INTERNATIONAL AND STRATEGIC STUDIES REPORT

OCT 7, 2017 ISSUE. 53

Institute of International and Strategic Studies, Peking University

Some Scientific Knowledge about Gas Hydrate and Hot Dry Rock

Li Kewen

Professor in the School of Energy Resource, China University of Geosciences (Beijing)

In recent months, major media such as CCTV and a number of social media have reported on China's major breakthrough in two types of renewable energy: gas hydrate (combustible ice) and hot dry rock[1]. Most people were not very familiar with either type of energy in the past, and I myself was very excited when I read these reports. These breakthroughs made in China are indeed of great significance and have an important and far-reaching impact on the promotion of China's energy production and consumption revolution. However, from a scientific point of view, it is necessary to properly analyze and understand these news reports and the two renewable clean energy sources.

1 Gas hydrate (Combustible ice): As the name implies, combustible ice is a substance that can be burned to ice. Its scientific name is natural gas hydrate, also known as methane hydrate. Its molecular formula is $CH_4 \cdot 8H_2O$. It is ice-like crystal material formed by water and natural gas (methane content is 80%~99.9%) under high pressure and low temperature, therefore also known as combustible ice. Dry hot rock: In layman's terms, it is dry and hot stone. Scientific definition: It is a high-temperature rock mass with a temperature greater than 200℃ and a buried depth of more than 1 km without internal fluid or only a small amount of underground fluid.

I. How many kilometers can a car run with 100 liters of Gas Hydrate?

On May 18, 2017, China for the first time successfully tested and collected combustible ice in Shenhu Sea Area, South China Sea. According to CCTV, "If a car using natural gas can run 300 kilometers with 100 liters of natural gas, it can run 50,000 kilometers with the same volume of combustible ice." Quite a number of news media also reprinted this news. Reading this story made many people very excited. What is the concept of a car running 50,000 kilometers? In short, an average domestic car does not need to be refueled within 2-5 years after it is fueled with combustible ice. So, how many kilometers on earth can a car with 100 liters of combustible ice run? One cubic meter of combustible ice can release approximately 0.8 cubic meters of water and 164 cubic meters of natural gas (in a standard state) after it has been decomposed. Well, 100 liters of combustible ice can get 16.4 cubic meters of natural gas (in a standard state). About 1 cubic meter of natural gas is equivalent to 1.17 liters of gasoline, which allows ordinary cars to run about 10-15 km. According to this calculation, a car that is fueled with 100 liters of combustible ice (that is, equivalent to 16.4 cubic meters of natural gas) at a time can run about 160 to 250 km instead of 50,000 km.

II. How many years can combustible ice be used in China?

According to the data provided by the Ministry of Land and Resources, the amount of geological resources with combustible ice in China is equivalent to 100 billion tons of oil. Many reports have pointed out that according to the rough estimate of current energy use in China, combustible ice can be used for more than one hundred years in China. This premise assumes that 100% of all this combustible ice can be mined, and that the total national energy consumption is not based on 2016 data. The total amount of energy consumption in 2016 in China was initially estimated at 3.05 billion tons of oil. From this we can see that if we use the total energy consumption in 2016 as the base figure for calculation, combustible ice (equivalent to 100 billion tons of oil) can be used for about 33 years in China. In fact, the amount of geological resources is not equal to recoverable reserves, and is impossible to be 100% mined out. So, what percentage (recovery) of combustible ice can be mined out? There is currently no clear and reliable answer to this question. This is because it is the first time that China has conducted trial production of combustible ice and there are only a few countries that have started trial production of combustible ice in the international arena. Moreover, all countries, including China, have stopped the exploitation of combustible ice. In addition, it is worth noting that there is also some uncertainty about the amount of geologic resources of combustible ice, especially in the current exploration wells.

III. When will combustible ice be commercially exploited?

At present, there are mainly the following methods for mining combustible ice: (1) thermal recovery method; (2) decompression method; (3) chemical injection method; (4) CO_2 substitution method; and (5) mixed mining method. At present, some experts think that the exploitation of combustible ice is technically feasible, but in fact, it is yet too early to conclude that the exploitation of combustible ice is feasible or mature. In addition to technical problems, another difficulty are the environmental issues. Unlike conventional natural gas or shale gas, combustible ice is not stored in a hard rock. The upper part of the reservoir is not a high-strength cap layer of a dense rock, but seawater or low-intensity strata. Due to this feature, during the mining process, the methane in the combustible ice may not be produced through the wellbore as designed, but may escape in large quantities into seawater and atmosphere through other locations, which will create new environmental problems (for instance, exacerbating the greenhouse effect). In addition, the massive decomposition of methane on the seafloor combustible ice reservoir will also reduce the strength of the seafloor formation, induce large-scale landslides and even tsunamis and other disasters, and destroy the seabed engineering facilities.

There are many forecasts and reports on when combustible ice can be commercialized. Currently the general view is that it will take around 15 to 20 years until it becomes commercialized, in other words, it will be possible only in the year 2030 and onwards. Recently, some experts predict that the production capacity of combustible ice in 2030 can reach 1 billion cubic meters. In fact, there is a lot of uncertainty in any forecast. So, in 2003 some experts also predicted that 15 years later, that is, in 2018, the commercial exploitation of combustible ice would certainly not be possible. There are many factors which influence the commercialization of flammable ice, including advanced mining technology, economy (mining costs), sustainability, environmental issues, as well as competitive costs of other energy sources. If international oil prices (around $50/bbl) and natural gas prices are hovering at current levels or even lower, the timing of commercial exploitation of combustible ice may be significantly delayed, even under the conditions of a revolutionary breakthrough in combustible ice mining technology. In the opposite case, it is possible to expect the advancement in this area.

IV. For how many years can the hot dry rock resources be used in China?

According to the data from China Geological Survey of the Ministry of Land and Resources, the amount of terrestrial hot dry rocks in the crust at 3-10 km depth is 856 trillion tons of standard coal. According to international standards, with 2% as recoverable resources, the national reclamation of hot dry rock resources on the land amounts to 17 trillion tons of standard coal, at the same level as the amount of resources in the United States. Based on the estimated total energy consumption of about 4.36 billion tons of standard coal in 2016 in China, the recoverable resources of hot dry rocks can be used for about 3900 years in China, which is several hundred times more than the useful life of combustible ice. However, the 2% -"international standard" mentioned in some reports is not an international standard in the real sense. Instead, it is the lower limit of the recoverable coefficient assumed by the experts in this area when they are unable to determine how much of the geothermal resources in hot dry rocks can be mined out. The upper limit is assumed to be 40%. If calculated according to the recoverable ceiling of 40%, then the recoverable resources of hot dry rocks can be used in China for tens of thousands of years.

V. What are the power generation costs of hot dry rock?

According to CCTV, hot dry rock power generation is not a subject to seasonal and climate constraint. The cost of generating electricity is one-half of wind power generation and one-tenth of solar power generation costs. A really important advantage of hot dry rock power compared to solar energy and wind power generation is the irrelevance of season and climate for it. However, according to the opinion of many people, the cost of generating electricity from hot dry rock presents a problem, either in terms of the cost of electricity production, or in terms of the initial investment cost. This may be due to the large difference between hot dry rock, wind and solar photovoltaic systems in the equivalent available coefficients[2], the corresponding coefficients are respectively 90%, 20%, and 15%, there are some differences in various regions. Let us take solar energy as an example. There are only 8 hours out of a whole day with strong sunlight. It is unlikely that 365 days a year will produce the sun every day. If there is no sun, the photovoltaic power station will not be able to generate electricity. This is why a 100-megawatt solar photovoltaic system is roughly equivalent to a 15-megawatt geothermal power plant. At present, the unit cost of a kilowatt-hour wind power generation is 7000-8000 RMB (1 US dollar is about 6.6 RMB), while that of the photovoltaic power generation system (including photovoltaic modules, development costs and construction costs) is about 8000-10000RMB. If it is converted to 100% of the equivalent available coefficient, the equivalent power costs of the current wind and photovoltaic power generation system are 35,000-40,000 RMB and 53,000-67,000 RMB per kilowatt respectively.

2 Equivalent available factor: the total hours in a year are divided by the annual operating hours of power plants.

The cost calculation of hot dry rock power generation is more complicated because it is greatly affected by the temperature and depth of the hot dry rock reservoir (the temperature at which the fluid reaches the ground is different, and, therefore, the power generation efficiency is also different). The current total cost of conventional geothermal (hydro-thermal) power generation systems, including drilling and ground-based power generation equipment, is around 20,000-30,000 RMB per kilowatt, depending on the temperature, depth and rock permeability of the thermal reservoir. If it is converted to 100% of the equivalent usable factor, the total cost of conventional geothermal power generation systems will still be much lower than that of wind and photovoltaic power generation. It is noteworthy that fluid coming from geothermal power generation can also be used for heating, bathing and other cascade processes. If this part of the economic benefits is given consideration, the economy of the conventional geothermal development system could also be improved. However, because hot dry rock does not have water, its cost-of-electricity estimates are more complex, and are probably around 50,000 RMB per kilowatt.

VI. When can hot dry rock geothermal energy be commercially exploited?

The method of extracting geothermal energy from hot dry rocks is mainly the so-called Enhanced Geothermal System (EGS) method. The process of the method is generally as follows: a counter well (production well and injection well) system is built in a hot dry rock reservoir through drilling. After fracturing in the counter well reservoir, by injecting water through an injection well, the water and the rocks come into contact and get heated, then they get returned to the ground for power generation or cascade utilization. After cooling down, the geothermal water is re-injected into the thermal reservoir for circulation to form an artificial heat exchange and fluid circulation system between the production well, the thermal reservoir and the injection well, thus realizing efficient development and utilization of geothermal energy.

In recent years, the international application of geothermal energy and power generation technology has developed very rapidly. The installed capacity of conventional geothermal power generation in the world has now reached over 13,000 megawatts, while in China, it is only about 27 megawatts, ranking 18th place among the 24 countries using geothermal power around the world, which is a very large gap with such developed countries as the United States. So far, there is no hot dry rock power station in China. The most famous in the world is France's Soultz hot dry rock power station, which has been in continuous operation for many years. For the moment, hot dry rock power generation is technically feasible and the key issue is drilling costs. However, as mentioned earlier, the total cost of a hot dry rock power generation system is lower than that of photovoltaic power generation, taking into account the equivalent available coefficients. In other words, if the state gives preferential policies to hot dry rock power generation, such as subsidies it gives to photovoltaic power generation, it is currently possible to conduct large-scale hot dry rock mining using the existing technologies. Of course, this also depends on many specific parameters, such as thermal storage temperature, for example.

VII. Conclusions

In various reports, it is often believed that China's solar photovoltaic power generation and wind power are ranked the first in the world, and even the direct use of geothermal energy in China is also ranked the first in the world. These reports give the impression that China always takes the leading position in the field of clean energy use, compared with all other countries. These figures and international rankings are true indeed and make one very excited. However, from another perspective, since the utilization of clean energy in China is so advanced and so large in scale, why is the environmental problem with smog in China, especially in Beijing, Tianjin and Hebei Province, still very serious? In fact, if the above data are calculated on the basis of per capita, China's rankings have lacked far behind other countries. From this perspective, the above mentioned doubt is not difficult to understand. Therefore, we should treat many reports and data rationally and scientifically.

Edited by Dr. Gui Yongtao and Dr. Anastasiya Bayok
Tel: 86-10-62756376 Email: iiss@pku.edu.cn
Fax: 86-10-62753063 Web: www.iiss.pku.edu.cn
Address: IISS, Peking University, Beijing, China