WHITE PAPER

Sustainable Collaboration in Oil and Gas Refining: Becoming a Super-Refiner

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IDC OPINION

Refining organizations must use sustainable collaboration in both operations and research to derive maximum value from their crude oil, distillates, residuals and the totality of their assets and supply chain. This means working across the silos of research and operations created by geography and organization, improving information sharing between operations and development, and consolidating all the fragmented, inaccessible, or poorly contextualized data into an environment that enables and promotes access to information from other parts of the organization. Any improvements or efficiencies gained in research and development (R&D) processes will reduce both risk and waste.

A sustainable collaboration environment is one in which information is collected and digitized from individual hard drives, physical libraries, notebooks, isolated servers, and even from the knowledge of engineers and scientists. The data and information are then available to the entire organization in a sustainable and maintainable structure. The system must provide a simple interface for finding and accessing the information. But more importantly, the system's interface must provide easy and straightforward ways to put structured and unstructured information into the system.

Another key factor in operating a sustainable collaboration environment is asset management. Uptime for the refining plant or its key operating assets has an obvious impact on gross refining margin (GRM). Using the collaborative environment and simulations to develop virtual twins of any asset or operation reduces the opportunity lost when assets are offline for either planned or unplanned incidents.

The key to residual optimization is taking full advantage of the R&D capabilities of a refining research organization. Unfortunately, the research operations of some refining organizations are scattered both physically and virtually. Many times, research staff are not collocated. Rather, they work in various parts of the organization with specific responsibilities in areas such as solvent integration and advanced process control. That type of organization leads to silos.

Typically, silos in information parallel silos in organizations. Information usually exists for things such as historical solvent performance, catalyst performance, testing, customer preferences, chemical data sheets, modeling of asset performance, and business modeling. The data and information not only are siloed but also tend to be fragmented, poorly indexed, and not easily accessible.

IDC Energy Insights believes that this is best overcome by the digital transformation of both the operational environment and the research environment that feeds the plant, the goal being to promote a research environment that drives flexibility in refining and being adaptable enough to respond to market changes, both upstream and downstream. Successful refining companies are transforming

themselves into resilient organizations that can rapidly change refining fractions and outputs without significant operational disruption. A few key activities for driving innovation in refining are as follows:

- Adopt the research, development, quality, and manufacturing (RDQM) framework as a high-level guide for developing a collaborative R&D environment.
- Use multivariate simulation and virtual environments to accurately model the impact of changing crude and additive inputs without having to go through lengthy trial and error in the plant.
- Develop virtual twins of the distilling process, including physical assets that provide an accurate testing environment for all operational parameters.
- Build detailed business models of GRM that are science based and can provide realistic scenarios for potential changes in raw materials, market pressures, and operational parameters.
- Capture and organize knowledge of personnel for use in optimization, research, development, and training.

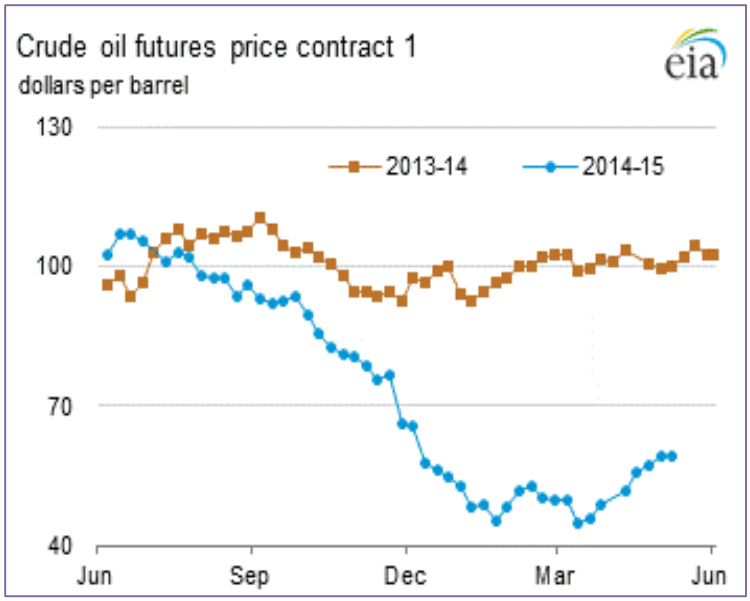
Applying the previously mentioned initiatives to a refining organization, both operationally and in R&D, lays the foundation for becoming a super-refiner.

SITUATION OVERVIEW

As Figure 1 shows, the upstream commodity environment is close to a disaster for the downstream side of oil and gas (O&G) companies. While in most industries, raw material prices would make operational managers dance on their desks, downstream commodity markets are pulling the rug out from under those managers. As oil prices continue to track down through 2016, commodity prices for refined products are tracking just as low with $1.00/gallon gasoline process within sight in the United States. That means GRMs are under immense downward pressures. And that is the real impact on the business unit and refining.

FIGURE 1

Crude Oil Futures Price Contract 1

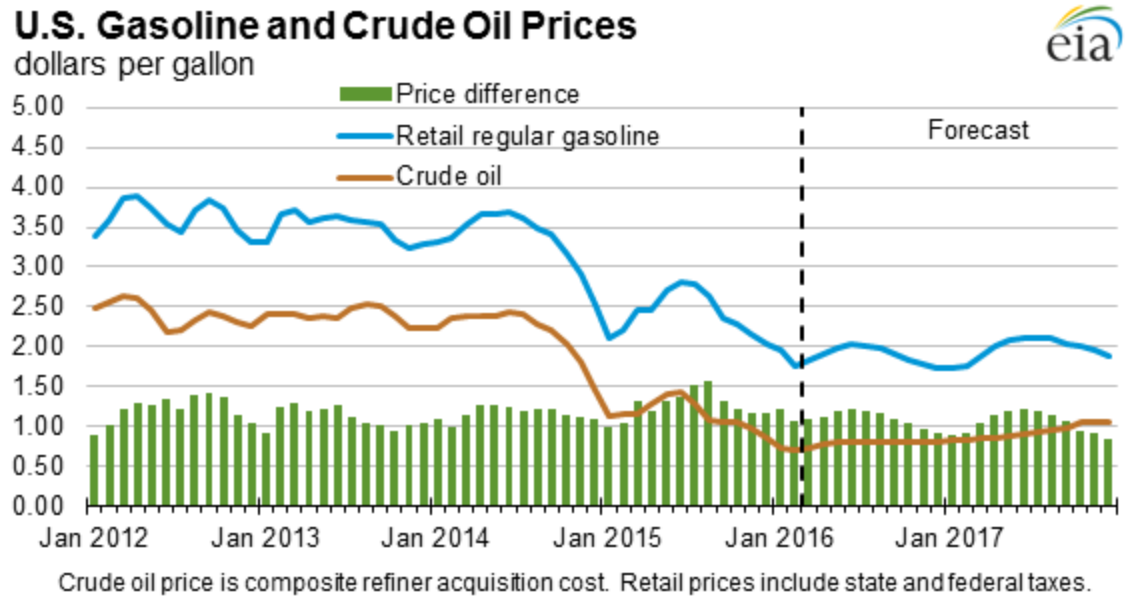


Source: U.S. Energy Information Administration, New York Mercantile Exchange (NYMEX)

Petroleum refining is about one thing: GRM. Figure 2 shows that even though crude prices are down, margins still remain US$1.00 and US$1.50. So pressure remains constant from a refining perspective. But oil and gas companies are more heavily depending on refineries for cash flow. Two of the biggest contributors to GRM, beyond upstream and downstream commodity pricing, are residual optimization and asset utilization. The fixed-cost line of a refining operation is very difficult to move. If a refinery is operating optimally, the variable costs are mostly overshadowed by the upstream and downstream commodity environments. But residual management and asset management are two processes that provide significant opportunity to move the fixed-cost line.

FIGURE 2

Margins for Refining Gasoline



Source: U.S. Energy Information Administration, *Short-Term Energy Outlook,* March 2016

Figure 3 highlights the impact of pricing volatility on investment strategies for oil and gas companies. In downstream activities, it's all about productivity and agility. Unlike other industries, oil and gas does not innovate new products to get out of a slump.

FIGURE 3

Top Downstream Oil and Gas IT Investment Drivers, 2015

n = 103

Source: IDC's *Vertical IT and Communications Survey,* February 2015

Innovation on product development in refining is about developing flexibility in shifting distillation fractions around crude input and capital availability. It's about getting the maximum high-margin fractions out of a barrel of oil and minimizing the low-margin residuals. That means most R&D is focused on advanced process controls in distillation, new cracking, separation, and blending technologies, or new additives and blending. The short of it is maximizing yields and minimizing residuals. And with GRMs under immense pressures, refining organizations are turning to new research methods for help.

Asset management is another area where development activities are crucial. As stated previously, asset management is a key component of GRM. And it's not just about downtime. As equipment and assets wear, they operate at a nonoptimal level. An important role for R&D in asset management is to be able to better predict wear of assets, as well as performance impact or process changes. Nothing frustrates production managers and engineers more than significant variability in maintenance planning and performance. R&D activities contribute greatly to helping engineering define specifications, design processes, and maintain operations.

The R&D function must always be working to maximize asset uptime and maintain quality. Even slight changes in blending or process controls can cause premature asset failure, increase maintenance cycles, and drop high-margin fraction yield. Therefore, all research efforts should be managed to not only provide new opportunity but also balance yield, downtime, and quality.

Current Innovation Opportunity

Any innovation process in the O&G industry must be about the optimization of processes and assets, especially if the plant is viewed as just one large asset. While considerable effort has gone into adjustments based on incoming crude and the downstream market, the adjustments are still very asset centric. The asset-centric approach is both inefficient and reactive. That doesn't mean asset performance isn't incredibly important, but it means one has to have a holistic view of the assets. A transformation in how organizations operate across silos is needed to make optimizing asset management as impactful as it should be. Typical refining organizations lack the science-based forecasting and simulation capabilities to efficiently alter the plant and its assets to quickly ramp up yields from significant changes in incoming crude or the downstream market. These inefficiencies lead to several issues:

- Chewing up refining capacity as the plant makes adjustments based on historical data and trial-and-error ramp-up procedures
- Reduction of processing gains and yields only through the refining and distillation processes
- Variability in corrosion and wear on plant assets leading to the inability to forecast production and asset performance accurately
- Dependency on a limited pool of knowledge workers who have developed their skills over a significant length of time
- Inaccurate distillation ratios leading to lost downstream market opportunities and reduced GRM
- Losing business to more flexible competitive refineries that swing their diesel and gasoline ratios without longtime commitments and capital investment

Refining organizations have always been about the science of distillation and cracking. However, these organizations have traditionally focused on static science based off of historical and empirical data collected and applied over decades of production. The static science approach, while providing consistency and reliability, leads to inflexibility when refining inputs and outputs are swinging wildly. A science-based innovation approach to manage the refining process can provide flexibility to respond to variability in incoming crude and dynamic market opportunities. As anyone with significant experience in refining knows, the more flexible and agile a refining plant is, the more opportunity there is to quickly adjust distillation ratios for maximum GRM and cash margins.

Top Challenges for Improving Operational Innovations

Maximizing uptime is the most important opportunity and challenge for downstream oil and gas refining organizations because downtime has an immediate impact on GRM. Unexpected asset events can even pose safety issues that must be minimized in scope and economic risk. Information and the ability to find and share it will help the understanding, and knowledge building is a critical aspect to better understand and predict events. The impact on innovation is that any process or chemistry change must always be viewed around the impact on production assets. In addition to these challenges, there are a few other pressures on GRM:

- Inefficient operations of plant and equipment, combined with strict and increasing compliance issues, mean that refining facilities are already managing significant risk to yields and GRM.

- Lower commodity prices put pressure on human resources budgets. Almost one-third of O&G companies are cutting staff, but over 30% of them are increasing spend on software and systems instead.
- Compliance and regulatory issues provide significant risk, and regulations continue to tighten.
- Inefficient change management processes for fractional outputs lead to a lack of agility and lost opportunity.
- New processes and technologies can pose risks to safety and operations while being integrated into standard operating procedures (SOPs).
- Raw material price instability makes forecasting GRM very inaccurate at times.

There are a number of approaches to improve plant, engineering, quality, and safety performance through innovation. One of the top approaches is to enable the refining organization's R&D groups to collaborate effectively with each other and with production engineers. PWC's survey of oil and gas executives highlighted the perception of innovation and collaboration in their organizations:

- 83% of senior executives at refining organizations say innovation is one of the most important investment areas.
- 85% have a plan in place for collaboration with customers over the next three years.
- 70% have a collaboration plan with suppliers over the next three years.
- Almost half plan to collaborate with academics and independent scientists over the next three years.[1]

The executives have a good understanding that collaboration is key to innovation. They also have a keen awareness that collaboration has to happen outside of their four walls.

RDQM Innovation Framework

It is useful to think about how innovation is performed within a number of different industries and how that insight can be applied to the refining industry. Innovation can be broken down into four key elements:

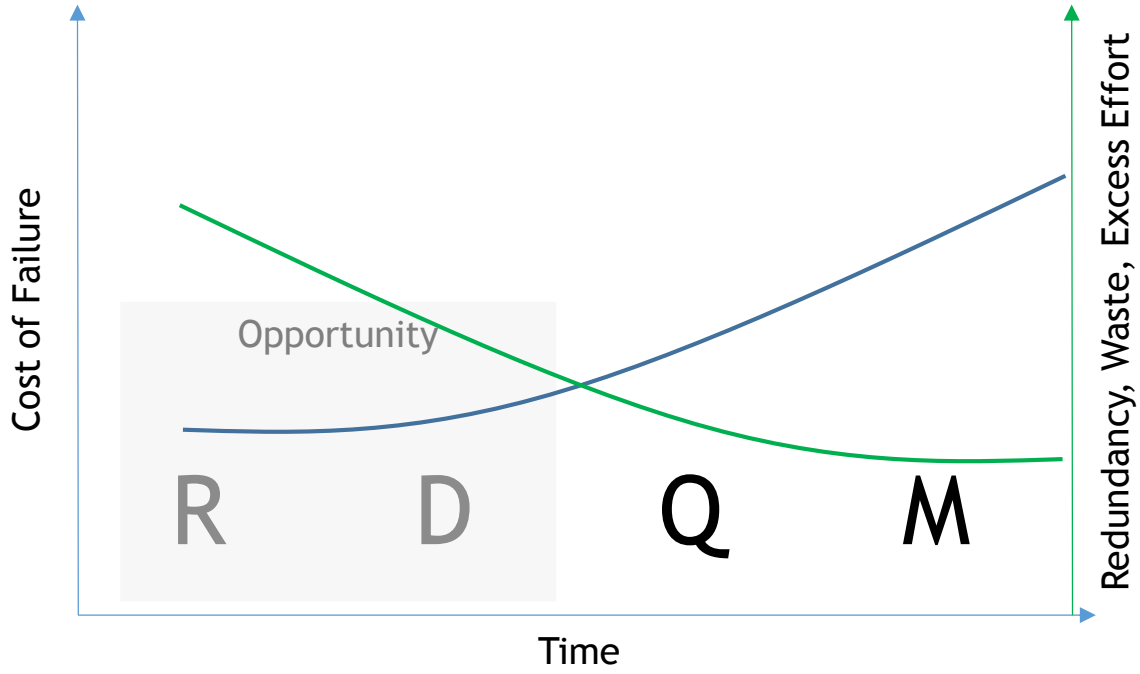
- Research
- Development
- Quality
- Manufacturing

With manufacturing being the equivalent of refining production, the approach to innovation in refining organizations is aligning resource requirements, risk, cost, and opportunity across a spectrum relative to time and cost of failure (see Figure 4). Such a framework provides guidance to innovators relative to the value of improving the innovation process earlier in the cycle, thus reducing the risk and cost of failure later on in the process. In Figure 4, the blue line represents cost of failure, and the green line represents the risk through redundancy, waste, and excess effort (as you can see, you want to fail and learn early). But refining organizations are currently hampered by waste and redundancy in the R&D phases. The goal is to use collaborative efforts in R&D to bring the green line down as close as possible to the blue line. The short of it is to detect and mitigate problems as early in the innovation process as possible.

[1] Source: PwC, *Breakthrough innovation and growth*. Base (oil and gas respondents), 2015

FIGURE 4

RDQM Failure Cost Curve



Note: Curves are not cumulative; waste elimination opportunities are unique to each of the four phases.

Source: IDC, 2016

An old production and manufacturing saying is that you research your way to world-class production. The RDQM framework in its simplest form involves researching and developing your way to quality and production. Refining companies have to drive their R&D groups to always look at the production process and asset capabilities. Too many times, R&D groups develop new blends and processes in isolation from changes that are happening in the refinery. They also tend to have a short memory. Disconnected and isolated R&D groups lead to significant efficiency losses and fail to learn from past project failures and successes. One head of production engineering at a midsize U.S. refiner stated that he has seen the same blend strategy reinvented at least a half-dozen times in his 20 years in the same company.

Traditionally, information storage in refining labs is notebooks, physical libraries, and the brains of engineers and scientists. Some of the better companies might have a content management system in place but still lack the overall business processes and tools to share critical information between RDQM silos. Siloed data and information play a key role in limiting the return on investment in research, not only creating redundant operations but also limiting the ability for research staff to make intellectual connections in adjacent research areas. Innovation keys on creativity and stimulation from multiple areas. Limiting information areas also limits potential stimulation in creative problem solving.

In addition, keep in mind that forward-thinking refining organizations view blending and process research in a portfolio format. With visibility into all research efforts, they are able to fail quickly and

move on to other projects that are more likely to succeed. These organizations are also able to quickly determine the asset impact of development efforts. As these projects are reviewed, asset investment efforts can be better aligned with what is coming out of the labs. Questions about adding cracking capacity versus new blending chemistry can be answered before limited capital is invested in physical assets. And clearly, making these types of decisions earlier in the RDQM framework minimizes redundancy, waste, and mistakes. As you move through the RDQM curves, you are also much more likely to eliminate any inefficiencies that will manifest themselves in production. Once a new process hits production, the risk is millions of dollars versus thousands of dollars in the early stages of RDQM.

It's also important to note that for refining organizations to truly optimize the opportunity and reduce innovation risk, they must be committed to collaboration, enabling access to research data and visibility across the innovation ecosystem at each element in the RDQM framework. Through collaboration, visibility, and data access, knowledge transfer and actionable insight are transferred across stakeholders to enable the efficient movement of the risk curves within the RDQM framework to support more cost-effective, successful, and rapid innovation.

The Virtual Twin as a Collaboration Point

Simulation is an important tool for refining R&D organizations. In refining, simulation can bring in chemical modeling, refining asset performance, yield management, business models, control reactions, and any other modeling capability that can present real-world response to changes. Almost all refining organizations use some form of modeling. Even something as simple as impact on yields from changing solvent suppliers is relatively common.

But the main issue is that simulations and modeling are typically done in isolation. One refining organization that IDC Energy Insights recently talked to stated that it has over 100 separate simulation tools in use. And it knows there are many more. All these modeling and simulation tools are based on assumptions at the input that are not formally connected to other assumptions in other tools. In other words, the assumptions are not aligned across all the models. The result is:

- Significant redundancy in labor to assemble all the inputs
- No exposure of the results to other parts of the organization, which leads to misalignment between organizations and poor assumptions being fed into decisions
- Lack of real-world operational impact validation
- Increased cost of the tools because of overlapping capabilities
- Limited knowledge of the tools' operations outside a small group

Uniting all the simulation tools and modeling in a single virtual twin of the refining operation would provide visibility and connectivity of the various research organizations into a central model. This central model, or virtual twin, would allow research and operations staff to review and adjust inputs and assumptions. It then allows a review of the impact on changes and new developments on other parts of the operations. The result is synchronized, consistent, and higher-impact decision making.

This can all be done without significant downtime to the refining assets. Seeing how decisions impact simulated yields without actually impacting real-world yields is one of the most important simulation goals of any R&D organization in refining. The virtual twin provides an opportunity to connect all the development work that is happening into an overall view of the impact on GRM.

The main thing holding back the development of the virtual twin is the siloed nature of the research organization and its information in refining. IDC Energy Insights predicts that 30% of refiners will be

using some form of virtual twin by 2018. The so-called super-refiner has a platform and an environment that unites the information flow between all silos. However, to build out that virtual twin capability, other refiners must connect all the data that their research organizations possess.

Financial Impact

The financial implications of sustainable and collaborative innovation in the operation of a refinery are multifaceted. The goal is to maximize GRM and cash margins through:

- Better and more predictable asset utilization, behavior, and uptime that maximize yields
- Response to downstream market pressures that optimizes the ability to adjust fractions quickly and minimize disruptions
- Agility for upstream crude availability and pricing by allowing rapid changes to distillation and fractional outputs
- Minimized risk from staffing disruptions through the capture of knowledge and applying that knowledge to minimize downtime and ramp-ups
- Improved project portfolio management to better prioritize high-impact and lower-risk R&D projects
- Improved investment management by better alignment of R&D and production operations

The GRM is bound to all of the previously mentioned points. Any one of those points is driven by a collaborative, sustainable, and aligned R&D organization. One of the hardest things to do in the O&G industry is shift the fixed-cost baseline of the refining organization. Aligning R&D with the RDQM framework and driving collaboration is one of the few initiatives that can shift the fixed-cost line. Also being able to use the virtual twin concept to predict the impact of innovation developments on GRM without having to risk asset operation is another critical step to becoming a super-refiner.

FUTURE OUTLOOK

The use of collaborative science-based innovation technologies, if developed with a focus on the distillation process, fractional optimization, and asset management, can generate good quality and higher GRMs that are better insulated from variability in outside pressures. In fact, IDC's *Vertical IT & Communications Survey* shows that over one-third of oil and gas executives expect to be investing in collaboration tools to drive innovation performance. The focus on innovation can create what IDC has termed the *super-refiner.* The super-refiner is a refining organization that has the following capabilities:

- Rapidly adjusts assets and blending capabilities to respond to upstream pricing
- Quickly adjusts flexible capital assets to maximize GRM based on upstream feeds and downstream commodity pricing
- Capture and share knowledge across silos and from throughout the organization
- Uses portfolio management to prioritize R&D investments and kill low-performing projects early
- Uses virtual twins in a unified simulation environment to minimize asset disruption from changes in process and feeds

The super-refiner will become the model for managing the optimized refining process and the collaborative innovative science behind it.

ESSENTIAL GUIDANCE

- Use the RDQM framework as a collaboration and continuous improvement framework.
- Use the virtual twin concept fed by your R&D organization to free your engineers and scientists to try new processes and chemistries without fear of killing asset utilization.
- Have a clear and concise vision of the technology vendors and their specific role in building the enablers for an RDQM framework.
- Always keep in mind that it's about operational innovation. If you develop it, you have to be able to refine it and predict yields.
- Strive to become a super-refiner through better use of your R&D assets and give them the tools needed to be agile on both sides of the stream.

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