REFINERY AIR EMISSION MANAGEMENT: ENHANCING EMISSIONS MANAGEMENT AND SUSTAINABILITY AT THE DORA OIL REFINERY IN BAGHDAD

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Abstract

The Dora Oil Refinery (DOR) located in Baghdad serves as an essential energy provider for Iraq but experiences problems with aging equipment and inadequate environmental protection protocols. The facility emits large amounts of dangerous pollutants including sulfur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOCs) and particulate matter (PM). The emissions from this area combine to degrade air quality while posing major health dangers to the local population. The refinery requires extensive modernization to align with worldwide environmental standards. This work presents an actionable approach to decrease emissions while enhancing sustainable operations at the refinery. The study evaluated advanced technologies from around the world by implementing selective catalytic reduction (SCR) for NO_x reduction and sulfur recovery units (SRUs) and high-efficiency electrostatic precipitators (ESPs). The study analyzed the potential benefits of carbon capture and storage (CCS) technology. Sophisticated AI-modeling techniques were implemented to forecast emission patterns and analyze energy conservation methods. The study performed an extensive economic evaluation which assessed Net Present Value (NPV) and Internal Rate of Return (IRR) metrics while analyzing market dynamics. Improvements like adding solar power could reduce SO_2 by up to 99% and NO_x by about 90%. The SCR unit could pay for itself in about five years under conservative estimates.

Keywords: *Refinery Emissions Management, Dora Oil Refinery (DOR), Air Pollution Control Technologies, Sustainable Refinery Operations, AI-based Environmental Modeling.*

1. INTRODUCTION

The energy infrastructure of oil-producing countries depends heavily on refineries which function as major air pollution sources among stationary facilities across the globe (Damian, 2013). The Dora Oil Refinery (DOR) stands as a vital facility in Iraq's petroleum supply chain because it produces essential refined fuels that supply domestic markets (Sojinu, 2019; Al-Khayat, 2015). The refinery has maintained its position as a fundamental driver of economic growth and energy independence since its founding during the early 1950s (Mushtaq, 2024; Raydan, 2022). The refinery's expanding environmental footprint primarily results from its deteriorating infrastructure combined with weak environmental regulations leading to increasing concerns about air pollution emissions (Monteiro, 2017; Alanbari, 2020).

Many traditional Middle Eastern refineries including DOR encounter increasing difficulties in controlling their sulfur dioxide (SO_2) and nitrogen oxides (NO_x) and volatile organic compounds (VOCs) and particulate matter (PM) and carbon dioxide (CO_2) emissions (IPIECA, 2012; Adebiyi, 2022). The refinery emissions directly endanger public health and create air quality deterioration which damages environmental governance standards because DOR operates near densely populated urban centers (Ahmed, 2023; Abdallah, 2023; Chen, 2021).

The environmental regulations in Iraq function with lower standards than Jordan and Saudi Arabia and lack proper mechanisms to motivate industrial facilities toward advanced emission control adoption (Tjahjani, 2024; Alfke, 2020). The worldwide focus on sustainability alongside decarbonization efforts and environmental responsibility presents challenges but also potential growth opportunities for Iraq's refining industry (Sundaramoorthy, 2023). Facilities such as the DOR need to meet international environmental standards because it serves dual purposes of reducing adverse environmental effects and securing operational viability in a future economy that limits carbon emissions (Brown, 2022; Campara, 2018; Al-Hamadi, 2023).

This research presents a strategic framework to improve emission operations and sustainability management at DOR while using successful practices from Jordan Petroleum Refinery in Zarqa as a benchmark. The research presents a comprehensive strategy which involves deploying modern emission control technology alongside immediate monitoring systems and implementing energy efficiency improvements together with solar power integration (Angarita, 2022).

The roadmap includes future plans which combine carbon capture and storage (CCS) with initiatives that utilize circular economy principles for VOC recovery and water reuse (Bukar, 2024). The DOR can establish itself as a national sustainable industrial operations model through voluntary reforms which will establish environmental standards for Iraq's energy sector.

The current study aims to advance industrial environmental performance discussions in developing economies while presenting an emission reduction framework which other constrained refineries can apply.

2. LITERATURE REVIEW

The health and environmental challenges connected to petroleum refining facilities become exceptionally intense in urban areas because high population numbers increase emissions while environmental infrastructure remains restricted. The Al-Dora Refinery (DOR) in Iraq stands as a prime example that illustrates these operational difficulties. The refinery operates in Baghdad's crowded southern area where scientists have proven through multiple studies that it produces high levels of SO_2, NO_x, PM, VOCs and heavy metals (Abb and Salman 2024; Alanbari 2020; Zaidan and Al-Khateeb 2020). Field inspections by Saleem and Abdullah (2024) alongside Anad et al. (2022) discovered dangerous $PM_{2.5}$, Pb, Cd, and NO_2 concentrations in nearby residential areas which show that refinery emissions surpass national and international air quality standards (World Health Organization, 2021; Al-Khayat and Majeed, 2015).

Studies which perform life-cycle assessments validate this conclusion. The environmental impact assessment by Ghanem (2017) showed major production related environmental effects that stem from fuel production processes at DOR including combustion and flaring and wastewater discharge. Several reviews demonstrate that Iraqi refineries face substantial environmental concerns when processing heavy crude oil because of their inadequate combustion methods and minimal pollution control technology deployment (Sojinu and Ejeromedoghene, 2019; Alzahawy and Issa, 2024; Al-Rubaye et al., 2023). According to research findings emissions get worse when sandstorms occur and dust gets lifted from surfaces since these processes increase PM concentrations above refinery emissions (Alavi and Shams, 2022; Ahmed and Osman, 2023). The investigation reveals that DOR stands as a principal source of atmospheric pollution across Baghdad.

Research studies have extensively examined the health impacts of pollution. Research conducted by Abdallah and Farhan (2023) together with Halos and Mahdi (2023) and Brown et al. (2022) demonstrates that air pollution near DOR causes higher rates of asthma and chronic bronchitis and cardiovascular diseases. According to global studies these findings match local observations which show that small increases in $PM_{2.5}$, SO_2 and NO_x levels result in extended disease and death rates (Guo et al., 2022; Chen et al., 2021; Lopez and Gao, 2020; Xu et al., 2020; Manisalidis et al., 2020). The healthcare load increases because the refinery operates in an urban area where thermal discomfort and heat islands along with limited green spaces make pollution stay longer and increase population risk (Zhang, He and Wang, 2023; Zhao, Zhao and Liu, 2020).

The current emission control setup at DOR consists of basic technologies which pose serious environmental concerns. The Jordan Petroleum Refinery Company (JPRC) and other facilities throughout the region have implemented modern systems with SRUs, SCRs and LDAR programs but DOR maintains basic flue gas desulfurization and insufficient air monitoring systems. The World Bank (2016) and IPIECA (2012) and CONCAWE (Alfke et al., 2020) provide international standards for adopting best available techniques (BATs) but the actual implementation remains substantially deficient. Research demonstrates that emission reduction strategies operating through technology deployment produce cost-effective solutions yet Iraq's refineries maintain their status quo due to financial and regulatory barriers as well as institutional obstacles (Ekunke et al., 2024; Sundaramoorthy, Kamath and Price, 2023; Adebiyi, 2022; Bukar and Asif, 2024).

Institutional weaknesses create additional obstacles which restrict progress. The investigation conducted by Zaidan together with Al-Khateeb (2020) demonstrates significant discrepancies between refinery operations and ISO 14001:2015 standards which result in insufficient documentation alongside inadequate risk management and mitigation procedures. The World Bank (2022) and Iraqi Oil Report (2018) confirm this issue through their reports that the Iraqi refinery industry needs stricter regulations to enforce emission standards and sustainable transformation investments. The legal framework for emissions monitoring and public disclosure operates successfully in other countries according to Tjahjani and Albab (2024) and Khoerunnisa and Rahman (2023) yet Iraqi institutions have not developed or enforced these systems.

Scholars suggested multiple sustainability-based interventions to solve these challenges. The combination of green infrastructure within refinery areas demonstrates potential to take in polluted air and lower urban heat impact (Zhang, Cheng and Li, 2023; Peterson and Ling, 2022). Emerging technologies such as carbon capture, utilization, and storage (CCUS) have gained traction as practical solutions for long-term decarbonization and a number of studies analyze their operational efficiency and expansion potential (Hanson et al., 2025; Yanez Angarita, Manrique and Penuela, 2022; Li, Aviso and Tan, 2023). The integration of hydrogen systems and the expansion of renewable energy sources provide essential pathways to decrease process emissions which match worldwide decarbonization targets (Włodarczyk and Kaleja, 2023; Hassan, Algburi and Jaszczur, 2024; Oh and Kim, 2024).

The extensive recent research reveals that the DOR generates major urban air pollution in Baghdad which produces widespread effects on environmental health and climate adaptation alongside public trust erosion. The scientific community agrees that modernization alongside improved governance needs to happen immediately but the practical implementation depends on political decisions along with institutional changes and investment from multiple sectors. The literature review establishes solid foundations for developing complete emissions management plans through analysis of worldwide best practices and regional assessments and Iraq-specific field data for DOR.

3. METHODOLOGY

This research examines the DOR refinery in Baghdad to analyze refinery air pollution alongside economic and environmental evaluation for developing pollution control solutions. This study uses multiple analytical methods including benchmarks and technology assessments combined with detailed emission analyses to deliver a comprehensive understanding.

The present emissions status requires data collection from multiple sources to establish a clear understanding. The research examined previous investigations together with technical papers and reports from World Bank 2022 IPIECA 2012 and studies published by Hashim and Abbas in 2020 and 2021. The results show that DOR produces large amounts of pollutants including SO_2, NO_x, VOCs, PM and CO_2.

We developed multiple projection scenarios that focus on minimizing emissions through the deployment of high-efficiency technologies including (SRUs), (SCR) systems, (VRUs), (ESPs), and (CCS) methods which follow (BATs) guidelines. We conducted an analysis of actual performance data together with case studies to determine the potential emission reduction capabilities of these technologies.

Artificial intelligence (AI) serves to forecast emission patterns while producing scenario-based statistics which help us understand expected pollution levels. AI solutions were used to measure yearly decreases of SO_2, NO_x, VOCs and PM after new control system installations. The simulations evaluated solar power adoption together with energy efficiency improvements to forecast CO_2 emissions under different energy scenarios.

The study emphasizes a real-time monitoring framework which consists of CEMS along with sensor networks and centralized data management. The system generates early alerts while tracking long-term patterns and maintains community transparency through CEMS data used for both public reporting and regulatory compliance purposes.

The research examined two energy efficiency enhancement approaches which included a pilot solar project and CHP systems to evaluate their sustainability and CO_2 emission reduction capabilities.

SCR technology installation feasibility was examined through financial evaluation of initial CapEx investments and ongoing OpEx costs and both avoided penalties and carbon credit revenue potential. The financial evaluation included assessment of Net Present Value (NPV) and Internal Rate of Return (IRR) as well as payback period calculations and analysis of how changing carbon prices and maintenance expenses affect these metrics (Li, 2023; Liu, 2021).

Overall, this comprehensive approach provides a solid framework for reducing emissions and promoting sustainability at the DOR refinery, drawing on case studies, industry best practices, and advanced modeling techniques.

4. RESULTS & DISCUSSION

The investigation demonstrates that DOR fails to achieve environmental standards because of aging pollution controls and obsolete infrastructure. The levels of SO_2, NO_x, VOCs, PM and CO_2 emissions persistently exceed the environmental standards specified by both international bodies and Iraqi authorities (Campara, 2018). The recommended technological advances together with strategic adjustments implemented through AI modeling present an encouraging path to enhance refinery operations while achieving sustainability targets.

4.1 Emission Reduction Potential through Technology Integration

Figure 1 shows that the implementation of (BATs) holds great potential to decrease emissions. High-efficiency (SRUs) operate to achieve up to 99% reduction of (SO_2) emissions. (SCR) systems cut (NO_x) emissions by about 90%, and (VRUs) together with (ESPs) eliminate more than 85% of (VOCs) and (PM). The active city of Baghdad requires these initiatives to protect public health while complying with regulatory standards.

The advancement of existing technologies from Jordan offers an exciting opportunity to drive substantial progress in Iraq. The implementation of better environmental practices in Iraq would enable the nation to become a sustainable refinery leader above pollution control standards.

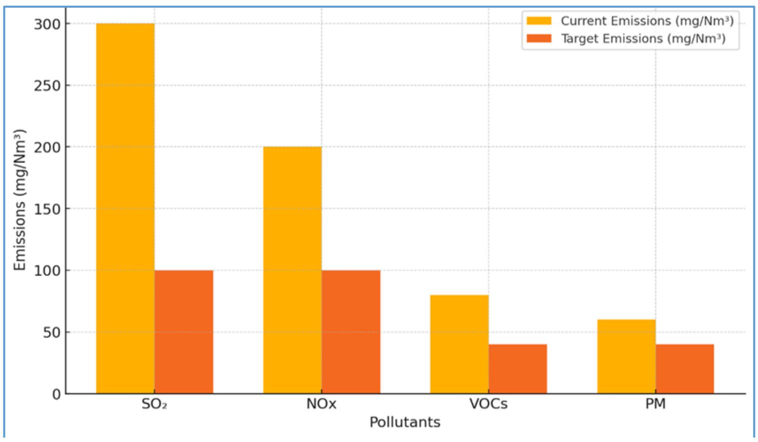

Fig. 1. Emission reductions of SO_2, NO_x, VOCs, and PM at DOR after applying recommended technologies. Data adapted from IPIECA (2012), Hashim et al. (2020), Alfke et al. (2020), and World Bank (2016, 2022).

4.2 Digital Monitoring and Transparency as a Regulatory Accelerator

This research presents a real-time monitoring system which brings about a fundamental transition in emission control operations as shown in figure 2.

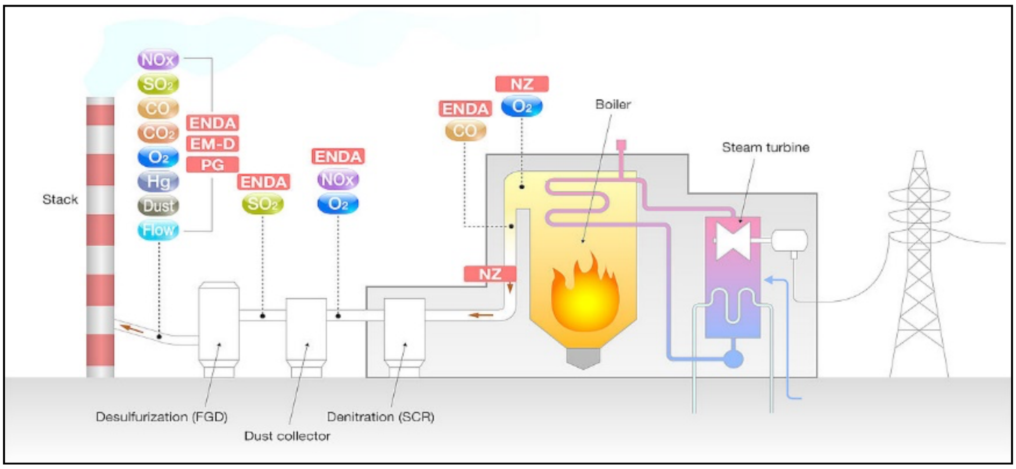

Fig. 2. Emissions control and power generation system with CEMS, including desulfurization, dust collectors, and de-nitration for SO_2, NO_x, VOCs, PM, and CO_2 control.

The combination of CEMS with fence line monitoring and centralized data management provides enhanced capabilities for operational tracking as well as external activity visibility. The simulated CEMS data used for AI predictions shows continuous reductions in sulfur dioxide and nitrogen oxides as well as volatile organic compounds and particulate matter throughout the year (see figure 3).

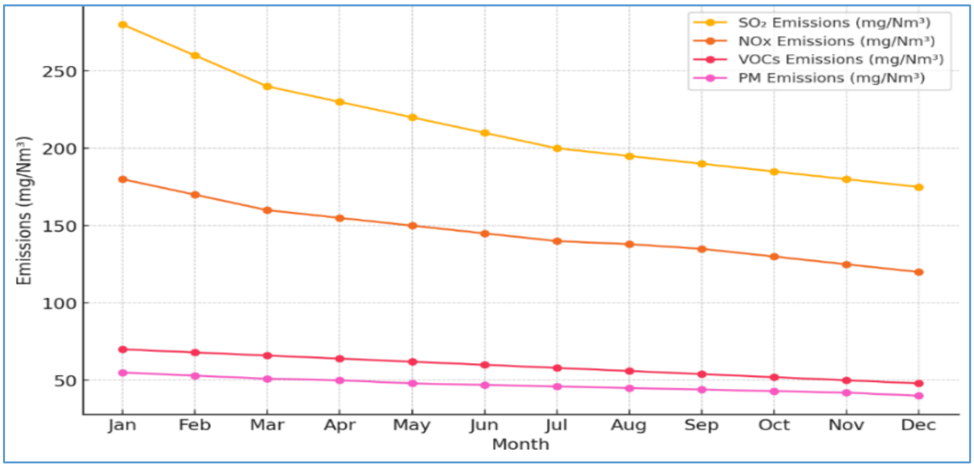

Fig. 3. AI-assisted trends showing year-round decline in SO_2, NO_x, VOCs, and PM emissions based on CEMS data, reflecting the effectiveness of control measures.

The current trend demonstrates that digital systems play a critical role in incident prevention and equipment maintenance and emission control. The Ministry of Oil and the Directorate of Oil Regulation have the opportunity to become leaders in Iraq through their implementation of specific monitoring protocols. Establishing transparent monitoring systems would establish public confidence while setting the stage for upcoming environmental regulations that currently lack emission reporting standards.

4.3 Energy Efficiency and Renewable Integration: A Twin Pillar Strategy

Reducing emissions becomes more achievable through the effective optimization of energy systems. The outdated machinery within refineries produces excessive CO_2 emissions and results in both wasted energy and environmental damage. The combination of modern heat exchangers with Combined Heat and Power systems delivers substantial energy efficiency improvements. The diagram in Figure 4 illustrates that utilizing solar power stands as an excellent choice because Iraq possesses abundant sunshine throughout the region.

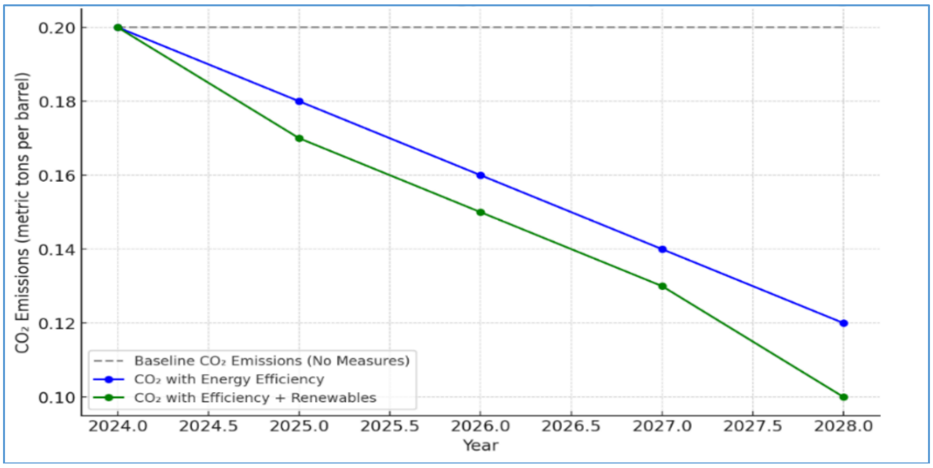

Fig. 4. AI-assisted CO_2 reduction trends, showing maximum decline from combined energy efficiency and renewable integration versus minimal change under baseline and efficiency-only scenarios.

The analysis of three distinct scenarios demonstrates that collaboration stands as the fundamental factor for success. The baseline scenario demonstrates that energy efficiency alone produces minimal CO_2 emission reductions which results in zero emission decrease. The optimal results emerge when energy efficiency combines with renewable energy to form a hybrid approach. The refinery needs renewable energy integration to achieve genuine sustainability targets because efficiency alone proves insufficient for these goals.

4.4 Carbon Capture and Circular Economy: Beyond Compliance

Decarbonization represents one of the most effective sustainable strategies to deal with climate change particularly when combined with (CCS) technologies. Estimates show that CCS technology could achieve a 90% reduction in CO_2 emissions within a five-year period, as presented in figure 5. Iraq has taken steps toward better carbon emission management in its oil and gas sectors which advances the global climate objectives.

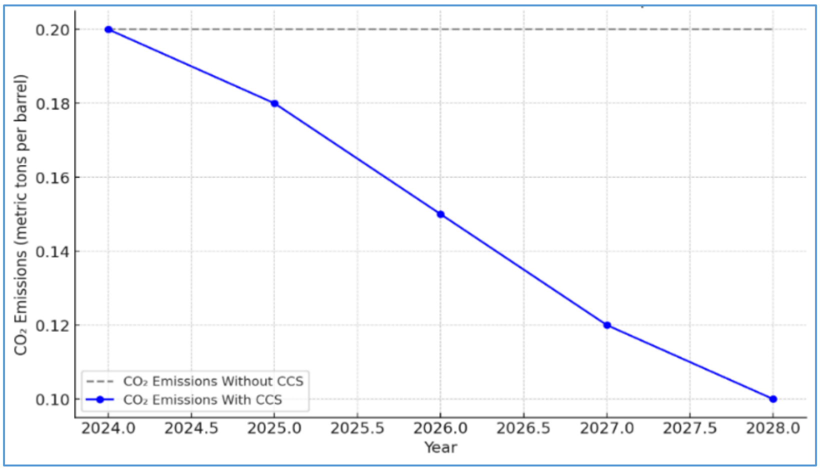

Fig. 5. Impact of CCS implementation on cumulative CO_2 emissions over time, showing significant reduction compared to the baseline. Data source: Alzahawy and Issa (2024).

Circular economy strategies which include water recycling and sulfur and VOC recovery enable organizations to enhance resource efficiency while creating additional financial opportunities. The sustainability approach of DOR demonstrates potential for genuine industrial innovation instead of just complying with emission regulations through the examples presented in Table 1.

Initiative	**Objective**	**Expected Impact**	**Implementation Timeline**
Carbon Capture and Storage (CCS)	Capture and store CO_2 emissions	90% reduction in targeted CO_2 sources	5 years
Circular Economy Practices	Resource recovery (e.g., sulfur, VOCs)	Reduce emissions, generate revenue	2 years
Water Recycling	Minimize water footprint	50% reduction in water usage	3 years

Table 1. Sustainability initiatives at DOR, outlining carbon capture, circular practices, and water recycling with defined environmental impacts and implementation timelines.

4.5 Community Engagement and Governance

Public involvement along with transparent information sharing stands as a fundamental necessity for the community. The data reveals that VOC and PM concentrations have steadily decreased through time which presents an optimistic development. DOR operates in an urban refinery setting that demands this kind of attention above all else. DOR should develop yearly environmental reports along with community advisory groups and real-time progress updates to build trust while reducing public concerns. The implementation of these steps would demonstrate their sincere concern regarding their community impact (see figure 6).

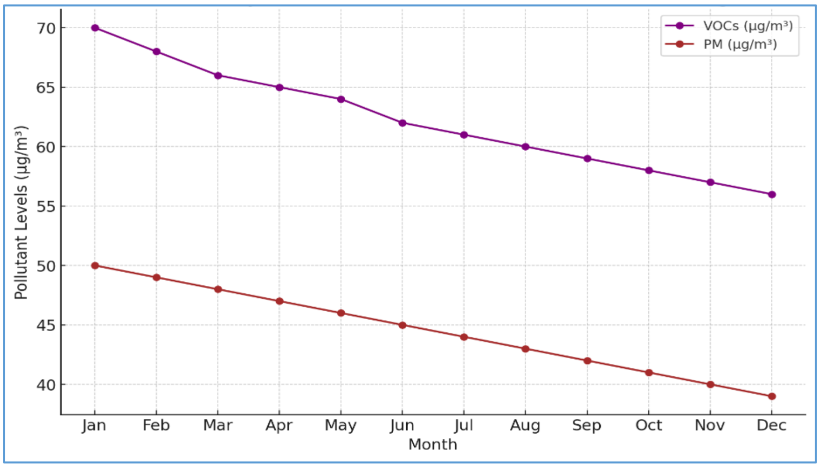

Fig. 6. AI-modeled decline in VOC and PM levels at the refinery's fence line, offering transparent insights into improving local air quality.

5. COMPARATIVE ANALYSIS WITH THE JORDAN PETROLEUM REFINERY

The two oil refineries JPRC in Zarqa and DOR in Baghdad show distinct contrasts in their sustainability approaches together with their emission management and regulatory compliance systems. Through the establishment of an extensive environmental management system JPRC focuses on clean energy and advanced pollution control technology and continuous monitoring. The data indicates that JPRC significantly outperforms DOR in controlling air emissions due to its sustainable practices see comparison table 2, below).

Aspect	DOR	JPRC	Key Takeaway
Regulatory Environment	Limited emissions standards	Stringent regulatory standards	Opportunity for DOR to lead voluntarily
Emissions Control	Basic controls	Advanced SRUs, SCR, VRUs	Investment needed to meet regional benchmarks
Monitoring and Reporting	Minimal requirements	Real-time monitoring, regular reporting	Potential for DOR to adopt similar transparency
Energy and Sustainability	Limited energy efficiency practices	Efficiency upgrades, solar integration	Solar pilot project viable at DOR

Table 2. Comparative overview of DOR and JPRC, highlighting key differences and lessons for improving emissions management and sustainability.

The Jordanian Ministry of Environment requires refineries to comply with stringent pollution guidelines. The refineries operate Continuous Emission Monitoring Systems (CEMS) while continuously submitting their environmental performance reports. Since Iraq is currently working on its emission rules older plants such as DOR operate without needing to comply with strict regulation and disclosure requirements. The absence of environmental standards allows Iraq's Ministry of Oil to establish superior practices through voluntary adoption which could later influence mandatory regulations.

The investment of JPRC in vapor recovery units along with selective catalytic reduction systems and efficient sulfur recovery units leads to substantial reductions of sulfur dioxide emissions by 99 percent and nitrogen oxides and volatile organic compounds by 90 percent. DOR continues to operate its flaring and combustion equipment which results in higher emissions levels. The data from Figure 7 demonstrates that DOR produces more pollution than JPRC in every significant emission category. The comparison demonstrates the financial advantages which result from investing in modern technology and the environmental damage that occurs when organizations fail to take action.

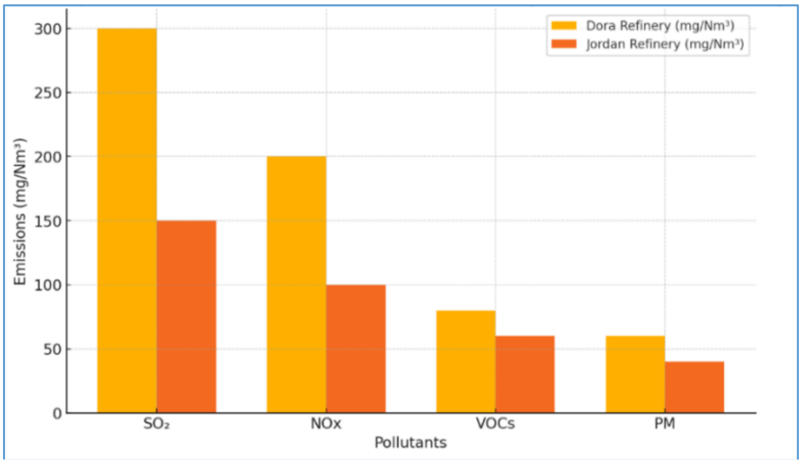

Fig. 7. Comparison of SO_2, NO_x, VOCs, and PM emissions between DOR and JPRC, highlighting higher levels at DOR and the need for improved emissions control.

The JPRC organization has established a long-term sustainability plan which addresses both energy efficiency together with renewable energy sources and pollution control measures. JPRC executes pilot solar projects simultaneously with equipment enhancements which cuts down carbon emissions and fuel use. The solar initiatives at DOR have the potential to create greater impact because Iraq has abundant sunshine throughout the year. Research conducted at DOR indicates that implementing renewable energy solutions along with infrastructure improvements would achieve more effective and sustained carbon emission reductions than focusing solely on energy efficiency measures.

JPRC conducts research on advanced carbon footprint reduction techniques which include Carbon Capture and Storage and circular economy practices for converting waste into valuable resources. The process involves salvaging beneficial substances which include sulfur along with hydrocarbons and water for subsequent utilization. These strategies are in their initial development phase yet DOR has already executed tests on their implementation particularly regarding sulfur extraction and volatile organic compound recovery. Through strategic planning which supports Iraq's climate targets DOR can achieve substantial emission reductions alongside discovering innovative waste utilization opportunities for profit generation.

The two companies have opportunities to exchange knowledge about community involvement practices. JPRC maintains an active practice of supporting local air quality observation while distributing public environmental reports and maintaining continuous stakeholder meetings to foster trust and decrease opposition. The public lacks access to information regarding Baghdad's populated regions because DOR provides limited transparency in this area. The implementation of similar transparency measures through community advisory panels and live monitoring at border points by DOR would enhance its reputation and secure better operational permissions (see table 3).

The final step to combine these insights involves a strategic road map for DOR which identifies essential areas to enhance such as emission management and digital tracking systems alongside renewable power integration and public disclosure transparency.

Recommendation	Expected Outcome	Implementation Priority
Install Advanced Emissions Control Technologies (e.g., SRUs, SCR)	SO_2 and NOx reduction, improved air quality	High
Implement Real-Time Monitoring (CEMS and Fence-Line)	Enhanced emissions control, public trust	High
Adopt Renewable Integration (Solar Power)	Reduced CO_2 emissions, operational savings	Medium
Engage Community through Transparency	Improved community relations, accountability	Medium

Table 3. Recommended improvements for DOR, prioritizing high-impact actions in emissions control, monitoring, and community engagement, with medium-priority measures targeting CO_2 reduction and transparency.

Figure 8 illustrates the potential decrease of SO_2, NO_x, VOCs and PM emissions over a five-year period when the recommendations are executed. Data demonstrates that pollution levels are decreasing across all sectors because of system modernization for operational and environmental benefits.

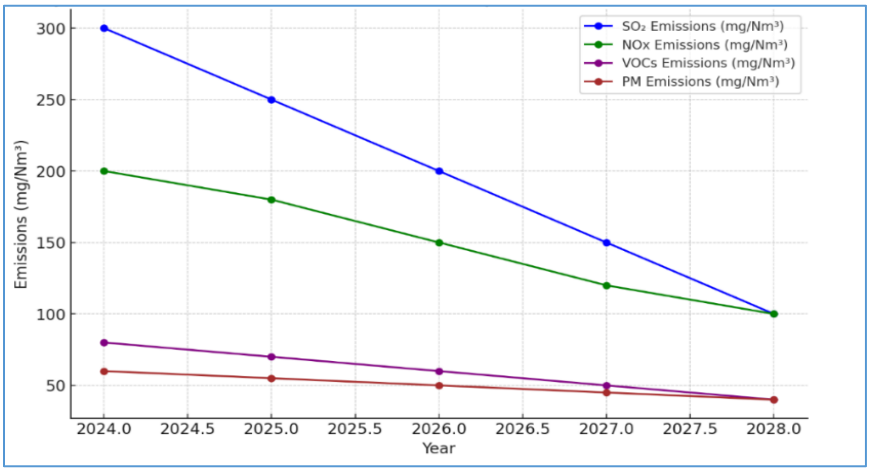

Fig. 8. AI-projected five-year emission reductions at DOR, showing significant declines in SO_2, NO_x, VOCs, and PM following adoption of recommended practices.

6. ECONOMIC FEASIBILITY AND SENSITIVITY ANALYSIS OF EMISSIONS CONTROL STRATEGIES AT THE DOR

We conducted a thorough evaluation to determine whether installing advanced pollution control systems at DOR would prove financially beneficial. The study concentrated on installing (SCR) systems because they currently demonstrate effectiveness in lowering NO_x emissions from refineries.

Our analysis covered a few key areas:

1. Cost Estimation: Our evaluation examined the installation expenses for SCR systems through industry standards as well as manufacturer price quotes. The analysis included the expenses related to any extra infrastructure requirements along with the installation process. We evaluated both initial and continuing expenses that involved annual maintenance alongside catalyst replacement and supplemental energy consumption.

2. Savings Projection: The savings calculation used several factors to determine the financial benefits that could be achieved. We based our cost savings calculations on reductions in penalty payments and revenue potential from environmental credit trading and regulatory avoidance. The baseline value for NO_x emission cost savings was $30 per ton which we applied to our NO_x reduction estimates.

3. Profitability Metrics: We calculated important financial figures like Net Present Value (NPV) and Internal Rate of Return (IRR) over a 15-year period with a 5% discount rate. These numbers help us understand if the investment would be worthwhile in the long run.

4. Sensitivity Analysis: We tested how robust our investment would be by examining two scenarios: a 20% increase in operating costs due to higher maintenance expenses and a drop in carbon credit value to $20 per ton. We wanted to see how these changes would impact both the payback period and NPV.

The initial financial results looked good. We estimated an NPV of $3.47 million, a payback period of five years, and an IRR of 19%. It seems that investing in SCR systems for pollution control could be a beneficial move (see table 4 below).

Metric	Value
Initial Investment (CapEx)	$2,500,000
Annual Operating Cost (OpEx)	$225,000
Annual Savings (Net)	$575,000
Payback Period	5 years
Net Present Value (NPV)	$3,468,303
Internal Rate of Return (IRR)	19%

Table 4: Financial metrics demonstrating the economic viability of adopting advanced emissions control technologies at DOR.

In conclusion, The sensitivity study looks really encouraging. It showed that the investment remains strong, even when times get tough. We see a positive net present value (NPV) and a reasonable payback period that ranges from 4.7 to 6.25 years. This suggests that, no matter how the market shifts—like with rising operating costs or lower carbon income—SCR deployment still makes sense financially (see table 5).

Scenario	Annual Savings	Payback Period
Baseline Carbon Credit ($30/ton)	$575,000	5 years
Lower Carbon Credit ($20/ton)	$400,000	6.25 years
Higher Maintenance Costs (+20%)	$530,000	4.7 years

Table 5: Sensitivity analysis of financial outcomes under varying scenarios, assessing impacts on annual savings and payback periods for emissions control investments.

Figure 9 shows how the Net Present Value grows steadily after hitting the break-even point in year five. Also, with international funding options like carbon markets, the long-term gains from emissions-reduction projects are likely to improve even more.

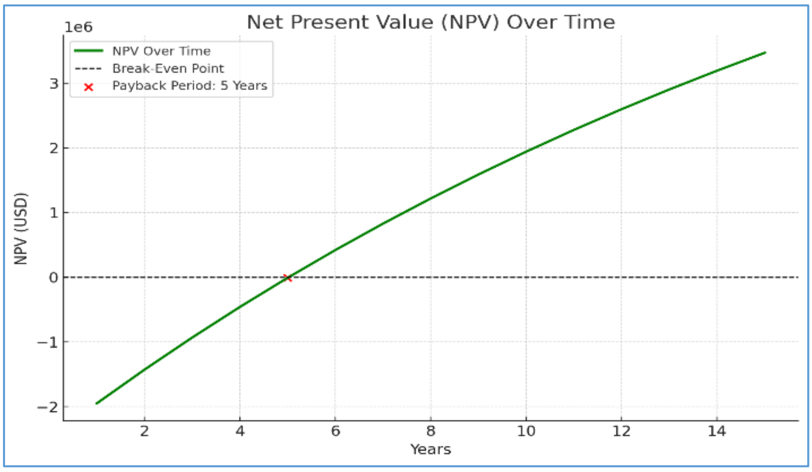

Fig. 9. NPV growth over time from SCR implementation, showing a clear break-even point at year five as cumulative savings exceed initial investment.

Investing in emissions control not only brings financial benefits but also helps improve operations and boosts the company's reputation. By reducing nitrogen oxide emissions, the refinery not only meets new international environmental standards but also contributes to cleaner air in the community. The strong performance of the Selective Catalytic Reduction (SCR) system makes a solid case for more investments in Iraq's refining sector focused on emission reductions. This shows that financial success and environmental care can go hand in hand. It’s clear that adopting technologies like SCR is a smart move for policymakers and refinery managers, meeting legal requirements while also promoting sustainable growth in the long run.

7. INNOVATIVE EMISSION CONTROL STRATEGIES FOR THE DORA REFINERY

The research establishes a vital contribution to refinery emissions management by applying established pollution control technologies including SCR, SRUs, ESPs and CCS to the DOR operating environment in Baghdad Iraq. Most existing studies examine these technologies in contemporary facilities which exist in controlled industrial zones yet this research investigates their adaptation for a dense urban area with obsolete infrastructure and insufficient digital systems and a disjointed environmental regulatory framework.

The DOR operates near expanding residential communities which creates increased health dangers from persistent exposure to high SO_2, NO_x, VOC and PM concentrations. The refinery infrastructure from the 1950s operates without modern emissions monitoring technology integration thus creating challenges for compliance and mitigation efforts. The local environmental governance framework lacks mandatory emissions standards and reporting protocols which makes it challenging to establish sustainable emissions reduction programs.

The study achieves its uniqueness through its capability to convert worldwide best practices into a practical local framework for environmental modernization. The research shows how emissions control technologies can be adjusted to conform to the limitations of conventional refinery systems operating with restricted capital expenditure frameworks. The study presents a three-phase implementation plan which integrates SCR, SRUs and CCS technology with artificial intelligence forecasting tools to generate multiple emissions simulations that measure the advantages of different technological routes. The AI modeling system presents a fresh approach to Iraqi conditions because it overcomes both data limitations and the slow pace of technological adoption that existed before.

The study presents a vital contribution through its organized comparison between DOR and Jordan (JPRC) which functions as a regional benchmark for environmental transparency and emissions management and energy efficiency. The comparative structure reveals the technological and regulatory differences between DOR and JPRC and presents strategies which can be adopted by other refining facilities to achieve regional environmental standards.

The research presents future-oriented strategic advice to multiple stakeholders that includes environmental policy makers as well as industrial operators and public administrators. The research indicates that policy makers must create enforceable emissions standards based on international standards and must establish environmental tax credits together with carbon trading systems and green bond programs to drive sustainable investment. The study recommends that refinery operators should implement modular emissions control systems with AI-based monitoring platforms and centralized data integration to achieve better and more economical compliance procedures.

Environmental regulators need to focus on installing CEMS with national platform connections to increase transparency in regulatory practices and build public confidence. International donors along with climate finance institutions should use their funding power to provide concessional financial support together with technical assistance for deploying clean technology specifically targeting CCS integration and solar projects and environmental engineering capacity development. Community involvement must become a standard practice through participatory governance systems which should establish environmental advisory panels and community audits with direct access to emission data for building trust and sustaining long-term social acceptance of operations.

In summary, this study bridges the gap between global environmental technology and local implementation realities in developing economies. It offers a replicable model for the modernization of legacy refinery infrastructure, integrating emissions control, digital transformation, and stakeholder participation into a cohesive strategy. The case of the DOR illustrates that environmental compliance and economic feasibility are not mutually exclusive, and that with tailored solutions, even outdated facilities can transition toward sustainability and operational excellence.

8. CONCLUSION

The DOR plays an essential role in Iraq's energy sector, but it faces significant challenges due to outdated emissions control systems and weak environmental safeguards. A recent study suggests that upgrading these operations is crucial, and it proposes solutions such as real-time monitoring, renewable energy integration, and utilizing the latest technologies. By implementing high-efficiency (SRUs) and (SCRs), emissions of (SO_2) could be reduced by up to 90%, while (NO_x) could drop by 99%. Furthermore, adding (CCS) along with solar power would help the refinery meet international environmental standards. The economic analysis indicates that these improvements are not only viable but also potentially profitable, particularly when considering carbon credits and penalties that could be avoided. When compared to industry leaders like the Jordanian JPRC, DOR has the potential to set a benchmark for sustainable refining practices. The study also stresses the need for transparency and community participation to build trust and foster regulatory compliance. Both lawmakers and business leaders can draw insights from these recommendations. By adopting these changes, the DOR can significantly reduce its environmental footprint, enhance economic performance, and lead the way for sustainable industrial growth in Iraq and the wider region, proving that environmental responsibility and economic progress can go hand in hand.

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ADDITIONAL INFORMATION

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