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Economics of Heat Loss Material Design in Transportation of Stranded Gases as Hydrates

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Abstract

The Transportation of gas as hydrate with time is a function of the nature of the Hydrate carrying material of which when poorly designed can lead to loss of gas due to untimely re-gasification and hinders profit making. It is on this note that after the production of hydrate with natural gas, the ability for the Hydrate to reach its final point without on-transit re-gasification is seen as to be a function of the nature of the carrier material designed. In this study a robust software, HYGAS, has been developed to analyse the economics of the newly designed (heat loss) carrier model for transportation of natural gas by means of hydrate. Key parameters including the flow rate of the feed gas, abandonment rate and decline rate were considered. Also, the fiscal Parameters like the Gas price, Inflation rate, Royalty are considered. Finally, the CAPEX, OPEX, Depreciation and income tax rate are also taken into consideration during the designing. From the design, it is observed that at 0% discount, Internal rate of returns (IRR) or breakeven will be at nine years to come and at 15% discount rate, the IRR or Breakeven will be at seven years to come. The program at various discount values inputted can continue to give corresponding breakeven until a Most favorable condition can be met. Hence, Profit maximization can be attained.

Keywords: Hydrate, Natural Gas

Introduction

The demand for energy in the world has been ever increasing. This has led to the discovery of a number of different new technologies. With the focus of the energy demand shifting towards cleaner sources of energy there has been a surge in the demand for natural gas. Over the last decade global natural gas consumption has steadily increased since many industrialized countries are substituting natural gas for coal to generate electricity. There is also significant industrialization and economic growth of the heavily populated Asian countries of India and China. The general consensus is that there are vast quantities of natural gas trapped in hydrate deposits in geological systems and this has resulted in the emerging importance of hydrates as a potential energy resource and an accompanying from hydrates (De-Silva and Dawe, 2011). Within the last two decades, the interest in Natural gas hydrates have grown significantly as reflected by the increase in the number of publications, the increased level of funding for research and the hosting of gas hydrate conferences.

Gas production from hydrate reservoir involves decomposition of the solid hydrate. Factors which determine when pipelines are profitable and efficient are;

1. The resource volume,
2. Transportation route,
3. The regulatory environment involved,
4. The size of the market and
5. The growth in demand.

Other times, excess reserves might also be regarded as stranded, if they require a paltry delivery rate in the bid to oversupply the products to the local markets. Moreso, a negative economics could be as a result of technical issues and complexities or very high expenses which might be associated with the recovery or gathering of the gas.

The global estimates of gas contained in hydrate deposits at standard conditions range from 2×1014m3 to 3.053×1018m3. This increasing worldwide interest also stems from the fact that gas hydrates are metastable and affected by pressure and temperature conditions. Change in pressure and temperature of the sediments in which they occur can result in the release of the methane which in turn could impact oceanic and atmospheric chemistry and ultimately the global climate.

Building new pipelines and/or railway systems for transportation of natural gases are expensive and labour intensive. In addition compressed natural gas [(CNG) at 20.67 to 24.82 Mpa (3000 to 3600 psia)] and liquefied natural gas (LNG) requiring cryogenic temperatures at less than 112k (-161^{0}c), also requires large capital investment.

Hydarate Structures

Gas hydrates are crystalline solids. They are more properly called clathrat hydrates to distinguish them for stoichiometric hydrates found in inorganic chemistry. The crystalline structure is composed of polyhedra of hydrogen-bonded water molecules. The polyhedral from cages that contains at most one guest molecule each. The cages are stabilized by van der waals forces between the water molecules and the enclatherated guest molecule. In extraordinary situations, two guest molecules may enter the same cage (Solan, 1998). Only a few kinds of cages may form depending on the size of the guest molecule.

Literature Review

Based on a proposed process for conversion of natural gas to natural gas hydrate, NGH, the amortized total capital investment, operation and maintenance costs and total cost for production of NGH was published in Javanmardi et. al. (2004). The effects of different operational conditions such as seawater temperature as cooling media and hydrate storage temperature were investigated. They also analysed economic parameters for marine transportation of NGH from Asaluyeh port in the south of Iran to varing gas market options. This analysis also includes estimation of required natural gas hydrate ships and their operation costs for different gas markets.

Song et. al. (2015) developed a lab scale twin roll press machine for pelletizing natural gas hydrate powder. Ice and hydrate powder were used for the pellet extrusion system. The effects of feeding pressure, pressure ratio, and rotating speed of the twin roll were investigated for producing high strength and stiffness hydrate pellets. The compressive strength and stiffness of pellet increased with increasing feeding pressure and rotation speed. In particular, there was a relatively large increase in the stiffness with an increase in rotating speed, and a relatively large increase in strength with increasing feeding pressure. The production ratio of pellets largely depended on the rotating speed of the twin roll. The results indicate the promising future of solid transportation of natural gas.

According to Ruppel (2011), despite the relative immaturity of gas hydrates R&D compared to that for other unconventional gas resources, the accomplishments of the past decade, summarized in detail by Collett et al. (2009), have advanced gas hydrates along the path towards eventual commercial production.

The U.S. Department of Energy (DOE), as directed by the Methane Hydrates R&D Act of 2000 and the subsequent Energy Act of 2005, has partnered with other government agencies, academe, and industry in field, modeling, and laboratory programs that have produced numerous successes (Doyle et al., 2004; Paull et al., 2010). These accomplishments have included the refinement of methods for pre-drill estimation of hydrate saturations and safe completion of logging and coring programs in gas hydrate-bearing sediments in both deepwater marine and permafrost environments. Within the next 4 years, US federal-industry partnerships are scheduled to oversee advanced logging and direct sampling of resource-grade (high saturation) gas hydrates in sand deposits in the deepwater Gulf of Mexico and completion of a long-term test of production methods on the Alaskan North Slope. In Japan, the government-supported methane hydrates program (now called MH21; Tsuji et al., 2009) has also relied on cooperation among the private, public, and academic sectors over past decade and plans to conduct an initial production testing of resource-grade gas hydrates in the deepwater Nankai Trough in 2012. The current MH21 effort has grown out of earlier advanced borehole logging and deep coring in 1999-2000 (MITI) and in 2004 (METI), as described by Tsuji et al. (2004, 2009) and Fujii et al. (2009). Canada has also worked with a consortium of partners to complete three major drilling programs in the permafrost of the Mackenzie Delta (e.g., Dallimore et al., 1999; Dallimore and Collett, 2005; Dallimore et al., 2008). Canada was the first country to ever produce small volumes of gas from hydrates during short duration (up to a few days) production tests at these wells. Since 2005, India (e.g., Collett et al., 2008; M. Lee and Collett, 2009; Yun et al., 2010), Korea (Park et al,2008; Ryu et al., 2009), China (Zhang et al., 2007; Wu et al., 2008), and private sector interests operating offshore Malaysia (Hadley et al., 2008) have also launched major, successful deepwater hydrate drilling expeditions, and Korea drilled the Ulleung Basin again in the second half of 2010 (S.R. Lee et al., 2011).

Methodology

The method used in developing the economics aspect of this study is;

Break even analysis or Rate of Internal Returns (IRR)

The economic implication of the said carrier material is of importance. Various factors like fiscal parameters, time to reach economic limit, Capex, Opex, Depreciation, etc. are taken into consideration for the net pay value (NPV). Thus enhancing the actual time for profit maximization to be achieved.

Cash Flow Analysis

$$\text{Inflation factor} = \left(IF_{i-r}\right)\left(\frac{IR}{100}+1\right) \tag{1}$$

or

$$IF = \left(IF_{i-1}\right)\left(1+\frac{IR}{100}\right)$$

IF = Inflation factor
IR = inflation rate (%)

Gas price Mod = IF X Gas Price (2)

Gross revenue = (comm. Product × IF)/100 (3)

Net revenue = gross revenue –royalty (4)

$$\text{Depreciation} = \frac{1}{n}\ (\text{C-S}) \qquad \text{– straight line} \tag{5}$$

n = estimated asset life (yr)
c = original investment ($) (including insulation cost)
s = estimated salvage value ($)
Taxable Income = Net Revenue – Total Tax
Net Cash Flow = Taxable Income – Total Tax Payable

NPV = Cash Flow x DF (6)

Where

DF = Discount Factor

$$DF = \left[DF_{i-1} + \left(\frac{DR}{100} \right) \right]^{-i} \quad (7)$$

Where

DR = Discount Rate (%)

i = current step in time

DF_{i-1} = preceding discount factor

Mathematical Models used in software

- Heat transfer
- Mass transfer
- Peng Robinson Equation
- NPV analysis

The Working Principle of Hygas Software

HyGas simply means "Hydrated Gas". The software was built primarily for data analysis purposes. **HyGas** works on the principle of Input – output logic and utilize a number of well known models such as the Fourier's' law, Exponential law, Peng Robison Correlation and Cash Flow Analysis for economic evaluation. Data are feed into the software via input boxes and simply click on the command buttons to compute the required information.

Economic Analysis of Design

This module examines the economic implication of the design. It is the most important module of the project. This is because the feasibility of the design depends largely on how much it will cost. Also, operators are concerned with how design could be optimized thereby using the lowest cost of material ever while design is maximized. The economic analysis presents at a glance the profitability tendency of the design while putting other factors into consideration. Figure 1, 2 and 3 present the Capital Expenditure (CAPE), Operating Expenditures (OPEX) and the depreciation respectively.

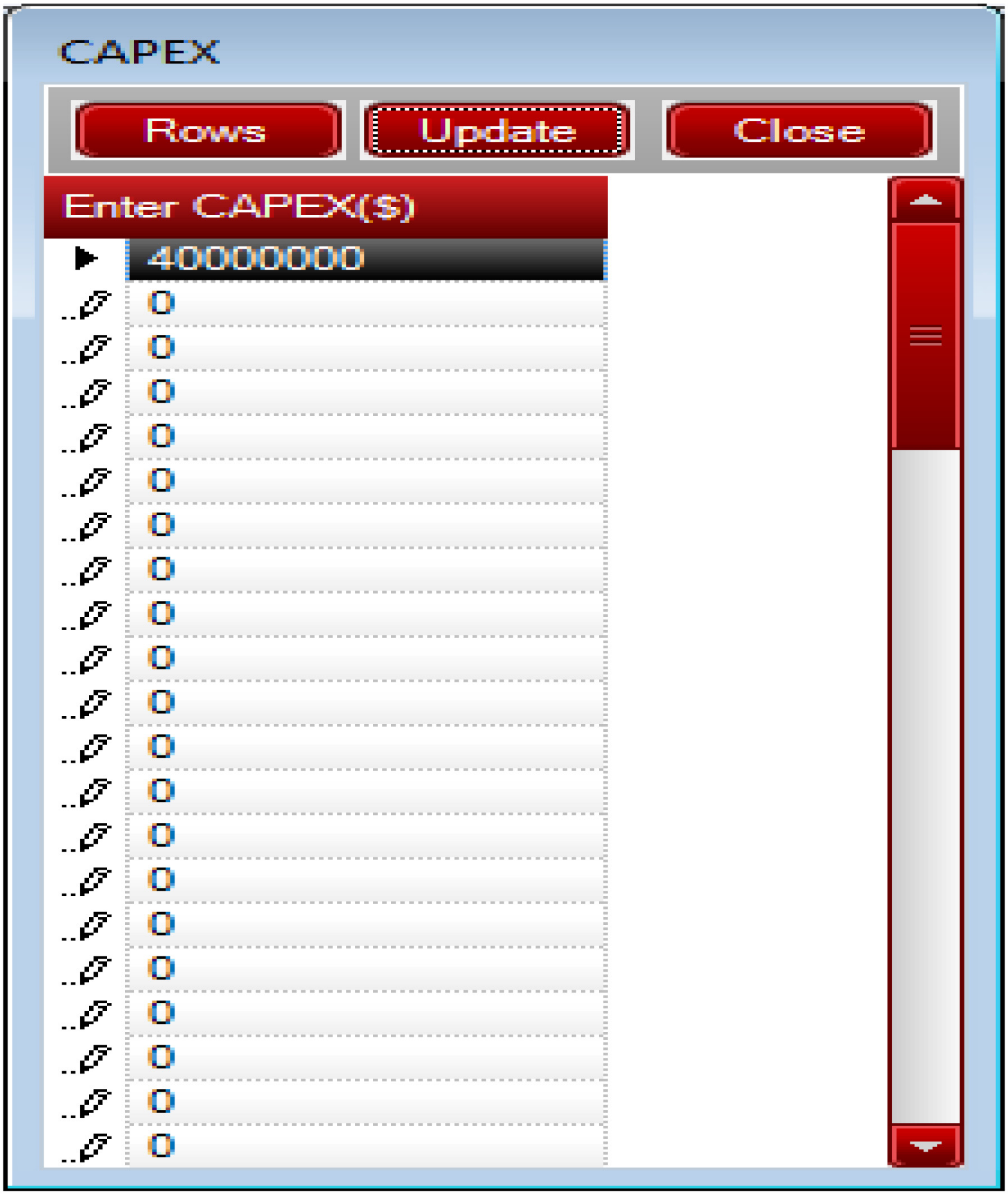

Figure 1—Shows Windows Capital Expenditure (CAPEX)

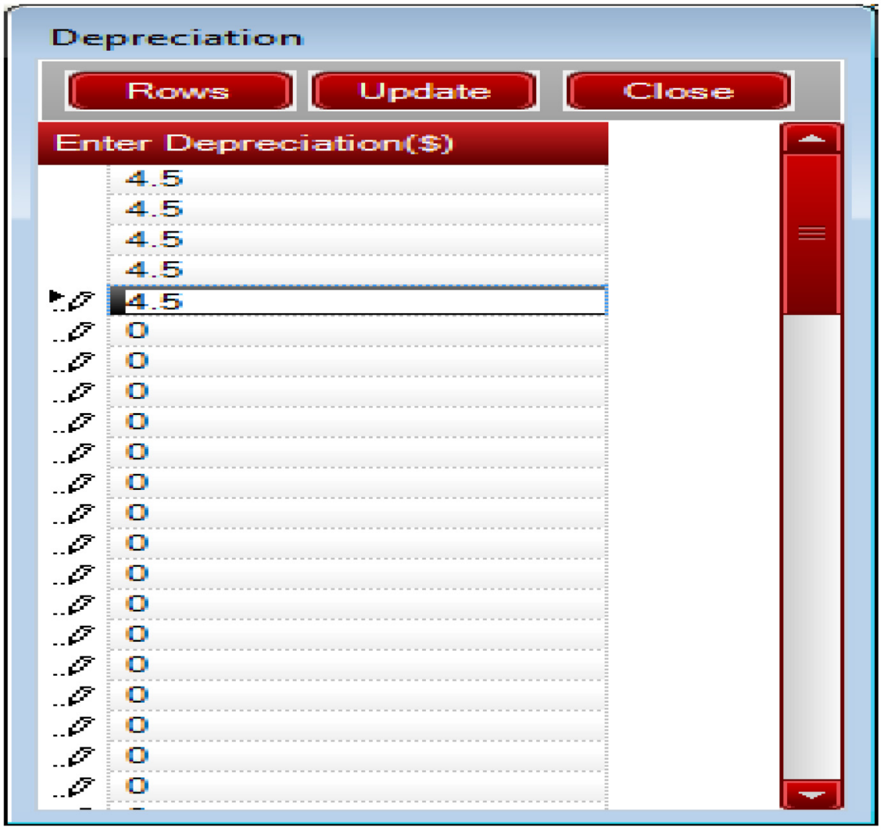

Figure 2—Shows Windows Operating Cost (OPEX)

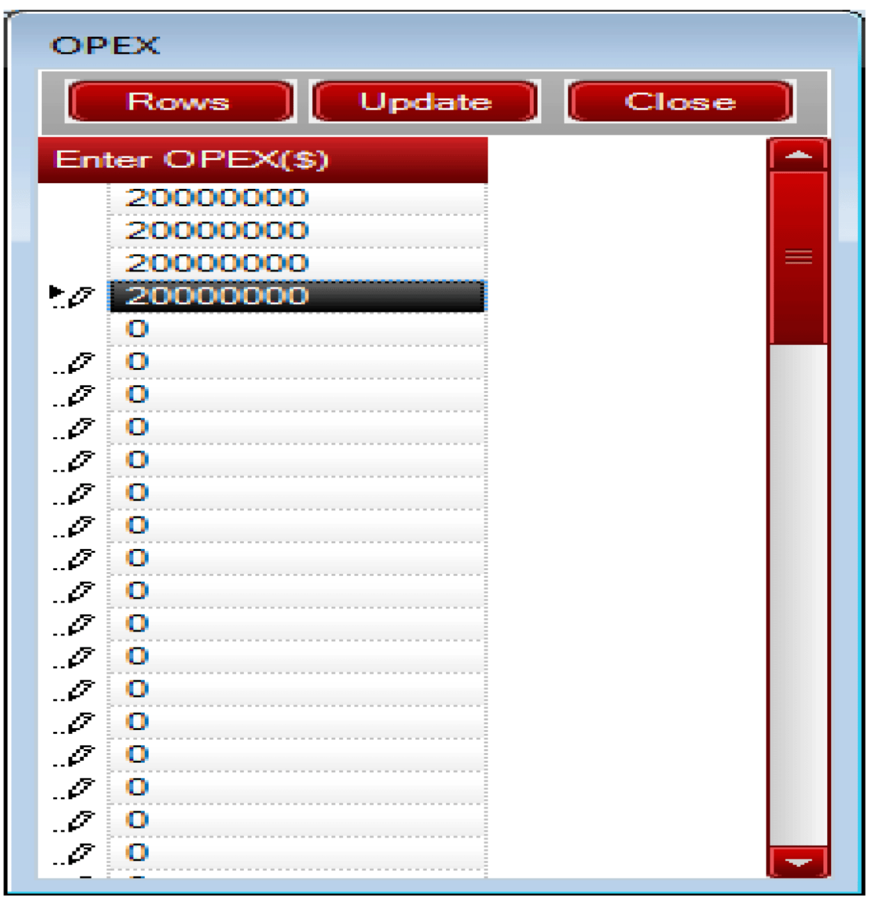

Figure 3—Shows Windows Depreciation

Figure 4 is the Full Graphics User interface (GUI) of HyGas Economic module. Cash Flow shows that at 0% discount rate, the break even time is approximately 8 years 9 months Figure 5 But when the discount rate was 15%, the internal rate of return (IRR) is approximately 7 years from investment time. The subsequent varying discount rates are presented in Figures 6 – 7.

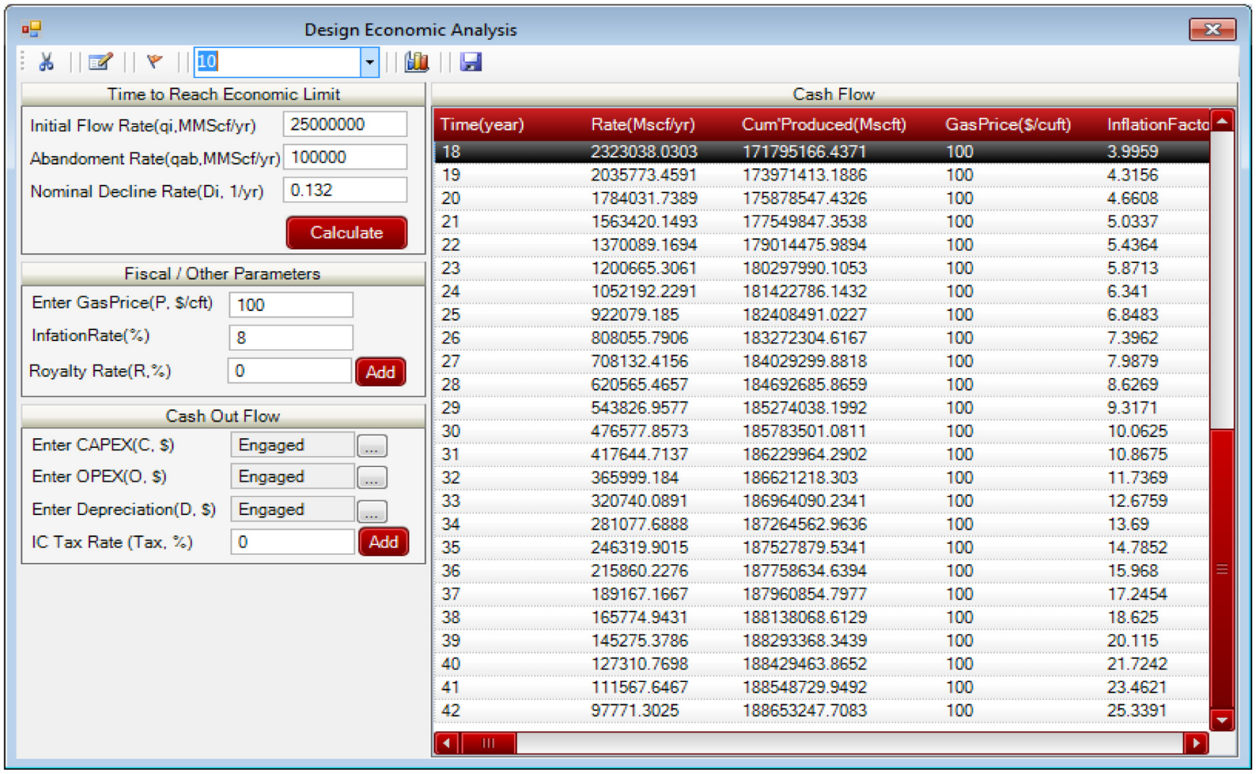

Figure 4—Shows CashFlow Windows for Design Economics

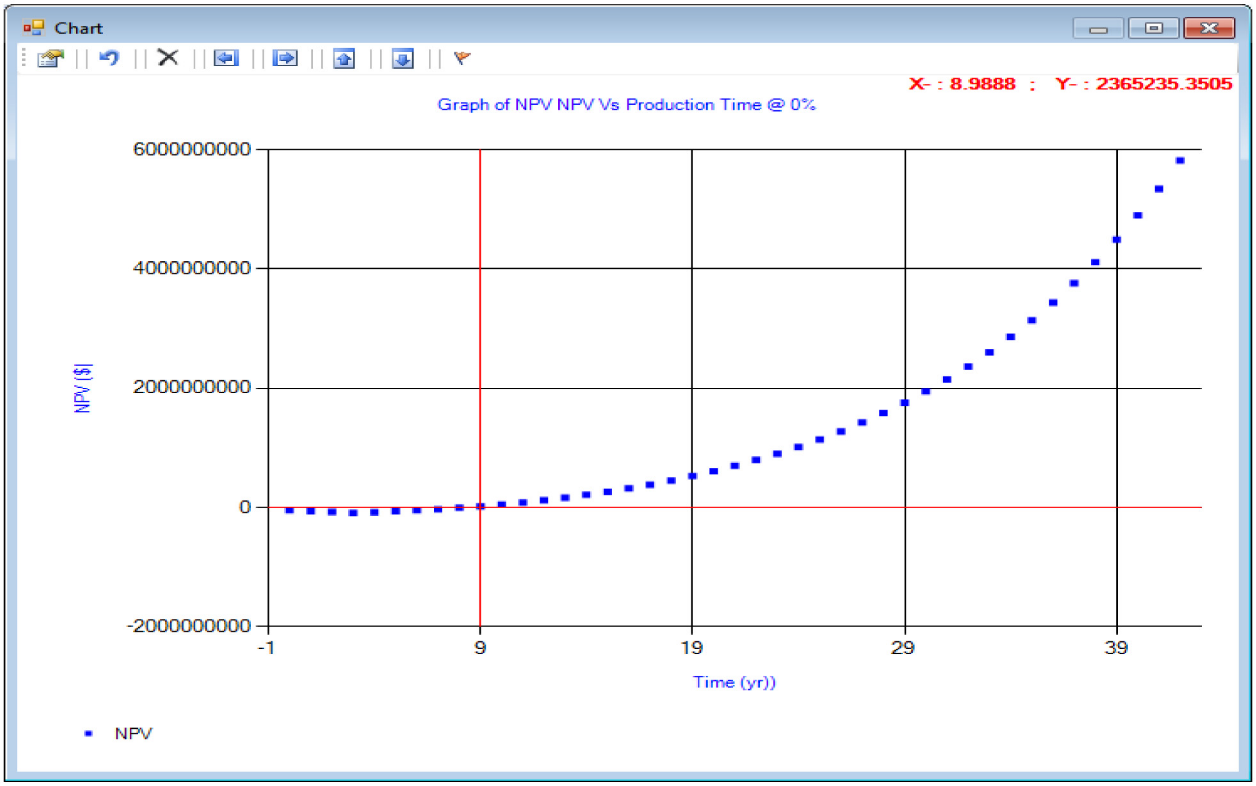

Figure 5—Shows Internal Rate of Return (IRR) at discount rate of 0%

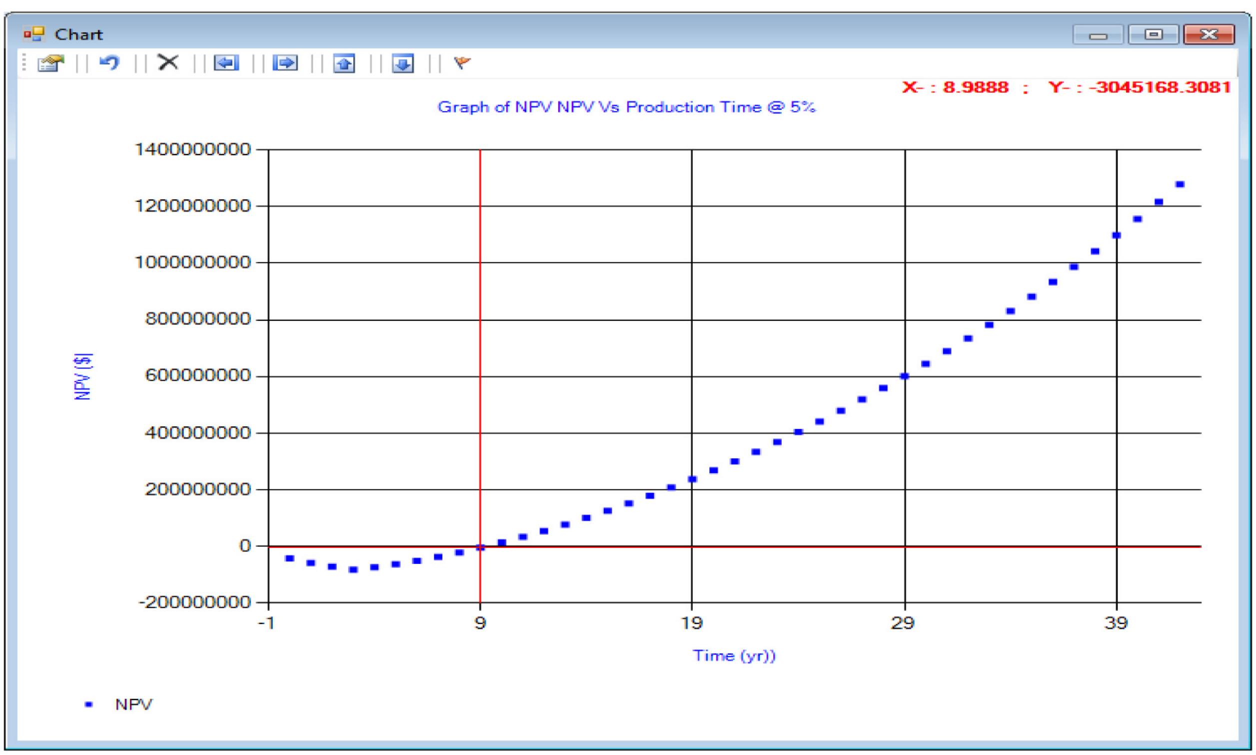

Figure 6—Shows Internal Rate of Return (IRR) at discount rate of 5%

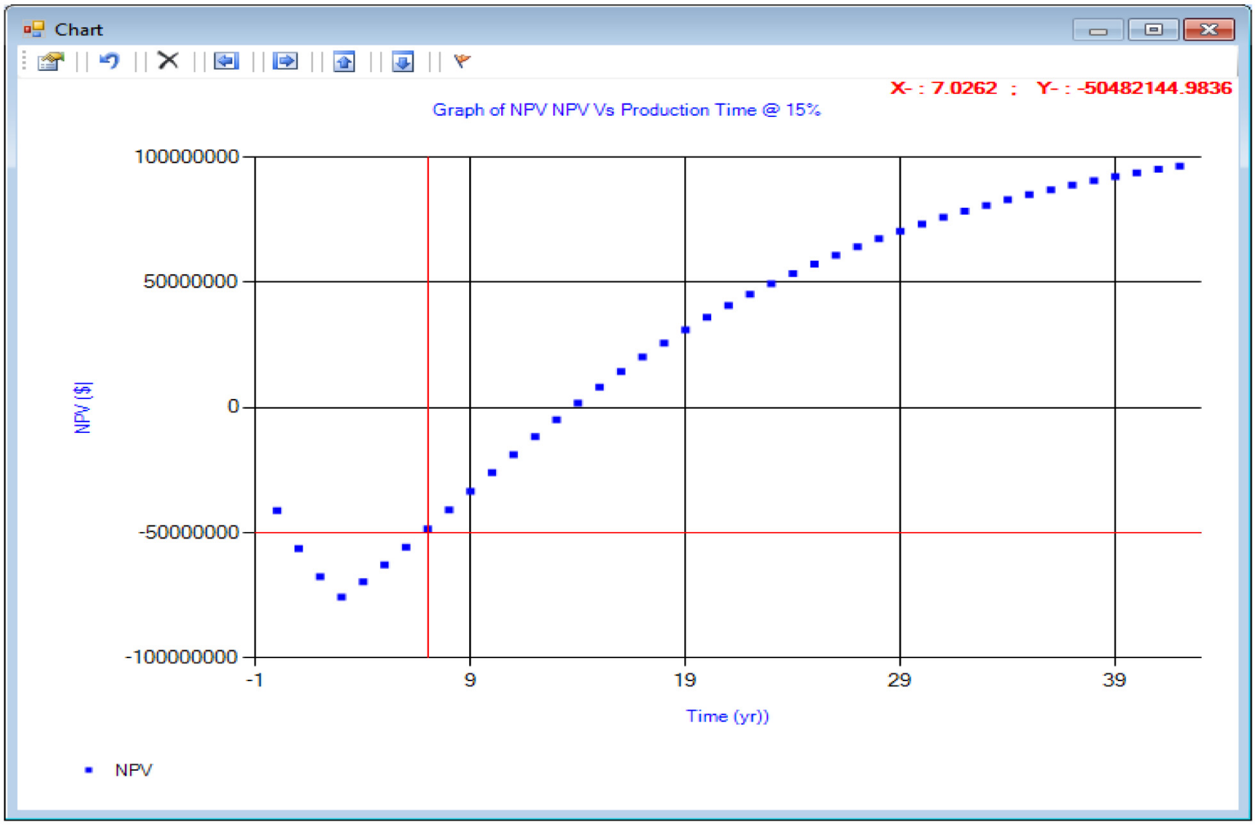

Figure 7—Shows Internal Rate of Return (IRR) at discount rate of 15%

Tables for Cash Flow Input Data

Table 1—Time to Reach Economic Limit

Input data	Parameter unit	Values
Initial inflow/production rate (qi)	Mmscf/yr	25,000,000
Abandonment rate (qab)	Mmscf/yr	100,000
Normal decline rate (Di)	1/yr	0.132

Table 2—Fiscal/ other parameters

Input data	Parameter unit	Values
Gas price (p)	$/cft	100
Inflation rate	%	8.0
Royalty rate	%	0

Table 3—Cash out flow

Input data	Parameter unit	Values
Capex (c)	$	40,000,000
Opex (0)	$	20,000,000
Depreciation (D)	$	4.5
Income tax rate (tax)	0	-

GRAPHS OF IRR OR BREAK EVEN ANALYSIS

At 0% discount rate or IRR the breakeven is about 9 years to come.

5% discount rate IRR or breakeven will be at about 9 yearrs to come.

At 15% discount rate the IRR or breakeven will be at 7 years to come.

Conclusion

The economic of carrier material design is another important aspect as breakeven point when profit maximization is to be advanced is a core issue, here economic elements like royalties, tax, etc. varied favourably, shows profit maximization at various point on this project.

The application of the hygas software can be seen in solving problems associated with Fourier's' law, Exponential law, Peng Robison Correlation and Cash Flow Analysis for economic evaluation.