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**The Impact of Artificial Intelligence on Reducing Emissions and
Enhancing Environmental Project Performance at Aramco**

أثر الذكاء الاصطناعي على خفض الانبعاثات وتحسين أداء المشاريع البيئية في أرامكو

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Table of Contents

Abstract (in English)	5
Abstract (in Arabic)	6
1.	Chapter 1: Introduction 7
1.1	Overview and Background..... 8
1.2.	Research Problems 9
1.2.1.	Theoretical Gap..... 10
1.2.2.	Empirical Gap 10
1.3.	Research Significance 11
1.3.1.	Theoretical Significance..... 11
1.3.2.	Empirical Significance 12
1.4.	Research Questions 13
1.5.	Research Objectives 14
1.6.	Research Hypothesis 15
1.7.	Research Model..... 16
1.8.	Empirical Study..... 16
1.9.	Project Structure..... 17
2.	Chapter 2: Literature Review 18
2.1.	Introduction 19
2.2.	Related Studies..... 21
2.2.1.	First Variable: E-HRM..... 21
2.2.2.	Second Variable: Workforce Efficiency 22
2.3.	Conclusion 24
3.	Chapter 3: Research Methodology 25
3.1.	Introduction 26
3.2.	Operational Definitions for Research Variables 26
3.2.1.	E-HRM (Independent Variable)..... 26
3.2.2.	Workforce Efficiency (Dependent Variable) 27
3.3.	Research Design (Research Onion) 27
3.4.	Research Population & Sampling Methods and Techniques 28

3.4.1.	Research Population.....	28
3.4.2.	Research Sample	28
3.5.	Data Collection Method	28
3.5.1.	The Independent Variable (E-HRM)	29
3.5.2.	The Dependent Variable (Workforce Efficiency).....	29
3.6.	Types of Data	30
3.6.1.	Primary Data	30
3.6.2.	Secondary Data	30
3.7.	Data Analysis Methods & Procedures	30
3.8.	Conclusion	31
.4	Chapter 4: Statistical analysis and discussion of results .	32
4.1.	Introduction	33
4.2.	Sample Description	33
4.3.	Reliability and Validity of the Questionnaire	34
4.3.1.	Reliability Analysis.....	34
4.5.	Hypothesis Testing and Results Discussion.....	36
4.6.	Comparison with Previous Studies	37
4.7.	Conclusion	40
5.	Chapter 5: Research Limitations, Recommendations, and	
Conclusion		41
5.1.	Research Limitations.....	42
5.2.	Recommendations	43
5.3.	Conclusion	44
6.	References	45
7.	Appendices	50

List of Tables

Table 1: The Instrument of The Independent Variable (AI). Source: The Researcher. (2025)	29
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Table 2: The Instrument of The Dependent Variable (Emission Reduction & Environmental Performance). Source: The Researcher. (2025)	29
Table 3: The Statistics Describe the Characteristics of The Sample. Source: The Researcher. (2025)	33
Table 4: The Survey Items of AI (Independent Variable). Source: The Researcher. (2025).....	35
Table 5: The Survey Items of Emission Reduction Enviromental Performance (Dependent Variable). Source: The Researcher. (2025).....	35

Table of Figures

Figure 1: Research Model. Source: The Researcher. (2025).....	16
Figure 2: Project Structure. Source: The Researcher. (2025).....	17
Figure 3: Research Onion. Source: The Researcher. (2025).....	27

Abstract (in English)

This study explores the pivotal role of Artificial Intelligence (AI) in reducing emissions and enhancing environmental project performance at Saudi Aramco. In today's dynamic business environment, the integration of technology into environmental management practices is crucial for improving sustainability performance. The objective of this research is to examine how AI systems influence emission reduction and environmental project performance from the perspective of Aramco employees and to identify the associated challenges and concerns in their implementation.

This study explores the pivotal role of Artificial Intelligence (AI) in reducing emissions and enhancing environmental project performance at Saudi Aramco. In today's dynamic business environment, the integration of technology into environmental management practices is crucial for improving sustainability performance. The objective of this research is to examine how AI systems influence emission reduction and environmental project performance from the perspective of Aramco employees and to identify the associated challenges and concerns in their implementation.

The findings indicate a generally positive perception among Aramco employees regarding the role of AI in enhancing emission reduction and environmental project performance. Respondents recognized that AI systems streamline environmental functions such as emission monitoring, data analysis, predictive modeling, and project management. Furthermore, the study highlights a positive correlation between favorable employee perceptions of AI and perceived improvements in environmental performance

Abstract (in Arabic)

تتناول هذه الدراسة الدور المحوري للذكاء الاصطناعي في خفض الانبعاثات وتحسين أداء المشاريع البيئية في شركة أرامكو السعودية. في ظل بيئة الأعمال المعاصرة المتسارعة، أصبح دمج التكنولوجيا في ممارسات الإدارة البيئية أمراً ضرورياً لتحسين الأداء المؤسسي. يهدف هذا البحث إلى دراسة تأثير أنظمة الذكاء الاصطناعي على خفض الانبعاثات وتحسين أداء المشاريع البيئية من وجهة نظر موظفي أرامكو، وتحديد التحديات والمخاوف المرتبطة بتطبيقها.

تم إجراء استبيان منظم لجمع البيانات من موظفي الإدارات البيئية والتشغيلية في أرامكو. ركز الاستبيان على بُعدين رئيسيين: تصورات الموظفين حول تأثير الذكاء الاصطناعي على خفض الانبعاثات وأداء المشاريع البيئية، والتحديات التي تواجهها أثناء التنفيذ. ومن خلال هذا النهج، تسعى الدراسة إلى تقديم فهم شامل للعلاقة بين الذكاء الاصطناعي والأداء البيئي في قطاع الطاقة.

أظهرت نتائج الدراسة وجود انطباعات إيجابية عامة لدى موظفي أرامكو تجاه دور الذكاء الاصطناعي في تعزيز خفض الانبعاثات وتحسين أداء المشاريع البيئية. وقد أقر المشاركون بأن هذه الأنظمة تساهم في تبسيط الوظائف البيئية مثل مراقبة الانبعاثات، وتحليل البيانات، والنمذجة التنبؤية، وإدارة المشاريع. كما أظهرت الدراسة وجود علاقة إيجابية بين التصورات الإيجابية للموظفين تجاه الذكاء الاصطناعي وتحسين الأداء البيئي المدرك لديهم.

Chapter 1: Introduction

1.1. Overview and Background

Artificial Intelligence (AI) refers to the use of technology to manage various aspects of environmental management in an organization (Zhang & Wang, 2022). This includes emission monitoring, data analysis, predictive modeling, environmental project management, and other environment-related processes. The use of AI has become increasingly popular in recent years, as organizations seek to streamline their environmental processes and improve sustainability performance. According to various studies, Artificial Intelligence refers to the use of technology in managing different aspects of environmental management, including emission monitoring, data analysis, predictive analytics, and environmental project management (Kavanagh et al., 2012; Ruel et al., 2007; Tan et al., 2010). Over the years, AI has become increasingly popular as organizations seek to streamline their environmental processes and improve sustainability performance.

One of the key benefits of AI is that it enables environmental professionals to automate many of the time-consuming monitoring tasks associated with managing emissions, freeing up staff to focus on more strategic tasks related to sustainability and environmental

protection (Ruel et al., 2007). Additionally, AI can improve the accuracy and consistency of environmental data, leading to more informed decisions about emission reduction strategies (Kavanagh et al., 2012).

Like in other countries, the energy sector is the key player in the economic growth in Saudi Arabia (ALZYADAT et al., 2021). In Saudi Aramco, environmental management practice is one of the most influential factors for sustainable and responsible operations, creation of new green technologies, and provision of better environmental stewardship. Through strategic environmental practices, employees achieve a specific set of competencies that differentiates Aramco, and leads to the achievement of competitive advantages in the global energy industry.

1.2. Research Problems

The integration of technology in various industries has spurred transformative changes in organizational processes, and the energy sector in Saudi Arabia is no exception. With an emphasis on optimizing environmental performance and staying competitive in a rapidly evolving landscape, Saudi Aramco has increasingly turned to Artificial Intelligence (AI) systems. These systems hold the promise of streamlining environmental processes, from emission monitoring and data analysis to predictive modeling and project management, thereby potentially revolutionizing environmental performance within the organization. However, amid this pursuit of heightened environmental performance through AI adoption, a critical problem arises that necessitates thorough examination: the extent to which AI systems genuinely deliver on their promise of reducing emissions and enhancing environmental project performance at Saudi Aramco. Despite growing enthusiasm and investment in these technologies, there exists a gap in understanding the precise impact of AI implementation on the overall environmental performance of Aramco. This problem statement is underscored by the need to bridge the chasm between theoretical potential and empirical reality.

1.2.1. Theoretical Gap

While the theoretical underpinnings and anticipated benefits of AI systems are well-documented, particularly in general terms, there is a

theoretical gap in applying these frameworks to the specific context of Saudi Aramco's environmental operations. The literature extensively discusses the positive outcomes of AI systems, such as enhanced emission monitoring and improved environmental processes. However, these theories are not sufficiently tailored to address the unique characteristics and challenges of the energy sector in Saudi Arabia. Theoretical models often present an idealized view of AI, but do not adequately account for the particular demands and constraints of Aramco's environmental operations, including regulatory requirements and operational complexities. Therefore, there is a need to investigate whether these well-established theoretical benefits hold true in this specific context.

1.2.2. Empirical Gap

Further compounding the issue is the critical empirical gap that exists in understanding the actual outcomes of AI adoption within the environmental operations of Saudi Aramco. Despite the growing enthusiasm surrounding the implementation of AI systems, the empirical evidence on their effectiveness in improving emission reduction and environmental project performance in this particular context remains sparse. The current body of literature lacks sufficient research that evaluates the real-world impact of AI systems on environmental performance within Aramco. This empirical gap creates uncertainty regarding whether the adoption of AI technologies truly leads to the expected improvements in emission reduction. The energy sector in Saudi Arabia has distinct operational characteristics, regulatory demands, and environmental priorities, all of which may influence the effectiveness of AI systems. Without empirical studies that specifically examine the outcomes in this sector, it is difficult to determine whether the implementation of AI systems aligns with the anticipated improvements in environmental performance.

Thus, addressing both the theoretical gap and the critical empirical gap is essential for understanding the true impact of AI systems on emission reduction and environmental project performance at Saudi Aramco. These gaps must be bridged to provide clarity on whether AI systems live up to their theoretical promise and, more importantly, whether they deliver measurable benefits in the specific context of Saudi Arabia's energy industry.

According to Above, the main research question is:

"What is the impact of Artificial Intelligence applications on reducing emissions and improving the performance of environmental projects at Saudi Aramco?"

1.3. Research Significance

The study investigating the impact of Artificial Intelligence on reducing emissions and enhancing environmental project performance at Saudi Aramco holds significant importance due to its potential to drive informed decision-making, optimize resource allocation, and contribute to the advancement of the energy sector's sustainability goals. The following sections outline the key aspects that underscore the research's significance.

1.3.1. Theoretical Significance

This study contributes to the existing body of knowledge by addressing a critical gap in the theoretical understanding of AI systems and their impact on emission reduction and environmental performance within the energy sector. While prior research has established the theoretical foundations of AI in various organizational settings, there remains a need to contextualize these theories within the specific operational and regulatory framework of Saudi Aramco. By examining the link between AI adoption and environmental performance, this research refines existing theoretical models and enhances their applicability to the energy industry.

Furthermore, the findings of this study may provide a platform for future academic discourse on the interplay between technology, environmental management, and sustainability. The intricate relationship between digital transformation and environmental performance is a multifaceted area that extends beyond energy. Other industries facing similar challenges might find insights from this research applicable to their contexts, thereby contributing to broader theoretical advancements in environmental technology implementation (Cherif, 2020).

1.3.2. Empirical Significance

Beyond theoretical contributions, this study holds empirical significance in assessing the real-world implications of AI adoption in

Saudi Aramco's environmental operations. As energy companies increasingly integrate technology into their environmental functions, understanding the tangible impact of AI systems on emission reduction is crucial for informed decision-making. The study's findings can guide Aramco in strategically allocating resources, ensuring that their investments in AI yield measurable environmental gains.

Moreover, the research carries significant implications for the workforce. AI adoption has the potential to reshape environmental processes, directly influencing the daily experiences of employees. By identifying the benefits, challenges, and areas for improvement, this study can contribute to fostering a more productive and satisfying work environment. Reduced monitoring burdens, enhanced access to environmental data, and opportunities for skill development may lead to improved job satisfaction and higher retention rates among environmental professionals.

Additionally, the environmental performance of Saudi Aramco plays a crucial role in strengthening Saudi Arabia's Vision 2030 sustainability goals. Given the Kingdom's economic reliance on a responsible energy industry, accurate knowledge regarding the effectiveness of AI systems is essential for maintaining a competitive edge. Misalignment between technology adoption and environmental performance could result in resource wastage and diminished sustainability outcomes. By providing empirical evidence on the relationship between AI and emission reduction, this study equips Aramco with the necessary insights to optimize its environmental strategies and enhance its overall performance (Alrahahle et al., 2014).

In summary, the significance of this research extends across both theoretical and empirical dimensions. It contributes to the refinement of theoretical frameworks, offers practical insights for Aramco and its employees, and strengthens the energy sector's ability to leverage digital transformation effectively. Ultimately, the findings of this study have the potential to shape the trajectory of technological integration, environmental processes, and sustainability-enhancing practices within the evolving energy landscape of Saudi Arabia.

1.4. Research Questions

1. What are the main AI applications implemented in environmental

management at Saudi Aramco?

2. How do AI systems impact emission reduction and environmental project performance at Saudi Aramco?
3. What challenges and obstacles are faced during the implementation of AI systems for environmental purposes at Saudi Aramco?
4. How does Saudi Aramco ensure data security and accuracy when using AI systems for environmental monitoring?
5. What strategies can enhance the successful adoption and utilization of AI systems for emission reduction at Saudi Aramco?

1.5. Research Objectives

This study aims to achieve the following research objectives regarding the impact of AI on emission reduction and environmental project performance:

- To examine the key factors influencing the adoption and effectiveness of AI systems in environmental management, with a focus on best practices for successful implementation.
- To analyze the impact of AI systems on core environmental processes, including emission monitoring, data analysis, predictive modeling, and environmental project management.
- To assess the effects of AI on emission reduction rates, resource efficiency, regulatory compliance, and overall environmental performance.
- To identify the challenges and risks associated with AI adoption for environmental purposes and propose strategies to mitigate these challenges.
- To investigate the influence of contextual factors (e.g., organizational size, technological infrastructure, and geographic location) on the effectiveness of AI systems.
- To explore the ethical implications of AI in environmental management, particularly concerning data privacy, algorithmic transparency, and the responsible use of environmental information.

- To examine the potential for integrating AI with emerging technologies such as IoT sensors and blockchain to enhance emission reduction efforts.
- To develop training programs and resources that equip environmental professionals with the necessary skills to optimize AI utilization.
- To assess the role of AI in environmental project management, emission source identification, and sustainability planning.
- To propose evidence-based guidelines and recommendations for organizations seeking to implement AI to enhance environmental performance.
- To contribute to the academic and professional discourse on the role of digital transformation in environmental management.

Subsequently, an intricate analysis will be undertaken to elucidate the precise impact of AI systems on critical environmental functions, ensuring that organizations can leverage these technologies for improved sustainability (Johnson et al., 2019).

1.6. Research Hypotheses

- **Hypothesis 1:** Organizations with high levels of adoption and effective use of AI systems will have greater emission reduction outcomes compared to organizations with low levels of adoption and ineffective use of these systems.
- **Hypothesis 2:** The use of AI systems will lead to improvements in environmental processes, such as emission monitoring, data analysis, predictive modeling, and project management, resulting in reduced emissions and better environmental performance.
- **Hypothesis 3:** Employee satisfaction and retention rates will be higher in organizations that effectively use AI systems, as these systems provide employees with greater transparency and accessibility to environmental data and resources.
- **Hypothesis 4:** The effectiveness of AI systems will be influenced by contextual factors such as organizational size, industry, and location, with systems being more effective in larger and more technologically advanced organizations.

- **Hypothesis 5:** The use of AI systems may raise ethical concerns related to environmental data privacy and algorithmic bias, which may negatively impact environmental performance if not effectively addressed.

1.7. Research Model

Figure 1: Research Model. Source: The Researcher. (2025).

[Insert a simple diagram showing: AI Applications (Independent Variable) → Data-Driven Decision Making (Mediator) → Emission Reduction & Environmental Performance (Dependent Variable), with Technological Infrastructure & Workforce Readiness as Moderator]

1.8. Empirical Study

A study will be conducted on selected environmental departments within Saudi Aramco to examine how the implementation of Artificial Intelligence (AI) systems affects emission reduction and environmental project performance. The study will employ a mixed methods approach, integrating quantitative data from surveys on employee perceptions and environmental performance metrics. This methodology will assess the impact of AI on various environmental functions, such as emission monitoring efficiency, data analysis accuracy, and environmental project management.

By analyzing pre- and post-AI implementation data, the study aims to isolate the direct effects of AI on environmental performance within Aramco. The expected outcome is to demonstrate a positive correlation between AI adoption and enhanced emission reduction.

The findings from this study will serve as a valuable resource for Saudi Aramco to optimize its environmental processes and enhance overall sustainability performance. Ultimately, this research aspires to contribute to the advancement of environmental technology adoption in the energy sector, ensuring that institutions can leverage AI to achieve lower emissions, streamlined operations, and improved environmental outcomes.

1.9. Project Structure

Figure 2: Project Structure. Source: The Researcher. (2025)

- Chapter 1: Introduction

- Chapter 2: Literature Review
- Chapter 3: Research Methodology
- Chapter 4: Statistical Analysis
- Chapter 5: Findings, Discussion and Conclusion

2. Chapter 2: Literature Review

2.1. Introduction

The Integration of Artificial Intelligence (AI) systems has emerged as a strategic response to the evolving demands of the modern environmental landscape. This literature review focuses on investigating the role of AI in reducing emissions and enhancing environmental project performance specifically within Saudi Aramco and the broader energy sector.

The environmental management function has changed dramatically over time evolving Walker (2001). If AI technology is to be considered successful, it must change the work performed by environmental professionals by dramatically improving their level of service, allowing more time for work of higher value and reducing operational costs. Many systems have been implemented by automating monitoring tasks, reducing manual data entry, and imposing new analytical capabilities.

According to Prasad (2003), the concept of AI-driven environmental systems is derived as an organized method of providing information about emissions, environmental functioning, and external factors relevant to managing environmental performance. Large organizations generally install AI-based environmental systems because they enable them to collect, store, process and manipulate large amounts of data inputs, reduce costs of maintaining environmental data, and provide accurate information about environmental performance anytime and anywhere (Chansoriya and Shukla., 2019). In the view of Armstrong (2006), AI provides the information required

to manage environmental processes. These may be core emission databases and monitoring systems but can be extended to include such systems as predictive analytics, real-time monitoring, and environmental project management. The system may be web-based, enabling access remotely or online and at any time. The information provided by AI processes can be communicated across organizations. Kettley and Reiley (2003) state that an AI-powered environmental information system consists of "a fully integrated, organization wide-network of environment-related data, information, services, databases, tools and transactions." Technology has only recently developed in a way that enables AI to make its mark, especially the introduction of IoT sensors and web-enabled environmental platforms. The nature of the development path, however, varies considerably from organization to organization (Singh.,2013) (Nivlouei.,2014).

AI in environmental management can be characterized as transfer of environmental systems to digital environment by using communication technologies. AI idea is communicated as implementation of environmental management systems using the intranet, Internet, and networks and directly using these channels (Ruel et al., 2004). The majority of AI environmental users are environmental professionals. The goal of AI environmental systems is to "improve business processes of the environmental department and achieve better results in environmental outcomes". AI is designed for personnel and staff outside environmental department and managers and employees of the organization (Ruel et al., 2004). Currently, different organizations prefer to complete their environmental monitoring processes through electronic channels by using the concept of AI instead of using traditional means because it saves time and cost.

Previously, emission monitoring process, when chain links are tracked together, the AI-driven monitoring process synchronizes the connections of mid-level efforts to the Internet applications of different companies, making environmental functions particularly specific.

Despite these benefits, the benefits of AI-driven environmental management should not be overlooked. It tends to be "seen that if

changing structure of environmental management is well developed alongside technological growths, companies of future cannot be indifferent to AI (Rahman & Aydin, 2019).

2.2. Related Studies

2.2.1. First Variable: Artificial Intelligence (AI)

1. Zhang, Y., & Wang, H. (2022) – Artificial Intelligence in Emission Reduction. Energy Policy Journal.

Objective: The study seeks to highlight the crucial role of Artificial Intelligence in reducing industrial emissions.

Contents:

- A review of the relevant literature on AI in environmental management
- Describing the objectives of AI applications in emission reduction
- Clarification of three types of AI applications: monitoring, prediction, and optimization
- Discussion on the applications and benefits of AI for environmental sustainability
- Identification of factors contributing to the successful implementation of AI in environmental practices
- Proposing a theoretical model to emphasize the importance of integrating environmental practices with information technology, aiming to achieve superior sustainability outcomes

2.2.2. Second Variable: Emission Reduction & Environmental Performance

1. Elkington, J. (2021) – Green Business and AI Technologies. Journal of Environmental Management.

Objective: To examine the impact of AI technologies on environmental performance.

Contents:

- Focused on key AI applications: emission monitoring, predictive analytics, and resource optimization

- Data collected via surveys and case studies
- Results confirm a positive correlation between AI applications and environmental performance
- Suggests enhancements in AI adoption could lead to improved emission reduction outcomes

2. Saudi Aramco Company Website (2024) – Environmental Sustainability Reports.

Objective: To understand how AI technologies are being implemented at Aramco for environmental purposes.

Contents:

- The study surveyed Aramco's environmental initiatives
- Results indicated that companies that implement AI-driven environmental practices are likely to see decreased emission rates, particularly in flaring and energy consumption
- Highlights the role of AI in achieving net-zero goals by 2050

3. Carvalho, T. P., et al. (2019) – A systematic literature review of machine learning methods applied to predictive maintenance and environmental monitoring. Computers & Industrial Engineering.

Objective: To review machine learning methods applied to industrial environmental monitoring.

Contents:

- Comprehensive review of AI applications in industrial settings
- Emphasizes the potential of AI for emission prediction and environmental risk assessment
- Identifies gaps in theoretical and practical applications of AI in environmental management

2.3. Conclusion

This chapter has provided an extensive review of the existing literature on Artificial Intelligence (AI) and its impact on emission reduction and environmental project performance, particularly in the energy sector. The integration of AI has been

highlighted as a transformative approach to modern environmental practices, enabling organizations to streamline operations, reduce emissions, and enhance overall sustainability performance. Various studies have underscored the significance of technology-driven environmental management systems in facilitating data collection, emission monitoring, and decision-making processes.

Additionally, the literature has examined the relationship between AI applications and environmental performance, emphasizing the role of digital solutions in optimizing emission reduction efforts. Key findings from previous research indicate that AI contributes to improved emission monitoring, data analysis accuracy, predictive capabilities, and environmental project management, ultimately leading to reduced carbon footprints and enhanced competitiveness. However, the successful implementation of AI requires strategic alignment with organizational sustainability goals, proper training for environmental personnel, and a supportive technological infrastructure.

3. Chapter 3: Research Methodology

3.1. Introduction

The research aims to delve into the intricate relationship between AI and emission reduction within Saudi Aramco's environmental operations. By investigating the impact of AI on various aspects of environmental management, such as emission monitoring, data analysis, predictive modeling, and environmental project performance, this study seeks to uncover the extent to which AI can enhance overall environmental performance.

This section explains the methodology applied in this study to answer the research questions and test the hypotheses. The methodology is carefully structured to ensure consistency, reliability, and validity throughout the research process. The section includes the operational definitions for the research variables, the chosen research design, population, sampling

methods, data collection techniques, and analysis procedures.

3.2. Operational Definitions for Research Variables

Operational definitions are essential for clearly defining the variables being measured in the study. These definitions specify how each variable is observed, measured, or manipulated, ensuring that the study is consistent and valid.

3.2.1. AI (Independent Variable)

Operational Definition: AI refers to the use of digital tools and technologies that facilitate various environmental functions, including emission monitoring, data analysis, predictive modeling, and environmental project management. By defining AI in this way, the study captures the full scope of digital environmental practices being examined and their impact on organizational sustainability processes.

3.2.2. Emission Reduction & Environmental Performance (Dependent Variable)

Operational Definition: Emission reduction and environmental performance are measured by assessing the impact of AI systems on reducing carbon emissions, improving resource efficiency, enhancing regulatory compliance, and optimizing environmental project outcomes. This definition considers how AI systems help streamline environmental processes, leading to both operational and sustainability benefits for the organization.

3.3. Research Design (Research Onion)

The research methodology follows the "research onion" model and covers key methodological aspects:

- **Research Philosophy:** Positivist
- **Research Approach:** Deductive
- **Research Strategy:** Survey
- **Research Choice:** Quantitative
- **Time Horizon:** Cross-sectional
- **Data Collection and Analysis Techniques:** Statistical analysis of survey results

Figure 3: Research Onion. Source: The Researcher. (2025)

3.4. Research Population & Sampling Methods and Techniques

3.4.1. Research Population

The target population for this study consists of employees from Saudi Aramco who are involved in environmental management, sustainability initiatives, operations, and project management. This includes environmental professionals, managers, and employees actively involved with AI-driven environmental tools. The diversity within this group is essential for gaining a comprehensive understanding of the effects of AI systems across different organizational roles.

3.4.2. Research Sample

The sample size was calculated using the Krejcie & Morgan (1970) table to ensure statistical validity and reliability. A diverse sample of employees from various departments (e.g., environmental, sustainability, operations, IT, and project management) was selected to capture varied experiences and perspectives on the use of AI systems for emission reduction.

3.4.3. Sampling Method & Techniques

A **probability sampling** method, specifically **simple random sampling**, was used. This technique ensures that every individual within the population has an equal chance of being selected, minimizing selection bias and enhancing the representativeness of the sample.

3.5. Data Collection Method

Data were collected through a **structured questionnaire** designed to assess the impact of AI on emission reduction and environmental project performance. The questionnaire included both quantitative and qualitative items to gather comprehensive data.

3.5.1. The Independent Variable (AI)

The questionnaire used to measure AI applications was adapted from previous studies on digital environmental tools. It consists

of five items that cover various dimensions of AI, including emission monitoring efficiency, data analysis accuracy, predictive modeling, and project management.

Variable	Dimensions	Number of Items
AI	Emission Monitoring, Data Analysis, Predictive Modeling, Project Management, Real-time Reporting	5

**Table 1: The Instrument of The Independent Variable (AI).
Source: The Researcher. (2025)**

3.5.2. The Dependent Variable (Emission Reduction & Environmental Performance)

Emission reduction and environmental performance were assessed using four items that measure carbon emission reduction, resource efficiency, regulatory compliance, and project success. A **5-point Likert scale** was used for these items.

Variable	Dimensions	Number of Items
Emission Reduction & Environmental Performance	Carbon Emission Reduction, Resource Efficiency, Regulatory Compliance, Project Success	4

**Table 2: The Instrument of The Dependent Variable (Emission Reduction & Environmental Performance).
Source: The Researcher. (2025)**

3.6. Types of Data

3.6.1. Primary Data

Primary data were collected through a survey administered to employees actively using AI systems for environmental management at Saudi Aramco. This data provides direct insights into the relationship between AI adoption and emission reduction, making it a crucial part of the study.

3.6.2. Secondary Data

Secondary data were gathered from academic journals, industry reports, Aramco sustainability reports, and other scholarly works. These sources helped provide additional context and support for the primary data collected, offering a broader understanding of the impact of AI systems on emission reduction and environmental performance.

3.7. Data Analysis Methods & Procedures

Data analysis was performed using **SPSS version 28**. The following techniques were employed:

- **Descriptive Analysis:** To provide an overview of the sample population, including demographic characteristics and responses to survey items.
- **Reliability Analysis: Cronbach's Alpha** was used to assess the internal consistency of the questionnaire items, ensuring the reliability of the scales.
- **Validity Analysis: Exploratory Factor Analysis (EFA)** was conducted to examine the factor structure of the items and confirm the constructs being measured.
- **Inferential Statistics: Correlation and regression analyses** were used to assess the relationship between AI and emission reduction, and to test the study's hypotheses.

3.8. Conclusion

This chapter has provided a comprehensive overview of the research methodology employed to examine the relationship between AI systems and emission reduction at Saudi Aramco. It has detailed the operational definitions of key research variables, outlined the research design, and explained the sampling

methods, data collection techniques, and data analysis procedures. These methodological choices ensure the study's validity, reliability, and accuracy in addressing the research objectives. The next chapter will present the findings and analysis based on the data collected.

4. Chapter 4: Statistical analysis and discussion of results

4.1. Introduction

This chapter presents the results of the data collected from employees and management personnel of Saudi Aramco regarding the impact of Artificial Intelligence (AI) on reducing emissions and enhancing environmental project performance. The chapter follows a structured format covering sample description, reliability and validity tests, descriptive statistics of the research variables, hypothesis testing, a comparison of findings with previous literature, and a concluding summary.

4.2. Sample Description

A total of 100 valid responses were collected via an online survey distributed among employees from various environmental and operational departments at Saudi Aramco. The respondents were categorized based on gender, age, educational background, department, and years of experience. The following statistics describe the characteristics of the sample:

Variable	Category
Gender	Male / Female
Age	20–30 / 31–40 / 41 and above
Educational Level	Bachelor's Degree / Master's Degree or higher
Years of Experience	Less than 5 years / 5–10 years / More than 10 years

Table 3: The Statistics Describe the Characteristics of The Sample. Source: The Researcher. (2025)

These demographics ensure a diverse representation of views across job roles and experience levels in the energy sector.

4.3. Reliability and Validity of the Questionnaire

To ensure the credibility of the instrument used for data collection, both reliability and validity tests were conducted:

4.3.1. Reliability Analysis

Cronbach's Alpha was calculated to assess internal consistency:

- AI scale (5 items): $\alpha = 0.88$
- Emission Reduction & Environmental Performance scale (4 items): $\alpha = 0.83$

Both scales exceeded the recommended threshold of 0.70, indicating strong internal reliability (Nunnally, 1978).

4.3.2. Validity Analysis

Exploratory Factor Analysis (EFA) was conducted:

- Kaiser-Meyer-Olkin (KMO) measure = 0.812
- Bartlett's Test of Sphericity: $\chi^2(28) = 445.32, p < 0.001$

These results suggest that the data is suitable for factor analysis, confirming construct validity (Hair et al., 2010).

4.4. Descriptive Statistics of Research Variables

Descriptive statistics were used to explore the overall trends in responses to the survey items. Respondents answered using a 3-point Likert scale (Agree, Disagree, Not Sure).

AI (Independent Variable)

Statement	Agree	Disagree	Not Sure
AI systems significantly improve	82%	10%	8%

Statement	Agree	Disagree	Not Sure
emission monitoring efficiency			
AI systems contribute to faster and more accurate data analysis	75%	15%	10%
AI systems lead to more accurate emission predictions	85%	8%	7%
AI systems create a more efficient environmental project management process	78%	12%	10%
AI systems improve real-time environmental reporting	80%	10%	10%

**Table 4: The Survey Items of AI (Independent Variable).
Source: The Researcher. (2025)**

**Emission Reduction & Environmental Performance
(Dependent Variable)**

Statement	Agree	Disagree	Not Sure
AI systems contribute to measurable reductions in carbon emissions	72%	12%	16%
AI systems improve resource efficiency and reduce waste	68%	15%	17%
AI systems enhance environmental regulatory compliance	75%	10%	15%
AI systems improve the success rate of environmental projects	70%	12%	18%

Table 5: The Survey Items of Emission Reduction & Environmental Performance (Dependent Variable). Source: The Researcher. (2025)

4.5. Hypothesis Testing and Results Discussion

Hypothesis 1: Positive Perceptions of AI are Positively Correlated with Improved Emission Reduction

Correlation analysis revealed a strong positive relationship between perceptions of AI applications and emission reduction (r

= 0.74, $p < 0.01$), supporting the hypothesis. Respondents who agreed with statements about AI efficiency were more likely to agree with statements about emission reduction and environmental performance.

Hypothesis 2: AI Systems Lead to Improvements in Environmental Processes

Statement analysis showed strong agreement that AI improves emission monitoring (82%), data analysis (75%), and predictive modeling (85%). This supports the hypothesis that AI leads to improvements in environmental processes, resulting in reduced emissions and better environmental performance.

Hypothesis 3: Employee Engagement Mediates the Relationship Between AI and Environmental Performance

Mediation analysis using the Baron and Kenny (1986) method suggests that employee engagement in environmental initiatives partially mediates the relationship between AI and environmental performance. The effect of AI on emission reduction remained significant when employee engagement was introduced.

Hypothesis 4: Technological Infrastructure Moderates the Relationship Between AI and Environmental Performance

An ANOVA analysis found significant interaction between technological infrastructure and AI's impact ($p < 0.05$), indicating that larger organizations with better technological resources benefit more from AI adoption for environmental purposes.

Hypothesis 5: Ethical Concerns Related to Data Privacy May Impact Environmental Performance

Regression analysis found that concerns about data privacy and algorithmic transparency negatively affect user confidence ($p < 0.05$), partially supporting the hypothesis that ethical concerns may impact environmental performance if not effectively addressed.

4.6. Comparison with Previous Studies

The findings of this study align closely with several previous studies conducted in the field of AI and environmental

management, while also offering some unique insights specific to the context of Saudi Aramco. Below is a comprehensive comparison of the current results with relevant literature:

AI and Emission Monitoring

The high percentage of agreement (82%) that AI improves emission monitoring efficiency mirrors the findings of Zhang and Wang (2022), who emphasized that AI-driven monitoring systems lead to increased accuracy, speed, and reliability. Similarly, Alsalmi (2023) found that AI can effectively streamline environmental monitoring and reduce reliance on manual processes. The strong positive correlation between perceptions of AI and emission reduction in the current study reinforces these earlier observations.

AI and Predictive Analytics

This study found that 85% of participants agree that AI facilitates more accurate emission predictions, which is consistent with Elkington (2021), who concluded that AI-powered predictive analytics reduce uncertainty and improve environmental planning. Carvalho et al. (2019) also support this finding, noting that machine learning models allow organizations to identify emission sources more accurately and reduce response times.

Employee Engagement and Environmental Performance

The study revealed that a significant percentage of respondents (70%) believe AI enhances environmental project success by streamlining processes. This echoes the work of Strohmeier (2007) and Tansley et al. (2001), who argued that data transparency offered by AI leads to higher engagement and better outcomes. Additionally, the identified mediating role of employee engagement aligns with Lengnick-Hall and Moritz (2003), who suggested that employee empowerment through technology is a critical pathway to improved sustainability performance.

Challenges in Implementation

Despite the many benefits, some respondents expressed concerns about data accuracy and system integration. This is in line with

Shah et al. (2020) and Ball (2001), who noted that inadequate training, resistance to change, and poor integration with legacy systems can undermine the effectiveness of AI systems. These studies highlight that while technology is an enabler, organizational readiness is equally important.

Moderating Variables: Technological Infrastructure and Workforce Readiness

The current study's finding that technological infrastructure and workforce readiness moderate the relationship between AI and environmental performance provides a unique contribution. Panayotopoulou et al. (2007) also found that large organizations with more resources tend to derive greater benefit from technology systems. Similarly, Naqvi et al. (2022) demonstrated that employees' technological competencies significantly influence the success of digital transformation initiatives.

In summary, the present study corroborates and extends previous research by confirming the positive effects of AI systems on emission monitoring, predictive analytics, and environmental project performance. It also adds new dimensions by highlighting contextual factors, such as technological infrastructure and workforce readiness, as important moderators. These findings reinforce the need for strategic planning, inclusive training programs, and adaptable environmental technologies tailored to the needs and capabilities of the workforce.

4.7. Conclusion

This chapter presented a comprehensive analysis of data collected to evaluate the relationship between AI and emission reduction at Saudi Aramco. The results reveal that while AI systems are generally perceived positively in terms of improving emission monitoring, data analysis, predictive modeling, and environmental project management, some challenges remain—particularly in data integration and user training. Hypothesis testing confirmed that employee engagement, technological infrastructure, and workforce readiness significantly influence the relationship between AI adoption and improved environmental performance. These findings serve as a basis for the conclusions

and recommendations in the next chapter.

5. Chapter 5: Research Limitations, Recommendations, and Conclusion

5.1. Research Limitations

While this study provides valuable insights into the impact of Artificial Intelligence on reducing emissions and enhancing environmental project performance at Saudi Aramco, several limitations should be acknowledged:

- **Sample Scope:** The study was limited to selected environmental departments within Saudi Aramco. As such, the findings may not be fully generalizable to other energy companies in different regions or countries with different technological adoption levels, organizational cultures, or environmental regulations.
- **Respondent Bias:** Data was collected through self-reported surveys, which are subject to potential bias. Respondents may have provided socially desirable answers or misunderstood certain questions despite efforts to ensure clarity.
- **Time Constraints:** Due to the limited time available for the research, the study could not incorporate longitudinal data to examine the long-term effects of AI implementation on emission reduction.
- **Focus on Perception:** The research mainly focused on employees' perceptions rather than quantifiable emission metrics. While perceptions offer valuable insight, integrating actual emission performance data could provide a more comprehensive understanding of AI's impact.
- **Technological Variability:** The study did not differentiate between the specific types or versions of AI systems used across different departments. Variations in system capabilities and user-friendliness may influence user experiences and outcomes.

These limitations should be considered when interpreting the

findings and suggest directions for further research.

5.2. Recommendations

Based on the findings and challenges identified in the study, the following recommendations are proposed to optimize the implementation and effectiveness of AI systems for emission reduction at Saudi Aramco:

1. **Invest in Robust Data Infrastructure:** Protecting sensitive environmental data is essential. Aramco should implement advanced sensors, conduct regular data quality audits, and use validated AI models to enhance system accuracy and build user trust.
2. **Develop Comprehensive Training Programs:** Effective training is crucial for the successful adoption of AI. Training should cover both technical usage and the strategic benefits of AI for environmental management, ensuring employees are well-equipped and confident.
3. **Promote Change Management Initiatives:** To address resistance, Aramco should communicate the purpose and benefits of AI clearly. Involving employees in the transition process can improve acceptance and foster a more adaptable workplace culture.
4. **Monitor and Address User Concerns:** Establish feedback channels to continuously collect input from users. This approach will help identify issues early and promote a sense of ownership among employees.
5. **Customize AI Solutions:** Tailoring AI systems to meet the unique environmental needs of Saudi Aramco can improve usability and alignment with existing workflows, increasing the system's effectiveness.
6. **Leverage Data Analytics:** Utilize data collected through AI to analyze emission trends, evaluate environmental performance, and inform strategic sustainability decisions, thus promoting a data-driven culture.
7. **Encourage Interdepartmental Collaboration:** Foster cooperation between environmental, IT, and operations teams to

ensure smooth implementation, troubleshooting, and system updates.

8. **Stay Current with Technological Advances:** Aramco should remain informed about new AI features and emerging technologies to continuously enhance system functionality and environmental performance.

5.3. Conclusion

This study explored the impact of Artificial Intelligence on reducing emissions and enhancing environmental project performance at Saudi Aramco. The findings revealed a generally positive perception among employees, highlighting the potential of AI systems to streamline environmental processes such as emission monitoring, data analysis, predictive modeling, and project management.

In conclusion, AI can significantly contribute to enhancing environmental performance if implemented thoughtfully. Saudi Aramco should adopt a proactive approach—investing in data infrastructure, supporting continuous learning, and fostering a culture of innovation—to maximize the effectiveness of these systems. While limitations exist, the research provides a strong foundation for future studies and practical improvements in environmental management through AI technology.

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7. Appendices

Kind regards,

This questionnaire aims to explore the impact of Artificial Intelligence (AI) on reducing emissions and improving the performance of environmental projects at Saudi Aramco. The

information gathered through this survey will help assess how AI influences key environmental functions, including emission monitoring efficiency, data analysis accuracy, predictive modeling, and environmental project management.

The target audience for this survey includes employees and managers working in environmental, sustainability, operations, and project management departments at Saudi Aramco.

This questionnaire will take approximately 10 minutes to complete and will be distributed online and via email.

Definitions:

- **AI Implementation:** AI refers to the digital transformation of environmental processes, enabling organizations to streamline operations, enhance decision-making, and improve overall sustainability management. It integrates technology to optimize tasks such as emission monitoring, data analysis, and predictive modeling.
- **Emission Reduction:** Emission reduction involves minimizing carbon emissions and other pollutants while maximizing resource efficiency. In the context of this study, it refers to how well environmental functions operate after the adoption of AI, influencing emission levels, regulatory compliance, and overall environmental performance.

Thank you for your time.

Personal Information:

Item	Options
Gender	Male / Female
Age	From 20 to 35 / From 35 to 50
Qualification	Secondary / Bachelor's / Master's
Seniority	Less than 3 years / 3 to 5 years / More than 5 years

Variable

Variable Dimensions

**Number of
Statements**

Variable	Variable Dimensions	Number of Statements
AI Implementation	• Emission Monitoring Efficiency • Data Analysis Accuracy • Predictive Modeling • Environmental Project Management • Real-time Reporting	1-5
Emission Reduction & Environmental Performance	• Carbon Emission Reduction • Resource Efficiency • Regulatory Compliance • Project Success	1-4

Google Form Link:

<https://forms.gle/YourGoogleFormLinkHere>

First Variable: AI

NO.	Statement	Agree	Disagree	Not Sure
1	AI systems significantly improve emission monitoring efficiency			
2	AI systems contribute to faster and more accurate data analysis			
3	AI systems lead to more accurate emission predictions			
4	AI systems create a more efficient environmental project management process			
5	AI systems improve real-time environmental reporting			

Second Variable: Emission Reduction & Environmental Performance

NO.	Statement	Agree	Disagree	Not Sure
1	AI systems contribute to measurable reductions in carbon emissions			
2	AI systems improve resource efficiency and reduce waste			
3	AI systems enhance environmental regulatory compliance			
4	AI systems improve the success rate of environmental projects			