Inquiry into the Pathways to Innovation

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Embracing X, Y, Z, and ∑ of innovation to harness technologies at the point of inflection

"Great is the human who has not lost his childlike heart."
— Mencius (Meng-Tse)

Inventions such as the steam engine and internal combustion helped humans overcome their physical limitations, thereby revolutionizing the meanings of space, mass, and time. Moreover, the scientific and technological developments of the past 25 years have harnessed cross-discipline interactions, further unleashing the power of the mind and of the human spirit. These intangible and unbounded influences, when nurtured with a strategic perspective, can disrupt the status quo and induce substantial innovation. To think beyond conventional boundaries, business leaders must be willing to alter their old mindsets and embrace change.

This article explores how greater discipline in the management of technology can be instilled in oil and gas companies to nurture resilience and agility of thinking in bringing together multiple streams of sciences and technologies. This combination can lead to the creation of "innovation-led" growth pathways to capture both planned and unforeseen outcomes that are profitable, perpetual, and sustainable.

In the context of emerging technologies, the paper addresses three fundamental questions of strategic importance in the energy industry:

1. To what extent will emerging technologies influence the future energy value chain?
2. What essential traits must leaders of energy companies embrace to enhance their innovative capabilities?
3. How can leaders of energy companies make technology and innovation drive strategic choices?

Emerging Technologies and the Energy value Chain in Transition

"The way to get good ideas is to get lots of ideas and throw the bad ones away."
— Linus Pauling

Technology has always played a critical role in the development of the energy value chain, from conventional fossil fuels to renewables, and from upstream to downstream. Current investment patterns and company statements suggest that while much of near- to mid-term research will focus on incremental technological improvements to reduce costs, increase productivity, and control risks, the oil and gas industry is rapidly expanding its innovation ecosystem to embrace newer and wider varieties of technologies. In this context, figure 1 (below) provides a snapshot of where some international oil companies (IOCs) are focusing their research and development (R&D) efforts. These initiatives allow companies to unlock new plays and energy forms (e.g. Arctic, heavy oil, oil sands, renewables, etc.), improve operating safety in harsher territories, deal with increasingly stringent environmental considerations (e.g. water and waste management, carbon-capture, and storage), and enable smarter ways to manage diverse and complex assets (integrated workflow).

FIGURE 1: EXAMPLES OF TECHNOLOGY INITIATIVES ACROSS THE ENERGY VALUE CHAIN (OUTSIDE-IN PERSPECTIVE)

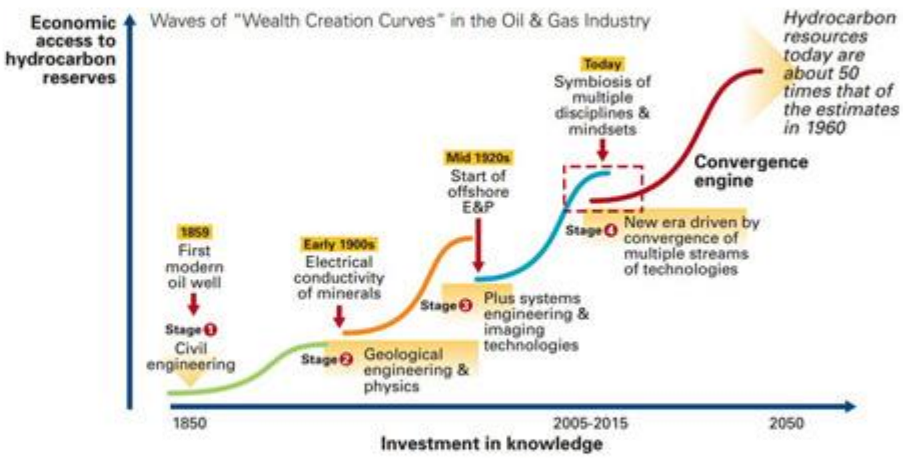
	Exploration	Production / Process	Renewables / Cleantech	Downstream
ExxonMobil	▪ 3D/4D seismic modeling ▪ Advanced image processing ▪ Remote reservoir resistivity mapping	▪ Multi-zone stimulation technology ▪ Advanced EOR technologies ▪ Real-time drilling optimization	▪ CCS (e.g. cryogenic freeze zone CO_2 removal from natural gas) ▪ Hydrogen production ▪ Energy efficiency (cogeneration)	▪ Heat exchanged anti-vibration technology ▪ Methanol-to-gasoline ▪ Hydrogen recovery ▪ Gas-to-liquids
Shell	▪ Geochemical prospecting technologies ▪ Ocean-bottom seismic nodes for deepwater/ pre-salt applications	▪ Reservoir surveillance for EOR ▪ Advanced reservoir rock modeling ▪ Abrasive jet drilling technologies ▪ Solid expandable technology ▪ Micro LNG technology	▪ CCS (e.g. advanced zone CO_2 removal from oil sands) ▪ Marine energy/ wave power ▪ Enzyme-based biofuels	▪ Advanced synthetic base oils to reduce engine friction ▪ Syngas to liquids, to chemicals, to power
Chevron	▪ Surface-based micro-seismic ▪ 3D/4D acoustic technology for high-res subsea imaging	▪ Flexible composite pipe for DW applications ▪ Surface-mounted artificial lift systems ▪ Advanced ceramic proppant ▪ Fiber-optic sensing technology	▪ Solar thermal ▪ Organic photovoltaic technology ▪ Micro wind turbines	▪ New materials (nanotechnologies, specialty chemicals)
bp	▪ Land seismic surveying ▪ Advanced image processing and modeling algorithms	▪ Smart fields (advanced comm equip) ▪ Miscible gas EOR ▪ Advanced water-flood technology	▪ Solar PV ▪ Onshore wind ▪ Cellulosic biofuels ▪ Hydrogen power couple with CCS	▪ Complex fuel and lubricant technology ▪ Advanced refinery technologies (e.g. "instant assays")

As scientific disciplines become more interconnected, and advances in systems engineering open up new possibilities, it is important for energy companies to transform their mindsets toward non-linear ways of thinking.

Some emerging technologies are generating new game-changing possibilities. In the upstream segment, for example, research is increasingly being focused on reducing costs and risks through the application of technologies not inherent to the energy sector. These include laser technology for drilling, microbial and molecular technologies for enhanced oil recovery, and reverse osmosis technology for water management. Increasingly advanced sensor and photonics technologies, sophisticated pattern-recognition techniques, along with high-resolution digital-imaging technologies (sourced from research in medical imaging), are helping locate new hydrocarbon reserves. Similarly, nanotechnology is beginning to influence the industry in a number of ways — from the application of functionalized nano particles for EOR and nano materials for surface modification of subsurface structures in reducing corrosion,[1] to self-healing nano surfaces for speedy completions.

One thing is certain — by fusing multiple technology streams, the frequency of game-changing innovations will only increase; and companies should be ready to respond appropriately. Figure 2 (below) shows the evolution of the industry through various stages of innovation and the impact these phases had on reserves additions or wealth creation.

FIGURE 2: THE INDUSTRY IS IN AN EARLY PERIOD OF STAGE 4 EVOLUTION



Essential Traits to Enhance Innovative Capabilities

"That so few now dare to be eccentric marks the chief danger of our time."
— John Stuart Mill

Leaders must find ways to develop and apply new technologies with a higher purpose. This includes tapping into the Earth's resources in a more responsible and sustainable fashion, while making related groundbreaking processes more accessible worldwide. Companies must continue to identify technical programs that will have the greatest impact on profits and competitiveness. But they must also ensure that they are in a position to adapt quickly to as well as benefit from game-changing technological developments.

Innovation is the product of two notions:

1. The perspective from or conscience with which leadership anticipates possibilities that are outside the normal line of sight.
2. The courage and creativity with which leadership breaks with conventional methods to realize new but unproven possibilities. Accordingly, corporate leadership needs to define, develop, and deploy a set of inventive mechanisms that will help organizations unlock creativity and innovation.

Studies have repeatedly confirmed that an organization's innovative potential can only approach its maximum when senior leaders commit to the creation of a self-reinforcing open and risk-taking culture.

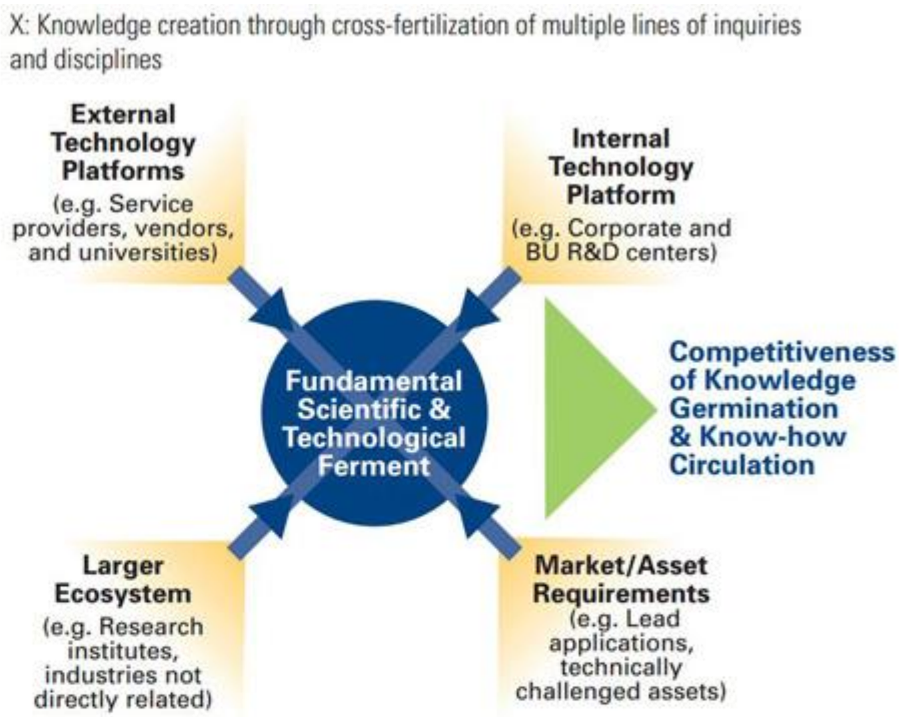
A truly innovative culture is a function of four components, which, for illustrative purposes, will be referred to as X, Y, Z, and Σ in this article. Together, these elements shape an organization's culture, its innovation discipline, and the dynamics of technology management at multiple levels of the decision-making hierarchy.

X: Cross-fertilization of knowledge and lines of inquiries

X represents formal and informal organizational mechanisms that enable ideas to germinate within a collaborative environment comprised of different business units and assets. X mechanisms should also facilitate collaboration with external innovation centers, such as technology vendors, partners, and academia/national labs.

Figure 3 (below) illustrates how the discipline of X enables organizations to cross-fertilize different streams of knowledge from different technology platforms — both on the supply and demand sides of the innovation equation.

FIGURE 3: KNOWLEDGE MULTIPLIER THROUGH CROSS FLOWS OF INQUIRY & SEARCH PROCESSES



While there are no standard off-the-shelf X solutions, below are a few fundamental prerequisites that boards and C-level executives should work on to realize the upsides of truly collaborative environments:

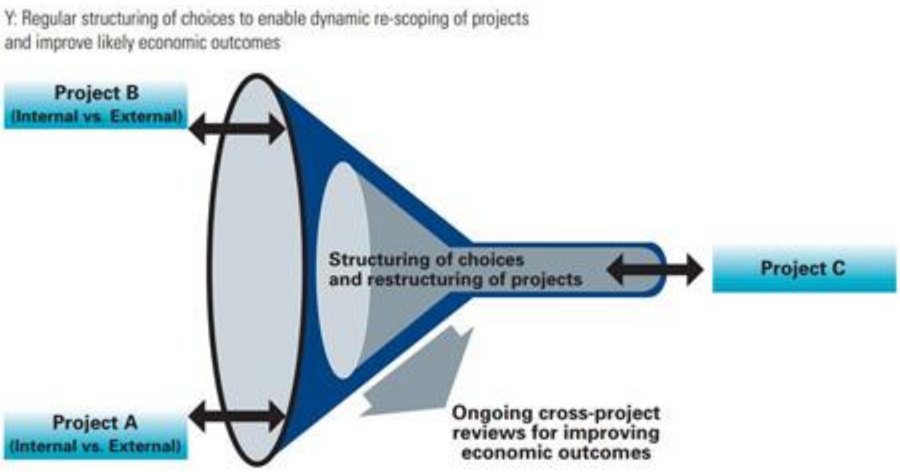
1. Studies indicate that the leadership qualities of scientists and technologists tend to bloom within a relatively flat structure with clearly defined roles and accountability and incentives to cooperate across functional boundaries. Accordingly, technology organizations must, as much as possible, move toward a network model so that the pathways of self-expression are continually uncovered.
2. It is equally important to have cross-functional management and advisory teams — whether at the portfolio or project level — that are accountable and responsible for the outcomes of innovation. This can mitigate competition between enterprise-wide and asset-specific priorities, and remove constraints that limit and/or suffocate the free flow of ideas.
3. At the project level, each team member must have a clear role not limited to his or her function, but that also encompasses the notion of cooperation within and across projects and internal or external scientific communities.

How X mode becomes operational in an organization is specific to the culture of the organization. Collaborative habits take time to form. The spirit of knowledge sharing only becomes natural when significant efforts are put in place to help smart people suppress their egos. Processes need to be developed, practiced, and fine-tuned creatively and objectively over extended periods and across all levels — until they become self-energizing and self-correcting forces.

Y: Dynamics management of technology projects and portfolios

Y represents a discipline that provides an organization with the ability to track and structure projects in a way that allows it to funnel a myriad of ideas (or conceptual breakthroughs resulting from X mode) into new innovation platforms. Y processes (see figure 4, below) help management to capture strategic and economic benefits without losing sight of the uncertainties associated with technological initiatives. As more and more information is generated during the life of a project, some tasks or experiments will need to be broken down into two or more platforms. In other cases, two or more projects/experiments might need to be combined to increase the likelihood of innovation efficiency and to enhance the economic value of the desired outcome.

FIGURE 4: DYNAMIC MANAGEMENT OF TECHNOLOGY PLATFORMS



The efficiency of innovation is seriously compromised when technology projects are run in isolation with limited or no reviews. Senior management operating in Y mode are required to play a significantly more involved role in managing portfolios — continually re-scoping specific projects in response to the likely outcomes at each review point of the stage gate process. As an organization goes through several iterations of instilling Y mode processes, its portfolio of technology projects becomes, on the one hand, more focused on long- and short-term corporate objectives; and, on the other, it becomes more flexible, more dynamic, and more capable of triggering game-changing moves.

In short, Y mode arms leadership to be more dynamic and involved in progress reviews of technology initiatives. This ensures that they are fully engaged in sorting through complex choices that technology projects throw up, as they go through different stage gates.

Z: Resiliency — capturing upside without sacrificing objectives

Z represents an organization’s capacity to adapt to and take advantage of unexpected outcomes of the process of scientific discovery, which often lie outside the construct of the original objective (see figure 5, below). For example, if an anti-corrosive coating that is being developed for deep-water pipes exhibits properties suited for the chassis of, say, a submarine, then organizational mechanisms should automatically capture that additional value while pursuing the original purpose.

FIGURE 5: MANAGING DISCIPLINE OF PROJECTS: INTEGRITY AND SERENDIPITY

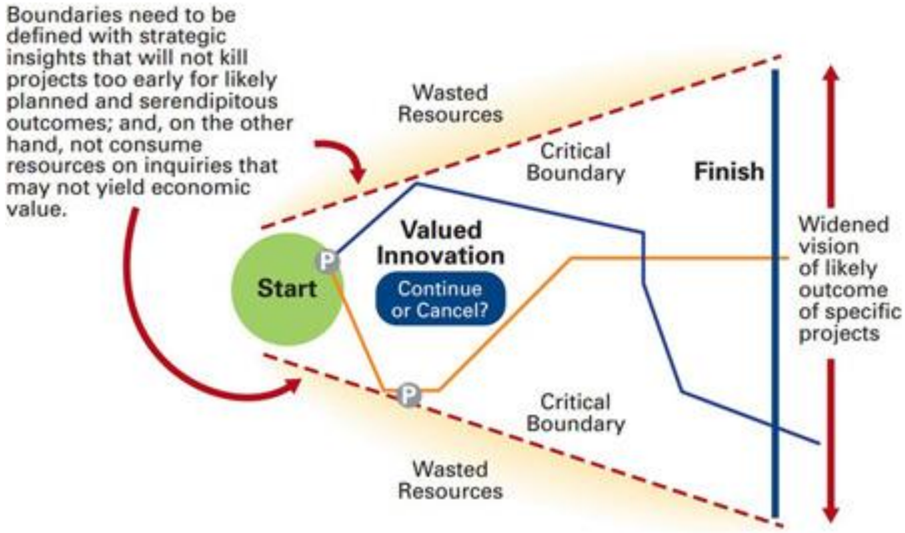


Figure 7 (below) illustrates the path a typical project might follow and how adopting an approach with wide boundaries opens up new possibilities outside the original scope of the project. This keeps the innovation process alive and often increases the chances of achieving an unintended and fortuitous outcome.

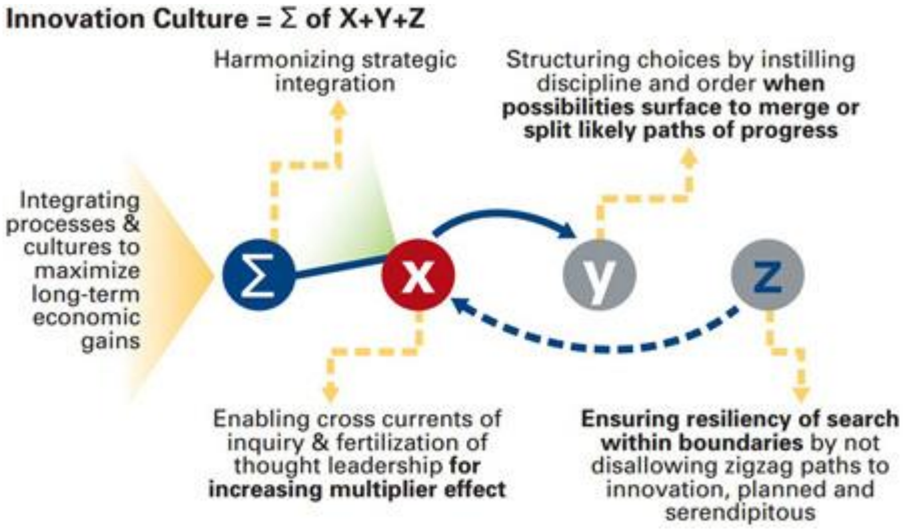
FIGURE 7: APPLICATION OF X, Y, Z, AND Σ MODEL IN GENENTECH, INTEL, AND 3M

	X Cross-pollination efficacy	Y Platform formation: fusion via knowledge management	Z Adaptability: "zigzag" path of scientific discovery	Σ Overall culture of innovation
Genentech	■ Colleagues move between R&D departments ■ Clear focus on product and purpose	■ Senior leadership role models foster casual, open communication, collaboration to restructure projects ■ Quick screening out of projects that do not clear internal hurdles	■ Employees are encouraged to take time to pursue own research interests ■ Learning environment with no fear of retribution	■ Achieved highest biopharma R&D productivity level from 2002–2008 — 4 successful new molecular entities (NMEs) — same as Pfizer, but with ~10% of the R&D spend ■ Leadership of the company manages the ∑ role
intel	■ Series of small "lablets" established near universities ■ VC unit holds minority stakes in a number of emerging technology companies	■ Research topics focused on product market needs and longer-range exploratory research platforms that are continually synergized or delinked	■ Longer-term projects given wider latitude, allowing project emphasis to evolve as needed	■ Technology Strategic Long-Range Planning Committee (TSLRP) project proposals open to all employees
3M	■ R&D done in operating units are encouraged to receive inputs from many sources including customers, sales, marketing and other R&D divisions	■ Hosts regular technology forums for scientists across projects to share ideas across the company and potentially develop the seeds of breakthroughs	■ Uses non-traditional metrics to assess potential value and performance of long-term technology projects	■ One of the world's most innovative companies, with a rich pipeline of breakthrough ideas that create new markets because of the quality orchestration of technology initiatives

∑: Leadership capacity that enables a symphony of X, Y, and Z

Σ refers to leadership's capacity to synchronize X (cross-fertilization of knowledge flows), Y (structuring of choices), and Z (accommodating unforeseen processes) across organizational units at all levels of decision-making (see figure 6, below).

FIGURE 6: LEADERSHIP CAPACITY TO ORCHESTRATE X, Y, AND Z



At a philosophical level, mode enables a holistic, cross-functional approach to innovation management, which fosters flexibility, openness to unorthodox ideas, acceptance of failure, and objective decision-making.

Figure 7 (above) illustrates how Genentech, Intel, and 3M practice X, Y, Z, and Σ.

Making Technology and Innovation Drive Strategic Choices

"Never before in history has innovation offered promise of so much to so many in so short a time."
— Bill Gates

In order for the X, Y, Z, and modes of an innovation system to be effective, it is essential to examine the foundation on which the central technology role and related innovation process are positioned. And, as the innovation capacity of an energy company grows, leaders must address several important issues with a fresh mindset in order to realize the full benefits of X, Y, Z, and Σ mode.

The role of the technology function within companies should be repositioned. Technologies and knowledge applications are usually scattered across assets that are physically distant from each other and are often not exclusively controlled by executives with a holistic understanding of a company's technological competitiveness. X, Y, Z, and Σ modes only become genuinely visible when an innovation-led environment is embraced from the CEO level down to managers and eventually to individual members of project teams.

Companies should reassess their levels of R&D commitment. Technology selection can be driven internally (by a company's asset portfolio needs) and/or externally (by how new technologies are evolving and, as a result, how the acquisition of new assets should be structured). With the external technology environment evolving rapidly, most companies will need to re-examine the size of their R&D commitments to ensure that they are competitive in proactively evaluating, accessing, and developing a full range of technologies — across various disciplines of inquiry and streams of thinking.

Working with new players toward new partnership models should be encouraged. Relationships between IOCs and hydrocarbons-rich nations have traditionally been defined by production-sharing contracts, which involve technology inputs from IOCs in return for resource access. As technology intensity increases and E&P capex rises, partnerships and strategic alliances between IOCs, NOCs, oil field service companies, governments, regulators, and academic institutions could evolve in numerous ways.

New partnership models will partly be defined by how organizations respond to shifts in technology. But they will also be influenced by the interaction of several other underlying trends:

1. New technologies will provide IOCs/majors with access to more diverse assets, making them less dependent on NOCs or specific regions of the world.
2. As NOCs commit more resources to R&D, their dependence on IOCs/majors for technology will gradually decline.
3. Service companies, which have historically been the providers of new technologies, will become more important to all operators as they improve their innovation processes.

However, to reduce technology-related risks, IOCs, NOCs, and engineering service companies should remodel the production-sharing contract as the innovation-sharing contract, perhaps with the support of research institutes funded by sovereign funds. Multi-tier partnerships have improved technical problem-solving and the flexibility of the innovation process in the aerospace, automotive, and electronics industries. Similarly, the oil and gas sector could embrace new models of risk-sharing while creating upside in the innovation process.

Conclusion

Oil and gas companies have a historic opportunity to reinvent their approaches to gaining access to a wide range of resources, while uncovering new technologies that might make non-conventional and renewable sources of energy economically and ecologically sustainable.

Success will be determined by the extent to which energy companies develop innovative ideas and apply technology-management processes to encourage:

1. Cross flows of knowledge to germinate new ideas (X);
2. The careful structuring and regular restructuring of projects (Y) to ensure dynamism within R&D portfolios;
3. Zigzag development (Z) in capitalizing both on planned and unforeseen outcomes, without losing sight of the original objective;
4. The harmonization Σ of X, Y, and Z to encourage creativity and capture economic benefits at all levels. Ultimately, board members and company executives will have to carefully reconsider the way technology is used.

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1. A broad spectrum of energy companies, from Saudi Aramco to start-ups like GEODynamics, have deployed products with nanostructure materials. These include controlled electrolytic metallic (CEM) technologies, an intervention-less nanostructured platform, which can be used to manufacture dissolving plugs, actuating hydraulic fracturing sleeves.