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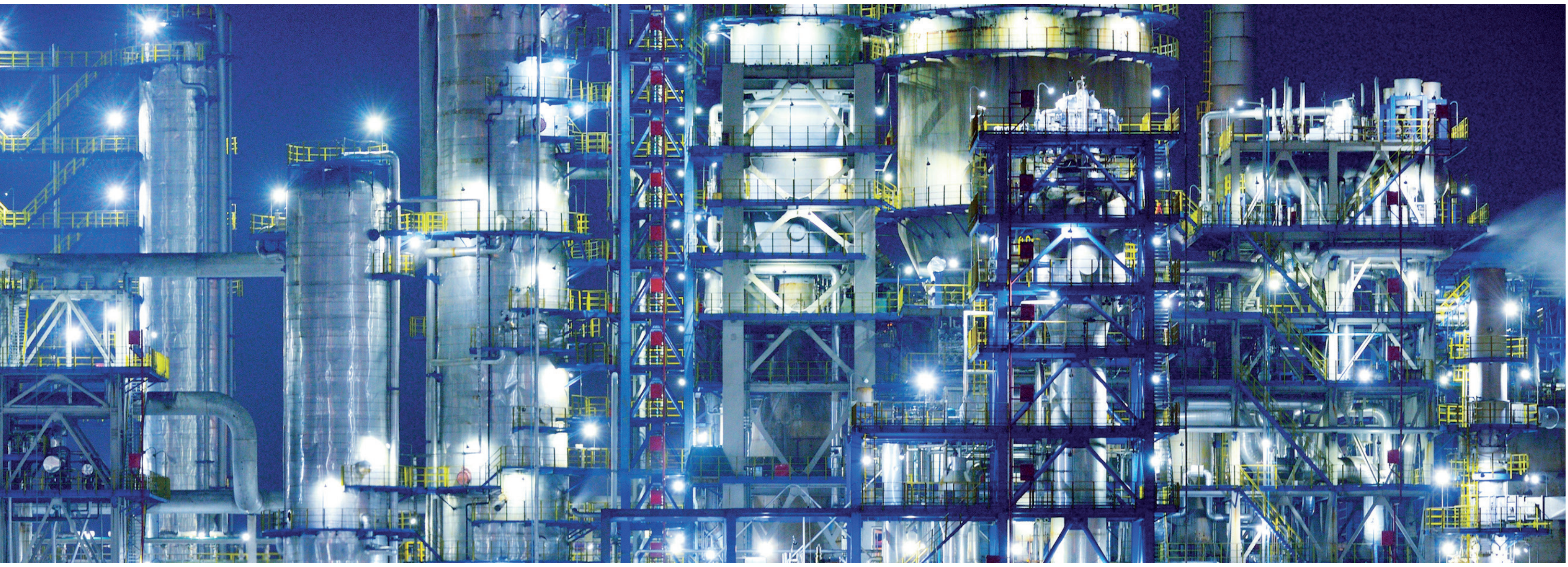

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CHEMICALS

Using advanced analytics to boost productivity and profitability in chemical manufacturing

Digital holds major promise for chemical companies, and employing advanced analytics in manufacturing presents some of the earliest-accessible and largest opportunities.

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We believe that digital will have a significant impact on many areas of the chemical industry,[1] with the gains in manufacturing performance potentially among the largest. Chemical manufacturers have already invested in IT systems and infrastructure that generate enormous volumes of data, but many have failed so far to take advantage of this mountain of potential intelligence. With cheaper computational power and better advanced-analytics tools now at their disposal, specialty- and commodity-chemical companies can put those data to work, gathering information from multiple sources and using machine-learning and visualization platforms to uncover ways to optimize plant operations.

Advanced analytics can substantially raise the level of understanding of what happens in a chemical plant's manufacturing operations; this can help chemical companies solve previously impenetrable problems and reveal those that they never knew existed, such as hidden bottlenecks or unprofitable production lines.

In this article we show how the three main advanced analytics–based tools—predictive maintenance; yield, energy, and throughput analytics; and value-maximization modeling—can help improve the performance of chemical producers' assets and supply chains.

Predictive maintenance analyzes the historical performance data of production units and their machinery to forecast when equipment is likely to fail, to limit the time it is out of service, and to identify the root cause of the problem. Yield, energy, and throughput analytics, referred to as YET, can be used to ensure that the individual production units are as efficient as possible when they are operating, helping to increase their yields and throughput or to reduce the amount of energy they consume. Value-maximization modeling, meanwhile, scrutinizes the thousands of parameters and conditions that have an impact on the total profitability of an integrated supply chain—from raw-materials purchasing through the complex and often interrelated chemical-manufacturing steps to final sales—and then provides intelligence on how best to capitalize on given market conditions.

Together, these advanced-analytics approaches can lead to earnings before interest, taxes, depreciation, and amortization (EBITDA) margin improvements of as much as five to ten percentage points. Beyond the margin improvement, companies that are fast adopters can use these approaches to establish a competitive advantage, even those companies struggling with overcapacity. They can do this by using the tools to constantly improve the way they manage their production systems and reallocate resources in real time, in the most efficient and value-creating way across their manufacturing.

Decreasing downtime through analytics

Chemical manufacturers can increase the operating time of critical assets by using the analysis of big data to find ways to anticipate their failure. Such predictive-maintenance systems gather historical data[2] to generate insights that can't be observed with conventional techniques. By applying advanced analytics, companies can determine the circumstances that tend to cause a machine to break. They can then monitor all relevant parameters so they can intervene before breakage happens, or be ready to replace a component when it does, and thus minimize downtime. Predictive maintenance typically reduces machine downtime by 30 to 50 percent and increases machine life by 20 to 40 percent.

Chemical companies are already starting to see substantial gains in this area. One major surfactants producer consistently ran into problems with recirculation and discharge pumps at its largest plant. When one of the pumps broke, the plant had to stop production for ten hours while a replacement was installed; these pumps are expensive, besides the cost impact of the production loss. Engineers had tested several hypotheses to determine the possible causes of failure; they also tried out alternative materials in the pumps and seals, as well as different process conditions, but none of them solved the problem.

An advanced-analytics approach changed all this. It combined a detailed analysis of data from hundreds of sensors with the plant engineers' expert knowledge, and reexamined the process variables and other data sources; it then enabled the company to develop a methodology to predict when a failure was imminent. The problem occurred with only some of the surfactant recipes, and not with all batches, suggesting the key lay in specific process conditions in the equipment. The team developed a model based on a "random forest" algorithm that took into account the specific parameter settings in production, such as extremes of temperature and temperature progression, together with information on the surfactant product type and recipe.

Under the new approach, when production is launched of the surfactants where the problems occur, each production batch is evaluated based on the algorithm. When it flags that a failure is imminent, the plant operators undertake a 15-minute cleaning of specific parts of the machinery to prevent the failure from occurring. The improvements to performance that resulted from using the advanced-analytics approach have been substantial. Instead of a ten-hour production loss plus costly spare-part replacement, the company is now dealing with just a 15-minute production interruption, and it has cut production losses by 58 percent and maintenance costs by 79 percent.

Doing more with less

In the same way that predictive maintenance can improve the uptime of an individual chemical-production asset, an advanced-analytics approach scrutinizing yield, energy, and throughput (YET) can maximize the asset's effectiveness. Even small percentage improvements in operational efficiency can significantly enhance EBITDA performance. The approach does that by balancing yield, energy use, and throughput—while also taking account of varying raw-materials costs—to maximize the profitability of each process step.

One specialty-chemical company was having output problems at a monomers furnace that makes a key intermediate at its largest site. The furnace's unstable production rate and low overall output meant that it represented a serious bottleneck for a high-margin segment of output. The company decided to undertake an advanced analysis of the data the furnace's sensors had collected over 615 days of production, comprising 600,000 samples, each with 63 tags—almost 40 million data points. This analysis identified critical throughput drivers and made it possible to build a model of the production process. The model quantified the interdependence of key variables, where the company had previously only been able to see qualitative correlations, and this provided a more accurate understanding of the process; a test run of the furnace confirmed the model's findings. The company's experts had long suspected that manipulating some of the levers identified in the model could improve productivity, but they never had the tools or data to confirm it. Based on its new advanced analytics–based understanding of its process, the company used the model to provide detailed, real-time guidance through a specially designed app for the plant's operators. The app showed operators how to adjust a range of process parameters to get the best performance. The result was an output increase of 18 to 30 percent, which represented a net profit-contribution increase of around €5 million a year. The company estimates that applying the same kind of advanced-analytics approach across all the different manufacturing operations at the site could generate a €30 million annual profit gain.

Sometimes the changes suggested by a YET model can be relatively simple. At one gold mine, the use of an advanced-analytics approach based on sensor data revealed some unsuspected fluctuations in oxygen levels during the chemical-leaching process. Fixing the oxygen supply increased yield by 3.7 percent, worth up to $20 million annually. At other times, the analysis will uncover the influence of parameters that will change over time, such as under different seasonal conditions. In those cases, the chemical manufacturer may set up new standard operating procedures to follow in various situations.

Optimizing complex production networks

Whereas predictive maintenance and YET analyses are designed to improve the performance and profitability of individual pieces of equipment, value-maximization modeling can optimize the interaction between those pieces of equipment across processes. This modeling is an advanced analytics–based technique that shows in real time how to maximize the rate of profit generation in complex production systems and supply chains, encompassing every step from purchasing to manufacturing to sales. Unlike the limitations of human planners, this advanced-analytics approach typically factors in as many as 10,000 variables and one million constraints to help producers figure out what to buy, what to make, and how they should make it to yield the most profit in each period.

The diverse nature of chemical companies' activities—frequently including both commodity and specialty manufacturing—suggests they can be prime beneficiaries of the value-maximization modeling approach. The nature of chemical companies' businesses and product lines means they must manage an enormous amount of complexity: volatile costs and prices, multiple plants, and products that can be made in various ways from diverse combinations of materials, involving output of different combinations of coproduct of varying values, as well as managing by-product flows. The economics of specialties production may demand maximizing output of a high-value product, while commodities production may prioritize holding down costs, but the former is typically built on the latter. Put simply, the businesses may have two separate profit and loss accounts, but they are connected to the same pipes.

The following example from one large, diversified chemical producer's plant shows the kinds of gains to be captured. The company was selling a broad range of goods from the site to a global marketplace through a mixture of spot and long-term contracts. Decisions on production and sales were based on a complex and arcane system of transfer prices, arbitrarily set by different regions and departments. Organizational responsibilities were scattered across multiple business units and corporate functions. Underlying all this was the typical chemical-industry challenge of commodity products underpinning specialties production, while the commodity output brought with it lower-value coproducts, multiplying the hurdles to maximizing profitability. Management had a hunch that suboptimal production and distribution decisions were leaving a lot of money on the table.

They were right. A mixed-integer programming model encompassing the 800 variables explored nonlinear cost curves and the 3,000 constraints related to production capacities, transportation, and contracts; the hundreds of steps in production with alternative routes and feedback loops; nonlinear price curves and raw-materials cost structures; and intermediate inventories.

Using the model, the team identified immediate changes that delivered a profit increase of €10 million a year. For example, it started making an intermediate product on an underused line instead of buying it from a third party. At the same time, the team shifted the production of another key intermediate to equipment that gave higher yields, thereby reducing raw-material consumption. It identified medium-term opportunities to expand capacity by increasing the throughput of some assets, and it increased sales revenues by raising capacity for some product categories.

The analytics approach revealed some counterintuitive improvements. The model suggested that eliminating the production of a commodity polymer made using the site's solvent-process plant would increase profitability overall. The company had been selling this lower-grade polymer to China—but generating limited returns in a commoditized market further burdened with high logistical costs. By shifting the intermediate material required to make the polymer to manufacturing another product, the company was able to make more profit. That switch might never have been suggested if the decision had been left to the manager of the polymer business—who previously had the decision rights (see sidebar, "The data-driven manufacturer").

The data-driven manufacturer

We have seen that with these advanced-analytics tools, a new kind of data-driven culture can quickly take root at chemical-manufacturing plants. The new approaches can model different courses of action, enabling chemical companies to make rapid changes in their short-term production planning to get the highest returns, as well as to make better strategic decisions for the long term. These approaches come with several associated advantages, such as enabling teams to have fact-based discussions to compare the impact of different parameters; fostering discussions that draw in broader expertise; and, as the approaches are based on objective data, allowing managers to make better decisions.

At one large chemical-production site, sales and operations planning had traditionally followed a linear pattern, proceeding from demand estimates and working back to supply planning. The company decided to employ a value-maximization-modeling approach, enabling it to model alternative production scenarios within minutes—for example, whether to make less of Product A and more of Product B, which currently sells at a higher margin, or whether to honor a request from a salesperson to deliver special quantities to a strategic customer, or whether it would be worth the risk to delay plant maintenance in order to make more product to capture additional orders.

The result was that the traditional planning meeting was replaced by a session where a broader group worked on multiple business scenarios and evaluated their respective risks and rewards. This opened the way to potentially capturing greater returns as well as helping the company target production to whichever mix would achieve the highest margins on a weekly basis.

Again, the rapidity with which these new approaches can model different courses of action can foster a new openness and flexibility of discussion, including shedding light on profitable counterintuitive actions. On a number of occasions, we have seen that “less is more.” In these instances, lowering overall production volumes and redirecting output, or reducing the number of batch product changeovers, generated higher margins, often to the surprise of senior-management teams.

These changes enabled the chemical company to boost its earnings before interest and taxes by more than 50 percent in some historically low-margin commodity segments, while the specialties side saw no disruption and maintained its high level of profitability (exhibit).

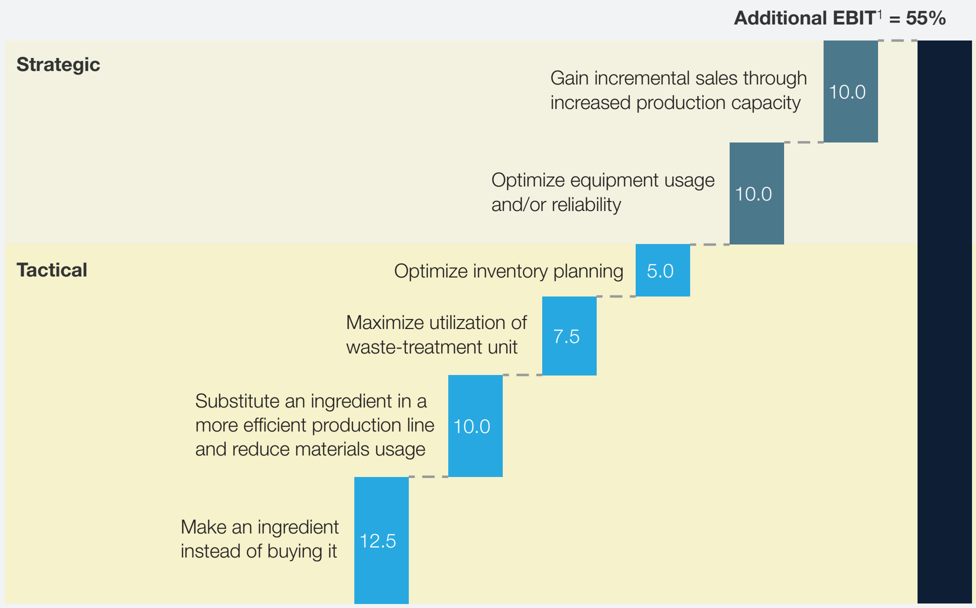
How to get there from here

As with most technology-enabled changes, simply deploying new analytics tools cannot deliver the full performance-improvement potential. Chemical producers must make changes on people, process, and technology fronts to ensure they not only aggregate and analyze their data but also get the most out of the findings. Each company faces its unique challenges, but we find the following steps are indispensable for most chemical companies.

Mastering data management. Advanced analytics requires the retrieval and cleansing of data and structuring it appropriately for the platform being used. This can take significantly more time than

Exhibit

By using value-maximization models, a chemical producer raised earnings at a plant by more than 50 percent.



[1] Earnings before interest and taxes.
Source: McKinsey analysis

many companies realize—as much as half of a data scientist's time—and requires employees with sophisticated IT expertise. They must know how to aggregate data from different types of sensors in different locations and how to store the information in various platforms.

Marrying analytics skills to domain expertise. Ensuring that the development of models is based on a true understanding of the chemical process requires a combination of data scientists, advanced-analytics-platform specialists, and manufacturing experts—as well as people who can serve as liaisons between these various constituencies. Talent of this kind, however, is scarce and sought after across all industries, including the financial sector.

For chemical companies, we believe an effective strategy is to build these capabilities in-house, which has the added advantage of ensuring the data experts understand the chemical processes.

Starting with pilots and scaling up. An analytics transformation starts by identifying processes to serve as pilots—real problems and opportunities that advanced analytics is likely to be able to address and from which it can quickly capture benefits. This can in turn build excitement in the workforce and support for making changes. Some chemical companies find this process is helped by setting up analytics labs within their operational units, bringing together analytics specialists and manufacturing experts. By prioritizing potentially high-value-creating use cases, the advanced-analytics program can often be at least partly self-funding.

Helping employees adapt to using analytics. To capture performance-improvement gains from analytics, chemical companies must also consider the human aspect. Our research shows that employee mind-set is the most important factor in successful analytics-enabled transformations. Chemical companies must invest in training their employees so they can understand how these tools can assist them and how they can lead to a change in their roles that can potentially make their jobs more rewarding. If there is no buy-in, they will reject the tools as a threat rather than an opportunity.

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Introducing advanced analytics to chemical-manufacturing operations is not a one-off exercise. These analytics will need to be repeatedly deployed to achieve the desired outcomes. Thus, chemical companies must approach this as an ongoing transformation that requires changes in mind-sets and ways of working, from top leadership to managers to process engineers to shop-floor operators. Chemical manufacturers that are able to mobilize their organizations to embrace this approach—continually applying and learning from advanced analytics, reactor by reactor, process by process, and plant by plant—will be able to achieve new breakthroughs in productivity and profitability. ■

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[1] See Alexander Klei, Marco Moder, Owen Stockdale, Ulrich Weihe, and Georg Winkler, "Digital in chemicals: From technology to impact," July 2017, McKinsey.com.

[2] This includes data from multiple sources and of different types, including structured and unstructured, machine- and nonmachine-based.

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