• Demand for process catalysts (which exclude environmental applications) is forecast to increase 4.4 percent per year to $3.3 billion in 2005, driven by accelerating growth in the petroleum refining sector and continued strength in new polymerization technologies.

• Best opportunities in the chemical processing catalysts market are expected in the fine chemical sector, especially in pharmaceuticals, where the development of new chiral and enzyme catalysts is spurring gains.

• The top seven catalyst suppliers -- Engelhard, Grace Davison, Akzo Nobel, Royal Dutch/Shell (via Criterion, CRI Catalyst and other operations), UOP, Atofina and Sud-Chemic -- accounted for 45 percent of the US market in the year 2000.
Catalysts, a new study from The Freedonia Group, provides you with an in-depth analysis of major trends in the industry and the outlook for product segments and major markets -- critical information to help you with strategic planning.

This brochure gives you an indication of the scope, depth and value of Freedonia’s new study, *Catalysts*. Ordering information is included on the back page of the brochure.

### Brochure Table of Contents

- Study Highlights ................................................................. 2
- Table of Contents and List of Tables and Charts .................. 4
- Sample Pages and Sample Tables from:
  - Market Environment ......................................................... 6
  - Catalysts by Market ......................................................... 7
  - Catalysts by Material ........................................................ 8
  - Industry Structure ............................................................. 9
  - Company Profiles ............................................................. 10
  - List of Companies Profiled ................................................ 11
- Forecasting Methodology ..................................................... 12
- About the Company ............................................................ 13
- Advantages of Freedonia Reports ........................................ 13
- About Our Customers .......................................................... 14
- Other Titles From Freedonia ............................................... 15
- Ordering Information .......................................................... 16
Demand for process catalysts (which exclude environmental applications) is forecast to increase 4.4 percent per year to $3.3 billion in 2005, driven by accelerating growth in the petroleum refining sector and continued strength in new polymerization technologies.

Petroleum refining will continue to be the largest market for catalysts, with advances driven by new government regulations, an increasing emphasis on heavy sour crude feedstocks and the impending phaseout of MTBE oxygenates.

Polymerization catalysts will continue to record the fastest gains of the three major catalyst segments, although growth will decelerate through 2005.

Best opportunities in the chemical processing catalysts market are expected in the fine chemical sector, especially in pharmaceuticals, where the development of new chiral and enzyme catalysts is spurring gains.

Metals will continue to dominate the catalyst market in value terms due primarily to the wide applicability of base metals and the high performance of precious metals.

The top seven catalyst suppliers -- Engelhard, Grace Davison, Akzo Nobel, Royal Dutch/Shell (via Criterion, CRI Catalyst and other operations), UOP, Atofina and Sud-Chemie -- accounted for 45 percent of the US market in the year 2000.

* Catalysts used in environmental applications, such as catalytic converters, are not covered within the scope of the study.
Study Highlights

Catalyst Demand
(million dollars)

<table>
<thead>
<tr>
<th>Item</th>
<th>1995</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>00/95</th>
<th>05/00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nondurable Goods Shpts (bil $)</td>
<td>1595</td>
<td>1887</td>
<td>2192</td>
<td>2620</td>
<td>3.4</td>
<td>3.0</td>
</tr>
<tr>
<td>$ catalysts/000$ nondurables</td>
<td>1.39</td>
<td>1.41</td>
<td>1.51</td>
<td>1.57</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Petroleum Refining</td>
<td>2220</td>
<td>2670</td>
<td>3310</td>
<td>4120</td>
<td>3.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Chemical Processing</td>
<td>720</td>
<td>870</td>
<td>1050</td>
<td>1270</td>
<td>3.9</td>
<td>3.8</td>
</tr>
<tr>
<td>Polymerization</td>
<td>505</td>
<td>700</td>
<td>920</td>
<td>1200</td>
<td>6.7</td>
<td>5.6</td>
</tr>
<tr>
<td>$/lb</td>
<td>0.35</td>
<td>0.38</td>
<td>0.42</td>
<td>0.47</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>$/lb excluding alkylation</td>
<td>2.04</td>
<td>2.22</td>
<td>2.48</td>
<td>2.81</td>
<td>1.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Catalyst Demand (mil lb)</td>
<td>6420</td>
<td>7065</td>
<td>7810</td>
<td>8690</td>
<td>1.8</td>
<td>2.1</td>
</tr>
</tbody>
</table>

% Annual Growth

- Petroleum Refining: 41.2%
- Chemical Processing: 32.6%
- Polymerization: 26.2%
- Catalyst Demand, 2000

SUMMARY TABLE

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List of Contents, Tables and Charts

I. EXECUTIVE SUMMARY
   Summary Table .............................................................. 3

II. MARKET ENVIRONMENT
   General .............................................................. 4
   Macroeconomic Outlook .............................................. 4
      Table - Macroeconomic Environment ...................... 6
   Manufacturing Outlook ............................................... 7
      Table - Manufacturers’ Shipments .......................... 9
   Market Volatility .................................................... 9
      Table - Catalyst Market Volatility, 1990-2000 .......... 11
   Chart - Catalyst Market Volatility .......................... 11
   Pricing Trends ....................................................... 12
      Table - Catalyst Pricing Trends .............................. 14
   Environmental & Regulatory Issues .......................... 14
      Clean Air Act Regulations .................................... 15
      Oxygenated Gasoline Program .............................. 16
      Reformulated Gasoline Program ............................ 17
      Diesel Fuel Regulations ....................................... 19
      Resource Conservation and Recovery Act ............... 20
      Catalyst Reclamation & Disposal .......................... 21
   International Activity ............................................. 23

III. OVERVIEW
   Supply & Demand ................................................... 24
      Table - Catalyst Supply & Demand ......................... 26
   Foreign Trade ....................................................... 26
      Table - Catalyst Imports & Exports ....................... 28
      Chart - Catalyst Imports by Source, 2000 ............... 28
      Chart - Catalyst Exports by Destination, 2000 ........ 29
   Market Overview .................................................. 29
      Table - Catalyst Demand by Market ...................... 30
      Chart - Catalyst Market Value, 2000 ...................... 31
      Chart - Catalyst Market Volume, 2000 .................... 31

IV. PETROLEUM REFINING CATALYSTS
   General ........................................................................ 32
   Refined Petroleum Products Outlook .......................... 33
      Table - Refined Petroleum Production .................... 35
   Petroleum Refining Process Outlook ....................... 36
      Table - Downstream Charge Capacity ...................... 38
      Chart - Gasoline Production Flow Chart ................. 39
   Catalyst Demand .................................................... 40
      Table - Petroleum Refining Catalyst Demand .......... 42
      Fluid Catalytic Cracking (FCC) ............................. 42
      Table - Fluid Catalytic Cracking Catalyst Demand .... 45
      Hydroprocessing .................................................. 46
      Table - Hydroprocessing Catalyst ........................ 48
      Demand by Process & Material .............................. 48
      Hydrotreating ...................................................... 48
      Hydrocracking ..................................................... 50
   Alkylation ............................................................... 52
      Table - Petroleum Alkylation Catalyst Demand ....... 54
      Other ................................................................. 54
      Table - Other Petroleum Refining Catalyst  ............. 56
      Suppliers & Market Share ...................................... 57
      Chart - Petroleum Refining Catalyst Market Share, 2000 .. 58

V. CHEMICAL PRODUCTION CATALYSTS
   General ........................................................................ 60
   Chemical Industry Outlook ....................................... 61
      Table - Chemical Shipments ................................. 63
   Catalyst Types ....................................................... 63
      Table - Chemical Processing Catalyst  ................ 65
      Demand by Process & Source ............................... 65
   Organic Synthesis .................................................. 66
      Table - Organic Synthesis Catalyst Demand .......... 67
   Oxidation ............................................................... 67
      Table - Oxidation Catalyst Demand ...................... 67
   Synthesis Gas ........................................................ 70
      Table - Syngas Catalyst Demand ............................ 72
   Hydrogenation ......................................................... 73
      Table - Hydrogenation Catalyst Demand ................. 74
Market Environment

The Market Environment Section discusses factors influencing catalyst demand, including pricing trends and environmental issues.

This information provides you with an understanding and an analysis of the climate in which the catalysts industry operates.

MARKET ENVIRONMENT

Catalyst Reclamation & Disposal

As catalysts are used in petroleum refining and chemical processing reactions, they can age or become poisoned by the build-up of metals or other materials. Manufacturers have three options to deal with these spent catalysts and their metallic byproducts: regeneration, reclamation and disposal.

Regeneration can recover between 75 and 95 percent of a catalyst’s original activity, extending the life of the catalyst and decreasing disposal costs. One commonly regenerated catalyst is sulfuric acid, which is used in the production of gasoline in oil refineries. Usually, a catalyst may only last 50 to 90 percent of the life of its fresh state. As a general rule, after the catalyst can no longer be regenerated to at least 75 percent of its original activity, it is reclaimed or disposed of. In addition, permanent poisons (e.g., arsenic, lead, vanadium, iron or silicon) in levels greater than about two percent generally spoil a catalyst for regeneration. Companies such as the Catalyst Recovery Group specialize in the regeneration of catalyst metals.

When a catalyst is unfit for regeneration, companies can choose to reclaim the metals and/or landfill the catalysts. Major factors in metal reclamation include proper physical handling, transportation, environmental concerns, potential end uses of the catalysts and the choice of an effective reclamation firm. Proper handling and transportation requires the use of packaging approved by the US Department of Transportation (DOT). Shipments of mixed catalysts can be most troublesome, since each type must be segregated and properly labeled. Catalysts must be tested prior to shipment to determine if the materials are classified as hazardous substances. A material safety data sheet must accompany each catalyst sent for reclamation; this sheet details the analysis of the catalyst and lists procedures and precautions for shipping and handling.

Despite these factors, reclamation of the metal in a catalyst is often an attractive alternative to disposal. Although metals reclamation may be expensive, the...
The Catalyst Sections provide demand for historical years and forecast growth to 2005 and 2010.

This information helps you:

• Analyze your company’s growth potential in the industry.

• Outline your strategic plans for five and ten years out.

• Establish sales goals.

### Catalyst Applications - Fine Chemicals

Demand for catalysts used in fine chemical applications is forecast to increase 4.4 percent per annum through 2005. The fastest growth of any chemical catalyst application is in pharmaceutical products, the fastest growth of any chemical catalyst application. However, in general, growth will be slower in the fine chemical market and slowing in specialty sectors such as flavors and fragrances and agrochemicals.

Products synthesized for the fine chemicals industry using catalysts include flavors and fragrances; herbicides, fungicides and insecticides; and active ingredients and intermediates for pharmaceuticals. Catalysts used include organometallic types, as well as those based on aluminum, nickel, copper, cobalt, platinum and palladium. These compounds catalyze a variety of reactions such as oxidation, reduction, and Heck reactions, which form carbon-carbon double bonds.

Growth of fine chemicals catalysts will stem primarily from increased demand for single-enantiomer products. In chiral applications catalysts can be used both to synthesize single-enantiomer products and to separate a racemic mixture into its enantiomers. These catalysts are becoming increasingly important in pharmaceutical applications since many drugs exhibit fewer side effects when delivered as a single enantiomer. Other opportunities lie in the flavors and fragrances industry. For example, in 2001 Rhodia ChiRex used its JACOBSEN catalyst technology to create single-enantiomer fragrances, the first nonpharmaceutical use of the technology.

In addition, both heterogeneous catalysts and biocatalysts will experience growth opportunities. Benefits of heterogeneous catalysts include simplifying the separation of product from catalyst. Because of dangers stemming from excess metal content in pharmaceuticals, regulations limit the amounts of certain metals, and catalysts used in fine chemicals are therefore often heterogeneous.

### Hydroprocessing Catalyst Demand by Process & Material

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroprocessing Capacity (mil bbl)</td>
<td>3950</td>
<td>4490</td>
<td>4795</td>
<td>5330</td>
<td>6150</td>
</tr>
<tr>
<td>lb catalyst/000 bbl capacity</td>
<td>10.9</td>
<td>15.6</td>
<td>15.6</td>
<td>17.3</td>
<td>19.0</td>
</tr>
<tr>
<td>Hydroprocessing Catalysts (mil lb)</td>
<td>43</td>
<td>59</td>
<td>75</td>
<td>92</td>
<td>117</td>
</tr>
<tr>
<td>$/lb</td>
<td>3.72</td>
<td>4.92</td>
<td>4.67</td>
<td>5.27</td>
<td>5.64</td>
</tr>
<tr>
<td>Hydroprocessing Catalysts</td>
<td>160</td>
<td>290</td>
<td>350</td>
<td>485</td>
<td>660</td>
</tr>
<tr>
<td>By Process:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrotreating</td>
<td>120</td>
<td>245</td>
<td>555</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocracking</td>
<td>40</td>
<td>45</td>
<td>65</td>
<td>85</td>
<td>105</td>
</tr>
<tr>
<td>By Material:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
<td>154</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>% hydroprocessing</td>
<td>19.8</td>
<td>29.1</td>
<td>31.8</td>
<td>36.2</td>
<td>40.0</td>
</tr>
<tr>
<td>Petroleum Refining Catalysts</td>
<td>810</td>
<td>995</td>
<td>995</td>
<td>995</td>
<td>995</td>
</tr>
</tbody>
</table>

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The Materials Section analyzes trends and considers the threats and opportunities for each major catalyst material.

The information presented will help you:

- Focus your sales and marketing efforts on high growth areas.
- Propose new areas for development.

Precious Metals

Nearly all precious metals have significant use as catalysts including gold, silver and the platinum group metals (platinum, rhodium, ruthenium, iridium and osmium). Demand is forecast to grow three percent per annum to 2005, from the previous five year pace despite improvement in the chemical processing sector. Growth in recent years has been severely impacted by volatility among precious metals, with platinum, palladium and rhodium prices skyrocketing in 2000 due to increased demand in the auto emission sector. Prices are expected to level out at more sustainable levels over the next decade and this will restrain growth in market value. Also restraining growth will be trends toward minimizing the use of expensive precious metals and competition from alternative catalysts. However, demand will benefit from improving catalyst performance, the development of catalysts based on alloys of several materials and the increasing popularity of chiral chemistry.

Precious metal catalysts are used for a variety of applications such as naphtha reforming and selective hydrogenation in refineries and steamcrackers, organic reactions such as hydrogenation and dehydrogenation, ammonia synthesis, gas purification, isomerization, reduction and chiral syntheses. For example, silver catalyzes such industrially important reactions as the epoxidation of ethylene to ethylene oxide, which is used to synthesize polyester resins, and the production of formaldehyde. Demand for precious metal catalysts will benefit from their use in enantioselective reactions, especially in the pharmaceutical and other fine chemical industries, as well as their high specificity compared to base metal types.

For example, ammonia is typically produced from natural gas using an iron (magnetite) catalyst. However, catalyst producers are switching over to higher-performing precious metals; Kellogg Brown & Root (KBR) has developed the KBR Advanced Ammonia Process, which uses a ruthenium catalyst on a proprietary sample.

### Zeolite Catalyst Demand
(million dollars)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Production (bil bbl)</td>
<td>2540</td>
<td>2770</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lbs/000 bbl gasoline</td>
<td>0.18</td>
<td>0.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zeolite Catalysts Demand (mil lb)</td>
<td>461</td>
<td>479</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$/lb</td>
<td>0.86</td>
<td>0.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zeolite Catalysts Demand Petroleum Refining</td>
<td>397</td>
<td>423</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals &amp; Polymers</td>
<td>390</td>
<td>413</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
% zeolites                     | 22.3 | 19.1 |      |      |      |
Total Catalyst Demand          | 1780 | 2220 |      |      |      |
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Industry Structure

Gain a better understanding of your competition and analyze your company’s position in the industry with information about:

- market share
- competitive strategies
  - product differentiation
  - research & new product development
  - market focus
  - low-cost leadership
  - catalyst services
- mergers, acquisitions & divestitures
- manufacturing
- marketing & distribution
- cooperative agreements

INDUSTRY STRUCTURE

Research & New Product Development

Growth in the catalyst industry is highly dependent on research and development (R&D) programs, which are designed to produce new catalysts that provide increased product yield, fewer undesirable byproducts and reduced process energy costs. R&D includes everything from developing an initial idea to securing patents and establishing potential processes and customer benefits.

To remain competitive, companies must continually develop new and more effective catalysts despite necessarily high R&D expenses. These high costs often threaten the development of low-volume catalysts required in specialty applications and create significant barriers to companies interested in entering the field. These expenses have even led to the formation of joint ventures specifically for R&D. For example, Exxon Mobil and Dow operate a 50/50 joint venture, Univation Technologies, for the research, development and licensing of technologies and catalysts for the production of polyethylene.

Although catalyst research activities are distributed among corporations, national laboratories and universities, the majority of catalyst R&D is conducted by industry, with national laboratories and universities playing smaller roles. Many catalyst manufacturers began stepping up R&D efforts in the mid 1990s in order to capitalize on changing fuel regulations, and others are currently investing in high-throughput experimentation and chiral chemistry.

Two crucial issues in current catalyst research involve how to make highly selective catalysts and, subsequently, how to get them on the market in the shortest possible time. Selectivity is important in reducing the amount of unwanted byproducts of chemical reactions while optimizing the yield of desired products. Environmental considerations are becoming increasingly important in this area as many catalytic byproducts have gained recognition as hazardous...
Company Profiles

The Profiles Section analyzes 44 companies active in the U.S. catalysts market. These profiles represent a sampling or cross-section of the types of companies involved in the industry.

Divisions, subsidiaries, joint ventures, etc., are discussed under appropriate parent companies.

Sources for profiles included:

- Information provided by key staff members in the respective companies
- Annual reports
- 10-K reports
- Security analysts reports
- Corporate product literature

COMPANY PROFILES

Royal Dutch/Shell Group of Companies
30 Carel van Bylandtlaan
2596 HR, The Hague
Netherlands
31-70-377-4540
http://www.shell.com

Criterion Catalyst & Technology Company
16825 Northchase Drive, Suite 1000
Houston, TX  77060
281-874-2600
http://www.criterioncatalysts.com

Sales:  
US Sales:  
Employm. 
US Catalyst Sales:

Key Products:  hydroprocessing, reforming and oxidation catalysts

The Royal Dutch/Shell Group of Companies, which is owned by Royal Dutch Petroleum Company (60 percent) and the Shell Transport & Trading Company plc (40 percent), is engaged in the oil, natural gas, chemicals, coal and metals businesses throughout the world. The Company operates in five primary segments: Exploration and Production; Downstream Gas and Power Generation; Oil Products; Chemicals; and Corporate and Other.

The Company is among the leading suppliers of catalysts to the US market with about six percent of total sales in the year 2000. The Company is the leading supplier of hydroprocessing catalysts through its Criterion subsidiary and also...
Companies Profiled

Air Products and Chemicals Incorporated
Akzo Nobel NV
MAKFining
Albemarle Corporation
Alcoa Incorporated
Adcats
Arch Chemicals Incorporated
Avantium Technologies
Combicat
BASF AG
Bayer AG
Borealis AS
Boulder Scientific Company
BP plc
ChevronTexaco Corporation
Advanced Refining Technologies
Crompton Corporation
CK Witco Corporation
Degussa Corporation
Aztec Peroxides Incorporated
E.ON AG
Laporte plc
Dow Chemical Company
Union Carbide Corporation
Univation Technologies LLC
DuPont (EI) de Nemours
Eastman Chemical Company
Engelhard Corporation
Exxon Mobil Corporation
MAKFining
Univation Technologies LLC
FMC Corporation
GenTek Incorporated
Grace (WR) & Company
Advanced Refining Technologies
Davison Chemicals
Haldor Topsøe A/S
Honeywell International Incorporated
AlliedSignal Incorporated
Imperial Chemical Industries plc
Synetix

Institut Francais du Petrole
Procatalyse North America
Japan Energy Corporation
Johnson Matthey plc
mg technologies ag
Zimmer AG
Millennium Chemicals Incorporated
Equistar Chemicals LP
Novolen
Mitsui Chemicals Incorporated
Nippon Shokubai Company Limited
OM Group Incorporated
Perstorp AB
Pharmacia Corporation
Monsanto Enviro-Chem Systems Incorporated
Philipp Brothers Chemicals Incorporated
Phillips Petroleum Company
PQ Corporation
Zeolyst International
Rhodia SA
Rohm and Haas Company
Royal Dutch/Shell Group of Companies
Basell NV
CRI International Incorporated
Criterion Catalyst & Technology Company
Montell Polyolefins BV
Zeolyst International
Sud-Chemie Group
United Catalysts Incorporated
Total Fina Elf SA
Atofina Chemicals Incorporated
MAKFining
UOP LLC

Order form on last page
Freedonia does not just collect and reprint data; Freedonia develops data. Our analysts thoroughly investigate an industry by extensively interviewing key industry participants and analyzing information from sources such as associations, government and trade literature. Once this research is complete, Freedonia establishes one set of forecasts. All writing, editing and forecasting is done in-house to assure quality and consistency. In cases where data does not exist, Freedonia develops the data based on input/output ratios, bills of materials and flow charts. The following chart summarizes Freedonia’s methodology:
About The Freedonia Group

The Freedonia Group, Inc. is a leading international industry study/database company.

Since 1985, Freedonia has published over 1,600 titles covering areas such as chemicals, coatings and adhesives, building materials, plastics, industrial components and equipment, health care, packaging, household goods, security, and many other industries.

Freedonia has produced a wide variety of titles, including:

- Waxes
- World Industrial Gases
- Solvents: Green & Conventional
- Activated Carbon

Because Freedonia is a reliable information source, our forecasts are cited in numerous publications such as *The Wall Street Journal*, *Chemical Week*, *Chemical Market Reporter* and *Oil and Gas Journal*.

Advantages of Freedonia Reports

In-house operations
Because all of our staff work at the same location, interaction between analysts and departments provides a strong system of checks and balances.

Consistency
Our Economics Group develops indicators that are used by all analysts. Therefore, every Freedonia study is based on a consistent set of economic assumptions (GDP, gasoline production, non durable goods shipments, etc.)

Reliable forecasts
Because all of our forecasts consider the environment in which a product or industry is operating, as well as threats and opportunities to the market, Freedonia forecasts are reliable indicators of future performance.

One-on-one interviews
All studies are produced by conducting interviews with key industry participants and end-users.

Proprietary electronic database
Freedonia’s analysts can tap into an extensive in-house electronic database containing corporate literature (including private company information), trade publications, government reports and many other sources of information.

Order form on last page
About Our Customers

Freedonia’s clients include major US and international companies in the manufacturing, services, consulting and financial sectors.

Typical purchasers of Freedonia studies:

- Key Executives
- Corporate Planners
- Market Researchers
- Financial Analysts
- Information Centers
- New Product Developers
- Merger & Acquisition Specialists

Since 1985 we have provided research to customers ranging in size from global conglomerates to one person consulting firms. More than 90% of the industrial companies in the Fortune 500 use Freedonia research to help with their strategic planning.

Some of Freedonia’s customers in the catalysts market include: Akzo Nobel, Dow Chemical Company, Engelhard Corporation, Honeywell International and Total Fina Elf.
Waxes
Wax demand in the US will expand 4% annually through 2005, supported by modest volume gains and an ongoing shift away from commodity waxes toward more expensive synthetic types. Fischer-Tropsch waxes offer particularly attractive growth opportunities in the paper, adhesives and coatings markets where they are used in specialty wax blends. This study analyzes the $1.3 billion US wax industry to 2005 and 2010 by type and market. It also presents market share data and profiles major companies.
#1504. . . . . . . . . 12/01. . . . . . . . . . $3,700

Water Management Chemicals
The US market for water management chemicals will grow 5% annually through 2005, driven by a shift in the product mix toward higher-value formulations. Increased water recycling in manufacturing and electric utilities will favor corrosion inhibitors, coagulants and flocculants, oxidizers and biocides, and chelating agents. This study analyzes the $3.4 billion US water management chemical industry to 2005 and 2010 by product, application and market. It also details market share and profiles key companies.
#1499. . . . . . . . . 1/02. . . . . . . . . . $3,700

World Fluorochemicals
World fluorochemicals demand will grow 3.4% annually through 2005, a marked improvement over the 1990s pace when the ban on CFCs had the most effect. Robust gains in HFCs will partially offset declines in CFCs, and stellar growth in fluoropolymers and specialty fluorochemicals will provide an added boost. This study analyzes the US$8 billion world fluorochemicals industry to 2005 and 2010 by product, market, region and for 13 countries. It also presents market share data and profiles key firms.
#1434. . . . . . . . . 7/01. . . . . . . . . . $4,500

Solvents: Green & Conventional
Following a lengthy period of decline, demand for solvents in the US will exhibit positive annual growth through 2005. While demand for conventional solvents will be flat, green solvents will post robust advances, capturing 20% of the market by 2005. Cleaning products and transportation will be the fastest growing markets. This study analyzes the $3.3 billion US solvents industry to 2005 and 2010 by product, function and market. It also presents market share data and profiles leading companies.
#1418. . . . . . . . . 5/01. . . . . . . . . . $3,700

Activated Carbon
Market value for US activated carbon demand will grow over 6% annually, with gains primarily attributable to tightening water and air pollution laws and new applications. Liquid phase uses (e.g., water treatment) will remain the largest outlet while gas phase applications (e.g., air purification, emission canisters) grow faster. This study analyzes the 364 million pound US activated carbon industry to 2004 and 2009 by type and application. The study also reviews trade, evaluates market share and profiles key firms.
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