Natural Gas

Introduction

World primary energy stands at about 9 billion toe in 2013 and it is projected to rise to 20 billion toe by 2035. Share of petroleum in the primary energy mix is the largest at 33% in 2013. Coal and natural gas are at 29% and 18% respectively. The share of natural gas in the primary energy mix is increasing steadily whilst the share of petroleum and coal are dropping. As per projections by 2035 the share of oil and coal would drop to about 25% while the share of natural gas would increase to about 24%.

Sri Lanka energy sector is dominated by imported petroleum. Per capita energy consumption in Sri Lanka is still very low. Although over 90% of the households are electrified, per capita electricity consumption is 449 kWh. The introduction of natural gas into the Sri Lanka energy mix may change this picture.

The discovery of natural gas in Sri Lanka has created tremendous interest among the energy sector professionals as well as the private sector investors. Cairns Lanka who was exploring for petroleum in Mannar Basin has discovered two gas deposits, exploitation of which appear to be commercially viable. While, energy sector professional are quite familiar with the natural gas, for the general public it is an unfamiliar subject.

Discovery of natural gas is an important milestone in the development of the energy sector of Sri Lanka. Having had no domestic resources of petroleum, Sri Lanka is largely dependent on imported fossil fuels to fulfil its energy needs. Discovery of domestic natural gas would give a tremendous boost to the economy by reducing the foreign exchange outflow required to import fossil fuels. Our energy security would be enhanced as the dependence on imported petroleum and coal is lessened.

A whole series of questions arises with this discovery of gas. How much of natural gas reserves are discovered? How can we exploit this resource to get the maximum benefit to the country? Would the gas be made available at competitive prices to other imported fossil fuels? The Pathfinder Foundation has organized a seminar on Natural Gas with the objective of creating awareness and to generate a discussion on the issues involved and make policy
recommendations to the authorities on the exploitation of this national resource. This paper is prepared based on the discussions at the seminar.

**What is Natural Gas?**

Natural gas is a fossil fuel like petroleum and is generally believed to be derived from deposits of plant and animal remains from millions of years ago. Natural gas can be produced as "associated" gas from oil fields during the extraction of crude oil or as "non-associated" gas from separate natural gas fields developed primarily for extraction of gas. A few decades back most of the associated gas from crude oil wells were flared due to inability of transporting it to consuming areas. With the development of liquefaction of gas to LNG and pipeline networks, flaring of associated gas has virtually ceased.

Natural gas is a hydrocarbon gas mixture consisting primarily of methane, but includes varying amounts of other light hydrocarbons, namely ethane, propane, and butane. Raw natural gas may contain CO2 and sometimes N2 which have no heating value. Sulfur in the form of hydrogen sulphide is also present as a major impurity.

Before natural gas can be used as a fuel, it must be processed to remove impurities, including water, and sulfur to meet the specifications of marketable natural gas. Carbon dioxide and nitrogen are typically removed from the natural gas while ethane, propane, and butane are usually removed and marketed separately as special fuels or as feedstock for the manufacture of petrochemicals. Similar to associated gas being present in crude oil wells, natural gas from gas fields contain associated liquid (condensate), which is also separated and sent to refineries for processing.

Natural gas produced from shale formations is known as shale gas. Because in shale formations permeability too low to allow gas to flow in economical quantities, shale gas wells depend on fractures to allow the gas to flow. Early shale gas wells depended on natural fractures through which gas flowed; almost all shale gas wells today require fractures artificially created by hydraulic fracturing. Since 2000, shale gas has become a major source of natural gas in
the United States and Canada. Following the success in the United States, shale gas exploration is beginning in countries such as Poland, China, and South Africa.

Natural gas is an energy source often used for power generation, heating. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of various petrochemical based plastics and artificial fibers.

In producing countries natural gas is transported via pipelines for use in power generation and other end uses. Natural gas produced in different areas is fed to an interconnected pipeline system known as a hub. The most important hub for natural gas in North America is the Henry Hub, located along the U.S. Gulf Coast. Henry Hub natural gas is used as a benchmark for pricing natural gas.

Natural gas is exported from many producing regions to regions of high demand. Russia and Norway supply natural gas by pipeline to European countries and Nigeria supply natural gas to West African countries via West African pipeline. Inter-continental exports of natural gas is in the form of liquefied natural gas (NLG).

**Liquefied Natural Gas**

LNG is natural gas that has been cooled to the point that it condenses to a liquid, which occurs at a temperature of -16 °C. Liquefaction reduces the volume of gas by approximately 600 times, thus making it more economical to store natural gas where other forms of storage do not exist, and to transport gas over long distances for which pipelines are too expensive. Liquefaction makes it possible to move natural gas between continents in specially designed ships. It has enabled countries that have large natural gas resources, but have no or very small domestic demand, (e.g. Qatar, Indonesia), to export regions of high demand.

Large investments are required to market natural gas through liquefaction as the developers must invest in a number of operations that are highly linked and dependent on one another. So called LNG value chain consists of the following:

- Exploration and production of gas
- Liquefaction to convert natural gas to liquid so that it can be transported in ships
• Shipping the LNG in special purpose built ships
• Re-gasification to convert the LNG from liquid phase to gaseous phase

New technology have been developed to allow the LNG to be converted back into natural gas onboard the ship, with natural gas going direct into the high pressure pipeline. Existing LNG carriers can be converted for this purpose at a reasonable cost. Such Energy Bridge Regasification Vessel (EBRV) to allow offloading of gas as high pressure gas, eliminating a regasification station at the receiving port.

Because of the large investments required to develop LNG facilities, most producers enter into long term supply contracts with the buyers to ensure the financial viability of these projects.

Large reserves of natural gas exist around the world in areas where there is no significant market or regional demand. Such gas reserves are considered as “stranded” are available in North Africa, West Africa, Middle East, South America, South East Asia. Some of the natural gas produced from these resources is liquefied and shipped to areas where usage of natural gas exceed indigenous supply e.g. Japan, South Korea.

As the distance over which natural gas must be transported increases, usage of LNG has become advantageous over usage of pipelines. In general liquefying natural gas and shipping via ocean transport become cheaper than transporting natural gas by offshore pipelines for distances of more than 700 miles or in on shore pipelines for distances greater than 2,200 miles

Worldwide Natural Gas Reserves and Production

Estimated reserves of natural gas of the world in 2013 were 6,845.6 trillion cubic feet. Table below give the 5 countries with the largest reserves. OPEC countries control about half of the world's gas reserves (48%) and three countries (Russia, Iran and Qatar) hold more than half (54%) of all recorded gas reserves while the top ten reserves holders own almost 80% of the total.
Reserves

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves, (trillion cubic feet)</th>
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<tbody>
<tr>
<td>Russia</td>
<td>1688</td>
</tr>
<tr>
<td>Iran</td>
<td>1187</td>
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<tr>
<td>Qatar</td>
<td>890</td>
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<tr>
<td>USA</td>
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<tr>
<td>Saudi Arabia</td>
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Production

<table>
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<tr>
<th>Country</th>
<th>Production, (billion cubic feet)</th>
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<tr>
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<td>24,058</td>
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<tr>
<td>Russia</td>
<td>21,685</td>
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<tr>
<td>Iran</td>
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<td>Norway</td>
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USA has overtaken Russia as the world’s largest producer of natural gas, mainly due to use of newly developed hydraulic fracking and horizontal drilling techniques. Fracking is pumping a fluid into a well at high pressure in order to break up the rock to release so called “tight gas” and “shale gas”. However, there is a lot of controversy about this technique as it is alleged that it pollutes the ground water and even causes seismic disturbances.

USA is also the largest consumer of natural gas. According to the U.S. Energy Information Administration, about 25% of the total energy consumption in the United States is natural gas. Within the 25%, about half is used by industry, while the other half by commercial and residential users.

Russia is the largest exporter of natural gas at 7,372 billion cubic feet (2012), virtually all to European countries by pipeline. Number of countries in Middle East and Asia exports natural gas as liquefied natural gas (LNG), mainly to Japan and South Korea.
Exports

<table>
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<tr>
<th>Country</th>
<th>Exports (billion cubic feet)</th>
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<tr>
<td>Russia</td>
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<tr>
<td>Qatar</td>
<td>4,267</td>
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<tr>
<td>Norway</td>
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<td>Indonesia</td>
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<td>Malaysia</td>
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Natural Gas Usage

Power Generation

Because of its clean burning properties, natural gas is increasingly being used for electric power generation in the world. Of the three fossil fuels used for electric power generation (coal, oil, natural gas), natural gas emits the least carbon dioxide per unit of energy produced. It emits 30% less carbon dioxide than burning oil and 45% less carbon dioxide than burning coal. Burning natural gas also releases lower amounts of nitrogen oxides, sulphur dioxide, particulates and mercury when compared to coal and oil.

As the world becomes more concerned about climate change, carbon dioxide emissions, and air quality, the use of natural gas for electricity generation is expected to increase.

Power generation is done via gas turbine or steam turbine operations. High efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle operation.

In United States, which is the largest natural gas consumer, about 34% of natural gas consumption was used to generate electricity.
Industrial Use

Natural gas is used as the raw material for a wide range of products. Steam reforming of natural gas produces hydrogen which is further processed to produce ammonia and urea fertilizer. By steam cracking of natural gas many intermediate raw materials of petrochemicals are produced. These are finally processed to produce plastics, pharmaceuticals, antifreeze compound etc.

Many industries which need clean fuels use natural gas as a source of heat. Glass, ceramics and tile industries use natural gas fired furnaces in their manufacturing processes.

Domestic Use

In countries with colder climates – Europe, United States – natural gas is used for domestic home heating. In United this contributes significantly to the price fluctuation of natural gas due to high demand during winter.

Transportation

Compressed natural gas can be used in automobile engines replacing gasoline and diesel. It is a cleaner fuel which generates fewer emissions compared to the conventional fuels. Many countries use CNG powered vehicles, especially in cities to combat air pollution. In 2012 there were 17.25 million natural gas powered vehicles worldwide. Iran operates the largest number of CNG vehicles at 3.3 million. Other countries leading in CNG vehicles are Pakistan-3.1 million, Argentina – 2.18 million, Brazil – 1.73 million, India and China at 1.5 million each.

CNG has a high octane value of about 120, and gasoline engines converted to run on CNG lose some efficiency, by not being able to get the full benefit of the high octane due to low compression ratio of the engines. However, CNG-specific engines are designed with a higher compression ratio to benefit from fuel's higher octane number.
Shipping industry has shown some interest in using LNG for bunkering. Due to the emission control measures imposed for shipping in the Baltic and North Seas along with the English Channel, where fuel sulphur is expected to be limited to just 0.1%. LNG offers one of the most prominent solutions, for reducing sulphur oxide, nitrogen oxide and carbon dioxide emissions while being economically feasible.

The first LNG bunkering facility in Europe for inland shipping was opened in the Seinehaven, in Rotterdam Botlek, in July 2014. However, LNG bunkering on a global scale may take a few decades to develop as it requires an unified approach between shippers and port operators with respect to construction of LNG fuelled ships and developing LNG bunkering facilities at ports.

Liquid Petroleum from Natural Gas

Natural gas can be converted to liquid petroleum products such as gasoline, diesel and jet fuel using the newly developed Gas-to-Liquid (GTL) technology. Different GTL processes have been developed to convert natural gas through what is known as Fischer-Tropsch synthesis. Some GTL processes produce synthetic gasoline from natural gas, while other processes produce synthetic crude oil that can be refined into gasoline, diesel etc. Royal Dutch Shell commissioned a 140,000 barrel GTL plant in 2011 in Qatar.

Whilst, there is a number of operating GTL plants, the technology is still in its infancy. Once the technology is fully established, the countries that have abundant natural gas but lack in liquid petroleum resources could produce all petroleum fuel requirements through GTL technology.

Natural Gas Market and Pricing

International Gas Union has identified the following price forming mechanisms in the global wholesale gas market (IGU Wholesale Gas Price Survey 2014). 44% of the gas traded is on Gas-on-Gas (GOG) competition, where gas price is based on supply and demand. 19% is price linked to crude oil. 33% of the world trade of gas is on regulated prices. 12% regulated on cost of supply, 14% regulated on social and political considerations and 7% regulated with prices below cost.
Globally natural gas price is indexed to three main regional markets, namely United States, UK and Japan. Gas market in US and UK is based on domestic resources. Gas prices are not pegged to crude and follow development of their own. In EU (except Netherlands), Japan and Korea markets have developed based on imports. Price is normally pegged to crude oil.

The United States market, system features open trading in gas as a commodity and pipeline capacity to move gas. The centrepiece of the pricing is Henry Hub, located along the U.S. Gulf Coast. Henry Hub price is the benchmark for natural gas spot trading market and for futures trading in the NYMEX. It is the average of the natural gas prices traded at this location from 13 interconnected pipelines.

US natural gas prices have been on a downward trend, mainly due to increased domestic gas production from fracking operations.

UK has one of the most price competitive gas markets. Like the US market it depends mainly on domestic resources, although some imports come from Norway via pipeline and LNG from other suppliers. UK’s National Balancing
Point (NBP) market price is widely used as benchmark for Europe’s wholesale gas market. UK NBP gas market is Europe’s longest-established spot-traded natural gas market.

Although similar in concept to the Henry Hub in the United States, NBP differs in that it is not an actual physical location. NBP is a virtual trading location and has been established by regulation. It is the largest trading hub in Europe.

Except Netherlands and Norway all European countries are dependent on imported natural gas, mainly through pipeline and part imported as LNG. Russia, Algeria and Norway are the main suppliers to Europe. Russian gas is supplies via pipeline. Algerian supplies come as LNG and via two pipelines across Mediterranean to Italy and Spain.

Gas from these sources is supplied on long term contracts. Because of the high investment in production and transportation costs (long distance for Russian and Algerian pipeline gas), these contracts provide for a high annual minimum pay corresponding to high load factor, which guarantees the payback for the investment and a minimum resource charge. The base price of gas would be re-calculated at regular intervals in line with the price movement of competing fuels. While gas oil and heavy fuel oil are the most common competing fuels reference to the other competing energies could be used. This type of contracts would ensure a reliable sales volume for the seller at prices close as possible to what can be sold in competition with other energies in the market. The netback calculated back to the wellhead provide for maximum specific price that can be obtained from the market without losing competitiveness.

Japan and Korea where there are no domestic resources, markets have developed totally based on imported LNG. Main supply sources are Qatar, Indonesia and Malaysia. Unlike US, UK and continental Europe, Japan and Korea have no gas hubs. Korea has one gas company and Japan maximum of two operators (one gas, one power utility) per region. Practically no pipelines exist between the regions.

For supply of LNG to Japanese market, the traditional contracting pattern has been long term contract. It provides a method of sharing risks between buyer and seller for these capital intensive investments. Buyers assume the volume risk through a take-or-pay contract and seller assumes the price risk through a
price escalation clause linked to changes in energy price levels. A typical contract links the LNG price to the Japanese Customs Cleared price for crude oil – JCC or the “Japanese Crude Cocktail “.

Most common form Japanese supply formula is \( P = C + S \times JCC \)

\( P \) - the Price in $/MMBtu,
\( C \) - a Constant Expressed in $/MMBtu
\( S \) - a coefficient (or "Slope"), a dimensionless number linking the JCC quotation in $/bbl with the LNG price
\( B \) - a constant in $/MMBtu

The JCC price is published monthly, but the contracts commonly averaged the monthly prices over some stated period, so that the monthly volatility of oil prices is dampened, unlike the European prices where gas price moves proportionally with oil prices. In the negotiations, the parties effectively set the base price by means of the size of the ‘\( C \)’ constant. A theoretical slope for the ‘\( S \)’ coefficient, assuming heating value equivalence between oil and gas would have be 0.172, but actual coefficients used in the contracts used somewhat different slope numbers.

To protect buyers and sellers from the volatility of oil prices, particularly during international oil market upsets, a cap and a floor price are introduced to most formulas. The ‘cap’ limits the operation of the JCC portion of the pricing formula during periods of high oil prices protecting the buyers and the floor price protects the sellers from a price collapse. The resulting upper and lower limits are commonly described as S-curves.

**Natural Gas Market in Asia**

India, besides production from domestic fields, imports natural gas as LNG on term contracts as well as spot purchases. India has a regulated pricing mechanism (Administered Pricing Mechanism) and the wellhead price of domestic natural gas is $ 4.2 per MMBtu. India received LNG at an average delivery price of $10 - $13 per MMBtu in 2013.

A Govt. appointed committee (Rangarajan Committee Report) recently proposed to increase the wellhead price based on price in Henry Hub, NBP,
LNG imports to India and LNG imports to Japan, which would have doubled the price to $8.2 per MMBtu. However the Government revised the formula to fix the wellhead price at $5.61 per MMBtu, applicable from 1st November 2014. The Government contends that this wellhead price is more than adequate for E & P companies to invest in further development of KG basin deep sea gas deposits.

Indonesia, which exports natural gas as LNG the export price is about $11 per MMBtu. However, the domestic pipeline gas averages $5.8 per MMBtu (Migas Indonesia). Similarly, in Malaysia, LNG export price is $10 per MMBtu. Domestic gas price has averaged $4.8 per MMBtu (Malaysian Energy Information Statistics). In both these countries the domestic gas, though lower than export price, is not subsidized, but still on a cost of plus basis. The country forego a “loss of revenue” from exports by keeping the domestic gas price low in order to provide low cost electricity and to support local industries.

Vietnam which produces gas from both on shore as well off shore fields, gas prices are regulated on cost plus basis. Current domestic price is about 6 $/MMBtu

**Natural Gas in Sri Lanka**

Sri Lanka has made available nine off-shore exploration blocks M1 to M9 in Mannar basin and five exploration blocks C1 to C5 in Cauvey basin. During the first bidding round in 2007 Cairn India obtained exploration rights to Block M2. In 2009/10 Cairn carried out EIA studies and 3D seismic investigations. During the exploration Phase 1 of the exploration program in 2011 Cairn drilled three wells and discovered natural gas deposits in two of the test wells. In the second phase of exploration one more well was drilled and found to be dry. Two discoveries, Dorado and Barracuda have a potential reserve of 2 trillion cubic feet (tcf) of gas. According to PRDS, the available seismic data indicate that Mannar basin may have up to 10 tcf in gas deposits. Exploitation of these resources may bring as much as US$ 200 billion in revenues to Sri Lanka.

GOSL has entered into a production sharing agreement with Cairns. Under the production sharing the exploration company (Cairns) bear all exploration and development costs. After paying a royalty on gross production to the GOSL, Cairns is entitled to a predetermined share of the production for cost recovery.
the remainder of the production known as profit gas is shared between GOSL and Cairns according to a formula based on the investment. Initially Cairn gets a higher percentage of profit gas and as the investment are recovered GOSL share increases. Cairn will also pay tax to GOSL on their share of the profit oil.

Cairn has invested about US$ 225 million in the exploration work carried out up to now. It is estimated that to develop the Dorado field which has a potential of 300 billion cubic feet of gas, an investment of approximately US$ 1500 million is required.

Knowledge and know-how are key elements in oil and gas exploration. The PRDS has maintained an open-data-room policy since 2012, which has resulted in over 30 major oil and gas companies sending their exploration teams to study available data jointly with the PRDS technical staff. Major oil companies such as ONGC, Shell, Exxon Mobil, Chevron, ENI and Total have shown serious interest in participating in future exploration activities in Sri Lanka.
All potential oil bearing geological formations in Sri Lanka are in offshore deep water. There is limited skill and experience in successfully operating in deep and ultra-deep water globally. PRDS has taken steps to identify and attract oil and gas companies that have a proven track record in deep water oil and gas exploration. Selecting the correct partner is critical for the country, as technically and economically successful exploitation of our hydrocarbon resources is not something we can do on our own yet.

For the economic exploitation of the discovered gas reserves, a market has to be developed for gas. As per PSA agreement Sri Lanka has the first option on gas. The price of gas is to be determined taking into account the prevailing government policy on natural gas and linkage with traded liquid fuel. If the gas is to be exported it is to be valued on the basis of competitive "arms length" sales in the region, for the purpose of profit sharing. Presently there is no national policy on natural gas and according to PRDS, such a policy is being prepared.

Primary user of natural gas in Sri Lanka would be the power sector. Existing combined cycle power plants could be converted to run on natural gas with minimal modifications. According to PRDS they are currently having discussions with the CEB on introducing natural gas into CEB generation system.

In developing the gas market in Sri Lanka PRDS has developed several scenarios. Initially gas would be supplied to the power sector, expanding into industry and transportation sectors under future stages of development. When fully developed Mannar gas could be used in other applications such as fertilizer manufacture, chemical industry, cold storage systems and as city gas supply. Under the NG 1 scenario PRDS estimates that gas demand would increase from 75 thousand cubic feet per day in 2018 to 1200 thousand cubic feet per day in 2040, with power sector being the largest consumer. Under the NG 2 scenario the projected demand would increase to 2200 thousand cubic feet per day.

According to PRDS Kerawalapitiya Power Plant which is currently operating on diesel would be the first plant to be converted to run on Mannar gas, and gas purchase agreements are being discussed with them. The price of gas would start at US$ 15 per million BTU and would decrease over time to reach about US$ 5. As the infrastructure need to be installed to get the gas out, it is difficult
to say when the gas would be made available. PRDS estimates that gas could be made available five years from the date of signing a firm purchase agreement.

The methodology for arriving at these figures for the price of gas is not clear. It is believed that it is based on cost recovery plus return on investment. The prices mentioned are well above prevailing gas prices in the region. However, it must also borne in mind that that Sri Lanka is a frontier region involving deep sea drilling and that we may have to provide generous returns to E & P investors in order to attract them to invest in exploration activities in Sri Lanka.

Commercialisation of present discoveries from Block M2 is our immediate priority. In order to ascertain the full hydrocarbon potential further data acquisition is essential, and this is a future activity of high priority. At the same time Sri Lanka need to increase the exploration activities in other potential blocks.

Sri Lanka is yet to formally include domestically produced hydrocarbons, especially natural gas into our national energy policy. A substantial domestic gas production may allow us to offset imported fuel used in our thermal power plants. In addition, other key users of energy such as public transport may tend to convert to gas use, and new industries such as fertilizer manufacture, petrochemicals may become possible with strong domestic supply. If the gas reserves exceed domestic requirements, it is required to provide acceptable commercialisation options to international companies for exploiting the reserves.

Prospective Demand and Economic Prices of Natural Gas in Sri Lanka

Natural gas may be used for power generation as well as non-power applications. We need to examine the prospective sectors where natural gas may be used, along with the current prices of competing fuels and the factors affecting the demand of natural gas against other fuels. It is important to look at the impacts on the end-use customers and products due to introduction of natural gas into our national energy pool.

The main demand for natural gas in Sri Lanka would be in the power sector. Sri Lanka power generation system is currently based on hydro, thermal oil, thermal coal and renewable generation. In the first half of 2014 the share of power generated by each stood at Hydro 30.8%, oil-34.2%, coal 29.8% and
renewable 5.2%. Production cost of electricity is highest with oil fired generation at 24.55 Rs/kWh with coal fired generation being the lowest at 6.4 Rs/kWh. As per PUCSL published data national average cost of supply of electricity was 20.85 Rs/kWh in the first half of 2014. The projected cost of generation for the second half of 2014 is 16.25 Rs/kWh, with coal dominating the generation mix at 40%.

Long Term Generation Plan of CEB envisages increased coal fired generation in the future, in order to reduce production costs. With the present expansion plan, it is projected that by 2022, the cost of generation would come down to 7.13 Rs/kWh, with the share of coal fired generating increasing to 65% of the generation mix.

In order for natural gas to establish as the primary fuel in the generation fuel mix it has to displace coal as the competing fuel, which is the dominant competing fuel in future power generation scenarios. At Natural gas price around USD 16 per million BTU, NG fired plants may replace oil fired plants, but would be of low merit order due to high production cost. If natural gas is priced below USD 7 per million BTU when coal is at USD 140 per ton, natural gas fired power plants may perform mid-merit duties. The “knock-out price” for natural gas to compete with coal and enter base load duties, the price has to be USD 5 per million Btu. The reported natural gas prices in the regional countries such as India, Indonesia and Vietnam are around these values.
It is believed that once the production commence from local fields, the production rates have to be kept reasonably constant without much variation due to inability to keep a buffer stock. If the production is to be kept at constant level the natural gas fired power plants need to function as base load stations. At the proposed gas price it is not possible to achieve even mid-merit dispatch. If the natural gas at a higher price is designated “mandatory purchase“ by the Government, then the objective of reducing average power generation costs to reach 7.13 Rs/kWh by 2022 cannot be achieved.

In the non-power applications energy consuming sectors such as transport, industry, city gas (households and small businesses) and hospitality industry may switch over to natural gas if the price is attractive. Manufacturing natural gas based fertilizer would also create a substantial demand for natural gas.
In projecting the future natural gas demand for non-power sectors, three scenarios have been looked at.

Scenario 1: Business as usual. Depending on price and availability, customers voluntarily switch over to natural gas over a long period of time.

Scenario 2: Government policy intervention. For example mandatory conversion of Busses and Three wheelers to gas (initially in Western Province).

Scenario 3: Government policy intervention as above and subsidies on conversion.

Non-Power Sector: Demand Curve for Hypothetical 100% Conversion to NG
It is seen that without Government policy intervention, the penetration of natural gas to non-power sector would be low.

**Oil and Gas Exploration Contracts**

The development of oil and gas fields requires large capital investments as well as technical know-how and experience in natural resources extraction. Given this reality countries often turn to international oil companies for capital and expertise, in developing their resources. In inviting foreign oil companies to develop natural resources of a country, the challenge faced is how the governance of the relationship with the foreign oil company be sufficiently balanced so that the hydrocarbon wealth is shared, taking into account the sovereign ownership of the resource on one hand, and the value-added by the foreign oil company in extracting the resource on the other hand. Over the past few decades, the governments have looked to increasingly sophisticated methods of contracting to deal with this challenge.

**Concessions**

Concessions are the oldest form of agreements governing the exploration of natural resources. Concessions, in their original format, vested property rights in the unproduced oil and gas in an area of land to the foreign oil company. If the company discovers oil or gas in that property, it belonged to the company. One time concession fee was paid to the state for this. This arrangement became untenable in the post-colonial era, when developing countries were promoting a new equitable economics order.
Modern concessions and licensing arrangements are contracts whereby the countries grants the investor exclusive rights to exploit natural resources in a given area for a specific period of time, in exchange for payment of royalties and taxes, without vesting the title to unproduced hydrocarbons. In principle, concession contracts do not involve collaboration in production activities, and the investor runs the operations and the government receives revenues.

Production Sharing

Early concessions were perceived to be unfair, and many newly independent countries pursued nationalization policies that cancelled foreign oil companies concessions. As middle and low income countries still needed the technical know-how of the foreign oil companies, but not willing to giving up sovereignty over their natural resources, Production Sharing concept was developed. PSAs were first developed in Indonesia in 1960s.

The main characteristic of the Production Sharing Contract is that state and the foreign oil company share the hydrocarbons produced and leave the title to the unproduced hydrocarbons with the state. The investment in exploration and production activities is borne by the oil company. Any hydrocarbons produced are shared between the state and the investor. The total production is divided into two parts as Cost Recovery Oil and Profit Oil. Capital investment and on-going production costs can be recovered from Cost Oil, and the remaining Profit Oil is split into two shares: the oil company share and the government share. In terms of cost oil, the oil company investing money in a PSA project recoups its money at a contractually stipulated rate. Some PSAs permit capital investors to recover 100 per cent of exploration and development costs before having to share the profit oil with the government. Other PSAs permit profit oil to be generated from the very start of production. In these cases, the amount of cost oil that can go towards recovering initial capital investment costs is stipulated as a percentage of the total production. Profit oil is shared between oil company and the state, usually based on the ratio of total accumulated income to total accumulated investment. Profit oil share of the oil company is normally subject
to tax. Some PSAs provide for a larger share of profits oil going to the state, but in exchange for larger stake, all taxes are foregone.

In a PSA the total risk of the investment is with the oil company. The oil company stand to make a profit only if substantial discovery of hydrocarbons is made.

It is important to note that profit sharing normally begins after the oil company reimburses its current operating and capital expenses. It is very difficult to verify these costs as reported by the investor, mainly due to lack of expertise in developing countries where most of the PSAs are in operation.

**Service Contracts**

Service contracts, like other forms of concessions and PSAs, are used to involve foreign oil companies in development of a country’s hydrocarbon resources. In a service contract foreign oil company develop or explore oil or natural gas fields on behalf of the host government in return for a pre-determined fee. In recent years many oil and natural gas producing countries have shown interest in adopting this type of contracts.

Under a service contract, state maintain field ownership and in most cases produces crude/gas ownership rights as well, and do not have to allocate them to the foreign company. Countries are interested in this type, because service contract enable them to give up less control over the field and over produced crude/gas to foreign oil companies while still using the expertise of these companies.

For countries that are beginning to explore their hydrocarbon resources, this type of contract is not suitable as the total risk of investment has to be borne by them.

**Joint Ventures**

Joint ventures involve contracts between the investor and a local partner. Joint venture projects for oil and gas exploration often involve an entity owned by the host state such as National Oil Company. While a main advantage of the joint development model is the distribution of risk among all parties involved in the project, it also requires sharing of the benefits earned. Like any contractual
arrangement for the development of country’s hydrocarbon resources, joint venture will stipulate the level of obligation that each member of the project carries. Joint ventures can be structured to include production sharing arrangements.

Policy Recommendations

Natural gas is a national resource that belongs to the people of Sri Lanka, and must be managed in a way that benefits the entire Sri Lankan society. In order to achieve this, the first priority of the Government would be to prepare a Policy document which would provide guidance for the sustainable development and utilization of the natural gas resource and maximization of the benefits therefrom.

National Gas Policy should cover issues of gas exploration, production, distribution, pricing, exports and imports. A clear and formal statement of Government’s objectives for long term development for natural gas should be addressed in the policy. The policy should provide for financial and fiscal terms to attract foreign investments in gas projects.

Natural gas is one of the most important energy sources for power generation, manufacturing industries, transportation, commercial and household use. As such, pricing of natural gas is a critical element for the economic development of the country and for a sustainable natural gas industry. An appropriate pricing mechanism should be established based on a set of key principles, including cost reflectivity, prudently incurred costs, reliability and quality of service, fair return on invested capital and capacity allocation to the most valued use. Pricing mechanism must ensure that natural gas to key sectors as power generation and industry is supplied at an affordable price.

The Government has entered into a Production Sharing Agreement with the international oil and gas company for exploration activities. Under the PSA, the foreign oil company bears the full risk of investments in the exploration activities. Investment costs are recovered through production sharing, with a portion of gas allocated as cost recovery gas and portion as profit gas. Initially the cost gas portion of the production is higher until the foreign oil company recovers full investment. Recently in many countries (India, Ghana) this type of
production sharing contracts come for criticism, where accusations have been levelled at the foreign oil company, that the costs are inflated thereby syphoning a larger portion of the profits through cost recovery oil. Inability of the Governments to properly audit the costs incurred by the operator due to lack of expertise is cited as the main cause of this. While, Sri Lanka is not in a position to invest in exploration activities and PSA is the only option available, it worth investigating the possibility of changing the format of the PSA in future contracts. One such change suggested is to do away with the cost recovery gas and for the foreign oil company to bid for a share of the profits at the exploration bidding round. This will eliminate the need to audit the exploration and development expenditure, as the cost recovery of the foreign oil company is embedded in the share of profits. India is contemplating in going for similar contracts in the future.

Following the discoveries of natural gas in the country, public expectations have increased based on the perception that discoveries are likely to yield immediate benefits. The expectations have to be moderated within realism and feasibility, lest they become a source of public discontent and disagreement. The expectations have to be managed since such benefits may take time to be realized. This situation calls for the need to increase awareness on the natural gas operations to the general public and stakeholders. It is in everyone’s interest that communication and flow of information about the natural gas industry to the public is maintained in a satisfactory condition all the time.

Natural gas resource is a potential source of revenue to the Government. However, it is critical that the revenue is managed in a manner that will bring about lasting benefits and welfare to the country. In addition to maximization of the retained share, revenues from natural gas resources must be invested strategically in order to generate sustainable returns beyond the exhaustion of the resource. It recommended that a special Fund be established and managed to ensure transparency and accountability over collection, allocation, expenditure and management of all natural gas revenues.
The Government and stakeholders have important roles to play in order to achieve transparency and accountability to the public as well as eliminating possible elements of corruption in the natural gas industry. It is suggested that the Government joins the Extractive Industry Transparency Initiative (EITI) to improve transparency and accountability as well as accessing information in relation to revenue accrued from extractive industry. There are currently 49 countries, with many developing countries as Indonesia, Ghana, Tanzania who are full members of this organization and over 80 largest oil, gas and mining companies who are members.

Sri Lanka is in its infancy of the natural gas industry, having discovered its first gas deposits. Presently there are no infrastructure facilities available for the gas industry. Natural gas industry consists of up-stream, mid-stream and down-stream segments. While, up-stream activities include exploration and production, mid and downstream involve gas processing, liquefaction, transportation, storage, regasification and distribution. While in the initial stage of development of the gas industry, the down-stream activities may be limited to gas processing and transportation by pipeline, as the industry takes off and more discoveries are made, infrastructure facilities would be required for the other down-stream activities. Such infrastructure facilities are of strategic importance and adequate investment in such facilities should be encouraged. However, ensuring non-discriminatory access is a critical issue which require owners and operators of facilities such as processing plants and pipelines to provide service to all customers in a transparent manner.

Initially natural gas is to be used in power generation. It has a large potential as a transportation fuel. However, without Government policy intervention penetration of natural gas into transport sector would be very slow. It is proposed to take following steps

a. Mandatory conversion of public busses and three wheelers to CNG
b. Provide financial aid to cover cost of conversion
c. Allow duty fee imports of CNG specific vehicles