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Gas Hydrates: The Energy Source of the Near Future*

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ABSTRACT

Gas Hydrates (Methane Hydrates) are ice-like crystalline solids formed by the trapped of gas molecules in a lattice by water molecules. They are formed under high pressure and low-temperature condition. They usually contain methane gas, which is the main component of natural gas. Water molecules surround the methane molecules trapping them in a 'cage' of water molecules to form gas hydrates (GH). They are commonly found in the continental margin (continental slope), seafloor sediments, and near-polar frost (permafrost) areas. Today, marine GH deposits, which can be defined as a type of shale gas on the seabed in economic terms, are seen as a "relatively clean energy source of the near future" and will be an important energy resource as part of the world's unconventional hydrocarbon revolution. Looking at Turkey, GH occurs at high-pressure and moderate temperatures in the Marmara, Mediterranean, and Black Sea. To carry out work in this area, the Geophysical seismic laboratory established within Dokuz Eylul University with the support of the State Planning Organization (DPT) served as a focal point in many research activities and conducted exploration studies between 2005 and 2018 by mapping GH and taking samples from the seafloor for the first time. Among these studies, the first phase of the National Gashydrate project has been completed and a priceless discovery with a national team has generated decades of energy potential.

Keywords: Black Sea, unconventional energy source, gas hydrates, geophysics, Mediterranean Sea

SHALLOW GAS HYDRATES (GH) ZONES are important for earth sciences and economics for three main reasons. First, the methane leaks that occur in these zones are a direct indicator of the presence of hydrocarbon reserves in the depths, and they form cover rocks suitable for the accumulation of methane gas in the layers beneath them. Second, methane hydrates themselves are also an important source of energy. They are called "zipped gas" because they contain 164 times more gas than its volume. Third, the formation and migration of methane in sediments can cause intense slope slides, resulting in tsunamis. GH formations can pose security threats in offshore operations and offshore structures such as gas pipelines and oil platforms. For these reasons, detailed research is essential.

GH deposits present in the world are mostly found in areas of thousands of square kilometers, under the seafloor, covered with sediments above. GH reserves will be the energy source of the near future due to the large methane volume they contain. 1 m^3 GH contains 164 m^3 gas and 0.8 m^3 water under standard pressure and temperature. Estimates of the total amount of GH stored under the seabed on a global scale range from 0.2 x 10^{15} m^3 to 7,600 x 1015 m^3.

Due to its great potential, GH, which contains, economically valuable hydrocarbon gases as energy raw materials, is now in the interest of many governments and leading oil/energy companies. Considering that existing oil and natural gas reserves are about to decline, the importance of GH reserves becomes clear. "Shallow GH Zones" in the marine environment can be detected by marine geophysical seismic surveys and other geophysical methods. Studies conducted in Japan have demonstrated through systematic studies that the GH accumulations/formations in marine sediments are sufficient to meet the gas requirement of Japan for 90 years. Other countries in South East Asia (China, India, South Korea) and the United States are exploring GH reserves located in national waters. A field drilling study conducted by the Japanese in 2013 showed that natural gas can be produced from offshore GH reserves. Similarly, comprehensive projects in the Gulf of Mexico, offshore production tests in Canada and Alaska, and offshore production tests carried out by China since 2017 have played a role in forming a widespread opinion that GH will be the energy source of the near future. It should be emphasized once again that Japan and China have started production at sea and will start production on a commercial scale by 2023. Similarly, some countries with economically significant power have targeted GH research with significant budgets for commercial production after 2023.

"Zipped" Gas Which is Lying Deep in the Seabed

When the near-future scenarios in the field of energy are examined, it is understood that coal-based energy/electricity production will reach its maximum level in a short time, particularly when power plants to be installed are taken into account alongside the existing resource-based installed power capacity. By the 2040s, it is predicted that natural gas-based energy production will outperform coal alongside a rapidly increased share of renewable energy resources (IEA World Energy Outlook, 2019).

Non-Conventional energy sources include GH, shale gas, geothermal energy, hydraulic, nuclear, solar, wind, and biomass. Alongside increased investment in alternative energy sources, new technologies in the energy field are rapidly being developed. Due to the large volume of methane they contain, it seems GH reserves will stand out as the main alternative/non-conventional (coal-oil-natural gas) energy source in coming years.

Shale gas (SHG) was not included in the conventional class of fossil fuels formed by the coal-natural gas-oil trio, which was relatively cheaper to extract at the beginning of the twentieth century when it was first discovered. The main factor determining this choice was the cost factor in obtaining these resources. In two examples, natural gas production has been carried out at competitive costs from SHG since 1905 in Louisiana in the United States, from GH in Messoyakha region (permafrost area) in Russia, from 1970 to the present day. On the other hand, it has been ignored for many years by oil companies. In general terms, in the energy sector, SHG and GH both can be an alternative in natural gas production. However, "these two unconventional energy sources have been thoroughly investigated in recent years and appropriate production technologies have been developed over time. As a result, since the 2000s, SHG has taken its present place in the oil industry and has become a "game-changer" energy source in terms of countries' policies towards energy sources" (World Energy Council Turkey, 2018: par.4)

The formation of the ice-like, crystalline GH composed of hydrocarbon gas molecules and water molecules surrounding them under the seafloor in high pressure and low-temperature environments depends on the combination of four factors: low temperature, high pressure, water, and natural gas which mainly consists of methane. These are the conditions required for the formation of gas hydrates and some modifiers (parameters) that control the formation process:

- Formation temperature (low temperature)**,
- Formation pressure (high pressure)**,
- Pore water salinity,
- Gas composition (biogenic/thermogenic methane),
- Presence of water and gas (fluid flow),
- Reservoir presence (porosity)

as listed like these (Sloan & Koh, 2007; Max et al., 2013).

When the conditions above are met, gas hydrate formation will begin in the sedimentary environment. In contrast, the absence of any of these conditions formation prevents gas hydrate formation.

Looking at the general features of GH, the stability curve stands out as a key characteristic. "The stability condition of GH is expressed by high pressure and low temperature, and these conditions are called 'thermobaric conditions'" (Gas hydrate, n.d.) If the temperature increases and/or the pressure drops, the GH structure decomposes into gas and water and passes into a two-phase state. There are 3 types of GH structures: structure I, structure II and structure H:

Structure I: these porosities can only hold small gas molecules (methane, ethane) whose molecular diameters do not exceed 5.2 angstroms.

Structure II: these can hold gases such as propane, isobutane with molecular dimensions of 5.9-6.9 angstroms. This type of structure was first produced in the laboratory and was first detected in nature in 1983 in an area with a water depth of 530 m.

Structure H: This type of structure was first found in nature in 1993 at depths similar to Structure II, in Jolliet, a large oil and gas production area in the Gulf of Mexico.

To summarize, the structure I gas hydrates may contain biogenic origin gases with structure II gases of biogenic origin, thermogenic origin gases, and structure H may contain biogenic origin gases and thermogenic origin heavy hydrocarbon gases. For this reason, the gas discovery of thermogenic origin in the region is an indicator of the large gas reserves deeper below GH.

The amount of methane gas captured/stored in GH all over the world is estimated to be twice the carbon held in all fossil fuels in the world and more than fifty times the oil and natural gas resources. Existing GH deposits have been determined with up-to-date technology, only a small part of them have commercial potential, the real reserve and its contribution to the country's economy are much higher. The available resources are enormous. Figure 1 shows the distribution of GH around the world.

The Distribution of Gas Hydrates in the World

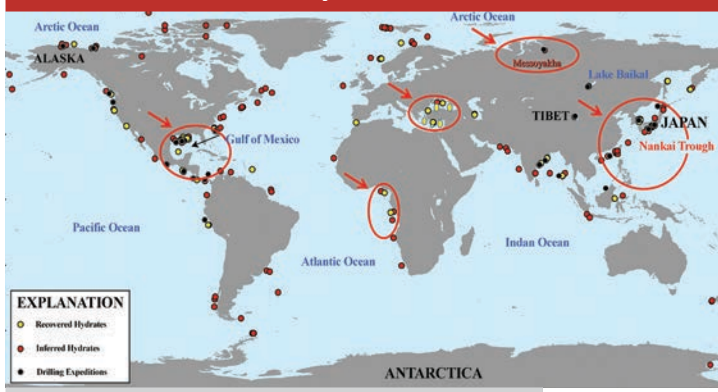

Figure 1. The distribution of Gas Hydrates in the world and the dots shown with a circle show the areas where important developments have taken place in Gas Hydrates. The map, which is drawn by author's research team, is shared by the courtesy of him

The areas within the circle in the figure show the Messoyakha area which is the first land production area in the world, GH areas in oil and gas fields such as Alaska, Gulf of Mexico, Angola Bay, and the Eastern Mediterranean, and GH areas such as the Nankai Trough where the first production was realized in the sea and the South China Sea. The potential to be obtained from the work to be carried out in the exclusive economic zone of the Black Sea, Marmara, and Eastern Mediterranean, which has an important place in terms of marine gas and GH accumulation, is one of the most indispensable resources to the Turkish economy.

GH is important economically, as it is important for Earth Sciences. Methane leaks on the seabed are a direct indicator of the presence of hydrocarbon reserves in the deeper layers. In addition to being an indicator of the presence of oil and natural gas deposits, GH is an energy source that expands 164 times against 1 unit on its own due to its transforms to natural gas. GH can be formed by leaks from which natural gas exits, and other oil and gas expulsion. The main risks that arise in shallow gas zones are slope slides (submarine landslides) that can lead to a tsunami, and the accumulation of GH just below the seabed creates unstable and loose ground stabilities. In this case, unfavorable conditions will occur for offshore structures such as natural gas pipelines, oil platforms, etc.

Methane gas has 20 times more global warm absorption capacity compared to carbon dioxide if it is released into the atmosphere. In other words, methane gas is a very dangerous greenhouse gas due to its contribution to climate change. GH-induced emissions as a methane sequester have been found to play a major role in triggering ice ages throughout geological cycles.

In this case, the fact that gas hydrates, which are stable in terrestrial and marine areas, begin to dissolve for any reason and reach the atmosphere can create a global catastrophe in the sense of climatic cycles and global warming. For this reason, the realization of gas production from natural GH and the consumption of produced gases are interpreted as the only way to prevent a catastrophe that can occur in a climatic sense. One of the most likely propositions that will remain unchanged in the coming short and medium term is that GH, which is much cleaner in terms of greenhouse gas emissions compared to conventional fossil fuels, will replace coal and oil.

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Additionally, the presence of natural gas was also determined as a result of investigating the core samples taken to determine the free gas deposits under the GH zone. A detailed study of these natural gas reserves has not yet been researched in Turkey, and this area is open to Priority Research.

The importance and main characteristics of GH can be summarized as such:

Apart from and as an alternative to conventional fossil fuels (coal-petroleum-natural gas), GH is a new energy source that can be described as "unconventional". As the energy source of the near future, GH is of great economic importance and also has a function as the main indicator, especially in oil and gas exploration.

GH is a good seal for hydrocarbons. As a hard impermeable underground layer, GH can create a reserve, allowing oil and gas to accumulate beneath it. GH, sampled on methane leaks, gas chimneys, mud volcanoes, and similar structures, is the most obvious sign of the presence of oil and gas in the depths with this GH-specific image, with the determination of the hydrocarbon presence at depth and the GH signature on marine geophysical seismic sections. The GH asset to be detected before drilling will constitute the most important indicator in terms of the positive results of offshore drilling, one of which costs hundreds of millions of dollars. Drilling in the right location due to the presence of GH will create an important variable in minimizing costs.

The most commonly used geophysical methods in gas hydrate research include:

- 2D / 3D seismic methods (conventional but more than high resolution)
- Multi-beam bathymetry depth measurement methods
- Side Scan Sonar Methods
- Seabed Heat Flux Measurement Method
- Well log geophysical measurements
- Electromagnetic Measurement Methods
- Ocean Bottom Seismometer (OBS) can be listed as geophysical methods

The presence of bottom-simulating reflections (BSR) is a direct hint of GH in Geophysical seismic sections. Since BSR reflections represent the base of the gas hydrate stability zone, these markers are also an isothermal boundary and therefore offer the ability to mimic the seabed, which is also considered the most typical feature of BSR markers.

Discovery of Gas Hydrates and Gas Hydrate Studies in Turkey

Before natural gas and oil discoveries in the Levantine Basin and Egyptian offshore areas in the Eastern Mediterranean, indicators of GH areas were already discovered. In the Mediterranean Sea, the GH structures in the Gulf of Antalya and the Anaximender submarine mountains in the west of Cyprus were determined by seafloor sampling. Additionally, structures such as the mud volcano, which also indicates the presence of GH, have been identified around the southeast of the island of Crete (Çifci et al., 1997).

Technological development efforts to obtain methane gas (and therefore energy) should be carried out in parallel with other countries of the world that are making progress in this regard. In addition to GH Reserve determination extraction-drilling and transport technology development should be started in parallel. Countries with oil and gas reserves often do not have the technology to extract their reserve. “Western countries”, on the other hand, gain rights and great gains on these reserves as they hold suitable technology. For this reason, it is of great importance to conduct both reserve- and technology-based studies .

Especially in the territorial waters of Turkey, the search for GH and the establishment of technology and systems that will enable them to obtain energy are seen as a priority target. It is very important to determine the amount of proven and accessible natural gas and GH reserves on the seabed and coast, to develop and implement current technologies in the necessary exploration and operation areas, as well as to create policies for the benefit of the country in the short, medium, and long term. Turkey is to formulate a general policy to develop hydrate-derived hydrocarbon focused on search technology for determining the reserves.

The development of technologies and methods for obtaining methane gas (natural gas) from GH is in the final stage, and recent improvements are being made on pioneering methods.

At the beginning of the century, oil deposits in the region were discovered as a determining factor in drawing of Turkey’s southeastern borders. Western companies intensively researched these resources, which are today in the south of the country borders, in the second half of the

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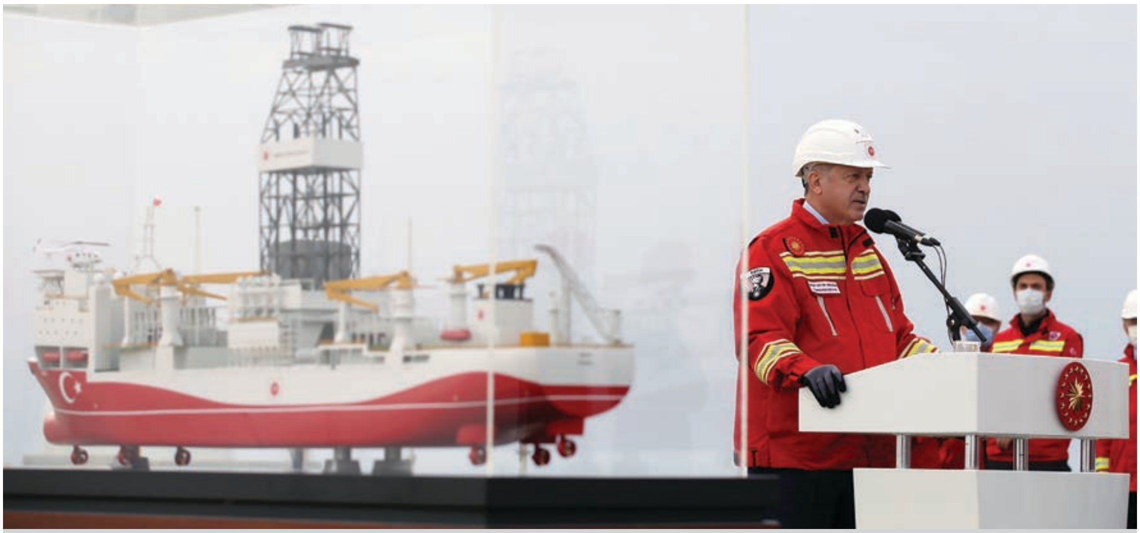
19th century. The areas were determined as a result of researches made by foreign geoscientists and were later shaped as country borders. Today, the same situation is repeated in the seas. Similar to the early 20th century impositions, Turkey may encounter threats such as the deprivation of wealth in the seas surrounding Anatolia. The current situation also points to developments in this direction. Therefore, the importance and urgency of focusing on marine research for Turkey is evident. Otherwise, if the Blue Homeland strategy and the research and exploration studies are not completed with determination, Turkey may be faced with imposing jurisdiction on the high seas. Lack of knowledge will also create a condition that weakens Turkey's position among other political factors. The results obtained in the projects we have conducted for GH research prove the accuracy and justification of the determinations and analyses made for the future of Turkey in the intervening period.

The most concrete step for GH studies in Turkey was an advanced research project supported by the State Planning Organization in 2003 called "seismic investigation of gas-saturated sediments and GH in the Eastern Black Sea shelf and slope of Turkey", coded 2003K120360. With this project, a Geophysics Seismic Laboratory (SeisLab) was established within Dokuz Eylül University, Institute of Marine Sciences and Technology (DBTE), whose main purpose is to conduct GH research (Çifci et al., 2003). With the support of TUBITAK, DPT, European Union (EU) and projects carried out together with some energy companies, the laboratory's infrastructure has been strengthened the laboratory is became only one in Turkey and intertanional level in the world. With additional knowledge and experience, they have acquired staff and researchers who have served in Seislab, taking part in research studies with Turkey's research, explaration and drilling vessels and making important and valuable contributions.

Along with the discovery and mapping of GH reserves, at the end of a joint collaboration of different academic units conducting coordinated studies in a multidisciplinary structure, the presence of GH was determined with certainty and reserve calculations were carried out.

With the discovery that GH, which is Turkey's domestic resource spread over an important area in the Black Sea, it seems that Turkey can become a "game-changer" center with its own energy resources. In addition to the fact that this discovery was made by Turkish researchers, thanks to the highest level of interest of our state in this issue, important opportunities will arise from the point of view of both our country and the region, without being limited to the framework of a project aimed only at research and discovery. At the first stage, the presence of GH reserves should be determined, mapped, and estimated in all potential areas. Later, new and original technologies should be developed to produce natural gas (mainly methane) from these reserves through coordinated efforts between different disciplines. In addition to determining this potential, the technologies needed to obtain gas from hydrates at the laboratory stage should be investigated and implemented. Studies show that the depressurezation technique is more effective in these methods.

This is the first phase of the National GH



President Erdoğan is in the Fatih drilling vessel. (TCCB, 2020, October 17)

project from the point of view of our country, successfully implemented in certain areas and "know-how" was created on this issue far beyond its economic dimension with a team consisting entirely of notional researchers.

Apart from purely geophysical methods for GH research, within the scope of multidisciplinary studies (geological, chemical, geochemical, microbiology, and Palynology), important observations and results related to GH accumulations/formations were obtained from the results of the analysis. It is possible to view the presence of GH with BSR fields and hydrate-containing core samples obtained from geophysical analyses.

By analyzing various hydrocarbons and metals in sediment samples with marine chemistry studies, information about the conditions of the areas where GH exists can be obtained. By determining the gas components in the amount of dissolved gas in water and mud samples, it can be determined that the gas is of thermogenic or biogenic origin. Furthermore, conducting analysis for the determination of biomarkers in geochemical samples and evaluating the results in this direction will provide information about the origin and source rock of hydrocarbons.

By microbiological analysis, numerical evaluations of organisms to determine the groups of microorganisms that use methane and other hydrocarbons as carbon sources are made and information about methane production in sediments is obtained. Studies conducted with microbial processes are strong candidates for potential GH fields, and in the long term, it is important to receive support from biological processes in the production of GH.

As part of the data obtained from geological and geophysical measurements, core analysis, and analysis of gas samples, the amount of gas in the place in the hydrate structure can also be calculated using estimated probability methods.

In this context, the objectives are (I) mapping the distribution of GH, (ii) determination of approximate reserves in the field, (iii) modeling of drilling and production techniques, and (iv) determination of possible production potentials and technology. In advanced projects, a team will explore and map reserve areas, while the engineering team will work in the field of production technology.

In the future, GH's share and role in the energy sector will be determined by the contribution of the financial sector and its support for possible investments.

The energy and the financial sector are developing together in this area. In the future, GH's share and role in the energy sector will be determined by the contribution of the financial sector and its support for possible investments. Research investments of countries other than Turkey in the energy source of the future can be seen. The developments observed in this regard between 2004-2020 are noteworthy. In this process, the budget spent solely for research exceeds billions of dollars. Many countries, such as oil and gas-deprived China, Japan, South Korea, India, and Germany, as well as the oil- and gas-rich United States, Brazil, Norway, and Iran have invested in this area.

The existence of GH is not unique to our planet (Mousis, 2020). In solar system, it is considered that gas hydrates are more abudant than the rocky materials. Jupiter, Saturn, Uranus, Neptune, Mars and Europa might include huge amounts of gas hydrates (Choukroun, 2020). For instance, on the surface of Titan (the largest moon of Saturn), the clathrate hydrates formed by multicomponents (i.e. ethane, xenon, methane and other preferred clathrate formers) are available. Due to harsh conditions in these planets, new types of clathrate structures (i.e. Type T) are discovered different than clathrate hydrate structures in Earth's nature. These hydrate structures are considered to be the most important indicator of water existence in the planets.

After the introduction of natural gas production from GH, various studies related to GH, gas production techniques, numerical, and experimental gas production simulations, as well as field trials, were continued. Advances have been made on key issues such as factors, efficiency, and economic value that govern the process of gas production from GH.

The government of Japan established a national program in 1995, and the Japan National Oil Corporation (JNOC) conducted its first production phase in the Nankai Trough in 2013 (Jiji Press, 2013). Again, drilling has been carried out in Canada's McKenzie Delta and plans to produce on a commercial scale starting in 2023 (Oyama & Masutani, 2017).

The first gas hydrate studies in the deep seas in the 2000s were carried out by Japan. Studies in Japan consist of three phases annually. It covers exploration, modeling, field testing, development technology, environmental safety, and work safety, and health plan. 2D and 3D geophysical seismic measurements were carried out in east Nankai Trench. In the second phase of the research, between 2009-2015, offshore GH production test preparations and the drilling of production test wells were planned and carried out in a 6-year plan. The first production test study was carried out in 2013, and the second stage production test study was conducted in 2017. Within the scope of the 3rd phase, it targeted production works on a commercial scale after 2018 and continued to work towards uninterrupted production.

The Hydrate Ridge located on the coast of Alaska, the Atlantic Ocean, the Pacific Continental Margin, Southern Mexico, the Central American Trench extending from Mexico to

Costa Rica, the Atlantic Continental Margin, the Blake Outer Ridge, the southeastern and western active margin of the United States shows that GH is spreaded in sediments. On the Blake Plateau on the southeastern continental slope of the USA, only one area of approximately three thousand km2 has methane reserves equal to approximately 30 times the annual gas consumption of the USA. In 2018, it was combined with an expanded gas hydrate production test with stratigraphic testing in the western part of the Hydrate-01 well in the Prudhoe Bay area. The final goal of this project is a long-term (12-24 months) gas hydrate production test (Collet, 2018). After many projects such as the northern slope of Alaska, the US has planned a new drilling and pressure coring project in the Gulf of Mexico in early 2022 (Collet, personal communication, 2020).

In South Korea, GH research was conducted in a three-phases project between 2000-2014 on a long-term basis in marine geophysics. Later, core and log work and drilling work were carried out. Additionally, following the collection of 2B and 3D seismic data, the GH production test was carried out in the 3rd phase in 2015 (Ryu et al., 2013).

Similar to these examples, India conducted Geophysical Research in 2006 to find target points for production testing purposes and conducted its most comprehensive research on GH in 2009 with drilling for GH purposes and 5 months of drilling and log studies in 2015 (Rogers, 2015). India has scheduled production tests in 2021 and 2022 with the National Gas Hydrate program.

Figure 2 shows the 15th (TTR, 2006) of the UNESCO-supported Research and Training Cruises in the Black Sea, and the burning of GH sampled from the seafloor together with oil. Besides the Black Sea, there is a dense Reserve in

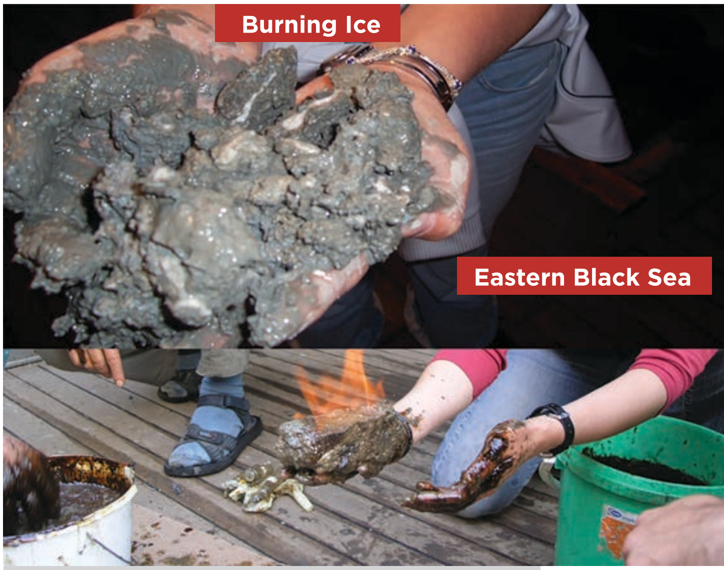


Figure 2. The 15th (TTR, 2006) of UNESCO-supported Research and Training Voyages in the Black Sea, along with oil on the ship deck, the burning of GH sampled from the seafloor is seen. The photograph, which is taken by author's research team during the fieldwork, is shared by his courtesy.

the Marmara Sea and especially in the Eastern Mediterranean. It is thought that 71.8 trillion m^3 methane is included in the methane hydrates in the Black Sea. While the potential in the Black Sea (assuming that a 1 m GH layer exists) can be calculated as 8.0 x 10^{10} m^3. In another study, depending on the geothermal gradient of 6.89 x 10^{13} and 9.66 x 10^{13}, the standard m^3 level (Parlaktuna & Erdoğmuş, 2001) was 13.6 trillion m^3 (Merey, 2019). The huge scale of gas potential that could theoretically be produced is noted. In the Eastern Mediterranean, it has been calculated that 552.3 trillion m^3 of methane hydrate can be found with the prediction that 98.16 standard trillion m^3 gas is the least producible part (Merey & Longinos, 2018; Merey, 2019). After high-resolution 3D geophysical seismic and test drilling, the amount of gas that can be produced can be calculated more accurately.

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The potential to be determined by exploration studies within the Black Sea, Marmara, and Eastern Mediterranean exclusive economic zone, which has an important place in terms of marine gas and GH accumulation in Turkey, is of great importance for the country's economy. The Black Sea, in particular, is a special sea with high amounts of methane production and GH accumulation. Therefore, Turkey thanks to its unique production technology, will become a global player in the field of energy with a potential to meet its needs for the annual gas consumption (Küçük, 2018).

China, which is the first country to achieve reliable continuous and stable gas production, carried out the same studies in different pilot areas within the scope of China's National GH Program. In 2007, GH drillings were carried out in the Shennu area in the South China Sea, the Pearl River delta in 2013, and the South China Sea in 2015 (Zhang et al., 2014; Shengxiong et al., 2017.) The first production drilling was completed in 2017. The daily maximum production was 35,000 m^3, the average daily production was 16,000 m^3, and 99% methane was produced from the extracted GH. The test production study carried out in the South China Sea has been completed with a 203-277 m drilling at a depth of 1,266 m. Test production took 7 days, 19 hours. During this period, 120,000 m^3 of methane gas was produced. The Government of China continues to work with determination to produce GH in the South China Sea, which has the most promising sediments in the world, within the scope of the 5-year plan, between 2016 and 2020. In line to produce natural gas from GH, with the production drillings carried out between May 10, 2017, and July 9, 2017, the entire oil industry has turned its eyes to China.

China managed to extract 861,400 m^3 of natural gas from "burning ice" in the South China Sea in March this year. The production process started on February 17 and was completed on March 18 with two world records.

China's Ministry of land and Natural Resources has reported that the volume of fuel obtained from gas hydrate in total is a new world record. It was noted that the month-long trial also established "a solid technical foundation for commercial use". Gas was extracted from a northern area in the South China Sea at a depth of 1,225 meters. The second world record is the highest gas production of 287,000 m^3 in a single day. In addition to being the first country in the world to evaluate gas hydrates using a horizontal drilling technique, China has also come to the fore with the most patents among other gas hydrate research countries. Associate professor Praveen Linga, from the Department of Chemistry and Biomolecular Engineering at the National University of Singapore, noted that China is the most advanced country in this field, compared to the results seen from Japanese Research, Chinese scientists have managed to extract much more gas. Therefore, he reported that this was a big step towards making gas extraction from gas hydrates feasible. China's Economy Diary newspaper reported in 2017 that China's Burning Ice (gas hydrate) reserves are equivalent to about 100 billion tons of oil, of which 80 billion tons are located in the South China Sea (Xie, 2020).

China Geological Survey (CGS) brought successfully off the natural gas hydrate extraction test project, which started on May 10 and lasted for seven days and 19 hours (CGTN, 2017)

It has long been known that intensive academic and industrial studies on GH are carried out in China. China currently has the appropriate technological tools/methods to extract GH from under the seabed in deep water. Undoubtedly this is a breakthrough that provides grounds for developing field projects all over the world.

Gas Hydrate Studies in Turkey

Long-term cooperation between Turkey and China can be realized to explore and extract GH resources in the seas surrounding our country. The vast cooperation potential in the seas and oceans surrounding three continents between the countries of the 21st Century Marine Silk Road and the Silk Road Economic Belt is of great importance and priority. There is a wide range of opportunities and possibilities for joint projects that can be carried out in the seas for the Blue Planet and the Blue Homeland. Among these, joint research and engineering projects with equal participation of third countries at coasts in the oceans are the first to come to mind. Among the large-scale projects that can be included in the scope of possible studies between countries, GH deserves special attention among other joint applications and projects due to the high economic gains provided to participating countries on the Marine Silk Road.

Especially when it comes to GH, it is seen that "Mother Nature" behaves much more equitably in the distribution of GH resources in the world, unlike traditional fossil fuels. The "Western civilization" can be described as the "coal-oil-natural gas" civilization since the "First Industrial Revolution" which started with the invention of the steam engine 250 years ago. "Nature" has been very selective in choosing the places rich in conventional fossil fuels mentioned above. It is a known fact that oil and natural gas resources are limited to some regions of the world. From this point of view, GH resources are much more evenly distributed compared to oil or gas and offer much more independence for countries near these resources.

Gas Hydrates, Renewable Energy Sources, and Global Warming

It is a clear fact that all countries worldwide need to reduce their use of fossil fuels and preferably eventually terminate them to mitigate the negative effects of climate change caused by human actions (anthropogenic climate change). Almost everyone in the world, relevant management bodies, non-governmental organizations, state and private sector organizations, etc. recognize that renewable energy sources should replace fossil fuels in the future.

However, the complete replacement of fossil fuels by renewable (clean and inexhaustible) resources can not be suddenly done. There will be a "pause and decrease interval" in the intervening time. From this point of view, it should be noted that the existence of GH and the opportunities it offers indicate a transition phase because it is a much cleaner source of energy compared to coal and oil. However, in the latest analysis, carbon stored in the geological layers of the Earth millions of years ago is released into the atmosphere in a way that increases the effects of global warming. In this context, using GH as a suitable option against oil and natural gas can provide great advantages and independence in terms of vital issues for a society such as eliminating external dependency in energy and ensuring supply security in energy.

Economic activities to be carried out in the marine environment are also an integral part of the talking mission. Life on this planet was born from the seas. The seas have been and will continue to be an indispensable resource for sustaining life on earth.

As the basis of all human activities, maximum care and diligence should be shown to protect the marine environment. In this case, the marine Silk Road refers to another area of cooperation along with possible cooperation mechanisms and business models for the achievement of energy companies and academic institutions, the private sector, and government agencies between China and Turkey. As a starting point, Turkey and China can form a partnership to conduct future activities together. This can be considered as the main axis in a wide range of economic activities to be carried out jointly on the continental shelves and Exclusive Economic Zones. Research and extraction of GH can be one of the best examples of cooperation to be realized.

In summary, the above-mentioned project ideas can be considered to be an integrated project package that will be implemented following the main principles and goals of the Belt and Road Initiative. To provide energy resources to our country, a joint agreement can be reached on the continuation of further stages of the project or new pilot areas. In addition to the above mentioned, it is known that some developed countries are targeting commercial-scale production with fairly large budgets for GH research in 2023. It is necessary to be ready to cooperate with countries that want to work on joint projects on this issue and not trail behind. Blue Planet and Blue Homeland concepts may include GH exploration and research in the Black Sea, Aegean Sea, Mediterranean, and all continental borders of the world.

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