A Review of Flare Gas Utilization for Power Generation in Oil Fields: Technologies, Applications, and Challenges

Revisión del Aprovechamiento del Gas de Antorcha para la Generación de Energía en Campos Petrolíferos: Tecnologías, Aplicaciones y Desafíos

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Abstract

Routine gas flaring remains one of the principal environmental and energy efficiency challenges associated with oil production. Although associated petroleum gas (APG) is commonly treated as a by-product, it represents a valuable energy resource that can be utilized for electricity generation and other productive applications, contributing to greenhouse gas emission reduction and improved operational efficiency. This paper presents a structured narrative literature review of the principal technologies available for APG utilization, including reciprocating gas engines, gas turbines, microturbines, combined heat and power systems, Organic Rankine Cycle technologies, gas reinjection, liquefied natural gas, compressed natural gas, and gas-to-liquids processes. The reviewed technologies are comparatively analyzed considering their technical characteristics, operational advantages, limitations, and suitability for remote oil-field applications. Special attention is given to the recent implementation of Ecuador's Optimization of Electricity Generation (OGE) program, which illustrates the practical application of APG recovery technologies under Amazonian operating conditions. The review highlights that no single technology is universally optimal and that successful implementation depends on gas availability, gas quality, infrastructure availability, and local energy demand. The findings provide an updated technical overview that supports future APG utilization projects in Ecuador and similar oil-producing regions.

Index terms— Associated petroleum gas, gas flaring, powergeneration, oil fields, Ecuador.

Resumen

La quema rutinaria de gas continúa siendo uno de los principales desafíos ambientales y de eficiencia energética asociados a la producción de petróleo. Aunque el gas asociado al petróleo (APG) suele considerarse un subproducto de la extracción, constituye un recurso energético valioso que puede aprovecharse para la generación de electricidad y otras aplicaciones productivas, contribuyendo a la reducción de emisiones de gases de efecto invernadero y al mejoramiento de la eficiencia operacional. Este trabajo presenta una revisión narrativa estructurada de las principales tecnologías disponibles para el aprovechamiento del APG, incluyendo motores alternativos a gas, turbinas de gas, microturbinas, sistemas de cogeneración, tecnologías de Ciclo Rankine Orgánico, reinyección de gas, gas natural licuado, gas natural comprimido y procesos gas-a-líquidos. Las tecnologías revisadas se comparan considerando sus características técnicas, ventajas operativas, limitaciones y su aplicabilidad en campos petroleros remotos. Se presta especial atención a la implementación reciente del programa de Optimización de Generación Eléctrica (OGE) en Ecuador, como ejemplo de aplicación práctica de tecnologías de recuperación de gas asociado en la Amazonía ecuatoriana. La revisión pone de manifiesto que no existe una tecnología universalmente óptima y que la selección depende de factores específicos como la disponibilidad y composición del gas, la infraestructura existente y la demanda energética local. Los resultados proporcionan una visión técnica actualizada que puede servir de referencia para futuros proyectos de aprovechamiento de APG en Ecuador y en otras regiones productoras de petróleo.

Palabras clave— Gas asociado al petróleo, quema de gas,generación eléctrica, campos petroleros, Ecuador.

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1. INTRODUCTION

Routine gas flaring remains a widespread practice in oil production, where associated petroleum gas is burned due to economic, technical, or logistical limitations. This process represents a significant environmental concern, as it contributes to greenhouse gas emissions including carbon dioxide and methane,while also generating local air pollutants that affect surround ing ecosystems and communities [1, 2].

From an energy perspective, gas flaring constitutes a considerable loss of potentially useful energy. The associated gas that is routinely burned could be utilized for electricity generation and other value-added applications, thereby improving the overall efficiency of oil production systems. Consequently, the reduction of routine flaring has become an important objective for both industry and policymakers.

The utilization of associated petroleum gas is directly aligned with the United Nations 2030 Agenda in support of the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 9 (Industry, Innovation and Infrastructure) [3]. In oil fields, recovery technologies can transform energy waste into a useful power source for local operations while reducing greenhouse gas emissions and promoting more resilient infrastructure in remote regions such as the Ecuadorian Amazon.

In recent years, increasing research attention has been directed toward the development and implementation of technologies for associated petroleum gas utilization. Among these, power generation systems have emerged as a practical alternative, particularly in remote oil fields where energy demand is present and gas transportation infrastructure is limited.

This paper presents a structured narrative literature review of the principal technological approaches for associated petroleum gas (APG) utilization, with particular emphasis on power generation technologies, their applications, operational characteristics, and implementation challenges [1, 4]. The remainder of this paper is organized as follows. Section II describes the review methodology, Section III presents the literature reviewof APG utilization technologies, Section IV discusses their applicability to remote oil-field operations, and Section V summarizes the principal conclusions.

2. REVIEW METHODOLOGY

This study was conducted as a structured narrative literature review focused on associated petroleum gas (APG) utilization pathways for power generation in oil fields, with special attention to applications in remote and infrastructure-constrained environments such as the Ecuadorian Amazon. The review combined peer-reviewed scientific literature with technical and institutional documents in order to capture both the technological state of the art and the practical implementation context of APG recovery projects.

2.1 Search Strategy and Sources

The bibliographic search was conducted using Scopus, ScienceDirect, SpringerLink, IEEE Xplore, and Google Scholaras the main academic sources. To complement the scientific literature with policy and implementation evidence, technical reports and public documents were also reviewed from institutions such as the World Bank Global Gas Flaring Reduction Partnership (GGFR), the International Energy Agency (IEA), EP Petroecuador, the Ministry of Energy and Mines of Ecuador, and Ecuadorian regulatory and environmental authorities when publicly available.

The search process was guided by combinations of the following keywords: “associated petroleum gas utilization”, “flare gas utilization”, “gas flaring”, “APG recovery”, “gas-to-power”, “flare gas power generation”, “microturbines for APG”, “gas engines in oil fields”, “associated gas Ecuador”, “OGE Petroecuador”, and “gas flaring mitigation”.

2.2 Time Window and Selection Criteria

The review prioritized literature published between 2015 and 2026, with particular emphasis on recent contributions from 2020 onward in order to capture current technological trends, environmental concerns, and ongoing gas-flaring reduction strategies. Earlier sources were retained only when they were considered necessary to describe foundational technologies, internationally recognized benchmark projects, or the historical evolution of Ecuador’s OGE program.

The reviewed documents were included when they met at least one of the following criteria: (i) they addressed gas flaring or APG utilization in oil and gas operations; (ii) they evaluated or described power generation technologies such as gas engines, gas turbines, microturbines, or hybrid heat-recovery schemes; (iii) they reported technical, environmental, or economic indicators relevant to APG recovery; or (iv) they provided country, project, or field-level evidence relevant to the Ecuadorian case or to remote oil-field applications. Documents were excluded when they focused exclusively on unrelated natural gas topics, lacked a clear connection to gas flaring reduction or APG recovery, or duplicated information already captured by more complete sources.

2.3 Analytical Approach

The selected sources were analyzed and grouped into four main themes: (i) global trends in gas flaring and APG recovery, (ii) APG utilization technologies, (iii) worldwide implementations and operational benchmarks, and (iv) the Ecuadorian OGE case and its implications for remote oil fields.

To strengthen the comparative value of the review, the main technological routes were assessed using a common set of criteria extracted from the literature, including typical scale, electrical efficiency, gas pre-treatment requirements, tolerance to gas composition variability, relative capital and operational intensity, technology maturity, and suitability for remote oil-field deployment. This comparative framework is summarized in Table 1 and serves as the basis for the discussion of technology suitability under Ecuadorian operating conditions, rather than providing a quantitative ranking of the reviewed technologies.

3. LITERATURE REVIEW

Gas flaring and its technological transformation has been extensively studied. It begins with a global assessment of flaring practices, followed by a detailed examination of the diverse recovery methods that have transitioned from theoretical proposals to industrial applications. By synthesizing recent academic research and technical reports, this state-of-the-art analysis establishes the groundwork for understanding how APG can be effectively reintegrated into the energy value chain, addressing the technical, environmental, and economic variables that dictate the success of these implementations.

3.1 Global Overview of Gas Flaring

Gas flaring has been extensively studied as a major environmental issue in the oil industry [1, 2]. It is currently recognized as one of the primary environmental challenges associated with oil production. The practice is particularly prevalent in regions with limited gas infrastructure or where the eco-nomic value of associated gas is not fully realized.

International studies have reported that a substantial volume of associated gas is flared annually, contributing significantly to global greenhouse gas emissions. This has led to the development of international initiatives aimed at reducing routine flaring and promoting the utilization of associated gas [1, 4].

Despite these efforts, flaring remains persistent because many oil fields are located far from gas gathering infrastructure, pro-duce relatively small or unstable APG streams, or require gas treatment before the recovered gas can be used safely and reliably. In low-volume or marginal fields, the economic return of conventional gas recovery infrastructure may also be insufficient, which explains why decentralized or modular utilization pathways have gained increasing attention. Fig. 1 highlights power generation as a leading application for APG recovery, reflecting the industry's shift toward on-site energy efficiency.

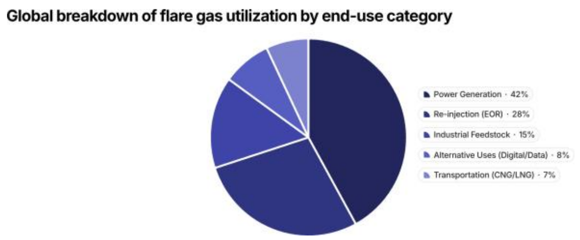

Figure 1: Global breakdown of flare gas utilization by end-use cate-gory. Source: Adapted from [1, 2]

3.2 Global Overview of Gas Flaring

A variety of technologies have been proposed and implemented for the utilization of flare gas. These can be broadly classified into energy conversion, gas processing, and reinjection methods. A simplified illustration of hydrocarbon reservoir structure and flare gas origins is shown in Fig. 2.

Power generation systems represent one of the most widely studied and implemented options. Gas engines and gas tur-bines are commonly used in medium and large-scale applications due to their high efficiency and operational reliability. These technologies are particularly suitable for oil fields with stable gas production and sufficient infrastructure.

Microturbines have gained increasing attention for smaller-scale applications. Their compact design, flexibility, and relatively low maintenance requirements make them suitable for decentralized energy systems and remote locations.

In addition to direct power generation, combined systems incorporating waste heat recovery technologies, such as Organic Rankine Cycles (ORC), have been explored to enhance energy efficiency [5]. These systems allow for additional energy recovery from exhaust gases, improving overall system performance.

Other alternatives, including gas reinjection, liquefied natural gas (LNG), compressed natural gas (CNG), and gas-to-liquids (GTL) technologies, have also been investigated. How-ever, these solutions typically require significant infrastructure and investment, limiting their applicability in certain contexts.

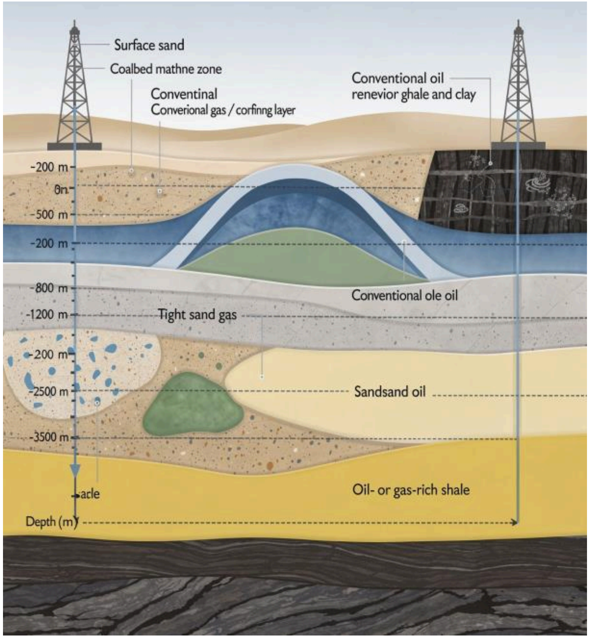

Figure 2: Hydrocarbon reservoir structure and flare gas origins. Source: Adapted from the original manuscript. Please verify image source and permissions before final submission

3.3 Applications Overview in Oil Fields

The implementation of flare gas utilization technologies has been reported in several oil-producing regions worldwide. These applications demonstrate the technical feasibility of converting associated gas into useful energy.

In Ecuador, large-scale initiatives have been developed to utilize associated gas for electricity generation in oil fields. These projects have successfully reduced diesel consumption and greenhouse gas emissions, while improving energy efficiency within oil production operations [6, 7].

However, such implementations have primarily been focused on centralized systems in large oil fields. Smaller or more re-mote fields often face additional challenges, including lower gas volumes, variability in gas composition, and limited access to infrastructure.

3.4 Applications Overview in Oil Fields

Despite the availability of various technologies, the utilization of flare gas presents several technical and operational challenges. One of the main issues is the variability in gas flow rate and composition, which can affect the performance and reliability of power generation systems [8, 9].

Additionally, the presence of contaminants in associated gas, such as hydrogen sulfide or heavy hydrocarbons, may require pre-treatment processes; therefore, system complexity and cost can increase substantially. Economic factors also play a critical role, as the feasibility of flare gas utilization depends on the balance between investment costs, operational expenses, and potential energy savings.

Logistical constraints, particularly in remote areas, further complicate the implementation of flare gas recovery systems, as they may require additional infrastructure and maintenance capabilities. Fig. 3 displays a generic P&ID process diagram of an associated petroleum gas conditioning system integrated with an electric generator. The main functional blocks include gas separation and scrubbing, gas cooling and compression, fuel conditioning, and power conversion through a reciprocating engine or turbine-generator unit.

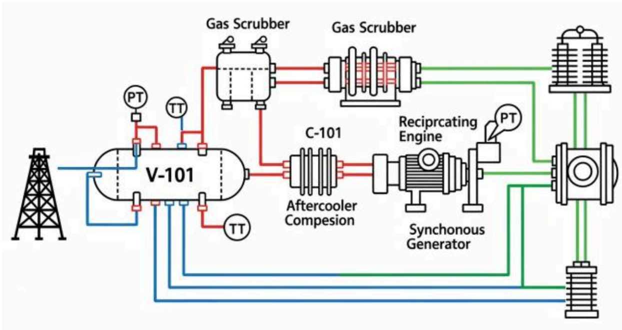

Figure 3: Associated petroleum gas processing P&ID diagram in-tegrated with power generation. Source: Adapted from the original manuscript. Please verify image source and permissions before final submission

3.5 Worldwide Implementations

This section examines several international benchmarks in flare gas utilization, categorized by their primary impact on the industry. The analysis distinguishes between projects where technological innovation and operational efficiency have been the main drivers, and those where success has been primarily dictated by strategic business models and robust governmental policies. By evaluating these diverse global experiences, ranging from large-scale power plants in mature fields to de-centralized digital solutions, this review identifies the critical success factors that can be adapted to other oil-producing regions, such as the Ecuadorian Amazon.

3.5.1 Technological Relevance and Operational Impact

From a technical perspective, the most significant implementations focus on the adaptability of generation systems to the inherent variability of associated gas. Global suppliers and operators have demonstrated the efficacy of high-efficiency reciprocating gas engines in critical environments [9, 3]. Such engines are commonly integrated with gas conditioning systems and differ from conventional diesel-based generation be-cause they can operate on treated APG streams while supporting modular deployment, on-site energy recovery, and diesel displacement in oil-field operations.

These technologies have achieved high utilization rates in large-scale projects such as the Yuzhno-

Priobskoye field in Russia, where gas-fired power plants successfully replaced diesel generation [10]. The operational impact of these cases lies in the integration of modular compression, dehydration and desulfurization units. This allows for on-site gas processing, ensuring a stable, low-maintenance energy source for pumping and drilling operations in remote areas, significantly reducing the operational carbon footprint [11].

3.5.2 Commercial Success and Government Support

On the other hand, the success of flare gas recovery is closely linked to innovative business models and robust regulatory frameworks. A landmark example of government support is the Nigeria Gas Flare Commercialization Programme (NGFCP), which established an open market by auctioning gas utilization rights to third-party investors [12]. This allowed small and medium enterprises to implement micro-generation solutions where primary operators found no profitability.

In the commercial sphere, the "Digital Flare Mitigation" strategy in the U.S. Permian Basin stands out. Companies such as Crusoe Energy utilize stranded gas to power mobile data centers dedicated to high-performance computing [13]. This model overcomes the economic barrier of remote gas lo-cations where traditional electricity demand or pipelines are absent, turning an environmental waste into a high-demand financial asset. Fig. 4 shows a global distribution of selected flare gas utilization implementations.

Figure 4: Global distribution of selected flare gas utilization implementations. Source: Adapted from the original manuscript based on [9, 10, 12, 13]. Please verify image source and permissions before final submission

3.6 OGE Project (Optimization of Electricity Generation) in Ecuador

This section provides a comprehensive analysis of the Optimization of Electricity Generation (OGE) project, the flagship initiative for flare gas valorization in Ecuador. The following sub-sections trace the project's trajectory from its inception as a strategic diesel-replacement program to its current role as a critical component in meeting judicial mandates for environmental protection. By detailing its historical evolution, current scaling efforts in key oil blocks, and long-term operational projections, this review highlights how the OGE project serves as a practical model for transitioning toward reduced carbon footprint in the Ecuadorian hydrocarbon sector.

3.6.1 Historical Context and Evolution (2009–2022)

The OGE&EE (Optimization of Electricity Generation and Energy Efficiency) project was originally conceived in 2009 with the primary objective of reducing the consumption of imported diesel in Amazonian operations. Between 2009 and 2015, Petroamazonas EP (now merged into EP Petroecuador) generated approximately 1.10 million MWh using associated gas, displacing the use of 193 million gallons of diesel [14]. During this period, milestones such as the interconnection of the Pañacocha Millennium Community in 2014 demonstrated the technical feasibility of using surplus gas for social development. Despite these advancements, the system faced scalability challenges, with persistent flaring intensity due to the lack of modular infrastructure at isolated or remote wellheads.

3.6.2 Current Implementation and Scaling (2024–2026)

Currently, the project is in a critical expansion phase driven by judicial mandates and new regulations issued in September 2024 (Resolution No. ARCH-003/2024), which demand the progressive elimination of gas flaring [15]. As of August 2025, Ecuador has achieved a historic milestone with the de-commissioning of 174 flares (165 from EP Petroecuador and 9 from private operators) [16]. Specific projects in the Pucuna and Auca Sur blocks entered full operation in January 2026, enabling annual savings of USD 7.7 million through on-site power generation [17]. Furthermore, the Cuyabeno Gas Utilization Project (Block 58) began its technical socialization in February 2024 and is projected to reduce 357,000 tons of CO_2 over the next decade.

3.6.3 Operational Status and 2030 Projections

To date, the utilization system is fully operational and integrated within the Amazon District, with an installed capacity projected to increase steadily to reach 64.3 MW by the end of 2026 in the Auca, Sacha, Shushufindi, and Indillana fields [16]. While the power generation infrastructure is ac-tive and expanding, total system effectiveness still faces logistical hurdles in frontier areas. However, the implementation of new industrialization technologies at the Shushufindi Industrial Complex to produce LPG and natural gasoline from associated gas reinforces the project's operational viability, aiming to meet the "Zero Routine Flaring" goal by 2030 in compliance with World Bank standards [18].

3.6.4 *Comprehensive Analysis of Gas Utilization in Ecuador*

Despite the significant progress made by the OGE project, Ecuador has not yet achieved full utilization of its associated petroleum gas. As of early 2026, it is estimated that the country effectively utilizes approximately 35% to 42% of the total associated gas produced in the Amazon region, primarily for internal power generation and LPG production at the Shushufindi Industrial Complex [19]. The remaining volume continues to be flared, representing a daily loss of approximately 100 million cubic feet (MMcfd). This underutilization is attributed to the geographic dispersion of mature fields and the high cost of implementing gathering systems in marginal or low-production wells.

The discrepancy between the decommissioning of flares and total gas utilization is a critical point of analysis. While 174 flares have been removed, many were located in clusters with high infrastructure accessibility. The remaining flares are of-ten in frontier areas where the gas-to-oil ratio (GOR) is lower, making traditional pipeline solutions economically unfeasible. Consequently, while current infrastructure is operating at nearly 90% capacity, the national energy balance shows that Ecuador still imports a significant amount of LPG and diesel that could, theoretically, be replaced if the recovery rate were increased to 75%, a target projected only for the end of the decade [18, 20].

Fig. 5 illustrates the three-stage transition of associated gas management in Ecuador. Stage 1 (Pre-2009) highlights the environmental impact and economic loss of routine flaring. Stage 2 (Current) shows the implementation of modular technology and the decommissioning of 174 flares. Stage 3 (2030 Goal) projects the integration of the Shushufindi Industrial Complex to achieve the Zero Routine Flaring target and national energy security objectives.

3.7 Discussion: Technology Suitability for Flare Gas Utilization in Remote Oil Fields

The literature shows that flare gas utilization cannot be assessed through a single “best technology” criterion, because the suitability of each route depends strongly on gas volume, flow stability, gas composition, contaminants, field remote-ness, and the existence of local energy demand or gas trans-port infrastructure. In this sense, the main contribution of the present review is not only to summarize available technologies, but also to interpret their relative suitability for re-mote oil-field conditions, which is particularly relevant for the Ecuadorian Amazon.

From a power-generation perspective, gas engines remain one of the most mature and efficient options for APG valorization when the associated gas stream is sufficiently stable and gas conditioning can be guaranteed. Their high electrical efficiency and modular deployment potential make them attractive for medium-scale on-site electricity generation, especially where diesel displacement is a strategic priority. However, their performance and reliability depend on controlling contaminants, liquids, and fluctuations in gas quality. For isolated wells with intermittent gas production, this requirement may increase both pre-treatment complexity and operating costs.

Microturbines, by contrast, appear especially attractive for low-to-medium scale flare-to-power applications in remote and dispersed fields. Although their electrical efficiency is generally lower than that of reciprocating gas engines, they offer important operational advantages in contexts where compact-ness, modularity, reduced maintenance burden, and decentralized deployment are more critical than peak conversion efficiency. For the Ecuadorian case, this distinction is important because many of the remaining flare points are not necessarily associated with large centralized facilities, but rather with mature or geographically dispersed assets where pipeline gathering and large gas-processing infrastructure may not be eco-nomically viable.

Gas turbines can be effective in larger centralized projects with stable APG supply and existing industrial infrastructure, but they are generally less attractive for small remote wells due to scale sensitivity and operating requirements. Simi-larly, ORC systems can improve the total energy efficiency of a flare-to-power system by recovering waste heat, but they should be interpreted as complementary technologies rather than primary APG utilization routes.

The literature also shows that LNG, GTL, and in some cases CNG can play an important role in associated-gas valorization, yet their applicability decreases significantly when the gas source is small, dispersed, unstable, or located in infrastructure poor environments. These routes tend to require greater capital intensity, more complex gas treatment, and stronger logistics integration than decentralized electricity generation. Asa result, while they may be viable in selected high-volume projects, they are less likely to become the dominant option for a broad portfolio of remote marginal flare sites in the Ecuadorian Amazon.

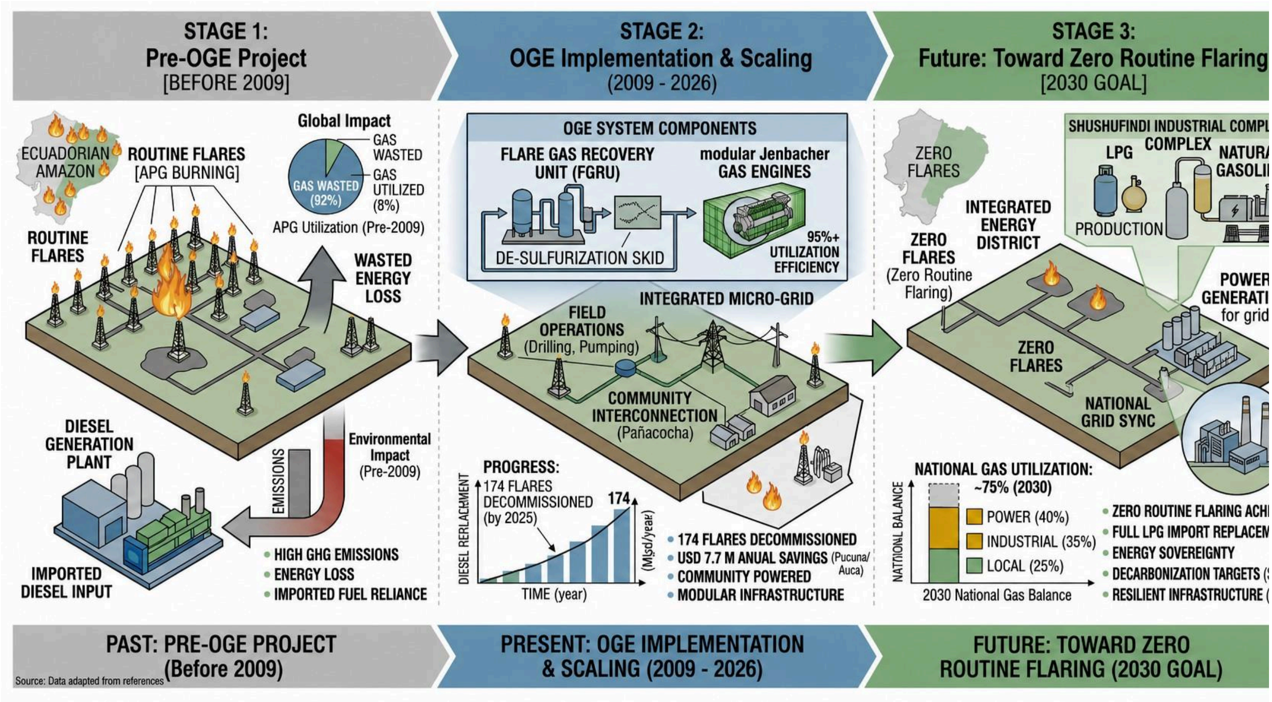

Figure 5: Evolutionary roadmap of the OGE Project in the Ecuadorian Amazon: from routine flaring to integrated energy assets. Source: Prepared by the authors (2026), based on technical data from EP Petroecuador [17], Ministry of Energy and Mines [19], and the World Bank Global Gas Flaring Tracker [18]

For Ecuador, the OGE experience confirms that flare gas utilization has already moved beyond the conceptual stage and has become part of the operational energy strategy of the oil sector. However, the reviewed evidence also suggests that the next challenge is no longer proving that associated gas canbe used, but rather determining which technologies are most suitable for the remaining flare points that are smaller, more dispersed, and more difficult to integrate into centralized systems. This is where the research gap becomes clearer: public information on Ecuador has focused primarily on large scale achievements, flare decommissioning milestones, and aggregated energy savings, whereas less attention has been given to technology screening criteria, field-level gas-quality constraints, modular flare-to-power architectures, and the comparative suitability of engines, microturbines, and hybrid recovery systems under remote Amazonian conditions. Therefore, the reviewed literature suggests that the mostpromising path for future research in Ecuador is a field-oriented comparative framework that combines gas characterization, production profile analysis, infrastructure constraints, and environmental performance criteria in order to identify the best flare gas utilization route for each type of oil-field condition. Such work would complement the present review and provide a more direct bridge toward future simulation, optimization, and mechatronic system design studies

4. CONCLUSIONS

This review examined the current state of flare gas utilization technologies for power generation in oil fields, with emphasis on their applicability in remote operating environments and on the Ecuadorian OGE context. The literature confirms that flare gas valorization is no longer a purely environmental aspiration, but an increasingly practical energy strategy for reducing routine flaring, improving operational efficiency, and decreasing diesel dependence in oil production systems. From a technological standpoint, the review shows that gas engines, gas turbines, and microturbines remain the most relevant routes for flare-to-power applications, although their suitability varies substantially with field conditions. Gas engines offer high electrical efficiency and strong commercial maturity, making them particularly attractive in medium-to-large projects with relatively stable APG supply and adequate gas conditioning. Microturbines, in turn, appear especially promising for small-scale, modular, and decentralized applications, where remote-field deployment, compactness, and operational flexibility are more critical than maximum conversion efficiency. Gas turbines remain more suitable for larger centralized projects, while ORC systems are best interpreted as complementary efficiency-enhancement technologies rather than primary APG utilization routes.

The review also indicates that LNG, CNG, GTL, and reinjection can be valid associated-gas management pathways, but their practical suitability depends strongly

Table 1: Comparative assessment of flare gas utilization technologies for oil-field applications

Technology	Typical scale	Efficiency / performance	Gas treatment and variability	Relative cost	Maturity	Suitability for remote Ecuadorian oil fields
Gas engines	Medium–large; ∼0.5 to >20 MW	∼35–45% electrical efficiency	Require dehydration, pressure stabilization and contaminant control; moderate tolerance to gas variability	CAPEX/OPEX: medium	High	High where APG flow is stable and volume is sufficient; less attractive for intermittent or very small wells.
Gas turbines	Medium–large; generally >3–5 MW	∼25–40% electrical efficiency	Require clean and stable gas supply; low-to-moderate tolerance to small fluctuating streams	Medium–high	High	Suitable for centralized facilities with sustained gas availability, but less flexible for dispersed marginal wells.
Microturbines	Small–medium; ∼30–500 kW; modular arrays possible	∼20–33% electrical efficiency	Require gas cleaning, but modular configurations offer better adaptability to low-to-medium flows	Medium	Medium–high	Very suitable for decentralized flare-to-power concepts in remote, low-to-medium-volume oil-field sites.
ORC / waste heat recovery	Complementary system	Improves total energy recovery from hot exhaust streams	Depends on the primary generation system; not a standalone APG utilization route	Medium	Medium–high	Useful as an efficiency-enhancement add-on in larger installations with available waste heat.
Mini-LNG / LNG	Medium–large; stable high-volume gas streams	Converts APG into transportable fuel	Requires substantial treatment, dehydration, compression and liquefaction; low tolerance to small unstable streams	High	Medium	Limited suitability for dispersed Amazonian sites unless gas volume and logistics justify investment.
CNG	Small–medium depending on transport scheme	Valorization route rather than direct power generation	Requires compression and quality control; moderate tolerance if flow and logistics are feasible	Medium	High	Moderate suitability where local demand or short-distance transport is available.
GTL	Large-scale, long-term high-volume projects	Converts gas into liquids or chemicals	Requires significant treatment and integrated processing; low tolerance to small or unstable streams	Very high	Medium	Low suitability for remote marginal flare sites due to capital intensity and process complexity.
Gas reinjection	Field-dependent	Reservoir-management route, not electricity generation	Requires compression and reservoir compatibility	Medium–high	High	Moderate suitability when reservoir conditions justify reinjection; does not directly displace diesel electricity generation.

on project scale, gas stability, infrastructure availability, and economic context. In dispersed or low-volume oil-field settings, especially in re-mote Amazonian operations, these routes are generally less flexible than direct gas-to-power alternatives and may require substantially higher capital investment and logistics complexity.

In the Ecuadorian case, the OGE program demonstrates that associated gas utilization has already produced relevant operational benefits through the replacement of diesel-based generation and the progressive reduction of routine flaring in selected oil blocks. However, the evidence reviewed in this manuscript also suggests that the main remaining challenge lies in the fields that are smaller, more dispersed, and less accessible, where conventional centralized solutions may not be sufficient. For these conditions, the most relevant decision is not whether flare gas should be utilized, but which technology is best suited to the gas volume, variability, contaminants, and remoteness of each field.

The main research gap identified is the limited availability of field-level comparative assessments tailored to Ecuadorian Amazon conditions, particularly those integrating gas characterization, technology selection criteria, operational constraints, environmental performance, and decentralized power-generation alternatives. Future research should therefore move toward techno-economic and environmental screening frameworks, sup-ported by simulation and field-informed data, to determine when gas engines, microturbines, hybrid systems, or other valorization routes provide the most robust solution for each flare gas source. The findings presented in this review may also serve as a reference for future APG utilization initiatives in Ecuador and other oil-producing regions facing similar technical and infrastructure constraints.

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