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SHAKTI SUSTAINABLE ENERGY FOUNDATION

Exploring Opportunities for Enhancing the Share of Natural Gas in India

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Abbreviations

BEE	Bureau of Energy Efficiency
CAGR	Compound Annual Growth Rate
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Authority
CGD	City Gas Distribution
CHP	Combined Heat & Power
CNG	Compressed Natural Gas
CPCB	Central Pollution Control Board
DPG	Distributed Power Generation
EPMC	Empowered Pool Management Committee
EPA	Environmental Protection Agency
FC	Fixed Cost
FO	Fuel Oil
GHG	Green House Gas
HT	High Tension
ICF	International Climate Fund
IGL	Indraprastha Gas Limited
ISGS	Inter-State Generating Stations
KVA	Kilo Volt Ampere
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MGL	Mahanagar Gas Limited
MMSCMD	Million Metric Standard Cubic Meter Per Day
MMTPA	Million Metric Tonne per Annum
MoEF	Ministry of Environment & Forests
MOU	Memorandum of Understanding
NFPA	National Fire Protection Association
NGV	Natural Gas Vehicles
NLDC	National Load Despatch Centre
OCGT	Open Cycle Gas Turbine
PCRA	Petroleum Conservation Research Association
PLF	Plant Load Factor
PNG	Piped Natural Gas
PNGRB	Petroleum and Natural Gas Regulatory Board
PSS	Pumped Storage Systems
RLNG	Re Gasified Liquefied Natural Gas
RRAS	Reserves Regulation Ancillary Services
SHR	Station Heat Rate
SPCB	State Pollution Control Board
T&D	Transmission & Distribution
TERI	The Energy and Resources Institute
TOD	Time of Day
VAT	Value Added Tax

VC	Variable Cost

Executive Summary

Natural gas is one of the cleanest and efficient forms of energy with an ability to attract scale. India has witnessed a declining trend in its consumption of natural gas in its primary energy mix in last five years. Apart from the decline in domestic gas production, switch over to liquid fuels from natural gas is also a crucial factor for decline in gas consumption. There are quite a few reasons for this drop, primarily the reason being lack of domestic supply, policy downsides and so on. Amidst the array of issues like infrastructure, taxation, operation of market, affordability etc. that the sector is already facing, and usage of natural gas applications exists in certain pockets of the country.

The study aims to identify and study key factors that would enable increased usage of gas in the country. This project also aims to support exploration of various possible end-uses of natural gas and to develop an action plan with appropriate policy and regulatory framework to tap the identified benefits.

A total of 24 natural gas end-use applications were identified, out of which 15 applications including Bulk Power, Ancillary Services, Peaking Power, Distributed Power Generation, Combined Heat and Power (CHP), Direct-fired Burners, Thermic Fluid Heaters, Furnace, Gas Geysers, Boiler, CNG Vehicles, LNG Vehicles, LNG Locomotives, Marine Vessels and Cooking were studied further. The applications were selected on the basis of analysis of market size, technology maturity, and competitive fuel analysis (economics of use, efficiency and ecosystem). However, few applications that may not be viable at the outset when viewed against select parameters but it is seeing a lot of traction from the government and with respect to environmental regulations were also selected for further study.

The study estimates a total universe of demand of 531 mmscmd of natural gas for the selected end-use applications by 2020 in India. The specific barriers for each of the selected potential natural gas based applications are as follows.

End-use Application	Major Barriers/Gaps
Bulk Power	• No emission considerations • Affordable gas availability challenges
Distributed Power Generation	• No government initiatives to promote gas-based gensets
Combined Heat & Power	• High capital cost of CHP equipment • Limited incentives for using CHP using natural gas • Gas availability constraints as CHP is not a priority sector as per gas allocation policy
CNG Vehicles	• Technical problems after conversion of vehicles • Excise duty on CNG fuel • Lack of government mandates

End-use Application	Major Barriers/Gaps
	• Pipeline connectivity and adequate fuelling infrastructure in the present context is an issue • Locking-in a certain technology creates barriers for the succeeding technology
Gas Geysers	• Low penetration of PNG markets • Subsidized LPG usage is popular • PNG gas geysers are economically unviable to LPG geyser at subsidized price • Commercial framework for using PNG pipe connection for geysers do not exist
LNG Vehicles	• Lack of LNG refuelling infrastructure
LNG Locomotives	• Government's focus on electrification of locomotives • Fuelling infrastructure challenges
Cooking	• Low penetration of PNG markets • Subsidized LPG usage • CGD infrastructure geographical spread
Ancillary Services	• No policy or regulatory enablers for purchasing gas based power as Ancillary Services • No takers for Ancillary Services - Market has severe issues to address for optimum base load generation • Hydro-based AS is most economical • No dedicated policy for Peaking Power • Utilities do not have any supply obligations and can resort to load shedding during peak demand • Fuel prices and gas availability

The study identified few applications where usage of gas can be scaled up in the future such as:

- Distributed Power Generation (DPG) – DPG is seen as a promising application with nearly 40% of the existing power being used by Industry and commerce. With significant demand potential in place, development of an enabling ecosystem for DPG can drive growth of natural gas use in the country.

- Combined Heat & Power - Incentives for CHP/CCHP application in the form of flexible financing options or rebates to procure expensive CHP equipment.

- Ancillary/Peaking Power - Usage of natural gas as a complementary fuel along with renewables to achieve the objective of achieving grid balance.

- LNG Locomotives – Next three years will see significant development in the LNG Locomotive space. This supported by development of refuelling infrastructure can help achieve this objective within the time frame identified.

- LNG Vehicles - Government support for implementation of amendment in the current Central Motor Vehicle Act (CMVA) to include LNG as a motor fuel and identification of dedicated LNG corridors. Government incentives for use of LNG as a fuel in trucks.

Enabling natural gas infrastructure planning by the Government with adequate line of sight of upcoming infrastructure is required in the coming years so that end-users can prepare themselves for the switchover. Another option is co-development of natural gas infrastructure by integrating natural gas application development in line with existing government initiatives like CNG corridors, LNG locomotives etc. The infrastructure need to be supported by security of supply and flexible supply contracts which can reduce supply risks in order to ease supply of gas for end-users especially for applications where the gas supply are on an intermittent basis.

India lacks in-house development of advanced and adequate gas-based technologies. Importing these technologies comes at a premium which eventually affects affordability of use of gas for end-use applications. Government and Institutional support for development of gas-based technologies through "innovation" can help develop adequate gas-based technologies that can provide reliable service with natural gas. Technological development can also be backed by incentives to make natural gas use commercially viable in these technologies which can in effect encourage equipment manufacturers to undertake R&D for end-use applications.

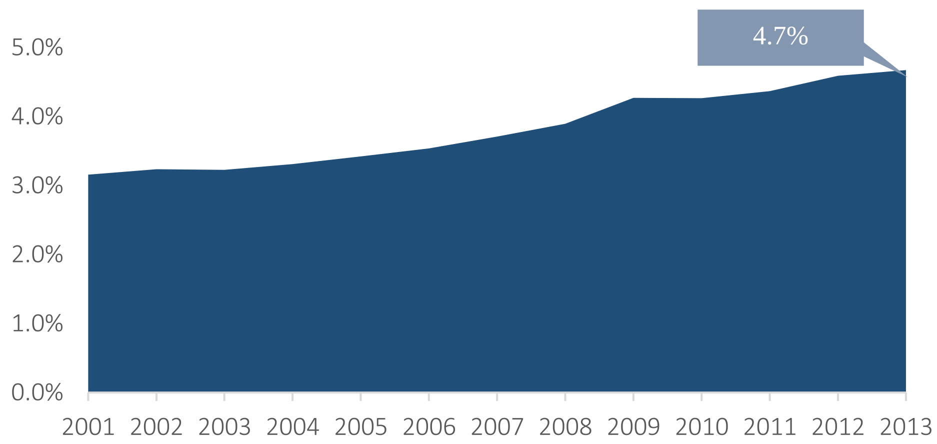
Environmental norms can be an enabling feature for high usage of natural gas in the country. However enforcement of these norms is a key challenge. Hence, environmental laws is to be backed by clean fuel initiatives/incentives for promoting use of natural gas in reducing GHG emissions. Currently, there are several initiatives around improving air quality, natural gas can be a key fuel to drive these initiatives.

In the current scenario, users are skeptical about affordability of natural gas and the supply options available to them in comparison to the ease of supply available from alternate liquid fuels. A necessary driver for use of natural gas is by creating awareness among end-users about the benefits of using natural gas from a long term perspective.

1 Introduction

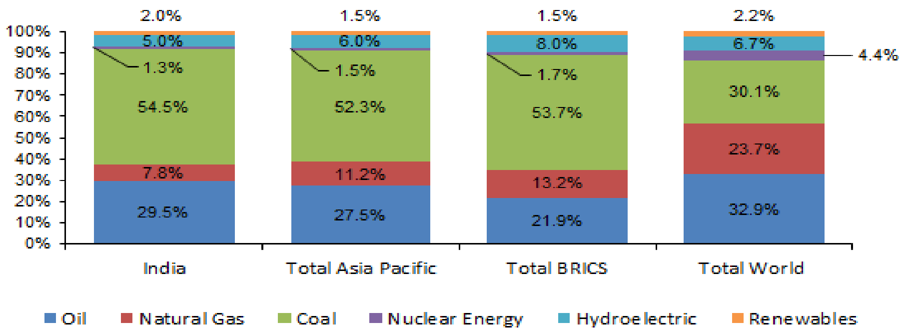
In the current scenario, India is one of the largest consumers of energy in the world with 4.7% share in global energy consumption (shown in the Figure 1). Of this, ~29.5% of its primary energy requirements is fuelled by oil and ~54.5% by coal, while cleaner fuels such as natural gas, hydro energy and renewable energy collectively account for only ~14.8% (7.8% natural gas, 2% renewable energy and 5% hydro energy) (shown in Figure 2)[1]. Due to increased dependence on coal and oil there has been a significant contribution to high green-house gas emissions (~2432 $MtCO_2e$ in 2010[2], equivalent to ~5.7% of global emissions).

Figure 1: India's primary energy mix



Source: World Energy Outlook, 2013

Figure 2: India's rising share in global energy consumption



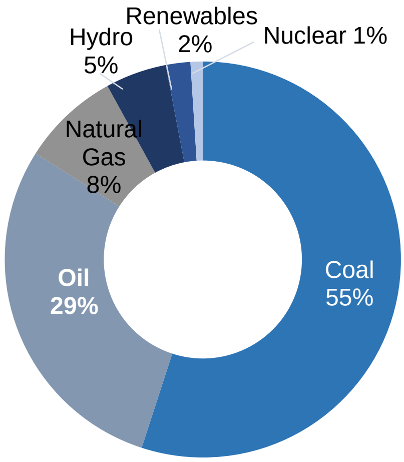
Source: BP Statistical Review of World Energy 2014

India's primary energy goals are focused at building a portfolio which is environmentally conducive, domestically sustainable and economically feasible. However, the extant energy scenario is not aligned with the country's envisioned objectives with Natural gas contributing to a mere 9% of the energy mix[3] (shown in Figure 3). Energy demand in India continues to rise, with

[1] BP Statistical Review of World Energy 2014
[2] World Resources Institute
[3] IEA, World Energy Outlook, KPMG Analysis

the country moving towards urbanization and with higher disposable income, the demand is set to grow significantly in the coming years. Coal dominates the country's energy mix with 55% share.

Figure 3: India's primary Energy Mix (2013)



Source: BP Statistical Review 2013

With a view to attain the set energy objectives it is imperative to move away from oil and coal, to cleaner and more sustainable fuels. Increasing the usage of natural gas in India's energy portfolio is an organic way to reach some of these envisioned objectives. To make this happen plentiful of initiatives are taken to include Natural gas as the primary fuel in various possible applications in India. The industry is understanding the benefits of equipping themselves with cleaner and environmentally sound fuel, in order to increase the share of penetration and to drive the shift we need to understand the importance of this proposition from different perspectives:

- From an energy security perspective: At present India imports over 85% of its total crude oil requirement.[4] Though the prices of most of the petroleum products are de-regulated, heavy reliance on oil imports poses a serious threat of destabilization caused by price shocks in the international market. Globally, oil has limited reserves and a low reserve to production ratio. In contrast, natural gas reserves both in India and across the world are substantially more. It is estimated that the world has approximately 55 years of reserves of natural gas considering current levels of consumption. With new conventional and unconventional reserves being added continually, the availability of natural gas is more certain than the alternatives. This is also likely to result in greater price stability as compared to other hydrocarbon and carbon fuels.

- From and environmental perspective: The environmental benefits of natural gas for transport and industrial segments is well known globally. NGV (Natural Gas Vehicle) programs in Delhi and Mumbai have led to significant improvement in the air quality and emission levels, more on account of penetration of NGV than the improvement of emissions norms for petrol and diesel vehicles. These are few examples to quote. Largely the shift to Natural gas usage is governed by environmental considerations.

- From an economic perspective: India's fuel subsidy bill is the single largest contributor to the breaches in the Fiscal Responsibility and Budget Management (FRBM) Act target. It is only in the recent past that with de-regulation of petrol and diesel prices and fall in crude prices, the fuel

[4] PPAC, KPMG analysis

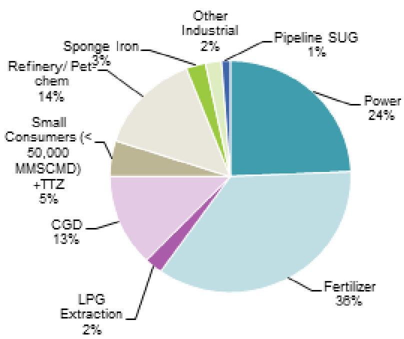
subsidy bill has significantly declined. Natural gas can play a very important role in India’s quest to stay within the fiscal targets that GoI has set for itself. Further, natural gas can reduce the impact of energy imports on currency/ balance of payments as the landed cost of natural gas at the Indian coast is lower than that of oil, and thus, the foreign exposure is significantly lower. Globally, even the most expensive natural gas is priced at, at least 15-20% of discount to crude. It is worthwhile to note that in mature gas markets, the gas prices are much lower than that of oil, and thus, the overall economy and currency savings are much higher and are a key incentive for replacement of oil. In the course plan of transition to a developed gas market and a self-sufficient economy several reforms are to be taken in increasing usage of Natural gas in India.

India’s gas consumption continues to be dominated by priority sectors such as power and fertilizer together consuming about 60% of the total consumption (Shown in Figure 4). The industrial and CGD segments have emerged a significant consumers of gas in the recent past with about 30-35% share. Though, gas in industrial and City Gas Distribution (CGD) segments faces tough price competition from liquid fuels, particularly fuel oil (FO), natural gas has managed to replace liquid fuels significantly in regions that are connected to the pipeline and distribution networks. The demand for natural gas is expected to grow substantially in the next decade.

While the demand from priority sector would continue to grow, it is however, the non-core sectors viz. refineries, petrochemical, other industrial and CGD segments which are likely to drive the incremental demand. As per PNGRB’s Vision 2030 document, the overall gas demand in the country is likely to increase to 517 MMSCMD by 2021-22 and further to 746 MMSCMD by 2029-30.

Currently, gas infrastructure in India is relatively under-developed when compared to the mature gas markets such as US, UK and Europe. This is causing a major limitation in unlocking the huge potential of gas as an efficient and reliable energy option for the country. However, gas transmission pipeline networks in India are expected to grow from extant 15,340 Kms to 28,000 Kms in next 5-6 years, putting in place most of the national gas grid connecting all major demand and supply locations. This proposition however needs more enabling reforms for smooth

Figure 4: Segment-wise breakup of gas consumption (FY 13-14)



Source: PNGRB

implementation to actually take place within the prescribed time frame.

Thus, with the infrastructure related to gas supply being actively addressed it is important to look at the various types of applications that could be fuelled by gas, and which could consequently address several of the energy sector’s socio-economic challenges.

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2 Objective of the Study

In order to enable India in reaching its energy goals as mentioned earlier, the report titled, "Exploring opportunities for enhancing the share of natural gas in India's energy mix to achieve a clean and secure energy future", intends to:

- Identify key 'end-use' applications that can be adopted and scaled in India
- Obtain relevant learnings from international experiences that can be adapted and used in India
- Identify key drivers of the ecosystem for promoting identified technologies
- Create a roadmap for scalable adoption of identified applications

In line with the above objectives, the aim of this draft report is to create an overall understanding of various end-use gas applications in the India, assess their potential, suitability and benefits in the Indian context and review international usage of NG end-use applications to derive important learnings from them on the basis of a five year perspective. This analysis will aid us in determining the road forward for increasing the penetration of natural gas through various end-use applications in India

The following aspects are covered for each identified end-use gas application:

- Description of the gas application
- Identified areas of use and benefits of application
- Policy and Regulatory Interventions
- Environment Impact and other Legislatures
- Cost Economics
- Macroeconomic Impact
- Technological and Service Maturity
- Industry Preference

As a part of this study a total of 23 energy based natural gas end-use applications are studied. These applications are classified based on their end-use into Power, Heating/Cooling, Products, Transport and other applications (shown in Figure 5). The sub-segments under each of these heads includes all the applications currently in use globally. Our further analysis will refine them largely on their relevance in the Indian context. The classification of applications are as below:

Figure 5: Natural End-Use Applications

Power	Heating / Cooling	Products	Transport	Other Applications
Bulk Power	Direct-fired Burners	Fuel Cells	CNG Vehicles	Cooking
Ancillary Services	Direct-fired Absorption Chillers	Hydrogen Cells	LNG Locomotives	Gas Lamps
Peaking Power	Space Heating		LNG Vehicles	Gas Dryers
Distributed Power Generation	Thermic Fluid Heaters			Gas Incinerators
Combined Heat and Power (CHP)	Furnace			Desiccant Dehumidification Systems
	Gas Geysers			
	Boiler			
	Gas Pool/Spa Heaters			

Source: KPMG Analysis

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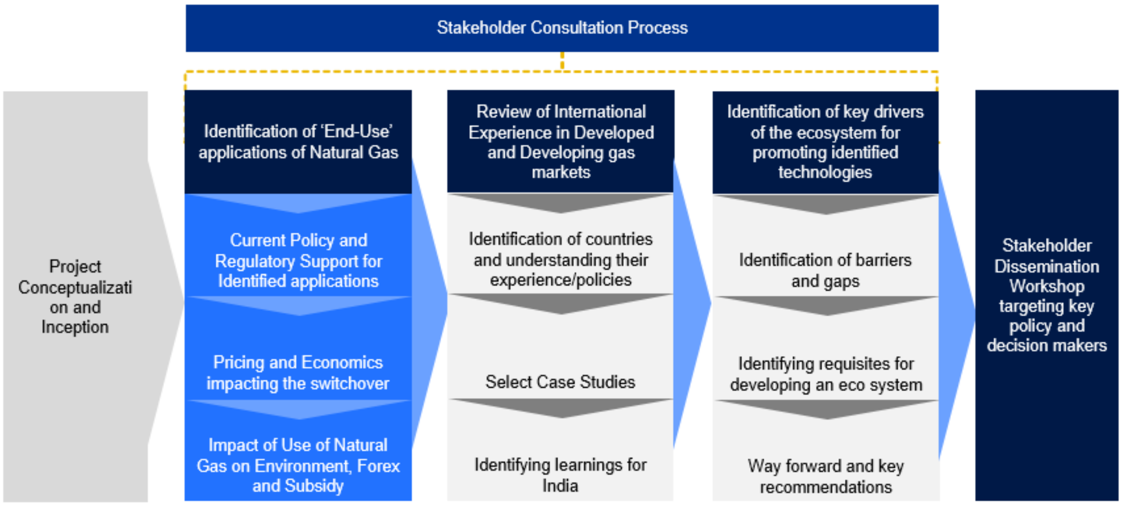
3 Methodology of the Study

A stakeholder consultation process will be undertaken at all levels of the study and the methodology of study will include 3 broad sections namely:

- Identification of 'End-Use applications of Natural gas'
- Review of International Experience in Developed and Developing gas markets
- Identification of key drivers of the ecosystem for promoting identified technologies

Figure 6: Illustration of Methodology of Study



Source: KPMG Analysis

3.1 Identification of 'End-Use applications of Natural gas

The study adopts the following 3-step approach for Identification of 'End-Use applications of Natural gas':

1. Preliminary selection of natural gas end-use-applications
2. Overview of selected natural gas applications
3. Parametric analysis of selected natural gas end-use-applications

At each step of the analysis appropriate assumptions and interactions with vendors and end-users will contribute to the analysis in order to get an on ground picture of the current scenario in India.

3.1.1 Step 1: Preliminary Selection of Natural Gas end-use-applications

The preliminary selection of applications is done on the basis of analysis of key parameters such as the market size, relevance in the Indian context, technology maturity and competitor analysis. The detailed description of each of the parameters is shown in Table 1. The applications which score well in all the parameters will be chosen for further study. However, certain applications will be further analysed irrespective of them not satisfying the criteria mentioned below. For example, the applications where the alternate fuel economics data are not available etc.

Table 1: Preliminary selection parameters

Description of Parameter for selection		✓	X
Size: Market potential of the end-use-application		Significant market potential of end- use-application	Negligible market potential of end- use-application
Relevance: Applicability in the Indian Context		Highly suitable/adoptable in the Indian Context	Not suitable/adoptable in the Indian Context
Technology Maturity: Level of advancement of the technology, whether in the preliminary lab testing and R&D phase or being implemented		Mature technology being implemented	Nascent Technology being tested internationally
Competitor Analysis	Ecosystem: Competitor's infrastructure, manufacturing base, skill availability, etc.	Competitor has a relatively weak/developing ecosystem	Competitor has a strong/mature ecosystem
	Economics: Alternate fuel price	Alternate fuel is relatively more expensive	Alternate fuel is inexpensive
	Efficiency: Efficiency of use - high/low	Competitor's technology is relatively more inefficient	Competitor's technology is efficient

Source: KPMG Analysis

3.1.2 Step 2: Overview of selected natural gas applications

The overview section is aimed at creating a basic understanding of the Natural Gas end-use-applications selected in Step 1 of the analysis framework mentioned above. At the end of this section we will be able to create an understanding on the following aspects:

- Description of the application – Concept of working of the technology, types of design, features and modes of operation will be covered under this sub-section
- Uses – Various uses of the application in industrial, commercial and residential segments

- Benefits – Benefits to end-users on usage of the application
- Policy and Regulatory interventions– Current and planned policy and regulatory interventions for promoting the use of the application itself or specifically for usage of gas in these applications
- Reasons for using Natural Gas – Benefits to end-users on usage of gas for these applications over its next best alternatives
- Current usage of Natural Gas – Current status on the level of Natural gas usage for the end-use-application

3.1.3 Step 3: Parametric analysis of selected Natural Gas end-use-applications

The selected applications in *Step 1* will be further analysed against specific parameters for understanding the advantage of using natural gas for these applications. The key parameters for analysis are (shown in Table 2):

- Economics of use
- Environmental impact and efficiency
- Macro-economic analysis
- Maturity - Application service and technology
- Industry preference

Table 2: Parameters for Analysis

S No.	Parameter	Description
1	Economics of Use	• Alternate Fuel/ Switchover Economics • Economic Viability at various gas prices
2	Environmental Impact and Efficiency	• CO_2 emissions • Legislature Mandates
3	Macro-economic analysis	Macroeconomic Implications of identified natural gas end-use applications - subsidy, foreign exchange, tax, etc.
4	Maturity - Technology & Application Service	• Commercial availability of the technology/application • Domestic vendors • Awareness of the application/technology among end-user segments • Level of skills available for implementation/installation of the technology/application • Visibility and current usage of the technology/application

S No.	Parameter	Description
5	Industry Preference	• Quality Standards • End use efficiency • Key target industry segments

Source: KPMG Analysis

The parametric analysis will help identify the key barriers for penetration of the selected natural gas end-use applications in India.

3.2 Review of International Experience

Under this section, the penetration of natural gas end-use applications internationally are studied to obtain key learnings for India. The following steps are undertaken:

- Identified countries as per the below categorization
- Developed natural gas markets where natural gas end-use applications have significant share in usage – US & UK
- Developing markets where the shift to natural gas use is part of their national level strategic - China
- Other countries where use of certain natural gas markets are successfully implemented
- Select case studies of Natural gas end-use applications in these countries
- Identify key learnings for India to bridge the major gaps/barriers

The countries where the Natural gas market is developed and has significant penetration in term of usage of end-use applications across sectors is dominant were chosen for further study. As India is a developing gas market, it would be worthwhile to study other developing natural gas markets where the share of gas in end-use applications is higher or are shifting towards a gas based economy aided by implementation of successful policy/regulatory measures.

For each identified natural gas market the key milestones[5] in use of identified natural gas end-use applications will be deliberated upon to bridge the gap existing in the Indian context.

Each of the case study will cover the following points in brief:

- Fast facts such as market size, policy enablers, incentives for application use etc.
- Success stories

[5] Case studies are attached in Annexures

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4 Analysis of parameters for preliminary selection of applications

Under this section, an exhaustive list of prevalent natural gas end-use applications were mapped against parameters such as market size, relevance, technology maturity and competitor analysis mentioned in the methodology section in order to identify the applications that can be focussed upon from a 5 year view. On the basis of analysis of few parameters such as comparison to the next best alternative, we can be certain that the application will not take off in the next 5 years. The preliminary analysis matrix is shown in Table 3.

Table 3: Preliminary selection matrix

End-use-application	Size	Relevance	Technology Maturity	Competitor Analysis		
				Ecosystem	Economics	Efficiency
Bulk Power	✓	✓	✓	✓	NFA[6]	✓
Ancillary Services	✓	✓	✓	✓	NFA	✓
Peaking Power	✓	✓	✓	✓	NFA	✓
Distributed Power Generation	✓	✓	✓	✓	NFA	✓
Combined Heat and Power (CHP)	✓	✓	✓	✓	NFA	✓
Direct-fired Absorption Chillers	✓	✓	✓	X	X	X
Gas Pool/Spa Heaters	X	X	✓	✓	X	X
Space Heating	X	X	✓	X	X	X
Direct-fired Burners	✓	✓	✓	✓	NFA	✓
Thermic Fluid Heaters	✓	✓	✓	✓	NFA	✓
Furnace	✓	✓	✓	✓	NFA	✓
Gas Geysers	✓	✓	✓	✓	NFA	✓
Boiler	✓	✓	✓	✓	NFA	✓
Fuel Cells	X	✓	X	X	X	✓
Hydrogen Cells	X	✓	X	X	X	✓
CNG Vehicles	✓	✓	✓	X	✓	✓
LNG Locomotives	✓	✓	✓	X	NFA	✓

[6] Needs further analysis (Covered in subsequent sections)

End-use-application	Size	Relevance	Technology Maturity	Competitor Analysis		
				Ecosystem	Economics	Efficiency
LNG Vehicle	✓	✓	✓	X	NFA	✓
Maritime Vessels	✓	✓	✓	X	NFA	✓
Cooking	✓	✓	✓	X	NFA	X
Gas Lamps	X	X	✓	X	X	X
Gas Dryers	X	X	✓	X	X	✓
Gas Incinerators	X	✓	✓	X	X	✓
Desiccant Dehumidification systems	X	✓	✓	X	X	X

Source: KPMG Analysis

The relevant applications that will be further analysed in this study are as follows:

a. Applications that are strong in all the parameters and need further analysis on the economics of use

- Bulk Power
- Ancillary Services
- Peaking Power
- Distributed Power Generation
- Combined Heat and Power (CHP)
- Direct-fired Burners
- Thermic Fluid Heaters
- Furnace
- Gas Geysers
- Boiler

b. Applications that may not be viable at the outset when viewed against select parameters but it is seeing a lot of traction from the government:

- CNG Vehicles – Competitive landscape for CNG vehicles is quite strong but owing to environmental considerations there will be significant development in this area

- LNG Vehicles – Lot of traction is happening in the NGV market segment especially for that of LNG trucks which own a larger share in the transport segment of developing gas markets like China. The government of India has also shown interest in similar lines and are trying to make LNG trucks feasible in the Indian context.

- LNG Locomotives – Government is largely looking at collaborating with foreign countries like Russia for partnership in development of LNG locomotives in India.
- Marine Transport – With regard to stricter emission regulations to be enforced in this segment, LNG can be a prospective fuel for marine vessels and it makes sense for India to focus on taking informed steps towards shift to cleaner fuels
- Cooking – Economics of gas is poor with respect to subsidized LPG but application is considered as PNGRB plans to develop CGD network on a pan-India basis.

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5 Applications – Power

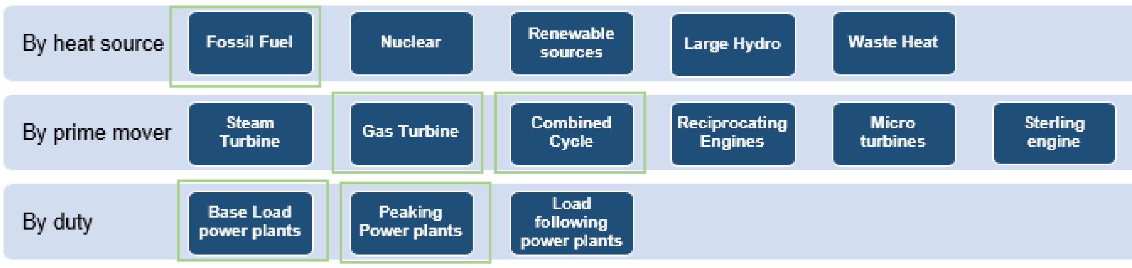
The power sector is in the priority list of gas allocation policy where a significant amount of natural gas is being used as a fuel for power production. Other than power production, natural gas is also used for peaking power applications and Ancillary services. There has been a significant growth in Distributed Power Generation and Combined Heat & Power applications in India. The use of natural gas for these applications is studied in the subsequent sections.

5.1 Bulk Power

Bulk power is produced from a power station, also known as a generating station, which is an industrial facility for generation of electric power. Thermal power stations comprise of generators and rotating machines which converts the mechanical power to electrical power. Mechanical power is produced by a heat engine that converts thermal energy from combustion of a fuel source into rotational energy. The fuel sources used for power generation includes fossil fuels, nuclear power and renewable sources. In India majority of the thermal power stations burn fossil fuels such as coal, natural gas and oil. The power sector ecosystem includes generation, transmission and distribution entities. The classification of power plants is shown in Figure 7 where power plants are categorized by:

- Heat source
- Prime mover
- Duty

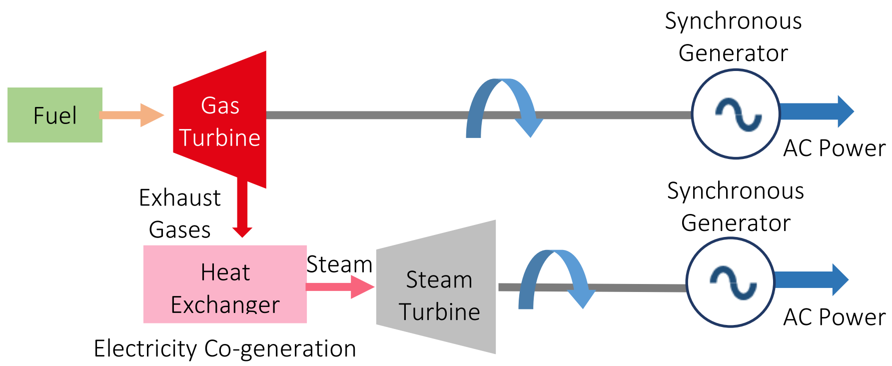
Figure 7: Classification of power plants



Source: KPMG Analysis

Majority of the Gas power plants in India are Combined Cycle (CC) plants where they have both a gas turbine fired by natural gas alongside a steam boiler and steam turbine which uses the hot exhaust gases from the gas turbine to produce electric power. The working of a Combined Cycle plants and that of a single system operation is illustrated below (shown in Figure 8 and Figure 9).

Figure 8: Combined Cycle Operation



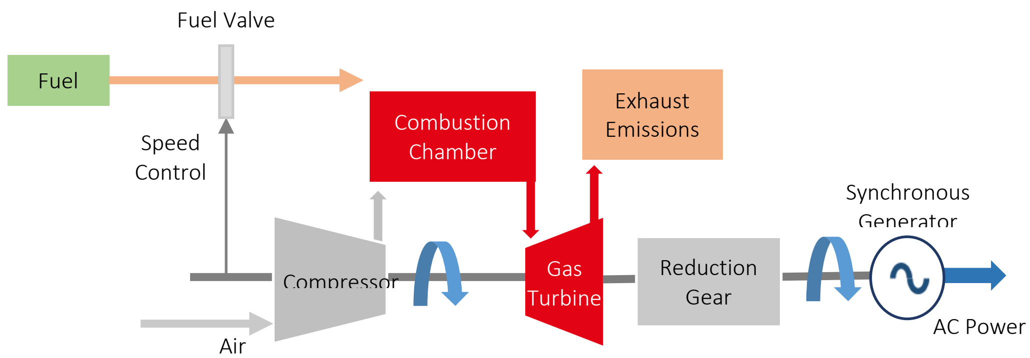
Source: mpoweruk-Gas turbines, KPMG Interpretation

Power plants can be scheduled to:

- Run steadily over a period of time, generally a day. These kind of power plants are referred to as Base load plants. These plants need not start or stop quickly during changes in system load and are used for all electricity applications in residential, industrial, commercial and transport segments.

- Plants which meet the daily peak load which may occur for one or two hours daily. These power plants are known as Peaking Power plants and they ensure security of the system during peak loads. These plants are used for similar applications such as residential, industrial, commercial and transport segments during the peak hours.

Figure 9: Single System Operation



Source: mpoweruk –Gas turbines, KPMG Interpretation

Benefits of power arise from a stable and reliable supply of power which can be achieved by a sound power generation portfolio and operational infrastructure. An operational system with the minimum possible Transmission and Distribution (T&D) losses can be beneficial to both the producer and consumer category of bulk power generation.

Policy & Regulatory Interventions and Other Enablers[7]

Owing to the importance of the power sector to every economy, the Indian government has taken several initiatives and mechanisms to formulate a robust policy and regulatory framework for the power sector as described in the following section[8].

- Electricity Act, 1910 – Infrastructural framework for supply of electricity
- Electricity Act, 1948 – Mandated creation of State Electricity Boards (SEBs)
- IIP process in 1991 – Brought about private investment in Power sector
- Electricity (Amendment) Act, 1998 – Transmission of Power made a separate activity
- Mega Power Policy, 1995 –Mega Power Plants Construction
- Regulatory Commission Act, 1998 – Provision for setting up of CERC
- National Electricity Policy – Competition and protection of a consumer
- Electricity Act, 2003 - Objective to introduce competition, protect consumer's interests and provide power for all
- National Tariff Policy – Tariff structuring methodology
- Memorandum of Understanding with states
- Andhra Pradesh Electricity Reforms Act
- Karnataka Electricity Reforms Act, 1999
- Orissa Electricity Reforms Act
- Electricity Act (amendment), 2015 draft

Gas power plants are quick response plants which can ramp up to 100% of their capacity in 5 to 20 minutes hence they are ideal for peak power generation. However, in India majority of the plants are constructed keeping in mind the base load generation. At present, there is a total installed capacity of 23,062 MW of gas based power in India. All India PLF levels of gas based power was 25% in 2014 owing to gas availability issues. Gas based plants are primarily used for base load generation even though they are highly suited for peak load generation.

5.1.1 Economics of Use

In order to determine the economics of use of bulk power, the affordable price limit of discoms is taken as the target price for gas based power generation plants, basis the scheme for utilization of Gas based power generation capacity. The corresponding natural gas price will help us determine the affordable gas price band for bulk power plants. According to the scheme for utilization of Gas based power generation capacity for the years 2015-16 and 2016-17, the

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[7] Other enablers include initiatives by institutions/organization/government for promoting use of natural gas in applications

[8] Partly sourced from DNB –India Energy Sector

Empowered Pool Management Committee will fix the target price (net purchase price for Discoms) and target PLF (supply of imported spot RLNG will be given up to target PLF) (as shown in Table 4).

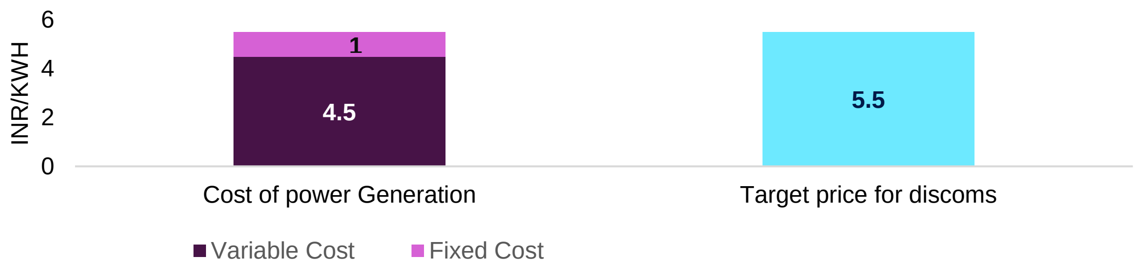
Table 4: Target PLF and Target Price – Gas Power Plants

	Indicative Target PLF (%)				Indicative Target Price (INR/kWh)
	FY 16		FY 17		
	5 Monsoon months	7 Non monsoon months	5 Monsoon months	7 Non Monsoon months	
Stranded Plants	25%	30%	30%	30%	5.5
Plants receiving domestic gas	25%	30%	30%	30%	4.9 (for incremental generation up to target PLF)

Source: Ministry of Power

In view of the above scheme, the variable cost of generation that the gas based power plants can afford is INR 4.5/kWh after excluding INR 1/kWh of fixed cost from the target price (shown in Figure 10).

Figure 10: Economics of Use – Bulk Power



Source: KPMG Analysis

At INR 4.5/kWh variable cost of generation, the estimated landed price of natural gas realized for running gas based power plants comes out to $ 8.28/MMBTU.

5.1.2 Macro-economic Impact

Power plants have significant macro-economic impact as they are completely government controlled. In order to promote the growth of power sector the government has introduced several schemes including tax benefit schemes to revive the sector from making losses due to affordable fuel sourcing and procurement/availability challenges.

Government has launched bidding for providing imported gas to stranded power plants through a subsidy mechanism in May 2015[9] during which the gas power plants submitted bids for the

[9] Business Standard Article – May 14,2015

subsidy amount they would require to sell the incremental electricity that they would produce from the gas supplied to them at subsidized rates. The landed price of natural gas for every state will vary, as per the taxation system in each state. This may lead to differences in landed price of gas in the normal scenario of procurement of gas for power plants.

5.1.3 Environmental Impact and Legislatures

Power generation contributes to significant amount of emissions as majority of power generation in India is met by coal. Hence, legislatures exists that mandate certain environmental norms for power generating plants as given below.

- The weighted average specific emissions for gas-fired power stations in FY 2013-14 was 0.49 t CO_2/MWh[10] which is 50% lesser than that of coal-fired stations
- National Conservation Strategy and Policy Statement on Environment and Development has provided guidelines for power plant projects (1992, Ministry of Environment & Forests - MoEF)
- Environment (Protection) Act, 1986 (EPA) and Rules 1986 - Under Section 23 of the act, following types of power plants clearance can be obtained from the State Government

o For co-generation power plants of any capacity;

o Gas/naphtha-based and coal-based power plants with a fluidized bed technology of up to 500MW capacity

- MoEF is responsible for making rules to implement the EPA and has adopted industry specific standards for effluent discharge and emissions for 24 designated industries. Thermal power plants fall in this list.
- The Environment Impact Assessment of Development Projects Notification,1994 and as amended in 1997 mentions about Post commission requirements for thermal power plant has been commissioned the following facts are relevant
- Monitor emissions and effluents obtain consent to operate under the Water Act, Air Act, comply with the standards laid down by the Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB)
- Factories Act 1948, Amendment, 1987 - The Act contains a comprehensive list of 29 categories of industries involving hazardous processes (First Schedule to the Act) which includes Power generating industries

On a high level monitoring the emissions and advocating usage of greener fuels is the goal of these regulations[11] .

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[10] Only gas-fired stations that do not use any other fuel. Stations that use naphtha, diesel or oil as a second fuel are excluded from the weighted average

[11] TERI Report No. 99PG64

5.1.4 Maturity

Gas power plants are commercially available and have a well-established market in place as far as the application usage and technology is concerned Globally, upgraded versions of technology is being used because of larger penetration of natural gas usage for bulk power generation. However, the usage is limited largely due to gas availability concerns.

Table 5: Bulk Power –Maturity

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	High	High	High	High	High	Low
Technology	High	High	Medium	High	Medium	Low

Source: KPMG Analysis

5.1.5 Market Size

According to CEA as of 31 March, 2015 the gas based generation capacity of India is 23062 MW. The western region has the highest gas-based power installed capacity. The regional gas based capacity is as shown in Table 6. The western region has the maximum capacity due to the fact that the gas infrastructure is robust in the western region. However the average gas PLF has dropped from 67% in FY 10 to 18.44% in FY 15.

Table 6: Regional Gas-based Capacity

Region	Gas based capacity (MW)
Northern	5331.26
Western	10915.4
Southern	4962.78
Eastern	190
North Eastern Region	1662.7

Source: CEA

Table 7: Market size potential – Bulk Power

Market size potential
~109.16 MMSCMD
Natural gas consumption for the total installed capacity of gas based power (23,062 MW) @ 75% PLF, SHR of 2100 kcal/kWh and Calorific value of 9880 kcal/SCM is taken for determining market potential. No future capacity addition up to 2020

Source: KPMG Analysis

5.1.6 Industry Speak

Gas power plants preference for Natural gas is governed by the rules of the general policy for the Natural gas market which implies that gas will be allocated according to sectoral priorities put forward by the government which states that if one customer is not in a position to take the gas the next one on the list becomes eligible

According to industry players Gas–fired plants are more efficient, relatively cheaper, and quicker to construct and have lower emissions provided that there is reliable availability of the fuel. The comparative analysis of a gas and coal plants on the basis of certain parameters are shown below in Table 8.

Table 8: Comparative Analysis of Gas and Coal Power Plant

Parameter	Natural Gas	Coal
Gestation Period	~ 3 years	~ 4 years
Capital Cost (INR Cr per MW)	~ 4.0	~ 5.5
Construction Risk	Low	Medium
Project Life	15 years	25 years

Source: KPMG Analysis

With respect to the health of the atmosphere and pollution concerns in India as most power is being thermally generated by Coal there is a great need for shift towards greener Natural gas fuel. Gas power is also considered as a worthy alternative fuel for meeting the needs of peak and captive power units and other sectors such as transportation, refineries and steel where it can substitute expensive liquid fuels.

5.1.7 Barriers

The major barriers for gas-based Bulk Power generation are summarized as follows:

•	Non-availability of gas is the significant barrier affecting gas-based power generation

•	Debt Obligations - Stranded gas based Assets not able to fulfilling debt obligations

•	Current tax regime issues – Petroleum Products and Natural Gas not included in the GST Amendment Bill as of now

•	Liquefied Natural gas (LNG) Price Risk due to dependence on Natural gas prices on international crude oil price

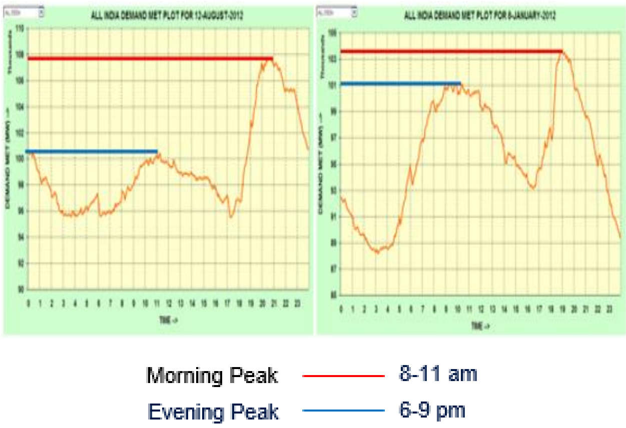
5.2 Peaking Power & Ancillary Services

5.2.1 Peaking Power Overview

Peaking power plants are power plants that generally run only when there is a high demand for electricity, known as peak demand. Demand for energy in India peaks during specific hours in a day. This occurs in two cycles during the day, in the morning and in the evening. Globally, this is also referred to as a two-peak challenge (shown in Figure 11). The power plants that specifically generate during these times to meet the spikes in demand during the peak demand hours are termed as 'peaking power plants'.

In 2013-14 there was an all India peak deficit of 4.5%, in 2014-15 it is expected to fall to 2%. In spite of falling significantly, the peak deficits in India are expected to persist. Traditionally Hydro (storage based) is a key source for peaking power. However, in India with the hydro (storage based) capacity additions stagnating there is an urgent need for additional capacity and alternate fuel options for specific peaking power plants. The distribution utilities in India are not ready to procure the expensive gas-based power even during the short period of peak power owing to their financial constraints and because there is no policy or regulation that mandates them to meet peak demand.

Figure 11: Two peaks – Morning and Evening



Source: NLDC, KPMG Analysis

Peaking Power Plants are used for generating power to cater to the peak demand. Hydro and Gas based power plants are most techno-economically suited for peaking power generation and are used in combination with base load plants to meet minimum demand.

During fluctuations of demand and supply adequate peaking power capacity ensures round the clock reliable power supply to consumers. They serve as an important element of the utilities portfolio of electric supply sources.

Policy & Regulatory Interventions and Other Enablers

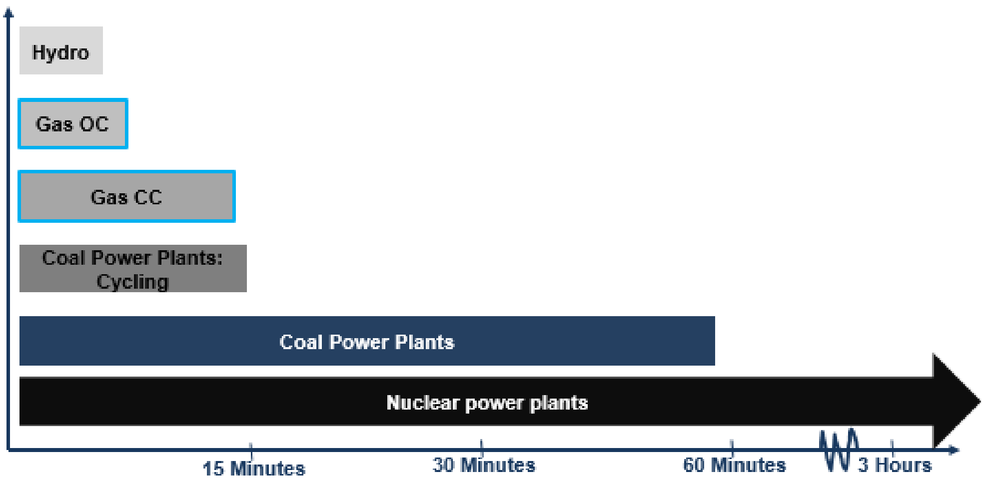
Currently there are no policy or regulations for pushing gas based peak power generation. Policy and Regulatory mechanisms directed towards Peaking Power in India are as follows:

- Proposed Peaking Power Policy by CERC
- National Tariff Policy, 2006 – Mentions the setting up of separate capacities for meeting peak demand and introduction of differential rates for peak and non-peak power
- Time of Day (TOD) tariff - Used mostly for industrial sector

However, utilities do not have any supply obligations and they can resort to load shedding during peak demand.

Natural gas based open cycle plants are best suited for peaking power production in the current Indian context due to its quick response rate (shown in Figure 12). Further alternate sources such as hydro based generation carries socio-political risks as well as rehabilitation and displacement issues. Further, with no storage based hydro capacity addition planned, gas is technically the most suitable option as a peaker plant.

Figure 12: Start up times – Various fuel sources



Source: KPMG Analysis

Gas based power generation in India as such is almost not functional due to non-availability of domestic gas and higher prices of RLNG. Further, most of the plants are developed to serve as base load generators and are not economically suitable for peaking operations.

5.2.2 Ancillary Services Overview

The literal meaning of the word 'ancillary' is 'providing support to primary activities or operations'. In context to the power sector, ancillary services are those supportive services which are needed to transmit power from the buyer to the seller ensuring maintenance of the overall stability and reliability of the grid. Ancillary Services consist of services that are required for:

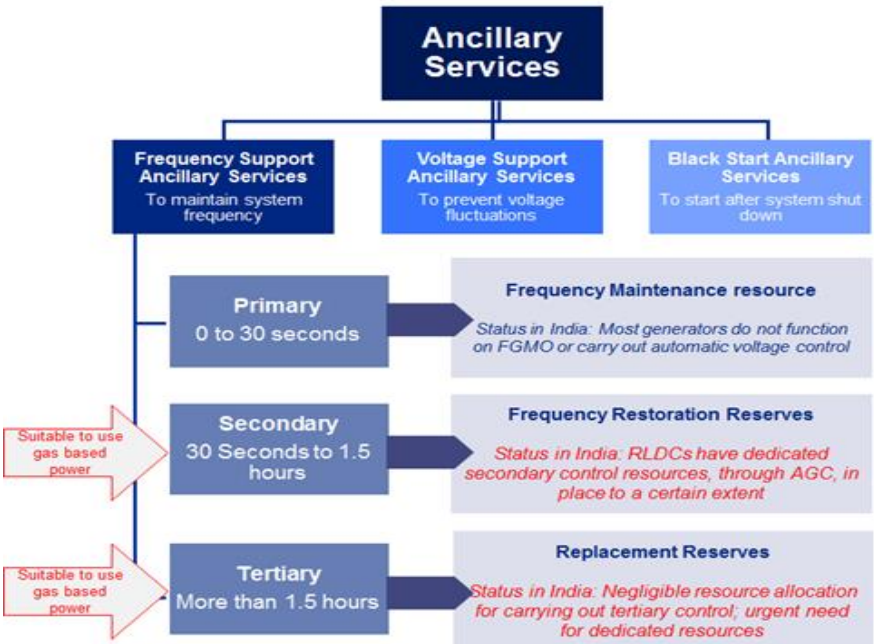
- Maintaining load – generation balance
- Maintaining voltage and reactive power support
- Maintaining generation and transmission reserves

The working of ancillary services are shown in Figure 13. The Section 5.2.3 of the National Electricity Policy (NEP) mandates that adequate reserves may be maintained to ensure secure grid operation but currently there are no functioning ancillary services in India. However, CERC Power Market Regulations 2010 has made provisions for introduction of Ancillary Services in the Indian Electricity Market in the future.

Ancillary Services can provide three main types of control on a power system, based on the time taken to provide this support:

- Primary Control: 1 to 30 seconds
- Secondary Control: Provided within 30 seconds and 1.5 hours
- Tertiary Control: Provided post 1.5 hours

Figure 13: Functioning of Ancillary Services



Source: KPMG Analysis, Ancillary Services Explanatory Memorandum

Box 1: Proposed framework for Ancillary services in India

Objective: The proposed Reserves Regulation Ancillary Services (RRAS) is to restore the frequency level at desired level and to relieve the congestion in the transmission network. The RRAS shall support both regulation up and regulation down service.

Nodal Agency: National Load Despatch Centre (NLDC) through the Regional Load Despatch Centres (RLDCs) shall be the nodal agency at the inter-state level and State Load Despatch Centre (SLDC) at the intra state level as and when such services are introduced.

Market Participants: All Inter-State Generating Stations whose tariff is determined or adopted by the Commission and are operating on part load and have not received full requisition shall be eligible to participate.

Role of Nodal Agency: NLDC shall prepare merit order stack of un-requisitioned surplus of ISGSs willing to participate in this mechanism, based on the variable cost of generation, declared capacity and take despatch decision. The stack would be made region-wise to factor in transmission constraints on any inter-regional or area boundary.

Involvement of NLDC based on contingency: Nodal agency shall stack un-requisitioned surplus capacities available from ISGS based on lower generation Cost to higher generation cost in each time block. Nodal agency shall direct the selected RRAS providers for regulation up and regulation down, as and when requirement arises in the system.

Dispatch of proposed service: Once the time period specified by the Nodal Agency starts, ancillary service will be deemed to have been triggered.

Withdrawal of Ancillary service: The Nodal Agency, on being satisfied that the circumstances leading to triggering of RRAS no longer exist shall then direct the RRAS provider to withdraw from the time block specified in the detailed procedure.

The framework also highlights necessary actions to be taken for energy accounting, settlement, scheduling of RRAS and the commercial mechanism

Source: Explanatory Memorandum for Ancillary Services

The primary use of ancillary services is to help manage real time imbalances in demand and supply of power, which hampers:

- the frequency levels or
- the voltage levels or
- the overall functioning of the grid

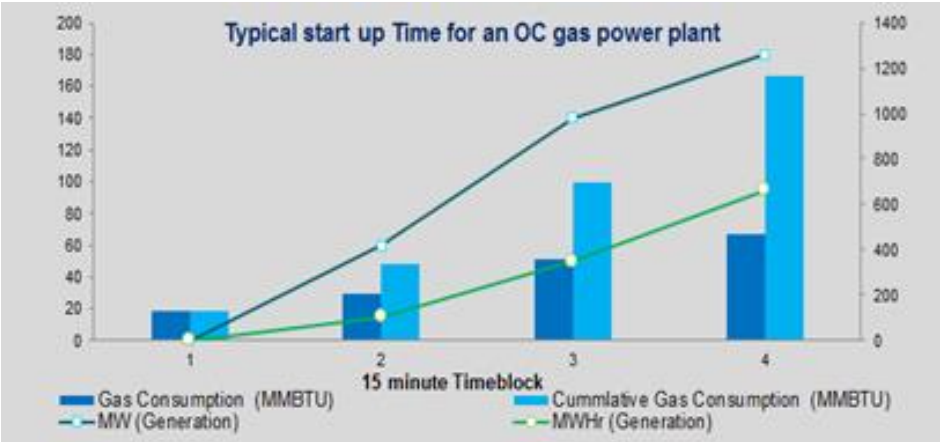
Ancillary Services are key for system reliability and stability. Contracting certain quick response plants specifically as Ancillary Service plants ensures that they are available at all times to manage system contingencies, thus minimizing load shedding and system failures.

Policy & Regulatory Interventions and Other Enablers

At present there are no policy or regulatory enablers for purchasing gas based power as Ancillary Services. The Central Electricity Regulatory Commission (CERC) has published a draft framework for procurement and dispatch of Ancillary Services. CERC has published a staff paper on "Introduction of Ancillary Services in Indian Electricity Market (2013).National Load Despatch Centre (NLDC) is recommended to be the nodal agency for implementation of the ancillary services as they have raised concerns over grid in-discipline of states.

Gas power plants are quick response plants which can ramp up to 100% of their capacity in 5 to 20 minutes. An Open Cycle Gas Turbine can ramp up within 10 minutes to its full capacity (as shown in Figure 14). This is especially an ideal usage for stranded gas capacity, where it is not feasible to use it as a base load generator. There is a huge potential for existing OC plant capacities as well which are operating at below average PLF standards can be used for ancillary services.

Figure 14: Start-up time for an OC gas power plant



Source: KPMG Market Research

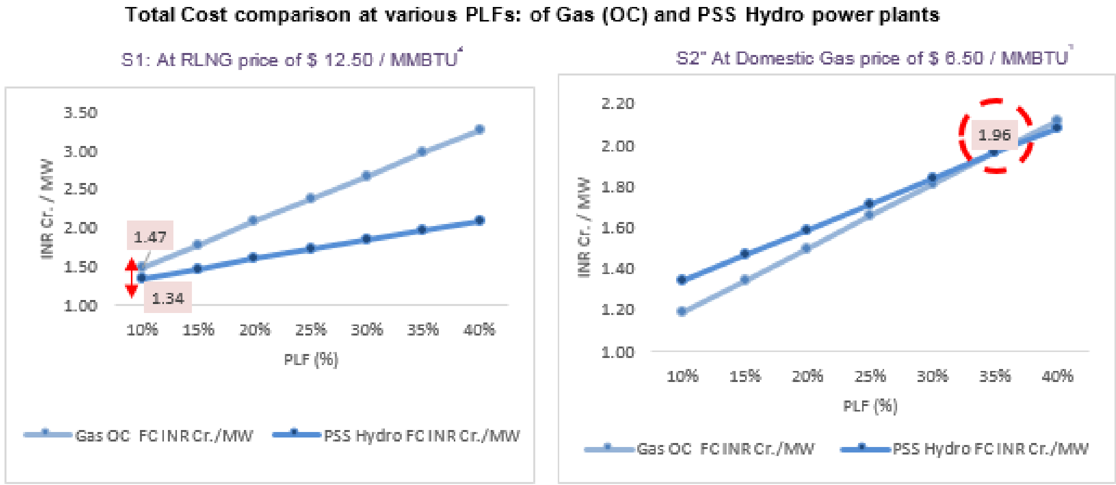
At present, gas power plants are primarily used as base load generators and peaking power plants and are not contracted as ancillary service providers. However, there is a large percentage of gas capacity pan India which are at present stranded due to lack of domestic gas availability and economic unfeasibility of running them as base load generators on RLNG. The plants are ideally suited to act as Ancillary Services support.

5.2.3 Economics of Use

5.2.3.1 Peaking Power

The economics of use for Peaking Power was done by comparison of the cost of using natural gas versus alternative fuel/energy source which in this case was Pumped Storage Systems Hydro (PSS Hydro).

Figure 15: Economics of Use – Peaking Power



Source: KPMG Analysis

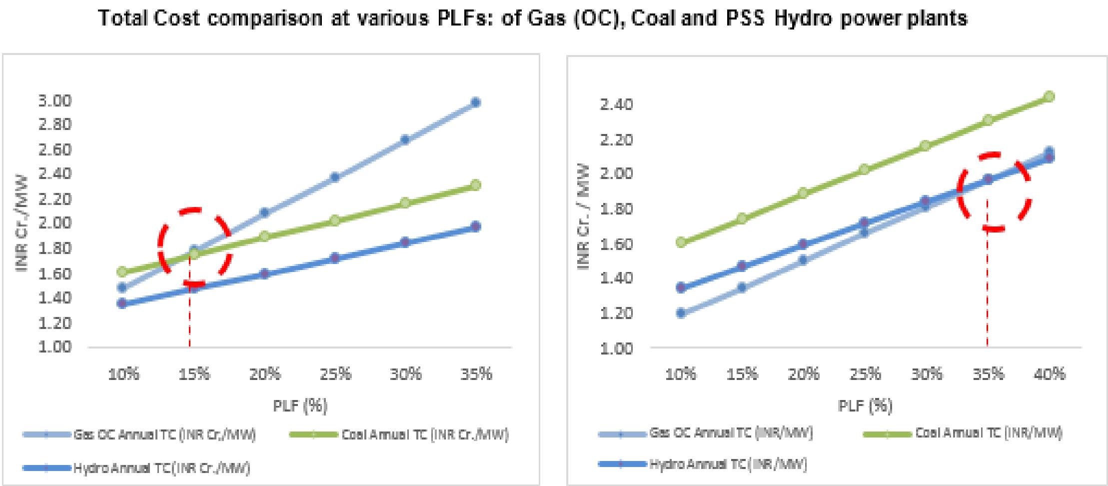
- A plant providing Peaking Power will be utilized only for a part of its capacity for provision of power during peak demand hours
- The resources ideally suited for providing peaking power are open Cycle (OC) gas plants and pumped storage (PSS) hydro power plants
- In the above graphs the total costs of using the two different sources of power for the provision of peaking power at various PLFs has been considered, in order to understand, which resource is most economically suitable for providing power during peak demand hours
- Two scenarios have been run, S1, where the price of RLNG (@ 12.5 $/MMBTU) and S2, where the price of domestic gas (@ 6.50 $/MMBTU) has been considered as a fuel source for Gas OC plants, respectively
- From S1, (Figure 15) we can observe that, if a gas power plant running on RLNG is available for provision for peaking power, then PPS Hydro based peaking power is the most economically viable option as compared to it, regardless of the extent to which it is being used, However, the economic advantages per unit is marginal
- From S2, (Figure 15) we can observe that, if a gas power plant runs on domestic gas and is available for provision for peaking power, then it is a more economically comparable to PSS hydro based AS up to a utilization (PLF %) of 35%

From a technical perspective Gas OC is comparable to PSS Hydro as they are both able to ramp up quickly to provide support during peak hours. However, at present Hydro capacity addition (storage based) is stagnant. In this case, for incremental peaking power needs, gas based capacity might be the go-to option for provision of peaking power.

5.2.3.2 Ancillary Services

The economics of use for Ancillary Services was done on the basis of comparison of the cost of using natural gas versus alternative fuel/energy source for Ancillary Services (AS) which in this case is coal (hot spinning) and PSS hydro plants.

Figure 16: Economics of Use – Ancillary Services



Source: KPMG Analysis

- A plant providing ancillary services (AS) will be utilized only for a part of its capacity for provision of real time quick response power

- The resources ideally suited for providing AS are open Cycle (OC) gas plants, coal based plants which are hot spinning and pumped storage (PSS) hydro power plants

- In the above graphs the total costs of using the three different sources of power for the provision of AS to at various PLFs has been considered, in order to understand, which resource is most economically suitable for providing AS

- Two scenarios have been run (shown in Figure 16); S1, where the landed price of RLNG (@12.5 $/MMBTU) and S2, where the landed price of domestic gas (@ 6.50 $/MMBTU) has been considered as a fuel source for Gas OC plants, respectively

- From S1, we can observe that, if a gas power plant running on RLNG is available for provision for AS, then PPS Hydro based AS is the most economically viable (as compared to both gas and coal based AS) option regardless of the extent to which it is being used. However, for low utilization levels (up to 15%) is more economically viable to use RLNG based gas power plants to supply AS as compared to coal based plants

- From S2 we can observe that, if a gas power plant runs on domestic gas and is available for provision for AS, then it is a more economically viable option as compared to coal at any utilization level, and comparable to PSS hydro based AS up to a utilization (PLF %) of 35%

From a technical perspective Gas OC is comparable to PSS Hydro as they are both able to ramp up to provide support within a time block (15 mins). Coal plants (even on hot spinning mode) may not be able to provide such quick support. Thus with a stagnant hydro (storage based) capacity at times, when AS support is need within 15 minutes, gas based AS might be the more viable option despite the coal being economically a better option

5.2.3.3 Cycling effect of coal

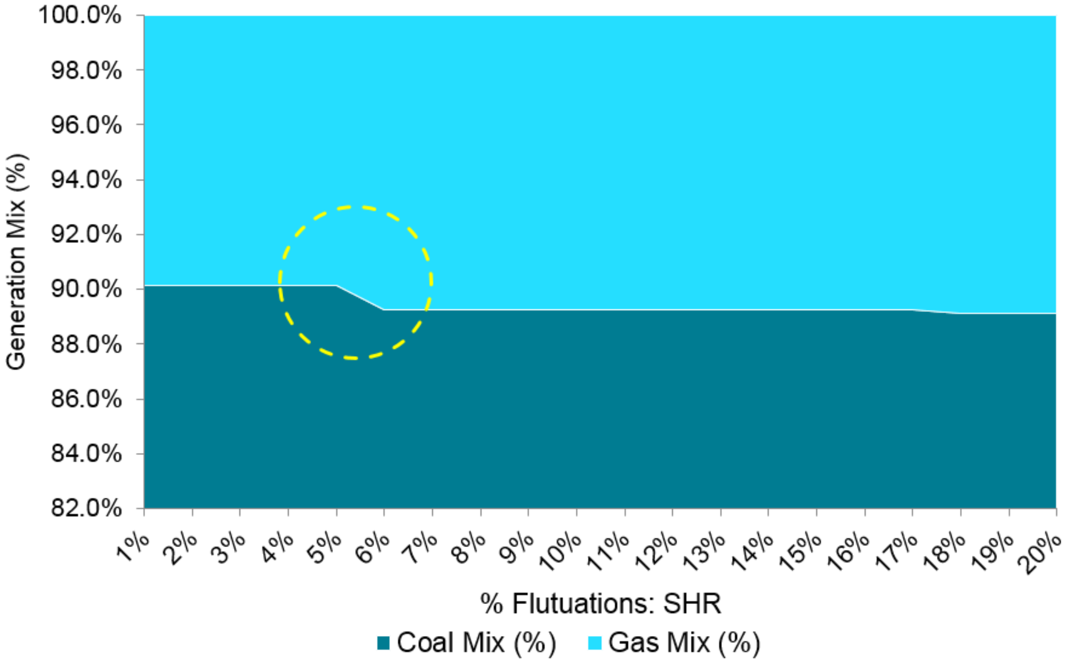
To understand the economic advantage of Gas based power plants over coal based power plants during cycling of coal plants, the following assumptions are considered for finding optimization of generation mix between coal & gas based power plants at RLNG price of $12.5/MMBTU. The assumptions considered are highlighted in Table 9.

Table 9: Assumptions for optimization of Generation Mix at RLNG price of $12.5/MMBTU

Optimization of Generation Mix	Capacity (MW)	PLF (%)	Capacity Mix (%)
Base load - Coal	15292.40	90.00%	90.14%
Balancing Load - Gas	1672	14%	9.86%
Cost of Generation (INR Cr.)	**FC**	**VC**	**TC**
Coal	20171	37252	57423
Gas OC (Existing)	1103	1704	2807
Grand Total	21274	38956	60230

Source: KPMG Analysis

Figure 17: Station Heat Rate Sensitivity



Source: KPMG Analysis

Basis the above assumptions, the optimum mix of gas based open cycle plants that can be supported during peak demand periods to minimize the total cost of generation is calculated as 9.88% of gas based and 90.14% of coal based power plants. When coal plants are operated at varying loads in response to ancillary/peaking power requirements, this would create cycling effect on coal plant and impact heat rates and cost of generation.

Sensitivity analysis has been carried out to see the impact of increase in SHR on the optimum generation mix as shown in Figure. We can see from the above simulation (shown in Figure 17) that, there is a kink observed for gas percentage mix in the total generation beyond SHR percentage increase of 5%. This is because of increase in gas percentage mix that could be accommodated in total generation mix increased from 9.85% to 10.73% to minimize the total cost of generation.

5.2.4 Macro-economic Impact

There is no direct macro-economic impact on factors such as subsidies, taxes and foreign exchange rate fluctuations on gas based Ancillary Services when compared against coal or hydro. Landed cost of gas may vary across states depending upon the taxation regime.

However for gas based peaking power plants the macro economic impact in relation to bulk power generation will apply as discussed earlier. Natural gas usage limits the impact on the economy and the currency in several ways as the delivered cost of RLNG on a per BTU basis at the point of consumption is lower than oil. The cost impact of crude import is correspondingly lower that results in import bill savings.

5.2.5 Environmental Impact and Legislatures

From an environmental perspective gas based power is a better option than coal as it emits a lower quantum of harmful CO_2. Hydro (including PSS Hydro) power plants has negligible emissions. However, they do have other environmental impacts such as soil erosion, ecological impacts, etc.

Peaking power has much lower emissions than its base load alternatives. Considering both global and local emissions impacts the scale of emissions from gas based peaking power plants is a small fraction of the emissions from coal based power plants (shown in Table 10).Since peaking power stations have high flexibility, they can cycle up and down in a short period of time thus reducing emissions even more significantly.

Table 10: Specific emissions of fossil-fuel fired stations

Coal (t CO_2/MWh) [12]	Gas (t CO_2/MWh)	Hydro (t CO_2/MWh)
1.03	0.49	0

Source: CEA

Peaking power has much lower emissions than its base load alternatives. Considering both global and local emissions impacts the scale of emissions from gas based peaking power plants is a small fraction of the emissions from coal based power plants

Since peaking power stations have high flexibility, they can cycle up and down in a short period of time thus reducing emissions even more significantly.

5.2.6 Maturity

Natural gas based power plants are used for base load applications and not for peaking power use. Hence, with regard to the visibility and skill required for the application as such, it is lower compared to the technology standpoint. Although, there is adequate awareness about the benefits of the technology for use in peaking power applications, gas availability constraints limit the use of the same.

Table 11: Peaking Power - Maturity

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	High	Medium	Medium	Medium	Medium	Low
Technology	High	High	High	High	High	Medium

Source: KPMG Analysis

[12] Weighted average specific emissions for fossil fuel-fired stations in FY 2013-14, in t CO2/MWh, CEA report

Gas based Ancillary service application usage is India is particularly nil hence the application maturity is lower compared to the technology front where adequate technology is available in the market with no takers for ancillary applications.

Table 12: Ancillary Services - Maturity

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	Medium	Medium	Low	Medium	Medium	Low
Technology	High	High	High	High	High	Medium

Source: KPMG Analysis

5.2.7 Market size

According to Central Electricity Authority, peaking shortages are likely to prevail mainly in the Southern and North-Eastern Regions to the tune of 19.8% and 4.0% respectively[13]. There was an overall anticipated deficit of 4108 MW in 2015-16.The regional anticipated peak demand and realised demand is shown in Table 13 below.

Table 13: Anticipated Peak Power Demand for 2015-16

Region	Peak Demand (MW)	Met (MW)	Surplus (+)/Deficit (-)
Northern	54,329	54,137	-192
Western	48,479	50,254	1775
Southern	43,630	35,011	-8619
Eastern	18,507	19,358	851
North-Eastern	2,650	2544	-106
All-India	156,852	152754	-4108

Source: CEA

A Mc Kinsey Company study[14] estimates that by 2030 more than 40% of the demand will be non-base load or peak power demand with a grid power demand likely to be 3450 TWh.

The Central Electricity Regulatory Commission (CERC) Power Market Regulations of 2010 has made provisions for introduction of the Ancillary Services in the Indian Electricity Market in the future. Further Regulation 8 provides that the Ancillary Services Market would be introduced by CERC at a later date. So currently there is no existing ancillary services market. Open Cycle (OCGT) plants are highly suitable in this context. Availability in India for secondary Frequency Support

[13] Anticipated All India Power Supply Position for the year 2015-16 , CEA
[14] Mc Kinsey & Company report on Environment and Energy Sustainability – An Approach for India

Ancillary Services (FSAS) in 2014 for Coal (Hot Spinning), Hydro (Storage) and Diesel is ~ 25,154 MW as shown in Table 14.

Table 14: Available capacity for Ancillary Service – Coal, Hydro and Diesel

Resource	Availability in India for Secondary FSAS in 2014 (~MW)
Coal (Hot Spinning)	21791
Hydro (Storage)	2335
Diesel	1028

Source: KPMG Market Research

Table 15: Market size potential – Peaking Power & Ancillary Services

Market size potential
~7.95 MMSCMD
According to the National Electricity Policy, a spinning reserve of at least 5%, at national level, would need to be created to ensure grid security, quality and reliability of power supply. Gas based Ancillary services and Peaking Power potential @ 12% PLF (3 hours usage per day) on total installed capacity (excluding RES). No future escalations are considered.

Source: KPMG Analysis

5.2.8 Industry Speak

According to the National Electricity Policy, in addition to enhancing the overall availability of installed capacity to 85%, a spinning reserve of at least 5%, at national level, would need to be created to ensure grid security and quality and reliability of power supply. Peaking power requirements are key from a consumer perspective and non-supply of peaking power by utilities also results in substantial costs to the exchequer in the form of indirect subsidies. In a way the additional costs of non-supply of peaking power are borne by consumers at large, base load generators and also by the exchequer in a substantial measure as consumers have to arrange for back up facilities. Commercial and Industrial players are installing gas-engine based modular decentralized plants to serve their peaking needs that provide both electricity and cooling. However many are held up or resistant to do so because of non-availability of gas. Ancillary and Peaking power facilities are highly desired by all segments of consumers and the government should considering scaling/enhancing existing facilities to cater to these requirements.

5.2.9 Barriers

The major barriers faced by the generators and consumers with regard to peaking power and ancillary services are summarised below:

- The Indian policy framework emphasizes on least cost of energy delivered and hence deliberates upon generation capacity creation in general. There is a need for diversifying the generation mix to address peaking demand policy goals
- Fuel prices and availability are the major supply side barriers for peaking power. In addition to hydro, gas and liquid fuels are the only options for peaking power. Since the prices of liquid fuels are market determined and linked to international markets and with India depending on imports for more than 80 percent of its liquid fuel needs it is unfeasible to build utility scale peaking power in the country
- Solar power plants ought to be attractive in case prices of oil and gas rise which could replace fossil-fuel demand for meeting peaking power by 2030

5.3 Distributed Power Generation

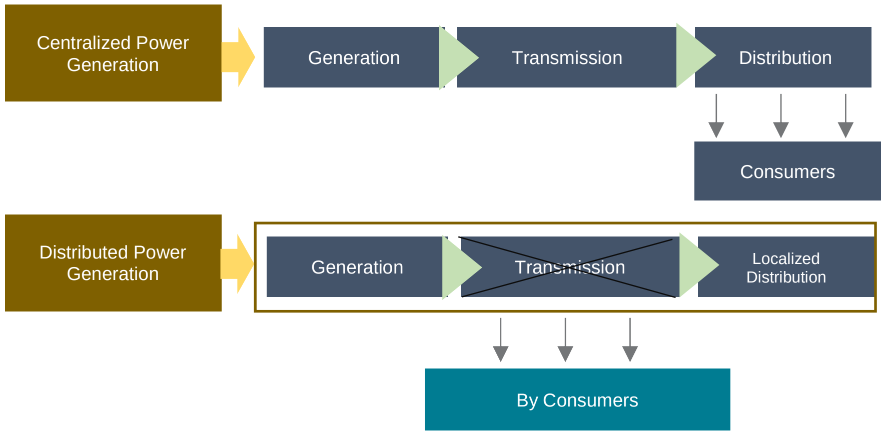
GE defines “distributed” power as anything under 50 megawatts, a category that stretches from basement or garage backup gen-sets to large-scale gas turbines. The key difference to be drawn, is between "distributed" generation and “central” generation -- the big utility-scale power plants that require long-term capital financing and project planning to bring on-line

Due to India’s increasing commercialization and industrialization, the generation from utilities has always been unable to keep pace with the rapidly growing demand. Hence, the captive and backup power segment has witnessed significant growth to ensure reliable and quality of power to sustain the economy growth. Beside availability of electricity, cost of electricity and its environmental impact is equally important for sustainable growth. Largely diesel based distributed power generation is in use in India. In this context, reducing the reliance on diesel based power generation will be of best interest to the economy.

Reciprocating engine technology is used in gas-based distributed power generators. This type of engine employs the expansion of hot gases to push a piston within a cylinder converting the linear movement of the piston into the rotating movement of a crankshaft to generate power.

This form of generating power on-site eliminates the cost, interdependencies, complexity and inefficiencies/losses associated with transmission and distribution of electricity (depicted in Figure 18).

Figure 18: Distributed Power Generation Illustration



Source: KPMG Interpretation

Distributed Generation (DG) can be achieved through solar energy, wind-powered systems as well as through natural gas-fuelled technologies. A genset comprises of an engine, alternator, voltage regulator, fuel system, cooling and exhaust system, battery charger, lubrication system, control panel, and a main assembly or frame. The engine has two parts- an internal combustion engine that burns natural gas and an electrical generator that converts the shaft power of the engine into electricity. DG systems can be used to generate a customer's entire electricity supply for peak shaving, standby or emergency generation etc. Distributed power generation is highly suitable for remote locations where construction of distribution and transmission lines are expensive and difficult.

Distributed Power Generation enables customers to control their electric consumption along with improved power quality and reliability. This form of technology provides faster response to additional power demand. With distributed generation in place, optimum usage of network is achieved as capacity additions can be done in small increments. Owing to negligible distribution and transmission losses, distributed generation is a better option in the Indian context.

Policy & Regulatory Interventions & Other Enablers

Currently there are no policy or regulations for pushing gas-based distributed power generation. However there are other policy/regulatory enablers for DG as mentioned below:

- The Electricity Act, 2003 – Highlighted DG in the context of rural electrification
- The National Electricity Policy, 2005 - DG facilities coupled with local distribution network be provided for rural electrification where conventional grid is not feasible
- RGGVY (Rajiv Gandhi Grameen Vidyutikaran Yojna) and RVE (Remote Village Electrification) schemes – Government allocated up to 90% capital subsidy for rural electrification projects using DG options

Gas micro turbine technology is seen as a promising application of distributed generation to cater to the shortage of power supply due to no reach of grid. Gas based DG ensures fuel security and quick response time and carries no risk related to fuel adulteration and theft. Natural gas is economically Competitive as compared to diesel & in certain states, as compared to industrial HT tariffs. Gas-based Captive plants need lower upfront costs than coal due to lower land requirement and efficient fuel transport.

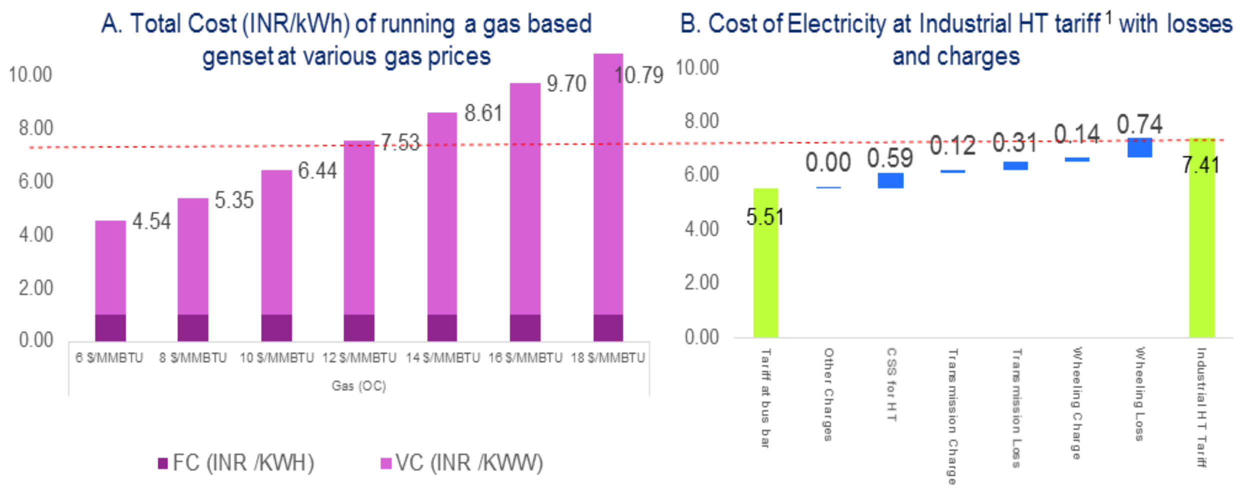
5.3.1 Economics of Use

The economics of use for distributed power generation is done on the basis of alternate fuel economics comparison. The analysis will be done for two cases; Captive power plants that is particularly used by industries and DG sets which is typically used for non-industry purposes. Diesel is the next best alternative fuel that is considered in both the cases.

Case 1: Industry use – Captive power plants < 50 MW

The capital cost of the gas-based genset considered for analysis is INR 9. 5 lakh.

Figure 19: Economics of Use – DPG (Captive Power Plants for Industry Use)



Source: KPMG Analysis

From the graph above, as a result of the economics study it was evident that Industrial tariffs in several states (especially Gujarat and Maharashtra) are high. Additionally grid connected power is subject to several charges and small losses. In such a case it may be more economical for industries, and even commercial and residential establishments, to produce their own power through distributed generation units (Gensets). Natural Gas is an efficient and environmentally friendly fuel option for a genset. However, it is important to understand whether gas gensets make economic sense to run, as compared to consuming electricity from the grid at Industrial HT tariffs.

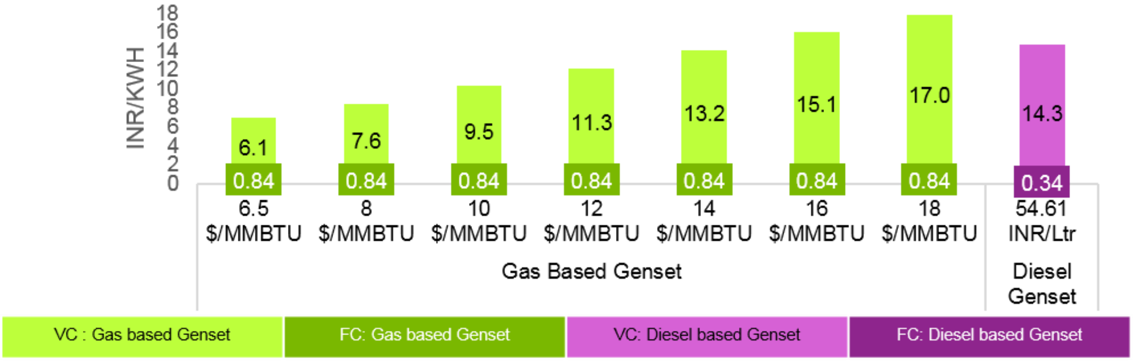
- Figure 19 - A depicts the total per unit (kWh) cost of running a gas based genset at various gas prices
- Figure 19 - B depicts Industrial HT tariff in the state of Gujarat, with the build-up of charges and losses

Upon comparing A and B we observe that it is more economical to set up a gas genset for own power consumption as compared to consuming power from the grid for gas prices of almost up to $ 12/MMBTU.

Case 2: Non-Industry use – Residential and Commercial Gensets

Cost comparison of using natural gas versus alternative fuel/energy source for backup power Genset. . The capital cost of the gas-based genset taken for analysis in this category is INR 105 lakh and for a diesel genset in this category was INR 42 lakh[15].

Figure 20: Economics of Use – DPG (Non-Industry Use Gensets)



Source: KPMG Analysis

In order to identify whether it is economical to use natural gas for running back up gensets, the cost of a Natural Gas Genset at various possible gas prices is compared to the next best alternative fuel, namely Diesel Genset for 625 KVA capacity.

From the above graph (Figure 20) we can observe that

- Fixed Cost (FC) of Diesel Genset is INR 0.34/KWH while the FC of a natural gas based genset for same capacity is INR 0.84/KWH
- However, on the basis of Variable Cost (VC), Natural Gas Gensets are economical for use 15 $/MMBTU of delivered price of natural gas
- The Total Cost (TC) per unit (KWH) of natural gas genset is only comparable to Diesel Genset at gas prices up to ~$ 14.5/MMBTU

Hence, it is economical to use natural gas based gensets up to ~$ 15/MMBTU of gas prices provided provision for supply of natural gas exists.

5.3.2 Macro-economic Impact

The landed price of natural gas for every state will vary, as per the taxation system in each state. This may render natural gas as a viable option for DPG in some states, while for other the taxes charged may result in the landed price being too high, to compete with industrial HT electricity tariffs in the state.

[15] KPMG Analysis (Quotes from Vendors)

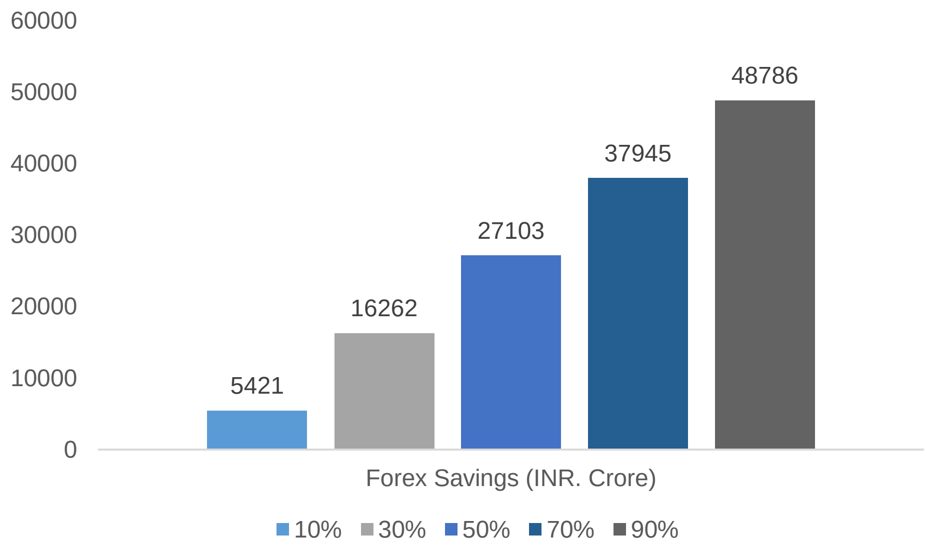
The Indian rupee has witnessed unprecedented volatility due to high import pressures as can be seen in the Figure 21 below. This has had severe impact on Indian economic growth.

Figure 21: Currency Movement

Source: Reserve Bank of India

Natural gas usage limits the impact on the economy and the currency in several ways as the delivered cost of RLNG on a per BTU basis at the point of consumption is lower than oil. The cost impact of crude import is correspondingly lower that results in import bill savings as can be seen in Figure 22 below which is the forex savings identified for diesel substitution (diesel yield of 29% considered for calculations).

Figure 22: Forex Savings (Diesel % substitution)



Source: KPMG Analysis

The PM10[16] pollution levels in India (100-150 ug/ m3) are substantially higher than many other countries hence there arises an urgent need to replace polluting fuels like diesel and FO with cleaner fuels like RLNG to ensure sustainability in long run while meeting the reliability and quality of power requirement. As per KPMG analysis[17], the switchover of diesel based generation to RLNG is likely to result in an average saving of ~22.6% ranging from 14.6 – 29.9% depending on the emission levels of existing diesel plants.

From an environmental perspective gas based power has less adverse impact (shown in Table 16) on the environment than Diesel and FO which are primarily used as alternative fuels for genset; and Coal which primarily powers grid electricity.

Table 16: Specific emissions for fossil fuel-fired stations

Gas (t CO_2/MWh)[18]	Diesel (t CO_2/MWh)	Oil (t CO_2/MWh)	Coal (t CO_2/MWh)
0.49	0.59	0.62	1.04

Source: CEA

There are several environment related legislatures put forth by the Government where canopies are must for DG sets and they must meet CPCB norms of government of India for noise Pollution effective July 2004, Environment protection Rules, 1986 schedule 1, by Ministry of Environment & Forest. Emission limits for gensets applications are prescribed by the CPCB (shown in Table 17). However, there are no specific norms set for gas-based DG gensets.

Table 17: CPCB Emission limits (DG sets)

Power Category	Emission Limits (g/KW-hr)		
	No_x + HC	CO	PM
Up to 19 KW	<= 7.5	<= 3.5	<= 0.3
19-75 KW	<= 4.7	<= 3.5	<= 0.3
75-800 KW	<= 4.0	<= 3.5	<= 0.2

Source: CPCB

The Bureau of Indian Standards (BIS) has notified mandatory maximum energy consumption limit in terms of Specific Fuel Consumption (SFC) for diesel generators up to 19 kW capacities.

16 Particulate Matter up to 10 micrometers in size
17 Note on Diesel Replacement with RLNG for Power Generation
18 Weighted average specific emissions for fossil fuel-fired stations in FY 2013-14, in t CO2/MWh, CEA report

5.3.3 Maturity

The penetration of gas based end-use applications is at the first hand governed by commercial availability of the application and the technology used for the application. In the case of distributed power generation we see that the market is mature with a lot of visibility and current usage of the technology and application in India. On a global scale, more mature technologies of gas based gensets are in use due to the deeper penetration of natural gas usage in developed markets. However, in India usage is low only because of gas availability constraints not due to any of the technology related factors.

Table 18: DPG - Maturity

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	High	High	High	High	High	Medium
Technology	High	High	High	High	Medium	Medium

Source: KPMG Analysis

5.3.4 Market size

As of January 2013, the total Natural gas based captive power capacity of India was 7,524 MW with a relative share of 13.4% (shown in Table 19). Share of gas based captive power plants (CPPs) are significant in sectors such as chemicals, petrochemicals etc.

Table 19: Captive power capacity across major fuel types

Fuel Type	Total Capacity (MW)	Relative share (%)
Coal	32730	58
Natural Gas	7524	13.3
Bagasse	5059	8.9
Wind	4396	7.8
Cogeneration	2816	4.9
Diesel/Liquid fuels	2627	4.7
Biomass	882	1.2
Others	322	0.57
Solar	11	0.01
Total	56367	100

Source: India Infrastructure Research

The major CPPs in India and their sectors are shown in Table 20 below.

Table 20: Major CPPs of India

Company	Captive power capacity (MW)	Fuel Type	Sector
Hindalco	4,065	Coal/Waste Heat Recovery	Aluminium
Essar Steel Limited	2,715	Coal/Natural Gas	Steel
Reliance Industries Limited	2,644	Natural Gas	Petrochemicals
Vedanta Aluminium Limited	1,859	Coal	Aluminium
NTPC SAIL Power Company Private Limited	1,314	Coal	Steel
National Aluminium Company Limited	1,256	Coal/Waste Heat Recovery	Aluminium
Jindal Steel and Power Limited	1,025	Coal	Steel
Bharat Aluminium Company Limited	810	Coal	Aluminium
Visa Steel Limited	634	Waste Heat Recovery/Coal	Steel
Indian Oil Corporation	564	Natural Gas/Liquid Fuel	Petrochemicals
J S W Steel Limited	530	Coal	Steel
Grasim Industries - Cement Business	529	Coal	Cement

Source: India Infrastructure Research

Table 21: Market size potential – DPG

Market size potential		
Industry Use (CPP)	~41 MMSCMD	For industry usage, current diesel/liquid fuels based captive power plants is taken as the market potential with an industry growth rate of 6.5% (IIP) up to 2020
Non-Industry Use (Gensets)	~ 27 MMSCMD	For non-industry usage, alternate fuel consumption of diesel for non-industry gensets are considered as the market potential and a genset market growth rate of 7.5% is used for escalation
Total	~ 68 MMSCMD	

Source: KPMG Analysis

5.3.5 Industry Speak

As per industry user segments even as grid power supply improves there will be perennial need for standby power as per Genset manufacturers and hence the growth of the industry is positive. With a genset power range of 10KVA – 200 KVA the Indian market uses about 100,000 units per year where major demand comes from smaller gensets from real estate, banking and financial services, retail and hospitality. The telecom industry is pushing the demand for gas based and renewable power based gensets in order to improve their carbon footprint. Also, industries state that they have become highly dependent on diesel due to power outages spanning as much as 16 hours per day, making them more vulnerable to price volatility.

A study conducted by Petroleum Conservation Research Association (PCRA), states that less than 50% consumers consider efficiency as an important parameter while purchasing new generator sets and as per ICF's analysis each percentage improvement in the engine (design) efficiency results in an improvement of about 2.4% in the Specific Fuel Consumption. The electrical conversion efficiencies for natural gas–fired reciprocating engines in the 5-kW range are about 24 %. For larger engines in the 250-kW and higher range the efficiency can exceed 33%. In the existing system if thermal energy is recovered from the exhaust gas and the engine cooling jacket is put to use the overall system efficiency can approach as much as 80%[19].

5.3.6 Barriers

The major barriers to the DG industry based out of the interaction with vendors and users are summarized as follows:

- Lack of gas infrastructure to source gas for genset applications in rural areas. In this regard, Solar powered gensets possess an advantage over gas gensets
- Lack of regulatory and institutional framework for gas-based gensets. Currently no specific initiatives are undertaken by government bodies like CPCB, Bureau of Energy Efficiency (BEE) to promote gas based gensets in line with their diesel genset performance improvement schemes

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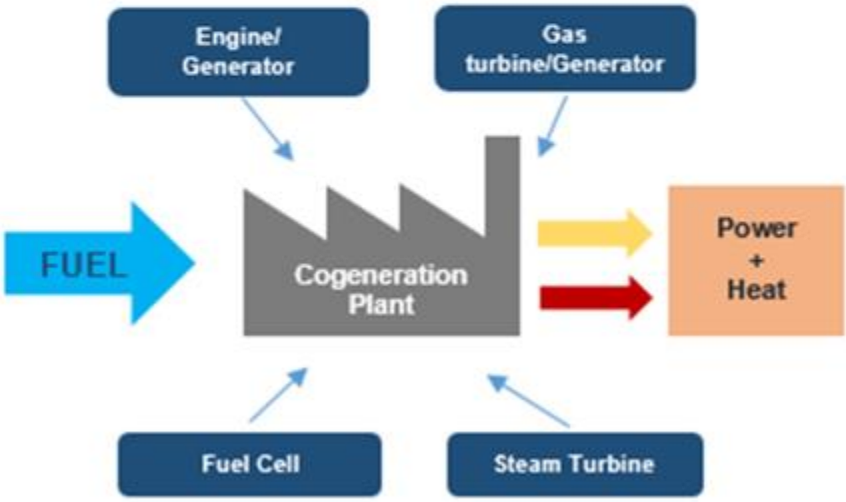
5.4 Combined Heat & Power

Combined Heat & Power (CHP) is the simultaneous production of electricity and heat from a single fuel source alternatively known as Cogeneration. CHP is also referred to as an integrated energy system that can be altered depending upon the end user. CHP uses natural gas, biomass, coal, biogas, coal, oil or waste heat as a fuel source.

[19] Shakti Sustainable Energy Foundation and ICF report on gas pricing

Figure 23: Cogeneration Principle



Source: Environment Protection Agency, KPMG Interpretation

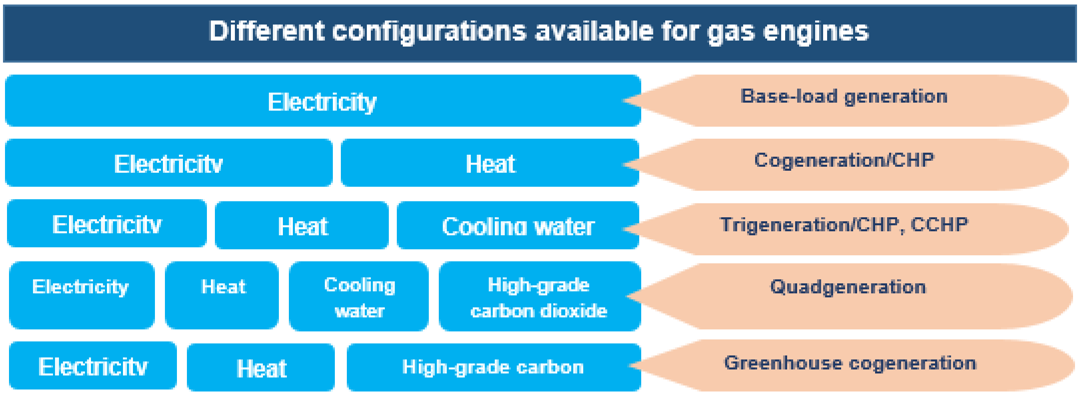
Common CHP system configurations are:

- Gas turbine or engine with heat recovery unit
- Steam boiler with steam turbine

Gas turbine or reciprocating engine CHP systems generate electricity by burning natural gas and then use a heat recovery unit to capture heat from exhaust system which is converted to useful thermal energy. Steam turbines in the usual scenario generate electricity as a by-product of heat generation which is not the case in a gas turbine and reciprocating engine CHP systems where the heat is a by-product of power generation. The basic working of a Cogeneration plant is shown in Figure 24. CHP plants also operated using biofuel engines, steam turbines, molten-carbonate fuel cells, solid-oxide fuel cells and small generation units are also run using a reciprocating or sterling engine. Micro-CHP, also referred to as distributed energy source (DER) which is less than 5 KW is used by residential and small business in the US. Micro-CHP installations uses technologies such as micro turbines, internal combustion engines, closed cycle steam engines, Stirling engines and fuel cells.

In the context of gas engines, CHP/Cogeneration is one amongst the several levels of configuration available. Other configurations possible in gas engines are shown in Figure 25. In India largely CHP and Combined Cooling, Heating & Power (CCHP) systems are prevalent.

Figure 24: Different Gas engine configuration



Source: Clarke Energy, KPMG Interpretation

CHP is used for onsite generation of electrical/mechanical power, waste-heat recovery for cooling, heating, dehumidification and other process applications. CHP provides seamless system integration for a variety of technologies, fuel types and thermal applications into existing building infrastructure. The potential users of CHP systems are large scale commercial players such as:

- Malls
- Offices
- Airports
- Residential complexes
- Multiplexes etc.

CHP systems are efficient as they require less fuel to produce a given energy output as compared to grid connected power. CHP systems aid fuel efficiency as there is reusability of fuel and reduces air pollution by curtailing GHG emissions. In the US and UK, CHP delivers tax benefits. For commercial applications they provide a stable and flexible power supply.

Policy & Regulatory Interventions and Other Enablers

Currently there are no policy or regulations for pushing gas-based CHP. However there are other policy/regulatory enablers for CHP which are as follows:

- BEE norms - Created a mandate to promote energy efficiency including CHP
- Cogen India Initiative – Cogeneration Association of India provides a platform for bringing together all relevant and concerned with an aim to make efforts remove barriers and create a supportive environment for cogeneration in India
- Non-governmental organizations Initiatives - The Energy and Resources Institute (TERI) and researchers at academic institutions conduct research and promotes CHP/DC

Gas turbine/engine systems are ideal for large industrial or commercial CHP applications requiring large amounts of electricity and heat. The use of natural gas as the main fuel for the CHP system offers advantages because the methane present in natural gas offers the highest hydrogen-to-carbon ratio among fossil fuels thereby combusting with the lowest GHG emissions. Additionally, gas turbine has a short start-up time and provides the flexibility needed for intermittent operation.

Gas turbine CHP systems are used in Industrial and Commercial clusters in the regions of Gujarat, Rajasthan, Haryana, Uttar Pradesh, Delhi, Madhya Pradesh, Andhra Pradesh and Tamil Nadu. However the relatively higher cost of Piped natural gas (PNG) remains a hindrance to widespread adoption of CHP technology in India.

Box 2: Case Study – Indo-German Trigen Project in AIIMS, New Delhi

This project is part of the Indo-German Trigen Project jointly implemented by the Bureau of Energy Efficiency (BEE) and the German Society for International Cooperation (GIZ) under the Indo-German Energy Programme (IGEN). This was an initiative taken in similar lines of our study purpose to raise awareness among decision makers in the public and private sectors of the advantages of CHP and to inspire Indian players to assess this technology as a market opportunity.

Problem: New Delhi has ambient temperatures of over 40°C during summer, which increases the air conditioning load during the day. In addition, the city frequently experiences power shortages.

Objective: To demonstrate the efficient generation of electricity, heating and cooling by setting up a CHP based plant at Jai Prakash Narayan Apex Trauma Centre

Fuel Source: Natural gas-fired CHP unit with 347 kWe of capacity

- The hospital's cooling capacity of 1.3 MWth is met by the VAM
- The heating capacity for warm water supply for the kitchen and laundry is ~ 20 kWe

Savings: The annual savings is about INR 13 million and the estimated payback period is over 3 years

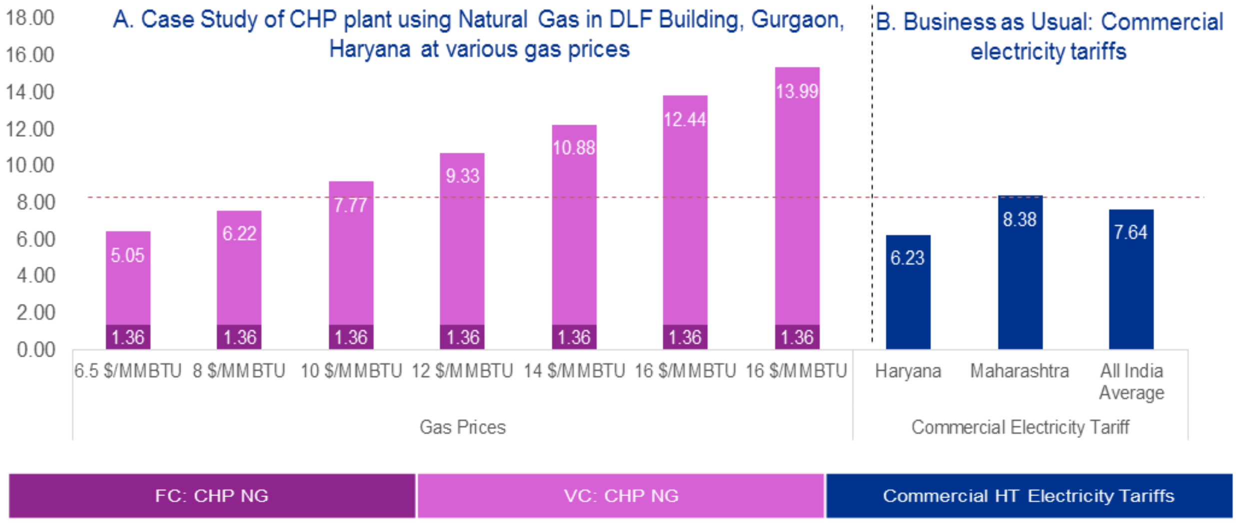
Source: IEA

5.4.1 Economics of Use

The economics of use for CHP plants was done on the basis of a cost comparison of using natural gas versus alternative fuel/energy source for Combined Heat and Power (CHP). The analysis was based on a realistic implementation of a CCHP plant in Gurgaon[20], Haryana which was built to run on natural gas.

[20] CDM PDD; Installation of CJP in commercial building of DLF building 10, KPMG Analysis

Figure 25: Economics of Use - CHP



Source: KPMG Analysis

Commercial tariffs in several states (especially Maharashtra and Tamil Nadu) are high. Further commercial establishments have almost constant demand for heating or cooling load which is an increased burden on its electricity units consumed. In such a case it may be more economical and efficient for commercial establishments to produce their own power and heat (for heating or cooling applications) from a CHP unit. Natural Gas is an efficient and environmentally friendly fuel option for a CHP unit. However, it is important to understand whether it makes economic sense to run gas based CHP units, as compared to consuming electricity from the grid at Commercial tariffs. From the graph above (Figure 26)

- *Scenario A* depicts the total per unit (kWh) (FC and VC split) cost of running a gas based CHP unit at various gas prices.
- *Scenario B* depicts Commercial tariffs in the states of Maharashtra and Haryana, and at an all India level.

Upon comparing A and B we observe that it is more economical to set up a CHP plant for own power consumption and to fulfil heating and cooling requirements, when the plant is being run on domestic gas at a landed price of ~ $ 8/MMBTU, as compared to consuming power from the grid. The environmental benefits upon installing the plant is discussed in subsequent sections.

5.4.2 Macro-economic Impact

The landed price of natural gas for every state will vary, as per the taxation system in each state. This may render natural gas as a viable option for CHP in some states, while for other the taxes charged may result in the landed price being too high, to compete with Commercial electricity tariffs in the state. CHP projects can claim Clean Development Mechanism (CDM) benefits as per approvals from National CDM Authority, Ministry of Environment and Forest, Government of India which can be a form of subsidy equivalent for such projects.

5.4.3 Environmental Impact and Legislatures

With reference to the case analysed above, CHP plants reduces GHG emissions in of the order of 92150 tonnes of CO_2 equivalent per year for 43.2 MW project. The purpose of the Clean Development Mechanism (CDM) as defined in Article 121 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change for achieving sustainable development for quantified emission limitation and reduction. CHP projects are included in the CDM mechanism with larger potential is in major industries, including steel, fertilizers and cement.

5.4.4 Maturity

CHP application is mature with respect to the commercial availability and awareness of the technology as such. There is sufficient knowledge/skill about the technology and application in India. However, we see that there are no adequate initiatives taken by the government to increase the visibility of the application even more because of which the current usage of the technology and application is low.

Table 22: Maturity - CHP

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	High	High	High	High	Medium	Low
Technology	High	High	High	High	Medium	Medium

Source: KPMG Analysis

5.4.5 Market size

There is no accurate data on CHP systems installed in India in terms of installed capacity, types of fuel used, distribution of this capacity in the various sectors, power and cooling/heating generated. According to IEA, one study estimates over 14 GW of industrial CHP potential in a wide range of sectors with nearly 9 GW outside the sugar industry adding up to a potential of ~35 MMSCMD of natural gas for CHP projects. As of March 2014, the total number of approved Natural gas CHP-based CDM projects amounted to 8, with a capacity of 115 MW as per National CDM Authority, Government of India.

Table 23: Market size potential – CHP

Market size potential
~35 MMSCMD
According to IEA, there is a potential over 14 GW of industrial CHP in a wide range of sectors with nearly 9 GW outside the sugar industry. Share of Natural gas as per current CHP systems in India is 50% (IEA).

Source: KPMG Analysis

5.4.6 Industry Speak

The use of CHP based space cooling has been increasing in commercial buildings as a move to achieve higher efficiencies and reduction in operation cost. The demand for CHP systems was likely served by chilled water-based central systems which is a target potential market for CHP-based space cooling applications. Various economic reforms through India's foreign investment policy has been a driver for foreign companies to enter the Indian market for CHP projects as FDI2 is freely allowed and industrial licenses are not required for development of cogeneration and trigeneration projects in India. According to U.S Environmental Protection Agency CHP systems result in a total system efficiency of 75% in comparison to 51% efficiency from conventional generation.

5.4.7 Barriers

The major barriers faced by Industries and Commercial players who are willing to incorporate CHP systems are summarized as follows:

- High capital cost of CHP equipment is a challenge for further deployment of these technologies particularly as policies benefit mainly biomass and bagasse CHP projects
- Incentives for CHP using conventional fuels like natural gas are limited
- Sale of surplus power from CHP units to the grid is currently expensive due to high surcharges and multiple transmission charges
- Complex pricing policies for natural gas produced domestically as well as high prices for imported natural gas is a significant barrier to gas-based CHP units
- Gas allocation policy with its prioritization of certain end-users over others for low-priced gas produced by state-owned companies can create challenges for deployment of natural gas-based CHP

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6 Heating/Cooling Applications

There are many applications/equipments available for business/commercial/residential heating applications such as Direct-fired burners (mainly in industries), boilers, furnaces, geysers, thermic fluid heaters, Pool/Spa heaters and heating appliances/systems for space heating. The cooling applications include Engine-driven chillers, Absorption Chillers and Desiccant systems. The energy efficient variants use natural gas as fuel.

6.1 Direct-fired Burners

Direct gas-fired burners are utilized primarily in industrial applications such as material drying and paint curing. Industrial gas burners are classified into different types such as:

- General purpose
- Packaged burners
- Radiant tube burners
- Kiln burners
- Dryers
- Self-recuperative burners
- Rotary aggregate burners

Natural gas burners are usually designed for direct fired make-up air and process applications. These burners are equipped with precise temperature control measures. The working of a direct-fired burner in a kiln is illustrated in Figure 27. For direct-fired burners used in kilns, it is necessary that the burners, valves and the gas piping should be suitably sized to allow sufficient volume of gas to heat the kiln efficiently.

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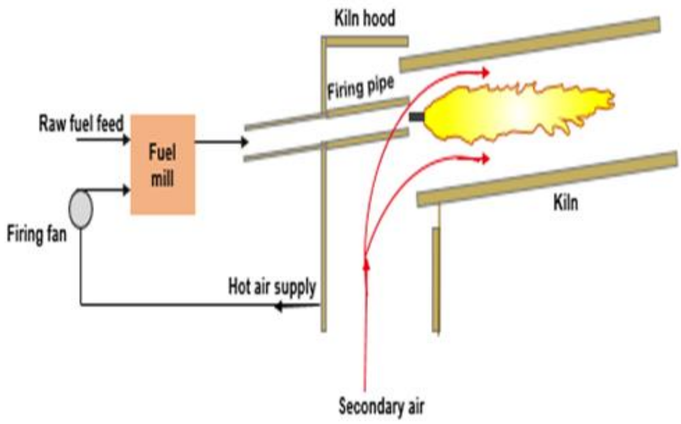
Figure 26: Direct-fired burning Illustration - Kiln



Source: Cement Kilns, KPMG Interpretation

Further it is important to ensure there is a proper ratio maintained between the gas (raw fuel feed) and air supplied (through firing fan) to the kiln in order to obtain the most rapid temperature rise. This is a critical aspect for natural gas firing as the gas pressure is fixed. Primary air is set by matching the burner tip with the air mixing device and Secondary air is set by ensuring that the area around the burner tip is not excessive and the flue (chimney) is correctly sized.

Direct-fired burners are used in ceramic industry where precise temperature control is required for consistent product quality. They are used for other applications such as Heat Treatment furnace, forging furnace, Stress relieving, Reheating, Turndish heating etc. Major high temperature applications are shown in Figure 28. In these applications the burner usually have three control actions; On/Off, High/Low and Modulating.

Direct-fired burners are also suitable for iron and steel, cement, non-ferrous metals, precious metals, ceramic, glass and food industries.

Direct-fired burners are ideal for temperature sensitive applications where efficient heating occurs. They are cost-effective when used in absence of heat exchangers. Direct-fired burner systems are simpler in design and combustion in direct-fired burners is complete and concealed.

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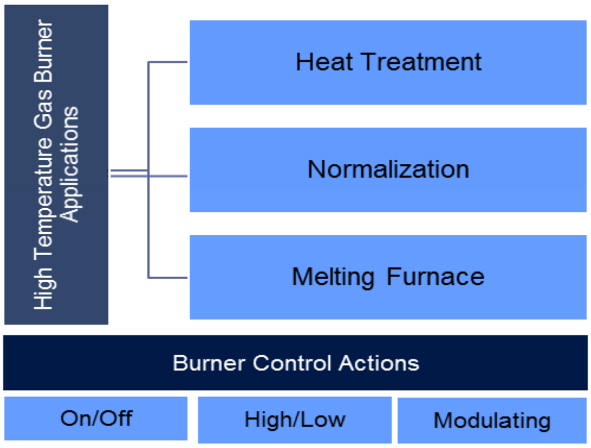
Figure 27: Burner Applications



Source: Umashankar International/Industrial Burners, KPMG Analysis

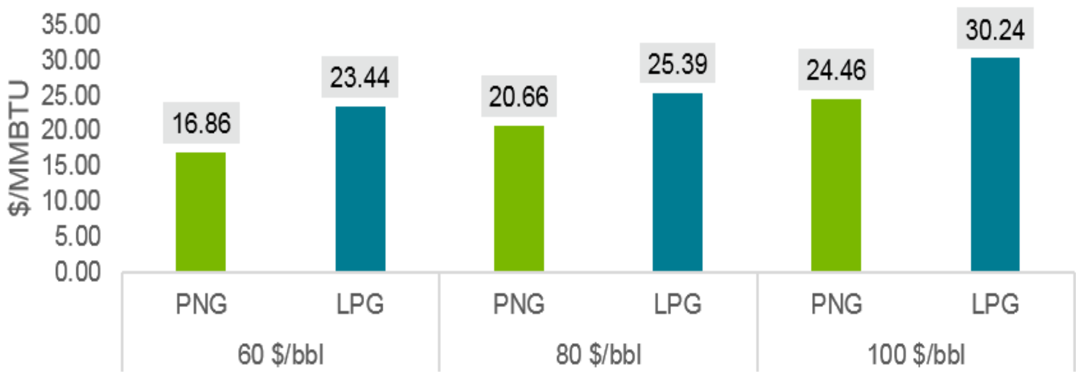
Policy & Regulatory Interventions and Other Enablers

At present there are no other policy and regulatory aspects related to burners and Gas-fired burners in particular. Gas-fired burners helps in maintaining a uniform temperature in chamber as air circulation is done with help of blowers from bottom to top. They are used in diverse industrial applications including as Foundry core ovens, Paint baking, Powder coating ovens, Burnout and Drying. Gas fired burners are widely used in textile industry for meeting the purpose of direct firing.

6.1.1 Economics of Use

For Direct-fired Burners the economics of use is analysed on the basis of heat equivalent comparison of natural gas (NG) and the next best alternate used namely Liquefied Petroleum Gas (LPG).

Figure 28: Economics of Use – Direct-fired Burners



Source: KPMG Analysis

Three different linkages to crude price: 60 $/bbl, 80 $/bbl and 100 $/bbl, are taken for computing the NG and NG equivalent[1] LPG delivered price to the consumer. The economic analysis is centred upon the fuel cost because this plays a major role for consumer's choice. Other factors such as the fixed cost of a Gas Direct-fired Burner and LPG Direct-fired Burner do not vary significantly hence are not considered in our study

From the above graph (Figure 29) it is clear that Natural Gas is economical as compared to that of LPG which is costlier in the range of 4.73-6.57 $/MBTU over the crude price range

Hence, natural gas has a clear cut cost advantage and qualifies as the best alternative to LPG.

6.1.2 Macro-economic Impact

As such there are no subsidies or forex impact on gas-fired burners. However, landed cost of gas can vary across states based on taxes applicable in the current taxation regime.

6.1.3 Environmental Impact and Legislatures

The Ministry of Environment & Forests has mentioned guidelines for environmental clearance subject to strict compliance of the terms and conditions for low NOx burner usage to limit NOx emissions.

6.1.4 Maturity

Direct-fired burners are extensively being used by industries where their process mandate the use of uniform-heating applications. The application service is commercially available and is strong among all the parameters. On the technology front, current burners are specifically designed for LPG usage as natural gas is not prevailing on a pan-India basis. Therefore, the availability of appropriate burner designs for PNG specific burners are few in number.

Table 24: Maturity – Direct-fired Burners

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	High	High	High	High	High	High
Technology	Medium	Medium	High	Medium	High	High

Source: KPMG Analysis

6.1.5 Market size

There is no accurate data for the exact market size and potential for direct-fired burners in India. Based on alternate fuel usage for different applications in Industries a combined potential of ~ 12 MMSCMD is estimated in the next 5 years where the usage is largely in application areas for Leading Textile Units, Large & Small Industries, Dairies and Bakeries.

Table 25: Market size potential – Direct-fired burners

Market size potential
~18.97 MMSCMD
Alternate fuel consumption of LPG, LSHS, FO, Bulk LPG which are alternatives to natural gas for industrial applications which included direct-fired burners, thermic fluid heaters, Furnaces and Boiler. A combined potential is determined for these applications with a growth rate of 6.5% (IIP).

Source: KPMG Market Research

6.1.6 Industry Speak

According to Industry users and vendors the most popular form of burners use is in heating tunnel kilns in the Ceramics Industry as uniform heating is required where only natural gas direct-fired burners can be used. They are preferred as they are low NOx burners and release no smoke (environment preference), has zero maintenance and is relatively less costly. These are the major influential decision factors in choosing gas burners. There are no specific barriers as such because usually process requirement mandates usage of gas burners.Burner design changes for LPG and Piped Natural Gas (PNG) usage is one concern that users had.

6.1.7 Barriers

There are no specific barriers as such because usually process requirement mandates usage of direct-fired gas burners.

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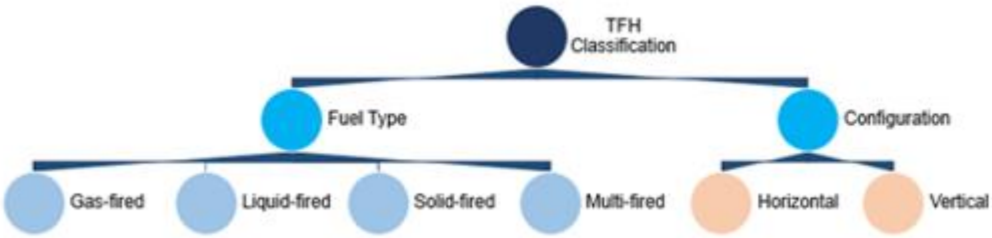
6.2 Thermic Fluid Heaters

Thermic Fluid Heaters (TFH) source is a heat source which contains a thermic fluid (heat carrier) that is heated and circulated through the user equipment where it transfers heat for the process through a heat exchanger. Thermal oil, glycol or water etc. are the heat mediums used. The fluid is then returned to the heater for reprocessing. These heaters are commonly directly fired by combustion of fuels namely Oil (Light & Heavy), Natural Gas, Coal, Wood, Husk, Bagasse etc. Dual fuel and Multi fuel fired Thermic Fluid Heaters are also available for customers to make use of energy efficient and economically available fuels. TFH is usually classified on the basis of fuel used for firing and the configuration of heater (shown in Figure 30).

Figure 29: Thermic Fluid Heater types



Source: RET Screen, KPMG Interpretation

The basic working of a TFH is shown in Figure 31. The major components of a TFH include:

- Heater – Thermic fluid is heated in the heater
- Exhaust – Removes waste gases/flue formed during heating of fluid
- Expansion Tank – The fluid after been used in the process passes increases in volume due to thermal expansion. Expansion tank acts a safe outlet.
- Aerator – Aids aeration and de-aeration of Thermic fluid during the entire process
- Circulation Pump – Draws thermic fluid from bottom of the tank for return to the heater

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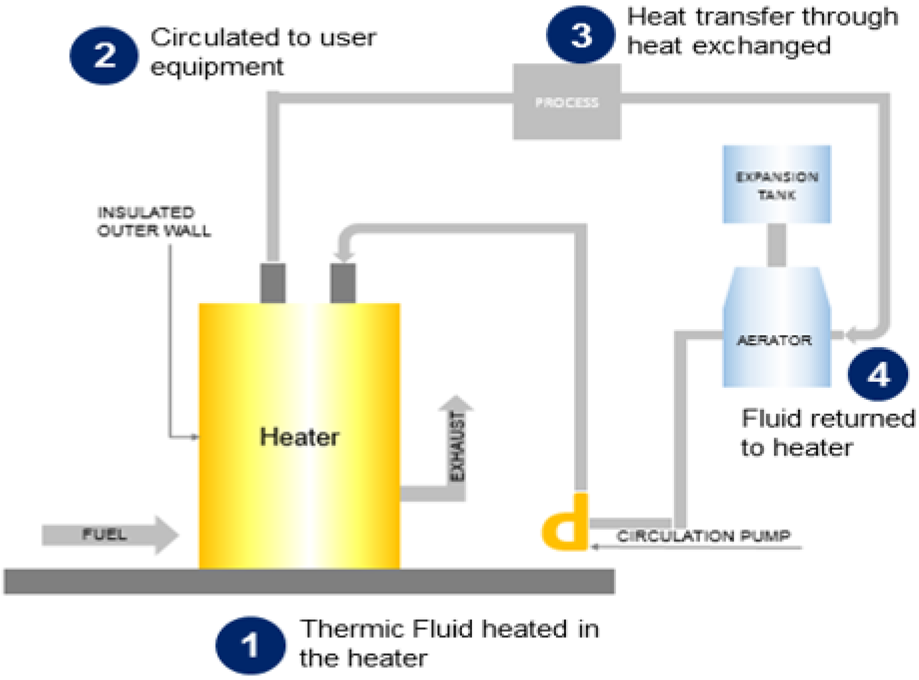
Figure 30: TFH Working



Source: RET Screen, KPMG Interpretation

TFH have wide application for indirect process heating and are used in different types of industries such as textile, chemical, rubber, edible oil, etc. TFH is required for indirect process heating with high process temperature requirements generally above 200 degrees Celsius.

TFH does not need water treatment and thus the issue of scale deposition/corrosion is resolved. Since they operate at low operating pressures it is safer than steam based TFH. If a process requires heating and cooling, both can be done with a single fluid, since the heating medium is a liquid higher efficiency of heat utilization can be achieved. They offer very high temperatures (up to 800 F) at very low pressures.

Policy & Regulatory Interventions and Other Enablers

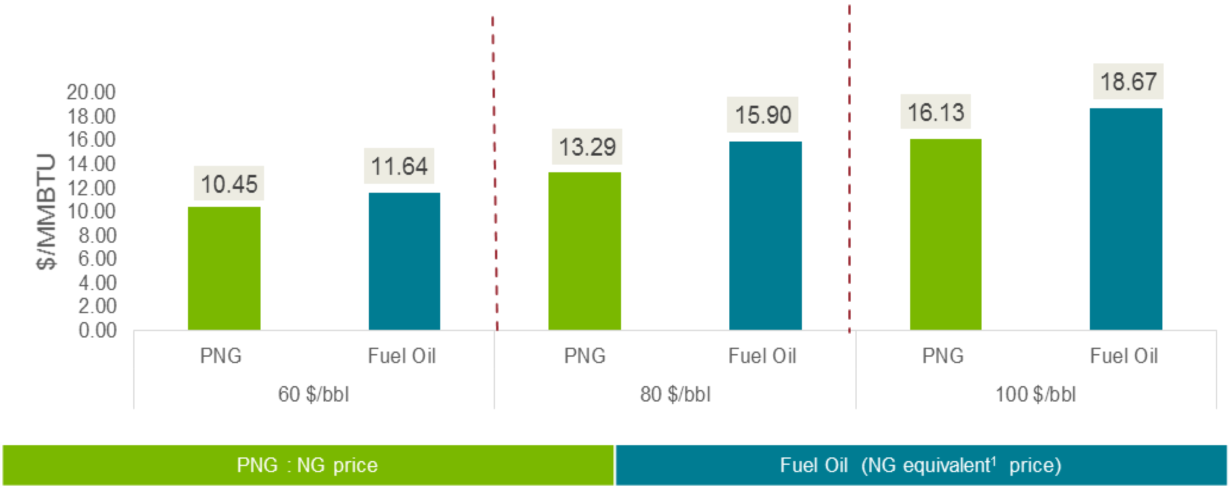
Currently, there are no other policy and regulatory aspects related to Thermic Fluid Heaters in India. However, Bureau of Indian Standards (BIS) specifies Oil and Gas Fired Thermic Fluid Heaters method of calculation of film temperature that has to be followed before installing TFH in industries.

Thermic Fluid heaters have a high thermal efficiency of about 88% on Net Calorific Value of Natural Gas without heat recovery unit. Even though the running costs of gas-fired TFH is higher than wood/coal fired TFH, they are beneficial in terms of initial investments and reduction in GHG emissions, from a long term perspective. Thermic Fluid heaters are replacing boilers in many industries due to their good thermal efficiencies as losses due to condensate drain, blow down and flash steam do not exist in a thermic fluid heater system.

6.2.1 Economics of Use

For Thermic Fluid Heaters the economics of use is analysed on the basis of heat equivalent comparison Natural Gas and the next best alternate used namely Fuel Oil (FO) as shown in Figure 32.

Figure 31: Economics of Use - TFH



Source: KPMG Analysis

Three different linkages to crude price: 60 $/bbl, 80 $/bbl and 100 $/bbl, are taken for computing the NG and NG equivalent[21] FO price. Analysis is centred upon the fuel cost because this plays a major role for consumer's choice. Other factors such as the fixed cost of a Gas TFH and FO TFH do not vary significantly hence are not considered in our study. There is no significant difference in the efficiencies of Natural Gas and Fuel Oil TFH hence it is not factored in the above calculations.

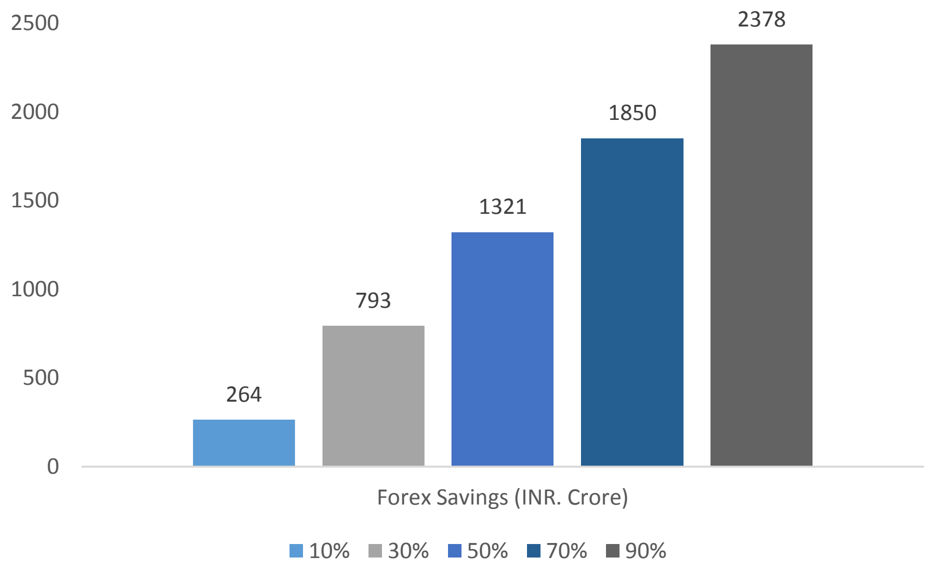
From the above analysis, Natural Gas is economical as compared to that of fuel oil which is costlier in the range of 1.2-2.5 $/MBTU over the crude price range. Prices are based on net of VAT analysis, however the prices may vary depending upon the differential taxes on FO in different states.

6.2.2 Macro-economic Impact

Natural gas usage limits the impact on the economy and the currency in several ways as the delivered cost of RLNG on a per BTU basis at the point of consumption is lower than oil. The cost impact of crude import is correspondingly lower that results in import bill savings as can be seen in Figure 33 below which is the forex savings identified for fuel oil substitution (fuel oil yield of 4% is considered for calculations).

[21] Amount of energy used by the burning of natural gas versus that of crude oil

Figure 32: Annual Forex Savings (Fuel Oil % substitution)



Source: KPMG Analysis

Each Litre of fuel oil replacement results in forex saving of USD 0.1213[22] (or 12.13 cents). The landed price of natural gas for every state will vary, as per the taxation system in each state hence the fuel prices of FO and PNG can vary.

6.2.3 Environmental Impact and Legislatures

From an environmental perspective gas based TFH (0.47 t CO2/MWh)[23] is a better fuel option than Fuel Oil (0.62 t CO2/MWh), as it emits a lower quantum of harmful CO_2. The Central Pollution Control Board (CPCB) has prescribed guidelines for installing TFH and their construction details based on applicability in each kind of industry.

6.2.4 Maturity

Thermic Fluid Heaters are largely used in food process industry applications and the application and technology are mature with limited use largely due to less visibility of the gas-based technology usage benefits for TFH.

Table 26: Maturity - TFH

Maturity	Commercial	Vendor Availability	Awareness	Skill/Know how	Visibility	Current

[22] KPMG Analysis

[23] Weighted average specific emissions for fossil fuel-fired stations in FY 2013-14, in t CO_2/MWh, CEA report

	Availability					Usage
Application Service	High	High	High	High	High	Medium
Technology	High	High	High	High	Medium	Medium

Source: KPMG Analysis

6.2.5 Market size

There is no accurate data available for TFH market size in India. There is no accurate data available for TFH market size in India. However, based on alternate fuel usage for different applications in Industries a combined potential of ~ 19 MMSCMD is estimated in the next 5 years.

Table 27: Market size potential – TFH

Market size potential
~18.97 MMSCMD
Alternate fuel consumption of LPG, LSHS, FO, Bulk LPG which are alternatives to natural gas for industrial applications which included direct-fired burners, thermic fluid heaters, Furnaces and Boiler. A combined potential is determined for these applications with a growth rate of 6.5% (IIP).

Source: KPMG Market Research

6.2.6 Industry Speak

TFH efficiency for different industries using solid fuels is in the range of 35 -65 % compared to ~ 80% for Gas/FO TFH hence Gas TFH is preferred. As per industry users the calorific value of gas is good hence preferred over other alternatives. The usage of fuel in TFH is largely determined on the basis of fuel availability. For instance, Gas based TFH is significantly used in Gujarat and nearby areas and wood-based TFH is used in Maharashtra etc. In other regions Fuel Oil is the next best preferred alternative. Food industries prefer Gas based TFH owing to environmental and quality concerns. They are a promising application for restaurant/hotel heating requirements as they emit much lower heat radiation than compared to burners which are used to heat utensils for food preparation. Fuel Oil/Electric Thermic Fluid Heaters are predominantly being used in areas where gas in not available hence this could be one potential barrier for TFH.

6.2.7 Barriers

The major barrier was with regard to the adaptation of gas-based TFH as Fuel Oil/Electric Thermic Fluid Heaters are predominantly being used when gas in not available.

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6.3 Furnaces

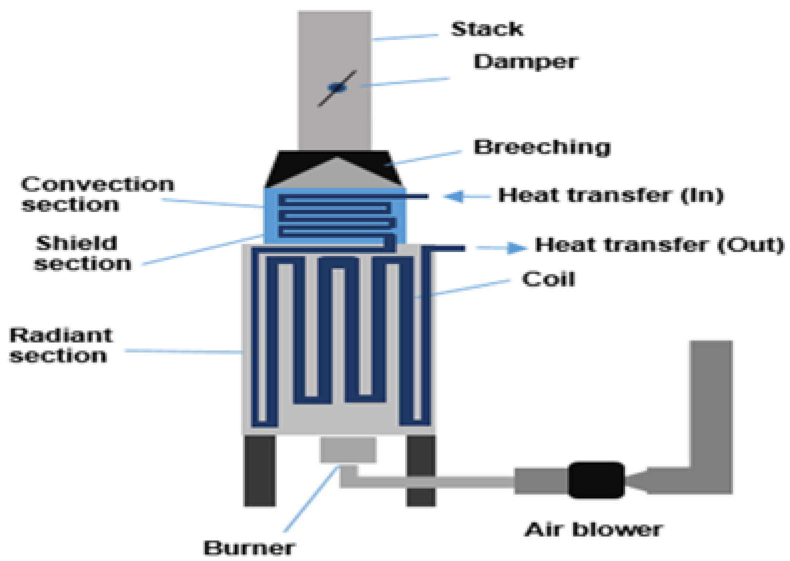
A furnace is an equipment which is used to heat materials in order to change shape (rolling, forging etc.) or melt metals for casting or for change of properties (heat treatment).

Furnaces fall into two main categories namely Conventional and Condensing Furnace. Depending upon the kind of fuel used for combustion, furnaces can be broadly classified as oil fired, coal fired or gas fired. Gas based furnaces are also categorized based on the burner and blower operation as:

- Single Stage Furnace
- Two Stage or Dual Stage Furnace
- Modulating Furnace

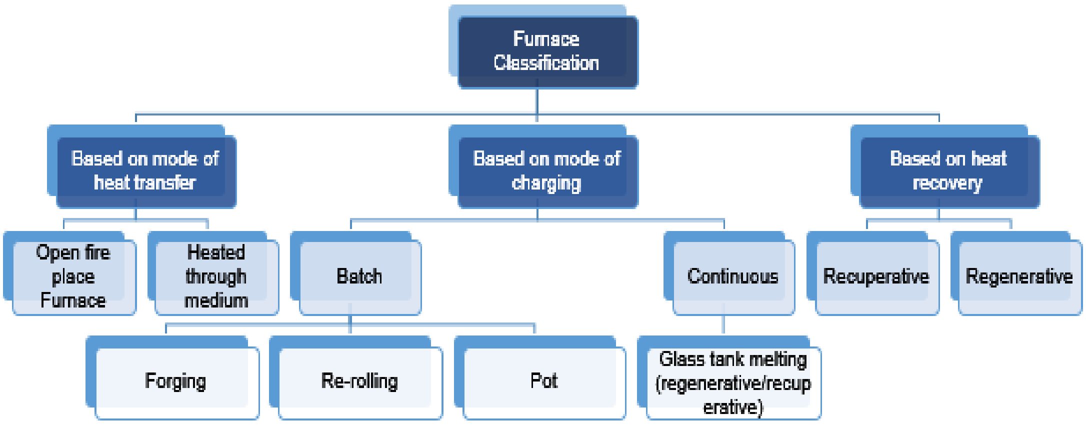
The basic working of a furnace is shown in Figure 34. The fuel flows into the burner and is burnt with the air provided from an air blower. The flames generated heat up the tubes which in turn heat the fluid inside in the first part of the furnace known as the radiant section. In this chamber, where combustion takes place the heat is transferred by radiation to tubes around the chamber. The heating fluid passes through the tubes and is heated to the desired temperature. The gases that originate from the combustion process are known as flue gases. The detailed classification of furnaces based on mode of heat transfer, charging and heat recovery are as shown in Figure 35.

Figure 33: Furnace Working



Source: Mechanical Engineering Publications, KPMG Interpretation

Figure 34: Furnace Classification



Source: enggpedia, KPMG Analysis

Gas Furnaces have varied applications in Industries such as for extraction of metals (smelting), oil refineries, chemical plants, heat treatment, melting, continuous and batch type applications etc. Natural Gas Furnaces can be used for residential applications as well but they are not prevalent in India. For Industrial applications Natural Gas Furnaces reduce pollution as they do not emit flue gases. They are Corrosion resistant, durable with less friction. For residential applications the gas furnace is reliable, efficient and quiet in operation.

Policy & Regulatory Interventions and Other Enablers

The Policy and Regulatory mechanisms for Furnaces are mentioned below:

- Indian Boiler Regulations, 1950
- NFPA 86: Standard for Ovens and Furnaces

Other enablers for gas based furnaces include:

- Supreme Court Order in 1996 - for mandating 292 industries to use energy efficient natural gas as fuel in the Taj Trapezium Zone
- The Energy & Resources Institute (TERI) Initiative – Developed innovative technologies like recuperative pot furnace and gas fired muffle furnace for use in glass industries
- Oil & Gas Conservation Awards – Awards are nominated for industries/ establishments that maintain high furnace efficiencies

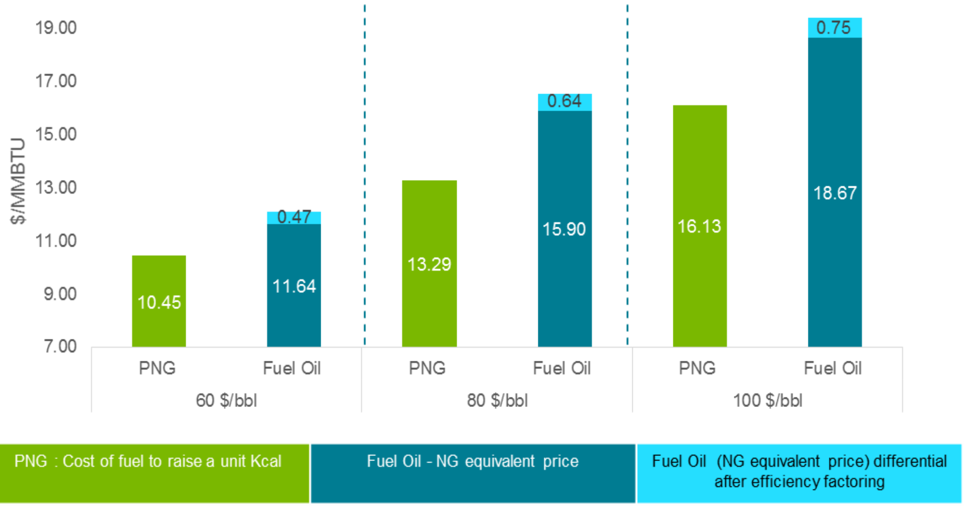
Natural gas furnaces are deployed to mitigate the impact on air quality from flue gas emissions and are the best suited in this category. Modern gas furnaces are highly efficient @ 80-90%, allowing only 10-20% of the heated air to escape up the chimney.

Most of the industrial areas along the existing gas pipeline networks especially in states like Gujarat, Maharashtra, and Uttar Pradesh etc. use Gas furnaces. Further as a green initiative towards mitigating pollution impact on heritage sites, the Supreme Court mandated certain factories using polluting furnaces in the “Taj Trapezium area” near Taj Mahal to shift to the use of natural gas within a definite time frame. Many glass industries are also shifting to natural gas due to environmental concerns on polluting furnaces.

6.3.1 Economics of Use

The economics of use for furnaces is analysed on the basis of heat equivalent comparison of natural gas (NG) and the next best alternate used namely Fuel Oil (FO).

Figure 35: Economics of Use - Furnace



Source: KPMG Analysis

Three different linkages to crude price: 60 $/bbl, 80 $/bbl and 100 $/bbl, are taken for computing the NG and NG equivalent FO price. Analysis is centred upon the fuel cost because this plays a major role for consumer’s choice. Efficiency factoring is taken into calculation as there is a ~4% difference in efficiencies of NG and FO furnaces.

From the above analysis, Natural Gas is economical as compared to fuel oil which is marginally costlier in the range of 1.7-3.3 $/MBTU over the crude price range. Prices are based on net of VAT analysis however the prices may vary depending upon the differential taxes on FO in different states.

6.3.2 Macro-economic Impact

Each Litre of fuel oil replacement results in forex saving of USD 0.1213 (or 12.13 cents) as discussed in earlier sections. Prices of fuels may vary from across states based on taxes applicable and there are no subsidies applicable for gas usage in furnaces.

6.3.3 Environmental Impact and Legislatures

From an environmental perspective Gas Furnace is better than FO as it emits a lower quantum of harmful CO_2 as shown in Table 28 & 29.

Table 28: Emission standards for fossil fuel fired stations

FO (t CO_2/MWh)	Gas ((t CO_2/MWh)
0.62	0.47

Source: CEA

CPCB has listed Industry specific standards for Furnace used in Iron & Steel and other industries as shown in Table

Table 29: CPCB Standards for furnaces

Unit	PM (mg/Nm3)
Arc Furnace in Calcium Carbide unit	150
Reheating Furnaces	150

Source: CPCB

CPCB also mentions about safety considerations like control mechanisms especially if the gas is burning inside a vessel such as a furnace where gases accumulate in the closed spaces and risks of explosion arise (others shown in Table 30).

Table 30: CPCB Equipment type guidelines - Furnace

Equipment Type	Size Category	Performance required
Warm Air Furnace, Gas Fired	<66KW	78% AFUE

Source: CPCB

6.3.4 Maturity

Furnaces have been used in all the major industries and hence the commercial availability of the service and technology in high. There are significant number of vendors for furnaces in India. Gas-based furnaces are preferred for better efficiency usages. However, the current usage is limited due to gas availability constraints.

Table 31: Maturity - Furnace

Maturity	Commercial Availability	Vendor Availability	wareness	Skill/Know how	Visibility	urrent Usage

Application Service	High	High	High	High	High	Medium
Technology	High	High	High	High	High	Medium

Source: KPMG Analysis

6.3.5 Market size

According to ASM International's Chennai Chapter the size of the Indian heat treating market is more than USD 1bn with a growth rate of 12% per annum (Estimate Figure, 2013)[24]. Data for furnace market, particularly that for Natural gas is not available as they are incorporated specific to each process they are used in Industries. For example in a boiler, furnace is used as a heat source; furnace is used for incineration etc. However, based on alternate fuel usage for different applications in Industries a combined potential of ~ 19 MMSCMD is estimated in the next 5 years.

Table 32: Market size potential – Furnaces

Market size potential
~18.97 MMSCMD
Alternate fuel consumption of LPG, LSHS, FO, Bulk LPG which are alternatives to natural gas for industrial applications which included direct-fired burners, thermic fluid heaters, Furnaces and Boiler. A combined potential is determined for these applications with a growth rate of 6.5% (IIP).

Source: KPMG Market Research

6.3.6 Industry Speak

Gas furnaces have a higher efficiency of 82%[25] in comparison to a FO furnace with an efficiency of 78%. In Iron & Steel industries, earlier electric furnaces were favoured over other type of furnaces for steel making as they enable concentrated heating and no energy was spent to heat the fuel in case of fuel fired furnaces. Gas based DRI (Direct reduced Iron) or HBI (Hot-briquetted Iron) is considered to be the cleanest and environment friendly steel making route. Today the situation is different because of electric power supply limits, power costs and furnace efficiency considerations; natural gas is increasingly used to augment the melting process. Small scale industries prefer electric induction furnaces as it comes at an affordable price even though the efficiency of electric induction furnace ranges between 60-80%[26]

[24] Heat Treat & Surface Engineering Conference & Expo 2013
[25] EIA
[26] Induction Furnace Market in India 2015-2019

6.3.7 Barriers

The major barriers that the industry faces are described below:

- Complex pricing policies for natural gas produced domestically as well as high prices for imported natural gas
- Availability of natural gas is a significant barrier for industries to shift towards gas-fired furnaces. Owing to environment concerns industries are willing to shift to gas-fired furnaces but are taking a back seat due to availability concerns
- Price of natural gas is a secondary concern for industries which require uniform heating with no particulate matter formulation while using other solid fuel fired furnaces in comparison to gas based ones

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6.4 Gas Geysers

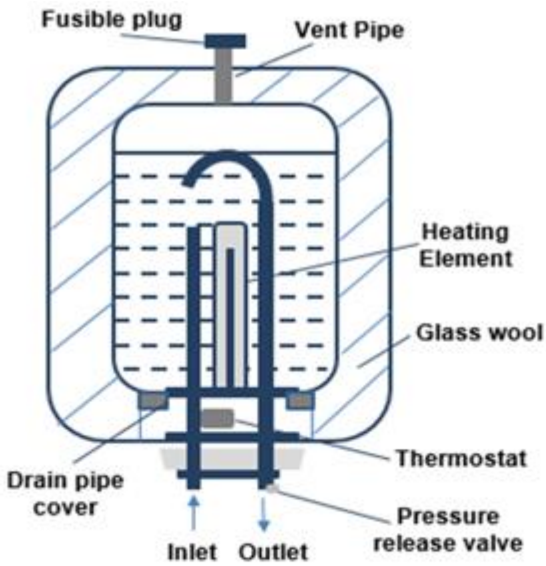
Equipment's that provide a supply of hot water are called geysers. They are available in two variants – Tank and Tankless. Tank Geysers are categorized further into electric and gas geysers. In a Gas geyser (shown in Figure 37), water moves through a pipeline which passes through a heat exchanger which has s water pipe covered with metal fins and a gas burner below which is ignited using an electric impulse created using batteries. The flames heat up the metal fins which in turn heat the water. The system starts up the moment the tap is switched on and off immediately after closing the tap. The process steps are mentioned in Figure 38.

Geysers are primarily used for

- Domestic applications - shower, bath, kitchen
- Light commercial applications - Small restaurants, cafes, etc.

Figure 36: Gas Geyser Construction

1. Hot water tap turned on
2. Water enters the heater
3. Water flow sensor detects water flow
4. Burner gets ignited and water flows through heat exchanger
5. Heat exchanger heats the water to designated temperature
6. Unit shut down once tap is turned off



Source: Carlson Dunlop

Geysers are convenient to use as they provide hot water instantly at the point of application. Other features of geysers such as the auto-off feature helps in energy saving. Tankless geysers provide continuous supply of water for a longer duration in comparison to tank variants.

Figure 37: Working of geyser

Source: Bijli Bachao

Policy & Regulatory Interventions and Other Enablers

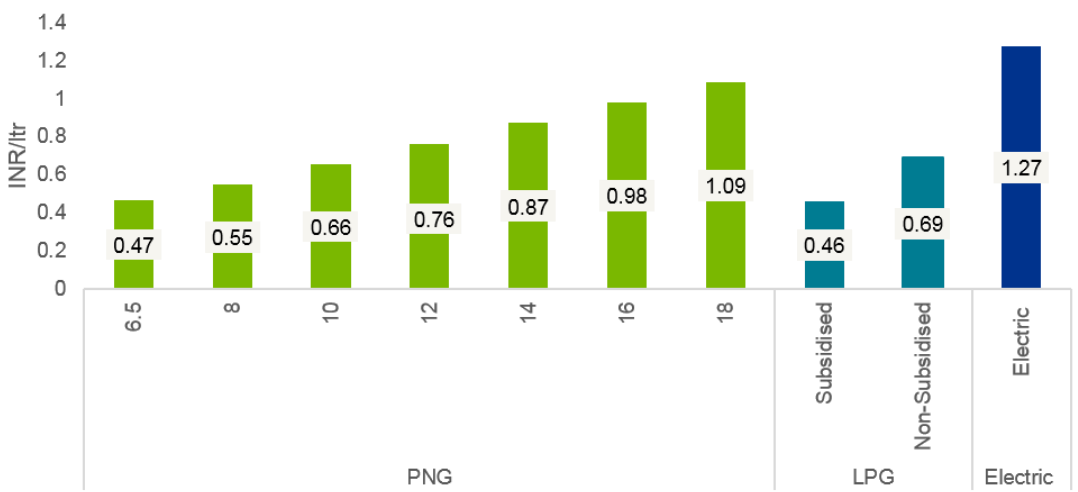
At present there are no specific policy or regulatory support for Gas Geysers in India other than the policy enabling PNG distribution through CGD Network which could increase usage of gas geysers as and when the accessibility to PNG takes place.

Gas is the fastest and economical way to heat water. One gets to save as much as 66% on water heating compared to an electric heater. They have much faster recovery rates and work during power outages. Due to cheaper import costs and less maintenance, majority of the electric water geyser manufacturers readily aid the sales of gas geysers through their pan-India distribution network. Gas geyser is being predominantly used in domestic segment. In the operational areas major gas companies like MGL, IGL, GAIL etc. aims to provide gas geysers as an economical and reliable solution for domestic customers.

6.4.1 Economics of Use

The economics of use for gas geysers are analysed by comparing cost of using natural gas versus alternative fuel/energy source like LPG and electricity for Gas Geysers.

Figure 38: Economics of Use – Gas Geyser



Source: KPMG Analysis

In order to test whether it is economical to use natural gas geysers for heating water cost of running these geysers at various possible gas prices is compared to the next best alternatives, namely, electric and LPG geysers. The analysis is centered upon the fuel cost because there is no significant difference in fixed cost of these geysers

From the above graph (Figure 39) we can observe that:

✓ Variable Cost (VC) analysis - The cost of running gas based geysers is lower than running an electric geyser across all possible delivered price range of natural gas

✓ The cost of running natural gas geyser is economical to non-subsidized price of LPG up to delivered price of $ 10.5/ MMBTU of natural gas at city gate station

✓ The cost of running gas geyser is not economical to subsidized price of LPG even at current domestic gas prices

Hence, natural gas based geysers cannot stand competitive to LPG geysers at subsidized price

6.4.2 Macro-economic Impact

Prices of PNG may vary across cities due to differential of taxes under the current taxation regime. Gas allocation policy acts as a subsidy equivalent for City gas distribution system.

6.4.3 Environmental Impact and Legislatures

There are no specific environmental mandates set for gas geysers but safety measures of usage are indicated by geyser manufacturers. Studies are being conducted with respect to the level of emissions/pollutants released by gas geysers but the Central Pollution Control Board has not provided any specific guidelines on the same. In case of LPG geysers, Indoor Air Pollution from Cooking Fuel was conducted and the ill-effects of placing cylinders indoors was not appreciated. Usage of PNG for geysers in this regard can be beneficial. Compared to Electric geysers, gas geysers will contribute to a miniscule amount of carbon emissions.

6.4.4 Maturity

Gas based geysers are commercially available with major players offering variants in this category of geysers. The use of gas for geyser application is not very extensively marketed hence the awareness of the application is comparatively very less to that of electric geysers.

Table 33: Maturity – Gas Geysers

laturity	ommercial vailability	Vendor Availability	wareness	Skill/Know how	isibility	rent Usage
ication Service	High	High	High	High	Medium	Medium
echnology	High	High	High	High	High	Medium

Source: KPMG Analysis

6.4.5 Market Size

The Indian water heater market is approximated at 2 million units a year and is growing at 12 per cent annually. The major players in the market are Venus, Racold, Bajaj, Crompton Greaves, Kenstar and Thermoking. The estimated potential for gas based geysers in India is ~ 66 MMSCMD with relatively more usage in the Northern regions.

Table 34: Market size potential – Gas Geysers

Market size potential
~66 MMSCMD
• Potential determined on the basis of natural gas consumption to heat 60 L of water in urban and rural households across Northern and Southern regions • Northern Region – Gas consumption in SCM to heat 60 L to raise the temperature by 35 degrees per day for 300 days • Southern Region – Gas consumption in SCM to heat 60 L to raise the temperature by 25 degrees per day for 150 days • 90% of urban households and 40% of rural households use water heaters

Source: KPMG Analysis

6.4.6 Industry Speak

Conventional gas storage units are relatively inefficient because of the heat loss from exhaust gases and walls of the storage tank. Water is kept hot at all times, and while this is a good convenience, it means energy is constantly used/lost. Electric heaters are much more energy efficient than gas units, but the savings in actual energy consumption are mitigated by the higher costs of electricity as opposed to gas. The gas geysers market is predominantly gas (LPG) cylinder distributed for domestic consumption as it was supplied on subsidized rates. Due to cheaper import costs, less maintenance, convenience of use most of the electric water heater (geyser) manufacturers have entered into Gas water heater category.

6.4.7 Barriers

The major barriers faced by gas geyser market (specific to PNG) are discussed below:

- Complex pricing policies for natural gas produced domestically as well as high prices for imported natural gas
- Availability of natural gas is a significant barrier for industries to shift towards gas-fired furnaces. Owing to environment concerns industries are willing to shift to gas-fired furnaces but are taking a back seat due to availability concerns
- The growth of gas water heater market has been hampered by low diffusion of piped natural gas networks

- Government subsidies are primarily encouraging penetration for the solar water heater category especially in the rural areas which can pose a challenge for further penetration of Gas water heaters

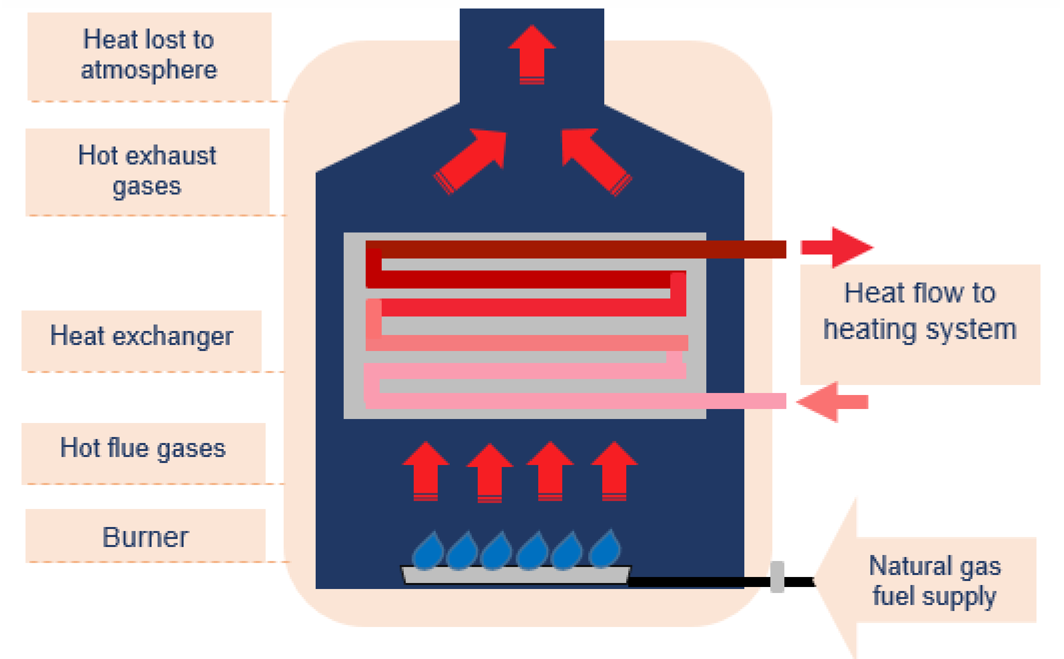
6.5 Boilers

A boiler is a closed vessel in which water is heated. The vaporized or heated fluid flows out of the boiler for use in various processes or heating applications. Gas boilers are used to heat water using natural gas as its fuel source. Gas boilers work by combustion i.e. they burn carbon-based fuel with oxygen to produce carbon dioxide and steam and they are categorized based on design into Conventional Boilers and Condensing Boilers.

- In a conventional design boiler lots of heat can escape with the exhaust gases that escape through a chimney on the top or side called flue gases.

- In a condensing boiler, the flue gases pass out through a heat exchanger that warms up the cold water returning from the radiators helping to heat it up and reducing work the boiler has to do. The basic working of a condensing gas boiler is shown in Figure 40 below.

Figure 39: Gas Boiler Working



Source: Gas Boiler Guide, KPMG Interpretation

The major components of a boiler include feed water heaters, fuel heater, stream traps, Flue, Deaerators, Pumps, Piping, Economizer, and combustion air blowers. The description of these components are as below:

- Feed water Heaters - “Waste steam" is reduced to condensate for return to the boiler in feed water heater

- Fuel Heater - Fuel heaters are used to reduce the fuel viscosity

- Steam Traps - Remove condensate, air, and non-condensable gases

- Flue - Products of combustion that need to be sent away from the boiler
- Deaerators - A special case of feed water heater that is designed to promote the removal of non-condensable gases from feed water.
- Pumps - Two types of pumps are used namely steam circulating and feed water pumps are used.
- Piping - Standard Specification for different pipes used in boilers should be maintained.
- Economizer - Heat exchange devices that improve the efficiency of the boiler
- Combustion Air Blowers - Maintain relatively constant air pressure over a wide range of airflows

Gas boilers are used for domestic, industrial and commercial applications. Boilers constitute the most important part of a central heating system used in domestic and commercial settings. They are used in Industrial applications for co-firing applications. Boilers are an essential equipment in all industries where there is a heat requirement.

Gas boilers primarily require less maintenance, are more cost effective and environment friendly with respect to their liquid fuel/solid fuel alternatives. High efficiency condensing boilers with additional heat exchanger make use of extra heat generated. Gas boilers can provide instant hot water for both domestic & commercial establishments.

Policy & Regulatory Interventions and Other Enablers

There are several policy and regulatory enablers for Boilers in India as prescribed under:

Indian Boiler Act, 1923 – The Act was enacted with the objective to provide mainly for the safety of life and property of persons from danger of explosions of steam boilers and for achieving uniformity in registration and inspection during operation and maintenance of boilers in India[27].

Indian Boiler Regulations, 1950 - Indian Boiler Regulations are the standards in respect of materials, design and construction, inspection and testing of boilers and boiler components for compliance by the manufacturers and users of boilers in the country[28]. These regulations are being updated regularly by amending them in line with the changes in boiler technology by the Central Boilers Board.

Other enablers specific to gas based Boilers is the Oil & Gas Conservation Award for Boiler Efficiency. Recognitions like these encourage industrial users to shift to greener and cleaner natural gas usage.

Gas boilers reduce emissions of CO_2 significantly in comparison to oil-fired and coal-fired boilers. For instance by incorporating gas co-firing CO_2 emissions can be reduced by 20-30%. Also by switching of fuel to Natural gas 20-35% reduction in Carbon emissions. No storage facility is required for Natural Gas as it is connected from a pipeline.

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[27] Delhi Government – Boiler Inspectorate

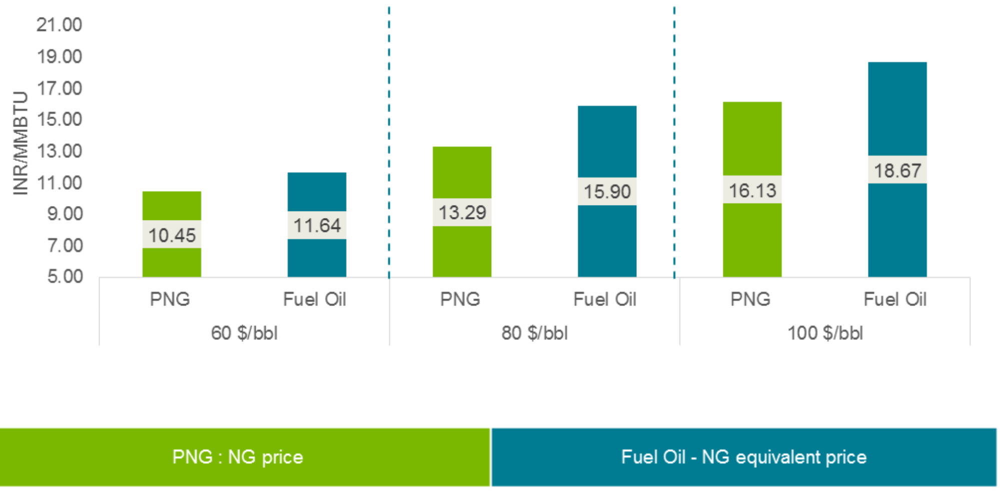
[28] Message from Chairman, Indian Boiler Regulations 1950

Natural gas fired boilers are in use in Industries largely where supply of gas is adequate especially in the regions near Gujarat. With boiler emission standards in place it is more adequate for industries to shift to Natural gas.

6.5.1 Economics of Use

For Boilers the economics of use is analysed on the basis of heat equivalent comparison of natural gas (NG) and the next best alternate used namely Fuel Oil (FO).

Figure 40: Economics of Use -Boilers



Source: KPMG Analysis

Three different linkages to crude price: 60 $/bbl, 80 $/bbl and 100 $/bbl, are taken for computing the NG and NG equivalent FO price. Analysis is centred upon the fuel cost because this plays a major role for consumer's choice. Efficiency factoring is not taken into calculation as there is no difference in efficiencies of NG and FO boilers.

From the above graph (Figure 41), Natural Gas is economical for use compared to that of fuel oil which is costlier in the range of 1.19-2.54 $/MMBTU over the crude price range. Prices are based on net of VAT analysis however the prices may vary depending upon the differential taxes on FO in different states.

6.5.2 Macro-economic Impact

Each Litre of fuel oil replacement results in forex saving of $ 0.1213 (or 12.13 cents). Prices of fuels may vary from across states based on taxes applicable and there are no subsidies applicable for gas usage in boilers.

6.5.3 Environmental Impact and Legislatures

From an environmental standpoint Gas Boiler is better than FO as it emits a lesser harmful CO_2 as shown in Table 35 below.

Table 35: Carbon emissions – Fuel-fired stations

FO (t CO_2/MWh)	Gas ((t CO_2/MWh)
0.62	0.47

Source: CEA

The Delhi Pollution Control Committee has mandated the closure of coal fired boilers in all industries and conversion to oil or gas based boilers as a move towards controlling Air pollution. The CPCB has also listed emission standards and Industry specific standards for installation of gas-fired boilers (shown in Table 36 & 37).

Table 36: Emissions Limits - CPCB

Steam generation capacity (tph)	Emission limit (mg/Nm3)
Less than 2	1200
2 to less than 10	800
10 to less than 15	600
15 and above	150

Source: CPCB

Table 37: CPCB Equipment Guidelines

Equipment Type	Size Category	Performance required
Boilers , Gas Fired	< 88KW	80% AFUE[2]

Source: CPCB

6.5.4 Maturity

Natural gas fired boilers are used in Industries largely where supply of gas is adequate especially in the regions near Gujarat. Hence, there is adequate awareness and visibility of the application and technology amongst industry players. The usage is limited largely due to availability of gas. Compared to global use of gas-fired technology in gas-based boilers, the use in the Indian context is comparatively lower.

Table 38: Maturity - Boilers

Maturity	mmercial ailability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	High	High	High	High	High	Medium
›chnology	High	High	High	High	High	Medium

Source: KPMG Analysis

6.5.5 Market Size

Boiler markets in India have been growing continuously for past few years with a Compound Average Growth Rate (CAGR) of 24.53%[29] with its major application in the power sector. As the power sector is dominated by coal as fuel, gas-fired boilers usage is relatively scarce.

However, based on alternate fuel usage for different applications in Industries a combined potential of ~ 19 MMSCMD is estimated in the next 5 years.

Table 39: Market size potential – Boilers

Market size potential
~18.97 MMSCMD
Alternate fuel consumption of LPG, LSHS, FO, Bulk LPG which are alternatives to natural gas for industrial applications which included direct-fired burners, thermic fluid heaters, Furnaces and Boiler. A combined potential is determined for these applications with a growth rate of 6.5% (IIP).

Source: KPMG Market Research

6.5.6 Industry Speak

Gas and FO boilers have same efficiencies which is ~89%[30]. Hence the prices of fuel (Natural gas and Fuel Oil) and environmental mandates are deciding factors for industries to shift towards gas-fired boilers. With green technologies in demand, the sector has witnessed growing entry of global players through JVs due to increased priority given towards reduction in CO_2 emissions[31].

6.5.7 Barriers

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[29] [1]NRR Power Solution Pvt Ltd - Indian Power Boiler Market: Present & Future
[30] KPMG analysis: Data sourced from Forbes Marshall (Engineering company for Boilers)

[31] NRR Power Solution Pvt Ltd - Indian Power Boiler Market: Present & Future

The major barriers with respect to Natural gas boilers is the availability of natural gas which acts as a significant barrier for industries to shift towards gas-fired boilers. Owing to environment concerns industries are willing to shift to gas-fired boilers but are taking a back seat due to availability concerns. The boiler market is facing threat from Chinese manufacturers as there is lack of manufacturing experience of Indian players with respect to super-critical based units. Chinese manufacturers are known for their timely delivery of units.

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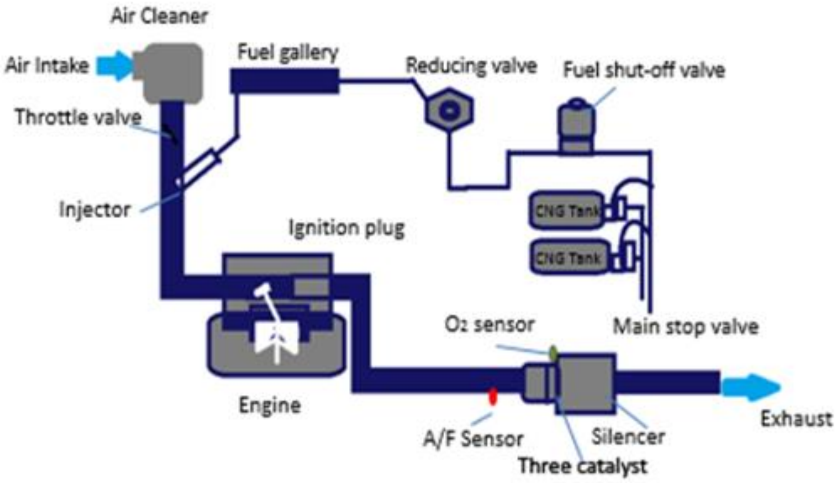
7 Transport Applications

Globally, Natural gas has been a key alternative fuel used for transportation. According to the Natural Gas Vehicle Coalition (US) there are more than 5 million Natural Gas Vehicles (NGVs) worldwide. There has been significant amount of technology development in CNG and LNG Vehicles. NGVs are gaining popularity due to stringent emission laws and includes all category of vehicles such as passenger cars, taxis, buses etc. and CNG is largely used as a fuel in these vehicles amongst the gas based transportation options,. However, for long haul operations LNG is a preferred fuel in trucks and locomotives. As a part of this study, CNG vehicles, LNG Vehicles and LNG locomotives will covered under this section.

7.1 CNG Vehicles

Compressed natural gas (CNG) is made by compressing natural gas to less than 1 percent of the volume it occupies at standard atmospheric pressure. CNG is stored and distributed in containers at a pressure of 2,900–3,600 psi. They are used either alone (dedicated), with a segregated gasoline system (dual fuel) or in conjunction with another fuel such as diesel (bi-fuel). CNG is used in place of petrol, diesel and LPG (Liquefied Petroleum Gas) fuels in vehicles. CNG displaces gasoline or diesel in a vehicle's internal combustion engine. The fuel gets mixed with air and is fed to the cylinder (IC) where the mix is ignited by a spark plug reciprocating the engine's piston which causes rotation of the piston which is attached to the engine shaft to move the vehicle. The detailed construction of a CNG engine is illustrated in Figure 42.

Figure 41: CNG Engine working



Source: Isuzu, KPMG Interpretation

CNG is used in traditional internal combustion engine automobiles that have been modified or in vehicles which were manufactured for CNG. It is used as a fuel in cars, tuk-tuks, pickup trucks, buses and trains. CNG is safer than other fuels in the event of a spill and it offers fuel savings and environmental benefits with lower emissions. CNG serves the lowest running costs i.e. it provides the cheapest mileage cost per km.

Policy & Regulatory Interventions and Other Enablers

There are many policy and regulatory interventions for CNG vehicles in India such as:

- PNGRB CGD bidding - For establishing City gas distribution networks across India, Five rounds of bidding has been conducted by PNGRB and the plan envisages setting up of CGD networks in 300 cities. With further expansion of the natural gas grid the prospect of its application in the transportation sector also increases
- Mumbai High Court order – Order on CNG conversion of Freight vehicles
- Railways Initiative - Launch of first CNG powered train in January 2015

CNG combustion produces fewer undesirable gases than other alternative fuels hence is preferred. Globally the use of CNG extend the life of the vehicle compared to alternative fuels such as diesel. CNG vehicles experience less engine knocking and has no vapour locking which occurs when liquid fuel changes state from liquid to gas while still in the fuel delivery system. Since CNG fuel is in gaseous state these vehicles have superior starting even under severe cold and hot weather conditions.

Currently in response to high fuel prices and environmental concerns, Delhi and other states like Gujarat, Maharashtra, Madhya Pradesh, Haryana, Rajasthan, Andhra Pradesh, Tripura and Uttar Pradesh etc. use CNG in most of their vehicles.

Box 3 : Case Study - Policy drivers for CNG in Delhi

The Delhi CNG programme was first of its kind implemented in India due to the rapid increase of automobile pollutants affecting the ambient air quality. The programme mandated conversion of diesel buses to CNG.

The wave of CNG reforms in Delhi began after the Environment Pollution (Prevention and Control) Authority, was created in January 1998, under the Environment Protection Act to advise the court on pollution control measures and also monitor implementation of the court orders. The order of July 28 1998 laid down the foundation of the CNG programme in Delhi that came in response to the recommendations that the Environment Pollution (Prevention and Control) Authority had formulated based on its deliberations with the Delhi government. The Delhi government had recommended the CNG programme for Delhi for which the Supreme Court put forth clear deadlines and timeline for implementation as below:

Directive	Time Frame
Strict Enforcement of restriction on plying of goods vehicles during the day time	15-08-1998
Elimination of leaded petrol from Delhi	01-09-1998
Phasing out/ban on plying of old commercial/transport vehicles - Vehicles more than 20 years old	02-10-1998
Phasing out/ban on plying of old commercial/transport vehicles - Vehicles more than 17 years old	15-11-1998
Phasing out/ban on plying of old commercial/transport vehicles - Vehicles more than 15 years old	31-12-1998
Ban on supply of loose 2T oils	31-12-1998
Supply of only pre-mix petrol to 2-stroke engine vehicles	31-12-1998
Establishment of two Independent Fuel Testing Labs	01-06-1999
Only non-Commercial vehicles complying with EURO-I norms to be registered in NCR	01-06-2000
Comprehensive Inspection & Maintenance facilities to be started by transport Department and Private Sector	31-03-2000
New ISBT to be built at Delhi's North and South-West Borders (to avoid pollution due to entry of inter-state buses)	31-03-2000
Replacement of all pre-1990 autos and taxis with new vehicles using clean fuel	31-03-2000
Expansion of Compressed Natural Gas (CNG) supply outlets from 9 to 80	31-03-2000
Ban on plying of buses more than 8 years old except on clean fuels	01-04-2000
Strengthening of existing air quality monitoring stations and setting up of new stations of critical pollutants	01-04-2000
Replacement, with financial incentives, of post-1990 autos and taxis with new vehicles on clean fuel	31-03-2001
Entire city bus fleet (DTC & Private) to be converted to single fuel mode on CNG	31-03-2001
Augmentation of public transport to 10,000 buses (from existing 6,600 buses)	01-04-2001
Automated inspection and maintenance facilities to be set-up for commercial vehicles	01-04-2001
Permission to ply less than 8 years old autos old autos & taxis and buses on conventional fuels till 30.09.2001 on special permits provided they have placed firm orders for new CNG vehicles or conversion of existing vehicle to CNG mode by 31.03.2001	31-09-2001

Incentives: The Government of Delhi has provided fiscal incentives like sales tax exemption and interest subsidy on loans for purchase of new replacement vehicles.

Penalties: In April 2002, the Supreme Court published a directive which imposed a daily penalty of 1’000 Rupee per day for each diesel bus still in circulation.

Status of Program: By December 2002, the last diesel bus had disappeared from Delhi’s roads and public transport included only busses running on CNG.

Post Implementation Challenges

- Shortage of CNG supply due to lack of infrastructure planning
- Unclear emission regulations for new vehicles using CNG as well as for in-use vehicles converted to CNG by ministry of road transport and highways (MRTH)
- No provisions defined in the existing regulations for the inspection of in-use buses after conversion to CNG
- No requirements for CNG authorized workshops have been defined
- Problems of conversion quality and maintenance quality - 12 busses caught fired a new regulation on CNG safety was published.
- Technology Constraint because of the absence of stress relief loops on CNG installations
- Vehicle industry Inhibition for large scale manufacturing of CNG retrofitted vehicles

After the successful implementation of the CNG programme in Delhi in 2002 nearly 14 polluted cities were identified in two court orders (April 5, 2002, and August 14, 2003 which include Agra, Lucknow, Jharia, Kanpur, Varanasi, Patna, Jodhpur, Faridabad, and Pune (as in the first order), and Hyderabad, Chennai, Bangalore, Ahmedabad and Solapur (as in the second order).

7.1.1 Economics of Use

The economics of use for CNG fuel is evaluated on the basis of relative prices of fuel and taxation. The calculations are done at indicative prices. The domestic supply proportion is higher for older Natural Gas Vehicles Programs in Delhi and Mumbai as they were the newer cities to rely on expensive RLNG hence these cities are considered for analysis. The payback period for each vehicle category (Private car, taxi, auto and bus) are calculated taking into account the average daily running and conversion costs (shown in Table 40). Petrol category conversion is considered for private cars, taxis and autos. Diesel fuel running buses are used for calculating the payback period.

Table 40: Payback period for CNG Vehicles – Delhi & Mumbai

Vehicles	Average Daily Run (KM)	Conversion Cost(INR)	Payback period (Months)	
			Delhi	Mumbai
Private Car	50	40000	8.4	9.2
Taxi	100	40000	4.3	4.8
Auto	100	25000	5.8	6.5
Bus	150	500000	11.5	13.4

Source: KPMG Analysis

Diesel prices considered for calculations are applicable as on 2 June 2015; Delhi – 55.55 INR/ltr, Mumbai - 63.5/ltr. The cost advantage of using CNG over petrol and diesel is shown in Table 41. Illustrative case for Uttar Pradesh is used for analysis.

Table 41: CNG Price Advantage over Diesel

Crude Oil price	60$/bbl	80$/bbl	100$/bbl
Expected Diesel price (INR/ltr)	56.82	60.41	70.41
Price advantage over Diesel @ CNG price of 43.3/kg[32]	24%	28%	39%

Source: KPMG Analysis

As a result of above analysis, differential in fuel prices essentially indicates that CNG's economic advantage as compared to diesel varies at different crude oil prices. CNG offers a price advantage of 39% at 100% crude oil price linkage and varies in the range of 24-39% for the above Crude oil price linkages. Macro-economic Impact

The inter-fuel taxation regime and subsidies have an impact on the end-user prices of fuels in India. The tax rates for various fuels; petrol, diesel and natural gas caries from 2% to 26% among various states resulting in disparity in fuel prices. Each litre of diesel replacement results in a forex saving of $ 0.12 (or 12 cents).

7.1.2 Environmental Impact and Legislatures

CNG vehicles emit nearly 25%2[33] less CO_2 g/KM emissions than equivalent category of Diesel vehicles. The Central Pollution Control Board has taken various initiative for improvement of fuel quality by introduction of compressed natural gas (CNG) and tightening of emission norms for vehicles that have monitored unabated increase of pollution. According to CPCB, the in-use vehicles fitted with CNG kits should meet the emission norms prescribed for gasoline vehicles as applicable to the prevailing norms corresponding to the year of manufacture of the vehicle.

7.1.3 Maturity

CNG vehicle technology has not able to perform in par with its alternatives in India. There is a lot of visibility for CNG vehicles for pollution control measures and from a cleaner fuel perspective, however the technology development for CNG is yet to address issues related to engine retrofitting and life of vehicles. Although, CNG vehicles are commercially available, they are not available in the premium category of vehicles.

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[32] The CNG price taken for calculations is the NCR price as of 18th May, 2015 (Source: IGL)

[33] Automotive Research Association of India, CSE India

Table 42: Maturity – CNG Vehicles

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	Medium	High	Medium	Medium	High	Low
Maturity	Medium	High	Medium	Medium	High	Low

Source: KPMG Analysis

7.1.4 Market size

As of 2014 the total number of CNG vehicles in India is 14, 77,746. The count of vehicles as per the type is shown in Table 43 below.

Table 43: CNG Vehicles in India (As per type)

Type	No. of vehicles
Cars / Taxis	899094
Autos	515208
LCV/RTVs	6956
Buses	26425
Others	30063

Source: KPMG Market Research

Table 44: Market size potential – CNG Vehicles

Market size potential
~60 MMSCMD
• Alternate fuel consumption of diesel by Cars & Utility Vehicles (Private & Commercial) and petrol consumption by Cars category of vehicles is considered as the market potential • Diesel consumption share – 22.09% (Nielson Report 2013) • Petrol consumption share – 35.83% (Nielson Report 2013) • Diesel consumption growth rate of 4 % (PPAC) • Petrol consumption growth rate of 7 % (PPAC)

Source: KPMG Analysis

7.1.5 Industry Speak

According to Automotive Research Association of India CNG vehicles are ~ 40% more fuel efficient than the Diesel vehicles in the three-wheeler category of vehicles (predominantly three-wheelers use CNG in India) hence opted by end-users. CNG is preferred significantly for pollution control measures and the usage has increased because of government mandates. Diesel and Petrol cars are preferred due to longer life of engines in comparison to CNG engines which is considered as a barrier for CNG usage.

7.1.6 Barriers

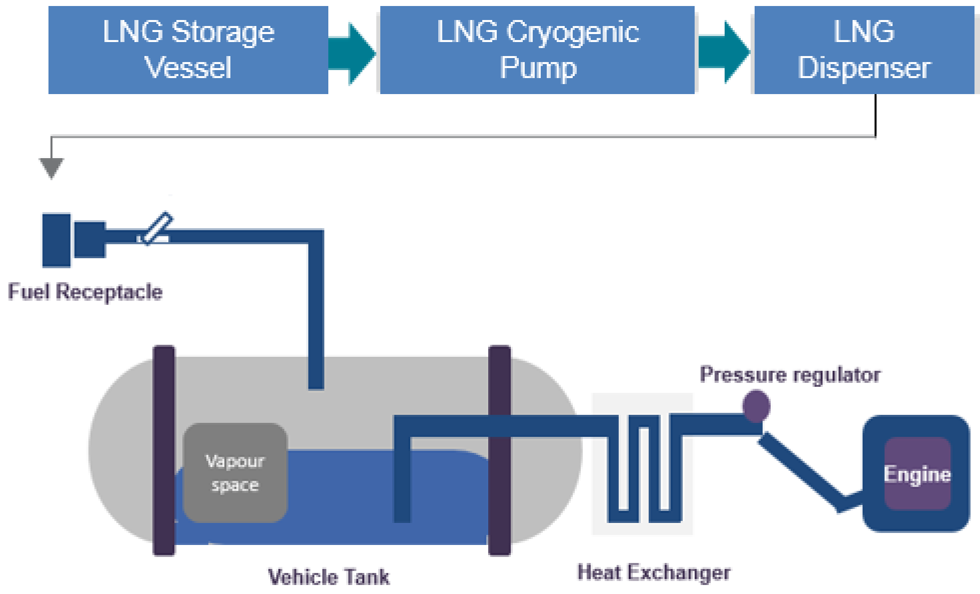
Major barriers with respect to CNG usage in India are:

- Almost all CNG powered vehicles in India utilize retrofitted engines where regular petrol engines have been retrofitted to be able to use CNG which poses a significant challenge because the combustion of CNG in retrofitted vehicles is less than optimal negating some of the 'cleaner' emissions claims made
- Use of CNG results in lower Particulate Matter (PM) emissions compared to conventionally used fuel and diesel. However it is said that it performs worse on other emissions components namely NOx emissions.
- A study for auto-rickshaws found that as much as one-third of CNG is improperly burned in two-stroke engines, resulting in higher levels of greenhouse gas emissions and higher levels of Particulate Matter emissions due to unburned lubrication oil
- CNG is predominantly used as kits that are retrofitted to gasoline engines where CNG is injected to the engines. Due to this the life of the engine reduces and the engine temperature increases in comparison to alternate fuels like petrol and diesel
- Safety hazards of CNG vehicles are also a prime barrier as there are many non-authorized providers of CNG kits

7.2 LNG Vehicles

Liquefied Natural Gas (LNG) is produced when natural gas cooled to - 259 degrees Fahrenheit through a process known as liquefaction. LNG is used as an auto fuel in vehicles where the fuel is stored in specially insulated storage containers/tanks due to its cryogenic nature. A vaporizer is mounted in the fuel system that converts LNG into gas (low pressure CNG) and runs the engine of the vehicle. LNG tanks operate at low pressures in the range of 70-150 psi. An LNG vehicle schematic is shown in Figure 43.

Figure 42: LNG Vehicle Schematic



Source: Petronet LNG, KPMG Interpretation

LNG is used in increased driving range for over the road trucking and off-road applications. However, the technology is still being evaluated for transportation needs especially for vehicles. China has over 100,000 LNG powered vehicles followed by United States. LNG vehicles can support heavy commercial vehicles that usually have long haul journey. LNG vehicles offers advantage over CNG vehicles for high-horsepower applications. LNG eliminates need for turbocharger because it boils at –160 C and can be easily converted to gaseous form without use of mechanical energy.

Policy & Regulatory Interventions and Other Enablers

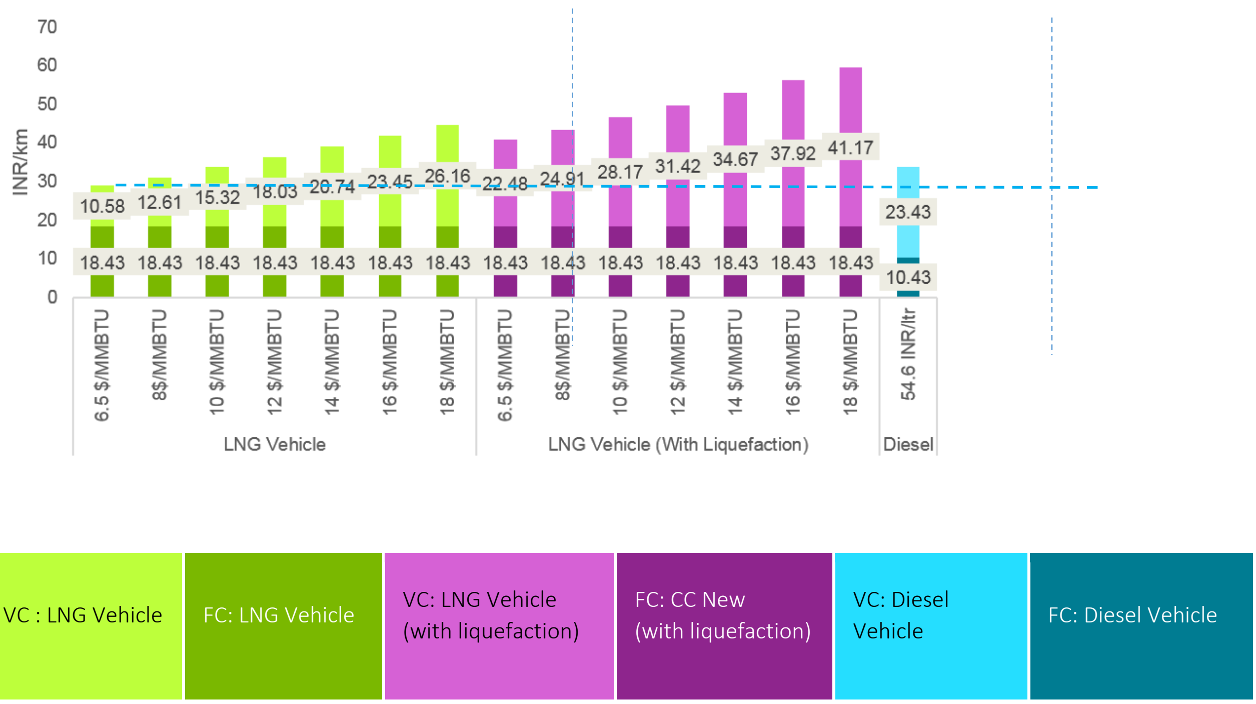
At present there are no policy or regulations around use of LNG for vehicles in India. There are many discussions and conferences that highlight the supply of LNG as fuel for vehicles. Petronet has taken initiatives for encouraging Penetration among consumers and Increasing LNG regasification capacity to meet India's growing Energy demand and highlights set up of LCNG stations (fed by LNG from the main terminal) for supply of LNG and CNG for vehicles.

Due to higher storage density of LNG, it is a more viable alternative to diesel fuel than CNG for heavy-duty vehicle applications. LNG fuelled heavy-duty natural gas engines achieves significantly lower NOx and particulate emission levels than diesel. At present LNG based vehicles are not in use in India. However globally especially in China and United States developments in vehicle efficiency has led to LNG usage in trucks, commercial transport fleets and shipping vessels. Companies such as Shell also believe that LNG could contribute to a larger part of the transport energy mix.

7.2.1 Economics of Use

Cost economics for LNG vehicles is done with respect to comparison of using natural gas versus alternative fuel/energy source used. The capital cost comparison for LNG Vehicles with the next best alternative diesel might look bleak but the economics might turn out to be positive from a long term perspective.

Figure 43: Economics of use – LNG Vehicles



Source: KPMG Analysis

In order to test whether it is economical to use LNG natural gas vehicles the cost of a LNG vehicle[34] at various possible gas prices is compared to the next best alternative fuel, namely Diesel (or HSD). Further two scenarios, namely LNG prices at fuel depot and LNG prices along with liquefaction charges are compared.

From the above graph (Figure 44) we can observe that

- Fixed Cost (FC) of a Diesel vehicle in the category class of vehicle analyzed is the lowest, while the FC of a LNG vehicle in the same class is nearly twice that of Diesel vehicle FC
- Variable Cost (VC) Analysis :
- Scenario 1 (LNG)- LNG vehicles are economical for use in the entire domestic price range and up to $ 16 /MMBTU of LNG landed price at sales point
- Scenario 2 (LNG with liquefaction charges) - LNG vehicles are economical for use only in the price range up to ~ $ 7.1/MMBTU of LNG price

The Total Cost (TC) per unit (KM) of Diesel vehicle is only comparable to LNG vehicles at gas prices up to ~$ 10/MMBTU and not with liquefaction charges.

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[34] T800 Class 8 LNG Power Truck (Source: Argonne National Laboratory)

However, it should be noted that initial capital investments for LNG vehicles are much higher than Diesel vehicles in the same category class and the required LNG fuelling station infrastructure are not available in the current context.

7.2.2 Macro-economic Impact

There would be significant forex savings for Diesel replacement in LNG vehicles as the use is directed towards long distances. Each litre of diesel replacement results in forex saving of $ 0.104 (or 10.4 cents) or INR 6.68. As an illustration discussed in earlier sections, a 10% reduction in Diesel Consumption results in approximate annual forex savings of INR 5420 Cr.

7.2.3 Environmental Impact and Legislatures

The life cycle carbon emissions of CNG and LNG are nearly identical. CNG/LNG vehicles emit [35]25 Mt CO2 which is much lesser than its Diesel counterparts which emit ~ 250 Mt CO2. LNG trucks reduces average energy consumption by [36]25% compared with a diesel engine of a similar model truck.

7.2.4 Maturity

A lot of research and development is being undertaken for use of the LNG technology in India. Awareness and visibility of the technology is currently very low but due to use of this technology in the US and China, there is considerable thought being put on making the application viable in the Indian context.

Table 45: Maturity – LNG Vehicle

Maturity	Commercial Availability	Vendor Availability	wareness	Skill/Know how	Visibility	Current Usage
Application Service	Low	Low	Low	Low	Low	Low
chnology	Low	Low	Low	Low	Low	Low

Source: KPMG Analysis

7.2.5 Market Size

In India there is huge traction on introducing LNG vehicles and the concept is at an inception stage. However, globally an additional 40 mmtpa of liquefaction will be required in LNG production to

35 Enerdata –Global Energy and CO_2 data (China)
36 Data relevant to trucks in China (Source: China Yuchai International's)

support a 50% market penetration of the high horsepower market which is projected to take place within the next 10-15 years.

Table 46: Market size potential – LNG Vehicles

Market size potential
~109 MMSCMD
• Alternate fuel consumption of diesel by HCV/LCV and Buses category of vehicles is considered as the market potential .Diesel consumption share sourced from Nielson Report 2013 • Diesel consumption growth rate of 4.11% is taken to determine 2020 potential

Source: KPMG Analysis

7.2.6 Industry Speak

In the US, LNG vehicles are preferred over CNG vehicles because of weight, vehicle cost, use where there is no pipeline access and fuel density/range factor. LNG vehicles are preferred over CNG when an operator is concerned about vehicle range. Environmental combustion advantage and Sustainability commitment are the major drivers globally for shift towards LNG vehicles. LNG Vehicles are largely preferred amongst long off road haul operations which include trucks and not passenger vehicles. As LNG has higher energy content per unit volume than CNG, it is more suitable for heavy duty vehicles like trucks and buses.

7.2.7 Barriers

The widespread availability of LNG/LCNG stations at present could be a major barrier for LNG vehicle market to grow at a pan-India basis after its inception. Early cycle introduction of natural gas due to the tendency for the mixture to pre-ignite because of its temperature in the cylinder as it compresses limits the amount of gas that can be substituted for diesel fuel. These vehicles will operate as dual-fuel engines providing 50-60% substitution of gas for diesel fuel on a duty-cycle basis. Further technology advancement can lower this rate. During chilling of NG to -160°C, LNG tanks slowly vent methane into the atmosphere when the truck engine is not in use which can challenge safety in such vehicles. These are few of the barriers to be addressed.

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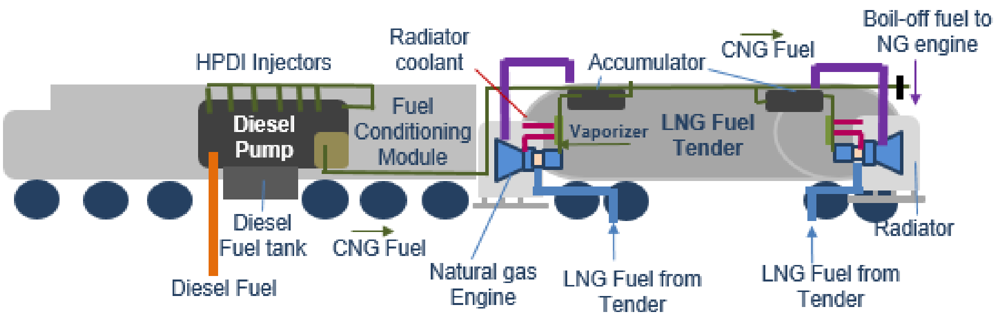
7.3 LNG Locomotives

Locomotive is a self-propelled vehicular engine either powered by steam, diesel, electricity or LNG (Liquefied Natural Gas) for pulling a train or individual railroad cars. LNG locomotive is a rail transport vehicle that is powered by LNG. The construction of a LNG Locomotive is shown in Figure 45. They use a dynamic gas blending engine which uses diesel fuel for combustion until intake temperature rises at which point natural gas is used. The specially designed engines are LNG-capable up to a fuel consumption ratio of 80% LNG and 20% diesel.

Figure 44: LNG Locomotive Construction



Source: IROAF, KPMG Interpretation

Locomotives are classified based on their use into passenger, freight and shunting (switcher) locomotives. LNG locomotives are primarily used for moving freight and other materials. Locomotives are considering the use of LNG because of the potential for significant fuel cost savings and the resulting reductions in future fuel operating costs. They pursue the advantage of being dual-fuel compatible with ability to switch back to 100% diesel fuel as and when required.

Policy & Regulatory Interventions and Other Enablers

The government is keen on taking this thought forward and hence policy and Regulatory interventions will occur in this segment. Various happenings in the LNG locomotive space are discussed below.

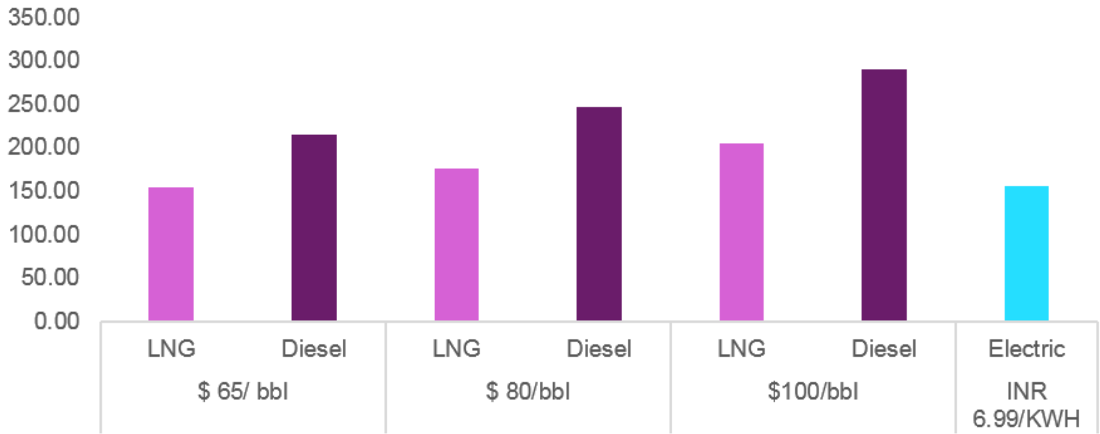
- Ministry of Railways is backing the Indian Railways Organization for Alternate Fuels to embark the project for Use of LNG in the railways system for main line locomotives such as ALCo (American Locomotive Company), EMD Electro-Motive Division)and gas turbine locomotives
- MoU has been signed with Indian Oil Corporation for LNG on-board enabling Indian Railways to adopt technologies like HPDI etc. for higher substitution of Diesel for main line engines and shunting engines.

LNG is preferred over diesel as it aids in reduced pollution as they significantly reduce emissions compared with diesel locomotives. LNG locomotives reinforces the advantage railroads hold over trucks in long-haul shipping. Indian Railways estimates that up to 50 % reduction in operating costs can be achieved with LNG-based locomotives. At present there are no LNG run locomotives in India but there are significant developments being undertaken around this sector by the Railway Board of India. Russian government has shown interest in partnering/assisting in the LNG-powered locomotives project proposed in India. Field-tests of the prototype are in progress. Post successful testing of which commercial production of LNG-based locomotives is planned.

7.3.1 Economics of Use

In order to test whether it is economical to use LNG in railways, fuel cost of a LNG & Diesel locomotive at three different linkages to crude price: $ 65/bbl, $80/bbl & $100/bbl compared to that of an Electric locomotive.

Figure 45: Economics of Use - Locomotive



Source: KPMG Analysis

From the above graph (Figure 46) we can observe that:

- At 65 $/bbl, the fuel cost of LNG locomotive is the lowest as compared to Diesel & Electric locomotive
- However, fuel cost per kilometer of LNG locomotive is economical to diesel locomotive over the entire crude price range
- The fuel cost savings per kilometre of LNG locomotive varies in the range of INR 60.83 to INR 85.39 over crude price from $ 65/bbl to $100/bbl
- At $65/bbl crude price, when we extrapolate fuel savings per kilometre to annual basis in line with the operational parameter of engine kilometres per day (631 KM/day), an incremental annual savings of INR 1.4 Crore would be achieved
- Although, the retrofitted LNG locomotive costs around INR 6.38 Cr, the payback period to railways would be as low as 4.6 years because of savings in running costs

Hence on the basis of above analysis it can be conclude that LNG Locomotives can emerge as future propulsion option for railways.

7.3.2 Macro-economic Impact

There would be significant forex savings for Diesel replacement in LNG vehicles as the use is directed towards long distances. Each litre of diesel replacement results in forex saving of $ 0.104 (or 10.4 cents) or INR 6.68. As an illustration, 10% reduction in Diesel Consumption results in approximate annual forex savings of INR 5420 Cr.

7.3.3 Environmental Impact and Legislatures

CO_2 emissions are typically lower with natural gas based locomotives (LNG) compared to a diesel driven locomotive. Diesel-NG hybrid fuel locomotive will reduce carbon dioxide emissions by 30 per cent over a locomotive duty cycle[37]. There are no environment mandates for LNG based locomotives as it is not started use in India. However the draft bid looks into safety and pollution control aspects of technology used in these locomotives.

7.3.4 Maturity

There is a lot of visibility and awareness of the technology and application as such. The government's initiative in developing a LNG locomotive is supporting the above statement. From a technology perspective, LNG railway technology has not reached its maturity as significant amount of research and development is being undertaken for use of the technology globally. India has no domestic vendors available however tenders have been floated to international vendors hence availability is high in this regard.

Table 47: Maturity – LNG Locomotives

Maturity	ommercial Availability	Vendor Availability	wareness	Skill/Know how	Visibility	Current Usage
Application Service	Low	Low	Medium	Medium	Medium	Low
Technology	High	High	High	Medium	High	Low

Source: KPMG Analysis

7.3.5 Market Size

[37] Caterpillar Locomotive Engines

Government of India is conducting discussions with foreign countries on collaboration for development of LNG locomotives in the country. Currently there are no operating LNG locomotives in India but there are many studies conducted to evaluate the feasibility and benefits of introducing LNG based locomotives in the country. Indian Railways has floated a global tender in this regard and once the bids are finalized, the first LNG-based train is expected to be functional by late-2016. Russia has shown interest to collaborate with India on this front.

Table 48: Market size potential – LNG Locomotives

Market size potential
~8.41 MMSCMD
Alternate fuel consumption of Diesel for Locomotives is considered as the market potential. Annual consumption of diesel for 2013-14 sourced from IRCTC (2.7 Bn litres). Diesel consumption growth rate of 2.78 % for railways in the last 10 years.

Source: KPMG Analysis

7.3.6 Industry Speak

Gas turbine locomotives provide additional benefits as there is more than 50 % reduction in exhaust emissions as compared to present day diesel locomotives running in Indian railways[38]. LNG locomotives are preferred as operating and maintenance costs would be less due to the less moving parts and because a gas turbine locomotive offers best power to weight ratio for a power generator. Gas-run locomotives are of interest because of reliability, cost, and efficiency and carbon footprints. Indian Railways estimates that equipping the entire fleet with LNG locomotives will generate annual savings of INR 6 Bn on its INR 160 Bn diesel bill and reduce emissions by 30%. However, refuelling infrastructure and uncertainty of LNG prices are the major barriers for functioning of LNG locomotives.

7.3.7 Barriers

Refuelling infrastructure and uncertainty of LNG prices are the major barriers for functioning of LNG locomotives.

7.3.8 Case Study on LNG Locomotives as future propulsion option for Indian Railways

Liquefied Natural Gas (LNG) has been the buzz word for last few years in several countries across many industries. The key drivers for this have been the rise in gas production levels supported by technological innovations and fall in natural gas prices as compared to crude oil prices. LNG has

[38] Draft functional requirement specification for design, manufacturing, supply and support for service and maintenance of high horsepower natural gas turbine locomotive (HPNGTL) for Indian Railways (IR)

emerged as an attractive proposition for potential fuel cost savings for long distance haul operations in addition to the environment benefits that it would provide to the nation. These advantages have led to two of the world's longest rail networks, namely United States and Russia in making efforts to transform diesel based locomotives into LNG based locomotives. BNSF, the second-largest freight railroad network in North America, is testing two LNG based locomotives and it foresees a potential savings of $18.7 billion from Class I LNG locomotives.

Thus, with LNG locomotives gaining prominence across other major rail networks, it is important to understand the role of LNG as a possible future propulsion option for Indian railways.

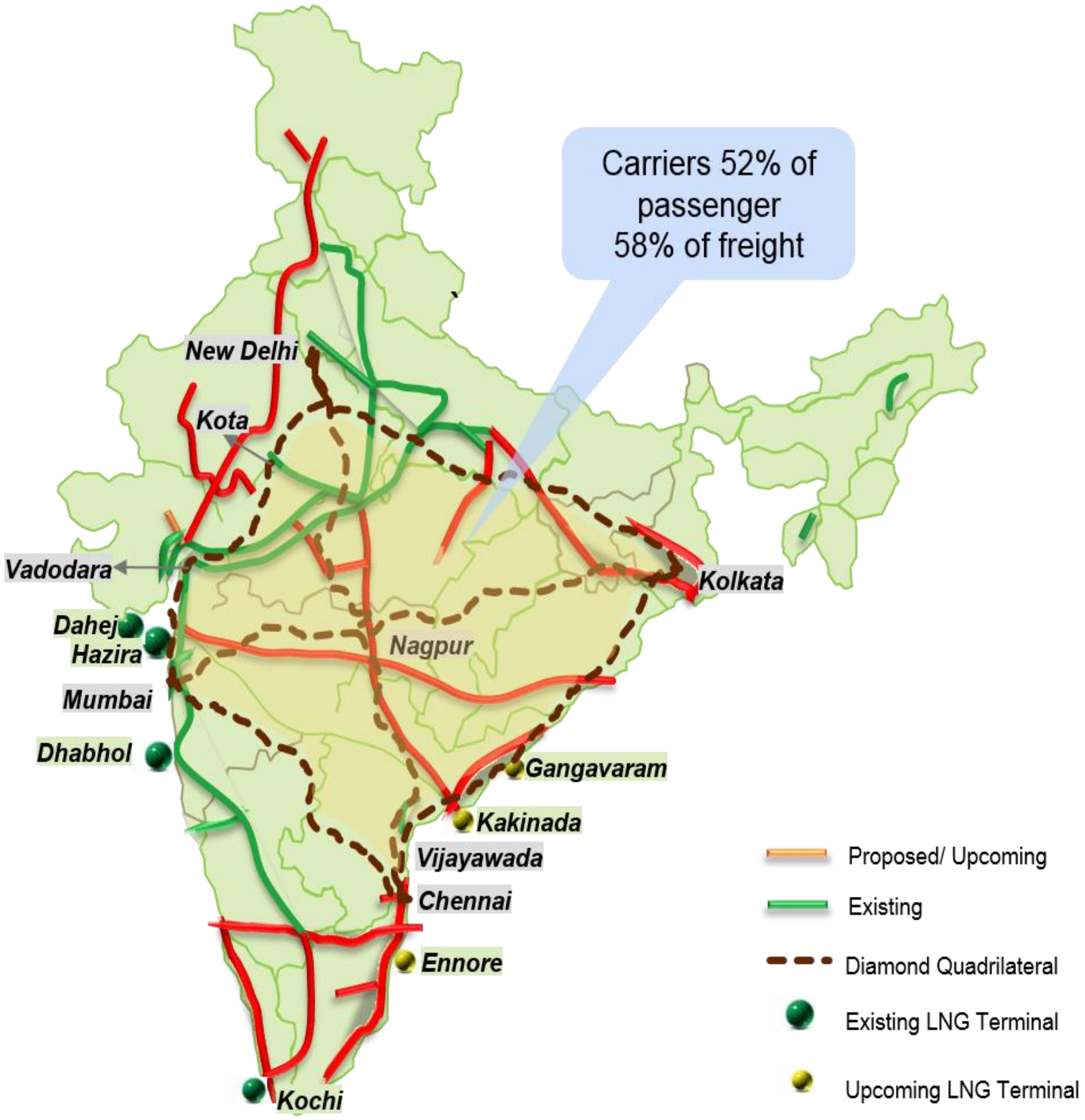
The Indian rail network, owned and operated by Indian railways is the fourth longest rail networks in the world traversing across the length and breadth of the nation with a network of 65, 000 route kilometres. It is now in the same league as countries such as the United States, Russia and China, with an originating freight loading of more than a billion tonnes in 2012-13. It runs 12000 trains and 7000 trains in its passenger segment and freight segments respectively.

The share of LNG in India's gas portfolio has been increasing with four existing regasification terminals at Dahej, Hazira in Gujarat, Dhabhol in Maharashtra and Kochi in Kerala with several upcoming LNG terminals in the planning stage. The imported LNG received at these terminals in liquid form is regasified and transported to several parts of the country through transmission pipelines. Traditionally, the natural gas is liquefied only at specific large LNG terminals limiting it to be used as a fuelling option only between LNG terminals. However, with advancement in technology, the traditional and complex LNG plants have now been transformed into modular, rapidly deployable solution for on-site production of LNG from PNG. This emerging solution of "LNG in a box"[39] can be an attractive option for rail locomotive fuelling. With this context, a business case has been undertaken to identify fuel savings in moving from Diesel based locomotives to LNG locomotives, for Indian railways.

To identify the rail corridors that could be catered with LNG for undertaking a pilot project and map the potential demand centers which have natural gas connectivity, high density corridors of the Indian rail network (Diamond Quadrilateral) is considered for further analysis. To understand the connectivity of the railway corridor with the existing and planned pipeline network, the two have been integrated in the map shown in Figure 47.

[39] Termed by General Electric

Figure 46: Integrated Map of Natural Gas Pipeline and Diamond Quadrilateral



Source: KPMG Analysis

The Delhi-Mumbai corridor is considered for carrying out cost benefit analysis for switch over to LNG locomotives as both these cities are the major commercial hubs for India with good connectivity with the gas pipeline network and high movement of rail traffic.

The analysis has been carried separately for two segments- Passenger rail segment and freight segment with a view that the operational parameters like engine kilometres per day per engine and fuel consumption of these segments vary and could impact the savings. The operational parameters extracted from railway data base for these two segments are given in Table 49.

Table 49: Operational Parameters of Passenger and Goods Segment for the Year 2013-14

Operational Parameters for the year 2013-14		
Description	Passenger	Goods
Fuel consumption per Engine Kilometre (Ltrs)	4	4.53
Engine kilometres per day per engine in use(Km)	631	429

Source: KPMG Analysis

Globally, locomotive engine manufacturers have started building LNG-diesel hybrid locomotives that can predominantly run on natural gas. LNG locomotive would cost around $2 Million whereas a retrofitted one costs around $1 Million. For our analysis, we have considered hybrid retrofitted LNG locomotive option with the mix of 80% LNG and 20% diesel for fuelling the locomotive primarily as:

- Cost Benefit: Retrofitted one costs less than a new locomotive
- Flexibility: Hybrid locomotive option gives flexibility of having diesel as a backup option in case of non-availability of LNG

Currently, R&D on pure LNG based locomotives is in progress. The cost of retrofitted LNG Locomotive would be ~INR 6.38 Crore which would be the initial investment for one locomotive.

Fuel Savings

The detailed cost build-up of LNG received at RLNG terminal-Dahej to delivery locations in Delhi and Mumbai with the price linkage to crude amounted to an average cost of 39.43 INR/SCM of NG. The cost component for producing LNG from PNG is considered as INR 10 per SCM of natural gas (~$4/MMBTU). Also, diesel price for both the locations with linkage to crude amounts to INR 53.67 per ltr. As the locomotive would be commuting from Mumbai to Delhi and refuelling can take place at both these locations, the average of cost of LNG & Diesel worked out for these two locations is considered for analysis (shown in Table 51).

Table 50: Cost of LNG & Diesel

Cost of LNG & Diesel at a crude price of $65/bbl		
Product	Units	Average Cost
LNG	INR/SCM of NG	39.43
Diesel	INR/ltr	53.67

Source: KPMG Analysis

On the basis of the cost of LNG & Diesel and other operational parameters, fuel savings per kilometre per engine for both the segments-passenger and freight have been calculated. The fuel consumption per engine kilometre for LNG locomotive is derived from the fuel consumption per kilometre of diesel based locomotive in energy equivalent terms. Table 51 & 52 depicts the fuel cost savings between hybrid LNG locomotive and diesel locomotive. The price of LNG is arrived at weighted average of LNG price (80%) and imputed diesel price in INR/SCM (20%).

Table 51: Fuel Cost Savings per KM for Passenger Segment

Fuel Cost Savings per KM (Passenger Segment)		
	Diesel	LNG
Price of fuel	53.67	43.76
Mileage (Ltr/KM for Diesel & SCM of NG/KM for LNG)	4	3.5
Fuel Cost per KM	214.7	153.8
Fuel cost savings per KM (INR/KM)	60.8	

Source: KPMG Analysis

Table 52: Fuel Cost Savings per KM for Goods Segment

Fuel Cost Savings per KM (Goods Segment)		
	Diesel	LNG
Price of fuel	53.67	43.76
Mileage (Ltr/KM for Diesel & SCM of NG/KM for LNG)	4.53	3.98
Fuel Cost per KM	243.1	174.2
Fuel Cost savings per KM (INR/KM)	68.9	

Source: KPMG Analysis

Basis the above analysis, passenger and goods segment would generate fuel savings of INR 60.8 and 68.9 per kilometre run of LNG locomotive over diesel locomotive. When these results are extrapolated on an annual basis, in line with the operational parameter- Engine kilometres per day cited in Table would lead to an incremental annual savings of INR 1.4 crore and INR 1.08 crore for passenger and goods segment. The prime reason for goods segment producing relatively lower annual savings compared to passenger segment is solely due to the lower average run of the goods vehicle on an annual basis (shown in Table 53).

To get an overall picture of the case, the following parameters are considered and evaluated.

- Initial investment for retrofitting of hybrid LNG locomotive
- Annual fuel cost savings
- Net present value (NPV)
- Internal Rate of Return(IRR) over period of 20 years
- Payback period for the investment

Table 53: Financial Analysis

Financial Analysis for one Locomotive		
	Passenger	Goods
NPV (Calculated @ Discount Rate of 14%) (INR Crore)	2.9	0.77
IRR	22%	16%
Payback (Years)	4.6	5.91
Discounted payback (years)	7.66	13.4

Source: KPMG Analysis

LNG locomotive emerges as a clear winner over diesel locomotive with NPV of INR 2.9 Cr and INR 0.77 Crore for passenger and goods segment. In addition to this, IRR and the payback period makes LNG as a potential alternative fuelling choice to Diesel making it an attractive proposition for Indian Railways.

Potential Savings of INR 7100 Crore:

Indian Railways currently holds 10,749 locomotives comprising of 5000 electric and 5749 diesel locomotives. Electric traction is highly capital intensive requiring high investment in creating generation capacity, power house and distribution network. However, it is marginally cost economical to LNG locos based on fuel cost comparison and the margins could alter depending on the global crude & gas price swings. Hence, LNG could be a choice of replacement to diesel locos and possible option while launching new locomotives.

The fully fuelled LNG locomotives with a tank capacity of 11, 000 litre would run up to a distance of around 1500 kilometer without refueling in between, eventually making it a viable option for such distances. Currently, there are about 52 Geographic areas and 90 cities connected with natural gas pipeline network and many more cities are expected to have pipeline connectivity in near future. Given that the major rail routes are already electrified, even if we consider switch over of 5% of existing diesel locomotives i.e. ~287 locomotives to LNG, potential annual savings would be in the quantum of INR 355 Crore and the aggregate fuel savings over diesel over a period of 20 years measured in terms of current crude price and exchange would amount to INR 7100 Crore to Indian railways.

LNG Locomotives for Future Dedicated Freight Corridors:

Ministry of Railways, under the directions of GoI, established a Special Purpose Vehicle (SPV) - Dedicated Freight Corridor Corporation of India Limited (DFCC) for construction, operation and maintenance of dedicated freight corridors. This project involves construction of six freight corridors traversing the entire country (shown in Table 54). Currently, the Eastern Corridor connecting the states of Punjab & West Bengal & the Western Corridors connecting the states of Haryana & Maharashtra are in advanced stage of construction and expected to be operational by December 2019. These two corridors would operate entirely through electric locomotives. However, the following balance four corridors are only in planning stage:

Table 54: Future Dedicated Freight Corridors

S.No	Corridor	Distance (Kms)
1	East – West Corridor (Kolkata – Mumbai)	2000
2	North-South Corridor (Delhi-Chennai)	2173
3	East Coast Corridor (Kharagpur-Vijayawada)	1100
4	Southern Corridor (Chennai-Goa)	890

Source: KPMG Analysis

Railways could consider LNG fuelled locomotive option for these corridors as natural gas pipeline connectivity at major locations along these corridors is a reality, moreover works for electrification of these corridors have not yet started and huge capital investment for electric traction could be avoided.

Current activities around LNG locomotives in India and way forward:

- Ministry of Railways - Indian Railways Organization For Alternate Fuels embarked on a project for :

✓ Use of LNG in the railways system for main line locomotives such as ALCo (American Locomotive Company), EMD Electro-Motive Division)and gas turbine locomotives

✓ MoU has been signed with Indian Oil Corporation for LNG on-board enabling Indian Railways to adopt technologies like HPDI etc. for higher substitution of Diesel for main line engines and shunting engines.

- Patiala based railway engine manufacturing unit initiated pre-production exercise to manufacture LNG locomotive

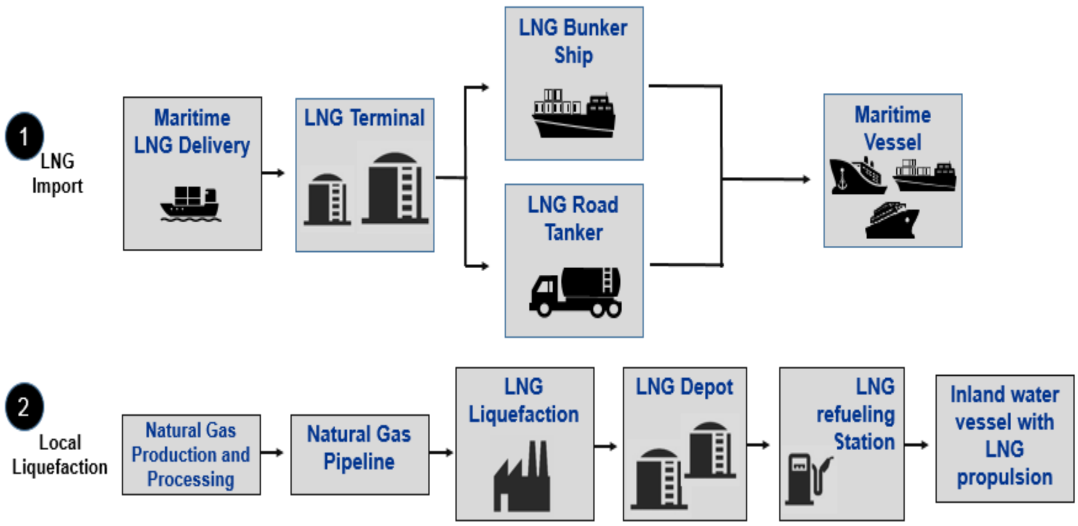
While there is huge upside potential for large scale deployment of LNG locomotives, it is equally important to address the following aspects to make LNG fuelled locomotive a reality:

- Identifying the railway networks & refueling stations along those networks where the economics of LNG locomotives makes most sense
- Adequate capacity creation in terms of LNG imports and tie up for supplies to meet the demand
- Parallel implementation road map for modular LNG fuelling infrastructure for on-site production of LNG at identified refueling stations and supporting policies and regulations with the involvement from key stakeholders- Railways, Gas Suppliers, OEMs & Regulator.

7.4 Marine Transport

A marine vessel is a ship or watercraft or other artificial contrivance used or capable of being used as a means of transportation on water. Marine vessels largely operate on liquid petroleum fuel also known as bunker fuels, which includes marine residual oil or marine distillate, residual fuel oil and high speed diesel. Vessels are categorized into Off-shore Supply/Service Vessel, Car/Passenger Ferry, Patro Vessel, Roll-on/Roll-off (Ro-Ro) Ship, LNG Tanker, Bulk Ship, Container ships etc. Merchant marine comprises of all ships engaged in the carriage of goods or commercial vessels, which excludes fishing vessels, tugs, offshore oil rigs, etc. LNG can be used as an alternate fuel in maritime transport. Globally the natural gas engine technologies used for large marine vessels are spark-ignited lean-burn and dual-fuel diesel pilot ignition.

Figure 47: LNG Supply options for Marine Vessels



Source: Federal Ministry of Transport and Digital Infrastructure (BMVI), Berlin

The purpose of a water vehicle identifies its utility with a maritime industry sub-sector which typically falls under transportation of passengers or cargoes, resource extraction, conducting combat or salvage operations, seismic operations etc. The advantages of maritime transport lie in its cargo capacity (transporting bulky and heavy goods) and fuel efficiency. Dry Bulk carriers[40], Containers[41] and Tankers[42] will benefit from using LNG as an alternative fueling option. Shipping produces less noise pollution and is a safer mode of transport when compared with trucks and trains.

Policy & Regulatory Interventions and Other Enablers

- Ministry of Shipping , Maritime Agenda by 2010-20

✓ Proposal for designation of an Emission Control Area (ECA) for specific portions of Indian coastal waters for the control of nitrogen oxides (NOx), Sulphur oxides (SOx), and particulate matter (PM) emissions

[40] Vessels that transport dry bulk goods such as grain, cement, coal, and steel.
[41] Container vessels transport containerized goods
[42] Vessels that transport bulk liquid products

✓ The new emission standards put forth by International Maritime Organization (IMO) to reduce maximum sulphur emissions limit for all ships operating in designated ECAs by 2015

- The Merchant Shipping Act of 1958 (MS Act)
- The Merchant Shipping (Prevention of Pollution of the Sea by Oil) Rules, 1974

LNG has low environmental emissions with regard to traditional fuels such as Marine Diesel Oil (MDO), residual fuel oil etc. and has slightly higher energy density compared to other marine fuels. The higher energy utilization of LNG help vessels save operating costs. LNG is considered to be the cleanest fuel that can meet existing and upcoming requirements for the main types of emissions of SOx, PM, NOx, and CO_2. Worldwide marine operators are turning to LNG to power vessels due to increase in marine fuel prices and due to tighter international emission regulations phasing in. In this regards, alternating fueling options become necessary. The imposition of Emission Control Areas[43] (ECAs) by the International Maritime Organization (IMO) is the primary regulatory directive driving adoption of LNG in the marine sector. Global refining, commercial shipping and bunkering industries will be affected as any ships/vessels travelling through ECAs will be forced to shift to low sulphur fuels. Delaying investments in cleaner technology in vessel fleets to comply with these regulations can lead to additional costs in the future for companies that have not tackled these issues proactively. In order to abide by these regulations, companies are preparing themselves by shifting to alternate fuels such as LNG, paying a premium for low-sulphur fuels, installing scrubbers to reduce SOx emissions etc.

Figure 48: Emission Control Areas - IMO

Source: Sigmahellas, IMO

As of date, Rolls-Royce has delivered a total of 63 LNG engines to ships globally. LNG is an option for not just new vessels but can be successfully retrofitted[44] into existing ships to provide significant economic and environmental benefits. According to Petronet, there are about 100 LNG-powered ships and 400-odd carriers worldwide running either fully or partly on LNG as a fuel. The

[43] Coastal regions where marine vessels must reduce emissions of sulfur oxides
[44] Bergen Viking (a 95 m long chemical and product tanker) has successfully retrofitted to LNG (Source: Rolls-Royce.com)

LNG terminal of Petronet LNG Limited (PLL) located at Puthuvype has successfully provided 130 tonnes of LNG to a marine vessel KVITBJORN during its maiden voyage from China to Europe. PLL expects that bunkering facilities can effectively add to the capacity utilization of the terminal. As per world fact book data, there are a total of 104 bulk carriers, 78 cargo carriers, 22 chemical tankers and 14 container vessels in India. These vessels are of 1000 GRT[45] (gross register tonnage) or above and holds a huge potential for shift to LNG fuel.

7.4.1Economics of Use

The economics of use for marine vessels will vary depending upon the annual vessel utilization and fuel use, delivered LNG price and vessel conversion costs. The economics will be significantly improved if the project can take advantage of existing LNG import or production capacity within a reasonable distance of the vessel home port. Since marine transport has to comply with global emissions regulations, the cost of complying with stricter emission regulations should also be considered that will require use of low sulfur fuels for marine vessels in the future. Especially for the vessels operating in the U.S waters and in the North American and Caribbean Sea ECA, will require a switch to more expensive distillate fuel or installation of expensive emission controls for vessels that currently burn residual fuels. These vessels include LNG carriers, cruise ships, cargo vessels and Great Lakes ore carriers.

According to Research and Markets[46], bunker fuel costs account for nearly 70% of the total voyage expenditure for a vessel and ship operators prefer purchasing bunker fuel from ports where the prices are reasonable. Some operators prefer purchasing a major portion of the total fuel requirement from a single port which offers fuel at economical prices.

Based on a study conducted by American Clean Skies Foundation on Natural Gas for Marine vessels, the typical fuel usage and fuel storage[47] volumes for typical marine vessels are shown in table 55 below.

[45] GRT is obtained by measuring the entire sheltered volume of a ship available for cargo and passengers and converting it to tons on the basis of 100 cubic feet per ton

[46] Source: Bunker Fuel Market - Global Industry Analysis, Size, Share, Growth, Trends, and Forecast 2014 - 2020

[47] Data provided is representative as within any class of vessels, a range of vessel sizes and operating conditions affect annual fuel usage. Assumptions - 68% engine load factor, 12 hours of daily operation for ferry, 15 hours for tug and 24 hours for ore carrier. All vessels assumed to operate ~300 days/year.

Table 55: Fuel usage and storage – Marine vessels

sel	Type		Daily Fuel Use (gal)	Typical minimum fuel storage On-board (days)	Volume of fuel storage		
					Distillate or Residual (ft^3)	LNG (ft^3)	CNG (ft^3)
Towing Tug	Distillate	3000	1417	14	2674	4830	12178
100-car Ferry	Distillate	6000	2268	7	2139	3864	9742
reat Lakes Ore Carrier	Residual	10000	6934	21	19,385	38,183	96264

Source: American Clean Skies Foundation on Natural Gas for Marine vessels

In the case study analysed, over a ten-year period the fuel savings are as shown in table 56.

Table 56: Fuel savings – Marine vessels

Vessel Type	Fuel Savings (USD Mn)
Typical tug	7
Medium-sized Ferry	11
Great Lakes bulk carrier	20

Source: American Clean Skies Foundation on Natural Gas for Marine vessels

7.4.2 Macro-economic Impact

There would be significant forex savings for Fuel Oil replacement in LNG marine vessels as the use is directed towards long distance travel. Each litre of Fuel Oil replacement results in forex saving of $ 0.121 (or 12.1 cents).

7.4.3 Environmental Impact and Legislatures

Ships emit almost 8% of global sulphur dioxide emissions[48] and shipping emissions are expected to increase by 5%[49] by 2020 due to increase in international shipping traffic in the northern hemisphere. The reduction in CO_2 emissions by using LNG is around 12% per tonne of fuel or 30%

[48] Source: Eurosif Shipping
[49] Source: The costly future of green shipping – Schroders

per MJ[50] of energy generated when compared with heavy fuel oil. LNG reduces Nitrogen Oxide (NOx) emissions by about 90 per cent[2] while Sulphur Oxide (SOx) and particulates emissions are negligible. LNG engines also reduce CO_2 emissions[51] by 25-30 % in general, compared to diesel or heavy fuel oil powered vessels.

7.4.4 Maturity

Table 57: Maturity – Marine Vessels

Maturity	Commercial Availability	Vendor Availability	Awareness	Skill/Know how	Visibility	Current Usage
Application Service	Low	Low	Medium	Low	Low	Low
Technology	Medium	Medium	Medium	Medium	Medium	Low

Source: KPMG Analysis

7.4.5 Market Size

Worldwide there are 42 LNG fuelled ships[52] are in operation as of 2013 excluding LNG carriers and inland waterway vessels and 30 are under construction. According to DNV Shipping 2020 study, 4.4 MT of LNG per annum is required by 2020 for 1000 LNG fuelled ships. Forecast for Middle East & India region as per the DNV study is ~90 ships by 2020.

Table 58: Market size potential – LNG Locomotives

Market size potential
~1.42 MMSCMD
As per DNV Shipping study approximately 9% of 4.4 MT forecasted for 1000 LNG fuelled ships in 2020 would be consumed in the Middle east and India region.

Source: KPMG Analysis

7.4.6 Industry Speak

Demand for LNG as a fuel in the shipping industry is increasing due to emissions reduction requirements by International Maritime Organization especially to cut the sulphur emission levels of bunker fuel. Stricter environmental regulations will thus provide incentives for using LNG as marine fuel which emits fewer Green House Gases. In the current Indian context bunker fuel facility at LNG terminal offers an additional stream of revenue and leads to increased utilization of

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[50] Indian Maritime University
[51] Source: Rolls-Royce
[52] Excluding LNG carriers and inland waterway vehicles

the terminal. Both LNG and methanol have recently been used worldwide as alternate marine fuels.

7.4.7 Barriers

Refuelling infrastructure at terminals and uncertainty of LNG prices are the major barriers for functioning of LNG fuelled ships. Cost for retrofitting or building a LNG propelled ship is highly capital intensive.

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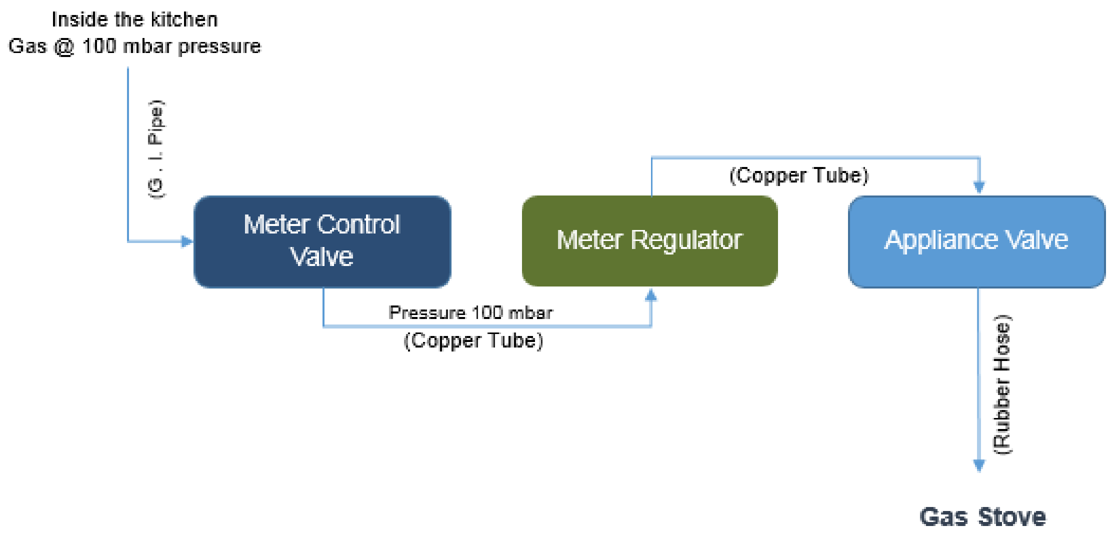
8 Other Applications

8.1 Cooking

Natural gas cooking uses cooktops that has a burner on top and uses gas (LPG or PNG) to burn a flame that is used to cook food. Natural gas cooking produces steam as a by-product. The gas stove burner consists of a burner attached to a small gas valve connected to the main gas line. When the knob is turned on the intake valve opens and gas flows through a venturi[53] tube - a wide pipe that narrows in the middle. The oxygen gas mixture that is formed as the gas passes through the tube is combustible and creates the flame. The schematic of PNG Domestic connection for Cooking is shown in Figure 48.

Figure 49: Schematic of PNG Domestic connection for Cooking



Source: KPMG Analysis

Natural gas cooking is mainly used in commercial kitchens (hotels, restaurants etc.), domestic applications and other establishments that require cooking facilities. Many new gas cooktops and ranges come with special high-Btu burners for rapid heating and low-Btu burners for simmering. Natural gas cooking is convenient and provides consistent supply hence is a reliable source of fuel. There is no specific utensil type required and no dependence on electricity provides hassle free cooking during power cuts. These cooktops/ranges are efficient, quick and provide accurate temperature control with fast response time.

- PNGRB CGD Bidding - Round 6
- Gas Utilization Policy – As per the policy CGD sector is prioritized after fertilizer, power and petroleum products

The key developments in the policy front are described in Table 55 below;

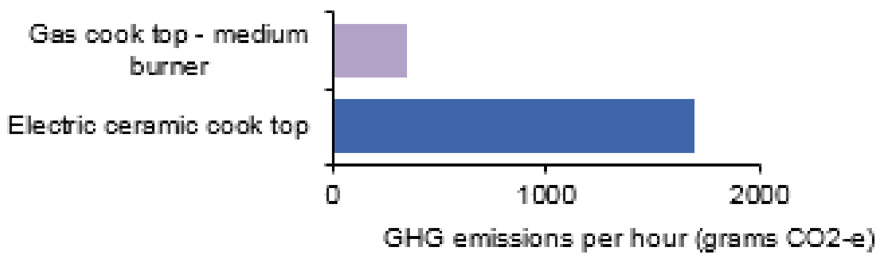
Table 59: CGD – Policies and Regulations

2006	PNGRB Act
2007	Government of India notified the Board and the Act
2008	CGD regulations notified by PNGRB
2008	Pipeline regulations notified
2009	PNGRB published EOI's for more than 60 cities (1st and 2nd Round of Bidding)
2011	3rd Round of CGD Bidding
2011	4th Round of CGD Bidding (Cancelled)
2013	4th Round of CGD Bidding (Resumed)
2015	5th Round of CGD Bidding

Source: PNGRB

Natural gas cooking ranges are quick, efficient and provide accurate temperature control. They heat quickly and reduce GHG emissions by around 75% when compared to induction cooking.

Figure 50: GHG emissions – Gas and Electric cooktop



Source: AGA

Currently five rounds of City gas distribution (CGD) bidding are completed in multiple cities where piped natural gas (PNG) networks are operative. The sixth round bidding has started. Industries and commercial establishments are the main consumers of piped natural gas.

8.1.1 Economics of Use

The economics of using PNG as a domestic cooking fuel is computed by the cost comparison of using natural gas versus alternative fuel/energy source for Cooktops

- In order to test whether it is economical to use natural gas cooktops, cost of piped natural gas (PNG) for boiling water at various possible gas prices is compared to the next best alternatives, namely, electric & LPG- Subsidized & non-subsidized based cook tops.
- Efficiency factoring is taken into calculation as there is large variation in efficiencies of gas based (40%) and induction based cooktops (84%)

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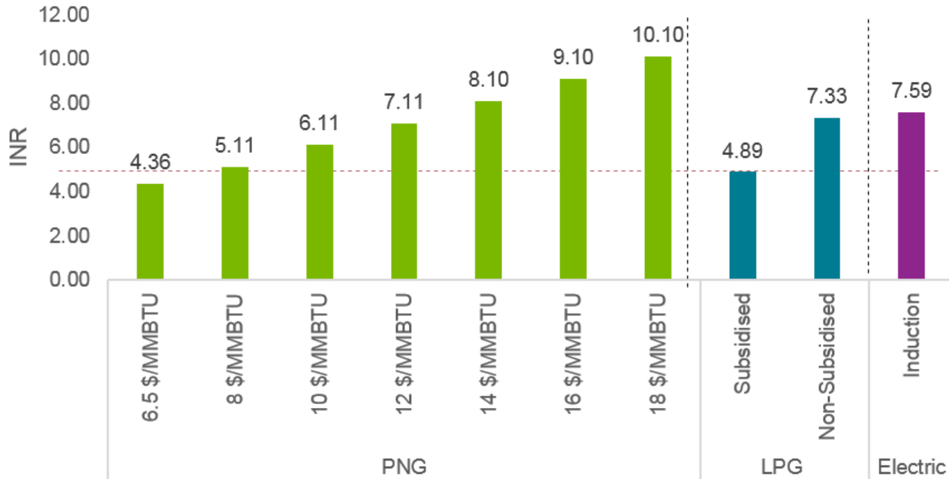
Figure 51: Economics of Use: Cooking



Source: KPMG Analysis

From the graph we can observe that:

- The cost of PNG is economical to subsidized and non-subsidized price of LPG around delivered price of $ 6.5/MMBTU and $ 12.5/MMBTU of natural gas at city gate station

- However, extensive pipeline network is laid by city gas distribution entities for supplying PNG to households and margins of PNG domestic segments to the entities remain at low level
- The cost of using natural gas based cooktops is lower than using an Induction cook top up to a delivered price of $ 12.5 /MMBTU of natural gas at city gate station

Hence, PNG is economical for use up to a delivered price of $ 6.5/MMBTU when compared to the subsidised price of LPG. In the scenario when LPG becomes non-subsidized, use of PNG will be economical up to a delivered price of $ 12.5/ MMBTU.

8.1.2 Macro-economic Impact

Gas allocation policy acts as a subsidy equivalent for City gas distribution system providing PNG for domestic and commercial cooking purposes.

8.1.3 Environmental Impact and Legislatures

When natural gas burns completely, it gives out carbon dioxide and water vapour which are the very components that is exhaled hence safer than its counterparts. CPCB monitor commercial setups on the basis of emission loads as a part of cooking using LPG/PNG in commercial setups especially restaurants, bakeries etc. CPCB evaluates air quality and puts forth safety measures in the light of diseases such as respiratory problems, TB and Lung diseases.

8.1.4 Maturity

The availability of PNG domestic gas for the purpose of cooking is based upon the CGD bidding scenario. In comparison to the alternative options, PNG availability is low. From a technology standpoint there is adequate availability of vendors but the usage is low in comparison to LPG usage.

Table 60: Maturity - Cooking

Maturity	ommercial Availability	Vendor Availability	wareness	I/Know how	Visibility	Current Usage
Application Service	Low	Low	Medium	Medium	Medium	Low
Maturity	High	Medium	Medium	Medium	Medium	Low

Source: KPMG Analysis

8.1.5 Market Size

India has a significant difference in choice of fuels in the rural and urban set up. Almost 80% of rural homes in India continue to use biomass (firewood), crop residue or cow dung as their primary cooking fuel[1.] Households in Urban India opts for cleaner and convenient cooking fuels like Liquefied petroleum gas (LPG) or PNG. As on 30.09.2014, there are a total of 2,670,423 households with Domestic PNG connections across the country (shown in Table 57). The consumption of gas in the CGD network during 2013-14 was around 15.48 MMSCMD out of which 8.60 MMSCMD was used for CNG (transport) & PNG (domestic).

Table 61: CGD Infrastructure

State	City Covered	Company	stic PNG	. PNG	Ind. PNG
Delhi	Delhi, Noida, Greater Noida, Ghaziabad.	IGL	496954	1421	673
Maharashtra	Mumbai, Thane, Mira-Bhayandar, Navi Mumbai, Pune, Kalyan, Ambernath, Panvel, Bhiwandi	MGL, MNGL	760130	2476	146
Gujarat	Ahmedabad, Baroda, Surat, Ankeleshwar	GSPC, Sabarmati Gas, Gujrat Gas, HPCL, VMSS,Adani Gas	1335046	16407	3842
Uttar Pradesh	Agra, Kanpur, Bareilly, Lucknow,	Green Gas Ltd. (Lucknow), CUGL(Kanpur)	13027	129	444
Tripura	Agartala	TNGCL	15413	279	47
Madhya Pradesh	Dewas, Indore, Ujjain, Gwalior	GAIL Gas, AGL	2803	29	67
Rajasthan	Kota	GAIL Gas	189	1	17
Assam	Tinsukia, Dibrugarh, Sibsagar. Jorhat	Assam Gas Co. Ltd	26934	890	371
Andhra Pradesh	Kakinada, Hyderabad,Vijaywada,Rajamundr y	BGL	2287	46	3
Haryana	Sonepat, Gurgaon, Faridabad	GAIL Gas, Adani Gas, Haryana City Gas	17640	37	279
Total			2670423	21715	5889

Source: PPAC

Due to higher per capita incomes of urban areas, larger per capita household expenditures, higher average levels of education and greater ecological consciousness; more urban homes opt for cleaner fuels like LPG or piped natural gas (PNG) in comparison to rural households. PNG connection are preferred with regard to safety aspects. For instance on an event of leakage, LPG expands 250 times whereas supply in PNG can be switched off through the appliance valve inside the kitchen and isolation valve outside kitchen premises which fully cuts off the gas supply. Households which have received PNG connections face a lot of issues with regard to billing and lack of knowledge of technicians in proper installation of PNG system; which makes LPG still a preferable and hassle free choice.

Table 62: Market size potential – Cooking

Market size potential
~47.16 MMSCMD
Alternate fuel consumption of Packed LPG for Domestic use is considered as the market potential for cooking. LPG consumption growth rate of 6.97% (PPAC) is considered.

Source: KPMG Analysis

8.1.6 Barriers

The major barriers facing the sector are summarized below:

- Many households despite being required by law have been reluctant to surrender their LPG cylinders when they receive connections to PNG resulting in an increasing number of double connections as the PNG network expands which leads to inefficient consumption and diversion of LPG cylinders for commercial use
- There are numerous PNG complaints mainly for delay in getting pipeline connection even though consumers have deposited their initial payment
- Waiting period for a PNG connection is not defined clearly by certain operators
- The biggest challenge for the CGD segment is the shortage of domestic gas which has made them to rely on costly imports of LNG. However, operators have observed consumer's willingness to pay for the high-priced LNG and thus have been able to operate successfully

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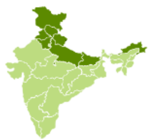
9 Snapshot of Analysis

The above analysis is summarized highlighting the key parameters (shown in Table 59) in order to narrow down to the applications which see a large potential in the short term period ahead by addressing the major gaps/barriers. The summary of the parametric analysis above is shown in Figure 51.

Table 63: Summary of Analysis – Parametric Key

Price Affordability ($/MMBTU)		Affordable in the entire range of gas prices considered
		Affordable up to gas price in the range $ 10-15 /MMBTU
		Affordable up to gas price in the range $ 6.5 -10 /MMBTU
Geographical Spread		Pan-India
		Pan-India with higher usage in northern regions
		National Highways and Golden Quadrilateral
		Diamond Quadrilateral Railway Corridors
Environmental Benefits		High carbon emission savings
		Alternatives have lower carbon emissions
		Alternatives have no carbon emissions

Efficiency		Highest efficiency amongst best next alternatives
		Alternatives have better efficiency
		Alternatives have the highest efficiency

Source: KPMG Analysis

The key parameters for each of the above applications are shown in Figure 52. Industrial applications like Burners, Furnaces, Boilers and Thermic Fluid Heaters although seem to be promising applications for natural gas usage based on the affordability and environmental benefits, the potential market size for the segment as a whole is less compared to other standalone applications. These applications are not considered for detailed international study. However, the high level schemes and enablers for these applications are covered in the subsequent sections. The assumptions are listed in table.

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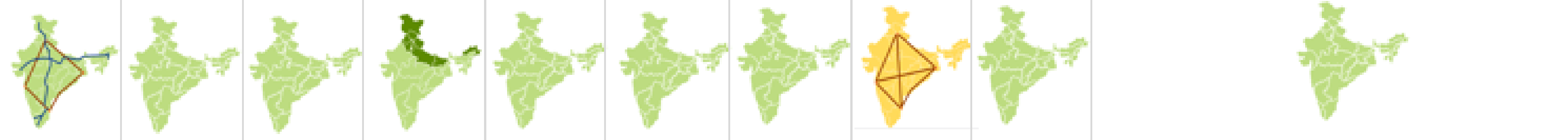
Figure 52: Summary of Parametric Analysis

End-use Application	LNG Vehicles	Bulk Power	DPG	Gas Geysers	CNG Vehicles	Cooking	CHP	LNG Locos	Ancillary Services & Peaking Power	Direct-fired Burners	Thermic Fluid Heaters	Boilers	Furnaces
Potential Market Size (mmscmd) 2020	*109.16*	*108*	*67.7*[a]	*66.22*	*60*	*50.8*	*35*	*8.41*	*7.95*	*18.97*[d]			
Price Affordability ($/mmbtu)	16	8.28	NI[b]-14.6 I[b]-11.8	10.5	All prices	S- 6.5 NS -12.45	11.27	All prices	13.49	All prices			
Geographical Spread													
Environmental Benefits	Medium	High	High	Low	Medium	Low	High	Medium	Medium	High	Medium	High	High
Efficiency	Medium	Medium	High	Low	Medium	Low	High	Low	Medium	High	Medium	High	High
Forex Savings	-	-	10.4[e] cents/l of Diesel replacement	-	10.4 cents/l of Diesel replacement	-	-	10.4 cents/l of Diesel replacement	-	-	10.4 cents/l of Diesel replacement	-	12.1[f] cents/l of FO replacement
Industry Preference	Not Preferred	Preferred	Preferred	Preferred	Preferred	Highly Preferred	Highly Preferred	Highly Preferred	Not Preferred	Preferred	Preferred	Preferred	Preferred
Selection for International Review	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗

Total Universe of Demand 531.41 MMSCMD

Source: KPMG Analysis

Table 64: Assumptions – Summary of Parametric Analysis

1	• Alternate fuel consumption of diesel by HCV/LCV and Buses category of vehicles is considered for evaluating market potential .Diesel consumption share sourced from Nielson Report 2013 • Diesel consumption growth rate of 4.11% is taken to determine 2020 potential
1[a]	• V - Price affordability for LNG Vehicles • VL - Price affordability for LNG Vehicles when liquefaction charges are considered
2	• Natural gas consumption for the total installed capacity of gas based power (23,062 MW) @ 75% PLF , SHR of 2100 kcal/kWh and Calorific value of 9880 kcal/SCM is taken for determining market potential • No future capacity addition up to 2020
3[a]	• Distributed Power Generation is categorized as per Non-Industry (NI) use which include Gas Gensets with capacity < 50 MW used in residential and commercial applications and Industry (I) Use which includes captive power plants with capacity < 50 MW • For non-industry usage, alternate fuel consumption of diesel for non-industry gensets is considered for evaluating the market potential and a genset market growth rate of 7.5% is used for escalation • For industry usage, current diesel/liquid fuels based captive power plants is taken as the market potential with an industry growth rate of 6.5% (IIP) up to 2020 • Market potential for Non-Industry - 27 MMSCMD • Market potential for Industry – 41 MMSCMD
3[b]	• NI - Non-Industry price affordability up to $ 14.6 /MMBTU • I - Industry price affordability up to $ 11.8 /MMBTU
3[e]	• Diesel yield of 29% per barrel of crude (EPA)
4	• Potential determined on the basis of natural gas consumption to heat 60 L of water in urban and rural households across Northern and Southern regions • Northern Region – Gas consumption in SCM to heat 60 L to raise the temperature by 35 degrees per day for 300 days • Southern Region – Gas consumption in SCM to heat 60 L to raise the temperature by 25 degrees per day for 150 days • 90% of urban households and 40% of rural households use water heaters
5	• Alternate fuel consumption of diesel by Cars & Utility Vehicles (Private & Commercial) and petrol consumption by Cars category of vehicles is considered for evaluating the market potential • Diesel consumption share – 22.09% (Nielson Report 2013) • Petrol consumption share – 35.83% (Nielson Report 2013) • Diesel consumption growth rate of 4 % (PPAC) • Petrol consumption growth rate of 7 % (PPAC)
6	• Alternate fuel consumption of Packed LPG for Domestic use is considered for evaluating the market potential for cooking • LPG consumption growth rate of 6.97% (PPAC)

7	• According to IEA, there is a potential over 14 GW of industrial CHP in a wide range of sectors with nearly 9 GW outside the sugar industry • Share of Natural gas as per current CHP systems in India is 50% (IEA)
8	• Alternate fuel consumption of Diesel for Locomotives is considered for evaluating the market potential • Annual consumption of diesel for 2013-14 sourced from IRCTC • Diesel consumption growth rate of 2.78 % for railways in the last 10 years
9	• According to the National Electricity Policy, a spinning reserve of at least 5%, at national level, would need to be created to ensure grid security, quality and reliability of power supply. • Gas based Ancillary services and Peaking Power potential @ 12% PLF (3 hours usage per day) on total installed capacity (excluding RES) is considered for evaluating the potential • No future escalations are considered
10,11, 12, 13	• Alternate fuel consumption of LPG, LSHS, FO, Bulk LPG which are alternatives to natural gas for industrial applications which included direct-fired burners, thermic fluid heaters, Furnaces and Boiler • A combined potential is determined for these applications with a growth rate of 6.5% (IIP)
13[f]	• Fuel Oil yield of 4% per barrel of crude (EPA)

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10 Road Ahead

In order to enhance the share of natural gas usage for the selected end-use applications which have a good potential in the short term period ahead, the penetration of natural gas end-use applications internationally are studied to obtain key learnings to develop an action plan for India. The countries that have a similar natural gas ecosystem to that of India, other markets where the growth of natural gas market have been exponential over the last few years and those where certain applications are successfully implemented are referenced to suggest a suitable work plan to address the major gaps identified. By supporting policy and regulations, the usage of natural gas in India’s energy portfolio may be increased in an organic way to reach some of India’s envisioned energy objectives.

The work plan is discussed is in Table below.

Figure 53: Work Plan - International References

End-use application	jor barriers/gaps	International References		Action Plan
	• No Emission Considerations • Affordable gas availability challenges		• US Environmental Protection Agency established a jurisdiction over power plant emissions • Coal-to-gas switching economic incentive • Investments in developing next generation combined cycle gas turbines	• Specific ‘Green’ Power Plant Policy targeting New Power Plant and Existing Power Plant Emissions • Incentive schemes for Technology upgrade in existing gas power plants
G	• No government initiatives to promote gas-based gensets		• Government’s 12th Five Year Plan for development of distributed energy • Local natural gas development planning for distributed power generation facilities	• Inclusion of Distributed Power Generation capacity as a part of key development projects • Incentives for collaborative scheme for CHP/CCHP projects using gas based generators
P	• High capital cost of CHP equipment -Challenge for further deployment of CHP particularly as policies benefit primarily biomass and bagasse CHP projects • Limited Incentives for CHP using natural gas • Gas availability constraints – CHP not a		• Regulations around tax incentives and credits for CHP systems • Production Incentives based on gas efficiency • Rebates to support customers who install natural gas based CHP systems • Funding programs undertaken by Gas utilities	• *Rebates for energy efficiency, performance rebates, and advanced gas technology in CHPs* • *Gas Utility driven initiatives for CHP projects for Commercial customers* • *Financing/Funding arrangements for natural gas CHP projects* • *CHP-Grid Integration projects where electricity can be sold to the grid without*

End-use application	jor barriers/gaps	International References		Action Plan
	priority sector as per Gas Allocation Policy		• Grid Electric's CHP Program for Advanced Gas Technology Incentives	*factoring transmission and distribution charges*
CNG Vehicles	• Unauthorized dealers of CNG kits compromise safety in CNG usage • Reduction in life of engine by retrofitting with CNG kits • Safety hazards a prime concern • Geographical spread in the present context is an issue		• *Well established public refuelling stations and home refueling options* • *Peak hour usage rebates* • *Income tax credit for natural gas refueling equipment's* • *Fuel tax credits for business's that use CNG as transportation fuel*	• *OEM technology upgrades to facilitate tri-fuel options* • *Infrastructure plan to increase the number of CNG fuel stations as a part of CGD bidding process* • *Centralized accreditation for efficient CNG kits as a part of safety norms* • *Rolling of CNG highways enabling CNG infrastructure creation*
			• *Tri-fuel technology that operate on gasoline, ethanol or natural gas* • *Conversion Incentives - Reduction in annual vehicle registration tax*	
Gas Geysers	• Low penetration of PNG markets • Subsidized LPG usage is popular • PNG gas geysers are economically unviable to LPG geyser at subsidized price		• Clean Energy Program to promote increased energy efficiency and use of clean sources of energy to fulfill state objectives • WARMAdvantage Program provides rebates for qualifying high efficiency water heaters	• Specific policies for domestic natural gas usage for heating requirements • GOI Incentives in the form of discounts for energy efficiency installations in households
LNG Vehicles	• Lack of LNG refueling infrastructure		• Expansion of access to Liquefied Natural Gas as a transport fuel • Increased financing for LNG Fueling Infrastructure projects along major highways	• Pilot project for enabling LNG truck usage for large fleet carriers • Planning document for future LNG highway refueling infrastructure
LNG Locomotives	• Electric locomotives have lower variable cost compared to diesel and LNG locomotives		• Regulatory initiatives to address issues related to onboarding of LNG locomotives	• *Pilot project for enabling LNG railway usage for long distance fleet and passenger locomotives*

End-use application	jor barriers/gaps	International References		Action Plan
	• Fuelling Infrastructure challenges		• Capital Investments planned for deployment of LNG locomotive projects	• *Planning document for future LNG Railway refueling infrastructure*
Cooking	• Low penetration of PNG • Subsidized LPG		• Well spread Gas Distribution Network • Energy Regulator's RIIO[1] initiative to monitor performance of gas utilities • RIIO targets set for six key areas namely safety, reliability, customer service, environment, connections and social obligations	• Utility driven initiatives for ensuring safety of PNG connections, ease of connection and withdrawal schemes • Shift from commodity based to Service oriented model of operation
Ancillary Service & Peaking Power	• No policy or regulatory enablers for purchasing gas based power as Ancillary Services (AS) • No takers for Ancillary Services as the market has severe issues to address for optimum base load generation • Hydro-based AS is most economical • No dedicated policy for Peaking Power Utilities do not have any supply obligations and they can resort to load shedding during peak demand • Fuel prices and gas availability are the major supply side barriers		• Nation Grid Balancing Services Scheme particularly designed to be able to deal with unforeseen demand increase and/or generation unavailability • Fast Reserves used to control frequency changes • Reserve services have well defined participation criteria, technical requirements and assessment process • Capacity Market rules favoring peaking power assets where different lengths of capacity agreement is available	• Identification of key Ancillary service providers • Incentives for using Gas based power generation for Ancillary Services – Creating reserve capacity market • Incentivizing peak power assets • Dedicated Gas based peaking power generation –OCGT plants

Annexures

A Natural Gas Markets – International Reference

Among top 13 energy consuming nations, we have analysed the share of Natural Gas in their primary energy mix. Amongst these nations the most evolved markets have gas pricing being determined based on market forces of demand and supply hence creating trading hubs for natural gas. For e.g. the US has a physical gas trading hub whereas the UK has a virtual trading hub for gas. As a part of this study key countries will be identified on which case studies for the relevant end-use gas applications will be carried out. This will include both mature and emerging markets.

Country	Approx. Share of NG in Energy Mix
Iran	60%
Russia	53%
Saudi Arabia	41%
UK	33%
US	30%
Canada	28%
Germany	23%
Japan	22%
South Korea	17%
France	16%
Brazil	12%
India	8%
China	5%

Figure 54: Share of Natural gas in Primary Energy Mix

Source: BP/Energy Economics/Statistical Review 2014

The penetration of natural gas in the world is over 23%. Certain countries have a greater contribution towards this share, with high penetration of natural gas based applications on account of specific initiatives taken by them, namely:

- Policy
- Regulatory
- Fiscal

As per study conducted by Shakti Sustainable Energy Foundation in association with ICF on "Facilitating development of appropriate natural gas (NG) pricing and allocation policies", a detailed analysis was conducted on the developed markets like US and UK; and on developing markets like China. The Indian gas market was compared to these countries on the basis of their competitive supply, supply infrastructure, regulatory environment and sustainable demand centres. We see that the developed markets are well equipped with adequate supply infrastructure and enabling regulatory environment. These factors could be the sole contributors towards increased usage of end-use applications hence further study of key applications in these countries can be helpful to build a road map for India.

Parameter / Country	Competitive Supply	Well-developed supply infrastructure	Regulatory environment – Unbundled; TPA[54] on infrastructure	Sustainable demand centres (without subsidy)
USA	✓	✓	✓	✓
UK	✓	✓	✓	✓
China	Controlled by 3 state-owned companies	Limited nature of pipeline connectivity is being addressed	None	
India	✓[55]	Negative	Negative	Negative[56]

Figure 55: Comparative Analysis of India with other markets

Source: Shakti Sustainable Energy Foundation and ICF report on gas pricing

The key aspects of the evolution of gas markets in these countries on the policy, regulatory and fiscal front are discussed in brief in the subsequent sections.

A.1 Developed Markets Overview – US & UK

A.1.1 Overview of US Natural gas Market

[54] Third Party Access
[55] Market lacks depth with supply concentration in a few players
[56] Consumers are heavily subsidized

The US Natural Gas market has ample domestic supply of gas at low prices which has favoured the development of gas market in the country. The industrial demand has been an anchor for NG market development, however the power sector has surpassed industrial consumption due to the low gas prices in the last decade which is lower than coal as well. Natural Gas has second highest share (~27%) in US energy mix (shown in Figure). It is widely used in industrial, residential, commercial and electricity generation sector.

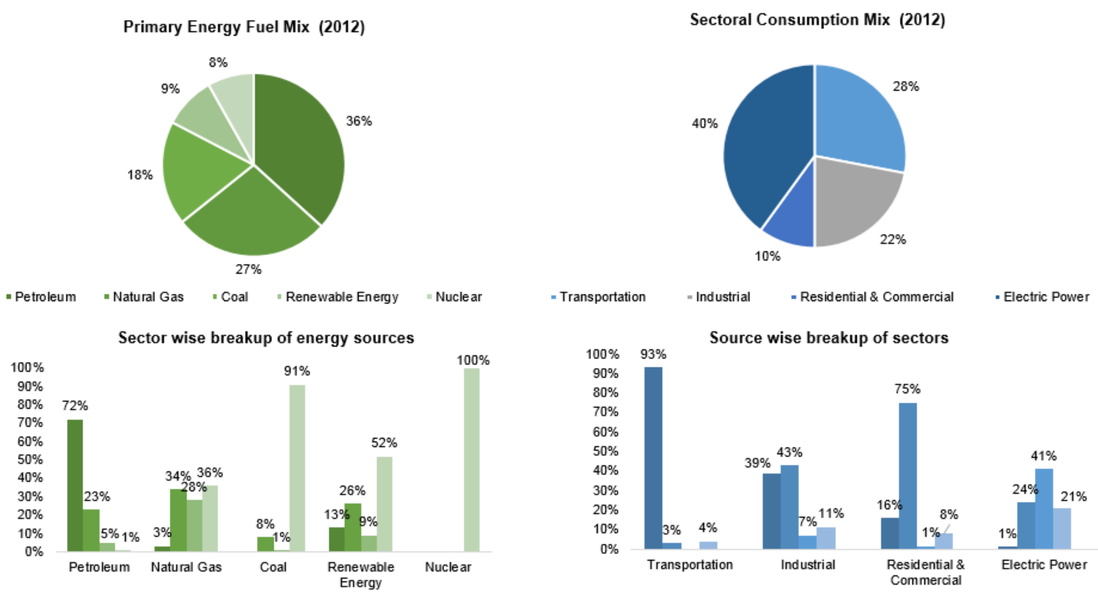

Figure 56: US Energy Fuel Mix & Sectoral Consumption Mix

Source: US Energy Information Administration, Monthly Energy Review (Jan'14)

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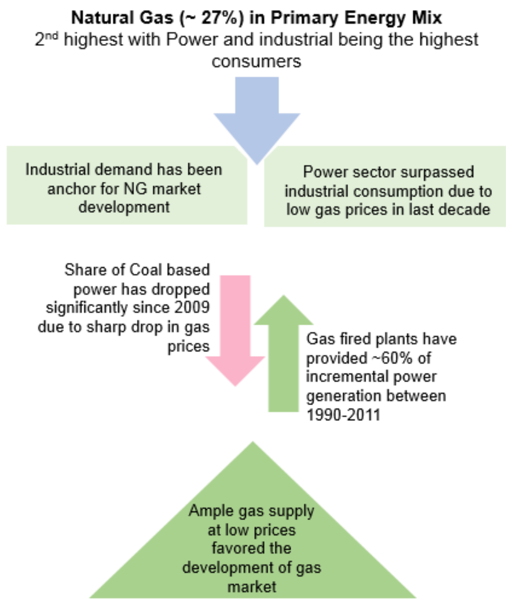

Key Milestones in the Policy and Regulatory Front
Evolution of competitive gas market in US

1938	**Natural Gas Act**	• Federal and State regulators for inter and intra state pipelines respectively • Cost of service regulation • Inter-state and Intrastate pipelines provided bundled service • No Price controls
1954	**Supreme Courts (SC) Phillips decision**	• SC interpreted that 'Just and reasonable rate' regulation required for producers along with pipelines • Take or Pay contracts between producers and P/L ; and between pipeline and LDCs • Price ceiling set on well-head prices for inter-state sales and no price control for intra-state sale
1978	**Natural Gas Policy Act of 1978**	• Artificially low well-head gas prices led to increasing gas demand-supply gaps and gas supply curtailments • Take or pay contracts continued • Partial phased deregulation of prices • Price ceilings extended to intra-state sales
1984-85	**FERC Orders 380 and 436**	• Non-discriminatory Voluntary TPA • Transportation minimums and maximums set. Within the boundaries pipelines are free to offer competitive rates • LDC's allowed to exit Take or Pay obligations to Pipelines • Netback pricing for new supplies
1989	**Natural Gas Wellhead Decontrol Act**	• Complete deregulation of gas prices (well-head price is market determined and gas price is pass through to end consumer)
1992	**FERC Order 636**	• Mandatory TPA • Full unbundling of transportation, storage & marketing

Figure 57: Key Policy and Regulatory reforms in the US Natural Gas Market

Source: Shakti Sustainable Energy Foundation and ICF report on gas pricing

Several steps have been taken by regulatory/government bodies in the reforming the sector into a competitive developed gas market. The overall impact these on the gas demand-supply are as follows[57]:

- Complete deregulation of prices in 1989 put a downward pressure on gas prices:
- Wellhead prices (real) decreased by 26% between 1988 and 1995, and city gate prices by 24%
- Large consumers were main beneficiaries with declines in gas prices by 26% to 31%
- Small consumers were not able to access the market as they saw limited benefits although real gas prices still dropped by 12%
- Wholesale markets provide price signals of gas demand-supply and incentivized domestic gas production
- Gas supply shock in 2000-01 signalled gas resources in North America not sufficient to meet demand
- Pricing developments (2000-08) was a key factor enabling shale gas development along with improved knowledge of US geology and availability of E&P techniques to produce shale gas

A.1.2 Overview of UK Natural gas Market

[57] Report by Shakti Sustainable Energy Foundation in association with ICF on "Facilitating development of appropriate natural gas (NG) pricing and allocation policies"

Initially in the UK Natural Gas Consumption accounted for only 5.4 % of all fuels consumed in 1970. The natural gas consumption grew steadily from this period. Gas consumption in 1970s-1980 replaced oil products and town gas manufactured from coal. In 1996, Natural Gas exceeded petroleum consumption for the first time. Even though incremental gas consumption has come from power sector (replacing coal) but this has been highly price-elastic because we see several instances where there have been shift to coal and other alternatives owing to increasing gas prices. In 2004, natural gas accounted for 41 % of all fuels consumed. However due to increased gas prices the share fell to 38% in 2006. Similar trend occurred during the 2010-12 period. Natural Gas share (33%) in UK primary energy mix is very close to share (35%) of petroleum products.

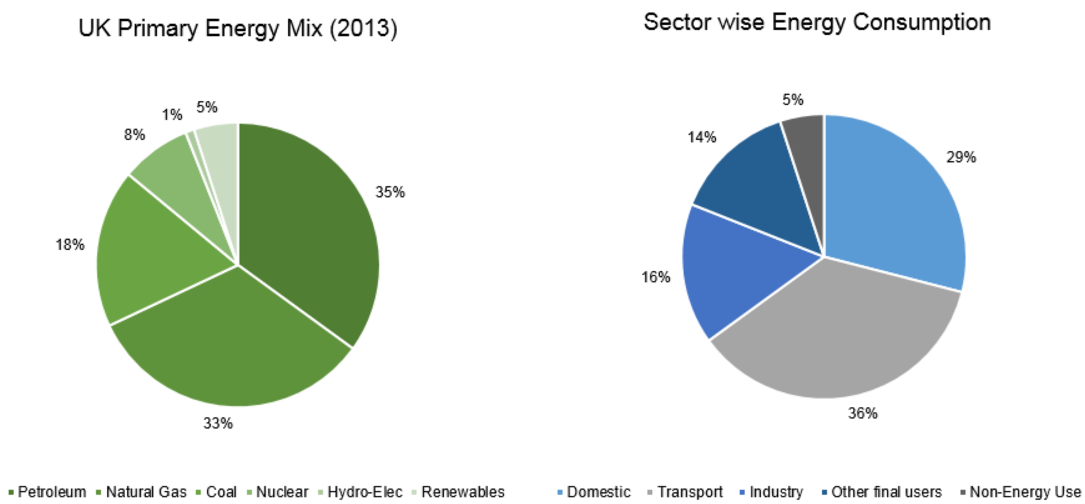

Figure 58: UK Energy Fuel Mix & Sectoral Consumption Mix

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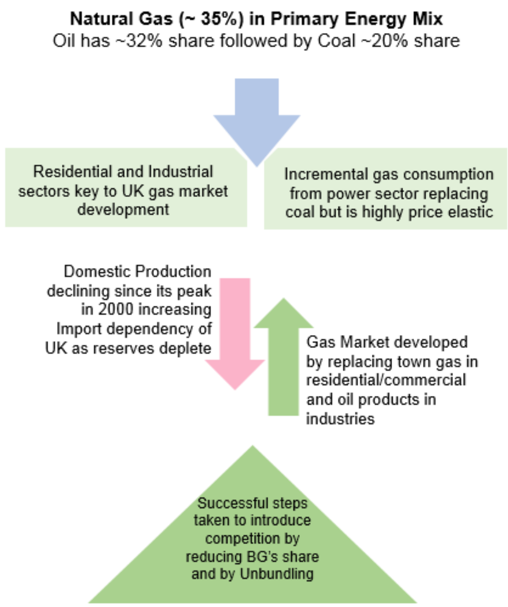


Key Milestones in the Policy and Regulatory Front
Evolution of competitive gas market in UK

1982	**Oil and Gas Enterprise Act**	• Upstream Competition
1986	**Gas Act 1986**	• Negotiated TPA and wholesale competition for large consumers • Regulator • Price controls for consumers <-2500 therms p.a • Privatization
1988	**MMC 1988 report**	• Reduction in BG's share in supply to 90% • BG to publish industrial prices • BG to publish information about common carriage terms
1991 -94	**OFT Review; Competition and Services (Utilities) Act 1992**	• Gas release to reduce BG's share in supply to 40% by 1955 • Legal unbundling by 1994 • Transparent and non-discriminatory terms of use of BG's pipelines and storage • Full Wholesale competition
1995 - 2002	**Gas Act 2005**	• Retail Competition • Full unbundling by divestment • Network Code for Open access and balancing • Removal of price controls for all end-consumers

Figure 59: Key Policy and Regulatory reforms in the US Natural Gas Market

The gas market in UK developed by replacing town gas in residential/commercial & oil products in industries which was successful majorly because of government's aggressive conversion program to convert each appliance to Natural gas and gas was promoted for industrial use as well. Demand in these markets further fuelled by the oil price increases in 1973 and oil price shocks of 1979. From 1990 onwards the power sector emerged as a major consumer due to low gas prices. The residential and industrial sectors are key to the UK gas market development

Key successful steps taken to introduce competition and remove barriers during 1990-96 were as follows:

- A market share target set to reduce BG's share of the contract market (excluding power generation) to 40% by 1995
- Release of gas to competitors in order to ensure that target was achieved
- Unbundling was introduced to remove barriers in Third Party Access which was completely\ achieved by 1997 followed by unbundling of BG's transportation & storage business by 2000
- BG was obliged to prepare "Network Code" by Gas Act 1995
- A new system of transparent and non-discriminatory tariffs for the use of its pipelines and storage facilities were set up where the new tariffs applied equally to BG's supply business of as to any other user of the pipeline system
- Pipeline infrastructure development was facilitated in the open unbundled market which was dictated by the Transportation Planning Code
- Managed transition to competitive markets through the Network code and trading markets which facilitated cooperation among participants in unbundled, de-integrated gas industry in UK that required

each participant to perform certain activities/processes that in the end lead to optimal system and balancing. The code also defined a system of entry-exit tariffs and created a need for short term trade by reducing the balancing period from 1 month to 1 day from 2002

- The Network code introduced National Balancing Point (NBP) which is a virtual point or location in order to promote the balancing mechanism detailed in the code. Here shippers nominate their buys and sells on the National Grid and the trades at NBP are made via the OCM trading system. The code also introduced over-the-counter (OTC) for day ahead transactions.

Demand side reforms was rolled out with a need to expand UK power sector in environmentally friendly way by using gas-fired power plants in a restructured electricity market. In the 1990s, mass rollout of Combined Cycle Gas Turbine (CCGT) plants led to NG being the dominant fuel for power generation. During this period, coal consumption declined by 55%.This was due to a number of factors such as:

- Availability of cheap natural gas
- Privatisation and liberalisation of the electricity industry
- Environmental regulations which disadvantaged new coal-fired generation compared to CCGT
- Improved turbine performance
- UK Energy Act of 1983 that allowed IPPs into the market who favoured CCGT over conventional generation investment

A.2 Developing Markets – China

A.2.1 Overview of China Natural gas Market

China's gas market is a developing market but even with a mere 5% share of natural gas consumption in its energy mix the government is largely focused on increasing this share significantly in the coming years. The major driving factor for raise of share of natural gas in the mix is due to environmental concerns due to which gas usage grew from nearly 25 BCM in 2000 to a total of ~130 BCM in 2011.

On January 1, 2013, the China State Council released the 12th Five Year Energy Development Plan[58], focusing on the future development of energy supply in China. The plan mentions the existing binding intensity and non-fossil energy targets along with focus on energy technology innovation and accelerated restructuring for efficient, clean and low-carbon energy.

The main objective of the third quarter is the optimization of energy structure with target of natural gas in primary energy consumption increased to 7.5% and the proportion of coal consumption is reduced to about 65%. The plan puts forth further actions on improving the supply of domestic gas penetration and speeding up the construction of natural gas distribution networks, gas storage facilities in order to expand the

[58] Industrial Efficiency Policy Database

coverage of natural gas supply. The plan has a vision to expand the natural gas consumer market by enhancing the scale of the residents using gas.

Other policies and the evolution of the natural gas market in China is shown in Figure .

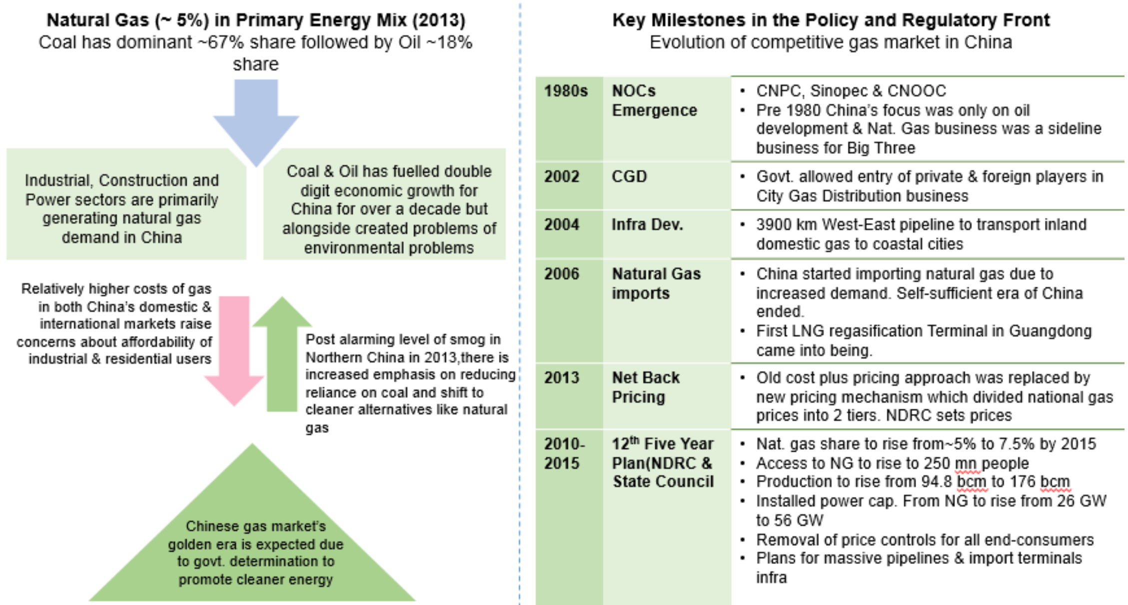


Figure 60: Evolution of Natural Gas Market in China

A.3 Summary of Selected Natural Gas Markets

Country	US	UK	China
Share in Primary Energy Mix (%)	27%	35%	4%
Sectors that consume gas	Industrial and Power	Residential and Power	Industrial, Residential and Power
Price controls on gas sales	✗	✗	✓
Unbundling (Transport and Marketing)	✓	✓	✗
Third-Party Access	✓	✓	✗

Competition in gas supply - Wholesale	✓	✓	✗
Competition in gas supply - Retail	✓[59]	✓	✗

[59] Residential choice programs

B International References - Application specific Case Studies

B.1 Bulk Power – US Case Study

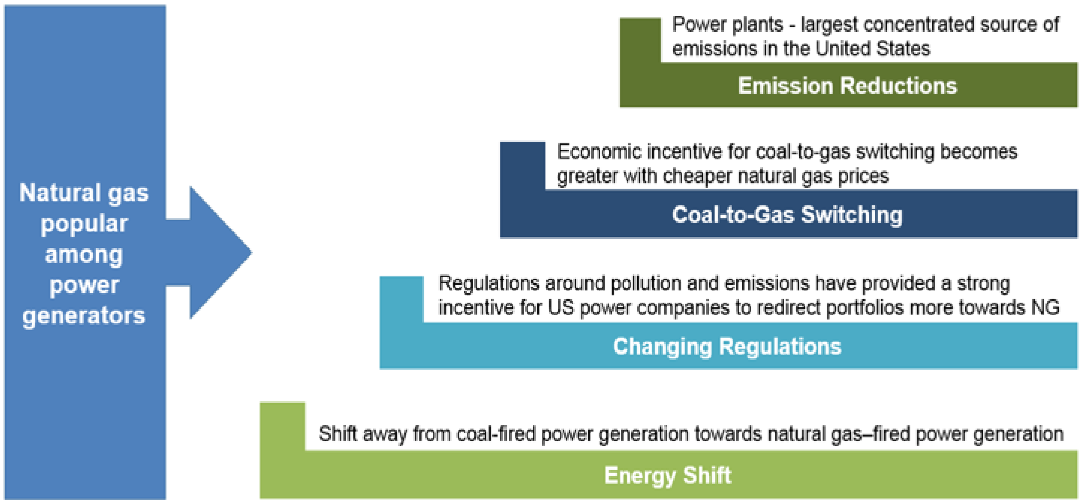
Natural Electricity Generation (2014) % share	*27%*
Natural Electricity Generation (2014) in Billion kWh	*1105*
Natural Gas Capacity Additions (Jan-Jun 2014)	*Combined Cycle -2179 MW* *Combustion Turbine – 131 MW* *Other – 9 MW*
Natural Gas Capacity Additions (Jan-Jun 2013)	*Combined Cycle -1380 MW* *Combustion Turbine – 3115 MW* *Other – 5 MW*
Projected natural gas share of U.S Energy market by 2040	*28%*
Energy Information Administration estimation of natural gas plants % of new power plant additions through 2040	*63%*

Success Story – *Natural Gas Popular among Power Generators*

Over the past decade the natural gas production in the United States has undergone a revolution with enormous quantities of natural gas from shale formations with the combination of hydraulic fracturing and horizontal drilling technology. The impact of abundant and low-cost natural gas is particularly important in the electric power sector. During April 2012, electricity generation from natural gas-fired plants virtually matched generation from coal-fired plants. However even though coal has regained some of its market share because of gradually rising natural gas prices, growth in natural gas generation is projected to continue in the future.[60]

In the recent past natural gas gained popularity among power generators. The major factors that led to the shift is highlighted in Figure.

[60] Source: U.S Department of Energy



Energy Shift

Natural gas prices have remained low for a sustained period due to production of the hydrocarbon in recent years has ramped up dramatically owing to development of abundant shale resources. Natural gas prices have been low both on an absolute basis and on a relative basis to coal.

Some power generation capacity is retiring and new capacity is being built to replace it and to meet growing energy demands. In this regard power companies are more likely to build new natural gas–fired plants over new coal-fired plants because in comparison to new coal-fired plants, natural gas–fired plants are largely more efficient, relatively cheaper and quicker to construct. One driving factor is that they encounter less resistance from residents near proposed plant sites as they have lower emissions.

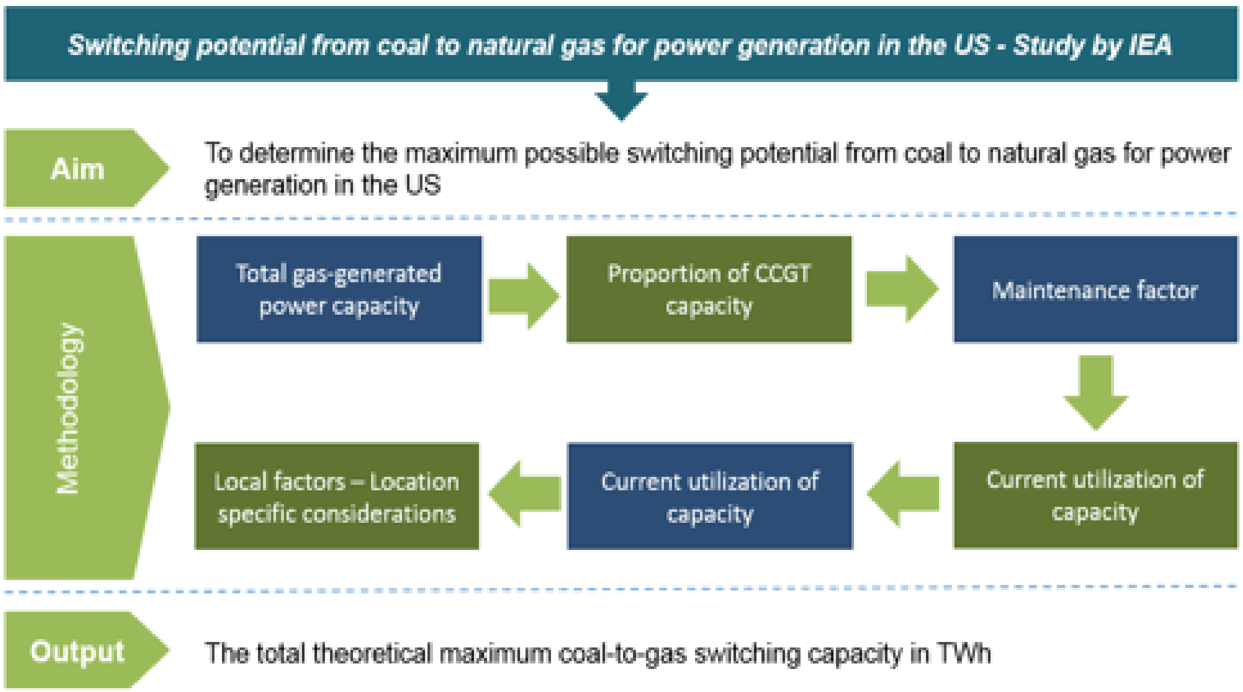
Changing Regulations

Regulations around pollution and emissions have provided a strong incentive for US power companies to redirect their portfolios more towards natural gas and away from coal. This can be achieved by both through shutting down existing coal plants and favouring natural gas when proposing new plant projects. The US Environmental Protection Agency now has jurisdiction over power plant emissions and recently introduced proposed restrictions on emissions for new power plants. In the light of above regulations Natural has gained popularity among power companies such as Duke Energy (DUK) and the Southern Company (SO).

The regulations support natural gas demand and provides a long-term floor for natural gas prices. The US producers weighted towards natural gas such as Chesapeake Energy (CHK), Devon Energy (DVN), South-western Energy (SWN), and Range Resources (RRC) see these trends in the Natural gas market has highly positive and the same applies to holders of natural gas ETFs such as the United States Natural Gas Fund (UNG).

Coal-to-gas switching

The relative price differential[61] between coal and natural gas is one of the major determinants of the magnitude of coal-to-gas switching that occurs. As natural gas becomes cheaper than coal the economic incentive for coal-to-gas switching becomes greater and vice-versa.



IEA has conducted a study to determine the possible switchover from coal to natural gas generation based on factors illustrated in Figure. IEA concludes that the open-cycle capacity is generally not likely to be used over coal hence the Combined Cycle capacity is considered. A realistic estimate of maintenance factor is taken into account. More importantly the study constituted local factors in determining whether the switchover is likely where consideration on long term coal contracts and less efficient coal plants were taken into account. These factors in addition to the existing coal capacity that can switchover gave a possible switchover capacity.

Emission Considerations

According to the US Energy Information Administration (EIA) "Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulphur oxides at the power plant".

Illustration - In the first quarter of 2013 the total carbon dioxide emissions from energy demand were 1,406 million metric tonnes which was higher than 1,345 million metric tonnes produced in the first quarter of

[61] NYMEX, Market Realist

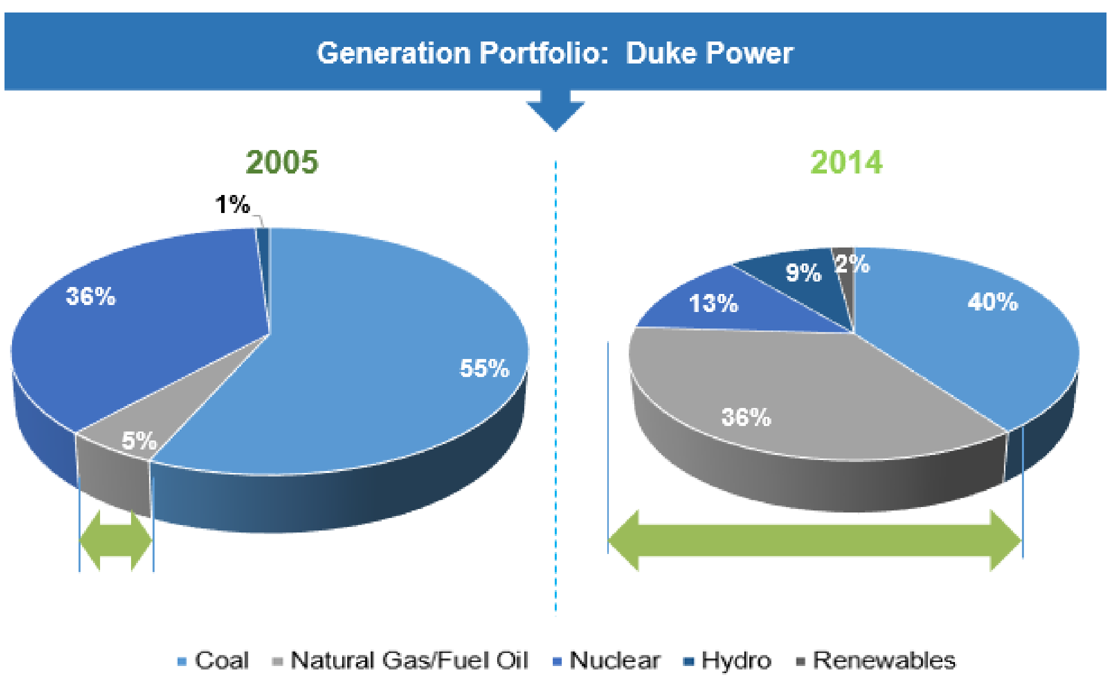
2012 because during this period more coal was burned relative to natural gas as natural gas prices had fluctuated to be relatively higher during this period.

According to the US Environmental Protection Agency "Power plants are the largest concentrated source of emissions in the United States, together accounting for roughly one-third of all domestic greenhouse gas emissions." In this regard power plants have become a major focus for emissions reduction.

Industry Lessons - Duke Power

Duke Power has made the transformation in their regulated fleet of power generation from 2005 to 2014. This is a result of modernizations and the retirements of older, less efficient coal and oil units. They have been working well along in making a big shift from a heavily coal-based mix to a balanced diversified portfolio with much less coal and more natural gas. Coal share declines from about 55% in 2005 to 40% in 2014[62].

As a result of lower natural gas prices their natural gas plants are operating as base-loads with capacity factors in the 70% to 80% range. Now, this may be the new normal and if it is we are ready. If it is, we are going to need to find efficiencies though at our coal plants and I can tell we are very focused on that and those efficiencies will go above and beyond what we are looking at from a synergy target perspective. Other than natural gas focused initiatives they are also working towards making their existing coal based generation cleaner.



62 Source: Duke Energy, Market Realist

Technology Innovations – General Electric US

GE's Power & Water division has invested heavily developing its next generation of combined-cycle natural gas-fired turbines which is named as the 9HA/7HA series. According to the company, the "H Class" is the world's most efficient gas turbine. The H class turbines have an efficiency rating over 61 %. Now their target is 65 % as the commercial developers are all pursuing similar goals.

According to their experts, it is a very technology-intensive endeavour to reach such higher firing temperatures particularly with such mature technology. To get ultra-high efficiencies a coordinated approach to bind several parameters including optimal pressure, firing temperature, advanced cooling technology and new components are required. The innovative methodology of achieving this as per their research team is directed at advanced coatings for turbine blades which allow the metals to reliably operate at higher temperatures.

B.2 Ancillary Services – UK Case Study

Success Story - *National Grid Reserve Services*

The National Grid Services in the UK is highly capable to deal with unforeseen demand increase and/or generation unavailability. For this the National Grid need to access to sources of extra power in the form of either generation or demand reduction. The additional power sources available to National Grid are referred to as Reserve. As different sources require different timescales in order to be ready to deliver the services the reserve services are categorized on an increasing timescale of getting in the state of readiness (as shown in Figure). The Fast Reserve category is used to control frequency changes that might arise from sudden, and sometimes unpredictable, changes in generation or demand.

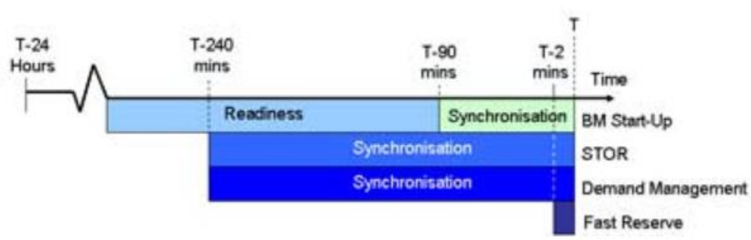


Figure 61: Reserve Services

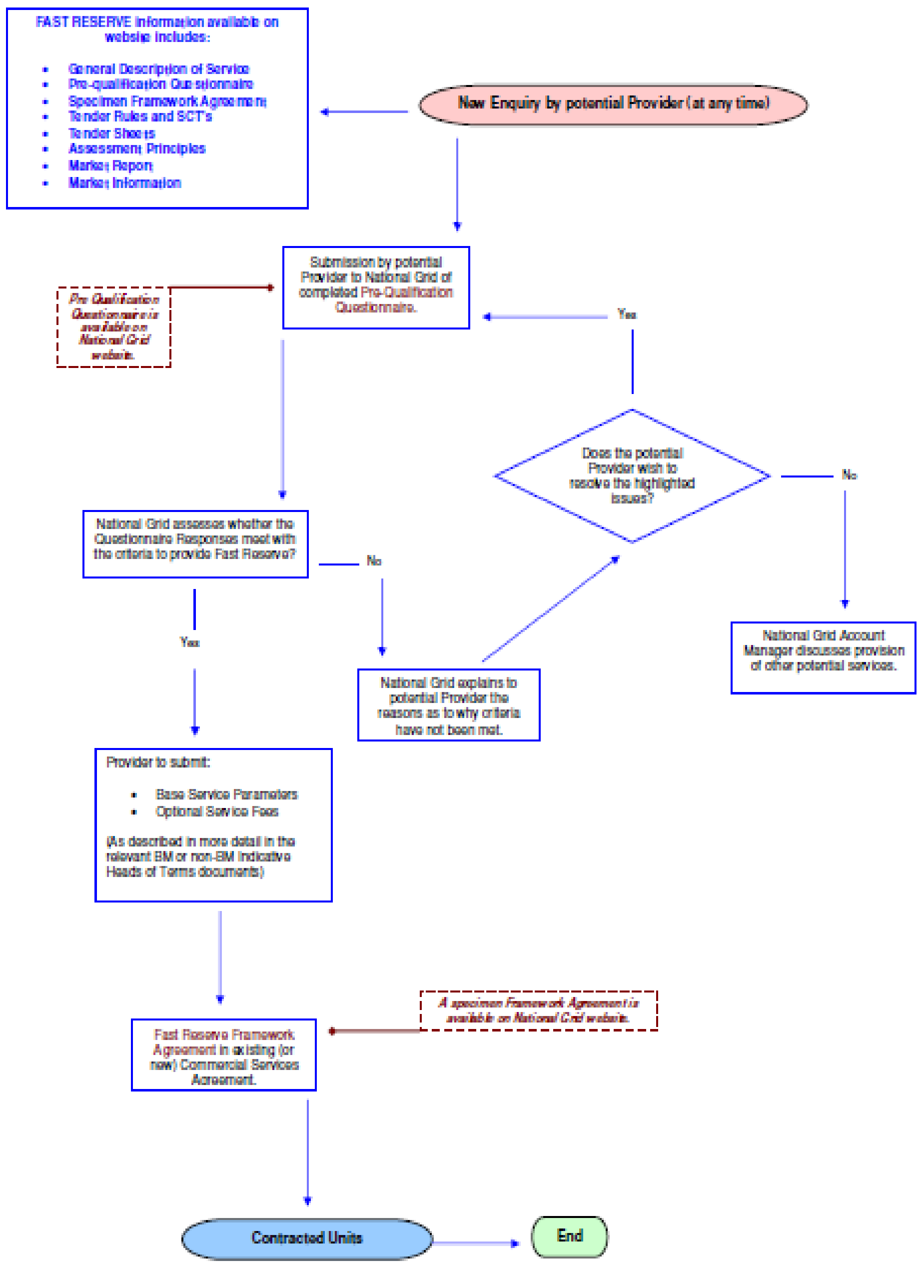
Source: National Grid Services

The Fast Reserve Program Process is described below:

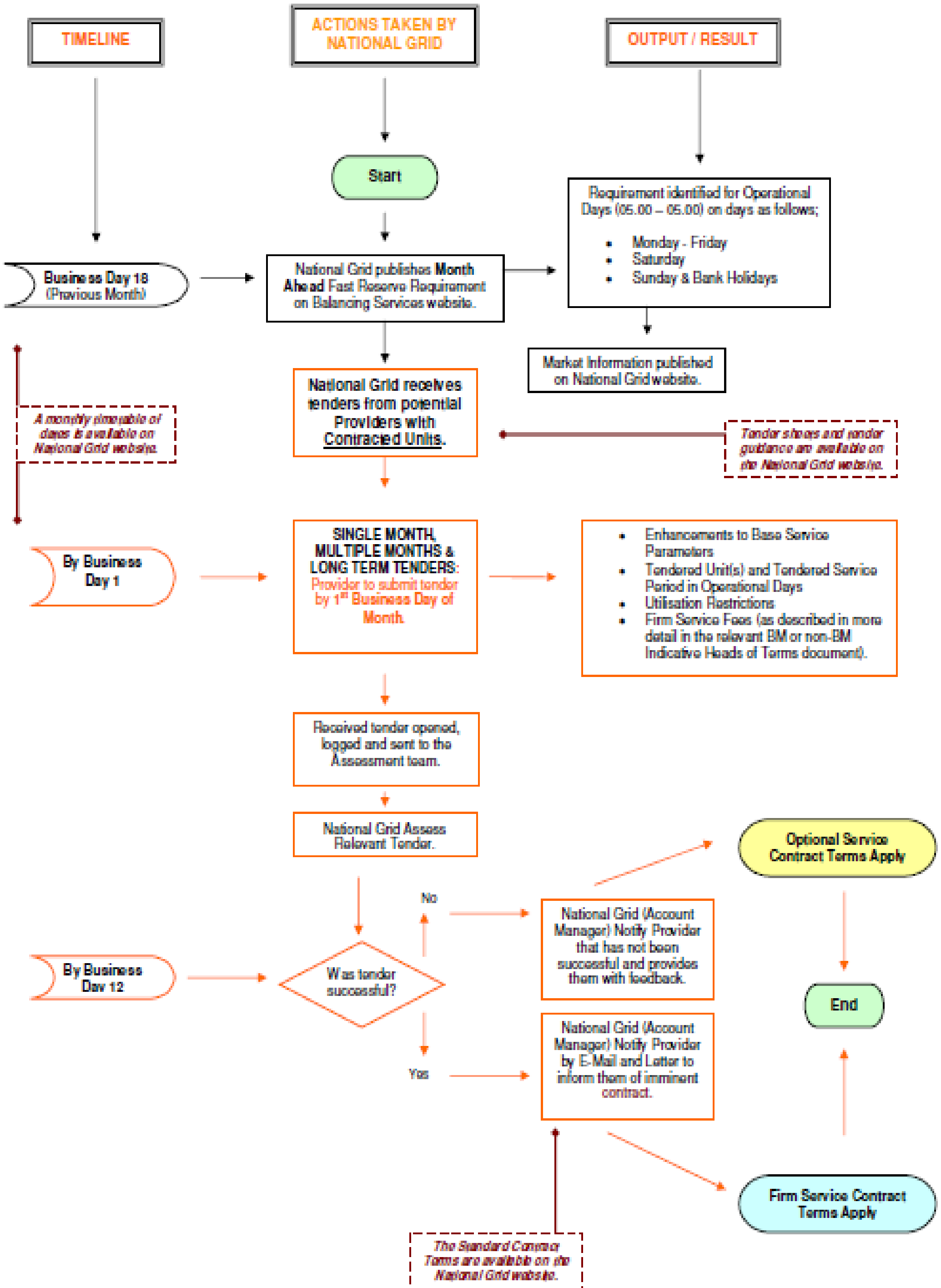
Participation Criteria	• Fast Reserve is procured via a monthly process • Requires pre-qualification to establish a Framework Agreement prior to tendering
Technical Requirements (Pre-Qualification Criteria)	• Active power delivery must start within 2 minutes of the dispatch instruction • Delivery rate in excess of 25 MW/minute • Reserve energy should be sustainable for a minimum of 15 minutes • Must be able to deliver minimum of 50MW
Assessment Process	• Cost-benefit assessment - Assess whether the cost of an accepted tender is likely to be less or greater than the cost of alternatives to deliver the equivalent service in that month • Other factors such as Performance, Utilisation Restrictions, Constraints etc. are also taken into account
Getting Paid	• Providers of the service will receive an Availability Fee for each hour in a Tendered Service Period where the service is available • A utilisation fee per MW/h is payable for the energy delivered • Provider may also be entitled to a per hour holding fee

Fast Reserve Process Flow Diagram for each of the processes namely Pre-qualification, issue of monthly tender, notification, utilization and final settlement is as follows.

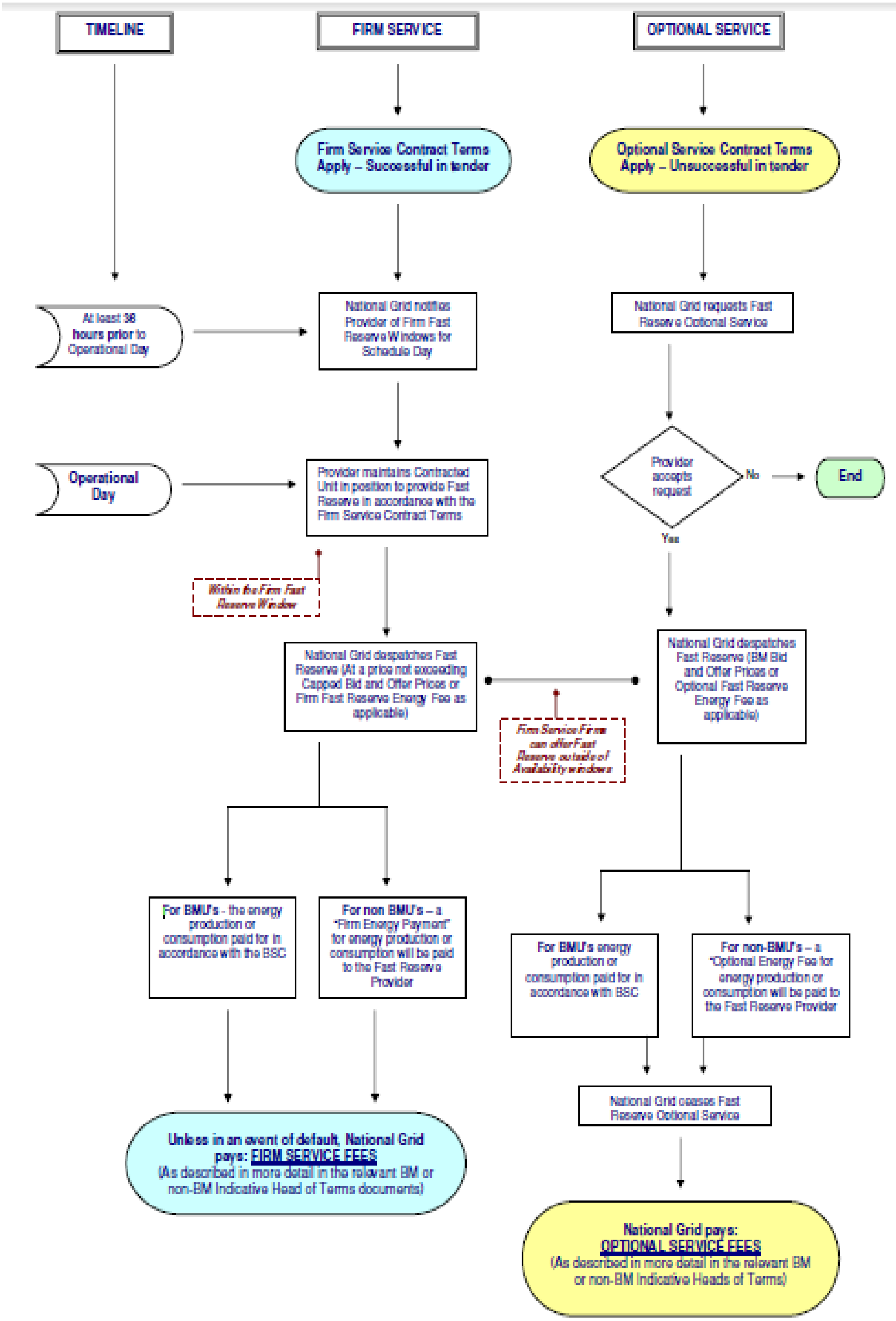
a) Pre-Qualification



b) Monthly Tenders



c) Notification, Utilisation and Payment


TIMELINE
FIRM SERVICE
OPTIONAL SERVICE
Firm Service Contract Terms Apply – Successful in tender
Optional Service Contract Terms Apply – Unsuccessful in tender
At least 38 hours prior to Operational Day
National Grid notifies Provider of Firm Fast Reserve Windows for Schedule Day
National Grid requests Fast Reserve Optional Service
Provider accepts request
No
End
Yes
Operational Day
Provider maintains Contracted Unit in position to provide Fast Reserve in accordance with the Firm Service Contract Terms
Within the Firm Fast Reserve Window
National Grid despatches Fast Reserve (At a price not exceeding Capped Bid and Offer Prices or Firm Fast Reserve Energy Fee as applicable)
National Grid despatches Fast Reserve (BM Bid and Offer Prices or Optional Fast Reserve Energy Fee as applicable)
Firm Service Firms can offer Fast Reserve outside of Availability windows
For BMU's - the energy production or consumption paid for in accordance with the BSC
For non BMU's – a "Firm Energy Payment" for energy production or consumption will be paid to the Fast Reserve Provider
For BMU's energy production or consumption paid for in accordance with BSC
For non-BMU's – a "Optional Energy Fee for energy production or consumption will be paid to the Fast Reserve Provider
National Grid ceases Fast Reserve Optional Service
Unless in an event of default, National Grid pays: FIRM SERVICE FEES
(As described in more detail in the relevant BM or non-BM Indicative Head of Terms documents)
National Grid pays: OPTIONAL SERVICE FEES
(As described in more detail in the relevant BM or non-BM Indicative Heads of Terms)

B.3 Peaking Power – UK Case Study

Existing Natural Gas Peaking Power Capacity	*30 GW CCGT*
UK Planning Inspectorate peaking power plant proposals in 2014	*300 MW*
Objective of UK Planning Inspectorate	*Work towards a lower carbon environment where low cost peaking plant will become more important in maintaining energy security and providing the necessary system balance*

Success Story – *Capacity Markets Favor Peaking Assets*

Power plant development market in the UK has historically been focused on combined cycle gas turbine (CCGT) plants rather than peaking power assets as CCGT plants have a clear efficiency advantage over peaking plants. The mature market hence poses fierce competition in the UK merit order system making it rigid to build investments for peaking assets except as onsite backup or for provision of ancillary services.

With the recent update in the capacity market rules and the availability of 15 year fixed price capacity agreements there has been a sharp increase in peaking power development interests of UK.

The UK government has designed the Capacity Market such that the peaking capacity is able to generate electricity at four hours' notice and the capacity is de-rated based on availability by technology type e.g. OCGT at 94% and CCGT at 88%.

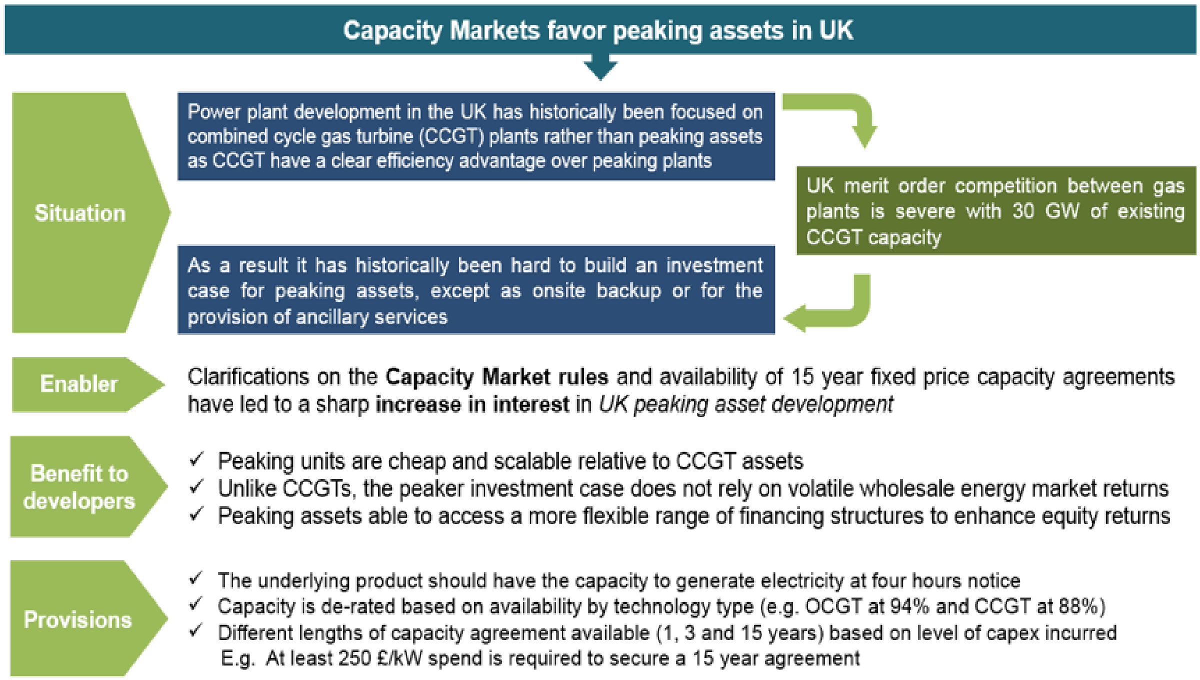
Owing to better peaking asset economics a much broader range of peaking generation technology options are suggested as for example[63]:

- High efficiency open cycle gas turbines (OCGT) with efficiency levels approaching those of older CCGT plants and capex costs ranging around 500 £/kW.
- Conventional OCGT with lower efficiency levels (35-40%), capex costs as low as 350 £/kW and fixed costs around 10 £/kW/year

Even though the options look bleak from an investment perspective there are two important benefits underlying this scheme as it removes concerns around the wholesale energy market margin risk that CCGT assets face and the peaking plant investment is focused on locking in capacity market margins under 15 year fixed price agreements which in effect reduces risk from volatile and wide spread margins.

[63] Timera Energy – Investment in UK Peaking assets

Incurring higher capex spend to achieve higher plant efficiency and hence lower variable costs. If a peaking plant runs at very low load factors then variable cost is a lower priority.



B.4 Distributed Power Generation – China Case Study

Success Story - *Gas generator sets demonstrate successes in China*

12th Five-year Plan

Distributed energy has stepped into a fast developing term in China as it is about to enter a scale development process as per the Twelfth Five-year Plan. The Plan envisages to build about 1000 natural gas distributed energy projects during the time frame and plans to build about 10 different kinds of typical distributed energy demonstrations.

Cummins Corporation established a joint venture with Jardine Matheson where the focus is on providing advanced energy efficient green power solutions. The use of overall clean Gas turbine generating unit's distributed-energy project is targeted for CCHP projects and the joint venture company will rely on the Cummins gas generator technology.

12th Five-year Plan for Guangdong Energy Development

Local natural gas development in the planning period are to reasonably allocate and establish natural gas power generation and distributed power generation facilities in the Pearl River Delta region. The newly installed gas power generation capacity is about 7.1 million kilowatts of which 6.3 million KW are cogeneration units and small distributed power generation stations are planned.

B.5 CHP – US Case Study

Total Natural Gas fueled CHP Projects as of 2014 (U.S Department of Energy)[64]	*97 projects with a total capacity of 1378.8 MW*
Technologies used	*Combustion Turbine, Reciprocating Engines, Fuel Cell, Micro turbine and Combined Cycle turbine*
CHP Technical Assistance Partnerships (CHP TAPs)	*Promote and assist in transforming the market for - CHP, waste heat to power, and district energy with CHP throughout the United States*
Combined Heat and Power Partnership of EPA	*Include federal, state, and local government agencies along with private organizations such as energy users, CHP project developers ,energy service companies, consultants, and equipment manufacturers*

Success Story – *Policies and Incentives major driver for CHP Generation*

There are several policies and incentives developed in the CHP market of US. These fall into different categories such as Bonds, Loans, Energy Regulation and Policy, Environmental Regulations, Feed-in-Tariff, Grants, Net-Metering Policy, Portfolio Standard, Rebates, Production Incentives, State Climate Change Plans, Taxes, Utility rates etc.

Policy/Incentive Name	Features
Energy Regulation and Policy	
2009 NH Statutes, Title 34, Chapter 374-G-To Encourage Utility Investment in CHP	CHP systems < 5 MW and must have an efficiency of at least 60% and emit <0.07 lb/MWh NO_X, 0.10 lb/MWh CO, and 0.02 lb/MWh VOCs.
Energy Improvement and Extension Act of 2008 extends existing tax incentives and introduces new tax	System must produce at least 20% of its useful energy as electricity and at least 20% as useful thermal energy

[64] US Department of Energy – Industrial Distributed Energy CHP Project Profiles Database

credits for qualifying CHP systems	
Production Incentive	
Industrial and Process Efficiency Performance Incentives	Incentives are provided on the custom application of commercially available technology. The program budget is USD 26.8 million for gas and incentives are directed towards gas efficiency and operational changes
Rebates	
Grid Electric's CHP Program for a combination of energy efficiency, performance rebates, and advanced gas technology incentives	The total incentive package cannot exceed 70% of total project cost and is subject to caps Performance rebates and energy efficiency incentives: • USD 900/kW per net kW for projects with 55% to 59.99% efficiency • USD 1,000/kW for projects with 60% or greater efficiency. The advanced gas technology program designed to add natural gas load during National Grid's off peak period. The incentive amount is determined by: • Additional margin gain from the project, up to 75% of the project's future margin. • 75% of the project cost. • Amount needed to buy down the payback period to 1.5 years.
National Grid (Gas) - Commercial Energy Efficiency Rebate Programs (Metro NY)	The program provides support services and incentives to commercial customers who install energy efficient natural gas related measures. Custom Incentives available for projects that demonstrate use of natural gas more efficiently than industry practices and/or more efficiently than the minimum building code requirements. Incentives are available covering up to a maximum of 50% of project costs, capped at USD 250,000 per site and/or per project.
NV Energy (Northern NV Gas) - SureBet Business Energy Efficiency Rebate Program	Commercial, industrial and institutional natural gas customers of NV Energy can take advantage of incentives for retrofit projects. Prescriptive rebates are available for High Efficiency Furnaces, Commercial Water Heaters Unit, Infrared Heaters , Pipe Wrap-Hot Water or Steam Boiler Linear Foot, High-Efficiency Pool Heater, Domestic Water Heater etc.
Southwest Gas Corporation's CHP Program	This program is limited to industrial or commercial customers in Arizona who install efficient CHP system Qualifying recipients can obtain funding ranging from USD 400 to USD 500 per kW (depending on efficiency) - and up to a maximum of 50% of the installed cost of any project - from the gas utility's demand-side management program

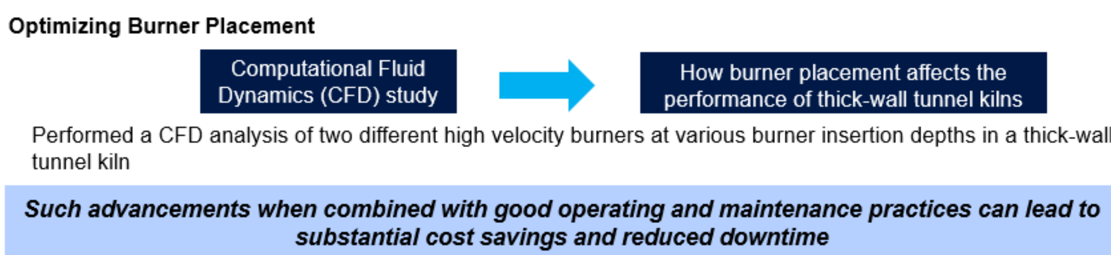
B.6 Direct-fired Burners – US Case Study

Success Story - *Hauck Manufacturing Company – Technology Improvements to reduce energy costs*

Technological improvements

- Heat treating/thermal processing industries to reduce energy costs by
- Advancements in burner designs
- Recuperative systems
- Pulse-fired control algorithms
- Impulse fired burner designs: Improves the combustion system through the use of Air/fuel ratio control, Preventative maintenance, preheated air etc.
- Impulse burners: New design for ceramic manufacturers to save energy and comply with emissions guidelines
- Pulse firing: Most efficient high fire rating which maximizes the energy reaching the product – Ultra-low NOx burners

Case Example - Ceramic Industry



B.7 Thermic Fluid Heaters – Canada Case Study

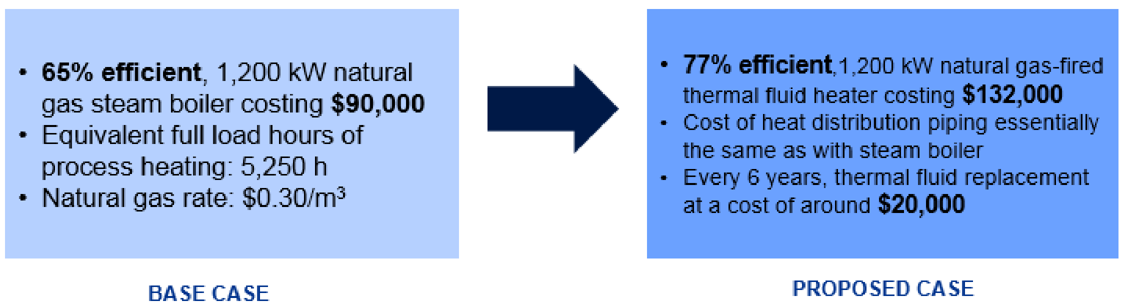
Success Story - *RETScreen Clean Energy Project Analysis – Natural Resources Canada*

RETScreen Clean Energy Project Analysis Software

- Assess projects incorporating a variety of heating and/or cooling equipment all working under various operating conditions (base load, intermediate load and/or peak load), for: single buildings or multiple buildings; industrial processes etc. Further, it permits analysis with a wide range of fuel options
- RETScreen Tool used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for thermal fluid heater projects typically for industrial process applications

- RETScreen Project Database allows user to open built-in project examples where the software's input and output cells automatically switch directly to the project chosen

Case example: Thermal fluid heater - Process heating - Food processing



B.8 Boilers and Furnaces – US Case Study

Success Story - *Rebates[65] and Incentives[66] accentuate Energy Efficient Boiler and Furnace*

ENERGY STAR Program

- ENERGY STAR is a U.S. Environmental Protection Agency (EPA) voluntary program that helps businesses and individuals save money and protect climate through superior energy efficiency measures.
- To encourage customers to buy energy efficient products ENERGY STAR partners occasionally sponsor special offers and offer rebates such as sales tax exemptions or credits, rebates on certified products.
- They sponsor recycling incentives for the proper disposal of old products.
- The rebates and incentives as per the scheme are mentioned in Table

Boilers	• Mail-in rebates of USD 150-400 on qualifying energy efficient boilers for commercial customers • Natural gas boiler (83.5% and greater AFUE) - USD 300 • Condensing natural gas boiler (90% or higher AFUE) – USD 500 • Additional USD 25 rebate when the dealer installs a new programmable thermostat with any qualifying heating system

[65] Money received when existing projects are upgraded to new energy saving projects
[66] Pre-approved projects with an objective to save energy where incentive amount is calculated on savings

	• Commercial Columbia Gas of Ohio offers commercial customers with annual natural gas usage less than 3,000 ccf a rebate of USD 200 off on the purchase of a new high efficiency natural gas boiler.
Furnaces	• Mail-in rebates of USD 250-400 on qualifying energy efficient furnaces • USD 150 incentive for a furnace with ECM blower • USD 150 rebate on ENERGY STAR High-Efficiency Gas Furnaces of 90 plus AFUE • USD 250 on furnaces with 95 plus AFUE

B.9 Natural Gas Vehicles (NGV) – US Case Study

No. of NGVs in the US	*152,300*[67] • *Light duty vehicles : 87000* • *Medium duty vehicles : 25800* • *Heavy duty vehicles : 39500*
Expected CAGR for NGVs for 2015-24	• *Light duty cars & trucks - 5.5%* • *Medium & Heavy trucks and buses - 3.2%*
Types	• *CNG (for travelling shorter distances)* • *LNG (for travelling long distances)* *Both considered as alternative fuels under the US Energy Policy Act of 1992*
Reasons for promoting natural gas vehicles in US	• *To reduce dependence on foreign oil* • *Improve local air quality* • *Combat climate change*

[67] NGV America 2015

Success Story – *Increased NGV Penetration Reforms in the US*

Important dimensions of shifting to natural gas vehicles in the US are discussed below. This along with strong government support and initiatives have led to increased penetration of natural gas vehicles fleet in the US.

- Home refuelling options to consumers: If a consumer's home is being heated by natural gas, a home refuelling system can fill the vehicle tanks overnight with the same feeder line used to heat the house
- Increasing availability of Public refuelling stations: Reputed fleets like Coca-Cola, Verizon, and Federal Express are switching to natural gas leading to increase in number of fuelling stations available to other public. Currently there are around 1564 CNG and 111 LNG stations in the country out which more than half are publicly accessible[68]
- Secure & abundant supply – There is no dearth of natural gas supply in the US therefore it is not subject to supply disruptions or price spikes even in an unlikely case of natural disasters. For instance during Hurricane Sandy, when gasoline and diesel vehicles were unable to refuel, NGV stations were operational and played an important role in rescue and recovery operations.

Steps taken to encourage NGV penetration in US

- The Safe, Accountable, Flexible, Efficient Transportation Equity Act: Provides a 50-cent tax credit per gasoline gallon equivalent (GGE) of compressed natural gas (CNG) and per liquid gallon of liquefied natural gas (LNG) sold for use as a motor vehicle fuel
- Peak Hour Usage Rebates: Some states such as California and Arizona permit certain alternative fuel vehicles to operate in high occupancy vehicle lanes during peak rush-hour periods
- The Energy Policy Act (EPA Act) of 2005: Provides for an income tax credit equal to 30 percent of the cost of natural gas refuelling equipment up to INR 30,000 in the case of large stations and USD 1,000 for home refuelling appliances
- Fuel Tax Credit for Natural Gas: USD 0.50 per gallon credit/payment for the business that use of natural gas as a transportation fuel

B.10 CNG Vehicle – Brazil Case Study

[68] NGV America

Success Story - *A leading country in natural gas technology for motor vehicles*

1975 - The Brazilian government implemented the National Alcohol Program financed by the government to phase out fossil-fuel based automotive fuels in favor of ethanol made from sugar cane as a response to the shock caused by the first oil crisis

1980 - 4 million cars and light trucks run on pure ethanol but the use of ethanol vehicles sharply declined after sharp increases in sugar prices that led to shortages of ethanol fuel

1990 - Research & Development efforts for alternative technology in ethanol only run engines

2003 - Second push took place in March 2003, when Volkswagen launched the first full flexible-fuel car

2004 - General Motors introduced the Multi-power engine which used the flex-fuel technology capable of using CNG, ethanol and gasoline. This model was aimed at the taxicab market

2006 - A four-fuel (tetra fuel) car was introduced by FIAT in Brasil and neighboring countries which can run on 100% ethanol, 20-25% ethanol blend, 100% gasoline or completely on natural gas. The technology is engineered to switch from gasoline/ethanol/blend to CNG automatically depending on the power required as per road conditions. The other option available is the retro-fitting of natural gas tanks which is more popular among the taxicab market

2007 - Adoption successful with 1.7 million flex-fuel cars in 2007, facilitated by extensive fuel distribution infrastructure with approximately 27,000 filling stations across the country

2010 - Other players entered in the market including Toyota, General Motors, Fiat, Ford, Renault, Honda, Mitsubishi, Nissan etc. with different models of flex cars and light trucks

Tri-fuel cars became popular as it provides users the choice of three different fuels based on availability and current market prices

***Incentives* -** Some states provide incentives to convert vehicles to natural gas such as a reduction in the annual vehicle registration tax. *For example,* conversion in Rio state provides a 75 % reduction in annual vehicle registration.

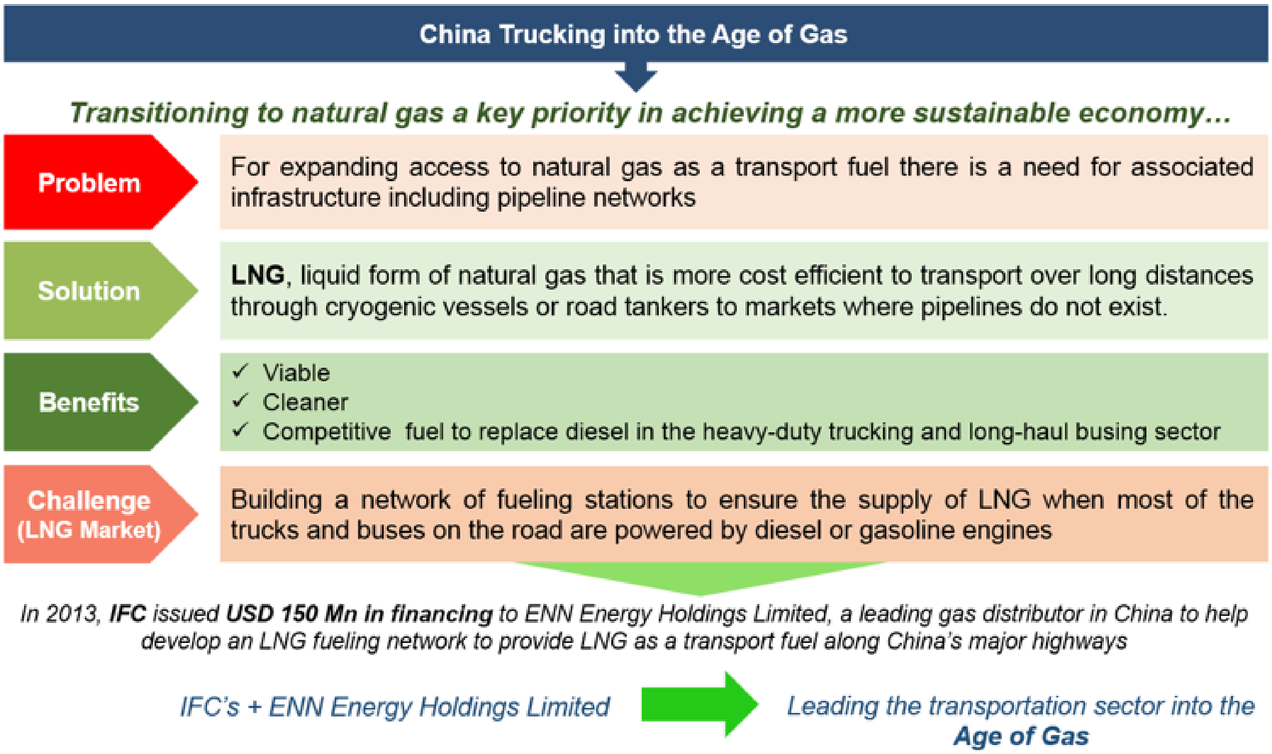
B.11 LNG Vehicles – China Case Study

Market size[69]	*In 2011 there were around 15,000 LNG vehicles in China and it is expected to reach about 150,000 in 2015*
Enabling Infrastructure	*During the period 2010-14, China has added 1,500 refueling stations for vehicles running on natural gas with half of those added in 2013*
Savings	*Switching from diesel to natural gas can pay for itself after 12 to 15 months and it saves 686,000 Yuan (USD 109,760) over a lifetime of 10 years*

Success Story – *China Trucking into the Age of Gas*

The use of natural gas in transport gained popularity in China due to the price differential between natural gas and diesel. This was further supported by the government in the form of subsidies to the local industry. During the period of 2000-13, the CO_2 emissions from gasoline and diesel have increased by 150 and 260% respectively. Hence, using natural gas to fuel the vehicles to bring down the high level of CO_2 emissions from transport sector was imperative. Although there is a well-defined market segment for LNG fuelled vehicles - primarily trucks, the challenge of adequate number of LNG fuelling stations still remains a challenge. There is a lot of traction around encouraging investments in this regard and many government initiatives are in line with the said goal. For example: The "More LNG Stations for Green China" project impulses the entire industry to build 10,000 LNG fuelling stations aiming at the promotion of LNG development in China. Funding Institutions like ICF has also provided adequate funding to a leading gas distributor in China for developing LNG fuel stations along major highways in China (shown in Figure). The central government has taken many steps in promoting green transportation in more than 100 cities within China.

[69] Enerdata, LNG World News –Jereh launches more lng stations for Green China Project, IFC



B.12 LNG Locomotives – US Case Study

Success Story - *Big Fuel savings from Class I locomotives to LNG*

BNSF, the second-largest freight railroad network in North America, is testing two LNG locomotives on a track in Pueblo and the project envisages a USD 18.7 billion fuel savings by deploying LNG locomotives on US class 1 rail roads.

Cost difference between building LNG locomotive with tender cars and a diesel locomotive	USD 1 Million
Total of Class 1 rail road locomotives in operation	25000
Price spread between LNG & rail road diesel (EIA projections)	USD 1.48 in 2012 to USD 1.59 in 2030 & USD 1.77 in 2040
Incremental savings over a period of 20 yrs per locomotive	USD 750,000
Total fuel savings basis 25% conversion of locomotives	USD 4.7 billion

Incremental cost of building 25% new locomotives	USD 6.25 billion
Cost of liquefaction infrastructure(25% LNG)	USD 1.9 billion

B.13 Marine Transport – Norway Case Study

Success Story – *Short sea cargo sets LNG fuel distance record*

Nor Lines Kvitbjørn, a 5000 dwt short sea cargo vessel is first of its kind that has successfully operated between Asia and Europe solely on LNG. The ship was designed based on Rolls-Royce Environment concept. According to Rolls-Royce this was the longest voyage undertaken by a LNG fuelled ship and is a significant milestone in the industry's transition from diesel fuel to LNG.

Voyage route – Kvitbjørn made its delivery voyage from Tsuji Heavy shipyard in China (Jiangsu) to Norway (Bergen) via Singapore with subsequent LNG bunkerings in India (Cochin) and Spain (Cartagena).

Technology support – Bergine engine of Rolls-Royce equipped with Environship concept. Environship incorporates a range of Rolls-Royce technologies which include a Bergen engine fuelled by LNG combined with other technologies pertaining to the ship's propeller, shaft generator, hull design etc.

B.14 Gas Geysers/Water Heaters – US Case Study

Water Heater Market in the US (2013)[70]	• *Gas storage units and Electric storage units dominate the market with a share of 47% and 43% respectively* • *Gas instantaneous constitutes 5% share*
Department of Energy Efficiency standards	*Shift to condensing units in gas water heaters due to this legislation*

Success Story – *Clean Energy Program*

New Jersey Clean Energy Program

New Jersey's Clean Energy Program (NJCEP) promotes increased energy efficiency and the use of clean, sources of energy to fulfil state objectives to reduce pollution, lower costs, and reduce demand

[70] BSRIA

for electricity. The program offers financial incentives, programs, and services for residential, commercial, and municipal customers.

- The *WARMAdvantage Program* provides rebates for qualifying high efficiency water heaters purchased during a specific time period. The incentives and eligibility criteria are shown in Table.

Water heater Rebate Levels		
Equipment Type	Minimum Efficiency Level	Incentives
Power Vent Gas Water Heater	• Energy Factor (EF) of 0.67 or greater • ENERGY STAR qualified and • Power Vented	USD 500
Tankless Gas Water Heater	Energy Factor (EF) of .82 or greater and ENERGY STAR qualified	USD 500
Gas Water Heater	90% or greater thermal efficiency with sealed combustion	USD 500
Heat Pump Water Heater	ENERGY STAR qualified	USD 500
Boiler[71] and Water Heater Combination Rebate	Qualifying criteria: • Integrated water heating and boiler unit (Combi Boilers) or • Qualifying standalone water heater or • An indirect water heater attached to the qualifying boiler	USD 900
Furnace and Water Heater Combination Rebate	Similar as above	USD 900 - 1,000 depending on rating

- The *Business Energy Advisor* program offer energy saving programs for different business types such as: Colleges and Universities, Congregational Buildings, Data Centers, Grocery Stores, Hospitals, Hotels and Motels, K-12 Schools, Laboratories, Large Offices, Manufacturing Facilities, Multifamily Residences, Restaurants, Retail Buildings, Small and Midsize offices, Warehouses, Agriculture.

Case Example - Managing Energy Costs in Large Office Buildings

Size: Large office buildings (those more than 100,000 square feet)

Electricity usage: Average of 20 kWh annually

[71] Residential Boilers

Natural gas usage: 24 cubic feet per square foot annually

Total Energy usage: In a typical office building, lighting, heating, and cooling represent almost 70 percent of total energy use. Water heating constitutes 5% of natural gas usage and 1% of electricity usage.

Technology solutions recommended for Heating, Cooling and Lighting applications

Heating Technologies: Gas Furnaces, Gas-Fired Tank Water Heaters, and Small Gas Boilers etc.

Lighting Technologies: Boosting Lighting Efficiency with Reflectors and Maintenance, Daylighting Controls, Indirect Lighting etc.

Cooling Technologies: Natural Gas Chillers, Economizers, Demand-Controlled Ventilation, Cool Thermal Storage, Packaged Rooftop Air Conditioners etc.

Gas-Fired Tank Water Heaters - *Guidelines prescribed before implementation*

- Pick the right size - Oversized heater is less efficient and more expensive
- Cost-effectiveness comparison - Different efficiency ratings comparison
- Energy star heaters - Selection of water heater that meets Energy Star specifications
- Consider the application before choosing heaters - Condensing water heaters can provide high energy savings throughout the lifetime versus other types
- Sealed combustion heater – For safety considerations choose a sealed combustion heater

Gas-Fired Tankless Water Heater variants are available in the US. Guidelines prescribed before implementation provide an economic calculation[72] (Shown in Table) for a Conventional Gas Water Heater and Gas tankless water heater based on application.

Application	Energy Factor	Incremental cost (in USD)	Annual Household energy cost for water (in USD)		Payback in years	
			Average Usage[73]	High Usage74	Average Usage	High Usage
Gas Conventional Water Heater						
Any application	0.58	NA	324	1116	NA	NA
Gas tankless water heater						

[72] Source: NJ Clean Energy Program

[73] 64.3 gallons per day, Natural gas rate is USD 1.10/therm and water temperature rise is 77 degree Fahrenheit

[74] 250 gallons per day, Natural gas rate is USD 1.10/therm and water temperature rise is 77 degree Fahrenheit

New Construction	0.82	700	227	783	8	2
Replacement upon failure	0.82	1,000-1,500	227	783	12-18	3-5
Retrofit	0.82	1,600-2,100	227	783	19-25	5-6

B.15 Distributed Power Generation – China Case Study

Gas Power Generation Market [75](2013)	*China's gas power generation market value stood at USD 652 million in 2013 and is forecasted to reach USD 1.7 billion by 2017*
Enabling factor	*Expansion in the China's distributed power generation market due to favorable policies supporting gas power generation that will allow the gas turbine market to grow in this period*

Success Story – *Gas generator sets demonstrate successes in China*

- Cummins Corporation established a *joint venture with Jardine Matheson* where the focus is on providing advanced energy efficient green power solutions. The use of overall clean Gas turbine generating unit's distributed-energy project can be achieved for CCHP projects. Distributed energy has stepped into a fast developing term in China as it is about to enter a scale development process as per the Twelfth Five-year Plan to build about 1000 natural gas distributed energy projects during the time frame and plans to build about 10 different kinds of typical distributed energy demonstrations. The joint venture company will rely on the Cummins gas generator technology.
- According to the *12th Five-year Plan* for the Guangdong[76] Energy Development the tasks that relate to local natural gas development in the planning period are to reasonably allocate and establish natural gas power generation and distributed power generation facilities in the Pearl River Delta region with the newly installed gas power generation capacity of about 7.1 million kilowatts of which 6.3 million KW are cogeneration units and small distributed power generation stations.

[75] Energy Global Data
[76] A coastal province of Southeast China

B.16 Boilers and Furnaces – US Case Study

Heating Equipment Market	*At the beginning of 2013 the sales of industrial and laboratory furnaces in the US amounted to US$4.5 billion*[77]
Natural Gas Preference	*Natural gas fires the vast majority of commercial boilers, including 85 percent of commercial boiler units and 87 percent of boiler capacity* *Natural gas is the second largest energy source and the largest purchased energy source for boilers*
Industrial usage	• *Food industry has some large boilers that are natural gas-fired package boilers with a capacity of less than 10 MMBTU/hr.* • *Primary fuels for chemical industry boilers are natural gas (43 percent), by-products (39 percent) and coal/coke/breeze (15 percent).*

Success Story – *Rebates and Incentives accentuate Energy Efficient Boiler and Furnace adaption in the US*

ENERGY STAR Program

ENERGY STAR is a U.S. Environmental Protection Agency (EPA) voluntary program that helps businesses and individuals save money and protect climate through superior energy efficiency measures. To encourage customers to buy energy efficient products ENERGY STAR partners occasionally sponsor special offers and offer rebates such as sales tax exemptions or credits, rebates on certified products. They sponsor recycling incentives for the proper disposal of old products.

Under EPA's leadership American businesses, consumers and organizations have made investments in energy efficiency technologies that are transforming the market for efficient products and practices. In the US, boilers and furnaces are extensively used for commercial and residential applications apart from industrial boilers. The different types of rebates available under the scheme from partners registered in the Energy Star program are highlighted in Table below.

Boilers	• Mail-in rebates of USD 150-400 on qualifying energy efficient boilers for commercial customers • Natural gas boiler (83.5% and greater AFUE) - USD 300

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	• Condensing natural gas boiler (90% or higher AFUE) – USD 500 • Additional USD 25 rebate when the dealer installs a new programmable thermostat with any qualifying heating system • Commercial Columbia Gas of Ohio offers commercial customers with annual natural gas usage less than 3,000 ccf a rebate of USD 200 off on the purchase of a new high efficiency natural gas boiler.
Furnaces	• Mail-in rebates of $250-$400 on qualifying energy efficient furnaces • USD 150 incentive for a furnace with ECM[78] blower • USD 150 rebate on ENERGY STAR High-Efficiency Gas Furnaces of 90 plus AFUE and USD 250 on furnaces with 95 plus AFUE

Energy-Efficiency Rebates for Business Equipment

SoCalGas[79] offers Energy-Efficiency Rebates for Business (EERB) for replacing inefficient gas-fired equipment with more efficient models. The rebates can help reduce the initial cost of your equipment and has the potential to help reduce operating costs. Rebates are available on the following types of equipment.

Equipment Type	Rebate / Unit
Commercial Boiler	$0.50-$4.00 / MBtuh
Space Heating Boiler	$0.50-$4.00 / MBtuh
Process Heating Boiler	$0.75-$1.50 / MBtuh

B.17 Cooking – UK Case Study

Success Story – *Sound gas distribution network across UK aid penetration of natural gas for cooking needs*

The gas distribution networks (GDNs) are the penultimate stage in the delivery process of natural gas for cooking requirements. There are eight distribution networks throughout UK which are owned by National Grid, Northern Gas Networks, SGN and Wales & West Utilities.

Case Example: Northern Gas Network

Safe and Reliable Gas Service network	2.7 million customers 37,000 km
Pipeline network upgrades	Invest heavily in the existing pipe network, replacing old metal pipes which are more prone to leaks with more durable plastic equivalents

[78] Electronically Commutated Motor

[79] Natural gas distribution company, California

Regulator	*Ofgem* - the energy regulator monitors performance through RIIO (Revenue = Incentives + Innovation + Outputs) through an eight year contract
Customer satisfaction for new connections	Averaged 8.61/10 for connection jobs – ahead of target Addressed the concern of customers on getting a gas pipe being fitted on time
Phone based application process	Developed a connections app in response to requests from customers resulting in increase of customer satisfaction scores as measured by Ofgem

RIIO Contract

The new contract ensures that gas distributors deliver a safe, efficient and value for money service where performance is measured against a wide range of targets (51 targets), some of which need to be met or exceeded in order to earn revenue or avoid financial penalties.

The targets are split into six key areas namely safety, reliability, customer service, environment, connections and social obligations. Under RIIO, the connections performance is also measured against a number of very specific criteria ranging from the percentage of customer quotes provided within a set deadline to the percentage of jobs completed on the date agreed with the customer.

Other milestones in Northern Gas Network's operations

- *Less time off gas* - With their well-established service offering they were able to reduce the time frame that customers were left without gas due to emergency repair work or planned improvement work

- *People as well as pipes* - Social obligations were met by helping to support some of the most vulnerable customers and protecting the region from Carbon Monoxide (CO) poisoning

- *Easier connections* - Improved the service customers receive when they apply for a new private gas connection

- *Leakage reduction* - Reduced the amount of gas lost due to pipe leaks which is an important environmental issue as gas escapes contribute to the build-up of harmful greenhouse gases in the atmosphere

About Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy. Based on both energy savings and carbon mitigation potential, we focus on four broad sectors: Power, Transport, Energy Efficiency and Climate Policy. We act as a systems integrator, bringing together key stakeholders including government, civil society and business in strategic ways, to enable clean energy policies in these sectors.

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