



THE VALVE MARKET REPORT



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An indispensable intelligence resource for business development executives
in these segments

- **Equipment Suppliers** – working to identify the most productive markets for products, reflecting market needs, opportunities, and regional and technological growth trends
- **Consulting Engineers** – conducting research to understand emerging technology trends to support informed equipment recommendations for clients
- **EPC Contractors** – seeking to stay upfront regarding emerging areas of activity and projects, for early involvement in the bidding process with the best available technology
- **Investors** – researching the latest market and technical product information for industries and companies attractive as profitable investment opportunities
 - **End Users** – in all industries

The Valve Market Report is one of the three products within the valve portfolio. Information used in tables/graphs are derived from the Valve Supplier Data Base and Valve Product Data Base. These data bases are separately available.



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FOREWORD

Resolute Research thanks you for purchasing The Valve Market Report. In this report, every effort has been taken to maintain a disciplined research methodology to ensure high data integrity and supportable market insights. It is our expectation that this report will be a valuable component of your strategic planning activity now and into the future.

Methodology of Report

Market Sizing

Critical to any market research is an accurate top-level assessment of the Total Available Market (TAM). This report uses a “sum-of-sales” analysis of hundreds of individual valve manufacturers to determine total worldwide valve revenues based on actual valve company valve sales.

Valve Segmentation

Total valve sales are comprised of different kinds of valves including gate, globe, ball, plug, butterfly, pinch, check, pressure relief, control, on/off and others. This report segments valve sales by valve type based on research of the valve companies described in the sum-of-sales analysis. This provides a reliable manufacturer-based segmentation of valve sales by valve type.

Geographic and Industry Segmentation

Clear assessment of industry and geographic segmentation of valve sales is critical to corporate strategic planning. This report utilizes detailed process flow diagrams to define template applications such as power plants, water treatment plants, wastewater treatment plants, desalination plants, refineries, pulp & paper plants, and other industrial plants to accurately profile the type, number, and value of valves within each plant. This template information is then combined with information on the number of existing plants and planned new-builds within each geographic area to provide a forecast for new and aftermarket valve sales by country, industry, and valve type.

What this Means

These research methodologies contribute to a sound assessment of valve markets and opportunities with the degree of valve segmentation necessary for most clients.

Scope of Report

Valve Types: gate, globe, ball, plug, butterfly, check, pinch, pressure relief, and others reflecting on/off service or process control.

Valve industries: oil & gas, refinery, petrochemical, chemical, power, metals & mining, pulp & paper, paints & coatings, food & beverage, pharmaceutical, semiconductor, water & wastewater, desalination, marine, and general industrial.

Valve Geographic Markets: 64 countries covering 96% of world GDP.

Valve suppliers: hundreds of valve manufacturers, worldwide.

Narrative: analysis of valve technologies, applications, markets, suppliers, OEMs, distributors, EPCs, trends, drivers, and forecasts.



EXECUTIVE SUMMARY

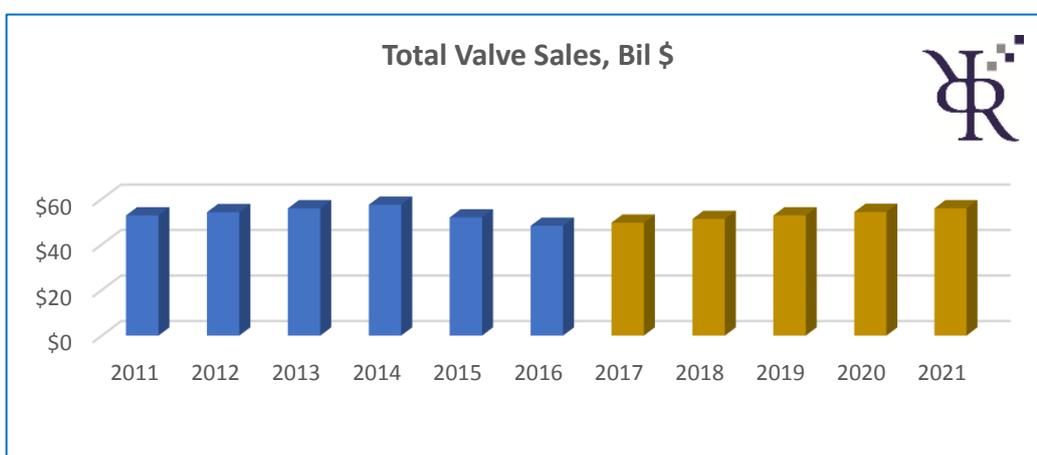
Worldwide **valve and actuator revenues** were approximately \$48.3-billion in 2016, as determined by a sum-of-sales rollup of valve company valve sales. This represents an approximate 7.4% decrease from valve sales of around \$51.9-billion in 2015. The collapse in crude oil pricing and upstream CapEx that began in the second half of 2014 was a major factor in the more than 10% overall reduction in valve sales worldwide in 2015, especially in North America where even greater percentage losses in oil & gas valve sales between minus 20% to minus 50% were experienced relative to 2014.

Valve revenue losses continued in 2016 for the following reasons, again, largely in the oil & gas sector:

- Oil & Gas, refinery, and petrochemical are collectively about 30% or more of valve sales, and the entire sector continued to see project cancellations and delays for new pipelines, refineries, and petrochemical plants in 2016 because of continued low oil prices, and low corporate “CapEx” expenditures over the period.
- The power industry in China experienced a pull back from earlier years, contributing to a setback in that sector as well.
- Similarly, marine construction remains at a low point due to current overcapacity, and contributed to decreases in valve sales, along with commodities markets like mining and metals that continued in a depressed condition relative to earlier times.

Although markets have stabilized to a degree, some major suppliers are projecting only moderate growth going forward in 2017, with greater growth in later years. Some valve suppliers are especially vulnerable due to a continued and disproportionate drop-off in large-size and high-value engineered valves for oil & gas pipelines, subsea installations, and severe-service valves used in power and steam generation.

Collapsing crude oil prices and upstream CapEx had a negative impact on selected valve sales, particularly in North America and in the upstream oil & gas sector in 2015 and 2016.



Significant legislation in certain regions will likely further negatively impact oil-related valve revenues, such as recent Alberta, Canada, climate-change plans that are moving toward phase-out of oil and coal-generated power plants, carbon pricing on greenhouse gas emissions, oil sands emissions limits, and methane emissions limits.

While these could ultimately prove beneficial, many in the industry fear that they could trigger further dislocations in an industry already severely stressed by the collapse in oil prices. Moreover, political uncertainties in South American countries such as Brazil and Venezuela will negatively affect additional industries. All these factors will play out over time and will be closely monitored by Resolute Research.

Setbacks similar to upstream oil & gas were also reflected in the mining industry relative to reduced demand for coal, metals and minerals, and in a consequent reduced demand for slurry and other types of valves. This is particularly relevant in a number of South American countries.

Reduced trade in bulk commodities in-turn spilled over into the rail and marine industries in terms of reduced demand for new rail cars and ocean-going merchant vessels, and a slowdown in orders for bilge and ballast valves, and other marine valves that will negatively impact the major shipbuilding countries in Asia.

These industry weaknesses were mirrored by the regional economic slowdowns in China and other developing countries, and by flat to low-GDP growth in several developed economies including Japan, Italy, France, and Spain.

An additional market driver occurring in 2016 was the Brexit vote by the United Kingdom to leave the European Union. While political and economic effects of this vote have not played out at this time, it is likely that the most significant effects will be felt in the financial sector, with some spill-over effects in the capital goods sector for pumps, valves, flow meters, and other industrial products, as well. Whatever effects actually occur, will be different for each country in the EU, and will be tracked on a continuous basis by Resolute Research for any needed adjustments in industrial-product forecasts.

The positive note looking ahead is that the Brexit vote may have only minor effects in the long run, and that with respect to oil & gas, mining, and marine markets the regional and sector-specific setbacks can be reversed with a return to higher oil prices, and with renewed traction of traditional GDP drivers including population growth, increased urbanization, and increased standard of living in the developing economies. This is expected to begin occurring in 2017.

The **business environment** in valves continues to reflect rollup within the industry, despite difficult economic conditions. The largest acquisition involves the August 2016 announcement by Emerson of the acquisition of the Pentair Valves & Controls business for \$3.1-billion.

Acquisitions by the large multi-national companies continue to be a major activity in the industrial valve market.



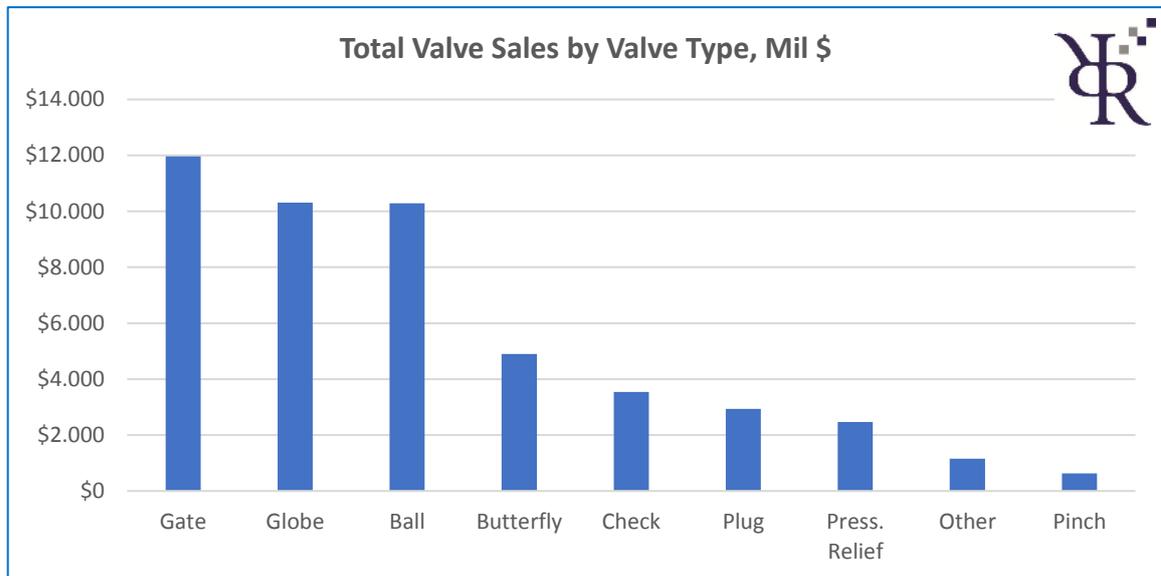
Other recent acquisitions in the valve industry include the acquisition of Apex Valves by Watts Water Technologies; Delta Industrial Valves by Weir Group PLC; Engine Monitor by W&O Supply; Guichon Valves by Valco Group; Bi-Torq Valve Automation by Strahman Valves; Roto Hammer Industries by Rotork; OPW Seal Products line by Nibco; Hunt Valve Company by May River Capital (private equity firm); EPE-Goldman by Indutrade; Transnordic by Hydraquip; Red Valve Company by Hillenbrand, Inc; and Jiangsu Xinghe Valve Company by Ham-Let. Also, AIV Europe has announced a partnership arrangement with Velan Valves.

The following table provides a snapshot of selected company acquisitions in the valve industry over the past year for which public financial information is available, along with the approximate “multiplier” for the acquisition. The multiplier is defined as the deal value divided by the latest published sales for the acquired company.

Purchaser	Target Company	Deal Value, Mil \$	Annual Sales of Target Company, Mil \$	Multiplier (Deal Value/ Annual Sales)	Acquisition Date
Schlumberger	Cameron	\$14.800,0	\$8.782,0	1,69	April 1, 2016
Emerson	Pentair Valves & Controls	\$3.150,0	\$1.832,6	1,72	August 18, 2016
Dover Corp	Tokheim Group SA's fuel dispenser systems business	\$465,0	\$310,0	1,50	January 7, 2015
Flowserve Corp	SIHI Group BV	\$372,5	\$350,0	1,06	January 8, 2015
TransDigm Group Inc	PneuDrualics Inc	\$325,0	\$64,0	5,08	August 19, 2015
IDEX Corp	Akron Brass Holding Corp	\$224,0	\$120,0	1,87	March 17, 2016
IMI plc	Bopp & Reuther GmbH	\$190,0	\$90,0	2,11	January 2, 2015
Rotork plc	Bifold Group Ltd	\$190,0	\$57,0	3,33	August 28, 2015
Hillenbrand Inc	Red Valve Co Inc	\$132,0	\$36,0	3,67	February 2, 2016
IDEX Corp	Alfa Valvole s.r.l.	\$117,0	\$35,0	3,34	June 10, 2015
Interpump Group SpA	Walvoil SpA	\$115,0	\$160,0	0,72	January 15, 2015
Weir Group plc	Delta Industrial Valves Inc	\$47,0	\$18,0	2,61	July 7, 2015
Mueller Water Products, Inc,	Singer Valve Inc.	\$34,0	\$20,0	1,70	January 30, 2017
Mueller Industries Inc	Sherwood Valve LLC	\$25,0	\$49,0	0,51	June 18, 2015
Rotork plc	Regal Beloit/Mastergear	\$25,0	\$22,0	1,14	April 29, 2016
KMG Chemicals Inc	Valves Incorporated of Texas	\$24,0	\$12,0	2,00	May 1, 2015
Watts Water Technologies Inc	Apex Valves Ltd	\$22,0	\$12,0	1,83	November 30, 2015
Ham-Let Ltd	Jiangsu Xinghe Valve Co Ltd	\$15,0	\$19,0	0,79	April 5, 2016
Rotork plc	Roto Hammer Industries Inc	\$12,0	\$5,0	2,40	September 29, 2015
Spirax-Sarco Engineering plc	Hiter Indústria	\$5,1	\$9,3	0,55	July 4, 2016



The **technology segmentation** of valves continues to show that sales of gate, globe, and ball valves dominate other valve technologies including butterfly, plug, check, pinch, pressure relief, and others.

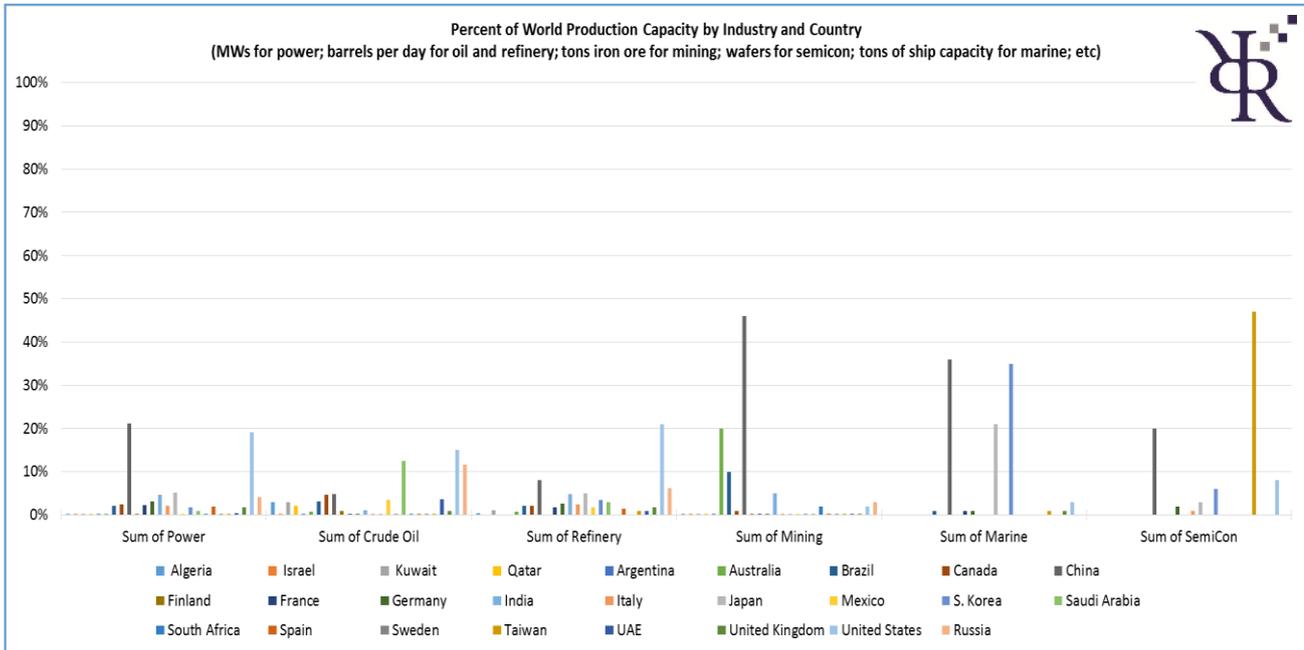


The **country segmentation** of valves reflects general economic activity, and therefore supports the largest sales volume in the United States, China, Japan, Germany, France, United Kingdom, Italy, and South Korea. However, country segmentation can exhibit significant variation for specific types of valves. The wellhead choke valves, for example, are disproportionately concentrated in the United States that has the largest share of oil & gas wellheads for any single country. Similarly, sales of high-pressure steam valves for utility power plants are currently concentrated in China and India to support the major build-out of new power plants in that region. So, the definitive assessment of country segmentation of valves is highly dependent on the particular type of valve.

The **industry segmentation** of valves is skewed on an overall basis toward Oil & Gas, Water & Wastewater, Chemical/Petrochemical, and Power as the largest markets for valves. However, there is significant segmentation of industries by country, as well. The illustration below highlights the following:

- In power, the dominance of the United States and China in terms of installed megawatts of power generation
- In upstream oil production, the significant dominance of Saudi Arabia, the United States, and Russia in terms of barrels per day production
- In refining, the significant dominance of the United States, but with growing opportunities in the Middle East and China as fuels consumption increases in developing nations
- In mining (with iron-ore production as the proxy), the significant dominance of China, Australia, and Brazil relative to the rest of the world

- In marine (merchant ships not including Navy), the near total dominance by China, Japan, and South Korea.
- In semiconductor fabs, the dominance by Taiwan, South Korea, China, and Japan for basic wafer production.



Market, technological, and regional trends in valve sales are addressed at the end of this report, reflecting attractive near-term opportunities most closely aligned with basic human needs in the areas of water, electricity, food & beverages, and pharmaceuticals. These sectors are relatively insulated from the uncontrollable price fluctuations in the oil & gas, and commodities markets.

The market dynamics in the United States are being especially closely watched for possible increased opportunities in valve sales related to new pipeline construction, power plant construction, and general infrastructure spending including water & wastewater treatment plants promised by the new Administration. The situation will be closely monitored by Resolute Research.

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VALVE SUPPLIERS

There are well over 800 valve manufacturers worldwide, and consequently the valve market is highly fragmented. The largest single supplier accounts for about 7% of the total available market, with most of the remaining companies accounting for typically just a fractional percent of market share. Nevertheless, mergers and acquisitions within the industry have resulted in consolidation such that the Top 35 companies generating approximately \$20-billion in valve sales now account for approximately 46% of total market value. The recent acquisition of the Pentair valves division by Emerson moves Emerson solidly into the number one position in valves.

The top 35 valve companies account for approximately 46% of total valves sales.

The company rankings listed below reflect a total market average across all valve types and industries. Actual market shares are highly dependent on market segment. In specific markets like municipal water treatment, power generation, HVAC, oil & gas, and others, the market shares will be significantly higher or lower for specific companies. Additionally, ranking will change year-to-year based on individual company performance, and on future mergers & acquisitions. Macro-economic events such as the 2014/2015 collapse in crude oil prices can also disproportionately affect certain companies, with consequent effects on positioning. The table below is useful for approximate market positioning and brand research.

Company	Ownership	Approx. Market share, %	Major Valve Brands
Emerson (incl. Pentair Valves)	Public	6.56%	Bettis, Dantorque, El-O-Matic, Hytork, Shafer, Damcos, EIM, Fisher, Virgo, Enardo, Biffi, Cash, Clarkson, Crosby, Dewrance, Fasani, FCT, Hancock, Intervolve, Keystone, KTM, Hindle, Kunkle, Penberthy, Sempell, Vanessa, Varec, Yarway, others
Flowserve Corporation	Public	2.48%	Accord, NAF, Anchor/Darling, Noble Alloy, Argus, Norbro, Atomac, Nordstrom, Automax, PMV, Durco, Serck Audco, Edward, Schmidt Armaturen, Flowserve, Valbart, Gestra, Valtek, Kammer, Vogt, Worcester Controls, McCANNA/MARPAC, Limitorque
Crane Co.	Public	2.07%	Xomox, Saunders, WTA, Alloyco, Center Line, Crane, Duo-Chek, Flowseal, Jenkins, Krombach, Noz-Chek, Pacific, Stockham, Triangle, Uni-Chek, Crane Nuclear, Crane Fluid Systems, Brownall, Hattersley, IAT, NABIC, Sperryn, Viking Johnson, Wade, Wask, Barksdale, Revo
Schlumberger Limited	Public	2.02%	Cameron, Demco, General Valve, Grove, Douglas Chero, Entech, Newco, Textstream, Techno, TK, Thornhill Craver, Navco, Nutron, Orbit, Ring-O, TBV, AOP, WKM, Wheatley, others
GE (Ind. Segment)	Public	1.83%	GE, Becker, Consolidated, Masonellan, others
IMI plc	Public	1.70%	Bopp & Reuther, Zikesch, CCI, InterAtiva, NH (Newman Hattersley), Orton, Remosa, TH Jansen, Trufflo Marine, Trufflo Rona, Z&J, Norgren, Buschjost, FAS, Herion, Maxseal, TA, Heimeier, Flow Design, Remosa, STI
Kitz Corporation	Public	1.65%	Kitz, Perrin, SCT, SGS, Toyo, TSO, others
Rotork plc	Public	1.52%	Bifold, Rotork, Mastergear, Centork, Soldo
Parker-Hannifin Corporation	Public	1.18%	Parker, PEGE, Bestobell, Conflow, Brettby, Gammatech
Metso Corporation	Public	1.10%	Metso, Neles, Jamesbury, Mapag, SNJ, Valvcon
ABB Ltd.	Public	1.09%	ABB
Auma Riester GmbH & Co. KG	Private	1.05%	Auma, Drehmo, Sipos
Aalberts Industries N.V.	Public	1.05%	Broen, BSM, Conbraco (Apollo Valves), Nexus, Ventrex
AVK Holding A/S	Private	1.04%	Flonidan, Glenfield, ICV, Mittelmann, HDL, G&W, Invicta, InterApp, JCH, Orbinox, TEC Artec, World-Valve, Wouter Witzel, Cyl Knife Valves, Premier Valves, Shimizu Kogyo, Bryan Donkin, Techflow, others
Mueller Water Technologies, Inc.	Public	1.00%	Meuller, Anvil, Gruvlok, Pratt, Jones, Milliken, US Pipe, Canada Valve
Belimo Holding AG	Public	0.89%	Belimo
Velan Inc.	Public	0.84%	Velan

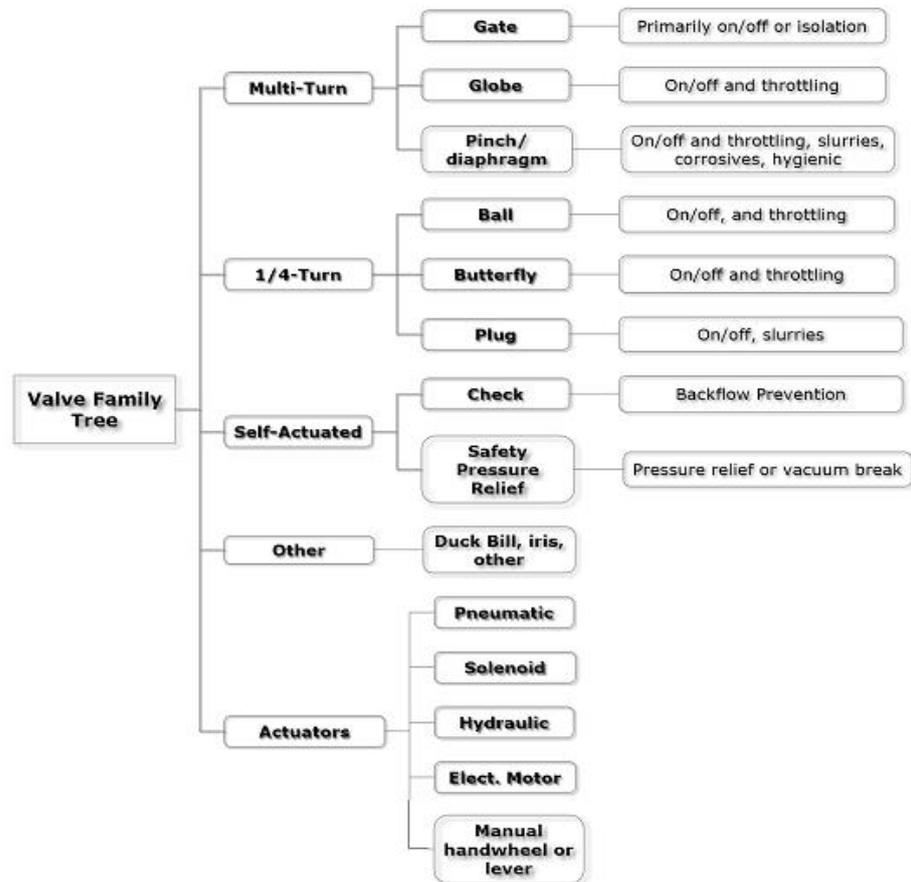
Valvitalia Group S.p.A.	Private	0.83%	Valvitalia, Delta, Rotor, Thevignot, Vanadour, Vitas, Others
VAT Group AG	Public	0.82%	VAT
National Oilwell Varco, Inc.	Public	0.79%	NOV
KSB Group	Public	0.79%	Amri, Sisto, Mil, KSB, Boa
Georg Fisher Piping Systems Ltd.	Public	0.78%	GF
Nibco, Inc.	Private	0.78%	Nibco, Chemtrol, Pex, HydroPure, Performance Bronze
Hoerbiger Automatisierungstechnik Holding GmbH	Private	0.74%	Hoerbiger
Aker Solutions Subsea	Public	0.72%	Aker, Aker Klyde, EI-drive
Circor International, Inc	Public	0.70%	Circle Seal-Atkomatic, Circor Tech, Contromatics, CPC-Cryolab, DeltaValve, GO Regulator, Hoke-Gyrolok, Hydroseal, KF Valves, Laurence, Leslie Controls, Mallard Control, Pibiviesse, Rockwood Swendeman, RTK, Schroedahl, Spence, TapcoEnpro, Aerodyne, Circor Industria, Hale Hamilton, RKK, Circor Bodet, Others
Bürkert GmbH & Co. KG	Private	0.64%	Bürkert
Neway Valve (Suzhou) Co., Ltd	Private	0.62%	Neway
Danfoss A/S	Private	0.59%	Danfoss
Kurimoto Ltd.	Public	0.56%	Kurimoto, Flotus
Schneider Electric	Public	0.54%	Schneider Electric
Siemens AG	Public	0.54%	Siemens, Acvatix
Balon Corporation	Private	0.47%	Balon
Saint Gobain S.A.	Public	0.46%	Furon, Siant Gobain, PAM
Larsen & Toubro Limited	Public	0.46%	L&T Valves

VALVE TYPES

A valve is a device that controls the flow of liquids, gases, or flowable granular solids. Valves control the rate of flow, the volume of flow, and the pressure or the direction of flow. As such, valves can be applied to simply turn on and turn off flow, or to regulate flow. They can also be applied to isolate other equipment such as pumps for repair or replacement. Valves may range in size from less than an inch to five or more feet in diameter, such as applied for large water, oil, or gas pipelines.

Valves can be broadly classified as **multi-turn**, **quarter-turn**, and several other types of **self-actuated valves** like check valves or pressure relief valves. Valves can be complex, and within each classification are additional specialized designs that are discussed later. Major valve types include gate, globe, ball, butterfly, plug, check, pressure relief, pinch, and others.

Over time, valves have evolved into special applications, where one type of valve outperforms or is better suited for an application than another type of valve. For example, gate valves are best suited for shutoff and wide-open unobstructed flow, and are rarely used for throttling. In contrast, globe valves are widely used for throttling control, along with several other types. See illustration below.



VALVE APPLICATION BY VALVE TYPE



Gate Valve: Typically applied for on/off service.

Gate Valves: Gate valves are multi-turn valves and are among the most commonly used valves in industry. They are available in relatively small sizes less than 2-inches up to very large sizes in the range of 60" or larger suitable for water, and oil & gas pipeline service. They are most often used for on/off service (isolation), and only rarely used as a control valve for modulating service due to highly non-linear flow relative to stem position, and due to issues associated with gate and seat erosion in throttling applications. The valves are available with rising stem or non-rising stem designs, where valve position is indicated by the height of the stem (rising stem designs) or by an arrow indicator linked to the gate (non-rising stem designs). They provide tight shutoff service, and are relatively easy to manufacture and repair relative to other valve types, and reflect a rugged construction suitable for many on/off applications. They are bi-directional, and can be selected to provide full-bore pipe opening for low pressure drop. As with most valves, gate valves are available in multiple configurations including solid **wedge gate**, **parallel gate**, **knife gate**, and **through-conduit gate**, among others. The solid wedge gate is the most common. Gate valves find wide usage in on/off/isolation applications in oil & gas (pipeline service and wellhead), power generation (including for slurry service with knife gate designs), marine and mining, and general industry. Gate valves perform well for liquids, gases, and slurries, including liquids with entrained solids.



Globe Valve: Widely applied as a modulating control valve, and for on/off service.

Globe Valves: Globe valves are multi-turn valves commonly applied to start, stop, or regulate flow in a system and, as such, are a common control valve. Globe valves may be manually operated by hand-wheel or by other automated actuator. They are available in three basic body configurations including T-Pattern, Right Angle, or Wye Pattern. The type of body configuration selected reflects application parameters including flow rate, pressure drop, temperature, steam service or water/liquid service and other factors. In the full-open position, there may be considerable pressure drop across a globe valve (compared to straight-through gate, ball, or plug valve) because of the disrupted flow path in a globe valve, particularly in T-Pattern and Right Angle Pattern valves. Globe valves are generally used in sizes 12-inches or below because of the force (torque) requirements to close some types of globe valves in high-pressure applications, although larger sizes are available. Advantages of globe valves include tight shutoff performance, modulating flow control, relatively short stroke for confined spaces (relative to gate valves), and easily replaced or refurbished discs and seats. There are numerous applications for globe valves as control valves in the water and power industries, as well as the general process industries.



Ball Valve: Typically applied for on/off service, and with special ball design as a throttling control valve.

Ball Valves: Ball valves are the most widely applied member in the family of quick-opening/closing quarter-turn valves. They generally feature a 90-degree rotating spherical ball with a central circular passage through the ball and aligning with the pipe connections to permit flow when in the open position. Advantages of these valves includes straight-through flow and therefore low turbulence, low operating torque, tight closure, and compact design. They are widely employed in many industries including general industrial, chemical, petrochemical, refinery, pulp & paper, power plants, gas and oil pipeline (full bore to permit pipeline pigging), water & waste water, and many other industries. There are two major types of ball valves including floating ball, and trunnion ball. In the floating design, the ball is not fully secured by a rigid anchoring permitting slight in-line movement such that line pressure compresses the ball against the seat to provide a tight seal when closed. In the trunnion design, the ball is held in place by an anchoring mechanism or trunnion at the top and bottom of the ball. The trunnion valves are more suitable for larger sizes and higher pressure applications. Floating ball designs are most common for line sizes below 6" and for mid to low-pressure applications. There are a number of basic body designs for ball valves including single-piece, two piece, three piece, welded, and several other types. They are also available in end-entry or top-entry for installation of the ball, with top entry designs suitable for in-line repair. Valve sizes may range from less than 1-inch to 48-inches or more for pipeline service. Ball valves are most commonly used for on/off or isolation service, but can be applied for modulating flow control where there is no requirement for extreme accuracy, and often utilizing a specially designed ball. Valves can be either manually handle operated, or actuator operated. Ball valves are most commonly supplied in the 2-port design (1 inlet and 1 outlet), although 3-port or even 4-port designs are available for special applications. Ball valves are available with soft seats or metal seats, depending on the service. Metal seats are best suited for severe service including high temperatures or pressures (or cryogenic service), flashing, or applications with gritty abrasive slurries. Soft seated valves, which are the most common, are best applied for less severe service on clean liquids and temperatures generally below 450F, and in applications requiring bubble-tight shutoff. Soft seats are often an engineered plastic like PTFE. Metal seats are often an alloy such as 316 Stainless Steel or Monel. Coated metal seats are available for especially severe service applications.



Butterfly Valve: Applied for on/off service, or for modulated flow control.

Butterfly Valves: Butterfly valves are another valve in the class of quick-opening/closing quarter-turn valves. They are often less expensive than other types of valves due to a small footprint and relatively light weight and smaller material content. They can be operated manually by a lever, gear, or by automatic actuator. Butterfly valves can be used for isolation (on/off operation), or for modulated flow control. The dominant construction feature of the butterfly valve is a quarter-turn rotating disk that provides valve closure when fully seated in a position perpendicular to the pipe axis, or

variable flow when the disk is rotated to any angle up to 90-degrees for fully open operation. In the full open position the disk and operating shaft remain in the flow path resulting in some pressure drop across the valve. The most common end connections include wafer, lug, or flange. There are three major designs of butterfly valves including concentric, double offset, and triple offset. The concentric design is the simplest and lowest cost and usually includes a metal disk and resilient rubber seat operated by a centrally located operating shaft. This is a general purpose valve. The double and triple offset valves are high-performance valves with an offset operating shaft to provide improved wear performance. The triple offset valve provides the highest wear protection of the seat sealing surface for long operating life. Butterfly valves are commonly applied in oil & gas terminals and for storage tank fill/drain, and for LPG and LNG, as well as water markets, power plant cooling-water systems, chemical plants, marine applications, and general industrial. They are not applied for oil & gas pipeline duty which requires an obstruction-less full-ported ball or gate valve to permit pipeline pigging.



Plug Valve: Widely applied for severe service with abrasive liquids.

Plug Valves: Plug Valves are a third valve among the class of quick-opening/closing quarter-turn valves. They reflect a relatively simple design, and are applied in a variety of applications. The dominant construction feature is a rotating cylindrical or tapered plug operating in a sleeve internal to the valve body. The plug most typically includes one circular hollow passage through the plug that permits flow when aligned with the valve inlet and outlet ports. A quarter turn of the operating handle rotates the passage away from the valve inlet and outlet ports, thereby closing the valve. There are two major designs of plug valves including simple quarter-turn designs, and a slightly more complex lift-and-turn design. The **simple quarter-turn design** has wide applications in severe service application including H₂S, CO₂, and abrasive high-wear applications including slurries in wastewater treatment plants or oil & gas pipelines with relatively infrequent operation. The **lift-and-turn design** provides features that protect and extend the life and integrity of the seals, and these valves are often applied in downstream applications such as isolation valves for fuel storage tanks, loading and unloading terminals, metering skids, and other zero-leakage applications that involve more frequent valve operations. The most common design plug valve is a simple two-port design (1 inlet and 1 outlet), although 3-port designs are available for special applications.

Pinch Valves: Pinch valves (also known as diaphragm valves) are a type of 2-port control valve that incorporates an elastic tube or flexible elastomeric diaphragm(s) that are pinched together to provide modulation or shutoff of flow through the valve. Pinch valves are most often used for abrasive slurries or liquids with entrained solids that will erode the plugs and seats of other types of valves, and for aggressive chemical applications to provide zero-leakage performance to the environment. Common applications include waste water, cement plants, chemical plants, food & beverage

plants, pharma plants, mining operations, and other similar applications. Pinch valves are generally not used for high temperature and high pressure applications.

Check Valves: A check valve (also known as a non-return valve) is used to prevent backflow in a pipe, or intermixing of fluids in a multi-fluid system. Three basic designs are prevalent including a “**swing disk**” check valve, “**ball lift**” check valve, or “**piston lift**” check valve. In a check valve, it is fluid flow that keeps the valve open, and loss of flow or flow reversal or gravity that causes valve closure.



Check Valve: Applied for back-flow prevention.

In operation, forward flow in the pipeline pushes against a hinged disk or wafer in the valve (or spring-biased piston or ball) to move it to some degree of open position depending on flow rate. No flow or reversal of flow moves the disk, ball or piston back into the closed position preventing backflow of fluid. As described, there are a number of different designs of check valves (e.g., disk, piston lift, or ball lift), with the particular selection depending on various criteria including application, fluid media, available space, valve orientation, and sizing considerations. Process connections may include flange, wafer, screw or welded. Check valves are often applied upstream of pumps and compressors to prevent damage in the event of reversed flow, as well as many other applications in process industries to maintain set pressures or prevent mixing of fluids in isolated systems. Check valves are found in virtually all industries including oil & gas, oil-field production, refinery, petrochemical, chemical, power generation, water treatment, and many others.

Pressure Relief Valves: A pressure relief valve (PRV) is a special valve applied to limit or control pressure in a vessel or process systems such as piping. They are applied for gas, liquid, and liquid/gas media. A typical example may be found in power plants where PRVs are applied to protect against a steam overpressure condition. In gas service (such as steam in a power plant), the relief valve is usually spring-actuated and “snap acting” and pops to the fully open position in the event of an overpressure condition. In other cases, the PRV may be “modulating” to provide proportional relief of system pressure. In most cases, there are code requirements for PRVs to prevent catastrophic failure of vessels or piping. There are also vacuum relief valves designed to admit air or an inert gas into a vessel or system in the event of a low-pressure event that could cause the collapse of the equipment. A typical example may involve a fuel storage tank where withdrawal of fuel or a sudden change in temperature could cause an internal negative pressure relative to atmospheric pressure and the collapse of the tank. PRVs are available in many types, and can be actuated by spring-action or by a pilot valve (pilot operated relief valve or PORV). Pressure relief valves are found in virtually all industries, with the heaviest concentrations in the power, refinery, chemical, and petrochemical industries due to the prominence of pressurized processes, and the presence of onsite power plants to produce high pressure process steam and electricity.

Other valves: There are other types of valves additional to those described above, but of smaller impact in terms of percent of market. These other types of valves can be separately identified and studied by Resolute Research as may be required by Customers.

Valve End Connections: Most valves are available with a selection of end connections including flange (flat face, raised face, ring), threaded (mostly for the smaller sizes of valves), wafer, butt-weld, socket weld, and sanitary clamp.

VALVE ACTUATOR TYPES

A valve actuator is a mechanism provided to fully open and close a valve, or to modulate the valve to some intermediate position between fully opened and full closed. Valve actuators are linear operating or rotary, and typically reflect one of the following drivers: **manual lever or hand wheel, pneumatic, hydraulic, or electric motor or solenoid.**

Traditionally, most valves have been manually operated in their capacity for occasional on/off operation as an isolation valve or bypass valve. However, increasing automation of more process functions to increase safety, improve efficiency, process control, and environmental protection; and to reduce operating costs have driven increased actuator sales for valves. Today, sales of actuators for integration into sophisticated digital control systems (DCS) is a growing segment of the overall valve market.

Pneumatic actuators most often use an air-pressure supply between 60 to 80 psi (4 to 6 bar). The quality of the air must be carefully controlled – especially in low-temperature environments – to avoid condensation and freeze up of supply lines. Pneumatic actuators are usually the most economical selection in terms of installed costs, especially in hazardous environments where the presence of electrical power or equipment presents an explosion hazard. Hydraulic actuators are applied where extreme fast acting and high-force requirements may exceed the capabilities of pneumatic actuators.

Electric actuators are available with DC motors, or AC motors in single-phase and 3-phase designs. Most suppliers also have optional designs that conform to NEMA VII guidelines for application in hazardous environments. Recent advances in motor technology, actuator capabilities, and cost reductions have made these types of actuators increasing popular in many applications, despite the higher first-cost of electric actuation relative to pneumatic actuation.

Actuation Type	Approx. Market Share, %	Typical Valve Application	Commentary
Manual only (handwheel or lever)	60%*	Infrequently operated isolation or bypass valves, or instrumentation valves.	Manual-only valves steadily being upgraded to automated functionality for increased plant efficiency, safety, and environmental protection.
Pneumatic	20%	Nearly any process-industry control valve, especially in hazardous areas.	Currently most widely applied process-industry actuator type, but facing increasing market pressure from electric actuators.
Hydraulic	5%	Control valve applications, often in oil & gas, involving high-force requirements	Primarily used where fast-acting, high-force actuation is required.
Electric	15%	Nearly any control valve application, but especially applications requiring precise instrumental valve control.	Growing applications due to simple, efficient, small-footprint designs, with fewer parts and less maintenance than pneumatic or hydraulic actuators.

*Includes self-actuated check valves and pressure relief valves.

Valve actuators can be supplied by the valve manufacturer along with the valve, or by separate actuator manufacturers such as AUMA, Rotork, and others.



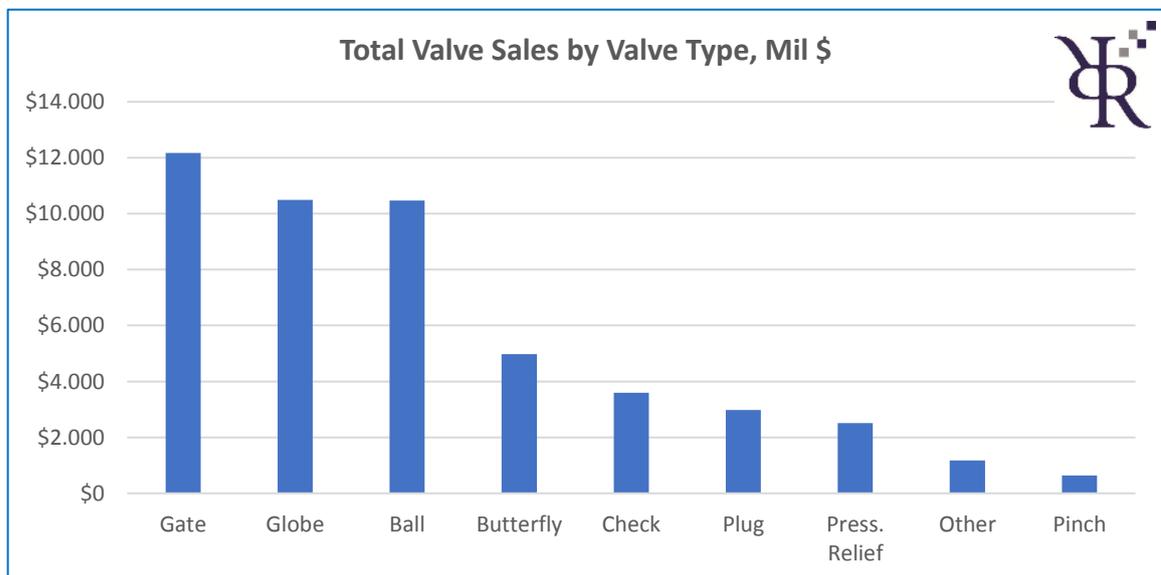
VALVE SALES BY VALVE TYPE

The family of multi-turn valves (gate and globe) comprise the largest family group of valves currently in use.

In terms of specific valves, gate valves are the most widely used valve because they are available in a full range of sizes from approximately 1-inch to more than 60-inches, with a wide selection of end connections and pressure ratings. They can, moreover, be used with gases, liquids and slurries, and are a common valve in oil and gas wellheads which number in the millions, as well as oil & gas pipelines. Gate valves are suitable for on/off, isolation, and shutoff service in virtually all industries.

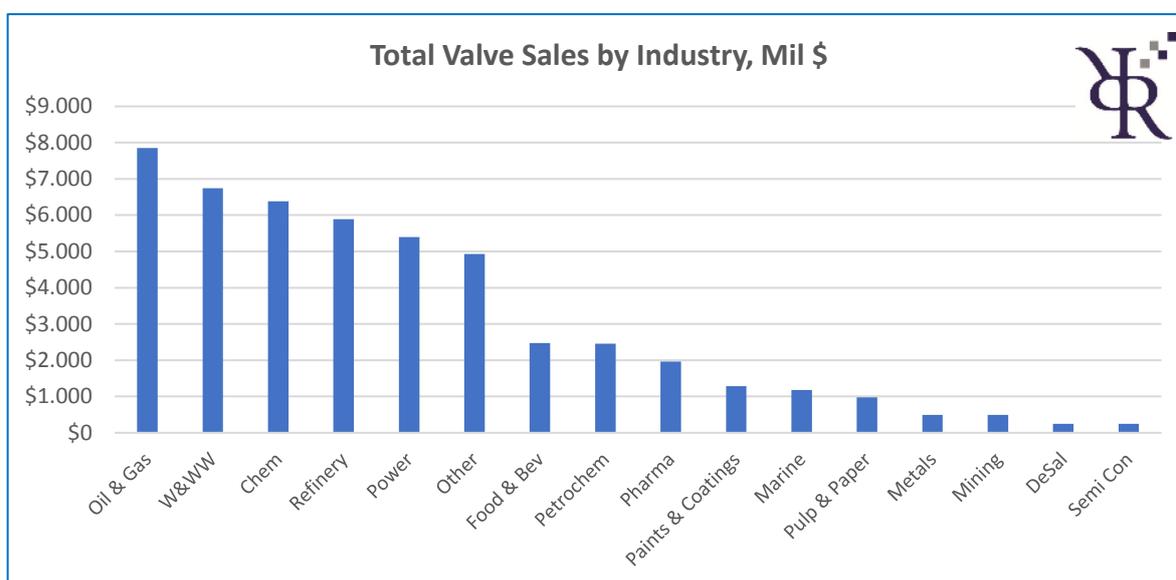
Quarter-turn valves have grown to a close second-place position (relative to gate and globe valves) because of desirable operational features including quick ¼-turn opening and closing, compatibility with many different media, low pressure drop in the fully open position, large range of sizes and end connections, and designs suitable for both control as well as on/off operation. The ball valve is the most widely used in the family of quarter-turn valves.

As shown (below), gate, globe, and ball valves account for more than two-thirds of total valve sales. The remaining one-third of valve sales are split among butterfly, plug, check, pressure relief, pinch, and 'other' valves.



VALVE SALES BY INDUSTRY

Although valves are found in virtually all industries, oil & gas, water & wastewater, chemical, refinery, and power are among the largest applications.



The **upstream** oil & gas industry is the largest user of valves to outfit the millions of wellhead “Christmas trees” that include usually 3 to 5 valves per tree in sizes of 2” to 8”, as well as to segment and control flow through millions of miles of gathering pipelines (2” to 20” valves) and cross-country trunk pipelines (up to 60” or larger) required to bring the crude oil and gas to refineries, and the refined product (gasoline, diesel, natural gas) to end-user markets. The United States has more than twice the total length of pipelines of all the other world nations, combined. Similarly, the United States has approximately 50% of the entire world’s operating wellheads.

The **downstream** oil & gas market consisting of refineries, gas plants, and refined-product storage/distribution terminals is another large market. There are approximately 650 refineries, worldwide, with each including an estimated 10,000 to 15,000 valves, and thousands of storage/distribution terminals which include valves for tank fill and drain, plus pressure relief and vacuum-break to protect tanks from rupture or collapsing under vacuum.

The **water & wastewater industry** includes hundreds of thousands of governmental water utilities, with more than 50,000 in the United States as estimated by industry analysts. Most of these water utilities service small communities, with a vastly smaller percentage serving the large urban centers having several millions of connected residents and businesses. Valve applications are found in water and wastewater treatment plants for handling raw water, treated water, sludge, and treatment chemicals, as well as transportation infrastructure including pipelines and pumping stations for

sewer lines and potable water lines. The essential and widespread infrastructure makes this a major market for pumps and valves, worldwide, with maintenance and replacement as major drivers in the developed world, and new infrastructure in the developing countries.

The **power industry** is a growing market, especially in the Middle East and Asia in countries including Saudi Arabia, China, India, Vietnam, and others. Growth in these regions reflects actual load growth for residential, commercial, industrial, and desalination applications. Power plants include nuclear, coal, oil, and natural gas fired plants, which include millions of dollars in valve investment per plant. New mega-watts planned per country is a key metric for forecasting valve prospects in advance of project start date.

The **chemical industry** is another growth industry, in terms of bulk chemicals like nitric acid, sulfuric acid, soda ash and others, and specialty chemicals and petrochemicals for plastics, pharmaceuticals and water treatment, as well as for agricultural fertilizers, herbicides, and insecticides. Most valves in these industries are in smaller sizes of approximately 1" to 12", and include the full family of valves such as gate, globe, ball, butterfly, plug, check, pinch, and pressure relief. The market is highly fragmented (excepting the petrochemicals market which is more concentrated along the lines of refineries), with many thousands of chemical plants, worldwide. The leading chemical-producing countries include the United States, Germany, Russia, China, Japan, United Kingdom, Italy, France, India, and Brazil. Major chemical producers are listed later in this report.

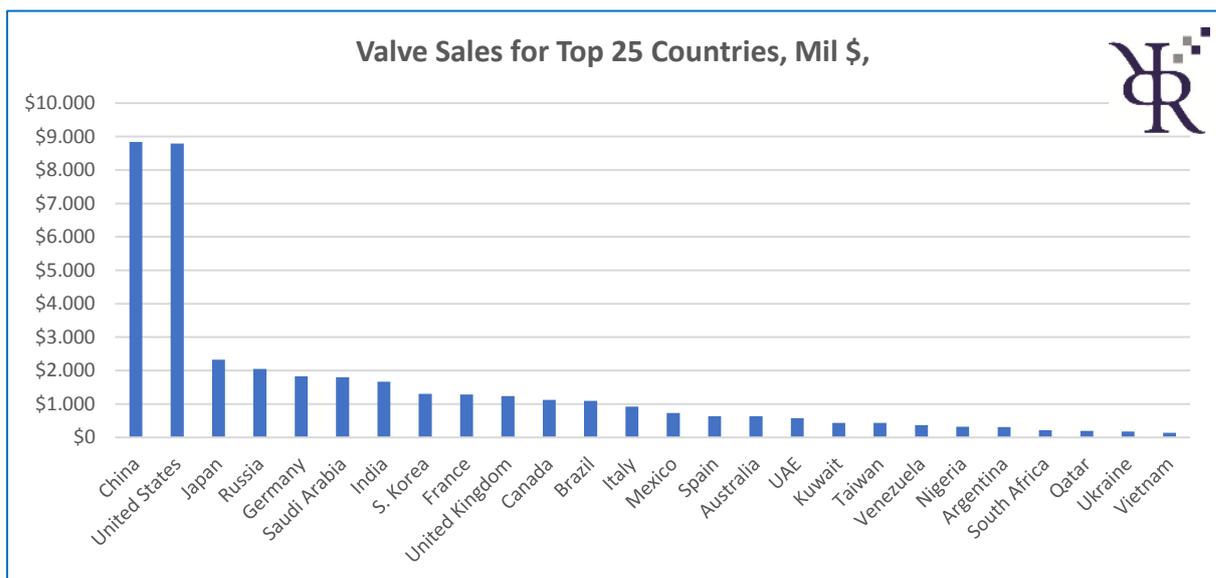
The other major industries are also large consumers of valves, and are provided in-depth analysis in the Valve Product Data Base available for purchase through Resolute Research.

VALVE SALES BY REGION AND COUNTRY

At a high level, the geographic distribution of valves reflects general economic activity, although the rapid growth in some countries, particularly China and India make purchases of valves greater than would be expected merely by GDP. Put another way, new valve sales are at a higher level in developing countries because of infrastructure expansion, whereas in developed countries in North America and Western Europe low organic growth is limiting valve sales largely to replacements and aftermarket parts (and exports).

Significantly, the geographic segmentation of valve sales may reflect anomalies related to concentration of a particular industry in a particular region. For example, there has been a disproportionate level of activity in pipeline valves in North America reflective of hydraulic fracturing for shale gas and oil and the consequent expansion of gathering pipelines linking the new wellheads. Similarly, there is a concentration of ultra-pure engineered-plastic chemical valves in Asia reflecting the high concentration of semiconductor foundries in Asia that require specialized valves for semiconductor production. So, it is critically important to consider valve type in any geographic segmentation study.

The graph below shows the segmentation of all valve types by major country. As shown, the United States and China dominate world markets on a country-by-country basis. The United States is skewed higher by the large value of valves used in the upstream oil & gas industry, and that is not repeated in any other country to the same degree. Country rankings are subject to change year-over-year because of major industry movements (like oil & gas) and the close revenue-positioning of many of the countries listed in the illustration.



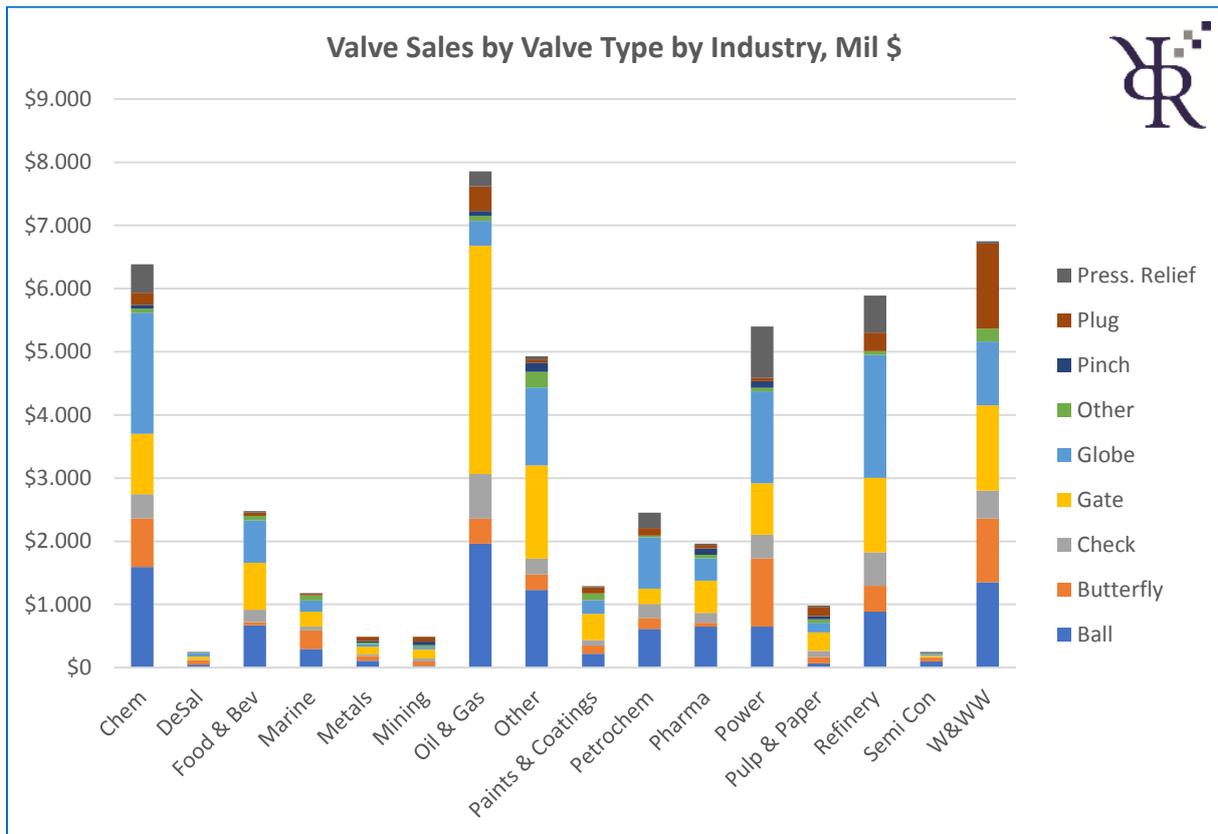
VALVE SALES BY INDUSTRY & VALVE TYPE

Distribution of valve sales by valve type and industry is characterized by several significant attributes.

The first attribute is the dominance of gate and ball valves in upstream oil & gas reflecting conformance to API Specification 6D/ISO 14313 for full-port “piggable” designs in large sizes required for pipeline service, plus the requirement for conformance to API Specification 6A/ISO 10423 for the smaller 2” to 8” Christmas tree valves in service on the millions of oil & gas wellheads, worldwide.

A second significant attribute is the wide usage of globe valves in the power, refinery, and chemical industries, reflecting the broad requirements for modulated steam used in process heating or power generation, and the broad requirements for modulated control valves in batching and blending common to industries like chemical, petrochemical, refinery, and food & beverage. This type of selective industry analysis is possible with the Valve Product Data Base which is available through Resolute Research.

The illustration below highlights basic segmentation of valve types by industry. The dominance of gate, globe, and ball valves across major industries is evident.



Calculation of new sales vs. aftermarket sales is a multi-variable operation that involves market growth rate, size of the installed base, product life expectancy, and other factors.

VALVE SALES BY NEW VS. AFTERMARKET

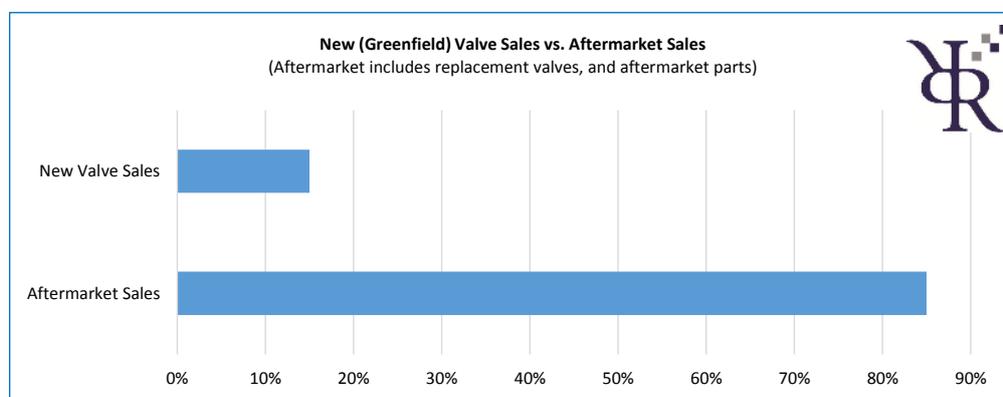
The distribution of valve sales by *new vs. aftermarket sales* is an important consideration in go-to-market strategy. It is a topic with multiple factors including the growth rate of the basic market, the size of the installed base, the average life-expectancy of the product, and the geographic region in question.

This last point is best illustrated by consideration of a real-world scenario. The installed base of coal-fired power plants in the United States is large, yet no new coal-fired power plants have been built for a significant time because of environmental and legislative issues. Therefore, the coal-fired power plant valve market in the US is virtually 100% aftermarket (parts and replacement valves). Conversely, the coal-fired power plant build rate in China and elsewhere in Asia is high, and most existing plants are less than 20 years old. In that region, valve sales are largely new sales. So, the market conditions of the region are important in assessing new vs. aftermarket sales.

That notwithstanding, new vs. aftermarket sales are fundamentally a function of the growth rate of the market, the size of the installed base, and the life expectancy of the product. In this context, a straight forward assessment can be made, with the other considerations required only to fine-tune the analysis.

- Assume an installed base of 100 units.
- Next assume an approximate 20-year life expectancy for the product
 - This suggests an annual replacement factor of 1/20 or 0.05
 - It can then be calculated that the annual aftermarket sales are equal to the installed base (100 units) times 0.05 or 5 units/year.
- The new-product sales can be inferred by taking total sales in the region, less the computed aftermarket sales.

As a general rule for **mature** markets, new valve sales vs. aftermarket valve sales and parts sales is broadly characterized as shown in the illustration below. As noted earlier, the situation is markedly different for an emerging market, such as Asia.



VALVE APPLICATION GUIDELINES

Valves must always be selected to meet the operating and safety requirements of the specific application in terms of flow capacity, pressure rating, temperature requirements, material compatibility requirements, among others. However, there are often options in terms of the particular technology selected (e.g. gate, globe, ball, etc.). The table below provides some general application guidelines for valves, reflecting valve type, size, function, and varying media characteristics.

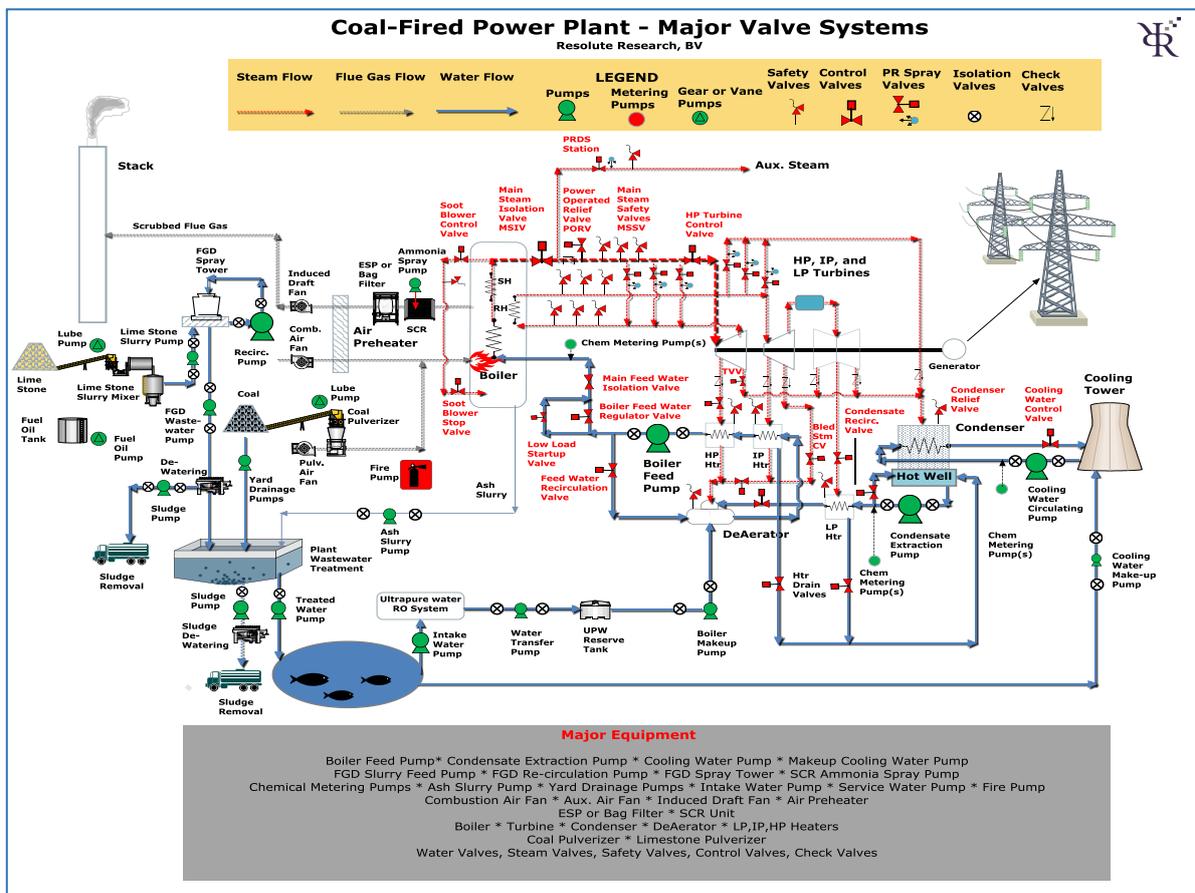
Attributes and Applications	Valve Type							
	Globe	Gate	Ball	Butterfly	Plug	C h e c k	Pressure Relief (PRV)	Pinch
Size Range, Inches*	1/8 to 30	1/8 to 48	¼ to 48	2 to 72	¼ to 30	¼ to 30	½ to 16	1 to 12
On/Off/Isolation	Prime Application	Prime Application	Prime Application	Prime Application	Prime Application	Not Applicable	Not Applicable	Prime Application
Control/Throttling	Prime Application	Not Suitable	Suitable (spec. ball)	Suitable	Suitable	Not Applicable	Not Applicable	Suitable
Over-Pressure Protection	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Prime Application	Not Applicable
Reverse-Flow Protection	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Prime Application	Not Applicable	Not Applicable
Water and Clear Liquids	Prime Application	Prime Application	Prime Application	Prime Application	Suitable	Prime Application	Suitable	Suitable
Abrasive Slurries	Not Suitable	Prime Application	Suitable (metal seat)	Suitable	Prime Application	Suitable	Not Applicable	Prime Application
Steam	Prime Application	Prime Application	Suitable	Gen. Not Used	Suitable	Suitable	Prime Application	Gen. Not Used
Sanitary/Hygienic Designs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Prime Application
Cryogenic Designs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not Applicable
Subsea Designs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not Applicable
Oil & Gas Pipeline (API 6D)	Gen. Not Used	Yes	Yes	Not Applicable	Yes	Yes	Yes	Gen. Not Used
Oil & Gas Wellhead (API 6A)	Yes	Yes	Yes	Not Applicable	Yes	Yes	Yes	Not Suitable

*The size range for valves is "typical" and not absolute. Some manufacturers may offer valves larger or smaller than those shown.

Control valves are also selected based on seat leakage classification. There are six common leakage classifications ranging from Class I to Class VI as specified in ANSI/FCI 70-2. The European equivalent standard is IEC 60534-4. Class I is the least stringent and is referred to as a dust-tight specification. Classes II, III, and IV must meet leakage limits of 0.5%, 0.1% and 0.01% of rated valve capacity, respectively. Class IV is often referred to as the metal-to-metal valve specification. Classes V and VI are for more critical applications requiring tighter seat sealing and are rated on a more complicated system referencing differential pressure or seat diameter. Class VI is often referred to as the soft seat specification, or "bubble tight" specification required for hazardous fluids or critical processes.

VALVE SELECTION BY PROCESS FLOW REQUIREMENT

Valves are often applied in similar ways within specific industries. For example, valves in coal-fired power plants (illustration below) are supplied to meet basic system functions including control of water intake, boiler feed, condensate extraction, cooling water circulation, flue gas scrubbing, chemical metering, steam pressure relief, steam de-superheating, and many other basic valve functions. Valves in these applications are subjected to similar process flow requirements relative to flowrate, pressure, and temperature because modern coal-fired plants are typically constructed to the 1,000-MW supercritical design model. This has led to similarities in the “spec envelope” for engineered valves in these applications, and to a high degree of standardization in plant design.



The process flow diagram for other industries, including refinery, wastewater treatment, seawater desalination, metals processing or other industry is a useful tool applied for analyzing valve technical requirements, as well as market size, market growth, and market trends for valves.



VALVE OPPORTUNITIES BY INDUSTRY

Valve opportunities vary by industry, region, and valve type depending on specific market dynamics.

For example, worldwide market dynamics have temporarily depressed growth in major industries including oil & gas, marine, pulp & paper, and metals and mining. The driving dynamic could be a collapse in prices such as in the oil and other commodities markets, oversupply of capacity such as in the marine market, or reduction in end-use demand such as in the print media market.

In other cases, the market dynamics may be more regional, such as in power generation, which has seen very little load growth in Organization for Economic Cooperation and Development (OECD) countries in North America and Western Europe, while there has been major load growth in developing economies such as China, India, and elsewhere in Asia.

The table below provides a snapshot of opportunities based on industry, region, and technology. All projections reflect near-term conditions and are subjected to change over time.

Industry Sector	Regional Opportunity		Valve Technology Opportunities	Comments and Market Drivers
	OECD Countries	Developing Countries		
Water & Wastewater	Favorable	Favorable	Gate, ball, and plug valves	Infrastructure rebuild in OECD; New builds and standard of living improvements in developing countries
Food & Bev	Favorable	Favorable	Stainless steel and engineered plastic sanitary valves	General population growth; improvement in standard of living for underdeveloped regions
Pharma	Favorable	Favorable	Stainless steel and engineered plastic sanitary valves	General population growth; improvement in standard of living for underdeveloped regions
Power	Neutral	Favorable	High-pressure, high temperature, high delta-P severe service steam and water valves, slurry valves	Low load growth with focus on renewables in OECD; load growth in developing regions, and including coal, gas, and nuclear power plants
Oil & Gas	Neutral	Favorable	Industry conformant high-pressure, high temperature valves, zero leakage valves	High production costs for unconventional resources in OECD; low production costs in developing regions and the Middle East
Refinery	Neutral	Favorable	Industry conformant high-pressure, high-temperature valves, cryogenic valves, zero leakage valves	Low fuels consumption growth in OECD; fuels consumption growth and industry expansion in developing regions
Metals & Mining	Unfavorable	Neutral	slurry valves	High extraction costs in OECD; low extraction costs and new resources in developing regions
Pulp & Paper	Unfavorable	Neutral	High-pressure, high temperature, high delta-P severe service steam and water valves, slurry valves	Lower demand for print media due to digital era; low cost production in developing regions, with opportunities in corrugated board and packaging
SemiCon Fabs	Unfavorable	Favorable	Stainless steel and engineered plastic high-purity valves	Low manufacturing capacity in OECD; growth of production capacity and consumption in developing regions
Marine	Unfavorable	Neutral	Bronze and stainless steel valves	Low manufacturing capacity in OECD; over-capacity worldwide; aftermarket opportunities for ballast water treatment and flue gas treatment driven by international environmental legislation

VALVE MATERIALS OF CONSTRUCTION

The materials of construction for valves generally reflect broad industry practices, and are different for different valve parts including housings, plugs, seats, shafts, seals, and packing materials. Nevertheless, some broad guidelines generally apply. For example, the food & beverage and pharmaceutical industries are large users of stainless steel valves (also oil refineries for resistance to sulfur corrosion, and desalination plants for resistance to seawater); the semiconductor industry is a user of engineered-plastic or super-duplex stainless steel valves that meet ultra-pure standards and can deal with aggressive chemicals; and the marine industry is a large user of bronze or super duplex stainless steel valves. In all cases, materials of construction must be carefully matched to the specific application, including consideration of process parameters like pressure, temperature, concentration (particularly for acids), abrasion, potential for stress crack corrosion, and other factors. For abrasive slurry applications, case-hardened materials may be used.

The following table provides general guidelines on valve wetted materials of construction relative to some common liquids. Depending on the application, other materials may be suitable as well.

Liquid Class	Liquid	Frequently used materials of construction
Waters	Fresh water	Brass, Bronze, 316 Stainless Steel
	Seawater	Bronze, 316 Stainless Steel, Duplex Stainless Steel, Inconel, Alloy 20
Slurries	Lime Slurry	Cast iron, Cast steel
Refined Fuels	Gasoline, Kerosene, Diesel	Carbon steel, 304 and 316 Stainless Steel, Alloy 20
Fuel Oil	Various	316 Stainless Steel
Vegetable Oils	Various	316 Stainless Steel, Alloy 20
Acids	Citric Acid	316 Stainless Steel, Alloy 20, Alloy B
	Hydrochloric Acid	Alloy B
	Sulfuric Acid	Alloy 20
	Nitric Acid	316 Stainless Steel, Alloy 20
Fruit Juices	Various	316 Stainless Steel, Alloy 20, Alloy B
Alcoholic Beverages	Beer	316 Stainless Steel, Alloy 20
	Whiskey & Wines	316 Stainless Steel, Alloy 20

VALVE INDUSTRY STANDARDS

Most industries require that valves and actuators meet an imposing set of industry standards to ensure fitness for purpose, quality, safety, and interchangeability within type and class. Worldwide, there are hundreds of different standards and specification related to valves.

In North America, valve standards are maintained by industry bodies including American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), American Petroleum Institute (API), American Society for Testing & Materials (ASTM), and Manufacturers Standardization Society (MSS).

Valve sales in Europe are also governed by standards and organizations dedicated to ensuring valve performance and quality. In Europe, valve manufacturers often become voluntary members of a national association, such as VDMA in Germany, ProFluid in France, BVAMA in the UK, AVR in Italy, NPAA in Russia, and others depending the country. These national associations may in turn become voluntary members of CEIR which is multi-national within Europe in scope. In addition to national associations, there are *national standards bodies* such as BSI in the UK, DIN in Germany, SNV in Switzerland, or ANFOR in France. Food & beverage sanitary applications are governed by the European Hygienic and Engineering Design Guidelines (EHEDG).

The CEN (European Committee for Standardization) is an organization that supports harmonization of European standards described above. Membership in CEN is generally restricted to members of the European Union. Harmonized Valve Standards are published in CEN/TC-69.

ISO provides a *worldwide* structure that supports defined quality and performance standards for valves and actuators on a worldwide basis. The section(s) of ISO that relate directly to valves are Technical Committees TC-153 (industrial valves), TC-185 (safety relief valves), TC-67 (oil & gas pipeline and wellhead valves), and TC-65 (process control valves). Compliance to all applicable valve standards (industry, national, and global) is essential for multi-national valve companies to be successful and is consequently handled by dedicated specialists knowledgeable in the field within each company.

VALVE SUPPLIERS BY VALVE TYPE

Listings of suppliers segmented by valve type are provided below. These segmented lists are not all-inclusive, but reflect significant suppliers. A more complete list is available in the Valve Supplier Data Base from Resolute Research.

Actuators: A-T Controls, AUMA Riester GmbH, Bray Controls, K-Controls, Rotork Controls, Emerson Process Management Valve Automation, GE-Dresser, Metso Flow Control, Nutork, Sirca International, St. Hans Controls, SIPOS Aktorik, others.

Globe Valves: Belimo, Bonney Forge, Circor, Conval, Crane, Emerson, Flowserve, GE, HP Valve, IMI, Johnson Valve, Kitz, KSB, L&T, Ladish Valves, Metso, Nibco, Parker, Powell, Milwaukee Valve, Samson, Eriks, Suzhou Douson, Valtorc, Velan, Weir Group, others.

Gate Valves: Circor Energy, Boteli Valve Group, Böhmer GmbH, Chaoda Valves Group, Derval Srl, Fangzheng Valve Group, Emerson, FMC, GE, IMI, ITT, Jinan Meide Casting Co., Kitz, Koflow Valve Group, KSB, L&T, Milwaukee Valve, MSA Rimeria Group, Powell Valves, SPX Flow, Valtorc, Velan, Zhejiang Guanli Valve, Ichinose Company, Xylem, Whenzhou Zhengte Valve, others.

Ball Valves: A-T Controls, Boteli Valve Group, Böhmer GmbH, Chaoda Valves Group, Circor Energy, CMEC SKVAL Co, Ltd, Crotti Fortunato, Emerson, FMC, Finazzi Osvaldo, FR Valve, S.r.l, GE, IMI, ITT, Kitz Corporation, Koflow Valve Group, Kong Jih Valve Industrial, KSB, L&T, Liviero Lino S.r.l., MSA Rimeria Group, Metso Valve Control, Fangzheng Valve Group, Zhejiang Oviko Group Group, Penta Srl, Pekos Valves S.A., Sferova S.r.l, Shanghai Shanghai Koko Group, SHK Valve Group, SPX Flow, Southern California Valve, Suzhou Viza Valve, Velan, Vinco Valves, Xuanda Industrial Group, Xylem, others.

Butterfly Valves: ABO Valve, Afcon Ningjin Yahua, A-T Controls, Bray Controls, Crane Chempharma & Energy, Chaoda Valves Group, Emerson, Fangzheng Valve Group, FMC, GE, HIPPO Valve, IMI, ITT, Jiangnan Valve Co., Kong Jih Valve Company, KSB, L&T, Metso Flow Control, Omal, OHL Gutermuth Industrial Valves, Powell Valves, SPX Flow, Velan, Walworth Valves, Xuanda Industrial, Xylem, Whenzhou Zhengte Valve, others.

Plug Valves: Australian Pipeline Valve, Crane, ChemPharma Flow Group, Emerson, Energy Valves Srl, Fangzheng Valve Group, FMC, IMI, ITT, Koflow Valve Group, L&T, Southern California Valve, SPX Flow, Xylem, Zhejiang Flowtech Machinery, others.

Check Valves: Circor Energy, Chaoda Valves Group, Crane, ChemPharma and Energy, Emerson, Fangzheng Valve Group, FMC, Flovel Valves, GE, Goodwin International, IMI, ITT, KSB, L&T, Milwaukee Valve, MSA Rimer Group, Powell Valves, Soosung Valve, Xylem, others.

Pressure Relief Valves: Emerson, Technical Srl, GE/Dresser, IMI, ITT, KSB, Curtiss Wright, FMC, Fukui Seisakusho, Leser, SPX Flow, Weir, IMI, Xylem, others.

Pinch Valves: AKO, Onyx, Cla-Val, Flowrox, Henry Pratt, others.

VALVE SUPPLIERS BY SPECIALTY APPLICATION

Most valve manufacturers offer valves that can be supplied in some capacity in nearly all market segments including power, oil & gas, refinery, chemical, water & wastewater, food & beverage, mining, and many others. These applications may include low pressure steam, water, slurries, and various non-aggressive liquids, which are found in nearly all industries.

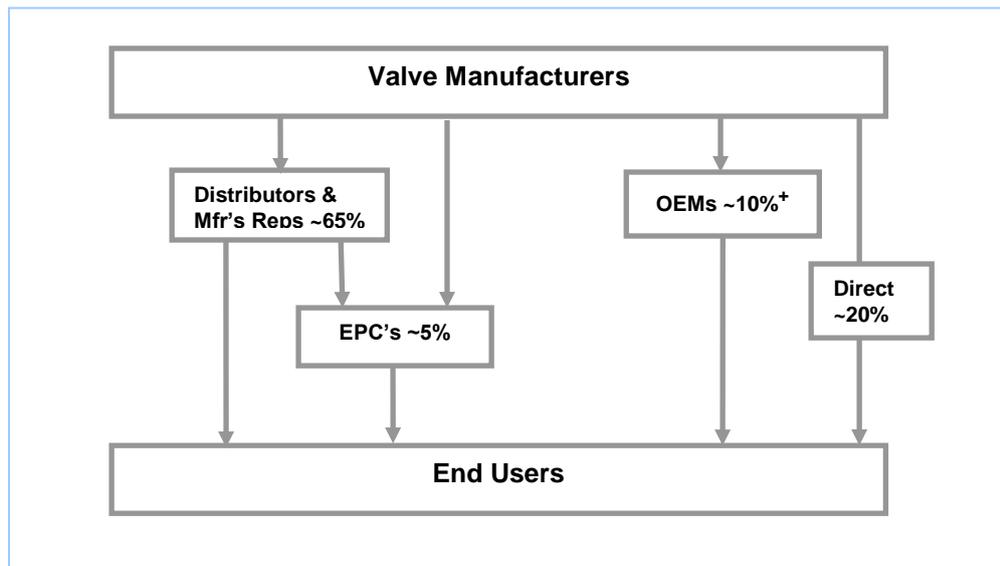
Therefore, a special categorization is necessary to provide meaningful differentiation by supplier for non-commodity “engineered” valves.

Engineered valves typically include either special applications or severe service system conditions that require a unique valve design or material of construction not offered by the hundreds of other commodity valve suppliers. The table below provides a breakout of several engineered valve applications not necessarily addressed by the manufacturers of commodity valve products.

Engineered Valve Applications	Prominent Suppliers (not intended as a complete list)
Cryogenic	Bonney Forge, Circor, Ebara, Flowserve, Kitz, Metso, Emerson (Vanessa, Narvik, KTM, Hindle, FCT, Fasani), Powell, SHK, Velan, others
Nuclear (N-Stamp)	Arca, Bray, IMI/Bopp & Reuther, BNL, Conval, CCI Sulzer, China Valves, Circor, Curtiss Wright, Crane, Dalian, Emerson/Fisher, Flowserve, GE Energy, Hayward Tyler, Hora, Henry Pratt, ITT Engineered Valves, KSB, Okano Valves, Thompson Valves, Neway, SPX Flow, Toshiba, Velan, Weir Group, others
Subsea	ABV, BuTech, Flowserve, Perar, Oceaneering, Dafram, Cameron, Valvole Srl, Severn Glocon, Oilgear, Oliver Valvetek, Petrolvalve, others
Hi-Pressure Safety Relief	Technical Srl, GE/Dresser, Emerson, Curtiss Wright, Fukui Seisakusho, Leser, Weir, IMI/Bopp & Reuther, others
Low Pressure Tank Venting	Braunsweiler/Protego, Varec, FNC, Enardo, Groth, Protectoseal, Safety Systems UK, Shand & Jurs, Emerson, Kito, Oceco, Cashco, others
Back Flow Prevention	Circor, Chaoda Valves Group, Crane ChemPharma and Energy, Emerson, Fangzheng Valve Group, Flovel Valves, Goodwin International, MSA Rimera Group, , Powell Valves, Soosung Valve, others
Compressor Anti-Surge	Emerson/Fisher, CCI, GE, Flowserve/Valtek, Metso, Mokveld, Severn Glocon, Mogas, Koso Kent, others
Sanitary/Hygienic Valves	Alfa Laval, GEA, Emerson (Keystone), Evoguard, GVS Valves, Sterivalves, Dixon, OMC Srl, Inoxpa, Kieselmann, Samson, SPX Flow, ITT Engineered Valves, Mucon, Goetze, Zoedale, others
General Industrial	See Resolute Research Valve Suppliers Data Base sold separately for a 800-plus listing of valve suppliers

VALVE CHANNELS TO MARKET

Distribution is a critical component in valve marketing, and a robust infrastructure has evolved to service the millions of valve end users. The traditional distribution channels include: direct sales to end users; distributor sales; OEM sales; and sales to engineering, procurement, and construction specialists (EPC's). A generalized value-chain graphic is shown below. It should be noted, however, that in some industries, such as food & beverage, OEM sales can be 60% or more of sales.



+ Note: Valve sales in the semiconductor, pharma/personal care and food & beverage industries are largely OEM sales involving skidded systems (90% OEM for pharma and 75% for food & beverage). Valve manufacturers increasingly offer skidded systems to customers.

Day-to-day
sales

Distributor Sales

Distributor/Rep sales comprise the largest segment of the valve market, and service residential, commercial, and industrial customers. Distributors often align their business along specific industry lines. For example, a distributor handling lines of stainless steel pumps, valves, and fittings will focus on the sanitary industries including food & beverage, pharmaceutical, and bio-tech. Distributors handling semiconductor manufacturers may specialize in stainless steel or engineered plastic valves and fittings. Some distributors may operate only locally, whereas others may be nationally or even internationally franchised with multiple outlets. The directories published by national associations of wholesalers & distributors are excellent resources for obtaining distributor lists segmented by industry.

“House”
accounts

OEM Sales

A significant portion of valve sales are to large OEM accounts sometimes referred to as “national” or “house” accounts. Even though pricing may be highly competitive for OEM sales, these accounts are highly valued by the manufacturer because the orders are substantial, the product is often configured identically for each order, and there is usually a predictable demand, delivery, and payment schedule over many years. It is estimated that globally there are over 20,000 OEMs and service providers for valves. Some of the major OEMs segmented by industry are listed below.

Semiconductor Industry OEMs

Semiconductor OEMs supply washing/rising, etching, and production equipment to the industry. Major OEMs include Applied Materials, Akrion, Celerity, Dainipon Screen, Edwards, FSI, Grand Plastics, Kanto, Kinetics, Lam Research, Marketech, Semitool, Semes, SEZ, Sumitomo, Syntonia, and Tokyo Electron.

Lubrication Industr OEMs

Lubrication OEMs supply skidded lubrication systems with reservoir tanks, pumps, valves, flow meters, filters, coolers, piping, and instrumentation for lubrication of turbines, compressors, generators, and other rotating equipment. Lubrication OEMs include Oil Filtration Systems, Filter Vac, Hilliard, Kaydon, Velcon, and others.

Cement Industry OEMs

OEMs supplying air-filtration systems to the cement industry (and also the power industry) include American Air Filter, CamCorp, Dantherm Filtration, Donaldson, Torit, Flex Kleen, Mac Equipment, Midwesco, Mikropul, Pnuemafil, TechFlow, Tri-Mer, US Air Filtration, and others.

Pull-through
demand for
aftermarket
sales.

There are many other OEMs supplying critical packaged systems with pumps and valves for niche application in virtually every industry sector. Identification of key OEMs is critical to successful valve marketing because of the “pull-through” demand OEM sales create for aftermarket and replacement parts sales.



EPC “projects”

Engineering, Procurement, and Construction (EPC’s)

Major plant construction projects in industries such as power, water & wastewater, desalination, semi-conductor, chemical, refinery, petrochemical, and cement are handled by specialist engineering firms that assume responsibility for designing the plant, gathering all equipment specifications, selection suppliers for major equipment, and engaging contractors for plant construction. Valve *manufacturer relationships with engineering firm, and inclusion on “approved vendor” lists are critical to the marketing strategy for any valve manufacturer.*

EPC “approved vendor” lists

Various types of engineering specialists have emerged depending on the scope of responsibility assumed by the firm. Some are engaged in front-end engineering and design (FEED), others in engineering and procurement (EP’s), other in engineering, procurement, and management (EPCM’s) with operating responsibilities after plant commissioning. In large projects, multiple EPC’s may be engaged for different segments of the project. It has been estimated that globally there are over 8,000 EPC firms in operation, and short lists of major EPC’s that handle a majority of world projects are listed below.

EPC’s in Power (sampling only)

Alstom, Bechtel, Babcock & Wilcox, Buckman Labs, Chiyoda, Coalogix, Cormetech, Doosan, Ducon, Foster Wheeler, Fisia Babcock Environment, GE Water, Hamon, Hitachi, Hyundai Heavy Industries, Lauren Engineers, Marsulex, Mitsubishi, Nalco, Peerless, RM Technology, Roberts & Schaefer, Sargent & Lundy, SIDEM, Wuhan, Wahlco, India: Bharat Heavy Electricals (BHEL), Larson & Toubro (L&T), TechnipFMC, Thermax, Doosan, National Thermal Power Corp (NTPC): China: B&W Beijing, China Western Power Industrial, Chongqing Electric Power, Dongfang Electric Corp, Harbin Power Engineering, Hebei Electrical Construction, Shangdong Electric Power Engineering, others.

EPC’s in Oil & Gas/Petrochemical/Refinery (sampling only)

ABB, Aker Solutions (Norway), Axens, Bechtel (USA), Black & Veatch, CB&I Chicago Bridge & Iron (purchased Shaw Group in 2012), Chiyoda (Japan), Clough Engineering, Daelim (S. Korea), Daewoo, Doosan, Exterran, EIL, Ferrostaal, Fluor, Foster Wheeler (USA), GE Energy, Global Industries, Hyundai Engineering & Construction (S. Korea), Haldor Topsoe, ITB, Intecsa, Jacobs Engineering, JGC (Japan), John Brown, Kawasaki, Kentz, KBR, Kobe, Linde, Larson & Toubro, Lamprell, Lurgi, M.W. Kellogg Ltd, Marie Technimont, TechnipFMC, McDermott International (USA), Mott McDonald, Mitsui Engineering, Mitsubishi Heavy Industries, Naizak, Ortloff, Petrofac, Propac, Penspen, Petrojet,

Sinopec, Snamprogetti, Saipem, Samsung Engineering, SBM, Shaw Group, Sinopec Engineering, SK Engineering, SNC-Lavalin (Canada), Sofregaz, Technicas Reunidas, Tartan, Technip (France), Topaz, Toyo Engineering, UOP, Unde, Wood Group, Worley Parsons, others.

EPC's in Water Treatment/Desalination (sampling only)

Accionia, Ambika Group, Black & Veatch, Burns & McDonnell, CH2MHill, Chennai, CB&I, Church & Dwight, Doosan, Foster-Wheeler, Enviro Solutions, Greeley & Hansen, Hatch Mott MacDonald, Hazen & Sawyer, HDO, JGC, Larson & Toubro, LG-Hitachi Water Solutions, Ovivo, Paramount, PD Naidoo, Punj Loyd, Samsung Engineering, Tetra-Tech, Tri-Tech Holdings, URS, Veolia, others.

EPC's in Cement (sampling only)

Ashoka Group, Babcock & Wilcox, Chanderpur Works, F.L. Smidth, Fives FCB, Global Consulting, Industrial Gears, Protech, Sabko Industries, others.

EPC's in Semi Conductor Fabs (sampling only)

CH2M Hill, Fluor, L&K Engineering, Jacobs Engineering, M+W Group, Samsung, others

EPC's in Pharmaceutical//Chemical/Fertilizer Plants (sampling only)

CH2M Hill, Chiyoda, EPC Group, Fluor, L&K Engineering, Hyosung, JCG Group, Jacobs Engineering, Linde Engineering, Technip, others.

The complete list is extensive and in many cases regional, particularly for the smaller plant builds.

Large construction project will draw the attention of well-established international firms such as those named above.

VALVE OEMs AND END USERS BY MAJOR INDUSTRY

Each industry sector includes thousands of valve end-users. Following are lists of major OEM or end-user customers, segmented by industry.

Semiconductor Industry

Major OEMs servicing the semiconductor industry include Applied Materials, Akrion, Celerity, Dainipon Screen, Edwards, FSI, Grand Plastics, Kanto, Kinetics, Lam Research, Marketech, Semitool, Semes, SEZ, Sumitomo, Syntonia, and Tokyo Electron.

A majority of semi-conductor foundry capacity is located in the Asia-Pacific region, specifically Japan, South Korea, China and Taiwan. Major foundries include Global Foundries, Taiwan Semiconductor Manufacturing (TSM), United Microelectronics Company (UMC), Chartered Semiconductor Manufacturing (CHRT), and Semiconductor Manufacturing International (SMI). These companies account for over 70% of micro-chip production, worldwide. Other smaller-scale facilities are located elsewhere in Europe and in the Americas.

Water & Wastewater Industry

End users of valves in the water and wastewater industry include thousands of municipal government bodies, worldwide. Access to the markets is through local distributors, as well as through large wastewater EPC firms such as Black & Veatch, Burns & McDonnell, CH2M Hill, Foster-Wheeler, Ovivo, Veolia, and many others listed earlier in this report.

Oil & Gas Industry

End users of valves in the oil & gas industry include the major oil & gas suppliers, as well as the refinery companies. The oil "Majors" include British Petroleum (BP), Chevron, Citgo, Conoco-Phillips, Exxon-Mobile, Irving Oil, Nippon Oil, Pemex, Petrobras, Saudi-Aramco, Shell, Sunoco, and others. Worldwide, there are over six hundred fifty refineries that are serviced by local distributors, as well as through the large oil & gas EPC firms.

Chemical and Petrochemical

End users of valves in the industrial chemicals and petrochemicals market include the majors such as BASF, Dow, DuPont, DeGussa, Eastman Chemical Company, Shell, Bayer, INEOS, ExxonMobile, SABIC, Braskem, Mitsubishi, Akzo Nobel, PPG, Shin-Etsu, EcoLab/Nalco, and others.

Each of these companies operates numerous facilities throughout the world, collectively amounting to thousands of production sites. Additional to the majors are thousands of smaller independent chemical companies. Access to markets is primarily through local distributors, as well as through large EPC firms specializing in chemical plant design, construction, and procurement.

Mining

The mining industry is highly fragmented with hundreds of mining companies, worldwide. The top 25 mining companies include: BHP Billiton, Vale, S.A., Rio Tinto, Arcelor Mittal, Anglo American, Plc, Xstrata Plc., RWE, Mitsubishi Corporation, Barrick Gold, Potash Corporation, Freeport McMoran, Goldcorp, Southern Copper Corp, Mosaic Company, Sasol Ltd, Newmont Mining, Wesfarmers Ltd, Copanhia Siderurgica Nacional, Eurasian Natural Resources, American Electric Power, Anglo Platinum Ltd, Aluminum Corp of China, Antofagasta Ltd, Impala Platinum, AngloGold Ashanti. Usually, mining market research is segmented by industry, i.e., coal, iron, copper, precious metals, rare earths, etc.

Paints & Coatings

The top 10 global coatings manufacturers are: Akzo Nobel nv, PPG industries, DuPont Coatings, Sherwin-Williams, BASF coatings, Valspar Corp, Kansai Paint, RPM International, Nippon Paint, and Jotun. The top 25 coatings manufacturers in North America are: PPG, DuPont, Sherwin-Williams, Valspar, RPM International, Behr Process Corp, Comex, BASF Coatings, Benjamin Moore, Ennis Paint, Rohm & Haas, Dunn-Edwards, Kelly-Moore, Cloverdale Paint, TIGER Drylac, Nippon Paint (US), True Value, Vogel Paint, Ace Hardware, Spraylat Corp, Tnemec Co., Quest Specialty Chemical, Elantas PDG, Lord Corp, and Yenkin Majestic.

Food & Beverage

Major end users of valves in the food & beverage industry are international processors including Anheuser-Busch, Con-Agra, Coca Cola, Danone Group, Dean Foods, General Mills, Kraft Foods, Nestle, PepsiCo, Swift, Tyson, Unilever Group, and others. Each of these companies and hundreds more maintain multiple production facilities throughout the world.

Pharmaceutical

Major end users of valves in the pharmaceutical industry are the global pharmaceutical companies and medical equipment suppliers including Abbott Laboratories, Bayer, Bristol-Myers-Squibb, Eli-Lilly, GlaxoSmithKline, Johnson & Johnson, Merck, Novartis, Pfizer, Roche, Sanofi Aventis, and others. Industry research analysis have identified over 1,500 additional companies in the United States involved in the manufacturing of pharmaceutical chemicals and end products.

Pulp & Paper

Major end users of valves in pulp & paper are the global paper companies including International Paper, Kimberly-Clark, Metsaliitto, Mondi Group, Nippon Unipac, Oji Paper, SCA, Smurfit Kappa, Stora Enso, and UPM. Paper production is highly regional, with most production in the United States, Sweden, Finland, Ireland, Japan, the United Kingdom, and South Africa, but with growing production in China.

TRENDS AND TREND DRIVERS

Trends and drivers in valve sales can be segmented as listed below:

- By national economic policy
- By geographic region
- By industry, and
- By technology

National Economic Policy Trends

National economic trade policy in many developing countries is designed to encourage domestic manufacture of industrial equipment by domestic suppliers. This will likely lead to increasing challenges for Western valve manufacturers to maintain traditional levels of equipment sales. However, it will also likely lead to a renaissance in innovation among western supplier to retain market competitiveness, and this will be a positive development for the industry.

Geographic Trends

Despite the forecasted slowdown of growth in China and some other Asian countries, the absolute magnitude of growth in China and India will outpace growth in the developed economies of North America and Western Europe, and the developing countries in South America. The higher level of growth, combined with the size of the economies in China, India, and South Korea make Asia the most attractive global market by Region. Growth drivers continue to be improvement in the standard of living, increased urbanization of the populations, and central government stimulus, particularly in China. The most conservative of GDP projections for China at 6.6% are more than twice the rate of projected growth for developed nations. However, it is significant to note that the majority of commodity valve manufacturing has already migrated to China and India. In 2016, Iran opened its market for foreign companies and this holds a significant promise because of the re-build of infrastructure.

Industry Trends

The industries most directly linked to basic human services and consumables can be expected to outperform other industries, and without the volatility recently experienced in the oil & gas, marine, and mining markets.

Attractive industries include:

- Power generation
- Water & wastewater treatment, and
- Food & beverage, and pharmaceutical production.

Power generation will be driven by **load growth** in developing nations, and by **fleet restructuring** (from coal to gas or renewables) in the developed countries. Japan presents a potentially large opportunity in power, pending resolution of national policy concerning 50 nuclear power plants that are currently off the grid following the Fukushima natural disaster. In the United States, growth in combined cycle gas turbine power generation to replace de-commissioned coal plants will be a driver for pump and valve sales.

Industries that will continue to face near-term challenges include:

- Oil & Gas
- Mining
- Pulp & Paper, and
- Marine

Volatility in **oil & gas** will persist as long as there is an oversupply of oil relative to demand. The current agreement among OPEC countries to limit production may help to increase oil prices, but the re-introduction of Iranian oil into world markets may offset the OPEC cutbacks, and cutbacks in North American production. The situation will be monitored by Resolute Research.

The **mining industry** has experienced a setback following the oil-price collapse that began in 2014. This rides on top of a more general and long-term trend that has seen mining operations shifting to developing nations in Asia and South America, creating significantly diminished opportunities in the developed nations in Europe and North America.

The **marine industry** is cyclical, and reached a peak in 2010 with the construction of a record tonnage of sea-going merchant vessels. The make-up of the fleet includes bulk carriers, container ships, tankers, and LNG/LPG transports, and specialized offshore oil & gas service vessels such as Floating Production, Storage and Offloading equipment (FPSOs).

As with other industries, the attraction of lower-cost construction outside of Europe and North America created a pivot to Asia such that currently Japan, South Korea, and China account for most of the world's merchant ship construction.

The peak construction and consequent oversupply of tonnage in 2010, plus a falloff in demand for oil tankers with the development of shale oil in North America has caused a downward trend in the marine industry. Offsetting factors include a projected need for additional LNG tanker to transport North American, Australian, and Middle East natural gas to energy-hungry Asian countries; however, this could be negatively impacted by overland supply of gas from Russia to China.

A significant positive opportunity for pumps and valves in the marine industry is driven by national and international environmental legislation that mandates new ballast water treatment systems and flue gas scrubbing systems for nearly 70,000 merchant vessels, worldwide. This legislation is already active in certain countries and is driving sales of centrifugal pumps and valves for ballast and bilge water, and slurry valves for treatment of flue gas in the retrofit market.

The **pulp and paper industry** had for many years been concentrated in the United States, and several European countries including Finland, Sweden, Germany, and the United Kingdom. Going back several decades, lower production costs and increased demand supported a major relocation initially to Japan, soon to be followed by China and several other Asian countries. Today, China accounts for more than 25% of paper production, and has supplanted the United States as the world leader. In total, Asia now accounts for more than 45% of total worldwide paper production. This trend has led to the decline of paper production capacity in the traditional western nations.

Another trend in the industry has been the general decline in demand for printed media (newspapers, magazines, and books) due to the digital era and downloadable digital media. This, too, has negatively impacted industry growth over the past decade. The industry was able to partially offset the decline in the print segment with increased production in the packaging and paper-board markets, which has helped to stabilize the industry. that notwithstanding, Asian producers have benefited the most and that trend is likely to continue.

Product & Technology Trends

Product and technology trends will likely focus on the following opportunities:

- Energy conservation
- Environmental protection
- Expanded valve capabilities for severe service applications
- Valve documentation

Energy Conservation: More efficient valve design (in terms of reduced pressure drop in the full-open position) are likely to have greater importance in the future. This could drive new valve designs, or preferential selection of existing valve types that have inherently lower pressure drop (for example a straight-through full-port gate, ball, or pinch valve vs. a globe valve).

Additionally, the growing use of variable speed drives for pumps could have a negative impact on overall sales of throttling valves in the future. Proponents of variable speed pumps focus on the total system energy savings, and the possible elimination of the throttling valve as a capital cost savings.

Environmental Protection: There will be increased focus on zero-leakage valves in response to more stringent environmental regulations regarding fluid and gas leakage to the environment, particularly through stem packing glands. Technologies poised to benefit include improved stem sealing, valve seat sealing, and flange sealing, especially as employed in the oil & gas, refinery, petrochemicals, and chemical markets. Non-rising stem gate valves, and rotating stem quarter-turn ball, butterfly, and plug valves will likely emerge as preferred option due to their inherent improved performance with regard to reduced stem leakage and fugitive emissions. These innovations will be driven and assisted by national and international regulations. Active bodies include Fluid Sealing Association (FSA), EPA, DOE, ISA and IMA, among others.

Improved emergency shut down (ESD) systems for valves is another area of opportunity for increased safety and environmental protection, particularly in the oil & gas, and petrochemicals sectors.

Additionally, increased application of closed loop cooling systems to replace “once-through” cooling of condensers in power plants will drive additional sales of centrifugal circulating pumps and the associated isolation and bypass valves. These changes will be especially focused on water stressed regions throughout the world.

Technology and Severe Service Innovations: There are also trends using the latest electronic technology to provide valve diagnostics and wireless communications, plus new designs and metallurgies to better address severe service applications. These product and technology innovations include:

- Increasing advancement of automated control systems, diagnostics, and tie-ins to digital control systems (DCS) for valves to increase plant operating safety and efficiency, and reduce operating costs.
- Increasing focus on improved materials of construction, such as duplex stainless steels and engineered plastics to increase safety and reduce downtime and loss of production, especially in severe applications in the power, off-shore oil & gas, refinery, chemical, and desalination industries.
- Higher pressure and temperature steam control valves and steam de-superheating valves operating at pressures beyond 3,000 psi and temperatures beyond 1,000F for boiler and turbine feed to service the higher operating pressures and temperatures of super-critical and ultra-super-critical boilers in the electric power market. These valves will continue to be in demand in China, India, Vietnam, and other Asian countries for power plants.
- Improved noise reduction for process control valves with high differential pressures or high flow using internal cages or downstream diffusers.
- Improved hard-coating (e.g. stellite) for highly erosive valve applications.

Valve Documentation

- Complete valve documentation provided by the supplier to the EPC or end-user is increasingly important for critical service application in oil & gas, refinery, petrochemical, power, and others.

Each of the above-listed trends is tempered by general economic activity, but these applications should outperform other sectors and provide opportunities for valve manufacturers even in a generally low-growth environment. The following table provides a high-level summary of expected trends over the upcoming 5-year period.

Industry Sector	Growth Trends				Comments
	OECD Countries		Developing Countries		
	1-Yr History	5-Yr Forecast	Recent History	5-Yr Forecast	
Water	GDP	> GDP	> GDP	> GDP	Infrastructure rebuild in OECD; New builds in developing countries.
Food & Bev	GDP	> GDP	> GDP	> GDP	Population driven expansion
Pharma	> GDP	> GDP	> GDP	> GDP	Population driven expansion
Power	< GDP	GDP	> GDP	> GDP	Low load growth in OECD; load growth in developing countries
Oil & Gas	< GDP	GDP	> GDP	> GDP	Low demand growth in OECD; demand growth in developing countries
Refinery	< GDP	GDP	> GDP	> GDP	Low demand growth in OECD; demand growth in developing countries
Mining	< GDP	< GDP	> GDP	> GDP	High extraction costs in OECD; new resources in developing countries
Pulp & Paper	< GDP	< GDP	GDP	GDP	Slowdown re digital era; low cost production in developing countries
SemiCon	< GDP	< GDP	GDP	GDP	Tapering of growth in OECD consumer electronics
Marine	< GDP	< GDP	GDP	GDP	Working off current over capacity

As a closing note, capital goods sales including valve sales, could improve in 2017 in the United States due to a roll-back in what some consider excessive environmental oversight by the EPA, and as a result of increased activity in oil & gas pipelines, gas turbine and possibly coal-fired power plants, and general infrastructure spending promised by the incoming new administration. The situation will be closely monitored by Resolute Research.

APPENDIX I. Country Listings

Over 60 countries (listed below) and comprising more than 96% of world GDP are included in the analysis provided in this report, and in the Resolute Research Valve Product Database that is available by separate order.

Algeria	Iran	Romania
Angola	Iraq	Russia
Argentina	Ireland	Saudi Arabia
Australia	Israel	Singapore
Austria	Italy	Slovakia
Bangladesh	Japan	South Africa
Belgium	Kazakhstan	Spain
Brazil	Korea, South	Sweden
Canada	Kuwait	Switzerland
Chile	Libya	Taiwan
China	Malaysia	Thailand
Colombia	Mexico	Turkey
Czech Republic	Morocco	Ukraine
Denmark	Netherlands	United Kingdom
Egypt	Nigeria	United States
Finland	Norway	Venezuela
France	Pakistan	Vietnam
Germany	Peru	New Zealand
Greece	Philippines	UAE
Hungary	Poland	
India	Portugal	
Indonesia	Qatar	

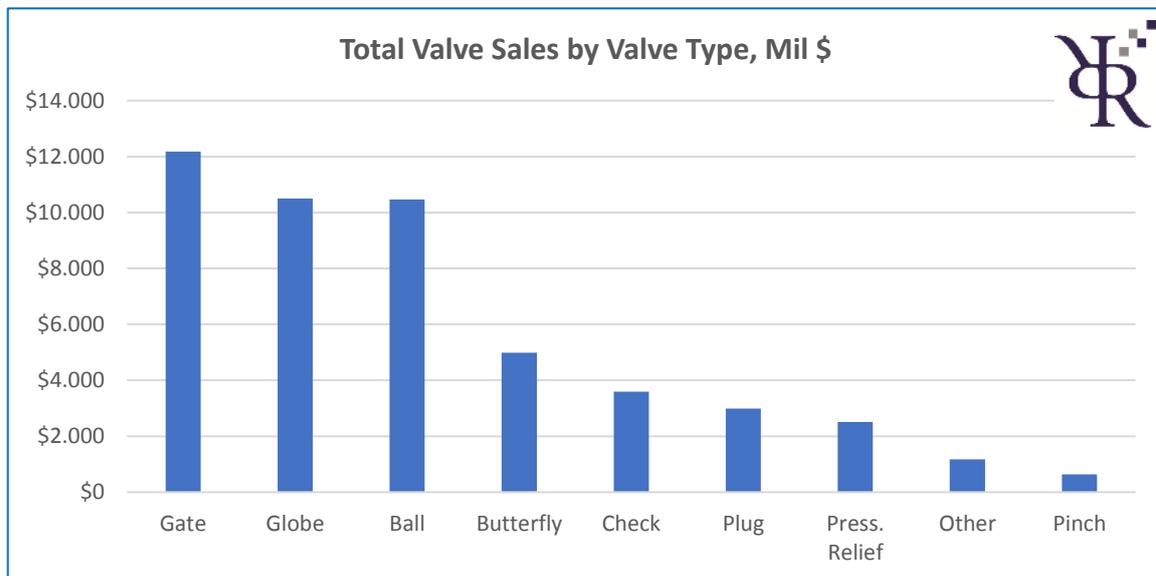
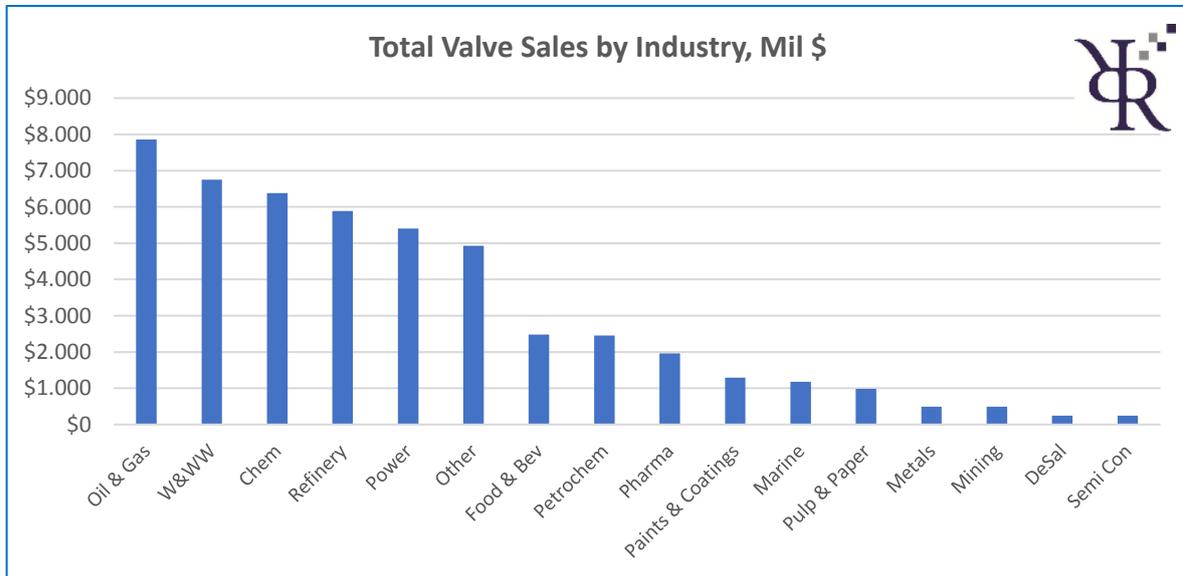
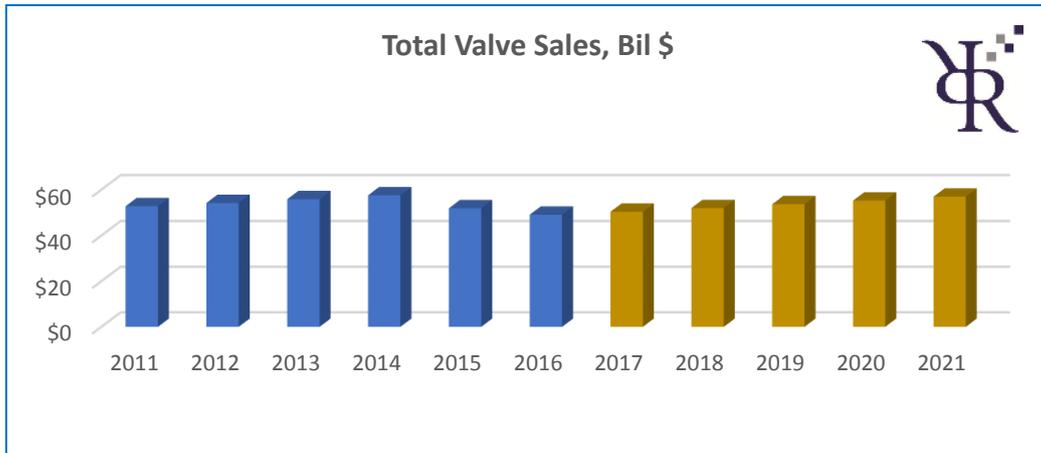
The graphs that follow in Appendix II provide basic segmentations for valves required by most Clients. For complete data, order Resolute Research **Valve Data Base** with detailed segmentations by region, country, pump type, and industry. A separate **Valve Supplier Data Base** is also available with listings and valve sales for hundreds of valve companies.

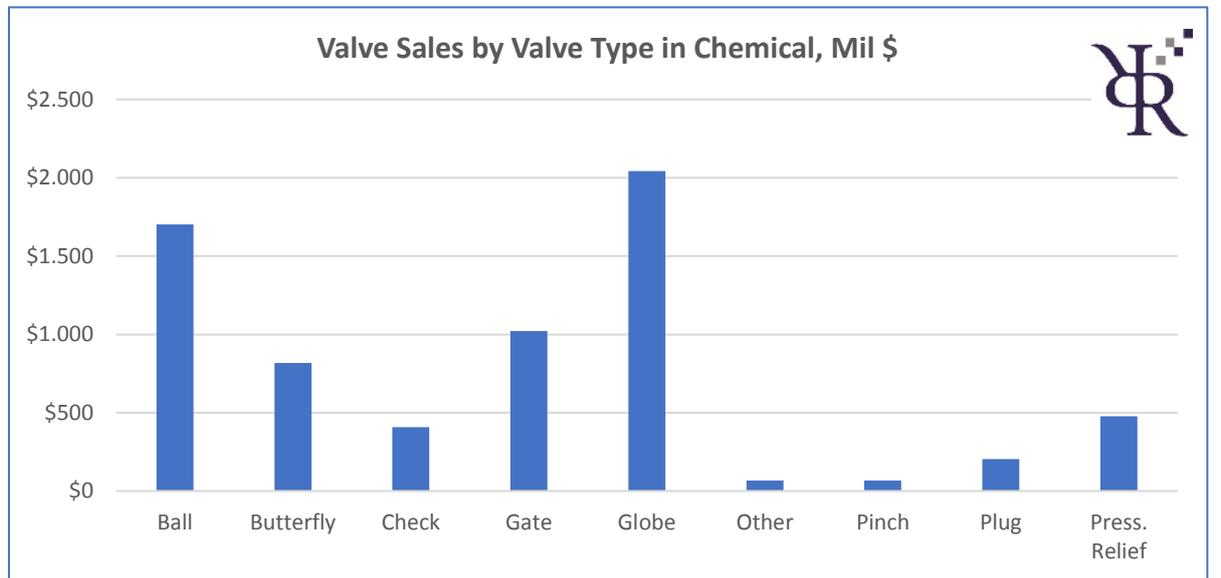
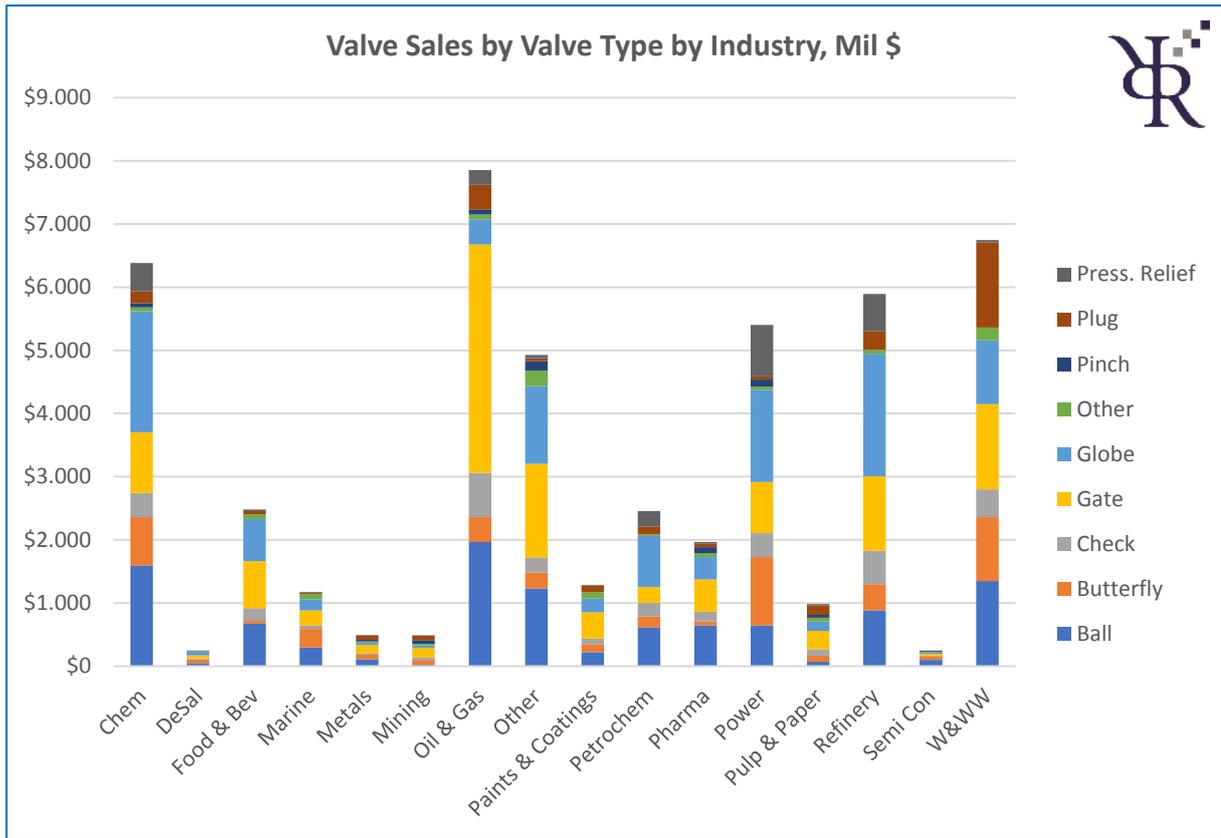
Contact Resolute Research for details.

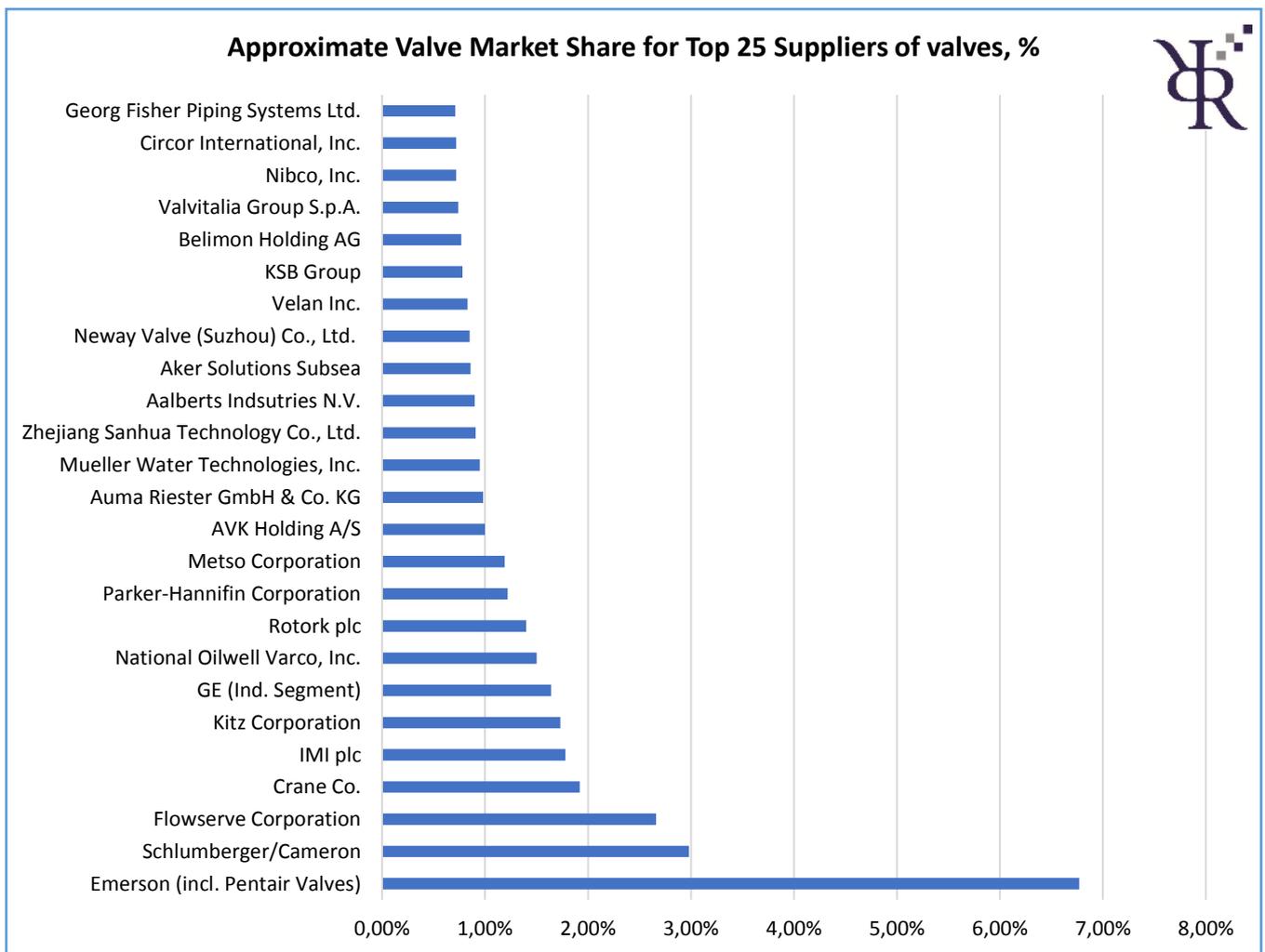
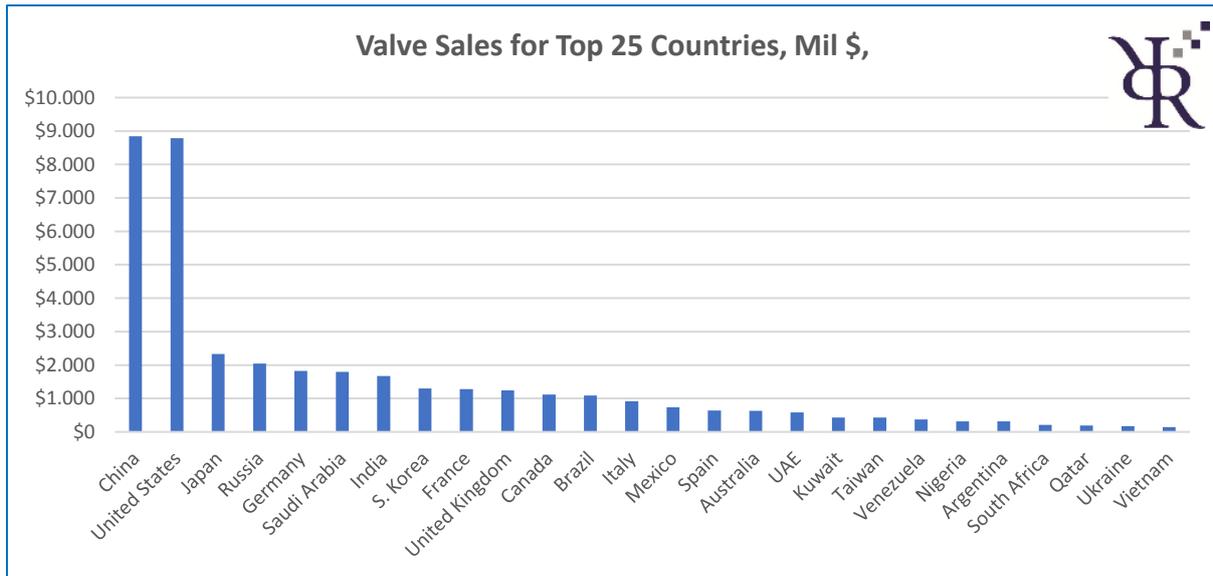
Lars van Pomp, l.v.pomp@resoluteresearch.com, +31 26 205 1515



APPENDIX II. Market Snapshots







Sample output from Valve Product Data Base

(available separately from Resolute Research)

4	Region	Country	Industry	Products	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
200	N. America	United States	Power	Plug	\$9,225	\$9,375	\$9,596	\$9,812	\$10,053	\$9,139	\$9,230	\$9,323	\$9,462	\$9,604	\$9,748
201	Asia	China	Power	Plug	\$22,428	\$24,783	\$26,879	\$29,122	\$31,415	\$28,559	\$30,473	\$32,453	\$34,498	\$36,568	\$38,762
202	Asia	Japan	Power	Plug	\$0,825	\$0,820	\$0,835	\$0,849	\$0,848	\$0,771	\$0,775	\$0,779	\$0,784	\$0,790	\$0,795
203	W. Europe	Germany	Power	Plug	\$1,774	\$1,842	\$1,849	\$1,855	\$1,885	\$1,714	\$1,739	\$1,767	\$1,792	\$1,815	\$1,839
204	W. Europe	France	Power	Plug	\$0,535	\$0,547	\$0,548	\$0,552	\$0,553	\$0,503	\$0,508	\$0,514	\$0,522	\$0,531	\$0,540
205	W. Europe	United Kingdom	Power	Plug	\$0,274	\$0,280	\$0,283	\$0,290	\$0,298	\$0,271	\$0,276	\$0,283	\$0,289	\$0,295	\$0,301
206	S & C America	Brazil	Power	Plug	\$0,346	\$0,360	\$0,366	\$0,377	\$0,377	\$0,343	\$0,329	\$0,328	\$0,331	\$0,338	\$0,344
207	W. Europe	Italy	Power	Plug	\$0,252	\$0,254	\$0,247	\$0,243	\$0,242	\$0,220	\$0,222	\$0,225	\$0,227	\$0,229	\$0,231
208	Asia	India	Power	Plug	\$8,171	\$8,748	\$9,218	\$9,901	\$10,681	\$9,710	\$10,448	\$11,253	\$12,119	\$13,052	\$14,057
209	N. America	Canada	Power	Plug	\$0,472	\$0,486	\$0,496	\$0,506	\$0,518	\$0,471	\$0,478	\$0,487	\$0,498	\$0,508	\$0,518
210	CIS	Russia	Power	Plug	\$0,627	\$0,655	\$0,678	\$0,687	\$0,691	\$0,628	\$0,621	\$0,629	\$0,641	\$0,650	\$0,660
211	W. Europe	Spain	Power	Plug	\$0,245	\$0,242	\$0,236	\$0,232	\$0,236	\$0,214	\$0,220	\$0,225	\$0,229	\$0,234	\$0,238
212	Asia	Australia	Power	Plug	\$0,183	\$0,187	\$0,194	\$0,199	\$0,204	\$0,186	\$0,190	\$0,196	\$0,202	\$0,208	\$0,214
213	N. America	Mexico	Power	Plug	\$0,182	\$0,189	\$0,197	\$0,200	\$0,204	\$0,186	\$0,190	\$0,196	\$0,201	\$0,207	\$0,214
214	Asia	S. Korea	Power	Plug	\$0,305	\$0,317	\$0,324	\$0,334	\$0,346	\$0,314	\$0,323	\$0,332	\$0,342	\$0,353	\$0,364
215	W. Europe	Netherlands	Power	Plug	\$0,078	\$0,079	\$0,078	\$0,078	\$0,079	\$0,071	\$0,073	\$0,074	\$0,075	\$0,077	\$0,078
216	Middle East	Turkey	Power	Plug	\$0,033	\$0,036	\$0,037	\$0,038	\$0,039	\$0,036	\$0,037	\$0,038	\$0,040	\$0,041	\$0,042
217	Asia	Indonesia	Power	Plug	\$0,087	\$0,093	\$0,099	\$0,104	\$0,110	\$0,100	\$0,105	\$0,111	\$0,117	\$0,123	\$0,131
218	W. Europe	Switzerland	Power	Plug	\$0,044	\$0,045	\$0,045	\$0,046	\$0,047	\$0,043	\$0,043	\$0,044	\$0,045	\$0,046	\$0,046
219	E. Europe	Poland	Power	Plug	\$0,112	\$0,118	\$0,120	\$0,122	\$0,126	\$0,114	\$0,118	\$0,123	\$0,127	\$0,131	\$0,136
220	W. Europe	Belgium	Power	Plug	\$0,061	\$0,062	\$0,062	\$0,062	\$0,063	\$0,057	\$0,058	\$0,059	\$0,059	\$0,060	\$0,061
221	W. Europe	Sweden	Power	Plug	\$0,104	\$0,106	\$0,106	\$0,107	\$0,110	\$0,100	\$0,104	\$0,107	\$0,109	\$0,112	\$0,114
222	Middle East	Saudi Arabia	Power	Plug	\$0,126	\$0,140	\$0,147	\$0,152	\$0,157	\$0,143	\$0,146	\$0,148	\$0,152	\$0,155	\$0,159
223	Asia	Taiwan	Power	Plug	\$0,155	\$0,158	\$0,161	\$0,166	\$0,173	\$0,157	\$0,159	\$0,163	\$0,167	\$0,172	\$0,176
224	W. Europe	Norway	Power	Plug	\$0,103	\$0,104	\$0,107	\$0,108	\$0,110	\$0,100	\$0,101	\$0,102	\$0,104	\$0,107	\$0,109
225	Middle East	Iran	Power	Plug	\$0,157	\$0,163	\$0,153	\$0,150	\$0,157	\$0,143	\$0,149	\$0,156	\$0,164	\$0,170	\$0,177
226	W. Europe	Austria	Power	Plug	\$0,045	\$0,046	\$0,047	\$0,047	\$0,047	\$0,043	\$0,043	\$0,044	\$0,045	\$0,045	\$0,046
227	S & C America	Argentina	Power	Plug	\$0,083	\$0,090	\$0,091	\$0,094	\$0,094	\$0,086	\$0,085	\$0,088	\$0,091	\$0,093	\$0,096
228	Africa	South Africa	Power	Plug	\$0,172	\$0,178	\$0,182	\$0,186	\$0,188	\$0,171	\$0,172	\$0,174	\$0,178	\$0,182	\$0,186
229	Asia	Thailand	Power	Plug	\$0,097	\$0,098	\$0,106	\$0,109	\$0,110	\$0,100	\$0,102	\$0,105	\$0,108	\$0,112	\$0,115
230	W. Europe	Denmark	Power	Plug	\$0,031	\$0,031	\$0,031	\$0,031	\$0,031	\$0,029	\$0,029	\$0,030	\$0,030	\$0,031	\$0,031
231	W. Europe	Greece	Power	Plug	\$0,057	\$0,052	\$0,048	\$0,047	\$0,047	\$0,043	\$0,043	\$0,044	\$0,045	\$0,046	\$0,047
232	Middle East	UAE	Power	Plug	\$0,051	\$0,053	\$0,057	\$0,060	\$0,063	\$0,057	\$0,058	\$0,060	\$0,061	\$0,064	\$0,066
233	S & C America	Venezuela	Power	Plug	\$0,087	\$0,091	\$0,097	\$0,098	\$0,094	\$0,086	\$0,077	\$0,077	\$0,078	\$0,077	\$0,077
234	S & C America	Colombia	Power	Plug	\$0,033	\$0,036	\$0,037	\$0,039	\$0,041	\$0,037	\$0,038	\$0,039	\$0,041	\$0,042	\$0,044
235	W. Europe	Finland	Power	Plug	\$0,060	\$0,061	\$0,061	\$0,060	\$0,060	\$0,054	\$0,055	\$0,055	\$0,056	\$0,057	\$0,058
236	Asia	Malaysia	Power	Plug	\$0,060	\$0,064	\$0,068	\$0,071	\$0,075	\$0,069	\$0,072	\$0,075	\$0,078	\$0,082	\$0,086
237	W. Europe	Portugal	Power	Plug	\$0,037	\$0,036	\$0,035	\$0,034	\$0,035	\$0,031	\$0,032	\$0,032	\$0,033	\$0,033	\$0,033
238	Asia	Singapore	Power	Plug	\$0,026	\$0,028	\$0,029	\$0,031	\$0,031	\$0,029	\$0,029	\$0,030	\$0,030	\$0,031	\$0,032

Sample output from Valve Supplier Data Base

(available separately from Resolute Research)

	Company	Ownership	Total Valve Sales, Mil \$	Sales Range, Mil \$	Total Valve Sales, % of Total	Major Valve Types by Supplier (other smaller lines may be carried as well)	Major Valve Brands	Major Actuator Brands
2								
3	3Z Corporation	Private	\$14,4	\$5-\$24	0,03%	Plug	3Z	
4	A-T Armaturen-Technik GmbH	Private	\$10,4	\$5-\$24	0,02%	Gate, Ball, Butterfly, Check, Pressure Relief, Other	A-T	
5	A + R Armaturen GmbH	Private	\$12,2	\$5-\$24	0,02%	Ball, Actuator	A + R	A + R
6	A.P.I. S.r.l.	Private	\$2,5	\$0,1-\$4	0,00%	Ball, Actuator, Other	API	API
7	A V Valves Ltd	Private	\$2,4	\$0,1-\$4	0,00%	Gate, Globe, Ball, Butterfly, Plug, Diaphragm, Check, Pressure Relief, Other	A V Valves	
8	Aalberts Industries N.V.	Public	\$469,0	\$250-\$499	0,90%	Gate, Globe, Ball, Check, Pressure Relief, Actuator	Broen, BSM, Conbraco (Apollo Valves), Nexus, Ventrex	BSM, Conbraco (Apollo Valves)
9	Abacus Valves International Ltd.	Private	\$1,7	\$0,1-\$4	0,00%	Check	Abacus	
10	ABB Ltd.	Public	\$55,0	\$50-\$249	0,11%	Actuator		ABB
11	ABO Valve, s.r.o.	Private	\$10,6	\$5-\$24	0,02%	Gate, Ball, Butterfly, Diaphragm, Check, Actuator	ABO	ABO

APPENDIX III. About Resolute Research BV

Resolute Research BV is an industrial market research specialist. We provide clients with high-quality market intelligence, including complete development of market drivers, suppliers, distribution channels, growth opportunities, trends, threats, and other market dynamics.

The aspect that makes Resolute Research BV unique in what we do is the focus on carefully chosen markets. Resolute Research BV does not conduct research in all markets but on a set of determined markets. These markets are all linked to the process industry.

Our experience spans major industries including oil & gas, refinery, petrochemical, chemical, power, metals & mining, pulp & paper, food & beverage, pharmaceutical, semiconductor, water and wastewater, desalination, and marine. Other industry segmentations can be developed on request.

We recognize that today's on-the-go business executives do not have the staff or time to digest multi-hundred page reports that may inefficiently address customer needs. Accordingly, Resolute Research specializes in providing focused yet highly granular reports with essential narrative backed up with high-impact graphs, charts, and process flow diagrams.

The Resolute Research promise to clients is that we will provide an easy-to-read yet detailed market analysis completely aligned with client expectations. The big picture overview with all appropriate segmentations and high-granularity breakouts is what we are all about.

Resolute Research would be pleased to be your preferred source for industrial market intelligence.

