-Alkali Business - Times of India." The Times of India. Accessed November 27, 2018. <https://timesofindia.indiatimes.com/business/india-business/Aditya-Birla-Chemicals-acquires-Solaris-Chemtechs-chlor-alkali-business/articleshow/20369648.cms>.
- 390 "Grasim." Accessed November 27, 2018. <http://www.grasim.com/chemicals.aspx>. (Grasim).
- 391 Panjiva.
- 392 "Aditya Birla Chemicals (Thailand) - Our Companies - About Us - Aditya Birla Chemicals." Accessed November 27, 2018. http://www.adityabirlachemicals.com/companies/ab_chem_thailand.html.
- 393 Economic Times.
- 394 Grasim.
- 395 Mahan, Simon, and Jacqueline Savitz. "Cleaning Up: Taking Mercury-Free Chlorine Production to the Bank." Oceana, July 2007. http://oceana.org/sites/default/files/reports/FINAL_Cleaning_Up.pdf. (Cleaning Up).
- 396 "Grasim Industries Ltd in the 'Chemicals' Sector." Aditya Birla Group. Accessed November 28, 2018. <http://www.adityabirla.com/about/grasim-industries-chemicals-sector>. (Aditya Sector).
- 397 Grasim.
- 398 Kat Industrial Consultants Pvt. Ltd. "Project Feasibility Cum Market Survey Report (Project Feasibility Report) On Caustic Soda From Salt By Soda Lime Process." Mann International, 1989.
- 399 Fritts, Sharon, and Ram Gopal. "Report of the Electrolytic Industries for the Year 1992." *Journal of the Electrochemical Society* 140, no. 11 (November 1993): 3337–63. See also: Gopal, Ram, and Daniel Gibbons. "Report of the Electrolytic Industries for the Year 1993." *Journal of the Electrochemical Society* 141, no. 10 (October 1994): 2918–33.
- 400 Ibid. See also: Uhde.
- 401 The Aditya Birla Group. "Redefining the Present Innovating for a Sustainable Future." Sustainability Report, 2015. <http://www.adityabirlachemicals.com/sustainability/pdf/ABG-2015-16-SusRep.pdf>. (SusRep).
- 402 Aditya Sector.

- 403 “Grasim Mulls New Products from Chlor-Alkali.” ICIS. Accessed November 28, 2018. <https://www.icis.com/explore/resources/news/2007/04/25/9023886/grasim-mulls-new-products-from-chlor-alkali>. (ICIS 11-28-18)
- 404 Cleaning Up.
- 405 SusRep.
- 406 ICIS 11-28-18.
- 407 Plunkett, Jack. “Plunkett’s Chemicals, Coatings & Plastics Industry Almanac.” Plunkett Research, Ltd., 2010.
- 408 Lanxess. “Manufacturing Sites: Nadga: Products.” Lanxess India. Accessed February 19, 2019. <http://lanxess.in/manufacturing-sites-india/nagda-site-india/products-nagda-india/>.
- 409 “Aditya Birla Chemicals (India) - Our Companies - About Us - Aditya Birla Chemicals.” Accessed November 28, 2018. http://www.adityabirlachemicals.com/companies/ab_chem_india.html. (Aditya Chemicals).
- 410 Grasim.
- 411 “Kanoriachem - Major Milestones.” Accessed November 28, 2018. <http://www.kanoriachem.com/about-us/major-milestones.html>. (Kanoria Milestones). See also: Sahu, Ramakant, Poornima Saxena, Sapna Johnson, Soundaram Ramathan, and Sugandh Juneja. “Mercury Pollution in Sonbhadra District of Uttar Pradesh and Its Health Impacts,” October 2012. http://cdn.cseindia.org/userfiles/Singrauli_Lab_Report_October_16_Final.pdf. (Sahu).
- 412 Grasim.
- 413 Sahu.
- 414 Pillay, Gautam, and Chao-Peng Chen. “Report of the Electrolytic Industries for the Year 1995.” Journal of the Electrochemical Society 143, no. 10 (October 1996): 3410–27.
- 415 Srinivasan, Venkat, Pankaj Arora, and Premanand Ramadass. “Report on the Electrolytic Industries for the Year 2004.” Journal of the Electrochemical Society 153, no. 4 (April 2006): K1–14.
- 416 “IFC Invests in India’s KCIL Chlor-Alkali Expansion.” ICIS, March 19, 2007 <https://www.icis.com/explore/resources/news/2007/03/19/9014579/ifc-invests-in-india-s-kcil-chlor-alkali-expansion>.
- 417 “India’s KCIL to Expand Chlor-Alkali Operations at Renukoot.” ICIS, April 1, 2004. <https://www.icis.com/explore/resources/news/2004/04/01/570207/india-s-kcil-to-expand-chlor-alkali-operations-at-renukoot>.
- 418 Mishra, V.K. “GIL/ENV/MoEF/16-17/218. Letter to Ministry of Environment Forests, & Climate Change, Government of India. Period of Compliance Report: April 2017 to September 2017.” Grasim Industries, December 20, 2017. <http://www.grasim.com/pdf/environmental-reports/EC-report-renukoot-II.pdf>.
- 419 Aditya Birla Chemicals (India) Limited. “Annual Report,” 2013 2012. http://www.adityabirlachemicalsindia.com/investors/downloads/annual_reports/ABCIL%20annual_report%202012-13.pdf. See also: “EU Chlor-Alkali Plant Conversions Not an Issue – Executive.” ICIS. Accessed November 29, 2018. <https://www.icis.com/explore/resources/news/2013/03/12/9648721/eu-chlor-alkali-plant-conversions-not-an-issue-executive>.
- 420 “Aditya Birla Chemicals | Search.” Accessed November 29, 2018. <http://www.adityabirlachemicals.com/search/index.asp>. See also: Aditya Chemicals. And, Kanoria Milestones.
- 421 “Pick of the Week: DCM Shriram Limited (DCMSHR).” HDFC Securities, August 28, 2017. (HDFC).
- 422 “Chlor Alkali | DCM SHRIRAM.” Accessed November 29, 2018. <https://www.dcmshriram.com/Chlor-Alkali>.
- 423 “INSIGHT: The Indian PVC Market – the Need for a Benchmark.” ICIS. August 26, 2016. <https://www.icis.com/explore/resources/news/2016/08/26/10029281/insight-the-indian-pvc-market-the-need-for-a-benchmark>.
- 424 FICCI.
- 425 Kadam Environmental Consultants. “Brief Summary of Proposed Project by Shriram Vinyl & Chemical Industries,” September 16, 2016. http://environmentclearance.nic.in/writereaddata/FormB/TOR/Brief_Summary/12_Jul_2016_085840503JNBEPLFTBriefSummaryofproject.pdf. (Kadam).
- 426 HDFC.
- 427 “ICRA.” Accessed November 29, 2018. <https://www.icra.in/Rationale/Index?CompanyName=DCM%20Shriram>. See also: “DCM Shriram Nearing Completion Of Indian Chlor-Alkali Expansions.” Market Report Company, June 28, 2006. http://www.mrcplast.com/news-news_open-319227.html. (MRC 6-28-06). And, “About Us | DCM SHRIRAM.” Accessed November 29, 2018. <https://www.dcmshriram.com/about-us>.
- 428 “India’s DCM Shriram to Sell PAC Plant for Rs55m.” ICIS, September 8, 2003. <https://www.icis.com/explore/resources/news/2003/09/08/517447/india-s-dcm-shriram-to-sell-pac-plant-for-rs55m>.
- 429 “India’s DSCL Expands Kota Calcium Carbide Capacity 79%.” ICIS, July 25, 2005. <https://www.icis.com/explore/resources/news/2005/07/25/2003669/india-s-dscl-expands-kota-calcium-carbide-capacity-79->.
- 430 “India’s DCSL Hiking Kota Caustic Soda Capacity to 102 Kt/Yr.” ICIS, June 17, 2005. <https://www.icis.com/explore/resources/news/2005/06/17/686362/india-s-dcsl-hiking-kota-caustic-soda-capacity-to-102-kt-yr>.
- 431 MRC 6-28-06. See also: Kadam.
- 432 “Latest French UPVC Windows & Doors Manufacturer & Installation Cost India - Fenesta.” Accessed December 3, 2018. <https://www.fenesta.com/>. See also: “(3) What Are the Top UPVC Windows and Doors Manufac... - Construction Materials - Quora.” Quora.com, August 26, 2017. <https://construction.quora.com/What-are-the-top-UPVC-Windows-and-Doors-Manufacturers-in-Delhi-NCR>.

- 433 "About Us." Shriram Axiall, 2014. <https://www.shriramaxiall.com/about-us/shriram-axiall.html>. See also: "Infrastructure: Compounding Plant Kota." Shriram Axiall, 2014. <https://www.shriramaxiall.com/about-us/infrastructure.html>. (Kota). And, DCM Shriram. "DCM Shriram Limited Annual Report '16-'17," 2017. <https://www.dcmshriram.com/sites/default/files/AR-2016-17-HRP.pdf>.
And, Anonymous. "Shriram Axiall Private Limited." Westlake Chemical, October 24, 2016. <https://web.archive.org/web/20181108201724/https://www.westlake.com/shriram-axiall-private-limited>.
And, Arora, Rajiv. "Medical Polymers In India: Technological Developments And Growth Pattern." Medical Plastics India. Accessed February 19, 2019. <http://www.medicalplasticsindia.com/mpds/2014/sept/coverstory8.htm>.
- 434 Kota.
- 435 "Calcium Carbide | DCM SHRIRAM." Accessed December 3, 2018. <https://www.dcmshriram.com/calcium-carbide>.
- 436 Mazo, R.S., and E. Munapo. "The Impact of the Presence on Global Markets of Calcium Carbide Originating from China on Other Industry Role Players: The Case of Sa Calcium Carbide." *Risk Governance and Control: Financial Markets & Institutions* 7, no. 4–2 (2017): 234–45. https://www.researchgate.net/publication/322105167_The_impact_of_the_presence_on_global_markets_of_calcium_carbide_originating_from_China_on_other_industry_role_players_the_case_of_sa_calcium_carbide_PTY_LTD.
- 437 "Unit: Shriram Alkali & Chemicals. 749, GIDC, Jhagadia - Bharuch-Gujarat, India." DCM Shriram, June 20, 2018. <http://www.greenco.in/gco/cienvaward18/DCM%20Shriram.pdf>.
- 438 "DCM Shriram Nearing Completion Of Indian Chlor-Alkali Expansions," Market Research Company, June 28, 2016. http://www.mrcplast.com/news-news_open-319227.html. (MRC 06-28-16).
- 439 Ibid. DCM Shriram. "Q3 FY18 Earnings Conference Call Transcript," January 22, 2018. https://www.dcmshriram.com/sites/default/files/DCM%20Shriram%20Limited%20-%20Q3%20%26%209M%20FY18%20-%20Concall%20Transcript_0.pdf.
- 440 "India's DCSL Hiking Kota Caustic Soda Capacity to 102 Kt/Yr." ICIS, June 17, 2005. <https://www.icis.com/explore/resources/news/2005/06/17/686362/india-s-dcsl-hiking-kota-caustic-soda-capacity-to-102-kt-yr>.
- 441 HDFC.
And, MRC 06-28-16.
- 442 "Press Release on Inauguration of the Expanded Capacity and Upgradation of Chlor Alkali & Captive Power at Shriram Alkali & Chemicals Plant at Bharuch, Gujarat." DCM Shriram, March 29, 2017. <https://www.dcmshriram.com/sites/default/files/Press%20Release.pdf>.
- 443 DCM Shriram. "DCM Shriram Ltd. announces its Q1 FY '18 financial results." August 1, 2017. <https://www.dcmshriram.com/sites/default/files/Press%20Release%20Q1%20FY%2018.pdf>.
- 444 "Dahej Complex." Chemicals Technology (blog). 2003. <https://www.chemicals-technology.com/projects/dahej/>. (Dahej).
- 445 Reliance Industries Limited. "Pre-Feasibility Report Proposed Expansion & Debottlenecking of Petrochemical Manufacturing Facility," April 2017. http://environmentclearance.nic.in/writereaddata/Online/TOR/26_Apr_2017_105044523CABI20QBPre-FeasibilityReport.pdf.
- 446 Reliance Industries Limited. "Pre-Feasibility Report for Debottlenecking & Expansion of Petrochemical Plant," March 2016. http://environmentclearance.nic.in/writereaddata/Online/TOR/0_0_15_Mar_2016_1407524731Pre-FeasibilityReport.pdf. (Reliance 3-16).
- 447 Reliance Industries Limited. "Expansion and Debottlenecking of Petrochemical Plant of Dahej Manufacturing Division (DMD), Dist. Bharuch, Gujarat," December 2016. <http://www.environmentclearance.nic.in/writereaddata/EIA/22122016BKO8CVEDMDEIA.pdf>. (Reliance 12-16).
- 448 Reliance 3-16.
- 449 Dahej.
- 450 Ibid.
- 451 Ibid.
- 452 Council of Scientific and Industrial Research (CSIR) - National Environmental Engineering Research Institute (NEERI). "Environmental Impact Assessment for Proposed Coal Based Captive Co-Generation Power Plant of Capacity 270 MW at Dahej Manufacturing Division of Reliance Industries Ltd., Dahej," July 2013. https://www.gpcb.gov.in/pdf/RELIANCE_IND_BRCH_EIA.PDF.
- 453 Reliance 3-16. See also: Reliance 12-16.
- 454 "RIL to Import 1.6 MT Ethane from US." *The Times of India*. August 23, 2017. <https://timesofindia.indiatimes.com/business/india-business/ril-to-import-1-6-mt-ethane-from-us/articleshow/60190877.cms>. (Times of India).
- 455 EIA. See also: Times of India.
And, "Exploration & Production." Reliance Industries Limited. Accessed December 5, 2018. <http://www.ril.com/OurBusinesses/Exploration.aspx>.
- 456 "Media Release: Reliance Commissions World's Largest and Most Complex Ethane Project in Record Time." Reliance Industries Limited, April 19, 2017. <http://www.ril.com/getattachment/f2edaa66-823e-437e-8c50-ad6869b33f08/Reliance-commissions-world%E2%80%99s-largest-and-most-comp.aspx>. (Reliance 4-17)
- 457 Ibid.
- 458 "Environment Clearance Granted For RIL's Rs 13,250 Crore Dahej Petrochemical Expansion." Plastemart, April 5, 2017. <http://www.plastemart.com/news-plastics-information/environment-clearance-granted-for-rils-rs-13-250-crore-dahej-petrochemical-expansion/41986>.

- 459 "Products & Brands." Reliance Industries Limited. Accessed December 5, 2018. <http://www.ril.com/OurCompany/ProductsAndBrands.aspx>. (Reliance Products) and "Polyvinyl Chloride (PVC) - Grades & Applications." Reliance Polymers. Accessed December 5, 2018. http://www.ril.com/DownloadFiles/Polymers/Reon_Leaflet.pdf. (Reliance Polymers)
- 460 "Reliance Comes to Europe for Hazira Funds." ICIS, May 31, 1992. <https://www.icis.com/explore/resources/news/1992/06/01/31505/reliance-comes-to-europe-for-hazira-funds/>. (ICIS 5-31-92)
- 461 Ibid.
- 462 "RELIANCE History." Dynamic Levels. Accessed February 19, 2019. <https://www.dynamiclevels.com/en/reliance-company-history>.
- 463 "India's Reliance Industries to Shut Hazira PVC Plant in January." ICIS, December 8, 2016. <https://www.icis.com/explore/resources/news/2016/12/08/10061056/india-s-reliance-industries-to-shut-hazira-pvc-plant-in-january/>. (ICIS 12-8-16)
- 464 "Hazira Power Station (Reliance)." SourceWatch, November 3, 2017. [https://www.sourcewatch.org/index.php/Hazira_power_station_\(Reliance\)](https://www.sourcewatch.org/index.php/Hazira_power_station_(Reliance)).
- 465 Reliance 1996-97 and Reliance Industries Limited. "Reliance Industries Limited Annual Report 1994-95." Annual Report, 1994-95. http://www.ril.com/getattachment/54dc0c5f-aa14-4a76-ba09-9d7a73b6733d/AnnualReport_1994-95.aspx. (Reliance 1994-95)
- 466 ICIS 5-31-92
- 467 Reliance 1996-97 and Reliance 1994-95.
- 468 Kootungal, Leena. "International Survey of Ethylene from Steam Crackers." *Oil & Gas Journal*, 2014.
- 469 ICIS 12-8-16.
- 470 Reliance 4-17.
- 471 Siripuram, Rohit. "Reliance Industries to Turnaround Hazira Cracker Unit in India to Boost Productivity." *Chemicals Technology*, August 27, 2014. <https://www.chemicals-technology.com/news/newsreliance-industries-to-turnaround-hazira-cracker-unit-in-india-to-boost-productivity-4356072>.
- 472 Suresh, R. "Laying Dedicated Pipelines under Regulation 19(2) of 'Petroleum and Natural Gas Regulatory Board (Authorizing Entities to Lay, Build, Operate or Expand Petroleum and Petroleum Product Pipelines) Regulations, 2010,'" March 7, 2018. <http://www.pngrb.gov.in/pdf/public-notice/App05042018.pdf>.
- 473 Reliance Products and Reliance Polymers.
- 474 "Corporate Information." Asahimas Chemical. Accessed December 19, 2018. <https://www.asc.co.id/?idm=1>. And Volkova, Margaret. "Asahimas Chemical Plans Further VCM Capacity Boost at Cilegon." MRCPlast, May 18, 2016. http://www.mrcplast.com/news-news_open-318224.html.
- 475 Ibid.
- 476 "Process." Asahimas Chemical. Accessed December 19, 2018. <https://www.asc.co.id/?idm=2>.
- 477 "Welcoming 25th ASC Anniversary." Asahimas Chemical. Accessed December 19, 2018. <https://www.asc.co.id/?idm=6>.
- 478 "AGC to Further Enhance Production Capacity of Vinyl Chloride Monomer in Indonesia." Asahi Glass Co., Ltd., May 12, 2016. http://www.agc-chemicals.com/file.jsp?id=160512en_news.pdf. (AGC 5-12-2016)
- 479 "PT Chandra Asri Petrochemical TBK: Company Presentation." presented at the Citi Asia Pacific Investor Conference, Hong Kong, February 8, 2018. <http://www.chandra-asri.com/files/attachments/downloads/Presentasi/2018/Investor%20Update-Citi%20Conference.%208%20Feb%202018.pdf>. (Chandra Asri 2-8-18)
- 480 "Asahimas Chemical to Triple Exports This Year." *The Jakarta Post*, February 13, 2016. <https://www.thejakartapost.com/news/2016/02/13/asahimas-chemical-triple-exports-year.html>. (The Jakarta Post)
- 481 Savinelli, R.F., and H.S. Burney, Jr. "Report of the Electrolytic Industries for the Year 1989." *Journal of the Electrochemical Society* 137, no. 10 (October 1990): 485C-503C.
- 482 Chen, Chao-Peng, and Mark Vreeke. "Report of the Electrolytic Industries for the Year 1996." *Journal of the Electrochemical Society* 144, no. 10 (October 1997): 3674-92.
- 483 "Asahi Glass Plans Coal Plant to Power Production." *Nikkei Asian Review*, April 8, 2015. <https://asia.nikkei.com/Business/Companies/Asahi-Glass-plans-coal-plant-to-power-production>.
- 484 "Kawasaki to Provide Two 150 MW Steam Turbine Power Facilities to Factory in Indonesia." Kawasaki Heavy Industries, Ltd., April 25, 2016. https://global.kawasaki.com/en/corp/newsroom/news/detail/?f=20160425_9174. And imam yah ke 5. *PT. Asahimas Chemical*, 2016. <https://youtu.be/aad2L0qWsyk?t=391>.
- 485 AGC 5-12-2016.
- 486 "Japan's Asahi Glass to Further Expand VCM Capacity in Indonesia." *ICIS News*, May 13, 2016. <https://www.icis.com/explore/resources/news/2016/05/13/9997852/japan-s-asahi-glass-to-further-expand-vcm-capacity-in-indonesia/>. <http://digitalaccess.thejakartaglobe.com/business/asahimas-chemical-to-spend-400m-on-plant-expansion/>
- 487 The Jakarta Post and AGC 5-12-2016.
- 488 "Moody's Assigns First-Time B2 CFR to Sulfindo; Outlook Stable." Moody's, January 29, 2018. https://www.moody's.com/research/Moodys-assigns-first-time-B2-CFR-to-Sulfindo-outlook-stable-PR_378647. (Moody's 1-29-18)
- 489 "Salim on the Move." ICIS, July 13, 1997. <https://www.icis.com/explore/resources/news/1997/07/14/44342/salim-on-the-move>. (ICIS 7-13-97)
- 491 "Company Overview of P.T. Sulfindo Adiusaha." Bloomberg. Accessed February 19, 2019. <https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapid=29250367>.
- 492 "Profile." Sulfindo. Accessed February 19, 2019. <http://www.sulfindo.com/profile.php>. And "Our Product." Sulfindo. Accessed February 19, 2019. <http://www.sulfindo.com/product.php>. (Sulfindo Product).

- 493 Moody's 1-29-18 and Chandra Asri 2-8-18.
- 494 Moody's 1-29-18.
- 495 Cleaning Up.
- 496 "Kobe Steel Consortium Completes Indonesian Caustic Soda Plant: Commercial Production Begins." Kobelco, June 25, 1998. <http://www.kobelco.co.jp/p001/pr980625e.htm>.
- 497 ICIS 7-13-97.
- 498 "SIM, SIP May Merge after SAU Buyout." *ICIS News*, October 10, 2004. <https://www.icis.com/explore/resources/news/2004/10/08/618836/sim-sip-may-merge-after-sau-buyout/>.
- 499 "Indon's Satomo Indovyl Restarts Mothballed PVC Plant." *ICIS News*, October 5, 2004. <https://www.icis.com/resources/news/2004/10/05/618596/indon-s-satomo-indovyl-restarts-mothballed-pvc-plant/>.
- 500 "Chlor Alkali Unit, Monomer Unit, Polymer Unit," January 20, 2008. PT Sulfindo Adiusaha. <https://web.archive.org/web/20080120142518/http://www.sulfindo.com/factory.php>.
- 501 "Chlor Alkali Unit, Monomer Unit, Polymer Unit," August 6, 2012. PT Sulfindo Adiusaha. <https://web.archive.org/web/20120806062736/http://www.sulfindo.com:80/factory.php>. See also: "Chlor Alkali Unit, Monomer Unit, Polymer Unit," PT Sulfindo Adiusaha. Accessed February 19, 2019. <http://www.sulfindo.com/factory.php>. And "Sulfindo Runs Merak EDC Unit at 95% after Debottlenecking Works." ICIS. Accessed February 4, 2019. <https://www.icis.com/explore/resources/news/2012/03/22/9543895/sulfindo-runs-merak-edc-unit-at-95-after-debottlenecking-works>.
- 502 Hyundai Motor Group. "Hyundai Engineering Prepares Base for Expansion into the Power Plant and Infrastructure Market of Indonesia," September 10, 2018. <https://www.hyundaimotorgroup.com/MediaCenter/News/Press-Releases/hegn-indonesia-180919.hub#.W82YhBNKifc>.
- 503 Sulfindo Product.
- 504 Moody's 1-29-18.
- 505 ICIS News. "Indonesia's Sulfindo Keeps EDC Unit Run Rate at 85% for Two Weeks." ICIS, July 5, 2012. <https://www.icis.com/resources/news/2012/07/05/9575438/indonesia-s-sulfindo-keeps-edc-unit-run-rate-at-85-for-two-weeks/>.
- 506 "Exports Rise at Abadan Petchem." Vazin Takvin Company, September 29, 2014. <http://www.vazintakvin.com/index.php/en/component/content/article?id=2562:exports-rise-at-abadan-petchem>.
- 507 International Affairs Department. "Iran's Petrochemical Industry Report. Annual Report." Government of Iran, 2015. http://www.nipc.ir/uploads/annualreport_2014_22893.pdf. See also: "Half of Abadan Petrochemical Complex Products Exported." The Islamic Republic News Agency (IRNA), September 28, 2014. <http://www.irna.ir/en/News/2739112>. And, Larionova, Anna. "Plans for Big Boost in PVC Output." MRC, July 9, 2018. http://www.mrcplast.com/news-news_open-340553.html.
- 508 "Home." National Petrochemical Company (NPC), Accessed February 4, 2019. <http://english.nipc.ir/>.
- 509 "PVC Project in Bandar Imam." Sazeh Consultants. Accessed February 4, 2019. https://sazeh.co/Project/Details/PVC_Project_in_Bandar_Imam.
- 510 ThyssenKrupp Uhde. "Vinyl Chloride and Polyvinyl Chloride," 2015.
- 511 "Arvand Petrochemical Company - Overview." Persian Gulf Petrochemical Industries Co. Accessed February 12, 2019. <http://arvandpvc.ir/en-us/showpage/63/overview>.
- 512 Ibid.
- 513 "Arvand Companys PVC Plant Progresses over 66%." PetroEnergy Information Network, March 7, 2006. <https://www.shana.ir/en/newsagency/81022/Arvand-Companys-PVC-Plant-Progresses-over-66>.
- 514 National Petrochemical Company (NPC). "Iran's Petrochemical Industry Report 2014," 2014. <http://english.nipc.ir/index.aspx?fkeyid=&siteid=71&pageid=3235>.
- 515 Shana. "Arvand Co. Plans to Upgrade Products." SHANA, June 22, 2015. <https://www.shana.ir/en/newsagency/243266/Arvand-Co-Plans-to-Upgrade-Products> (Arvand Upgrade).
- 516 "Iran Adding 0.5m Tonnes of PVC to Be Net Exporter." ICIS News, February 26, 2008. <https://www.icis.com/explore/resources/news/2008/02/26/9103857/iran-adding-0-5m-tonnes-of-pvc-to-be-net-exporter/>. See also: "Iran's Arvand Petrochemical Eyes PVC Exports to China, India." ICIS News, September 20, 2010. <https://www.icis.com/resources/news/2010/09/20/9394487/iran-s-arvand-petrochemical-eyes-pvc-exports-to-china-india/>.
- 517 Arvand Upgrade.
- 518 "Arvand Petrochemical Project Progress near 90%." PetroEnergy Information Network, February 10, 2008. <https://www.shana.ir/en/newsagency/126510/Arvand-Petrochemical-Project-Progress-near-90>.
- 519 "Exports Rise at Abadan Petchem." Vazin Takvin Company, September 29, 2014. <http://www.vazintakvin.com/index.php/en/component/content/article?id=2562:exports-rise-at-abadan-petchem>.
- 520 Yarime. See also: Moorhouse, John. *Modern Chlor-Alkali Technology*. Vol. 8. John Wiley & Sons, 2008. https://books.google.com/books?id=5xBtFC3tRb0C&pg=PA13&ots=_b438vqwLh&dq=japan%20caustic%20soda%20capacity%202000&pg=PA13#v=onepage&q=japan%20caustic%20soda%20capacity%202000&f=false.
- 521 "1. Overview of the Soda Industry." Japan Soda Industry Association, 2017. http://www.jsia.gr.jp/english/data/statistics_01.pdf.
- 522 "Still Some Distance to Go." ICIS, December 18, 2000. <https://www.icis.com/explore/resources/news/2000/12/18/128923/still-some-distance-to-go>

- 523 Taiyo Vinyl Corporation. "Taiyo Vinyl Corporation Takes Measures to Enhance PVC Operations," September 21, 2018. http://www.taiyo-vinyl.co.jp/images_en/news_180921en.pdf.
- 524 Asahi Glass Co., Ltd. "AGC to Establish a System toward Reorganization of Its Domestic Chlor-Alkali Business—Making Hokkaido Soda into a Subsidiary—," February 28, 2012. <http://www.agc.com/en/news/pdf/20120228e.pdf>.
- 525 FICCI.
- 526 "AGC History." AGC Chemicals, 2016. <http://www.agc-chemicals.com/na/en/company/history/index.html>.
- 527 "Japan's Asahi Glass to Shut Chiba Caustic Soda Unit for Turnaround." ICIS, February 9, 2017. <https://www.icis.com/explore/resources/news/2017/02/09/10077374/japan-s-asahi-glass-to-shut-chiba-caustic-soda-unit-for-turnaround>.
- 528 "AGC History." AGC Chemicals, 2016. <http://www.agc-chemicals.com/na/en/company/history/index.html>.
- 529 Yarime. Also: Rudd, E.J., and W. Bruce Darlington. "Report of the Electrolytic Industries for the Year 1980." *Journal of the Electrochemical Society* 128, no. 7 (July 1981): 258C-277C.
- 530 "First Successful Practical Application of Fluorinated Resin Recycling Technology in the World | News | AGC." AGC Chemicals, March 18, 2004. <http://www.agc.com/en/news/detail/20040318e.html>.
- 531 "Japan's Asahi Glass Runs Chiba Chloromethanes Plant at 100%." ICIS, July 23, 2013. <https://www.icis.com/explore/resources/news/2013/07/23/9689811/japan-s-asahi-glass-runs-chiba-chloromethanes-plant-at-100->
- 532 Asahi Glass Co., Ltd. "Asahi Glass Environmental Report," 2001. <http://www.agc.com/en/csr/pdf/2001.pdf>.
- 533 "AGC - Chiba Plant." AGC, n.d. http://www.agc.com/en/csr/sitereport/factory_chiba/index.html.
- 534 "AGC - Kashima Plant." AGC, n.d. http://www.agc.com/en/csr/sitereport/factory_kashima/index.html.
- 535 "Japan's Asahi Glass to Shut Chiba Caustic Soda Unit for Turnaround." ICIS, February 9, 2017. <https://www.icis.com/explore/resources/news/2017/02/09/10077374/japan-s-asahi-glass-to-shut-chiba-caustic-soda-unit-for-turnaround>.
- 536 Yarime.
- 537 Ibid.
- 538 "On the Scales." *ICIS News*, December 19, 1994. <https://www.icis.com/explore/resources/news/1994/12/19/985/on-the-scales/>.
- 539 Bird, Winifred A., and Elizabeth Grossman. "Chemical Aftermath: Contamination and Cleanup Following the Tohoku Earthquake and Tsunami." *Environmental Health Perspectives* 119, no. 7 (July 1, 2011): a290–301. <https://doi.org/10.1289/ehp.119-a290>.
- 540 "Japan's AGC Resumes Normal Ops at Kashima PO Plant." ICIS, June 15, 2017. <https://www.icis.com/explore/resources/news/2017/06/15/10115796/japan-s-agc-resumes-normal-ops-at-kashima-po-plant>.
- 541 ChemSystems. "Propylene Oxide," January 2009. http://thinking.nexant.com/sites/default/files/report/field_attachment_abstract/200811/0708_6_abs.pdf.
- 542 "Product Profile: Epichlorohydrin." ICIS News, October 19, 2003. <https://www.icis.com/explore/resources/news/2003/10/20/527103/product-profile-epichlorohydrin>.
- 543 "Japan's Kashima Chlorine & Alkali, Kashima VCM to Restructure by Dec." ICIS News, November 12, 2012. <https://www.icis.com/explore/resources/news/2012/11/12/9613012/japan-s-kashima-chlorine-alkali-kashima-vcm-to-restructure-by-dec>.
- 544 Ibid.
- 545 "Company's History - Shin-Etsu Chemical." ShinEtsu, 2019. <https://www.shinetsu.co.jp/en/company/history.html>.
- 546 "Japan's Kashima Chlorine & Alkali, Kashima VCM to Restructure by Dec." *ICIS News*, November 12, 2012. <https://www.icis.com/explore/resources/news/2012/11/12/9613012/japan-s-kashima-chlorine-alkali-kashima-vcm-to-restructure-by-dec/>.
- 547 "Japan's Shin-Etsu Chemical Achieves Full Output at Kashima PVC Plant." *ICIS News*, May 31, 2011. <https://www.icis.com/explore/resources/news/2011/05/31/9464487/japan-s-shin-etsu-chemical-achieves-full-output-at-kashima-pvc-plant/>.
- 548 Yarime.
- 549 Uehara, Yosuke. "PVC Star in the Lone Star State." *Journal of Japanese Trade & Industry*, 1987. https://www.jef.or.jp/journal/pdf/cov6_8707.pdf.
- 550 "On the Scales." *ICIS News*, December 19, 1994. <https://www.icis.com/explore/resources/news/1994/12/19/985/on-the-scales/>.
- 551 "Updated Current Situations at the Shin-Etsu Group's Plants Impacted by the Great East Japan Earthquake (10th Report)." ShinEtsu, May 31, 2011. <https://www.shinetsu.co.jp/en/news/archive.php?id=279>.
- 552 "Shin-Etsu Group Current Situation Impacted by the 2011 off the Pacific Coast of Tohoku Earthquake (6th Report)." ShinEtsu, March 25, 2011. <https://www.shinetsu.co.jp/en/news/archive.php?id=266>.
- 553 Tullo, Alexander H. "Shintech Will Spend \$1.5 Billion to Cement Role as Largest Vinyl Producer." *Chemical & Engineering News*, July 25, 2018. <https://cen.acs.org/business/petrochemicals/Shintech-spend-15-billion-cement/96/i31>.
- 554 "Asahi Kasei - Chemicals." Asahi Kasei Corporation. Accessed February 12, 2019. https://www.asahi-kasei.co.jp/asahi/en/services_products/sector/material/chemicals.html.
- 555 Asahi Kasei Corporation. "Asahi Kasei Annual Report 2017." Annual, 2017. https://www.asahi-kasei.co.jp/asahi/en/ir/library/asahikasei_report/pdf/17en.pdf.
- 556 "On the Scales." *ICIS News*, December 19, 1994. <https://www.icis.com/explore/resources/news/1994/12/19/985/on-the-scales/>.
- 557 Pope, Frederick. "Report on the Japanese Chemical Industry." *Far Eastern Survey* 18, no. 25 (1949): 295–298. https://www.jstor.org/stable/3024205?seq=1#page_scan_tab_contents.

- 558 Renner, J., and K.E. Woodard, Jr. "Report of the Electrolytic Industries for the Year 1978." *Journal of the Electrochemical Society* 126, no. 7 (July 1979): 243C-261C. See also: "Membrane Process Chlor-Alkali Electrolysis | Asahi Kasei Corporation." Asahi Kasei Corporation. Accessed February 12, 2019. <http://www.asahi-kasei.co.jp/salt-electrolysis/en/index.html>.
And, "Energy Conservation in the Primary Aluminum and Chlor-Alkali Industries." Hittman Associates, Inc., October 1980. <https://www.osti.gov/servlets/purl/6589904>.
- 559 Leitz, F.B., and C.J. Harke. "Report of the Electrolytic Industries for the Year 1976." *Journal of the Electrochemical Society* 125, no. 1 (January 1978): 5C-22C.
- 560 "Membrane Process Chlor-Alkali Electrolysis | Asahi Kasei Corporation." Asahi Kasei Corporation. Accessed February 12, 2019. <http://www.asahi-kasei.co.jp/salt-electrolysis/en/index.html>.
- 561 Mahan, Simon, and Jacqueline Savitz. "Cleaning Up: Taking Mercury-Free Chlorine Production to the Bank." Oceana, 2007. http://oceana.org/sites/default/files/reports/FINAL_Cleaning_Up.pdf.
- 562 Darlington, W. Bruce, and Marino Y.C. Woo. "Report of the Electrolytic Industries for the Year 1981." *Journal of the Electrochemical Society* 129, no. 8 (August 1982): 275C-294C.
- 563 Asahi Kasei Group. "CRS Report 2013," November 2013. https://www.asahi-kasei.co.jp/asahi/en/csr/library/report/pdf/csr_report2013e.pdf.
- 564 "Asahi Kasei - Product Categories." Asahi Kasei Corporation. Accessed February 12, 2019. https://www.asahi-kasei.co.jp/asahi/en/services_products/sector/material/chemicals.html.
And "PVDC Latex Applications." Asahi Kasei Corporation. Accessed February 12, 2019. http://acpvdc.com/en/latex_application.html.
- 565 "For Tomorrow 2015' Mid-Term Management Initiative (FY2011–2015) Progress and Outlook." Asahi Kasei Corporation, May 21, 2012. http://www.irwebcasting.com/20120521/2/ac3c280c73/media/120521_asahikasei_en_01.pdf.
- 566 Ranta-Korpi, Matti, Pasi Vainikka, Jukka Konttinen, Antti Saarimaa, and Milena Rodriguez. "Ash Forming Elements in Plastics and Rubbers." University of Jyväskylä, 2014. <https://www.vtt.fi/inf/pdf/technology/2014/T186.pdf>.
- 567 "Asahi - Chemicals." Asahi, n.d. <https://www.asahi-kasei.co.jp/advance/en/business/chemical/index.html>.
- 568 "Asahi Kasei - Product Categories." Asahi Kasei Corporation. Accessed February 12, 2019. https://www.asahi-kasei.co.jp/asahi/en/services_products/sector/material/chemicals.html.
- 569 "Japan's Kanegafuchi Chemical Industry Has Changed." *ICIS News*, September 1, 1991. <https://www.icis.com/explore/resources/news/1991/09/02/14309/japan-s-kanegafuchi-chemical-industry-has-changed/>.
- 570 Walton, Clifford W., and Eric J. Rudd. *Proceedings of the Symposium on Energy and Electrochemical Processing for a Cleaner Environment*. The Electrochemical Society, 1998. <https://books.google.com/books?id=5Xy5jHSwgTwC&pg=PA91&lpg=PA91&dq=Takasago+Plant+kaneka+membrane&source=bl&ots=h3nXONSXCe&sig=JFCRzfEdM-NEW-LE72SjfnokZcwY&hl=en&sa=X&ved=0ahUKEwJE1fSCravicAhXsm-AKHb4AN8Q6AEITzAJ#v=onepage&q=Takasago%20Plant%20kaneka%20membrane&f=false>.
- 571 "Kaneka Corporation - Company History." Kaneka Corporation. Accessed February 12, 2019. <http://www.kaneka.co.jp/en/corporate/chronicle/>.
- 572 Yarime.
- 573 "Japan's Kaneka to Shut VCM Plant in Mid-July." *ICIS News*, April 7, 2012. <https://www.icis.com/explore/resources/news/2012/07/04/9575064/japan-s-kaneka-to-shut-vcm-plant-in-mid-july/>.
- 574 "Japan's Kaneka to Shut Takasago PVC Unit on 7 November." *ICIS News*, September 21, 2012. <https://www.icis.com/explore/resources/news/2012/09/21/9597455/japan-s-kaneka-to-shut-takasago-pvc-unit-on-7-november/>.
- 575 Frey, H.E. "Polyvinyl Chloride Resins." CEH, September 1973.
- 576 Mahan, Simon, and Jacqueline Savitz. "Cleaning Up: Taking Mercury-Free Chlorine Production to the Bank." Oceana, 2007. http://oceana.org/sites/default/files/reports/FINAL_Cleaning_Up.pdf.
- 577 Yarime.
- 578 "On the Scales." *ICIS News*, December 19, 1994. <https://www.icis.com/explore/resources/news/1994/12/19/985/on-the-scales/>.
- 579 Yarime.
- 580 "Kaneka Group Responsible Care Report." Kaneka Corporation, 2009. <https://www.kaneka.co.jp/en/csr/pdf/report2009.pdf>.
- 581 Ruddle, Kenneth, William B. Morgan, and James R. Pfafflin. *The Coastal Zone: Man's Response to Change*. CRC Press, 1988. https://books.google.com/books?id=8MEwo773SXE&pg=PA508&lpg=PA508&dq=Takasago+Plant+kaneka+mercury&source=bl&ots=JGpKTjGS14&sig=w9ZVBxrvDi8Qw1VluUBjqMXwMLg&hl=en&sa=X&ved=0ahUKEwi_7—er-qvcAhWjVt8KHtc8CVMQ6AEITzAJ#v=onepage&q=Takasago%20Plant%20kaneka%20mercury&f=false.
- 582 "Japan's Toagosei to Produce PVC for Kaneka in April '11." *ICIS News*, May 25, 2010. <https://www.icis.com/explore/resources/news/2010/05/25/9362212/japan-s-toagosei-to-produce-pvc-for-kaneka-in-april-11/>.
And "Overview | Kaneka Vinyls and Chlor-Alkali Solutions Vehicle," 2017. <http://www.pvc.kaneka.co.jp/en/outline/index.html>.
And "Kaneka Corp. Environmental Management System Certificate of Conformity." Japan Chemical Quality Assurance Ltd., December 14, 2011. <http://vinisol.com.br/docs/KANEKA%20-%20ISO%2014001.pdf>.
- 583 "Dissolution of Okayama Chemical Co., Ltd. as a Joint Venture | Press Releases | Asahi Kasei." Asahi Kasei Corporation. Accessed February 12, 2019. <https://www.asahi-kasei.co.jp/asahi/en/news/2011/e120307.html>.
And Osaka Soda Co., Ltd. "Osaka Soda Report 2017," October 2017. <http://sub.osaka-soda.co.jp/ch/eco/pdf/osreport2017eng.pdf>.

- 584 "Dissolution of Okayama Chemical Co., Ltd. as a Joint Venture | Press Releases | Asahi Kasei." Asahi Kasei Corporation. Accessed February 12, 2019. <https://www.asahi-kasei.co.jp/asahi/en/news/2011/e120307.html>.
- 585 "On the Scales." *ICIS News*, December 19, 1994. <https://www.icis.com/explore/resources/news/1994/12/19/985/on-the-scales/>.
- 586 Yarime. See also: Mahan, Simon, and Jacqueline Savitz. "Cleaning Up: Taking Mercury-Free Chlorine Production to the Bank." *Oceana*, 2007. http://oceana.org/sites/default/files/reports/FINAL_Cleaning_Up.pdf.
- 587 Osaka Soda Co., Ltd. "Osaka Soda Report 2017," October 2017. <http://sub.osaka-soda.co.jp/ch/eco/pdf/osreport2017eng.pdf>.
- 588 "Product Profile: Epichlorohydrin." *ICIS News*, October 19, 2003. <https://www.icis.com/explore/resources/news/2003/10/20/527103/product-profile-epichlorohydrin>.
- 589 "Daiso Co., Ltd. Consolidated Financial Results," May 8, 2015. <http://www.osaka-soda.co.jp/en/release/index/index-7689851182344095530/main/0/link/1431066750.pdf>.
- 590 "Japan's Daiso Shuts Mizushima ECH Plants for Turnaround." *ICIS*, March 24, 2015. <https://www.icis.com/explore/resources/news/2015/03/24/9870514/japan-s-daiso-shuts-mizushima-ech-plants-for-turnaround>.
- 591 "Tokuyama Corporation - Company History." Tokuyama Corporation. Accessed February 12, 2019. <https://www.tokuyama.co.jp/eng/company/overview/history.html>.
- 592 "Tokuyama Corporation - Chlor-Alkali and Vinyl Chloride Business." Tokuyama Corporation. Accessed February 12, 2019. https://www.tokuyama.co.jp/eng/products/chemicals/chlor_alkali/index.html.
- 593 "Japan's Tokuyama to Shut VCM Plant on 1 October for Maintenance." *ICIS*, August 30, 2012. <https://www.icis.com/explore/resources/news/2012/08/30/9591103/japan-s-tokuyama-to-shut-vcm-plant-on-1-october-for-maintenance>.
- 594 Yarime.
- 595 "Tokuyama Corporation - Vinyl Chloride Monomer." Tokuyama Corporation. Accessed February 12, 2019. https://www.tokuyama.co.jp/eng/products/chemicals/chlor_alkali/vinyl_chloride_monomer.html.
- 596 "Tokuyama Corporation - ZEST Series of Polyvinyl Chloride Resin." Tokuyama Corporation. Accessed February 12, 2019. https://www.tokuyama.co.jp/eng/products/chemicals/chlor_alkali/polyvinyl_chloride.html.
- 597 "Japan's Shin Dai-Ichi to Shut Tokuyama PVC Plant in August." *ICIS*, July 26, 2011. <https://www.icis.com/explore/resources/news/2011/07/26/9479832/japan-s-shin-dai-ichi-to-shut-tokuyama-pvc-plant-in-august>.
- 598 "Tokuyama Corporation - Chlor-Alkali and Vinyl Chloride Business." Tokuyama Corporation. Accessed February 12, 2019. https://www.tokuyama.co.jp/eng/products/chemicals/chlor_alkali/index.html.
- 599 IBID
- 600 "Tosoh Corporation - Company Profile, Information, Business Description, History, Background Information on Tosoh Corporation." *Reference for Business*, 2019. <https://www.referenceforbusiness.com/history2/63/Tosoh-Corporation.html#ixzz5MIAnMmlA>.
- 601 "Japan's Tosoh Corp Plans to Restart Nanyo Caustic Soda next Week." *ICIS*, June 8, 2017. <https://www.icis.com/explore/resources/news/2017/06/08/10114006/japan-s-tosoh-corp-plans-to-restart-nanyo-caustic-soda-next-week>.
- 602 "Tosoh Plans Turnarounds at Japan VCM Plants in Mid-Mar, May, Sept." *ICIS*, January 16, 2015. <https://www.icis.com/explore/resources/news/2015/01/16/9853080/tosoh-plans-turnarounds-at-japan-vcm-plants-in-mid-mar-may-sept>.
- 603 "Japan's Tosoh Corp Shuts 200,000 Tonne/Year Nanyo MDI Plant." *ICIS*, September 13, 2016. <https://www.icis.com/explore/resources/news/2016/09/13/10033376/japan-s-tosoh-corp-shuts-200-000-tonne-year-nanyo-mdi-plant>.
- 604 Yarime.
- 605 Yarime.
- 606 Tosoh Corporation. "Responsible Care Report 2004," February 2005.
- 607 Tosoh Corporation. "Annual Report 2017," 2018. <https://www.tosoh.com/investors/annual-reports/2017/strategy>.
- 608 "Taiyo Vinyl - -Company Profile." Taiyo Vinyl Corporation. Accessed February 12, 2019. <http://www.taiyo-vinyl.co.jp/en/company/index.html>. and Taiyo Vinyl Corporation. "Taiyo Vinyl Corporation Takes Measures to Enhance PVC Operations," September 21, 2018. http://www.taiyo-vinyl.co.jp/images_en/news_180921en.pdf.
- 609 "About Tosoh Guangzhou Chemical Industries." Tosoh Corporation, 2019. <https://www.tosoh-guangzhou.com/about-us>.
- 610 Kirihiara, Hirotaka. "Recovery Technology of Halogen from Liquid Waste out of Vinyl Chloride Plant & Others." n.d. http://krcc.or.kr/krccfile/board/051205/KirihiaraHirotaka_TosohCorp.pdf.
- 611 "Tosoh Operations in Asia." Tosoh Corporation, 2019. <https://www.tosoh.com/worldwide/asia-operations>.
- 612 "Tosoh - Methylene Diphenyl Diisocyanate." Tosoh, n.d. <https://www.tosoh.com/our-products/polyurethanes/mdi>.
- 613 "Tosoh - Calcium Hypochlorite (Niclón)." Tosoh, 2019. <https://www.tosoh.com/our-products/chlor-alkali/calcium-hypochlorite>.
- 614 "Tosoh Corporation - Company Profile." *Reference for Business Encyclopedia*, n.d. <https://www.referenceforbusiness.com/history2/63/Tosoh-Corporation.html#ixzz5MIBE60JJ>.
- 615 "Japan's Tosoh Corp Plans to Restart Nanyo Caustic Soda next Week." *ICIS*, June 8, 2017. <https://www.icis.com/explore/resources/news/2017/06/08/10114006/japan-s-tosoh-corp-plans-to-restart-nanyo-caustic-soda-next-week>.
- 616 "Tosoh Plans Turnarounds at Japan VCM Plants in Mid-Mar, May, Sept." *ICIS*, January 16, 2015. <https://www.icis.com/explore/resources/news/2015/01/16/9853080/tosoh-plans-turnarounds-at-japan-vcm-plants-in-mid-mar-may-sept>.
- 617 Taiyo Vinyl Corporation. "Taiyo Vinyl Corporation Takes Measures to Enhance PVC Operations," September 21, 2018. http://www.taiyo-vinyl.co.jp/images_en/news_180921en.pdf.

- 618 "Tosoh Corp to Restart Its Cracker in Yokkaichi after Maintenance." Market Report Company, April 18, 2016. http://www.mrcplast.com/news-news_open-317546.html.
- 619 Yarime.
- 620 Yarime.
- 621 Brelsford, Robert. "Japan's Tosoh Lets Contract to Expand Ethylene Capacity." *Oil & Gas Journal*, December 7, 2017. <https://www.ogj.com/articles/2017/12/japan-s-tosoh-lets-contract-to-expand-ethylene-capacity.html>.
- 622 "Taiyo Vinyl Corp. - PVC - Product Information." Taiyo Vinyl Corporation, 2019. <http://www.taiyo-vinyl.co.jp/en/products/th.html>.
- 623 "History." Engro Polymer & Chemicals Limited. Accessed February 4, 2019. <https://engropolymer.com/company/history.php>. (Engro History)
- 624 "Caustic Soda." Engro Polymer & Chemicals Limited. Accessed February 4, 2019. https://engropolymer.com/business/market_development/caustic_soda.php. (Engro Caustic).
- 625 Engro History.
- 626 Engro Caustic. See also: Siddiqui, Salman. "Engro Polymer Announces Rs10b Expansion Plan." *The Express Tribune*, December 29, 2014. <https://tribune.com.pk/story/1595466/2-engro-polymer-announces-rs10b-expansion-plan/>. (Siddiqui).
- 627 Engro Polymer and Chemicals Limited. "Expansion of Engro Polymer and Chemicals Limited's PVC and VCM Manufacturing Plant," September 6, 2018. [http://epasindh.gov.pk/downloads/dd%20tech/R8E03FIQ%20-%20EIA%20%20\(Main%20Report\)%207.10.18.pdf](http://epasindh.gov.pk/downloads/dd%20tech/R8E03FIQ%20-%20EIA%20%20(Main%20Report)%207.10.18.pdf). (Engro Expansion).
- 628 Engro History. See also: "Engro Polymer & Chemicals Limited ('EPCL') First Analyst Briefing," August 1, 2008. <https://engropolymer.com/pdf/analyst/SECURITYANALYST%201H2008.pdf>.
- 629 "Engro Polymer & Chemicals Limited." *Business Re*, August 18, 2016. <https://fp.brecorder.com/2016/08/2016081876102/>. See also: Engro History. And, Engro Expansion.
- 630 Engro Expansion.
- 631 "GPCA '16: Pakistan Engro PVC Plants Due for Debottlenecking in '18." *ICIS News*, November 29, 2016. <https://www.icis.com/explore/resources/news/2016/11/29/10058443/gpca-16-pakistan-engro-pvc-plants-due-for-debottlenecking-in-18/>. (ICIS 11-29-16).
- 632 Ibid.
- 633 Siddiqui.
- 634 Engro Polymer and Chemicals Limited. "Expansion of Engro Polymer and Chemicals Limited's PVC and VCM Manufacturing Plant," September 6, 2018. [http://epasindh.gov.pk/downloads/dd%20tech/R8E03FIQ%20-%20EIA%20%20\(Main%20Report\)%207.10.18.pdf](http://epasindh.gov.pk/downloads/dd%20tech/R8E03FIQ%20-%20EIA%20%20(Main%20Report)%207.10.18.pdf).
- 635 Ilyas, Faiza. "Serious Concerns Raised over Increased Pollution in Port Qasim." *Dawn*, October 26, 2018. <https://www.dawn.com/news/1441362/serious-concerns-raised-over-increased-pollution-in-port-qasim>.
- 636 "Engro Polymer, Tianchen China Sign Contract to Set up Plant." *The International News*, August 28, 2018. <https://www.thenews.com.pk/print/360257-engro-polymer-tianchen-china-sign-contract-to-set-up-plant>
- 637 Farooq, Mohammad. "Engro Polymer Signs Contract with Tianchen Corp for Integrated Manufacturing Facility." *Pakistan Today*, August 27, 2018. <https://profit.pakistantoday.com.pk/2018/08/27/engro-polymer-signs-contract-with-tianchen-corp-for-integrated-manufacturing-facility>.
- 638 "Engro Polymer Secures \$35mn Ijarah Financing with IFC." *Customnews.Pk Daily*, November 8, 2018. <https://custom-news.pk/2018/11/08/engro-polymer-secures-35mn-ijarah-financing-with-ifc/>.
- 639 "Engro - 50 Years," 2019. <https://www.engro.com/50years/>.
- 640 "PVC (Poly-Vinyl-Chloride)." Engro Polymer & Chemicals, April 6, 2018. <https://engropolymer.com/business/pvc.php>.
- 641 ICIS 11-29-16.
- 642 Siddiqui.
- 643 "Qatar Vinyl Company - About Us," n.d. <http://qapco.com/qvc/>. Also, "Qatar Petroleum to Integrate Qatar Vinyl into QAPCO." *ICIS News*, February 27, 2017. <https://www.icis.com/resources/news/2017/02/27/10082562/qatar-petroleum-to-integrate-qatar-vinyl-into-qapco/>. (ICIS 02-27-17).
- 644 "Achieving Our Full Potential 2015 Integrated Report." Qapco, n.d. <http://www.qapco.com/wp-content/uploads/2016/09/QAPCO-Integrated-Report-2015.pdf>.
- 645 "QP Mulls Qatar Vinyl Company-Qapco Integration." *Gulf Times*, February 26, 2017. <https://www.gulf-times.com/story/534398/QP-mulls-Qatar-Vinyl-Company-Qapco-integration>.
- 646 Gulf Chemicals and Petrochemicals Association. "Qatar Vinyl Company (QVC)," 2019. <https://gpca.org.ae/congulf/blog/qatar-vinyl-company-qvc/>.
- 647 "QP Activities: Subsidiaries and Joint Ventures: Qatar Vinyl Company (QVC)." Qatar Petroleum, 2018. <https://www.qp.com.qa/en/QPActivities/Pages/SubsidiariesAndJointVenturesDetails.aspx?aid=46>.
- 648 Alhadala, Hassan E., and Mahmoud M. El-Halwagi. "Qatar's Chemical Industry: Monetizing Natural Gas." *American Institute of Chemical Engineers*, February 2017. <https://www.aiche.org/sites/default/files/cep/20170238.pdf>. (Alhadala). See also: ICIS 02-27-17. And, "Qatar Chemicals 2016." *Global Business Reports*, n.d. https://www.gbreports.com/wp-content/uploads/2016/02/Qatar_Chemicals_2016_IE.pdf.

- 649 ICIS 02-27-17.
And, Alphadala.
- 650 Norsk Hydro. "Fact Sheet: Hydro in Qatar," April 9, 2010. <https://www.hydro.com/en/press-room/Archive/2010/Qatalum/Fact-sheet-Hydro-in-Qatar/>.
- 651 "Arkema 2013 Reference Document Including Annual Financial Report," 2013. <https://www.arkema.com/export/sites/global/.content/medias/downloads/investorrelations/en/finance/arkema-2013-reference-document.pdf>.
- 652 Weidner, John W., and Marc Doyle. "Report on the Electrolytic Industries for the Year 1999." *Journal of the Electrochemical Society* 147, no. 10 (October 2000): 3953–74.
- 653 Qatar Petroleum. "Mesaieed Industrial City," 2018. <https://www.qp.com.qa/en/QPActivities/QPOperations/Pages/IndustrialCitiesDetails.aspx?IID=6>.
- 654 Chemicals-technology.com. "Mesaieed (Qatar Vinyl)," 2013. <https://www.chemicals-technology.com/projects/mesaieed>.
- 655 "Qatar Vinyl to Finish Expansion Study by Mid-2007." *ICIS News*, March 6, 2007. <https://www.icis.com/explore/resources/news/2007/03/06/9011255/qatar-vinyl-to-finish-expansion-study-by-mid-2007/>. See also: "QVC Expansion 'Not before 2007.'" *Gulf Industry Online*, 2003, Vol. 12 Issue 4 edition. http://www.gulfindustryworldwide.com/news/2142_QVC-expansion-8216not-before-20078217.html.
- 656 Qatar Petroleum. "QVC Products," n.d. <http://qapco.com/qvc/qvc-products/>.
- 657 "Feedstock Prospects Encourage QVC Expansion." *Gulf Industry Online*, 2004, Vol. 13 Issue 5 edition. http://www.gulfindustryonline.com/news/2701_Feedstock-prospects-encourage-QVC-expansion.html.
- 658 Engro Polymer. "Engro Polymer & Chemicals Limited ('EPCL') First Analyst Briefing," August 1, 2008. <https://engropolymer.com/pdf/analyst/SECURITYANALYST%201H2008.pdf>.
- 659 "INSIGHT: Saudi Arabia's Shift to Petrochemicals Underscored by Aramco-SABIC Merger." *ICIS News*, October 26, 2018. <https://www.icis.com/explore/resources/news/2018/10/26/10268852/insight-saudi-arabia-s-shift-to-petrochemicals-underscored-by-aramco-sabic-merger/>. See also: "Sabic to Increase PVC/VCM Capacity at Al Jubail." *ICIS News*, November 13, 2006. <https://www.icis.com/explore/resources/news/2006/11/13/1105365/sabic-to-increase-pvc-vcm-capacity-at-al-jubail/>.
- 660 "SABIC to Acquire Shell Stake in Sadaf Chemicals Joint Venture in Saudi Arabia," January 22, 2017. <https://www.sabic.com/en/news/5862-sabic-to-acquire-shell-stake-in-sadaf-chemicals-joint-venture-in-saudi-arabia>.
- 661 Uhde.
- 662 Spore, Everette, and B.V. Tivak. "Report of the Electrolytic Industries for the Year 1985." *Journal of the Electrochemical Society* 134, no. 4 (April 1987): 179C-219C. (Spore).
- 663 "Merchant Research & Consulting, Ltd. Informs That New Research Reports, Covering Various Chemical Markets Have Been Recently Added at Its Website.," March 29, 2003. <https://www.businesswire.com/news/home/20160329005867/en/New-Chemical-Markets-Research-Reports-Merchant-Research>.
- 664 "SABIC to Turn around Jubail PVC, VCM in Q4 2008." *ICIS News*, August 16, 2007. <https://www.icis.com/explore/resources/news/2007/08/16/9053180/sabic-to-turn-around-jubail-pvc-vcm-in-q4-2008/>.
- 665 "Shell Selling 50% SADAF Stake to SABIC." *Oil & Gas Journal*, January 23, 2017. <https://www.ogj.com/articles/2017/01/shell-selling-50-sadaf-stake-to-sabic.html>.
- 666 "Sadaf Complex Grows in Strength." *Oil & Gas News*, 2004. http://www.oilandgasnewsworldwide.com/Article/15076/Sadaf_complex_grows_in_strength.
- 667 Spore.
- 668 U.S. International Trade Commission. "U.S. Global Competitiveness: Building-Block Petrochemicals and Competitive Implications for Construction, Automobiles, and Other Major Consuming Industries. Report to the Committee on Finance, U.S. Senate, Investigation No. 332-230, Under Section 332(g) of the Tariff Act of 1930." U.S. International Trade Commission, August 1987. <https://www.usitc.gov/publications/332/pub2005.pdf>.
- 669 Uhde.
- 670 "Sadaf Invites Bids for Al Jubail Caustic Soda Revamp." *ICIS News*, March 7, 2000. <https://www.icis.com/explore/resources/news/2000/03/07/107099/sadaf-invites-bids-for-al-jubail-caustic-soda-revamp/>.
- 671 "Sabic to Increase PVC/VCM Capacity at Al Jubail." *ICIS News*, November 13, 2006. See also: "SABIC to Turn around Jubail PVC, VCM in Q4 2008." *ICIS News*, August 16, 2007. <https://www.icis.com/explore/resources/news/2007/08/16/9053180/sabic-to-turn-around-jubail-pvc-vcm-in-q4-2008/>.
- 672 "Sabic Board of Directors Report 2017," 2017. https://www.sabic.com/assets/en/Images/SABIC-Board-of-Directors-Report-en_tcm1010-12628.pdf.
- 673 1985 stats
- 674 "Sadaf Complex Grows in Strength." *Oil & Gas News*, 2004. http://www.oilandgasnewsworldwide.com/Article/15076/Sadaf_complex_grows_in_strength.
- 675 "Taiwan VCM Corporation - Company Overview," 2015. <https://www.tvcm.com.tw/en-us/dirAbout/frmAbout1.aspx>.
- 676 Sahara Petrochemicals and Saudi Arabian Mining Co. "Ma'aden Annual Report 2017," 2017. <https://www.maaden.com.sa/download/2017-Annual-Report-En.pdf>.
- 677 Sahara Petrochemicals and Saudi Arabian Mining Co "The Story of Ma'aden," n.d. <https://www.maaden.com.sa/en/about/history>.
- 678 "Sipchem Reveals Firm Intention for Merger of Equals with Sahara," December 7, 2018. <https://www.refiningandpetrochemicalsme.com/petrochemicals/24494-sipchem-reveals-firm-intention-for-merger-of-equals-with-sahara-company>.

- 679 Chemicals-technology.com. "Sahara Petrochemicals CA-EDC Project," n.d. <https://www.chemicals-technology.com/projects/ca-edc-project/>.
- 680 Sahara Petrochemicals. "Sahara & Ma'aden Petrochemicals Company (SAMAPCO)," 2018. <https://www.saharapcc.com/en/pages.aspx?pageid=45>.
- 681 Ibid. See also: "SAMAPCO Starts Commercial Ops at S Arabia Chlor-Alkali Plant." *ICIS News*, July 1, 2014. <https://www.icis.com/explore/resources/news/2014/07/01/9796651/samapco-starts-commercial-ops-at-s-arabia-chlor-alkali-plant/>.
- 682 "SAMAPCO Starts Commercial Ops at S Arabia Chlor-Alkali Plant." *ICIS News*, July 1, 2014. <https://www.icis.com/explore/resources/news/2014/07/01/9796651/samapco-starts-commercial-ops-at-s-arabia-chlor-alkali-plant/>.
And Ma'aden. Saudi Arabian Mining Company. "Ma'aden Annual Report 2017," 2017. <https://www.maaden.com.sa/download/2017-Annual-Report-En.pdf>.
- 683 Ma'aden. Saudi Arabian Mining Company. "Ma'aden and Al Sahara Affiliate 'SAMAPCO' Exports Its First Shipment of Products," October 9, 2013. https://www.maaden.com.sa/en/news_details/115.
- 684 Wook, Chung. "Korea's Hanwha Chemical Sells CA Factory to Local Rival Unid." *Pulse News*, May 25, 2016. <https://pulsenews.co.kr/view.php?sc=30800021&year=2016&no=375455>.
- 685 "Global Chlor-Alkali Report." IHS Markit, January 30, 2018. <http://www.owichloralkali.com/Portals/0/IHS%20%201-31-2018%20%20Global%20Chlor-Alkali%20-%20Monthly%20Market%20Report%20Issue%2073.pdf>.
- 686 Sisa.
- 687 FICCI.
- 688 Wook, Chung. "Korea's Hanwha Chemical Sells CA Factory to Local Rival Unid." *Pulse News*, May 25, 2016. <https://pulsenews.co.kr/view.php?sc=30800021&year=2016&no=375455>. See also: Unid. "Unid - History," n.d. <http://www.unid.co.kr/eng/aboutus/history.asp>.
- 689 "Hanwha Chemicals 2016 Sustainability Report." Hanwha Chemicals, 2016. http://www.bizulsan.net/e-brochure/pdf/hpc_eng.pdf.
- 690 "Unid - Overview," 2010. http://www.unid.co.kr/eng/product/chemi_flow.asp.
- 691 "Hanwha Chemicals 2016 Sustainability Report." Hanwha Chemicals, 2016. http://www.bizulsan.net/e-brochure/pdf/hpc_eng.pdf.
- 692 Wook, Jung. "Hanwha Chemical to up Caustic Soda Production on Price Hike." *Pulse New*, February 17, 2017. <https://pulsenews.co.kr/view.php?year=2017&no=114664>.
- 693 Ibid. See also: Volkova, Margaret. "Hanwha Chemical to Shut PVC Plant in Ulsan for Maintenance." *MRC*, August 17, 2017. http://www.mrcplast.com/news-news_open-330606.html.
- 694 Hanwha Chemical. "Investor Relations 2012." 2012. <https://slideplayer.com/slide/5982408/>. (Hanwha 2012).
- 695 Hanwha Chemical. "Hanwha Chemical - History and Milestones," 2018. <http://hcc.hanwha.co.kr/en/company/history>. (Hanwha History).
- 696 Ibid.
- 697 Wook, Chung. "Korea's Hanwha Chemical Sells CA Factory to Local Rival Unid." *Pulse News*, May 25, 2016. <https://pulsenews.co.kr/view.php?sc=30800021&year=2016&no=375455>.
- 698 Hanwha Chemical. "Hanwha Chemical Receives New Tech Certificates for Developing Technologies for the Future," December 21, 2016. https://www.hanwha.com/en/news_and_media/press_release/hanwha-chemical-receives-new-tech-certificates-for-developing-techno.html.
- 699 "Unid - History," n.d. <http://www.unid.co.kr/eng/aboutus/history.asp>.
- 700 Min-hee, Jung. "Hanwha Chemical Succeeds in Localizing CPVC." *Business Korea*, March 23, 2016. <http://www.businesskorea.co.kr/news/articleView.html?idxno=14175>.
- 701 "Hanwha L&C - "Materials for the Future," 2011. https://www.hlcc.co.kr/company/hanwhaL&C_eng_web.pdf.
- 702 Gazette.
- 703 Hanwha History.
- 704 "S Korea's Hanwha Runs Newly Expanded Caustic Soda Plant at 100%." *ICIS News*, July 3, 2017. <https://www.icis.com/explore/resources/news/2017/03/07/10085397/s-korea-s-hanwha-runs-newly-expanded-caustic-soda-plant-at-100-/>.
- 705 "S Korea's Hanwha to Shut Ulsan Chlor-Alkali Units in Mid-October." *ICIS News*, July 23, 2012. <https://www.icis.com/explore/resources/news/2015/09/25/9926990/south-korea-s-hanwha-to-shut-pvc-unit-in-october/>.
- 706 "S Korea's Hanwha to Shut Yeosu VCM Plant in Mar; Ulsan Unit in Nov." *ICIS News*, February 6, 2014. <https://www.icis.com/explore/resources/news/2014/02/06/9750698/s-korea-s-hanwha-to-shut-yeosu-vcm-plant-in-mar-ulsan-unit-in-nov/>.
- 707 "South Korea's Hanwha to Shut PVC Unit in October." *ICIS New*, September 25, 2015. <https://www.icis.com/explore/resources/news/2015/09/25/9926990/south-korea-s-hanwha-to-shut-pvc-unit-in-october/>.
- 708 Hanwha 2012.
- 709 Hanwha History.
- 710 "Hanwha to Cut Yeosu Chlor-Alkali Plant Op Rates." *ICIS News*, May 5, 2008. <https://www.icis.com/explore/resources/news/2008/05/05/9121283/hanwha-to-cut-yeosu-chlor-alkali-plant-op-rates/>.
- 711 "S Korea's Hanwha Runs Newly Expanded Caustic Soda Plant at 100%." *ICIS News*, March 7, 2017. <https://www.icis.com/explore/resources/news/2017/03/07/10085397/s-korea-s-hanwha-runs-newly-expanded-caustic-soda-plant-at-100-/>.
- 712 "S Korea's Hanwha Chemical Shuts ECH Plant on Pipe Leakage." *ICIS News*, May 19, 2010. <https://www.icis.com/explore/resources/news/2010/05/19/9360647/s-korea-s-hanwha-chemical-shuts-ech-plant-on-pipe-leakage/>.

- 713 "S Korea's Hanwha to Shut Yeosu ECH Plant on 1 September." *ICIS News*, August 27, 2009. <https://www.icis.com/explore/resources/news/2009/08/27/9243110/s-korea-s-hanwha-to-shut-yeosu-ech-plant-on-1-september/>.
- 714 Hanwha 2012.
- 715 "S Korea's Hanwha Runs Two TDI Lines in Yeosu at Full Capacity." *ICI News*, November 6, 2014. <https://www.icis.com/explore/resources/news/2014/11/06/9835925/s-korea-s-hanwha-runs-two-tdi-lines-in-yeosu-at-full-capacity/>.
- 716 "Hanwha Chemical Acquires Majority Stake in TDI Producer KPX." *PUDaily*, August 21, 2014. <http://www.pudaily.com/News/NewsView.aspx?nid=47251>.
- 717 LG Chem. "Milestone - LG Chem," n.d. <http://www.lgchem.com/global/lg-chem-company/about-lg-chem/company-history>. (LG Milestone).
- 718 "LG Chem Eyes Dec Trial Runs at Expanded EDC, Caustic Soda Units." *ICIS News*, November 29, 2012. <https://www.icis.com/explore/resources/news/2012/11/29/9619292/lg-chem-eyes-dec-trial-runs-at-expanded-edc-caustic-soda-units/>.
- 719 "LG Chem Drops \$2.4 Billion on Upgrades to Yeosu Plant." *Korea Joongang Daily*, July 24, 2018. <http://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3050970>. See also: "LG Chem's Yeosu Cracker Returns to 100% Operating Rate." *ICIS News*, July 24, 2017. <https://www.icis.com/explore/resources/news/2017/07/24/10126663/lg-chem-s-yeosu-cracker-returns-to-100-operating-rate/>. And, LG Milestone.
- 720 "Asia Naphtha Backwardation to Weaken on Cracker Turnarounds." *Osterman Market Intelligence*, March 9, 2015. <http://es.osterman-co.com/omi-old/omi-publica/omi-articles/asia-naphtha-backwardation-to-weaken-on-cracker-turnarounds/>.
- 721 LG Milestone.
- 722 "LG Chem Eyes Dec Trial Runs at Expanded EDC, Caustic Soda Units." *ICIS News*, November 29, 2012. <https://www.icis.com/explore/resources/news/2012/11/29/9619292/lg-chem-eyes-dec-trial-runs-at-expanded-edc-caustic-soda-units/>.
- 723 Gazette.
- 724 Det Norske Veritas (DNV). "DNV Business Assurance. Management System Certificate. Certificate No. 50958-2009-HSO-KOR-DNV. LG Hausys, Ltd. Cheongju Plant.," November 21, 2012.
- 725 Panjiva.
- 726 "Lotte Chemical Company History," n.d. <https://www.lottefinechem.com/en/company/history>.
- 727 Ibid.
- 728 "Caustic Soda Plant Likely to Be Shut by Samsung Fine Chemicals." *MRC*, January 26, 2015. http://www.mrcplast.com/news-news_open-305357.html.
- 729 "Lotte Chemical Company History," n.d. <https://www.lottefinechem.com/en/company/history>. See also: "S Korea's Samsung to Sell Chem Units to Lotte for around \$2.6bn." *ICIS News*, October 30, 2015. <https://www.icis.com/explore/resources/news/2015/10/30/9938393/s-korea-s-samsung-to-sell-chem-units-to-lotte-for-around-2-6bn/>. (ICIS 10-30-15)
- 730 "ETEC E&C: Major Experience 2009." eTEC E&C, 2009. https://www.etcenc.com/common/download.asp?path=bbs/JCMT&file=47_150914133000_69288.pdf&name=Major%5FExperience%2Epdf.
- 731 "Lotte Chemical Company History," n.d. <https://www.lottefinechem.com/en/company/history>.
- 732 Yokogawa. "Fine Chemical Plant Automates All Operations and Reduces Production Losses with Yokogawa's Exapilot," n.d. <https://www.yokogawa.com/library/resources/references/fine-chemical-plant-automates-all-operations-and-reduces-production-losses-with-yokogawas-exapilot/>. See also: "Company Overview of LOTTE Fine Chemical Co., Ltd.," Bloomberg, n.d. <https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=4149357>. And, Samsung Fine Chemicals. "Annual Report 2014." Samsung Fine Chemicals, March 5, 2015. (SFC)
- 733 ICIS 10-30-15
- 734 SFC.
- 735 FICCI.
- 736 Ibid.
- 737 Formosa Group (Cayman) Limited. "U.S.\$1,000,000,000 3.375 per Cent. Guaranteed Notes Due 2025 Unconditionally and Irrevocably Guaranteed by Formosa Plastics Corporation, Nan Ya Plastics Corporation....," April 14, 2015.
- 738 "Formosa Cuts PVC/Chlor-Alkali Ops on Power Outage." *ICIS News*, October 3, 2007. <https://www.icis.com/explore/resources/news/2007/10/03/9067147/formosa-cuts-pvc-chlor-alkali-ops-on-power-outage/>. See also: Volkova, Margaret. "Formosa to Shut PVC Plant in China for Maintenance." *MCR*, September 23, 2015. http://www.mrcplast.com/news-news_open-312201.html.
- 739 "Formosa Plastics Group Annual Report 2011," 2012. http://formosa.co.jp/outline/images/pdf/Formosa_Plastics_Group_E.pdf.
- 740 Formosa Plastic. "Formosa Plastic - Worldwide Company Profile," 2018. <https://listofcompanies.co.in/2012/01/12/formosa-plastics-corporation/>.
- 741 Ibid.
- 742 Formosa Plastic. "Formosa Plastic - Worldwide Company Profile," 2018. <https://listofcompanies.co.in/2012/01/12/formosa-plastics-corporation/>. See also: Human Rights Watch. "Toxic Justice: Human Rights, Justice and Toxic Waste in Cambodia," 1999. <https://www.hrw.org/reports/1999/cambotox/cambo996-01.htm#TopOfPage>.
- 743 Foundation of Taiwan Industry Service (FTIS). "Formosa Plastics Corporation-Jen Wu Plant," 2005. https://www.ftis.org.tw/water/wcopa_2005/eng_company/company06.htm. And SGS Taiwan Ltd. "Formosa Plastics Corp. Jen-Wu Plant OSHAS 18001:2007." SGS Taiwan Ltd. System and Services Certification, 2007. http://www.fpc.com.tw/fpcuploads/pdocument/pdocument_160328152528.pdf.

- 744 ICIS News. "Taiwan's Formosa Plastics to Restart Jenwu VCM Line by 27 June," 06/25/20105. <https://www.icis.com/explore/resources/news/2010/06/25/9371093/taiwan-s-formosa-plastics-to-restart-jenwu-vcmline-by-27-june/>.
- 745 ICIS News. "Taiwan's Formosa Plastics Cuts June PVC Offers by \$30/Tonne," May 24, 2016. <https://www.icis.com/explore/resources/news/2016/05/24/10001045/taiwan-s-formosa-plastics-cuts-june-pvc-offers-by-30-tonne/>.
- 746 ICIS News. "Taiwan's Formosa Plastics Corp Delays Ningbo PVC Project," September 14, 2004. <https://www.icis.com/explore/resources/news/2004/09/14/613170/taiwan-s-formosa-plastics-corp-delays-ningbo-pvc-project/>.
- 747 ICIS News. "Taiwan's FPC Shuns Jenwu Plant Shutdown; PVC Buyers Relieved," March 30, 2010. <https://www.icis.com/explore/resources/news/2010/03/30/9346874/taiwan-s-fpc-shuns-jenwu-plant-shutdown-pvc-buyers-relieved/>.
- 748 ICIS News. "Pollution Charge May Shut Formosa's Jenwu, Taiwan Vinyls Facility," March 26, 2010. <https://www.icis.com/explore/resources/news/2010/03/26/9345993/pollution-charge-may-shut-formosa-s-jenwu-taiwan-vinyls-facility/>.
- 749 Worldwide Company Profile. "Formosa Plastic." 2012. <https://listofcompanies.co.in/2012/01/12/formosa-plastics-corporation/>. (Worldwide)
- 750 ICIS News. "Taiwan's Formosa Plastics Shuts Mailiao PVC Plant for Maintenance," August 19, 2014. <https://www.icis.com/explore/resources/news/2014/08/19/9812172/taiwan-s-formosa-plastics-shuts-mailiao-pvc-plant-for-maintenance/>.
- 751 Polymerupdate. "Mailiao EDC and VCM Plant to Be Shut by FPC," June 11, 2018. <https://www.polymerupdate.com/blog/plastic-news/2018-06-11-Mailiao-EDC-and-VCM-plant-to-be-shut-by-FPC.aspx?id=951&year=2018>.
- 752 ICIS News. "Taiwan's FPC Shuts Chlor-Alkali, Vinyls Units in Mailiao," May 13, 2011. <https://www.icis.com/explore/resources/news/2011/05/13/9459592/taiwan-s-fpc-shuts-chlor-alkali-vinyls-units-in-mailiao/>.
- 753 Worldwide.
- 754 Ibid.
- 755 "Formosa Plastics Group Annual Report 2011," 2012. http://formosa.co.jp/outline/images/pdf/Formosa_Plastics_Group_E.pdf.
- 756 Panjiva.
- 757 ICIS News. "US PPG Acquires 40% Stake in Taiwan Chlorine Industries," April 11, 2017. <https://www.icis.com/explore/resources/news/2017/04/11/10096755/us-ppg-acquires-40-stake-in-taiwan-chlorine-industries/>.
And "Taiwan Chlorine Industries - About Us," 2005. http://www.tciwestlake.com.tw/html/us-about_us.html#2.
And PPG Industries. "PPG Industries Form 10-Q." US Securities and Exchange Commission, July 20, 2018. https://www.marketscreener.com/PPG-INDUSTRIES-14090/pdf/863831/PPG%20Industries_SEC-Filing-10Q-2.pdf.
- 758 "Taiwan Chlorine Industries - About Us," 2005. http://www.tciwestlake.com.tw/html/us-about_us.html#2. (TCI)
- 759 JOC.com. "PPG Industries Starts Up Chlor-Alkali Plant in Taiwan," May 31, 1988. https://www.joc.com/ppg-industries-starts-chlor-alkali-plant-taiwan_19880531.html.
- 760 TCI.
- 761 Cleaning Up.
- 762 Chiyoda Corporation. "Major Projects," 2016. https://www.chiyodacorp.com/projects/pdf/MajorProjects_Dec2016.pdf.
- 763 CPDC. "China Petrochemical Development Corporation Annual Report 2016," May 8, 2017. <https://www.cpdcc.com.tw/uploads/new01496226301.pdf>. See also: CPDC. "China Petrochemical Development Corporation Annual Report 2017," March 27, 2018. <https://www.cpdcc.com.tw/uploads/Files/CPDC%202017%20Annual%20Report.pdf>.
- 764 TCI.
- 765 ICIS News. "Thai Thasco to Decide on New Caustic Soda Line by End-'03," April 25, 2003. <https://www.icis.com/explore/resources/news/2003/04/25/194412/thai-thasco-to-decide-on-new-caustic-soda-line-by-end-03/>.
- 766 Mach, Václav, Jindrich Petrik, Akarapon Teebthaisong, and Autthaporn Ritthichat. "POPs at Four Thai Hot-Spots: Map Ta Phut, Samut Sakhon, Tha Tum, and Khon Kaen," 2017. https://www.researchgate.net/publication/321144245_POps_at_Four_Thai_Hot-spots_Map_Ta_Phut_Samut_Sakhon_Tha_Tum_and_Khon_Kaen.
- 767 "AGC Chemicals - Milestones," 2018. <http://www.acth.co.th/home/about.php?dir=MzA=&pageid=Mg==>.
- 768 ICIS News, August 3, 2003. <https://www.icis.com/explore/resources/news/2003/08/01/508546/thasco-likely-to-pick-ray-ong-for-caustic/>.
- 769 Yarime.
- 770 Yarime.
- 771 "AGC: Japaner prüfen Kapazitätsausbau bei Vinythai." *Plasticker-News*, October 10, 2018
- 772 ICIS News. "Thailand's Thasco to Expand Caustic Soda Plant in Q1 '04," September 27, 2002. <https://www.icis.com/explore/resources/news/2002/09/27/181418/thailand-s-thasco-to-expand-caustic-soda-plant-in-q1-04/>.
- 773 Chemorbis.
- 774 Asahi Glass Co. Ltd. "Asahi Glass to Sell Entire Shares of Thai Plastic and Chemicals Public Company," June 15, 2004. <http://www.agc.com/en/news/detail/20040615e.html>.
- 775 Ninsuvannakul, Prawit, and Apiporn Pasawat. "Submission of the Opinion of the Business on the Tender Offer (Form 250-2) of Thai Plastic and Chemicals Public Company Limited," November 24, 2016. <https://www.set.or.th/set/pdfnews.do?newsId=14799446871000&sequence=0>.
- 776 Solvay. "Solvay Completes the Sale of Its Vinythai Stake to AGC Asahi Glass," February 23, 2017. <https://www.solvay.com/en/press-release/solvay-completes-sale-its-vinythai-stake-agc-asahi-glass>.
And "Asahi Glass to Acquire Vinythai of Solvay Group." *Plastics Insight*, December 9, 2016. <http://www.plasticsinsight.com/asahi-glass-acquire-vinythai-solvay-group/>.
And "Japan's Asahi Glass Buys Solvay Stake in Vinythai." *ICIS News*, December 14, 2016. <https://www.icis.com/explore/resources/news/2016/12/14/10062599/japan-s-asahi-glass-buys-solvay-stake-in-vinythai/>.

- 777 Bertrams, Kenneth, Nicolas Coupain, and Ernst Homburg. *Solvay: History of a Multinational Family Firm*. 470-473: Cambridge University Press, n.d. https://books.google.com/books/about/Solvay.html?id=SmdRQe8aTBcC&printsec=frontcover&source=kp_read_button#v=onepage&q=thailand&f=false.
- 778 "Japan's Asahi Glass Buys Solvay Stake in Vinythai." *ICIS News*, December 14, 2016. <https://www.icis.com/explore/resources/news/2016/12/14/10062599/japan-s-asahi-glass-buys-solvay-stake-in-vinythai/>.
- 779 Vinythai. "Vinythai About Us - Our Plants," 2018. <http://www.vinythai.co.th/en/About%20us/4/Our%20plant/8/>.
- 780 "Vinythai Prepares for VCM Expansion, Signs Ethylene Contract with Thai Olefins." *Plastemart.Com*, March 5, 2005. <http://www.plastemart.com/news-plastics-information/vinythai-prepares-for-vcm-expansion-signs-ethylene-contract-with-thai-olefins/6771>.
- 781 Bertrams, Kenneth, Nicolas Coupain, and Ernst Homburg. *Solvay: History of a Multinational Family Firm*. 470-473: Cambridge University Press, 2013. https://books.google.com/books/about/Solvay.html?id=SmdRQe8aTBcC&printsec=frontcover&source=kp_read_button#v=onepage&q=thailand&f=false.
- 782 Ibid.
- 783 Vinythai. "Vinythai-About Us/Overview," 2018. <http://www.vinythai.co.th/en/About%20us/4/Overview/9/>.
- 784 "AGC: Japaner prüfen Kapazitätsausbau bei Vinythai." *Plasticker-News*, October 10, 2018.
- 785 BeLuThai Member Directory. "Vinyl Thai Public Company Limited," 2019. <https://beluthai.org/vinythai-public-company-limited/>.
- 786 Panjiva.
- 787 Vinythai-About Us/Overview," 2018. <http://www.vinythai.co.th/en/About%20us/4/Overview/9/>. See also: Vinythai. "Vinythai Annual Report 2017," 2017. <http://www.vinythai.co.th/media/www/index/5305741521615262.pdf>.
- 788 Petkim. "Manufacturing-Plants-Chlorine-Alkali-CA-Plant," 2010. <http://www.petkim.com.tr/Sayfa/2/724/MANUFACTURING-PLANTS-CHLORINE-ALKALI-CA-PLANT.aspx>. (Petkim Chlor-Alkali).
- 789 Ibid.
- 790 "Petkim Corporate - About Us," 2010. <http://www.petkim.com.tr/Sayfa/2/790/CORPORATE-ABOUT-US.aspx>.
- 791 Petkim Chlor-Alkali. See also: Petkim. "Manufacturing-Plants-Vinylchloride-Monomer-VCM-Plant," 2010. <http://www.petkim.com.tr/Sayfa/2/725/MANUFACTURING-PLANTS-VINYLCHLORIDE-MONOMER-VCM-PLANT.aspx>. (Petkim VCM).
- 792 Volkova, Margaret. "Start-up of Turkish New USD6B STAR Oil Refinery Delayed to 2019." *MRC*, November 19, 2018. http://www.mrcplast.com/news-news_open-345469.html.
- 793 Petkim VCM. See also: Petkim PVC.
- 794 Petkim Chlor-Alkali.
- 795 Petkim. "4Q17 Results Investor Presentation." Petkim, January 3, 2018. http://www.petkim.com.tr/UserFiles/file/Petkim_4Q17_v2.pdf.

Chlorine and Building Materials: A Global Inventory of Production Technologies and Markets

Phase 2: Asia

Healthy Building Network Mission

To advance human and environmental health by improving hazardous chemical transparency and inspiring product innovation.

Healthy Building Network
1710 Connecticut Avenue, NW 4th Floor
Washington, DC 20009
tel: (202) 741-5717 or (877) 974-2767
info@healthybuilding.net
www.healthybuilding.net

© 2019 Healthy Building Network