Algerian Journal of Research and Technology
https://doi.org/10.58681/ajrt.26100101
A.J.R.T Volume 10 (N°01) (2026) 01 - 11

Simulation of the Production of Liquefied Natural Gas (LNG) from Flare Gas Using Aspen HYSYS: A Critical Review

Lucky LeeLee Princess[1]*, Emeka Okafor[1]

[1]*Department of Petroleum and Gas Engineering, University of Port Harcourt, Port Harcourt, Nigeria*

***Corresponding author:** princesslee729@gmail.com

Received. May 10, 2026. Accepted. June 21, 2026. Published. July 25, 2026

DOI: https://doi.org/10.58681/ajrt.26100101

Abstract. Routine gas flaring remains both an environmental burden and a loss of potentially marketable energy. This review critically evaluates the use of Aspen HYSYS and related process-simulation approaches for converting flare gas to liquefied natural gas (LNG), with emphasis on the complete process chain rather than on isolated recovery units. A structured literature review was organized around five technical themes: flare-gas feed variability and pretreatment, thermodynamic-model selection, liquefaction-cycle configuration, energy and exergy performance, and techno-economic/environmental assessment. The evidence shows that the technical feasibility of flare-gas liquefaction depends strongly on removal of CO_2, H_2S, water and heavy hydrocarbons before cryogenic cooling; appropriate representation of hydrocarbon phase behavior, commonly with the Peng–Robinson equation of state; and careful matching of refrigerant composition, pressure levels and heat-exchanger temperature profiles. Single mixed-refrigerant/PRICO configurations are attractive for small-scale applications because of their relative simplicity, whereas cascade and pre-cooled mixed-refrigerant systems can offer improved thermodynamic performance at the cost of greater process complexity. Across the reviewed literature, compressor power and cryogenic heat-exchanger performance emerge as dominant optimization targets. However, direct studies integrating real flare-gas variability, complete pretreatment, LNG liquefaction, dynamic operation, exergy analysis, emissions quantification and economic optimization in one Aspen HYSYS framework remain limited. The review therefore proposes a research framework in which feed characterization, pretreatment, liquefaction, nitrogen/heavy-component management, energy optimization, dynamic validation and sustainability assessment are treated as an integrated problem. This synthesis clarifies the specific contribution that future Aspen HYSYS studies should make beyond simply reproducing conventional natural-gas liquefaction flow sheets.

Keywords. Flare gas; LNG; Aspen HYSYS; Mixed refrigerant; PRICO; Cryogenic liquefaction; Process optimization; Gas flaring.

INTRODUCTION

Gas flaring is the controlled combustion of natural gas that cannot be immediately processed, transported or utilized. Although flaring can serve operational and safety functions, persistent routine flaring represents a major loss of hydrocarbon resources and contributes to greenhouse-gas emissions.

The World Bank reported that global flaring reached 167 billion m³ in 2025, illustrating that the problem remains substantial despite long-standing reduction initiatives (World Bank, 2026). For oil- and gas-producing economies, the challenge is therefore not only to suppress emissions but also to develop technically robust routes for converting variable associated or refinery flare gas into saleable products.

LNG is one such route because liquefaction reduces natural-gas volume dramatically and allows gas that is remote from pipeline infrastructure to be stored and transported. However, converting flare gas to LNG is more demanding than liquefying a stable pipeline-quality natural gas. Flare streams can vary in flow rate and composition and may contain CO_2, H_2S, water, nitrogen and C_2+ hydrocarbons.

These constituents affect hydrate and solid formation, LNG heating value, methane recovery, refrigerant duty and the operability of cryogenic heat exchangers (Mokhatab et al., 2014; Campbell, 2018; Poling et al., 2007).

Aspen HYSYS is widely used for natural-gas processing because it integrates thermodynamic property methods, separators, absorbers, fractionation columns, compressors, expanders, heat exchangers and refrigeration loops within a common simulation environment (Aspen Technology Inc., 2022).

Nevertheless, the usefulness of a simulation depends on the physical realism of the flow sheet, the selected thermodynamic model, and the quality of feed data and the definition of optimization constraints.

The objective of this article is therefore to critically synthesize—not merely describe—the literature relevant to LNG production from flare gas using Aspen HYSYS. The review addresses four questions: (i) what process steps are essential for transforming raw flare gas into LNG; (ii) which simulation and liquefaction choices most strongly affect performance; (iii) what limitations recur across previous studies; and (iv) what integrated research framework is needed for future flare-gas LNG studies.

REVIEW METHOD AND SCOPE

The review was structured around publications and technical sources dealing with flare-gas recovery, LNG/SSLNG liquefaction, Aspen HYSYS or Aspen Plus simulation, mixed-refrigerant and PRICO processes, natural-gas pretreatment, exergy/energy optimization and techno-economic assessment.

Studies were retained when they contributed directly to at least one stage of the flare-gas-to-LNG chain: feed characterization, impurity removal, hydrocarbon recovery, cryogenic liquefaction, refrigeration optimization, energy/exergy analysis, dynamic operation or economic/environmental evaluation.

To avoid treating fundamentally different studies as equivalent, the evidence was grouped by technical function rather than by publication sequence. Direct flare-gas LNG studies were distinguished from supporting studies on LPG/NGL recovery, conventional LNG liquefaction, flare-gas power generation and GTL.

The latter are included only where they provide transferable information on pretreatment, separation, refrigeration, optimization or flare-gas variability. This thematic approach makes it possible to identify where evidence is strong and where the literature still lacks an integrated flare-gas LNG simulation.

PROCESS REQUIREMENTS FOR FLARE-GAS-TO-LNG CONVERSION

Feed variability and pretreatment

The first technical distinction between flare gas and conventional LNG feed is variability. Flare gas may originate from separators, pressure-relief systems, refinery units or associated-gas handling systems; consequently, its methane content, heavy-hydrocarbon fraction, acid-gas content and flow rate can change with plant operation.

A liquefaction model that assumes a single clean-gas composition without testing variability can therefore overestimate methane recovery and underestimate refrigeration duty.

Before cryogenic cooling, water and acid gases must be reduced to very low levels to prevent hydrate, ice and CO_2 solid formation.

Heavy hydrocarbons must also be controlled because they can freeze or create undesirable LNG specifications at low temperature. Studies on IFPEX-type processing and flare-gas NGL/LPG recovery demonstrate the importance of integrating dehydration and hydrocarbon separation before deep refrigeration (Ndunagu et al., 2022; ElBadawy et al., 2017). For a complete Aspen HYSYS model, pretreatment should therefore be represented explicitly rather than assumed implicitly.

Thermodynamic model selection

For methane-rich hydrocarbon systems, cubic equations of state are widely used. The Peng–Robinson equation of state is particularly common in LNG and natural-gas simulations because it provides a practical representation of vapor–liquid equilibrium over broad pressure and temperature ranges (Mokhatab et al., 2014; Aspen Technology Inc., 2022). However, no property package should be selected solely by convention.

Systems containing appreciable water, methanol or strongly associating components may require specialized property treatment. Accordingly, the simulation basis should be matched to the actual unit operation: hydrocarbon cryogenic sections can be modelled with an appropriate cubic EOS, while solvent-based treating sections may require dedicated thermodynamic packages.

Liquefaction configurations

The reviewed literature identifies three main families relevant to flare-gas LNG: single mixed-refrigerant (SMR/PRICO), cascade refrigeration and pre-cooled mixed-refrigerant configurations. SMR/PRICO uses one multicomponent refrigerant to approximate the cooling curve of natural gas. Its low equipment count and compactness make it particularly attractive for small-scale or modular flare-gas applications (Basharahil, 2018; Remeljej and Hoadley, 2006).

Cascade systems use separate refrigerants at different temperature levels and can achieve strong thermodynamic performance but require more compressors, exchangers and control loops. Pre-cooled mixed-refrigerant systems reduce the load on the coldest refrigeration stage but increase process complexity.

The correct comparison is therefore not simply which cycle gives the lowest theoretical power. For flare-gas applications, the preferred cycle must balance specific energy consumption, methane recovery, refrigerant inventory, equipment count, turndown capability, tolerance to feed variation and ease of control. This trade-off is frequently missing when conventional LNG-cycle results are transferred directly to small flare-gas systems.

CRITICAL SYNTHESIS OF PREVIOUS RESEARCH

Flare-gas recovery studies: useful but not equivalent to LNG liquefaction

Several studies demonstrate that flare gas can be recovered and monetized through LPG/NGL production, electricity generation or GTL. Edeh and co-workers used Aspen HYSYS fractionation to recover LPG from refinery flare gas, showing the value of demethanization and downstream fractionation (Edeh and Ikedi, 2023).

Studies at Algerian facilities similarly demonstrate that methane-rich flare streams possess substantial energy value and can support power generation, NGL recovery and other utilization routes (Mahfoud and Mahfoud, 2025; Guella et al., 2024). These studies are important because they establish feed recoverability and separation strategies, but they do not by themselves demonstrate a complete LNG process. An LNG study must additionally establish cryogenic methane liquefaction, refrigerant-cycle closure, heat-exchanger feasibility, LNG product quality and boil-off behavior.

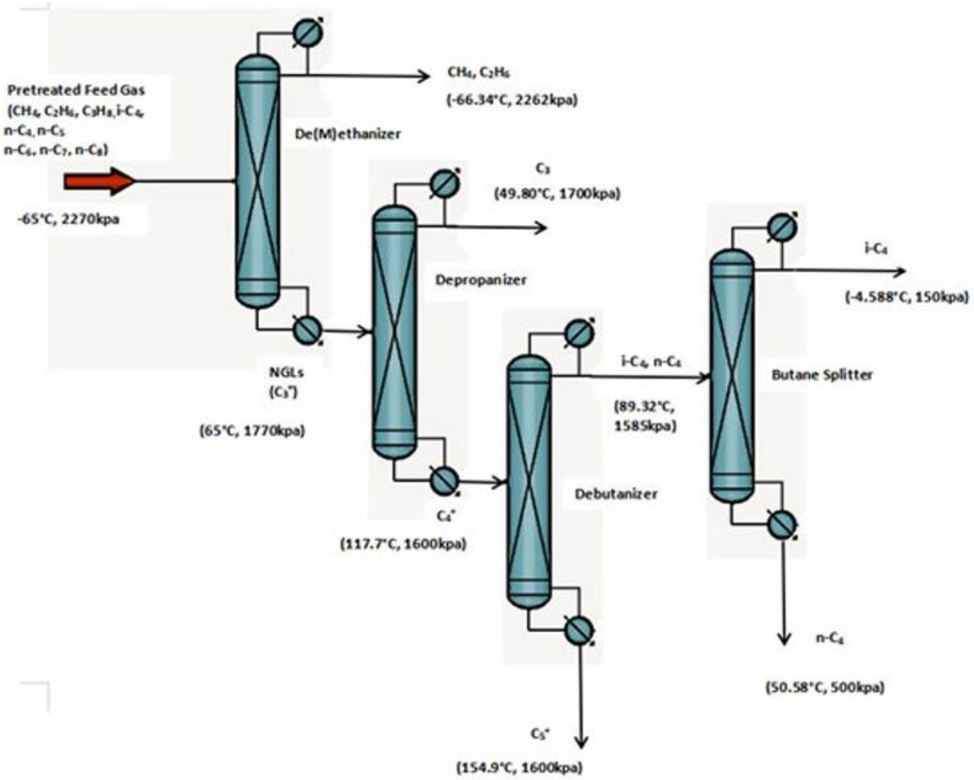

Fig.1. Simulation of LPG From Flare Gas (Edeh and Ikedi, 2023).

Small-scale LNG and economic feasibility

Small-scale LNG studies show that flare-gas monetization can be economically attractive under favorable feed availability, LNG price and capital-cost conditions (Putriastuti et al., 2021). The principal lesson is that thermodynamic optimization and economic feasibility are

inseparable: reducing compressor duty or exchanger area has limited value if the design becomes too complex or cannot tolerate fluctuating feed.
Conversely, a simple process with excessive specific energy consumption may not be commercially viable. Future simulation studies should therefore report both process performance and economic consequences of the selected operating conditions.

Mixed-refrigerant optimization

Recent work further strengthens this conclusion. Almeida-Trasvina and Smith (Almeida-Trasvina and Smith, 2022) evaluated structural modifications to single mixed-refrigerant cycles for small-scale LNG and showed that refrigerant composition and process configuration must be optimized together to reduce shaft-power demand.

More recent process-comparison research has also emphasized feed-flexibility and robust optimization across different LNG cycle configurations, reinforcing the need to test flare-gas LNG designs against changing feed composition rather than a single nominal case.

Research on PRICO and other mixed-refrigerant cycles consistently shows that refrigerant composition, circulation rate, high- and low-side pressures and exchanger approach temperatures strongly affect compressor power and LNG yield (Basharahil, 2018; Remeljej and Hoadley, 2006).
Optimization studies using Aspen HYSYS coupled with numerical algorithms demonstrate that substantial energy reductions are possible when these variables are optimized simultaneously rather than one at a time.
For flare gas, however, the optimum refrigerant composition cannot be assumed to remain constant when methane concentration, nitrogen content or C_2+ fraction changes. Feed variability should therefore be included explicitly in sensitivity and robustness analyses.

Thermo-economic flare-gas LNG studies

Thermo-economic work on refinery flare-gas liquefaction using modified PRICO configurations provides some of the strongest direct evidence for the feasibility of producing LNG and NGL from refinery flare gas (Barekat-Rezaei et al., 2018). Such work demonstrates the importance of minimizing compressor work while simultaneously managing sulfur species and heavier hydrocarbons. Its limitation for the present research field is not technical relevance but incomplete coverage of dynamic operation, process-control behaviour, exergy destruction and life-cycle environmental performance. These omissions define a clear direction for Aspen HYSYS-based research.

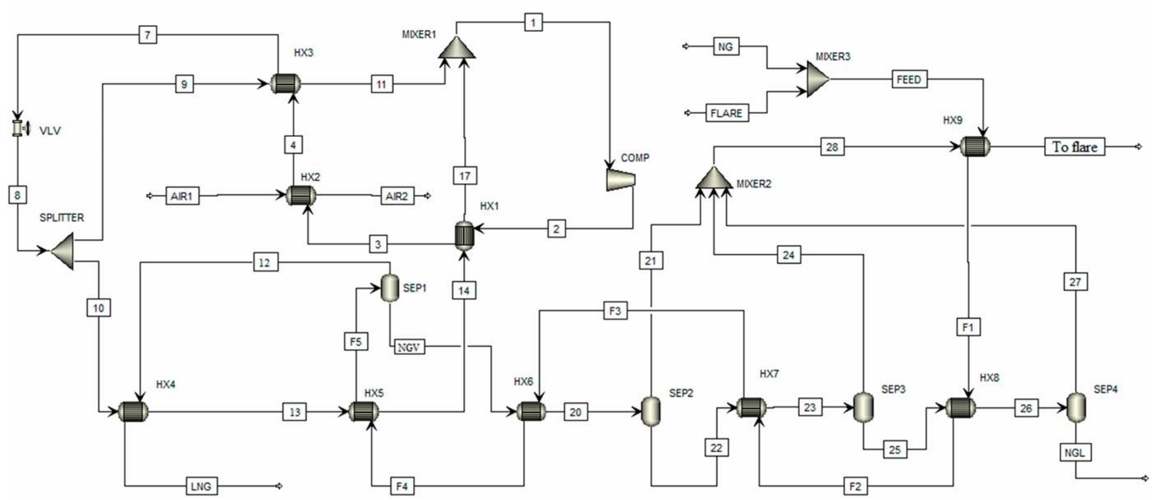

Fig. 2. Flare recovery process with the production of LNG and NGL (Barekat-Rezaei et al., 2018)

Comparative synthesis of recent studies (2020-2025)

Table 1 deliberately emphasizes studies published from 2020 to 2025 and separates direct flare-gas evidence from transferable LNG optimization evidence. The comparison shows that recent LNG research increasingly combines rigorous simulation with algorithmic optimization, exchanger-feasibility constraints, exergy analysis and economics, whereas recent flare-gas studies more often evaluate recovery routes, pretreatment or alternative products rather than a complete optimized flare-gas-to-LNG train. This mismatch is the central research opportunity identified by the present review.

Table 1. Critical comparison of recent flare-gas recovery and LNG liquefaction studies, with emphasis on 2020-2025.

Study /year	Feed/ application	Simulator/ model	Process/ cycle	Variables / optimization	Key performance finding	Economic dimension	Critical gap / relevance to flare-gas LNG
He Lin (2020)	High-ethane NG; LNG + ethane coproduction	Aspen HYSYS V10; PR EOS; GA	Integrated SMR + cryogenic distillation	MR variables + distillation conditions	Scale-dependent configuration choice; links separation and liquefaction	Economic comparison included	Not flare gas; useful for heavy-component management before LNG.
Putriastuti et al. (2021)	South Sumatra flare gas; small-scale LNG	Economic/scenario model	SSLNG development from flare gas	Flare rate, gas/LNG price, CAPEX	Demonstrates direct commercial route from flare gas to SSLNG	NPV, IRR, payback + sensitivity	Limited cryogenic process detail; economics should be coupled to rigorous HYSYS.
Santos et al. (2021)	Conventional natural gas	Aspen HYSYS + MATLAB; Nelder-Mead	Energy-efficient SMR	MR composition, pressures, expansion configuration	Reported network duty 750.2 kJ/kg NG	Energy-focused	Clean-feed assumption; provides optimization variables transferable to flare-gas LNG.
Santos et al. (2021)	Conventional natural gas	Rigorous simulator + Kriging surrogate	SMR with valve/turbine alternatives	MR component flows, pressures, expansion temperature	Improved previous local-search results by 3.36-5.32%	Not primary focus	Strong method for constrained optimization; flare-gas variability still absent.
Wu et al. (2021)	Purified NG; small-scale LNG	Aspen HYSYS V10	Optimized single-stage MR	Feed T/P, MR circulation, compression/throttling stages	Compressor power -29.8%; cooling-water load -21.3%; exergy efficiency improved	No detailed project economics	Shows value of staging and exergy analysis; assumes purified stable feed.
Rehman et al. (2021)	Conventional NG	Process simulation + operational optimization	SMR	Operating variables and improvement potential	Identifies practical rather than purely	Limited	Useful benchmark for realistic SMR gains; not flare-specific.

					theoretical improvement potential		
Almeida-Trasvina Smith (2022)	Small-scale LNG; conventional NG	Process simulation/optimization	Structurally modified SMR cycles	MR flow/composition, suction/condensing pressures, cycle structure	Shows structural changes can reduce shaft-work demand with modest complexity	Cost implications discussed	Highly relevant to compact flare-gas LNG, but feed pretreatment/variability not central.
Ndunagu et al. (2022)	Flare gas	Aspen HYSYS/process simulation	Methanol-based gas processing; NG/LPG recovery	Pretreatment and separation variables	Demonstrates flare-gas conditioning and hydrocarbon recovery	Limited LNG economics	Direct pretreatment relevance; does not complete cryogenic LNG cycle.
Uwitonze et al. (2022)	Small-scale natural gas	Aspen HYSYS	Dual-effect SMR integrated with NGL recovery	Refrigeration + demethanizer/heat integration	Integrates LNG and NGL recovery in compact flowsheet	Process-efficiency emphasis	Strong analogue for flare gas with heavies; needs variable raw flare-gas testing.
Pereira et al. (2022)	NG at four processing scales	Aspen HYSYS V10 + MATLAB PSO	SMR, C3MR, DMR, MFC, AP-X	Process complexity, scale, optimized energy	AP-X lowest energy at large scale; SMR highest profit at small scale	CAPCOST; scale comparison	Critical evidence that minimum energy is not automatically best economics for small flare-gas plants.
Santos et al. (2022)	Conventional natural gas	Rigorous simulation + Kriging/GAMS	SMR with 1-3 expansion stages	MR/process variables under exchanger constraints	Multiple expansion stages yielded 12.02-14.70% savings vs single stage	Not primary focus	Demonstrates efficient constrained optimization; should be extended to recovery/purity and flare variability.
Edeh Ikedi (2023)	Refinery flare gas	Aspen HYSYS	LPG recovery/fractionation	Demethanization and fractionation	Shows recoverable hydrocarbon value from flare gas	Limited	Useful upstream separation evidence, but no LNG refrigeration section.
Jin et al. (2023)	LNG carrier boil-off gas	Aspen HYSYS + GA	SMR BOG reliquefaction	MR/process variables; SEC objective	Optimized SMR for methane-rich BOG	Energy-centered	Relevant to BOG recycle/reliquefaction in flare-gas LNG plants; not raw flare gas.
Guella et al. (2024)	Real GL1/Z-Arzew flare gas, Algeria	Aspen HYSYS V12; steady state	Electricity, LPG and GTL alternatives	Technical/economic comparison of utilization routes	GTL highest value potential; electricity viable but lower CO_2 benefit	Explicit economic comparison	Excellent Algeria benchmark, but it does not simulate flare gas to LNG; ideal comparator for this review.
Elgarahy et al. (2024)	Flare-gas recovery literature	Comprehensive review	Multiple FGR routes	Technical, environmental, modelling, economic criteria	Supports integrated multi-criteria assessment	Strong economic coverage	Review-level evidence; highlights need for integrated decision framework rather than one performance

							metric.
Mahfoud Mahfoud (2025)	Skikda refinery flare gas, Algeria	Aspen HYSYS steady state	NGL recovery + gas-turbine electricity	Turboexpander and turbine configurations	Electricity route identified as commercially attractive for studied case	Economic comparison	Site-specific Algeria evidence; no complete LNG liquefaction train.
Abdollahi et al. (2025)	Power-plant NG peak shaving	Aspen HYSYS V11 + MATLAB GA; PR EOS	Modified MR LNG cycle	MR composition, flow, pressure; exchanger constraints	SEC 0.37→0.31 kWh/kg LNG; exergy efficiency 37%; COP 2.4	NPV 4.2m; IRR 13.1%; PBP ~6.5 y	Strong recent energy-exergy-economic optimization; feed is pipeline NG, not variable flare gas.

The 2020-2025 evidence therefore supports three conclusions. First, MR composition cannot be optimized independently of pressure level, circulation rate and exchanger temperature approach. Second, a lower compressor duty is not sufficient evidence of a superior design when methane recovery, LNG purity, temperature-cross avoidance and economic performance are omitted. Third, the Algerian GL1/Z-Arzew and Skikda studies provide valuable site-specific economic comparators, but neither closes the methodological gap addressed by an integrated Aspen HYSYS flare-gas-to-LNG model. A defensible future study should combine the flare-gas realism of these Algerian investigations with the constrained MR optimization methods demonstrated in recent LNG research (He and Lin, 2020; Santos et al., 2021a; Santos et al., 2021b; Wu et al., 2021; Rehman et al., 2021; Uwitonze et al., 2022; Pereira et al., 2022; Santos et al., 2022; Jin et al., 2023; Abdollahi et al., 2025).

ASPEN HYSYS FRAMEWORK FOR AN INTEGRATED FLARE-GAS LNG STUDY

A rigorous Aspen HYSYS study should represent the flare-gas-to-LNG chain as an integrated sequence: flare-gas collection and inlet separation; acid-gas removal; dehydration; heavy-hydrocarbon/NGL control; staged compression with intercooling; pre-cooling; main cryogenic heat exchange; refrigerant compression, cooling and expansion; final LNG flashing/separation; boil-off-gas handling; and, where required, nitrogen rejection. The process should be solved first as a stable steady-state model before optimization or dynamic conversion.

The principal performance indicators should include methane recovery, LNG purity, LNG temperature and pressure, specific compressor energy, total refrigeration duty, minimum exchanger approach temperature, exergy efficiency, refrigerant circulation rate and emissions avoided. An optimization is physically meaningful only when heat exchangers remain thermodynamically feasible; a mathematically lower refrigerant flow or compressor duty that produces a temperature cross must be rejected as infeasible.

Variables that require sensitivity analysis

At minimum, sensitivity analysis should examine feed methane fraction, nitrogen and CO_2 content, feed pressure, MR composition, MR circulation rate, compressor discharge pressure, JT/expander outlet pressure and minimum cryogenic exchanger approach temperature. These variables should be evaluated against both energy consumption and LNG recovery. This is essential because maximizing recovery alone can increase compressor work, while minimizing energy alone can reduce refrigeration capacity or violate exchanger temperature constraints.

MAJOR RESEARCH GAPS

A recent comprehensive review by Elgarahy et al. (Elgarahy et al., 2024) confirms that flare-gas recovery should be evaluated through an integrated technical, environmental, modelling and economic framework. This broader evidence supports the present review's argument that LNG should not be judged only by liquefaction efficiency: pretreatment requirements, process complexity, emissions reduction, product value and economic robustness must be assessed together.

The literature reveals six connected gaps. First, relatively few studies simulate the complete flare-gas-to-LNG chain from raw variable feed through pretreatment to final LNG and boil-off gas. Second, many studies use a single nominal feed composition and therefore do not establish robustness to flare-gas variability. Third, optimization often concentrates on compressor power without simultaneously enforcing methane recovery, LNG specification and exchanger-feasibility constraints. Fourth, dynamic simulation and process-control studies remain limited even though flare systems are inherently variable. Fifth, exergy destruction and environmental benefits are often reported separately from economic performance rather than integrated into a multi-objective assessment. Sixth, there is limited published work using representative Nigerian refinery/associated flare-gas compositions in a fully integrated Aspen HYSYS LNG model.

These gaps show why a new study should not be presented merely as another HYSYS flow sheet. Its contribution should be the integration of realistic feed characterization, pretreatment, cryogenic liquefaction, constrained MR optimization, nitrogen/heavy-component management, dynamic or sensitivity analysis, and environmental/economic evaluation within one reproducible framework.

FUTURE RESEARCH DIRECTIONS

Future research should prioritize: (i) dynamic Aspen HYSYS models that quantify the response of compressors, separators and cryogenic exchangers to feed-flow and composition disturbances; (ii) multi-objective optimization that balances LNG recovery, methane purity, specific energy, exchanger feasibility and cost; (iii) robust MR formulations that remain effective over realistic flare-gas composition envelopes; (iv) explicit nitrogen rejection and boil-off-gas recycle strategies; (v) exergy and pinch analyses to locate irreversibility and heat-integration opportunities; (vi) validation against plant, pilot or published industrial data; and (vii) integration of carbon-abatement metrics and techno-economic analysis so that the environmental value of avoided flaring is evaluated together with LNG production economics.

CONCLUSION

This critical review shows that converting flare gas to LNG is technically plausible but cannot be evaluated adequately by describing isolated flare-gas recovery studies or conventional LNG simulations. The decisive engineering issue is integration. Raw flare gas must first be conditioned to protect the cryogenic section; the thermodynamic model must be appropriate for the relevant fluids; the liquefaction cycle must match the scale and variability of the feed; and optimization must respect heat-exchanger and product-quality constraints.

Among the available liquefaction options, SMR/PRICO is especially attractive for small-scale flare-gas applications because of its compact flow sheet, while cascade and pre-cooled mixed-refrigerant cycles remain important alternatives where higher complexity can be justified. Across all configurations, compressor power, MR composition and circulation, pressure levels and cryogenic exchanger temperature profiles are central performance variables.

The principal unresolved research need is a validated, integrated Aspen HYSYS framework that combines realistic flare-gas variability, complete pretreatment, LNG liquefaction, constrained optimization, dynamic behavior, exergy analysis and techno-economic/environmental assessment. Addressing these elements would move the literature from descriptive process simulation toward a decision-ready engineering basis for sustainable flare-gas monetization.

REFERENCES

Abdollahi, S. A., Sadabad, A. N., Alamdardehi, S. A. M., Aslani, N., Zarezadeh, R., Majidi, H. 2025. "Genetic algorithm optimization of a modified peak shaving energy storage system with mixed refrigerant system." *Scientific Reports*, 15: 41134. https://doi.org/10.1038/s41598-025-24873-0

Almeida-Trasvina, F., Smith, R. 2022. "Structural Modifications on Single Mixed Refrigerant Cycles for Performance Improvements in Small-Scale LNG Processes." *Industrial Engineering Chemistry Research*, 61(7): 2825–2842. https://doi.org/10.1021/acs.iecr.1c03699

Aspen Technology Inc. 2022. *Aspen HYSYS User Guide*. Aspen Technology Inc., Bedford, MA.

Barekat-Rezaei, E., Farzaneh-Gord, M., Arjomand, A., Jannatabadi, M., Ahmadi, M. H., Yan, W.-M. 2018. "Thermo–Economical Evaluation of Producing Liquefied Natural Gas and Natural Gas Liquids from Flare Gases." *Energies*, 11(7): 1868. https://doi.org/10.3390/en11071868

Basharahil, A. O. 2018. *Optimization of Mixed Refrigerant Compositions for the PRICO Natural Gas Liquefaction Process Using HYSYS Optimizer*. M.Sc. project report, University Teknologi Malaysia.

Campbell, J. M. 2018. *Gas Conditioning and Processing*. Campbell Petroleum Series, Norman, Oklahoma.

Edeh, I., Ikedi, C. S. 2023. "Simulation of the Production of Liquefied Petroleum Gas (LPG) from Flare Gas System." *Journal of Oil and Gas Research Reviews*, 3(1): 28–34.

ElBadawy, K. M., Teamah, M. A., Shehata, A. I., Hanfy, A. A. 2017. "Simulation of Liquefied Petroleum Gas (LPG) Production from Natural Gas Using Fractionation Towers." *International Journal of Advanced Scientific and Technical Research*, 6(7): 148–153. https://doi.org/10.26808/rs.st.i7v6.16

Elgarahy, A. M., Hammad, A., Shehata, M., Ayyad, A., El-Qelish, M., Elwakeel, K. Z., Maged, A. 2024. "Reliable sustainable management strategies for flare gas recovery: technical, environmental, modeling, and economic assessment: a comprehensive review." *Environmental Science and Pollution Research*, 31(19): 27566–27608. https://doi.org/10.1007/s11356-024-32864-3

Guella, S., Khalfi, Y., Ouazani, F., Benouis, K., Guet, M. E. A. 2024. "Flare gas recovery at an LNG plant GL1/Z-Arzew." *Chemical Papers*, 78(17): 9119–9131. https://doi.org/10.1007/s11696-024-03732-8

He, T., Lin, W. 2020. "Design and optimization of integrated single mixed refrigerant processes for coproduction of LNG and high-purity ethane." *International Journal of Refrigeration*, 120. https://doi.org/10.1016/j.ijrefrig.2020.08.013

International Energy Agency. 2022. *World Energy Outlook 2022*. IEA, Paris.

Jin, C., Lim, Y., Xu, X. 2023. "Performance analysis of a boil-off gas re-liquefaction process for LNG carriers." *Energy*, 278: 127823. https://doi.org/10.1016/j.energy.2023.127823

Mahfoud, B., Mahfoud, H. E. 2025. "Study on converting flare gas into usable energy at the SKIKDA gas refinery." *Studies in Engineering and Exact Sciences*, 6(1): e13358. https://doi.org/10.54021/seesv6n1-010

Mokhatab, S., Mak, J. Y., Valappil, J. V., Wood, D. A. 2014. *Handbook of Liquefied Natural Gas*. Gulf Professional Publishing.

Ndunagu, P. U., Joel, O. F., Akuma, O., Alaike, E. E. 2022. "Production of Natural Gas and Liquefied Petroleum Gas from Flare Gas using Methanol Based Process." *Nigerian Journal of Technological Development*, 19(1). https://doi.org/10.63746/njtd.v19i1.825

Pereira, M. A. M., Santos, L. F., Caballero, J. A., Ravagnani, M. A. S. S., Costa, C. B. B. 2022. "Energy and economic comparison of five mixed-refrigerant natural gas liquefaction processes." *Energy Conversion and Management*, 272: 116364. https://doi.org/10.1016/j.enconman.2022.116364

Poling, B. E., Prausnitz, J. M., O'Connell, J. P. 2007. *The Properties of Gases and Liquids*. 5th ed. McGraw-Hill, New York.

Putriastuti, M. A. C., Yusgiantoro, F. C., Haryanto, Margenta, I. D. M. R. 2021. "A feasibility study of flare gas utilization through a small-scale LNG development in South Sumatra, Indonesia." *IOP Conference Series: Earth and Environmental Science*, 753: 012029. https://doi.org/10.1088/1755-1315/753/1/012029

Rehman, A., Qyyum, M. A., Qadeer, K., Zakir, F., He, X., Nawaz, A., Lee, M., Wang, L. 2021. "Single mixed refrigerant LNG process: Investigation of improvement potential, operational optimization, and real potential for further improvements." *Journal of Cleaner Production*, 284: 125379. https://doi.org/10.1016/j.jclepro.2020.125379

Remeljej, C. W., Hoadley, A. F. A. 2006. "An exergy analysis of small-scale liquefied natural gas (LNG) liquefaction processes." *Energy*, 31(12): 2005–2019. https://doi.org/10.1016/j.energy.2005.09.005

Santos, L. F., Costa, C. B. B., Caballero, J. A., Ravagnani, M. A. S. S. 2021. "Design and optimization of energy-efficient single mixed refrigerant LNG liquefaction process." *Brazilian Journal of Chemical Engineering*, 38(4): 669–682. https://doi.org/10.1007/s43153-021-00111-8

Santos, L. F., Costa, C. B. B., Caballero, J. A., Ravagnani, M. A. S. S. 2021. "Kriging-assisted constrained optimization of single-mixed refrigerant natural gas liquefaction process." *Chemical Engineering Science*, 241: 116699. https://doi.org/10.1016/j.ces.2021.116699

Santos, L. F., Costa, C. B. B., Caballero, J. A., Ravagnani, M. A. S. S. 2022. "Framework for embedding black-box simulation into mathematical programming via kriging surrogate model applied to natural gas liquefaction process optimization." *Applied Energy*, 310: 118537. https://doi.org/10.1016/j.apenergy.2022.118537

Sonibare, J. A., Akeredolu, F. A. 2004. "A theoretical prediction of non-methane gaseous emissions from natural gas combustion." *Energy Policy*, 32: 1653–1665.

Uwitonze, H., Chaniago, Y. D., Lim, H. 2022. "Novel integrated energy-efficient dual-effect single mixed refrigerant and NGLs recovery process for small-scale natural gas processing plant." *Energy*, 254: 124373. https://doi.org/10.1016/j.energy.2022.124373

World Bank. 2026. *Global Gas Flaring Tracker Report: June 2026*. Global Flaring and Methane Reduction Partnership, Washington, DC.

Wu, X., Wang, Z., Dai, X., Ge, Q., Liu, F. 2021. "Optimization Design and Analysis of Single-Stage Mixed Refrigerant Liquefaction Process." *Frontiers in Energy Research*, 9: 766588. https://doi.org/10.3389/fenrg.2021.766588