

American Journal of Economics and Business Management

Vol. 9 Issue 5 | **pp.** 418-425 | **ISSN:** 2576-5973
Available online @ https://www.globalresearchnetwork.us/index.php/ajebm

Article

International Experience in Resource Efficiency At Thermal Energy Enterprises and Opportunities for Its Adaptation to The Conditions of Uzbekistan

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Abstract: This paper examines the international experience of leading countries - Germany, Japan, South Korea, China, and the United States - in improving resource efficiency at thermal energy enterprises, with a focus on identifying best practices applicable to Uzbekistan's energy sector. The study systematizes key technological, institutional, and regulatory approaches used in high-efficiency thermal power sectors, including combined heat and power (CHP) systems, integrated energy management frameworks, digital monitoring tools, and market-based policy instruments. Drawing on theoretical frameworks for measuring resource efficiency and comparative institutional analysis, the paper assesses the compatibility of international practices with the structural, regulatory, and economic conditions in Uzbekistan's thermal energy sector. A structured adaptation framework is proposed, comprising three tiers: immediate regulatory and metrological measures, medium-term technological upgrades, and long-term system transformation aligned with national sustainable development priorities. The findings provide a methodological basis for evidence-based policy design and enterprise-level management reform in Uzbekistan's heat and power generation industry.

Keywords: resource efficiency, thermal energy enterprises, international experience, combined heat and power (CHP), energy management systems, Uzbekistan energy sector, best available techniques (BAT), adaptation framework, heat rate, carbon intensity.

Citation: Yakubova M. A. International Experience in Resource Efficiency At Thermal Energy Enterprises and Opportunities for Its Adaptation to The Conditions of Uzbekistan. American Journal of Economics and Business Management 2026, 9(5), 418-425

Received: 10th Feb 2026
Revised: 21th Mar 2026
Accepted: 08th Apr 2026
Published: 15th May 2026

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1. Introduction

The thermal energy sector stands at the intersection of economic development and environmental sustainability. Thermal power plants and district heating enterprises consume the largest share of primary energy in most industrializing economies and simultaneously account for a disproportionate share of greenhouse gas emissions, water consumption, and solid waste generation. According to the International Energy Agency, thermal power generation accounts for approximately 38% of global primary energy consumption and is responsible for over 40% of energy-related CO_2 emissions worldwide [1]. Consequently, improving resource efficiency in this sector has become a strategic priority not only for climate policy but also for national energy security and industrial competitiveness.

Uzbekistan's thermal energy sector presents a particularly compelling case for reform. The country's electricity generation is overwhelmingly dependent on natural gas-fired thermal power stations, which collectively account for over 85% of installed capacity [2]. These plants were largely constructed during the Soviet era and continue to operate with

heat rates and efficiency parameters significantly below modern international benchmarks. The average net electrical efficiency of Uzbekistan's thermal power fleet is estimated at 33–36%, compared with 45–55% achievable by modern combined-cycle gas turbine (CCGT) plants [3]. This efficiency gap represents both a substantial economic loss and a significant environmental burden [4].

Against this backdrop, the international experience of countries that have successfully reformed their thermal energy sectors offers valuable lessons. Germany's Energiewende, Japan's Top Runner Programme, South Korea's energy intensity reduction targets, China's mandatory heat rate standards, and the United States' ENERGY STAR industrial programme have each generated measurable improvements in resource efficiency at the enterprise level [5]. However, direct transplantation of these practices is not straightforward: institutional contexts, regulatory frameworks, capital market conditions, and technological capacities differ substantially between advanced economies and transition economies such as Uzbekistan.

The purpose of this paper is to systematically analyse international best practices in resource efficiency at thermal energy enterprises and to assess the conditions, constraints, and mechanisms through which these practices can be meaningfully adapted to Uzbekistan's context [6], [7], [8]. The research object is the thermal energy enterprise as an organisational and technological unit; the research subject is the set of resource efficiency practices, instruments, and institutional arrangements developed internationally and their transferability to Uzbekistan.

The study contributes to the growing body of literature on technology transfer and institutional adaptation in energy transitions, with specific empirical grounding in Central Asian energy sector conditions [9]. Its practical significance lies in informing enterprise managers, sector regulators, and national policymakers about actionable pathways to improve resource efficiency.

2. Materials and Methods

The study employs a multi-method research design combining systematic literature review, comparative institutional analysis, and analytical framework construction. The systematic review covered peer-reviewed journal articles indexed in Scopus and Web of Science (2005–2024), OECD and IEA technical publications, World Bank sector assessments, and national regulatory documents from selected countries. Search terms included combinations of 'thermal power efficiency', 'heat rate improvement', 'energy management systems', 'CHP best practices', and 'energy sector reform transition economies'.

Comparative institutional analysis followed the methodology outlined by Hall and Soskice and adapted for energy sector comparisons by Markard, Raven, and Truffer. This approach allows systematic comparison of country-level practices across four dimensions: (1) technological solutions adopted; (2) regulatory and policy instruments employed; (3) market and incentive structures; and (4) organizational and managerial practices at the enterprise level. Countries were selected based on documented efficiency gains, the relevance of their structural conditions to Uzbekistan, and the availability of verifiable data.

The adaptation framework was constructed using the 'fit-and-stretch' methodology proposed by Lall for technology transfer assessment, supplemented by the Contextual Integrity Framework of Nissenbaum for institutional compatibility analysis. Quantitative benchmarking drew on the IEA's energy efficiency indicators database and the World Bank's Regulatory Indicators for Sustainable Energy (RISE) dataset. Uzbekistan-specific data were sourced from the Ministry of Energy of the Republic of Uzbekistan and official statistical publications of the State Committee on Statistics.

The reliability of conclusions was ensured through triangulation across multiple data sources, explicit acknowledgment of data limitations, and transparent documentation of analytical assumptions. Where quantitative data were unavailable or unreliable, qualitative assessment informed by expert literature was employed.

3. Result and Discussion

Theoretical Foundations: Resource Efficiency in Thermal Energy Enterprises

Before examining international practices, it is necessary to establish the theoretical framework for resource efficiency measurement in the thermal energy context. In thermal power generation, the primary resource efficiency indicator is the heat rate (HR), defined as the amount of thermal energy input required to produce one unit of electrical output:

$HR = Q_{input} / W_{output}$ [kJ/kWh or BTU/kWh],

where Q_{input} is the total fuel heat input (in kJ or BTU), and W_{output} is the net electrical energy output (in kWh). A lower heat rate denotes higher efficiency. The relationship between heat rate and net electrical efficiency (η) is given by [10]:

$\eta = 3{,}600 / HR \times 100\%$ (when HR is expressed in kJ/kWh).

For combined heat and power plants, the primary energy savings (PES) indicator is additionally employed to capture the simultaneous production of heat and electricity [11]:

$PES = 1 - [1 / (CHP_{H\eta} / Ref_{H\eta} + CHP_{E\eta} / Ref_{E\eta})] \times 100\%$,

where $CHP_{H\eta}$ and $CHP_{E\eta}$ are the heat and electrical efficiencies of the CHP unit, and $Ref_{H\eta}$ and $Ref_{E\eta}$ are the reference efficiencies for separate heat and electricity production [12]. A positive PES value confirms that the CHP system uses less primary energy than producing the same outputs separately.

Resource efficiency in this sector also encompasses auxiliary energy consumption ratio (AECR), specific water consumption (SWC), specific CO_2 emissions intensity (CEI), and specific solid waste generation [13]. Taken together, these indicators constitute a multi-dimensional resource efficiency scorecard for thermal energy enterprises, consistent with the broader methodological framework of Coelli et al. [14].

German Experience: Integrated CHP Systems and Regulatory Incentives

Germany is one of the most advanced cases of CHP-based resource-efficiency improvement in the thermal energy sector. Under the Cogeneration Act (Kraft-Wärme-Kopplungsgesetz, KWKG), first enacted in 2000 and substantially revised in 2016 and 2020, CHP plants receive financial incentives in the form of surcharges on electricity sold to the grid and self-consumed [15]. The legislative framework is complemented by the Energy Efficiency Act (Energieeffizienzgesetz, EnEfG) of 2023, which mandates large energy consumers to implement certified energy management systems in accordance with DIN EN ISO 50001.

The results of Germany's CHP policy are well-documented. Pehnt et al. [16] report that CHP-based electricity generation increased from approximately 12% of total generation in 2000 to over 19% by 2020, with associated annual primary energy savings of 40–45 TWh. At the plant level, modern German gas CHP units achieve total efficiencies (heat plus electricity) of 80–92%, compared with 38–45% for conventional condensing power plants. The specific CO_2 emissions intensity of CHP-generated electricity is correspondingly 40–55% lower [17].

A critical institutional element of Germany's success is the mandatory energy audit and management system requirement. Under DIN EN ISO 50001, certified energy management systems require enterprises to establish an energy policy, set measurable efficiency targets, implement monitoring and measurement procedures, and conduct regular management reviews. By 2022, Germany had over 8,500 ISO 50001-certified organizations - the highest number globally - with thermal energy enterprises accounting for a disproportionately large share.

Japanese Experience: Top Runner Programme and Technological Standards

Japan's approach to resource efficiency in the energy sector is characterized by prescriptive technological standards combined with market-based competitive pressure. The Top Runner Programme, established under the Act on the Rational Use of Energy (Energy Conservation Act) in 1998, sets mandatory efficiency standards based on the most efficient product currently available on the market, requiring all producers to reach or exceed that benchmark within a defined period.

For thermal power generation equipment, Japan's Ministry of Economy, Trade and Industry (METI) has progressively tightened efficiency standards for gas turbines, boilers, and heat exchangers. Kimura and Suzuki document that average thermal efficiency of gas-

fired power plants in Japan improved from 39.2% in 1990 to 47.8% by 2020, driven largely by the Top Runner standards and mandatory reporting under the Energy Conservation Act. Large thermal power plants (over 1,500 kW) must appoint a certified Energy Manager and submit annual energy consumption and efficiency reports to METI.

Japan has also pioneered the concept of exergy analysis as a diagnostic tool for identifying thermodynamic inefficiencies within thermal energy systems. Rosen and Dincer describe exergy analysis as a method that identifies the location, magnitude, and thermodynamic cause of process irreversibilities - information unavailable from conventional energy (first-law) analysis alone. The exergy efficiency of a thermal process is defined as:

$\psi = Ex_{output} / Ex_{input}$,

where Ex_{output} and Ex_{input} represent the useful exergy outputs and total exergy inputs, respectively, measured in kJ or kW [13, p. 141]. Unlike energy efficiency, exergy efficiency has a theoretical maximum of 100% (for a reversible process), making it a more precise diagnostic benchmark for identifying improvement potential.

South Korean and Chinese Experiences: Mandatory Standards and Digital Monitoring

South Korea's experience illustrates how mandatory energy intensity reduction targets, combined with enterprise-level digital monitoring infrastructure, can drive systemic efficiency improvements across the thermal power fleet. Under the Korea Energy Master Plan and subsequent Presidential Decrees on Energy Use Rationalization, thermal power operators are required to achieve annual heat rate improvement targets of 0.5–1.0%. Non-compliance triggers financial penalties calibrated to the scale of the efficiency gap.

A distinguishing feature of South Korea's approach is the real-time plant performance monitoring system operated by the Korea Power Exchange (KPE). This system collects plant-level heat rate, availability, and emissions data at 15-minute intervals from all grid-connected generators, enabling both regulatory oversight and competitive benchmarking among operators. Park and Kim demonstrate that the introduction of mandatory real-time monitoring in 2012 was associated with a statistically significant reduction in average heat rate variance across the Korean thermal fleet, suggesting that transparency and accountability mechanisms have measurable efficiency effects independent of capital investment.

China's experience is instructive for a different reason: it demonstrates how efficiency standards can be effectively implemented at scale in a large, heterogeneous power sector. China's mandatory heat rate standards for coal-fired power plants, administered by the National Energy Administration (NEA), set differentiated benchmarks by plant size and technology type. Under these standards, plants failing to meet minimum efficiency thresholds face operational restrictions or mandatory retirement. The Chinese approach also incorporates energy consumption quota management: each thermal enterprise receives an annual energy consumption quota, and excess consumption is subject to progressive surcharges.

Zhang et al document that China's mandatory heat-rate standards contributed to the retirement of approximately 77 GW of inefficient small-scale coal-fired capacity between 2006 and 2015, with measurable improvements in average fleet efficiency. The average coal consumption rate of Chinese thermal power plants decreased from 392 g/kWh in 2000 to 305 g/kWh by 2020 — a 22% improvement over two decades.

United States Experience: ENERGY STAR and Plant-Level Benchmarking

The United States Environmental Protection Agency (US EPA) ENERGY STAR programme for industrial energy management provides a voluntary but institutionally well-supported framework for plant-level resource efficiency benchmarking. The programme, operating since 1992, establishes sector-specific Energy Performance Indicators (EPIs) that allow individual plants to compare their energy intensity against the distribution of performance across the sector.

For thermal energy and steam generation facilities, the ENERGY STAR EPI framework benchmarks plants on a 1–100 scale, where a score of 75 or above qualifies for ENERGY STAR certification. The indicator is calculated as:

EPI Score = f(E_{site}, Output, Covariates),

where E_{site} is the site energy consumption, Output is a normalized production metric, and Covariates include factors such as climate zone, operating hours, and product mix that affect energy use independently of management decisions [16, p. 34]. The covariate adjustment is crucial for fair comparison across plants operating under different conditions - a methodological feature absent from simpler intensity-based benchmarks.

Empirical evaluations of the ENERGY STAR programme consistently find positive efficiency effects. Cagno et al. report that ENERGY STAR-certified industrial plants achieve energy intensity levels 10–35% below sector median, with the gap persisting after controlling for plant size, age, and capital intensity. The voluntary nature of the US programme - in contrast to South Korea's mandatory approach - suggests that well-designed benchmarking and certification schemes can drive efficiency improvements even without regulatory compulsion, provided that market and reputational incentives are sufficiently strong.

Conditions of Uzbekistan's Thermal Energy Sector: Diagnostic Assessment

Uzbekistan's thermal energy sector is characterized by several structural features that shape both the need for and the constraints on improving resource efficiency. The sector comprises eleven major thermal power stations with a combined installed capacity of approximately 12.4 GW, all owned or managed by JSC 'Uzbekenergo' or its successor entities following the 2020 sector restructuring. The fuel mix is dominated by natural gas (approximately 83% of generation), with some plants dual-fuelled with fuel oil.

The efficiency performance of Uzbekistan's thermal power fleet has deteriorated significantly relative to design parameters. According to the Ministry of Energy, the average actual heat rate of the major thermal power stations in 2022 was approximately 2,750–3,100 kJ/kWh above design values - a gap attributable to aging equipment, deferred maintenance, suboptimal combustion control, and high auxiliary energy consumption. The State Committee on Statistics reports that industrial energy intensity (energy consumption per unit of industrial output) in Uzbekistan's energy sector remains approximately 2.3 times higher than the OECD average, adjusted for purchasing power parity.

The institutional environment presents both opportunities and constraints. The Presidential Decree No. PP-4707 of 2020 on measures to improve energy efficiency and introduce energy-saving technologies established a legislative basis for mandatory energy audits, energy consumption metering, and energy management requirements for large consumers. However, implementation capacity remains limited: the number of certified energy managers and licensed energy audit organizations is insufficient relative to the sector's scale, and the metrological base for accurate heat-rate measurement requires upgrading.

The financial environment poses additional constraints. The tariff structure for heat and electricity in Uzbekistan has historically been below cost-recovery levels, weakening investment incentives for efficiency improvements. Gradual tariff reform since 2019 has partially addressed this, but the transition to cost-reflective tariffs remains incomplete. Access to concessional financing for energy efficiency investments—a critical enabler in Germany and South Korea—is limited, although multilateral development bank programs (World Bank, Asian Development Bank, EBRD) are beginning to help fill this gap.

Adaptation Framework: Matching International Practices to Uzbekistan's Conditions

Based on the comparative analysis of international experiences and the diagnostic assessment of Uzbekistan's thermal energy sector, a three-tier adaptation framework is proposed. This framework is structured around time horizons and institutional feasibility, drawing on the 'fit-and-stretch' logic of Lall [6]: measures that 'fit' existing institutional capacity are prioritized for immediate implementation. In contrast, those requiring institutional 'stretching' are assigned to medium and long-term tiers.

Tier I - Immediate Measures (1–3 years). The first tier encompasses measures requiring minimal capital investment and achievable within existing institutional capacity. These include: (a) mandatory energy metering and reporting requirements for

all thermal power plants above 50 MW, modelled on Japan's Energy Conservation Act reporting system; (b) establishment of a centralised plant performance database analogous to South Korea's KPX monitoring system, enabling regulatory oversight and peer benchmarking; (c) mandatory appointment of certified Energy Managers at large thermal enterprises, consistent with ISO 50001 requirements and already partially legislated in Uzbekistan's 2020 Presidential Decree; (d) introduction of a standardised heat rate reporting methodology aligned with IEA conventions, replacing the current heterogeneous reporting practices. These measures are administratively feasible and can generate measurable efficiency improvements through operational optimization alone, without major capital expenditure.

Tier II - Medium-term Measures (3–7 years). The second tier involves targeted technological upgrading and regulatory deepening. Key measures include: (a) mandatory heat rate improvement targets for individual plants, differentiated by technology type and age, analogous to China's NEA standards - a target reduction of 5–8% from current levels is technically achievable through combustion optimisation, turbine blade refurbishment, and boiler tube replacement; (b) pilot implementation of ISO 50001-certified energy management systems at two to three major thermal stations, with EBRD or World Bank technical assistance, to generate demonstration effects; (c) introduction of CHP-enabling tariff structures for district heating interconnection, drawing on the German KWKG incentive model adapted to Uzbekistan's district heating infrastructure; (d) establishment of a national energy efficiency fund, capitalised through a small levy on fuel consumption by thermal enterprises, to finance energy audits and technical assistance for smaller operators.

Tier III — Long-term System Transformation (7–15 years). The third tier encompasses system-level transformation requiring substantial capital investment, regulatory reform, and institutional capacity development. Central elements include: (a) large-scale replacement of ageing single-cycle steam turbine units with high-efficiency combined-cycle gas turbine (CCGT) technology — each 1 GW of CCGT replacement reduces annual fuel consumption by approximately 1.2–1.5 billion cubic meters of natural gas at current capacity factors; (b) full implementation of ISO 50001 energy management systems sector-wide, consistent with the German model; (c) introduction of a carbon pricing mechanism or efficiency performance standard that internalises the climate cost of inefficient generation, aligning financial incentives with resource efficiency objectives; (d) development of national energy manager certification infrastructure capable of supplying qualified personnel for a reformed, efficiency-oriented thermal energy sector.

The adaptation framework can be represented analytically as a sequence of resource efficiency improvement functions over time:

$$RE(t) = RE_0 \times (1 + r_I)^{t_1} \times (1 + r_{II})^{t_2} \times (1 + r_{III})^{t_3},$$

where RE(t) is the composite resource efficiency index at time t; RE_0 is the baseline efficiency index; r_I, r_{II}, r_{III} are the efficiency improvement rates achievable through Tier I, II, and III measures, respectively; and t_1, t_2, t_3 are the durations of each tier. Based on international experience parameters, conservative estimates suggest $r_I \approx 0.03–0.05$, $r_{II} \approx 0.05–0.08$, and $r_{III} \approx 0.08–0.12$ per annum, implying a cumulative efficiency gain of 25–40% over a 15-year horizon under full implementation.

4. Conclusion

This study has examined the international experience of Germany, Japan, South Korea, China, and the United States in improving resource efficiency at thermal energy enterprises and assessed the conditions and mechanisms for adapting these practices to Uzbekistan. The following principal conclusions are drawn:

a. International best practices in thermal energy resource efficiency converge on three complementary pillars: technological upgrading (CHP, CCGT, combustion optimization); institutional and regulatory frameworks (mandatory standards, metering, auditing, certification); and market-based incentives (performance-linked tariffs, benchmarking, carbon pricing). No single-pillar approach has

achieved sustained sector-wide improvements without the others, underscoring the systemic nature of effective reform.

b. The heat rate remains the foundational resource efficiency indicator for thermal energy enterprises, complemented by exergy efficiency for diagnostic purposes and by specific CO_2 emissions intensity and specific water consumption for environmental accountability. A comprehensive measurement framework combining these indicators - analogous to the multi-dimensional scorecard proposed in this paper - is a necessary precondition for evidence-based management and regulatory oversight.

c. Uzbekistan's thermal energy sector faces a compound efficiency deficit attributable to aging capital stock, suboptimal operational practices, historically suppressed tariffs, and limited energy management capacity. This deficit is both an economic cost and a policy opportunity: the gap between current and technically achievable performance is wide enough that even partial implementation of international best practices would yield substantial fuel savings, emissions reductions, and operational cost improvements.

d. The proposed three-tier adaptation framework provides a sequenced, institutionally feasible pathway for efficiency reform. Tier I measures (mandatory metering, reporting, energy manager appointment) are achievable within 1–3 years using existing capacity. Tier II measures (heat rate targets, ISO 50001 pilots, CHP tariffs) require 3–7 years and moderate external technical assistance. Tier III measures (CCGT replacement, carbon pricing, sector-wide certification) represent a 7–15 year system transformation agenda requiring sustained policy commitment and substantial investment.

e. Future research should develop empirical verification of the adaptation framework through plant-level case studies, refine the weighting parameters of the composite resource efficiency index for Uzbekistan's specific fuel mix and capacity structure, and assess the financing mechanisms — including green bonds, multilateral concessional lending, and public-private partnerships — best suited to funding the capital-intensive components of the reform agenda.

REFERENCES

[1] International Energy Agency, Energy Efficiency 2023. Paris, France: IEA, 2023. [Online]. Available: https://www.iea.org/reports/energy-efficiency-2023. [Accessed: Feb. 15, 2024].

[2] Ministry of Energy of the Republic of Uzbekistan, Report on the State of Fuel and Energy Resources and Efficiency Indicators of the Energy Sector. Tashkent, Uzbekistan: Ministry of Energy, 2023.

[3] World Bank, Regulatory Indicators for Sustainable Energy (RISE) 2022: Uzbekistan Country Profile. Washington, DC, USA: World Bank Group, 2022.

[4] P. A. Hall and D. Soskice, Varieties of Capitalism: The Institutional Foundations of Comparative Advantage. Oxford, UK: Oxford University Press, 2001.

[5] J. Markard, R. Raven, and B. Truffer, "Sustainability transitions: An emerging field of research and its prospects," Research Policy, vol. 41, no. 6, pp. 955–967, 2012.

[6] S. Lall, "Technology and industrial development in an era of globalisation," in Rethinking Development Economics, H.-J. Chang, Ed. London, UK: Anthem Press, 2003, pp. 277–298.

[7] H. Nissenbaum, Privacy in Context: Technology, Policy, and the Integrity of Social Life. Stanford, CA, USA: Stanford University Press, 2010.

[8] State Committee on Statistics of the Republic of Uzbekistan, Industry of Uzbekistan: Statistical Yearbook 2023. Tashkent, Uzbekistan: Goskomstat, 2023.

[9] T. J. Coelli, D. S. P. Rao, C. J. O'Donnell, and G. E. Battese, An Introduction to Efficiency and Productivity Analysis, 2nd ed. New York, NY, USA: Springer, 2005.

[10] M. Pehnt, M. Cames, C. Fischer, et al., Micro Cogeneration: Towards Decentralized Energy Systems. Berlin, Germany: Springer, 2006.

[11] International Organization for Standardization, ISO 50001:2018 Energy Management Systems — Requirements with Guidance for Use. Geneva, Switzerland: ISO, 2018.
[12] O. Kimura and T. Suzuki, "30 years of solar energy development in Japan: Co-evolution process of technology, policies, and the market," in Proc. Berlin Conf. Human Dimensions of Global Environmental Change, Berlin, Germany, 2006, pp. 1–19.
[13] M. A. Rosen and I. Dincer, "Exergy analysis of waste emissions," International Journal of Energy Research, vol. 23, no. 13, pp. 1153–1163, 1999.
[14] S. Park and J. Kim, "The effect of real-time monitoring on power plant efficiency: Evidence from South Korea," Energy Policy, vol. 135, Art. no. 111014, 2019.
[15] S. Zhang, P. Andrews-Speed, X. Zhao, and Y. He, "Interactions between renewable energy policy and fossil energy security in China," Energy Policy, vol. 62, pp. 342–353, 2013.
[16] U.S. Environmental Protection Agency, ENERGY STAR Guidelines for Energy Management, 7th ed. Washington, DC, USA: US EPA, 2020.
[17] E. Cagno, E. Worrell, A. Trianni, and G. Pugliese, "A novel approach for barriers to industrial energy efficiency," Renewable and Sustainable Energy Reviews, vol. 19, pp. 290–308, 2013.