Hydrogen technologies in the energy supply system of the housing and communal sector

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Abstract: The energy supply system used in the housing and communal sector is a crucial element of the construction industry. The energy efficiency of buildings can be improved by using hydrogen technologies, such as fuel cells, hydrogen gas turbines, innovative hydrogen storage and distribution systems, etc. The use of these elements for the energy supply systems will require special safety measures and space-planning solutions. However, along with the generation of energy from renewable energy sources, this will decarbonize the housing and communal sector.

1. Introduction

One of the important elements in the construction industry is the energy supply system. According to researchers, the large volume of energy is spent on the construction and maintenance of buildings, while energy consumption may increase by 45% in the next decade [1]. According to the International Energy Agency, the housing and communal sector accounts for 30% of the world's energy consumption [2].

Currently, in most countries, including Russia, the centralized power supply systems use energy generated by nuclear, hydropower and condensing stations. Large power plants meet basic needs. Due to the economy of scale, they are economically viable for providing large consumers, including the housing and communal sector, with energy resources. However, the centralized energy supply system is characterized by a significant amount of losses in distribution networks; in addition, the consumption of natural gas and coal for generating electricity and heat causes greenhouse gas emissions: about 28% of global CO₂ emissions are due to the energy supply of buildings [2].

The issue of energy efficiency of the housing and communal sector has been discussed for a long time. It can be improved through the partial or full use (for low-rise buildings) of distributed energy supply systems in buildings and renewable energy sources (RES). Wind turbines and solar panels can be used in crisis situations. However, renewable energy sources used for the energy supply systems are
dependent on climatic conditions. To solve this problem, storage batteries are used. Hydrogen technologies are an alternative option for using renewable energy sources in the energy supply systems.

2. Hydrogen technologies

Many experts are skeptical about the use of hydrogen technologies in the construction industry. The problem is physicochemical properties of hydrogen: metallic embrittlement, volatility, bulk density, and explosion hazard. As a result, the question of hydrogen storage arises; nevertheless, there are technologies that can solve this problem.

Currently, hydrogen is not used in the construction industry and energy supply systems of the housing and communal sector. However, the hydrogen technologies are at the stage of demonstration projects.

3. Fuel cells (FE) convert the chemical energy into the electrical energy

Electricity is therefore generated with a minimal impact on the environment. The power and size of fuel cells depend on the needs of consumers; in addition, fuel cells can generate both electrical and thermal types of energy, which increases the energy efficiency of these systems [2]. The FC may be used in the construction industry.

The efficiency of electricity generation by fuel cells ranges from 30% to 55%; with cogeneration of electrical and thermal energy, this indicator can increase to 90%. (Table 1) [3].

| Type                                | Energy generation efficiency | Combined cycle efficiency | Capacity       |
|-------------------------------------|-----------------------------|----------------------------|----------------|
| Proton exchange membrane fuel cells (PEMFC) | 30 – 35%                    | 50 – 70%                   | 0.1 кВт        |
| Phosphoric acid fuel cells          | 35%                         | 70–80%                     | 11 МБт         |
| Molten carbonate fuel cells (MCFC)  | 45 – 50%                    | 70 – 80%                   | 3 – 60 МБт     |
| Solid oxide fuel cells (SOFC)       | 45 – 60%                    | 70 – 90%                   | 1 – 100 МБт    |

Japan is one of the world centers developing hydrogen technologies, including fuel cells; the fuel cells are at the stage of industrial production. The Ene-Farm program provides households with low-power energy and is a distributed generation subsystem whose main purpose is to supply power to small consumers in the housing and communal sector. The power of generators varies from 0.3 kW to 1 kW; electricity from centralized networks is used in case of insufficient capacity of the installation [4]. The efficiency of its combined cycle is 87% [4]. The next step is energy supply from household devices to the common power grid. This will allow consumers to save on energy services by selling the energy generated by their own devices. Several Japanese companies are already involved in this area. The Ene-Farm project aimed at supplying energy to low-power consumers has a high level of hydrogen efficiency.

The fuel cells can be used both for distributed generation and centralized energy supply. According to forecasts, the efficiency of solid oxide fuel cells (SOFCs) with a combined operation cycle is 90%.
According to MIE forecasts, their capacity may be up to 100 MW [5, 6, 7, 8]. When using megawatt class solid oxide fuel cells, the centralized energy supply system is limited by a small number of operating cycles. According to forecasts, by 2030, the life cycle of SOFC will be 40,000 - 60,000 hours [2]. According to this indicator, fuel cells are worse than traditional fuel and RES generation technologies. The advantage of FCs is their compactness and a wide range of capacity indicators. As a result, the energy supply of buildings under the distributed generation scheme is more efficient: the Enfarm systems are more efficient due to the cogeneration of electricity and heat energy. The fuel cells with proton exchange membranes used for such systems have a long life cycle and low maintenance costs; the delivery of small volumes of hydrogen is not technologically difficult.

When using hydrogen technologies, the energy is supplied to consumers not only through the fuel cells. Mitsubishi Hitachi Power Systems develops gas turbine and combined cycle systems. Currently, the company has created several gas turbine units using a gas mixture (20% H2 / 80% CH4 and 30% H2 / 70% CH4). They allow for the use of hydrogen with a reduced level of CO2 emissions and save natural gas. The company aims to create a hydrogen CCGT unit with a system efficiency of at least 65% [9].

Let us consider the energy supply system for consumers in the housing and communal sector:

![Figure 1](image1.png)

**Figure 1.** Energy supply to consumers in the housing and communal sector: a distributed generation system.

![Figure 2](image2.png)

**Figure 2.** Energy supply to consumers in the housing and communal sector: a centralized energy supply system.

The centralized energy supply system (fig. 2) is based either on the use of gas turbine power plants, or megawatt fuel cells. With a distributed generation scheme (Fig. 1), low-power TEs are installed in buildings. Hydrogen is supplied through the pipeline systems or in cylinders.

4. **Transportation and storage of hydrogen**

To supply energy to the housing and communal sector, an extensive transport system with an infrastructure for storage and distribution of hydrogen is required. Currently, methods of storing compressed and liquefied hydrogen are technologically mature; however, they are not efficient and safe: low hydrogen content per unit volume of storage, large cryogenic plants and a high hazard class. Therefore, the methods should be improved. To deliver hydrogen to buildings, medium and small distribution pipelines and tanks are required. One solution is the use of composite materials.

Hydrogen can be delivered in a compressed or liquefied state, but this requires materials resistant to hydrogen embrittlement, compressor units, cryogenic stations for cooling and liquefying hydrogen. As a result, financial resources are required to build a hydrogen power supply system.
5. The use of hydrogen in the natural gas infrastructure
Hydrogen can be used in existing natural gas networks. According to some studies, depending on the equipment used, 5-15% hydrogen can be added to natural gas and used for power supply of buildings [10-15]. With technological control and adherence to the permissible hydrogen content, there are no risks for gas pipeline networks and end users. With the electrolysis method of production, hydrogen can facilitate the integration of renewable energy sources into the existing power supply systems, reduce the consumption of natural gas and carbon dioxide emissions, and allow testing hydrogen storage and supply systems.

The use of hydrogen in the energy supply system designed for the housing and communal sector depends on the type and location of buildings, equipment and hydrogen costs. The use of hydrogen for energy supply purposes is compatible with renewable energy sources: electrolysis plants produce hydrogen using electricity generated by solar or wind power plants, which makes it possible to accumulate RES energy, given their stochastic nature.

Currently, the most widespread method of hydrogen production is the technology of reforming of natural gas. Due to the spread of renewable energy sources, the share of hydrogen production based on water electrolysis may increase [2]. In the electrolysis production, the final cost of hydrogen depends on the cost of energy consumption; with a decrease in the cost of electricity generated from renewable energy sources, the cost of hydrogen can decrease. In addition, unlike reforming, this process does not produce CO₂. Due to this, the use of hydrogen can decarbonize the construction process.

Despite this, hydrogen produced from renewable energy sources, as well as hydrogen technologies are expensive.

6. Conclusion
To create a hydrogen energy infrastructure, a large volume of investment is required: fuel production, creation of energy storage and transport systems, and re-equipment of buildings require a larger volume of investment in comparison with the traditional energy supply systems. Nevertheless, energy efficiency and environmental safety are the basis for hydrogen technologies used in the construction industry. Hydrogen can be used in the existing natural gas infrastructure to improve the energy efficiency of buildings.

The use of fuel cells combined with renewable energy sources can provide a building with heat and electricity. CHP cogeneration improves the energy efficiency of energy supply systems, thereby improving the overall efficiency of the energy system. The results are lower operating costs and a lower volume of greenhouse gas emissions.

With the development and distribution of renewable energy sources, the use of hydrogen technologies can solve energy, environmental and economic problems and ensure the high quality of energy supply to the housing and communal sector. However, the rate of hydrogen technology implementation depends on several critical factors, in particular, the final price of hydrogen and the cost of the technology.

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