The Economic Importance of Chemicals in the APEC Economies

Purpose: Information
Submitted by: SOM Chair
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EXECUTIVE SUMMARY

The Economic Importance of Chemicals in the APEC Economies

Background/Key Issues

- This new document, “The Economic Importance of Chemicals in the APEC Economies”, is being provided to Ministers by the Chemical Dialogue as a point of information. Commissioned by the Chemical Dialogue in 2010, the paper provides a rigorous economic analysis (in easy to understand terms) of the contributions of chemicals to the region’s economy in terms of economic growth, jobs and, importantly, as an enabler of innovative technologies across almost all advanced technology sectors.
- For example, products of chemistry have made it possible to manufacture side door panels for automobiles that are both lighter (i.e., more fuel efficient) and safer.
- In contrast to traditional analyses of the contribution of chemicals to the economy (e.g., direct output and direct jobs) and examining supplier relationships, the study includes downstream industries or final end-users that are dependent on chemicals.
- The study looks at the dependence upon chemistry in various sectors at four levels:
  - Actual production of chemicals (e.g., 59% of global chemical production and 66% of chemical industry jobs are in the APEC region);
  - Industries manufacturing industrial products that purchase chemicals and use them to make products that form the raw materials or intermediate inputs for other industries;
  - Industries manufacturing consumer products and other final goods and which purchase chemicals directly, or buy industrial parts and components based on chemistry; and,
  - Wholesale, retail and service industries based on chemistry-derived products.

Required Action/Decision Point

It is recommended that Ministers:

Welcome the contributions by innovative chemicals to the sustainable development of the APEC economies.
The Economic Importance of the Chemical Industry in the APEC Economies

Economics & Statistics
American Chemistry Council

January 2011
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- Apparel
- Appliances
- Automotive
- Batteries
- Cement
- Computers
- Consumer Electronics
- Footwear
- Furniture
- Jewelry
- Medical Equipment
- Mobile Phones / Telecommunications
- Personal Care Products
- Power Tools
- Rubber Products
- Semiconductors
- Solar Panels
- Wind Energy
Overview of the Global Chemical Industry

The global chemical industry is a crucial component of global economic and social development. It is a science, technology and knowledge-based industry that is essential to a sustainable international economy and improved health and nutrition around the world.

The global chemical industry is not only important in terms of size, but also in terms of its features – the chemistry industry is highly technical and receives significant capital investment. In addition, the business of chemistry is one of the most-knowledge intensive industries in the manufacturing sector – its employees are highly trained and educated.

In 2009, turnover of the global chemical industry was valued at about $3.44 trillion. Industrialized economies account for 58% of world production, but the main growth centers of chemicals sales and production are in emerging markets, especially in Asia and the Pacific. The value of the global business of chemistry by major regional bloc is shown in Figure 1. The chemical industries of APEC member economies\(^1\) account for 59% of global chemical manufacturing operations, more than double that of the EU 27.

Figure 1: APEC as a Share of the $3.44 Trillion Global Chemical Industry

Globalization of the business of chemistry and the development of world markets began in the 1960s, when companies invested in production facilities in foreign markets. World economic growth, the reduction of tariffs and other barriers, the promotion of world trade, as well as advances in telecommunications and transportation, continue to foster this

\(^1\) The APEC economies are Australia; Brunei; Canada; Chile; China; Hong Kong, China; Indonesia; Japan; Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; the Philippines; Russia; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam.
globalization. Furthermore, globalization of investments and markets has spread industry capital resources, technology, and managerial capabilities around the world, resulting in the emergence of multinational chemical companies. Today, some 7.6 million people are directly employed in the APEC chemical industry, about 66% of the world total. Counting indirect employment, that figure rises to more than 22 million people. Including the employment from induced expenditures would result in an overall employment figure several times that.

Table 1: The APEC Chemical Industry in Figures

<table>
<thead>
<tr>
<th>Economies</th>
<th>Shipments ($ billions)</th>
<th>Exports ($ billions)</th>
<th>Imports ($ billions)</th>
<th>Domestic Sales ($ billions)</th>
<th>Employment (thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>$19.4</td>
<td>$12.1</td>
<td>$19.1</td>
<td>$26.4</td>
<td>58</td>
</tr>
<tr>
<td>Brunei</td>
<td>n/a</td>
<td>n/a</td>
<td>0.2</td>
<td>0.2</td>
<td>n/a</td>
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<tr>
<td>Canada</td>
<td>37.3</td>
<td>35.6</td>
<td>39.4</td>
<td>41.1</td>
<td>94</td>
</tr>
<tr>
<td>Chile</td>
<td>8.7</td>
<td>3.3</td>
<td>4.5</td>
<td>9.9</td>
<td>30</td>
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<tr>
<td>China</td>
<td>635.3</td>
<td>89.3</td>
<td>117.1</td>
<td>663.1</td>
<td>4,564</td>
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<tr>
<td>Hong Kong, China</td>
<td>1.1</td>
<td>22.5</td>
<td>26.5</td>
<td>5.1</td>
<td>7</td>
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<tr>
<td>Indonesia</td>
<td>18.3</td>
<td>8.6</td>
<td>12.5</td>
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<td>Japan</td>
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<td>Korea</td>
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<td>Malaysia</td>
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<td>11.9</td>
<td>11.4</td>
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<td>Mexico</td>
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<td>11.1</td>
<td>24.9</td>
<td>57.4</td>
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<tr>
<td>New Zealand</td>
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<td>3.3</td>
<td>4.1</td>
<td>9</td>
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<tr>
<td>Papua New Guinea</td>
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<td>0.2</td>
<td>0.2</td>
<td>n/a</td>
</tr>
<tr>
<td>Peru</td>
<td>4.5</td>
<td>1.1</td>
<td>2.8</td>
<td>6.1</td>
<td>33</td>
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<tr>
<td>Philippines</td>
<td>9.4</td>
<td>1.6</td>
<td>5.7</td>
<td>13.5</td>
<td>46</td>
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<tr>
<td>Russia</td>
<td>63.9</td>
<td>26.1</td>
<td>24.0</td>
<td>61.8</td>
<td>563</td>
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<tr>
<td>Singapore</td>
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<td>16.7</td>
<td>18.1</td>
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<td>Chinese Taipei</td>
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<td>Thailand</td>
<td>8.2</td>
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<td>United States</td>
<td>674.2</td>
<td>148.7</td>
<td>154.0</td>
<td>679.4</td>
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<tr>
<td>Viet Nam</td>
<td>6.2</td>
<td>1.4</td>
<td>9.4</td>
<td>14.2</td>
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<td><strong>Subtotal - APEC</strong></td>
<td><strong>$2,032.9</strong></td>
<td><strong>$560.2</strong></td>
<td><strong>$585.8</strong></td>
<td><strong>$2,058.5</strong></td>
<td><strong>7,555</strong></td>
</tr>
<tr>
<td><strong>APEC/World (%)</strong></td>
<td>59.1%</td>
<td>37.9%</td>
<td>39.6%</td>
<td>59.9%</td>
<td>65.8%</td>
</tr>
<tr>
<td><strong>World Total</strong></td>
<td><strong>$3,438.8</strong></td>
<td><strong>$1,477.8</strong></td>
<td><strong>$1,477.8</strong></td>
<td><strong>$3,438.8</strong></td>
<td><strong>11,483</strong></td>
</tr>
</tbody>
</table>

Note: All figures are for 2009, except some employment (2008)
Sources: UNIDO, CEFIC, ACC, FERI, and Global Insight
World trade is an important element of globalization in the business of chemistry. And the APEC chemical industry exports $560 billion per year in chemistry. Moreover, exports as a share of shipments are gaining.

The global recession had a profound impact on the APEC chemical industry, adversely affecting virtually every economy. Manufacturers of consumer durables, including automobiles, appliances, furniture, and other products that depend directly or indirectly upon the chemical industry, were among the first to be affected by the downturn, which was further intensified by the banking crisis. A recovery emerged in 1st quarter 2009, and volumes in most APEC economies have regained their previous peaks. Growth was centered in the emerging markets, but in a number of economies, recovery has lagged. Although 2011 and 2012 are expected to remain challenging economically, the longer-term prospects for the APEC chemical industry as a key enabler of a sustainable future remain positive. The prospects for dynamic growth are quite favorable.

**Increasing Chemistry Demands from Changing Demographics in APEC Economies**

In addition to its importance fueling new and high-value added production, the products of chemistry support higher living standards throughout the world. While the chemical industry is already a vital part of APEC economies, underlying demographic trends also point to a growth in chemistry demand as populations grow and become more prosperous. According to the US Census Bureau, the combined population of APEC economies will grow 5.6% over the next decade from 2.7 billion in 2010 to 2.9 billion by 2020. The additional 178 million new residents of these economies will consume products containing chemistry, thus boosting demand for chemistry.

In addition, as many APEC economies advance further and as per capita incomes rise, per capita consumption of chemistry products will also increase. Figure 2 shows the per capita demand for chemistry in APEC economies. Chemistry sales in the more developed APEC economies average $1,725 per person. Increasing affluence and a shift toward higher consumption of chemistry and chemistry-containing goods by a growing middle class could substantially boost chemistry demand in APEC economies. To illustrate the potential sales of chemistry products, we estimate that if over the next decade all APEC economies moved to a per capita consumption level of $863, half of the developed economy average, chemistry sales in the region would grow by 56.5% by 2020. The largest impact would be from increasing per capita consumption which would increase consumption by 50.8% assuming constant population. Looking at just the increased chemistry sales from population growth alone given current consumption patterns, sales would increase 5.6%.
Figure 2: Per Capita Chemistry Consumption in the APEC Economies

**Per Capita Chemistry Sales**

Figure 3 shows the potential incremental gain in chemistry sales from these two effects: increasing population and a movement toward higher per capita consumption as consumers in emerging APEC economies become increasingly affluent. The economies with the largest potential gains include China, Indonesia, and the Philippines. Economies that are already consuming at least $823 of chemistry products per capita and have stable or declining population will see no gain. These include Japan, Singapore, New Zealand, Brunei, and Chinese Taipei.
Economic Contributions of the APEC Chemical Industry

The economic contributions of the APEC chemical industry are numerous, though often overlooked in traditional analyses that consider only the direct jobs and output of the industry. In addition to the jobs created directly by the industry, additional jobs are supported by the purchases of the chemical industry and by the subsequent expenditure-induced activity. The chemical industry pays its employees’ wages and salaries and purchases supplies and services (including transportation, contract workers, warehousing, maintenance, accounting, etc.). These supplier businesses, in turn, make purchases and pay their employees. Thus, several rounds of economic spending and re-spending are generated by the chemical industry.

The dependency of the APEC economies on the business of chemistry is much more extensive than standard output and job multipliers derived using input-output (I-O) analysis indicate. The latter primarily focuses on supplier relationships rather than downstream customer industries or final end-uses. Looking downstream, APEC economies depend upon chemistry at four levels:
1. Actual production of chemicals;
2. Industries manufacturing industrial products that purchase chemicals and use them to make products that are the raw materials or intermediate inputs for other industries;
3. Industries manufacturing consumer products and other final goods, which purchase chemicals directly or buy industrial parts and components based on chemistry; and,
4. Wholesale, retail and service industries based on chemistry-derived products.

The robust network of relationships between chemical manufacturing and the consumer is complex, but is key to a number of major consumer products, including apparel, appliances, furniture, home furnishings, light vehicles, and sporting goods, as well as agriculture and construction. Many of the products of the chemical industry in themselves can be classified in some of these other industries. For example, pharmaceuticals and personal care products could very well be classified as industries manufacturing consumer products and other final goods, while agricultural chemicals could be classified as industries manufacturing industrial products used as intermediate inputs for other industries. Services are becoming the means by which chemistry is delivered to the ultimate consumer.

Almost every industry purchases some products and services of chemistry and, therefore, directly depends upon the chemical industry. Indeed, most manufactured goods consume or are processed with chemistry products, either directly or indirectly. We examined industries which typically spend more than 5% of their purchases on chemistry, a rough criterion for dependence. The industries examined (as listed in Table 2) excludes some industries such as aerospace where chemistry is essential for operations. For example, synthetic hydraulic fluids are critical for operation of high-performance aircraft. As a result, the listing undercounts the actual dependency of an economy on chemistry. Typical chemistry-dependent industries in the US are listed in Table 2. For the United States, these industries account for 35% of GDP, 30% of total employment, and 29% of total payrolls.
### Table 2: Chemistry-Dependent Industries in the US

<table>
<thead>
<tr>
<th>Intermediate Goods:</th>
<th>Construction:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Residential Building Contractors</td>
</tr>
<tr>
<td>Oil and Gas Extraction and Metal Mining</td>
<td>Nonresidential Building Contractors</td>
</tr>
<tr>
<td>Water and Sewage Treatment</td>
<td>Specialty Trade Contractors</td>
</tr>
<tr>
<td>Textiles and Fabrics</td>
<td></td>
</tr>
<tr>
<td>Engineered Wood Products</td>
<td></td>
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<tr>
<td>Paper and Paper Products</td>
<td></td>
</tr>
<tr>
<td>Petroleum Products</td>
<td></td>
</tr>
<tr>
<td>Rubber and Plastic Products</td>
<td></td>
</tr>
<tr>
<td>Nonmetallic Mineral Products</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>Windows and Doors</td>
<td></td>
</tr>
<tr>
<td>Metal Coating</td>
<td></td>
</tr>
<tr>
<td>Industrial Machinery</td>
<td></td>
</tr>
<tr>
<td>Commercial and Service Industry Machinery</td>
<td></td>
</tr>
<tr>
<td>Ventilation and HVAC Equipment</td>
<td></td>
</tr>
<tr>
<td>Semiconductors and Electronic Components</td>
<td></td>
</tr>
<tr>
<td>Electrical Equipment and Components</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wholesale Distribution:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Wholesalers</td>
<td></td>
</tr>
<tr>
<td>Druggist Goods Wholesalers</td>
<td></td>
</tr>
<tr>
<td>Farm Supplies</td>
<td></td>
</tr>
<tr>
<td>Paint Wholesalers</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Services:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing Labs</td>
<td></td>
</tr>
<tr>
<td>Specialized Design Services</td>
<td></td>
</tr>
<tr>
<td>Scientific Research &amp; Development (R&amp;D) Centers</td>
<td></td>
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<tr>
<td>Photographic Services</td>
<td></td>
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<tr>
<td>Veterinary Services</td>
<td></td>
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<tr>
<td>Facilities Support Services</td>
<td></td>
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<tr>
<td>Document Preparation Services</td>
<td></td>
</tr>
<tr>
<td>Services to Buildings and Dwellings</td>
<td></td>
</tr>
<tr>
<td>Waste Management &amp; Remediation Services</td>
<td></td>
</tr>
<tr>
<td>Health Care Services</td>
<td></td>
</tr>
<tr>
<td>Auto Repair</td>
<td></td>
</tr>
<tr>
<td>Personal and Laundry Services</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumer and Other Final Products:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Food, Beverages and Tobacco</td>
<td></td>
</tr>
<tr>
<td>Textile Mill Products</td>
<td></td>
</tr>
<tr>
<td>Apparel and Leather Products</td>
<td></td>
</tr>
<tr>
<td>Printing</td>
<td></td>
</tr>
<tr>
<td>Book and Periodical Publishing and Software</td>
<td></td>
</tr>
<tr>
<td>Audio/Visual Recording</td>
<td></td>
</tr>
<tr>
<td>Computers</td>
<td></td>
</tr>
<tr>
<td>Household Appliances</td>
<td></td>
</tr>
<tr>
<td>Mobile homes</td>
<td></td>
</tr>
<tr>
<td>Light Vehicles and Parts</td>
<td></td>
</tr>
</tbody>
</table>

The analysis of industries that were dependent upon chemistry that was developed for the United States was extended for the APEC economies. It is based on those industries identified as being chemistry-intensive and their relative share of value-added compared to the overall economy. Sources include the IHS Global Insight World Industry Service (WIS) and various governmental and intra-governmental agencies. Because of the paucity of detailed industry data, downward adjustments were made to be conservative, and the results of this analysis are intended to be a rough guide on the chemistry-dependency of the various APEC economies.
The results of this analysis of the share of APEC economies dependent upon chemistry are presented in Figure 4. The analysis indicates that on average about 36% of the APEC economies are comprised of industries dependent upon the chemical industry. One factor accounting for the large share of emerging economies’ share of GDP arising from chemistry-dependent industries reflects the relatively large agricultural sector in those economies as well as mining. An allowance was made for subsistence farming, which may not be chemistry-intensive. That is, downward adjustments were made to be conservative.

The APEC Chemical Industry as a Solutions Provider
Chemistry contributes to a strong and vibrant economy, and plays a vital role in supporting emerging technologies. From a qualitative viewpoint, the role that chemistry plays in many key emerging technologies within the APEC region is presented in this section.

Agriculture: Despite rapid industrial development and the emergence of advanced financial and other service sectors, agriculture remains vitally important to most East Asian economies. In modern agriculture, chemistry contributes 29% of the value of material inputs that go into production. Chemistry is used in the agricultural industry in a number of ways:
Twenty-one chemical elements are known to be essential to normal development and growth of plants and trees, particularly nitrogen (often supplied in the form of ammonia), phosphorus and potassium.

Fertilizers are various combinations of three basic elements (nitrogen, phosphorous and potassium) that are added to soil to replace or supplement essential nutrients to promote plant (and especially crop) growth. Phosphorous and potassium are respectively found in phosphate rock and potash.

Commercial fertilizers have helped farmers produce more abundant crops. For example, 37% of US agriculture production is directly attributable to the use of fertilizers.

There are more than one million harmful insects and some 1,500 plant diseases that compete with and damage crops — resulting in lower yields, higher prices, potentially poorer quality food and increased dependence on foreign imports for many APEC economies.

Crop protection products include fungicides, herbicides, insecticides, miticides, and pesticides that help control weeds, harmful insect pests, and plant diseases that afflict crops as well as disinfectants, rodenticides, and other products used to control germs and pests.

**Aircraft:** China’s aircraft industry is an emerging player. Although chemistry contributes only 4% of the value of material inputs that go into aircraft production, its role is critical. Chemistry is used in the aircraft industry in a number of ways:

- Caustic soda and sodium aluminum fluoride are used to convert bauxite ore into corrosion-resistant aluminum, which is a lightweight structural material with a greater strength-to-weight ratio than most other metals and materials — allowing for less fuel consumption.
- Polycarbonate (made from bisphenol A and phosgene) can be made into a high-grade engineering thermoplastic — a plastic that can withstand high mechanical stress, temperature extremes, and a hostile environment. This resin is used to reduce the weight of aircraft and to provide impact resistance, design flexibility, corrosion resistance and cost savings from parts consolidation. Polycarbonate aircraft windshields are transparent and impact-resistant.
- Synthetic rubber is heat and oil-resistant, since it is also very strong, it can be safely used for aircraft hosing.
- Fire-retardant insulation keeps delicate electronic components from catching on fire.
- Manufactured textiles are used for comfortable, flame-resistant airplane seat covers. These seats are made of buoyant polyurethane foam that also serve as flotation devices.
- Aircraft operation is made possible by synthetic lubricants — products of the chemical industry.

**Apparel:** Southeast Asia now dominates the manufacture of apparel. Chemistry contributes 36% of the value of material inputs in clothing and is used in a number of ways:
- Low-cost, crease-resisting fabrics like nylon, polyester, rayon and acetates are made from petroleum.
- Chlorine is used to bleach cotton fibers to make white cotton fabrics. Dyes made from organic and inorganic chemicals give vibrant color to clothing.
- Polyurethane imparts elasticity to garments and is used in waistbands, socks and exercise clothing.
- Waterproof coatings made from fluoropolymers are used in many coats and jackets.
- The wicking properties of polypropylene make it a good material for active sports clothing.
- Water- and stain-resistant coatings are sometimes added to protect fabrics.

**Appliances:** China has emerged as a leading producer of appliances. Chemistry contributes 27% of the value of material inputs used to make refrigerators and freezers and 16% of the value of material inputs used to make washing machines and clothes dryers. Chemistry is used in the appliance industry in a number of ways:

- Many chemicals are used in the processing and refining of durable steel alloys and copper to make refrigerator components.
- Easy-to-clean plastic drawers are made from acrylonitrile-butadiene-styrene (ABS) resins.
- Hydrochlorofluorocarbons (HCFC) and hydrofluorocarbons (HFC) are used as refrigerants and contribute far less to ozone depletion than chlorofluorocarbons.
- Polyurethane foams blown into steel refrigerator forms increase energy efficiency by insulating the cold air space compartment from warmer outside air.
- Neoprene (chloroprene) seals are used to keep refrigerants from leaking.
- Many chemicals are used in the processing and refining of durable steel alloys used to make washing machine and dryer components like the housing and clothes bins.
- Water-based silicone adhesives are used to bind components together.
- Styrene-butadiene rubber (SBR) is used to make flexible hoses that carry water to the washing machine.
- Air ducts, made from fire-resistant aluminum (aluminum oxide), vent hot air from dryers.
- Polyvinyl chloride (PVC) is used to insulate wires and electrical cables.
- Paints—often made white by titanium dioxide—are used to protect the metal housing from corrosion.

**Automobiles:** China, Malaysia and other Southeast Asian economies are emerging as leading centers of automotive design and assembly. Chemistry contributes 12% of the value of material inputs used to make automobiles and other vehicles and is used in a number of ways:

- Nylon and polypropylene carpet fibers and styrene-butadiene rubber (SBR) are used to make carpeting.
- Durable and affordable polyvinyl chloride (PVC) resins are used to insulate electrical components.
• Synthetic rubber (SBR) is used to make tires, fan belts and hoses.
• Increasingly, high-strength, lightweight polymers are replacing heavier metal parts—contributing to increased fuel efficiency without sacrificing safety. For example, strong, impact-resistant and lightweight polycarbonate resins are used to make side panels in some new cars.
• Epoxy, urethane and acrylic adhesives and sealants are used to attach parts without added weight and to dampen external noise.
• Polyurethane foams make seats comfortable and make fenders durable and shock absorbent. They are also used as insulation in door panels.
• Life-saving airbags are made from high-strength nylon fabric and are deployed using non-combustible nitrogen or argon gas.
• Drivers and passengers are protected during crashes by impact-resistant polymers (such as polyvinyl butyral) that are combined with regular glass to make shatter-resistant safety glass.
• Paints protect the underlying steel frame from corrosion.
• Ethylene glycol, propylene glycol, and other antifreeze agents protect engine parts from freezing in cold weather.

**Batteries:** A number of APEC economies have targeted electric vehicles and battery technology as leading-edge industries of the 21st century. Chemistry contributes 34% of the value of material inputs that go into batteries and is used in a number of ways:

• Primary or dry cell batteries convert the chemical energy of ammonium chloride into electrical energy to generate a low-voltage electric current. Ammonium chloride is the electrolyte — it provides high ionic conductivity of the charge between the zinc and graphite electrodes. Dry cell batteries are used to run flashlights, radios, clocks and other household items.
• Secondary or storage batteries include automobile batteries. They use highly conductive dilute sulfuric acid as the electrolyte. Storage batteries often use lithium for electrodes since it has high electrical conductivity. Lithium provides the highest capacity per unit weight of all metals, making it an ideal material for the anode. Lithium batteries are used to run pacemakers in heart patients.
• Other chemicals used in batteries include polypropylene resins, which are used to separate the positive and negative charges to prevent short circuiting and are molded to form the battery case. Polypropylene is used for its strength and barrier properties, ease of fabrication, and low cost.
• The voltage of any battery cell is established by the cell chemistry. Nickel-cadmium cells are about 1.2 volts. Lead-acid cells are about 2.0 volts; and lithium cells may be as high as 4.0 volts.

**Cement:** The cement industry is critical to infrastructure and other developmental investment in Asia. Chemistry contributes only 8% of the value of material inputs in cement but is critical in its use. Chemistry is used in the cement industry in a number of ways:

• Calcium carbonate is essential for making Portland cement.
Chloride and other accelerators are often used to quicken the pace of concrete setting, thus shortening construction schedules and reducing costs.

Lignin-based set retarders are used to prevent concrete from setting too fast, thus preventing future structural problems.

A variety of other chemical additives produce specialized properties that enhance the durability of concrete, reduce shrinkage, absorb noise and prevent erosion and washout.

“Smart cements” that can detect cracks in bridges and other structures are made by introducing carbon fibers to the mix. If cracks emerge below the surface, electricity that flows through the carbon network in the cement is interrupted, signaling a potential safety problem.

Computers: China and Malaysia are centers for the manufacture of computers, peripherals, and storage devices. Chemistry contributes 8% of the value of material inputs into computer peripherals, such as USB sticks, external hard drives, and printers. In addition to the electronic components, chemistry is used in a number of ways:

- Acrylonitrile-butadiene-styrene (ABS) is a polymer that is made into uniformly tough molded objects. Its high-impact strength, toughness, hardness and heat and chemical resistance make ABS suitable for electronic applications.
- Silicone-based adhesives are used in computers because of their thermal conductivity.
- Nitrogen gas is used to create an oxygen-free atmosphere for semiconductor manufacture. Polycrystalline silicon production depends on silane and dichlorosilane gas.
- Sulfuric acid and hydrochloric acid are used to clean metal on circuit boards.
- Gaseous phosphine, diborane and arsine are used to manufacture semiconductors. Sulfuric acid is used to clean circuit boards, and ammonium persulfate is used to etch circuits.
- Epoxy novolac compounds resist high temperatures and are used to encapsulate integrated circuits and semiconductors.
- Phenolic resins offer excellent electrical resistance, which makes them a good material for electronic circuit boards.
- Polycarbonate resins (made from bisphenol A and phosgene) are tough polymers used to make CDs and computer keyboards as well as printer and disk drive housings.
- Molded urethane paper rollers help printers run smoothly.

Consumer Electronics: China, Korea and Malaysia are leading manufacturing centers for consumer electronics. Chemistry contributes 15% of the value of material inputs that go into audio and visual equipment. Chemistry is used in consumer electronics in a number of ways:

- Acrylonitrile-butadiene-styrene (ABS) is a polymer that is made into uniformly tough molded objects. Its high-impact strength, toughness, hardness and heat and chemical resistance make ABS suitable for TV and radio housing.
- Polyvinyl chloride (PVC) is used for wire sheathing because of its good insulation properties, stability and toughness. The colored pigments added to wire sheathings help
identify complex circuits, ease repair of audio and visual equipment, and help prevent accidents.

- Solvent dyes are soluble in chlorinated hydrocarbons such as trichloroethylene. Solvents help give these dyes ideal dispersive properties making it easy to color the plastics used in TV and radio housing.
- Because of its special electrical properties, such as the ability to control the rate of transfer of electricity, potassium carbonate is used to make television monitor glass.

**Footwear:** The manufacturing of boots, shoes, and athletic footwear has migrated to China and other Southeast Asia economies. Chemistry contributes 25% of the value of the material inputs used to make and package shoes, sneakers and other footwear. Chemistry is used in a number of ways:

- Low-cost waterproof urethane adhesives are used to bond the various pieces of footwear together making it more affordable.
- Polyurethane foam supports help protect runners from injuries.
- Nylon is used to make shoelaces and webbing. Nylon’s high strength and resistance to rot make it a natural choice for athletic footwear.
- Nitrile rubber (made from acrylonitrile) is used in shoe soles to provide critical support and resistance to wear.

**Furniture:** China and other economies of Southeast Asia are emerging as global leaders in the manufacture of wood furniture. Chemistry contributes 16% of the value of material inputs used to make and package wood household furniture. Chemistry is used in a number of ways:

- Butyl acetate-based lacquers and epoxy resin and acrylic coatings are used to protect wood furniture.
- Organic and inorganic dyes are used to stain woods to provide a variety of desired finishes.
- Paints are used to decorate and protect wood furniture.
- Polyurethane and phenolic resin adhesives are used to make strong cross-linked composite wood. These adhesives are also used to join high-quality veneers to lower-quality wood or wood products.

**Jewelry:** Jewelry has emerged as a major export sector in Thailand and other Southeast Asian economies. Chemistry contributes 3% of the value of material inputs used to make jewelry and is used in various ways:

- Cyanide is used to separate gold and silver particles from gold-bearing ore during mining.
- Silica-based chemicals remove more impurities during smelting.
- Specialized tools made with extremely hard industrial diamonds (carbon) are used to cut gemstones.
- Solvents are used to clean jewelry surfaces, and mild abrasives are used to polish finished jewelry.
• Acetylene and oxygen generate heat to soften silver, gold and platinum so that jewelers can form them into jewelry.
• Plastic bags and satin (nylon)-lined cardboard containers are often used to package finished fine jewelry.

**Medical Equipment:** China, Malaysia and other APEC economies have targeted medical equipment as emerging industries of the 21st century. Chemistry contributes 27% of the value of material inputs used to make medical equipment and is used in a number of ways:

• Easy-to-clean and maintain acrylonitrile-butadiene-styrene (ABS) resins are used in therapy whirlpools.
• Polyvinyl chloride (PVC) resins are used to protect wires and cables in state-of-the-art diagnostic equipment.
• Synthetic diamonds (carbon) are used to make very sharp surgical knives.
• Polypropylene and polystyrene are used to make many kinds of medical equipment, including catheters, stethoscope diaphragms and oxygen tents.
• Tubing for stethoscopes, blood pressure testing equipment and anesthesia apparatus is made from synthetic rubber.
• Nylon (made from caprolactam) is used to make blood pressure cuffs.

**Mobile Phones / Telecommunications:** The last 10 years has seen the rapid development of mobile telephony in China and other East Asian economies. Chemicals make up 12% of the value of material inputs that go into telephones and are used in a number of ways:

• Acrylonitrile-butadiene-styrene (ABS) and acetal resins are used for telephone housings because of their high-impact strength, toughness, hardness, and heat and chemical resistance.
• Dyes are added to the resins to create different colors.
• Telephone cables are made from fire-resistant polyvinyl chloride (PVC).
• Many chemicals are used to process and refine copper which is used in telephone cables.
• Pigments add color to plastic telephone housings.
• Sodium cyanaurite is used to gold-plate electrical components to resist corrosion.
• Carbon grains in telephone handsets vibrate in response to sound waves, creating the electric signal that connects voices to one another.
• Soda ash is used to make ultrapure impurity-free glass for fiber-optic cables, which can carry hundreds of telephone calls at a time.

**Personal Care Products:** The emergence of a large middle class in China and other economies is resulting in growing demand for cosmetics, toiletries and other personal care products. Chemistry contributes 68% of the value of material components in cosmetics and 60% of the value of material inputs used to make and package toiletries and other personal care products.
• UV radiation absorbers—such as aminobenzoates, cinnamates, homomenthyl salicylate, dipropylene salicylate and hydroxybenzophenones—are added to many cosmetic products to protect skin from harmful UV radiation.
• Cellulose esters and polymers are used as thickening agents to bind ingredients together.
• Biocides prevent spoilage on the shelf and at home.
• Ethyl acetate and butyl acetate give nail polish a tough, glossy finish.
• Titanium dioxide, methoxycinnamate and dimethicone are used in foundation make-up for their concealing properties.
• The diverse color palette for lipsticks, eye liners, mascara and blush is provided by iron oxides and other pigments.
• Disinfecting benzoyl peroxide is added to cover-up creams to help diminish blemishes.
• Sodium bicarbonate has mild abrasive properties that help toothpastes clean teeth. Because of its alkaline properties, sodium bicarbonate is also used to make deodorants.
• Fragrances are added to many hand lotions, shampoos and other toiletries.
• Glycerin is used in hand and face lotions to soften skin.
• Aluminum sulfate is used in antiperspirant to prevent opening of sweat glands. Zinc chloride acts as an antibacterial agent.
• Alcohols, sulfates and other surfactants are used in cosmetics for their cleansing properties.

Power Tools: China, Malaysia and other Southeast Asian economies are leading manufacturers of handheld power tools for professional and consumer do-it-yourself (DIY) applications. Chemistry contributes 14% of the value of material inputs used to make power tools. Chemistry is used in a number of ways:

• Rigid and inherently flame-resistant plastic housings are made from polyvinyl chloride (PVC) and polysulfone resins. PVC is also used to insulate wires and electrical cables.
• Shock-absorbing polystyrene helps reduce vibration and increase safety.
• Dry carbon-based lubricants keep mechanical parts working longer.
• Many chemicals are used in the processing and refining of durable steel alloys used to make power tool components like saw blades and drill bits.
• Urethane, silicone-based and epoxy resin adhesives bind handles and plastic housings to working tool components.

Rubber Products: With natural rubber resources in the region and a developing automotive industry, the manufacture of tires and other rubber products has grown rapidly in China, Malaysia, Indonesia, Thailand, and Vietnam. Chemistry contributes 54% of the value of material inputs used to make tires and 47% of the value of material inputs used to make hoses and belts. Chemistry is used in a number of ways:

• Strong and elastic styrene-butadiene rubber (SBR) is used to make tires for passenger cars, light trucks, aircraft and bicycles.
• Sulfur and sulfur compounds added during the vulcanization process increase strength and elasticity.
• Carbon black and silica are added to improve resistance to tears and abrasion.
• Pigments such as titanium dioxide are added to create “whitewalls.”
• Zinc oxide is added as a reinforcing agent in rubber compounds.
• Stabilizers and antioxidants, such as phenolic resins, are added to SBR to improve durability.
• Strong fabrics made from polyester and nylon envelop steel radials and the inflatable portion of a tire.
• UV-resistant coatings are added to make tires last longer
• Polyvinyl chloride (PVC) is used to make durable garden hoses.
• Nitrile rubber, a copolymer of acrylonitrile and butadiene, has excellent oil and solvent resistance and is used to make hoses and belts in automobiles and other machinery.
• Because of its good abrasion resistance and temperature properties, nitrile rubber is used in steam hoses and belts that are subject to large amounts of friction.

**Semiconductors:** The manufacture of semiconductors and other electronic components in China and Malaysia has grown rapidly. Chemistry contributes 33% of the value of material inputs used to make semiconductors and is used in a number of ways:

• Nitrogen and argon gases are used to create an oxygen-free atmosphere for semiconductor manufacture.
• Production of ultrapure silicon depends on silane and dichlorosilane gas.
• Silicon wafers are polished using ammonium hydroxide.
• Exposure to pure oxygen produces a thin oxide layer, which is followed by a coating of hard silicon nitride. Light-sensitive photo-resist polymers (i.e., hydroxystyrene) are then applied to the silicon wafer.
• Organic photo-resist strippers remove the photo-resist after the pattern has been transferred to the chip. Etchants (sulfuric acid) carve patterns into the chip.
• Gaseous phosphine, diborane and arsine are used to manufacture semiconductors.
• Integrated circuits and semiconductors are encapsulated by epoxy novolac or synthetic polyamide compounds.

**Solar Energy:** Solar energy provides a clean, renewable alternative to traditional, fossil fuel energy sources. China has leapfrogged the West to emerge as the world’s largest manufacturer of solar panels. Chemistry is used in a number of ways:

• Chlorine chemistry is used to purify the silica for the integrated circuits found in solar cells.
• Caustic soda and aluminum oxide contribute in the production of structural aluminum casing on solar panels.
• Tin oxide coats solar panel glass to provide an electroconductive path for collecting energy from the sun.
Polyphenylene resins feature strength and other properties for absorber panels. Acrylic and polycarbonate resins are used to provide protection for the panels as well as clarity. Polyester films are used for their optical properties and polyvinyl butyral is used as a protective film.

Solar panel semiconductors are made from amorphous silica, copper indium diselenide, and cadmium telluride.

**Wind Energy:** Wind energy also provides a clean, renewable alternative to traditional, fossil fuel energy sources. China vaulted past competitors in Denmark, Germany, Spain and the United States to become the world’s largest maker of wind turbines. Chemistry is used in a number of ways:

- Polyester is used for structuring and shaping wind turbine blades.
- Blades contain carbon fibers and epoxy resins for extra strength and durability.
- Polyglycol and polyalphaolefin are used to lubricate gears and prevent cracking. It has been shown that turbines with these synthetic lubricants require less maintenance than those with traditional oils.

The above examples illustrate how chemistry is essential to society and the economy. When the science of chemistry is applied, it helps improve safety, health, and productivity. An economy’s food, safe water supply, clothing, shelter, health care, computer technology, transportation and every other important facet of modern life all depend upon the business of chemistry. Characterized by noted business historian Alfred Chandler as a “high-tech” industry, the business of chemistry has transformed life and work throughout the world, made possible extended and healthier lifespans through medical advances, improved people’s quality of life, raised standards of living, improved the environment, created countless economic benefits, and allowed for a myriad of social benefits. Chemistry is the solutions provider for the emerging industries of the 21st century.

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The Economics & Statistics Department provides a full range of statistical and economic advice and services for ACC and its members and other partners. The group works to improve overall ACC advocacy impact by providing statistics on American Chemistry as well as preparing information about the economic value and contributions of American Chemistry to our economy and society. They function as an in-house consultant, providing survey, economic analysis and other statistical expertise, as well as monitoring business conditions and changing industry dynamics. The group also offers extensive industry knowledge, a network of leading academic organizations and think tanks, and a dedication to making analysis relevant and comprehensible to a wide audience.

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