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JOURNAL "INNOVATION SCIENCE AND  
TECHNOLOGY" HAS BEEN REGISTERED  
UNDER THE NUMBER **C-5669633** BY THE  
AGENCY FOR INFORMATION AND MASS  
COMMUNICATIONS (AOKA) OF THE  
REPUBLIC OF UZBEKISTAN, EFFECTIVE  
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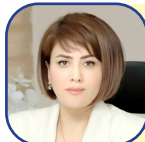
**Website:** <https://ist-journal.uz>

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Electronic publication, Issue 1. 129 pages. Approved for  
publication on January 23, 2025.

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# ALGORITHM FOR THE DEVELOPMENT AND EVALUATION OF THE EFFICIENCY OF ENERGY-SAVING MEASURES FOR FUEL OIL FARMS OF THERMAL POWER PLANTS

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**Abstract:** This article explores the development of a methodology for analyzing and assessing the effectiveness of initiatives aimed at reducing energy consumption in fuel oil systems at thermal power plants. Given the complexity of operations within these systems, it is crucial to employ an integral method to evaluate current technological processes, as well as potential improvements or modifications. This issue becomes even more relevant in the context of energy sector modernization and the ongoing search for investments to finance infrastructure upgrades. Therefore, the article highlights the necessity of establishing a methodology for calculating and assessing the efficiency of measures implemented to reduce energy consumption in fuel oil systems at thermal power plants.

**Key words:** energy, energy efficiency, algorithm, methodology, analysis, fuel oil systems, technology, processes, investment.

## INTRODUCTION

Today, fuel oil is still used in the operation of thermal power plants and industrial boilers as the primary or backup fuel source. The main challenge of using fuel oil is the energy required for heating it during storage and preparation for combustion. The operating costs of systems running on fuel oil are significantly higher than those running on gas or coal and can account for more than 9% of the total boiler load. Therefore, it is strongly recommended to conduct a thorough analysis of potential energy consumption reductions in fuel oil systems at both large and smaller industrial and municipal facilities.

Due to the variety of procedures involved in fuel oil operations, a comprehensive analysis of the effectiveness of existing processes, as well as planned improvements or expansions, is essential. In the context of energy reforms and the need to attract investments for infrastructure upgrades, studying this issue is of critical importance. The primary objective of this study is to develop a methodology for analyzing and evaluating the effectiveness of initiatives aimed at reducing energy consumption in fuel oil systems in thermal power plants.

## LITERATURE REVIEW

The pursuit of energy efficiency in fuel oil systems at thermal power plants has garnered significant attention in both international and local research. A comprehensive study published in *Energies* by researchers from Udmurt State University examined strategies to enhance energy efficiency in oil-producing enterprises. The study emphasized the implementation of energy management systems based on ISO 50001:2018 standards and highlighted technical measures such as the adoption of energy-saving designs for electric submersible pump units and the utilization of pumps and submersible motors with superior technical characteristics. These initiatives led to energy savings ranging from 15% to 43% and a reduction in specific energy consumption by two to four times<sup>1</sup>.

In the context of thermal power plants, a paper in the *International Journal of Engineering Research and Development*<sup>2</sup> focused on energy management practices to identify areas for improving energy efficiency. The study underscored the importance of monitoring energy consumption patterns and implementing predictive maintenance systems to reduce energy waste. It also highlighted the role of advanced monitoring and control technologies in optimizing energy use.

1 [https://www.mdpi.com/1996-1073/15/1/259?utm\\_source=chatgpt.com](https://www.mdpi.com/1996-1073/15/1/259?utm_source=chatgpt.com)

2 [https://www.ijerd.com/paper/vol11-issue11/Version\\_3/J5116380.pdf?utm\\_source=chatgpt.com](https://www.ijerd.com/paper/vol11-issue11/Version_3/J5116380.pdf?utm_source=chatgpt.com)

Locally, research conducted by Uzbek scholars has explored the application of combined heat and power (CHP) systems in thermal power plants. These studies have demonstrated that CHP systems can significantly improve fuel utilization efficiency by simultaneously generating electricity and useful heat, thereby reducing overall fuel consumption and emissions.

Furthermore, a review article in *Magna Scientia Advanced Research and Reviews*<sup>3</sup> explored various energy efficiency measures for oil rig operations, highlighting the potential of electrification, heat recovery systems, and the integration of renewable energy sources. The review emphasized that implementing these measures not only reduces the carbon footprint of oil platforms but also results in significant cost savings and aligns with global sustainability goals.

Collectively, these studies provide a robust foundation for developing and evaluating energy-saving measures in fuel oil systems of thermal power plants, emphasizing the importance of technical innovations, energy management practices, and the integration of renewable energy sources.

## RESEARCH METHODOLOGY

This research is based on scientific publications by Russian and foreign authors concerning the classification of energy policy and energy efficiency, as well as legislative and other regulatory documents. Data from scientific and practical events organized on this topic also played an important role in shaping the methodological framework. A systematic approach, along with methods of logical, comparative, and statistical analysis, was employed to analyze and address research questions.

## ANALYSIS AND RESULTS

Due to the complexity of operations performed in fuel oil use systems, it is crucial to employ an integral method to analyze current technological processes and identify potential improvements or additions. This becomes even more significant in the context of energy sector renewal and the search for investments to finance system upgrades. Therefore, the primary objective of this analysis is to develop a methodology for calculating and evaluating the effectiveness of measures aimed at reducing energy consumption in fuel oil systems of thermal power plants.

The following key parameters are used for calculations related to the thermal, hydraulic, and thermodynamic aspects of fuel oil supply processes at thermal power plants:

1. The layout and total number of boiler installations at the energy facility.
2. The standard fuel oil consumption for each boiler and the total consumption for the entire facility.
3. The number, type, and performance of heating devices installed in each tank.
4. Average external temperature indicators for winter and summer.
5. Dimensions of fuel oil storage tanks at full load.
6. The minimum allowable storage temperature of fuel oil in tanks, set at no lower than **+35°C**.
7. The time interval required for the full use of fuel oil from one tank when supplying all or individual boilers.

Based on the specifications of a given type of fuel oil, an additional set of initial data is compiled.

At the outset of the modernization planning process, the current technological structure is analyzed using well-established methodologies, including structural, thermal, and thermodynamic approaches. This enables the assessment of the performance of individual components or devices. Subsequently, through a technical and economic analysis, the operating costs of the fuel oil system are determined, and its most inefficient elements are identified. If the operating costs exceed the established limits for facilities with low production costs for heat and electricity, further analysis is conducted. Additionally, if the potential for reducing energy consumption is found to be underutilized, corrective measures are implemented to enhance the existing operational model.

### **Simplified Overview of Key Calculation Steps:**

*1. Identification of the Main Characteristics of the Fuel Oil Use System.* At this stage, the efficiency and heating capacity of boilers are analyzed based on approved methods for certain types of boilers, as described in the technical documentation or used during operation. The volume of fuel oil burned in each boiler is calculated, along with the total volume of fuel oil consumed by all boilers at the station. This affects the required amount of fuel oil storage, taking into account different types of storages (main, reserve, etc.), delivery methods, and stock standards. Additionally, the fuel consumption for each burner and their performance is assessed. The pressure inside the system and the pressure generated by the pump for transporting fuel oil to the burners are measured. Furthermore, the thermophysical properties of fuel oil are analyzed based on its average temperature in the heating device.

3 [https://magnascientiapub.com/journals/msarr/sites/default/files/MSARR-2022-0050.pdf?utm\\_source=chatgpt.com](https://magnascientiapub.com/journals/msarr/sites/default/files/MSARR-2022-0050.pdf?utm_source=chatgpt.com)

*II. Drawing Up a General Plan for the Fuel Oil Supply System and Designing Fuel Oil Pipelines with Steam Accessories.* The graph theory method is used in planning, where the route of the fuel oil pipeline is represented as a network with vertices indicating departure points, endpoints, and transitions between pipeline sections with different flow characteristics. Parameters such as the type of fuel oil, details of the pipeline route—including temperatures, local resistances, and other critical data—are analyzed. Based on this analysis, pipe diameters and total pressure losses along the entire route are determined. Hydraulic analysis also reveals the energy costs required to transport fuel oil through the system.

*III. Initiation of the Selection of a Thermal Engineering System Concept for Fuel Oil Maintenance.* This process includes consideration of three main types of schemes for transporting liquid fuel to burners: dead-end (end-to-end), circulating, and combined (dead-end circulation). The determination of a suitable scheme depends on the specific requirements for liquid fuel usage—whether as a primary, backup, or emergency energy source—as well as on its properties specified in the technical documentation, the fuel supply method to the burners, and the system's operating conditions. The main difference between these schemes lies in the range, types, and models of equipment used in each.

*IV. Selection of Key and Auxiliary Equipment for Fuel Oil Supply Systems.* The selection process takes into account the functional characteristics of the equipment. When upgrading the current thermal configuration of the fuel oil service, it is necessary to determine the appropriate main and auxiliary equipment. **Burners and Nozzles:** It is necessary to define the dimensions of the burners and nozzles for each boiler while determining their key technical parameters.

**Heating Oil Equipment:** The primary function of heating oil heaters in power plants and boiler houses is to bring fuel oil to the required viscosity for efficient combustion in burners and nozzles. These units ensure that the fuel oil reaches the necessary temperature and viscosity, maintaining its circulation from storage tanks to boiler nozzles.

At energy facilities, fuel oil is stored in specialized tanks designed to facilitate its reception, heating, delivery, and disposal. The dimensions of these tanks are regulated by established norms and standards. Typically, at least two tanks are required to store fuel oil used as the primary, reserve, and startup fuel, while a single tank is usually sufficient for emergency situations.

The choice of a heating method for fuel oil storage tanks is crucial. Fuel oil from different sources must be continuously maintained in a heated state, not only to ensure its fluidity and prevent the formation of water and solid deposits but also to meet the required temperature for proper usage. Various heating technologies are utilized for this purpose, including external circulation heaters, installed heating elements (such as steam heaters and heat exchangers), vibrating heaters, rotating screw heaters, and electric heaters. The circulating heating method is recommended for its ability to rapidly warm up the fuel oil, ensure uniform heat distribution, and minimize the accumulation of water and sediment.

The selection of appropriate pumps and filters is based on calculations of pressure and fuel oil flow for each section of the pipeline. Pumps must be chosen to provide the necessary parameters for efficient fuel oil transfer.

The fuel oil pumping process is carried out at specialized drain stations equipped with steam systems for heating oil products inside tankers, as well as devices for moving mobile heating units and folding bridges. When developing infrastructure to support fuel oil supply, key characteristics of railway platforms—such as their number and size—are determined based on annual transportation volumes and load capacity standards for liquid cargo.

*V. Analysis of the Design and Connections in the Heating System.* The analysis of the design and connections in fuel oil heating systems plays a central role in the development of new systems or significant improvements to existing ones. The complexity of modern heat supply systems arises from the wide range of computational operations required, which depend on both the system's architecture and the equipment used.

Studies of complex engineering structures have demonstrated that cyclic connections can be broken using various techniques, leading to multiple computational sequences. The primary objective is to select the optimal method to simplify the computational process. In analyzing the structure of a fuel oil-based heating system, the goal is to determine the optimal calculation sequence and identify cycles within the system. Optimizing the calculation procedure helps reduce the number of iterations, improve calculation accuracy in mathematical modeling, and enhance solution stability when analyzing system performance characteristics.

In the analysis of such thermal engineering systems, a method based on graph theory was applied.

*VI. Thermal Analysis of the Fuel Oil Supply System.* Thermal analysis of the fuel oil supply system involves calculations related to the thermal parameters of various system components, particularly in areas where heating oil is either heated using a coolant or where significant heat losses occur. Key elements in this process include steam-powered fuel oil pipelines, heating oil equipment, and storage tanks.

The analysis of steam-transporting pipelines focuses on determining the final thermal properties of both fuel oil and steam at the system's outlet, considering insulation thickness. Conversely, it can also involve determining the necessary insulation thickness required to achieve the desired output parameters.

The analysis of heating oil is conducted under conditions of a continuous thermal process, taking into account the low thermal inertia of such equipment in thermal power plants. In these facilities, regenerative heat exchangers are commonly used to heat fuel oil. This necessitates the use of well-established formulas for calculating thermal balance and analyzing heat transfer processes.

**Calculation of Thermal Parameters for Fuel Oil Storage Tanks.** To estimate total heat losses when heating fuel oil in storage tanks or maintaining its temperature within a specific range, standard methods described in specialized manuals can be used. Alternatively, mathematical models developed by **Yu.G. Nazmeev** can be applied. By analyzing discrete data, it is possible to develop methods for improving the efficiency of circulating heating in fuel oil tanks, including optimizing the configuration and location of exhaust nozzles.

**Assessment of the Energy Efficiency of Technological Schemes for Fuel Oil Handling.** Typically, a **thermal efficiency coefficient** is used to evaluate energy efficiency. The methodology for calculating this indicator involves analyzing the thermal energy flow introduced into the **AML** system and assessing the amount of heat lost to the surrounding atmosphere. In addition to thermal analysis, it is crucial to determine the share of energy costs associated with each component of the equipment, node, or link within the process chain, as well as for the system as a whole. The study of heating oil supply is conducted separately for **winter and summer** periods, taking into account outdoor temperature variations and temperature gradients.

*VII. Thermodynamic Study of Heating Processes in Fuel Oil Systems.* An increasingly utilized approach, known as **exergetic analysis**, is based on principles derived from the **second law of thermodynamics**. This method allows for evaluating the contribution of each stage to the overall system efficiency and identifying the segments with the highest energy losses. The efficiency of thermal engineering systems using the exergetic method is estimated through the **coefficient of exergetic efficiency**. Calculating this indicator helps assess the level of thermodynamic efficiency and highlights the importance of identifying measures to reduce energy consumption. Furthermore, it enables the development of optimal strategies to improve the efficiency of thermal technology systems under these conditions.

*VIII. Analysis of Heat and Electricity Costs in the Fuel Oil Service System.* In the course of this analysis, which is carried out after studying the thermal and thermodynamic aspects, components or complexes of equipment in a thermal engineering system that exhibit relatively low energy efficiency are identified. The analysis of the costs of thermal and electrical energy required for the operation of the fuel oil infrastructure is conducted as part of the operating costs.

The calculations include the total amount of energy required for the operation of pumps that transport fuel oil through the system, as well as for circulation pumps that heat fuel oil in reservoirs and for equipment operation during fuel oil pumping. Heat costs are also taken into account, including the operation of steam installations in fuel oil pipelines, heating of fuel oil during pumping, its heating in devices, and atomization in burners.

*IX. Estimation of the Share of Fuel Oil Costs in Total Domestic Expenses.* The percentage of the cost of maintaining the fuel oil system within the total operating costs for the internal needs of a thermal power plant or boiler house is determined by comparing the cost of electricity and heat associated with the operation of the fuel oil system with the total cost of electricity and heat required for the facility's operation.

The percentage ratio of fuel oil system costs within total operating expenses is calculated by comparing the electricity (YYY) and heat (QQQ) costs incurred due to fuel oil system operation with the overall electricity and heat costs necessary for the facility's operation. Based on the results of such calculations, the feasibility of developing and implementing measures to optimize electricity and heat consumption, as well as eliminating identified inefficiencies, is determined.

*X. Strategies to Improve the Efficiency of Electricity and Thermal Energy Use in Fuel Oil Supply Systems.* The development of strategies to enhance energy efficiency in fuel oil supply systems may include various approaches. For instance, this may involve revising the heating system configuration, introducing more advanced fuel oil heating methods in storage facilities—such as circulating heating—upgrading outdated equipment to newer, more efficient models, or modifying existing equipment to improve performance, for example, by adding ribbed surfaces to enhance heat transfer in fuel oil heaters.

Additionally, heat transfer enhancement methods may be employed, including the use of spiral finned channels, which help achieve the desired temperature and increase heating capacity.

Upgrading fuel oil pumps to more advanced versions enhances resource efficiency and reduces the need for multiple heating devices within the heat supply circuit. Another method for lowering operational costs is to minimize the number of cycles through the heating elements, significantly decreasing energy consumption for fuel oil circulation. Studies have also explored the possibility of optimizing heater performance by lowering the

parameters of heating steam. For thermal power plants that can utilize steam with reduced characteristics—following appropriate calculations and regulatory approvals—this approach may be economically justified.

Improving the efficiency of fuel oil heaters by enhancing heat transfer processes is particularly crucial when fuel oil combustion occurs under conditions of limited oxygen access. Achieving the required fuel oil temperature above 160°C is challenging with standard equipment, as anticipated in conventional designs. For instance, reducing fuel consumption to increase heating temperature or lowering pressure after the first pump (to increase recirculation volume) could impose additional strain on the second pump.

## CONCLUSION AND RECOMMENDATIONS

The use of advanced heaters equipped with enhanced heat transfer technologies effectively addresses challenges in maintaining the required fuel oil temperature. This is achieved by incorporating ribbed elements into the heater design, which improves heat transfer efficiency. However, decisions regarding heater modifications or changes to the thermal engineering design of the fuel oil supply system should be made on a case-by-case basis, considering the specific requirements of each thermal power plant, boiler house project, and equipment set.

The proposed approach for analyzing and evaluating the effectiveness of initiatives to reduce energy consumption in fuel oil heating systems at thermal power plants enables a thorough assessment of resource and energy expenditures required for storing and preparing fuel oil for use. It also helps identify areas where energy losses are most significant and where increased attention is necessary.

Examining the current fuel oil heat supply system at thermal power plants provides insights into strategies for improving efficiency. These include modernizing outdated equipment, upgrading specific segments to enhance heat transfer processes, or introducing new fuel oil supply system configurations to optimize performance.

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**Proofreader:** Zokir ALIBEKOV

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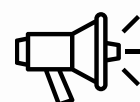
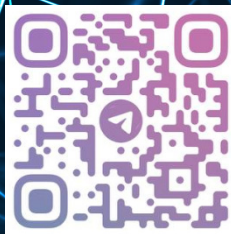
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