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Comparative Economic Analysis of CNG and LNG Transportation

Anthony O. Chikwe, Anthony N. Ebue*

Department of Petroleum Engineering, Federal University of Technology Owerri, Imo State, Nigeria
*Corresponding Author: ebueanthonyemeka@gmail.com

Abstract There are many possible technologies of transporting gas from production fields to consumers elsewhere as a fuel or as a chemical feedstock in a petrochemical plant, where gas is converted into valuable products. The methods for transportation of natural gas also known as gas optimization options include Pipelines (PNG), Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG), Gas to Hydrates (GTH), Gas to Liquids (GTL), Gas to Commodity (GTC) such as glass, cement or iron and Gas to Wire (GTW) i.e. electricity.

Comparative Economic analysis of CNG and LNG transportation was performed using Net Present Value (NPV), Payout time, Profit per Dollar invested, and Discounted cash flow – Rate of return (DCF-ROR). Using the economic indicators, the following results were obtained: present value (PV) @ 5% for CNG is $260791151 while for LNG is ($33503022), present value per dollar (PV/$) for CNG is $0.12601 while for LNG is ($0.574), Pay Out (P.O) for CNG is 5.6 years while for LNG is 14.7 years, Net Cash Recovery (NCR/NPV) for CNG is $545,550,000 while for LNG is $79,300,000, Profit Per Dollar (P/$) for CNG is $2.598 while for LNG is $0.3605, and finally the Discount Cash Flow – Rate of Return (DCF-ROR) for CNG is 18% while for LNG is 2.74%.

Keywords Economic analysis, LNG and CNG Transportation, Economic Indicators**,** Discount Cash Flow- Rate of Return, comparative economic analysis, gas optimization option

1. Background of Study

Millions to hundreds of millions of years ago and over long periods of time, the remains of plants and animals (such as diatoms) built up in thick layers on the earth's surface and ocean floors, sometimes mixed with sand, silt, and calcium carbonate. Over time, these layers were buried under sand, silt, and rock. Pressure and heat changed some of this carbon and hydrogen-rich material into coal, some into oil (petroleum), and some into natural gas.

Natural gas is a fossil energy source that formed deep beneath the earth's surface. It is the light-end of natural occurring hydrocarbon mainly Methane which varies from 50% to 90% or above with heavier Alkanes and impurities such as carbon dioxide (CO_2), hydrogen sulphide (H_2S), helium (He), nitrogen (N_2), water (H_2O) taking the remaining part and sometimes radioactive element in trace quantities. Natural gas also contains smaller amounts of natural gas liquids and non-hydrocarbon gases, such as carbon dioxide and water vapor. We use natural gas as a fuel and to make materials and chemicals.

Table 1: Typical Composition of Natural Gas

Methane	CH_4	70% - 90%
Ethane	C_2H_6	0 – 20%
Propane	C_3H_8	
Butane	C_4H_{10}	

Carbon Dioxide	CO_2	0% - 8%
Oxygen	O_2	0 – 0.2%
Nitrogen	N_2	0 – 5%
Hydrogen Sulphide	H_2S	0 – 5%
Rare Gases	A, Ne, He, Xe	trace

In the world today Natural gas has been found to be growing rapidly in terms of consumption, which in turn triggers its production and distribution to the final consumer. The reason for this massive increment in consumption is the cleanliness of its combustion compared to other fossil fuels. There are many ways and technologies of transporting gas from production fields to consumers as a fuel or as a feedstock in a petrochemical plant or production plants, where they are converted into various forms of energy. The methods or gas optimization options for transportation of natural gas includes Gas to Wire (GTW), Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG), Gas to Hydrates (GTH), Gas to Liquids (GTL), Gas to Commodity (GTC) and Pipeline (PNG) etc.

2. Economic Comparison between CNG and LNG Transportation

The shipping cost of Liquefied natural gas has been fluctuating over the years due to the following reasons.

a) Geopolitical sensitivity
b) Contractual agreement between parties
c) Tides and waves of the ocean/seasons
d) Pandemics e.g. COVID-2019 etc.

All this affects both the transportation cost and the availability of Natural Gas for transport. Considering the fact that all these and other factors affects the charter rate of both CNG and LNG, it should be noted that the calculation done in this work did not account of these fluctuation in charter rates.

Economics Advantages of CNG transportation over LNG

There are a number of distinct variations which makes the transportation of CNG more advantageous than LNG transportation. This will provide some insights in understanding the best option to choose as more economical. [12]

Some of these are:

a) There is no need for regasification since there no phase change. The cost of liquefaction is between one dollar and one dollar five cents per million BTU, but with CNG there is no need for regasification; but there is a cost of pressurizing the gas, but the process is much less expensive.
b) The energy of the compressed gas can still serve as energy back to grid or recovered as electricity by using expanders when taken it to some of the final consumers and since the product being discharged is not a cryogenic liquid it can be transmitted into a simple pipeline system.
c) Since the gas is not going to pass through any change of phase, its quality will be maintained even to the extent of representing the original reservoir fluid which may discovered through fingerprinting. All the efforts made to remove all the impurities in the natural gas which may cause harm and plugging of LNG pipelines to the equipment used in liquefaction cost more than compression.
d) The material for containment for CNG are relatively cheaper than that of LNG which requires high quality Nickel steel, Aluminum or Stainless steel which is needed to carry cryogenic LNG. Most CNG carriers are developed to use fine normalized steel grains which are cheaper. [12].
e) Size variation is a huge difference in CNG and LNG vessel; the flexibility of controlling and handling CNG vessels is due to its minimal size, while in LNG vessel which could be fitted with large 4 to 6 tanks reduces its flexibility and increases cost of handling.
f) CNG vessel containment system can be fitted into another system without going through so many process, hence CNG vessels are suitable for retrofit on an existing vessel unlike LNG vessel containment that is very costly and passes many processes. [12].

g) Decreases in shipping costs increase net present value (NPV) and returns to equity for producers that deliver LNG on ship basis. Lower shipping costs increase profit margins for buyers though lager tankers enjoy economies of scale and Advances in propulsion systems reduced operating cost [8].

Economic Advantages of CNG over LNG transportation can be summarized according to new research [3] in the following points.

1. Requires a stable volume.
2. Civil worked required.
3. Limited for short distances and low volume.
4. Longer implementation.
5. Supply equipment consumes gas and electricity.
6. Limited storage during transportation, hence moves faster covering more distance.
7. Single wall tank, makes tank cheaper.

Economics Advantage of LNG transportation over CNG.

1. Flexibility; seasonal contracts and transports can be negotiated.
2. Scalable supply according to your needs.
3. Optimal solution for long distances and lager volume.
4. Greater volume transported in less space.
5. Double wall tank, making it safer.
6. Transported at low pressure at about 50psi while CNGs pressure is at (3000 to 3600) psi.

In a research from [3]

3. Methodology

Description of Economic Indicators to be Used

The Economic Indicators used are the major indicators that can tell us about the overall performances of the better alternative to pursue when dealing with Transportation. The indicators used are

a) Net Cash Recovery: The Net Cash Recovery is money remaining when all the expenses have been deducted from the money at hand. The net Cash Recovery can be negative or positive. Positive NCR are always preferable but when comparing two positive NCR; the one that is higher is chosen as the optimum alternative.

Mathematically;

$$NCR = \sum_{i=0}^{k} income\ or\ revenue - \sum_{i=0}^{k} tax, expenses \quad (3.1)$$

b) Profit per Dollar: Profit per Dollar measures the profit per each dollar invested against the profit made. It is the ratio of Net Cash Recovery and Investment. It an abstract measure, not often use in economic calculation but it is useful when it comes budget ranking; when you don't have enough capital to cover all project in budget period.

$$\text{p/\$} = \frac{\text{NCR}}{\text{Investment}} \quad (3.2)$$

or

$$\frac{P}{\$} = \frac{\sum_{i=0}^{k} income\ \ or\ revenue - \sum_{i=0}^{k} tax, expenses}{Investment} \quad (3.3)$$

c) Present Value: Present value is the value of the money now that you ought to have in the future. It takes account of the time value of money. This indicator is good one because it helps us to forecast the performance of money invested in future.

From future value equation the present value can be calculated as follows

$$F = P(1+i)^{n} \quad (3.4)$$

Where

F = future value of the money.

P = Present Value of the money

i = the interest rate

n = the number of years.

Making the present value the subject of the formula we have

$$P = \frac{F}{(1+i)^n} \quad (3.5)$$

d) Present Value per Dollar (PV/$): These Indicator measures the present value of money per dollar invested. It is the ratio of present value at a particular rate and the amount invested. It can also serve as a substitute for profit per dollar (P/$). When there is less capital for a project; the present value can be used for choosing the project that comes first by taking the one with the higher PV/$. Mathematically:

$$PV/\$ = \frac{PV@\ Discount\ \ rate}{Investment} \quad (3.6)$$

e) Pay out: The payback tells us how long it will take for us earn back our initial investment. Payout occurs when our cumulative NCR goes positive. Mathematically

$$P.O = N + \frac{L}{k} \quad (3.7)$$

Where N = The Last period (year) before the Cumulative cash flow turns positive.
L = The last cumulative cash flow that is negative.
K = The cash flow that is after the first negative value of cumulative cash flow.

f) Discount Cash Flow rate of return: This is the interest rate that discounts the net present value of the project to zero. DCF-ROR is a powerful indicator; some economist also chooses to define it as the bank rate of interest you make on your investment for a particular project.

Sensitivity analysis

This is used to check the robustness of alternatives to changes in variables used in arriving at the value of the alternatives under consideration. The usual approach is to hold all inputs constant while you vary other inputs. In turn this will help you to know the rate at which these changes affect your result. The rate of this change helps one to understand the project's feasibility and predict the outcome of the project.

Acceleration case/projects

Acceleration projects are one the common cases in the oil and gas, where these may occur are conversion of wells from beam to hydraulic or electrical submergible pumping, infill drilling and other areas where it is necessary. Acceleration projects are evaluated by means of the rate of return. The net present worth and the future worth modification for incremental ROR analysis [1]. Acceleration of projects tends to reach to outcome faster rather than taking the normal route but getting to the outcome quicker comes with a price; this price may be known as premium. This premium is the money paid to get what should take longer in shorter time. It can be used to forecast projects and their outcomes.

Cost Evaluation of CNG and LNG Transportation

LNG Shipping Cost/Charter Rates

The money paid for the shipping LNG has always been an indicative of significant worth of distinct part to include in the assessment of new LNG project breakeven economics, or in choosing the most economical viable condition for LNG vessels. Shipping cost calculations are often focused on current short-term charter rate. The charter rate rose dramatically in the early 2010s, due to high demand of Power (electricity) in Asia coupled with the Fukushima disaster which created a tight LNG spot market. During the early 2013, LNG carrier short-term charter rates fell dramatically from $155,000/day in 2012 to $24,500/day in 2015 [16].

The pandemic that hit the world in late 2019 (COVID-19) affected every business sector including the LNG market, this caused a depression in the shipping industry. LNG exports cargo fell by 0.2% though the gas industry experienced a record commissioning of 134 LNG carrier, with this trend, the demand for LNG carrier was subdued which resulted in the decline of the charter rates. The average charter rate as of July 2020 was $24,000/day. It rose again to $90,000/day which is the record high for the month of December hence the average price for transporting LNG becomes $43,000/day. There have been years when the price was averaged to $124,000/day to $119,000/day [14].

In a research done by [9]. They observed that the owner of a ship within the range of 135,000 m³ to 140,000 m³ costing $200 to $220 million is estimated to ask for payment within the range of $45,000/day to $55,000/day. From the analysis done so far in this research work, we will assume an average amount of $55,000/day throughout the period of 20yrs as the charter rate of the 145,000m3 which falls in the range $45,000 to $65,000.

LNG Ship Prices

According to [9]; the building cost of LNG has decreased over the years from $280 million in the mid-1980s to $155 million during ending of 2003. There has been a great variation in the prices of LNG Ships and this variation is based new technology been incorporated into the vessel, the capacity of the vessel and power requirements and the cost of steel which has been on the increase. Considering the recent upgrade in technology; there has been an increase in the number and capacity of LNG vessel. The average size of the current fleet is almost 120,000m³, whereas the average size of vessels currently in the order book is 156,000m³.

Currently the world largest LNG ship is the MOZAH vessel of Qatar developed in 2006 – 2007 and was launched in 2008 which has a capacity of 266,000m³. In this work we will consider a 149,000 m³ which cost about $220 million.

Operating Cost of LNG ship

There some elements to be considered when in the operating cost of an LNG ship; these are

a) Fixed cost: they are incurred irrespective of employment of the vessel and voyage cost. These are the crew maintenance, administration, and insurance. The fixed cost varies between operators
b) The voyage cost: these are cost that are incurred while on voyage taken as the fuel used, boil of gases (BOG), bunkers and port charges. It is also noteworthy that about 50% of BOG produced while on voyage is used as fuel while on voyage.

The operating cost of an LNG ship varies between $9,000/day and $16,000/day. In these work we will be using operating cost of $14,000/day. We also assume that the tax which may be considered as port charges are also included in these operating cost.

CNG shipping cost

From research done by [4]. Which pointed out that compressed natural gas(CNG) as an alternative to liquefied natural gas transported as marine CNG has a better transportation tariff (between $0.9 per MMBtu – $2.23 per MMBtu) depending on the distance. However, any distance that is more than 2500 miles the cost of CNG transportation becomes significantly higher because of the great difference in volumes of natural gas states (liquid or gas) transported.

In this work we will be using average transportation of $120300/day considering the fluctuation in prices.

There are two types CNG Ships based on container vessel:

1. Coselle Type
2. Pressured bottle type

In this work we will be considering the coselle type CNG carrier though still at its infancy; the reason for considering Coselle type is because it's cheaper to acquire than the conventional pressure bottle type carrier. Most companies that is involved in one way or the other has proposed many type of design but the future for coselle type is very bright. The coselle type allows greater compression ratio at lower pressure and compressed gas liquid technology which mixes with condesate [13].

The total fuel consumed during a round trip is four million standard cubic feet per day (4 MMscfd) for ship fuel and one million standard cubic feet per day (1 MMscfd), a total of five million standard cubic feet per day (5 MMscfd) which represents 1.5% of the capacity of the ship.

CNG Ship Price

Coselle type CNG carrier are newer in the game of transportation, it can be assumed that their development came into the scene in late 1990s. The ship costs $210 million which is a bit cheaper than LNG ship but has a

larger capacity. The C84 means that the ship has 84 coselle and a capacity of 349mmscf. Coselle types are carriers that has a 10-inch pipe wound around a circular container; this pipes are where the gas is injected.

Operating Cost of CNG Ship

The operating and maintenance cost were estimated to be $6.132 million per year per ship (coselle type). Converting it to dollar/day we have $16800/day. It is also necessary that ship owners should take account of their expenses in order to breakeven in their investment and track records. The operating cost encompasses the port fees, tax; if there is any and crew maintenance fee and any other miscellaneous money that is paid.

The operating cost varies among operators that's why it's a negotiable fee; since it's so it better we choose the average operating cost for a particular year or throughout the years of operation which is $16800 per day.

Summary/ Break Down of Cost

Table 2

	CNG	LNG
Vessel price/ cost of Ship.	$210 million	$220 million
Average Operating Cost.	$16800/day	$14,000/day
Capacity.	349 mmscf	145,000 m^3
Average Charter Rates per year	$43909500	$20075000

From the above table it is assumed that the number of years taken into account was the 20yrs of the vessel's life that is from 2000 to 2020.

Calculations and Economic Evaluation

The calculation will be done based on the economic analysis in contrast to the Vessel life span i. e, the life span of the vessel in question. The calculation will involve a life span of 20years. The cost of the vessels will serve as capital expenditure, whereas the it will be deducted from revenue.

Assumption

1. There is an initial cost of tanker vessel, already stated in table above which is the average cost of vessel. The reason for using the average cost is the fluctuation in price of materials used for building the ship, for example the price of steel which increases on a regular basis.
2. The lifecycle of both LNG and CNG vessel is 20 years.
3. The distance is considered to be 2500miles, the reason for this is CNG ship transportation tends to be uneconomical above 2500miles. To make both comparable, we will assume distance travelled to be 2500miles i.e. 2500miles is the distance between loading and unloading terminals.
4. Charter rater is uncertain and fluctuates regularly, hence an average charter rate is chosen.
5. Individual ship capacity is taken to be 145,000m^3.
6. Ship's speed is varied between 9 to 19knots; though this parameter does not have effect in the calculations. If this parameter is at maximum can reduce the number of days spent while on voyage.
7. Overhaul is assumed to be after the 20year period because the trend created is assumed to be continuous so as to get a uniform result.
8. The Boil off ratio is taken as 0.15% per day for LNG.
9. Loading time varies between the two means of transportation i.e. 2days is taken as the average time spent for loading, unloading, berthing and delays.

The table and table below are the economic calculation of LNG and CNG transportation respectively taken account of the project life span of 20 years. The calculation is done using Microsoft Excel.

4. Results and Discussion

Table 3: CNG economic table calculations

CNG VESSEL OF 349mmscf CAPACITY																	
Year	Revenue ($)	INV ($)	Exp/Operating Cost/Tax ($)	Net Cash Recovery(NCR) ($)	CUM Cash flow($)	DISC FACTOR @ 5%	PV @ 5% ($)	DISC FACTOR @ 10%	PV @ 10% ($)	DISC FACTOR @15%	PV @ 15% ($)	DISC FACTOR @ 30%	PV @ 30% ($)	DISC FACTOR @ 60%	PV @ 60% ($)	DISC FACTOR @ 100%	PV @ 100% ($)
0	0	210000000	0	-210000000	-210000000	1.00	-210000000	1.00	-210000000	1.00	-210000000	1.00	-210000000	1.000000	-210000000	1.000000	-210000000
1	43909500	0	6132000	377777500	-172222500	0.952	35978571	0.909	34343182	0.870	32850000	0.769	29053675	0.625000	23610338	0.500000	18888750
2	43909500	0	6132000	377777500	-134445000	0.907	34285306	0.826	31221074	0.756	28565217	0.592	22353550	0.390625	14756836	0.250000	9444375
3	43909500	0	6132000	377777500	-96667500	0.864	32633625	0.751	28382795	0.658	24839319	0.455	17195039	0.244141	9223022	0.125000	4722188
4	43909500	0	6132000	377777500	-58890000	0.823	31079643	0.683	25802541	0.572	21599408	0.350	13226953	0.152588	5764389	0.062500	2361094
5	43909500	0	6132000	377777500	-21112500	0.784	29599660	0.621	23456855	0.497	18782094	0.269	10174579	0.095367	3602743	0.031250	1180547
6	43909500	0	6132000	377777500	156665000	0.746	28190752	0.564	21324414	0.432	16332256	0.207	7826599	0.059605	2251714	0.015625	590273
7	43909500	0	6132000	377777500	54442500	0.711	26847764	0.513	19385831	0.376	14201962	0.159	6020461	0.037253	1407322	0.007813	295137
8	43909500	0	6132000	377777500	92220000	0.677	25569299	0.467	17623483	0.327	12349532	0.123	4631124	0.023283	879576	0.003906	147568
9	43909500	0	6132000	377777500	129997500	0.645	24351713	0.424	16021348	0.284	10736723	0.094	3562403	0.014552	549735	0.001953	73784
10	43909500	0	6132000	377777500	167775000	0.614	23192108	0.386	14564862	0.247	9338020	0.073	2740310	0.009095	343584	0.000977	36892
11	43909500	0	6132000	377777500	205552500	0.585	22087722	0.350	13240783	0.215	8120018	0.056	2107931	0.005684	214740	0.000488	18446
12	43909500	0	6132000	377777500	243330000	0.557	21035926	0.319	12037076	0.187	7060885	0.043	1621485	0.003553	134213	0.000244	9223
13	43909500	0	6132000	377777500	281107500	0.530	20034215	0.290	10942796	0.163	6139900	0.033	1247296	0.002220	83883	0.000122	4612
14	43909500	0	6132000	377777500	318885000	0.505	19080205	0.263	9947996	0.141	5339043	0.025	959459	0.001388	52427	0.000061	2306
15	43909500	0	6132000	377777500	356662500	0.481	18171623	0.239	9043633	0.123	4642646	0.020	738045	0.000867	32767	0.000031	1153
16	43909500	0	6132000	377777500	394440000	0.458	17306308	0.218	8221485	0.107	4037084	0.015	567727	0.000542	20479	0.000015	576
17	43909500	0	6132000	377777500	432217500	0.436	16482198	0.198	7474077	0.093	3510508	0.012	436713	0.000339	12800	0.000008	288
18	43909500	0	6132000	377777500	469995000	0.416	15697332	0.180	6794615	0.081	3052615	0.009	335933	0.000212	8000	0.000004	144
19	43909500	0	6132000	377777500	507772500	0.396	14949840	0.164	6176323	0.070	2654448	0.007	258410	0.000132	5000	0.000002	72
20	43909500	0	6132000	377777500	545550000	0.377	14237942	0.149	5615385	0.061	2308216	0.005	198777	0.000083	3125	0.000001	36
			NCR =	545550000			260791151		111621153		26461895		-84737590		-147042708		-172222536

Table 4: LNG economic table calculations

LNG VESSEL OF 149000m³ CAPACITY																	
Year	Revenue ($)	INV ($)	Exp/Operating Cost/Tax ($)	Net Cash Recovery(NCR) ($)	CUM Cash flow ($)	DISC FACTOR @ 5%	PV @ 5% ($)	DISC FACTOR @ 10%	PV @ 10% ($)	DISC FACTOR @15%	PV @ 15% ($)	DISC FACTOR @ 30%	PV @ 30% ($)	DISC FACTOR @ 60%	PV @ 60% ($)	DISC FACTOR @ 100%	PV @ 100% ($)
0	0	220000000	0	-220000000	-220000000	1.00	-220000000	1.00	-220000000	1.00	-220000000	1.00	-220000000	1.000000	-220000000	1.000000	-220000000
1	20075000	0	5110000	14965000	-205035000	0.952	14252381	0.909	13604545	0.870	13013043	0.769	11511538	0.625000	9353125	0.500000	7482500
2	20075000	0	5110000	14965000	-190070000	0.907	13573696	0.826	12367769	0.756	11315690	0.592	8855030	0.390625	5845703	0.250000	3741250
3	20075000	0	5110000	14965000	-175105000	0.864	12927330	0.751	11243426	0.658	9839730	0.455	6811561	0.244141	3653564	0.125000	1870625
4	20075000	0	5110000	14965000	-160140000	0.823	12311743	0.683	10221296	0.572	8556287	0.350	5239662	0.152588	2283478	0.062500	935313
5	20075000	0	5110000	14965000	-145175000	0.784	11725469	0.621	9292088	0.497	7440250	0.269	4030510	0.095367	1427174	0.031250	467656
6	20075000	0	5110000	14965000	-130210000	0.746	11167113	0.564	8447352	0.432	6468782	0.207	3100392	0.059605	891984	0.015625	233828
7	20075000	0	5110000	14965000	-115245000	0.711	10635346	0.513	7679411	0.376	5625898	0.159	2384917	0.037253	557490	0.007813	116914
8	20075000	0	5110000	14965000	-100280000	0.677	10128901	0.467	6981283	0.327	4892085	0.123	1834551	0.023283	348431	0.003906	58457
9	20075000	0	5110000	14965000	-85315000	0.645	9646572	0.424	6346621	0.284	4253987	0.094	1411193	0.014552	217769	0.001953	29229
10	20075000	0	5110000	14965000	-70350000	0.614	9187212	0.386	5769655	0.247	3699119	0.073	1085533	0.009095	136106	0.000977	14614
11	20075000	0	5110000	14965000	-55385000	0.585	8749726	0.350	5245141	0.215	3216625	0.056	835026	0.005684	85066	0.000488	7307
12	20075000	0	5110000	14965000	-40420000	0.557	8333072	0.319	4768310	0.187	2797066	0.043	642327	0.003553	53166	0.000244	3654
13	20075000	0	5110000	14965000	-25455000	0.530	7936259	0.290	4334827	0.163	2432231	0.033	494098	0.002220	33229	0.000122	1827
14	20075000	0	5110000	14965000	-10490000	0.505	7558342	0.263	3940752	0.141	2114963	0.025	380075	0.001388	20768	0.000061	913
15	20075000	0	5110000	14965000	4475000	0.481	7198421	0.239	3582502	0.123	1839116	0.020	292366	0.000867	12980	0.000031	457
16	20075000	0	5110000	14965000	19440000	0.458	6855639	0.218	3256820	0.107	1599231	0.015	224897	0.000542	8113	0.000015	228
17	20075000	0	5110000	14965000	34405000	0.436	6529180	0.198	2960745	0.093	1390636	0.012	172997	0.000339	5070	0.000008	114
18	20075000	0	5110000	14965000	49370000	0.416	6216267	0.180	2691587	0.081	1209243	0.009	133075	0.000212	3169	0.000004	57
19	20075000	0	5110000	14965000	64335000	0.396	5922159	0.164	2446897	0.070	1051521	0.007	102365	0.000132	1981	0.000002	29
20	20075000	0	5110000	14965000	79300000	0.377	5640151	0.149	2224452	0.061	914366	0.005	78743	0.000083	1238	0.000001	14
			NCR =	79300000			-33503022		-92594513		-126329184		-170379142		-195868336		-205835014

Net Cash Recovery/Net Present Value (NCR/NPV)

The NCR of both CNG and LNG is gotten from Table above respectively.

The NCR for LNG transportation is $79,300,000 while that of CNG is $545,550,000. Considering only NCR; it is a good project to invest in the with higher NCR in this case the NCR of CNG transportation, which is a lot bigger than the LNG's transportation NCR. In general, it is wiser to invest in transportation of CNG because of the higher NCR.

Profit per Dollar (P/$)

Using Equation 3.4, the profit per dollar (which is the profit made per dollar invested) was calculated to be $0.3605 for LNG transportation which means that for every dollar invested a return of 3.605cents is made. Having zero as the result of profit /dollar means that the money invested didn't yield any profit rather what was invested was gotten back. While

For CNG transportation the profit per is $2.598; it can be seen clearly that the P/$ for CNG transportation is more lucrative, because each dollar invested yielded $2.598 which is higher the LNG transportation. Considering these indicators and comparing both, it will be an optimal decision to choose the one with higher P/$; hence CNG transportation will be a very lucrative project to invest in.

Present Value (PV)

From table 3.4.1 the PV @ 5% for is denoted as -33503022 dollars written as ($33503022) the bracket shows that it is negative PV which is for LNG's transportation, while the PV at 5% for CNG transportation is stated explicably in table 3.4.2 and it reads $260791151. Comparing the two PVs; you will see that the one for CNG is bigger; not just bigger but also positive. The optimal decision here is to choose the CNG transportation for it will be more profitable when discounted at the rate of 5%.

Present Value per Dollar (PV/$)

This is an abstract measurement; it is not often used in economic evaluation. It serves as a ranking tool for project. By considering the one with higher PV/$; it becomes the better project to venture into. Looking at our economic table above and from the calculation done above; the PV/$ at 15% gives$0.12601 for CNG transportation while LNG transportation gives ($0.574) which is on the negative part. Considering one of the higher value it will be LNG transportation but since it is a negative value it is a better decision to go for CNG transportation since it is a positive value.

Pay Out (P.O).

From the result gotten from above it can be seen clearly that CNG has a lower transportation pay out of 5.6 years; this means that you start getting returns after 5 – 6 years of investing in the project

While LNG has a higher transportation pay out of 14.7 years; this mean that returns start coming in after 14 – 15 years of investing in the project.

Since Pay Out is a measure of efficiency, it's a wiser decision to go for the one with lower pay out because the quicker you get your money back from a project you invested in the better and you may choose to re-invest or keep as returns. Therefore, the P.O of 5.6 years is clearly the best option which is for CNG transportation.

Discount Cash Flow – Rate of Return (DCF-ROR)

Table 5: Summary of results

	CNG Transportation Results	LNG Transportation Results	OPTIMAL DECISION
(NCR/NPV)	$545,550,000.	$79,300,000	CNG Transportation with higher NCR
Profit per Dollar (P/$)	$2.598	$0.3605	Higher CNG profit per dollar is an optimal decision.
Present Value (PV)@ 5%	$260791151	($33503022)	Since CNG transportation is positive it wiser to the project
Present Value per Dollar (PV/$)	$0.12601	($0.574)	Snice LNG transportation is negative is then more valuable to go for CNG transportation
Pay Out (P.O)	5.6 years	14.7 years	Lower payout is an optimal decision
Discount Cash Flow – Rate of Return (DCF-ROR)	18%	2.74%	Lower LNG transportation ROR ensures against borrowing while higher ROR of CNG provides higher investment/operation money; hence higher DCF-ROR

Figure 1: Cashflow vs Discounted for LNG Transportation

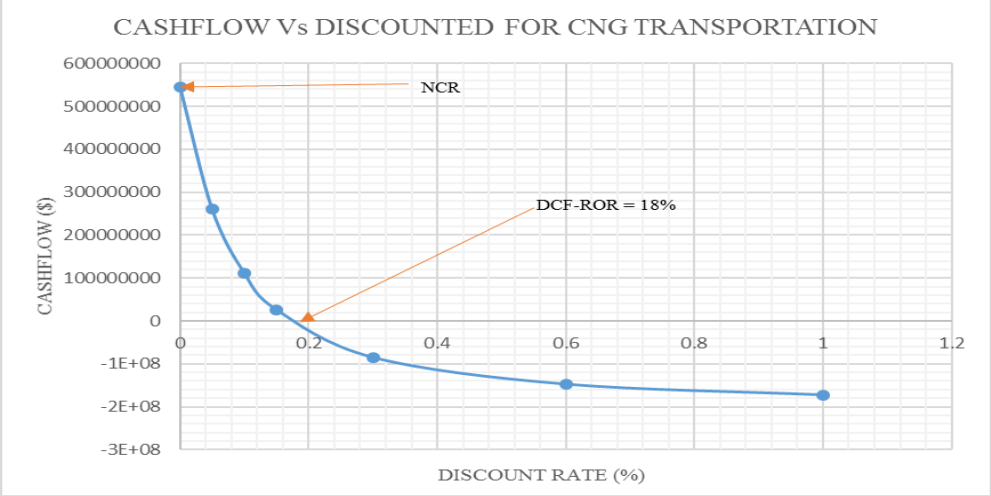

Figure 2: Cashflow vs Discounted for CNG Transportation

Sensitivity Analysis for CNG and LNG Transportation

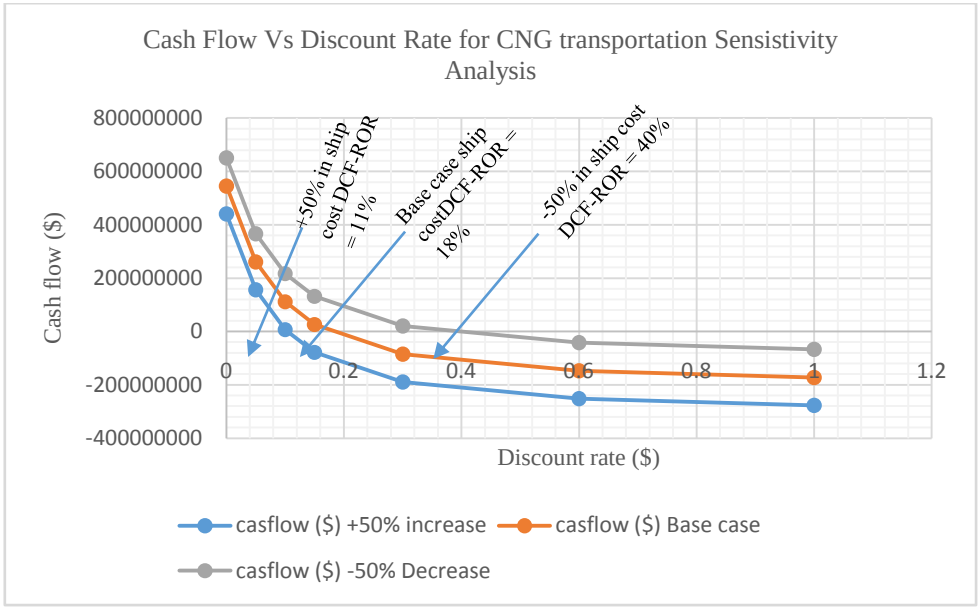

Figure 3: Cash Flow vs Discount Rate for CNG transportation Sensitivity Analysis

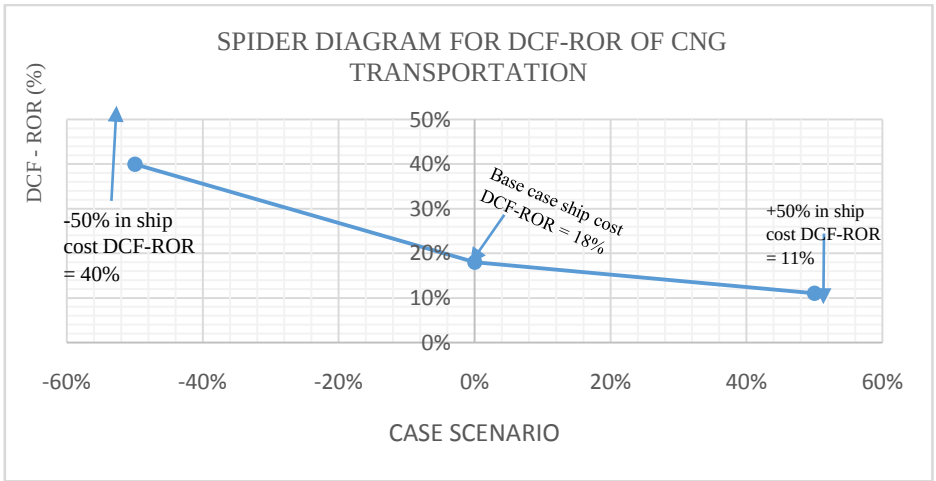

Figure 4: Spider Diagram for DCF-ROR of CNG Transportation

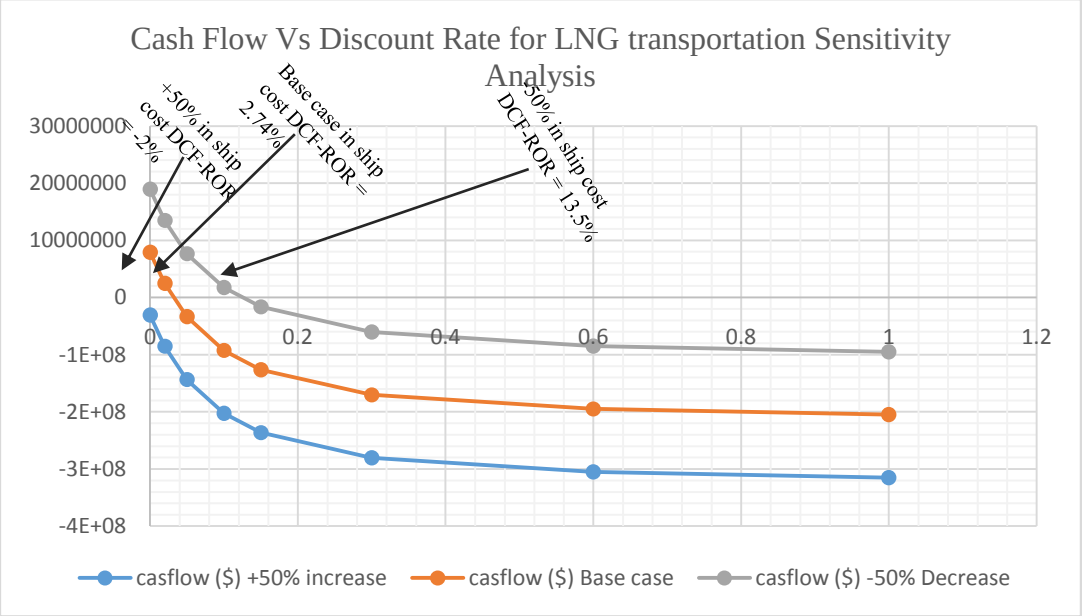

Figure 5: Cash Flow Vs Discount Rate for LNG transportation Sensitivity Analysis

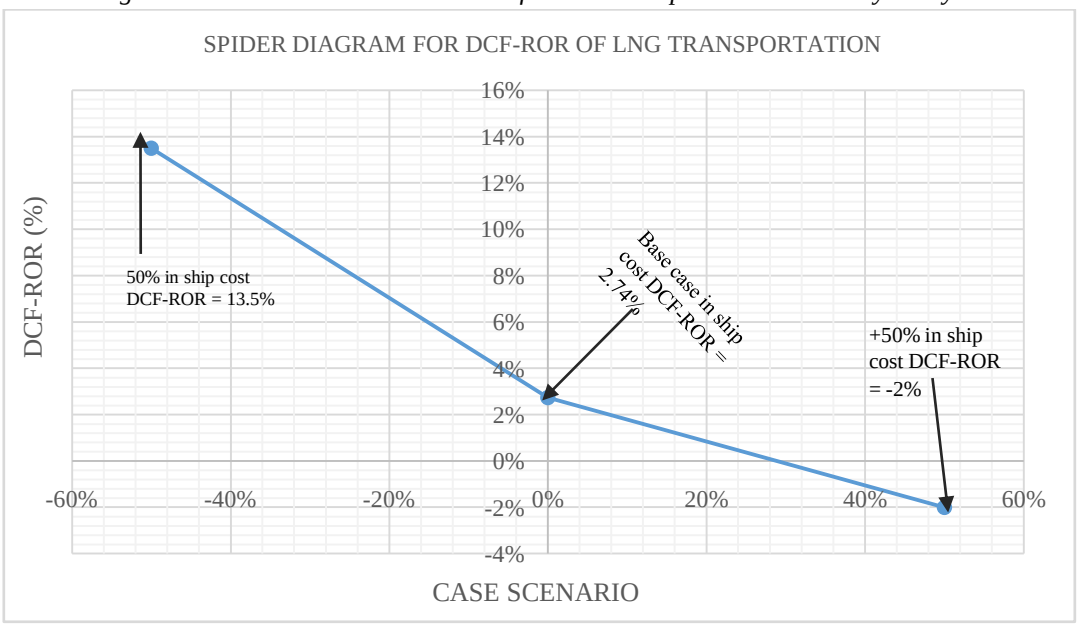

Figure 6: Spider Diagram for DCF-ROR of LNG Transportation

As we can see from figure above that the plot for 50% increase in the graph did not pass through zero; recall that DCF-ROR can only be found when the plot passes through zero, but in this it did not. To then find this we will assume the plot to continue or we use dotted lines projected further to spot our DCF-ROR. In this graph we can clearly see that DCF-ROR is from the negative side of the graph which is -0.02 or -2%

Acceleration Case Results

Table 9: Acceleration case of CNG Transportation

ACCELERATION CASE OF CNG TRANSPORTATION																			
Year	Net Cash Recovery(NCR) ($) A	Net Cash Recovery(NCR) ($) B	INC-Cashflow($) B-A	CUM. INC. Cashflow ($)	Disc. Factor @ 2%	PV @ 2% ($)	DISC FACTOR @ 5%	PV @ 5% ($)	DISC FACTOR @ 10%	PV @ 10% ($)	DISC FACTOR @15%	PV @ 15% ($)	DISC FACTOR @ 30%	PV @ 30% ($)	DISC FACTOR @ 60%	PV @ 60% ($)	DISC FACTOR @ 100%	PV @ 100% ($)
0	-210000000	-319110000	-109110000	-109110000	1.000	-109110000	1.000	-109110000	1.000	-109110000	1.000	-109110000	1.000	-109110000	1.000	-109110000	1.000	-109110000
1	37777500	75555000	37777500	-71332500	0.980	37036765	0.952	35978571.43	0.909	34343182	0.870	32850000	0.769	29059615	0.625	23610938	0.500	18888750
2	37777500	75555000	37777500	-33555000	0.961	36310554	0.907	34265306.12	0.826	31221074	0.756	28565217	0.592	22353550	0.391	14756836	0.250	9444375
3	37777500	75555000	37777500	4222500	0.942	35598582	0.864	32633624.88	0.751	28382795	0.658	24839319	0.455	17195039	0.244	9223022	0.125	4722188
4	37777500	75555000	37777500	42000000	0.924	34900571	0.823	31079642.74	0.683	25802541	0.572	21599408	0.350	13226953	0.153	5764389	0.063	2361094
5	37777500	75555000	37777500	79777500	0.906	34216246	0.784	29599659.75	0.621	23456855	0.497	18782094	0.269	10174579	0.095	3602743	0.031	1180547
6	37777500	75555000	37777500	117555000	0.888	33545339	0.746	28190152.15	0.564	21324414	0.432	16332256	0.207	7826599	0.060	2251714	0.016	590273
7	37777500	75555000	37777500	155332500	0.871	32887587	0.711	26847763.95	0.513	19385831	0.376	14201962	0.159	6020461	0.037	1407322	0.008	295137
8	37777500	75555000	37777500	193110000	0.853	32242732	0.677	25569299	0.467	17623483	0.327	12349532	0.123	4631124	0.023	879576	0.004	147568
9	37777500	75555000	37777500	230887500	0.837	31610522	0.645	24351713.33	0.424	16021348	0.284	10738723	0.094	3562403	0.015	549735	0.002	73784
10	37777500	75555000	37777500	268665000	0.820	30990708	0.614	23192107.94	0.386	14564862	0.247	9338020	0.073	2740310	0.009	343584	0.001	36892
11	37777500	0	-37777500	230887500	0.804	-30383047	0.585	-22087721.8	0.350	-13240783	0.215	-8120018	0.056	-2107931	0.006	-214740	0.000	-18446
12	37777500	0	-37777500	193110000	0.788	-29787301	0.557	-21035925.6	0.319	-12037076	0.187	-7060885	0.043	-1621485	0.004	-134213	0.000	-9223
13	37777500	0	-37777500	155332500	0.773	-29203236	0.530	-20034214.8	0.290	-10942796	0.163	-6139900	0.033	-1247296	0.002	-83883	0.000	-4612
14	37777500	0	-37777500	117555000	0.758	-28630624	0.505	-19080204.6	0.263	-9947996	0.141	-5339043	0.025	-959459	0.001	-52427	0.000	-2306
15	37777500	0	-37777500	79777500	0.743	-28069239	0.481	-18171623.4	0.239	-9043633	0.123	-4642646	0.020	-738045	0.001	-32767	0.000	-1153
16	37777500	0	-37777500	42000000	0.728	-27518862	0.458	-17306308	0.218	-8221485	0.107	-4037084	0.015	-567727	0.001	-20479	0.000	-576
17	37777500	0	-37777500	4222500	0.714	-26979276	0.436	-16482198.1	0.198	-7474077	0.093	-3510508	0.012	-436713	0.000	-12800	0.000	-288
18	37777500	0	-37777500	-33555000	0.700	-26450271	0.416	-15697331.5	0.180	-6794615	0.081	-3052615	0.009	-335933	0.000	-8000	0.000	-144
19	37777500	0	-37777500	-71332500	0.686	-25931638	0.396	-14949839.6	0.164	-6176923	0.070	-2654448	0.007	-258410	0.000	-5000	0.000	-72
20	37777500	0	-37777500	-109110000	0.673	-25423175	0.377	-14237942.4	0.149	-5615385	0.061	-2308216	0.005	-198777	0.000	-3125	0.000	-36
	545550000	**436440000**	**-109110000**			**-48147063**		**3514531.359**		**33521614**		**33621169**		**-791143**		**-47287573**		**-71406248**

Table 10: Acceleration case of LNG Transportation

ACCELERATION CASE OF LNG TRANSPORTATION																			
Year	Net Cash Recovery(NCR) ($) A	Net Cash Recovery(NCR) ($) B	INC-Cashflow($) B-A	CUM. INC. Cashflow ($)	Disc. Factor @ 1%	PV @ 1% ($)	Disc. Factor @ 2%	PV @ 2% ($)	DISC FACTOR @ 5%	PV @ 5% ($)	DISC FACTOR @ 10%	PV @ 10% ($)	DISC FACTOR @15%	PV @ 15% ($)	DISC FACTOR @ 30%	PV @ 30% ($)	DISC FACTOR @ 60%	PV @ 60% ($)	DISC FACTOR @ 100%	PV @ 100% ($)
0	-220000000	-235860000	-15860000	-15860000	1.000	-15860000	1.00	-15860000	1.00	-15860000	1.00	-15860000	1.000	-15860000	1.000	-15860000	1.000	-15860000	1.000	-15860000
1	14965000	29930000	14965000	-895000	0.990	14816832	0.98	14671569	0.952	14252381	0.909	13604545	0.870	13013043	0.769	11511538	0.6250	9353125	0.50000	7482500
2	14965000	29930000	14965000	14070000	0.980	14670130	0.96	14383891	0.907	13573696	0.826	12367769	0.756	11315690	0.592	8855030	0.3906	5845703	0.25000	3741250
3	14965000	29930000	14965000	29035000	0.971	14524882	0.94	14101854	0.864	12927330	0.751	11243426	0.658	9839730	0.455	6811561	0.2441	3653564	0.12500	1870625
4	14965000	29930000	14965000	44000000	0.961	14381071	0.92	13825347	0.823	12311743	0.683	10221296	0.572	8556287	0.350	5239662	0.1526	2283478	0.06250	935313
5	14965000	29930000	14965000	58965000	0.951	14238684	0.91	13554262	0.784	11725469	0.621	9292088	0.497	7440250	0.269	4030510	0.0954	1427174	0.03125	467656
6	14965000	29930000	14965000	73930000	0.942	14097707	0.89	13288492	0.746	11167113	0.564	8447352	0.432	6469782	0.207	3100392	0.0596	891984	0.01563	233828
7	14965000	29930000	14965000	88895000	0.933	13958126	0.87	13027933	0.711	10635346	0.513	7679411	0.376	5625898	0.159	2384917	0.0373	557490	0.00781	116914
8	14965000	29930000	14965000	103860000	0.923	13819926	0.85	12772483	0.677	10128901	0.467	6981283	0.327	4892085	0.123	1834551	0.0233	348431	0.00391	58457
9	14965000	29930000	14965000	118825000	0.914	13683095	0.84	12522043	0.645	9646572	0.424	6346621	0.284	4253987	0.094	1411193	0.0146	217769	0.00195	29229
10	14965000	29930000	14965000	133790000	0.905	13547619	0.82	12276512	0.614	9187212	0.386	5769655	0.247	3699119	0.073	1085533	0.0091	136106	0.00098	14614
11	14965000	0	-14965000	118825000	0.896	-13413484	0.80	-12035796	0.585	-8749726	0.350	-5245141	0.215	-3216625	0.056	-835026	0.0057	-85066	0.00049	-7307
12	14965000	0	-14965000	103860000	0.887	-13280678	0.79	-11799800	0.557	-8333072	0.319	-4768310	0.187	-2797066	0.043	-642327	0.0036	-53166	0.00024	-3654
13	14965000	0	-14965000	88895000	0.879	-13149186	0.77	-11568432	0.530	-7936259	0.290	-4334827	0.163	-2432231	0.033	-494098	0.0022	-33229	0.00012	-1827
14	14965000	0	-14965000	73930000	0.870	-13018996	0.76	-11341600	0.505	-7558342	0.263	-3940752	0.141	-2114983	0.025	-380075	0.0014	-20768	0.00006	-913
15	14965000	0	-14965000	58965000	0.861	-12890095	0.74	-11119215	0.481	-7198421	0.239	-3582502	0.123	-1839116	0.020	-292366	0.0009	-12980	0.00003	-457
16	14965000	0	-14965000	44000000	0.853	-12762470	0.73	-10901192	0.458	-6855639	0.218	-3256820	0.107	-1599231	0.015	-224897	0.0005	-8113	0.00002	-228
17	14965000	0	-14965000	29035000	0.844	-12636109	0.71	-10687443	0.436	-6529180	0.198	-2960745	0.093	-1390636	0.012	-172997	0.0003	-5070	0.00001	-114
18	14965000	0	-14965000	14070000	0.836	-12510999	0.70	-10477885	0.416	-6218267	0.180	-2691587	0.081	-1209249	0.009	-133075	0.0002	-3169	0.00000	-57
19	14965000	0	-14965000	-895000	0.828	-12387128	0.69	-10272436	0.396	-5922159	0.164	-2446897	0.070	-1051521	0.007	-102365	0.0001	-1981	0.00000	-29
20	14965000	0	-14965000	-15860000	0.820	-12264483	0.67	-10071016	0.377	-5640151	0.149	-2224452	0.061	-914366	0.005	-78743	0.0001	-1238	0.00000	-14
	79300000	**63440000**	**-15860000**			**-2435556**		**8289569**		**28754549**		**40641412**		**40680849**		**27048919**		**8630044**		**-924214**

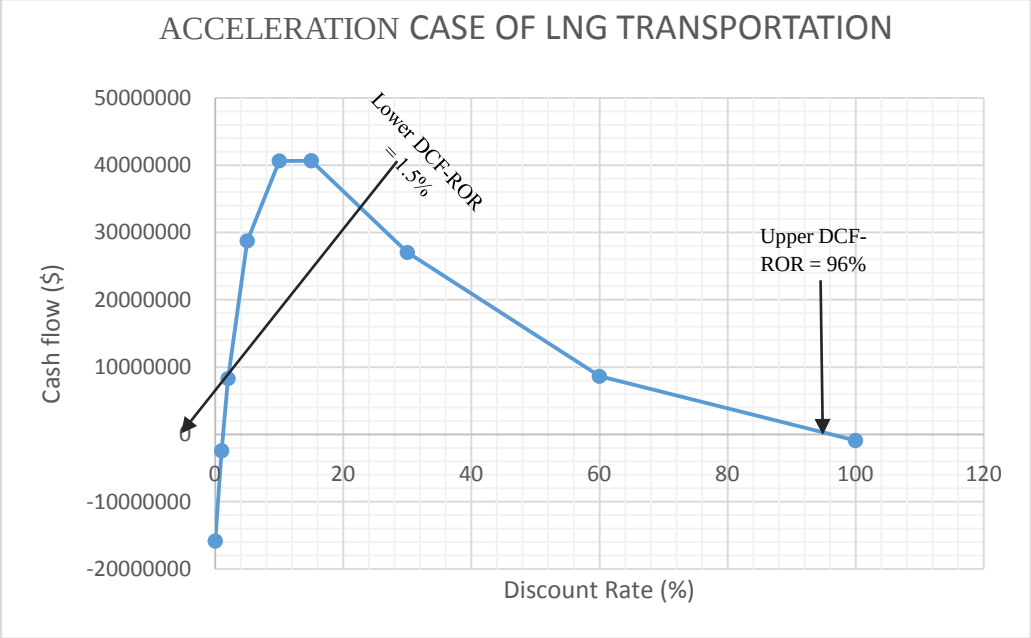

Figure 7: Acceleration Case of LNG Transportation

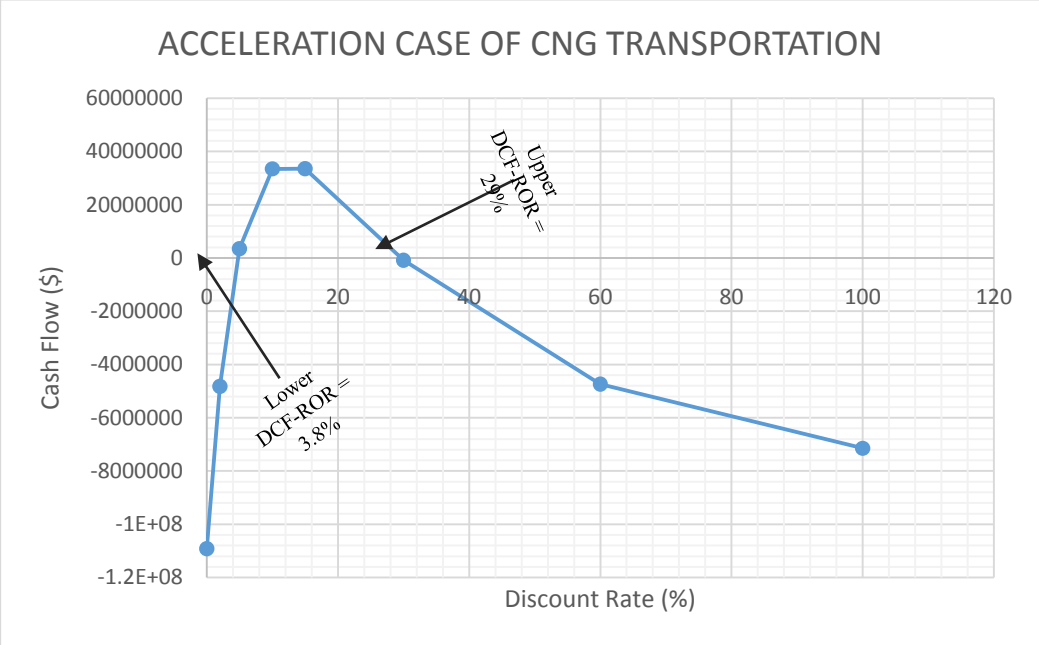

Figure 8: Acceleration Case of CNG Transportation

From figure above which is the acceleration case plot of LNG transportation, we could see that there are two DCF-ROR; Lower and Upper DCF-ROR. Before we continue the discussion I would like to introduce to you some criteria;

a) There should be an upper DCF-ROR that advantageously competes with the DCF-ROR from conventional projects.

b) The project should depict a lower DCF-ROR; as low as possible to show a reasonable "borrowing from ourselves" cost. Also note that this lower DCF-ROR is an after tax loan cost.

c) The Present value per Dollar should be of a great magnitude at over $1.00 to insure against risk. These criteria will help us decide which the project is more viable; for mere looking at the values gotten from the acceleration case can result to indecisive scenario.

LNG acceleration results;

Investment = $15860000 NCR = ($15860000)
P/$ = $1.00 Pay Out = 1.1year
PV @ 15% = $40680849 PV/$ = 2.56
Lower DCF-ROR = 1.5% Upper DCF-ROR = 96%

CNG acceleration results;

Investment = $109110000 NCR = ($109110000)
P/$ = $1.00 Pay Out = 2.9 years
PV @ 15% = $33621169 PV/$ @ 15% = 0.308
Lower DCF-ROR = 3.8% Upper DCF-ROR = 29%.

As we can see LNG acceleration case has shown to be a good viable option because it has obeyed the three criteria though the PV/$ is not above $1.00; looking at the other. LNG acceleration case has an Upper DCF-ROR of 96% while CNG acceleration case has Upper DCF-ROR of 29%; recall from the criteria, we need a very high DCF-ROR. Consequently, LNG depicts this with a value of 96%. This favorably competes with the DCF-ROR from conventional projects.

LNG acceleration case also has least Low DCF-ROR of 1.5%; this ensures that a low after tax loan cost while CNG acceleration Lower DCF-ROR which is 3.8% is not low enough to compete with it. In general, it is a viable option to go invest in LNG accelerated numbers. This also shows that LNG is flexible when it comes to varying the parameters to see effects. It is always advisable to perform sensitivity analysis after a project has been accelerated for this gives a deeper insight, helps to make better decision.

5. Conclusion

The Economic Indicators has shown profound insight on which gas optimization between LNG and CNG transportation is more viable. This work did not take account of any eventualities that may seem to affect CNG and LNG transportation. These include, Contractual agreement involved between receiving Feed gas and the one involved processing it. With all these been considered; it always a better option to transport LNG using Vessel to far distance (globally). We have seen so far how the six economic indicators have helped us perform calculations and also in decision making by analyzing various problems or assumptions for the cash flow. In other words, the cash flow for the proposed project is an estimate; there is no guarantee that it is accurate in terms of prediction on outcome but the main purpose is make sure that your predictions are reasonable correct. CNG base case results looks better because the distance been considered is assumed to be within 2500 nautical miles. Remember CNG transportation is not cost effective for distance above 2500 nautical mile. The Acceleration case result has shown that LNG transportation is more flexible and its parameters are adapting to changes; it has shown that it will be profitable when distance exceeds 2500 nautical miles.

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