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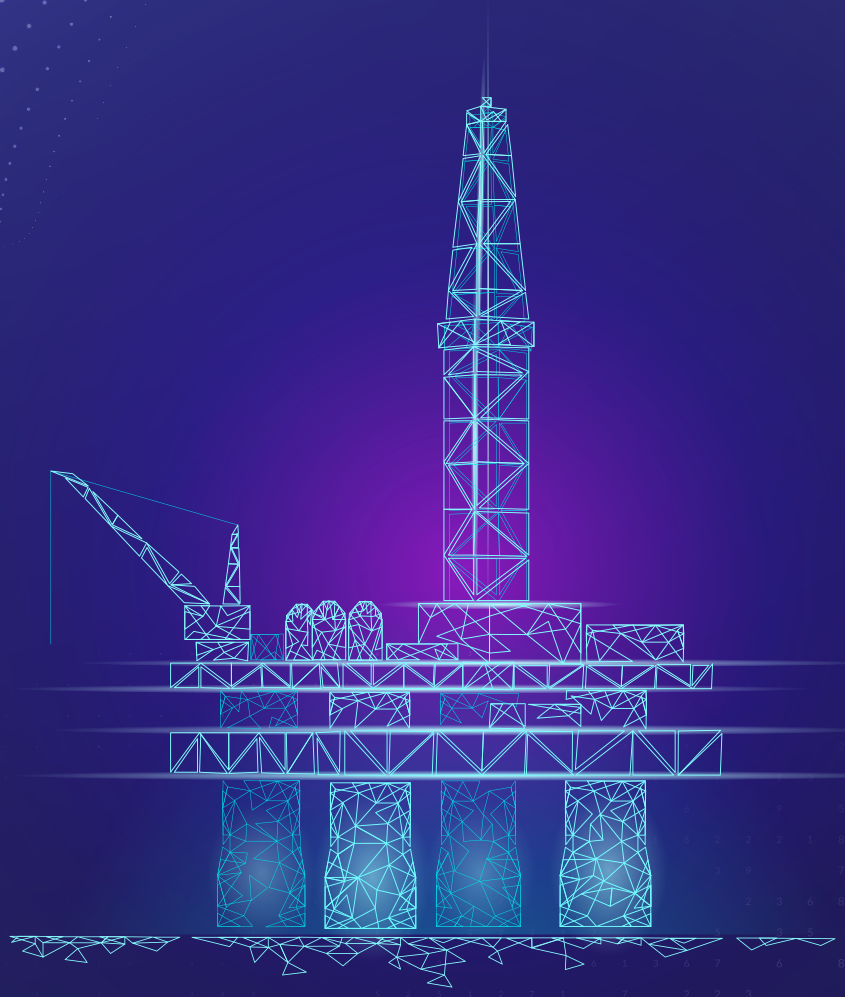

Accelerating Oil and Gas Effectiveness with Quantum Computing

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As we all know, the petroleum industry is one of the most important components of our global economy.

Yet the boom in global demand, combined with the inflexibility of the industry's supply chains has made efficient management more complex and more challenging, increasing costs while impacting delivery and supply levels, which then impacts pricing. Supply chain management in the oil and gas industry is critical since logistics costs alone can be the greatest portion of operating expenses.

Despite the importance of supply chain management and its growing complexity, and even with digitization improvements, the petroleum industry is still focusing on improving the efficiency of managing its supply chains.

The logistics network in the petroleum industry is highly inflexible, which arises from requirements of upstream production development planning, long lead times to build gathering and processing infrastructure, the limitations of modes of transportation, and energy planning and management.

Effective supply chain management can increase the efficiency and competitiveness of a petrochemical plant and its supply as a whole. In a supply chain, a company is linked to its upstream suppliers and downstream distributors as materials, information, and capital flow through the supply chain. This ensures that organizations achieve their best possible return on investment while meeting diverse consumer demands as effectively as possible. It also empowers organizations to better monitor and minimize the risk within their supply chains in the case of natural disasters or other interruptions.

More efficient and cost effective supply chain practices in the energy sector represent important factors for maintaining continuous supplies of commodities, the reduction of lead times, and distribution costs. Despite the great challenges in the oil industry's supply chain, opportunities for improvements and cost savings do exist.

Opening new production sites or distribution centers closer to dispersed customers is one way to reduce the lead time and transportation costs. However, the ROI from acquisition of such facilities, if feasible, depends on assumptions that can be negatively impacted when other links in the chain are not handled efficiently.

These factors are pushing companies to either absorb the increase in costs or pass the costs on to customers who are already facing increasing prices.

Companies have recognized that improved supply chain efficiencies represent a significant opportunity for cost savings, specifically in the logistics area.

Key factors for reducing costs and increasing the company's profits in managing supply chains include:

- Demand management
- Efficient distribution of petroleum products
- Better transportation scheduling
- Improved inventory management
- Increasing the quality and relevance of analysis and information

In the complex oil and gas supply chain, the key to optimizing bottom-line results is to manage all of these elements as a single, optimized process instead of the separate factors/silos of today. This is the promise of supply chain optimization with quantum computing.

We see it all around us today. As supply chain crises have increased, it's become apparent that the planning and rapid replanning of sourcing, production, and logistics are integral to the stability of our energy supply chain.

This requires a shift from optimizing individual areas of the supply chain, where we analyze diverse actions independently – to an integrated single supply chain, optimized and re-optimized quickly as diverse factors rapidly change due to global events.

The focus must be on speed of response, aka being highly adaptable in our dynamically changing market to assure that we can deliver effectively, at reasonable cost and continued profitability. As we all know, the challenge is that our classical computing systems are reaching their limits.

As data volumes increase geometrically, and the interdependence of our supply chains grows increasingly complex, the computations required to optimize our supply chains are outpacing our ability to accurately and efficiently solve them. Especially in the highly compressed timeframes demanded by today's on-demand and dynamic economy.

Quantum computing is a critical technology for oil and gas companies. That's because with steadily increasing global demand, optimization becomes more critical. This increased complexity is overwhelming the ability of classical computers to process the optimization computations businesses need. Quantum computing promises to be the answer to this increasing challenge.

Here's how quantum computing contributes to lower cost and efficient energy delivery while simultaneously maintaining bottom line results for oil and gas companies.

Optimization is Key for Seamless, Efficient Oil & Gas Supply Chains

Quantum computing is an entirely new paradigm for solving complex problems, such as defining the best possible supply chain operations. These complex problems, or computations, require the analysis of extremely large amounts of data to orchestrate the components of intricate supply chain operations. These operations range from planning and sourcing to production and logistics scheduling to assuring deliveries that avoid out-of-gas situations.

Quantum computers are ideally suited for such computations because:

- Predictive and prescriptive analytics are key components of oil and gas optimization computations and simulations. Quantum computing computes and delivers faster, more precise results for these types of computations. They are inherently designed to solve such problems in a way that eliminates the limitations we are experiencing with classical computing today. As a result, they can process more complex information, faster, and deliver a diversity of precise results.

- Optimization algorithms drive these analyses. Different optimization models are applied in various fields, yet the fundamentals remain the same. As the complexity and amount of data involved continues to increase geometrically, and classical computing reaches its limits, we need better ways of solving these problems. Quantum computers deliver a better way.

The graphic below offers an example of how optimization problems scale in a delivery example.

Optimization Problem Scale

As you can see, the volumes of data scale geometrically as the number of locations for delivery increase. This is one reason classical computers are struggling to solve these critical computations. They are simply too large when they expand to all the potential options that need to be evaluated.

Now let's look at this data volume in oil and gas. According to Accenture, oil rigs are equipped with about 30,000 sensors, generating 1.5 terabytes of data each day—the equivalent of downloading 428,571 mp3 songs. Only 1 percent of that data is analyzed, leaving massive potential largely untapped.

Scale is where quantum computing comes into its own. Quantum systems solve problems through an entirely different process than classical computers. They process far larger volumes of data, with more complex algorithms that apply a diversity of constraints and goals across all the facets of the oil and gas supply chain.

Additionally, quantum computing delivers a diversity of solutions that meet all the requirements of the stated optimization. Classical systems only identify the single most optimal solution. The one best answer.

We used to assume that was good enough. Not anymore. Here's why.

Often, an answer that is only different in its results by .0004 may be the better solution given a specific situation. Yet classical systems only deliver one result. Period. Not all of the results that match your requirements. Quantum computers deliver all the possible options, ranked by their match to your requirements. This gives business experts the chance to review multiple options to make the best decision. It also aids in assuring that the answers are indeed the best possible results, increasing accuracy.

In addition to improving supply chain integration and optimization, quantum computing will also accelerate key analysis enabled by artificial intelligence and machine learning.

Oil and Gas Opportunities with Quantum Computing

Quantum computing is key to the complex computations demanded as part of the supply chain of the future.

As evidence, at the recent KPMG Global Energy Conference in Houston, oil and gas executives named quantum computer technology as the next big breakthrough for the oil and gas sector.

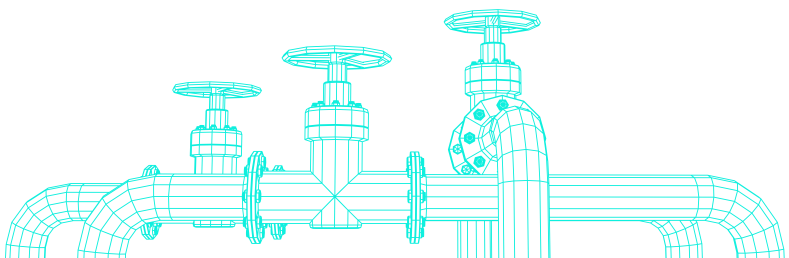
Quantum computing offers the opportunity to impact oil and gas across so many different arenas. These include everything from a driverless supply chain, more efficient and interconnected organizations across up-mid and downstream organizations.

Quantum computers can optimize the sourcing, extraction, processing, logistics, and other services. It can also accelerate and improve the replanning response to risks and interruptions. Quantum optimization can drive the seamless integration of supply chains, replacing today's silos where each activity is being planned independently.

The optimization and level of efficiency in virtually all energy sector operations have a direct impact on the profitability of a program.

Examples of optimization value include:

- Enhance solutions for routing product from extraction through processing, transportation and storage to the consumer in the most cost efficient method



- Provide insights and solutions to the personnel scheduling challenges that exist when operating multi-shift, large scale pumping or refining
- Perform gathering system and water management calculations that can provide best choice solutions that will save valuable budget space
- Identifying the optimum locations for temporary and permanent facilities that will provide optimum profit potential

There are a number of areas that can benefit from quantum optimization and quantum computing overall. Let's examine them across the petroleum supply chain.

Oil and Gas Opportunities with Quantum Computing

Supply chain management in the oil and gas industry includes configuration, coordination and continuous improvement of sequential operations across the upstream, midstream, and downstream.

Upstream Optimization Opportunities

Raw material extraction and/or production comprise the elements of an oil and gas upstream supply chain. Upstream organizations, often referred to as exploration and production, identify oil and natural gas deposits and engage in the extraction of these resources from underground.

Activities in upstream that are targets for optimization with quantum:

- Survey and exploration, including aerial, seismic, geophysical, and geological
- Test or appraisal drilling, including wildcat and test wells.
- Long and near-term development planning.
- Workover scheduling to increase production at the least cost.
- Planning decommission of uneconomic wells.
- Workforce and haul scheduling for efficient and safe exception based pumping

The goal of upstream operations is to deliver the greatest possible return on investment with the safest and smallest operational footprint.

Seismic 3D and 4D reservoir modeling are used to produce quantities of natural resources and to provide surface drilling locations among other vital data sets. Such flow simulations demand large classical computing resources and can take hundreds of hours to complete. When certain variables are updated or changed to the data sets, the entire process has to be repeated.

Quantum offers to accelerate computations and deliver more precise insights.

A sample of the activities that could benefit from the efficiency of quantum are:

Precise point of penetration locations

- Use existing data sets and workflows to determine a more accurate position to enhance recovery

Optimized drilling program to integrate into existing infrastructure

- Factor existing gathering, transmission, and storage networks to create the most accurate positioning of facilities and infrastructure

Gathering system capacity optimization

- Produce what is needed based upon accurate and precise production data, saving crucial budget for where it is needed

Midstream Optimization Opportunities

Midstream firms are involved in the infrastructure that is used in transporting crude oil and petroleum products. The midstream includes facilities and processes that operate between the upstream and downstream organizations.

Midstream infrastructure can include pipelines, trucking fleets, tanker ships, and rail cars. The core of midstream operations is in the storage areas or gathering systems where materials are held until they are moved downstream to refineries for processing.

Quantum computing offers the opportunity for refinery operations to more precisely staff and manage continuous production cycles, including:

Personnel scheduling

- Thousands of employees working multiple shifts require large computations and constant updating

Optimized drilling program to integrate into existing infrastructure

- Demand production updating as well as natural environmental projections require optimization

- Material management accuracy can increase profitability

Gathering system capacity optimization

- Temporary refining facilities demand precise location projections including network optimization for distribution

- The future success of a new refining facility can include thousands of variables that require large compute processing

Downstream Optimization Opportunities

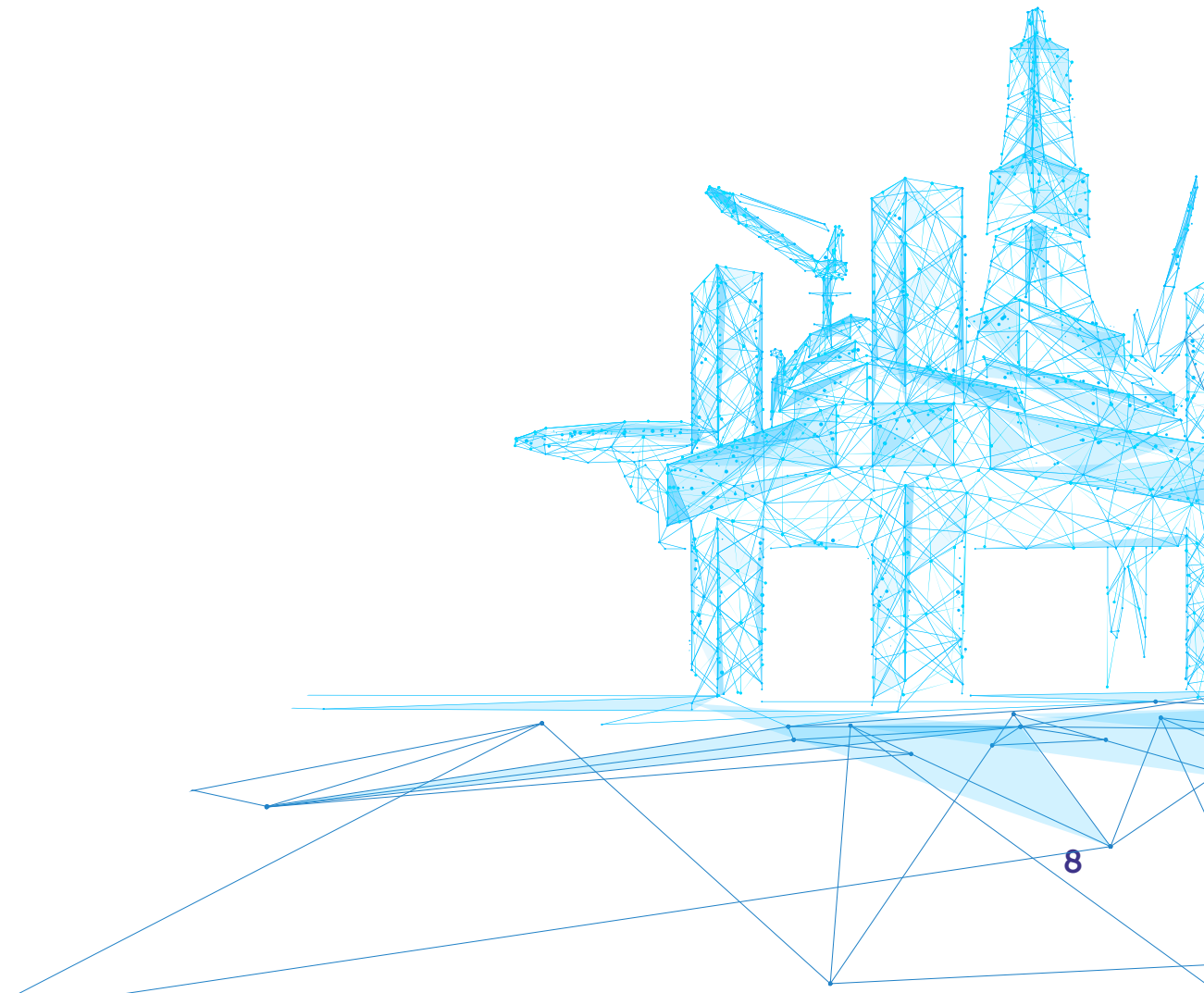
Downstream refers to the processing, delivery, and sales of refined oil and gas products. The firms in this area are focused on margins for business success.

Downstream operations include refineries, sales, and marketing. Refineries process crude oil into useful products including gasoline, fuel oils, and other petroleum products. Sales and marketing services deliver the finished products.

The global network of pipelines, rail, storage and truck logistics is a complex system spanning diverse geographies and operations. Optimizing logistics requires thousands of hours of computations for initial planning, as well as for critical updates to respond to any production or weather changes.

Logistics for the oil and gas industry require vast and complicated computations. Classical systems are running out of the power needed to solve these computations in a timely manner.

Quantum computing offers the same advantages to oil and gas logistics as it does to any other complex delivery system, including minimizing costs of transportation, eliminating out of supply or significant oversupply situations and optimizing the overall profitability of all resources within and being delivered by the logistical chain.



The Bottom Line

It's clear quantum computing offers significant benefits to the oil and gas industry. The question is not if, but when.

What can you do to get started in exploring this powerful yet oh-so-dramatically different paradigm?

Here are six key questions to explore as you develop your strategic path to quantum.

1. What would your best case, end-to-end optimized supply chain deliver as bottom line value to your business?

2. What specific elements in this supply chain - from extraction to delivery - contribute the most value when optimized?

3. Which of these computations/use cases best lend themselves as quantum-possible applications for immediate exploration?

4. Which quantum computing infrastructures (hardware and software) should you explore to deliver a complete evaluation of all potential infrastructures? How do up, mid, and downstream segments differ in their processing demands? Do they require different quantum hardware and software?

5. What are the best benchmarking approaches to evaluate real world potential and not just science experiments? What would your ideal end-to-end supply chain system look like, including enterprise constraints and decision variables?

6. What are your ROI requirements to move from exploration to quantum adoption?

Quantum computing is in the future for oil and gas companies. Those organizations that explore the opportunities today will be prepared to take advantage of quantum value for bottom-line performance as the technology matures.