Enhancing Middle Stream of Fluorocarbon Gas Management in Malaysia through AI-Driven Solutions

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Abstract
Fluorocarbon (FC) gases, widely used in refrigeration and air-conditioning (RAC) systems, pose significant environmental risks due to their ozone depletion potential (ODP) and global warming potential (GWP). In Malaysia, the midstream (usage) phase of FC gas management remains a critical hotspot for emissions, primarily due to undetected leaks and inefficient maintenance practices. Traditional reactive approaches to leak detection and maintenance are insufficient to address these challenges, necessitating a shift toward proactive, AI-driven solutions. This study explores the potential of digital technologies, including IoT-enabled sensors, predictive maintenance algorithms, and blockchain-based inventory systems, to enhance FC gas management in Malaysia. Using a mixed-methods approach, the research employs the DPSIR (Driving Forces, Pressures, State, Impacts, and Responses) framework and SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to identify key challenges and opportunities in the current FC gas lifecycle. The findings reveal that AI-driven predictive maintenance and real-time leak detection can significantly reduce emissions, improve energy efficiency, and extend the lifespan of (refrigeration and air conditioning) RAC equipment. Furthermore, integrating blockchain technology can enhance transparency and compliance in FC gas inventory management. The study concludes that adopting these digital solutions, alongside structured training programs for technicians, can transform Malaysia's midstream FC gas management, aligning it with global sustainability goals. This research contributes to the growing body of knowledge on AI-driven environmental management and offers actionable insights for policymakers and industry stakeholders.
Key Words: *AI-driven predictive maintenance, IoT-enabled leak detection, fluorocarbon gas management, RAC equipment.*

1. INTRODUCTION

Fluorocarbon (FC) gases, such as hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs), are widely used as refrigerants in refrigeration and air-conditioning (RAC) systems. Even though these gases have played a critical role in replacing ozone-depleting substances (ODSs) like chlorofluorocarbons (CFCs), their significantly high global warming potential (GWP) has classified them as a growing climate threat. FC gases are capable of capturing heat at intensities that surpass those of carbon dioxide (CO_2) by thousands of times (Mylona et al., 2017; Sovacool et al., 2021), making their regulation a central concern under international climate and ozone protection frameworks especially the Montreal Protocol, Kigali Amendment and Paris Agreement (Pallav Purohit et al., 2025).

A critical emission hotspot lies in the midstream phase, encompassing usage and maintenance practice of RAC systems (Zanghelini et al., 2014; Solano–Olivares et al., 2019; Rewlay-ngoen & Papong, 2020; Sovacool et al., 2021). The inefficient maintenance practices to detect the FC gas leaks (direct emission) can reduced energy efficiency of RAC equipment (indirect emission) (Park et al., 2021). These challenges not only contribute to greenhouse gas emissions but also result in operational inefficiencies and economic losses. Despite this, policy and research have historically prioritized the upstream (production/import) and downstream (disposal) phases. In Malaysia, midstream challenges are further compounded by limited regulatory enforcement, insufficient technician training, and the absence of real-time monitoring.

Considering rapid artificial intelligence (AI) technologies advancement, there is now significant potential to transform how FC gas leaks are monitored, prevented, and managed during the middle stream by enabling real-time data collection, predictive maintenance, and automated response systems. This paper aims to explore the potential of AI-driven technologies to address these challenges in Malaysia, focusing specifically on the midstream phase of FC gas management. The findings of this study will contribute to the growing body of knowledge on AI-driven environmental management and provide actionable insights for policymakers, industry stakeholders, and training institutes in Malaysia. This paper is structured as follows: Section 2 provides a comprehensive literature review of FC gas management challenges and technological advancements. Section 3 outlines the methodology, including the DPSIR framework and SWOT-AHP analysis. Sections 4 and 5 present the findings and conclusion, respectively.

2. LITERATURE REVIEW

FC-gas leakage is a significant source of direct emissions during the midstream phase that has been identified as a critical hotspot for emissions (Zanghelini et al., 2014; Solano–Olivares et al., 2019; Rewlay-ngoen & Papong, 2020; Sovacool et al., 2021). Studies has demonstrated that leakage rates can vary widely depending on system design, maintenance practices, and refrigerant type. For example, HFCs such as R-410A and R-32 are widely used in modern systems but their considerable GWPs, pose a particularly problematic issues concerning leakage (Sovacool et al., 2021; Martinho et al., 2023). Despite existing of international framework, the lack of stringent technical controls and the reliance on reactive maintenance practices have resulted in undetected leaks, reduced cooling efficiency, and increased environmental harm (Adeyemi et al., 2022). However, previous study has inadequately addressed the midstream, mainly phase due to a predominant on others components of the FC-gas lifecycle and specific technical challenges. The midstream phase is frequently received less attention compared to the upstream and downstream phase, where the environmental consequence is more clearly observable especially downstream. For instance, a significant amount of research has concentrated on the application of phase change materials within the domestic refrigeration system to improve efficiency and decrease energy usage, rather than focusing on the midstream on preventive leakage of FC-gas (Omara & Mohammedali, 2020). In addition, the priority on addressing safety and environmental risks related to low-GWP refrigerants has primarily been directed towards end use safety (Cheekatamarla & Sharma, 2024). The lack of consumers awareness and engagement in the FC-gas management, as highlighted in studies on consumers behaviour, suggests that midstream phase are not well understood or prioritized by stakeholders (Martinho et al., 2022).

In Malaysia, the current approach to FC-gas management primarily focuses on the upstream (import/production) and downstream (end-of-life) phases, with limited attention given to the midstream (usage) phase. This gap is exacerbated by the widespread use of unskilled or uncertified technicians, poor maintenance practices (Pardo Martínez & Cotte Poveda, 2022; Martinho et al., 2023), and the absence of real-time monitoring systems. As a result, FC gas leaks often go undetected until significant refrigerant loss occurs, leading to increased emissions and operational inefficiencies. To address these challenges, there is a growing need for proactive, technology-driven solutions that can enhance the monitoring, detection, and management of FC-gas during the midstream phase.

Recent advancement in digital technologies, featuring AI and Internet of Things (IoT) sensors, significantly enhances the accuracy and effectiveness of FC-gas monitoring, detection, and management during the midstream phase by enabling real-time data collection, predictive maintenance, and automated response systems. IoT sensors, including pressure and temperature sensors, provide real-time monitoring of refrigeration systems, thereby allowing for ensuring early detection of anomalies and potential leaks, which is essential for maintaining system integrity and preventing environmental threats associated to FC-gas leaks (Nazif, Taib, Din, et al., 2022; Dandavate et al., 2024). The integration of IoT and AI facilitates predictive maintenance, which effectively reduces downtime and maintenance costs while simultaneously improving energy efficiency and sustainability by optimizing operational parameters such as energy consumption and pressure levels (Dandavate et al., 2024). Furthermore, system driven by IoT allow for remote monitoring and early warning, allowing for early warning and alerts by triggering notification (Suresh et al., 2023). Additionally, blockchain technology can enhance the transparency and integrity of FC gas inventory management, ensuring accurate tracking of refrigerant usage and compliance with environmental regulations. The decentralized and unchallengeable nature of blockchain ensures that every movement of FC-gas are recorded in a manner that is resistant to modification, thereby enhancing traceability and accountability throughout the entire FC-gas lifecycle (S. K et al., 2024). The integration of AI-driven technologies in the FC-gas management presents provides a holistic approach that significantly enhances operational efficiency and environmental sustainability in the midstream phase of FC-gas management.

However, despite the potential of these technologies, their application in Malaysia's midstream FC gas management remains largely underdeveloped and the focus of AI-driven solution mostly on energy efficiency for RAC equipment. This is because energy efficiency can be enhanced through well-establish technologies for example optimizing system components and operations. Whereas FC-gas leak detection requires advanced models to accurately identify leaks, especially slow or microleaks, which are difficult to detect with conventional methods. This gap reveals a significant research need that inquiries and develops regional AI-driven solutions, for the unique challenges of Malaysia's midstream FC gas management. Addressing this gap is essential not only to mitigate environmental harm but also to align Malaysia with global frameworks such as the Montreal Protocol, Kigali Amendment, and Paris Agreement. In this era of technologies, Malaysia can transform its midstream FC gas management practices, setting a benchmark for other developing countries especially that facing similar challenges. This study intends to fill this gap by assessing the feasibility and potential impact of AI-driven solutions in assisting Malaysia to improve midstream FC gas management and providing actionable insights for policymakers, industry stakeholders, and training institutes.

3. METHODOLOGY

3.1. DPSIR Model

To identify current issues in the lifecycle management of FC gas in Malaysia, this study applies the DPSIR (Driving Forces, Pressures, State, Impacts, and Responses) framework. The DPSIR model helps illustrate causal links between human activities, environmental impacts, and policy responses (Loizia et al., 2021), and serves as a valuable tool for understanding the effects of human actions and guiding strategic responses (Kaur et al., 2020). The study begins by defining each DPSIR category, as shown in Table 1, using preliminary data from interviews with relevant local stakeholders. 19 subject matter experts were consulted, including representatives from government agencies (Ozone Unit, Climate Change Division) , industry players (Malaysian Air-Conditioning & Refrigeration Association (MACRA)) and training institutes (Industrial Training Institute (ILP)) involved in FC gas management. A purposive sampling method was employed to ensure that respondent had sufficient knowledge and experience in FC gas management. So, these stakeholders were selected based on their expertise and active involvement in FC gas-related activities, ensuring a diverse and representative sample. Secondary data from a desktop review were also used to complement the interviews, inform the development of interview questions, and support further analysis.

The DPSIR framework is used to highlight the gaps in current FC gas management in Malaysia, with a particular focus on the Pressure category, supported by secondary data. This approach provides a clear understanding of the cause-effect relationships, showing how gaps in management (Pressures) influence the current state and environmental impacts, while also identifying best practices from selected developed countries (Responses). The outputs from the DPSIR analysis are then used to establish criteria and sub-criteria for the SWOT-AHP model, which will be evaluated by local stakeholders.

Table 1: *DPSIR framework categories (Zhou et al., 2015; Moss et al., 2021)*

Category	This study
Driving Forces (D)	Demand and emission of FC gas from RAC equipment.
Pressures (P)	Gap on FC gas management in Malaysia
State (S)	Current status FC gas management in Malaysia
Impacts (I)	The environmental impact of FC gas emission and economic loss
Responses (R)	Adoption of AI-driven technology in FC gas management

3.2. SWOT-AHP model

The SWOT-AHP method is employed in this study to prioritize strategic decisions for improving midstream FC gas lifecycle management in Malaysia (Genc et al., 2018). A questionnaire adapted from Li et al. (2020) was used to weight criteria and sub-factors (Li et al., 2020), and was distributed to a focused group of four key stakeholders from Ozone Unit and MACRA due to the limited availability of experts in Malaysia with specialized knowledge in FC gas management. According to Fugard and Potts (2015), sample sizes can range from as low as 2 to over 400 participants (Fugard & and Potts, 2015). Limited sample sizes may be considered valid in situations where the group of experts is constrained, as demonstrated in studies involving small collectives of decision-makers such as corporate executives or political fig. (Isihara et al., 2020). In this study, these stakeholders represent both government and industry perspectives, playing critical roles in shaping policies, enforcing regulations, and implementing practices related to FC gas management in Malaysia.

The experts performed pairwise comparisons to assess the relative importance of each factor, using Triangular Fuzzy Numbers (TFNs) for accuracy. The weightings were analyzed using R software, and the consistency of expert judgments was evaluated through the Consistency Ratio (CR); any responses with a CR above 0.1 were returned for revision, following Saaty's (2004) guidelines.

Individual expert inputs were aggregated into group assessments (e.g., government and industry), and the average priority vector was used to rank the SWOT elements. Final scores for each sub-factor were calculated by multiplying their individual scores by the cumulative score of their respective SWOT category. These scores, combined with expert insights, previous studies, and interrelationships within the SWOT matrix, were used to formulate strategic recommendations for enhancing FC gas management through AI-driven approaches.

4. RESULT AND DISCUSSION

The findings of this study, structured around the DPSIR framework and SWOT analysis, reveal critical challenges and opportunities in Malaysia's midstream fluorocarbon (FC) gas management. A DPSIR framework was used to organize key information on FC gas management in Malaysia, reviewing the current knowledge on the driving forces, pressures, state and impact. More extensive literature review was done for the response to the FC gas management. This information was organized in separated section. Appendix 1 shows the summarizes the DPSIR analysis results and can be used as a supporting schematic to the remaining discussion.

5. The Potential Issues and Challenges in FC Gas Lifecycle Management in Malaysia

5.1. Driving Forces (D)

The global demand for refrigeration and air conditioning (RAC) systems is rapidly increasing, driven by climate change, urbanization, and economic growth. By 2050, air conditioning demand is expected to triple, with over 6 billion units already in use worldwide, significantly contributing to energy consumption and GHG emissions (Kian Jon et al., 2021). Beyond residential and commercial use, RAC systems are also critical in sectors like healthcare, food preservation, and data centers (Xu & Wang, 2020). Most RAC equipment uses fluorocarbon (FC) gases as refrigerants due to their efficient thermodynamic properties. However, leaks or malfunctions, particularly during the operational phase (midstream), release FC gases into the atmosphere, which have high ozone depletion potential (ODP) and global warming potential (GWP) (Fu et al., 2025), contributing directly to ozone layer damage and climate change.

To address this issue, global regulations have been established. The Montreal Protocol, enforced in 1989, was the first international agreement to phase out ozone-depleting substances like CFCs and HCFCs (DOE & UNDP, 2017). These were replaced by HFCs, which, while ozone-safe, have a very high GWP and are now among the fastest-growing GHGs. In response, the Kigali Amendment was introduced in 2016 to limit global HFC use. This amendment not only targets HFC reduction but also promotes improvements in energy efficiency of RAC systems, contributing to lower electricity demand and further GHG reductions, making it a key component in global climate change mitigation (P. Purohit et al., 2020).

5.2. Pressure (P)

The rising demand for RAC equipment in Malaysia, driven by its tropical climate and rapid economic growth, places significant pressure on midstream FC gas management. High temperatures (27–31°C) have increased RAC use, especially in residential and commercial buildings (Aqilah et al., 2021). However, FC gas leaks during equipment use—often due to poor maintenance and undetectable faults—contribute significantly to GHG emissions. One key issue is the missed opportunity to pair FC gas management with energy savings. Malaysians tend to value cost savings over environmental benefits, leading to low engagement in FC gas initiatives (Mei et al., 2017; Nazif, Taib, Fadhil, et al., 2022). Research shows that undercharged air conditioners may operate 17% below rated efficiency (Rogers et al., 2019), and optimal FC gas levels can improve energy performance and indoor air quality (Baniassadi et al., 2022). Integrating FC gas control with energy efficiency can reduce emissions and support climate goals, as highlighted by Purohit et al. (2020), who estimate that phasing out HFCs alongside efficiency improvements could prevent up to 631 Pg CO_2 equivalent emissions by 2100 (P. Purohit et al., 2020). Yet, Malaysia still lacks real-time monitoring systems and skilled technicians to fully realize these benefits.

Other critical challenges include limited infrastructure and high operational costs for FC gas reclamation and destruction. Malaysia has only one facility for each—Westech (M) Sdn Bhd for reclamation and Kualiti Alam for destruction—making transportation and processing expensive. Although these facilities were supported by international initiatives such as JICA, industry participation remains low due to cost concerns, especially since the Montreal Protocol does not cover installation expenses for destruction plants (Taib et al., 2019). Additionally, Malaysia lacks a comprehensive database to track FC gas usage and emissions during operation and disposal, limiting its ability to comply with international agreements like the Paris Agreement and Montreal Protocol. The Third Biennial Update Report (2020) only includes emissions data from mobile air-conditioning, with no information from stationary systems (KASA, 2020). Without accurate data, effective planning and mitigation are impossible. Moreover, the absence of clear national guidelines and low public awareness further hinder FC gas management, especially at the midstream and downstream phases. To address this, the government must develop standardized regulations and educational initiatives targeting both consumers and maintenance professionals (Saifullah Md et al., 2017; Nazif, Taib, Fadhil, et al., 2022).

5.3. State (S)

The current state of Malaysia's midstream FC gas management reveals critical gaps, particularly in environmental performance and technical practices. The sector is mainly regulated at the import/export level, with FC gas sourced from countries like China, India, and the USA. While the Royal Malaysia Customs Department manages import permits with oversight from the Department of Environment (DOE), there is no regulation limiting the amount of FC gas in imported RAC equipment. The Environmental Quality (Refrigerant Management) Regulation 2020 introduced rules for HCFC use and RAC maintenance, but it lacks technical control measures to prevent FC gas emissions during equipment operation and disposal. Poor maintenance culture, reliance on uncertified technicians, and minimal enforcement of regulations further exacerbate the issue. Although Malaysia has over 19,000 certified RAC technicians through the Certification Service Technician Program (CSTP), low enforcement discourages companies from hiring skilled professionals. As a result, maintenance is often reactive, increasing the likelihood of FC gas leakage and environmental harm.

Environmental awareness among consumers remains low, and FC gas leakage data, especially at the midstream stage, is scarce. A study by Nazif and Taib (2019) using IoT sensors estimated up to 60% FC gas loss in the food and cold chain sector due to poor installation and maintenance practices. These leaks often go undetected until significant amounts are lost, reducing cooling efficiency and increasing electricity consumption (Nazif & Taib, 2019). The lack of AI-driven solutions further hampers early leak detection and regulatory enforcement. Real-time monitoring and predictive maintenance technologies could help reduce maintenance costs by up to 40% and improve equipment reliability by 30–50% (Gupta & Kaur, 2024). However, their adoption in Malaysia remains limited. The absence of reliable emissions data also prevents accurate reporting under international frameworks like the Nationally Determined Contribution (NDC). To address these systemic issues, Malaysia must prioritize midstream FC gas management, enhance enforcement of existing regulations, and promote the adoption of AI-driven and preventive maintenance technologies.

5.4. Impact (I)

Malaysia's midstream FC gas management challenges have serious environmental and economic consequences, hindering progress toward sustainable development goals. Environmentally, the direct release of fluorocarbon (FC) gases during the operation and servicing of RAC equipment significantly contributes to ozone depletion and global warming due to their high ODP and GWP values. While FC gases are safely contained when equipment functions properly, emissions often occur at the midstream stage due to poor maintenance and undetected leaks. In Malaysia, limited research exists on these emissions, but a study by Nazif and Taib (2019) found that up to 60% of R507—a gas with GWP 3,985 times higher than CO_2—can be lost through undetected leaks (Nazif & Taib, 2019). Such emissions not only accelerate climate change but also threaten biodiversity and ecosystem health.

Economically, poor FC gas management increases costs for both consumers and businesses. Leaks reduce system efficiency, raise electricity bills, and lead to more frequent breakdowns and shorter equipment lifespans (Zhang et al., 2023; Lin & Zhang, 2024). As the cooling systems work harder to maintain temperatures, wear and tear increase, requiring costly repairs and replacements. Microleakages caused by aging or improper installation worsen energy consumption and accelerate equipment deterioration (Zhao et al., 2024). These inefficiencies are especially disruptive in sectors reliant on continuous cooling. Adopting proactive maintenance strategies and technologies such as AI and digital twins can improve system reliability and reduce operational costs. Addressing FC gases leakage is therefore essential not only for environmental protection but also for economic efficiency.

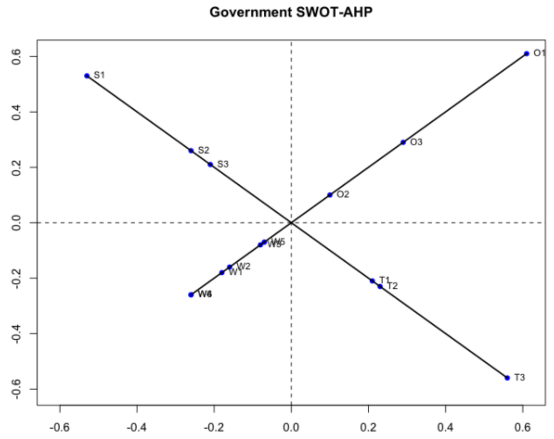
5.5. Response (R)

To address the environmental and economic challenges of midstream FC gas management in Malaysia, this study proposes AI-driven technologies and policy reforms aimed at improving system efficiency and aligning with global sustainability goals. Key among these is the adoption of IoT-enabled leak detection systems, which monitor refrigerant levels, pressure, and temperature in real time to identify leaks early—before they escalate. Unlike traditional direct methods, these indirect systems offer greater accuracy, detecting even small leaks (as low as 10%) (Nazif & Taib, 2019) and enabling remote monitoring through Wi-Fi, reducing emissions and system downtime. When integrated with machine learning, these technologies support predictive maintenance, which helps optimize repair schedules, prevent system failures, and extend equipment lifespan. Studies show predictive maintenance can cut maintenance costs by up to 40% and improve equipment reliability by 30–50%, reducing electricity use and carbon emissions (Gupta & Kaur, 2024).

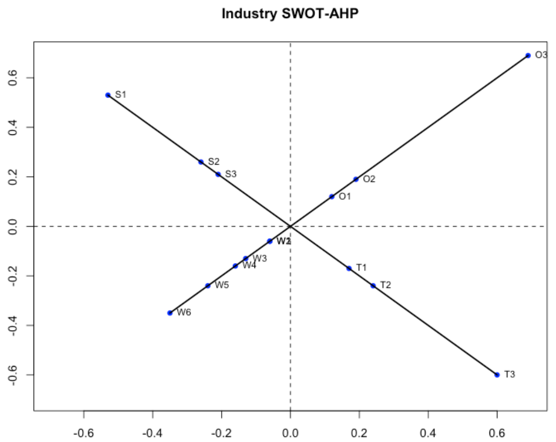
In addition, blockchain technology can enhance transparency and accuracy in tracking FC gas usage and emissions. By securely recording and verifying data across the supply chain, blockchain improves GHG reporting and supports compliance with international environmental standards (Nielsen et al., 2021; Alotaibi et al., 2024). This approach enables Malaysia to better meet its NDC targets and global climate commitments. Together, these technologies tackle the root causes of inefficiencies and emissions in the RAC sector while driving energy efficiency, economic savings, and sustainable growth. Integrating AI-driven tools and strengthening stakeholder collaboration positions Malaysia as a regional leader in sustainable cooling practices.

5.6. The potential of improvement on middle FC gas management in Malaysia

To implement the findings from the DPSIR framework, a SWOT-AHP analysis was conducted to assess strengths, weaknesses, opportunities, and threats in Malaysia's midstream FC gas management. This involved input from government and industry stakeholders to prioritize critical factors (see Appendix 2 and Fig. 1). For government stakeholders, the top two priorities were W4 (Unavailable Best Practices Standards) and W6 (Lack of Inter-Agency Collaboration), with weights of 0.259 and 0.257, respectively. W4 highlights the absence of consistent, standardized guidelines for FC gas handling, which impairs proper compliance and increases environmental risks. W6 emphasizes the need for better coordination among government agencies to improve enforcement and policy implementation. Although S1 (Import Licensing) and S2 (Environmental Quality Regulation 2020) are recognized as strengths, they are undermined by W1 (Lack of Enforcement), demonstrating the need for stronger compliance mechanisms. Opportunities like O1 (Authorized Training Centres) and O3 (Recovery Facilities) were also highly ranked, as they support skills development and emission reduction.



Government agency



Industry Players

***Fig1** SWOT-AHP analysis*

For industry stakeholders, operational concerns took priority. W5 (Unavailable FC Gas Inventory) ranked highest (0.241), pointing to the urgent need for a centralized database to manage FC gas use and emissions. W6 was again a high priority (0.349), due to its role in causing uncertainty and delays from inconsistent government communication. W3 (Lack of Incentives for Innovation) was third (0.127), suggesting a need for investment in IoT and AI technologies for predictive maintenance. Opportunities O3 (Recovery Facilities) and O2 (Cement Kilns) were also valued by industry for their practical role in emission reduction.

To address these issues, AI-driven technologies like blockchain for inventory tracking and IoT for real-time leak detection are recommended. These solutions directly tackle major weaknesses, especially W5 and W2 (Poor Maintenance Practices). Structured training through Authorized Training Centres (O1) can equip technicians to use these advanced tools effectively. Based on the analysis, key recommendations include: the government should establish standardized guidelines (W4), improve inter-agency coordination (W6), and mandate blockchain-based systems with incentives for AI adoption. Meanwhile, the industry should invest in recovery facilities and cement kilns (O3; O2), collaborate on centralized inventory systems (W5), and upskill technicians (O1). Aligning these actions can significantly enhance Malaysia's FC gas management, reduce environmental harm, and strengthen the country's position in sustainable cooling practices.

6. Conclusion

This study highlights the urgent imperative for the enhancement of Malaysia's midstream FC gas management, whereby previously neglected emissions hotspots can be systematically addressed using an AI-driven technologies. Through the implementation of the DPSIR framework, critical environmental pressure have been recognized in association with maintenance practice, alongside the ensuing data-related challenges and an inconsistent regulatory framework, while the SWOT-AHP further specifies priority areas reliant on particular stakeholders, including the lack of best practice standards (W4), poor coordination between agencies (W6), and lack of inventories for FC gases (W5). With this information in mind, emerging technology may present Malaysia with a unique opportunity to align practical applications with policy frameworks, consequently enhancing midstream FC gas emissions management across the entire lifecycle, which encompasses the integration of technologies such as IoT leak detection systems, predictive maintenance algorithms, and blockchain-based inventory systems. These advancements in technology are possess the capacity to improve system reliability and transparency, as well as regulatory compliance as Malaysia work to achieved their climate commitments.

Based on the findings, it is recommended that governmental organization focus on the development of standards guideline for the FC gas management in Malaysia and advocate for the establishment of inter-agency framework for data sharing, supported by the application of blockchain technology. Since FC gas management in Malysia involved few government agencies.

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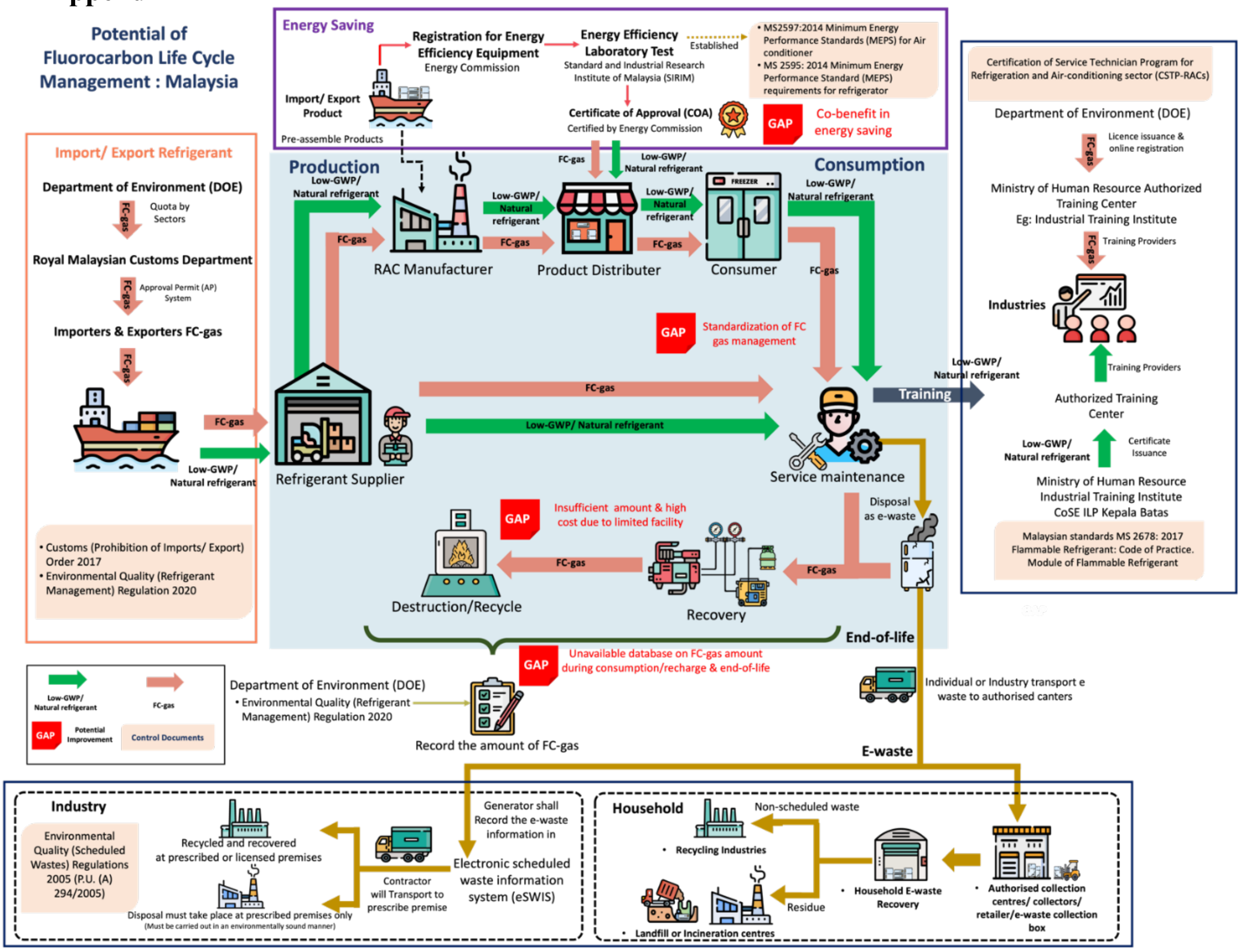
Appendix 1



Appendix 2

Category	SWOT Element	Description
Strengths (S)	Presence of Import Licensing	The requirement for import licenses helps regulate the entry of fluorocarbon gas, ensuring that only approved amount of substances are imported into the country.
	Presence of Environmental Quality (Refrigerant Management) Regulation 2020	The regulation provides a structured framework for managing fluorocarbon gases, addressing their lifecycle from import to disposal. It is promoting compliance and environmental responsibility among stakeholders in the industry.
	Presence of Authorized Training Center (ATC)	Authorized training centers offer specialized skill-building programs for RAC (Refrigeration and Air Conditioning) technicians, enhancing their skills and knowledge in fluorocarbon gas handling and management.
Weaknesses (W)	Lack of Enforcement on Environmental Quality (Refrigerant Management) Regulation 2020	Despite the presence of regulations, insufficient enforcement limits their effectiveness, leading to potential non-compliance and increased environmental risks.
	Lack of Site Monitoring for Direct Emission	The absence of regular site monitoring increases the risk of direct fluorocarbon gas emissions from leaks or mishandling, contributing to environmental harm and regulatory violations.
	Lack of Incentives/ Polluter Pay Mechanism	The absence of financial incentives, discourages industries and businesses from adopting best practices in fluorocarbon gas management, leading to slowing progress toward sustainability and continued environmental harm.
	Unavailable Best Practices Standards on FC Gas Management	The lack of standardized guidelines for managing fluorocarbon gas creates inconsistencies approaches in handling, preventing and disposal methods, leading to inefficiencies and environmental risks.
	Unavailable FC Gas Inventory/Database	The absence of a centralized inventory or database hampers the ability to track fluorocarbon gas usage, emissions, and recovery, making it complicating management efforts and policy development.
	Lack of Communication/ Collaboration/ Connectivity Inter-Government Agency	Poor coordination among government agencies leads to fragmented efforts in implementing and enforcing fluorocarbon gas management regulation.
Opportunities (O)	Presence of Authorized Training Center (ATC) to Improve the RAC Technician Skill	Leveraging ATCs can enhance the skills of Refrigeration and Air Conditioning (RAC) technicians, leading to better management of fluorocarbon gas.
	Presence of Cement Kilns to Destruct the FC Gas	Utilizing cement kilns for the destruction fluorocarbon gas, providing a cost-effective and environmentally friendly solution for disposal.
	Presence of Recovery Facility	Existing recovery facilities allows for the efficient collection and recycling of fluorocarbon gas, reducing emissions, minimizing waste and environmental impact.
Threats (T)	Low Destruction, Recovery & Recycle Rate	Current practices show low rates of fluorocarbon gas destruction, recovery, and recycling. Hence, undermines efforts to manage fluorocarbon gas effectively and minimize environmental impact.
	Low Awareness on Proper Management Among Consumers	Consumers' lack of knowledge about proper fluorocarbon gas management contributes to improper handling and increased leakage.
	High Destruction Cost	The high costs associated with the destruction of fluorocarbon gas may discourage proper disposal practices, leading to illegal dumping or misuse.