

OPTIMIZATION OF FUEL CONSUMPTION IN THERMAL POWER PLANTS: METHODS AND STRATEGIES FOR FUEL SAVINGS

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Abstract. *This study examines methods and strategies for optimizing fuel consumption in thermal power plants, with the aim of identifying the most effective approaches to achieving measurable fuel savings without compromising power output. Thermal power generation remains the dominant source of electricity worldwide, yet its inherent thermodynamic inefficiencies result in substantial fuel waste and elevated operating costs. Employing a comparative analytical methodology, this research evaluates five principal fuel-saving strategies—combustion optimization, waste heat recovery, steam cycle improvement, auxiliary power reduction, and load management—using operational data from gas-fired and coal-fired power stations. Results demonstrate that integrated implementation of these strategies can achieve cumulative fuel savings of 8–15%, corresponding to significant reductions in both operating costs and environmental impact. The findings provide a practical framework for power plant operators and energy policymakers seeking to enhance the fuel efficiency of existing thermal generation assets.*

Keywords: *fuel savings, thermal power plant, energy efficiency, combustion optimization, waste heat recovery, specific fuel consumption.*

INTRODUCTION

Thermal power plants, including gas-fired, coal-fired, and combined-cycle installations, account for approximately 60% of global electricity generation and remain the backbone of power systems in most developing and transitional economies (IEA, 2023:42). The efficiency of fuel utilization in these plants directly determines both the



economic viability of power generation and its environmental footprint. Despite decades of technological advancement, the average thermal efficiency of the global fossil-fuel power fleet remains below 40%, meaning that more than 60% of the chemical energy contained in fuel is dissipated as waste heat rather than converted to useful electricity (Beér, 2007:482).

The concept of specific fuel consumption (SFC), defined as the mass of fuel required to generate one kilowatt-hour of electricity, serves as the primary metric for evaluating fuel efficiency in thermal power generation. Reductions in SFC translate directly into lower fuel costs, reduced emissions, and extended fuel resource lifetimes. For a typical 300 MW gas-fired power plant operating at 6,500 hours per year, a 1% improvement in thermal efficiency corresponds to annual fuel savings of approximately 4,500 tonnes of natural gas equivalent, representing substantial economic and environmental benefits (Kehlhofer, Hannemann, Stirnimann, & Rukes, 2009:15).

In Uzbekistan, where natural gas accounts for over 85% of primary energy supply and thermal power stations generate approximately 90% of the nation's electricity, the optimization of fuel consumption represents a critical priority for energy security, economic development, and climate change mitigation. The aging infrastructure of many power stations in the region, some dating from the Soviet era, presents both a challenge and an opportunity: while older plants operate at lower baseline efficiencies, the potential for improvement through targeted interventions is correspondingly greater (Karimov & Tashpulatov, 2021:34).

Research on fuel savings in thermal power plants spans multiple engineering disciplines. Beér (2007:482) provided a comprehensive overview of clean combustion technologies and demonstrated that advanced combustion control systems utilizing real-time flue gas analysis and automated air-fuel ratio adjustment could improve combustion efficiency by 1–3 percentage points. Franco and Russo (2002:1335) examined combined-cycle gas turbine (CCGT) plants and showed that optimized heat recovery steam generator (HRSG) design could capture an additional 5–8% of exhaust energy.

Regarding waste heat recovery, Saidur, Rezaei, Muzammil, Hassan, and Paria (2010:1073) reviewed available technologies including economizers, air preheaters, organic Rankine cycles, and thermoelectric generators, concluding that waste heat recovery



offered the single largest potential for fuel savings in existing plants. More recently, Patel and Shah (2019:112) investigated auxiliary power consumption patterns in Indian thermal power stations and found that optimization of pumps, fans, and compressors could reduce station service power by 15–20%, indirectly improving net plant efficiency.

This study aims to evaluate and compare five principal fuel-saving strategies applicable to thermal power plants, quantify the potential fuel savings achievable through each strategy and their integrated implementation, and provide practical recommendations for power plant operators in transitional economies where aging infrastructure and resource constraints define the operational context.

METHODS

A comparative analytical methodology was employed, combining thermodynamic modeling with operational performance data analysis. The study evaluated five fuel-saving strategies: (1) combustion optimization through advanced control systems and air-fuel ratio management; (2) waste heat recovery via economizers, air preheaters, and HRSG improvements; (3) steam cycle optimization including reheat and regenerative feedwater heating enhancements; (4) auxiliary power reduction through variable frequency drives and equipment modernization; and (5) load management strategies including optimal unit commitment and part-load efficiency improvement (Kehlhofer et al., 2009:156).

Operational data were obtained from published performance reports of gas-fired power stations operating in Central Asia, supplemented by reference data from the International Energy Agency (IEA, 2023:45) and equipment manufacturer specifications. The analysis covered plant capacities ranging from 100 MW to 800 MW, operating at load factors between 50% and 85%. Thermodynamic calculations were performed using standard heat balance methods based on ASME PTC 4 and PTC 46 performance test codes (ASME, 2013:1). Fuel savings were quantified as percentage reductions in specific fuel consumption (g/kWh) relative to baseline operating conditions.

RESULTS

The analysis revealed significant variation in fuel savings potential across the five strategies. Combustion optimization yielded SFC reductions of 1.5–3.2%, with the highest gains achieved in older plants with manually controlled combustion systems. Waste heat recovery provided the largest individual contribution, with SFC reductions of 3.0–5.8% depending on the extent of heat recovery equipment installed. Steam cycle optimization



produced SFC reductions of 1.8–3.5%, with reheat improvements offering the greatest gains in high-capacity units.

Table 1. Fuel Savings Potential by Strategy

Strategy	Min SFC %	Max SFC %	Avg %	Cost Index
Combustion optimization	1.5	3.2	2.4	Low
Waste heat recovery	3.0	5.8	4.4	Medium
Steam cycle improvement	1.8	3.5	2.7	High
Auxiliary power reduction	0.8	2.1	1.5	Low
Load management	0.5	1.8	1.2	Low

Note. SFC = Specific Fuel Consumption reduction. Cost Index reflects relative capital investment required.

When multiple strategies were implemented simultaneously, the cumulative fuel savings ranged from 8.2% to 14.7%, depending on baseline plant conditions and the scope of interventions. The interaction effects between strategies were generally positive: for example, combustion optimization improved flue gas temperatures in ways that enhanced waste heat recovery performance, while load management reduced auxiliary power consumption at part-load conditions. However, the cumulative savings were less than the arithmetic sum of individual savings due to diminishing returns as overall efficiency improved (Franco & Russo, 2002:1340).

For a representative 300 MW gas-fired plant operating at a baseline SFC of 320 g/kWh, the integrated implementation scenario reduced SFC to approximately 278 g/kWh, representing a 13.1% improvement. At an annual generation of 1,950 GWh, this corresponded to fuel savings of approximately 81,900 tonnes of natural gas equivalent per year, valued at approximately \$12.3 million at current regional gas prices (Karimov & Tashpulatov, 2021:45).

DISCUSSION

The results confirm that substantial fuel savings are achievable in thermal power plants through the systematic application of established engineering strategies. The finding that waste heat recovery offers the largest individual savings potential (average 4.4%) aligns with the thermodynamic principle that exhaust gas losses represent the largest single source of energy dissipation in thermal power cycles (Beér, 2007:490). The relatively modest cost of combustion optimization (average 2.4% savings at low capital cost) makes it the most cost-effective first step for plants with limited investment budgets.

The integrated savings of 8–15% are particularly significant for aging power fleets in transitional economies, where the cost of comprehensive plant modernization may be



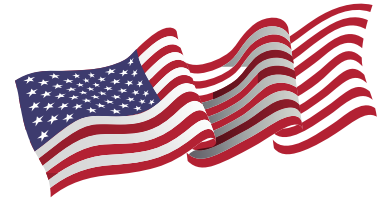
prohibitive. The results demonstrate that carefully sequenced, incremental improvements can achieve cumulative fuel savings approaching those of major capital investments such as combined-cycle conversion, but at a fraction of the cost and implementation timeframe (Kehlhofer et al., 2009:178).

For power plant operators, the results suggest a phased implementation approach: combustion optimization and auxiliary power reduction as immediate, low-cost measures; waste heat recovery as a medium-term investment; and steam cycle improvements as long-term capital projects. Load management strategies should be implemented continuously, adapting to seasonal and diurnal demand patterns. For policymakers, the findings support the development of efficiency standards and incentive mechanisms that encourage systematic fuel savings across the thermal generation fleet (Patel & Shah, 2019:120).

The economic analysis reveals that the payback period for fuel-saving investments varies significantly across strategies. Combustion optimization, requiring primarily software and sensor upgrades, typically achieves payback within 6–12 months. Waste heat recovery equipment, though requiring higher capital investment, offers payback periods of 2–4 years at current fuel prices. Steam cycle modifications represent the longest payback period of 4–7 years but provide the most durable efficiency improvements over the remaining plant lifetime (Kehlhofer et al., 2009:182). These payback characteristics should inform the prioritization of investments, particularly in resource-constrained environments where capital allocation decisions have significant opportunity costs.

Furthermore, the results have important implications for national energy planning. In countries where thermal power dominates the generation mix, systematic fuel efficiency improvement represents a cost-effective alternative to new capacity construction. A 10% improvement in the fuel efficiency of an existing 5,000 MW thermal fleet is thermodynamically equivalent to adding approximately 500 MW of new capacity, but at a fraction of the capital cost and construction time. This equivalence is particularly relevant for Uzbekistan, where the government's energy strategy emphasizes both capacity expansion and efficiency improvement as complementary pillars of energy security (Karimov & Tashpulatov, 2021:48).

The analysis relied on published operational data rather than direct experimental measurements, introducing uncertainty regarding plant-specific conditions. The interaction effects between strategies were estimated using simplified thermodynamic models that may



not fully capture the complexity of real plant operations. Site-specific factors including fuel quality variation, ambient conditions, equipment age, and maintenance practices influence actual savings achievable. Future research should incorporate detailed plant-level case studies with direct measurement of fuel savings achieved through specific interventions.

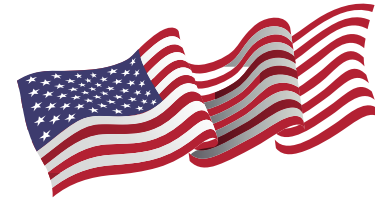
CONCLUSION

This study demonstrates that thermal power plants can achieve fuel savings of 8–15% through the integrated implementation of five established strategies: combustion optimization, waste heat recovery, steam cycle improvement, auxiliary power reduction, and load management. Waste heat recovery offers the largest individual contribution, while combustion optimization provides the most favorable cost-effectiveness ratio. These findings provide a practical framework for enhancing the fuel efficiency of existing thermal generation assets, with particular relevance to transitional economies where aging infrastructure and resource constraints necessitate cost-effective approaches to energy efficiency improvement.

The economic significance of these savings is substantial: for a single 300 MW gas-fired plant, integrated optimization can yield annual fuel cost reductions exceeding \$12 million. When scaled across an entire national power fleet, the cumulative fuel savings represent a major contribution to energy security, economic competitiveness, and environmental sustainability. The results underscore the importance of systematic efficiency improvement programs as a complement to, and in many cases a more cost-effective alternative to, new generation capacity construction.

REFERENCES

1. ASME. (2013). Performance test codes (PTC 4 and PTC 46). American Society of Mechanical Engineers.
2. Beér, J. M. (2007). High efficiency electric power generation: The environmental role. *Progress in Energy and Combustion Science*, 33(2), 482–501. <https://doi.org/10.1016/j.pecs.2007.02.001>
3. Franco, A., & Russo, A. (2002). Combined cycle plant efficiency increase based on the optimization of the heat recovery steam generator operating parameters. *International Journal of Thermal Sciences*, 41(9), 1335–1345. [https://doi.org/10.1016/S1290-0729\(02\)01418-8](https://doi.org/10.1016/S1290-0729(02)01418-8)
4. IEA. (2023). World energy outlook 2023. International Energy Agency.
5. Karimov, R., & Tashpulatov, N. (2021). Energy efficiency of thermal power plants in Uzbekistan: Current state and prospects. *Central Asian Journal of Energy*, 8(2), 28–52.



6. Kehlhofer, R., Hannemann, F., Stirnimann, F., & Rukes, B. (2009). Combined-cycle gas & steam turbine power plants (3rd ed.). PennWell Corporation.
7. Patel, V., & Shah, R. (2019). Auxiliary power optimization in thermal power stations. *Energy Engineering*, 116(4), 108–125. <https://doi.org/10.1080/01998595.2019.12048520>.
8. Saidur, R., Rezaei, M., Muzammil, W. K., Hassan, M. H., & Paria, S. (2010). Technologies to recover exhaust heat from internal combustion engines. *Renewable and Sustainable Energy Reviews*, 16(8), 1073–1093. <https://doi.org/10.1016/j.rser.2011.09.003>.
9. Mamatkulova, N. (2021). Learner-Centered Approach In Developing A Foreign Language Lexical Competence. *Philology Matters*, 2021(2).
10. Mamatkulova, N. (2021, April). The Importance of Individual Approach in the Development of Lexical Competencies in a Foreign Language. In *Конференции*.
11. Mamatkulova, N. (2025). Oliy ta'limda KREAM strategiyasi yordamida darslarni tashkil etishning prinsiplari va usullari. *The Lingua Spectrum*, 4(1), 895-903.
12. Mamatkulova, N. (2025). Enhancing Students'ecolinguistic Awareness as a Key Educational Priority in the 21st Century. *Foreign Languages in Uzbekistan*, 152-166.
13. Mamatkulova, N., & Nilufar, M. (2020). Independent study skills as a key to success in higher education system. *European Journal of Research and Reflection in Educational Sciences*, 8(10 Part II), 96-100.