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Economic and environmental analysis of a Steam Assisted Gravity Drainage (SAGD) facility for oil recovery from Canadian oil sands

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HIGHLIGHTS

- An hypothetical industrial scale facility based on SAGD has been studied.
- A DCFA and a LCA of the hypothetical plant have been carried out.
- An economic–environmental model for SAGD technology optimization has been developed.
- Cost competiveness and environmental impacts have been calculated.

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ABSTRACT

As conventional oil production becomes limited, transportation fuels are being produced from other unconventional fossil resources such as oil sands. Oil sands are a combination of clay, sand, water and bitumen. Vast quantities of oil sands resources have been found worldwide. The largest known reservoir of oil sands in the world is located in the province of Alberta (Canada). Several techniques for the extraction of the oil from oil sands have been developed in recent decades. Steam-Assisted Gravity Drainage (SAGD) is the most promising approach for recovering heavy and viscous oil resources. In SAGD, two closely-spaced horizontal wells, one above the other, form a steam-injector and producer pair. The reservoir oil is heated by the injected steam and drains to the producer under the effect of gravity. First aim of this work is an economic optimization and evaluation of an hypothetical industrial scale facility (named LINK), located in Alberta. All data relating to LINK plant have been obtained from a review of the existing literature references or have been assumed. A Discounted Cash Flow Analysis (DCFA) of LINK plant has been performed. Costs of existing projects have been found in literature. The results show that the hypothetical plant LINK is a profitable investment and that the investment cost has a significant effect on the competitiveness of the LINK facility. Second purpose of the present work is an environmental analysis of the LINK plant: in order to evaluate GHG emissions from LINK plant, a LCA analysis has been carried out. The calculated emissions from oil sand production by SAGD technology have been compared with values relating to conventional crude oil pathways and to recovery and extraction of bitumen through surface mining from literature. The comparison demonstrated that SAGD is a promising technology also from an environmental point of view. An economic–environmental model for SAGD technology optimization has been developed.

1. Introduction

As conventional oil production becomes constrained, transportation fuels are being produced from other unconventional fossil resources such as bitumen deposits. According to the International Energy Agency's (IEA) World Energy Outlook 2001 [1], these include oil sands, enhanced oil recovery, coal-to-liquids and gas-to-liquids synthetic fuels, and oil shale. Oil sands are a combination of clay and sand (80–85%), water (5–10%), and bitumen (10–18%), a heavy black dense, viscous mixture of high-molecular-weight hydrocarbons. Vast quantities of oil sands resources have been found worldwide. The largest known reservoir of oil sands in the world is located in the province of Alberta (Canada), with accumulations of oil exceeding 60 mm in thickness, at depths between 0

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and 600 m, with a very high viscosity (2 × 106 cP). Alberta's oil reserves are currently [2] the third largest in the world with 174 billion barrels of oil reserves.

The increasingly limited availability of oil produced from conventional sources and the realignment of world oil prices upward settling above $100 per barrel [3] over the past year are spurring a substantial transformation of oil technology and market and they are making the exploitation of the Canadian oil sands a very important goal for the whole oil & gas world. Therefore, understanding the economics of Alberta's oil sands is important to understanding global oil & gas investment competitiveness.

Several techniques for the extraction of the oil from oil sands have been developed in recent decades. Since the eighties, new technologies for the production of viscous oils have been developed, which have changed the outlook of the world's oil procurement.

The most commonly used in-situ process is Steam Assisted Gravity Drainage (SAGD). With the SAGD technique (Fig. 1), a pair of horizontal wells is drilled from a central well pad [5]. In a plant nearby, water is transformed into steam which then travels through above-ground pipelines to the wells and enters the ground via a steam injection (top) well. The steam heats the heavy oil to a temperature at which it can flow by gravity into the producing (bottom) well. The steam injection and oil production happen continuously and simultaneously. The resulting oil and condensed steam emulsion is then piped from the producing well to the plant, where it is separated and treated. The water is recycled for generating new steam.

With a large part of oil sands production coming from the employment of SAGD technology, the number of new plants using this technology is likely to increase significantly as the Canadian economy recovers from the current slowdown. Given existing and announced investments, as well as projects under development, production is expected to triple by 2020 [6].

2. Literature review

SAGD oil extraction technique, as the other ones, has different implications for economic costs and requires capital investments in the billions of dollars. This work aims to assess the economic feasibility of an industrial scale plant, based on the SAGD technology. The financial performance assessment of the SAGD technology is an important issue, since there is indeed a strong need for oil-sands production to be economically viable: oil-sands projects may never have breakeven economics approaching those of conventional oil, but significantly reducing breakeven costs is imperative and achievable. By improving the practices by which large oil-sands capital projects are designed and executed, project managers can reduce total life-cycle costs for new oil sands by as much as $10 per barrel [7]. In fact, when compared to conventional oil production, the operating costs in an oil sands project are 30 percent higher than the operating costs for conventional oil production. However, the total cost per barrel of energy from the oil sands project is less than the total cost per barrel of conventional oil production, because the royalty and tax charges from the oil sands projects are extremely low [8]. According to the Energy Market Assessment [9], US$30 to $35 per barrel for West Texas Intermediate (WTI) is needed to obtain a 10 percent Return on Investment.

Table 1 indicates a summary of oil sands operating costs and supply costs classified by major recovery processes [9]. The operating costs component reflects the cash costs of operation (roughly, the average variable costs), while supply cost includes this operating cost as well as costs associated with production, including: capital costs, taxes, royalties, and rate of return on investment (roughly, the average total cost). Operating costs for mining/extraction processes of bitumen were evaluated at around C$6 to C$10 per barrel (C$2003) and at between C$9 and C$12 per barrel (C$2005). Supply costs for an integrated mining/upgrading type were estimated at about C$22 to C$28 per barrel for SCO (Synthetic Crude Oil) (C$2003) and at around C$36 to C$40 per barrel for SCO (C$2005). There was an operating cost increase of up to an average case of C$3 per barrel for the mining/extraction type between the NEB estimates in 2004 and 2006. There has also been a dramatic supply cost increase of up to C$13 per barrel for the integrated mining/upgrading type between the NEB estimates in 2004 and 2006.

When compared to the 1970s, most of the supply costs categorized by main recovery type decreased with improvements in technologies. However, natural gas prices increased by 88 percent and capital costs also went up by 45 percent between 2003 and 2005. These facts brought about the general cost increases for the same period. Operating costs for SAGD in-situ technology were estimated at around C$10 to C$14 per barrel of bitumen in 2005

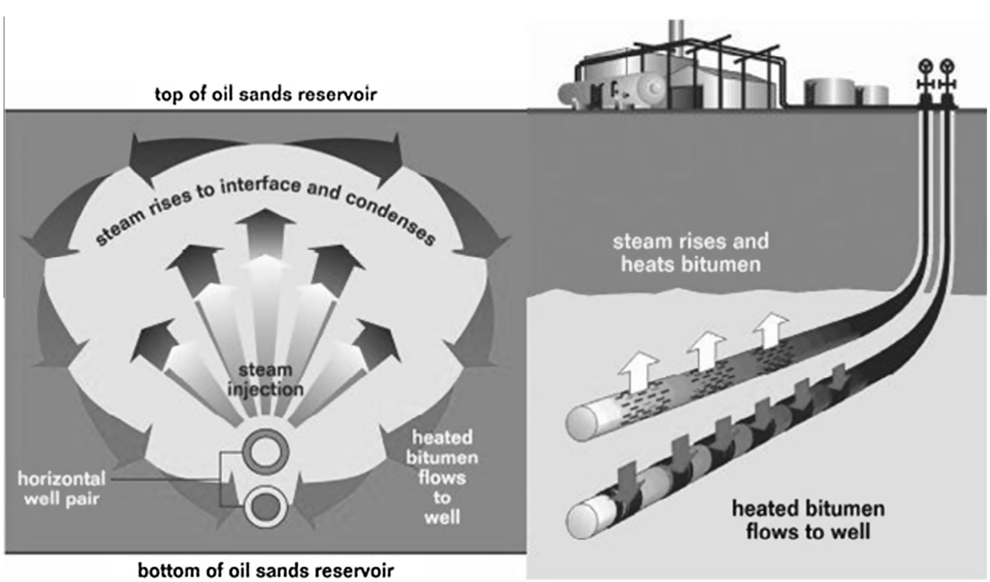

Fig. 1. SAGD process [4].