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Study of Oil Linked LNG Pricing Model in Japan

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ABSTRACT

A need for change in traditional crude oil linked LNG (Liquefied Natural Gas) pricing mechanism is strongly felt by Japanese buyers, as they have been adversely affected due to wild fluctuations in global oil prices in past 10 years. This study aims to establish the imperfectness in present LNG pricing mechanism by analyzing it against carefully selected economic & energy variables. Around 10 years' monthly data was analyzed for correlation using linear regression models. The same variables were compared with a diametrically opposite Henry Hub Index of US, which is an open market pricing mechanism. We observed the current LNG pricing mechanism's strong correlation with unrelated parameters and on other hand with no or very little correlation with some of the very important parameters. Crude oil prices were very strongly correlated as expected but there was little or no correlation with alternative energy sources such as coal prices, renewable energy etc. Other market fundamentals such as demand/supply gap, JPY/USD exchange rate, Henry Hub Index have also not shown any correlation with oil linked LNG prices. However, Japan is not likely to switch over to market based pricing system entirely and major part contract is still expected be pegged with some reference point. The study suggests that the reference point should be changed from oil alone to a basket of competitive & alternative energy indices such as coal, oil products, renewable energy etc. The balance LNG should be sourced through Hub pricing based on market fundamentals. This study is expected to provide a direction to negotiate better terms with inclusion of the recommended parameters in the new contracts.

INTRODUCTION

Japan is by far the largest importer of LNG in the world and accounted for 32.3% of worldwide Import LNG cargo volume in 2016. Until recently, majority of LNG import prices in Japan were closely linked with crude oil index JCC (Japanese Crude Cocktail: A basket of crude oil prices). As there was no specific LNG pricing model available in the past, crude oil being a well-established market worldwide was used as a benchmark to LNG pricing in Japan. Oil linked LNG pricing provided a stable supply of gas at a relatively stable price range which is especially suitable for big investment projects.

The linkage between oil and LNG pricing is based on some formula. The exact details of formula and terms of the contract are not very transparent and limited between buyers & sellers. Various studies have demonstrated that relationship was characterized by a time lag of about 5 months between world crude prices and LNG prices with an addition of S-curve to dampen the effect of extreme high & low oil prices on LNG prices. However due to various changes in last few years such as dramatic rise and collapse of crude oil prices, worldwide changes in demand and supply dynamics etc., the pure oil linked pricing mechanism was under pressure and a requirement for an alternative price Mechanism is felt.

First signs of trouble were felt when Crude oil prices soared above $100/bbl and as a result linked LNG prices skyrocketed too. This was followed up by Fukushima Nuclear Power Plant disaster & shutdown in 2011. As a result LNG demand went up by 20 bcm. The additional requirement was compensated by purchase through

Spot and other Index based LNG resources which were relatively cheaper. Since majority of LNG supplies in Japan is done through oil linked long term contracts, the LNG import prices in Japan were much higher than

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most parts of the world. Below price data from year 2011 to 2013 gives a glimpse of wide price spread, arbitrage opportunities and inability of Japanese buyers to buy freely from cheaper options due to long term oil linked contracts.

- Henry Hub $2 to $5/mmbtu,
- European Hubs $8 to $11/mmbtu,
- Asian LNG oil linked contract prices $15 to $18/mmbtu;
- Asian LNG spot prices $13 to $19/mmbtu.
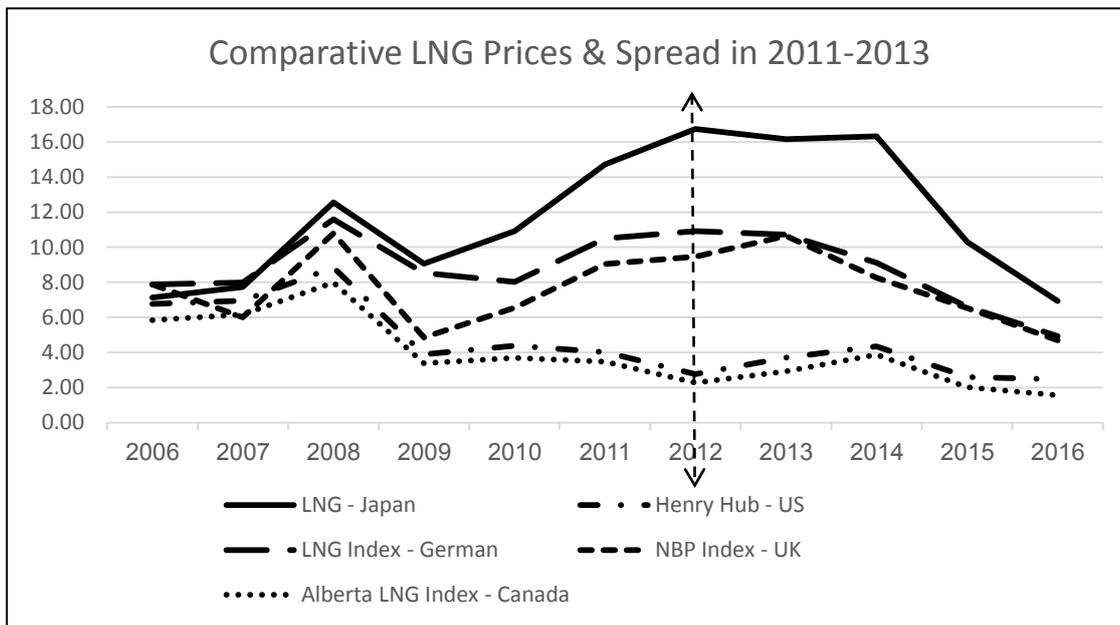
Gas Market Types:

Most Asian gas prices are pegged with crude oil, whereas US gas prices are based on Henry Hub pricing index which is an open market based system. On other hand Europe has started moving from traditionally oil linked pricing system and over 60% of gas sold in Europe is now based on hub prices.

There are 3 broad categories of LNG markets based on different pricing mechanisms:

1. Oil Linked LNG Pricing (Mainly Asia-Pacific)
2. Gas on Gas Hub Pricing: Based on Supply/Demand Balance (Mainly US, UK & Canada Markets: Henry Hub, NBP etc.)
3. Mixed Pricing: Brent/Oil Product(s) link and part Hub pricing (Continental Europe market)

1. Oil Linked LNG Pricing:
In absence of a well-established reference point, the LNG prices were tagged with crude oil in North Asian countries like Japan, Korea & Taiwan. In 80s, LNG prices were calculated basis government selling crude oil prices. Later in 90s LNG prices was linked to JCC (Japan Crude Cocktail) prices. The exact details of formula to link crude oil and LNG prices and terms of the contract are not very transparent and limited between buyers & sellers. Various studies have demonstrated that relationship was characterized by a time lag of about 5 months between world crude prices and LNG prices. In order to absorb wild fluctuations of crude oil in world market an S type curve was introduced with lower

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slopes at both ends. The slop of S curve at middle and at both ends is decided between contracted parties. Broadly speaking the LNG oil linked price formula is linked with oil, expressed as follows:

LNG = A x OIL + B

Where: LNG = LNG Prices, OIL = Crude oil Prices (JCC), A = Slope, B = Constant)
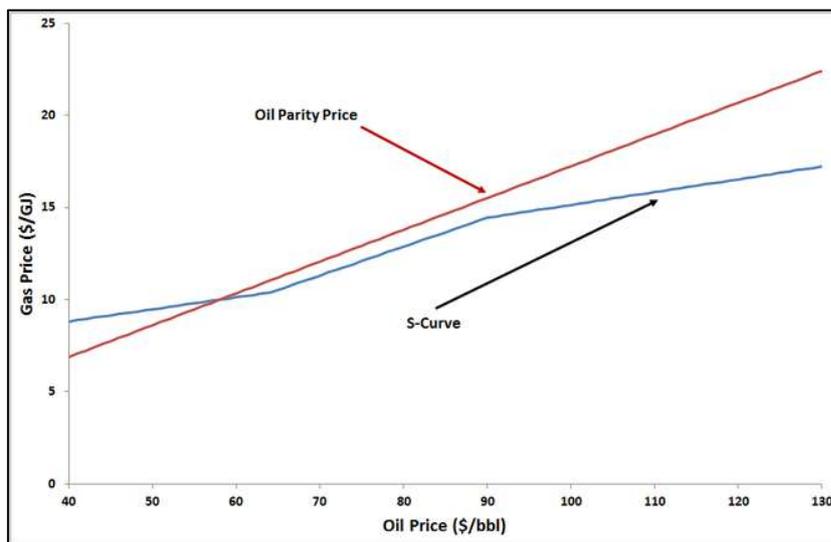
Source: Japanese S-Curve Contract prices Adapted from Global Natural Gas Markets Overview: A Report Prepared by Leidos, Inc., Under Contract to EIA (www.eia.gov/workingpapers/pdf/global_gas.pdf); http://reneweconomy.com.au

2. Gas on Gas Hub Pricing:
This is the case of an established gas market with many buyers and sellers at the same place and the price is determined based on local or regional gas supply and demand, depending on the area covered & popularity of such as hub. The gas fundaments form the basis of gas pricing and trading is done in and open and transparent manner. US, Canada & most of Europe have such kind of hub pricing, named as Henry Hub (US), National Balancing Point (NBP, UK) etc. Adoption of such Hub pricing protected these countries from much higher oil linked gas pricing.

Depending on the prevailing market conditions, the short term gas pricing can be volatile but the long term price security for high investment projects, which has been a key attracting point for oil linked pricing can be achieved through Gas future contracts which are traded freely in a hub system.

With much liquidity all new supplies and demand even large in size can be accommodated in Hub trading system without individual buyers and sellers entering into a new contract and negotiations.

Henry Hub & it's relevance in this study:

Although Henry Hub is a US Gas price index, it has been extensively discussed and analysed in this study. US gas market is the most dynamic of all the world gas markets and its gas index Henry Hub is considered to be a pure free market based index. Japan's oil linked pricing & open market Henry Hub are two extremes of LNG pricing system and a comparative analysis between the two is expected to provide the necessary direction and scale of change for the oil linked pricing system of Japan.

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Sabine Pipeline LLC owns and operates Henry Gas Processing Plant in Louisiana, which is the largest gas collection and interconnection facility in Southern Louisiana US. Gas wholesale prices are referenced to Henry Hub, the interconnection point for thirteen 13 major US inter and intrastate pipelines. The movement of Henry Hub Index is purely based on actual demand & supply conditions of gas at the Hub. Since 1990, the New York Mercantile Exchange (NYMEX) has adopted Henry Hub as the benchmark point for gas trading.

The US is the most developed and deregulated market LNG market with a transparent pricing at work. As the US is fast becoming a net exporter of LNG having Henry Hub as the base price, it is expected that America's hub pricing mechanism will increasingly be used and set an international benchmark price for natural gas.

3. Mixed Pricing:

As name suggests, a mix of both Hub pricing and Crude Oil/Oil Product linked pricing mechanism is prevalent in most of the Central and Southern Europe.

Most long term gas contracts are linked with Brent crude oil or other oil products/energy reference, such as diesel, kerosene or even coal. Although the hub pricing system is also making good progress in these regions.

Review of Literature and Research Structure

1. Jonathan Stern and Howard Rogers (2013) in the paper 'The Pricing of Internationally Traded Gas: the search for new fundamentals (IEEJ, March 2013) indicated that Oil linked LNG pricing has no fundamentals and an Alternative pricing mechanism for the LNG outside US is necessary. They further said that LNG prices outside America have been traditionally linked to oil prices as oil index is well established and LNG is an alternate fuel to oil and to support long term investment of projects. The oil linked prices were not based on fundamentals and begin to strain when fundaments such as supply & demand changed. Need for an alternative Price mechanism was felt.

2. Ken Koyama (2012 in the paper 'An Analysis on Asian Premium for LNG Price, (IEEJ: March 2012) stated that oil linked LNG Prices are higher than Import LNG from US to Japan including the shipping cost. He further stated that Japan's oil linked LNG import prices were much higher than LNG prices in other parts of the world including British NBP Index and Henry Hub Index of US. This is to the extent that LNG imported to Asia from US based on HH pricing + shipping cost is cheaper than Japan's oil linked prices. This price gap is known as Asian Premium should be reduced or eliminated.

3. Kenneth B. Medlock Iii (2014), In the paper 'Natural Gas Price In Asia: What To Expect And What It Means' (James A. Baker III Institute for Public Policy, Rice University) discusses about changes In Supply Dynamics with new avenues opening up & Shale Gas boom in US. Competition in LNG supply side is increasing up due to change in supply dynamics with US Shale gas boom and new supply avenues opening up all over world. This will eventually need to change gas pricing model in Asia.

4. Mark Agerton (2014), In paper, Global LNG Pricing Terms and Revisions: An Empirical Analysis (James A. Baker III Institute for Public Policy Rice University) Points Out at Lack of Transparency in LNG contracts and the exact relationship with Oil. Most LNG is sold under confidential, bilateral long-term contracts, particularly in Asia. Thus, though prices are indexed to crude oil, actual prices, contract terms and price revision clauses are not known. There is lack of transparency in price determination in Asia. The paper tries to establish an empirical relationship between LNG import prices and crude oil prices.

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5. John Simpson (2009), in the paper, 'Spot Natural Gas Prices: A Theoretical Party to Party Bargaining Framework' (*Asian Social Science (Vol.5, No. 10, www.ccsenet.org/journal.html*) establishes that hub based gas prices are influenced by oil prices, which in turn is influenced by Stock global market and coal index. He further emphasized that Gas prices and gas price changes are influenced by oil price and oil price changes which in turn are influenced by global stock price index value and index value changes and the coal price index values and index value changes. The global gas market could in future, when markets become larger and more efficient, use these variables to assist in partially forecasting future spot gas prices, but also to assist in spot price bargaining in an expansion of the party to party bargaining model.

6. Jonathan Stern (2013), in the paper 'A crisis of fundamentals International gas pricing in Europe and Asia (Energy Policy, Volume 64, January 2014, Pages 43-48) describes that Oil based LNG pricing is losing its relevance. International gas prices in Europe and LNG importing Asia no longer reflect market fundamentals. This became highly problematic in Europe post-2008 and in Japan post-Fukushima. The result has been a significant switch to hub pricing in Europe. In Asia, no substantial action has been taken beyond some new contracts based on Henry Hub prices. In Asia the 'crisis of fundamentals' was only just starting to be addressed with a transition to market pricing an urgent imperative, but still a distant prospect.

7. Seksun Moryadee , Steven A. Gabriel , Hakob G. Avetisyan (2014) in paper 'Investigating the potential effects of U.S. LNG exports on global natural gas markets' (Energy Strategy Reviews, Volume 2, Issues 3–4, February 2014) investigates that that Cheaper US prices could replace expensive Asian & European Gas suppliers. This paper investigates the potential effects of U.S. LNG exports on the domestic and global markets. Less expensive U.S. LNG is competitive in European and Asian gas markets and could displace more expensive suppliers in European and Asian gas markets.

8. Don Maxwell , Zhen Zhu (2011) in the paper 'Natural gas prices, LNG transport costs, and the dynamics of LNG imports' (Energy Economics, Volume 33, Issue 2, March 2011, Pages 217-226, https://doi.org/10.1016/j.eneco.2010.06.012) establishes an Imperial relations between Henry Hub with UK & Asian prices. This paper examines the empirical relationship between U.S. LNG imports, the Henry Hub price of natural gas relative to U.K. and Asia gas prices, and a proxy for LNG transportation costs using monthly data from 1997 to 2007.

9. PEARSON Andrew & ROS Thierry (2011) in the paper 'High oil price triggers LNG bargain hunt' (Petroleum Economist. Mar 2011, Vol. 78 Issue 2, p26-26) argues that despite very high LNG price due High oil price, it was not east for Asian buyers to switch on cheaper Spot LNG. Andrew Pearson, head of LNG research at consultancy Wood Mackenzie, says most contracts are sensitive to big increases in oil prices since around 85-90% of LNG purchased in the Asia- Pacific region is on long-term, oil-linked agreements. LNG analyst Thierry Bros claims it is difficult for many Asia buyers to rely on spot LNG.

10. Péter Erdős (2012) in paper 'Have oil and gas prices got separated?' (Energy Policy, Volume 49, Oct 2012, Pages 707-18,https: //doi.org/10.1016/j.enpol.2012.07.022) describes that US Gas prices is no longer linked with Oil since 2009, while as Asian & part Europe gas is still linked with Oil. VEC models are applied to investigate the relationship between oil and natural gas prices. While natural gas prices in Europe and Asia react to oil price, US gas price decoupled from oil in 2009. Since 2009, the US gas price has decoupled from the European and Asian gas prices.

11. Kenneth Barry Medlock III (2012) in paper, 'Modeling the implications of expanded US shale gas production' (Energy Strategy Reviews, Volume 1, Issue 1, March 2012, Pages 33-41, https://doi.org/10.1016/j.esr.2011.12.002) says that Shale gas boom will influence the Supply dynamics and traditional oil linked LNG pricing mechanism. North American shale gas development has major implications for global natural gas trade. Shale makes global supply more elastic, enhances liquidity, and

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lowers long term price. Shale has implications for traditional pricing paradigms, such as oil indexation. Shale has shifted perceived LNG opportunities away from North America and toward Asia. The potential for future shale development in Asia could also be paradigm shifting. Globally, longer term supply focus moves away from Russia, Iran, Qatar and Venezuela.

12. Jonathan Stern (2016), in paper 'The new Japanese LNG strategy: a major step towards hub-based gas pricing in Asia, (Oxford Institute for Energy Studies, OXFORD ENERGY COMMENT, June 2016), discussed about initiative toward hub based pricing mechanism in Japan to diversify the portfolio. New strategy of hub based pricing which favours a move to market prices, will diversify its purchase portfolio away from long term contracts.

13. Article 'Shale-gas LNG offers price evolution, not revolution (Petroleum Economist. Jun 2013, Vol. 80 Issue 5, p28-28. 1p) suggests that Asian players may not switch completely from oil linked pricing to hub based pricing. The article further says that liquefied natural gas (LNG) supplies from the U.S. and East Africa will have less impact on Asian import costs than expected. It considers the emergence of competitively priced supplies tied to natural gas spot prices, which some industry players believe could end oil-indexed contracts and control the expansion of traditional producers. However, analysts do not support the argument that Asian buyers will switch away from long-term deals tied to oil spot prices.

14. Nhu Che, Tom Kompas (2014) in paper 'The Structure and Dynamics of Liquefied Natural Gas Pricing in Asia and the Pacific and implications for Australia' (Crawford School of Public Policy, The Australian National University, Crawford School Research Paper No. 14-09, November 2014) says that the role of the base price and non-oil linked factors in LNG price formation are instead becoming more important for Asian LNG pricing. The Asia-Pacific gas market's JCC linked mechanism remains important, but its contribution to LNG pricing is becoming less significant. This paper provides a modelling approach for analysing the structure and dynamics of LNG pricing in the Asia and the Pacific region over the past decades. The role of the base price and non-oil linked factors in LNG price formation are instead becoming more important

15. Ken Koyama (2015) in paper, 'Time Lag between Crude Oil and LNG Price Movements, IEEJ October 2015' establishes that Correlation between JCC & LNG has a time lags of about five months. Based on crude oil price data future LNG import prices can be estimated. LNG prices under long-term contracts for Asian market are linked to average CIF crude oil import price called the Japan Crude Cocktail (JCC) price, with some specific coefficients and factors taken into account. However the correlation is accompanied by a time lags of about five months to be reflected in the LNG import price for Japan. The result has interesting implications in a sense. Based on daily crude oil price changes, we can anticipate the movements and direction of Japanese LNG import prices for up to almost half a year ahead.

16. Bachmeier, L J. (2006) in paper, 'Testing for Market Integration Crude Oil, Coal and Natural Gas' (*The Energy Journal,* Vol. 27, No. 2, 55-72), analysed that there is a weak integration between crude oil, coal & Natual Gas, in US market. This paper evaluates the degree of market integration both within and between crude oil, coal, and natural gas markets. Using daily price data for five very different crude oils, we conclude that the world oil market is a single, highly integrated economic market. On the other hand, coal prices at five trading locations across the United States are cointegrated, but the degree of market integration is much weaker, particularly between Western and Eastern coals. Finally, we show that crude oil, coal, and natural gas markets are only very weakly integrated. Our results indicate that there is not a primary energy market. Despite current price peaks, it is not useful to think of a primary energy market, except in a very long run context.

Research Methodology

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1. **Research Questions**:
   1.1   What are the underlying factors shaking the traditional oil linked LNG pricing mechanism in Japan and other parts of the World?
   1.2   To explore an alternative pricing mechanism suitable for Asia and Japan, in particular.

2. **Research Design**:

A number of economic indicators (variables) and competitive fuels were identified through Literature Review of various research papers and journals, which may directly or indirectly affect the LNG prices. Correlation of these variables with Japan LNG prices and Henry Hub LNG prices were carried out. This helped us to establish the imperfectness of Oil based pricing model and provided a direction for a better model in future contracts. A better model, which takes care of price stability for long term projects and at the same time covers the short term price volatilities, in order to be mutually beneficial for both sellers and buyers.

The difference in inherent characteristics of the two extreme pricing models will be analysed, i.e. Oil pegged Japan LNG and market based US Henry Hub. Regression Analysis showed us varying degree of correlations between various indicators with Japan LNG & Henry Hub pricing when compared with a set of economic indicators and competitive fuels. This information could be used to decide the most suitable pricing mechanism for Asian especially Japan market.

To test the hypotheses, the 'R Square', 'Pearson Correlation' and Sig. (2 tailed) for each variable against dependant variable (i.e. LNG Japan Price & Henry Hub Prices) were calculated using Linear Regression on SPSS software. These correlations are listed in a tabular form to clearly present pairs of variables that had either strong, weak or insignificant correlations (positive or negative).

The graphs of Linear Regressions were also extracted to clearly see the correlation and spread of the dependent variables Japan LNG and Henry Hub with the rest of the independent variables. The lines of regression and the corresponding R-Square values for each graph fully supported the trends that were observed using the Pearson-correlations of the variables.

In general, pairs of variables with a stronger correlation also possessed a higher R-Square value. However the R-Square value must be checked along with Pearson Correlation for checking the positive or negative correlation and Sig. (2 tailed) to check if the model is significant or not.

- R-Square value close to 1 indicates a strong correlation and near Zero values shows no correlation. However without checking Sig. (2 tailed) value, R-Square should not be interpreted.
- Pearson Correlation value close to +1 indicates a strong positive & -1 indicates and strong negative correlation. However without checking Sig. (2 tailed), Pearson Correlation should not be interpreted.
- Sig. (2 tailed): value > 0.05 indicates that model is insignificant and could not fit the data. Sig. (2 tailed) value < 0.05 indicates a better fit. E.g. If Sig < 0.01, then the model is significant at 99%, if Sig < 0.05 then the model is significant at 95%.

3. **Data Collection**

Historical data of the identified indicators from 2007 to May 2017, were collected from various secondary sources. This is a very important time period in view for the Oil & Gas industry due to below mentioned reasons:

   3.1   Oil Price wild fluctuations from 2008
   3.2   Supply Demand Dynamic change, Shale gas boom from 2007 onwards

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3.3   Financial crisis of 2007-2008 & recovery

3.4   Fukushima disaster & Nuclear Power Plant Shut down in 2011 raised the demand for LNG in Japan.

4. Definition of Variables

Brief description of the variables as follows:

4.1   Dependent Variables

LNG Prices (Japan Oil Linked LNG Prices & US Henry Hub Prices) were checked for correlation with other variables, which could have affected the LNG Prices apart from oil prices & demand & supply.

4.2   Independent Variables
4.2.1   Crude Oil Prices
4.2.2   LNG Demand:
4.2.3   LNG supply
4.2.4   Availability of New Markets & Purchase Options
4.2.5   Changes in Geo Political conditions

4.2.1   Crude Oil Prices

a.   World Economy: It has been observed that World economy influence the oil demand and prices.

b.   Increased Supply due to Shall Oil Boom & New Oil Resources

c.   Global stock price index values: Stock prices in a global index are representation of global supply and demand conditions and eventually effects global energy prices

d.   Japan Economy: Japan being the biggest LNG importer influences the Demand & Supply situation around the world and hence the prices.

e.   JPY/USD Exchange Rates: JPY/USD have been fluctuating rapidly over the years. A devalued JPY asks for more USD to be spent for the same LNG prices.

f.   COAL Prices Index & Index Value Changes: Oil price and oil price changes are influenced significantly by global stock price index values and index value changes and the coal price index values and index value changes

g.   Japan stock price index values:

Indicators Used: JCC prices, Brent prices, coal prices, JPY/USD exchange rate, Japan Nikkei Stock Index, Japan GDP, US GDP, US Stocks S&P 500 Index

4.2.2   LNG Demand

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   a. Demand Decrease: World Economy Slowing Down and may put a limited downward pressure towards Demand.
      i. Asia represents the main source of uncertainty on the demand side of the global gas market. In summary across the large and growing Asian gas consumers.
      ii. Japan: Lack of clarity on the pace and scale of nuclear restarts
      iii. South Korea: Uncertainty around gas vs coal usage in the power sector
      iv. India: Questions over infrastructure, domestic pricing and affordability of gas vs coal.
      v. China: Economy slowing down and uncertainty on domestic production.
   b. Demand Increase: LNG demand increased due to Fukushima Nuclear disaster in March 2011 and delay in recommissioning of the reactor and Government restrictions. A restart may put pressure on LNG demand though.
   c. Demand to increase: More emphasis on Cleaner Energy (LNG being cleaner than Oil & Coal) with Government Support and increase of LNG in Industrial area.
   d. Increase of Renewable Energy Usage will reduce the LNG demand. Prices and usage of Renewable energy is increasing.
   e. Crude Oil Prices: An increase or decrease in crude oil prices affects the LNG demand in 2 ways.
      i. As an alternative Fuel, LNG demand goes up with an increase of crude oil prices and vice-versa, in open markets where oil and LNG prices are not linked by contract formulas.
      ii. In oil linked LNG markets, an increase in Oil price increase the LNG prices as well and may have decrease the LNG demand and vice versa.
   f. Average Temperature during the winters going high: Will slowly decrease the demand in long term. However overall effect will be insignificant to be considered in this study.

Indicators Used: LNG Consumption US, Japan and World, Renewables Consumption in TWH

4.2.3   LNG supply

   a. Increased Supply: With Shale Oil Boom, US became the net exporter of LNG from a major LNG Importer. Overall the Global LNG trade was the highest ever in history (258.0 MT) and the growth is expected to continue at least for next few years.
   b. More Pipelines Supply Available: Availability of a better pipeline network will provide more flexibility on supply side.
   c. Supply Options through New LNG Resources: Through new projects and expansion of existing facilities in US, Australia, East Africa & Asia Pacific.
   d. More Functioning FSRUs in Market: More no. of FSRUs in service felicitating more flexibility in term of supplies at new and remote places with lesser investment.
   e. Falling Shipping Cost: shipping costs have been falling since 2008 due to excess tonnage (i.e. more no. of ships in the market than required). Low shipping cost encourage arbitrage opportunity to buy form US & European markers and eases the supply side.

Indicators Used: LNG Production US, LNG Production World, Shipping Cost (Spot rates for Qatar and Japan were used as reference, being the world's largest exporter and importers of LNG.

4.2.4   Availability of New Markets & Purchase Options

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a. Spot LNG Prices: An oversupply LNG is expected for next 3 years along with more number of Ships available, which will is favorable for an increased activity of LNG Spot cargo. Will further boost supply side and expected to keep the LNG prices on lower side. Supply Options through New LNG Resources: Through new projects and expansion of existing facilities in US, Australia, East Africa & Asia Pacific.

b. Availability through Henry Hub, British & European Hubs:
The sudden spike of oil prices from 2008 onwards resulted in oil linked LNG contract prices significantly higher in Asia than US & European index prices. This coupled with low shipping cost environment provided, provided alternative options and excellent arbitrage opportunity to the Asian buyers. Possibility of new LNG Hubs in Tokyo, shanghai & Singapore to capture to local market fundamentals.

Indicators Used: Henry Hub, UK NBP Index, Canada (Alberta) Index, German, LNG Index, Japan Spot prices and a relatively new Spot Index JKM (Japan Korea Marker).

4.2.5 Changes in Geo Political conditions

1. Demand to Increase: More emphasis on Clean & Renewable energy with Government support. Restart of Nuclear Plant will be a Political decision based on public sentiments. Moving away from Coal & Oil to LNG & Renewable energy would be seen in future.

2. Political Risk Premium & Financial Risk Index of a Country: LNG contract prices demands for premium depending on the political & financial stability of the buyers and sellers countries.

3. Pipeline supply due to global cooperation between nations: Better political understanding between Nations will lead to better pipelines network and will bring more liquidity in the marker.

Indicators Used: None for this study.

4.3 Summary of Variables

	Sub Variables	Independent Variables	Dependent Variable
1A	World Economy	Crude Oil Prices	LNG Prices
1B	Increased Supply due to Shall Oil Boom & New Oil Resources		
1C	Global stock price index values		
1D	Japan Economy		
1E	JPY/USD Exchange Rates		
1F	COAL Prices Index & Index Value Changes		
1G	Japan stock price index values		
2A	Demand Decrease: World Economy Slowing Down	LNG Demand	
2B	Demand Increase: Impact of the Fukushima disaster in March 2011		
2C	Demand to increase: More emphasis on Cleaner Energy (than Oil & Coal) with Govmnt Support		
2D	Increase of Renewable Energy Usage		
2E	Crude Oil Prices		
2F	Average Temperature During the Winters going high: Demand Decrease		
3A	Increased Supply, Shall Oil Boom	LNG supply	
3B	More Pipelines Supply Available		
3C	Supply Options through New LNG Resources		
3D	More Functioning FSRUs in Market		
3E	Falling Shipping Cost		
4A	Spot LNG Prices	Availability of New Markets & Purchase Options	
4B	Supply Options through New LNG Resources		
4C	Availability through Henry Hub, British & European Hubs		
5A	Demand to Increase: More emphasis on Clean & Renewable energy with govmnt support	Changes in Geo Political conditions	
5B	Political Risk Premium & Financial Risk Index of a Country		
5C	Pipeline supply due to global cooperation between nations		

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5. Data Analysis : Results & Their Interpretation
5.1 Co-relation of Japan LNG* Prices with Oil and other Parameters:
* In this study Japan LNG Price is referred to Japan's Oil Linked LNG Prices.

5.1.1 Japan LNG Vs JCC Crude Oil Prices:
- The R Square Value is 0.725 & Pearson Correlation: 0.851 with a Sig. value as 0.000. This shows a very strong correlation between JCC Crude Oil prices & Japan LNG Prices and the model is good fit with a confidence level of close to 100%.
- This confirms our base concept that Japan LNG prices are closely linked with crude oil prices.

5.1.2 Japan LNG Vs Brent Crude Oil Prices:
- The R Square Value is 0.601 & Pearson Correlation: 0.775 with a Sig. value as 0.000. This shows a very strong correlation between Brent Crude Oil prices & Japan LNG Prices and the model is good fit with a confidence level of close to 100%.
- This confirms our base concept that Japan LNG prices are closely linked with crude oil prices

  NB: JCC Crude Oil prices are closely related with Brent prices with addition of shipping cost and JPY/USD exchange rates

5.1.3 Japan LNG Vs US Henry Hub Index Prices:
- The R Square Value is 0.013 & Pearson Correlation: -0.116 with a Sig. value as 0.197. There is no statistically significant correlation between Japan LNG & US Henry Hub prices
- Since one is oil linked and other is market based, there is no relation between the two.

5.1.4 Japan LNG Vs Japan Spot Prices:
- The R Square Value is 0.781 & Pearson Correlation: 0.884 with a Sig. value as 0.00. This shows a very strong correlation between Japan LNG & Japan Spot LNG Prices and the model is good fit with a confidence level of close to 100%.

- Japan spot LNG price is based on additional demand, when Japan oil linked LNG price rises. This provide an arbitrage opportunity for US or European LNG, which could be cheaper than Japan LNG including shipping cost.

5.1.5 Japan LNG Vs Japan Shipping Rates (from Qatar to Japan)
- The R Square Value is 0.694 & Pearson Correlation: 0.833 with a Sig. value as 0.00. This shows a correlation between Japan LNG & Japan shipping LNG Prices and the model is good fit with a confidence level of close to 100%.
- Shipping rates depends on Cargo to be moved and shipping tonnage availability. Higher shipping rates will push up the Japan LNG prices.

5.1.6 Japan LNG Vs Platt's JKM Spot Prices:
- The R Square Value is 0.739 & Pearson Correlation: 0.859 with a Sig. value as 0.00. This shows a very strong correlation between Japan LNG & JKM Prices and the model is good fit with a confidence level of close to 100%.
- This is a new spot Index being introduced by Platts, having the similar characteristics as Japan Spot price.

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5.1.7   Japan LNG Vs Coal Prices:
- The R Square Value is 0.077 & Pearson Correlation: 0.278 with a Sig. value as 0.002. This shows both values (Japan LNG & Coal prices) are having a weak correlation.
- When oil prices go up it adds some pressure on alternative fuels such as coal etc.

5.1.8   Japan LNG Vs JPY/USD:
- The R Square Value is 0.168 & Pearson Correlation: -0.409 with a Sig. value as 0.00. This shows both values (Japan LNG Vs JPY/USD) are having a weak negative correlation.

5.1.9   Japan LNG Vs Japan (Nikkei) Stock Exchange:
- The R Square Value is 0.081 & Pearson Correlation: -0.285 with a Sig. value as 0.001. This shows both values (Japan LNG Vs Japan (Nikkei) Stock Exchange) are having a weak negative correlation.

5.1.10   Japan LNG Vs Japan GDP:
- The R Square Value is 0.168 & Pearson Correlation: -0.409 with a Sig. value as 0.00. This shows both values (Japan LNG Vs Japan GDP) are having a weak negative correlation.

5.1.11   Japan LNG Vs US GDP:
- The R Square Value is 0.001 & Pearson Correlation: 0.027 with a Sig. value as 0.765. This shows both values (Japan LNG Vs US GDP) are Not correlated and the model is not significant as Sig. value is higher than 0.05.

5.1.12   Japan LNG Vs US Stocks:
- The R Square Value is 0.000 & Pearson Correlation: -0.020 with a Sig. value as 0.824. This shows both values (Japan LNG Vs US Stocks) are Not correlated and the model is not significant as Sig. value is higher than 0.05.

5.1.13   Japan LNG Vs German LNG Index Prices:
- The R Square Value is 0.574 & Pearson Correlation: 0.758 with a Sig. value as 0.007. This shows a strong correlation between Japan LNG & German LNG and the model is good fit
- Correlation as European LNG indices are still not fully delinked with oil.

5.1.14   Japan LNG Vs UK NBP Index Prices:
- The R Square Value is 0.565 & Pearson Correlation: 0.751 with a Sig. value as 0.008. This shows a strong correlation between Japan LNG & German LNG and the model is good fit
- Correlation as European LNG indices are still not fully delinked with oil.

5.1.15   Japan LNG Vs Canada LNG Index Prices:
- The R Square Value is 0.030 & Pearson Correlation: -0.173 with a Sig. value as 0.611. There is no statistically significant correlation between Japan LNG & Canada LNG Prices as Sig. value > 0.05

5.1.16   Japan LNG Vs World Supply/Demand Gap:
- The R Square Value is 0.223 & Pearson Correlation: 0.473 with a Sig. value as 0.142. There is no statistically significant correlation between Japan LNG & World Supply/Demand Gap, as Sig. value > 0.05

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5.1.17   Japan LNG Vs US Supply/Demand Gap:
- The R Square Value is 0.137 & Pearson Correlation: 0.370 with a Sig. value as 0.263. There is no statistically significant correlation between Japan LNG & US Supply/Demand Gap as Sig. value > 0.05

5.1.18   Japan LNG Vs Renewable Consumption:
- The R Square Value is 0.108 & Pearson Correlation: 0.328 with a Sig. value as 0.324. There is no statistically significant correlation between Japan LNG & Renewable Consumption, as Sig. value > 0.05

5.2 Correlation of US Henry Hub Index Prices with Oil and other Parameters:

5.2.1   Henry Hub Index Vs JCC Crude Oil Prices:
- The R Square Value is 0.054 & Pearson Correlation: 0.233 with a Sig. value as 0.009. This shows both values (Henry Hub Index & JCC crude oil) are not correlated but the model is statistically significant.
- As per our base concept Henry Hub is not linked to crude oil prices.

5.2.2   Henry Hub Index Vs Brent Crude Oil Prices:
- The R Square Value is 0.084 & Pearson Correlation: 0.289 with a Sig. value as 0.001. This shows both values (Henry Hub Index & JCC crude oil) are not correlated but the model is statistically significant.
- As per our base concept Henry Hub is not linked to crude oil prices.

5.2.3   Henry Hub Index Vs Japan Spot LNG Prices:
- The R Square Value is 0.657 & Pearson Correlation: 0.810 with a Sig. value as 0.00. This shows a very strong correlation between Henry Hub Index & Japan Spot LNG Prices and the model is good fit with a confidence level of close to 100%
- The spot cargo is sourced at market price and hence showing strong correlation with Henry Hub prices.

5.2.4   Henry Hub Index Vs Japan Shipping Spot Rates (from Qatar to Japan):
- The R Square Value is 0.067 & Pearson Correlation: 0.260 with a Sig. value as 0.010.
- There is no statistically significant correlation between Henry Hub Index Vs Japan Shipping Rates, as Sig. value > 0.05

5.2.5   Henry Hub Index Vs Platts' JKM Spot Prices:
- The R Square Value is 0.648 & Pearson Correlation: 0.805 with a Sig. value as 0.00. This shows a very strong correlation between Henry Hub Index & JKM Prices and the model is good fit with a confidence level of close to 100%
- This is a new spot Index being introduced by Platts, having the similar characteristics as Japan Spot price.

5.2.6   Henry Hub Index Vs Coal Prices:
- The R Square Value is 0.208 & Pearson Correlation: 0.456 with a Sig. value as 0.00.
- This shows both values (Henry Hub Index & Coal prices are having a weak positive correlation.

5.2.7   Henry Hub Index Vs JPY/USD:

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- The R Square Value is 0.026 & Pearson Correlation: 0.162 with a Sig. value as 0.070. There is no statistically significant correlation between Henry Hub Index Vs JPY/USD index, as Sig. value > 0.05

5.2.8   Henry Hub Index Vs Japan (Nikkei) Stock Exchange:
- The R Square Value is 0.002 & Pearson Correlation: -0.040 with a Sig. value as 0.658. There is no statistically significant correlation between Henry Hub Index Vs Nikkei index, as Sig. value > 0.05.

5.2.9   Henry Hub Index Vs Japan GDP:
- The R Square Value is 0.006 & Pearson Correlation: 0.079 with a Sig. value as 0.379. There is no statistically significant correlation between Henry Hub Index Vs Japan GDP index, as Sig. value > 0.05.

5.2.10   Henry Hub Index Vs US GDP:
- The R Square Value is 0.266 & Pearson Correlation: -0.515 with a Sig. value as 0.000. This shows both values (Henry Hub Index Vs US GDP) are mildly negative correlated.
- Associated with more investment towards Shale technology and increased availability of Gas at lower price.

5.2.11   Henry Hub Index Vs US Stocks:
- The R Square Value is 0.112 & Pearson Correlation: -0.334 with a Sig. value as 0.000. This shows both values (Henry Hub Index Vs US Stocks) are mildly negative correlated.
- GDP generally have a positive correlation with stock exchange.

5.2.12   Henry Hub Index Vs German LNG Index Prices:
- The R Square Value is 0.119 & Pearson Correlation: 0.345 with Sig. value as: 0.299 There is no statistically significant correlation between Henry Hub Index Vs German LNG prices, as Sig. value > 0.05.

5.2.13   Henry Hub Index Vs UK NBP LNG Index Prices:
- The R Square Value is 0.098 & Pearson Correlation: 0.313 with a Sig. value as 0.348. There is no statistically significant correlation between Henry Hub Index Vs NBP Index, as Sig. value > 0.05.

5.2.14   Henry Hub Index Vs LNG Canada Index Prices:
- The R Square Value is 0.994 & Pearson Correlation: 0.997 with a Sig. value as 0.000. This shows a correlation between Henry Hub Index & Canada Index price and the model is good fit with a confidence level of close to 100%
- US & Canada LNG markets are very closely linked.

5.2.15   Henry Hub Index Vs World Supply/Demand Gap:
- The R Square Value is 0.116 & Pearson Correlation: -0.340 with a Sig. value as 0.306. There is no statistically significant correlation between Henry Hub Index Vs World Supply/Demand Gap, as Sig. value > 0.05
- Despite the great potential, Henry Hub's usage in world market is still limited.

5.2.16   Henry Hub Index Vs US Supply/Demand Gap:

- The R Square Value is 0.627 & Pearson Correlation: -0.792 with a Sig. value as 0.004. This shows a very strong correlation between Henry Hub Index & US Supply/Demand Gap and the model is good fit with a confidence level of close to 100%

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- With increased gap between supply and demand, more Henry Hub prices will come down. This confirms our base concept of Henry Hub is a pure demand/supply based model.

5.2.17   Henry Hub Index Vs Renewable Consumption:
- The R Square Value is 0.663 & Pearson Correlation: -0.814 with a Sig. value as 0.002. This shows a strong negative correlation between Henry Hub Index & renewable energy consumption and the model is good fit with a confidence level of close to 100%.
- Increase renewable energy consumption eases demand of LNG further and will bring down the LNG prices.

<table>
<tr><th colspan="5">5.3 Summary of Data Analysis</th></tr>
<tr><th>No.</th><th>Variables</th><th>Statistical Coefficients</th><th>JapanLNG</th><th>HenryHub</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">JapanLNG</td><td>Pearson Correlation</td><td>1.000</td><td>-0.116</td></tr>
<tr><td>R Square</td><td></td><td>0.013</td></tr>
<tr><td>Sig. (2-tailed)</td><td>NA</td><td>0.197</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">JCC Crude</td><td>Pearson Correlation</td><td>0.851</td><td>0.233</td></tr>
<tr><td>R Square</td><td>0.725</td><td>0.054</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td>0.009</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Brent</td><td>Pearson Correlation</td><td>0.775</td><td>0.289</td></tr>
<tr><td>R Square</td><td>0.601</td><td>0.084</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td>0.001</td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">Henry Hub</td><td>Pearson Correlation</td><td>-0.116</td><td>1.000</td></tr>
<tr><td>R Square</td><td>0.013</td><td></td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.197</td><td>NA</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">JPN Spot LNG</td><td>Pearson Correlation</td><td>0.884</td><td>0.810</td></tr>
<tr><td>R Square</td><td>0.781</td><td>0.657</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td>0.000</td></tr>
<tr><td rowspan="3">6</td><td rowspan="3">LNG Shipping Spot Rate</td><td>Pearson Correlation</td><td>0.833</td><td>0.260</td></tr>
<tr><td>R Square</td><td>0.694</td><td>0.067</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td>0.010</td></tr>
<tr><td rowspan="3">7</td><td rowspan="3">Japan Korea Marker (LNG Spot)</td><td>Pearson Correlation</td><td>0.859</td><td>0.805</td></tr>
<tr><td>R Square</td><td>0.739</td><td>0.648</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td>0.000</td></tr>
<tr><td rowspan="3">8</td><td rowspan="3">Coal</td><td>Pearson Correlation</td><td>0.278</td><td>0.456</td></tr>
<tr><td>R Square</td><td>0.077</td><td>0.208</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.002</td><td>0.000</td></tr>
<tr><td rowspan="3">9</td><td rowspan="3">JPY / USD Exchange Rates</td><td>Pearson Correlation</td><td>-0.409</td><td>0.162</td></tr>
<tr><td>R Square</td><td>0.168</td><td>0.026</td></tr>
<tr><td>Sig. (2-tailed)</td><td>0.000</td><td>0.070</td></tr>
<tr><td>10</td><td>Nikkei</td><td>Pearson Correlation</td><td>-0.285</td><td>-0.040</td></tr>
</table>

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		R Square	0.081	0.002
		Sig. (2-tailed)	0.001	0.658
11	**Japan GDP**	Pearson Correlation	-0.409	0.079
		R Square	0.168	0.006
		Sig. (2-tailed)	0.000	0.379
12	**US GDP**	Pearson Correlation	0.027	-0.515
		R Square	0.001	0.266
		Sig. (2-tailed)	0.765	0.000
13	**US Stocks**	Pearson Correlation	-0.020	-0.334
		R Square	0.000	0.112
		Sig. (2-tailed)	0.824	0.000
14	**German LNG**	Pearson Correlation	0.758	0.345
		R Square	0.574	0.119
		Sig. (2-tailed)	0.007	0.299
15	**UK NBP**	Pearson Correlation	0.751	0.313
		R Square	0.565	0.098
		Sig. (2-tailed)	0.008	0.348
16	**Canada LNG**	Pearson Correlation	-0.173	0.997
		R Square	0.030	0.994
		Sig. (2-tailed)	0.611	0.000
17	**World Supply/Demand Gap**	Pearson Correlation	0.473	-0.340
		R Square	0.223	0.116
		Sig. (2-tailed)	0.142	0.306
18	**US Supply/Demand Gap**	Pearson Correlation	0.370	-0.792
		R Square	0.137	0.627
		Sig. (2-tailed)	0.263	0.004
19	**Renewable Consumptions**	Pearson Correlation	0.328	-0.814
		R Square	0.108	0.663
		Sig. (2-tailed)	0.324	0.002

6. Research Findings

- As expected, present oil linked LNG pricing is strongly correlated with crude oil price and oil prices are the sole deciding factor for LNG prices.
- On other hand open market's Henry Hub has shown little correlation with Crude oil.
- LNG prices' heavy dependency on Crude oil is unreal, which has shown little correlation with open market LNG. This will certainly lead to undesirable extremes.
- Current Japan LNG Pricing has no relation with market fundamentals such as Demand/Supply, JPY/USD Exchange Rate, market based Index Henry Hub etc.
- Current Japan LNG Pricing has no relation with alternative energy sources such as   Coal prices, Renewable energy.

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- Henry Hub, a pure demand and supply based pricing model has shown good correlation with important Indicators such as Demand/Supply, Canada LNG prices, GDP, Renewables and other alternative energy sources such as Coal.
- Japan LNG prices show strong correlation with European LNG indices, which are still about 60% oil linked.

Conclusion & Recommendations

The statistical analysis of Japan LNG prices and its relations with other variables have brought out the inherent characteristics of oil Linked LNG pricing. Japan LNG prices by virtue of oil linking, have shown little or no correlation with important indicators such as demand/supply of LNG, coal prices, expansion of renewable energy and other important economic indicators such as JPY/USD Exchange Rates. The contract buyers were obligated to buy LNG at very high prices which was completely out of sync from LNG market fundamentals and prevailing open market prices. 'Destination Clause' and 'Take or Pay Clause' also put the contract buyers at great disadvantage and a change in LNG pricing system is the way out.

Based on this study, below important points are recommended to be included for a better pricing mechanism when negotiating new contracts.

- The pricing should incorporate market fundaments such as demand & supply status. A regional Hub should be made with a mutual participation of all major players in the regions, to create a large trading Hub to provide enough liquidity.
- A balanced reference point comprises of a basket of energy products & economic factors such as prices of coal, oil, oil products, renewable energy, shipping cost, currency exchange rate would give a more stable pricing structure and prevent LNG prices being running away due to linked with a single commodity such as oil.
- Henry Hub Index has all the flexibility and openness to become a world index. Another possibility could be to form a global index by converging various prevailing LNG indexing in the world. However we do not foresee Japan to completely abandon the oil linked contracts & go entirely for Henry Hub or other global index. This is to avoid shocks due to inherent volatility of a demand and supply based open index. However as mentioned above part of the cargo should be sourced from open market.
- Long term contracts could still be continued as they provide better long term stability against volatility of market based LNG prices. However new long term contract should be made to provide flexibility that about +/- 20-30% of the contracted quantity could be cancelled or sourced from a nearby hub or delivered to another destination.

- A mixed or hybrid type of contracts with some portion of oil/oil basket mix and rest from hub pricing will provide necessary stability and market advantage at the same time.

- We can expect shifting towards more spot cargo in a free market, shipping rates should also be incorporated in the pricing mechanism or new contracts. As shipping rates are known to fluctuate violently and may diminish the benefits of better priced LNG.

- New contracts to be made with Destination Free clause and provide flexibility in Pay or Take Clause, so that all or part cargo can be discharged at other places as per prevailing demand/supply situation.

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Data in the this Dissertation work is sourced from a variety of public and private domains, including the BP Statistical Review of World Energy, Cedigaz, the International Energy Agency (IEA), the Oxford Institute for Energy Studies (OIES), the US Energy Information Agency (EIA), the US Department of Energy (DOE), company reports and announcements.