

Worldwide regulations and policy trends on gas production from gas hydrates

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Received: 26 March 2023 / Accepted: 31 July 2023

Abstract. Gas hydrates are considered near-future energy resources with their vast amounts all around the world, especially in permafrost and marine environments. Since the beginning of the 2000s, there have been many gas hydrate exploration, drilling, coring, and production trials in the world. The countries (*i.e.*, Japan, China, India) that need urgent energy resources are in a rush to produce feasible natural gas from gas hydrate reservoirs. However, according to available production trial data, there are many obstacles to reaching the commercial level of gas production. Due to the sensitive nature of gas hydrate reservoirs, the health, safety, and environmental risks of all production trials should be discussed. Moreover, it is crucial to control the risks of these production trials. This study aims to investigate the worldwide regulations and policy trends related to gas hydrate production trials.

Keywords: Gas hydrate, Methane, Environmental risks, Sustainability, Hydrate policy, Regulations, Legislation.

1 Introduction

Worldwide energy demands continue to be on the rise, especially after recent COVID-19 effects and other political conflicts. According to the report of the *U.S. Energy Information Administration (EIA, 2021)*, global energy consumption is likely to increase by approximately 50% in all energy resources (*i.e.*, natural gas, petroleum, coal, nuclear, and renewables) unless there are no technological developments or policy changes. Currently, there is a motivation to reduce carbon footprints with clean energy in the world. Natural gas is considered a relatively clean fossil fuel so gas hydrates are important targets for energy companies and countries (Chen and Merrey, 2021). Gas hydrate experts state that gas hydrate might be a bridging fuel, in the transition toward renewables (Henriques, 2018). Overall, gas hydrates are near-future energy resources with their vast amounts in the permafrost and marine environments.

Gas hydrates are ice-like crystalline structures formed by gas (*i.e.*, mainly methane) and water molecules at high-pressure and low-temperature conditions. These conditions exist in the marine sediments (95–99%) and permafrost regions (1–5%). 1 m³ of gas hydrate is composed

of approximately 0.8 m³ of water and 164–180 m³ of gas (mostly methane) (Chen and Merrey, 2021). Thus, it is obvious that gas hydrates include the huge potential of natural gas (methane). The terms “*gas hydrates*”, “*methane hydrates*” and “*natural gas hydrates*” are interchangeably used in the literature.

Since the 1970s, many gas hydrate reserve estimations varying from 0.2×10^3 to 3.053×10^6 standard trillion m³ (tcm) with an average of 1.527×10^6 tcm were conducted relying on very limited data. According to Chong *et al.* (2016), the technically recoverable gas hydrate potential is approximately 300 tcm in the world. On the other hand, Pang *et al.* (2021) claimed that only 41.46 tcm of technically recoverable gas hydrate is available. However, the recent consensus about gas hydrates is as in the followings:

- They are considered near-future energy resources.
- They are relatively clean energy resources compared to other hydrocarbons (*i.e.*, oil, coal, etc.).
- Due to their vast distribution all around the world as seen in Figure 1, they can be transitional energy resources from hydrocarbons to commercial renewable energy resources.

Especially after the mid-1990s, the number of gas hydrate exploration, drilling, and/or production activities

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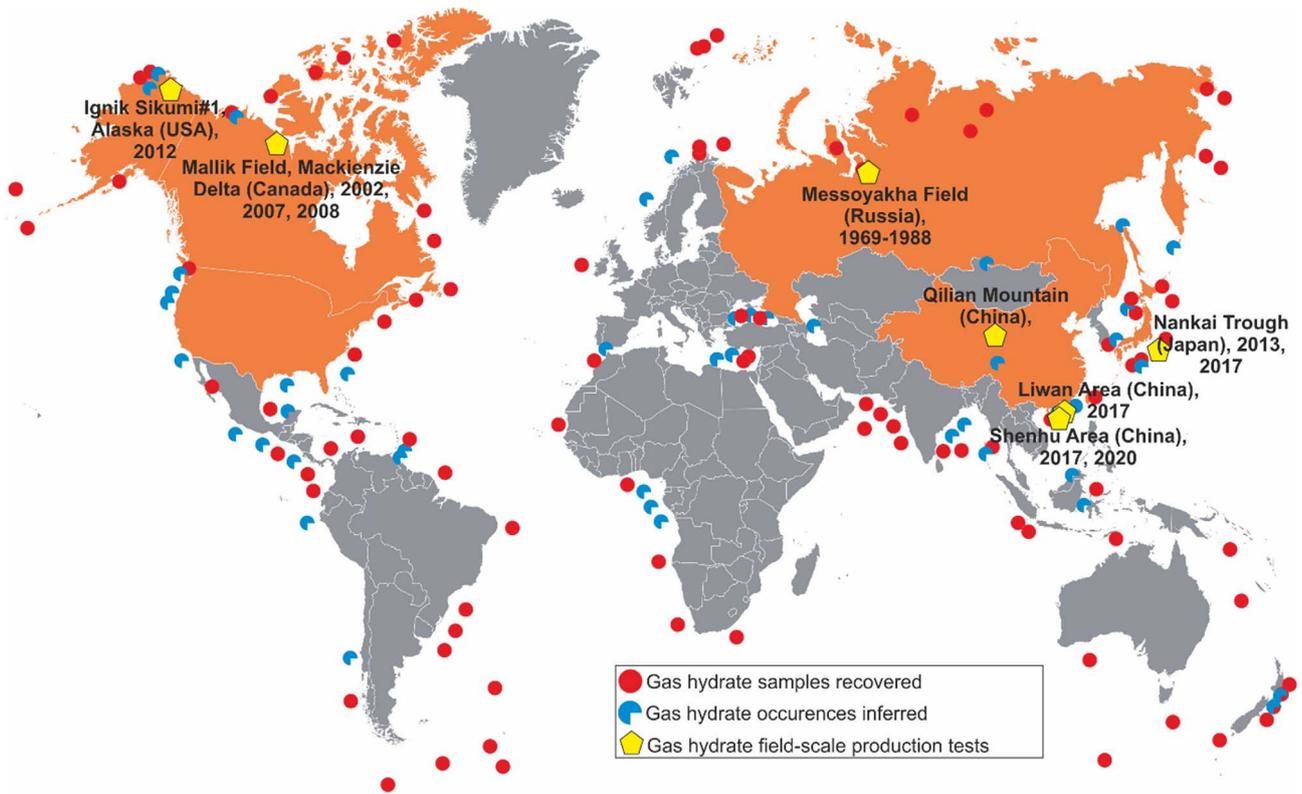


Figure 1. Gas hydrate distributions and field test locations in the world (Orange color indicating the countries that conducted gas hydrate production trials).

(mainly in the USA, Japan, China, Korea, Canada, and India) has increased (Collett, 2019). The vast gas hydrate reserve and the declining trend in conventional hydrocarbon reserve was the main reason for the increase in gas hydrate projects (Pang *et al.*, 2021). Figure 2 summarizes the significant gas hydrate projects in the world. The countries (mainly China, Japan, India, and the USA) implementing gas hydrate projects and trying to produce the commercial level of natural gas from gas hydrates are mainly the world's largest and most rapidly growing economies. By relying on its current commercial level of shale gas and shale oil production, the USA is not in a hurry to produce gas from gas hydrates but is still they conduct gas hydrate projects for providing other energy resources in the future. On the other hand, China, Japan, and India try to obtain a commercial level of gas production from gas hydrates by the 2030s owing to their huge energy demands.

Partain and Yiallourides (2020) evaluated the risks, rewards, and legal framework related to hydrate occurrence in Europe. They stated the concerns (*i.e.*, landslides, gas seeps, etc.) related to the exploitation of gas hydrates and also proposed the necessity of optimal policy strategies. Zhao *et al.* (2017) stated that special attention is essential for gas production from gas hydrates by considering the possible environmental risks associated with hydrate production trials. Moreover, they said that there are limited documents related to the national gas hydrate policies

regulating gas hydrate field-scale studies in the world. Yan *et al.* (2020) evaluate China's environmental management and risk avoidance policies and regulations on the exploitation of gas hydrates. They said that the current legal framework in China is still far from preventing the risks associated with gas production from gas hydrates and this legal framework does not consider human health and mostly concentrated on environmental effects. Moreover, there are no specific details for gas hydrates in the Chinese-related legal frameworks. According to Chang (2020), it is essential to apply the United Nations Convention on the Law of the Sea and other treaties while examining the rules applicable to the exploitation of gas hydrates.

For more than 20 years, there is essential experience in gas hydrate exploration, drilling, and production trials. There is uncertainty about the environmental effects of long-term gas hydrate production and the feasibility of currently available gas hydrate production trials. Thus, the gas hydrate industry needs longer production trials. There are no exact gas hydrate-related regulations in the world and most of the gas hydrate activities are evaluated as those in conventional oil and gas activities, which is wrong. Thus, gas hydrate production risks should be evaluated in both engineering and energy law/regulation aspects. This study, it is aimed to discuss the gas hydrate activities since the beginning of the 2000s and suggest what the regulations/laws should include about gas hydrates.

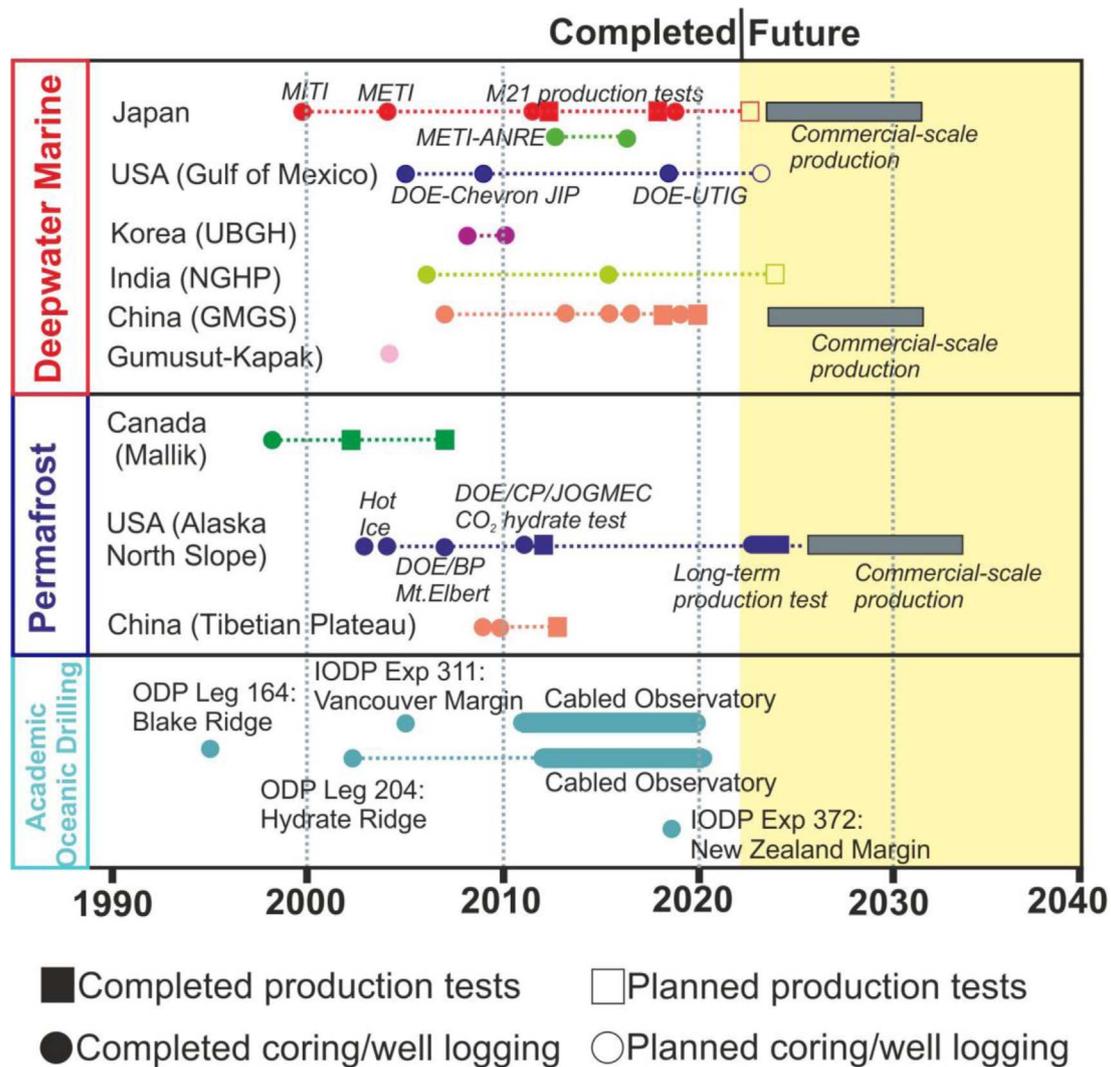


Figure 2. Timeline of significant gas hydrate exploration activities, drilling activities, and production trials in the world (Modified from Collett (2019)).

2 Current gas hydrate production technology and environmental risks

Figure 3 shows the gas production rates in the recent gas hydrate production trials. The gas production rates range from $10 \text{ m}^3/\text{day}$ to $2.87 \times 10^4 \text{ m}^3/\text{day}$ with an average rate of $6.47 \times 10^3 \text{ m}^3/\text{day}$. The duration of these production tests is from 12.5 h to 60 days (Li *et al.*, 2018). As seen in Figure 3, the gas hydrate industry aims to increase the duration of gas hydrate production tests as possible. Longer production tests provide better production data, reservoir characteristics, history matching with simulators, feasibility estimations, and potential environmental risks related to gas hydrate production. However, the gas hydrate production trials were terminated early due to several technical problems (*i.e.*, sand production, pump failure, high water-gas production ratio, etc.). To reach the commercial level of gas production in gas hydrates, the gas flow rates are between 1.6×10^5 and $3.0 \times 10^5 \text{ m}^3/\text{day}$ as illustrated in

Figure 3 (Chen *et al.*, 2022; Ma *et al.*, 2020; Yu *et al.*, 2019) should be obtained for a single well. For this reason, the gas hydrate industry aims to increase average gas production rates in gas hydrate production trials above $1.5 \times 10^5 \text{ m}^3/\text{day}$ (Chen *et al.*, 2022) by the 2030s.

Gas hydrates are stable inside the sediments at high-pressure and low-temperature conditions. By disturbing these equilibrium conditions with pressure reduction, temperature increase, and chemical interaction, it is possible to release free gas from gas hydrates together with free water. In the Mallik Site (Permafrost) of Canada, the thermal method and the combination of the depressurization method and thermal method were applied in 2002, 2007, and 2008 but the duration of this was short as seen in Figure 3. Yet, these international (USA, Japan, Canada, India) gas production tests in Canada were the pioneering production trials activating other next gas hydrate production trials. In Qilian Mountain (permafrost) of China, the combination of the depressurization method and thermal

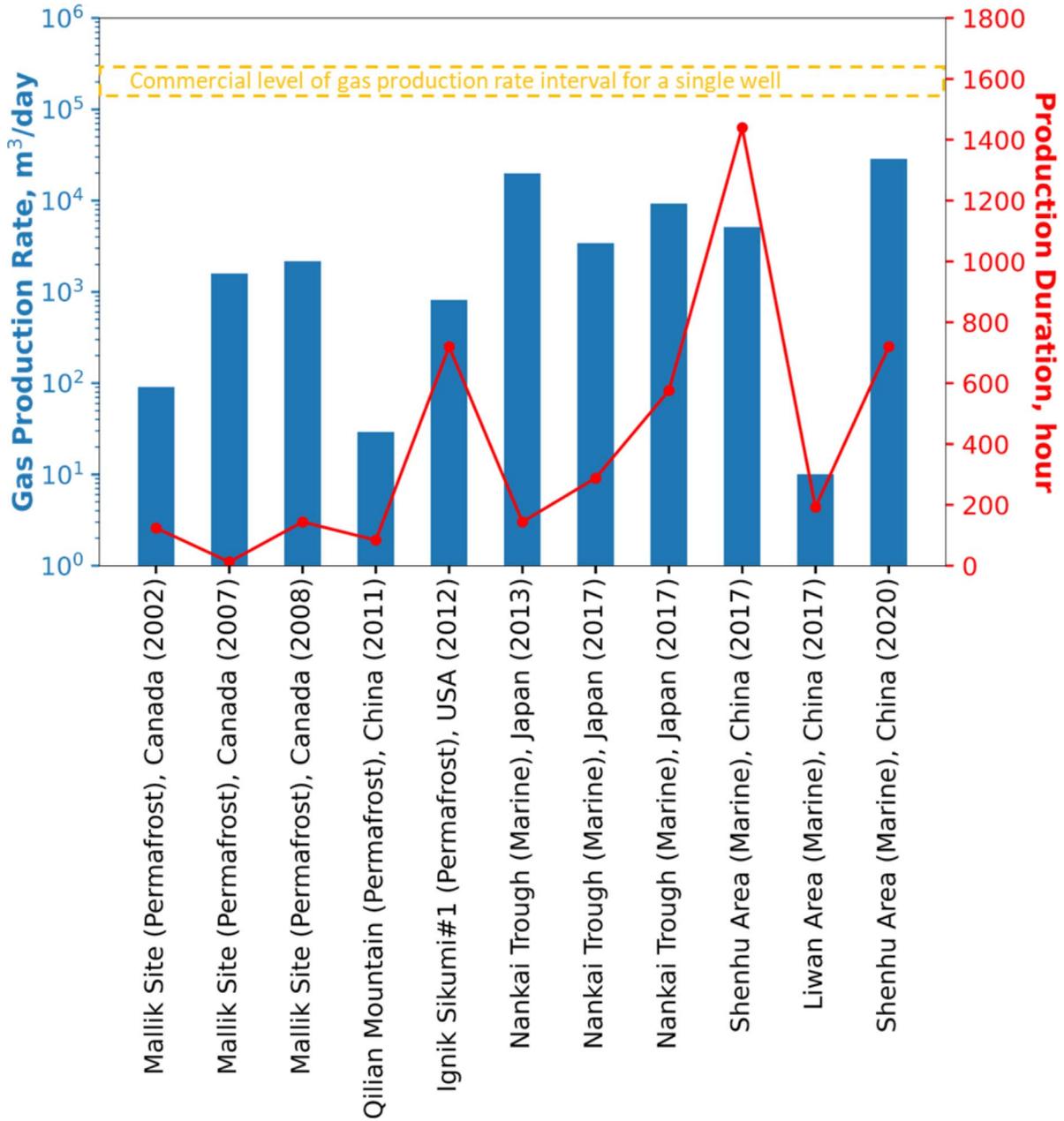


Figure 3. Gas hydrate production trials in the world.

method was implemented for only 84 h. The $\text{CH}_4\text{-CO}_2$ replacement method was conducted for the first time in the Ignik Sikumi#1 well in the permafrost region of Alaska, USA for 30 days. The first marine gas hydrate production trial (at a water depth of ~1000 m) “2017-Nankai Trough, Japan” is a milestone tone for the gas hydrate industry. This test showed that it is possible to drill and complete gas hydrate wells in the marine environment and provide gas production from gas hydrates. However, this test was terminated within 6 days due to sand production-related problems while applying the depressurization method and other factors (*i.e.*, weather conditions). In 2020, two different production trials were conducted in two wells in the

Nankai Trough by applying the depressurization method for 12 days and 24 days (Fig. 3). Although essential modifications were done after the 2017-Nankai Trough test, sand producing-related and related pump failures and high water-gas production ratio were still problems faced during the depressurization tests in the Nankai Trough in 2020.

As seen in Figure 2, China focused on gas hydrates in the late 2000s. However, it is quite aggressive to produce commercial levels of gas from gas hydrates. In 2017 and 2020, gas hydrate production trials were conducted in the Shenhu Area and Liwan Area in the South China Sea (Fig. 3). China is the second country that conducted marine gas hydrate production trials. It is the first country to apply

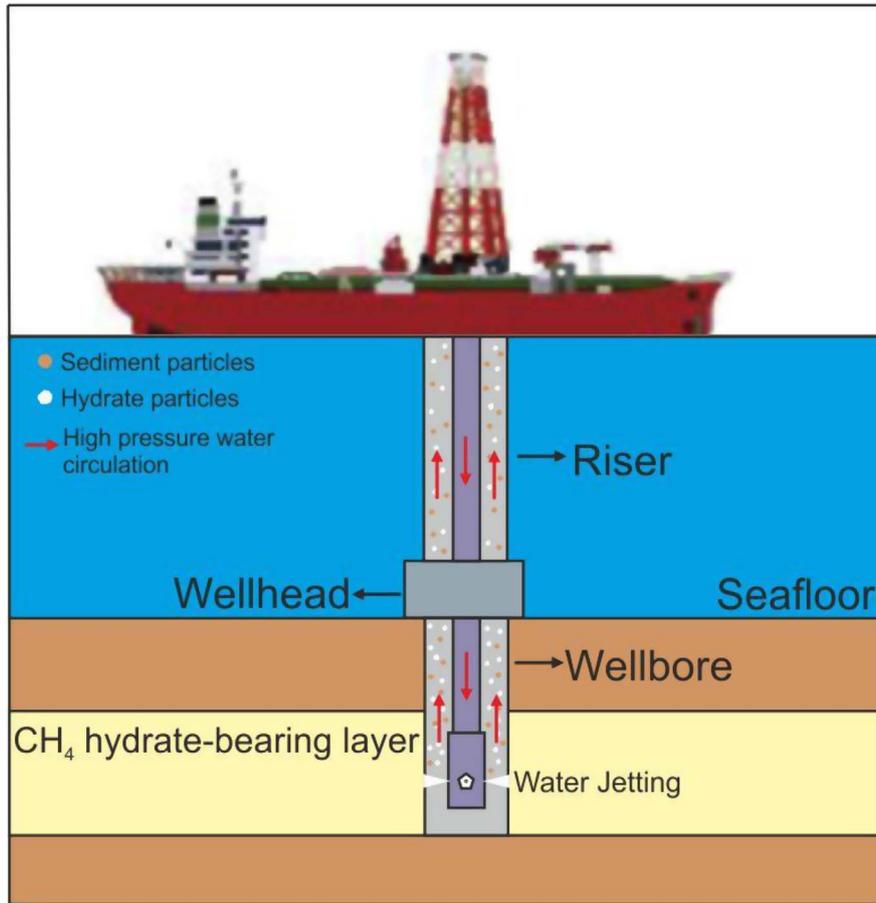


Figure 4. Solid fluidization method for gas hydrate production.

horizontal drilling technology in gas hydrate production trials. According to 2022 data (L. Chen and Merey, 2021), the longest gas hydrate production trial in the world (at a water depth of 1266 m) was conducted in the Shenhu Area in 2017 for 60 days (Fig. 3). China is also the first country conducted gas hydrate production trials in clayey silty hydrate-bearing sediments. In other tests in the world, high permeable and porous sand-bearing sediments were preferred in gas hydrate production trials. The reason for China's concentration on clayey silty-bearing hydrates is the non-availability of the most preferred sand-bearing hydrates in the South China Sea. However, additional efforts (*i.e.*, horizontal well combined with mini-fracturing in the 2020-test (at a water depth of 1225 m) in the Shenhu Area in Fig. 3) were essential to maximize gas production from clayey silty-bearing hydrates (Ye *et al.*, 2020). Thus, the commercial level of gas production from silty-clayey-bearing hydrates is much more difficult compared to gas production from sand-bearing gas hydrates due to the necessity of horizontal wells and other well stimulation techniques.

Due to the lack of sand-bearing hydrates (with high permeability, high porosity, and high gas hydrate saturation) in South China, China has to focus on clayey silt-bearing hydrates. However, it is quite difficult to obtain high gas flow rates from these hydrates. With horizontal drilling

and mini-fractures around the wellbore, gas hydrate dissociation, and gas production were provided by applying the depressurization method in the 2020 production test in the Shenhu Area of the South China Sea in Figure 3. China's urgent energy need is pressure on Chinese gas hydrate projects so this caused the field-scale trial of environmentally risky gas hydrate production techniques (*i.e.*, the solid fluidization method). To illustrate, in 2017, another gas hydrate production trial was conducted in the Liwan Area of the South China Sea at a water depth of 1310 m. 81 m³ of gas was recovered by applying the solid fluidization method during a 192-h operation time. As described in Figure 4, by injecting high pressure through the nozzles, water jetting is created along with the gas hydrate-bearing sediments. Fine hydrate particles and sediment particles are moved to the surface by circulation. This is a quite dangerous method, which might create geomechanical risks. The solid fluidization method might also affect seabed ecology and the environment. This example shows that national/international regulations are essential for field-scale gas hydrate production trials in the world.

Depressurization, thermal injection, CH₄-CO₂ replacement, and solid fluidization were applied in the short-term field-scale gas hydrate production trials in the world. Currently, none of these techniques provide a commercial level of gas production from gas hydrates. The industry

needs long-term gas hydrate production trials for more reliable data. The following questions should be answered:

- How can the high water production rate be lowered?
- How can the commercial level of gas production be provided?
- How can sand/fines production and sediment movement in the reservoirs be avoided?
- How can artificial lift techniques be optimized?
- How can environmental risks (*i.e.*, geomechanical failures) be minimized?
- How can gas hydrate exploration, drilling, well completion, and production costs be minimized?
- Are well-stimulation techniques (horizontal/deviated production well, wellbore heating, and hydraulic fracturing) safe and feasible?
- Can gas prices in gas hydrates be competitive with imported natural gas (LNG, etc.) and renewable energy?

For this purpose, a long-term gas hydrate production test (at least 1 year if technical and economical conditions are appropriate) in the permafrost region has been planned in the Prudhoe Bay of Alaska, the USA in 2023-2024 (Merey and Zhu, 2023). This depressurization test will be applied in this long-term gas hydrate production trial (Collett *et al.*, 2022) because it is considered the most promising gas hydrate production method. The selection of this location is mainly due to:

- The availability of many conventional oil and gas well data and other geological data decreases the cost of exploration in the project.
- Significantly lower cost of drilling (approximately 10 times) and production test in the onshore compared to the offshore areas.

Moreover, new gas hydrate production tests are expected in China and Japan, especially after many delays due to COVID-19 (Merey and Zhu, 2023).

Similar long-term production tests are also planned in Japan and China by the 2030s as seen in Figure 3. Overall, the exploitation of gas hydrates in the world is still at the stage of research and development and the gas industry tries to implement novel production/well completion techniques to obtain the commercial level of gas production. However, until the application of these novel gas hydrate production trials, enough laboratory scale and numerical scale studies should be conducted and they should not be applied until sure that these production methods do not cause catastrophic environmental problems (*i.e.*, reservoir subsidence, slope failure, geomechanical risks, ecological risks as shown in Fig. 5). On the other aspects, the countries needing urgent energy resources are more aggressive to provide a commercial level of gas production from gas hydrates. Thus, national/international regulation and policy frameworks are essential directly for gas hydrate exploration activities, drilling activities, and mainly field-scale gas hydrate production trials.

3 Gas hydrate-related policy and regulations

The gas hydrate industry has made great efforts for the exploitation of gas hydrate reservoirs since the beginning of the 2000s as shown in Figure 2. Important technological improvements were done related to gas hydrate exploration, gas hydrate drilling, gas hydrate coring, and other field-scale operations. Safe gas hydrate well drilling and completion are currently possible. However, gas hydrate production is problematic due to sand production risks, geomechanical risks, high water production rate, and low gas production rate. Although it is difficult to make a feasibility study related to gas hydrate production with changing natural gas prices, gas hydrate reservoir properties, and other gas hydrate production difficulties, Vedachalam *et al.* (2020) stated that \$4.66–8.6/MMBtu natural gas pricing is essential for feasible gas production from gas hydrate reservoir (with 200 MD permeability, and % 75 of gas hydrate saturation). For the feasible gas hydrate production from the gas hydrate reservoir in the Krishna-Godavari Basin, India, 9.0 USD/MMBTU natural gas prices are essential according to the techno-economic study by Deepak *et al.* (2019). Walsh *et al.* (2009) stated that \$US2008 3.37–3.85/MMBTU is more expensive to produce marine gas hydrates than conventional marine natural gas reservoirs. Thus, the optimal gas production method for gas hydrates should provide:

- Environmentally minimum risks during the production.
- Continuous high gas production rate and low water production as possible.
- Competitiveness with other energy resources.

In the planning of a long-term gas hydrate production test (probably in 2022–2023) in the Prudhoe Bay of Alaska, USA, many efforts were done between 2015 and 2017 to decide on the site selection for this test. The depressurization test is likely to be applied for at least a year in the production test well. For example, according to the regulations of the State of Alaska, all producing wells' roads should be accessible by either ice roads or gravel roads in the permafrost region (Collett *et al.*, 2022). Site selection, drilling fluid selection, and other field-related operations were designed according to the regulations of the State of Alaska. There are many conventional oil and gas wells in the area so similar regulations were applied for the gas hydrate production trial well.

Most oil and gas regulations of countries were made according to the conventional oil and gas reservoirs. Unconventional oil and gas reservoirs were not feasible for a long time. However, especially after the beginning of 2000, unconventional oil and gas reservoirs were important targets with the declining conventional oil and gas reservoirs. With the improvement in horizontal drilling and hydraulic fracturing technology, feasible gas production from shale gas and shale oil reservoirs are currently possible, mainly in the USA. However, due to huge water requirements, potential environmental risks (earthquake risks and

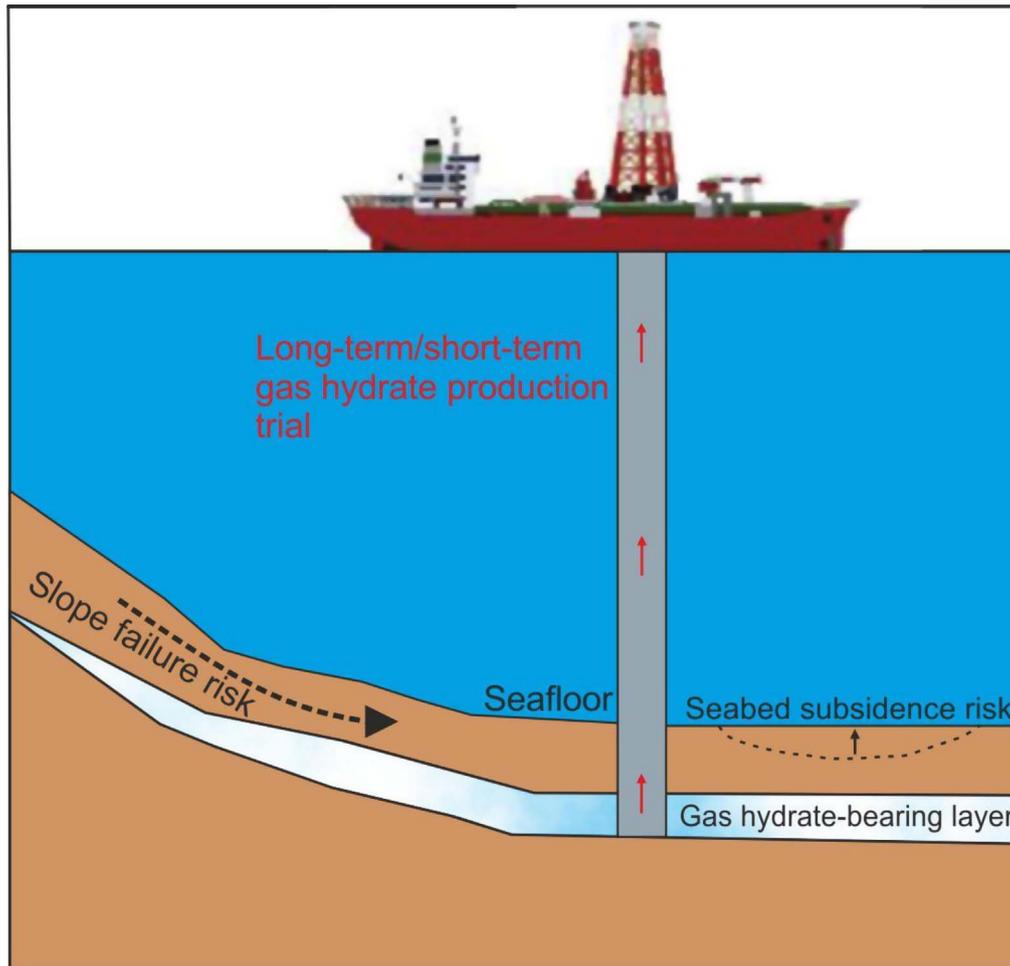


Figure 5. Environmental risks during the long-term/short-term production trials.

groundwater pollution) related to hydraulic fracturing, and other environmental concerns, some countries (mainly EU countries and other European countries) are against hydraulic fracturing operations.

That is why France banned fracking in 2011 with Law 835 of the Assembly of France. Then, hydraulic fracturing was banned in Bulgaria in 2012. In the same year, Denmark declared a moratorium on fracking. Similarly, the Netherlands announced a moratorium for 5 years on hydraulic fracturing by relying on the report about the environmental and social effects of fracturing. Then, Germany prohibited hydraulic fracturing with several exceptions in 2016. With Law 1 of 2017, Spain banned fracking and in the same year, Ireland also did the same. In 2019, the UK announced a moratorium on hydraulic fracturing until the improvement of no direct link between hydraulic fracturing and earthquake triggering. There are other countries (*i.e.*, Uruguay, Argentina, Colombia, Brazil, Costa Rica, etc.) banning or declaring a moratorium on hydraulic fracturing as well (Herrera, 2020).

On the other hand, more than 20 years of horizontal drilling, and hydraulic fracturing operations in shale gas and shale oil reservoirs in the USA have shown that as long

as essential precautions are taken, it is possible to minimize the environmental effects of shale gas and shale oil production. However, it is also a fact that there is a link between seismic activity increase due to hydraulic fracturing and water injection despite low earthquake magnitudes.

The unreliability of renewable energy resources, COVID-19-related effects, and political conflicts related to the Russian invasion of Ukraine make countries find alternative energy resources. Recently, these factors and increasing natural gas prices have made the UK reconsider its 2-year pause on hydraulic fracturing (Jacobs, 2022).

Gas hydrate production from gas hydrates is much riskier than gas production from shale gas reservoirs. Shale gas reservoirs are generally 1000–3000 m below the surface. However, gas hydrates exist very close (a few hundred meters below the seafloor) to the seafloor. Moreover, the solid nature of gas hydrate keeps the loose sediments together. After dissociating gas hydrates into free gas and free water by depressurization, thermal stimulation, and chemical injection, sediments will be much looser. Considering the huge natural gas potential in shale gas reservoirs and gas hydrate reservoirs, the prohibition of production trials is not a solution. This is because countries need

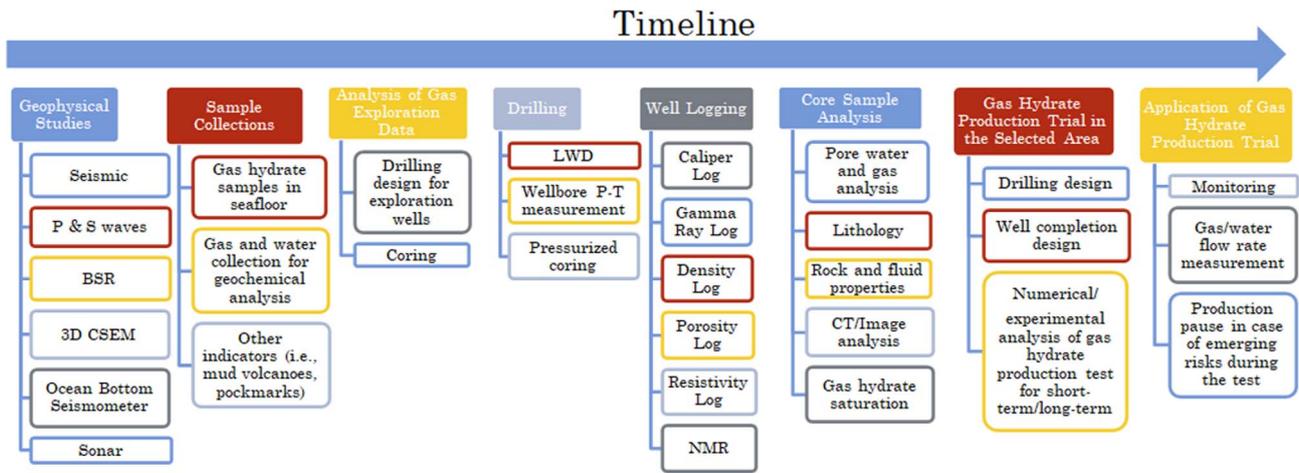


Figure 6. Timeline for a gas hydrate project until the gas hydrate production trials.

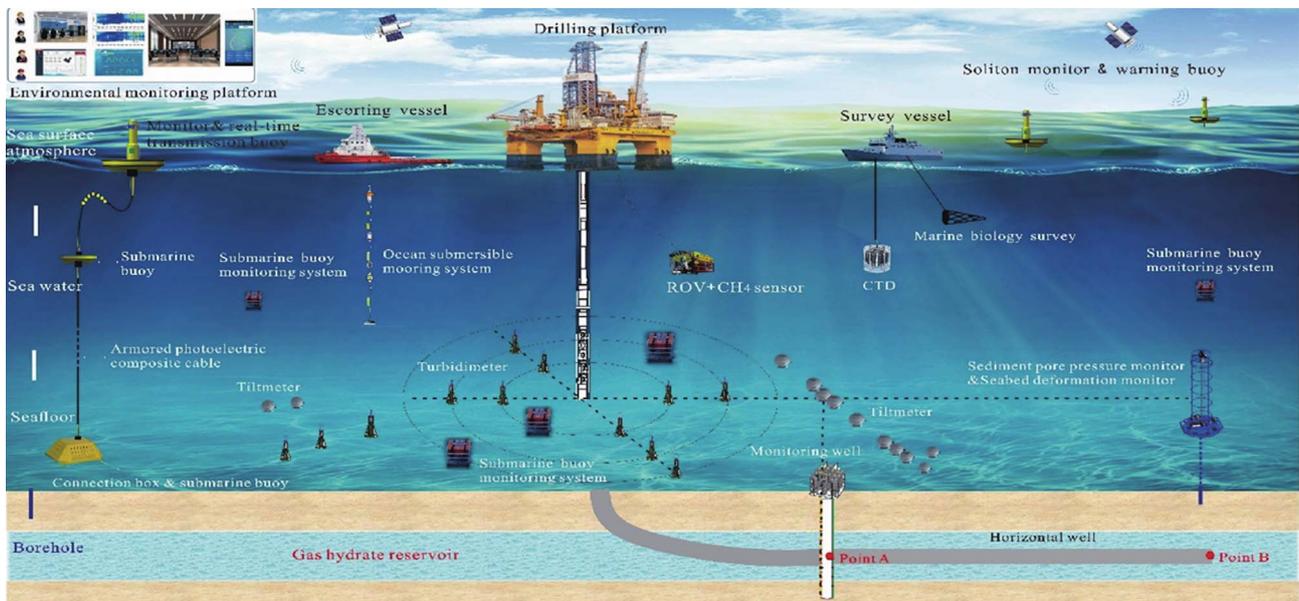


Figure 7. Sketch of the environmental monitoring system developed in the 2020-gas hydrate production test in the Shenhu Area of the South China Sea (Ye *et al.*, 2020).

natural gas (a relatively clean energy resource) until renewable energy is more reliable. However, it is possible to regulate production trials.

The gas hydrate industry gained important experience in the gas hydrate production trials in the Mallik Site (Permafrost region) of Canada in 2002, 2007, and 2008. Although the duration of these production trials (Fig. 3) was very short, the data collected in these production trials are useful to implement offshore gas hydrate exploration, drilling, coring, and production trials in Japan, India, China, and Korea. Despite good results, in 2012, Canada announced that it is no longer financing further research into gas recovery from methane hydrates after financing gas hydrate projects for 15 years (Arango, 2013). The sensitive nature of the permafrost region in the Mallik Site is one of the reasons.

Generally, the petroleum law of countries was prepared for conventional hydrocarbon reservoirs. In most petroleum laws of countries, there is no direct statement related to shale gas, gas hydrates, and hydraulic fracturing. For example, Turkish Petroleum Law 6491 was revised and approved in 2013. In Section 1, Article 2 (1-çç) of this law, it is stated “*Dangerous act: an act or negligence during the conduct of a petroleum operation that endangers or is likely to endanger the life, limb or health of a person within the field, and gives rise to environmental pollution, destruction or depredation of properties or places under the Law No. 2863 and dated 21/7/1983 on the Conservation of Cultural and Natural Properties.*”. In Section 10, Article 22 (7) of this law, it is stated “*Petroleum right holder shall not commit or permit another to commit a dangerous act directly or indirectly during his petroleum operation. Petroleum right holder*

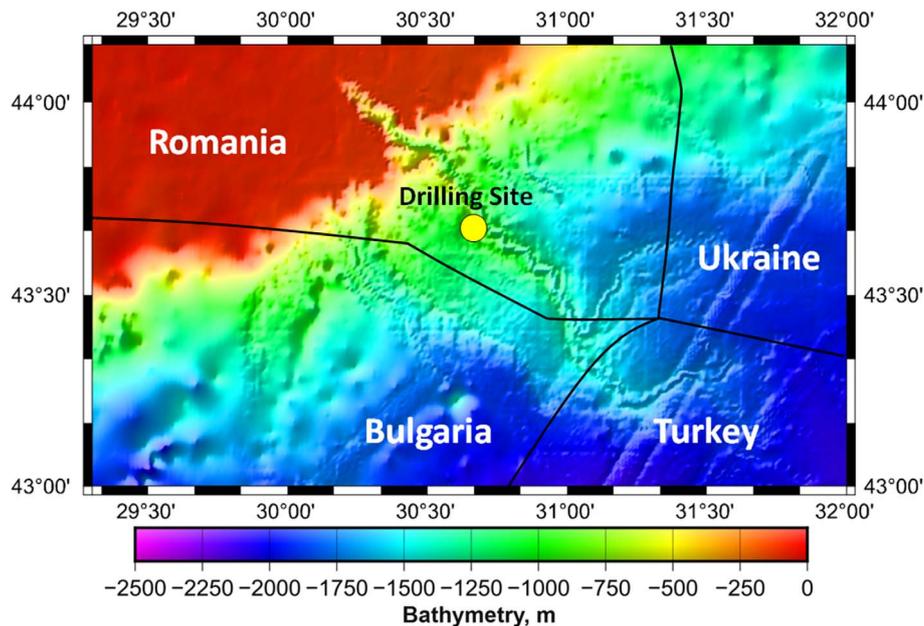


Figure 8. Danube Delta in the Western Black Sea, where there is a high gas hydrate potential.

may install the required facilities and equipment for the petroleum operation under the license provided that it does not disrupt the lives of local people, harm the environment or nature or endanger them.” Special regulations should be added to petroleum laws regulating oil and gas production from unconventional hydrocarbon reservoirs.

As seen in Figure 2, until the gas hydrate production trial, at least 10 years of gas hydrate exploration, drilling, logging, coring, and other engineering studies were conducted in all countries. Figure 6 summarizes the timeline for a gas hydrate project until the gas hydrate production trials are conducted. The industry tries to choose the best location (high gas hydrate saturation, high porosity, high permeability, low environmental risks, etc.) for gas hydrate production trials. Currently, there is no feasible gas production from gas hydrates and gas hydrate production is at the level of the research and development stage. Hence, gas hydrates currently are not energy resources for private oil and gas companies to get profits soon after spending the budget for their exploration, drilling, and production activities. Thus, in Canada, the USA, Japan, China, India, Korea, and other countries, only national oil and gas companies spare the budget for the exploitation of gas hydrates, and generally, the exploitation of gas hydrates is the national policy of a country for providing energy security and accessing to reliable and affordable sources of energy.

Monitoring during the gas hydrate production trials is crucial. Especially, while trying the long-term production test, possible risks should be followed by several sensors and production should be stopped if the environmental risk appears during the production trials. Thus, the regulations related to gas hydrate production trials should include the obligation of a detailed monitoring system. For instance, Figure 7 shows the sketch of the environment monitoring

system used in the 2020-gas hydrate production test in the Shenhu Area of the South China Sea. This monitoring system mainly includes Remotely Operating Vehicles (ROV), monitoring well with temperature sensors, sea-level air measurements, seabed water methane content, satellite data, and other environmental measurements. A similar system should be an obligation for gas hydrate production trials and the production trials should be terminated in case of even small risks.

Every country has different oil and gas laws and regulations. However, especially the application of environmentally risky gas hydrate production trials near the borders of different countries will affect the neighboring countries as well. To illustrate, the Danube Delta in the Western Black Sea has a high gas hydrate potential. One of the gas hydrate samples in nature was recovered on the seafloor of this delta in the 1970s. There are many gas hydrate indicators (*i.e.*, seismic data, gas seeps, gas hydrate samples, etc.). In November–December 2017, 4 holes were drilled to investigate the gas hydrate potential of the region by collecting drilling data, log data, and core data in the Romanian sector (Riedel *et al.*, 2020) as shown in Figure 8. The drilling site is near the steep slopes where the gas hydrate production test might be risky. Currently, there are no gas hydrate production trials in the region but exploration activities continue. Without significant data collection and design, if a quick gas hydrate production trial would be implemented, potential environmental risks (*i.e.* slope failure) during the production would not affect only Romania, it would also affect negatively the environment and ecology in the neighboring countries (Bulgaria, Turkey, and Ukraine). Hence, it is important to provide a coordination mechanism with neighboring countries if the gas hydrate production trial location is close to the borders.

Overall, the drilling, well completion, and production operations' permit and regulations change from countries and states. By relying on the data and experience gained from gas hydrate production tests since 2002, universal regulation standards should be discussed and brought to extract gas from these important gas hydrate reservoirs safely and economically. However, currently, the key challenges of the gas hydrate industry are:

- The necessity of specific technology for gas hydrate extraction and related high costs.
- Lack of pipelines, transportation problems, and other production facilities.
- Competition with conventional natural gas reservoirs and renewable energy resources.

With the developing technology and long-term production tests in gas hydrate reservoirs, the gas hydrate market might compete with other energy resources. However, universal regulation standards should be suggested for safe drilling, completion, and production operations in gas hydrate reservoirs.

5 Conclusions and political implications

This study focuses on the worldwide regulations and policies on gas production from gas hydrates. The enormous efforts in gas hydrate exploration, drilling, coring, logging, and production test trials have been conducted since the beginning of the 2002s mainly in Canada, the USA, Japan, India, China, and Korea. Currently, the gas hydrate industry can safely conduct gas hydrate seismic, drilling, well completion, well logging, coring, and other related operations. However, the gas hydrate production stage is problematic due to unfeasibility, low average gas production rates, high water production rates, sand production problems, and geomechanical risks associated with gas hydrate production. The longest gas hydrate production duration is only 60 days. Longer gas hydrate production trials (more than a year) are essential but the regulations and oil and gas laws should be revised/proposed by considering the potential environmental risks of gas hydrate production trials. A set of a permission system is necessary for each step in [Figure 6](#) until the gas hydrate production test's application. This permission system should be regulated by regulations and updated oil and gas laws.

The banning of gas hydrate exploration and production trials is not a solution as long as countries need natural gas as a potential future energy source. Some countries (*i.e.*, the UK) are currently rethinking starting hydraulic fracturing in shale gas reservoirs after recent political conditions in Russia-Ukraine and increasing natural gas hydrates as they need urgent natural gas. The exploitation of gas hydrates should continue as long as the regulation and permission systems for gas hydrate production trials work appropriately. Coordination with the neighboring countries is essential because they have similar environmental risks during the gas hydrate production trial near their borders.

Overall, mostly the gas hydrate industry takes steps slowly to reach the commercial level of the exploitation of

gas hydrates. More than 20 years of experience have shown that there is a limited and controllable risk of seismic, drilling, coring, and logging in gas hydrate reservoirs as long as essential engineering precautions are taken. However, the high rate and continuous gas hydrate production stage is the most difficult part. The gas hydrate industry wants to extend the duration of gas hydrate production trials so by monitoring potential problems associated with production, it is aimed to improve numerical simulators and bring new solutions to provide feasible gas production by the 2030s. However, these processes during gas hydrate production should be followed by regulations and updated oil and gas laws. Moreover, the countries should be transparent in sharing the regulation steps on how and why they permit gas hydrate production trials and this will be crucial to developing special regulations and laws related to gas hydrates.

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