Mining of Mineral Deposits
ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)
Journal homepage http://mining.in.ua
Volume 10 (2016), Issue 4, pp. 11-18

UDC 622.324.5 https://doi.org/10.15407/mining10.04.011

METHANE HYDRATES – AUSTRALIAN PERSPECTIVE

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ГІДРАТИ МЕТАНУ – АВСТРАЛІЙСЬКА ПЕРСПЕКТИВА

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ABSTRACT

Purpose. To analyze Australian methane hydrate resources, exploration, and production, its current state and future potential.

Methods. Analysis of data published in different sources concerned with geological surveys and government reports related to Australian natural gas reserves, production and consumption of gas in Australia. Analysis of theoretical and experimental research into methane hydrates properties and prevention of gas hydrate deposits formation in pipes during production and transportation of natural gas.

Findings. The study of gross figures associated with the present state of gas production in Australia testified that enough gas is extracted to meet the current needs. Increase in natural gas consumption in future creates good chances for developing gas production from unconventional deposits, specifically getting methane from gas hydrates deposits. While predicting main trends in the efficient exploration and use of methane hydrates resources it is necessary to consider their possible impact on the environment.

Originality. On the basis of the conducted analysis, the current state of methane hydrates research in Australia is examined. For its gas industry, it is critical to estimate their reserves and assess methane extraction from gas hydrates deposits in the near future.

Practical implications. The obtained results can be used to evaluate the investment attractiveness of future exploration of methane hydrates resources in Australia.

Keywords: *natural gas, methane hydrates, Australia, gas hydrates deposits, energy resource, environment, hydrate formation inhibitors*

1. INTRODUCTION

The energy consumption is growing through the whole human history with acceleration. The previous century was highest on energy consumption growth overall, as well as per human capita. Over the 20th century, the population on Earth grew four-fold, exceeding 6.3 billion, while the energy consumption grew by over an order of magnitude, from 0.9 billion tons of oil equivalent (TOE) in 1900 to 10.88 billion TOE at the end of 2006 (Makogon, Dunlap, & Holditch, 1997). It is obvious that modern civilization growth in the future will depend on numerous factors, but the quality and quantity of energy used will be one of the most important among them.

Australia has a unique position to support economic growth and growing global demand for energy. Nearly 20 cents in every dollar that Australia earns overseas comes from energy resources and there is potential for much more (Energy Resource Assessment, 2012). Although current trend for energy consumption is focused on renewable energy, the non-renewable energy resources will also continue to play an important role in Australia and in the world. These resources are dominated by the fossil fuels: crude oil, condensate, liquefied petroleum gas and shale oil; conventional natural gas and unconventional gas: coal seam gas, tight gas, shale gas, methane hydrates; black and brown coal, as well as the nuclear energy fuels – uranium and thorium (potential).

The stock of non-renewable energy resources is ultimately finite, but there is still good potential for discovering new economically viable reservoirs to replace the resources that are mined or produced, and so ensure future supply.

Australia has a large and diverse energy resource endowment with comparative advantages that enable it to play an important role in supplying the rest of the world with its energy needs (Table 1).

Table 1. Australian non-renewable energy resources 2012 (Australian Gas Resource Assessment, 2012)

Resource	Economic Demonstrated Resources (EDR), EJ*	Sub-Economic Demonstrated Resources (SEDR), EJ*	Resources Life at Current Production Rate, years
Black coal	883.4	1046.5	90
Brown coal	362.0	896.3	490
Crude oil	7.0	8.4	10
Conventional gas	122.1	180.4	63
Unconventional gas	71.0	153.0	130
Uranium	651.3	660.2	140

*1 EJ (Exajoule) = 10^{18} J

Australia is currently the world's largest coal and one of the largest uranium exporters, and is ranked sixth in terms of LNG exports. The penetration of gas in the Australian energy market is similar to that of the Organization for Economic Cooperation and Development (OECD) countries and world average (Australian Gas Resource Assessment, 2012).

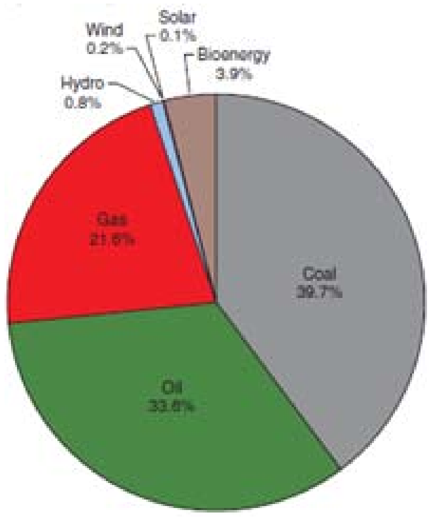
The conducted research anticipates the significant changes in the Australian energy market over the next two decades (Energy Resource Assessment, 2012). The major factors expected to affect Australian market include economic and population growth, energy prices, and costs and developments in alternative energy technologies. Technology is expected to play a critical role in the transition toward a lower emissions economy. This includes technology to improve efficiency in extraction and use of energy, to reduce costs of cleaner technologies, and to develop and commercialize new technologies to access new energy sources. Australia's total energy production (including uranium exports), is projected to increase by 3.2 per cent per year to reach around 35.1 EJ by 2029 – 2030. During this time Australia's primary energy consumption is projected to increase by 1.4 per cent per year to reach around 7.7 EJ by 2029 – 2030. The primary fuel mix is expected to change significantly, with the share of coal expected to decline to 23 per cent by 2029 – 2030. In contrast, the share of gas is expected to rise to 33 per cent and wind to 2 per cent (Energy Resource Assessment, 2012). Figure 1 shows Australia's contemporary primary energy consumption and its projection by 2029 – 2030.

Australia's gas resources are large enough to support projected domestic and export market growth beyond 2030 and are expected to grow further. Gas is a relatively flexible and clean energy source and is projected to be the fastest growing fossil fuel over the period to 2030. Figure 1 shows the expectation to significantly increase gas share of Australia's energy production. The global demand for natural gas is also projected to increase by 1.5 per cent per year to reach 149.1 EJ in 2030 (World Energy Outlook, 2009).

2. METHANE HYDRATES OCCURRENCE

Methane hydrates are solid crystalline compounds where gas molecules are encaged inside the lattice of ice crystals. The amount of naturals gas trapped in hydrate deposits in Earth crust is huge. The global methane hydrate inventory is likely to be in the range of 350000 EJ (for comparison, the global inventory of all other fossil fuels combined, including coal, is estimated to be in the same order of magnitude as the hydrates inventory alone) (Makogon, Holditch, & Makogon, 2007).

(a)



(b)

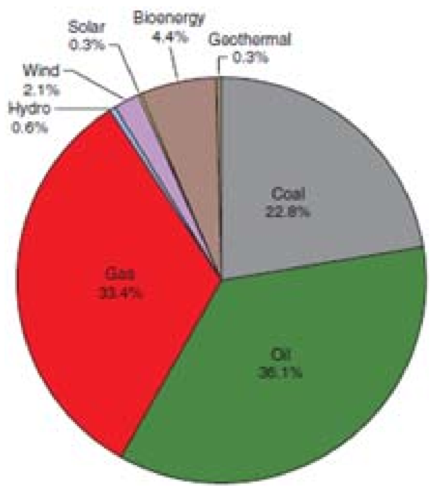


Figure 1. Australia's primary energy consumption 2007 – 2008 (a) and 2029 – 2030 (b) (Australian Energy Projections…, 2013)

The amount of such resources could make methane hydrates deposits to be a substantial future energy source. The petroleum resource pyramid (McCabe, 1998) illustrates how a smaller volume of easy to extract conventional gas and oil is underpinned by larger volumes of more difficult and more costly to extract unconventional gas and oil (Fig. 2).

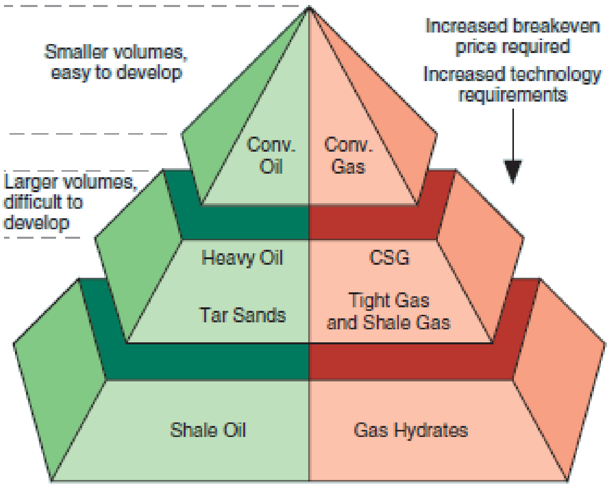


Figure 2. Petroleum resource pyramid (McCabe, 1998)

The methane hydrates deposits are more evenly distributed on the planet than are sources of oil or conventional natural gas. Figure 3 shows known hydrate accumulations and global distribution. Thus, the production of methane from methane hydrates deposits will be accessible to many countries.

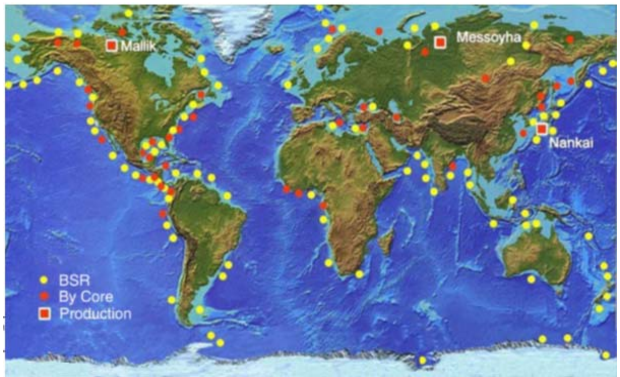


Figure 3. Map of discovered gas-hydrate deposits: BSR – deposit located by seismic refraction (Makogon, Holditch, & Makogon, 2007)

Some already existing technologies can be used to find and develop such deposits. However, significant research and development will be necessary to explore those deposits in economically viable manner. Also the ecological aspects of exploring gas hydrates deposits must be considered. Both the economic and the ecological aspects depend upon the development of new technologies. In addition, it should be noticed, that majority of methane hydrates are very different in nature, so different technologies may have to be employed.

Methane hydrates have quite unique properties some of them bring advantages and some disadvantages for their use as an energy source.

Methane hydrates (or clathrates) are non-stoichiometric crystalline solids comprised of methane gas trapped within the cavities of a rigid "cage-like" lattice of water molecules (Fig. 4). Van der Waals interactions between the trapped (enclathrated) "guest" molecule and the surrounding water cage walls stabilize and support the individual polyhedra forming the hydrate lattice and restrict the translational motion of the guest molecule (Buffett, 2000). Hydrate structures are classified into three categories based on the geometries of their constituent water cages and each crystalline structure contains geometrically distinct water cages with different size cavities which typically accommodate only one guest molecule ranging in diameter from 0.40 – 0.90 nm (Sloan, 2003).

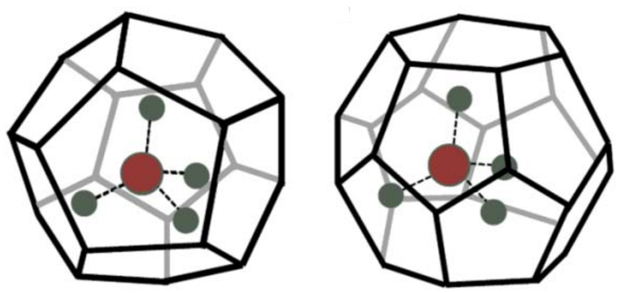


Figure 4. Small dodecahedral (a) and large tetradecahedral (b) water cages for structure I (sI) hydrates with one "guest" molecule (methane) occupying each cavity (Sloan & Koh, 2007)

Structure I (sI) hydrates are the most commonly encountered naturally occurring hydrate structure, structures II (sII) and H (sH) hydrates accommodate larger guest molecules, typically propane (sII) or combinations of methane gas and nexohexane or cycloheptane (sH). For sI hydrates, the unit cell consists of 46 water molecules arranged into two small dodecahedral cages (Fig. 4), thus, full occupancy, the molar guest to water ratio for an sI hydrate is 1: 5.75 (Sloan & Koh, 2007).

Methane hydrates deposits form under favourable thermodynamic conditions. Such conditions occur in geologic formations with low temperature and high pressure. That is why most methane hydrates deposits have been discovered in permafrost or in deep ocean sediments. For example, methane hydrate can be stable from 20 nPa to 2 GPa at temperatures from 70 to 350 K (Makogon, Dunlap, & Holditch, 1997). Figure 5 shows the phase diagram for methane hydrate formation.

Hydrates possess high acoustic conductivity and low electrical conductivity, which is used in effective methods of finding and evaluating methane hydrates deposits. The experimentally established specific values of the heat of the formation or decomposition of hydrates of methane under temperature of melting ice is 18.1 ± 0.3 kJ/mole (Handa & Tse, 1986).

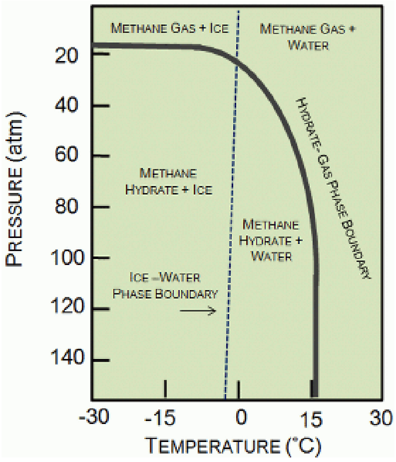


Figure 5. Phase diagram for methane hydrate formation (Kvenvolden, 1993)

3. NATURAL GAS RESOURCES IN AUSTRALIA

Natural gas is the third largest contributor to Australia's primary energy consumption after coal and oil. In 2007 – 2008, gas accounted for 22 per cent of Australia's total energy consumption. Australia's primary gas consumption increased from 74 PJ in 1970 –1971 to 1249 PJ in 2007 – 2008 (1 Petajoule (PJ) = 1015 J) – an average rate of growth of 7.9 per cent per year (Australian Energy Resource Assessment, 2014).The robust growth in gas consumption over this period mainly reflects sustained population growth and strong economic growth, as well as its competitiveness and government policies to support its uptake. Total identified gas resources are sufficient to enable significant expansion in Australia's domestic and export production capacity. Australian gas production is projected to reach 8.5 EJ in 2029 – 2030 (Australian Energy Resource Assessment, 2014).

Natural gas as flexible and relatively clean energy source is projected to be the fastest growing fossil fuel over the period to 2030 in Australia. The unconventional gas resources (coal seam gas (CSG), tight gas, shale gas, and methane hydrates) mining to this period are projected to account for about 30% per cent of gas total. Location of Australian gas resources and gas infrastructure are shown in Figure 6.

As can be seen from Figure 6, Australia has substantial gas resources. Unconventional gas onshore basins shown in Figure 6 mostly belong to CSG and shale gas resources, offshore – mostly belong to methane hydrates deposits. Although the true size of Australia's potential gas resources is unknown and could be significantly larger than the identified resources the total identified gas resources are sufficient to enable significant expansion in Australia's domestic and export production capacity. Australia's combined identified gas resources are in the order of 393 EJ (this is equal to around 180 years of gas at current production rates, of which EDR accounts for 67 years) (Australian Energy Resource Assessment, 2014). There is no current publicly available resource assessment of Australia's undiscovered gas resources that adequately reflects the knowledge gained in recent years during the active programs of government pre-competitive data acquisition and increased company exploration during the resources boom. Better assessment of Australia's potential gas resources would be aided by both more scientific information and further exploration drilling.

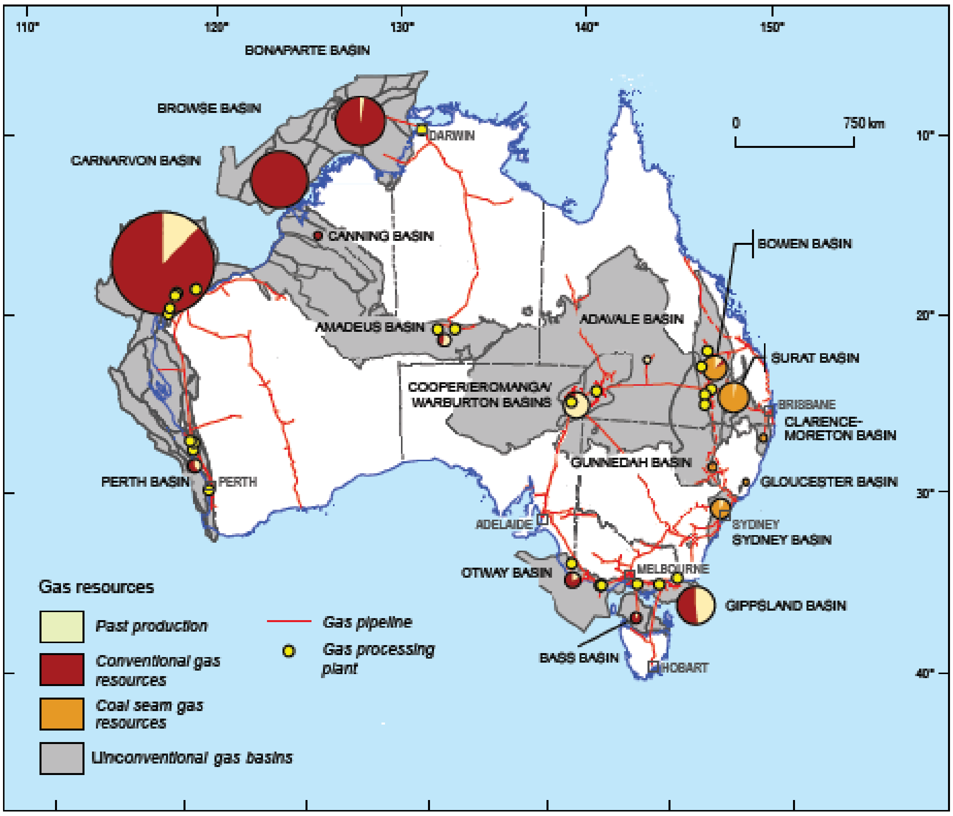


Figure 6. Location of Australian gas resources and gas infrastructure (Oil and Gas Resources…, 2008)

The significance of conventional gas resources, as well as, already developed technology for CSG mining, represent obstacles for utilization of methane hydrates resources in Australia as methane hydrates deposits and natural gas extraction from those deposits required further investigations. Currently, in spite of substantial methane hydrates deposits in the world only three of them came into production stage, two of them onshore within the permafrost area: Mallik (Canada) and Messoyaha (Russia) and only one offshore: Nankai (Japan) (Figure 3).

4. METHANE HYDRATES AS A PART OF NATURAL GAS SOURCE IN AUSTRALIA

Although, methane hydrates is a solid substance it can be mined as coal. Now it is not efficient to mine methane hydrate in Australia because it is contained in geologic layers at the bottom of the ocean. The production of methane hydrates means dissociating methane hydrate in the layers and collecting the resultant methane gas through wells and production systems. To dissociate methane hydrate that is stable at low temperature and under high pressure, the temperature should be increased or pressure should be decreased. Therefore, the operation of the "increasing temperature" or "decreasing pressure" of layers bearing methane hydrate is the actual way of the production of methane from hydrates.

The future of methane hydrates resources exploration and development in Australia largely depends upon price of gas, as it requires significant investments. Accessing gas found in deeper waters in a commercially viable manner brings a need for greater efficiencies – the application of world-leading subsea technologies, the design of equipment that is compact and energy efficient, and the utilization of optimum processing and low emissions technologies.

Australian gas producers have typically faced different prices for domestic and export gas. Domestic prices have historically been much lower than international prices, although domestic gas prices have been rising in recent years. Australian gas prices have historically been relatively stable because of provisions in long term contracts that include a defined base price that is periodically adjusted to reflect changes in the consumer price index (CPI). In addition, prices have been capped by the price of coal (a major competitor for use in electricity generation). When economic conditions are favourable, it does not take a lot of time to develop gas producing projects in Australia (Figure 7).

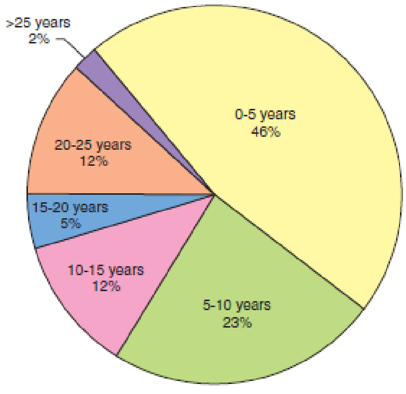


Figure 7. Development time for gas producing projects in Australia (Oil and Gas Resources…, 2008)

Nowadays in Australia, there is no mining of methane hydrates deposits, although the exploration and only test works are conducted. The technology used for those works is mirroring the operations similar to the rapid development of unconventional gas resources in North America in the 90's that transformed the continent. Such capabilities now shifted to focus on producing the vast known resources of methane hydrates profitably. Innovation, similar to what took place in regard to unconventional CSG resources, will be the major factor in closing the gap to achieve profitable commercial recovery. Profitability is a requirement that plays to the strengths of the experienced innovators. Experience is the key: lessons learned by pioneering recovery of CSG in Australia should be directly translated to meet challenges of unlocking methane hydrates deposits. An important focus of increasing profitability of developing gas hydrate deposits can be mining methane gas hydrate in cycles of technological installations using OTEC (ocean thermal energy conversion) for production of electricity and fresh water (Denysov & Klymenko, 2016).

The additional support for utilization of methane hydrates deposits was given at the meeting of Indian Ocean Rim Association (IORA) in year 2014 where the "Blue Economy" was launched. The Ministers Meeting came to the conclusion that the Indian Ocean has enormous potential for harnessing "Blue Economy" resources, part of which is methane hydrates deposits (Figure 3) and that the "Blue Economy" concept has the potential to act as a key catalyst for sustainable development through the Indo-Pacific region (Blue Economy, 2014).

Apart from economic problems for the development of methane hydrates deposits in Australia there are some environmental concerns specifically in regard to climate change. Due to methane lower concentration in the atmosphere than carbon dioxide, the infrared absorption bands of methane are less saturated and therefore methane is a more powerful greenhouse gas. Methane has 25 times more potent greenhouse gas effect than carbon dioxide (Climate Change, 2007). Thus, development of methane hydrates deposits could have a significant effect on the climate if methane escapes into the atmosphere. As a result, there is concern over any uncontrolled release of methane from hydrate formations. Methane hydrates are particularly fragile: the sediment in which they are located is inherently unstable once removed from the high pressures and low temperatures of the deep sea. Any dissociation can result in leakage and extraction will be inefficient. Additionally, the role that methane hydrates play in stabilizing the seafloor should be better understood. For example, drilling deep into oceanic deposits could affect both marine life and the seabed, potentially causing sediment to slide down the continental slope.

On the other hand, cleaner-burning gas from hydrates may help to displace coal consumption in Australia driving coal out of the Australian electricity markets. This scenario could potentially yield climate benefits and cleaner air – assuming the displaced coal stays in the ground. Therefore, modest leakage rates from mining methane hydrates will not destroy potential climate benefit of burning hydrates instead of coal. Methane hydrate deposits seem intrinsically vulnerable and tend to melt and release methane. As it floats in water, so the only factor holding it is a high pressure. A few degrees of warming in the deep ocean can have a significant impact on the stability of the hydrate, and it is known that the temperature of the deep ocean responds to changes in surface climate, albeit with a lag of centuries to millennia. Hence, there are concerns that climate change could trigger significant methane releases from hydrates and thus could lead to strong positive carbon climate feedbacks (Schiermeier, 2008).

As potential ecological and environmental risks are already being flagged, the considerable rewards of releasing methane from methane hydrate fields must therefore be balanced with risks. Therefore, more research may be required to determine the likelihood of such risks materializing and whether there are ways of mitigating them. The framework of risk assessment for environmental impacts from mining methane hydrates suggested by (Vulnerability and Opportunity…, 2008) is presented in Figure 8.

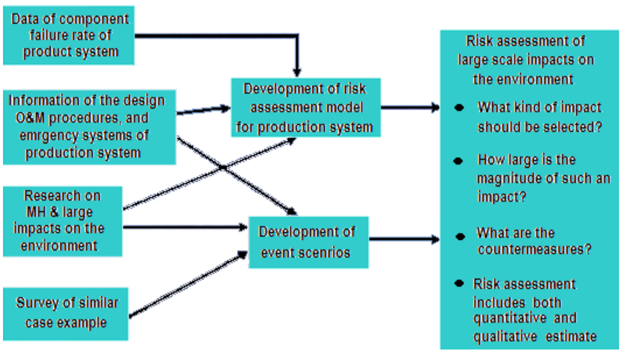


Figure 8. Framework of risk assessment of large scale impacts on environment

The topics that also require further study include:

1) potential ground subsidence associated with production;

2) disposal of produced water.

Any oil and gas activity in each proposed development must also consider disruption of sensitive ecosystems.

In addition to economic and environmental dimensions in sustainability paradigm should be evaluated a social dimension for establishment methane hydrates industry in Australia, as well. The contribution of methane hydrates to the social and developments goals will depend on regions and community development rich in methane hydrates deposits in Australia, their methane hydrate endowment, and human capital endowments. Each of those geographic regions should determine where methane hydrates fit in larger development framework and whether extraction, processing and marketing of natural gas from methane hydrates provides a net advance in achieving its goals or if investments in alternative technologies and/or alternative sources of revenue. Figure 9 depicts the notion of community wellbeing groups in the six areas (domains).

Except using methane hydrates as energy resource there are some features of methane hydrates which make them undesirable and need a proper attention. When drilling in oil- and gas-bearing formations submerged in deep water, the reservoir gas may flow into the well bore and form methane hydrates owing to the low temperatures and high pressures found during deep water drilling.

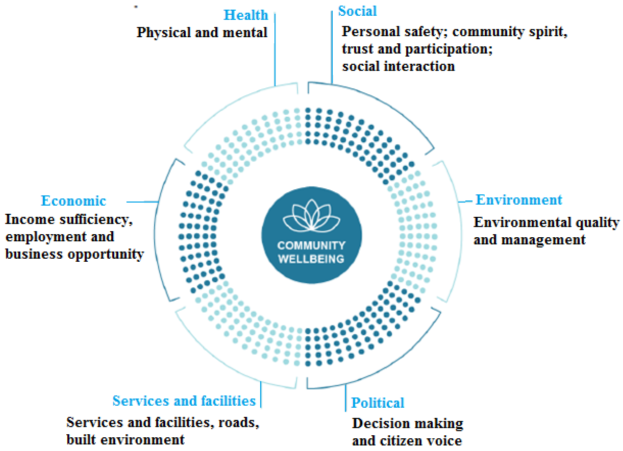


Figure 9. Public acceptance: community wellbeing domains (Walton, McCrea, & Leonard, 2014)

The methane hydrates may then flow upward with drilling mud or other discharged fluids. Those methane hydrates are hindrances in deep water oil and gas pipelines. These conditions may also occur with the decrease of pressure across the choke and as the gas cools along the various flow lines and pipelines and/or as a result of other operating, shut-down and transient conditions. The resulting hydrates can adversely affect the normal operation of equipment and so must be prevented. The precautions measures must be taken to reduce such hydrates formation. Methane hydrates formation in described conditions has a proper attention within gas and oil industry in Australia. The high research capability has also been established in Australia to investigate this phenomenon by collaborating together by leading government research agency, Commonwealth Science and Research Organisation (CSIRO) and University of Western Australia (UWA). They developed methane hydrate flow loop (Hytra Loop) to study hydrate behaviour in gas-dominant flows. This unique experimental equipment is used to quantify the rate of hydrate build up in pipelines (Fig. 10).

Figure 10. Layout of the experimental the hydrate flow loop (Commonwealth Scientific…, 2013)

Conducting research is delivering advanced knowledge of methane hydrate formation and evolution in gas-dominant flows, to improve the design and operation of offshore gas production pipelines using data collected from the experiments, as well as theoretical models of hydrate dynamics within pipelines. The experiments will allow researchers to investigate methods to prevent flow disruptions in subsea pipelines, particularly blockages from methane hydrate crystals which form at high pressure and low temperature.

Now Australian gas industry is using hydrate inhibitors to prevent hydrates formation in pipelines. Currently mono-ethylene glycol (MEG) is preferred hydrate inhibitor, which is store in gas processing facilities and pumped to the dedicated lines and flows back with the gas steam through feed gas pipelines. Recently proposed gas by Chevron Australia Pty Ltd gas processing facility on Barrow Island to make liquefied natural gas will have a special hydrate inhibitor recovery system (Report and recommendations…, 2009). The system uses MEG (plus salt and other water soluble chemicals) from the bottom of the three phase separator will be directed to the hydrate inhibitor recovery (HIR) package. This package will heat the liquids to vaporize the water, thus concentrating the MEG, so it is suitable for re-use.

5. CONCLUSIONS

To understand both vulnerability and opportunity of methane hydrates in Australia, it is necessary to improve existing estimates of hydrate occurrences, their geographical distribution and depth profile. In addition, dynamics of the hydrates inventory under changing environmental conditions, mainly pressure and temperature, need to be better understood, particularly the sensitivity of deep ocean temperature to surface climate change and temperature transfer into the deposits. Methane hydrates may offer a great opportunity as an energy source in Australia, but at the same time can become an important driver of climate change from destabilization due to global warming. A key development to avoid unintended climate effects will be to integrate policies of energy security and climate change. Taking this integration one step further would be a "preventive exploitation" of dissociating methane hydrates and thus prevent escape of methane to the atmosphere while providing a high quality fuel. Therefore, development of new technologies should accompany that of hydrate extraction technologies to clear the way for methane hydrates to become a "bridge fuel" towards a low carbon future. Those technologies may be easier to develop and deploy than other alternatives in Australia as they can be built on existing infrastructure and partly developed and deployed technologies. An integrative approach that is addressing all dimensions of sustainability (economic, environmental, and social) for methane hydrates is needed to avoid negative side effects of their deployment.

ACKNOWLEDGMENTS

We wish to thank Dr. Edward Rravets, Technical Consultant, Rainbow Pty. Ltd., China for his support and encouragement for the work presented here. We also thank Mr. Oleg Pogreb, Technident Pty. Ltd. for his willingness to share his knowledge, information and data on unconventional gas production in Australia.

REFERENCES

Australian Government. (2008). *Oil and Gas Resources of Australia 2008 Report*. Research Report. Canberra: Geoscience Australia.

Australian Government. (2012). *Australian Gas Resource Assessment*. Research Report. Canberra: Department of Resources, Energy and Tourism.

Australian Government. (2012). *Energy Resource Assessment*. Research Report. Canberra: Department of Resources, Energy and Tourism.

Australian Government. (2013). *Australian Energy Projections to 2029-30*. Research Report. Canberra: Department of Resources, Energy and Tourism.

Australian Government. (2014). *Australian Energy Resource Assessment*. Research Report. Canberra: Department of Resources, Energy and Tourism.

Buffett, B.A. (2000). *Clathrate Hydrates*. Annual Review of Earth and Planetary Sciences, *28*(1), 477-507. https://doi.org/10.1146/annurev.earth.28.1.477

Commonwealth Scientific and Industrial Research Organisation. (2013). *CSIRO Energy Flagship*. Research Report. Canberra: CSIRO.

Dendy Sloan, E., & Koh, C. (2007). *Clathrate Hydrates of Natural Gases*. Third Edition. Chemical Industries. Golden, Colorado: Colorado School of Mines https://doi.org/10.1201/9781420008494

Denysov, Yu.P., & Klymenko, V.V. (2016). Gas-Hydrate Installation for Generation of Electrical Energy and Seawater Desalination. *Visnyk Vinnytskoho Politekhnichnoho Instytutu*, (3), 65-72.

Environmental Protection Authority. (2009). *Report and Recommendations of the Environmental Protection Authority*. Research Report. Perth: Chevron Australia Pty Ltd.

GCP & IIASA. (2008). *Vulnerability and Opportunity of Methane Hydrates*. IIASA-GCP Hydrates Workshop. Austria: Global Carbon Project & International Institute for Applied Systems Analysis.

Handa, Y.P., & Tse, J.S. (1986). Thermodynamic Properties of Empty Lattices of Structure I and Structure II Clathrate Hydrates. *The Journal of Physical Chemistry*, *90*(22), 5917-5921. https://doi.org/10.1021/j100280a092

IEA. (2009). *World Energy Outlook*. Specialty Report. Paris: International Energy Agency & Organisation for Economic Co-operation and Development. https://doi.org/10.1787/weo-2009-en

IORA. (2014). *Blue Economy*. New Delhi: Indian Ocean Rim Association.

IPCC. (2007). *Climate Change 2007*. Synthesis Report. Geneva: Intergovernmental Panel on Climate Change.

Kvenvolden, K.A. (1993). Methane Hydrates – Geological Perspective and Global Change. *Reviews of Geophysics*, *31*(2), 173. https://doi.org/10.1029/93rg00268

Makogon, Y.F., Dunlap, W.A., & Holditch, S.A. (1997). Recent Research on Properties of Gas Hydrates. In *Offshore Technology Conference* (pp. 10). Texas: Houston. https://doi.org/10.4043/8299-ms

Makogon, Y.F., Holditch, S.A., & Makogon, T.Y. (2007). Natural Gas Hydrates – A Potential Energy Source for the 21st Century. *Journal of Petroleum Science and Engineering*, *56*(1-3), 14-31. https://doi.org/10.1016/j.petrol.2005.10.009

Peter J. McCabe. (1998). Energy Resources – Cornucopia or Empty Barrel? *American Association of Petroleum Geologists Bulletin*, 82 (1998), 2110-2134. https://doi.org/10.1306/00aa7bee-1730-11d7-8645000102c1865d

Schiermeier, Q. (2008). Fears Surface over Methane Leaks. *Nature*, *455*(2008), 572-573. https://doi.org/10.1038/455572a

Sloan, E.D. (2003). Fundamental Principles and Applications of Natural Gas Hydrates. *Nature*, *426*(6964), 353-363. https://doi.org/10.1038/nature02135

Walton, A., McCrea, R., & Leonard, R. (2014). *CSIRO Survey of Community Wellbeing and Responding to Change: Western Downs region in Queensland*. Technical report. Australia: CSIRO.

ABSTRACT (IN UKRAINIAN)

Мета. Аналіз австралійських ресурсів гідрату метану, поточного стану розвідки гідратних покладів і потенціальних перспектив їх розробки у майбутньому.

Методика. Аналітичне вивчення даних, опублікованих у різних джерелах даних геологічних пошуків та урядових звітів, пов'язаних із австралійськими запасами природного газу, видобутком і споживанням газу в Австралії. Аналіз теоретичних та експериментальних досліджень властивостей гідратів метану, попередження відкладення газогідратів у трубах при видобуванні й транспортуванні природного газу.

Результати. Аналіз валових показників сучасного стану видобутку природного газу показав, що його добувається достатньо для забезпечення поточних потреб споживання в Австралії. Зростання споживання природного газу в майбутньому визначає перспективу використання газу з нетрадиційних покладів, зокрема метану із покладів газових гідратів. При прогнозуванні основних напрямків ефективного дослідження й використання ресурсів гідратів метану необхідно враховувати їх можливий вплив на навколишнє середовище.

Наукова новизна. На підставі проведеного аналізу описано поточний стан дослідження гідратів метану в Австралії, показана важливість для газової промисловості уточнення у найближчому майбутньому їх запасів та видобутку метану із газогідратних покладів.

Практична значимість. Представлені результати можуть бути використані для оцінки інвестиційної привабливості майбутньої розвідки ресурсів гідратів метану в Австралії.

Ключові слова: *природний газ, гідрати метану, Австралія, газогідратні поклади, енергетичні ресурси, навколишнє середовище, інгібітори гідратоутворення*

ABSTRACT (IN RUSSIAN)

Цель. Анализ австралийских ресурсов гидрата метана, текущего состояния разведки гидратных залежей и потенциальных перспектив их разработки в будущем.

Методика. Аналитическое изучение данных, опубликованных в различных источниках данных геологических изысканий и правительственных отчетов, связанных с австралийскими запасами природного газа, добычей и потреблением газа в Австралии. Анализ теоретических и экспериментальных исследований свойств гидратов метана, предупреждения отложений газогидратов в трубах при добыче и транспортировке природного газа.

Результаты. Анализ валовых показателей современного состояния добычи природного газа показал, что его добывается достаточно для обеспечения текущих потребностей в Австралии. Рост потребления природного газа в будущем определяет перспективу использования газа из нетрадиционных залежей, в частности метана из залежей газовых гидратов. При прогнозировании основных направлений эффективного исследования и использования ресурсов гидратов метана необходимо учитывать их возможное влияние на окружающую среду.

Научная новизна. На основании проведенного анализа описано текущее состояние исследования гидратов метана в Австралии, показана важность для газовой промышленности уточнения в ближайшем будущем их запасов и добычи метана из газогидратных залежей.

Практическая значимость. Представленные результаты могут быть использованы для оценки инвестиционной привлекательности будущей разведки ресурсов гидратов метана в Австралии.

Ключевые слова: *природный газ, гидраты метана, Австралия, газогидратные залежи, энергетические ресурсы, окружающая среда, ингибиторы гидратообразования*

ARTICLE INFO

Received: 21 July 2016
Accepted: 11 October 2016
Available online: 30 December 2016

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