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## ON THE ISSUE OF FUEL CONSUMPTION OF A THERMAL POWER PLANT

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**Abstract.** The article addresses the problem of rational fuel use at Thermal Power Plant No. 1 in Semey, which is essential for ensuring reliable and efficient heat and power supply. The relevance of the study is determined by the need to analyze the annual fuel consumption structure for planning supplies and optimizing boiler operation. The methodology is based on data from the automated fuel supply control system. Annual consumption volumes were calculated for three steam boilers of type E-90-3.9-440 and two hot-water boilers of type KV-TK-116.3-150. The results showed that coal is the plant's dominant fuel: annual consumption reached 162,678 tons, accounting for more than 99% of the balance. The highest value was recorded for steam boiler No. 6 — 42,577.4 tons. The other steam boilers consumed 31,903.7 and 34,687.7 tons. Hot-water boilers used 22,467.4 and 31,041.8 tons, and their combined consumption exceeded 53,000 tons, which is comparable to the steam boilers and confirms their significant role in covering the heat load. Fuel oil use was relatively low and limited to startup and combustion stabilization, with a total of 778 tons per year. The maximum value was observed in steam boiler No. 7 — 198.5 tons. The findings confirm a balanced load distribution, stability of the fuel scheme, and efficiency of the plant's operation. The results can be applied to fuel supply planning, optimization of combustion regimes, and improving the reliability of heat supply in Semey.

**Keywords:** fuel consumption, steam boiler, hot-water boiler, coal, fuel oil, automated control system



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## ЖЫЛУ ЭЛЕКТР СТАНЦИЯСЫНЫҢ ОТЫН ТҰТЫНУ МӘСЕЛЕСІ

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**Аннотация.** Мақалада Семей қаласындағы №1 жылу электр орталығында отынды ұтымды пайдалану мәселесі қарастырылады. Бұл мәселе аймақ тұрғындарын жылу және электр энергиясымен сенімді әрі тиімді қамтамасыз ету үшін ерекше маңызға ие. Қазақстан энергетикасында көмірдің үлесі жоғары болғандықтан, нақты кәсіпорындардағы отын құрылымын талдау ғылыми және тәжірибелік тұрғыдан өзекті болып табылады. Зерттеудің өзектілігі — жылдық отын тұтыну көлемін анықтау арқылы отын жеткізуді жоспарлау, қазандық жұмысының режимдерін оңтайландыру және жалпы жүйенің тұрақтылығын бағалау қажеттілігімен түсіндіріледі. Әдістеме автоматтандырылған отын беру басқару жүйесінің нақты деректерін пайдалануға негізделді. Жылдық тұтыну көлемдері үш Е-90-3,9-440 бу қазандығы және екі КВ-ТК-116,3-150 су қыздыру қазандығы үшін есептеліп, олардың салыстырмалы жүктемесі анықталды. Нәтижелер көмірдің негізгі отын екенін көрсетті: жалпы шығыны 162 678 тонна болып, құрылымның 99%-дан астамын құрайды. Ең жоғары тұтыну №6 бу қазанында тіркелді — 42 577,4 тонна. Басқа бу қазандықтары тиісінше 31 903,7 және 34 687,7 тонна жұмсады. Су қыздыру қазандықтары аздау тұтынғанымен (22 467,4 және 31 041,8 тонна), олардың жиынтық көлемі 53 000 тоннадан асып, бу қазандықтарымен салыстырмалы деңгейге жетті және жылу жүктемесін жабудағы маңызды рөлін айқындады. Мазут шығыны шамалы болды және негізінен қазандықтарды іске қосу мен жануды тұрақтандыру үшін қолданылды. Жылдық көлемі 778 тоннаны құрады, оның ішінде ең жоғарысы №7 бу қазанында — 198,5 тонна. Алынған нәтижелер жүктеменің теңгерімді бөлінуін, отын схемасының тұрақтылығын және станция жұмысының тиімділігін растайды. Қорытындылар болашақта отын жеткізуді жоспарлауда, жану режимдерін жетілдіруде және Семей қаласының жылу жабдығының сенімділігін арттыруда қолданылуы мүмкін.

**Түйін сөздер:** отын тұтыну, бу қазандығы, су қазандығы, көмір, мазут, автоматтандырылған басқару жүйесі

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## К ВОПРОСУ О РАСХОДЕ ТОПЛИВА НА ТЕПЛОВОЙ ЭЛЕКТРОСТАНЦИИ

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**Аннотация.** В статье рассматривается проблема рационального использования топлива на теплоэлектроцентрали № 1 города Семей, что имеет важное значение для обеспечения надёжности и эффективности тепло- и энергоснабжения. Актуальность исследования определяется необходимостью анализа структуры годового топливопотребления для планирования поставок и оптимизации режимов работы котельного оборудования. Методика основана на использовании данных автоматизированной системы управления подачей топлива. Проведён расчёт годовых объёмов потребления для трёх паровых котлов типа Е-90-3,9-440 и двух водогрейных котлов типа КВ-ТК-116,3-150. Результаты показали, что уголь является основным топливом станции: его годовой расход составил 162 678 тонн, что превышает 99% в структуре потребления. Наибольшая нагрузка приходится на паровой котёл № 6 — 42 577,4 тонн. Для двух других паровых агрегатов расход составил 31 903,7 и 34 687,7 тонн. Водогрейные котлы потребляют меньше — 22 467,4 и 31 041,8 тонн соответственно, однако их суммарный расход превышает 53 000 тонн, что сопоставимо с показателями паровых котлов и подтверждает их важную роль в покрытии тепловой нагрузки. Расход мазута невелик и ограничивается функциями розжига и стабилизации горения. Годовой объём составил 778 тонн, наибольшее значение зафиксировано у парового котла № 7 — 198,5 тонн. Сделанные выводы свидетельствуют о сбалансированном распределении нагрузки, устойчивости топливной схемы и эффективности эксплуатации станции. Результаты могут быть использованы при планировании топливоснабжения, совершенствовании режимов горения и повышении надёжности теплоснабжения города Семей. Ключевые слова: потребление топлива, паровой котёл, водогрейный котёл, уголь, мазут, автоматизированная система управления.

**Ключевые слова:** потребление топлива, паровой котёл, водогрейный котёл, уголь, мазут, автоматизированная система управления

**Introduction.** Energy supply for industrial and residential consumers in modern cities is predominantly provided by combined heat and power plants (CHPs), which play a key role in the cogeneration of thermal and electrical energy (Lepiksaar et al., 2023; Ogbuabia et al., 2023; Smagulova et al., 2023; Chen, 2022; Safari et al., 2025).

Amid the global intensification of the greenhouse effect, rising atmospheric pollution, and increasingly stringent environmental requirements, the reliability and operational efficiency of coal-fired CHP plants have become critically important (Li et al., 2025; Wang P. et al., 2025). Maintaining stable and efficient plant operation is essential not only for ensuring uninterrupted energy supply but also for reducing pollutant emissions, optimizing fuel consumption, and improving overall energy efficiency, thereby supporting sustainable and environmentally responsible power generation (Wang C. et al., 2023).

Recent advances in intelligent coal-fired power technologies have significantly improved the reliability and operational efficiency of CHP plants (Liu et al., 2025).

CHP-1 in the city of Semey is the only thermal power plant in the city and has been in operation since 1931, supplying thermal energy and steam to both residential and municipal facilities as well as industrial enterprises. The heat consumers are located on the left bank of Semey and include residential buildings, administrative institutions, and industrial sites (BAQ.KZ, 2023). Figure 1 presents the thermal schematic of the steam circuit of CHP-1 in Semey, illustrating one of the two main pathways of heat generation at the plant.

The main source of thermal energy in the presented scheme is the steam boiler unit (1) of type E-90-3.9-440, designed to produce high-pressure water steam (Serikkazinov et al., 2025). CHP-1 operates three such steam boilers. The generated steam is directed to the steam turbine (2), where it is converted into mechanical rotational energy that drives the electric generator (3) to produce electricity. The installed electric capacity of the plant is 18 MW. The generated electricity is used primarily for internal needs.

After exiting the turbine, the exhaust steam enters the condenser (4), where it transitions to the liquid phase. The condensate pump (5) transfers the condensate to the feedwater tank (6), from which water is returned to the boiler using the feedwater pump (9). To compensate for losses, chemically treated water is supplied to the circuit via pipeline (10).

Thermal energy for district heating is extracted from the turbine system and delivered to heat consumers (7), while circulation in the heating network is maintained by the district heating pump (8).

It is worth noting that, in addition to steam boilers, CHP-1 also operates two hot-water boilers of the KV-TK-116.3-150 type, which are used to produce thermal energy depending on district heating demand (Khazhidinova et al., 2023). The thermal capacity of CHP-1 reaches 413 Gcal/h, which enables coverage of a significant portion of the annual thermal load.

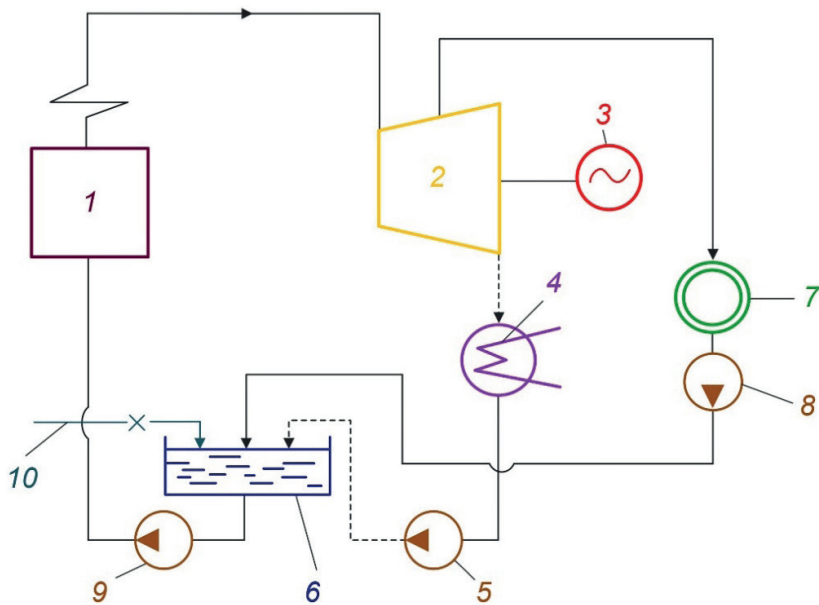


Figure 1. Thermal schematic of the steam circuit of CHP-1 in Semey: 1 — boiler unit E-90-3.9-440; 2 — steam turbine; 3 — electric generator; 4 — condenser; 5 — condensate pump; 6 — feedwater tank; 7 — heat consumers; 8 — district heating pump; 9 — feedwater pump; 10 — pipeline supplying chemically treated water

The city's district heating system is a complex and dynamic mechanism, whose efficiency largely depends on the rational use of fuel. The primary fuel used at CHP-1 is Karazhyra coal, delivered by rail and stored in an open yard. For boiler startup and combustion stabilization, fuel oil grade M-100 is used, delivered in rail tankers and stored in dedicated reservoirs (Stepanova et al., 2024). The main factors affecting fuel consumption are presented in Figure 2.

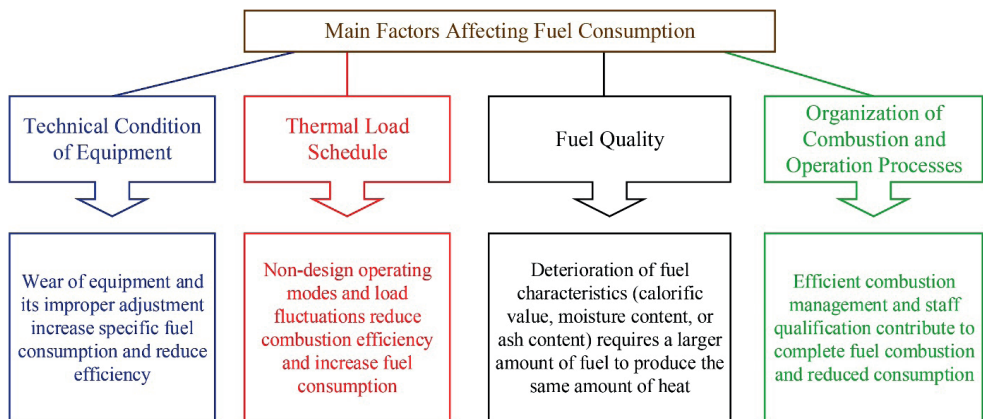


Figure 2. Main Factors Affecting Fuel Consumption

The equipment and boiler units of the CHP plant are relatively new — installed after 2015, which ensures stable operation and compliance with modern technical requirements.

The use of two types of fuel provides flexibility in the operation of boiler units, depending on production conditions and seasonal fluctuations in heat demand.

To ensure that the fuel meets established technical requirements and to support the efficient operation of the boiler equipment, fuel quality analysis is carried out in the laboratory at the CHP plant.

To ensure reliable and efficient operation of the fuel supply system, an automated control system (ACS) for fuel supply has been implemented at the CHP. The main function of this system is to monitor and regulate the fuel delivery processes from the storage yard to the boiler units in accordance with the current thermal load (Serikkazinov et al., 2025; Khazhidinova et al., 2023; Stepanova et al., 2024).

The automated control system (ACS) provides:

- automatic control of main and auxiliary fuel supply mechanisms (belt and scraper conveyors, crushers, feeders);
- monitoring of process parameters (fuel consumption, bunker levels, operation of actuators);
- equipment protection from emergency situations through the implementation of interlock and alarm algorithms;
- collection, storage, and real-time display of information on equipment status and process parameters.

The system is equipped with specialized software. The use of the automated control system (ACS) significantly improves control accuracy, reduces fuel losses, minimizes the human factor, and enhances the overall reliability of the fuel supply process. Additional advantages of the ACS include faster decision-making, stable equipment operation under variable loads, reduced risk of overloads and fuel delivery failures, and simplified maintenance through a built-in diagnostics and parameter archiving system (Janta-Lipińska et al., 2024; Lee et al., 2025).

The aim of this study is to analyze the structure of fuel consumption at CHP-1, determine the annual volumes of coal and fuel oil usage, and identify the operational characteristics of the boiler equipment. The results make it possible to assess the current efficiency of fuel resource utilization.

**Material and methods.** The object of this study is the fuel supply system of CHP-1 in the city of Semey, which includes steam and hot-water boilers operating on solid and liquid fuels. The aim of the research is to conduct a quantitative and qualitative analysis of the annual fuel consumption at the plant, taking into account the specifics of operating different types of boiler equipment.

The analysis is based on actual operational data on annual fuel consumption for the 2024 - 2025 heating period. These data were obtained from operator workstation readings and from the interface of the automated fuel supply control system (ACS). The 2024 — 2025 heating period represents the most recent fully completed reporting period at the time of the study.

The analysis was based on actual data on annual fuel consumption for a defined reporting period. Data were obtained from readings displayed on operator station monitors and in the ACS interface, ensuring high accuracy and real-time data collection. Coal and fuel oil consumption for each boiler was recorded separately, allowing for a comparative assessment of thermal load levels and operating intensity.

To visualize and interpret the data, a diagram of annual fuel consumption was compiled, with coal consumption presented as bars and fuel oil as a line chart. The visual representation made it possible to identify both absolute consumption values and the share of each fuel type in the overall consumption structure. Particular attention was given to the ratio between steam and hot-water boilers. Since hot-water boilers are operated on par with steam boilers, the fuel distribution analysis was carried out without a preliminary division into base and peak units.

Thus, the applied research method represents a systematic technical analysis with elements of statistical processing of operational data. This approach makes it possible to reasonably assess the effectiveness of the current fuel supply structure at CHP-1 and identify key trends and features in the operation of thermal equipment.

**Results and discussion.** Figure 3 shows the annual fuel consumption by boiler units.

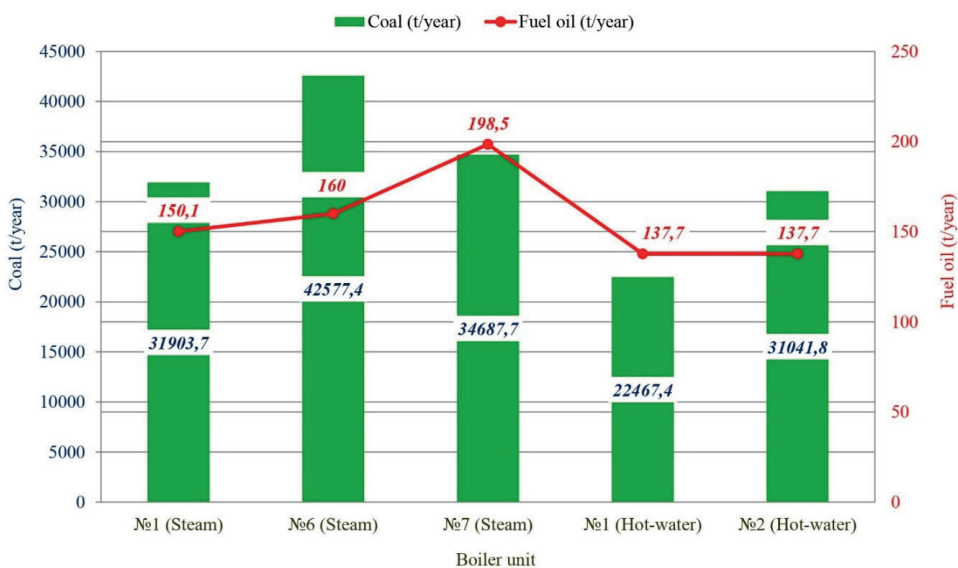


Figure 3. Annual fuel consumption by boiler units

The highest coal consumption is recorded for steam boiler No. 6 of type E-90-3.9-440 and amounts to 42,577.4 tons per year, indicating a high thermal load and intensive operation. For the other steam boilers, this indicator is 31,903.7 and 34,687.7 tons per year, respectively. Hot-water boilers show lower coal consumption volumes — 22,467.4 and 31,041.8 tons per year, which corresponds to their operational purpose.

Fuel oil consumption is significantly lower compared to coal. The highest consumption of fuel oil is observed for steam boiler No. 7 — 198.5 tons per year, likely due to more

frequent startups and the need to stabilize combustion. For steam boilers No. 1 and No. 6, fuel oil consumption is 150.1 and 160.0 tons per year, respectively. Hot-water boilers No. 1 and No. 2 consume equal amounts of fuel oil — 137.7 tons per year each, which indicates stable operating conditions and a standardized ignition approach.

The total annual coal consumption amounts to approximately 162,678 tons per year, while the total annual fuel oil consumption is 778 tons per year. This confirms that coal is the main fuel used at CHP-1 for all boiler types. Fuel oil is primarily used as startup and auxiliary fuel, as evidenced by its minor share in total consumption and the distribution pattern across boiler types.

The analysis of annual fuel consumption at CHP-1 in Semey provides a comprehensive understanding of the operational balance between steam and hot-water boilers. The results obtained in this study generally confirm the well-documented trends in the literature, according to which coal remains the predominant fuel for combined heat and power plants in Kazakhstan and other Central Asian countries (Ogbuabia et al., 2023; Smagulova et al., BAQ.KZ, 2023). The calculated annual coal consumption of more than 162,000 tons, representing over 99% of the total fuel balance, is consistent with previous studies emphasizing the critical role of coal-fired boilers in ensuring regional energy stability (Li et al., 2025; Wang C. et al., 2023; Stepanova et al., 2024).

Compared with earlier works that mainly focused on combustion efficiency of non-design or low-grade Karazhyra coal (Serikkazinov et al., 2025; Khazhidinova et al., 2023; Stepanova et al., 2024), this study expands the scope by analyzing not only combustion aspects but also the overall fuel consumption structure at the plant level. This comprehensive approach highlights the operational significance of hot-water boilers, whose total annual coal consumption (over 53,000 tons) is comparable to steam boilers. Previous studies tended to describe hot-water boilers as auxiliary or peak-load equipment (Wang P. et al., 2025; Wang C. et al., 2023); however, our findings demonstrate their permanent contribution to covering base thermal loads, which represents a distinctive feature of Semey CHP-1.

The relatively small share of fuel oil consumption (778 tons per year, less than 1% of the balance) confirms its strictly auxiliary role. This is consistent with international practice, where liquid fuels are primarily used for boiler startup and flame stabilization (Chen M., 2022; Li et al., 2025). At the same time, the observed differences in fuel oil consumption across boilers (e.g., higher use in steam boiler No. 7) suggest possible differences in startup frequency or operational regimes, which require additional investigation.

The strength of this study lies in the use of actual operational data from the automated control system, which ensures accuracy and minimizes subjective interpretation. Such an approach corresponds to modern research practices in the field of intelligent coal-fired power plant monitoring (Liu et al., 2025). Nevertheless, the study also has limitations. It covers only one reporting period and does not analyze seasonal variations in fuel consumption, which may affect the overall balance. In addition, the environmental dimension — such as emissions of SO<sub>2</sub>, NO<sub>x</sub>, and particulate matter — was not included in the present analysis, although this factor is becoming increasingly relevant

in the context of sustainable power generation (Li et al., 2025; Janta-Lipińska et al., 2024).

Future research should therefore focus on a more detailed assessment of seasonal consumption patterns, efficiency of individual boilers under varying loads, and the integration of advanced combustion optimization technologies, including artificial intelligence-driven control systems (Safari et al., 2025; Lee et al., 2025). In addition, linking fuel consumption data with environmental performance indicators would provide a more holistic evaluation of the plant's operation.

In summary, this study contributes to the understanding of fuel consumption patterns at CHP-1 in Semey, confirms the predominance of coal as the primary energy resource, and emphasizes the significant role of hot-water boilers in ensuring the reliability of district heating. The findings provide a useful basis for practical applications in fuel supply planning, optimization of combustion regimes, and enhancement of energy security in the region.

**Conclusion.** The analysis of the annual fuel consumption at CHP-1 in the city of Semey made it possible to determine the fuel consumption structure and identify operational features of the boiler equipment. Coal from the Karazhyra deposit is the primary fuel for all types of boilers – both steam and hot-water. Its share in total consumption constitutes an overwhelming majority – more than 99%, with a total annual consumption of approximately 162,678 tons.

Fuel oil grade M-100, with an annual consumption of 778 tons, serves a strictly limited auxiliary function. Its use is mainly associated with boiler startup and combustion stabilization during initial operating modes, which is particularly relevant during start-up and unstable operating conditions.

It is important to note that the hot-water boilers at CHP-1 do not operate as peak-load or standby units, but function alongside the steam boilers, providing a significant share of the thermal load. This is reflected in the high coal consumption — over 53,000 tons per year for the two hot-water boilers, which is comparable to that of the steam units.

The joint operation of steam and hot-water boilers at CHP-1 allows for flexible response to varying loads and ensures the supply of both electricity and heat in accordance with current demand. Thus, the fuel consumption structure of CHP-1 demonstrates stability and efficiency, as evidenced by the balanced load distribution among boiler units.

The scientific novelty of the study lies in the comprehensive assessment of fuel consumption for both steam and hot-water boilers, taking into account their joint operation, which makes it possible to more objectively characterize the load structure and the efficiency of energy resource utilization.

The practical significance of the work consists in the possibility of using the obtained results to optimize fuel regimes, improve the planning of coal and fuel oil supplies, increase combustion efficiency, as well as to develop measures for energy saving and enhancing the reliability of the city's heat supply system.

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