Industrial Heating Device Using Nuclear Transmutation to be Mass-produced before 2030

Prototype of "Heat Module" is fabricated for demonstration tests

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Commercialization of a heating device that utilizes the heat emitted during atomic transmutation is just around the corner. A new energy-related venture company, Clean Planet (Chiyoda-ku, Tokyo), has built a prototype for mass production and is currently conducting demonstration tests. The company plans to build a pilot plant in Kawasaki by 2030 and establish a mass production system.

Clean Planet was established in 2012 and is working on the commercial application of "Quantum Hydrogen Energy (QHe)" at the "Condensed Matter Nuclear Reaction Research Division" in the Research Center for Electron Photon Science at Tohoku University, which was established in Sendai City in 2015 in collaboration with Tohoku University, and at its product development base in Kawasaki City.

Quantum Hydrogen Energy (QHe) is a term used by Clean Planet to describe a technology that can generate more heat than is put into a nickel-based composite metal material with a nano-sized structure when a small amount of hydrogen is absorbed and heated. The company is working to commercialize this technology as the QHe IKAROS engineering project.

Such phenomena are called "condensed matter nuclear reactions," "new thermal reactions between metallic hydrogens," and "low-energy nuclear reactions" by researchers, and research on these phenomena has been intensifying in many countries (Figure 1).

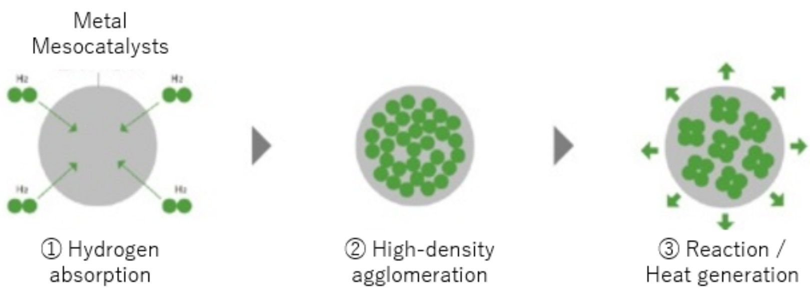

Figure 1: Image of condensed matter nuclear reaction including Quantum Hydrogen Energy (Source: NEDO)

The principle of energy generation is basically the same as that of ITER, an experimental thermonuclear fusion reactor that is being promoted under an international framework including Japan, the United States, and Europe. The enormous amount of energy released by the mass loss associated with the fusion of hydrogen atoms is extracted as heat in a heat exchanger.

However, the reaction system of thermonuclear fusion and Quantum Hydrogen Energy is different. In thermonuclear fusion, two hydrogen atoms fuse to form helium, whereas Quantum Hydrogen Energy is considered to be mainly a many-body reaction involving three or more hydrogen atoms simultaneously. Multiple elements have been identified as the products of the reaction that should have undergone nuclide conversion.

The current energy density is two orders of magnitude below the theoretical value of fusion, and compared to the chemical reaction by hydrogen combustion, it produces an enormous amount of energy, 10,000 times more than that of hydrogen combustion (Figure 2).

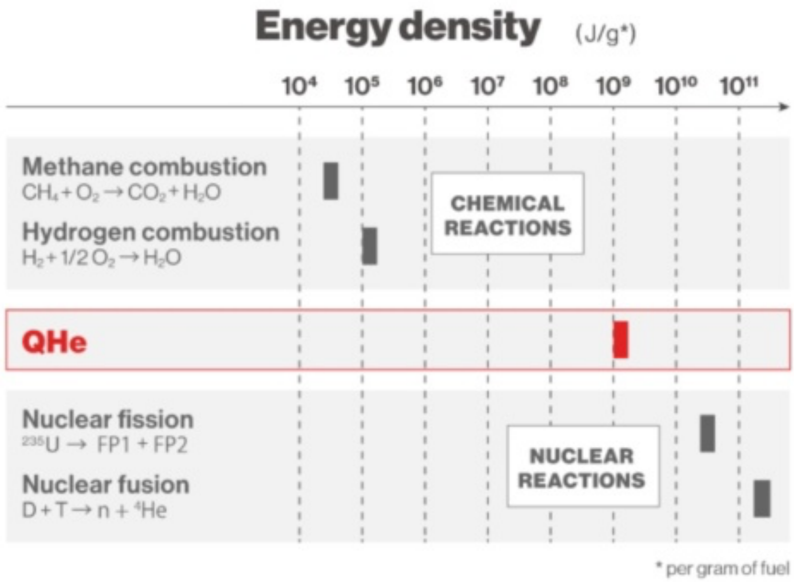

Figure 2: Quantum hydrogen energy (QHe) vs. energy density of methane and hydrogen combustion, fission, and thermonuclear fusion. Quantum hydrogen energy reaches 10,000 times that of chemical reactions. (Source: Clean Planet)

Above all, the advantage over thermonuclear fusion is the ease of engineering. While thermonuclear fusion requires large-scale facilities, such as magnetic confinement of plasma at 100 million degrees Celsius or the use of high-power laser radiation, Quantum Hydrogen Energy induces the fusion of hydrogen atoms by absorbing hydrogen in a metal sheet and heating it to several hundred degrees Celsius under certain conditions.

Because it only requires heating to a few hundred degrees Celsius, which is common in the industrial field, it can be made of ordinary materials such as stainless steel, and unlike thermonuclear fusion, neutrons and gamma rays are not emitted during the reaction, making it compact and potentially applicable to factories, buildings, and homes.

Heat generation lasted for 589 days

The method discovered by Clean Planet is to place a chip (heating element) consisting of multiple layers of 14nm (nanometer) nickel and 2nm copper in a vacuum, fill it with hydrogen, and heat it to several hundred degrees Celsius, which releases heat more than the input energy for a long period of time. Experiments using chips of several centimeters square have observed heat output exceeding the input energy, and qualitative reproducibility has achieved 100%. For example, in one case, heating at 900°C continued to emit excess heat at 920-930°C for 589 days (Figure 3). The COP (coefficient of performance: the number of times the heat energy is obtained compared to the input/consumed energy) is said to be more than 1.2 based on the verification so far.

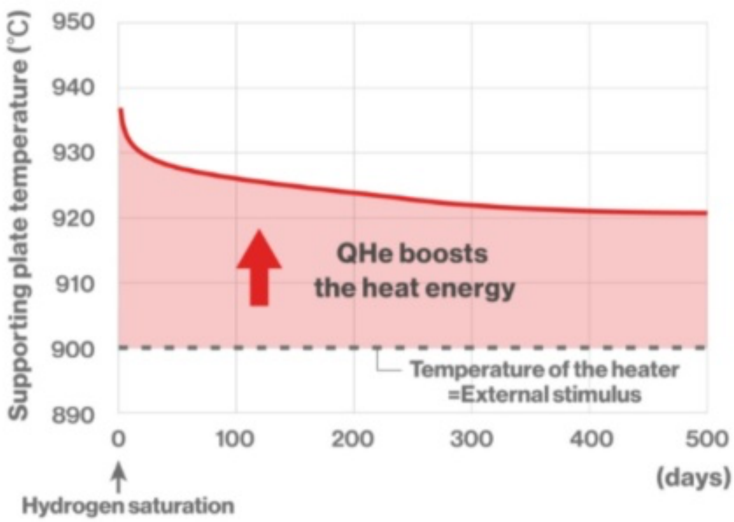

Figure 3: In one case, the heat emission lasted for more than 500 days after the initial hydrogen injection (Source: Clean Planet)

If system efficiency can be improved by increasing the size of the heating element and reducing heat loss, and if the operating period for a single hydrogen injection and heating can be extended to several months or longer, the COP is likely to exceed 10.

Based on these results, in September 2021, Clean Planet and Miura Co., Ltd., a major boiler equipment manufacturer, signed a joint development agreement for an industrial boiler that uses Quantum Hydrogen Energy.

Since then, Clean Planet has been working to produce the heating element in the form of thin and large sheets instead of small chips on the premise of improving COP and preparing for mass production. Last fall, the company developed a "heat module" in which a large sheet is housed in a metal cylinder. The prototype is 6 cm in diameter, 63 cm long, and weighs 4 kg, and is designed to generate heat equivalent to 2 kW. The company is considering increasing the amount of heat generated by further enlarging the area of the sheet and extending the length of the module (Figure 4).

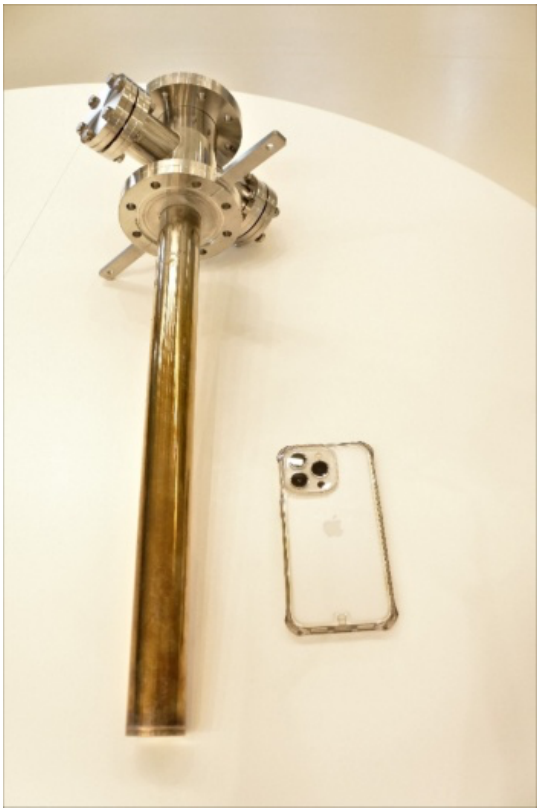

Figure 4: Heat module fabricated. A heating element, which is the reaction field, is placed in this tube. On the right is a typical smartphone (Photo by Nikkei BP)

When the enlargement of the metal sheet advances, it is expected to be possible to generate heat of 1,000°C or higher. There is also a safety mechanism as the nickel melts and the layer structure breaks down when the temperature exceeds 1,400°C, stopping the heat generation. Therefore, in principle, thermal runaway does not occur, which makes it safe.

For commercialization, the "heat module" will be installed in a cylinder-shaped heat exchanger, and heat will be extracted by circulating water or air. The heat module is designed to be versatile enough to meet the heat needs of various industries, such as the chemical industry, food and beverage manufacturing, and agriculture, according to the company. It is envisioned that the number of heat modules attached to the heating system will be determined depending on the required volumes as well as heat temperature.

The company is currently working on the verification of the heat modules. Although the reproducibility of Quantum Hydrogen Energy is said to be 100%, there are still issues to be solved in terms of quantitative reproducibility, such as maintaining the assumed heat generation for a targeted period. The company plans to improve the performance of the heat module and solidify the design specifications considering actual operation in heating processes, and to begin preparations for mass production in a few years, with plans to put mass production on track before 2030. A pilot plant will be established possibly in Kawasaki City, and the company is also considering overseas production in the near future.

Possible target COP10

As the movement toward "net-zero by 2050" gains momentum globally, thermonuclear fusion is once again in the limelight as a CO_2 free next-generation energy source. The tokamak method, which magnetically isolates the plasma state, is being promoted within an international framework. In the laser fusion method, new technologies are being proposed by venture companies globally, including in Japan. However, most of them are expected to begin construction of DEMO reactors as early as the 2030s, and commercialization is not expected until the 2040s or later (Figure 5).

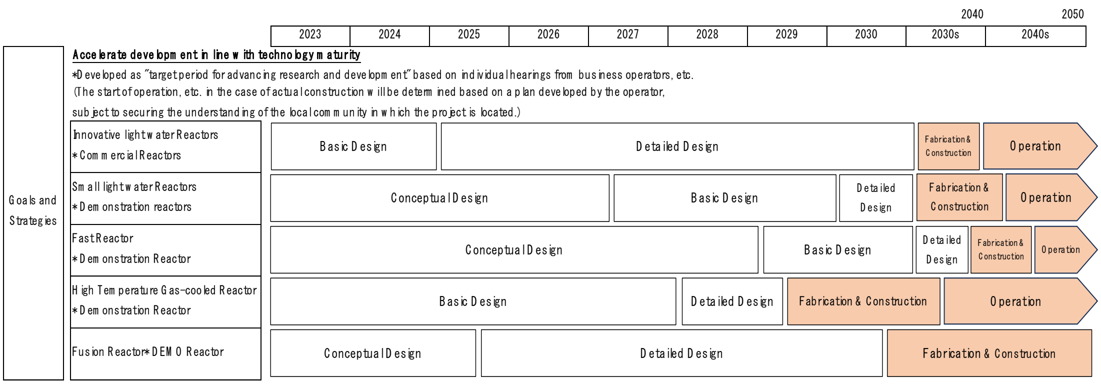

Figure 5: Development schedule for the next-generation innovative reactor as indicated in the basic policy for realization of GX (Source: Ministry of Economy, Trade and Industry of JAPAN)

Quantum hydrogen energy, on the other hand, has the potential to become a widespread distributed heat source for industrial applications without CO_2 emissions before 2030.

What makes the Clean Planet technology more attractive than thermonuclear fusion is that, whereas tokamak and laser fusion assume a DT reaction with deuterium (D) and tritium (T), quantum hydrogen energy uses common hydrogen (light hydrogen) as fuel to produce heat, and also produces no radiation, including neutron beams. The important point is that there is no radiation, including neutron beams with quantum hydrogen energy where there is with thermonuclear fusion. Besides, quantum hydrogen energy uses common hydrogen (light hydrogen) as fuel, therefore, hydrogen produced by electrolyzing water with excess electricity from solar panels on the roofs of factories, buildings, and commercial facilities could be used. This would open up the possibility of decarbonizing both the electricity and heat needed in the facility.

In the future, Clean Planet envisions using steam from quantum hydrogen energy to power a steam turbine generator. If this is realized, hydrogen produced by photovoltaic power generation could be converted to heat to generate electricity with an efficiency of about COP10, and even if the thermal efficiency of the steam turbine itself is low, the overall hydrogen-based system may be able to convert hydrogen to electricity with an efficiency significantly higher than that of fuel cell systems.

The current challenge with fuel cells is that when hydrogen derived from renewable energy is converted back into electricity using fuel cells, the total energy loss is significant, but when combined with quantum hydrogen energy, renewable energy hydrogen can be leveraged. It has the potential to dramatically increase the efficiency of a renewable energy-driven energy system.

Patents granted in 21 countries

Condensed matter nuclear reactions involving quantum hydrogen energy were once called Cold Fusion. In 1989, researchers at the University of Utah in the U.S. published this phenomenon, which brought it into the international limelight. The University of Utah reported that when palladium electrodes were immersed in heavy water and electricity was applied, excess heat was observed that could not be explained by a chemical reaction. At the time, research in this field went downhill, in part because of the lack of reproducibility of the phenomenon. However, some researchers have continued their research steadily. In addition to the traditional electrode method, heat generation method associated with deuterium absorption into palladium nanoparticles as well as nuclide conversion method associated with deuterium gas permeation through the palladium thin film have been reported, gradually increasing the reproducibility of the method.

The quantum hydrogen energy of the Clean Planet is revolutionary in that it uses light hydrogen instead of deuterium to generate excess heat, and that it uses relatively inexpensive base metals such as nickel and copper as the reaction field instead of rare metals such as palladium to generate heat at a practical level (Figure 6).

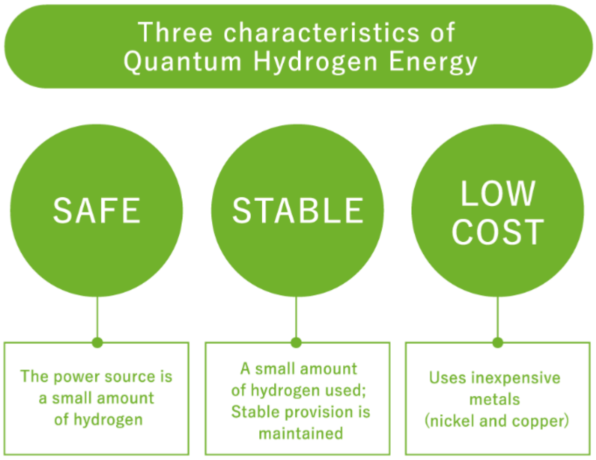

Figure 6: Characteristics of quantum hydrogen energy (Source: Clean Planet)

In the future, it has great potential as a distributed energy source, when combined with photovoltaic power generation, which has already reached a low-cost and been widely available.

Venture companies have emerged lately in the field of thermonuclear fusion, which has been widely reported. In the field of condensed matter nuclear reactions, a number of energy-utilizing ventures have also sprung up in the United States, Italy, and Israel. In the U.S., major IT companies are also participating, and this year a national project under DOE was launched with the participation of the Massachusetts Institute of Technology (MIT), Stanford University, and others. Clean Planet is leading the pack. The company has applied for 183 patents in 21 countries and 69 patents have been granted, which is outstanding worldwide in the field of condensed matter nuclear reactions.

Based on these recent research progress, Mitsubishi Estate invested in Clean Planet in January 2019, Miura Industries in May 2019, and Mitsubishi Corporation in July 2022. In April 2023, Hiroshi Komiyama, former president of the University of Tokyo and currently chairman of Mitsubishi Research Institute (MRI), as well as Carl Page, a global environmental investor in Silicon Valley, joined the advisory board. Recognition is gradually increasing both domestically and internationally.

On the other hand, it is also true that the principles of condensed matter nuclear reactions are not fully understood even today. Current nuclear physics cannot explain how nuclear transmutation can occur in an environment of a few hundred degrees Celsius and not emit neutrons or gamma rays along the way. Although several researchers worldwide, including Professor Emeritus Akito Takahashi of Osaka University and Associate Professor Peter Hagelstein of MIT, have proposed theories to explain the phenomenon, there is no established theory that everyone accepts.

Clean Planet conducts research and development at two locations, one in Sendai City and the other in Kawasaki City. Tohoku University's Research Center for Electron Photon Science, located in Sendai City, is responsible for basic research, led by Professor Yasuhiro Iwamura, who achieved results in this field during his tenure at Mitsubishi Heavy Industries, while the center in Kawasaki City is responsible for development toward commercialization. Tohoku continues to analyze the nuclear reaction products of quantum hydrogen energy, but the mechanism is complex and theoretical construction does not seem to be a simple matter. Identifying reaction products alone requires a great deal of time and effort, including analysis of contaminants, and the current system may be limited in its ability to quickly elucidate the theory.

In some industrial technologies, the discovery of phenomena such as high-temperature superconductivity and their industrial applications precede the elucidation of their mechanisms. On the other hand, the theoretical underpinnings will contribute significantly to improving the controllability and social acceptance of quantum hydrogen energy. As its promise as an industrial technology becomes apparent, more research institutes and companies are expected to become involved in this field, and as the base of research and development expands, it is hoped that the elucidation of mechanisms will progress in parallel with product realization.

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