

# Low Emission Microbial Upgrading and Recovery (LEMUR) A Potential Route to Low or Zero Emission Energy Recovery from Oilfields

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## Summary

The world oil inventory is dominated by oils with low recovery factors, i.e., heavy and super heavy oils and bitumens and by residual oils in watered out oil fields. Water flood technologies for conventional recovery are fairly mature yet leave most oil (65% or more) in the reservoir. Average recovery of heavy oils worldwide is even lower (17%) than conventional oil recovery. Recovery technologies for the volumetrically dominant non-conventional heavy oils and bitumens are largely based around thermal or solvent based technologies that have high capital and production costs combined with lower market price than conventional resources. These technologies are costly, both environmentally, in terms of carbon dioxide emissions associated with recovery and upgrading, or economically in terms of steam, solvent or upgrading costs. Thermal and catalytically based *in situ* upgrading technologies are being developed for heavy oils and bitumens and may assist with reducing economic and environmental penalties but these require high reservoir temperatures, typically well over 300°C on process timescales, to effect thermal carbon-carbon bond cleavage and reduction of molecular mass to cause viscosity reduction and API gravity increase (Vinegar et al., 2006).

In contrast, the recent discovery of anaerobic biological cracking of liquid petroleum hydrocarbons to methane (methanogenesis) occurs catalytically through biological action at temperatures as low as 10°C, albeit at slow rates naturally (Head et al., 2003; Aitken et al., 2004; Jones et al., 2008). While not all oilfields are biologically active (Wilhelms et al., 2001; Adams et al., 2006), crude oil biodegradation and methanogenic microbial processes are common in reservoirs that have remained cooler than 80°C as is the case in some WCSB heavy oil reservoirs we have studied (Adams et al., 2006). The discovery of the MADCOR process (Methanogenic Alkane Degradation by Carbon dioxide Reduction), as it has been termed, raises many possibilities for reduced emission to atmosphere energy recovery (REAR) processes as methane is quantitatively produced from biodegraded alkanes, utilising water as co-reactant, with molecular hydrogen gas being the principal intermediate (Jones et al., 2008).

The basic recovery process proposed involves the acceleration of the natural methanogenic biodegradation of hydrocarbons. Because degradation rates slow for increasingly large (less volatile) hydrocarbon components, this process will be more efficient and operate on production time scales for heavy oils and

stranded conventional oils. This technology is not suitable at this time for superheavy oil or bitumen resources because of their high level of degradation. The most suitable oils contain some n-alkanes and other light end aromatic components. We estimate that naturally +80% of all the hydrogen in the degrading alkanes and water pass through a hydrogen gas intermediate. This raises the possibility, if the process could be dramatically accelerated and hydrogen could be recovered, of a truly green energy recovery process with hydrogen gas as the energy recovery vector. Unfortunately, it has been shown that the thermodynamic window in which active hydrogen generation occurs limits hydrogen generation to conditions of low partial pressures of hydrogen (Dolfing et al., 2008), so actively flushed or dynamically managed recovery systems are required for hydrogen production (Larter et al., 2004). Nevertheless, the attraction of a true zero carbon emission to atmosphere recovery process based on accelerated hydrogen production from biologically active oilfields, means that several groups are actively pursuing this holy grail. In this paper we focus on accelerated methane recovery from stranded oil in oilfields, which could result in a green transition technology for the oil industry enabling rapid emission reductions by using existing infrastructure (Larter 2008).

What are the key factors to overcome in demonstrating commercial significance for accelerated methanogenesis as an energy recovery process? Five factors are important:

1. Not all oil fields are appropriate for the process and thus selection of appropriate field settings using appropriate geological, biological and chemical screening technologies is crucial for development of the process.
2. Management of the microbial flora of the petroleum reservoirs entails having the appropriate organisms active in the reservoir and limiting the activity of hydrogen or methane consuming organisms (Larter et al., 2004).
3. It has been shown previously using numerical models of the biodegradation process that the rate controlling step in natural petroleum biodegradation is not supply of hydrocarbons to oil water contacts but is supply of key nutrients to the reaction zones (Larter et al., 2003;2006; Oldenburg et al, 2006). This means that optimized nutrient delivery to reaction zones is crucial to provide commercial rates of gas generation.
4. A key step is the management of process conditions such that the desired combination of gas and oil flow to production wells occurs (Gates et al., 2008) which is not straightforward in liquid saturated reservoirs when process latency times are sometimes long. This involves combinations of optimized reservoir engineering with embedded process control strategies in the simulations using oil, gas and water isotopic, and chemical analyses as well as microbial analyses (Gates et al., 2008).
5. Finally, an optimized tandem economic model for field development is required given the latency time of the process startup and the competing economics of improved gas and oil recovery from the process.

Thus the process is not simply a biological one, but is better described as an optimized, biologically assisted engineering recovery process following on from conventional oil recovery. We review the progress of the industry towards demonstration of low carbon emission commercial methane or hydrogen gas production from oilfields using Low Emission Microbial Upgrading and Recovery (LEMUR™) technology (figure 1).

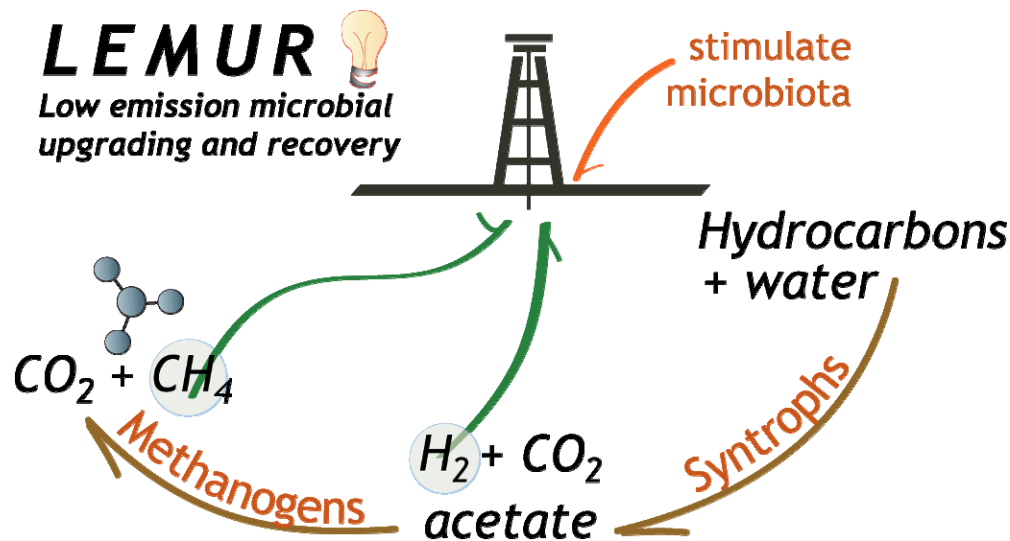


Figure 1. LEMUR process schematic.

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