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ECONOMIC AND ENVIRONMENTAL INDICATORS OF HIGH-TEMPERATURE SUPERCONDUCTOR PRECURSOR SYNTHESIS IN THE LARGE SOLAR FURNACE (PARKENT)

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The efficient and environmentally friendly synthesis of next-generation high-temperature superconducting (HTS) materials represents one of the most pressing challenges facing contemporary science and industry. When conventional furnaces are employed, the synthesis process requires significant energy consumption and results in the release of harmful carbon emissions into the atmosphere, thereby reducing both the economic and ecological efficiency of the process. From this perspective, the use of concentrated solar energy in the Large Solar Furnace (Parkent) provides a promising approach for the synthesis of HTS materials [1]. This method not only reduces energy expenditures but also minimizes environmental impacts, making it a “green technology”.

The primary objective of this study is to analyze the economic and environmental indicators of the synthesis process of $Bi_{1,7}Pb_{0,3}Sr_2Ca_{(n-1)}Cu_{(n)}O_y$ HTS precursor materials using concentrated solar energy in the Large Solar Furnace. At the same time, this research aims to substantiate the advantages of solar-based synthesis compared to conventional methods, specifically by reducing energy consumption, lowering carbon emissions, and enhancing the overall efficiency of the synthesis process.

It is well known that, before the practical implementation of any promising technology or development, its economic feasibility and profitability must be evaluated. From this perspective, the synthesis process of high-temperature superconductor (HTS) precursors in the Large Solar Furnace (LSF) was compared with conventional furnace technology to assess its economic efficiency [2].

During the analysis, the results of experiments conducted in both the conventional furnace and the LSF were compared. It was determined that, in a conventional furnace, an average of 125 g of $Bi_{1,7}Pb_{0,3}Sr_2Ca_{(n-1)}Cu_{(n)}O_y$ can be synthesized within 1 hour, requiring 1.1 kW·h of electrical energy. In this case, the specific energy consumption is 8.8 kW·h/kg. In contrast, the LSF enables the synthesis of up to 10 kg within 1 hour with an average energy consumption of 12 kW·h, resulting in a specific value of 1.2 kW·h/kg [3].

The total cost was calculated using the following formula:

$$C = E \cdot Pe \qquad (1)$$

where: C – total cost (UZS/kg), E – electrical energy consumption per 1 kg of material (kW·h/kg), Pe – price of 1 kW·h of electrical energy (UZS/kW·h).

Based on the current tariff of 900 UZS/kW·h for Groups I and II consumers, the total cost of precursor synthesis per kilogram, derived from electrical energy consumption, was:

$$C_{LSF} = 1080\ \text{UZS/kg}, \quad C_{conv} = 7920\ \text{UZS/kg}$$

The economic efficiency coefficient was determined as:

$$K = \frac{C_{conv}}{C_{LSF}} = \frac{7920}{1080} = 7.33 \qquad (2)$$

The energy savings were calculated as:

$$\Delta E = E_{conv} - E_{LSF} = 8.8 - 1.2 = 7.6\ \text{kW·h/kg} \qquad (3)$$

The corresponding economic benefit is:

$$S_c = \Delta E \cdot P_e = 7.6 \cdot 900 = 6840\ \text{UZS/kg} \approx 0.53\ \text{USD/kg} \qquad (4)$$

The results demonstrate that the synthesis of HTS precursors in the Large Solar Furnace is more than seven times more cost-efficient compared to conventional furnace technology.

During the synthesis process carried out using the Large Solar Furnace (LSF), the amount of CO_2 emitted into the atmosphere is significantly reduced due to the savings in electrical energy. The specific mass of reduced CO_2 emissions is determined by the following equation:

$$M_{CO_2} = \mu_{CO_2} \cdot \Delta E \qquad (5)$$

where: μCO_2 – the specific mass of CO_2 emissions released (kg/kW·h) during the combustion of fuel for the production of 1 kW·h of energy, ΔE – the amount of specific electrical energy saved (kW·h/kg).

It is known that the CO_2 emissions produced per 1 kW·h of energy generation through natural gas and coal combustion are 0.437 kg/kW·h and 0.798 kg/kW·h, respectively. Based on this, the reduction of CO_2 emissions when using the LSF was calculated as follows (Fig.1).

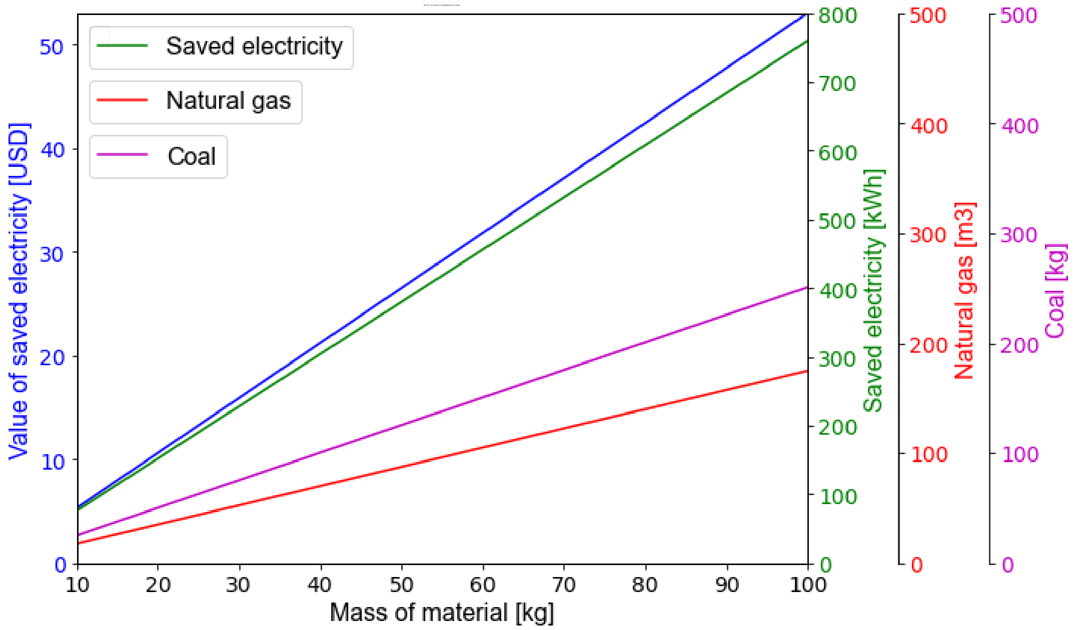

Figure 1. Dependence of the amount and value of saved electrical energy on the mass of material.

Furthermore, the economic value of the reduced CO_2 emissions can be evaluated using the following equation:

$$C_{CO_2} = c_{CO_2} \cdot M_{CO_2} \quad (6)$$

where c_{CO_2}– the specific payment rate established for 1 ton of CO_2 emissions (USD/t CO_2).

The analysis results show that the synthesis of $Bi_{1,7}Pb_{0,3}Sr_2Ca_{(n-1)}Cu_{(n)}O_y$ HTS precursors in the Large Solar Furnace enables a reduction of CO_2 emissions per kilogram of precursor by 3.3212 kg when natural gas is used and by 6.0648 kg when coal is used, compared to conventional furnace technology (Fig.2). This not only provides economic benefits but also ensures environmental sustainability.

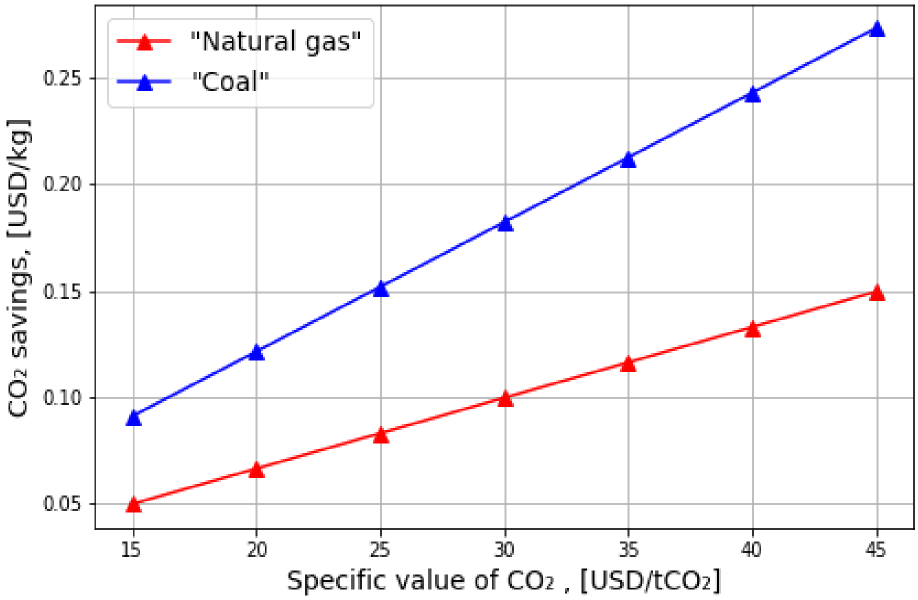

Figure 2. Dependence of CO2 emission savings on the specific CO2 value when burning the considered fuel types.

The synthesis of high-temperature superconductor (HTS) precursors using conventional furnaces is characterized by high energy consumption and significant CO_2 emissions. In contrast, the application of concentrated solar energy in the Large Solar Furnace substantially reduces energy consumption, minimizes carbon emissions, and emerges as an economically and environmentally efficient "green technology."

References

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