In collaboration with

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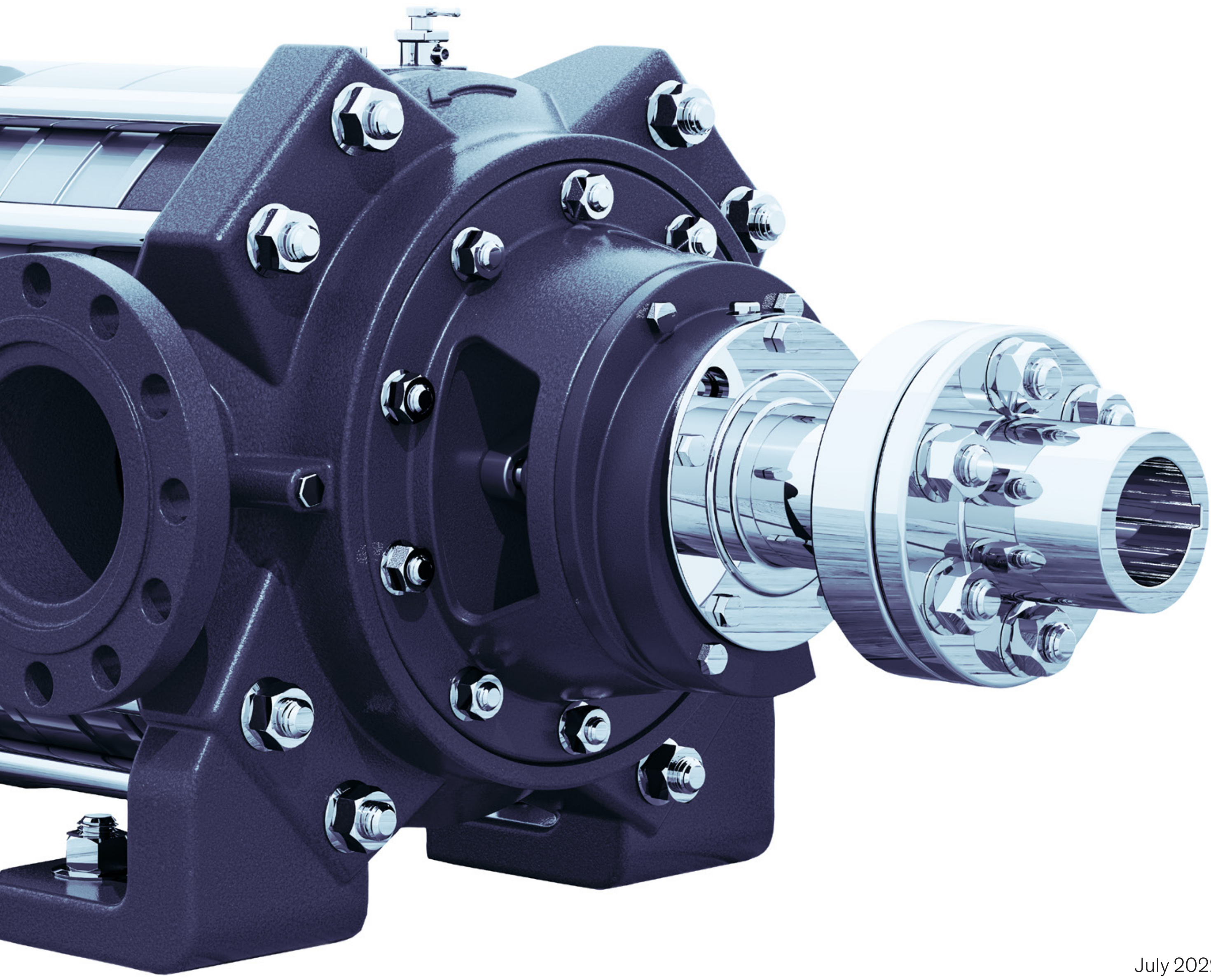
Smart fluid hydraulics

Preparing for the imminent revolution in the fluid systems industry



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Introduction

This article is a collaborative effort by Christian Bayer of Aalen University and Harald Bauer, Michael Becker, Franz Ramsauer, and Markus Simon of McKinsey's Advanced Electronics Practice.

Fluid-hydraulics pumps play a pivotal role in two global industries: they are the bread-and-butter business of the fluid hydraulics-equipment industry, and they are the metaphorical heart of the process industry. After all, fluid-hydraulics pumps power a broad range of production processes, from pharmaceuticals and chemicals to oil and gas. And, just like their biological counterparts, pumps are outsize energy consumers compared with other equipment systems.

Due to their critical importance and high energy consumption, there is much that suggests that recent technological leaps concerning the usage and deployment of pumps in process industries—that is, smart-pump technology, or "smart fluid hydraulics"—will lead to a revolution in the fluid-systems industry.[1] Above all, this is because smart fluid hydraulics promise drastic gains in energy efficiency, uptime, and productivity. Higher up-front investment costs in smart fluid hydraulics will be more than offset over time by lower operating expenses. It should be noted that while this significant ROI can be expected for applications such as booster stations and cooling circuits and for players in the chemicals and food and beverage industries, it may be less likely for other applications and process-industry players.

The promise of energy efficiency gains is particularly important for two reasons. Amid sharply rising energy costs, especially in recent months, investment in efficiency optimization for pumps is becoming more critical than ever for ensuring competitiveness for individual process-industry players. Additionally, as environmental regulations ("green deals") continue to tighten, industry players need to drastically reduce their energy consumption to reach CO_2 emissions targets and to earn or maintain the right to play. This is a global trend, although regions are progressing at different rates, with Europe ranking among the front-runners.

Based on extensive McKinsey research (see sidebar "Insight sources for this report"), this publication offers players in the fluid hydraulics–equipment industry[2] and in the process industry deep insights into current challenges and opportunities when it comes to applying this technology. To this end, we discuss key perspectives on the smart fluid hydraulics–equipment industry, introduce and describe practical smart-pumps use cases and their relevance by end-user industry, and provide guidance on the strategy-development building blocks that players and end customers can use to prepare their organizations for the changes ahead.

Insight sources for this report

We drew upon several sources in conducting analyses and developing the perspectives presented in this report:

— *Client work:* findings from our recent work with clients in fluid-hydraulics applications along with our close observations of players in adjacent spaces facing similar disruptive technological events

— *Industry experts:* interviews with more than 20 McKinsey and industry experts on operations in process manufacturing, fluid-hydraulics equipment, and sustainability

— *Academic experts:* research cooperation with our external adviser, Christian Bayer, a professor of economics at Aalen University

— *End users:* a qualitative online survey of 24 leading process manufacturers with a focus on the food and beverage and pulp and paper industries and with representatives from operations, procurement, or maintenance

[1] While the current push toward smart fluid-hydraulics technologies is quickly gaining steam, the efforts are not new. More than 15 years ago (around 2004), pump manufacturers began developing smart, energy-efficient product solutions, but several issues led to low levels of customer acceptance. For further details, see sidebar "Overview of key steps in the run-up to smart fluid hydraulics" on page 18.
[2] This refers to players along the entire fluid-hydraulics value chain, including pump OEMs and producers and suppliers of components such as motors, frequency converters, sensors, cabinets, tubing, valves, and process-automation equipment and software.

We have distilled the following four key insights from our research on the imminent smart fluid-hydraulics revolution, along with seven use cases, which will be discussed in detail later in this report:

The pump market is massive in its value—and in its energy consumption. Today, the global industrial pump market is worth $70 billion and is on track to grow by 20 to 30 percent ($85 to $90 billion) in just three years. At the same time, pumps account for nearly 15 percent of all energy consumption in the European Union.

Smart fluid-hydraulics systems hold huge savings potential. There are three primary use cases for smart fluid hydraulics: 1) energy efficiency optimization, 2) predictive maintenance, and 3) simultaneous optimization of fluid-hydraulics systems. The relevance of use cases and the ease of implementation vary significantly by end-user industry. The largest share of energy consumption comes from buildings (residential and commercial) and has largely been addressed. The next segment to be considered includes process industries such as steel, oil and gas, and pulp and paper due to their outsize energy consumption. Process industries such as pharmaceuticals and food and beverage could be added because an increasing number of players in these industries are concerned about their CO_2 footprints. For these segments, energy-efficiency optimization plays a particularly important role. First, it enables greater cost savings as energy costs rise sharply, and second, it is critical for complying with increasingly strict CO_2 emissions regulations and ultimately achieving global zero-emissions targets by 2050 or 2060. Additionally, in each process industry, there are common auxiliary processes, such as those related to heating and cooling or pressure regulation. These processes are not core to a particular industry, but their shared relevance means there is significant energy-saving potential across industries—a fact of which regulators are quite aware.

Component manufacturers and OEMs can start their strategic road mapping with five high-impact moves. These players can take the following steps to best integrate smart hydraulics pumps into their plans for the future: 1) reassess company strategies and technology road maps, 2) consider integrated systems instead of manufacturer-independent systems,[3] 3) focus efforts on a limited number of relevant use cases, 4) define and build required future digital capabilities, and 5) develop marketing and sales strategies. In addition to these no-regret moves, component manufacturers and OEMs might consider extending their technology portfolios, executing M&As and strategic partnerships, and building digital-business incubators.

End customers prioritize cost and ROI when it comes to fluid hydraulics. For the food and beverage and pulp and paper industries, our customer survey reveals that customers' key purchasing criteria are cost and ROI, while they see regulations and how they might affect the use of smart products in fluid-hydraulics applications as less relevant. However, to retain the license to play, manufacturers need to reach regulatory efficiency targets. End customers should thus start their strategic road-mapping process with three principles: 1) take full advantage of the latest technologies for reducing operating expenses and increasing yield; 2) reassess plant operating expenses and energy consumption in particular; and 3) leverage the green movement. Additional considerations for end customers include shaping the future competitive landscape and public opinion, forming strategic partnerships with core suppliers, applying new technologies to both core and auxiliary processes, and reaping capital market benefits from improved ESG ratings.

[3] Organizations are currently developing uniform data exchange protocols for seamless data transfer between components from different manufacturers.

This section discusses key aspects of the current and future fluid hydraulics–applications industry as well as the context and driving forces behind technological advancement in the industry. The resulting overview and insights serve as a backdrop for understanding the emerging fluid-systems revolution.

Part A

The current fluid hydraulics–application landscape and drivers of change

Key aspects of the industry in 2020 and in 2025

The following overview of the global fluid hydraulics–applications market covers market size and revenue sources, main pump technologies, major player types, market structure and regional differences, and the market's key drivers and sectors of growth.

Market size and revenue sources

Recent McKinsey research shows that the global industrial pump market is worth approximately $70 billion today.[4] By 2025, the market is projected to be worth $85 billion to $90 billion. When looking at market size and segments, it is best to consider the specific application of a given pump, such as general construction, water and wastewater, power generation, or oil and gas. The pumps used in the core processes of each application vary widely by size, by pump technology, and by load profile. The fluid used in a specific application determines the pump technology, operating conditions, and load profile.

Pump technology varies by application, but auxiliary pumps—while smaller in market volume—play a part in nearly every industry. However, core-process pumps are still the defining factor in any specific application. Use-case examples for auxiliary pumps include water supply, heating and cooling, variable-pressure generation, and disposal of liquids. Auxiliary pumps use much more smart technology than core-process pumps due to ecodesign directives for such product groups.

Recent McKinsey research shows that the global industrial pump market is worth approximately $70 billion today. By 2025, the market is projected to be worth $85 billion to $90 billion.

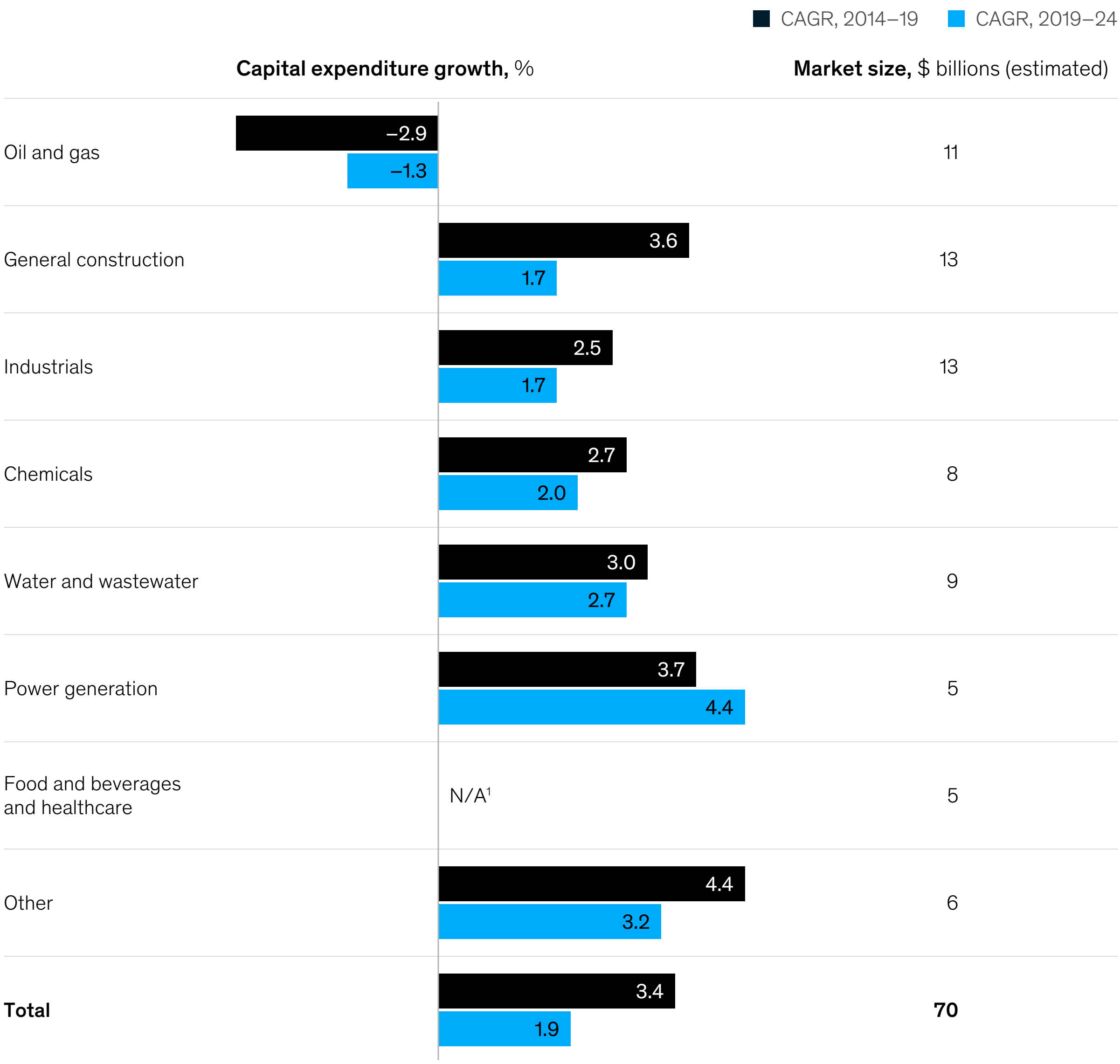
[4] For further details, see Harsha Krishnamurthy, Nick Santhanam, Shekhar Varanasi, and Zhibo Zhao, "Creating value in the specialty-pumps market," McKinsey, September 14, 2021. Unless stated otherwise, all figures in this section are taken from this publication.

While overall market revenue is expected to increase, capital expenditure growth is expected to decline. Compared with the five-year interval from 2014 to 2019, capital expenditure growth will likely decline across all end customers and applications by 2024—from as little as 10 percent in water and wastewater to more than 50 percent in general construction (Exhibit 1).

Original equipment accounts for approximately 70 percent of the global industrial-pump market, while aftermarket represents the remaining 30 percent. There are three distinct design archetypes for original equipment: standard pumps, special purpose pumps, and engineered pumps.

Exhibit 1

Compared with the previous five-year period, capital expenditure growth from 2020 to 2024 is expected to decline across all end customers and applications.



[1]Capital expenditures for the food and beverage and healthcare industries through 2024 are expected to be in line with 2014–19 or slightly higher.
Source: McKinsey analysis

Aftermarket breaks down into three main revenue sources:

OEM parts. These are the replacement parts for the key components of pumps (impeller, pump housing, and shaft). They are manufactured by pump OEMs and are often relabeled by third-party brands. Especially for high-value spare parts, all major pump companies have invested in their capacity to reverse-engineer parts. OEM parts make up more than half (50 to 55 percent) of all aftermarket revenue.

Third-party parts. These are the replacement parts for the subcomponents of pumps (seals, bearings, motors, and so on). These parts are manufactured by non-pump OEMs and represent approximately 10 to 15 percent of aftermarket revenue.

Service. A single provider is typically responsible for all maintenance, replacement of parts, and overhaul for a particular pump end user. Although most OEMs run their own service businesses, providers are often independent pump-service companies, either serving multiple brands or working under an exclusive contract with just one OEM.[5] This professional service makes up 30 to 40 percent of the industrial-pump aftermarket.

In total, the global pump market is highly fragmented with the top three players covering only about 15 percent of the market. A heterogeneous long tail of small-size players with sales below $1 billion covers more than 70 percent of the market.

As low-cost players in Asia have steadily increased their shares in the commoditized-pumps segment, specialty-pump OEMs and distributors have focused on differentiation through product quality, reliability, and service to drive organic growth, especially in regulated or critical applications such as oil and gas.

Main pump technologies

The smart fluid hydraulics–equipment industry currently covers five main pump technologies: centrifugal pumps; positive-displacement pumps; other pumps; pump sets, also known as extended products; and pump services. The fundamental technologies, operating features, and market size of each are described below.

Centrifugal pumps add kinetic energy to a fluid using a spinning impeller. This pump has a suction head and a pressure head. The impeller, which itself is driven by a motor, pushes fluid outward into a diffuser. Pumps of this type are characterized by a variable flow–pressure relationship. These pumps are simple and safe to operate. They require minimal maintenance and parts replacement, have long operating lives, and suffer less wear than other pump categories. Centrifugal pumps are the largest segment, with a global market size of $30.3 billion in 2019, $8.6 billion of which was in the European Union.[6] Approximately 79 percent of this value was generated from single-stage, multistage, and submersible pumps that were used for higher-pressure applications.

Positive-displacement pumps pressurize fluid by trapping a fixed amount of fluid with each piston stroke, which is then squeezed and displaced. These pumps work on highly viscous fluids and require more system safeguards than other pump categories. Positive-displacement pumps and pressure pumps[7] are primarily used in systems requiring pressurized water and oil, such as in the chemicals industry and in wastewater, mining, food, pharmaceutical, general

[5] The scope of service for independent pump service companies depends on local service volume. Pump manufacturers often try to acquire successful service companies and put an exclusivity agreement in place. In general, smaller pumps have less service potential; for example, in residential buildings, heating circulation pumps get replaced instead of repaired.

[6] Avinash Kumar, *Global Pumps Market Factbook, Forecast to 2025*, Frost & Sullivan, December 4, 2019.

[7] Positive-displacement pumps capture confined amounts of liquid and transfer it from the suction head to the discharge port; in other words, flow is created, and pressure results. Conversely, pressure pumps create pressure, and flow results.

process, and energy applications. Positive-displacement pumps accounted for $8.1 billion in revenue in the global pumps market in 2019, with the majority of revenue coming from diaphragm, piston, and gear pumps. The European Union accounted for $1.6 billion of that revenue.[8]

Other pumps, including specialty pumps, cover a wide range of technical specifications. They include jet engines, electromagnetic power, and gas compressor technology. The flow–pressure relationships and displacement volumes differ across verticals and application areas, from handheld jet pumps to large gas-lift systems (Exhibit 2).

Pump sets combine a fluid-hydraulics unit and a drivetrain unit, which itself consists of an electric motor and an optional variable-speed drive (VSD). Typically, fluid hydraulics and drivetrains are sold as separate modules. Special configurations where both are sold as an integrated system started entering the market in 2010. The share of these integrated systems is expected to increase significantly and across multiple applications.

Pump services primarily cater to shifts in end-user approaches to plant maintenance, attempts to reduce operating expenses, and aging asset infrastructure. These services encompass the following:

— analysis, including pump and system checks and consultations about optimizing system availability and energy management

— increasing energy efficiency and reducing operating costs, including by retrofitting equipment

[8] Ibid.

Exhibit 2

Special pump configurations cover a wide range of technical specifications.

Examples of special pump configurations

Sewage pump

Centrifugal pump (residential-heating pump)

Submersible pump

Split-tube motor pump

Source: Expert interviews

— commissioning, including installation, assembly, and trial operation

— operation, including inspection, automation, monitoring, and spare-parts supply

— repair, including upgrades and reverse-engineering

Revenue for these services reached $15.6 billion globally in 2019 across the full range of verticals.[9]

Since pump sets and pump services are still largely new, their importance is likely to increase sharply—and soon. Pump sets are being integrated into industry because of the need to become smarter—that is, taking advantage of joint optimization—and more energy efficient. Technology innovations in this area over the past two decades reveal a clear shift. While a wide range of pump-technology developments has improved fluid-hydraulics efficiency, new approaches will be necessary to improve it further. To continue increasing energy efficiency, optimization must go beyond fluid hydraulics itself. For example, motor and inverter integration from 2005 to 2015 used local sensor data to enable "intelligent" pump operation, which allowed OEMs to function as providers of pump systems. After 2015, however, OEMs began investing in digital services and analytics. In combination with cloud technology, these investments allowed OEMs to develop and provide smart services, such as pump checks, system analysis, plant-availability optimization, energy management, monitoring, and automation. This in turn helped customers minimize operational losses and maximize uptime. These digital services and analytics will only increase in value in the future as uniform data exchange protocols between components of different manufacturers—most notably, in the form of a 2020 VDMA initiative—are developed.[10]

Major player types

Beyond heterogeneous technologies, there are currently four main player archetypes within the industrial-pump ecosystem that span the product and solutions value chain:

Pump manufacturers provide the fluid-hydraulics system and—in the few cases where the product is integrated—the motor with its electricity frequency converter.

Electric product and parts suppliers predominantly focus on drivetrain components but also supply components for the inverter and for control and monitoring.

Specialized suppliers are similar to general pump manufacturers in terms of their location along the value chain, but they work in the custom fluid hydraulics–solutions space for specific applications. Specialized suppliers include OEMs that sell firefighting units, snow cannons, or hygienic pumps for the pharmaceuticals and food and beverage industries.

Plant-automation companies provide solutions for command, control, and monitoring solutions in the form of both software and hardware. Plant-automation companies include automation and control integrators and engineering, procurement, and construction companies (EPCs) that install overall fluid-hydraulics systems.

In line with Industry 4.0 efforts, digitalization and automation in fluid-hydraulics applications will also grow in importance. Innovators are expected to develop new one-stop solutions for hardware and software using cloud interfaces and tools, while new business models, such as pay-on-demand water pumps, are already emerging and are likely to spread.

[9] Ibid.
[10] Verband Deutscher Maschinen- und Anlagenbau (Mechanical Engineering Industry Association).

The demand for smart products comes primarily from companies in industrialized countries, which use them widely. In emerging markets, by contrast, limited resources lead to lower demand.

Accordingly, market leaders with more than $2.1 billion[11] in sales are starting to build ecosystems by expanding their product portfolios with complementary offerings. For example, one major player provides pumps, motors, control cabinets, sensors, and control technology—in other words, everything required to fully outfit a wastewater treatment plant down to its concrete shell. This player is thus able to coordinate all individual components through its dual role as an OEM and an EPC; achieve uncaptured energy efficiencies through its role as operator; and consolidate the smaller suppliers of pumps, motors, control cabinets, sensors, and control technology through acquisitions or in the aftermath of insolvencies.

Because of these capabilities, this player even becomes more competitive than established motor suppliers whose motors could become dispensable. In addition, unlike smaller players, the player in question is large enough to successfully invest in AI. The same is very much true for another player, which is in a similar position with its product and service portfolio of pumps, motors, frequency converters, software, electronics manufacturing, and so on. This other player is also capable of two things: offering a completely decentralized water supply and wastewater networks with unrivaled system efficiencies *and* operating them in the future.[12] Players that are unable or unwilling to keep up with these industry developments will likely be relegated to "workbench" status—that is, only implementing the solutions of or producing parts for more capable and innovative players—and could later be replaced by companies in Eastern Europe and, eventually, Asia.

At the same time, these industry developments not only provide answers to the central question of which pump technologies and which types of players will be new or clearly more or less important in 2025 than they are today, but also offer context for the use cases discussed in Part B.

[11] €2 billion. All converted values have been noted and use the May 3, 2022, conversion rate.
[12] A similar development path as well as similar competitive forces and solution offerings can also be observed in building fans, for example.

Market structure and regional differences

The global fluid hydraulics–applications industry has a rather heterogeneous and small-scale market structure because of significant regional differences, including the following:

— *Customer structure.* Customer size and power vary across applications and regions. The size of application can range from plumbers installing heat-circulating pumps in residential houses to industrial process plants to a few EPCs capable of building nuclear power stations. Regional differences are also important to consider. While wastewater companies in Germany, for example, are public and numerous, those in the United Kingdom are private and limited in number. In strategy studies, it is therefore important to look at the specific product, application, and regional customer structure.

— *Quality expectations for products.* For companies in Asia, the standards for pump quality and efficiency are less stringent for some applications, such as water—and they are even looser if sufficient water resources are available. By contrast, because they have stricter standards, European corporate customers typically require good value for their money.

— *Distribution structures.* Utilities and corporate customers in Asia tend to rely on proven technologies and established, standardized products, leading to a focus on installers as distributors. Their European counterparts, however, seek the latest technology, which they typically source directly from OEMs and manufacturers.

— *Demand patterns for smart products.* The demand for smart products comes primarily from companies in industrialized countries, which use them widely. In emerging markets, by contrast, limited resources—for example, less access to capital for investments or less access to information for making a strong business case for smart products—lead to lower demand. Demand for smart fluid hydraulics in emerging markets is higher in regions with stronger infrastructure and more educated populations. The only exceptions in this context are flagship projects such as the Smart City Beijing project.

How will market structure and regional differences change by 2025?

Among others, two potential game-changing trends are emerging in the market:

— *Intensified OEM–distributor partnerships.* Successful OEM–distributor partnerships enable OEMs to rapidly deliver superior service, such as integrated solutions, relatively short lead times, and robust aftermarket support, to end customers. In order to be considered attractive partners, best-in-class distributors need to find ways to differentiate themselves to both OEMs and end customers. Leading distributors give OEMs access to regional customers through local service centers, established customer relationships, and supply chain partnerships.

— *Shift from small OEMs and distributors to larger, consolidated entities.* Local and regional distributors are aligning with larger players to pursue growth in adjacent end markets and geographies—and they can be expected to continue to do so. For example, from 2010 to 2020, one player made about two dozen acquisitions, including of a leading distributor of flow-control and process-automation products. Market-wide, such actions have led to a shift from small OEMs and distributors serving regional markets to consolidated entities serving broad geographies with expanded line cards, superior in-house technical capabilities, and reduced reliance on third-party providers.

In general, project and EPC businesses, OEMs and end-customer businesses, and dealer businesses should be distinguished from one another. In Asia, the share of standard products—as opposed to the share of specialized products—is generally higher, and so is the share of dealer businesses. However, the trend toward smart products affects everyone. It started with defining standards in new ecodesign-oriented systems and is now moving toward setting standards for modifying existing systems. This also leads to consolidation among OEMs and dealers that can keep up with the new technology—and among those that cannot due to a lack of qualifications.

Key drivers and sectors of growth

As low-cost players in Asia have steadily increased their shares in the commoditized-pumps segment, premium OEMs and distributors have focused on differentiation through the quality, reliability, and service capabilities of their products. This differentiation has driven organic growth, especially in regulated applications such as small and medium-size water applications (heating, cooling, and variable pressure) and in critical applications such as chemicals, pharmaceuticals, and oil and gas. Furthermore, leading OEMs and distributors have continued looking toward acquisitions as a means of creating value.

Investments in R&D are also an important way OEMs have continued to differentiate their high-quality products, many of which have needed to meet increasingly demanding technology specifications. Over the past two decades, customer pain points have spurred incremental product innovations. In fluid hydraulics–fracking operations in oil and gas, for example, worn-down impellers have been increasingly replaced with ceramics to increase average time to failure. And in healthcare, ongoing issues with the leakage of fine solids has prompted OEMs to develop new materials and designs to improve seal quality.

Over the next ten years, innovative products will be needed to address new challenges, such as evolving regulations around energy efficiency and sustainability, lean operation of increasingly complex integrated-flow solutions, accident prevention in high-risk workplaces, and reliable equipment performance in extreme environments. Meanwhile, distributors and OEMs should scale up solution design and delivery capabilities for end customers, expanding their portfolios of products and brands while pursuing complementary acquisitions.

Triggered by the emergence of smart-pump technology, equipment players have already started to adapt and shift their offerings from the individual-component level to the system level. This is because energy efficiency gains have been, and will continue to be, significant revenue boosters for the global fluid hydraulics–applications industry. Each technology leap that has resulted in higher efficiency has been followed by a significant increase in sales, which will be explored later in this section.

The quest for efficiency gains: A central driver of innovation

To understand how and why process-industry players have sought greater efficiency, we have provided an overview of this trend: where efficiency-driven innovation stands today, and where it is likely to go. By mapping out the trajectory of this driving force, process-industry players can better understand the landscape they'll be acting in now and in the future.

The rationales behind process-industry players' quests for efficiency gains
Forty-two percent of total power consumption in the European Union comes from industrial processes. Among all equipment types within the industry sector, pumps consume the highest share of energy at 30 percent (Exhibit 3). Given these sizable shares, it makes sense that process players look at the energy efficiency of pumps when trying to reduce total energy consumption in order to meet regulatory energy efficiency targets or CO_2 emissions reduction targets and to optimize their cost structures.

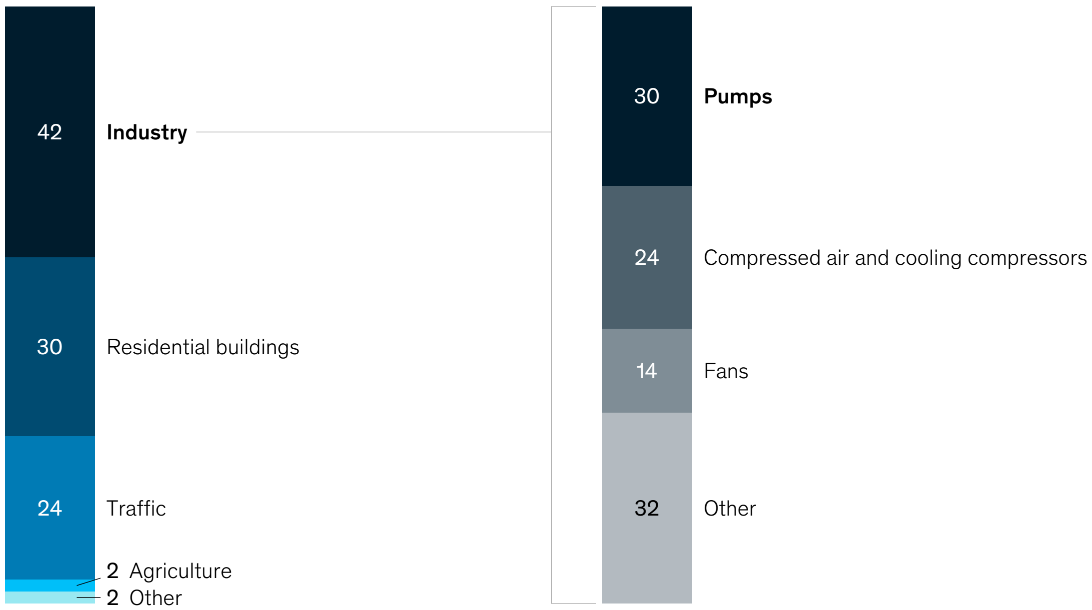
The pursuit of even higher efficiency is triggered by the two largest lifetime cost categories in fluid-hydraulics systems: energy (45 percent of total cost) and operations, maintenance, and repairs (30 percent of total cost). Investment, installation, disposal, and downtime costs make up the remaining 25 percent of lifetime costs.[13]

[13] This percentage distribution varies widely across applications and industries. Thus, depending on the case or application, the arguments that follow vary in their strength and relevance.

Exhibit 3

Pumps account for almost 15 percent of total energy consumption in the European Union.

Energy consumption in European Union, %



Source: EU Commission; Fraunhofer Institute for Systems and Innovation Research (ISI); KSB; MaschinenMarkt Vogel; McKinsey analysis

Currently, systems are typically optimized by optimizing each component on a stand-alone basis. The highest potential for energy savings, however, comes from optimizing the efficiency of the fluid-hydraulics system overall—in other words, the simultaneous optimization of the entire fluid-hydraulics module. Some manufacturers are already providing integrated products that optimize all parts from several component providers. The growing need for increased energy efficiency will only increase the prevalence of solutions that aim to optimize the overall fluid-hydraulics system.

For the global fluid hydraulics–applications industry, the path toward energy efficiency is about more than just pursuing cost savings or complying with regulations; it also allows organizations to boost revenue and sales. Pump metering, control components enabling predictive maintenance, digital twins, and steering technologies have all led to significant increases in energy efficiency—and thereby in cost-effectiveness—and spurred revenue growth.

Equipment players have started to adapt their offerings and shift from individual, component-level offerings to system-level solutions. Revenue boosts are expected to continue following efficiency gains, and the impact will likely be even more pronounced in light of the technological leap that is currently taking place.

Process-industry players' increasing interest in efficiency gains
Particularly when coupled with today's high inflation and energy price volatility, recent green deals and international governmental commitments to carbon neutrality are expected to boost the need to optimize energy efficiency along the entire value chain—not only to decrease cost and increase competitiveness, but also and perhaps even more so to earn and retain the right to play. Such green deals include the European Union's "Fit for 55," which foresees a 55 percent reduction in greenhouse gas emissions by 2030 and carbon neutrality by 2050, and China's sustainability targets in its 14th Five-Year Plan, which aim for carbon neutrality by 2060.

To achieve CO_2 emissions goals, energy generation must shift from fossil fuels to renewables. However, this shift also means an increase in electricity consumption and thus an increase in electricity costs. Therefore, additional energy efficiency gains are required to counterbalance these growing costs.

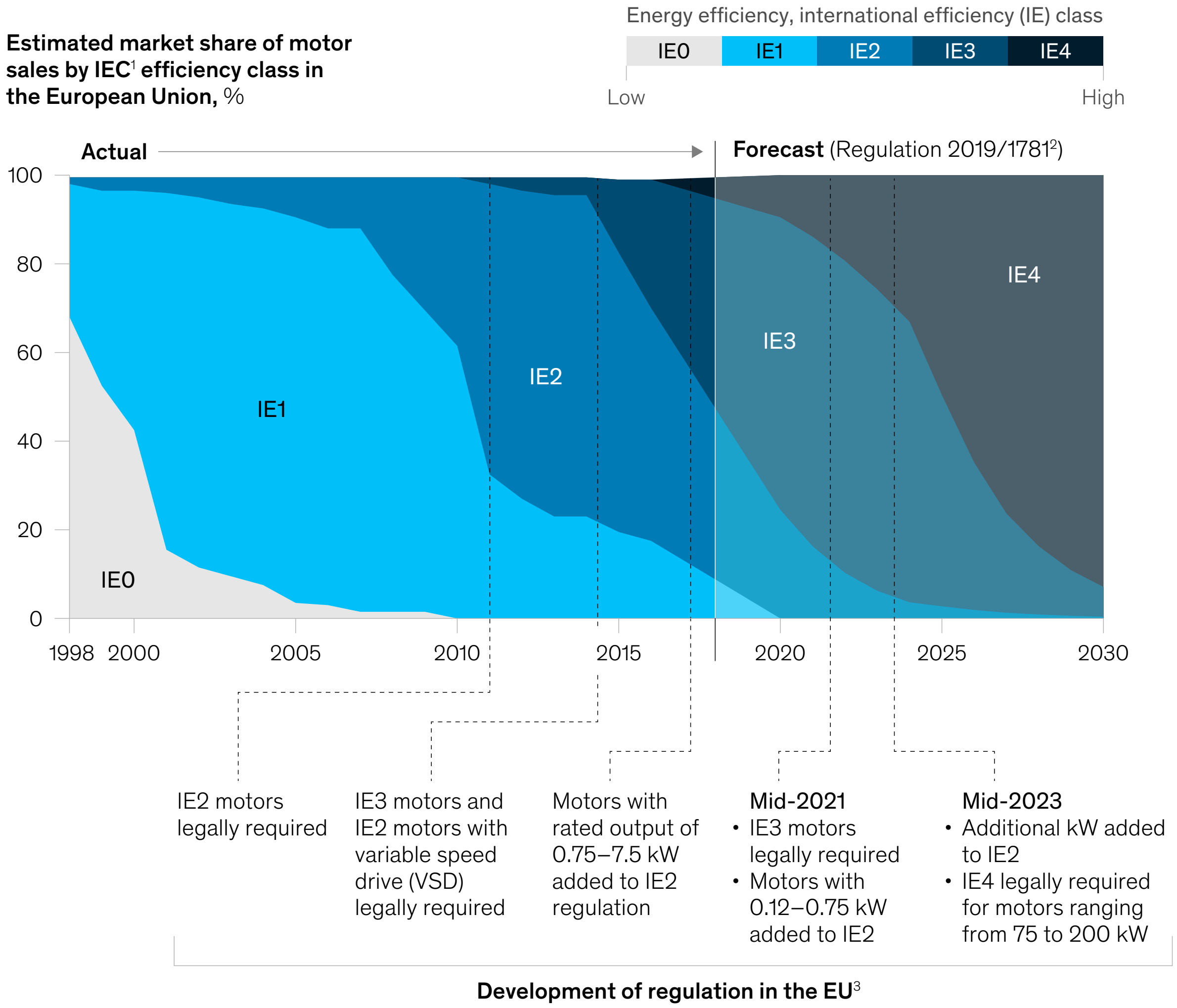
Saving energy is particularly challenging in energy-intensive verticals such as pulp and paper production. This is because production in this sector consists of several processing steps—from the pulp line (wood processing, cooking, washing, bleaching, drying, and so on) to chemical recovery (evaporation, using recovery boilers, causticizing and recausticizing, using lime kilns, and so on)—and almost every one of them requires pumps.

Along with pulp and paper, oil and gas and steel rank among the more energy-intensive industries. For these industries, governmental regulation of CO_2 emissions performance standards may cause severe disruptions. Two examples—one from inside the process industry and one from outside it—suggest, however, that regulatory pressure can not only facilitate but also accelerate the development of viable new business models that prepare companies to meet stricter emissions targets:

— *Electric motors.* National energy-efficiency regulations have been driving the shift toward international efficiency class 4 (IE4) electric motors and VSDs since the 1990s (Exhibit 4). IE2 motors were legally required by 2011, and in 2014, regulations tightened further to require IE3 motors or IE2 motors with VSD. In 2017, the IE2 requirement broadened to

Exhibit 4

National energy-efficiency regulations have been driving the shift toward international efficiency class 4 electric motors and variable speed drives since the 1990s.



[1]International Electrotechnical Commission.
[2]European Commission Regulation 2019/1781 of October 1, 2019, regarding ecodesign requirements for electric motors and VSDs pursuant to Directive 2009/125/EC, amending Regulation 641/2009, and repealing Regulation 640/2009. Forecast for 2021–30 extrapolated based on past trends; IE5 development not taken into account.
[3]European Commission Regulation 640/2009 of July 22, 2009, which implemented Directive 2005/32/EC regarding ecodesign requirements for electric motors.
Source: European Commission; International Energy Agency (IEA)

include motors with a rated output of 0.75 to 7.50 kilowatts. As a result, IE3 is currently the most common electric motor type. The share of IE2 motors is steadily diminishing as the share of IE4 motors increases.

— *Automotive.* While there has been talk inside and outside the industry about vehicle electrification for decades, it was an EU CO_2 mandate in 2009 that was a leading driver in the automotive industry's embrace of significant and widespread electrification. This mandate set fleet emissions targets of 130 grams of CO_2 per kilometer for 2015, 95 grams of CO_2 per kilometer for 2021, 81 grams of CO_2 per kilometer by 2025, and 43 grams of CO_2 per kilometer by 2030. These standards paved the way for commercialization and market adoption of electric vehicles. Electric-vehicle sales in the European Union increased their yearly growth rate from 39 percent in 2017, 2018, and 2019 to 137 percent in 2020. With demand rising from one all-time high to another—especially when coupled with the ongoing semiconductor shortage—many OEMs are currently facing challenges along the supply chain and in production. Most notable among these challenges are extremely long delivery times, with many customers waiting more than a year between placing their orders and receiving their electric vehicles.

In view of this, there is much to suggest that process-industry players—and, by extension, pump manufacturers—should prepare themselves and their respective organizations for similar regulatory scenarios. Smart-fluid-hydraulics players can be expected to develop customer-tailored offerings to meet increasing regulatory pressure.

Three waves of technological innovation

Since 2000, the drive to reduce the lifetime costs associated with fluid-hydraulics pumps has triggered three successive waves of technological innovation—each with its own business rationale and rollout status (Exhibit 5):

Predictive maintenance. Innovations in pump metering and control systems have enabled predictive maintenance in fluid-hydraulics technology since 2000. At the heart of the technological advances in this wave are sensors that monitor operating conditions and algorithms that interpret sensor data. This wave of innovations that began about 20 years ago has helped players minimize equipment downtime with emergency alerts and other helpful systems. Emergency-shutdown features and other technology also help avoid secondary damage that can arise when initial issues go unnoticed.

Exhibit 5

Three waves of technological innovation have sought to reduce the lifetime costs associated with fluid-hydraulics pumps.

1
Since 2000

Pump metering and control allow for predictive maintenance

2
Since 2010

Highly energy-efficient devices, digital twins, and steering technologies increase energy efficiency

3
Since 2020

Simultaneous hydraulics fluid systems (eg, subprocesses within a brewery) are optimized

Source: Expert interviews; McKinsey analysis

This technology is available for all major fluid-hydraulics processes and is responsible for a reduction in operating expenses, a benefit that continues to this day—pumps in all applications today come equipped with sensors.

Energy efficiency beyond fluid hydraulics. Since about 2010, fluid-hydraulics innovations have enabled very high levels of energy efficiency. By leveraging earlier predictive-maintenance innovations, pumps equipped with sensors, digital twins, frequency converters, and VSDs enable automatic, real-time adjustments in operations, further reducing both energy consumption and wear on pump systems—and thereby also reducing operating expenses. Building-services companies often use smart pumps to meet EU product-design requirements. Energy-efficiency technologies can be implemented in all fluid-hydraulics processes.

At present, industries differ in their usage of sensor data across process steps depending on how the data is being used, how critical a step is, operating procedure, and any relevant legal requirements, as well as the sophistication of the customers themselves.

Simultaneous optimization of the overall fluid-hydraulics system. While pump manufacturers had already started developing smart, energy-efficient product solutions back in 2004 (see sidebar "Overview of key steps in the run-up to smart fluid hydraulics"), the most recent wave of cost reduction only really began in 2020. This wave focuses on optimizing complete systems—pumps, engines, inverters, and sensors. These technology innovations are built on digital representation of the complete (fluid hydraulics) infrastructure, standardized communication interfaces between components of different manufacturers, and real-time decision support systems based on predefined rules and machine learning algorithms. Simultaneous optimization aims to enable autonomous steering of the entire plant, which in turn has the potential to improve yield, increase process safety, and further reduce energy consumption, wear, downtime, and secondary damage.

These application-dependent technologies are still in the early stages of development, and OEMs and system integrators are taking the lead. Nevertheless, there are already several clearly outlined and practice-proven use cases in various process industries. The most important and representative of these are introduced and discussed in detail in Part B. ■

Overview of key steps in the run-up to smart fluid hydraulics

The current push toward smart fluid-hydraulics technologies is gaining steam, but efforts made to achieve this are not exactly new. More than 15 years ago (around 2004), pump manufacturers had already begun developing smart, energy-efficient product solutions and subsequently managed to achieve three important successes:

1. First breakthroughs

The first real catalyst in the development of smart fluid hydraulics came with the ecodesign directives of the European Commission.[1] These directives were implemented to put industries on track with the following guidance:

> *"Energy efficiency improvement—with one of the available options being more efficient end use of electricity—is regarded as contributing substantially to the achievement of greenhouse-gas-emission[s] targets in the Community. Electricity demand is the fastest growing energy end-use category and is projected to grow within the next 20 to 30 years in the absence of any policy action to counteract this trend. . . . Energy saving is the most cost-effective way to increase security of supply and reduce import dependency. Therefore, substantial demand-side measures and targets should be adopted."*[2]

This directive applied to "energy-using products" (except cars) with significant market volume, environmental impact, and high potential to become more environmentally friendly. The scope of this directive would later expand to also include "energy-related products."

Concrete quantitative measures were defined per product group by the European Union and immediately became local law in all European countries via measures such as regulation 640/200 for energy efficiency classes for electrical motors, regulation 641/2009 for wet-running circulation pumps, and regulation 547/2012 for water pumps. The "efficiency bar" for those product groups was raised several times, and products not fulfilling these ecodesign requirements were taken off the market.

2. The kick start: Government-enforced environmental protection measures

These government-enforced environmental protection measures were the kick start for higher-efficiency motors and a high penetration of smart pumps in both building services (for example, circulator pumps for heating) and in heating and cooling circuits, as well as for variable-pressure units across all sectors.

The European Union is investigating further product groups, and preliminary studies have already been published, such as one on sewage pumps and compressors in 2014. Studies for process pumps used in the food and beverage, pharmaceuticals, chemicals, and oil and gas industries are expected. And pump manufacturers are investing in smart fluid hydraulics, even going beyond fluids by simultaneously optimizing pump design, motors, and frequency converters via extended product approaches and digital twins.

3. Recent developments: Standardized communication protocols and digital business models

Formerly, heterogeneous communication protocols between the different components of a fluid hydraulics system were a major obstacle. The Open Platform Communications Unified Architecture (OPC UA) for Machinery initiative of the German association VDMA[3] is developing a standardized communication protocol that will enable seamless interoperability between components of a fluid-hydraulics system across manufacturers.

Based on smart fluid hydraulics, pump manufacturers have started to develop and extend their digital business models through technologies such as condition monitoring, remote maintenance, and optimization of operating conditions with variable load profiles. The aim is for digital business models to make up 20 percent of revenue in smart fluid hydraulics. A few manufacturers have started to optimize and offer fluid-hydraulics systems consisting of several pumps, valves, and so on as an integrated system, such as in sewage pumps, and some have even begun to apply artificial intelligence to their products. This optimization is estimated to lead to energy savings of up to 60 percent.

Despite these technological advances, several issues in the past few years have led to low levels of customer acceptance. The first barrier has been the short-term cost focus of purchasing departments. Those responsible for procurement have not been primarily guided by the principle of a customer-lifetime-cost approach, in which higher up-front costs are accepted to enable lower operations costs later on. Second, most customers considered early smart solutions to be too complex and not secure enough. What's more, energy prices have been low, and the groundswell of support for sustainability has only recently reached the high levels we see today. This meant that "dumb metal parts" that only operated efficiently under very specific conditions—for example, under a specific pressure or load—have not seemed so bad, and the promise of energy savings has not been very compelling.

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[1] European Commission directives 2005/32/EC and 2009/125/EC.
[2] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast), *Official Journal of the European Union*.
[3] Verband Deutscher Maschinen- und Anlagenbau (Mechanical Engineering Industry Association).

Pumps power industries around the world, from chemicals to pulp and paper. Upgrading to smart pumps will make these industries smarter as well—as long as they do so with appropriate business rationales and use cases in mind. We outline these as they pertain to specific sectors and dive deep into considerations and examples organizations should take into account.

Part B

Smart fluid hydraulics: The next frontier of the fluid-systems industry

Transforming industry by optimizing fluid-hydraulics systems

Given the importance of industrial pumps in the global economy—and in the process-industry sector specifically—several key questions arise:

— What are the business rationales and key use cases across verticals for smart fluid-hydraulics products?

— To what degree will these use cases improve KPIs such as energy efficiency, total cost of ownership, and operational uptime?

— How should usage be tailored to specific verticals?

— What will change in daily operations, production processes, and internal resource requirements? For example, how will talent acquisition change in each of these areas?

— What will the associated ROI and payback period be once smart technology is implemented?

In the following, we will shed light on these questions in the context of seven use cases that demonstrate the manifold applications of smart fluid-hydraulics technology, as well as its enormous potential for improving performance and efficiency.

To do this, we first highlight how five focal industries in the process-industry sector—chemicals, pharmaceuticals, food and beverage, oil and gas, and pulp and paper—prioritize each business rationale (Exhibit 6). Second, we discuss these rationales in more detail, as well as their associated use cases. Importantly, we find that the focal industries prioritize business rationales differently based on their particular needs and interests. To reflect this heterogeneity, we averaged priority levels by industry based on estimates from both functional and industry experts at McKinsey, which we verified using bottom-up calculations that include various cost and revenue levers. We then generated a heat map using these data. As a tool, the heat map can help players easily identify relevant use cases in their industries to start or continue their journeys toward becoming organizations that are fully enabled by smart fluid-hydraulics technology.

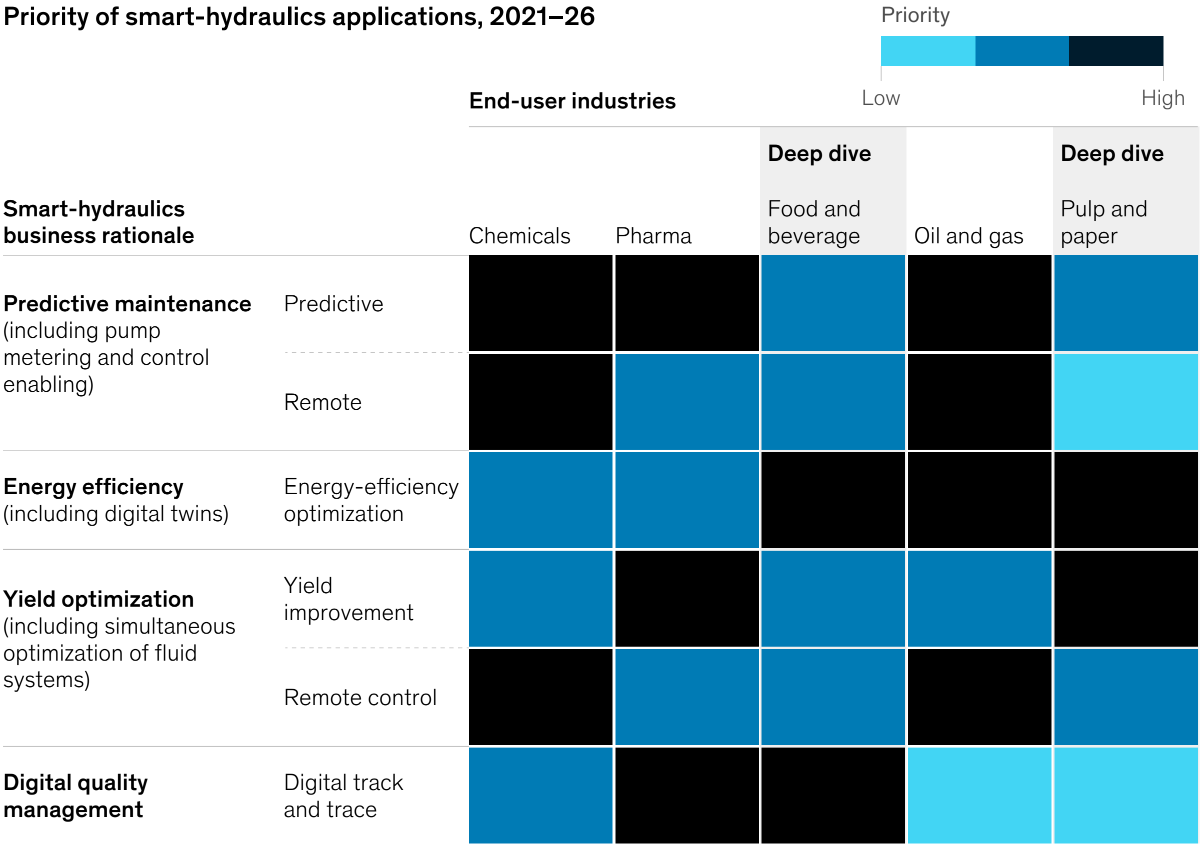
For all business rationales, including their associated use cases, digital quality management is a key enabler. Among other things, it may facilitate cost reductions along all major lifetime-cost categories for equipment users. Digital quality management has significant potential in terms of cost savings, yield optimization, and competitive advantage, in addition to being very effective in addressing the increasingly critical and urgent challenge of energy reduction.

The future ubiquity of smart fluid-hydraulics technology will have a large impact on the business rationales of all five focal industries because of how heavily they rely on manufacturing machinery. The five industries might experience the effects of this technology on business rationales differently due to their specific process and equipment needs. Recent regulatory commitments and sustainability trends may even accelerate the need for changes in several focal industries. In the following, we briefly introduce and discuss the rationales with a view toward the priorities highlighted in Exhibit 6.

Exhibit 6

Smart-product use cases differ by end-user industry because of different process and equipment requirements.

Priority of smart-hydraulics applications, 2021–26



Source: Expert interviews; McKinsey Smart Products in Hydraulics Applications Survey 2021

Chemicals: Increase output, reduce downtime. The chemicals industry in the Western Hemisphere is very mature, so potential improvements primarily center around increasing output and reducing downtime. Predictive maintenance and remote simultaneous optimization are of critical importance in this context. In terms of price differentiation and cost pass-through to customers, specialty and base chemicals must be distinguished. For specialty chemicals, price differentiation and cost pass-through to customers is similar to that of the pharmaceuticals industry, which we discuss below. For base chemicals, overcapacities and full amortized equipment result in a low or medium ability to pass through costs. Here, automation may result in additional cost advantages due to reduced manual effort. This is one important reason why fluid-hydraulics equipment in the chemicals industry is typically used for up to 50 years. Another reason for these long equipment lifetimes is that energy efficiency is only of medium priority, because in terms of total costs, the main drivers are raw material costs and personnel costs, at least for chemical companies in Europe. The third driver of equipment longevity is a combination of the widespread "never touch a running system" mindset in the chemicals industry and the fact that every change to a given production setup needs to be audited comprehensively.

Pharmaceuticals: Meet the highest process and product quality standards. Pharmaceuticals ranks among the most regulated industries, especially in terms of processes, products, and required documentation. The highest process and product quality standards—such as clean-room requirements for pharmaceutical products—are enabled by predictive maintenance and simultaneous optimization; these factors matter the most. Similar to specialty chemicals, pharmaceutical players can differentiate on price and pass along cost increases.

Food and beverage: Increase energy efficiency. The food and beverage industry is characterized by a persistent cost pressure linked to tight profit margins. Except for well-known brands and products, differentiating on price and passing through costs is more challenging for food and beverage players compared with chemical and pharmaceutical players. This particularly applies to products that end customers consider to be commodities. Therefore, increasing energy efficiency in the form of higher throughput and outcome, increased automation, or reduced operating costs serves as top priority.

Oil and gas: Ensure safe, continuous operations via predictive maintenance. Oil and gas ranks among the industries with the largest disruptions looming ahead, above all in the areas of economic outlook and predictive and remote maintenance systems.

First, recent sustainability efforts, such as regulatory commitments and trends toward renewables, have put pressure on the long-term demand and profitability outlook for oil rigs, refineries, and so on. In addition, ongoing oil and gas price fluctuations affect respective profit margins. Given these fluctuating profit margins in a highly commoditized market, increasing energy efficiency will be a key success factor in addressing cost pressure.

Second, the oil and gas industry not only has a societal obligation to avoid environmental hazards but is also required to provide safe workplaces. Further, due to long turnover times driven by high capital expenditures, implementation times are longer on average than in other focal industries. Against these backdrops, predictive and remote maintenance systems are key to ensuring safe, continuous processes and to minimizing production downtimes.

Pulp and paper: Improve sustainability. Pulp and paper may suffer most from external cost pressure and tight profit margins. Digital offerings have reduced demand for print media, while increasing reliance on e-commerce has boosted demand for packaging material. Meanwhile, sustainability advocates are pushing for the careful application of clean water and energy—for example, in the form of wastewater treatment. Overall, increased energy efficiency will be a key success factor in the industry. To leverage the full cost and throughput potential of production processes, companies in the industry should put top priority on the simultaneous improvement of the overall fluid system. For instance, reusing wastewater or capturing its energy in the production process is beneficial from the perspective of both cost and sustainability. However, implementation is typically slow due to long turnover times driven by high capital expenditures.

Key use cases to achieve the next level of energy efficiency

In the following, we describe seven use cases in greater detail to elaborate the specific pain points that smart fluid-hydraulics technology can address, to provide insights into that technology and its applied methods, and to estimate the impact of smart fluid-hydraulics technology in various dimensions specific to particular use cases.[14]

Use case 1: Rightsize equipment

How the use case works: By continuously measuring and recording the load profile of pumps, intelligent pressure sensors can indicate any potential for optimizing energy efficiency and availability. This real-time information can help maximize availability by detecting and preventing pump usage—whether that usage is intended or unintended—and reduce operating costs.

Example applications and impacts

An automotive OEM plant: An automotive OEM plant implemented intelligent pressure sensors and discovered significant misalignment between the operational mode of the pumps and the selected optimal operating point. By making the corresponding adjustments, the plant was able to go from six pumps in operation to three. This reduced the plant's energy consumption by 28 percent and contributed to other reductions in operating expenses and capital expenditures.

A global chemical company: An efficiency analysis at a global chemical company revealed a significant mismatch between the pumps it had deployed and its actual load profile: the tubular casing pumps were significantly oversized. Rightsizing generated significant savings.

Residential buildings: A Dubai-based property management and development firm came to realize that three of its tower buildings were equipped with oversized pumps that ran at constant speed, wasted energy, vibrated excessively, caused noise issues, weren't reliable—and also had savings potential. Changing to close-coupled, end-suction pumps with variable-frequency drives, which were provided to the firm free of charge under a performance-based contract, led immediately to impressive results: the three buildings cut their pumps' electricity consumption by 46 to 81 percent and achieved total energy savings—including from air conditioners, fans, and lights—of 20 to 25 percent. What is more, noise issues were solved, and the energy savings paid for the pump upgrade.

Use case 2: Reduce energy consumption with partial load profiles

How the use case works: Variable-speed pumps measure the actual system's demand in real time and adjust the operating conditions of the pump (flow rate and pressure) accordingly by altering the motor speed.

Example applications and impacts

A household-appliances OEM: Adding variable-speed pumps to refrigeration units that were already highly efficient helped one household appliances manufacturer cut energy consumption in the refrigeration process by about 40 percent.

[14] To ensure that these descriptions are as vivid and concrete as possible, most of them focus on one specific industry or application. However, use cases generally extend across all industries mentioned and are typically easily transferred to related applications. Nevertheless, technological adaptations may become necessary when changing industry or application context for a specific use case. The general logic, however, remains the same.

Wastewater management: By using a supervisory control and data acquisition (SCADA) system, a wastewater management operator has a constant view of their 2,500 pumping stations as well as the ability to monitor and control each station individually to effectively respond to man-made and natural peak flow times. Data from the entire network also help operators optimize processes at all pumping stations and wastewater treatment plants, creating a basis for preventive maintenance.

A dairy plant: In a milk processing company that uses an ice water system to cool milk, frequency-controlled pumps with positive-temperature-coefficient (PTC) thermistors and a specific control convey the ice water from the ice water basin via a distributor into seven consumer circuits. This ensures demand-oriented and energy-saving system operation. Due to the intelligent pump control, the plant additionally saves up to 70 percent in electrical energy during pump operation.

Use case 3: Optimize pump efficiency

How the use case works: Multiple technologies deployed in combination can increase the efficiency of an entire pump system. For this reason, fitting pumps with both a variable-speed system and an intelligent pressure sensor and adding shut-off and control valves, swing check valves, strainers, and expansion joints can optimize the efficiency of heating, air conditioning, water, and sanitation systems.

Example applications and impacts

A university hospital: A university hospital in Belgium replaced its 217 outdated pumps with more than 250 new high-efficiency pumps that are connected to the system and consume up to 80 percent less energy than their predecessors. For the hospital, this resulted in an energy reduction of more than 643,000 kilowatt-hours per year, which corresponds to 140 tons of CO_2 emissions per year and annual cost savings of about $70,000. What is more, control and maintenance have become much more efficient than before: because all new pumps are connected to the system, they can easily be controlled and monitored.

A strategic combination of multiple smart fluid-hydraulics technologies has the potential to address nearly all system inefficiencies.

Another university hospital: By replacing uncontrolled pumps with controllable high-efficiency pumps, a hospital was able to reduce its energy consumption by 31 percent, or approximately 50 megawatt-hours of electricity. The replacement also resulted in a highly reliable water supply, a higher level of safety in accordance with the latest hygiene provisions, and enhanced comfort for patients.

Buildings: When renovation at a Danish bank required the installation of three circulator loops for heating, managers also decided to replace three older pumps with energy-efficient, reliable, and easy-to-install circulators. As a result, the bank saved 60 percent of its energy costs just on the operation of the new pumps.

Use case 4: Optimize systems comprehensively

How the use case works: A strategic combination of multiple smart fluid-hydraulics technologies has the potential to address nearly all system inefficiencies. This applies in particular to smart valves and meters used in combination with efficient pumps and variable-speed systems.

Example applications and impacts

A printing-machines manufacturer: One part of a printing-machine manufacturer's production relied on four fixed-speed pumps designed for an operating point that far exceeded what was required. After installing smart flow-rate measurement systems and pumps with variable-speed systems, operation now mainly consists of a single pump and intelligently engages a second and third pump only when needed. This has led to cost savings of approximately 90 percent.

Industrial cooling: Leveraging pumps with intelligent controls significantly improved cooling-tower efficiency for a global chemical company, resulting in 22 percent savings on operating expenditures and 128.26 fewer metric tons of CO_2 emissions per year. At this rate of savings, the investment was paid back in just under two years.

A packaging manufacturer: A UK packaging manufacturer, for which cooling-system reliability and control are essential, used intelligent pumps and controls in a retrofitting project that maximized reliability and led to energy savings of 52 percent. These improvements drove a total operational cost savings of about $16,585 a year.

Use case 5: Boost system efficiency

How the use case works: Replacing existing pumps that are equipped with a variable-speed system with an optimally matched system of pumps, valves, and automation products allows the use of high-efficiency motors. These are ideal for fluctuating load requirements, and when these motors are paired with an intelligent speed-control system, they clearly exceed the efficiency offered by an IE3 motor when it comes to part-load ranges.

Example applications and impacts

High-efficiency motors: When compared with IE3 motors, the high-efficiency motor not only achieves energy savings of 73 percent but also boasts a space-saving design so that the complete pump set requires just a small installation area.

Power generation: The water-cooling demands of the 1,200-megawatt Anpara Power Station in India are significant. A total of five vertical-turbine pumps supply the required cooling water by extracting and transporting raw and process water to be used in cooling. The pumps

An ecosystem of intelligent pumps with cloud connectivity and digital services enables real-time monitoring, remote control, fault prediction, and system optimization. It also supports both capacity utilization and predictive maintenance.

also play a role in irrigation and drainage and ensure overflow protection. The use of state-of-the-art materials and technologies means that the pumps achieve an exceptional hydraulics efficiency of about 90 percent and a significant reduction in energy costs.

Use case 6: Implement smart grids and data-driven monitoring

How the use case works: Installation of smart grids enables measuring actual consumption—for example, of fresh water—on a daily basis. Based on these comprehensive data, a normal demand curve can be estimated and may serve as the basis for monitoring and tracking deviations, bottlenecks, and leaks.

Example applications and impacts

A water service: Using a smart leak-detection network, water utility operators in the United States discovered that a widely known waterfall, previously thought to be a natural phenomenon, was, in fact, the result of an underground pipe that had burst. This leak, which had gone unnoticed for more than two decades, had caused the town to lose approximately 5.53 billion gallons of water. The installation of new water mains and a smart network resulted in savings of $2.6 million because of reduced water losses.

Water utilities: An English water utility's smart network resulted in several benefits: fair billing, where customers only pay for what they use; immediate problem detection, such as leaks or burst pipes; rapid repairs; improved customer satisfaction, since water pressure and temperature are constantly monitored; greater availability of data, enabling the utility to understand overall network performance; and water savings, as customers that are provided with web-accessible insight into their water consumption use 13 percent less water on average.

A food and beverage plant: A food-processing plant solved the challenges it was facing when dosing peracetic acid by leveraging smart digital-dosing pumps. These are not only safe and accurate, but they can also pinpoint exactly where an issue occurs. This allows the company's customers to monitor what's happening in real time, identify when an event happened, and keep events in their records. The food-processing plant now benefits from less downtime, fewer maintenance calls, and lower chemical costs.

Industrial services: A US supplier of services to power, oil and gas, chemicals, and other industries had difficulty monitoring pumps that underwent cavitation intermittently, which was causing impeller wear and possible failure. Introducing Internet-of-Things (IoT) monitoring that is based on information from the field provided via an IoT platform improved profitability via remote monitoring and predictive maintenance of complex fluid-control systems. Key benefits so far include avoidance of a $16 million cavitation problem, reduced unplanned maintenance costs and emergency work orders, and enhanced equipment availability and efficiency.

Use case 7: Develop new business models

How the use case works: An ecosystem of intelligent pumps with cloud connectivity and digital services enables real-time monitoring, remote control, fault prediction, and system optimization. It also supports both capacity utilization and predictive maintenance.

Example applications and impacts

Utilities: First utility equipment providers started with pay-on-demand offerings, such as in wastewater applications that include remote control. In total, this enables a significant reduction in capital expenses for municipalities and other players.

A chemical company: To improve its system reliability and ensure minimum system loss, a US adhesives manufacturing company installed a solution covering intelligent pumps, cloud interfaces, and digital offerings in its cooling-tower application. Thanks to constant temperature control, the company now has less system complexity with no need for traditional regulation valves. Additional benefits are minimum system loss, 77 percent energy savings, and $43,266[15] saved a year.

Another chemical company: A plastics factory in Israel developed an energy-efficient cooling system that creates ice during the night, when it is cooler and electricity is as low as a fifth of the peak price. Two variable-speed controllers allow the system's twin pumps to respond to two temperature sensors and thereby manage the flow of cooling water from ice storage to a heat exchanger, which passes the water at a constant temperature of 14°C into the air conditioning system. Smart cooling means that the factory benefits not only from the savings from nighttime power rates but also from the energy efficiency of the on-demand pumping technology, which ensures the factory is cooled to the required temperature.

[15] €41,112, converted with our underlying FX rate.

Developing a robust strategy now will make the difference for industry players and end users in the future. Below, we present strategic insights tailored to each group, including industry challenges and drivers, as well as actions that could allow organizations to take full advantage of smart fluid-hydraulics technology. With these structural foundations in place, organizations will be poised to thrive in the coming fluid-hydraulics revolution.

Part C

Building blocks for strategy development in the fluid hydraulics–applications industry

Core elements of strategy development

Due to its high energy consumption, the process industry can find huge potential in smart fluid-hydraulics products. The first OEMs have started introducing these products and may have already gained a competitive advantage. There is, however, still great growth and sales potential to be captured for companies that are developing new technologies. We have distilled a set of pragmatic no-regret moves that can help industry followers develop strategies for component and service offerings and enable them to compete with early movers. Some of these actions apply to all industry players,[16] while others are most applicable to OEMs and pump manufacturers. Additionally, we offer strategic insights that are derived from our most recent survey findings on what matters most for end customers.

1. Pragmatic high-impact moves for all players

There is certainly no single standardized approach to getting started and enabling an organization to implement and monetize smart fluid hydraulics. Our observations of the most successful players in adjacent industries with similar digitalization challenges, however, reveal effective approaches and perspectives that aspiring players in the fluid hydraulics–equipment space might adopt to achieve impact at scale.

Reassess company strategy and technology road maps. The introduction of smart fluid hydraulics entails a profound rethinking of the value chain for industry players, potentially including new revenue streams and capabilities—or possibly cannibalization. To implement a system or solution view, equipment OEMs need to reassess their company strategies, define their technology road maps, and make a conscious decision on when to develop which type of smart fluid-hydraulics application.

Consider integrated systems instead of single components. To leverage the full potential of smart fluid hydraulics, optimization of the overall fluid system matters. From a strategic point of view, successful players offer a one-stop solution to customers and serve as an interface between single-component players and end users. By contrast, single-component players will further lose strategic relevance and end up as extended workbenches suffering under severe cost pressure.

Focus efforts on a limited number of relevant use cases. The players most likely to achieve sustainable success will be the ones that focus on a limited number of use cases instead of trying to target as many use cases as possible.

Define and build required future digital capabilities. Fluid-hydraulics players will need to build a strong, cross-functional internal team in possession of both an agile mindset and digital and software skills. They would be well advised to establish and nurture external partnerships with others in their business and technology ecosystems. Here, companies should begin thinking about which aspects of smart fluid hydraulics they want to own as well as which are best addressed through outsourcing, long-term collaboration, or other types of partnerships. In this context, companies also need to find answers to questions concerning data ownership and cybersecurity. They should then start identifying potential partners and engaging them pragmatically.

Develop a marketing and sales strategy. End customers are not always clear about the benefits of the latest fluid-hydraulics solutions on the market, but the main business rationales behind these solutions can still be attractive to them. Product marketing should clearly describe the underlying business cases and outline their benefits.

[16] That is, component manufacturers, OEMs, and system integrators.

2. Cooperation as a key factor in product and service development

To successfully establish smart fluid-hydraulics applications, products, and services, pump OEMs may pursue a three-step strategic approach:

Step 1: Segment the market to find solutions for specific end-customer applications. The first step is to segment the market according to application-specific characteristics, such as operating conditions, fluid-hydraulics equipment, energy usage, size, legal requirements for products, processes and documentation, IT affinity, and customer digital maturity and process know-how. One key insight of market segmentation is that it is generally not very promising for mechanical-engineering companies that serve multiple end-customer industries to count on technology rollouts in "lighthouse" industries such as automotive to generate further synergies with new end-customer industries. This is because while individual mechanical-engineering companies may not be best positioned to address a given lighthouse industry market, they are well placed to be successful with applications in other end-customer industries. What's more, a manufacturer of fluid-hydraulics components, for example, will need different solutions to meet the specific needs of the different end-customer industries that it serves.

Companies operating fluid-hydraulics machines are willing to invest in smart fluid-hydraulic products and applications if they can bring clear and quantifiable benefits within a reasonable payback period.

Step 2: Demonstrate the added value created for end customers. Segmentation should be followed by a detailed consideration of added value from the customer's perspective. Indeed, companies operating fluid-hydraulics machines are willing to invest in smart fluid-hydraulics products and applications if they can bring clear and quantifiable benefits within a reasonable payback period. Accordingly, end customers have so far been particularly interested in applications that improve throughput and equipment uptime (such as predictive maintenance), that increase product quality or reduce rejects (such as fault detection), or that reduce resource consumption (such as fluid-hydraulics energy efficiency). In all such cases, the user-friendliness of the application is of paramount importance to customers, since high training costs or errors in operation can quickly erode, and indeed exceed, any added value.

Step 3: Define the company's business model and unique selling proposition. The final step is to specify the best business model for the pump OEM, to clearly define its unique selling proposition vis-à-vis competitors, and to comprehensively assess the technological advantage as well as risks of the new business model. Exploring the answers to the following key questions can help:

— Will the application layer be monetized at fixed prices—either in return for a one-time payment or under alternative payment models such as subscription models and marketplace fees—and tailored to end customers' needs and willingness to pay? For example, a company could offer software-related services available on a monthly or annual subscription basis.

— Is the application an integral part of a combined offer, such as a product that includes a software application, or does the provider need to risk basing the application's monetization on the actual value added for the end customer? In the latter scenario, a company could evaluate new performance-based compensation models linked to predefined indicators, such as a certain reduction in energy consumption or equipment downtime.

End customers expect providers to generate the promised measurable added value, to participate in the outcomes achieved under performance-based compensation models, and to share in associated risks. Finally, end customers' preferences regarding capital expenditures and operating expenses may need to be considered, too.

3. Smart fluid hydraulics products and solutions: What matters for end customers

In the following, we aggregate and discuss the results from our recent cross-industry end-customer survey (see sidebar "Key facts about the end-customer survey") according to purchasing drivers and criteria, key barriers and most-desired features, and further aspirations concerning smart products in fluid-hydraulics systems. Industry players should consider these fresh insights into what matters most for end customers when developing their strategies—particularly the insights that are most relevant to their core businesses.

Key facts about the end-customer survey

The survey comprised more than 25 questions related to the status of technology implementation, future plans for investment, and key drivers, barriers, and purchasing criteria.

Respondents included key users from the operations, procurement, and maintenance departments of leading process manufacturers.

Respondents came from various organizations in focal industries—namely, pulp and paper and food and beverage—around the world.

Survey demographics
Twenty-four respondents from food and beverage and pulp and paper were involved in our survey (exhibit).

Global respondents came from organizations of varying sizes, with the number of full-time-equivalent (FTE) employees ranging from fewer than 1,000 to more than 30,000, and annual revenues ranging from less than $500 million to more than $10 billion.

We found that organizations tended to be either small or big, with few in between:

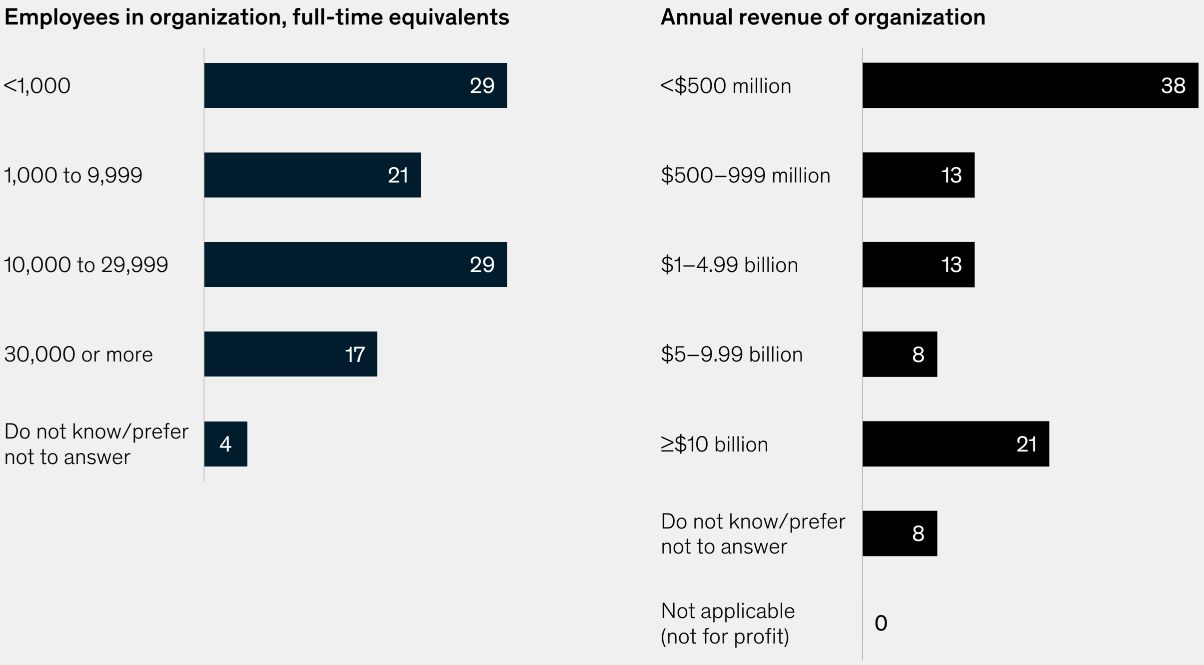
— Thirty-eight percent of respondents work in an organization with less than $500 million in revenue, while 21 percent work in an organization with more than $10 billion in revenue.

— Twenty-nine percent of respondents work in organizations with fewer than 1,000 FTE employees, while 46 percent of respondents work in organizations with 10,000 or more FTE employees.

Exhibit

McKinsey's end-customer survey included organizations with a broad range of sizes and revenues.

Share of respondents (n = 24), %



Note: Figures may not sum to 100%, because of rounding.
Source: McKinsey Smart Products in Hydraulics Applications Survey 2021

Purchasing drivers and criteria

The reasons why players in process industries look to smart products are clear. First and foremost, they see the solutions provided by smart equipment—such as energy efficiency—as ways of reducing operating expenses. They also see smart products as a tool that helps keep production up and running and minimizes downtime—an important factor across the board. Differences by sector emerge when we look at third- and fourth-level drivers. Specifically, the quest for improvements in process yield is much more important to pulp and paper players than it is to food and beverage players, and labor safety is a bigger driver in food and beverage than in pulp and paper. Among the least relevant reasons on average for process-industry players to use smart products in fluid-hydraulics applications is green regulation (Exhibit 7)—which is surprising given the recent momentum in the regulatory landscape.

Our survey of decision makers in various process industries indicates that, when they look at which smart product to purchase, they tend to apply a classical procurement view. Specifically, purchasing decisions for smart products hinge significantly on the up-front cost, the ROI, and the smart product's compatibility with existing equipment.

A more granular look reveals some variation by industry (Exhibit 8). For example, ROI is a much more relevant consideration in food and beverage than in pulp and paper, and a product's features are more important than compatibility for decision makers in pulp and paper.

Exhibit 7

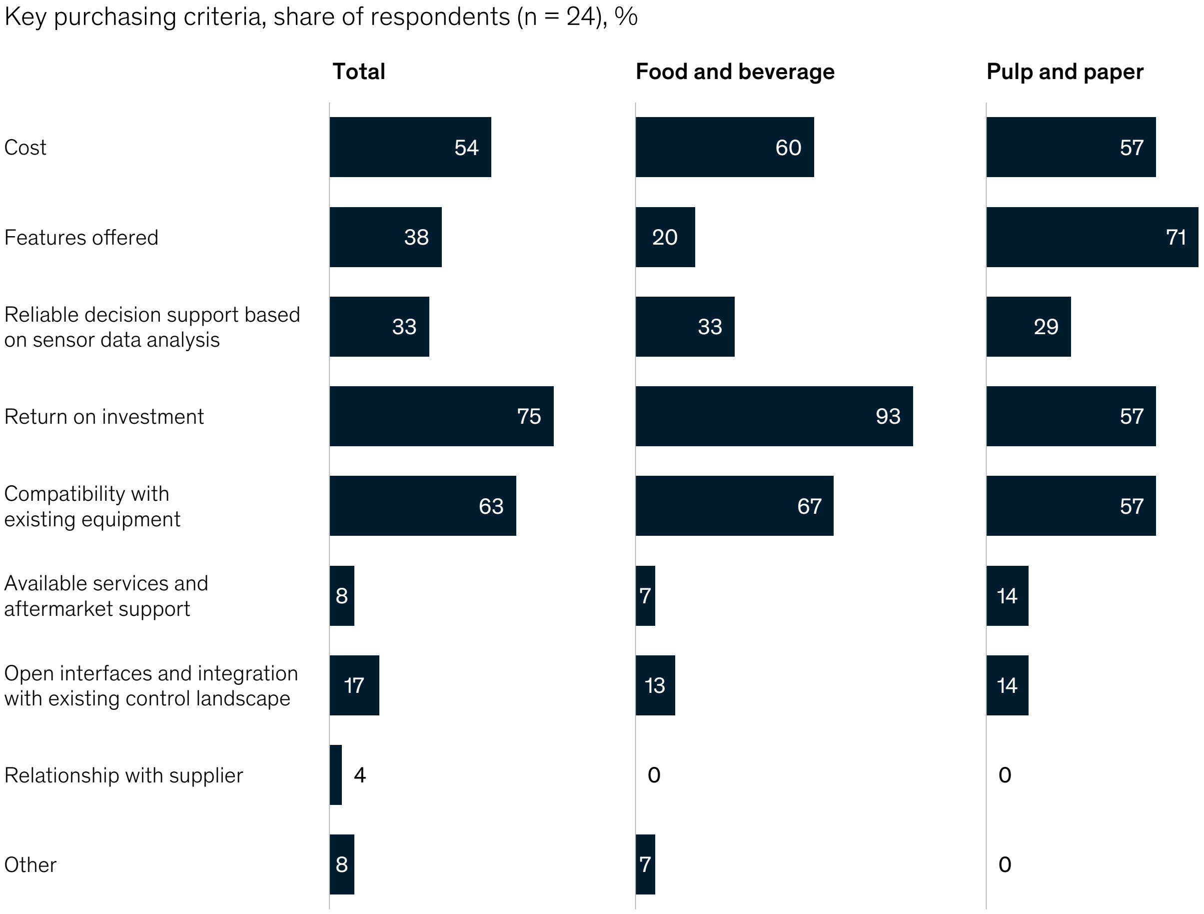
Process-industry players cite green regulations as among the least relevant reasons to use smart products in fluid-hydraulics applications.

Key drivers, share of respondents (n = 23), %

Source: McKinsey Smart Products in Hydraulics Applications Survey 2021

Exhibit 8

The classical procurement view of end customers applies to purchasing decisions for smart products.



Source: McKinsey Smart Products in Hydraulics Applications Survey 2021

Key barriers and most-desired features

Several benefits can be derived from smart fluid-hydraulics technology, but unless those benefits are clear to process-industry players and aligned with their particular strategies, the adoption of these technologies will be lackluster at best. We have derived a few important insights into obstacles and customer preferences:

The benefits of smart fluid-hydraulics products appear to be at least partially unclear to end customers. In our survey, respondents point to a lack of clarity regarding the business impacts and benefits of smart fluid-hydraulics products as a key barrier to acquiring them. Additionally, high cost and the perception of low ROI are also seen as barriers. Respondents also admit to a lack of technological know-how within their companies.

Total cost of ownership and automated production targets are clear, but the journey to achieving these targets might be challenging. The most desired benefit from smart fluid hydraulics is, by far, an attractive total cost of ownership driven by energy optimization. Process-industry players understand that sensor data and AI features could lead to fully automated production, but they worry that simply installing these technologies will not be enough.

Further aspirations

Among other things, smart applications (especially those for plants) need to be fully embedded in the existing infrastructure instead of serving only a single application. In this context, the capacity of smart fluid hydraulics to be easily installed and used is essential to widespread end-customer adoption. Additionally, completely autonomous operations—for example, in the form of completely unmanned and fully informed decision systems, including off-premises monitoring—rank among the features that make up the next S-curve.

Core strategic insights for end-customer organizations

We have thus far focused on critical strategy-development elements for players in the fluid hydraulics–applications industry. Now, we will turn our attention to end-customer organizations. In the following section, we describe specific strategic insights for five end-customer industries—chemicals, pharmaceuticals, oil and gas, food and beverage, and pulp and paper—that managers could consider when developing successful and tailored smart-fluid-hydraulics strategies for their organizations.

For each industry, we discuss the strategic insights relevant to smart fluid hydraulics in three categories: emerging trends, key levers for performance improvement, and focus areas for smart pumps and fluid hydraulics. Note that the strategic insights provided only refer to the industries' core processes and not to their auxiliary processes. This is because auxiliary processes, such as those for heating or cooling, may be distinguished by operating under partial vs. full loads, deployment of variable speed drives (VSDs), or size rather than by the respective focal industry. In contrast, core processes are rather heterogeneous across industries in terms of pump size and energy consumption, and they generally deploy large pumps that operate under full loads, as seen in the oil and gas, chemicals, and pharmaceuticals industries. Reducing redundancies and optimizing operating conditions in core processes can therefore reduce costs significantly.

1. Chemicals

Overall, the chemicals industry is currently undergoing a digital adoption wherein many players have started significantly investing in their digital and analytics capabilities to increase their resilience in the market. In addition, many chemical companies are operating on the edge of traditional cost opportunities because traditional cost-reduction programs that supported resilience in previous downturns may be insufficient in the next downturn or recession. Recent supply chain disruptions arising from the COVID-19 pandemic may also increase inflation and lead to volatility in raw materials and energy.

It is well worth distinguishing between the chemicals industry in Europe and in Asia. This is because old, depreciated plants in Europe and new, modern plants in Asia are facing a global decline in demand, at least for some core products. In view of this, smart fluid hydraulics that allow companies to streamline and automate manual activities represent an important lever for yield enhancement in chemical plants in Europe. By contrast, yield enhancement in Asia can primarily be achieved through leveraging state-of-the-art fluid-hydraulics systems that allow multiple plants to be controlled by a central station.

What is more, chemical companies may further reduce their energy consumption by various means in the circular economy context, such as through potential fluid-hydraulics applications. Higher automation levels and decentralized control towers will also reduce the need for manual labor via valve control, for example. Finally, improved planning may enhance reliability and optimize production processes.

For smart fluid hydraulics, this may particularly boost trends such as advanced process control via control rooms, sensor- or robotics-based maintenance, and shop floor steering and information digitalization.

2. Pharmaceuticals

In the past decade, the pharmaceuticals industry has faced some fundamental changes, including the introduction of megafacilities that use economies of scale to improve costs and facilitate technological investments; a shift toward best-cost countries;[17] the strategic use of contract manufacturing organizations (CMOs); the emergence of data as a competitive advantage for business operations and performance; increased local production, mainly due to supply chain disruptions; and revised product portfolios (for example, biologics outpacing the market for small molecules).

In pharmaceuticals, innovators, generics producers, and CMOs must be distinguished by their differing cost pressures and ROI timelines. Innovators focusing on R&D, sales, and distribution face a comparatively low cost pressure and may see two to three years as an acceptable ROI period. In contrast, cost pressure matters more for generics producers and CMOs, resulting in a targeted ROI of one to one-and-a-half years. Hence, smart applications for fluid hydraulics might be particularly important for the latter producers.

Filling and packaging lines in the pharmaceuticals industry usually have an efficiency level of only 40 percent because the rest of the generally available uptime needs to be used for retooling, maintenance, and troubleshooting. Accordingly, yield to be leveraged with smart fluid hydraulics can be rather substantial. What is more, in combination with AI applications, smart fluid-hydraulics pumps can boost yield in core processes; for example, they could support the agile production of smaller batches with heterogeneous quality requirements. Last but not least, smart fluid hydraulics may improve yield in auxiliary processes, such as clean-in-place and sterilize-in-place processes.

In combination with AI applications, smart fluid-hydraulics pumps can boost yield in core processes.

[17] This shift to best-cost countries might be reversed in the future as production returns to high-cost countries that increase their automation while maintaining the high quality of their products.

3. Oil and gas

Recent high inflation and volatility in raw-material prices have affected oil and gas prices, while interest in sustainability has challenged the long-term profitability of oil and gas players as well as their ability to make new investments. For example, while inflation has boosted investment in fracking and technology such as mobile liquefied-natural-gas terminals, sustainability concerns have resulted in reduced fracking. In addition, oil and gas players must take measures to prevent natural disasters such as oil spills.

In the entire oil and gas value chain, pumps play a pivotal role in transporting crude oil from its source—via pipelines, tanks, and systems—to customers. It comes as no surprise that most maintenance, monitoring, and control efforts are linked to pumps and their associated core and auxiliary processes.

Although pumps must be continuously controlled, there is a large discrepancy between facilities equipped with sensors and remote-control capabilities (including central control rooms) and those that still rely on the manual effort of technicians. Hence, players in the oil and gas industry could greatly benefit from smart fluid-hydraulics processes, particularly advanced process control via control rooms and smart sensors; predictive maintenance, including appropriate algorithms for the early detection of leakages and downtime; and sensor-based monitoring to control vibrations and inlet and outlet pressure.

4. Food and beverage

The food and beverage market is likely to continue its growth, fueled by increased consumption of high-end products such as luxury-brand bottled water, by marketing around products such as flavored ready-to-drink coffee, and by health trends such as low-calorie carbonates.

Yield improvement represents a key lever in performance uplift, especially for beverages. While the market previously deprioritized energy costs, recent developments in energy markets and increased regulatory attention may change this.

In combination with AI applications, smart fluid-hydraulics pumps can boost yield by supporting the agile production of smaller batches of different product categories. In addition, predictive maintenance and process control may increase uptime and pass-through. Ultimately, optimizing overall fluid-hydraulics systems enables additional energy cost savings—for example, through reusing heating and cooling processes.

5. Pulp and paper

The increase in e-commerce has boosted the demand for packaging material, while the shift from print to digital media has reduced the use of pulp and paper in print products such as newspapers. One of the key drivers of this industry is cost pressure, which has been increased by recent trends in circular economies and sustainability, such as the efficient reuse of wastewater.

Simultaneous improvement of overall fluid systems should be a top priority for pulp and paper players to reach their full cost and throughput potentials. For instance, players can reuse hot wastewater in the production process to heat fresh water, a process that is beneficial from both a cost and a sustainability angle. However, implementation is typically slow due to long turnover times driven by high capital expenditures. Advanced process control in control rooms and predictive maintenance could improve yield and reduce downtime and costs.

Outlook

Across industries, the process sector, with its wide use of fluid-hydraulics equipment and its high energy consumption, has huge potential for the application of smart fluid-hydraulics systems. Albeit with limited adoption, smart fluid-hydraulics systems are already helping to reduce costs for players in a range of process industries today. However, the current high inflation and volatile market environment, especially with respect to energy prices, may further boost the adoption of smart fluid-hydraulics systems. The next promising technology advancement, simultaneous optimization, is in an even earlier stage of development, but implementation and scaling should take place soon. As smart fluid hydraulics becomes commercial, first movers among end users and equipment OEMs can take advantage of their beneficial positions to move ahead of the competition.

We demonstrated—based on three practical business rationales—that technology leaps in smart fluid hydraulics can lead to performance boosts and competitive advantages as well as new business models in the industrial equipment and machinery sectors. Six pragmatic recommendations guide the way to getting started.

Testing the first prospective applications of smart fluid hydraulics does not require long preparation or a large up-front investment. Jumping in can produce early results and help companies make quick progress on embracing the full potential of smart fluid hydraulics. In view of current developments in energy policy and rapidly rising energy prices, the resulting boost for energy efficiency could provide an increasingly important competitive advantage.

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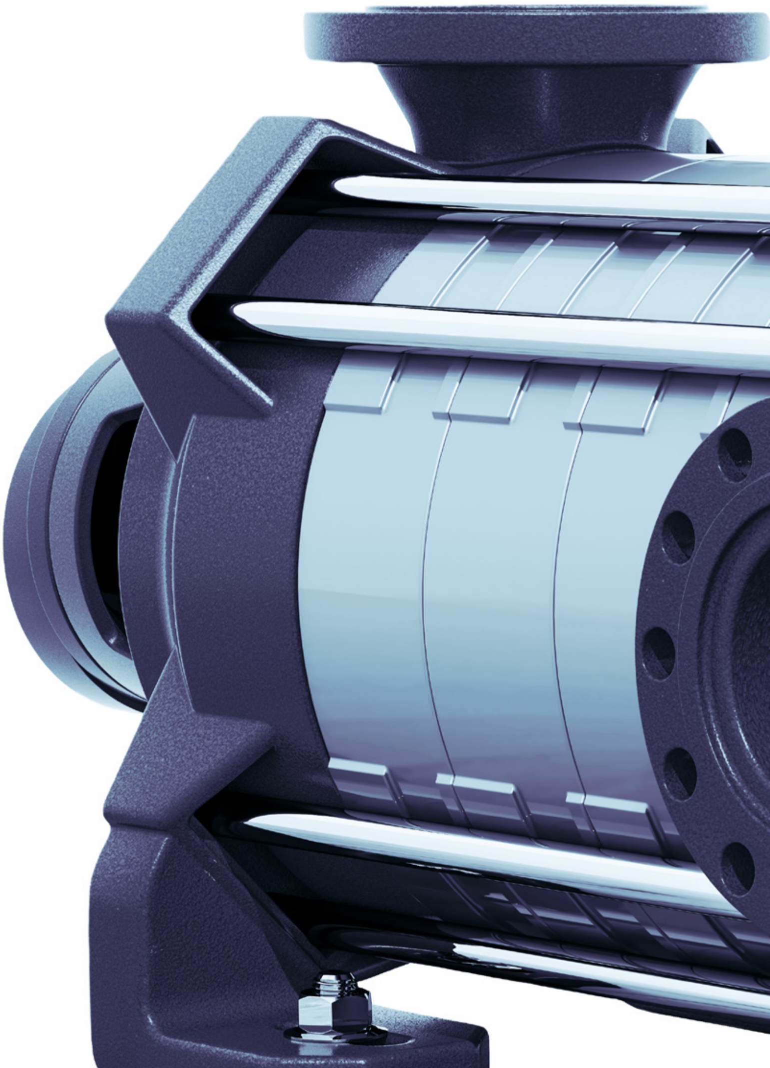

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