



## **STUDY OF ENVIRONMENTALLY SOUND AND ENERGY-EFFICIENT METHODS OF CHEMICAL PRODUCTION IN THE CONTEXT OF THE CONCEPT OF SUSTAINABLE DEVELOPMENT**

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<b>ABSTRACT</b>	<b>KEYWORDS</b>
The article discusses modern approaches to the development of environmentally friendly and energy-efficient methods of chemical production. The key principles of sustainable development, the use of green technologies, new generation catalysts, renewable energy sources and closed production cycles are analyzed. efficiency.	Sustainable development, green chemistry, energy efficiency, environmental safety, catalysis, chemical production.

### **Introduction**

The growth of global chemical production is accompanied by an increase in the burden on the environment and energy consumption. In this regard, the problem of creating environmentally friendly and energy-efficient technologies is becoming central in the chemical industry. The concept of sustainable development involves the harmonization of economic growth, social stability and environmental security. In the chemical industry, this is reflected in the need to switch to processes that minimize resource consumption, reduce waste levels and introduce harmless or low-toxic reagents.

The concept of sustainable development includes three key elements: environmental safety, economic efficiency and social responsibility. In chemical production, these criteria are implemented through the principles of "green chemistry", including:

- waste prevention;
- use of safe solvents;
- use of renewable raw materials;
- energy-saving processes;
- increasing the atomic efficiency of reactions.

These principles have become the methodological basis for the development of innovative technological schemes aimed at reducing the negative impact on ecosystems.

## **Energy-efficient methods for the production of chemicals**

### **1. Use of new generation catalysts**

Catalysts based on nanomaterials, organometallic frameworks (MOFs) and biocatalysts allow reactions to be carried out at lower temperatures and pressures, which significantly reduces energy costs. Catalytic processes are highly selective, which contributes to an increase in the yield of target products.

### **2. Application of renewable energy sources**

Heliochemical, photochemical, and electrolytic synthesis methods use solar energy, electricity, and other renewable resources. For example, the photocatalytic hydrogen process can reduce the use of fossil fuels.

### **3. Intensification of processes**

Microreactors, ultrasonic and plasma activation accelerate chemical reactions without increasing power consumption. These methods improve safety, shorten production cycles and reduce emissions.

## **Environmentally friendly methods for obtaining chemicals**

### **1. Biotechnological processes**

Enzymatic and microbiological synthesis methods allow the production of chemicals under mild conditions without the use of toxic reagents. They are a key area of development of "white biotechnology".

### **2. Replacing toxic solvents with green alternatives**

Instead of traditional organic solvents, ionic liquids, supercritical CO<sub>2</sub>, and water in a supercritical state are used. Such media are safe and provide high solvent power.

### **3. Creation of closed production cycles (Circular Chemistry)**

The use of closed-loop cooling, heat recovery and waste reuse systems reduces the ecological footprint. Closed loops reduce the need for raw materials and minimize emissions.

## **Digitalization and modeling as a tool for sustainable development**

Modern instrumental methods, such as machine learning, 3D modeling, and calculation programs (CFD, Aspen Plus), make it possible to predict optimal process parameters, minimize energy consumption, and reduce environmental risks. Digital twins of chemical plants are an effective means of increasing the sustainability of production.

## **Application of green technologies in world and domestic practice**

In developed countries, low-carbon technologies are being actively introduced, such as catalytic oxidation, combined biochemical processes, and the production of biodegradable polymers. In the industry of Uzbekistan, measures are also gradually being implemented to modernize chemical complexes: transition to energy-saving equipment, treatment facilities of a new type, introduction of automated emission control systems.

The study of environmentally friendly and energy-efficient methods of chemical production is the most important direction in the development of the modern chemical industry. The application of green chemistry principles, the introduction of new generation catalysts, the digitalization of processes and the use of renewable energy sources create the basis for the sustainable and environmentally friendly development of the industry. The expansion of research on biocatalysis, the creation of closed production cycles and the integration of digital technologies into the control of chemical processes seems promising.

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