Gas on Gas Competition in Shanghai

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Abstract

In common with other major economic centres in China, Shanghai's energy consumption has been increasing rapidly in order to support the high growth rate of its economy. In order to achieve rational, efficient and clean use of energy, together with improved environmental quality within the city, the Shanghai municipal government has decided to expand the supply and utilization of natural gas. Shanghai plans to increase the share of natural gas in its primary energy mix to 7 per cent by 2010, up from 3 per cent in 2005. This increase in natural gas demand has to be matched with a corresponding increase in supply. To date, the Shanghai region has relied on offshore extracted natural gas but this supply is limited due to the size of the reserves. Since 2005, the West–East pipeline has provided an alternative for Shanghai but demands from other regions could reduce the potential for expanding supplies from that source. Since domestic production will not be sufficient to meet demand in the near future, Shanghai is building a liquefied natural gas (LNG) regasification terminal at the Yangshan deep water port that would allow an additional supply of more than 3 billion cubic metres per year of natural gas. Malaysia has already committed to supply LNG to the Shanghai terminal at a price that is significantly higher than the wholesale "city-gate" price for natural gas transported via pipeline, but still lower than the gas price to end-use consumers. The presence of both an LNG terminal and a transmission pipeline that connects Shanghai to domestic gas-producing regions will create gas-on-gas competition. This study assesses the benefits of introducing such competition to one of China's most advanced cities under various scenarios for demand growth. In this paper, the impact of imported LNG on market concentration in Shanghai's gas market will be analysed using the Herfindahl Hirschmann Index (HHI) and the Residual Supply Index (RSI). Our results show that Shanghai remains a supply constrained gas market that will continue to rely upon gas

supplies from the western provinces and imported LNG. After 2017, the gas market in Shanghai can be regarded as unconcentrated since its HHI fall below 1800 under a Very High Growth scenario. In terms of RSI, the gas market can be considered competitive at Low, Moderate and High growth consumption between 2012 and 2015.

1. Introduction

Natural gas currently provides about 20 per cent of global energy supply in a range of generally stationary uses, including industrial process heat, residential and commercial space and water heating, as well as increasingly power production. Although gas plays only a small part in meeting the rapid growth in energy needs of developing countries, this situation is likely to change in the current climate of high oil prices, the expansion of the global LNG market, and increased environmental concerns.

China is now the world's second-largest energy producer and consumer. Natural gas meets only 3 per cent of China's total primary energy demand, yet its gas consumption is already the second highest in Asia. From 1990 to 2007, the average annual rate of growth for natural gas consumption in China amounted to 9.32 per cent. According to the government's 11th Five-Year Plan, natural gas consumption is expected to continue its rapid rate of growth, with its share in the primary energy mix reaching 5.3 per cent by 2010. A report on the National Energy Strategy by China's Energy Research Institute predicts that the average annual rate of growth for natural gas will reach 9.44 per cent and consumption will reach around 165 billion cubic meters by 2020 if a business-as-usual approach is adopted (ERI, 2005)[1]. Forecasts by the IEA[2] expect a similar rate of growth (10 per cent), but the US EIA[3] expects it to be a more modest 6.5 per cent. Despite variation in future projections, the lowest estimate would still require China to source significant natural gas supplies outside of its domestic resources with immediate effect. This means that regardless of which projection the Government decides is most plausible, China remains a supply-constrained gas market that will continue to rely upon supplies of international pipeline gas and imported LNG.

[1] Scenario A in the ERI's Overview of the National Energy Strategy.
[2] Reference scenario in World Energy Outlook 2007.
[3] Reference case in International Energy Outlook 2007.

Most of the current demand for natural gas in China comes from the industrial, commercial and residential sectors particularly in the coastal areas. Future demand will be mainly driven by two factors, the need for new sources of energy to fuel economic growth and improve living conditions, and the desire to reduce the consumption of coal and thus the level of pollution and its adverse impacts on the environment.

Potentially China has significant natural gas resources, both onshore and offshore, although their distribution is geographically imbalanced. Significant onshore natural gas reserves exist in the western regions but the major consumers are located in the eastern coastal areas where the economy is the most developed. Total recoverable offshore reserves in the East China Sea are estimated at just 20 billion cubic metres (bcm) although potential resources could be much higher (ABARE, 2003). While there have been promising new discoveries, over the next decade China will need to import significant amounts of gas since, although domestic gas production is increasing rapidly, it is not at a pace fast enough to satisfy demand growth.

This imbalance in the distribution of gas reserves has led to the transmission of natural gas from the west to the east. China's first West-East gas pipeline came into operation in January 2005. It carries 12 bcm/year of gas from the Tarim Basin in Xinjiang to eastern consuming regions, including the Shanghai area. To meet increasing demand, a 5 bcm/year expansion of the pipeline is currently underway (IGU,2006; IEA, 2007; Ni, 2007; Peyrouse, 2007).

The construction of a second, parallel, pipeline that can increase the total transportation capacity of the West-East pipeline started in early 2008. The design capacity of the 2nd West-East pipeline is reported to be 30 bcm per year. Under an agreement signed in 2006,

Turkmenistan will supply this capacity over a 30 year period (IGU, 2006; Ni, 2007; Peyrouse, 2007).

The Sichuan basin in southwest China currently accounts for the majority of China's onshore non-associated gas reserves and production. The Puguang field in northeastern Sichuan province alone has 322 bcm of proven reserves (IEA, 2007). Most of the gas produced in Sichuan is for consumption within the province. However, a pipeline to supply gas from the Puguang field to growing markets on the eastern seaboard, including Shanghai, is being constructed. The 1702 km pipeline will have an initial annual capacity of 12 bcm with maximum capacity projected to reach 15 bcm per year (Ni, 2007).

Shanghai, located at the heart of the Yangtze River delta, is the most populous and wealthy region of the People's Republic of China. It is widely regarded as China's most important cultural, commercial, financial, industrial and communication centre. Energy consumption in Shanghai has been growing at between 6 and 8 per cent annually, with the annual growth of electricity demand in excess of 10 per cent per year (Lin et al, 2004). Shanghai, with very limited local energy resources, relies heavily on imported coal, oil, natural gas, and electricity. While coal still constitutes over half of Shanghai's primary energy consumption, oil and natural gas use have been growing in importance. In order to secure energy supplies to power Shanghai's fast-growing economy, the Municipality of Shanghai has made diversification of its energy structure one of its priorities.

Shanghai started promoting natural gas in 1996 in order to reduce air pollution. In 2006, natural gas consumption per capita reached 165 m^3 or almost four fold per capita consumption in China as a whole. According to the Shanghai Statistical Yearbook for 2007,

gas consumption reached 2.258 bcm in 2006, an increase of 29 per cent compared to consumption in 2005. Shanghai's strong demand growth is due to a conversion project in the residential sector from town gas manufactured from coal to natural gas and the operation of three gas-fired power plants that came on-line over the past four years.

Currently, Shanghai receives natural gas supply from the offshore Pinghu pipeline and the 1st West-East Pipeline. Additional supply in the form of LNG is expected in the near future. The construction of the first Shanghai LNG re-gasification terminal located at the eastern part of the Yangshan Deep-Water Port will be completed in 2009. When Shanghai LNG enters the gas market, the market in Shanghai may still be regarded as an oligopoly but with an increased degree of competition. The intention of this paper is to evaluate the degree of competition in the gas market using the Herfindahl Hirschmann Index (HHI) and the Residual Supply Index (RSI) over the years to 2020 as the Municipality of Shanghai receives additional supplies of gas via pipeline from other provinces and LNG through its import terminal from a number of overseas sources.

2. Supply and Demand for Natural Gas in Shanghai

2.1 Supply

The gas market in Shanghai is heavily concentrated with currently only two source of supply, the offshore Pinghu pipeline and the 1st West-East Pipeline. In order to promote energy security, the Municipality of Shanghai intends to diversify its gas sources. Shanghai proposes to have five sources of natural gas by 2011, namely the 1st West-East pipeline, the offshore

Pinghu pipeline, the Sichuan-East pipeline, imported LNG, and the 2nd West-East pipeline. By 2010, the amount of natural gas received by the Municipality of Shanghai is expected to reach more than 5.5 bcm per annum.

The Pinghu oil and gas field was the first comprehensive oil and gas field discovered and developed in the East China Sea. The first phase of development was completed in 1999 and deliveries of natural gas to Shanghai commenced in April the same year. The second-phase went on-stream in November 2006 and this raised its capacity by approximately 75 per cent, to 0.66 bcm/year. With further expansion of the offshore pipeline, the delivered volume could be boosted to 0.8 bcm/year. The field, which holds proven reserves of 26 bcm, is jointly operated by CNOOC (30%), Sinopec (30%) and Shanghai Power and Gas (40%). The wholesale city-gate price for gas supplied from the Pinghu field is reported to have been around 4.70 $/MMBtu in 2005 (Miyamoto, 2006).[4]

Shanghai received around 2.27 bcm of natural gas from the 1st West-East pipeline in 2007. It is unclear whether it will receive addition gas supplies when the expansion of the 1st West-East pipeline is finished. However, Shanghai is expected to receive about 2 bcm of natural gas annually from the 2nd West-East pipeline when it comes on-line. Under a gas sale agreement between PetroChina and the Shanghai Natural Gas Pipeline, gas supply from the West-East pipeline is currently sold at about 4.53 $/MMBtu (Miyamoto, 2006).

Construction of the Sichuan-East pipeline is expected to commence in 2008 and to be fully operational in 2010. The volume of gas provided by Sichuan to Shanghai will reach 1.55 bcm in 2010 and 1.9 bcm in 2011. The Sichuan-East pipeline will be operated by Sinopec.

[4] The term city-gate price refers to the price paid to upstream companies by the wholesale gas corporation in each province. These prices are determined by the National Development and Reform Commission (NDRC).

Construction of the first phase of the Shanghai LNG Terminal commenced in January 2007 and is expected to be completed in 2009. Initial capacity of this terminal is 3 million tonnes per year. Annual capacity of the Shanghai LNG terminal may be expanded eventually to six million tonnes of LNG (Kambara, 2007). This LNG terminal is owned by Shanghai LNG Co. Ltd., a joint venture between Shanghai municipal utility Shenergy (55%) and CNOOC (45%). On July 31st 2006, the Petronas subsidiary, MLNG Tiga, entered into a sales and purchase agreement with Shanghai LNG to supply LNG to the terminal for 25 years. Shanghai will receive around 1.1 million tonnes of LNG in the first three years of the contract, with that amount rising to 3 million tonnes by 2012 (Ni, 2007).

2.2 Demand

In order to achieve rational, efficient and clean use of energy, together with improved environmental quality within the city, the Shanghai Municipality has undertaken to expand the supply and utilization of natural gas. Shanghai plans to increase the share of natural gas in its primary energy mix to 7 per cent by 2010, up from 3 per cent in 2005. Sales of natural gas in Shanghai have increased more than ten fold since the year 2000 and have exceeded 2.7 bcm/annum since 2006. The number of household users also recorded spectacular growth, a 16 per cent increase in 2006 compared to the previous year. Gas users in the Municipality have exceeded 6.5 million households and daily gas supply to the residential sector amounts to 9 million cubic meters of town gas and 5 to 6 million cubic meters of natural gas.

Town gas is still a significant source of energy in Shanghai even though it has considerably less calorific value per unit of volume compared to natural gas. Fuel conversion from town

gas to natural gas is regarded by the Municipality as a measure to save energy. By 2020, Shanghai intends to meet all of its gas demands with natural gas. The switch to natural gas is supported by the fact that much of the infrastructure needed to bring gas to each household is already in place.[5] Therefore, natural gas demand from the commercial and residential sectors could increase considerably in the future.

Currently about 32 per cent of natural gas demand in Shanghai comes from energy intensive industries.[6] These industries account for 50 per cent of the city's total energy demand. In order to meet environmental and energy efficiency targets, a switch from fuel oil and coal to natural gas in the industrial sector is required. Industry is therefore poised to be the largest user of natural gas in the Municipality, although construction of natural gas power plants is also a priority (Jiang, 2008).

Escalating gas demand from residential as well as large industrial users has caused a tight gas supply and demand situation. Due to the lack of adequate supplies of natural gas, gas-fired power plants in Shanghai have failed to generate sufficient electricity to meet peak demand. Gas-fired power plants have combined requirements in excess of 10 million cubic meters a day if they run at full capacity. However, limited gas supply has been one of the main causes of power shortages amounting to more than 2 million kilowatts during peak load in Shanghai since 2006.

3. Competition in the Shanghai Gas Market

[5] The network of pipes originally designed to distribute town gas can be used for natural gas distribution.
[6] Energy intensive industries in Shanghai comprise smelting of ferrous materials, oil processing, coking, nuclear fuel processing, textiles, and chemical production.

This section analyses the competitiveness of the gas market in Shanghai under a range of scenarios based on the Herfindahl Hirschmann Index (HHI) and the Residual Supply Index (RSI), whilst also examining the degree to which market power exists. The following scenarios are considered in this study:

- Scenario: Low (L); where the rate of growth of demand is 9.44 per cent per year until 2020 and additional supply of gas in the form of LNG is taken only when supply from the Sichuan-East pipeline has reached maximum capacity. This scenario assumes that the rate of growth in Shanghai will follow the NDRC projection for the average growth rate of natural gas consumption in China.
- Scenario: Moderate (M); where demand grows at 10 per cent per year until 2020 and additional domestic gas supply is prioritized. This scenario assumes that the rate of growth in Shanghai will follow the IEA projection of the average growth rate for natural gas consumption in China.
- Scenario: High-Pipeline (H-P); where the demand growth rate is 14 per cent per year until 2020 and additional domestic gas supply is prioritized. This scenario assumes that natural gas consumption in the Municipality of Shanghai will reach 15 bcm by 2020.
- Scenario: High-LNG (H-L); where the rate of growth of demand is 14 per cent per year until 2020 and additional LNG supply has more priority than gas supply from the Sichuan-East pipeline and the 2nd West-East Pipeline.
- Scenario: Very High-Pipeline (VH-P); where the rate of growth of demand is 20 per cent per year until 2015, then 5 per cent per year until 2020. In this scenario, domestic gas supply is prioritized and natural gas consumption in the Municipality of Shanghai reaches 12 bcm by 2015.

- Scenario: Very High-LNG (VH-L); where the rate of growth of demand is 20 per cent per year until 2015, then 5 per cent per year until 2020. In this scenario, additional LNG supply has a greater priority than gas supply from the Sichuan-East pipeline and the 2nd West-East Pipeline.

In each scenario, it is assumed that Shanghai will respect its existing commitment for obtaining gas supply from the West-East pipeline, Pinghu offshore pipeline, and Malaysian LNG. In addition, the possibility of expanding the annual capacity of the Shanghai LNG terminal after 2012 to 6 million tonnes is also considered. We assume that the additional LNG supply will be contracted from three different producers, each exporting up to 1 million tonnes of LNG per annum.[7]

3.1 Herfindahl-Hirschman Index

The Herfindahl-Hirschmann Index (HHI) calculates the sum of the squared market shares of each supplier in the industry, which may be interpreted as an estimate of market concentration.[8] There are three categories of market concentration that can be identified from this index: Unconcentrated (HHI below 1000), Moderately Concentrated (HHI between 1000 and 1800), and Highly Concentrated (HHI above 1800). The HHI is expressed as:

$$HHI = \sum_{i=1}^{n} (S_i \times 100)^2 \qquad (1)$$

where n is the number of market suppliers and S_i is supplier i's market share.

[7] It is common practice in major LNG importing nations, such as Japan, for one LNG receiving terminal to receive supply from a number of different sources. Possible additional sources of LNG for the 2nd phase Shanghai LNG terminal are Australia, Brunei, Indonesia, and Qatar.
[8] For a more detailed description of the HHI, see Carlton and Perloff (2005).

One of the attractive features of the HHI is that it has foundations in oligopoly theory. If firms have homogenous products and engage in Cournot Competition then the higher is the HHI, the higher the industry price-cost margin is likely to be.

Figure 1 shows that the HHI in the Shanghai gas market declines from 6510 to 1646 under the range of scenarios to 2020. The market starts off very concentrated when it relies on only two sources of supply: the offshore Pinghu pipeline and the 1st East-West pipeline. Under the Very High growth scenario, the gas market in Shanghai can be regarded as having a very low level of concentration after 2017, when its HHI falls below 1800. For the High growth scenario, the degree of concentration for Shanghai's gas market shifts from moderately concentrated to low levels by 2019. Shanghai will need gas from all possible sources of supply under the High and Very High growth scenarios, forcing the market to become more diversified and therefore less concentrated. The market will always be concentrated under the Low and Medium growth scenarios because lower levels of demand would limit the number of sources of supply required to supply Shanghai until 2020.

FIGURE 1 ABOUT HERE

In every scenario, a valley-peak pattern occurs where the HHI decreases, then increases, and then decreases again. The increase in the HHI is due to the greater reliance on LNG supply which makes the market temporarily more concentrated. Once the 1st phase of the LNG terminal has reached maximum capacity, additional gas supply would come from the Sichuan-East pipeline, and possibly elsewhere, thus reducing the relative importance of LNG as well as market concentration in the Shanghai gas market.

The decision to give priority to LNG in the High and Very High scenarios leads to a lower HHI after 2015. The main cause of the relatively modest reduction of the HHI is the assumption that contracted LNG volumes during the second phase from non-Malaysian suppliers are less than gas supply allocated to Shanghai from any pipeline. By receiving additional supplies from different LNG exporters, the Shanghai gas market becomes more diversified and thus less concentrated than if all had been supplied from Malaysia.

3.2 Residual Supply Index

Considering the HHI in isolation can lead to deceptive conclusions regarding the rigour of competition, because it only provides a partial (and rather simplistic) measure of market structure. Another index that can be used to analyse market concentration is the Residual Supply Index (RSI). For a given level of demand, the RSI for firm *i* measures the percent of supply remaining in the market after subtracting firm *i*'s supply capacity. The RSI is expressed as:

$$RSI_i = \left(\sum_{i=1}^{n} \frac{Q_i}{D} \right) - \frac{Q_i}{D} \qquad (2)$$

where n is the number of market suppliers, Q_i is supplier i's available capacity, and D is market demand.

If the residual supply of firm *i* is less than 100 per cent of demand, firm *i* is needed to meet that demand and is, therefore, a pivotal supplier in the market. An overall RSI for the entire market can also be calculated. The RSI for a market in a given time period is the minimum

RSI_i among all suppliers in the market. An RSI exceeding 120 per cent is an indicator of a reasonably competitive market (Rahimi & Sheffrin, 2003).

Figure 2 shows that the RSI in the Shanghai gas market ranges from 23 per cent to 159 per cent for the scenarios under consideration. Until 2010, the RSI never exceeds 120 per cent because sources of supply are limited to the 1st West-East pipeline, the offshore Pinghu pipeline, the Sichuan-East pipeline and the 1st phase of Shanghai LNG terminal. Between 2012 and 2015, however, the gas market can be considered competitive at Low, Moderate and High growth of consumption. The RSI never exceeds 120 per cent for the Very High growth scenario.

FIGURE 2 ABOUT HERE

The decision to give priority to pipeline gas or LNG in the High and Very High scenarios only makes a temporary difference in the corresponding RSI values. In 2012, the 2nd phase of the LNG terminal will be implemented and the 2nd West-East pipeline along with the Sichuan-East pipeline will be able to operate at full capacity. Until gas consumption in Shanghai reaches a level where it requires supply from every available source, the RSI is more affected by available infrastructure than on-going consumption.

When the gas market experiences very rapid growth in consumption, every supplier is pivotal in meeting demand. Once all the planned gas pipelines and 2nd phase of the LNG terminal are completed, consumption will be high enough to require supply from every available source. With increased consumption, Shanghai will see the value of its RSI decrease as each gas supplier becomes increasingly more important in meeting demand.

4. Benefits of Gas on Gas Competition

4.1 Price Competition

Initial concerns that LNG would be too expensive for China may have been exaggerated. Compared to other major cities in China, Shanghai has the highest natural gas price, reaching up to 2.1 RMB/m^3 or approximately 7 $/MMBtu. Shanghai's current gas price indicates that in coastal China, LNG can be competitive with pipeline gas. Since no contract has yet been signed for the Sichuan-East pipeline, the 2nd West-East pipeline and the 2nd phase of LNG terminal, gas on gas competition can be expected in Shanghai in the near future.

Competition between projects to provide gas to Shanghai is complex because it depends on more than just the relative costs of gas and LNG transportation. While LNG from Asia-Pacific exporters may provide lower transportation cost for Shanghai, long-distance pipelines such as the West-East pipeline and the Sichuan-East pipeline can offer better "city-gate" prices because of economies of scale. For example, the negotiated price of Turkmenistan gas for the 2nd West-East pipeline is approximately $80 per thousand cubic meters or around $2.22 /MMBtu (Peyrouse, 2007).

By specifying the price at which domestic pipeline gas must sell, the Chinese government has effectively placed a price cap on competition from LNG. Even though city-gate prices only apply to domestic supply, clearly it will have a significant impact on the long-term contractual price of LNG that will be imported for the 2nd phase of the LNG terminal. It is

highly likely, therefore, that when the Shanghai Municipality decides to expand the re-gasification capacity of its LNG terminal, competition will be limited to exporters who can offer prices that are comparable to those of domestic pipeline gas and the current LNG contract with Malaysia.[9] Thus, interactions between domestic pipeline gas and imported LNG in the gas market can enable Shanghai to maintain a strong bargaining position when exploring possibilities for additional supplies of LNG.

4.2 Security of Supply

The choice between pipeline gas and LNG will be influenced not only by economics but by energy security policy at the national, as well as municipal, level in addition to political risk considerations in the LNG and gas exporting countries. The Central Government's policy on natural gas supply gives priority to the development of indigenous gas reserves. This emphasis on domestic supply could delay the time-frame for construction of the 2nd phase of Shanghai's LNG terminal. However, Shanghai Municipality's intention to diversify energy sources in order to increase security of supply provides an excellent argument why Shanghai should rely more on imported LNG than domestic pipeline gas. In the event of a natural disaster affecting one of the major pipelines, Shanghai's LNG terminal can receive additional cargoes of imported LNG to compensate for a temporary reduction in domestic supply.

According to the China National Petroleum Corporation, the 2nd West-East pipeline will pass through 13 provinces, autonomous regions and municipalities.[10] Allocations of pipeline gas from the 1st West-East pipeline were determined by the NDRC, and it is expected that the it

[9] The contract between Petronas and Shanghai LNG Co. Ltd. is reported to entail a FOB price of around $5.6 to $5.8 /MMBtu at $60/barrel oil. This price is considerably lower than for deliveries to Japan, South Korea and Taiwan for contracts taken out at about the same time.

[10] Xinjiang, Gansu, Ningxia, Shaanxi, Henan, Anhui, Hubei, Hunan, Jiangxi, Guangxi, Guangdong, Zhejiang and Shanghai.

will also decide on gas allocation for the 2nd West-East pipeline. Even if Shanghai's initial request to obtain more supply from the West-East Pipeline is granted by the NDRC, it will not necessarily guarantee a secure and stable supply of pipeline gas in the long term. Increased demand from the upstream provinces on the pipeline may reduce available supply to Shanghai. In this context it should be noted that Shanghai currently consumes less than a quarter of the total annual capacity of the 1st West-East pipeline. Further, with Shanghai's relatively high level of prosperity it is possible that the NDRC will give priority to the poorer upstream provinces to access affordable pipeline gas.

5. Conclusion

Regardless of which scenario is the most plausible, Shanghai remains a supply constrained gas market that will continue to rely upon pipeline gas supplies from the western provinces and imported LNG. After 2017, the gas market in Shanghai can be regarded as of low concentration since its HHI falls below 1800 for the Very High Growth scenario. In terms of RSI, the gas market can be considered competitive at Low, Moderate and High growth consumption scenarios between 2012 and 2015. With increased consumption, Shanghai will see the RSI of its gas market decrease as each supplier becomes increasingly more important in meeting demand. A decrease in RSI is followed by a decrease in HHI making the gas market in Shanghai more diversified and competitive.

Gas on gas competition in Shanghai should be encouraged since there can be positive outcomes resulting from the interaction between pipeline gas and imported LNG in the market. The main benefits of such a competition would be increased security of supply and a

strong bargaining position for negotiating LNG long-term contract prices comparable with those of domestic pipeline gas supplies.

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Figure 1: The Herfindahl-Hirschmann Index for the Six Scenarios

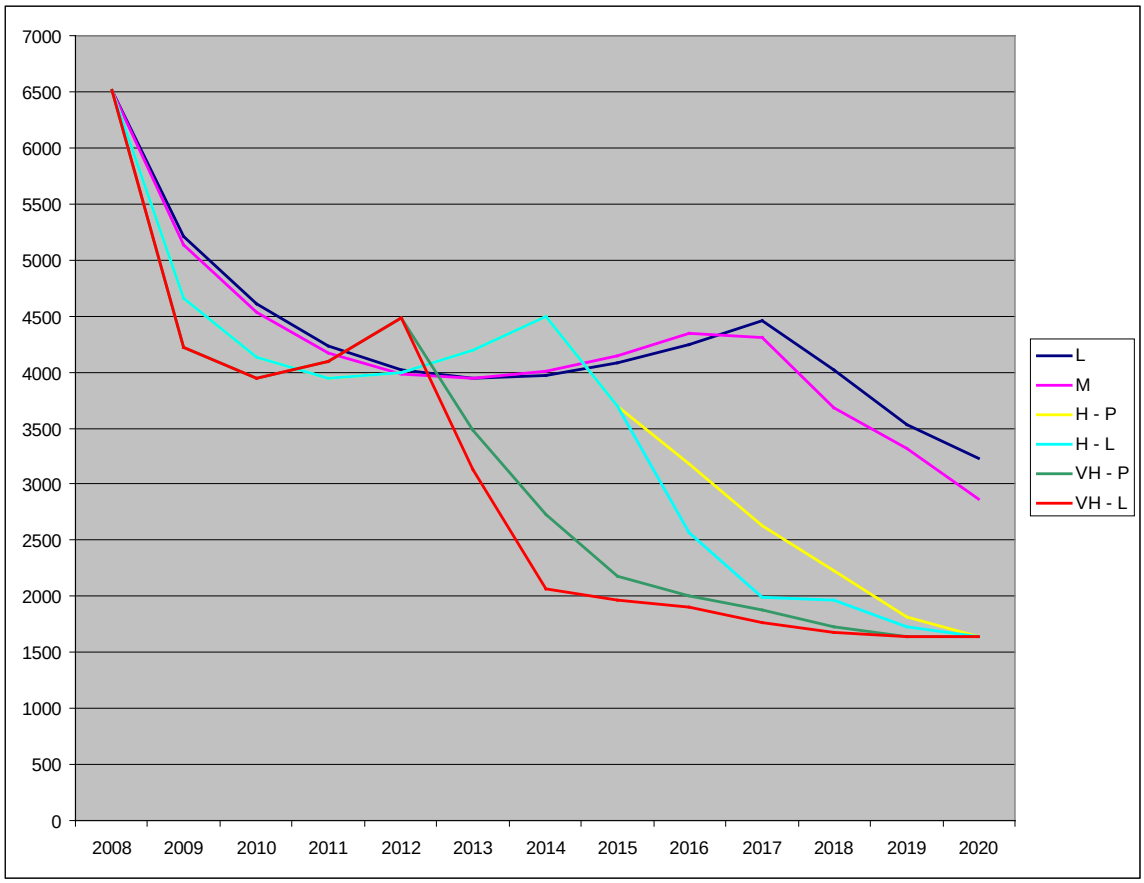

Figure 2: Residual Supply Index for the Six Scenarios