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**The Fourth Energy Transition. Hydrogen Energy:  
Prospects for the Development**

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The world is gradually coming to the point that renewable energy sources are beginning to displace fossil fuels. The energy sector has already passed three energy transitions, and has made a big leap into the fourth one. The Central European countries, primarily Germany and France, are still the leaders of the energy transition. Thanks to their contribution, the European Union (EU) has adopted a program according to which the EU will abandon the use of fossil energy sources by 2050. In the future, the struggle for efficient energy sources and progressive de-carbonization of the atmosphere will inevitably continue in the process of active hydrogen energy development. This will require a significant reduction in the cost of hydrogen production and the introduction of acceptable solutions for its transportation, storage and use.

A distinctive feature of the fourth energy transition is that instead of one technological revolution, as it was before, there are a lot of technological breakthroughs in the field of energy efficiency, namely: reduction of carbon dioxide emissions into the environment (the transition to renewables and hydrogen, the use of storage and carbon capture). As a result, the structural restructuring of the economy and technological progress have made it possible to move away from increasing energy consumption to ensure production and economic growth. Primary energy consumption has stabilized in most

countries of the world, even in China, and it is worth noting that GDP growth rates have remained at the same level.

For example, programs to reduce greenhouse gas emissions have been established and are being actively implemented in the EU, Asia, and North America. For this purpose, emission regulation (quota) systems and carbon taxes were introduced. Gradually, internal combustion engines began to fall under the ban and switch to electric motors. In all spheres of society clear plans are being created for the introduction of renewable energy sources.

The goal has been set to achieve "climate neutrality" by 2050 (bringing emissions to the same level and absorbing carbon dioxide). In the EU, by 2030, it is planned to reduce coal consumption by 70%, oil and gas – by 30%. As for China, they announced plans to become carbon neutral by 2060. Since 2021, China has introduced an emissions trading system. If we talk about Japan and South Korea, they plan to achieve neutrality by 2050 [1].

The most important aspect is the fight against climate change. At the international level, the discussion on climate was completed, and the thesis on climate change caused by anthropogenic greenhouse gas emissions was adopted as a consensus. Insurers have already recorded a steady increase in the number of natural disasters, and the consequences of climate change by 2100 are evaluated as extraordinary: possible damage to global GDP is estimated at 30-45%.

To counteract the climate threat at the global level, emergency measures have been taken in recent years to reduce carbon dioxide emissions (de-carbonization). States have gone to previously unimaginable costs and measures to decrease these emissions. In 2015, the Paris Agreement was adopted, aimed at keeping the growth of the average temperature on the planet within 1.5°C from the pre-industrial level and the transition to a low-carbon development model.

Hydrogen energy is an industry based on the use of hydrogen as a means of energy production, transportation and consumption. Hydrogen is an omnipresent element on the Earth surface and in space, the heat of its combustion is high, and the product of combustion in oxygen is water, which is re-introduced into the circulation of hydrogen energy. The latter is one of the types of alternative energy, and many consider it environmentally friendly.

Soon the energy industry will cease to exist in the form in which we now know it. For example, houses will be equipped with autonomous hydrogen generators. Hydroelectric power plants, nuclear power plants as well as all the grids that transmit electricity will never prove necessary. But at the same time, hydrogen is produced precisely due to a significant consumption of electricity.

The danger of using hydrogen as a fuel deals with two reasons: the high volatility of hydrogen, because of which it penetrates through very small holes, and the ease of ignition. There is also a danger of filling an enclosed space with hydrogen. It is more dangerous than gasoline because it burns in a mixture with air in a wider range of concentrations [2].

But so far, hydrogen makes up less than 1% of the EU's energy balance. It is used as a component in the production of ammonia (nitrogen fertilizer) as well as in oil refining. The hydrogen train and the network of hydrogen filling stations for vehicles in operation have been created in Germany. Hybrid cars powered by electricity and hydrogen are beginning to become widespread in the EU countries. This is a promising direction: with the help of fuel cells a chemical reaction occurs, during which hydrogen is converted into electricity. The efficiency of hybrid engines exceeds 80% and the performance of internal combustion engines is about 40%. Leading automakers Toyota, BMW and Mazda are converting engines of some models into motors running on hydrogen. However, so

far cars with a hydrogen engine are several times more expensive than those with traditional ones [3].

Taking into account the requirements of the fourth energy transition, modern solutions in the energy sector, such as electricity demand management, the use of energy-saving technologies and energy storage, will help domestic companies succeed in transforming their production.

It is obvious that the practical use of hydrogen energy will require large investments, including the creation of the necessary infrastructure.

They invest more than they receive in the field of obtaining and using hydrogen. There are also problems with the storage of this energy carrier. Nevertheless, we can say that hydrogen fuel is a promising form of energy, which will be the near future of many countries of the world.

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