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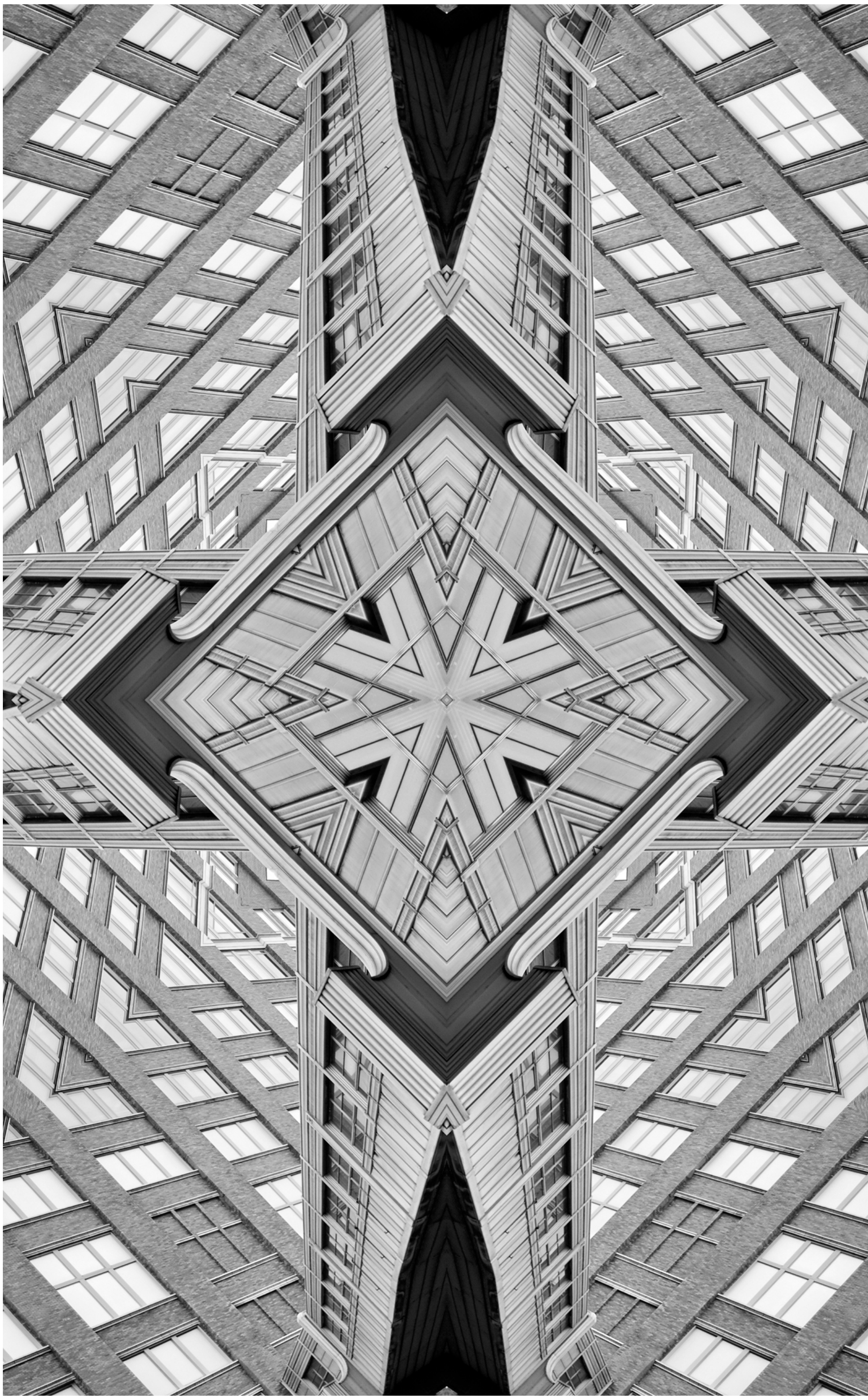

Unlocking the Potential of Marine Natural Gas Hydrate Energy in India

Vedachalam Narayanaswamy

Abstract

Natural gas is an efficient bridge fuel between high-emission fuels and renewable energy systems. Due to limited conventional natural gas reserves, India imports more than half of its natural gas requirements. Increased production of natural gas from domestically available resources could help India reduce gas imports, achieve national emission intensity targets, and honour international climate commitments. Marine gas hydrates are a vast energy resource, and its sheer size demands evaluation. This brief discusses the strategic importance of marine gas hydrates, ongoing global exploratory programs, the various techniques attempted hitherto for the production of methane from gas hydrates and their efficacy, and India's initiatives in commercialisation. India has to make clear determinations by increased investments on hydrate research, development of Indian reservoir-specific production technologies, and financial incentives for promoting commercial-scale natural gas production from local marine gas hydrate reservoirs.

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Introduction

Global investments in clean energy technologies and fuels increased six-fold to US$282 billion between 2004 and 2019, and could surpass US$1 trillion by 2030.[1] Governments are tailoring their post-pandemic economic recovery programmes to incorporate the phase-out of fossil fuels and the parallel deployment and use of renewable and cleaner fuels. The UN Climate Change Conference in Glasgow (COP26) in 2021 reiterated the pillars of a global strategy that will advance the implementation of the Paris Agreement through more sustainable and low-carbon pathways.[2] The essential elements include reducing cost of low-emission technology and promoting an economy-wide green transition.

Natural gas is the most environment-friendly combustible resource that could be used as backup for stochastic renewable energy sources, and as a peak spiker fuel, as natural gas-based power plants could be started and stopped more rapidly during peak load periods. In view of its advantages, the global natural gas demand is expected to reach 5.23 trillion m^3 (TCM) in 2040.[3] In India, 29 percent of the natural gas demand is from fertiliser production (mainly urea), 20 percent from city gas distribution, and 19 percent from the power sector. Some 62 percent of the installed electricity generation capacity and 70 percent of energy production is contributed by the hydrocarbon fuels, with 52 percent from coal-fired and 10 percent from natural gas-fired power plants.[4] Natural gas plays an important role in the Indian electricity generation portfolio for reconciling the climate goals with India's energy security and bridges the delays in the deployment of the renewable energy systems that have higher gestation periods.

Energy Resources in India and Cleaner Generation

India's energy resources and their exploitation levels are shown in Table 1. India has 7.1 percent of global reserves of conventional coal, 0.33 percent of oil, and 0.07 percent of natural gas. Without import substitution, and with the present rate of fossil resource consumption, domestically available coal will last for only 77 years, oil for 4.5 years, and NG for 19.6 years.[5]

Table 1: Energy Resources in India and Utilisation

Resources	Available quantity	Exploitation level as of 2022
Conventional hydrocarbons		
Oil	5.5 BB	38 MT
Natural gas	4.9 TCM	31 BCM
Coal	66.8 BT	602 MTPA
Unconventional hydrocarbons		
Coal bed methane	1.23 TCM	153 million m^3
Shale gas	2.72 TCM	Yet to be taken up on commercial scale
Shale oil	3.8 BB	
Gas hydrates	1894 TCM	
Renewable		
Onshore wind	102 GW	36 GW
Offshore wind	350 GW	Yet to be taken up on commercial scale
Solar	>220GW	34 GW
Hydroelectric	150 GW	46 GW
Biomass	1843 MT/	10 GW
Waste to energy	6 GW	154 MW

Source: International Energy Agency (IEA)[6]

The Power Generation Portfolio under IESS determined effort scenario till 2047 is shown in Table 2.[7] The national installed power generating capacity is expected to reach 1145GW in 2047.

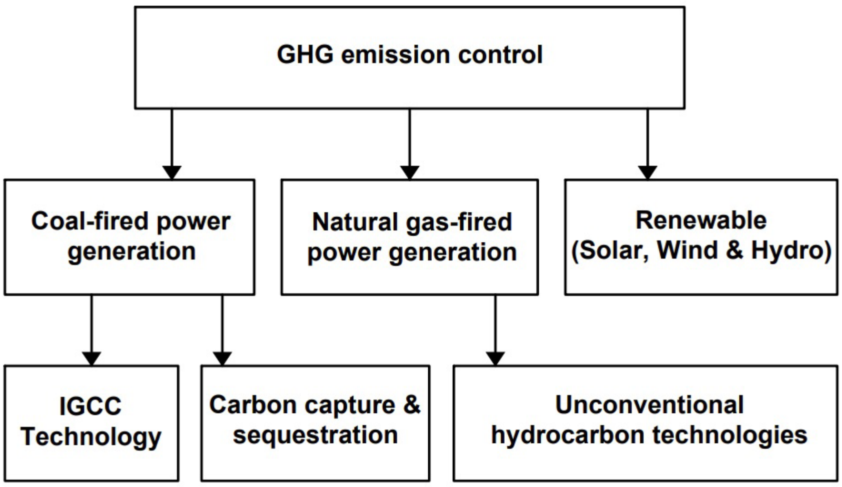
Table 2:
Power Generation Installed Capacity till 2047

Source	2020	2030	2047
Coal	52%	45%	30%
Natural gas	10%	6%	6%
Renewable	16%	33%	50%
Hydro	19%	12%	11%
Nuclear	3%	3%	3%

Source: NITI Aayog, 2023[8]

The efforts in the emission reduction undertaken for achieving cleaner generation include the deployment of renewable energy systems such as solar and wind; implementation of the supercritical, Integrated Gasification Combined Cycle (IGCC) and Carbon Capture and Sequestration (CCS) technologies in the coal-based power generation; and increased use of natural gas produced from the onshore and offshore unconventional hydrocarbons for natural gas-based power generation (see Fig. 1).

Fig. 1:
GHG Emission Reduction Efforts in the Power Sector

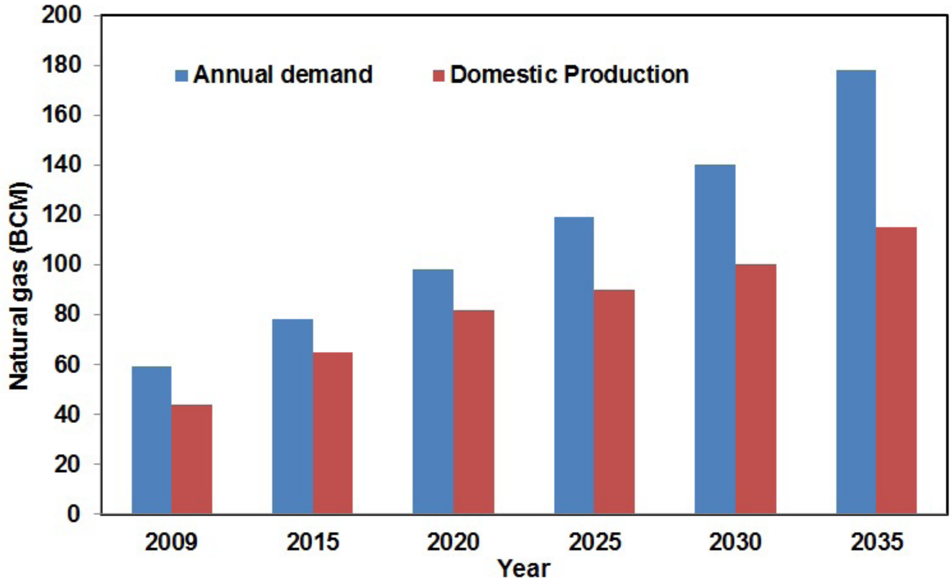


Source: Author's own

The Importance of Natural Gas

The sedimentary basins in India contain ~1.24 TCM of technically recoverable natural gas. The quantity is only 0.1 percent of the global natural gas reserves. At present, some 30 percent of the domestic natural gas production is from onshore hydrocarbon fields and 70 percent from offshore. During 2018-19 and 2019-20, the domestic natural gas production was 33 billion m^3 and 31 billion m^3 (BCM), respectively. During the same period imports were 20 and 34 BCM, respectively, which were 47 percent and 53 percent of the natural gas demand. The increasing gap between demand and domestic production is shown in Fig. 2. More than 40 percent of the natural gas imports were from Qatar in the form of liquefied natural gas (LNG) shipped through LNG carriers. The imported LNG was handled through six LNG terminals with a total capacity of 42.5 Million Ton Per Annum (MTPA). The Dahej terminal in Gujarat has the capacity of 17.5MTPA with a capacity utilisation of 70 percent. For facilitating the transfer of LNG, the natural gas pipeline network is 17,000 km, handling 360 million m^3 /day.[9]

Fig. 2: Growing Demand-Supply Gap in Natural Gas, India



Source: NITI Aayog, 2023[10]

In order to meet the widening demand-supply gap, India plans to increase natural gas imports through cross-border pipelines (Table 3). The projects, if realised, could together deliver ~59 BCM of natural gas annually to India. The Turkmenistan–Afghanistan–Pakistan–India (TAPI) alone could save US$0.25 billion annually by avoiding the use of the LNG carriers.[11] Considering the geo-politically sensitive regions the pipelines will traverse, including the territories of Pakistan and Afghanistan, the US$5-billion UAE-Oman-India undersea LNG pipeline is under discussion. It will have a capability to deliver 31 million metric standard cubic meters per day of gas to India under a 20-year long-term supply contract. Taking into account the geopolitics involved in realising the cross-border pipelines, ensuring supply of natural gas during geopolitical disruptions and refraining from paying higher spot prices, India adopts import diversification strategies. Understanding the importance of realising a natural gas-based economy, India has laid the foundations for the import of natural gas from countries with well-established markets such as the United States, Qatar, Russia and Australia, as well as the emerging markets in gas-endowed countries in Africa, West Asia, Southeast Asia, and the Gulf. The Indian oil and gas companies are involved in the joint development of gas resources in Mozambique's Offshore Area 1, an offshore block where there are ~ 2 TCM of recoverable natural gas reserves.[12]

Table 3: Cross-Border Pipelines Under Consideration

Pipelines	Length (km)	Cost (US$ billion)	Maximum capacity (bcm/year)	India's share in total capacity (bcm/year)
Iran-Pakistan-India (IPI)	2700	7.4	55	33
Turkmenistan-Afghanistan-Pakistan-India (TAPI)	1800	7.6	33	15
Myanmar-Bangladesh-India (MBI)	900	1.5	11	11
UAE-Oman-India	2000	5	11	-

Source: Kulkarni, Sanket Sudhir[13]

In the unconventional hydrocarbon segment (Table 1), India hosts ~4 TCM of coal bed methane (CBM), 2.7 TCM of shale gas, and 1,874 TCM of natural gas hydrate in the offshore continental margins. During the period April-June 2020, approximately 153 million m^3 of CBM were produced.[14] Two shale wells have been drilled to depths up to1300m in the Cambay basin, which produced 0.3 and 0.9 million m^3/day, respectively. The exploitation of shale gas could be subjected to close scrutiny due to heightened public activism, strong judicial supervision, and issues of scarcity in land and water.[15] The production of natural gas from these domestic hydrocarbon resources is essential considering the technical and geo-political challenges in realising trans-national gas pipelines. By 2047, 10 percent of natural gas reserves are expected to be produced from these domestic unconventional hydrocarbon resources.[16]

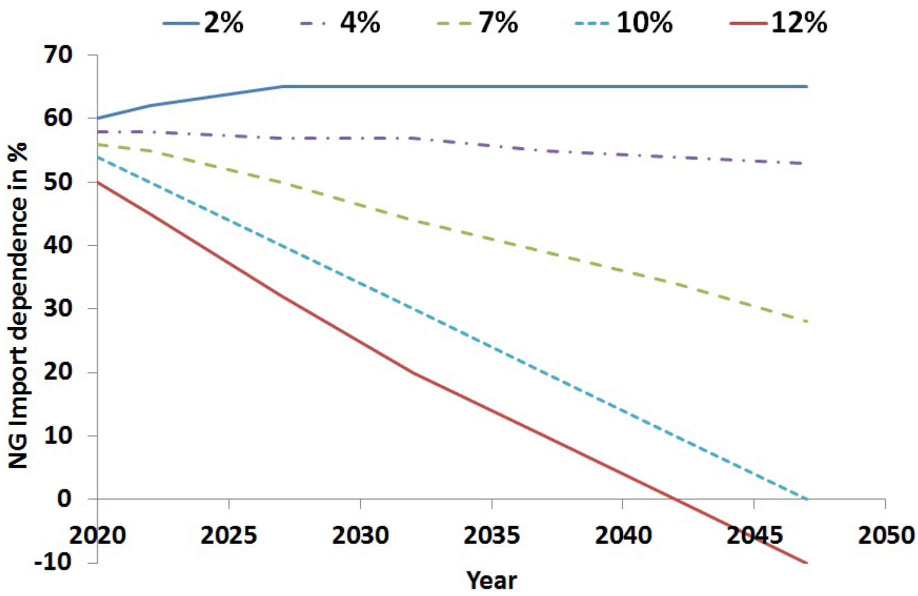
The advantages of increased natural gas production are analysed using IESS. The results indicate (Table 4 & Fig. 3) that if 224 BCM of natural gas (with a corresponding gas production growth rate of 12 percent) is domestically produced by 2047, the country could possibly achieve NG import dependence and further domestic production will make India a net exporter of natural gas.

Table 4: NG Production Scenarios and Advantages

Production by 2047	Power production by 2047	NG import dependence (%)	% share in power generation
127 BCM (determined effort)	50 GW	48	6
170 BCM	83 GW	26	8
224 BCM	132 GW	0	12
270BCM	185 GW	-10	14

Source: IESS 2047,[17] *NITI Ayog 2023*[18]

Fig. 3: Import Dependence with Increased NG Production



Source: IESS 2047[19]

As of 2022, India had 25GW of natural gas-fired power plants. They operate at a very low load factor as gas is expensive at US$ 6-7/mm BTU. The availability of cheaper and abundant gas can help make the resource more viable for power production. The share of the natural gas-based power plants in national electricity generation and the cumulative emission reduction is summarised in Table 5.

Table 5:
Influence of Increased Natural Gas Use in Decarbonisation

Natural gas production by 2047	Installed capacity of natural gas based power plants	% share in the electricity sector	Cumulative emission reduction in % over determined effort scenario
127 BCM (determined effort)	50 GW	6.0%	-
170 BCM	83 GW	8.1%	2.8%
224 BCM	132 GW	11.9%	4.1%
270BCM	185 GW	14.3%	6.3%

Source: IESS 2047[20]

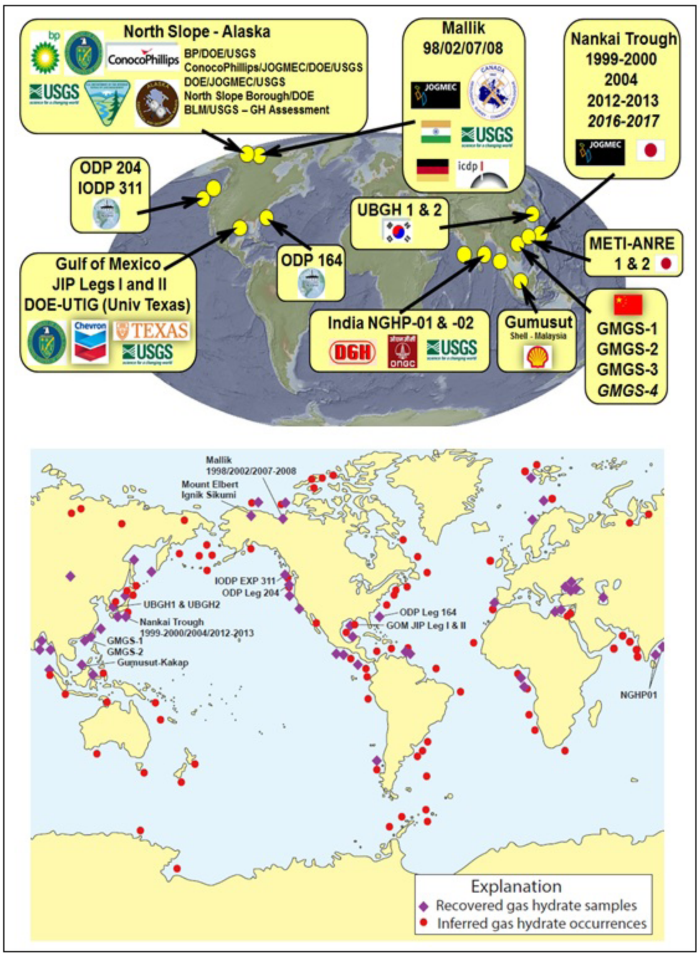
Marine Gas Hydrates

Natural Gas Hydrates (NGH) is considered to be a promising source of natural gas which occurs in permafrost (permanently frozen) regions and oceanic sediments, where suitable pressure and temperature conditions prevail. They are solid crystalline materials composed of water cages containing gas molecules that form and dissociate through a highly reversible chemical reaction. Methane is a dominant gas, but traces of other hydrocarbon gases may also occur. One m^3 of NGH contains more than 160 m^3 of methane gas at atmospheric pressure (1 bar) and temperature (>20°C).[21]

Over 230 NGH potential deposits have been identified globally. NGH could exist at subsurface depths ranging from about 130 to 1100 m in permafrost regions, and at water depths between 800 and 4000 m in offshore continental margins.[22] The amounts of methane gas sequestered in these NGH bearing oceanic sediments are enormous, with the global speculative estimates ranging from 3114 to 7,634,000 TCM.[23] Although identification is possible by indirect methodology, such as geophysical exploration techniques and ground-truthing by sampling methodology, understanding the reservoir conditions with reference to the site is required, and so is developing a suitable technology for extraction. Changing the pressure and temperature conditions of the NGH reservoir, results in methane gas dissociation. Various methods for dissociating NGH such as thermal stimulation, depressurisation and inhibitor injection are in the conceptual or field testing stages. However, a suitable technology for extraction on a commercial basis is yet to be achieved in practice (although depressurisation appears to be most promising), taking into account the environmental and techno-economic challenges.[24]

In marine settings, detailed drilling operations have confirmed the presence of the potential marine NGH reservoirs in the US Gulf of Mexico, the Nankai Trough in Japan, Ulleung basin in Korea, Pearl mouth basin in the South China Sea and in the Krishna-Godavari (KG) basin in the east coast of India (Fig. 4).

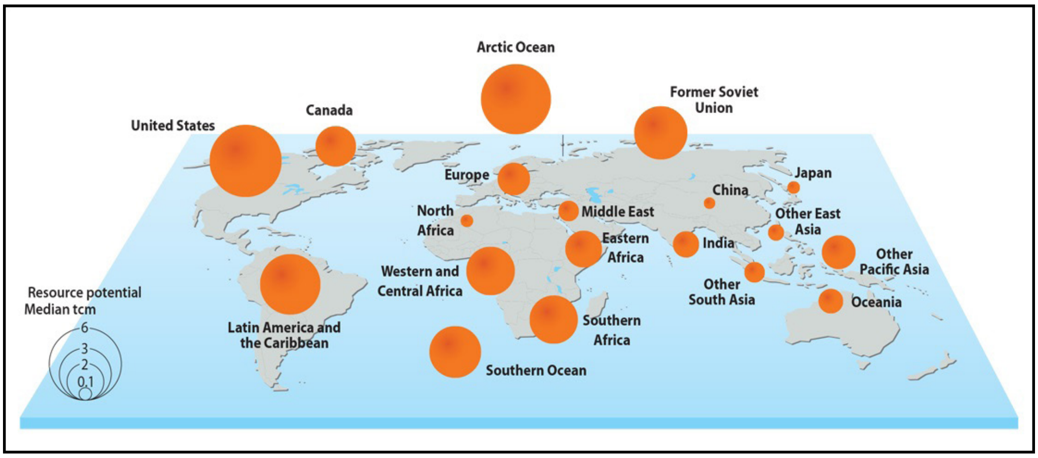
Fig. 4: Notable NGH Field Development Programs



Source: United States Geological Survey[25]

The premier exploratory drilling programs (Fig. 5) include the US Department of Energy's Ocean Drilling Program (ODP) and the Integrated Ocean Drilling Program (IODP) in the Gulf of Mexico; Korea Gas Hydrate Expedition (KGHE) in the Ulleung basin in the east sea of Korea; the Guangzhou Marine Geological Survey (GMGS) done in the Shenhu and Dongsha areas in the South China Sea; and the National Gas Hydrate Program (NGHP) expeditions done in the Indian continental margins.[26] Based on the outcome of the exploratory drilling programs, the globally distributed NGH resource potential is shown in Fig. 5.[27]

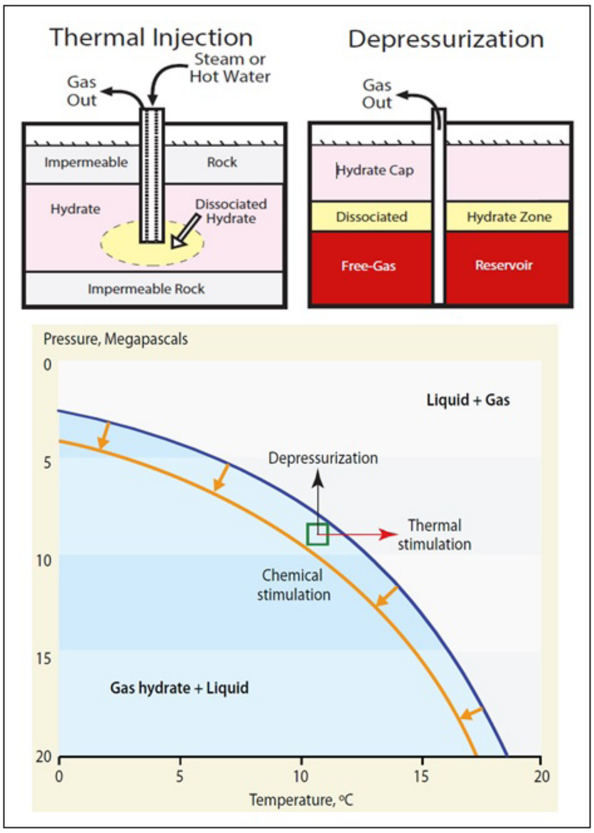
Fig. 5: NGH Resource Potential in Various Countries



Source: United States Geological Survey[28]

The recovery of methane from NGH is a scientific and a technical challenge, and much remains to be understood on the geologic, engineering and the economic factors controlling the ultimate energy resource potential. Fig. 6 shows various techniques and Table 6, the different combinations of field tests conducted in the permafrost regions and marine settings to determine the methane gas/water production, efficiency, gas recovery and production rates.[29,30]

Fig. 6:
Techniques for Dissociating Natural Gas Hydrates



Source: Vedachalam, Ramesh, Srinivasalu, Rajendran, Ramadass, and Atmanand[31] *& Vedachalam, Ramadass, and Atmanand*[32]

The world's first offshore methane gas production test was demonstrated in March 2013 in the Daini Atsumi Knoll area of the Eastern Nankai Trough off the Pacific coast of Japan. Over six days, a cumulative gas production of 120,000 m^3 was reported by Japan Oil, Gas and Metals National Corporation (JOGMEC) and Japan Petroleum Exploration Company (JAPEX).[33] Even though the test was terminated soon due to excessive sand production, the results of the production test provided valuable information that pointed to the challenges in long-term production. The results were used to improvise the NGH reservoir simulator Cambridge Methane Hydrate Geomechanics Simulator (CMHGS), which was later used to simulate a 50-day production. The simulation results reported confident results on the geo-technical behaviour of the NGH bearing sediments and the well bore design under various production scenarios. The test served as a breakthrough to the NGH research community for methane gas production from marine settings by the depressurisation technique.[34]

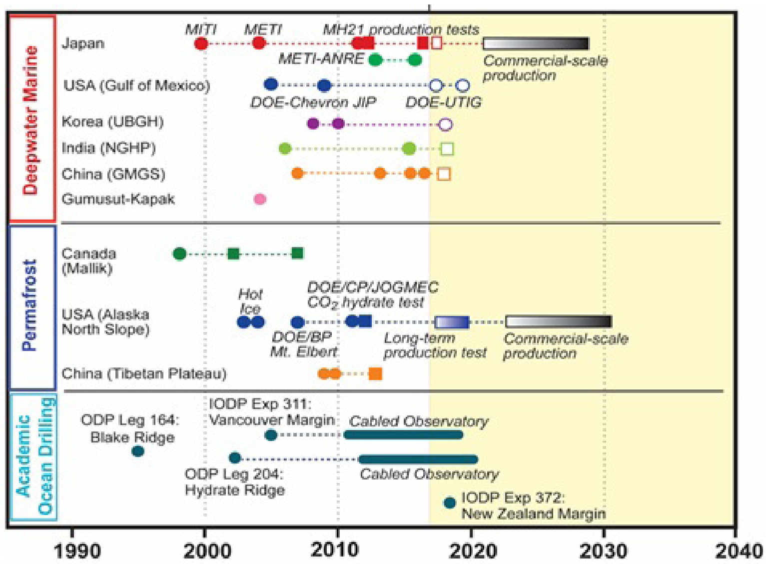
Table 6: Test Locations and Techniques Adopted[35]

Field/ Location	Year	Method	Production period	Gas produced (m^3)
Permafrost regions				
Mount Elbert well, Alaska	2007	Depressurisation	11 h	-
Malik site, Canada	2002	Thermal	5 days	516
	2007	Depressurisation	12.5 h	830
	2008	Depressurisation	139 h	13,000
Ignik Sikumi, Alaska	2012	CO_2–CH_4 exchange	6 weeks	24,085
Marine settings				
Nankai trough, Japan	2013	Depressurisation	6 days	120,000
Shenhu Area, South China Sea	2017	Depressurisation	6 days	160,000

Source: United States Geological Survey[36]

The global road map towards the commercial exploitation of NGH is shown in Fig. 7. In the marine settings, Japan is expected to embark on a commercial scale production of methane from NGH deposits in the next few years.

Fig. 7:
NGH Commercialisation Roadmap

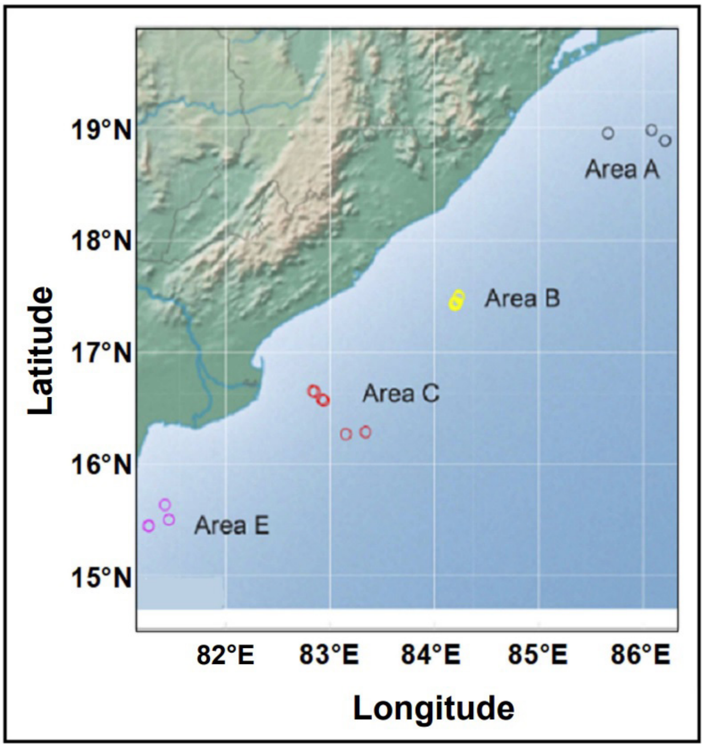


Source: United States Geological Survey[37]

Indian Scenario

Considering the strategic importance of NGH, the National Gas Hydrate Program (NGHP) of India, spearheaded by the Directorate General of Hydrocarbons (DGH) and Oil and Natural Gas Corporation (ONGC) have completed two detailed drilling expeditions NGHP-01 and 02, in 2006 and 2015, respectively, in the continental margins of India. The 113-day NGHP-01 drilling expedition using the drill ship JOIDES Resolution drilled 39 boreholes in water depths ranging from 907 to 2674 m and established the presence of NGH in the KG basin, Mahanadi basins, and near the Andaman Islands. The well NGHP-01-10D drilled at a water depth of ~1050 m in the fractured KG basin showed 90-percent NGH saturation in a 120m thick section occurring 40m below the sea floor (mbsf).[38]

Fig. 8:
42 Locations in Offshore Eastern India Drilled Under NGHP-02



Source: Collett, Ray, William , Pushpendra, Sandip, Krishan, Sunil, et al. [39]

The samples collected during the NGHP-02 from 42 wells drilled at 25 sites (42 boreholes at depths ranging between 239 m and 567m below the seafloor) (Fig. 8) and wire-line logging and coring of 17 sites in the KG and the Mahanadi Basins using Japanese Deep Drilling Vessel Chikyu in the KG basin revealed that the NGH were mainly of the microbial origin, S1 structured and the hydraulic permeability of the samples were found to increase by 10–100 times during dissociation. The Logging While Drilling (LWD) bottom hole assembly consisted of latero-log resistivity measurements and derived borehole resistivity images, nuclear magnetic resonance (NMR), multi-pole sonic tools, density and neutron measurements, and neutron spectroscopy.[40]

NGHP-02 is one of the most extensive research programs to date for drilling and pressure core collection. The expedition explored two distinct NGH accumulations in the KG basin with layer type and fracture type settings with hydrate thickness ranging from 20 to 100 m at 200 mbsf in 2200 m water depths. The accumulation that comprises of thinly inter-bedded layers, with contrasting key parameters over very short distances, internal aquifers and variable permeability is expected to pose challenges in reliable production.[41] The geochemical analysis put the natural gas to be primarily composed of methane mostly from microbial sources however part contribution from deeper sources was not ruled out. An area of ~150 km^2 is identified as a prospective zone in the KG basin.[42] The amount of methane gas in the KG basin is ~1500 times more than India's conventional natural gas reserves and a small fraction of it is estimated to be sufficient to provide energy to India for the next 100 years.

As an initial step, towards the extraction of the methane gas from the potential NGH reservoirs, the Ministry of Earth Sciences - National Institute of Ocean Technology (MoES-NIOT) developed numerical models to understand the spatio-temporal effectiveness of the thermal stimulation technique based on in-situ sediment heating using electrodes and hot water circulation in the KG, Mahanadi and Andaman basins. Subsequently, a numerical NGH reservoir modeling and production simulation software IndHyd1.0 for evaluating the spatio-temporal effectiveness of the depressurisation-based methane gas production technique is also developed by MoES-NIOT.[43]

For understanding the behaviour of the rising methane gas bubbles during production leaks from the deep marine NGH reservoirs, a numerical methane gas bubble dissolution model (BDM) for quantitatively characterising the vertical dissolution pattern is also developed.[44] The National Geophysical Research Institute (NGRI) and National Institute of Oceanography (NIO) are pursuing the scientific studies for the identification, delineation and evaluation of the prospect zones. A pilot production well is planned by NGHP to ascertain the field-specific variants that influence the productivity, such as reservoir heterogeneity, structural and lithological complexity, hydraulic isolation and geo-mechanical effects. The economic viability depends on the production technique, hydrate saturation, reservoir petro-physical properties, capital and operating costs of the production systems.

Environmental and Techno-Economic Challenges

Various countries have undertaken deep-ocean drilling to locate potential NGH deposits and gather the geological factors controlling the occurrence of NGH. However, technologies for producing methane from the marine NGH deposits are in the infancy stage. The results of the demonstration experiments carried out in the hydrate-rich sandy reservoirs in the Nankai Trough region of Japan and in the South China Sea in 2013 and 2017, respectively, serves as a base data for the investigations. Due to the absence of demonstrated long-term well productivity data, numerical NGH reservoir simulator tools were developed to optimise the location-specific recovery strategies (methane gas/ water production), geotechnical characterisation and to precisely forecast production economics. The technical and environmental challenges associated with methane gas production from marine NGH reservoirs are shown in Fig. 9.

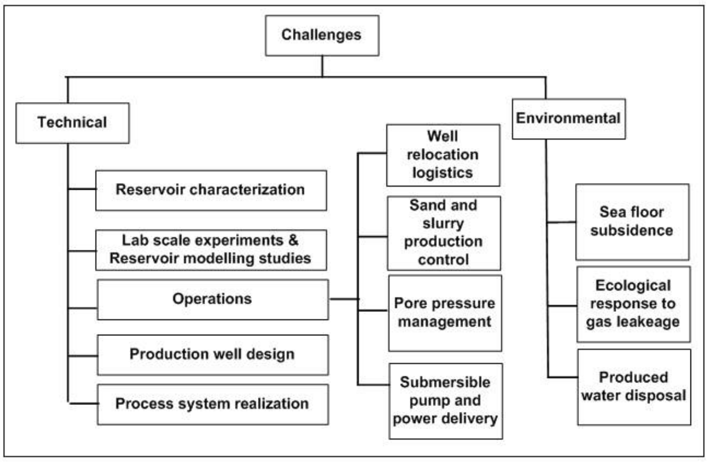
Environmental

The environmental challenges during methane gas production from marine NGH deposits include sea floor subsidence, ecological response to gas leakage and produced water disposal. NGH dissociation releases methane gas and excess pore water which substantially reduces the geo-mechanical stability of the seafloor. Hence, large-scale prolonged production could lead to seafloor subsidence and subsequently destabilisation of the production well head leading to subsea methane gas leaks. Thus the spatial-temporal limits for a NGH well need to be ascertained prior to commercial gas production.

Quantitative assessment on the dissolution pattern of the methane gas bubbles released into the marine environment during a potential leak from the typical subsea well head in the KG basin indicate that, during a typical scenario, the quantity of gas leak shall not exceed 28 m^3 and the released dissolves within 150m from the sea floor. However, the quantity is less compared to a leak in a conventional subsea gas well head where the quantity is enormous, a typical example being British Petroleum operated Deep Water Horizon oil spill in the Gulf of Mexico during 2010 in which ~4.9 million barrels of crude got released at 1522m water depths that resulted in huge enormous environmental damages.

Further, methane gas production from NGH is safer as once the depressurisation is stopped, the methane gas production ceases which is quite safe compared to conventional gas wells. The produced water collected in the FPSO comprises pore water of varying salinity and fine sediments. The temperature, density and the nutrient content of this water significantly varies from the water properties in the sea surface. The resulting indirect and cumulative impacts to the marine biota and the dynamics of the marine ecosystem from these displacements should be analysed. The water in turn needs to be treated to meet the environmental norms and subsequently disposed into the sea water surface. The FPSO should have sufficient capacity to handle, treat and dispose the produced water. These environmental impacts need detailed studies (Fig. 9).

Fig. 9: NGH Exploitation Challenges

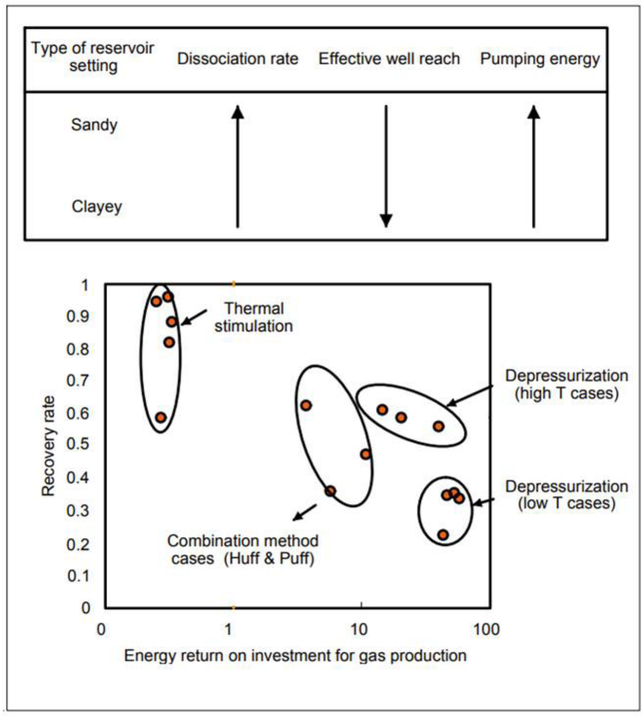


Source: Author's own

Techno-economics of production

The economics of production from a hydrate well (Fig. 10) depends on the type of reservoir setting (sandy or clayey), rate of recovery defined by the petro-physical properties and the production technique (thermal, depressurisation and combination) adopted. Further, the economic viability is highly dependent on the producibility of the target zone, hydrate saturation, petro-physical properties of the reservoir such as thermal properties, formation permeability, sediment porosity, spatial variability/heterogeneity in the depositional environment, capital and operating costs associated with the field development including floating production unit (FPU) systems, artificial lift systems such as electric submersible pumps or subsea processing including separation, multi-phase pumping, produced water disposal systems, challenges associated with flow assurance during start-ups and well shutdowns.

Fig. 10:
Economics of Production Techniques



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Efforts to Harness the Potential

The Indian government predicts domestic natural gas production of about 33 billion m^3/year from the unconventional resources during 2047, which is 15 percent out of the total national natural gas demand.

At present, global NGH research is focused on four aspects including documenting the geological parameters that control the occurrence and stability of the marine gas hydrates, assessing the volume of natural gas sequestered within potential hydrate accumulations, analysing the characteristics of the NGH and analysing the production response for various engineering techniques based on numerical modeling and field-scale experiments, and identifying and predicting natural and induced environmental and climate impacts resulting out of production from natural gas hydrates. From the ongoing developments, it is identified that a combination of technological advances and favourable global/regional market conditions shall make gas hydrate production economically viable.

Economic considerations for production include the mapping of the economically extractable marine hydrate locations taking into account the producability of the target zone, the amount of gas-in-place, geology of the depositional environment, appropriate technology, capital costs, production costs, proximity to the large energy markets, gas pipeline networks, local tariffs and taxes. It is the responsibility of the respective country to determine where marine gas hydrates fits in a larger development framework and whether the extraction, processing, and marketing of natural gas from marine hydrates provides a net advance in achieving its goals.

In the unconventional segment, the abundant quantity of methane gas available in the marine gas hydrates settings in India provides an excellent opportunity for India, the way the United States and China benefited from the abundant availability of domestic shale gas and coal-bed methane. Focused and sustained efforts are required in developing marine gas hydrate reservoir numerical simulators for understanding the significance of the petro-physical parameters; identify appropriate technologies, long-term production economics, geotechnical simulators for understanding the seafloor stability and environmental impact assessments to determine the safe level of long-term production pertaining to the marine gas hydrate reservoirs in India. An imperative is to develop suitable geotechnical tools for carrying out increased spatial sampling which is essential for precisely estimating the spatial variability and the production potential. Foreign drill ships are currently engaged for collecting gas hydrate core samples. Considering the enormous gas hydrate potential, development of a dedicated drill ship (like Japan's Chikyu) is crucial.

Based on the field experimental results reported from the Nankai Trough, establishing an experimental gas hydrate production well in the prospective location KG basin reservoir for assessing the long-term production potential is recommended. Suitable temperature monitoring wells in the proximity of production well could help to understand the spatial thermal and hydrodynamic response, which serve as important inputs for production capacity assessment and to fine tune the gas hydrate production simulators. Spatially distributed seabed located methane gas leakage measurement systems are required for environmental impact assessment during the dissociation/production process. Seabed subsidence measurement systems to quantify the seafloor subsidence and specific technologies for precision control of the riser water level and sand/slurry control mechanisms could be beneficial for ensuring long-term production. Development of compact multiphase and multistage high-flow borehole pumps and associated electrical power delivery systems are to be developed.

Lessons are to be learnt from the shale gas revolution in the US on the efforts undertaken from year 2000 till date. During the period, shale gas production increased from 3 bcf/day to 70 bcf/day.[45] This revolution that made shale gas technically viable and economically cheaper was possible only by means of consistent efforts by federal government and multiple private entrepreneurs in developing massive hydraulic fracturing, horizontal well drilling, advanced earth imaging and component technologies for site testing and characterisation, and various demonstration projects undertaken. At the present juncture, the economics of methane gas produced from the marine gas hydrate in India should not be compared with the natural gas import prices, as the capacity development in utilising the domestic resource could reduce the production cost in the long-term and help achieve import reduction.

In the present Indian scenario, gas price is administered through Administered Pricing Mechanism (APM) and this does not give much encouragement to spend on exploring NGH reservoirs or alternate unconventional hydrocarbon resource. To overcome this, policies for doing ease of business in India (based on the return of experiences from Cairn retrospective tax issue) should be implemented to attract foreign investment and private players should be encouraged (including international companies) to participate in the exploration and gas production in prospective delineated NGH blocks in the KG basin.

Increased motivation, investment in hydrate research, special tariffs and tax considerations are essential in bringing the marine methane hydrate production from a prospective to a contingent state.

Dr. N. Vedachalam *is Senior Scientist and Program Director at the National Institute of Ocean Technology, an autonomous ocean research centre under the Ministry of Earth Sciences. He has previously worked with Birla Group, General Electric, and Alstom Power Conversion, France.*

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Ideas . Forums . Leadership . Impact

20, Rouse Avenue Institutional Area,
New Delhi - 110 002, INDIA
Ph. : +91-11-35332000. **Fax :** +91-11-35332005
E-mail: contactus@orfonline.org
Website: www.orfonline.org