# Tunnels and Barriers in Energy Technology Innovation. Or,

## *Why is the oil industry so conservative when dramatic technological change is needed?*

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**Summary**

Innovation is crucial for development of novel, carbon efficient technology for *in situ* heavy oil recovery, however, current company and professional discipline structures inhibit the necessary creative collaboration of multidisciplinary teams. As most major oil companies have shut down R&D departments and society calls for reduced emissions, small industry directed technology companies or University applied research groups working with industry may be a route to shift the energy industry into the next paradigm. Our experience reveals that small (5-10 person), multidisciplinary groups of experts interacting in a flexible, trusting and dynamic culture allows for generation and testing of a multitude of creative ideas for refinement into industry deployable novel technologies.

**Introduction**

*Climate change* impacted by emissions of carbon dioxide ($CO_2$) from fossil fuel combustion and *energy security* have been identified as two of the greatest global challenges we are facing in this century. Development and implementation of practical and sustainable solutions to these issues may require a paradigm shift in the energy industry facilitated by innovative technology. Although traditionally the energy industry is driven by minimizing production and downstream costs and maximizing resource recovery, currently no legislative structures penalize operators or customers for inefficient carbon management and thus only token efforts are made to address this issue throughout the producer-customer energy use chain.

In an attempt to align priorities for climate change and energy security, the provincial and federal governments of Canada have joined with many nations around the world to put in place policies and programs to reduce the carbon footprint of fossil energy systems. Three of the most important routes to achieve improved economy and efficiency and reduced carbon footprint are:

1. **Carbon-Efficient Recovery and Processing (CERP)**, which entails changing petroleum extraction and processing technologies to improve their efficiency and profitability and reduce $CO_2$ emission intensity.
2. **Carbon Capture (CC)**, which typically involves the capture of $CO_2$ in the flue gas of point source fossil energy processing systems (e.g. coal fired power plants or upgraders), and pipelining it to geological storage sites. With *in situ* processing, carbon dioxide in principle need never leave the reservoir and collateral carbon capture(CCC) of carbon dioxide may thus be effected.
3. **Carbon Storage (CS)**, which employs storage of carbon dioxide or other carbon vectors in surface storage facilities, subsurface aquifers or oil reservoirs where $CO_2$ can also enhance oil recovery (EOR).

While carbon capture and storage are more recent themes of major interest, more efficient processing has been an industry objective for many decades. We might therefore expect to see an explosion of innovation and new solutions tried in the field but it is clear that this is not the case.

All three technology areas (CERP, CC, CS) are impacted by subsurface geological heterogeneity and its impact on efficient engineering of energy recovery from and carbon dioxide disposal into the subsurface. In terms of in situ recovery of oil sands, few new processes are being field tested currently and of those that are, it is often smaller companies who are taking the risks (e.g. Petrobank and Toe-to-Heel Air Injection, THAI; Greaves and Turta, 2000). While bitumen thermal recovery using Steam Assisted Gravity Drainage (SAGD) and Cyclic Steam Stimulation (CSS) processes has matured, examination of published ERCB applications suggests often a narrow range of well configurations are considered for optimization of production strategies( though creative operating strategies do exist). This is especially the case for gravity drainage recovery processes, controlled most strongly by reservoir and fluid heterogeneities, which are often ignored or are secondary factors in placing wells and designing operating strategy. Few companies have examined alternative well configurations beyond traditional SAGD and CSS operations (good counter examples are Shell- Peace River- ERCB reports, Encana-Gupta and Gittins, 2007) even though the resource is very heterogeneous with thin pay, shale barriers, top/bottom water and variations in viscosity.

While only a very few major and supermajor oil companies still have research laboratories and permanent research staff, there are abundant potentially inventive scientific and engineering staff in oil companies. *So what prevents a plethora of inventions and creativity to these issues thus leaving all our eggs largely in the CSS or SAGD baskets?* The paper addresses two points: (1) *why is there this mismatch of need for innovation and an apparent lack of it?* and (2) *what structural changes are needed to quickly develop and deploy more effective recovery strategies in our current carbon sensitive and energy security climate?*

## Theory and/or Method

We discuss why the unconventional oil industry appears less innovative than one might think given the range of talent available, the size of the problem and capital investment potentially available to develop new processes. The analysis is from the perspective and experience of an academic research group and its associated technology spinoff companies working directly with the unconventional oil industry. Our team has experienced investment in our expertise and technologies suggesting that university spinoffs and small, industry focused technology companies are viable models for innovative technology development.

## Discussion and Examples

*Why has a talent laden industry with abundant capital chosen to base much of its future development on very consistent deployment of SAGD?* SAGD (Butler, 1991) is an elegant technology ideally suited for thick, homogeneous, shale-free unlithified reservoirs saturated with uniform petroleum fluids, but is less appropriate for geologically heterogeneous, shale-rich reservoirs with large fluid viscosity variations where steam chamber development is variably attenuated. Despite two decades of development and abundant evidence of great complexity of both reservoir permeability and fluid properties in such reservoirs (Larter et al., 2008 and refs therein), published ERCB in situ operator applications indicate most models of development assume simplified geological models and uniform fluid properties with very standard well placements to maximize total recovery. The observed variable and often poor production response of the pilot reservoirs to the uniform deployment of SAGD may reflect this huge variability in reservoir and fluid properties with a decreasing number of “ideal” or even suitable reservoirs. *Why then is there such uniformity of process deployment and so few alternative recovery processes being tested in the field?*

Our belief is innovation derives from a metastable environment where a dynamic admixture of several types of inventive individuals operate together in a sea of creativity where diverse ideas from many disciplines and perspectives must be integrated and tested together. Key types of people include (1) boffin[1] inventors, who generate large numbers of ideas most of which will be impractical, (2) multidisciplinary synthesizers or technology spotters who can connect apparently disparate ideas from widely diverse sources into technology nuggets and (3) technology facilitators (idea rationalizers or idea engineers and technicians) who can distill tangible, testable concepts and bring a technology to market in the prevailing economic climate without inhibiting the sometimes chaotic idea generation process. Many avenues must be explored and large numbers of free ranging ideas generated to take the initial invention through the proof of concept, refinement and finally technology transfer to industry. All inventor types must coexist together!

For optimal creativity, the innovation process is neither too organic nor too organized with trust, equal say, and confidence among participants being essential. A key facet of our process is that the facilitators of the team ensure that ideas from even mild mannered or junior participants are heard. Just as with art and culture, freedom of expression is essential in the invention process. Company structures or traditions that formalize process or compartmentalize key players will stifle creativity and inventions. We have found many activities including game playing, Myers-Briggs style personality exercises and plain old beer and green tea drinking sessions all help to free up ideas for the technology spotters to pounce on, and the rationalizers to develop. This process is very difficult to organize on a large scale so generally has to operate within self managed teams of around 5 to 10 inventive folk, which provide sufficient multidisciplinary expertise but are not too large and thus ensure effective communication. This perhaps is why disproportionately, smaller organizations are more inventive than larger better resourced ones. Thus, the key players of an innovative team must come from a range of disciplines and have a wide range of personalities. Innovation and invention should be the objective, not an accidental byproduct of other processes.

Innovation is by its nature multidisciplinary. Indeed one might argue that disciplines themselves remain one of the main cultural obstacles to invention if they attain guild-like status and significance for their members. Successful disciplines will evolve and even partly disappear as has happened to chemistry for example, which has become a pervasive embedded backbone of biology, materials, medicine, etc. For the unconventional energy industry to fully develop its creativity the disciplines of reservoir geology, geochemistry, geophysics and reservoir engineering with their own associations must similarly merge!

Geography need not be a factor in success and communication between participants. Having the range of inventive skill types and a desire to work together in the team is more important than being in the same building. Our experience with international projects demonstrates that international collaborations can deliver creativity and innovation, even when team members are on different continents. Conversely, there is abundant evidence that collocation of the right types of people into separate engineering and geology groups in the same building is not always effective at innovation, especially if that is not an objective.

Our research group and Gushor Inc. spinoff has used the boffin-spotter-facilitator invention model to produce several, we think, innovative technologies quickly from a small diverse pool of co-inventors. We have intentionally tried to combine reservoir engineering, geoscience, analytical chemistry, and numerical modeling ideas plus crucially, concepts external to the industry that have yielded technologies that have been deployed in the industry in the areas of bitumen recovery. For instance, new concepts to extract fluids from core were brought in from recent sediment sampling, storage time viscosity corrections were based on food and environmental science research, and novel recovery processes reliant on using mobile water arose from collaborations of scientist and engineers. We review some of these as invention process examples.

*So, if it is not difficult, why is the unconventional energy industry less than inventive given its massive size and talent?* While most energy companies do not have R&D capability, several large multinationals have big R&D arms with incredibly talented inventive people yet often organizational charts are overly

[1] A Boffin is "a scientist or technical expert" (dictionary.com); (British slang) a scientist or technician engaged in ("*military")* research (Websters); a scientist who is considered to know a lot about science and not to be interested in other things (Cambridge); *informal*, *old-fashioned* a scientist or expert (Collins)

structured and compartmentalized and short term business delivery objectives may trump, even in the R&D sections, the flexibility needed for the creative process to support paradigm shift levels of invention. Large bureaucracies promote dividing of staff into recognizable tribes (engineers, geologists, geophysicists, etc.), further inhibiting communication and rapid testing of early stage ideas. In the absence of testing, gurus and tradition (which are cheaper in the short term than experiments) emerge and a few key people control whole organizational approaches and acceptable directions such that options may quickly become limited. In small companies or research groups, environments can be more dynamic. Another factor is that innovation may be curbed by external regulatory factors or by internal work overload with high production costs, variable resource quality, high capital costs, and oil price volatility also tending to curb risk taking and innovation even though this is the solution to many of these problems.

Industry structures and traditions are the main enemy of innovation in our experience as they compartmentalize thinking at a time when hybrid skills are needed. This is unfortunately promoted by current academic structure as well with separated engineering and geoscience activities in many but not all universities and UoC's ISEEE initiative is an attempt to change this terrain. In an industry where we try to recover complex fluids through complex porous media, geologically savvy, numerate engineering practitioners are needed for many of our challenges(Corbett, 2008). We are encouraged that at least one medium size Canadian company is promoting this concept. Typically however, our system, with its separate faculties of engineering and science; professional bodies with very traditional and very limited narrow views of their subjects and separate professional organizations for geoscientists and engineers all competing for journal, conference space and memberships, hinder rather than help grease the wheels of creativity as they promote tradition and stereotypes. Disciplinism (fundamentalist belief in the central importance of your own skill set) and a highly compartmentalized discipline based organizational structure in most major oil companies and many universities is, in our view, the major restraint on creativity. Separated geological and engineering activities are an inefficient way of solving practical and invention problems in the unconventional oil and gas industry. So bring on the numerate geoengineer.

## Conclusions

Innovation derives from a metastable environment where a dynamic admixture of several key types of inventive individuals operate in a sea of creativity in which many ideas from many disciplines and perspectives must coexist together at one time. Key types of people include (1) boffin inventors, who generate large numbers of ideas, (2) multidisciplinary synthesizers/ technology spotters who can connect disparate ideas into technology nuggets and (3) technology facilitators who can eventually distill tangible, testable concepts and bring a technology to market without inhibiting the idea generation process.

Industry and discipline based structures and traditions are the main enemy of innovation in our experience as they compartmentalize thinking in a process that needs hybrid skills. Separated geological and engineering activities are an inefficient way of solving practical and invention problems in the unconventional oil and gas industry. To develop new reduced emission energy recovery technology, we need geologically savvy, numerate engineering practitioners to grease the wheels of creativity. Small technology and research focused companies or university initiatives may contribute to the development of new innovative technology that will enable the required paradigm shift in this industry but reorganization of geoscience and engineering activity in the Universities and major oil companies is long overdue.

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