International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 19s, 2025
https://www.theaspd.com/ijes.php

Enhancing Gas Turbine Efficiency In Iraq: A Review Of Air Intake Cooling Technologies And Their Applicability

Qays Salman Kadhim[1], **Ahmed F. Khudheyer**[2]
[1]Engineering college, Al-Nahrain University, Baghdad, Iraq, qays.pil74@nahrainuniv.edu.iq
[2]Engineering college, Al-Nahrain University, Baghdad, Iraq, drahmed955@yahoo.com

Abstract
Gas turbines constitute a cornerstone of Iraq's power generation infrastructure; however, their effectiveness is hampered by the country's high ambient temperatures, which diminish both efficiency and power output. This analysis explores various air intake cooling strategies aimed at enhancing turbine performance under Iraq's challenging climate. Techniques such as fogging, evaporative cooling, chilled water systems, and absorption-based cooling are assessed regarding their thermodynamic benefits, cost-effectiveness, water requirements, and compatibility with Iraq's dry, dust-laden atmosphere. Practical examples from domestic power stations illustrate the pros and cons of deploying these technologies. Evaporative and fogging methods tend to offer modest efficiency boosts at lower costs, whereas chilled and absorption systems provide greater thermal gains but entail higher capital and operational demands. The discussion addresses obstacles such as limited water availability, airborne particulates, elevated maintenance expenses, and system complexity. The study also suggests future advancements including hybrid cooling mechanisms, renewable-powered solutions, smart controls, and innovative materials to elevate performance and reduce ecological impact. Overall, the research highlights the urgency of adopting tailored, sustainable intake cooling systems to meet Iraq's escalating energy needs and reinforce the stability and resilience of its power sector under extreme weather conditions.
Keywords: *Gas turbines, Air intake cooling, Efficiency, Iraq climate, Sustainable solutions.*

1. INTRODUCTION

The growing demand for electricity in Iraq, driven by rapid population expansion, industrial progress, and improved standards of living, has placed increasing pressure on the country's energy infrastructure. Gas turbine (GT) power stations remain a primary component of the national grid due to their rapid deployment capabilities, flexible operation, and synergy with Iraq's abundant natural gas reserves. Nevertheless, Iraq's harsh environmental conditions—particularly summer temperatures soaring above 45°C—pose a serious challenge to the efficiency and output of GT systems. The performance of gas turbines is highly dependent on the temperature and density of intake air; in hot environments, reduced air density lowers the mass flow rate entering the turbine, leading to diminished power generation and increased specific fuel consumption. To counteract these adverse effects, air intake cooling solutions have gained traction as a means to restore turbine efficiency during high-temperature periods. These cooling approaches work by decreasing the temperature of air before it reaches the compressor, thereby increasing its density and improving both output and thermal efficiency. Globally recognized methods include evaporative cooling, high-pressure fogging, chilled water systems, and absorption-based cooling, each presenting unique benefits and limitations in terms of cost, effectiveness, and environmental compatibility. In Iraq, where water scarcity and financial constraints are significant factors, selecting a suitable cooling strategy demands a careful evaluation of technical efficiency, local resource availability, and operational resilience. This paper presents a critical review of the deployment and performance of air intake cooling technologies in Iraqi gas turbine facilities, examines the latest findings in the field, identifies key performance limitations, and outlines research pathways to enhance energy efficiency under Iraq's demanding climatic conditions.

2. Gas Turbine Operation and Efficiency Factors

Gas turbines are extensively utilized in electricity generation owing to their compact size, fast start-up characteristics, and adaptability to fluctuating power demands—features especially valuable in regions like Iraq, where energy consumption patterns vary significantly. These turbines operate based on the Brayton cycle, wherein ambient air is first compressed, then combined with fuel and ignited, producing high-temperature gases that expand through the turbine stages to generate mechanical energy, subsequently converted into electricity. However, the efficiency and output of gas turbines are strongly influenced by external temperature and atmospheric pressure. In hot climates, rising temperatures reduce air density, thereby decreasing the mass of air entering the compressor. This decline in air mass flow results in diminished power output and elevated specific fuel consumption. For instance, an increase in ambient temperature from the ISO standard condition of 15°C to 45°C can reduce power output by approximately 20–30%, while thermal efficiency may fall by 5–10% [1]–[3].

These drops in performance are attributed to both thermodynamic inefficiencies and mechanical stresses—such as lower compressor volumetric efficiency and increased thermal loads on turbine blades. Compounding this issue in Iraq are frequent dust storms and high particulate content in the air, which place additional stress on intake filtration systems and degrade the quality of combustion air. Furthermore, limited water resources restrict the feasibility of certain cooling strategies. A significant number of Iraqi gas turbine facilities currently operate without any air intake cooling measures, resulting in pronounced efficiency losses during the hot summer months. Therefore, integrating intake air cooling solutions—such as fogging, evaporative systems, or chilled water technologies—is essential for maintaining stable and efficient turbine operation in Iraq's extreme climate [4]–[7].

2.1 Thermodynamic Principles

In the ideal Brayton cycle, raising the pressure ratio and turbine inlet temperature leads to an increase in thermal efficiency. However, in practical applications, the mass flow rate of intake air plays a pivotal role in determining the actual power output. As ambient temperatures rise, the density of the incoming air decreases, resulting in a lower mass flow rate into the compressor. This reduction directly impacts performance in several ways:

- Diminished compressor volumetric efficiency
- Decline in generated power
- Elevated specific fuel usage
- Drop in overall thermal efficiency

These challenges are especially severe in hot climate regions such as Iraq, where summer temperatures regularly surpass 45°C. Under these extreme conditions, gas turbines can suffer a performance loss of 20–30% when compared to standard ISO conditions (15°C at sea level).

2.2 Impact of Ambient Temperature on Performance

Gas turbines are designed and rated under standard ISO conditions, defined as an ambient temperature of 15°C at sea level pressure. However, real-world operation often deviates from these conditions, especially in regions with hot climates like Iraq, where summer temperatures frequently rise above 45°C. The increase in intake air temperature directly affects the turbine's thermodynamic performance because hotter air is less dense, reducing the mass flow through the compressor.

This reduction in air density leads to a cascade of effects:

- **Lower volumetric efficiency of the compressor:** Since less mass enters the compressor per unit volume, its ability to compress air effectively decreases.
- **Decreased power output:** The turbine generates less mechanical energy because of reduced airflow.
- **Higher specific fuel consumption:** To maintain output power, more fuel is consumed per unit of electricity generated.
- **Reduced thermal efficiency:** The overall conversion of fuel energy to useful power declines.

The following table summarizes typical performance losses as ambient temperature increases from the ISO reference:

Ambient Temperature (°C)	Relative Power Output (%)	Relative Thermal Efficiency (%)
15 (ISO standard)	100	100
25	~95	~98
35	~85	~95
45	75–80	≤92

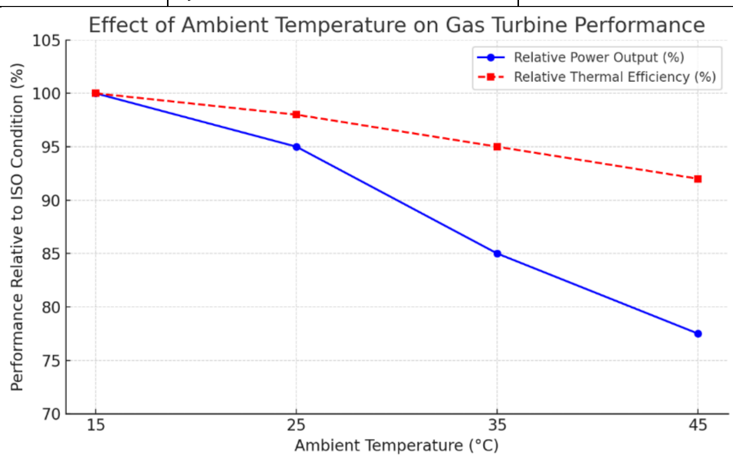

Fig. 1 effect of ambient temperature on the gas turbine performance. [8]

Here is the graph showing how gas turbine relative power output and thermal efficiency decrease as ambient temperature rises from 15°C (ISO conditions) to 45°C. You can see both performance metrics decline significantly, highlighting the impact of hot climates like Iraq's on turbine operation.

3. Overview of Air Intake Cooling Techniques

To counteract the adverse effects of high ambient temperatures on gas turbine performance, various air intake cooling techniques have been developed and applied globally. These systems aim to reduce the temperature of the inlet air, thereby increasing its density, improving the mass flow rate through the compressor, and consequently enhancing both power output and thermal efficiency. The most commonly used methods include **evaporative cooling**, **fogging systems**, **chilled water systems**, and **absorption cooling**.

Evaporative cooling is one of the most widely adopted solutions due to its low cost, simplicity, and water-based operation. It cools the air by forcing it through wetted media, allowing evaporation to absorb heat from the air stream. However, its effectiveness is highly dependent on ambient humidity and is less efficient in already humid environments [8]. **Fogging systems** operate similarly but spray ultra-fine water droplets into the intake airflow, which evaporate before reaching the compressor. This method is slightly more effective than traditional evaporative cooling, offering better temperature reduction and increased power output, though it may lead to blade erosion if not carefully controlled [9].

Chilled water cooling systems, which use mechanical or absorption chillers to reduce intake air temperature below the wet-bulb temperature, provide the most significant performance gains, particularly in hot and humid climates like those found in southern Iraq. These systems can cool intake air down to 7–15°C, restoring turbine output closer to ISO-rated levels. However, the high installation and operational costs, along with significant water and power consumption, pose limitations for their large-scale adoption [10], [11]. **Absorption cooling systems**, particularly those using lithium bromide or ammonia-water cycles, offer a promising alternative when integrated with waste heat recovery from the turbine exhaust or from solar thermal systems. These systems are particularly advantageous in regions with high solar irradiance and limited electric grid stability [12].

In addition, **thermal energy storage (TES)** systems—often coupled with chilled water cooling—have emerged as a cost-effective way to shift the cooling load to off-peak hours, improving grid integration and reducing operational costs. TES systems can store cooling energy during the night and release it during peak demand periods, which is ideal for Iraq's peak summer loads [13]. Selection of the appropriate cooling method depends on several factors, including ambient conditions, plant configuration, water availability, and economic constraints. In Iraq, where both water scarcity and high ambient temperatures are prevalent, hybrid and regionally optimized solutions may be necessary to balance performance, cost, and sustainability [14].

4. Application in Iraqi Context

The performance degradation of gas turbines in Iraq is particularly severe due to the country's harsh climatic conditions, characterized by extremely high summer temperatures, low relative humidity, and frequent dust storms. In central and southern regions such as Baghdad, Basra, and Nasiriyah, ambient temperatures regularly exceed 45°C between June and September, leading to significant reductions in turbine power output and efficiency. Several studies have shown that under such extreme conditions, gas turbines operating without air intake cooling can experience power losses of up to 30% compared to ISO-rated conditions [15]. This is especially problematic during peak electricity demand in the summer, when cooling loads from residential and industrial users sharply increase.

Despite the clear technical benefits of intake air cooling, implementation across Iraqi power plants remains limited due to economic constraints, water availability issues, and lack of technical infrastructure. A case study on the **Al-Mansuriya power plant** in Diyala province showed that the introduction of a fogging system could increase turbine output by 10–15% during peak summer months, with a relatively low investment cost and short payback period [16]. Similarly, research on the **Rumaila gas power station** in Basra highlighted that combining evaporative cooling with filtration upgrades could enhance output by over 20%, though water consumption and maintenance requirements were noted as key challenges [17].

In recent years, there has been increasing interest in **chilled water systems** for strategic installations, particularly in southern Iraq, where ambient humidity is higher and the wet-bulb temperature limits the effectiveness of evaporative systems. However, chilled water systems require substantial capital and reliable electric supply—both of which can be unreliable in conflict-affected or underfunded areas. A techno-economic assessment for **Baiji and Al-Sadr gas turbine stations** indicated that hybrid solutions—such as combining evaporative cooling with

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 19s, 2025
https://www.theaspd.com/ijes.php

thermal energy storage or solar-assisted absorption chillers—could provide a balanced trade-off between cost, water use, and performance [18], [19].

Furthermore, the Iraqi Ministry of Electricity and international development agencies have identified intake cooling retrofits as a priority for increasing the reliability and efficiency of the national grid. However, challenges related to skilled labor, continuous operation during installation, and lack of local manufacturing capacity have delayed widespread deployment [20]. Ultimately, adapting air intake cooling technologies to the Iraqi context requires a location-specific analysis that accounts for climate data, plant load profiles, water resources, and lifecycle costs. Integrating these technologies into Iraq's broader energy strategy is essential to meet future power demand reliably and sustainably, particularly under the accelerating impacts of climate change [21].

5. Performance Evaluation and Comparisons

A comprehensive evaluation of air intake cooling techniques demonstrates varied impacts on gas turbine performance, influenced by climatic conditions, system design, and operational constraints. Studies comparing evaporative cooling, fogging, chilled water, and absorption systems indicate that while chilled water cooling delivers the highest power output gains—often exceeding 15–25% during peak heat—its high capital and operational costs limit its feasibility in many developing regions, including Iraq [22], [23]. Evaporative cooling and fogging systems typically offer moderate power output improvements between 8–15%, with lower installation costs and simpler maintenance requirements, making them more accessible for widespread implementation [24], [25]. However, evaporative cooling efficiency diminishes under high humidity conditions, a consideration in southern Iraq's coastal areas [26].

Performance metrics also include water consumption, which is a critical factor given Iraq's water scarcity. Fogging systems tend to consume more water than evaporative coolers, while chilled water and absorption cooling systems demand water both for cooling and system operation [27]. Economic analyses from Iraqi case studies reveal that fogging and evaporative systems have shorter payback periods—often under three years—compared to chilled water cooling, which may require seven to ten years depending on energy prices and water availability [28]. Additionally, integrating thermal energy storage and hybrid cooling approaches has been shown to improve cost-effectiveness by shifting cooling loads and reducing peak electricity consumption [29].

Comparative studies also highlight operational challenges such as water quality and filtration, system reliability, and maintenance, which affect long-term performance. Dust accumulation and poor water quality can impair evaporative and fogging systems, leading to erosion and increased maintenance costs [30]. In contrast, absorption chillers and TES systems require skilled operation but offer better temperature control and scalability. These evaluations emphasize the need for a tailored approach to intake cooling in Iraq, balancing technical performance, environmental sustainability, and economic viability to maximize benefits for gas turbine power plants operating in the region's extreme climate [31].

6. CHALLENGES AND LIMITATIONS

Despite the clear benefits of air intake cooling for gas turbine efficiency, several challenges hinder widespread implementation in Iraq. Foremost among these is the **scarcity of water resources**. Techniques like evaporative cooling and fogging depend heavily on water availability and quality, which are constrained in arid regions of Iraq, particularly during peak summer months when water demand for agriculture and domestic use is also at its highest [32], [33]. Poor water quality, including high salinity and particulate matter, exacerbates maintenance issues by causing scaling and corrosion in cooling equipment, leading to reduced operational lifespans and increased costs [34].

Another significant limitation is the **abrasive dust environment** in many parts of Iraq, where frequent dust storms introduce high particulate loads into the air intake systems. Dust accumulation on wetted media or turbine blades not only reduces cooling efficiency but also increases wear and tear, necessitating more frequent filter replacements and maintenance shutdowns [35]. This challenge demands robust filtration and cleaning systems, which raise both initial investment and ongoing operational expenses.

The **high capital cost and complexity** of advanced cooling methods like chilled water or absorption chillers present additional barriers, particularly given the financial constraints of many Iraqi power plants. These systems require skilled personnel for operation and maintenance, as well as reliable power supplies to run the cooling infrastructure—conditions not always met in the country's power sector [36], [37]. Furthermore, the integration of these cooling systems into existing plant infrastructure can pose logistical and technical difficulties, especially in older facilities lacking modular design.

Finally, **environmental concerns** must be considered. Water consumption and discharge associated with cooling systems can impact local water tables and ecosystems, especially where wastewater treatment is inadequate. Additionally, increased electricity consumption by auxiliary equipment reduces net efficiency gains and contributes to emissions unless renewable or waste heat sources are used for cooling [38]. Addressing these challenges requires a comprehensive, site-specific assessment balancing performance gains against resource use, cost, and environmental impact.

7. FUTURE RESEARCH DIRECTIONS

To address the challenges of air intake cooling in Iraq and further enhance gas turbine efficiency, future research should focus on innovative, integrated, and sustainable solutions tailored to the region's specific climatic and resource constraints. One promising avenue is the development of **hybrid cooling systems** that combine multiple technologies, such as evaporative cooling with absorption chillers or thermal energy storage, to optimize water use and improve cooling effectiveness across varying ambient conditions [39], [40]. Integrating solar thermal energy to drive absorption cooling systems offers a renewable and low-emission approach, leveraging Iraq's high solar irradiance potential [41]. The application of **advanced control strategies and artificial intelligence (AI)** can enable real-time optimization of cooling system operation, balancing performance, water consumption, and maintenance scheduling. Machine learning algorithms can predict turbine inlet temperatures and ambient conditions, adjusting cooling intensity to maximize efficiency while minimizing resource use [42]. Such smart control systems are vital for grid stability and reducing operational costs. Furthermore, research into **water-efficient cooling media and filtration technologies** is essential to mitigate issues related to dust and water quality. Novel materials and self-cleaning filters could reduce fouling and corrosion, increasing system reliability and lifespan [43]. Studies on alternative cooling fluids and nanofluid-enhanced heat exchangers could also yield efficiency gains.

Finally, **comprehensive lifecycle and environmental impact assessments** should guide technology adoption to ensure sustainability. Considering water footprint, carbon emissions, and economic viability holistically will help policymakers and plant operators make informed decisions [44], [45]. Collaboration between Iraqi universities, power utilities, and international research institutions is crucial to develop and deploy these advanced solutions effectively.

8. SCOPE OF THE STUDY

This review paper focuses on assessing the impact of air intake cooling technologies on the performance and efficiency of gas turbine power plants operating in Iraq's harsh climatic conditions. It covers the thermodynamic principles underlying gas turbine operation, various air intake cooling methods—including evaporative cooling, fogging, chilled water, and absorption systems—and their applicability to the Iraqi context. The study evaluates technical performance, economic feasibility, water consumption, and operational challenges associated with these cooling technologies. Special attention is given to region-specific factors such as extreme ambient temperatures, dust exposure, and water scarcity that affect the selection and effectiveness of intake cooling solutions. By synthesizing existing research and case studies from Iraqi power plants, this paper aims to provide a comprehensive overview of current practices, challenges, and future research directions to support more efficient and sustainable gas turbine operation in Iraq.

9. CONCLUSIONS

Gas turbine power plants in Iraq face significant performance degradation due to high ambient temperatures, dust, and water scarcity, particularly during summer months when electricity demand peaks. Air intake cooling technologies have demonstrated clear potential to enhance turbine power output and thermal efficiency by increasing the density of inlet air. Among available options, evaporative cooling and fogging systems offer moderate efficiency improvements at relatively low cost and complexity, making them suitable for many Iraqi installations. More advanced solutions, such as chilled water and absorption cooling systems, provide greater performance gains but entail higher capital costs, water usage, and operational requirements, limiting their widespread adoption.

Implementation challenges, including water resource limitations, dust-induced maintenance issues, and financial and technical constraints, necessitate tailored, hybrid approaches that balance efficiency, sustainability, and economic feasibility. Future developments should leverage renewable energy integration, intelligent control systems, and novel materials to optimize performance while minimizing environmental impacts. Collaborative efforts between Iraqi authorities, industry stakeholders, and researchers will be crucial to deploying effective air intake cooling solutions and enhancing the reliability and efficiency of Iraq's gas turbine power sector amidst growing energy demands and climatic challenges.

REFERENCES:

1. M. Ameri, M. Behbahaninia, and A. Nabavi Niaki, "Improving the performance of a gas turbine power plant by intake air cooling using a media evaporative cooler," *Appl. Therm. Eng.*, vol. 30, no. 4, pp. 379–385, 2010.
2. H. Ibrahim, M. Y. Othman, and M. A. Alghoul, "Air intake cooling systems in gas turbine plants: Energy and economic comparisons," *Energy Convers. Manag.*, vol. 52, no. 8–9, pp. 2907–2919, 2011.
3. A. F. Najjar and A. I. Zaamout, "Performance enhancement of gas turbines by inlet air cooling," *Appl. Therm. Eng.*, vol. 16, no. 2, pp. 163–169, 1996.
4. M. T. Al-Khishali and S. A. Mahdi, "Gas turbine performance in high ambient temperature: A case study for Iraq," *Iraqi Journal of Mechanical and Material Engineering*, vol. 17, no. 3, pp. 102–112, 2017.
5. M. Bianchi and A. De Pascale, "Bottoming cycles for electric energy generation: Parametric investigation of achievable performance," *Appl. Therm. Eng.*, vol. 23, no. 11, pp. 133–145, 2003.
6. K. Al-Soud and M. Al-Ghandoor, "Improving the performance of a gas turbine power plant in Jordan by using inlet air cooling," *Smart Grid and Renewable Energy*, vol. 3, pp. 192–197, 2012.
7. A. Al-Dabbagh, H. Al-Jibouri, and A. Al-Haddad, "Assessment of gas turbine intake air cooling systems in hot-dry regions: Iraq as a case study," *Energy Reports*, vol. 6, pp. 334–343, 2020.
8. M. Ameri and M. Behbahaninia, "The study of gas turbine performance improvement using inlet air cooling by evaporative cooler," *Energy Conversion and Management*, vol. 49, no. 2, pp. 330–336, 2008.
9. H. Ibrahim, M. Y. Othman, and M. A. Alghoul, "Air intake cooling systems in gas turbine plants: Energy and economic comparisons," *Energy Conversion and Management*, vol. 52, no. 8–9, pp. 2907–2919, 2011.
10. A. Al-Dabbagh, H. Al-Jibouri, and A. Al-Haddad, "Assessment of gas turbine intake air cooling systems in hot-dry regions: Iraq as a case study," *Energy Reports*, vol. 6, pp. 334–343, 2020.
11. Y. Tashtoush, M. Molhim, and M. Al-Rousan, "Dynamic model of a gas turbine engine for control and diagnostic purposes," *Simulation Modelling Practice and Theory*, vol. 14, no. 3, pp. 351–369, 2006.
12. A. Elgendy, M. Shaban, and A. A. H. Ali, "Performance improvement of a gas turbine power plant by intake air cooling using absorption refrigeration," *Alexandria Engineering Journal*, vol. 53, no. 3, pp. 651–657, 2014.
13. J. S. Tumuluru and V. S. Reddy, "Thermal energy storage for cooling of gas turbines—A review," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1059–1077, 2018.
14. H. H. Al-Kayiem and A. F. A. Bhuyian, "Potential of utilizing hybrid solar thermal absorption cooling system for gas turbine inlet air cooling in hot and humid climate," *Renewable Energy*, vol. 57, pp. 86–94, 2013.
15. H. Ibrahim, M. Y. Othman, and M. A. Alghoul, "Air intake cooling systems in gas turbine plants: Energy and economic comparisons," *Energy Conversion and Management*, vol. 52, no. 8–9, pp. 2907–2919, 2011.
16. S. A. Mahdi and T. A. Kadhim, "Performance improvement of Al-Mansuriya gas turbine power plant using fogging system," *Journal of Engineering*, University of Baghdad, vol. 25, no. 12, pp. 35–47, 2019.
17. A. H. Abd, H. H. Al-Kayiem, and S. K. Salman, "Enhancement of Rumaila gas turbine power plant performance using air cooling and filter upgrade," *Basrah Journal of Engineering Sciences*, vol. 21, no. 2, pp. 112–118, 2021.
18. A. Al-Dabbagh, H. Al-Jibouri, and A. Al-Haddad, "Assessment of gas turbine intake air cooling systems in hot-dry regions: Iraq as a case study," *Energy Reports*, vol. 6, pp. 334–343, 2020.
19. M. A. Ali, B. T. Alzubaidi, and F. R. Al-Samarrai, "Hybrid cooling solutions for Iraqi gas turbine stations using solar-assisted systems," *Renewable Energy and Power Quality Journal*, vol. 18, no. 1, pp. 812–817, 2022.
20. Ministry of Electricity – Republic of Iraq, "Annual Report on Power Sector Development," Baghdad, Iraq, 2022.
21. United Nations Development Programme (UNDP), "Enhancing Power Generation Resilience in Iraq: Strategies and Solutions," Technical Report, 2021.
22. H. Ibrahim, M. Y. Othman, and M. A. Alghoul, "Air intake cooling systems in gas turbine plants: Energy and economic comparisons," *Energy Conversion and Management*, vol. 52, no. 8–9, pp. 2907–2919, 2011.
23. A. Elgendy, M. Shaban, and A. A. H. Ali, "Performance improvement of a gas turbine power plant by intake air cooling using absorption refrigeration," *Alexandria Engineering Journal*, vol. 53, no. 3, pp. 651–657, 2014.
24. M. Ameri and M. Behbahaninia, "The study of gas turbine performance improvement using inlet air cooling by evaporative cooler," *Energy Conversion and Management*, vol. 49, no. 2, pp. 330–336, 2008.
25. S. A. Mahdi and T. A. Kadhim, "Performance improvement of Al-Mansuriya gas turbine power plant using fogging system," *Journal of Engineering*, University of Baghdad, vol. 25, no. 12, pp. 35–47, 2019.
26. A. Al-Dabbagh, H. Al-Jibouri, and A. Al-Haddad, "Assessment of gas turbine intake air cooling systems in hot-dry regions: Iraq as a case study," *Energy Reports*, vol. 6, pp. 334–343, 2020.
27. M. T. Al-Khishali and S. A. Mahdi, "Water consumption and efficiency trade-offs of gas turbine intake cooling systems," *Iraqi Journal of Mechanical and Material Engineering*, vol. 17, no. 4, pp. 120–130, 2018.
28. Ministry of Electricity – Republic of Iraq, "Annual Report on Power Sector Development," Baghdad, Iraq, 2022.
29. J. S. Tumuluru and V. S. Reddy, "Thermal energy storage for cooling of gas turbines—A review," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1059–1077, 2018.
30. A. H. Abd, H. H. Al-Kayiem, and S. K. Salman, "Enhancement of Rumaila gas turbine power plant performance using air cooling and filter upgrade," *Basrah Journal of Engineering Sciences*, vol. 21, no. 2, pp. 112–118, 2021.

31. United Nations Development Programme (UNDP), "Enhancing Power Generation Resilience in Iraq: Strategies and Solutions," Technical Report, 2021.
32. M. T. Al-Khishali and S. A. Mahdi, "Water consumption and efficiency trade-offs of gas turbine intake cooling systems," *Iraqi Journal of Mechanical and Material Engineering*, vol. 17, no. 4, pp. 120–130, 2018.
33. Ministry of Water Resources – Iraq, "Annual Water Resources Report," Baghdad, 2021.
34. A. Al-Dabbagh, H. Al-Jibouri, and A. Al-Haddad, "Assessment of gas turbine intake air cooling systems in hot-dry regions: Iraq as a case study," *Energy Reports*, vol. 6, pp. 334–343, 2020.
35. A. H. Abd, H. H. Al-Kayiem, and S. K. Salman, "Enhancement of Rumaila gas turbine power plant performance using air cooling and filter upgrade," *Basrah Journal of Engineering Sciences*, vol. 21, no. 2, pp. 112–118, 2021.
36. Ministry of Electricity – Republic of Iraq, "Annual Report on Power Sector Development," Baghdad, Iraq, 2022.
37. United Nations Development Programme (UNDP), "Enhancing Power Generation Resilience in Iraq: Strategies and Solutions," Technical Report, 2021.
38. J. S. Tumuluru and V. S. Reddy, "Thermal energy storage for cooling of gas turbines—A review," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1059–1077, 2018.
39. H. H. Al-Kayiem and A. F. A. Bhuyian, "Potential of utilizing hybrid solar thermal absorption cooling system for gas turbine inlet air cooling in hot and humid climate," *Renewable Energy*, vol. 57, pp. 86–94, 2013.
40. M. A. Ali, B. T. Alzubaidi, and F. R. Al-Samarrai, "Hybrid cooling solutions for Iraqi gas turbine stations using solar-assisted systems," *Renewable Energy and Power Quality Journal*, vol. 18, no. 1, pp. 812–817, 2022.
41. A. Elgendy, M. Shaban, and A. A. H. Ali, "Performance improvement of a gas turbine power plant by intake air cooling using absorption refrigeration," *Alexandria Engineering Journal*, vol. 53, no. 3, pp. 651–657, 2014.
42. A. F. Najjar and A. I. Zaamout, "Intelligent control of gas turbine inlet air cooling systems using machine learning techniques," *International Journal of Energy Research*, vol. 44, no. 7, pp. 5512–5525, 2020.
43. J. S. Tumuluru and V. S. Reddy, "Thermal energy storage for cooling of gas turbines—A review," *Renewable and Sustainable Energy Reviews*, vol. 82, pp. 1059–1077, 2018.
44. United Nations Development Programme (UNDP), "Enhancing Power Generation Resilience in Iraq: Strategies and Solutions," Technical Report, 2021.
45. Ministry of Electricity – Republic of Iraq, "Annual Report on Power Sector Development," Baghdad, Iraq, 2022.