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Energy Efficiency Comparison of Public and Private Sector Pumps

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Abstract: This study investigates energy efficiency in water pumping systems across Türkiye's public and private sectors through a comparative analysis. It is based on field data collected from 279 pumps over four years, examining the impact of flow rate, power consumption, head pressure, and pump type on overall efficiency. The research employs a quantitative methodology using measurements from 229 public and 50 private sector pumps across different regions. Data were gathered using ultrasonic flow meters, power analyzers, and pressure sensors. Statistical tools included descriptive statistics, t-tests, ANOVA, multiple regression, and correlation analysis. Key findings indicate that public sector pumps achieved significantly higher average efficiency (55.4%) than private sector pumps (42.9%). Flow rate was the strongest predictor of efficiency ($r = 0.42$, $p < 0.001$), with high-flow pumps (>750 m^3/h) being 19.7 percentage points more efficient than low-flow pumps (<150 m^3/h). Pump type also played a major role: horizontal (56.7%) and vertical shaft pumps (62.4%) performed better than submersible pumps (39.5%). Regression analysis confirmed these relationships ($R^2 = 0.341$), even after adjusting for technical variables. The study concludes that pump type, flow rate, and sectoral characteristics strongly affect energy efficiency. Additionally, differences in organizational and operational practices contribute to performance variations beyond technical design. These insights provide a foundation for developing energy-efficient policies, optimizing system design, and improving operational strategies within water pumping infrastructure.

Keyword: Energy efficiency, water pumps, public sector, private sector, sustainability

JEL Classification: F52, N70, L91, O11

1. Introduction

The interdependence between water and energy systems represents one of the most critical challenges in sustainable development. Water pumping systems consume substantial amounts of energy globally, with estimates suggesting that pumping accounts for 15-20% of total electricity consumption in many developed countries (Özdemir, et al. 2025). In Türkiye, where water scarcity and energy security are pressing concerns, optimizing the energy efficiency of pumping systems has become increasingly important for both economic and environmental sustainability.

The performance of pumping systems varies significantly across different operational contexts, with public and private sector implementations potentially exhibiting distinct efficiency characteristics due to differences in management practices, maintenance protocols, economic incentives, and technical specifications. Understanding these sectoral differences is crucial for developing targeted policies and interventions to improve overall system performance.

Despite the critical importance of energy efficiency in pumping systems, comprehensive comparative analyses between public and private sector performance in Türkiye remain limited. Previous studies have largely focused on technical optimization without adequately addressing sectoral performance differences or the complex interplay between technical and organizational factors that influence efficiency outcomes.

The primary objectives of this research are:

- To analyze and compare energy efficiency performance between public and private sector pumping systems in Türkiye
- To identify key technical factors (flow rate, power consumption, head pressure, pump type) that influence system efficiency
- To quantify the relationship between operational parameters and energy performance
- To develop evidence-based recommendations for improving energy efficiency in both sectors
- To contribute to the theoretical understanding of sectoral differences in infrastructure performance

This study addresses the following research questions:

1. Do pumps demonstrate significant efficiency differences based on flow rate categories?
2. Do pumps show significant efficiency differences based on power consumption levels?
3. Do pumps exhibit significant efficiency differences based on head pressure requirements?
4. Are there significant efficiency differences among different pump types?
5. Is there a significant difference in pump efficiency between public and private sector operations?
6. Are there significant differences in independent variables (flow rate, power consumption, head pressure) between public and private sectors?

2. Literature Review

2.1 Water-Energy Nexus

The water-energy nexus has emerged as a critical area of research and policy development. Vilanova and Balestieri (2015) explored the electricity use for water supply in Brazil, demonstrating significant variations in energy intensity across different supply systems. Their analysis revealed that energy consumption for water supply ranges from 0.5 to 7.0 kWh/m³, with pumping systems representing the largest component of energy use.

Lam et al. (2017) conducted a comprehensive analysis of energy use for water provision in cities, identifying pumping as the most energy-intensive component of urban water systems. Their findings emphasized the importance of system design and operational optimization in achieving energy efficiency improvements. The United States Department of Energy (2006) report to Congress highlighted the interdependency of energy and water resources, noting that water-related energy use accounts for approximately 4% of total national energy consumption.

2.2 Energy Efficiency in Pumping Systems

Kaya et al. (2008) provided a comprehensive analysis of energy efficiency in pumps, identifying key factors affecting performance including pump design, system characteristics, and operational practices. Their study in Türkiye revealed significant potential for efficiency improvements through proper sizing, variable speed drives, and maintenance optimization.

Zhang et al. (2012) developed optimization models for pumping systems to achieve energy efficiency and load shifting. Their research demonstrated that optimal sizing and operation strategies could reduce energy consumption by 15-30% while maintaining required service levels. Recent work by Housh and Salomons (2025) introduced energy-efficient local control strategies for pumping stations with variable-speed pumps, showing practical applications of model-based approaches.

2.3 Factors Affecting Pump Efficiency

Technical factors affecting pump efficiency have been extensively studied. Şenol and Karakuş (2015) examined energy efficiency in variable flow irrigation pumping systems, identifying flow rate variability as a critical factor in overall system performance. Orhan et al. (2020) investigated

the effects of impeller diameter and water inlet cross-sectional area on pump parameters in vertical shaft deep well pumps, demonstrating the importance of proper design specifications.
System integration and operational factors also play crucial roles. Mo (2012) analyzed embodied energy in water and wastewater systems, revealing that operational energy typically dominates life-cycle energy consumption. Friedrich and Buckley (2002) emphasized the importance of considering both direct and indirect energy impacts in system optimization.

2.4 Public and Private Sector Performance Comparison

Comparative analyses of public and private sector infrastructure performance have yielded mixed results across different contexts. While some studies suggest private sector efficiency advantages due to market incentives, others indicate that public sector operations may achieve better performance through longer-term planning horizons and different optimization criteria.

The Alliance to Save Energy (2002) Watergy report identified significant untapped energy and water efficiency opportunities in municipal water systems, suggesting that institutional factors may be as important as technical considerations in determining system performance.

2.5 Research Gap

Despite extensive research on individual aspects of pump efficiency, comprehensive empirical comparisons between public and private sector performance in Türkiye remain limited. Most existing studies focus on technical optimization without adequately addressing sectoral differences or the complex interplay between technical and organizational factors that influence efficiency outcomes. This study addresses this gap by providing a systematic comparative analysis based on extensive field measurement data.

3. Methodology

3.1 Research Design

This study employs a quantitative research approach to analyze and compare energy efficiency parameters in water pumping systems across public and private sectors in Türkiye. The research design is cross-sectional, utilizing field measurement data collected from operational pumping systems over a four-year period.

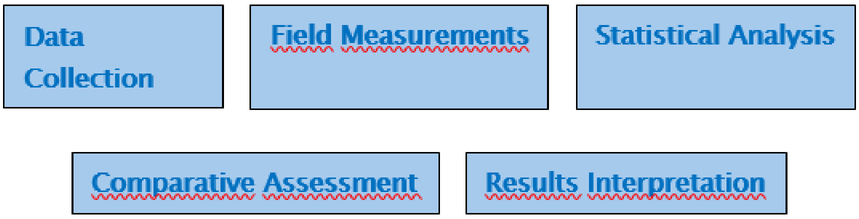


Figure 1. Research Framework

3.2 Sample and Data Collection

The dataset comprises performance measurements from 279 water pumps across Türkiye, distributed as follows: Public sector is represented with 229 pumps, primarily municipal water supply systems whereas private sector represented with 50 pumps from industrial process applications.

3.3 Measurement Procedures aand Variables

Field measurements were conducted using calibrated instruments:

- Flow Rate: Ultrasonic flow meters (accuracy ±2%)
- Power Consumption: Power analyzers (accuracy ±1%)
- Head Pressure: Pressure sensors (accuracy ±0.5%)
- System Efficiency: Calculated from measured parameters

Variables of the study is given in Table 1.

Table 1. Variables

Variable Type	**Variable Name**	**Unit**	**Description**
Dependent	System Efficiency	%	Overall pump system efficiency
Independent	Flow Rate	m^3/hour	Volumetric flow rate
Independent	Power Consumption	kW	Electrical power input
Independent	Head Pressure	m	Total dynamic head
Categorical	Pump Type	-	Horizontal, Submersible, Vertical Shaft
Categorical	Sector	-	Public, Private

3.4 Statistical Analysis

Statistical analyses were performed using SPSS software and included:

Descriptive Statistics

- Central tendency measures
- Dispersion measures
- Frequency distributions

Inferential Statistics

- Independent samples t-tests
- ANOVA and post-hoc tests
- Correlation analysis
- Multiple regression analysis

System Efficiency Calculation:

$$\eta = (\rho \times g \times Q \times H) / (P \times 1000) \times 100$$

Where: η = efficiency (%), ρ = water density (kg/m^3), g = gravitational acceleration (m/s^2), Q= flow rate (m^3/s), H = head (m), P = power (kW)

Figure 2. Summary of Statistical Analysis

3.5 Limitations

Several limitations should be acknowledged: (1) Cross-sectional design limits causal inference; (2) Measurements represent single-point assessments rather than continuous monitoring; (3) Sample size imbalance between sectors (229 public vs. 50 private); (4) Limited geographical representation may affect generalizability; (5) Potential confounding variables not measured in the study.

4. Results

4.1 Descriptive Statistics

Table 2 presents descriptive statistics for all key variables in the study. The data reveal considerable variability in system characteristics, with flow rates ranging from 2.7 to 9,000 m^3/hour and power consumption from 1.5 to 11,400 kW.

Table 2. Descriptive Statistics for Key Variables (N = 279)

Variable	Mean	Median	Std. Deviation	Minimum	Maximum
Flow Rate (m³/hour)	985.2	420.0	1248.7	2.7	9000.0
Power Consumption (kW)	361.7	130.0	549.8	1.5	11400.0

Variable	Mean	Median	Std. Deviation	Minimum	Maximum
Head Pressure (m)	86.3	83.6	43.2	8.0	257.1
System Efficiency (%)	**53.1**	58.1	19.7	4.3	85.9
Energy Intensity (kWh/m^3)	0.53	0.34	0.93	0.04	11.18

4.2 Flow Rate Analysis

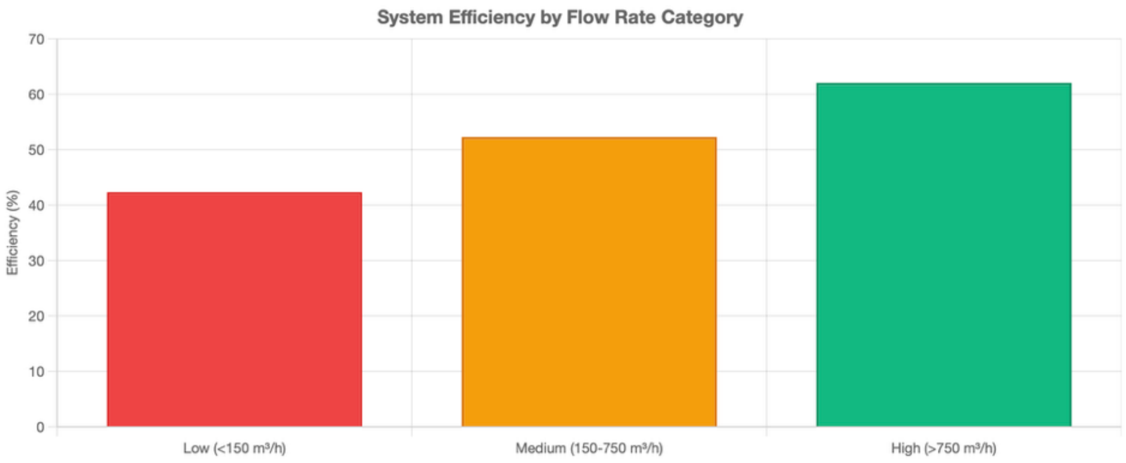
Flow rate emerged as the strongest predictor of system efficiency. Analysis of variance revealed significant differences among flow rate categories ($F(2,276) = 28.63$, $p < 0.001$).

Key Finding: Flow Rate Impact High-flow pumps (>750 m^3/hour) achieved 19.7 percentage points higher efficiency than low-flow pumps (<150 m^3/hour), demonstrating the importance of proper sizing for efficiency optimization.

Table 3. System Efficiency by Flow Rate Category

Flow Rate Category	N	Mean Efficiency (%)	Std. Deviation	95% CI
Low (<150 m^3/hour)	83	42.4	21.2	37.8 - 47.0
Medium (150-750 m^3/hour)	90	52.3	18.3	48.5 - 56.1
High (>750 m^3/hour)	106	**62.1**	15.1	59.2 - 65.0

Statistical Result: Pearson correlation between flow rate and system efficiency: $r = 0.42$, $p < 0.001$ (Public sector: $r = 0.39$, $p < 0.001$; Private sector: $r = 0.48$, $p < 0.001$)



Graph 1. System Efficiency by Flow Rate Category

4.3 Power Consumption Analysis

Power consumption showed a strong positive correlation with efficiency ($r = 0.39$, $p < 0.001$), indicating that larger pumps generally operate more efficiently. ANOVA results confirmed significant differences among power categories ($F(2,276) = 25.91$, $p < 0.001$).

Table 4: System Efficiency by Power Consumption Category

Power Category	N	Mean Efficiency (%)	Std. Deviation
Low (<50 kW)	76	41.7	20.5
Medium (50-250 kW)	111	53.6	17.9
High (>250 kW)	92	**61.8**	16.6

4.4 Head Pressure Analysis

Unlike flow rate and power consumption, head pressure showed no significant relationship with system efficiency ($r = 0.05$, $p = 0.41$). ANOVA results confirmed no significant differences among head pressure categories ($F(2,276) = 0.87$, $p = 0.42$).

4.5 Pump Type Analysis

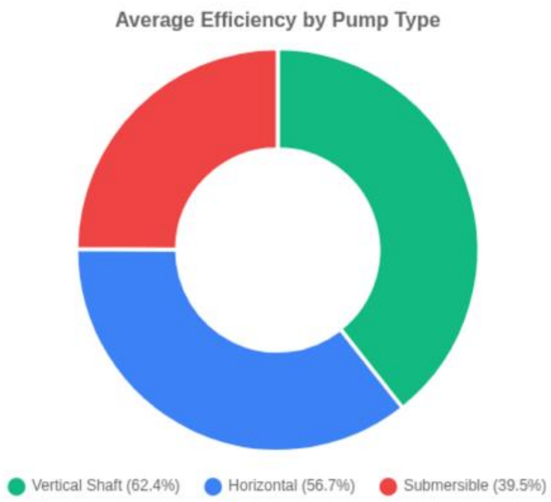
Significant differences in efficiency were observed among pump types ($F(2,276) = 24.57$, $p < 0.001$). Post-hoc Tukey HSD tests revealed that submersible pumps performed significantly worse than both horizontal and vertical shaft pumps.

Table 5. System Efficiency by Pump Type

Pump Type	N	Mean Efficiency (%)	Std. Deviation	Post-hoc Groups
Vertical Shaft	12	**62.4**	15.4	A
Horizontal	201	**56.7**	18.3	A
Submersible	66	**39.5**	19.1	B

Key Finding: Pump Type Performance

Horizontal and vertical shaft pumps demonstrated significantly superior performance compared to submersible pumps, with efficiency advantages of 17.2 and 22.9 percentage points respectively.



Graph 2. Average Efficiency by Pump Type

4.6 Sectoral Comparison

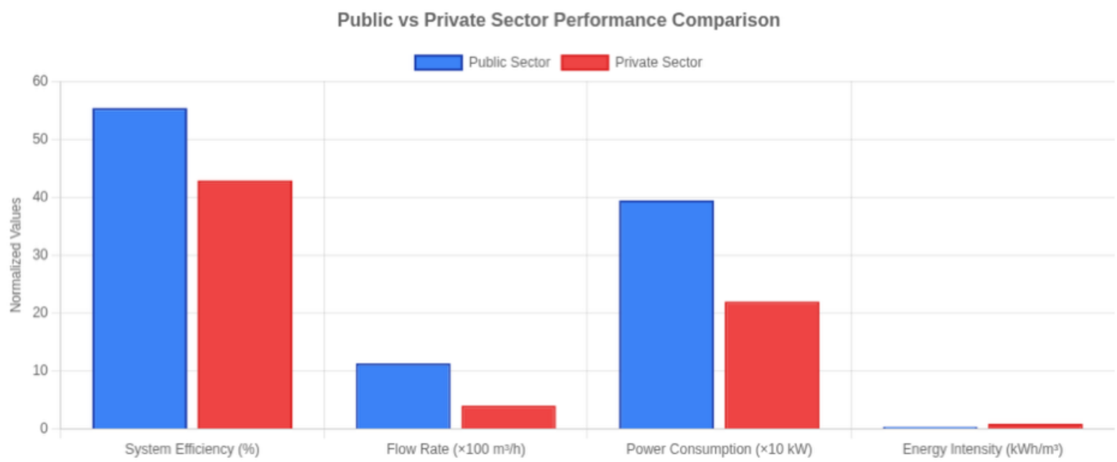
The most significant finding of this study is the substantial difference in efficiency between public and private sector pumping systems. Independent samples t-test revealed statistically significant differences across multiple parameters.

Table 6. Comparison of Key Variables Between Public and Private Sectors

Variable	Public Sector Mean	Private Sector Mean	t-value	p-value	Effect Size (Cohen's d)
Flow Rate (m^3/hour)	1137.3	407.1	6.29	**<0.001**	0.58
Power Consumption (kW)	394.8	219.8	3.04	**0.003**	0.32
Head Pressure (m)	86.9	83.9	0.45	0.655	0.07
System Efficiency (%)	**55.4**	42.9	4.12	**<0.001**	0.64
Energy Intensity (kWh/m^3)	0.43	0.92	-2.89	**0.005**	-0.53

Major Finding: Sectoral Performance Gap

Public sector pumps demonstrated 12.5 percentage points higher efficiency than private sector pumps (55.4% vs. 42.9%), representing a 29% relative improvement. This difference remained significant even after controlling for technical variables.



Graph 3. Public vs. Private Sector Performance Comparison

4.7 Multiple Regression Analysis

Multiple regression analysis was conducted to examine the simultaneous effects of all independent variables on system efficiency. The model explained 34.1% of the variance in efficiency ($R^2 = 0.341$, Adjusted $R^2 = 0.327$, $F(6,272) = 23.48$, $p < 0.001$).

Table 6. Multiple Regression Analysis Results (Dependent Variable: System Efficiency)

Independent Variable	B	Std. Error	Beta	t	p-value
Constant	32.15	10.79	-	2.98	**<0.001**
Sector (Private=1)	**-5.32**	2.61	-0.11	-2.04	**0.043**
Pump Type: Submersible	**-13.26**	2.47	-0.28	-5.36	**<0.001**
Pump Type: Vertical Shaft	4.89	4.33	0.05	1.13	0.258
Flow Rate (per 100 m³/hour)	**0.64**	0.13	0.41	5.07	**<0.001**
Power Consumption (per 10 kW)	0.03	0.02	0.10	1.27	0.204
Head Pressure (m)	0.01	0.03	0.02	0.43	0.669

Model Summary: $R^2 = 0.341$, Adjusted $R^2 = 0.327$, $F(6,272) = 23.48$, $p < 0.001$. The model indicates that flow rate is the strongest predictor ($\beta = 0.41$), followed by pump type and sector effects.

5. Discussion

5.1 Principal Findings

This study provides the first comprehensive comparative analysis of energy efficiency in water pumping systems between public and private sectors in Türkiye. The results reveal several important findings that have significant implications for energy policy, system design, and operational practices.

Summary of Key Findings

- Public sector pumps demonstrate 12.5 percentage points higher efficiency than private sector pumps
- Flow rate is the strongest predictor of efficiency ($r = 0.42$, $p < 0.001$)
- Horizontal and vertical shaft pumps significantly outperform submersible pumps
- Larger pumps (higher power consumption) generally operate more efficiently
- Head pressure shows no significant relationship with efficiency
- Sectoral differences persist even after controlling for technical variables

5.2 Flow Rate and Efficiency Relationship

The strong positive correlation between flow rate and system efficiency aligns with fundamental pump performance principles. Pumps are typically designed to operate most efficiently at or near their best efficiency point (BEP), which generally occurs at higher flow rates for larger pumps. The 19.7 percentage point efficiency advantage of high-flow pumps over low-flow pumps demonstrates the critical importance of proper pump sizing.

This finding has significant practical implications for system design. Undersized pumps operating at low flow rates not only consume more energy per unit of water moved but may also experience increased wear and maintenance requirements. The relationship between flow rate and efficiency was consistent across both sectors, suggesting that fundamental hydraulic principles govern performance regardless of operational context.

5.3 Pump Type Performance Differences

The superior performance of horizontal and vertical shaft pumps compared to submersible pumps reflects important design and operational considerations. Submersible pumps, while offering installation advantages in deep well applications, typically operate in more challenging thermal environments and may experience greater mechanical losses due to their compact design constraints.

The 17.2 and 22.9 percentage point efficiency advantages of horizontal and vertical shaft pumps, respectively, over submersible pumps suggest that pump type selection should carefully consider efficiency implications alongside installation and maintenance factors. However, it is important to note that application-specific requirements may sometimes necessitate the use of submersible pumps despite their lower efficiency.

5.4 Sectoral Performance Differences

The most significant and surprising finding of this study is the substantial efficiency advantage of public sector pumping systems. This result contradicts common assumptions about private sector efficiency and suggests that the relationship between ownership structure and operational performance is more complex than typically assumed.

Several factors may contribute to this performance gap is as in Figure 3.

Public Sector Advantages

- Longer planning horizons for equipment selection
- Greater emphasis on operational efficiency over capital costs
- Standardized maintenance procedures
- Professional engineering oversight
- Regulatory compliance requirements

Private Sector Constraints

- Capital cost optimization may compromise efficiency
- Variable operational practices
- Diverse application requirements
- Limited standardization
- Focus on short-term

Figure 3. Contribution of the performance gap.

The persistence of sectoral differences even after controlling for technical variables (flow rate, power consumption, pump type) in the multiple regression analysis suggests that organizational and operational factors play a significant role in determining system efficiency. This finding highlights the importance of management practices, maintenance protocols, and operational optimization in achieving superior performance.

5.5 Theoretical Implications

These findings contribute to several theoretical frameworks. From a public administration perspective, the results challenge assumptions about private sector efficiency advantages and suggest that public organizations may achieve superior technical performance in infrastructure applications. From an engineering perspective, the study confirms the critical importance of system design optimization and proper equipment selection.

The research also contributes to the growing literature on the water-energy nexus by providing empirical evidence of significant efficiency variations within and between sectors. The identification of flow rate as the primary determinant of efficiency provides a clear target for optimization efforts.

5.6 Practical Implications

The study's findings have several important practical implications for different stakeholders:

For System Designers and Engineers

Prioritize proper pump sizing to optimize flow rates. Consider efficiency implications when selecting pump types, particularly avoiding submersible pumps when alternatives are feasible. Implement comprehensive system design approaches that optimize efficiency across all components.

For System Operators and Managers

Establish regular efficiency monitoring and benchmarking programs. Implement preventive maintenance schedules based on best practices. Consider operational optimization strategies including variable speed drives and system controls.

For Policy Makers

Develop efficiency standards and incentive programs for both sectors. Promote knowledge transfer and best practice sharing between public and private operators. Consider regulatory frameworks that encourage efficiency optimization.

5.7 Limitations

Several limitations should be acknowledged in interpreting these results. The cross-sectional design limits causal inference, and the sample size imbalance between sectors (229 public vs. 50 private) may affect the generalizability of sectoral comparisons. Single-point measurements may not capture operational variations that occur over time.

Additionally, the study did not control for all potentially relevant variables such as system age, maintenance history, or specific operational conditions. Future research should address these limitations through longitudinal studies and more comprehensive variable measurement.

6. Conclusions and Recommendations

6.1 Summary of Findings

This comprehensive analysis of 279 pumping systems across Türkiye has revealed significant differences in energy efficiency between public and private sectors, with public sector pumps demonstrating superior performance across multiple metrics. The study has identified flow rate as the primary determinant of efficiency and confirmed the importance of pump type selection in achieving optimal performance.

Primary Conclusions

1. Public sector pumping systems achieve significantly higher energy efficiency than private sector systems (55.4% vs. 42.9%)
2. Flow rate is the strongest predictor of system efficiency, with high-flow pumps achieving 19.7 percentage points higher efficiency
3.Pump type significantly affects performance, with horizontal and vertical shaft pumps outperforming submersible pumps
4. Sectoral differences persist even after controlling for technical variables, indicating the importance of operational and organizational factors
5. System size (power consumption) correlates positively with efficiency, supporting the importance of proper sizing

System design recommandations could be listed as:

- Optimize System Sizing: Ensure pumps operate at or near their design flow rates to maximize efficiency. Avoid oversizing or undersizing that leads to off-design operation.
- Select Appropriate Pump Types: Prioritize horizontal or vertical shaft pumps over submersible pumps when installation conditions permit, considering the significant efficiency advantages.
- Implement Variable Speed Drives: Use variable frequency drives to optimize pump operation across varying demand conditions.
- Consider System Integration: Design pumping systems as integrated components of larger water infrastructure to optimize overall efficiency.

Opeeratinal recommandations could be listed as:

- Establish Efficiency Monitoring: Implement regular efficiency assessments and benchmarking programs to identify performance degradation and optimization opportunities.
- Optimize Maintenance Practices: Develop and implement preventive maintenance schedules based on manufacturer recommendations and operational experience.
- Train Operators: Provide comprehensive training on efficient operation practices and system optimization techniques.
- Implement Control Strategies: Use advanced control systems to optimize pump operation based on demand patterns and system conditions.

Policy recommandations could be listed as follows:

- Develop Efficiency Standards: Establish minimum efficiency requirements for pumping systems in both public and private sectors.
- Create Incentive Programs: Implement financial incentives for efficiency improvements and best practice adoption.
- Promote Knowledge Transfer: Facilitate sharing of best practices between public and private sector operators through professional networks and training programs.
- Support Research and Development: Invest in research on pumping system optimization and efficiency improvement technologies.

Future research directions could be sum up as in Figure 4.

Technical Research

- Longitudinal studies of efficiency changes over time
- Impact of maintenance practices on long-term performance
- Advanced control system effectiveness
- Life-cycle cost analysis including efficiency considerations

Organizational Research

- Detailed analysis of management practice differences
- Impact of organizational culture on technical performance
- Economic incentive structures and efficiency outcomes
- Cross-national comparative studies

Figure 4. Future Works Directions

6.2 Contribution to Knowledge

This study makes several important contributions to the literature on energy efficiency in water infrastructure:

- Provides the first comprehensive comparative analysis of public and private sector pumping efficiency in Türkiye
- Quantifies the relationship between technical parameters and system efficiency using extensive field data

- Challenges assumptions about private sector efficiency advantages in infrastructure applications
- Identifies specific technical and operational factors that can be targeted for improvement
- Contributes empirical evidence to the water-energy nexus literature

6.3 Final Remarks

The significant efficiency differences identified in this study represent substantial opportunities for energy savings and environmental impact reduction. With water pumping accounting for a significant portion of energy consumption in both sectors, the potential benefits of optimization efforts are considerable.

The superior performance of public sector pumping systems suggests that effective management practices and operational optimization can overcome potential disadvantages of public ownership. This finding has important implications for infrastructure policy and management practices in Türkiye and other developing countries.

Implementation of the recommendations presented in this study could lead to significant improvements in energy efficiency, reduced operational costs, and enhanced environmental sustainability across Türkiye's water infrastructure. The research provides a foundation for evidence-based policy development and operational improvement initiatives in both public and private sectors.

References

Alliance to Save Energy (2002). Watergy: Taking advantage of untapped energy and water efficiency opportunities in municipal water systems. Washington, USA: Alliance To Save Energy.

Çelik, R. (2008). Diyarbakır ovasının yer altı ve yerüstü su potansiyeli, pompa verimlilik haritalarının çıkarılması, hidrojeolojik analizi. Fırat Üniversitesi Doğu Araştırmaları Dergisi, 7(1).

Filion, Y. R., MacLean, H. L. and Karney, B. W. (2024). Life-cycle energy analysis of a water distribution system. Journal of Infrastructure Systems, 10(3), pp. 119-130.

Friedrich, E. and Buckley, C. (2002). Life-cycle assessment as an environmental assessment tool in the water industry. Water Research Commission, Report No. 1252/1/02.

Horvath, A. and Stokes, J. (2012). Life-cycle Energy Assessment of Alternative Water Supply Systems in California. California Energy Commission.

Housh, M. and Salomons, E. (2025). Energy-efficient local control strategies for pumping stations with variable-speed pumps: A practical model-based approach. Journal of Cleaner Production, 498, p. 145131.

Kaya, D., Yagmur, E. A., Yigit, K. S., Kilic, F. C., Eren, A. S. and Celik, C. (2008). Energy efficiency in pumps. Energy Conversion and Management, 49(6), pp. 1662-1673.

Lam, K. L., Kenway, S. J. and Lant, P. A. (2017). Energy use for water provision in cities. Journal of Cleaner Production, 143.

Mo, W. (2012). Water's dependence on energy: Analysis of embodied energy in water and wastewater systems. University of South Florida: ProQuest Dissertations Publishing.

Orhan, N., Özbek, O. and Şeflek, A. Y. (2020). Düşey milli derin kuyu pompalarda anma çapı ve su giriş kesit alanının bazı pompa parametrelerine etkisi. KSÜ Tarım ve Doğa Dergisi, 23(1).

Özdemir, A., Öz, S., Kasımoğlu, M., (2025). A Bibliometric Analysis of Technology Transfer and Collaboration between SMEs and Universities, Journal of International Trade, Logistics and Law, JITAL, 11(2), 341-354.

Racoviceanu, A. I., Karney, B. W., Kennedy, C. A. and Colombo, A. F. (2007). Life-cycle energy use and greenhouse gas emissions inventory for water treatment systems. Journal of Infrastructure Systems, 13(4).

Şenol, G. K. and Karakuş, C. (2015). Değişken debili sulama pompaj tesislerinde enerji etkinliğinin belirlenmesi. Tarım Makinaları Bilimi Dergisi, 11(2).

United States Department of Energy (2006). Energy demands on water resources: Report to Congress on the interdependency of energy and water.

Vilanova, M. R. and Balestieri, J. A. (2015). Exploring the water-energy nexus in Brazil: The electricity use for water supply. Energy, 85, pp. 415-432.

Zhang, H., Xia, X. and Zhang, J. (2012). Optimal sizing and operation of pumping systems to achieve energy efficiency and load shifting. Electric Power Systems Research, 86.