From laboratory to power plant: fusion energy, a crucial contribution to the energy transition

Marvel Fusion

Thanks to new technical and scientific breakthroughs, it should soon be possible to put this promising technology into practice through stable and efficient processes in a commercial power plant.

Author: Dr Georg Korn, Chief Science and Technology Officer, Marvel Fusion

The energy transition is already beginning to take effect: only 51 per cent of German electricity is still being generated from coal, natural gas or nuclear power. However, the difficulty of reducing it further will increase with each percentage point if a reliable basic supply of electricity to individuals and businesses is to be ensured.

At the same time, there is a clear social and political will to continue reducing this number, for climate protection and safety reasons. The EU has once again upped its climate change targets, and the US has re-entered the Paris Agreement – both indicating their commitment to this common goal.

Global demand for energy is also growing significantly. Estimates show that global electricity demand will have more than tripled by 2050 to 60 terawatt hours. Forecasts indicate that not even half of this demand will be met by renewables. These calculations don't yet factor in the effect of the aim to convert highly energy-intensive industries such as manufacturing, chemical and steel and concrete production to clean, sustainable electricity sources.

On a global level, solar and wind energy and hydroelectric power are only able to meet a fraction of the existing energy demand in many regions. As demand increases, the situation is exacerbated further.

A new energy source is needed to meet the growing demand for carbon-free electricity. Fusion energy could be the crucial catalyst needed to provide sources of high-density, emission-free energy around the clock at competitive prices.

Thanks to new technical and scientific breakthroughs, it could now be possible to bring this promising technology out of the laboratory for the first time and into stable and efficient processes in a commercial power plant.

Laser-induced fusion energy addresses the existing challenges of alternative forms of energy. These include the dependence of solar and wind energy on weather, with associated under- and overproduction, risks linked to costs and network stability, long distances between production and consumption sites, and extensive land use for wind turbines and solar fields.

The last of these in particular is causing increasing problems with acceptance not only in the general population, but also among landscape and nature conservationists. While citizens are undoubtedly interested in “green” energy, they also fear for habitats and species diversity. Power plant operators and municipal and private owners, as well as politicians, are increasingly finding themselves caught between conflicting interests.

Production close to metropolitan areas and economic centres

In this fraught area, laser-driven inertial confinement fusion provides a solution and a crucial additional energy source. It significantly reduces overall pollution, as the fusion process does not create CO2 and the operation of the plant does not produce any hazardous or polluting emissions or long-lasting waste. It also makes it possible to produce electricity reliably and on demand close to the metropolitan and economic centres that need it. Last but not least, it increases network stability and reduces the need for power lines that are difficult to install.

The scientific and technical issues around inertial confinement fusion, as monitored by the German start-up Marvel Fusion, are under intensive investigation. The specific challenge lies in achieving the rapidly growing scientific and technical results in stable and efficient processes within a commercial power plant.

Significant process has now been made in achieving this, not only in the fusion concept itself but also in the technical components and the understanding of the ongoing processes.

Until now, magnetic confinement fusion has been the most promising path for commercial fusion power plants. This uses magnets to confine the plasma, making it significantly less dense than in laser fusion. The energy is obtained from the fusion of the hydrogen isotopes deuterium and tritium, which are heated to a plasma state at high temperatures.

In the case of laser-induced fusion, the fuel in the target and the laser as an energy source are decoupled, allowing for a rapid exchange of components. The peak output, repetition rate and intensity of the lasers are much higher today than just a few years ago, which means that these factors could now allow for sustained operation in a power plant. The fact that the 2018 Nobel Prize in physics went to a team of laser researchers headed by Gérard Mourou and Donna Strickland shows the extreme intensity of the momentum in the field of laser research.

A safe, clean and reliable energy source

New scientific breakthroughs are also being made in the area of fusion fuel. The hydrogen isotopes that have largely been used in the existing approaches, deuterium (D) and tritium (T), primarily convert the energy released through fusion into fast neutrons.

Marvel Fusion is identifying other fuel combinations that are safer, cleaner and more reliable. This includes the metalloid boron, which is readily available globally and is harmless in both environmental and safety terms. In the process developed by the start-up Marvel Fusion, protons (hydrogen particles) are fused with boron-11 nuclei using high-power lasers, releasing mainly electrically charged alpha particles (charged helium nuclei) that can be converted directly into electricity.

The boron-proton reaction releases significantly fewer neutrons than the fusion of deuterium and tritium. The neutrons, of which there are comparatively few, are also slower. Both factors significantly reduce induced radioactivity. It should also be noted that, with this reaction, the raw materials are not radioactive and can therefore be stored safely.

The continuous production of carbon-free energy with 1 GW of installed capacity for a period of one year requires less than 500 kg of fuel. By comparison, a 1 GW coal power plant requires 2.4 million tonnes of coal, assuming 40% efficiency, and releases 4.4 million tonnes of CO2 per year.

Boron-proton fusion requires high temperatures. In initial experimental demonstrations of this reaction, the amount of energy initially needed to be fed in was even greater than could potentially be produced. Since then, however, the development has become so predictable that Marvel Fusion will be able to achieve a net energy output of several times the input.

The company is benefiting here from advances in nanotechnology. These now make it possible to produce very finely structured fuel configurations, which have a particular composition that allows them to increase the overall probability of fusion at the atomic level and drastically reduce the temperature required for the fusion process.

A fusion power plant adapts to existing energy demand

Inertial confinement fusion is safe and secure in a number of respects: as well as using safe, non-radioactive fuels, the power plants also ensure that the supply to network regulators and consumers is secure and that power plant operations are safe. A power plant that runs on this principle can be commissioned in a very short time and its output adapted to existing demand.

Similarly, it can be shut down in a tenth of a second as needed, or automatically stop running in the absence of deliberate commands. There is no chance of an uncontrolled chain reaction taking place. The fusion reaction stops as soon as the laser is no longer being operated. This also applies to potential emergency situations, such as earthquakes or aircraft crashes.

No radioactive substances are delivered to or stored at a fusion power plant to start the fusion process. During the reaction, only small quantities of material are activated; these can be handled easily by the system and decay within a few weeks. No laborious, risky or costly storage is necessary.

Nevertheless, this new procedure will need to prove itself in business terms. The aim is to achieve production costs of five to ten cents per kilowatt hour. A practical demonstration of both the procedure and implementation for everyday use are expected to be provided by an impending research facility and by an inaugural power plant (from 2030).

Laser-induced inertial fusion not only has the potential to meet the huge energy demands of industrialised countries, but also those of emerging and developing countries with growing populations and economies. It tackles the key issues associated with conventional and alternative energy production, thereby making a significant contribution to the energy revolution and to CO2 reduction.

CONTACT

Marvel Fusion GmbH
Blumenstraße 28
80331 Munich, Germany
press@marvelfusion.io