Tame the power of the Sun, nuclear fusion, as the energy source for the next century

Zhou Xinyu

As the advancing of modern science and technology, human society is growing bigger and stronger. As a result, the requirement for energy is growing up too. In 1900, the whole human society consumed 12128 terawatt-hours. It took 50 years for this number to be doubled. After 1950s, this number have been doubled again and again for approximately every 20 years. (Smil 2017; OurWorldInData) On the other hand, even the current power supply is not enough to satisfy the need of whole human beings. Thus, we could expect the gap between energy supplement and energy demand would become even larger in the future.

Of course, human society could build more power plants, as we did in the past century. However, this would lead to some other problems. Currently, the main energy source could be categorized into 5 kinds: fossil fuel; hydroelectricity; wind; solar; and nuclear power. Nearly all of them has some serious disadvantages. Fossil fuel is a kind of unrenewable resources with huge amount of carbon dioxide emission, which is believed to be the main cause of global warming. Hydroelectric station and wind power plants could only be built around special locations: rivers and wind site, makes it impossible for these kinds of energy to be deployed in a large scale. It is also nearly impossible for wind power plants to be combined into a large-scale electrical network since wind itself is not so predictable. Solar power plants could be built anywhere but it would need a huge amount of land to place photovoltaic boards.

Nuclear power could be divided into 2 categories: nuclear fission and nuclear fusion. In nuclear fission, heavy nuclei are divided into multiple kinds of relatively lighter nuclei after absorbing a neutron. This process would release considerable energy, thus contribute to the power supplement. However, fission fuel is also considered as unrenewable resources. Also, consuming fission fuel would produce so-called nuclear waste, which is extremely hard to be cleaned up.

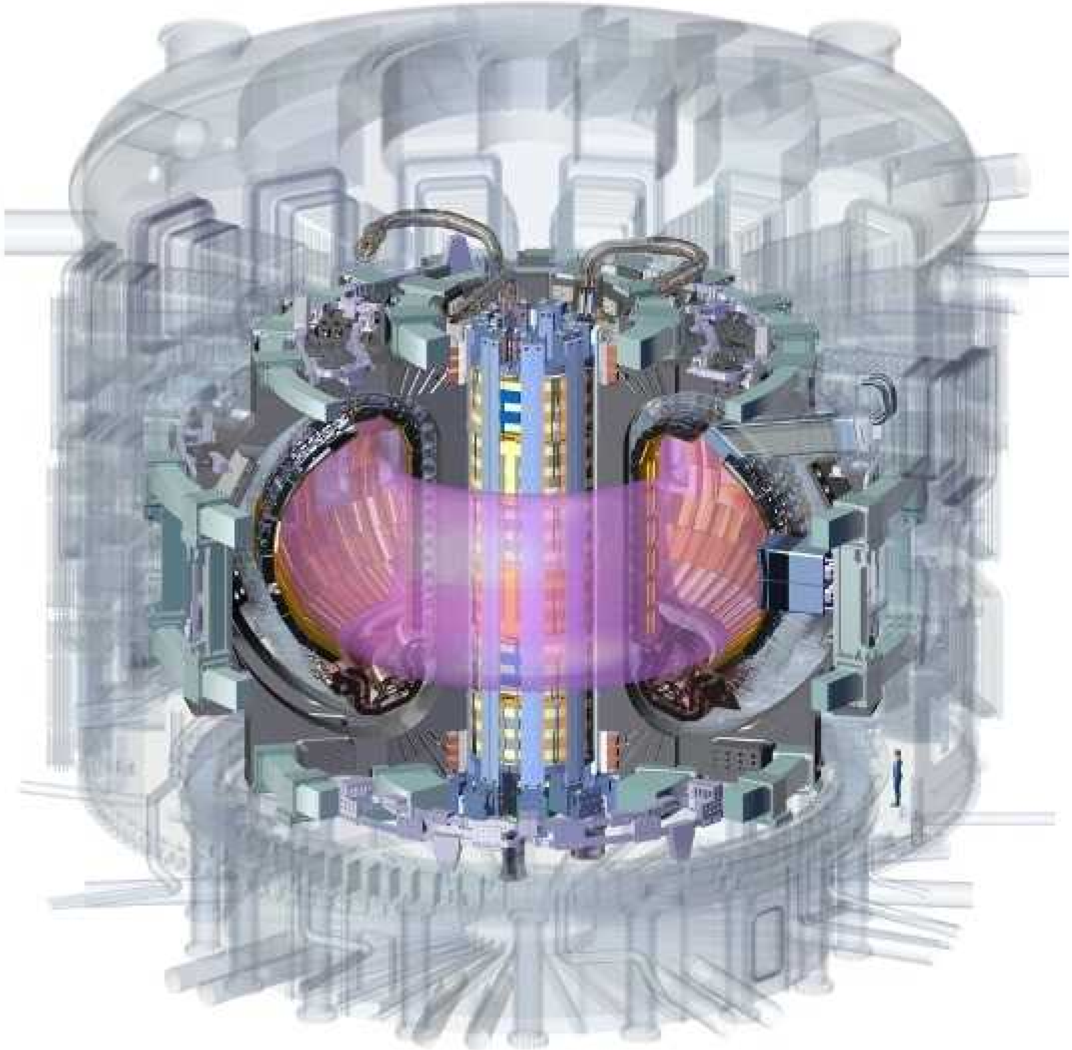

Figure 1. illustration of core fusion device in ITER (Credit © ITER Organization, http://www.iter.org/)

All the energy source mentioned above have some serious disadvantages, and that makes researchers turned their sight to nuclear fusion. Nuclear fusion is a reaction in which 2 or more light nuclei combined into a heavier nucleus and subatomic particles such as neutrons. This process would release energy even much greater than nuclear fission. It is the main energy source of Sun and Stars. For fuels of equal mass, nuclear fusion could provide 50 times more energy than fission. We could expect considerable amount of energy if we could build a nuclear fusion power plant—an artificial sun.

However, it is quite challenging in practice to reproduce controllable nuclear fusion. To perform nuclear fusion reaction, high environment temperature ~several millions of Celsius degrees is necessary. With that high temperature, it is quite hard to confine fusion fuel, which has turned into high temperature plasma, in the reaction location.

Many researchers around the world have already been working in this field in past decades. Artsimovich+ (IAEA, 1969) designed an inspiring fusion device, Soviet T-1, as the first so-called tokamak, and reached performance ten times higher than any other devices that time. The design was a plasma ring with twisted toroidal magnetic field, with which it could not only confine the plasma inside the reaction ring, but also prevent the magnetized plasma from collapsing by suppressing various of instabilities. All the following (magnetic confined) fusion devices adapt similar core design, which are all called tokamak. After that, researchers around the world realized that it would be much more economical if different countries cooperate with each other in this field. Thus, the international fusion society started pursuing a global collaboration.

The global collaborating nuclear fusion project, ITER in France has been initialed in 2005. As its proposal, ITER would be the largest fusion device around the world until now, and it would be the first fusion device which could produce net energy. With the biggest vacuum vessel, 840 cubic meters, it could generate 500MW of fusion power from only 50MW of input energy. The Q-value, ratio of output power over input power, is a key factor of energy production. The world has been pursuing the so-called plasma energy breakeven point for 60 years. It means that more energy is produced by fusion than the input heating energy, which requires $Q>1$. In the past history, The Joint European Torus(JET) has reached $Q=0.67$, as the world record. ITER would break through $Q=1$ boundary and reach $Q=10$ in plan, as the first one in history. The first plasma, which means ITER start running, would be in 2025, and the nuclear fusion would be initialed in 2035, as planned. The scientists expect that it will reach a temperature of 150 million Celsius degrees, which is 50% higher than current record of 100 million degrees. In the expected future, it will gain net energy with nuclear fusion, for the first time in human history, which will help build real nuclear fusion power plants. (Reichert 2020; ITER) Above ITER, there would be only one step left to adapt fusion energy for daily life.

In the expected future, humankind would face the shortage of energy supplement. While current energy sources all have various serious problems, nuclear fusion stands out. First founded on the Sun, the nuclear fusion energy would be a clean, sustainable, and powerful energy source for humankind after 2050 at the earliest. The power of the Sun, nuclear fusion, should be the energy source for the next century.

Reference:

[1] Vaclav Smil(2016), Energy Transitions: Global and National Perspectives, Praeger

[2] Hannah Ritchie and Max Roser (2020) - "Energy". *Published online at OurWorldInData.org.* Retrieved from: 'https://ourworldindata.org/energy' [Online Resource]

[3] Artsimovich, L. A. In Proc. 3rd Int. Conf. Novosibirsk 11–17 (IAEA, 1969).

[4] Reichert, S. Inside ITER. Nat. Phys. 16, 895–897 (2020).

[5] ITER. ITER-the way to new energy. https://www.iter.org/ access by July 9th, 2021