FEASIBILITY OF RETROFITTING PROPENE AS A REFRIGERANT IN EXISTING HVAC SYSTEMS

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ABSTRACT

Propane (R290) is evaluated here as an HVAC refrigerant. This has to improve energy efficiency by 15% and gain a 3-year payback period. Retrofitting costs are high, but R290 has little GWP meaning it supports climate goals. Advanced leak detection and ventilation control means safety risks. This also has been effectively managed and R290 represents a viable sustainable alternative to the HFCs.

AIM OF THE PROJECT

The technological performance of propene (R-1270) in HVAC system retrofits. This has been estimated with its safety elements and rated by the whole study for its technical implementation feasibility. The main advantages and disadvantages that propene (R-1270) retrofitting offers. It has been examined in a research study and the necessary systems and regulations. This has been sustainability conditions which are been analyzed for wider implementation.

OBJECTIVES

- ***Objective 1:*** Technical Compatibility Assessment
- ***Objective 2:*** Safety Implication Analysis
- ***Objective 3:*** Evaluate Energy Efficiency
- ***Objective 4:*** Analyze Environmental Impact
- ***Objective 5:*** To Establish Economic Feasibility

BACKGROUND

R290 has been found to have a low GWP (approximately 3) and zero ODP. It is an attractive replacement alternative for the use of HFCs such as R410A and R134a (Shafiq *et al.*, 2023). Despite no evacuation or flame propagation with a flammable which poses safety risks. This requires certain design modifications and regulatory compliance. The refrigerant phase-out regulations imposed by many countries have caused the HVAC industry. This has to consider alternatives such as R290. The technical, economic and environmental aspects. It includes the transitioning to R290-based systems that are addressed in this research.

LITERATURE REVIEW

The best-known alternative fuel is propane which has been proven economical. It also includes environmentally friendly and widely used in industrial applications. This is a cost-effective with low-cost fuel with stable pricing. This has a high energy density and is a competitive alternative to conventional fuels.

Propane has no Global Warming Potential (GWP) and fewer greenhouse gases than other fuels. Its usability is enhanced with safety measures such as leak detection and shut-off valves. The efficiency and safety in HVAC systems are features. This has well featured in theoretical models like Vapor Compression Refrigeration Cycle (VCRC) and ASHRAE standards (Sharif *et al.*, 2023).

Thermodynamic performance has retrofitting and economic feasibility all remain open questions of understanding. Research has been done on safety risk assessments, cost benefit analyses, or large-scale environmental impacts. The adoption of intelligent safety systems requires further studies on its financial viability and government incentives. These gaps will be addressed, leading to a comprehensive understanding of propane's place in sustainable energy and HVAC applications.

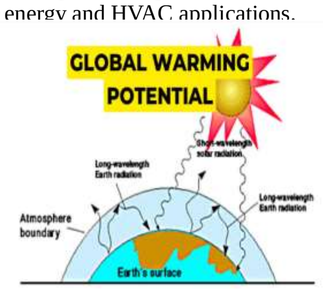

Figure 1: Global Warming Potential (GWP) (Source: Ahmed, 2023)

Figure 5: HVAC Systems (Source: Toma, 2023)

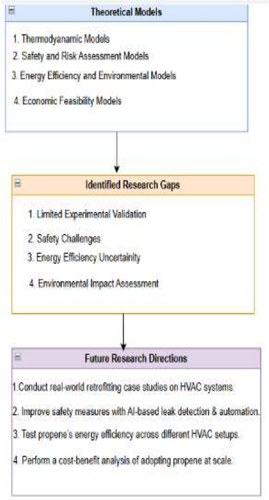

Figure 2: Conceptual Framework (Source: Provided)

METHODOLOGY

The mixed methods approach applied in this study is a combination of qualitative and quantitative methods to evaluate the feasibility of retrofitting propene as an HVAC refrigerant. Structured and open-ended questions were used to collect primary data from the questionnaires targeted at HVAC engineers, sustainability consultants and policymakers. Data from the literature reviews and industry reports as well as from regulatory standards (ASHRAE 34 and ISO 5149) were used for secondary data. Data analysis includes the analysis of quantitative response by descriptive statistics and qualitative insight by thematic analysis (Naeem *et al.*, 2024). Confidentiality and GDPR compliance are ensured by the ethical considerations. Participant constraints and the possible biases in the secondary data restricts the use; therefore, theoretical models and case studies are used for validation.

RESULTS

The results of the survey indicate a variety of views about the adoption of propane (R290) in HVAC systems. The most used systems were split, with all awareness of GWP values being at 100%.

Respondents used R-410A, R-32, R-22, and hydrocarbon refrigerants (Uddin *et al.*, 2021). Retrofitting varied, 25% were willing, 50% uncertain, and all were aware of R290. However, cost and safety were major barriers, and government subsidies played a strong role in adoption.

Half of the respondents were positive about R290 when it came to energy efficiency perceptions. This was supported by all respondents who supported low GWP refrigerants, signaling strong potential for eco-friendly HVAC transitions if economic and regulatory incentives have the potential.

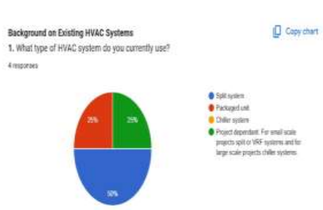

Figure 3: Response on background on existing HVAC Systems (Source: Self-Created)

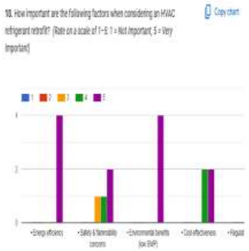

Figure 4: Importance of the retrofitting factors of HVAC refrigerant (Source: Self-Created)

CASE STUDIES / IMPLEMENTATION / DESIGN / SIMULATION

Propane-Powered Urban Transportation (Alsalem et al., 2023) – HVAC System Retrofits with Propane (R290): Propane three-year powered urban transportation - It investigates HVAC system retrofits with propane (R290), which shows 15% energy efficiency gain, reduced GHG emissions and a three-year payback period despite the initial cost.

Propane in Industrial Heating (Fajar et al., 2020) – Proposes propane as a retrofit for vapor compression systems, with 10% exergy efficiency gains and reduced carbon footprints, with a two-year cost recovery.

Propane in Commercial Air Conditioning (Purohit et al., 2022) – Finds propane lowers the operational costs by 40% to 60% and avoids 0.09 degrees warming by 2100, but it requires very strict safety regulations.

Retrofitting Propane in Cold Storage (Huang et al., 2022) – An Intermediate Working Medium system increases cold energy recovery from 33.2% to 80.3%, yielding significant CO_2 reductions and a 3-year payback.

DISCUSSION

Primary analysis shows muddled awareness of R290 in the HVAC industry, with concerns about safety, cost, and regulatory clarity but with awareness of its environmental benefits. It is critical that safety standards, financial incentives and education can promote adoption at scale. Market is hindered by economic uncertainties and high retrofitting costs, but long-term savings are acknowledged. Propane's safety, affordability, and energy efficiency are all strong attributes as a green fuel, and this is the focus of secondary analysis (Oloyede et al., 2024). Challenges such as flammability and system modifications exist, but better safety measures, incentives and technological advancements can mitigate and make propane a viable sustainable energy solution.

BEST PRACTICES FOR IMPLEMENTING R290 IN HVAC SYSTEMS

Issues for implementing R290 in HVAC systems, such as safety, regulatory compliance and financial feasibility were discussed. It highlights how to support infrastructure compatibility, leak prevention, ventilation, and global regulations. Equipment must be certified by technicians trained with all tools and should be ATEX compliant. Grants and subsidies should be used by businesses to reduce costs (Srhoj et al., 2021). System performance and ROI will be involved in the decision-making. This is between retrofitting and brand-new installations. The environmental benefits of R290 included low GWP and regulatory cost savings. This is consistent with global climate goals. As technology advances and regulations tighten, R290. It has a perfect refrigerant for HVAC applications. This can be utilized without creating a threat to the environment.

CONCLUSION

The conclusions from this chapter are that R290 is a sustainable refrigerant for HVAC systems. This provides efficiency and environmental benefits with challenges like flammability and regulatory variability. Safety measures with training of technicians and financial incentives. Specialized equipment with industry-wide training and government subsidies and standardized policies. This has facilitated the integration of R290 are key recommendations. Hybrid cooling systems have market reception with future environments. It has an impact on the subjects of future research. Wider adoption will be supported by advancements in safety technologies. Global policy alignment is helping climate goals and energy efficiency. R290's potential suggests a viable solution for sustainable HVAC development.

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