Gas Hydrates – The Solution For India's Growing Energy Demand.

Vivek Thamizhmani, Subhashini Sankar, Debi Prasanna Behera

Abstract: Most of the fossil fuel needs for India has been met for many years from other countries. India imports around 83% of fossil fuel as of 2017(1). When BJP (Bharatiya Janata Party) came into power in 2015, there was a clear mandate made to make India free from fossil fuel dependency. In 2018 India made headlines, when Petroleum Minister of India, Mr. Dharmendra Pradhan had announced that the country could serve their complete energy need for the next 300 years. The Ministry of Petroleum and Natural gas (MoP&NG), Government of India had conducted National Gas Hydrate Program Expedition 02(NGHP-02) from 03-03-2015 to 28-07-2015 in the eastern coast of India where they have discovered several gas hydrate accumulations. These data were backed by US Geological Survey which has reported that India's gas hydrate reserve would just be in second place to United States which has the world's largest gas hydrate reserve. Significant quantities of Natural gas hydrates (NGH) have been found in Kerala-Konkan Basin of the west coast, Krishna-Godavari basin of east coast, the Mahanadi basin, Cauvery basin. These basins unaided contribute around 95 – 125 trillion cubic feet of estimated reserves.

Index terms: Gas hydrates, Carbon, Production, Structure, India.

1 INTRODUCTION

Natural gas hydrates also are called clathrate hydrates. Clathrate hydrates are nothing but water occupied solids; making it to mirror ice-like structure. This contains either of the two molecules the narrow non-polar molecules (gases) or the polar molecules with broad hydrophobic[1] moieties[2] are captured inside "cages" of hydrogen bonded, frozen water molecules. Gas Hydrates are formed under severe conditions of high pressure and low temperature when commonly occurring gases such as oxygen, hydrogen, nitrogen, carbon dioxide, methane, hydrogen sulfide, argon, krypton and Xenon comes in touch with water. Clathrates are chemically depicted as non-stoichiometric[3] consolidation of gas and water molecules. Gas hydrates are guest molecules[4] that are bounded by a three spatial[5] cage like lattice framework bound by host water molecules. Unless otherwise the cage is shattered, the bounded gas molecules cannot outbreak from the enclosed water molecules. Non polar molecules are natural gases such as methane, ethane and propane, normally these gases are low in molecular weight. Hydrates are formed in favor of the following circumstances:

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- Temperature should be between 39.2°F and 50 °F
- Pressure should be between 1450 psi and 4351 psi
- Gas concentration should exceed the solubility limit.

So far there have been three configurations have been discovered. They are cubic configurations (I and II) and Hexagonal configuration (H). Configuration I is the prevailing one among other configurations. Configuration I is seen to cover small diameter molecules (0.39 to 0.89 nm).

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A unit cell in S1 configuration, the units cells are organized in body focused packing/ around 46 water molecules being arranged in dodecahedral cages, individually with 12 pentagonal faces (Fig 1). The packing is adequate o encompass methane, ethane and lesser width molecules such as H_2S and CO_2.

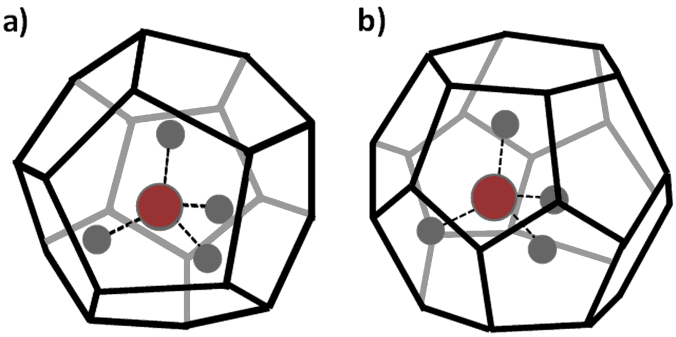


Fig 1: *Structure 1 -Dodecahedral and Tetra decahedral water cages with CH_4 as guest molecule*

Structure II hydrates Structure II (sH) packing has a diamond like packing, thus the cages are big enough to encompass methane, ethane and other larger molecules such as propane and isobutene. Structure H(sH) can accommodate a mix of methane gas and nexohexane or cycloheptane. But Structure II and Structure H(sH) (Fig 2)is rarely seen in the gas hydrate environment. Cage configuration decides the amount of CH_4 that a clathrate hydrate structure can encompass. A molecule of CH_4 will exist for evert 5th molecule of H_20. 1 mole of CH_4 . The chemical formula for clathrate hydrate is CH_4 . $5.75H_20$ or $4CH_4$. $23H_20$. So for every 5.75 moles of water there is 1 mole of CH_4, this conforms to 13.38% CH_4 by mass.

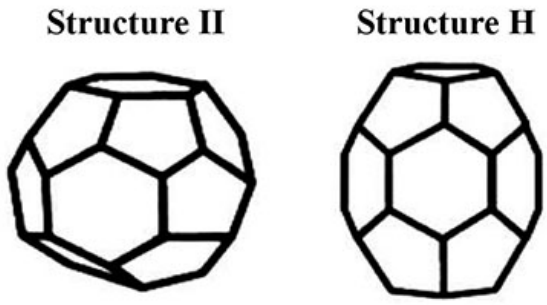
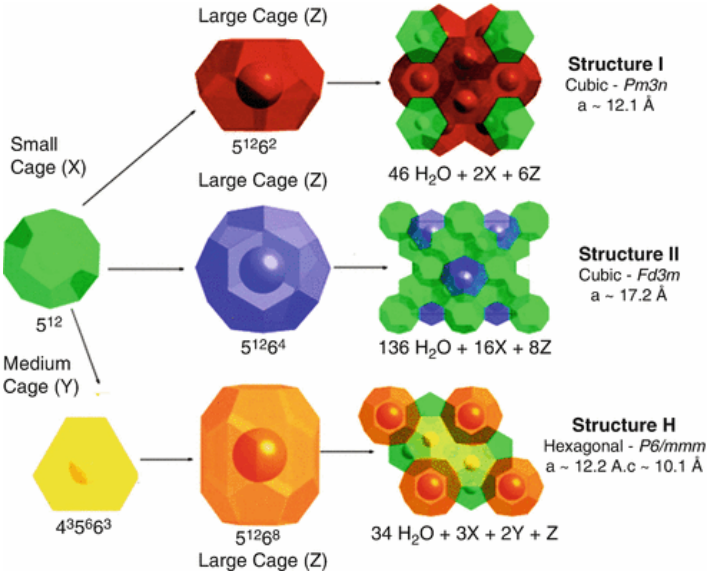


Fig 2: *Structure II and Structure H Gas Hydrates*

Despite this the actual configuration is relying on the number of methane moleules that could adapt onto the numerous cage structures of H_20 framework. The most frequent clathrate hydrates structures are laid out in Fig-3. A detailed description of the clathrate hydrates is given in the table 1



In Table 1, the common chamber radii is calculated based on the number of oxygen at the margin of each chamber and these are estimates made from geometric models. Apart from that we characterization, chambers per unit cell, organizational number and water per unit cell.

Clathrate Hydrate Structure	Structure I		Structure II		Structure III		
Chamber	S	L	S	L	S	M	L
Characterization	5^{12}	$5^{12}6^2$	5^{12}	$5^{12}6^4$	5^{12}	$4^35^66^3$	$5^{12}6^8$
Chambers per unit cell	2	6	16	8	3	2	1
Common Chamber Radii (A)	3.9	4.2	3.9	4.7	3.0	4.0	5.6
Organizational Number	21.9	23.9	19.9	27.7	19.9	19.9	35.7
H_20 per unit cell	46		136		34		

*** S – Small, M- Medium, L – Large

2. WHY INDIA SHOULD THINK TO EXPLORE CLATHRATE HYDRATES?

India falls under the Emerging and developing country (EDC). It is presently the world's largest democracy and is the most fleeting economies. It is projected that India would be the third largest democracy after USA, China by 2025. It is very natural to see a linear trend with amount of energy consumption and GDP. The Government has pushed to reach an 8% economic growth over its tenure and also by meeting the energy demands at a low cost is a large-scale trial for a developing nation. The plain philosophy in attaining such stance is done by becoming a nation of using energy economically and by not importing fossil fuels from outside. By 2040, India's dividend on energy requirement will be around 10.5 to 11%, predicated by monetary development and population expansion. India will account for 1/4th of the global energy demand between 2017 and 2040. Without any new energy resource to meet the country's demand, either through production or importing from others, India will depend on their coal productions, which will double CO2 emission by 2040. India's frontier in gas production won't keep with tread of energy demand, thus gas imports will increase. The following tables points out India's energy production, consumption and market specific utilization today and expected in 2040

	Coal, Mtoe	Oil, Bcf	Oil, Mb/d
India's Production in 2019	400	1024	0.9
India's Production in 2040	710	2613	1

	Transport Mtoe	Industry Mtoe	Non-combusted Mtoe	Building, Mtoe
India's Market specific energy utilization in 2019	104	382	50	218
India's Market specific energy utilization in 2040	253	990	114	571

	Oil Mb/d	Gas Bcf	Coal Mtoe	Nuclear Mtoe	Hydro Mtoe	Renewable Mtoe
Primary Energy utilization by India in 2019	5	1907	424	8	31	22
Primary Energy utilization by India in 2040	9	6551	917	43	56	306

Table 2: *India's Energy outlook -2019 and forecast 2040*

To summarize India's needs by 2040 :

- Energy utilization for India just from primary energy source would be greater than 150%
- Energy utilization ratio between India and the rest will be greater than 10.5%

- Due to surge in energy needs, India will bolster coal production which will reach to record breaking high of 57%
- All the above combined with less investment seen in Non conventional energy sources and renewable energy. India is projected to emit more than 115 % of CO_2
- From 2017 to 2040, population of India increases by more than 260 million and the economy would increase 3 times its size and the country's GDP will double.

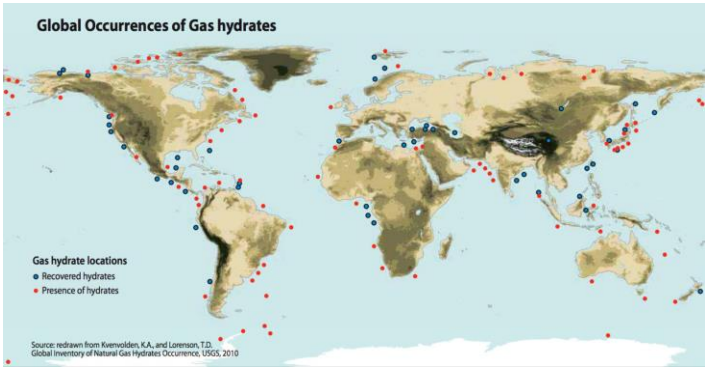
It is very clear from the previous table; India needs to confide on other countries for its energy requirements. In the year 2019, India has imported around 9.7 trillion dollars worth of petroleum commodities. 28 percent of all imports made by India come from Oil and gas business. In 2019, the Prime Minister of India has set a target to reduce hydrocarbon import by 8.5 to 9% as the country moves forward. But in reality, India has imported a record breaking high of 83%, as per the recent records of 2019. In 2018, the world's third largest importer of oil is India and US was second. But in just one year, US has shown a significant improvement and became a net exporter of crude oil, petroleum products and liquefied natural gas. This significant change is mainly due to its production seen from unconventional shale resources. This pushes India to second place. This raises concern as India's population is the second largest in the world. India needs to start looking out of the box. The place first where to start first is to find where hydrocarbon does exist in large numbers within the country and how to exploit it efficiently and cost effectively. In fossil fuels, the major content is carbon. All life species are made up of carbon. Carbon is composed of the natural and man-made sources. Carbon-dioxide one of the most prevalent forms of carbon is found in atmosphere. The respiration of plants and animals releases carbon in the atmosphere. Carbon is seen in lithosphere, presenting itself as carbonate rocks. The birth of carbonate rocks arise from marine plankton that had descended to the basement of ocean floor, millions of years ago were divulged to both extreme warmth and pressure. Carbon makes up a major part in fossil fuels. Carbon is present in soil from deceased and putrefied animals and animal wastage. Carbon is also found in biosphere, widely spread across all plants and animals. The existence of all species on a fundamental level comes from carbon-dioxide. Carbon is present in all greenery across the biosphere. Photosynthesis, the process by which energy from the sun is converted to chemical energy or food is only possible by the presence of carbon dioxide in air. Carbon is also found to present hydrosphere where it is diffused in basins and sea water. The carapace of many marine species such as tortoise, snails is formed due to the presence of carbon. The plants in sea use the carbon for the same photosynthesis process that occurs in land. So without carbon there is no viand for the oceanic community. So what India needs is to find a carbon source that is large in numbers in their homeland, so that reduce our imports. The following lists out the presence of carbon across earth.

1. Clathrate Hydrates or Gas Hydrates has $1000*10^{16}$ gms of carbon
2. Hydrocarbons has $500*10^{16}$ gms of carbon
3. Clay has $140*10^{16}$ gms of carbon
4. Diffused biological constituents in H_2O has $98*10^{16}$ gms of carbon
5. Region biome has $83*10^{16}$ gms of carbon
6. Marshland has $50*10^{16}$ gms of carbon
7. Alternative has $6.7*10^{16}$ gms of carbon. It is very clear from the above, that gas hydrates can be the next big thing in hydrocarbon production. But where are they present.

3. PRESENCE OF GAS HYDRATES:

Gas hydrates is found to be present in all oceans as well as at some parts of the land too. Some of the prominent areas where gas hydrates are found in large numbers are:

a. Large centralization of hydrates is being under investigation in sands of the Mallik Gas hydrate site located on the Richards Island in Beufort Sea, Canada.
b. In the northern Alaska province, around 53.8 trillion cubic feet of natural gas are found to be seen in Nanushuk formation, Tuluvak – Schrader Bluff- prince creek formations and Sagavanirktok formation. The gas hydrates are found in permafrost in a depth range of 200 -1200 m.
c. The earliest research on gas hydrate happened near the coast of Black Ridge, offshore North Carolina. From a seismic survey conducted in the region, gas hydrates presence was discovered. Production from this basin is very demanding due to the large amount of clay content.
d. Since 1985, the Integrated Ocean Drilling Program Expedition 311, conducted a series of seismic survey at the Northern Cascadia Margin a field off the Pacific coast of the United States. They conducted a series of seismic surveys, coring, drilling across the sea floor. The intention was to gather more insight into the substructures. Abundance of quality data from the subsurface helped in developing models of gas hydrates, to enable production from them.
e. The now defunct minerals management system along with United States Geological survey have estimated that the Gulf alone would hold around 6500 tcf of gas hydrate, which if developed economically can meet the country's demand till 2300. This discovery is special because of the biological colonies that have matured here.
f. A team of scientists from India (Oil and Natural gas corporation), Japan (Japan drilling company) and the United States (United States Geological Survey) carried over an exploration on two areas. One being Andaman Islands and other is in Gulf of Bengal. During their expedition, they had discovered a reservoir rock containing gas hydrates that was 426 ft thick.
g. Svalbard is positioned between Norway and North Pole. A study conducted in 2019 said " the volume of natural gas cornered in hydrate deposits is said to be equal to all the other hydrocarbons combined.



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h. The Messoyakha gas hydrate reservoir was the first major breakthrough to provide substantial confirmation of the presence of gas hydrate. The reservoir is a anticline structure with 1400 to 1600 ft of permafrost lying above it. It is located in the West Siberian basin of Taymyrsky Dolgano-Nenetsky District.

i. The gas hydrate drilling expedition was carried out in Ulleung basin, East sea of Korea from 2007 to 2010. Using wire line logging techniques, coring and surveying, the physical attributes, rock and fluid properties of core were analyzed and huge consolidation of gas hydrates were reported.

j. On the continental slope and shelf of Nankai Trough found below the Pacific Ocean, a huge gas hydrate deposit is seen. From geological analysis, the amount of gas volume present in Nankai is found to be 3.6 trillion cubic feet. It was first discovered by the United States Department of energy. The gas hydrate zone here is the focus of research as Japan energy needs tend to rise steeply over the upcoming years.

k. The permafrost in Qilian Mountain, which has an area of around $2.50*10^{18}$ acres located in the Qinghai Tibet plateau, Northwest China has confirmed the presence of gas hydrates in the fractured siltstones, oil shale, mudstones and in the sandstones too. China has the world's third largest permafrost basin with a total area approximating $7 *10^{17}$ acres.

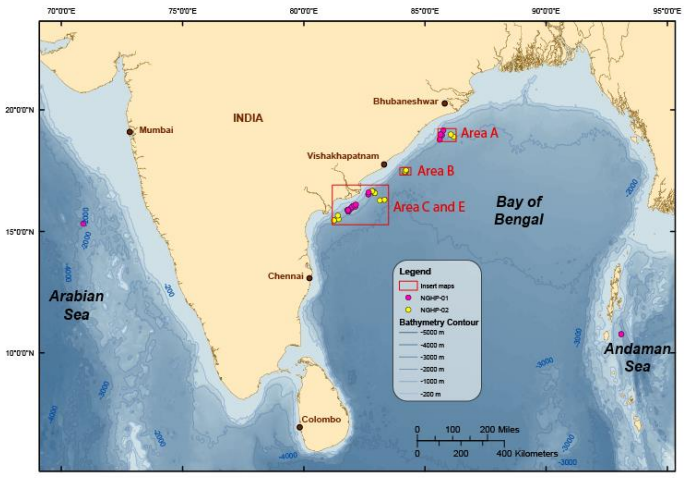
l. Gas hydrates were discovered in Shenhu area, Pearl River Mouth basin, South China sea in 2007. The reservoir rock was found to be 32.5 to 141.5 ft in thickness. It contained only a small proportion of ethane and propane, while the methane content was around to be 96 to 99%. Over gas hydrate region the ratio of methane to ethane is higher than 1000, whereas below the gas hydrate region the ratio is found to be less than 100. The extent of sulphate methane articulation is 56 to 89 feet below sea level. From the analysis of data, the formation of gas hydrate was mainly due to the microbial activity and also in small amounts due to the methane flow upward.

m. From 3D seismic data and log data, gas hydrates were detected in Gumusut-Kakap by Shell at Malaysia in 2007. This deep seated hydrocarbon formation contains around 87 to 90% Methane. Gumsust-Kakap field is a deep water field, which has been contributing the country energy demands for many years. The reservoir is said to be 3875 feet deep. It attained it peak oil production rate of 148000 barrels per day. The gas hydrate reservoir now will compliment the producing field even more.

n. Substantial tectonic signals were registered using bottom simulating reflector (BSR) in Hikurangi trough in the bed of Pacific Ocean in 1980's. BSR can help in determining the lower limit of the hydrate stability in rock fragments. Hikurangi trough. The economic potential for production from such reservoirs depends on several factors such as gas flow rate, total recoverable gas volume.

4. LOCATION OF GAS HYDRATES IN INDIA

The United States Geological Survey (USGS) had published the results of India's Natural gas hydrate program in their website. The following is a detailed summary of the outcomes of those expedition. The elementary aim of the expedition was to probe and to observe the highly saturated gas hydrate in the sandstone reservoirs that to could eventually be a highly producible fossil source. Producing from such reservoirs is similar to producing from conventional sources. The ultimatum in producing from such reservoirs is the commercial viability and safety included. Before production can be initiated, we have to get quality and quantitative data to find out if there are any issues in producing from such reservoirs. The Natural gas hydrate program is a joint venture between the Ministry of Petroleum and Natural gas and Directorate General of Hydrocarbons. D/V Chikyu owned by Japan Agency for Marine- Earth Science and Technology was used and was operated by Japanese Drilling Company. The expedition took place between March 2015 and July 2015 of the eastern cost of India. Schlumberger provided logging while drilling service, wireline logging and formation testing. Geotek coring performed the coring operations. Additional research support was also provided by the US Department of Energy, the National Institute of Advanced Industrial Science and Technology (AIST), Japan Oil and Metals National Corporation.



Around 41 holes were drilled in time span of 150 days, in which 25 LWD holes were logged. The total length drilled was approximately around 32000 feet. Four areas (A, B, C and D)

were evaluated. The formation evaluation data confirmed the presence of highly concentrated gas hydrate accumulations which are highly apt for natural gas extraction. The Areas B and C of the Krishna Godavari basin encompass clathrate hydrate accretion in sand-rich structure, thus they are ideal for future production. Comprehensive reservoir systems were found with sediment grain sizes accounting from coarse–silts to gravel. The gas drifted from deeper systems to reservoir rocks and they are generated primarily from microbial sources. The properties of the gas hydrate zone are significant heterogeneity thus shaping into a complicated reservoir rock to produce, but it has enough permeability all through the rock for prevalent fluid flow over the gas hydrate systems. From exploration stand point of view, the detection of gas hydrate reservoirs are supported by extensive petroleum system reservoirs. Thus from both these expeditions the valuation of these hydrates is expected around 140 tcf of natural gas, this is around 33% of the entire gas reserves of United States.

5. CONCLUSION:

It is very clear that all countries are moving towards gas hydrates as it large in numbers and could save us from the depreciating conventional fossil fuel. India, a country with more than 1 billion in population needs to act fast and capture this energy source to meets its country growing demands. There is a vast amount of gas hydrate reserves present in India's western and eastern coasts. Thus the government along with oil companies should focus on tapping this precious resource to meet our energy demand and reduce the amount of import from other countries as we move forward as a developing nation.

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