RENEWABLE ENERGY : BIOGAS

India Landscape 2012

Athena Infonomics India Pvt Ltd

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Abbreviations:

MTOE – Million Tonne of Oil Equivalent

LPG – Liquid Petroleum Gas

CBG – Compressed Biogas

CNG – Compressed Natural Gas

LNG – Liquid Natural Gas

YoY – Year on Year

MoP&NG – Ministry of Petroleum and Natural Gas

JV – Joint Venture

CAGR – Compounded Annual Growth Rate

TMT – Thousand Metric Tonnes

TWh – Thousand watt hours

GW – Giga watt

Kcal – Kilo calories

BTU – British Thermal Unit

CO_2 – Carbon Dioxide

H_2S – Hydrogen Sulphide

CH_4 – Methane

SKO – Superior Kerosene Oil

MS – Motor Spirit

HSD – High Speed Diesel

APM – Administered Pricing Mechanism

Section I

1.1 India – Energy Requirements & Growth

An economy's development would be reflected in its consumption of energy. Growth in developing economies, for instance, would be indicated to a large extent by the utilization of industrial energy. India is an illustration of one such developing economy. In order to be able to sustain a growth rate of roughly 9 % and to accommodate some elasticity, one would require the supply of energy to increase at approximately 6.5 % a year. This ability to meet our demands would in turn rest on our capacity to expand Indian production in critical sub sectors of energy. These sub sectors would include mostly petroleum and coal and also face a challenge of meeting the deficits through imports.

The pattern of energy demand that would be needed to satisfy the projected growth rate has been furnished in Table 1.

The import requirements associated with the above energy projections are also shown in the table below. It is worth noting that dependence on imported oil is expected to increase from 76% in 2010-11 to 80% by the end of the Twelfth Plan. Import dependence on natural gas is projected to increase from 19% in 2010-11 to 28.4% in 2016-17. In the case of coal, it will increase from 19.8% in 2010-11 to about 22.1% in 2016-17.

Table 1: Projected Primary commercial Energy Requirement
(Million tons of oil equivalent)

	2010-11*	2016-17@
Oil	164.32	204.8
Of which imports	125.5 (76.4%)	164.8 (80.5%)
Natural Gas & LNG	57.99	87.22
Of which imports	10.99 (19%)	24.8 (28.4%)
Coal	272.86	406.78
Of which imports	54 (19.8%)	90 (22.1%)
Lignite	9.52	14
Hydro	10.31	14.85
Of which imports	0.48 (4.6%)	0.52 (3.5%)
Nuclear	6.86	9.14
Renewable	0.95	1.29
Total Energy	**522.81**	**738.07**
Total Imports	**190.97**	**280.12**
% of Total Energy	**36.53**	**37.95**

Note: Provisional data; @ On the assumption that annual demand/growth would be 6.5 per cent. up to 2016-17. The figures include use of oil and gas feed stock for fertilizer and other non-energy usage.*

Source: 12th Plan Approach, Planning Commission of India

Given a case of abundant energy reserves available on the global scale, the large influx of energy imports may not signify potential trouble, considering the price factor. However the notion of energy security would still be a cause for concern. In reality however, the energy prices are rising and the cost of importing is turning into an exorbitant affair and the magnitude of the costs in only set to increase. This leads to the increased pressure on increasing indigenous energy efficiency and simultaneously also increasing the domestic energy reserves.

Another important factor to be considered is that of pricing. The valid rationale behind energy pricing would be to ensure a good supply with a prerequisite to ensure an adequate demand. This is applicable in the very nature of demand management due to the fact that consumers of energy would have no incentive to use the resources optimally, if energy is underpriced. Additionally, it is relevant to encourage growth of domestic supply because under-pricing would impose a large burden on domestic producers of energy, leading to a decrease of resources that should accrue to them for making new financial investments in these domains. Thus, in the long run, we must move beyond non renewable sources of energy.

The need to increase indigenous sources of energy production is also directly related to the pattern of economic development, as mentioned earlier. Subsequently, the growing consumption of energy has resulted in an increased dependence on fossil fuels such as coal and oil. Rising prices of the same and potential inadequacy in the future creates concerns about the security of energy supply needed to sustain the economic growth. Furthermore, an increased reliance on in imports of non renewable sources of energy would have a detrimental effect on economic development, resulting due to the huge expenditure that stems from imports. This issue coupled with the environmental concerns lead to a potential 'snowball' effect on the energy front owing to which one is increasingly stressing upon a sustainable path of the other i.e. energy development.

One such renewable source of energy that is currently drawing huge attention in India is 'Biogas'. Despite being a clean source of energy with a plethora of added advantages, it is yet to make a prominent mark in the commercial space, owing to a multitude of reasons that will explored later in the report.

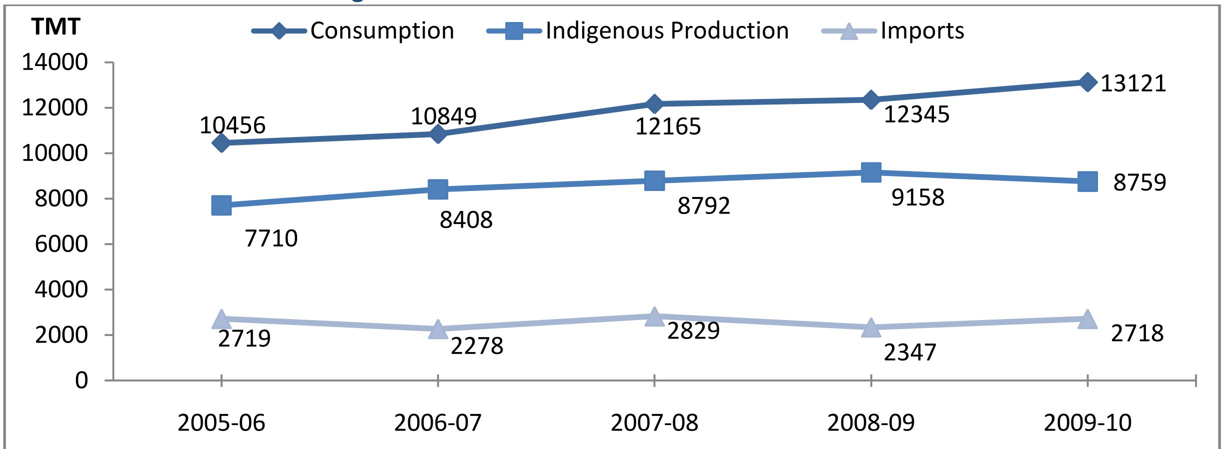
1.2 Importance of LPG and Natural Gas in Indian Energy Markets and their applications

From the table illustrated in the previous section, it is clear that the energy requirements of India are increasing at a rapid rate. LPG forms a major part to fulfil this energy need of the country. Natural gas on the other hand is moving towards being the most preferred fuel due to its inherent environmentally benign nature, greater efficiency and cost effectiveness.

1.2.1 Liquefied Petroleum Gas (LPG)

LPG clearly forms one of the major energy sources in India. The consumption of LPG has seen a steady increase over the past five years. Most of the LPG supply comes from indigenous production and about a quarter of the supply comes from imports.

Figure 1 : Growth in LPG Market in India



Source: Indian Oil Corporation, Hindustan Petroleum, Bharath Petroleum, Oil and Natural Gas Corporation and Gas Authority of India Limited

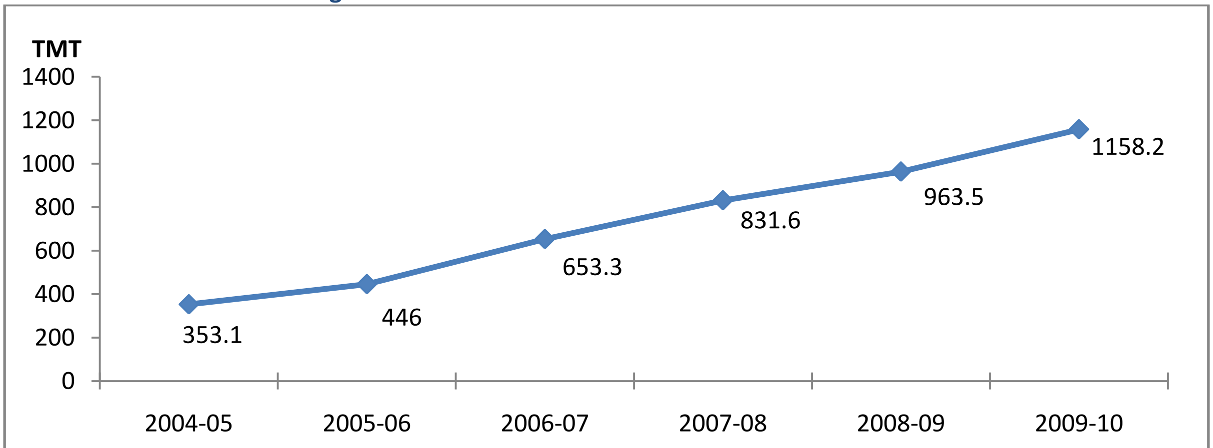
92.3% of LPG consumption in India is done so as a domestic fuel. Apart from being used for domestic purpose, 3.4% of LPG is used in commercial and industrial establishments, as a fuel during manufacturing processes. Apart from these main uses, about 2.4% of LPG is used as a vehicular fuel.

The following are the main purpose of LPG usage in India:

- Domestic: For use in household cooking
- Commercial: For use in hotels, bakeries, canteens, etc
- Auto: For use as fuel in automobiles
- Industrial: For use in production and manufacturing process

Commercial & Industrial LPG sales has seen a rapid growth of about 300% in the last six years. This implies a good demand for commercial LPG, as an important source of industrial energy.

Figure 2 : Commercial & Industrial LPG Sales



Source: Ministry of Petroleum and Natural Gas

As the demand for commercial and industrial LPG is growing at a rapid rate, there is an obvious need to look at alternative fuel sources. Also, as the energy mix cost is going up, renewable energy like Biogas can play an important role.

As an industrial fuel, LPG is used by several sectors in the production processes. Given below (Table 2) is a list of sectors and related processes where LPG is used:

Table 2: Uses of LPG

Industry	Application
Agriculture	Grain drying/ Weed killing/ Preservation of fruits/ Tobacco curing/ Tea drying
Automobile	Heat treatment/ Paint baking
Ceramics	Biscuit and Gloss firing of porcelain & stoneware
Chemicals and Drugs	Heating and Drying
Electrical	Bulbs and Tube lights manufacturing/ Filament manufacturing/ Battery manufacturing
Food	Baking/ Boiling/ frying/ milk drying
Glass	Melting/ holding/ feeding/ working/ Fire polishing
Metallurgical	Annealing/ Billet heating/ Melting/ Descaling/ Stress relieving/ Mould/ Cupola/ Ladle heating
Metal Working	Steel cutting/ Hole piercing/ Welding of non ferrous metals
Packaging	Metal box soldering
Textile	Drying/ Singeing/ Velvet processing calendaring/ Print drying/ Dyeing
Transport	Engine fuel
Miscellaneous	Aerosols propellant/ Amarjyotis/ Torches/ Bird scarers/ Bitumen Melting in water proofing industry and road making

Source: Oil Companies and Athena Infonomics Research

Trends show that the LPG imports are increasing at a rate of 6 % YoY, to meet increased consumption owing to expansion of both domestic and commercial markets. The current government has drafted a policy to make LPG accessible to 75% of families in India by 2015. This target is going to further propel domestic consumption. The prices of LPG are bound to rise further owing to a forecasted higher demand. The gap between domestic and commercial prices of LPG is going to widen further, to cater to the increased domestic demand, thereby increasing pressure on imports; thus, creating a huge demand for an alternative fuel such as Biogas.

1.2.2 Natural Gas

Natural gas has emerged as the most preferred fuel due to its inherent environmentally benign nature, greater efficiency and cost effectiveness. According to the Ministry of Petroleum and Natural Gas, gas usage in India amounted to 59 billion cubic meters in FY 2009/10, up from 43 billion cubic meters in FY 2008/09. The usage split would between energy and non-energy purpose is 61% and 39% respectively.

Table 3: Trends of Natural Gas Consumption in India

(in BCM)

Trend of Natural Gas Consumption in India (2001-02 to 2010-11)										
Year	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
Net Availability[1]	28.037	29.963	30.906	30.775	31.325	30.791	31.478	31.75	46.486	51.23
Sale by Producing Companies[2]	24.191	25.871	26.71	26.505	26.858	26.771	26.974	27.063	40.831	46.042

** Provisional*

NOTE: 1. Denotes natural gas available for consumption, which is derived by deducting gas flared from gross production by producing companies.
2. Denotes gas available for sale, which is derived by deducting internal use of gas by producing companies from Net Availability.

Source: Ministry of Petroleum & Natural Gas, Oil and Natural Gas Corporation, Oil India Limited & Directorate General of Hydrocarbons

Being efficient, non-polluting and relatively economical, natural gas satisfies most of the requirements for fuel in a modern day industrial society. The periodic uncertainty and volatility in both the price and supply of oil have also helped natural gas emerge as a major fuel in the energy sector across countries.

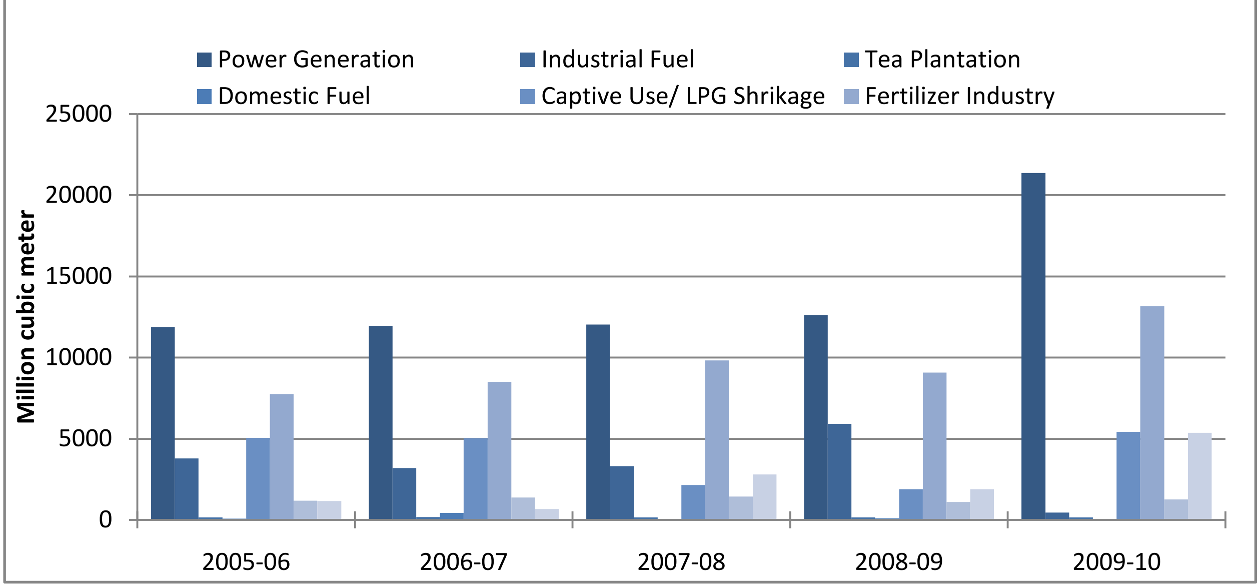
The table below displays a list of sectors and related processes where natural gas is used:

Table 4: Uses of Natural Gas in various sectors

Sector	Natural Gas is used
Generation of electricity by utilities	As fuel for base load power plants
	In combined cycle/co-generation power plants
Fertilizer Industry	As feed stock in the production of ammonia and urea
Industrial	As an under boiler fuel for raising steam
	As fuel in furnaces and heating applications
Domestic and commercial	For heating of spaces and water
	For cooking
Automotive	As a non-polluting fuel
Petrochemicals	As the raw material from which a variety of chemical products
	e.g. methanol, are derived

As seen below, the most important use for natural gas is in power generation, followed by the fertilizer industry where it is used as a raw material for producing ammonia and urea.

Figure 3 : Industry wise Off-takes of Natural Gas



Source: Oil and Natural Gas Corporation, Oil India Limited, Gas Authority of India Limited and Directorate General of Hydrocarbons

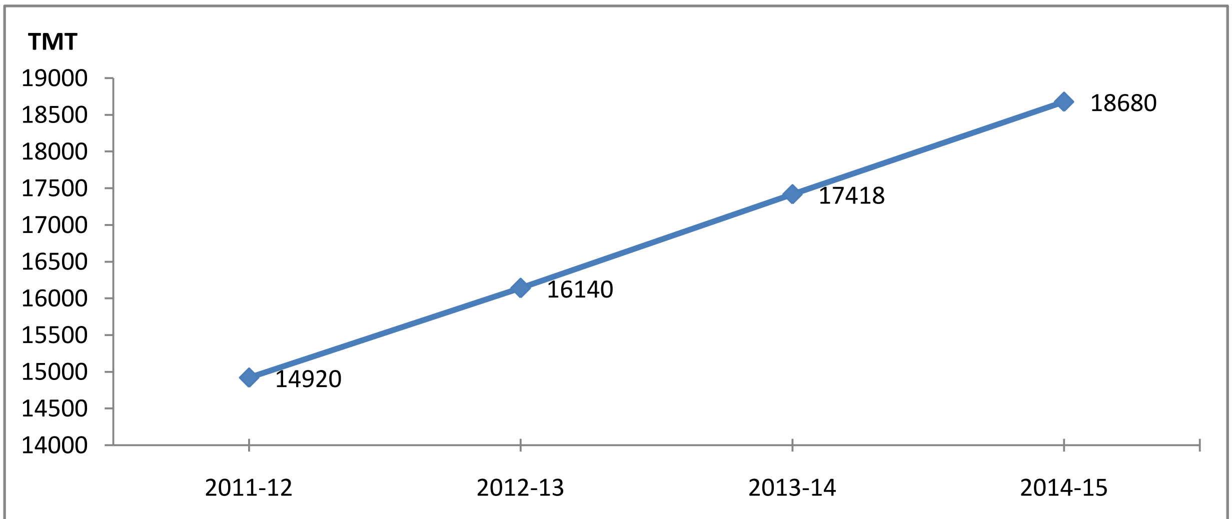
1.3 Forecasted Demand for LPG and CNG

1.3.1 LPG Demand Outlook

Owing to the Government of India's policy to spread the domestic use of LPG and to partly replace subsidized Kerosene, the demand for LPG is only going to increase in the future. These will the major factors driving the in the increased demand of LPG.

As seen inFigure 4 (below), the LPG demand is being forecasted at 18680 TMT for 2014-2015 by the Ministry of Petroleum. This comes to a CAGR of 5.5%. This demand is going to drive the production and imports of LPG and consequently drive the increase in price too.

Figure 4 : LPG Demand

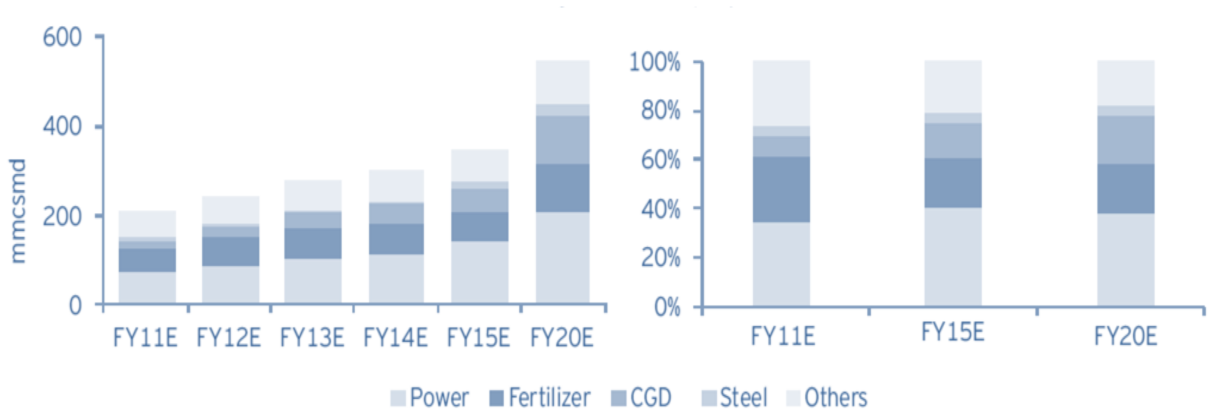


Source: Ministry of petroleum and Natural Gas

1.3.2 Natural Gas Demand Outlook

From
Figure 5 (above), it is clear that the demand for natural gas especially from the power generation and fertilizer sectors is expected to further increase. Government of India is encouraging all non-gas fertilizer plants to switch over to gas. Current subsidy for urea based on naphtha is expected to be phased out by the government. With natural gas going to replace liquid fuels in major processing industries, there is a potential for Biogas to be an alternative source of energy - as an industrial fuel, domestic fuel and for tea industry.

Figure 5 : Sector-wise Natural Gas Demand Projection Natural Gas Demand Outlook



Source: Ernst & Young Analysis, 'Exploring opportunities Growth potential in the Indian natural gas market'

1.4 Forecasted Supply/Availability of LPG and CNG

1.4.1 LPG Availability

As can be seen from the forecasted figures above, the demand for LPG is expected to increase to 18680 TMT for 2014-2015. The table below gives the breakup of the expected indigenous production of LPG and the imports required to fill the gap between supply and demand.

Table 5 : Estimated Supply of LPG (TMT)

	2011-12	2012-13	2013-14	2014-15
Indigenous Production	11375	11815	13145	13625
Imports Requires	3545	4325	4273	5055

Source: Ministry of petroleum and Natural Gas

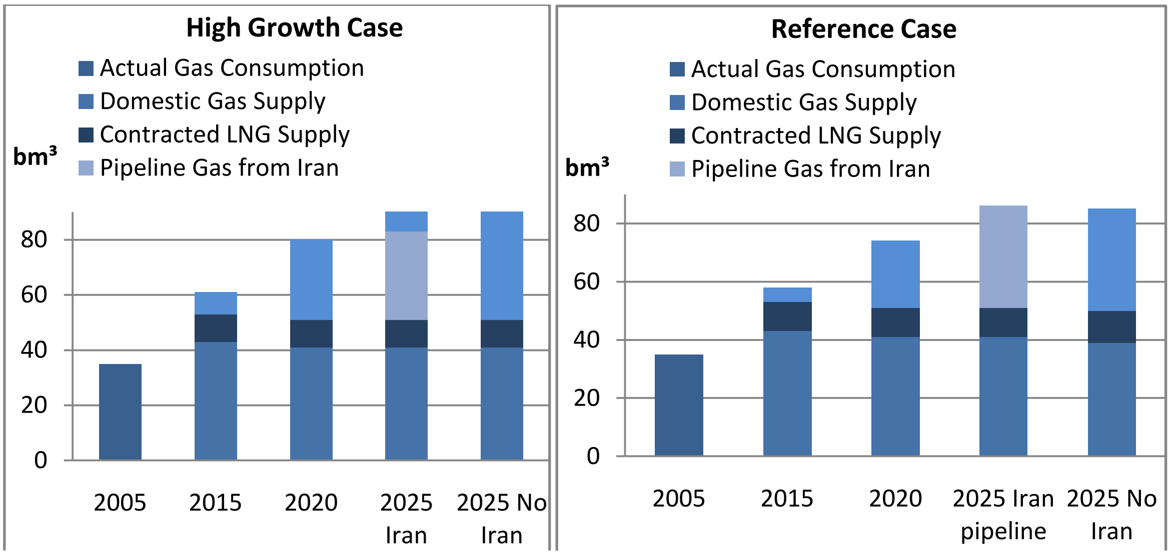
It is clear that the imports of LPG are growing at a CAGR of 9%, which in turns means more foreign exchange reserves being used to purchase LPG from the international market. This will affect the economy as a whole and also result in the cost of LPG increasing for commercial and industrial consumers, while the domestic consumers continue to pay subsidized prices.

It is therefore necessary for oil companies to look for alternative fuels which can be sourced locally and are also cost effective. Biogas is one such renewable energy and its increased usage can reduce the overall burden on the oil companies and the government as well.

1.4.2 Natural Gas Availability

From the above sections, it is clear that natural gas is becoming a fast booming fuel for commercial and industrial use and the demand is only going to increase. A shortfall in the supply of natural gas is predicted keeping in view the current trends of increasing demand.

Figure 6 : Natural Gas Supply Projections



Source: International Energy Agency

The power and the fertilizer industry are the major consumers of natural gas. With the government responsible to reduce the power deficit, is encouraging more power plants to be setup, thereby increasing the demand for natural gas. As this is a high priority sector the future supply would also majorly diverted to towards power generation.

In case of the fertilizer industry, the government's current subsidy for urea based on naphtha is expected to be phased out. Government of India is encouraging all non-gas fertilizer plants to switch over to gas based production, thereby with a potential for increased gas demand from fertilizer industry too.

This increase in demand from the power and the fertilizer industry will not only increase the cost of natural gas, but also hamper the availability of natural gas to other industries. This shows a clear need for an alternative yet clean fuel for the industries in demand. Biogas is one such fuel which can help fulfil this demand of the industries and act as a replacement for natural gas.

Table 6: Natural Gas Prices

US dollars per million Btu					
	LNG	**Natural gas**			
	Japan	EU	UK	US	Canada
Year	***cif***	***cif †***	***(Heren NBP Index)****	***Henry Hub †***	***(Alberta) ‡***
2000	4.72	2.89	2.71	4.23	3.75
2001	4.64	3.66	3.17	4.07	3.61
2002	4.27	3.23	2.37	3.33	2.57
2003	4.77	4.06	3.33	5.63	4.83
2004	5.18	4.32	4.46	5.85	5.03
2005	6.05	5.88	7.38	8.79	7.25
2006	7.14	7.85	7.87	6.76	5.83
2007	7.73	8.03	6.01	6.95	6.17
2008	12.55	11.56	10.79	8.85	7.99
2009	9.06	8.52	4.85	3.89	3.38
2010	10.91	8.01	6.56	4.39	3.69

† Source: Heren Energy Ltd., Energy Intelligence Group, Natural Gas Week.

Note: Btu = British thermal units; cif = cost+insurance+freight (average prices).

Section II

2.1 Biogas As An Alternate Fuel

Organizations across the globe, including governments, are making strides towards reducing their dependence on oil. Countries in Europe and America are giving financial incentives to companies to develop technologies that can harness alternate sources of energy. In this context, biogas is of significant relevance.

The advantages of adopting biogas on a large scale are abundant. An obvious advantage would be the reduction in dependence on non renewable sources of energy such as coal and petroleum. In addition to enhancing the energy utilization process, there are certain other aspects which have characteristic advantages of incorporating biogas into our energy map.

2.1.1 Advantages Of Biogas

Reliability

Biogas not only is a renewable energy source but is also a reliable fuel. Unlike other renewable energy sources such as wind or solar energy, biogas production is relatively unaffected by the weather conditions.

Versatility

Biomass is the only renewable energy source that is suitable for generating heat, power, gas and liquid fuels as well. The energy obtained from biogas is not only environmental friendly, but also is incredibly versatile. E.g. the waste heat that is a by-product from biogas generation process can be used to heat greenhouses or even for cooling. In particular, usage of biogas as an automobile fuel and as an injection into the existing natural gas grids will increase significantly in the coming years.

Environmental Compatibility

Combustion of biogas does not produce any additional carbon dioxide (CO2), unlike the combustion of fossil fuels. The CO^2 emission that originates from the use of biogas matches the amount that plants need to grow and produce the renewable resources. In this way no additional carbon dioxide is being produced, which otherwise is considered to be harmful to the environment.

Production Process and By-products

The production of biogas results in high-quality fertilizer as by products. Nitrate, phosphor and potassium remain nearly untouched during the biological process. Almost half of Nitrate by-product is ammonium, which plants absorb fast and easily. The other part is organic nitrate, an ideal long term fertilizer for crop plants.

Avenue for safe disposal of bio-waste

Biogas is produced from renewable resources, agricultural residues and certain industrial effluents or even waste. Normally these wastes deteriorate the environmental quality of the region where they are produced. The collection and energy exploitation of these materials through anaerobic digestion, not only provides significant amounts of green energy to the grid, but also mitigates the pollution effects on the local ecosystems.

2.2 International Experience With Biogas

Bio-energy is already making a substantial contribution to supplying global energy demand, and can make an even larger overall contribution by facilitating greenhouse gas savings and other environmental benefits. Besides contributing to the energy security and improving trade balances, encouraging biogas provides opportunities for social and economic development in rural communities, and helps the management of waste, thus improving resource management.

Estimates indicate that bio-energy could sustainably contribute between 25% and 33% to the future global primary energy supply (up to 250 EJ) in 2050. It is the only renewable source that can replace fossil fuels in all energy markets – in the production of heat, generation of electricity, fuels for transport, etc.

In Germany, biogas dissemination gained momentum through the need for alternative energy in an economy struck by war and energy crisis. As a remedy for slow development, simple and affordable technological changes were adopted. Large scale production of biogas was seen in 1980, with the formation of the German Technical Cooperation (GTZ). This resulted in a scheme that incorporated biogas technology dissemination in Latin America, Asia and Africa. Many such programs were launched in Bolivia, Colombia, Nicaragua, Kenya, Tanzania, Morocco, Caribbean Islands and Thailand.

Efforts in biogas exploration and usage in China covers a period of more than 50 years.[1] Initial plants were built in the 1940s by financially prosperous families. Extensive research and technological development took place in the 1970s and this was promoted by the Chinese government by means of an outreach program. In rural areas, over 5 million small biogas plants have been constructed and at present, over 20 million people use biogas as cooking fuel.

2.3 Uses Of Biogas In India

While technically biogas can be produced from any type of organic material, most times, biogas is produced from organic waste. This waste could comprise agricultural and crop waste, human waste and animal waste (cow dung for instance). With a calorific value of about 5000 kilo Cal / m3, biogas is an excellent fuel for heating purposes as well as for generating electricity.

It is estimated that India can produce power of about 17,000 MW using biogas. This is over 10% of the total installed electricity capacity in India.

[1] Biogas Digest: Volume 1 [Information & Advisory Service on Appropriate Technology]

2.3.1 Biogas in households and communities

Biogas production in India has been quite dominant at household and community levels (especially in rural areas) rather than on a large scale commercial or industrial level. In villages especially, thousands of small biogas plants use the cattle waste (cow dung, etc) and provide biogas used for home heating and cooking. It is estimated that over 2 million such biogas plants have been installed all over India.

Such use of biogas systems in agrarian communities indirectly contributes to an increase in agricultural productivity. This is because producing heat using biogas is not only more efficient, but also more agricultural and animal waste can be re-used by the farmers as organic fertilizer. Moreover, the slurry that is returned after methanogenesis is superior in terms of its nutrient content and can be used as a soil conditioner and plant nutrient (fertilizer).

2.3.2 Biogas for electricity production

The use of biogas for electricity generation in India is a recent phenomenon, but this trend catching up. In many cities across India, sewage treatment centres and organic waste treatment plants (those treating municipal solid waste) already use anaerobic digesters to generate biogas and electricity. Some of the industries that generate significant amounts of solid or liquid organic waste also have installed digesters and gas engines for in-house electricity production. Many of these require sizable investments, but it is estimated that they have a good return on investment as the main feedstock (organic waste) that they use is essentially free.

2.3.3 Biogas in the Indian industry

Use of digesters at industrial complexes (to treat the waste generated at the factory) is also increasing. For the factories this is an excellent avenue to dispose of waste in a cost effective manner while at the same time generate heat and/or electricity. Industries that have an especially high potential for using anaerobic digestion include cattle and poultry industry, sugar, breweries, pulp and paper industry, leather tanning industry, and the fruits & vegetables processing industry. As pointed out earlier, some of these industries are already producing electricity from biogas, and this trend is likely to grow in future.

Many Indian industries, in their quest to become more environment conscious, are turning to biogas as one of their energy sources. In Sep 2009, for instance, PepsiCo India, a division of PepsiCo, installed a biogas plant at its Pune based Frito-Lay manufacturing unit. It is the first plant within Frito-Lay's global operations to use biogas. Companies such as Sintex Industries have introduced novel biogas digesters for the small users of this renewable energy resource.

2.3.4 Future prospects for biogas in India

With the Indian government keen on promoting usage of renewable resources for energy production, it is likely that there will be a greater thrust and higher incentive for concepts such as biogas production from waste. An increasing awareness among the public regarding sustainable use of resources will only enhance the production and usage of biogas. It can hence be expected that biogas will have a significant growth in India at all levels of usage (household, commercial, industrial) for different purposes such as heat generation, electricity production, etc.

It is also possible to earn carbon credits for biogas-based power or heat generation in India. For instance, in April 2008, Andhyodaya, a non-government agency working in the field of promoting water management and non-conventional energy and social development distributed the first instalment of the biogas carbon credit to farmers in the state of Kerala. Andhyodaya had helped construct 15,000 biogas plants in the state and earned carbon credits. This trend is likely to grow further.

Both the central and the state governments in India have recognized the significance of biomass-based energy in the context of development of the rural population. Steps are already being taken in this regard. For instance, in Feb 2010, the Haryana Government has formulated a Rs. 85 crore project for setting up 50,000 family size biogas plants to harness the potential of generating biogas for cooking and use the remnants as organic manure in the fields.

In sum, India has significant potential for generating heat and electricity from waste in the form of biogas. While only a portion of the potential has been tapped, it is likely that more investments in this direction could accelerate exploitation of this source and realize the true potential in future.

2.4 Biogas – Sustainability

Emerging and developing countries are home to 80% of the world’s population but consume only 30% of global commercial energy. As energy consumption rises with increase in population and living standards, the need to expand access to energy in new ways is growing as is the awareness of the environmental costs. This quest for alternative sources of energy leads to emphasis being laid on renewable energy (RE) sources. RE sources also offer other distinct advantages such as energy independence, climate change mitigation, rural development, improved health and lower health costs (linked to air pollution).

In this quest for alternative sources of energy, factors such as environmental friendliness and compatibility, sustainability and cost effectiveness are the major driving forces. Apart from these environmental and ecological considerations, rising cost of imports of LPG and CNG to meet local demands make it necessary to identify other feasible sources of energy. Hence the development and deployment of renewable energy in India is driven by the need to:

- Expand cost-effective energy supplies
- Sustain accelerated deployment of renewable energy system and devices
- Augment energy supply to remote and deficient areas to provide normative consumption levels to all sections of the population across the country

In the long run sustainability would be another major factor that would be given significant consideration while defining the path of energy sources development in India. In the current scenario there is a growing pressure on oil companies to substitute part of petroleum fuels with bio-fuels such as Ethyl alcohol in Motor spirit and Bio diesel in diesel to reduce the dependence on imported crude and also to meet the pollution norms. However use of CNG/NG alone would not be sufficient to meet the growing demand for alternative energy to reduce dependence on petroleum products as there are numerous challenges being faced by the oil industry such as limited reserves and escalating prices which only reiterate the need to identify and implement sources of energy that are not in danger of depletion.

The Indian government realizes the importance of promoting such sustainable energy sources and as part of this its promotion of biogas production. Keeping such factors in view, the Petroleum Ministry and oil industry is making a conscious effort to promote other forms of renewable energy. Biogas and bio-methane are among such renewable sources of energy that the oil industry and the Petroleum Ministry should consider in meeting India’s future energy needs in a cost effective and a sustainable manner.

Section III

3.1 What is Compressed Biogas?

Biogas in its raw form is comprised of 55 - 58% methane, 37 - 40% carbon dioxide, 0.5 - 1.0% hydrogen sulphide and the rest is water vapour and other impurities. The composition quality is not suited for any high-end industrial use due to the low calorific value vis-à-vis other fuels and the corrosive nature of hydrogen sulphide can destroy the interiors of an expensive industrial plant.

It is possible to overcome these limitations by upgrading the quality of biogas to form bio-methane (Methane content ~95 - 98%). This quality up gradation technology is known as "Biogas Conditioning". Biogas Conditioning involves the removal of impurities such as hydrogen sulphide, carbon dioxide, Nitrogen, Siloxanes, water vapour and other impurities. The resulting pure gas is indistinguishable from natural gas (Methane - CH_4). The bio-methane resulting from the biogas conditioning is of industrial quality and can also be injected into a natural gas pipeline as it is now considered to be "pipeline quality gas".

Bio-methane (upgraded biogas), like Liquefied Petroleum Gas (LPG) cannot be converted to liquid state under normal temperature. Therefore, compressing this into cylinders makes it easily usable and allows it to be easily transported too. The resulting form of bio-methane is referred to as Compressed Biogas (CBG).

3.2 Bio-methane Specification

Upgraded biogas (bio-methane) and natural gas are very similar in their composition - comprising primarily of Methane (> 96% by volume). Hence, they are indistinguishable and can be considered as substitutes for all uses and can replace each other in their usage. Given the nascent stage that the biogas industry is in, there is little data available on the required specifications of bio-methane for industrial or automotive use. However, given the near identical composition of bio-methane and natural gas, it is imperative that the specifications for CBG will mirror those of the already existing CNG.

The Bureau of Indian Standards (BIS) has prescribed the following specifications for CNG for automotive use and should serve as an indicator to define CBG standards for industrial use as well.

3.3 Uses of Upgraded Biogas

Biogas can be used for all appliances designed to use natural gas as a fuel. However, not all gas appliances require the same gas standards - leading to a considerable difference between the requirements of appliances designed to use stationary biogas and pipeline quality gas.

3.3.1 Heating

Heating purpose is the most commonly known use of biogas, for both industrial and domestic uses. One of the major advantages is that the operating costs of gas based equipment are generally lower than those of equipment that use other energy sources. It is however recommended to reduce the hydrogen sulphide concentration to values lower than 1,000 ppm, due to its corrosive properties.

3.3.2 CHP Engines

The utilisation of biogas in internal combustion engines has been a long established and extremely reliable technology. Gas engines have comparable requirements for gas quality as boilers do, but require lower concentration of hydrogen sulphide for optimal performance. Diesel engines are preferred as they can be rebuilt into a more efficient dual fuel engine where around 8-10% of diesel is used primarily during ignition. Engines can be used to produce both heat and electricity. The dual fuel engine has higher electricity efficiency and modern engines also allow recovery of the heat in form of valuable steam.

3.3.3 Fuel

CBG can be utilized as a fuel for internal combustion engines with the same configuration as those using natural gas as a fuel. Engines however require a much higher quality gas with higher calorific value, low levels of hydrogen sulphide and ammonia, low particle content and low water content. The Bureau of Indian Standards (BIS) has released the specifications of gas for automobiles - which in turn are applicable for other engines as well. These specifications are given in more detail in the following sections.

3.3.4 Fuel Cells

Fuel cells (FC) are power generating systems that produce DC electricity by combining fuel and oxygen (from the air) in an electrochemical reaction. There is no intermediate process involved which first converts fuel into mechanical energy and heat. Therefore fuel cells have extremely low emissions. However, fuel cells are yet to be developed into a commercially viable technology as of today.

3.4 Use of bio-methane in conjunction with conventional fuels

Bio-methane can also be utilized in tandem with conventional fuels (mainly diesel) through means of a bi-fuel system. The bi-fuel system operates by blending diesel and bio-methane in the combustion chamber. The gas is pre-mixed with air before it enters the chamber. This mixture is ignited when the diesel injector sprays a quality reduced diesel fuel into the chamber.

3.5 Production of bio-methane from biogas

The sub sections provide an overview of the processes used to remove impurities from biogas. The sections also discuss and review the associated environmental impacts and the possibility of upgrading biogas to produce various higher-grade fuels such as:

- Compressed bio-methane (CBM), which is equivalent to compressed Natural Gas (CNG)
- Liquid hydrocarbon replacements for gasoline and diesel fuels (created using the Fischer-Tropsch process)
- Methanol
- Hydrogen
- Liquefied bio-methane (LBM), which is equivalent to liquefied natural gas (LNG)

3.5.1 Upgrading Biogas to Bio-methane

Biogas upgrading, or "sweetening," is a process whereby most of the carbon dioxide, water, hydrogen sulphide, and other impurities are removed from raw biogas. Because of its highly corrosive nature and unpleasant odour, hydrogen sulphide is typically removed first; even though some technologies allow for concurrent removal of hydrogen sulphide and carbon dioxide.

Table 7: General Data for most popular biogas upgrading process

Principle	Name	Type of regeneration	Pre treatment	Working pressure (barg)	Methane losses
Adsorption	Pressure Swing Adsorption	Vacuum	Water vapour, H_2S	4-7	2
Absorption	Water scrubbing	None , air stripping	None	7-10	<2
	Polyethylene glycol	Air stripping	Water vapour, H_2S	7-10	<2
	Mono ethanol amine MEA	Heating	H_2S	atmospheric	<0.1
Membrane separation			Water vapour, H_2S	8 – 10	>10

Source: Dirkse Milieutechniek

Table 8: Biogas Upgrading Process

Process	Description	Advantages	Disadvantages
Adsorption	CO_2 higher, C_xH_y, H_2S, SI-FI, Cl – components, odours will be removed by activated carbon / carbon molecular sieve	· High quality gas	· H_2S pre-treatment
		· Dry process	· 3 to 4 parallel streets needed
		· No use of chemicals	· CH4 level not stable
		· No process water demand	· Complex process
		· No waste water	· High investment cost
		· Partial removal N_2 and O_2	
		· No bacterial contamination of off gas	
		· Proven technology	
Gas scrubbing	CO_2 and H_2S are absorbed by means of scrubbing fluid (e.g. water, amines, glycol ethane etc.)	· High gas quality	· Disposal of waste water
		· Interesting investment cost	· Use of process water
		· No pre treatment necessary	
		· Compact process	
		· Proven technology	
		· Re-use of CO_2	

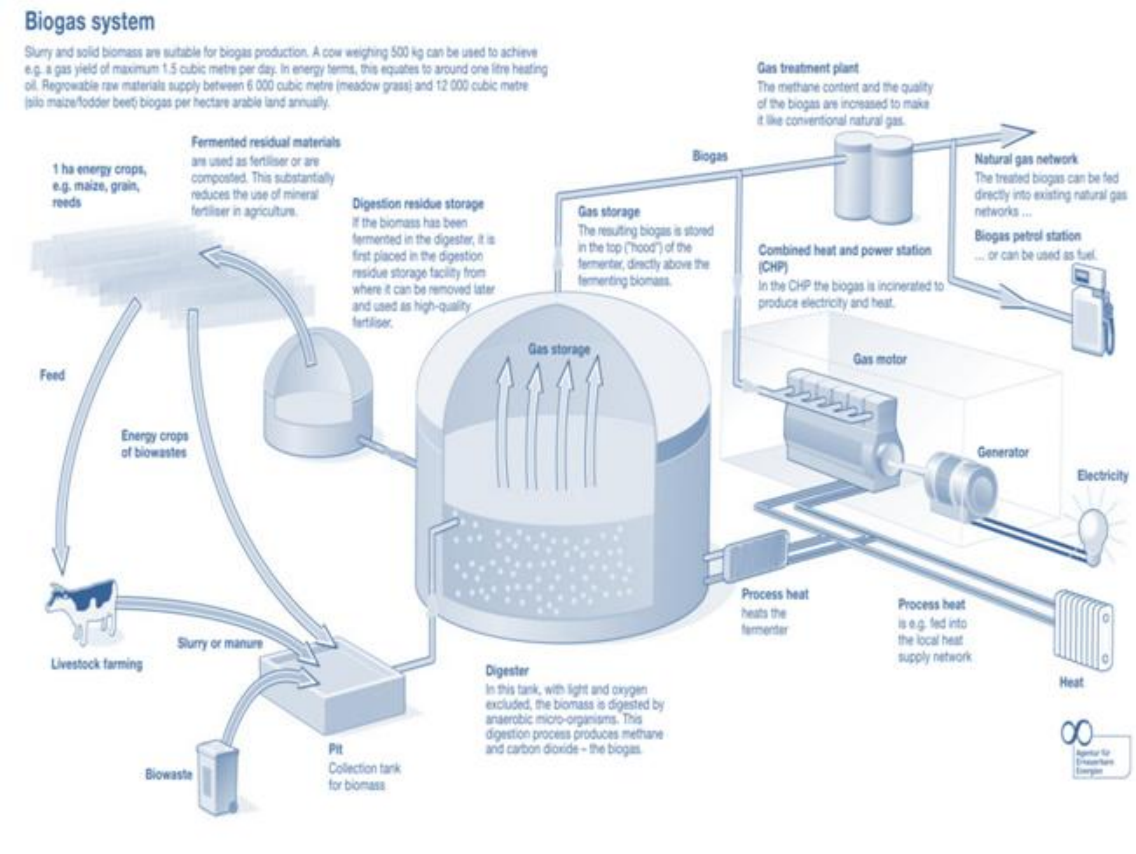
		possible	
Membrane process	CO_2 is separated due to different permeation rates at a membrane	· Dry process	· Pre treatment necessary
		· No chemicals	· Low CH4 recovery
		· Kw mechanical wear	· High investment costs
		· Compact process	· High energy demand
			· Unstable long-term behaviour
			· Still few references
CO_2 liquefaction	**CO_2 is liquefied by high pressure and low temperatures and separated by rectification column**	**· Very high gas quality**	**· Pre treatment necessary**
		· No chemicals	· Low CH4 recovery
		· No water	· High investment costs
		· Compact process	· High energy demand
		· Re-use of CO_2 possible	· Unstable long-term behaviour
			· Lack of references

Source: dirkse-milieutechniek

3.7 Compressing Bio-methane

Bio-methane compressed to about 3,600 psi is referred as compressed Bio-methane (CBM) or compressed biogas (CBG). Compositionally, it is equivalent to compressed natural gas (CNG), an alternate vehicular fuel, which contains about 24,000 Btu/gallon compared to approximately 120,000 for gasoline and 140,000 for diesel fuel. Consequently, CNG (or CBM) vehicles have both larger fuel tanks and a more limited driving range than traditionally fuelled vehicles. Bi-fuelled vehicles that could switch from CNG (or CBM/CBG) to gasoline would allow for longer driving ranges and less dependence on CNG refuelling stations.

Figure 7: Biogas System



3.6 Case Studies

3.7.1 The biogas plants in Kristianstad, Sweden

This was Sweden's first biogas plant which co-digested food wastes, manure etc. One important driving force for the construction of the biogas plant at Karpalund in Kristianstad was the need for the local food-processing plants to treat their waste. In addition, the local authority introduced a new system for household waste collection, and they developed appropriate treatment methods for the resulting source-sorted food wastes.

The new biogas plant in Karpalund, was run by a waste management company owned by the local authority, which started operations in December 1996. The first upgrading plant, located at the sewage treatment plant, opened in 1999 and is run by the technical office of the municipality of Kristianstad.

Several new investments were made in the following years to extend the biogas system in Kristianstad. These investments increased the capacity of the biogas plant, while an additional upgrading plant opened in 2007. The system is still being extended. For example, a KLIMP grant has been received to build a new biogas reactor at Karpalund to replace one of the older reactors, which will instead be used as an intermediate storage facility for the digestion residues. A new facility for the pre-treatment of agricultural crops is also planned, and two gas turbines will be installed to generate electricity from the biogas.

One of the strengths of the biogas project in Kristianstad is the number of cooperating partners involved. Thus, households, agriculture farms and food industries co-operate by delivering substrate to the biogas plant. Production and distribution of the gas is carried out as a collaboration between the local authority, the energy company Eon, and the bus company, Skånetrafiken. The plant at Karpalund was the first in Sweden to co-digest source-sorted household waste, manure and food industry wastes. Kristianstad now has a complete biogas system with two production plants, two upgrading facilities, its own pipeline distribution system for biogas and several filling stations. Landfill gas from the Härlövs landfill is also collected and used.

Kristianstad is working towards the long-term goal of becoming a municipality which does not consume fossil fuels.

The biogas plant and substrate

The biogas plant at Karpalund has two reactors, 4000 and 4500 m^3 in size. The process is mesophilic, and the reactors are continuously mixed as one-step processes with a retention time of 22 days. The substrate consists of source-sorted household waste collected in paper bags, liquid manure and slaughterhouse, distillery and dairy wastes. The plant has a capacity to treat 80,000 to 100,000 tons of raw waste per year. The new reactor will increase the capacity to 150,000 tons per year. The food waste is first chopped and then mixed with the remaining substrate. The raw material first passes through a magnetic separator and a fine mill on its way to the mixing tank where it is stored for 3 to 7 days before further treatment. Prior to digestion, the material is heated and pasteurized at 70˚C for at least one hour in three parallel tanks.

Upgrading and use of the biogas

The biogas plant at Karpalund produces 40,000 MWh of biogas per year, and the sewage treatment plant contributes a further 6,000 MWh. Both upgrading plants employ the water wash technique. In 2007, Eon bought 13,300 MWh of biogas as vehicle fuel, equivalent to more than 1.4 million litres of petrol. The production of upgraded biogas is expected to increase in the coming years. Some of the biogas is used for heating. The gas being produced at the disused landfill at Härlövs near Kristianstad has also been collected since 1989 in a comprehensive pipe system.

Distribution of the biogas

The biogas produced at the Karpalund plant is led through pipelines to the sewage treatment plant and to Allöverket for upgrading. The gas pipe network in Kristianstad has a total length of 10 km. The first public filling station opened in 1999 at the sewage treatment plant. A common bus depot for Skånetrafikens entrepreneurs opened in 2002 at Allöverket. Another filling station for biogas opened in 2004 in northern Kristianstad.

Bio-manure

After digestion, the bio-manure passes through two screw sieves where undesirable materials such as plastics and coarser particles are removed. The bio-manure is dewatered and the excess water is returned to the reactor. The bio-manure is stored in a closed gas-tight tank which is mixed. The certified bio-manure is spread on nearby agricultural land owned by farmers who supply manure as raw material to the plant. Each ton of bio-manure contains 55 kg of nitrogen (43 kg as ammonium), 4.5 kg of phosphorous and 16.5 kg of potassium.

Financing

The total investment cost to date is c. 107 million SEK, which has been partly financed through state grants (19 million SEK), mainly from LIP and KLIMP. The development of biogas in Kristianstad will be economically viable in the long-term, given that the demand for alternative fuels is continually increasing.

3.7.2 The biogas plant in Linköping, Sweden

Linköping Biogas AB was formed in 1995 in a collaboration between the Technical Office of the local authority, the co-operative agricultural company ‘Swedish Meats’, Konvex and LRF (the national farmers association) through the company ‘Lantbrukets Ekonomi AB’. A pilot biogas project was carried out between 1990 and 1994. Following an evaluation, a full-scale biogas plant was built at Åby, near Linköping, which started operating in spring 1997.

In 2004, the Technical Office became sole owner of the plant and Linköping Biogas AB changed their name to ‘Svensk Biogas i Linköping AB’ (Swedish Biogas in Linköping). The biogas was upgraded right from the beginning, to use as a vehicle fuel for the city buses. The first public filling station in Linköping for biogas was opened in 2001, and several more have opened since. A number of improvements and extensions to the biogas plant and distribution system have been made since 1997, which have increased the production and use of biogas.

‘Svensk Biogas i Linköping’ were among the first in Sweden to upgrade biogas to vehicle fuel quality. Significant developments to the process have taken place during the eleven years that the plant has been in operation. The biological process has been specially adapted to enable the digestion of substrate comprising large amounts of slaughterhouse wastes that are rich in energy and proteins. Up to 1000 m3 of methane is extracted per ton of organic material. The process has been stable for many years, despite high contents of nitrogen in the form of ammonium (5.1 g per litre) and a relatively high phosphorus content. Svensk Biogas has also received attention as a result of the biogas train (Amanda), which has been running between Linköping and Västervik since April 2006.

The biogas plant and substrate

The substrate, which totals 45,000 tons per year, consists of 55% waste products from slaughterhouses and 45% of other food wastes. The slaughterhouse waste is finely ground and mixed with the other substrates in a homogenizing tank. The substrate is then pasteurized by heating with steam to 70˚C for one hour. The material is then cooled before being pumped into the two reactors, each of which has a volume of 3,800 m^3. Decomposition takes place at 38˚C in a continuously mixed one-step process with a retention time of 30 days.

Upgrading and use of the biogas

All the biogas produced at Åby is upgraded to use as vehicle fuel. As early as 1992, some of the biogas produced at the town sewage treatment plant was upgraded in a smaller plant (capacity 150 Nm^3 biogas per hour) using the PSA technique. This supplied five town buses with biogas fuel. A new upgrading plant based on the water wash method opened in 1997. It has a capacity to upgrade 500 Nm^3 of biogas per hour. A third plant, using the same technique, was built in 2002, with a capacity of 1,400 Nm^3 of biogas per hour. Including the gas from the sewage treatment plant, approximately 65,000 MWh of upgraded biogas is produced each year, which supplies fuel to the town's buses, refuse lorries and a number of filling stations in the region.

A train (Amanda) was converted from diesel to biogas in 2006. The train operates on the line between Linköping and Västervik and can run 600 km on one completely filled tank.

Distribution of the biogas

The three upgrading plants are all located at the biogas plant in Åby. The upgraded biogas is distributed through 8 km of buried pipelines under a pressure of 4 bars to the bus depot and to public filling stations in the area. At the bus depot, the gas is pressurized to 250 bars, and the buses are filled slowly overnight. Svensk Biogas own and run thirteen different biogas filling stations in Linköping and the surrounding region.

Bio-manure

After digestion, the bio-manure is cooled to 20˚C and storage in a tank before being delivered to 30 farmers in the surrounding area. Roughly 45,000 tons of bio-manure is produced annually (figure from 2007). The bio-manure has a dry weight content of 4.2% and a nitrogen content of 6 kg per m3 and is certified according to SPCR 120. The bio-manure is spread with conventional techniques for liquid manure application.

Financing

Roughly 130 million SEK has been invested in the construction of production and distribution systems for biogas in Linköping. Most of this was self-financed, although grants from LIP and KLIMP have been obtained on a number of occasions (17 million SEK in total). These grants were used to finance improvements to the biogas and upgrading plants as well as investments in new gas filling stations and vehicles. The biogas project in Linköping is expected to be economically profitable in the long-term.

Section IV

4.1 Demand for CBG

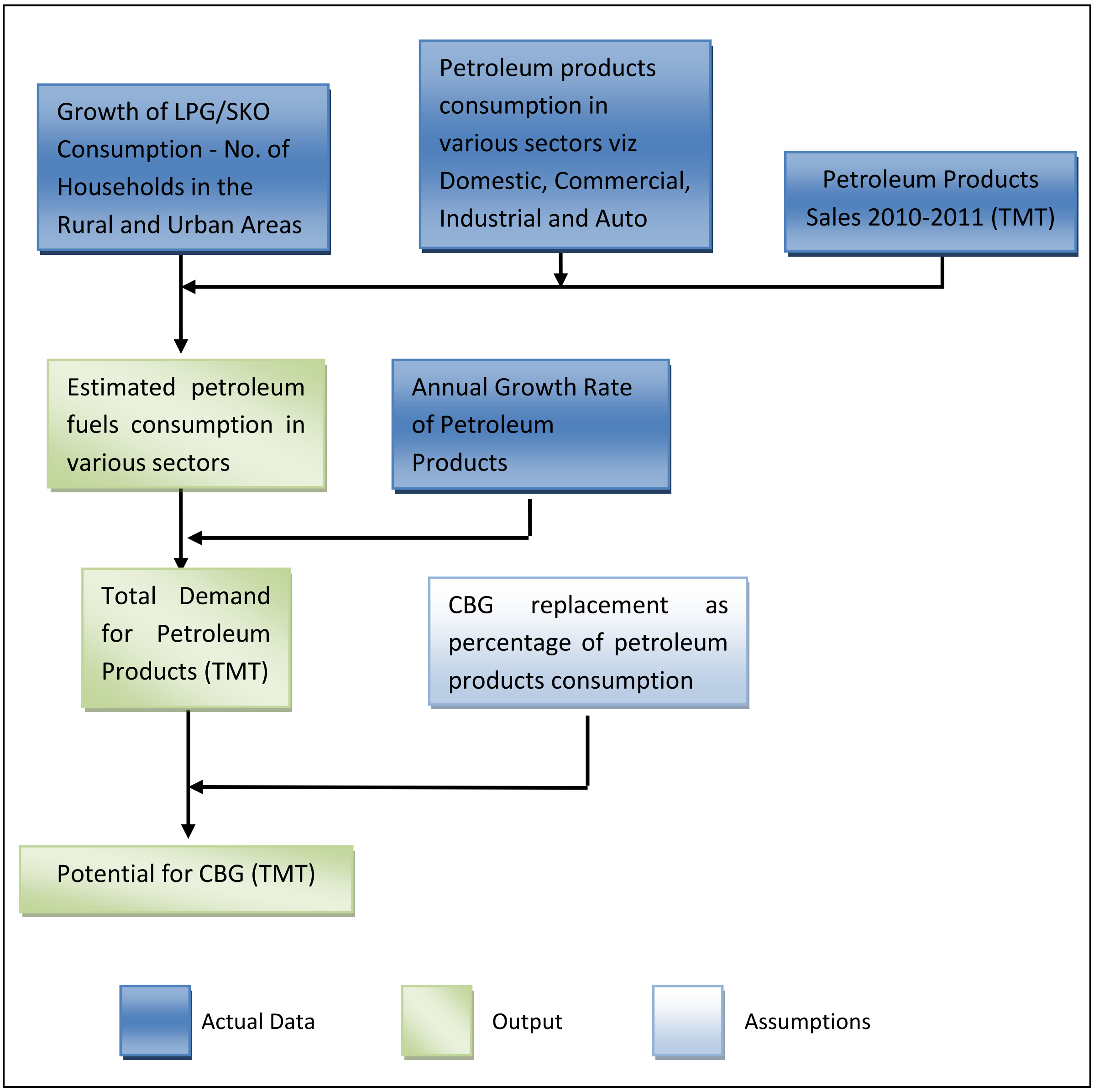
The methodology followed to estimate the demand of CBG is by assessing CBG as a replacement fuel for existing petroleum products. The growth of petroleum products has been forecasted to identify the potential quantity that can be replaced using CBG.

Table 9: Petroleum Products Sales 2010-2011 (TMT)

State	LPG	SKO	MS	HSD
South India	4238	1647	4126	16887
Rest of India	14029	8926	14029	59861
All India	18267	10573	18155	76748

Source: Oil Companies

Figure 8: Methodology for estimating CBG in India



Source: Athena Infonomics Research

4.2 Estimating Market Potential of CBG in India

Step 1:

To get the domestic consumption pattern of LPG and SKO, we have used the Central Government's assumption that an average household consists of four individuals. Hence the number of households in Southern India and the Other States is estimated by dividing the total population respectively by four.

Table 10: Number of Households in the Rural and Urban Areas

	Population		Households (4 people per household)	
	Rural	Urban	Rural	Urban
India	833087662	377105760	208271916	94276440
Andhra Pradesh	56311788	28353745	14077947	7088436
Karnataka	37552529	23578175	9388132	5894544
Kerala	17455506	15932171	4363877	3983043
Tamil Nadu	37189229	34949729	9297307	8737432
Total South	148509052	102813820	37127263	25703455
Others	684578610	274291940	171144653	68572985
All India	833087662	377105760	208271916	94276440

Source: Census of India, 2011

Once the number of households has been established, the growth of LPG and SKO consumption for domestic purposes is calculated by using the growth rates as given in Table 11. This is based on the Government of India's policy that by 2017, 75% of the urban and 65% of rural households will have access to LPG/SKO for domestic consumption. Based on this we have tracked the growth to be at an annual rate of 5% year on year, as the present consumption is at 40% and 50% for rural and urban households.

Table 11: Growth of LPG/SKO Consumption - No. of Households

Rural	2012	2013	2014	2015	2016	2017
% growth	40%	45%	50%	55%	60%	65%
Total South	1,48,50,905	1,67,07,268	1,85,63,632	2,04,19,995	2,22,76,358	2,41,32,721
Other states	6,84,57,861	7,70,15,094	8,55,72,326	9,41,29,559	10,26,86,792	11,12,44,024
All India	**8,33,08,766**	**9,37,22,362**	**10,41,35,958**	**11,45,49,554**	**12,49,63,149**	**13,53,76,745**

Urban	2012	2013	2014	2015	2016	2017
% growth	50%	55%	60%	65%	70%	75%
Total South	1,28,51,728	1,41,36,900	1,54,22,073	1,67,07,246	1,79,92,419	1,92,77,591
Other states	3,42,86,493	3,77,15,142	4,11,43,791	4,45,72,440	4,80,01,090	5,14,29,739
All India	**4,71,38,220**	**5,18,52,042**	**5,65,65,864**	**6,12,79,686**	**6,59,93,508**	**7,07,07,330**

Source: Athena Infonomics Research

Step 2:

To find the petroleum products usage in various categories such as domestic, commercial, industrial and auto sectors based on information available with oil companies we have estimated the consumption of the above categories as a percentage of the total petroleum products consumption in India (Table 12).

Table 12: Petroleum products consumption pattern in various sectors

Category	LPG	SKO	MS	HSD
South				
Domestic				
Urban	7.5 Kg/month/household	10 lts/month/household		
Rural	6.5 Kg/month/household	3 lts/month/household		
Commercial				
Urban	8%			
Rural	4%			
Industrial				
Captive power				9%
Others		3%		5%
Auto				
Cars	5%		40%	11%
Two/Three wheelers	3%		60%	
Commercial				75%
Total Other States				
Domestic				
Urban	8.5 Kg/month/household	10 lts/month/household		
Rural	7.5 Kg/month/household	3 lts/month/household		
Commercial				
Urban	10%			
Rural	8%			
Industrial				
Captive power				8%
other		3%		5%
Auto				
Cars	4%		40%	12%
Two/Three wheelers	3%		60%	
Commercial	3%			75%

Source: Oil Companies, Athena Infonomics Research

The consumption pattern of the petroleum products in various categories (Table 12) are applied to the sales figures of petroleum products in 2011, as given in Table 9**Error! Reference source not found. Error! Reference source not found.**. By doing this we will get the usage of petroleum products in various categories (Table 13).

Table 13: Petroleum products consumption in various sectors (TMT)

Category	LPG	SKO	MS	HSD
South				
Domestic				
Urban	1157	1542		
Rural	1158	535		
Commercial				
Urban	339			
Rural	170			
Industrial				
Captive power				1520
Others		49		844
Auto				
Cars	212		1650	1858
Two/Three wheelers	127		2475	
Commercial				12665
Total Other States				
Domestic				
Urban	3497	4114		
Rural	6161	2464		
Commercial				
Urban	1403			
Rural	1122			
Industrial				
Captive power				4789
other		268		2993
Auto				
Cars	561		5612	7183
Two/Three wheelers	421		8417	
Commercial	421			44896

Source: Oil Companies Annual Report, Athena Infonomics Research

Step 3:

The annual growth rate of petroleum products (Table 14) was analysed by looking at the past trends of sales in petroleum products and the rate at which they are growing. The growth rates are then applied to the petroleum products consumption in various categories to estimate the future demand of these products.

Table 14: Annual Growth Rate of Petroleum Products

LPG	SKO	MS	HSD
9%	-4%	4%	6%

Source: Oil Companies Annual Report, Athena Infonomics Research

The total demand for petroleum products from 2013 to 2017 for domestic, commercial, industrial and auto sectors has been established using the assumptions given in Table 15.

Table 15: Total Demand for Petroleum Products (TMT)

South India – Tamil Nadu, Karnataka, Andhra Pradesh and Kerala					
	2013	**2014**	**2015**	**2016**	**2017**
Domestic	4873	5355	5836	6318	6799
Commercial	604	659	718	782	853
Industrial	2702	2859	3027	3204	3392
Auto	33038	35032	37148	39391	41770

Other States					
	2013	**2014**	**2015**	**2016**	**2017**
Domestic	18077	19916	21755	23595	25434
Commercial	3000	3270	3564	3885	4235
Industrial	8991	9505	10052	10632	11248
Auto	75356	79624	84141	88920	93979

All India					
	2013	**2014**	**2015**	**2016**	**2017**
Domestic	22950	25271	27592	29913	32234
Commercial	3604	3929	4282	4668	5088
Industrial	11692	12365	13079	13836	14641
Auto	108394	114657	121288	128311	135749

Source: Athena Infonomics Research

Step 4:

After determining the forecasted consumption of petroleum products in various categories, the percentage of the market share for CBG as a replacement for the petroleum products (Table 16) is applied to estimate the market potential of CBG.

Table 16: CBG replacement as percentage of petroleum products consumption

Domestic	2013	2014	2015	2016	2017
South	0.19%	0.28%	0.31%	0.35%	0.38%
Others	0.25%	0.26%	0.33%	0.38%	0.40%

Commercial	2013	2014	2015	2016	2017
South	0.40%	0.43%	0.48%	0.56%	0.60%
Others	0.35%	0.38%	0.40%	0.43%	0.46%

Industrial	2013	2014	2015	2016	2017
South	0.45%	0.51%	0.57%	0.61%	0.65%
Others	0.30%	0.35%	0.41%	0.47%	0.51%

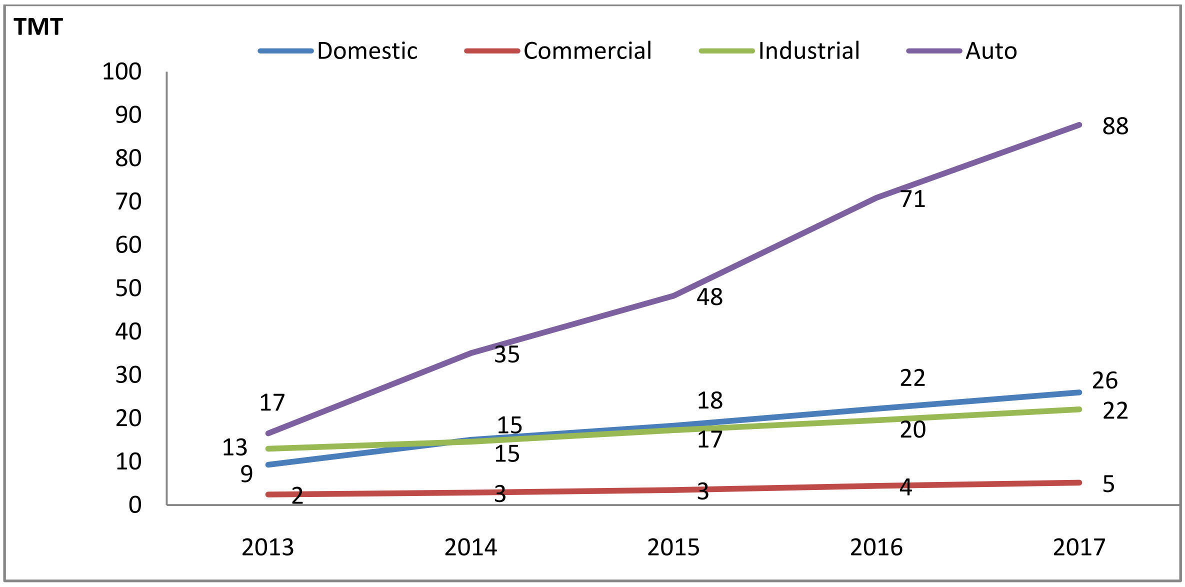
Auto	2013	2014	2015	2016	2017
South	0.05%	0.10%	0.13%	0.18%	0.21%
Others	0.28%	0.30%	0.31%	0.33%	0.35%

Source: Athena Infonomics Research

4.3 Market Potential for CBG

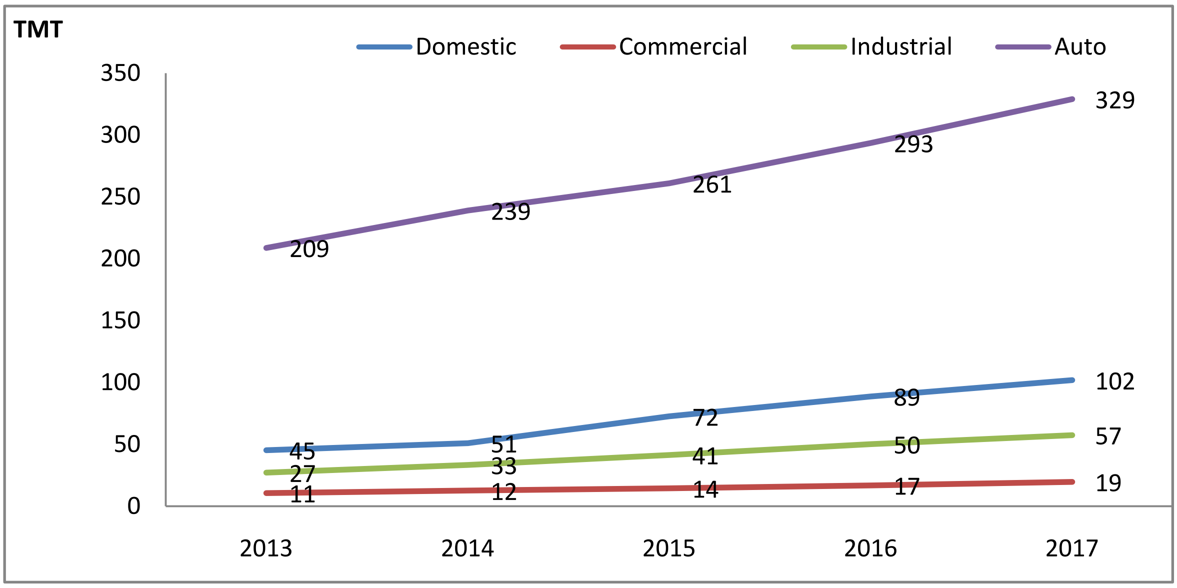
Using the above assumption the total market potential for CBG in India as a replacement for petroleum products (Table 16) is determined in South India, Rest of India and All India potential.

Figure 9: Potential for CBG in South India



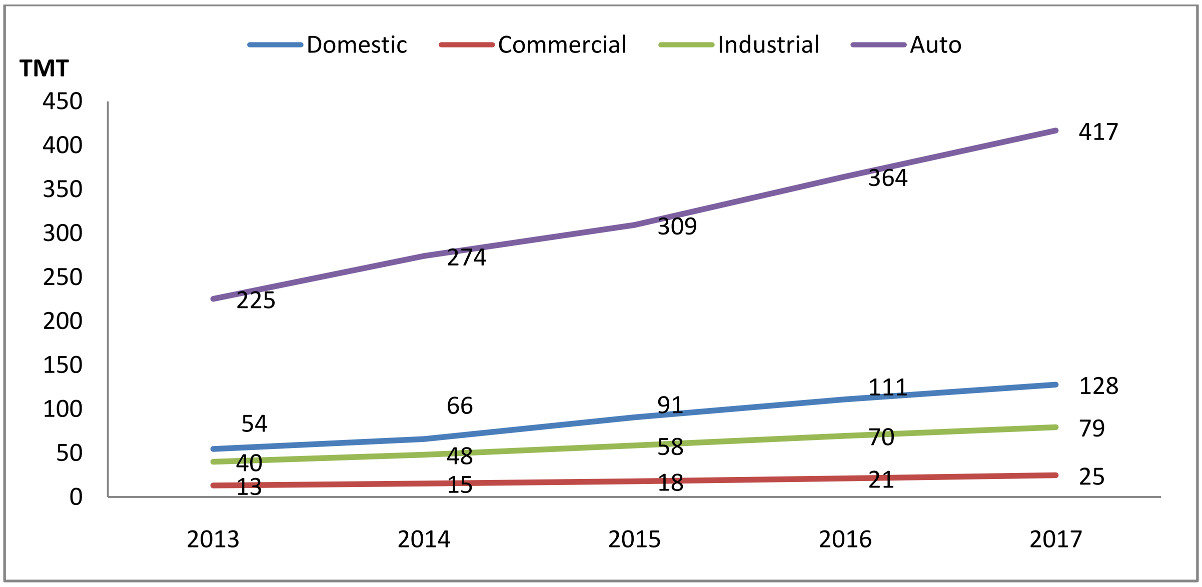
Source: Athena Infonomics Research

Figure 10: Potential for CBG Rest of India



Source: Athena Infonomics Research

Figure 11: Market Potential for CBG in India



Source: Athena Infonomics Research

The total potential for CBG as a replacement fuel in 2017 is 0.648 million MT. This translates to about 90 plants having a capacity of 48,000 m3/day of raw biogas production.

According to the Ministry of New and Renewable Energy (MNRE)[2] the total biogas potential in India are about 17,000 MW from agro-residues and plantation waste and 12 million family type biogas plants from animal waste. This translates to about 31 million MT of raw biogas production.

Given India's biogas potential, as per the estimates above we will use approximately 1.5 million MT for the upgrading process for production of CBG. This will cater to the market demand of CBG in 2017 at 0.648

[2] http://www.mnre.gov.in/akshayurja/june09-e.pdf

million MT. When compared to the MNRE study, as stated above, it converts to approximately 400 – 450 MW of the total potential of 17,000 MW.

4.4 Target Markets

As per the estimates given in Figure 11, we can observe the demand for CBG and the growth potential in various consumer categories viz Domestic, Commercial, Industrial and Auto. Table 17 lists the advantages and disadvantages in marketing CBG in these categories.

Table 17: Advantages and Disadvantages of Marketing CBG in Various Consumer Categories

Market	Pros	Cons
Domestic	- One of the largest markets, by volume of sales. - For rural market, biogas without odour through pipeline may be an option.	- Hard to penetrate market, due to the LPG subsidy available from the Central Government. - Consumer's unwillingness to pay premium while LPG subsidy is available. - Consumers not willing to incur additional cost in conversion kits.
Commercial	- Relatively easy market to penetrate. - Non-availability of LPG subsidy makes it easier to market.	- Many consumers would not want to change from traditional use of LPG. - Cost of the conversion kit will be recovered only if there is a high consumption rate.
Industrial	- Large consumption volumes. - High price of industrial LPG will favour CBG marketing. - End customers will be willing to invest in a conversion kit, as savings from conversion to CBG is significant.	- Catering to the huge demand will be a challenge. - Upfront cost higher due to large gas quantity demand which results in higher capacity cascades / cylinders and higher transportation cost. - Customers will have to be located within a limited radius, as transporting large volumes over long distances would be a challenge.
Auto	- Largest market for CBG. - Established market in northern and western India as CNG is being used in the industry. (CBG can be used as a direct replacement for CNG)	- Most difficult market to penetrate, as there is no established infrastructure in most parts of the country. - Conversion cost high for bi fuel operation which potentially could be a deterrent. - Lack of established supply chain for CBG. - Investments required for setting up gas dispensing stations / infrastructure would be high. - Transportation of large volumes of CBG from the plant to the gas stations would be of higher risk.

Section V

5.1 Marketing and Distribution of Compressed Biogas

5.2 Marketing

Having established products such as LPG, CNG and HSD in the market, marketing of Compressed Biogas will play a significant role in the success of the product both in the short term and long term. While marketing CBG some of its advantages such as pricing, ease of conversion, cleaner combustion properties, eco-friendly, inexhaustible and local source of energy and transparent pricing will need to be bought to the forefront.

5.2.1 Price

Compressed Biomethane will have a significant advantage over its competitors in terms of pricing. The retail price of the CBG will be pegged at a minimum of 25 % lesser than LPG. This automatically makes it the single important aspect around which the marketing strategy can be built around.

5.2.2 Ease of conversion

Users of LPG, CNG and HSD would require conversion kits in order to switch over to Compressed Biogas. Given the considerable savings achieved by using CBG it would negate the cost associated with conversion. Custom made kits similar to those being used by CNG users are readily available making the conversion a simple process.

5.2.3 Cleaner combustion properties

Bio-methane is one of the cleanest fuels and releases a low level of pollutants as compared to coal and other petroleum alternatives. It burns cleanly and is practically sulphur free - thus producing virtually no sulphur dioxide (SO_2). The low level of pollutants and impurities in our product thus helps reduce the equipment wear and tear.

5.2.4 Eco - friendly

A variety of organic materials can be used in biogas plants exclusively, or in combination with others, without substantial technical alternation to the facility. Typically, crops commonly used for the generation of energy are processed together with biogenic waste, thus providing site-specific adaptability of the energy mixture used.

The cultivation of energy crops is generally associated with the formation of monoculture. However, due to the diversity of resources that can be used for the production of biogas this is no longer a necessary concern. Moreover, farmers tend to be interested in cultivating a large variety of plants in order to ensure fertility of their cropland.

The production of biomethane necessitates comprehensive understanding of the preservation of biodiversity contextualized within a multifaceted landscape. The cultivation of fuel crops for the production of biogas is capable of being integrated into existing agro-ecosystems, and provides opportunities for the responsible use of natural resources

5.2.5 Versatility of application.

Biomethane is more flexible in its application than any other renewable source of energy. Its ability to be injected directly into the existing natural gas grid allows for energy-efficient and cost-effective transport. This allows gas grid operators to enable consumers to make an easy transition to a renewable source of gas.

The diverse, flexible spectrum of applications in the areas of electricity generation, heat provision, and mobility creates a broad base of potential customers. Biomethane can be used to generate electricity and heating from within smaller decentralized, or large centrally-located combined heat and power plants. It can be used by heating systems with a highly efficient fuel value, and employed as a regenerative power source in gas-powered vehicles. The utilization of biomethane as a source of energy is a crucial step toward a sustainable energy supply

5.2.6 Inexhaustible and local source of energy

Unlike the source of LPG, CNG and HSD which will be exhausted in the foreseeable future, source for biogas is inexhaustible. The production of biogas from regional resources creates jobs, especially in agriculture, supply logistics, engineering, and plant construction and maintenance. This allows local farmers to profit in particular from resulting developments in related “non-food” sectors of local economic development. These sectors provide increased planning security and create an opportunity for alternative sources of revenue. As plant operators or partial plant owners, the commercialization and injection of biogas allows farmers to become direct beneficiaries of overall regional economic prosperity.

5.2.7 Transparent pricing

CBG pricing model will rely on pegging the price of the product to the existing LPG prices.

The price will be clearly broken down into the sum of its components and will be inclusive of all taxes and charges.

5.3 Distribution

Distribution forms a crucial part of the biomethane business. Supplying the gas to the end user in an efficient manner with minimal costs involves carefully designing the distributor network. Also adopting the latest methods in storage is important as well. Below are the ways by which biomethane can be transported to the customer:

5.3.1 Compressed Biomethane in Cylinders or Cascades

Distributing gas in cylinders or cascades is the most traditional form of transporting used by gas suppliers. As the energy density of biomethane is extremely low at ambient pressure, it must be compressed to relatively high pressures (e.g., 170 – 200 bars) to be safely transported in vehicles. To supply to commercial and industrial consumers it would be ideal to use skids of 640 kg gas capacity.

5.3.2 Distribution of Liquefied Biomethane

One of the potential ways of addressing transportation issues associated with biomethane distribution is to liquefy the gas. Liquefied Biomethane allows for long distance transportation. However, this distribution method has additional technical challenges. The disadvantage being that after the liquefied biomethane has been transported; it will have to be re-gasified before it can be used for any purpose.

One of the major advantages of transporting liquefied biomethane is the readily available infrastructure in the market; in the form of LNG tankers, etc. Liquefied Biomethane can use the exact transportation vehicles that are currently being used for transporting LNG.

5.3.3 Distribution via Dedicated Biomethane Pipelines

Using dedicated pipelines may be one of the most efficient ways to distribute biomethane. It is very much similar to process used by the natural gas pipelines. If the consumers of the biomethane are relatively close to the point of production it would be ideal to have dedicated biogas pipelines (underground or aboveground). The biomethane could then be piped directly to industrial consumers or to gas stations for vehicular use. The major advantage in this method is that there is no need for compression, which is one of the most cost intensive processes, involved in other distribution methods. It can be transported through the pipeline in low pressures such as 6 - 7 bars, just enough to push the gas to the end consumer location.

5.3.4 Distribution via the Natural Gas Pipeline Network

Distribution via the existing natural gas pipeline is the most economical way of transporting biomethane. The natural gas pipeline network offers a readily established distribution system. Once the biomethane is piped into the natural gas distribution network, it can be used as a direct substitute for natural gas in domestic gas appliances, commercial or industrial gas equipment, and CNG refuelling stations.

The disadvantage is that the natural gas pipelines are typically owned by private or gas utilities. In such a case the biomethane producer must negotiate an agreement with the pipeline owner (i.e., the local gas utility) to use their distribution networks. The main concern would be that the biomethane injected into the natural gas pipeline network needs to meet the gas utility's pipeline gas quality (e.g., gas composition) standards.

5.3.5 Other forms of Distribution

Apart from the above common methods of biomethane distribution, there are also other forms of distribution models such as using bob tail trucks or trailer trucks.

Bobtail trucks can be used to transport biomethane in large tanks, and fill the cylinders or cascades or tanks at the customer's premises. This would be an ideal option when supplying to the rural domestic market. They can have a small grid in the village and one main tank which supplies to the grid.

Trailer trucks are used to transport higher volumes of biomethane. A high capacity cascade is permanently mounted on the trailer and then with the help of trucks it is transported to the customer location. The trailer is then left at the premise and locked into place and connected to the inlet pipeline for the gas. This is would be most advantageous if the customer is a bulk consumer of biomethane.

Section VI

6.1 Conclusion

With increased energy consumption by the developing countries to sustain their fast growing pace, the pressure on energy production is ever increasing. This leads to exploring alternative sources of energy and developing technologies to produce efficient and environmental friendly energy sources.

Anaerobic digestion and biogas upgrading are considered as mature technologies in the renewable energy space. Bio-methane, which is akin to natural gas, is a well known replacement for LPG, CNG, HSD and other fossil fuels.

Countries like Germany, Sweden and the USA are at the forefront of technology development in this field and their experience has shown that industrial size bio-methane plants can be run successfully and profitably too. The availability of bio wastes is a very important factor to be considered while adapting to such a technology. In case of India, the organic wastes generated have a potential to displace the equivalent of over 44,676 million m^3 of natural gas per year.

Not only does this address the issue of a gap of energy sources but also it is extremely environmental friendly. The biogas production processes use industrial waste from distilleries, starch mills, sago mills, sugar mills and other sources as feedstock and thus provide a safe and reliable alternative for waste disposal.

The distribution process does not need a major overhaul. Bio-methane can be distributed and consumed using conventional natural gas infrastructure (where it exists) as well as high pressure cylinder systems. From a consumer perspective, the cost of modifying equipment to facilitate the use of bio-methane is minimal and they can be recovered in a matter of months.

To conclude, bio-methane production from organic waste is a practical, sensible and inexpensive solution to mitigate greenhouse gases emissions, improve air quality and provide a safe, clean and practically inexhaustible source of energy.

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