© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

Flare-Gas Recovery Technologies for Advancing Energy Security, Environmental Performance, and Resource Efficiency

EROMOSELE ASIBOR[1], DANIEL EDET ISONG[2]
[1] Nigeria Petroleum Development Company Ltd, Edo State, Nigeria
[2] Independent Researcher, Port Harcourt, Nigeria

Abstract- ***This paper develops a source-to-market decision framework that treats safety, recovery reliability, product route, emissions, and economics as linked design variables. The study responds to the problem that routine and non-routine flaring wastes saleable hydrocarbons, creates combustion emissions, and signals weak integration between production and gas-handling capacity. It uses an integrative conceptual review of scholarly and professional literature published to date. The framework organizes eight decision functions: source measurement and compositional characterization, flare network hydraulic analysis, technology screening, availability and turndown modelling, economic evaluation, implementation risk review, performance monitoring, continuous optimization. It applies those functions across flare header and knockout drum, compression train, gas treating and dehydration unit, natural gas liquids recovery section, export pipeline interface, power-generation or reinjection system. The analysis treats uncertainty, process safety, reliability, environmental performance, resource efficiency, economics, and organizational control as connected requirements. The proposed architecture links a system definition, evidence register, model assumptions, intervention portfolio, verification plan, and learning cycle. Its central proposition is that traceable decisions convert recoverable associated gas into fuel, pipeline gas, liquefied petroleum gas, natural gas liquids, electricity, reinjection gas, or chemical feedstock when decisions preserve traceability from measured conditions to selected actions and verified outcomes. The paper offers testable propositions, an implementation roadmap, asset-specific application protocols, and a research agenda. The framework supports case-study testing and quantitative extension without claiming universal performance before field validation.***

Keywords: flare-gas recovery; process engineering; reliability; process safety; risk management; asset integrity; environmental performance; decision framework

I. INTRODUCTION

Flare-recovery decisions require explicit release scenarios, dependable evidence, verified safeguards, and clear operating authority (Kaplan & Garrick, 1981; Reason, 1997; Center for Chemical Process Safety, 2007; International Organization for Standardization, 2018). Flaring of associated and non-associated gas is one of the clearest symptoms of this evidence gap in upstream and midstream oil and gas operations. Satellite-based inventories built from nighttime infrared imagery indicate that global gas flaring has persisted at a large and roughly stable volume for more than a decade despite repeated industry and government commitments to reduce it (Elvidge et al., 2009; Elvidge et al., 2016). The World Bank's Zero Routine Flaring by 2030 initiative and the earlier Global Gas Flaring Reduction Partnership regulatory review were established specifically to convert this diagnosis into coordinated technical and policy action across producing countries, yet country-level compliance and recovered-volume reporting remain uneven (World Bank, 2015; World Bank Global Gas Flaring Reduction Partnership, 2004). This persistence, despite decades of engineering and policy attention, is the empirical starting point for the decision framework developed in this paper (Komi & Adeniji, 2020; Okonkwo & Okeke, 2018a; Eyetsemitan & Fadayomi, 2020) (Komi & Adeniji, 2020; Patrick et al., 2020; Okonkwo et al., 2018). (Aifuwa et al., 2020; American Petroleum Institute, 2015; Cheremisinoff, 2013)

A flare-gas recovery project succeeds when process design, relief protection, compression reliability, product demand, and operating responsibility work together. In the context of flare-gas recovery, routine and non-routine flaring wastes saleable hydrocarbons, creates combustion emissions, and signals weak integration between production and gas-handling capacity. The scale of the waste is well documented: Ismail and Umukoro (2012) estimate that flared associated gas represents a substantial share of a producing country's domestic energy supply potential, and Anomohanran (2012) links measured flare volumes in the Niger Delta directly to a greenhouse gas inventory contribution that rivals emissions from several other national sectors combined. Ejiogu (2013) frames the persistence of flaring in Nigeria as fundamentally a policy and cost problem rather than a purely technical one, arguing that the absence of a credible domestic gas-purchase market removes the commercial incentive that would otherwise justify recovery investment; the same commercial logic applies, with different regulatory detail, wherever recovered gas has no assured offtake route. Ubani and Onyejekwe (2013) reach a related conclusion from an independent environmental-impact analysis of the same region, and Osiki (2018) traces the persistence of Niger Delta flaring across five decades of production, from 1956 through 2007, indicating that the underlying commercial and regulatory gap long predates the specific policy debates reviewed above. Local actions affect adjacent equipment, utilities, product quality, emissions, workforce exposure, and supply continuity. A defensible framework must therefore define both the physical process and the decision system through which evidence becomes action. For natural gas liquids recovery section, the decision model must represent acid-gas corrosion, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects; material selection for these sour-service interfaces follows the compositional and hardness limits set out in ISO 15156 (International Organization for Standardization, 2015b). Availability and turndown modelling supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience to update the decision rather than remaining in a separate record (International Organization for Standardization, 2016; Okonkwo & Okeke, 2018b) (Okonkwo et al., 2019; Okonkwo et al., 2018). (Fabiano & Currò, 2012; Hinderaker & Njaa, 2010; Ismail & Umukoro, 2012)

A recurring weakness in the flare-gas recovery literature is that technology screening is treated as a menu choice among compression, gas-to-liquids, gas-to-power, and reinjection routes rather than as a decision embedded in safety, reliability, and commercial constraints that vary by asset. Wood, Nwaoha, and Towler (2012) show that gas-to-liquids routes for monetizing otherwise-flared gas span several distinct process chemistries with materially different capital intensity, minimum economic scale, and product slate, so a route selected on chemistry grounds alone can still fail on scale or logistics grounds at a specific asset. Liquefied natural gas has similarly been presented as a proven stranded gas monetization option for larger associated gas volumes (Coyle, Durr, & Shah, 2003), and a systematic comparison of liquefied natural gas, compressed natural gas, gas to liquids, and natural gas hydrate routes finds that the available carbon credit incentive can shift the ranking among these options (Khalilpour & Karimi, 2009). World Bank Global Gas Flaring Reduction Partnership assessments of modular and mini-scale gas-to-liquids units reach a similar conclusion from the deployment side, reporting that unit economics and reliability, not conversion chemistry, typically determine whether a small-scale monetization project proceeds from pilot to sustained operation (World Bank Global Gas Flaring Reduction Partnership, 2015; World Bank Global Gas Flaring Reduction Partnership, 2019). The paper's specific contribution is to close this gap: it treats safety, recovery reliability, product route, emissions, and economics as linked design variables inside one traceable decision architecture rather than as separate studies whose conclusions are reconciled informally after the fact. For export pipeline interface, the decision model must represent off-specification gas, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects. Economic evaluation supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

to update the decision rather than remaining in a separate record (Dogbatsey & Ebhojie, 2018; Badmus & Ozowara, 2018) (Dagodzo & Ahiaeke, 2020). (Odejobi & Ahmed, 2018; Okojie et al., 2020; Osiki, 2018)

Regulatory design also shapes which technical options are worth screening. Lade and Rudik (2020) show, using operating data from the Bakken shale play, that flaring limits enforced inconsistently across operators and time periods raised the effective cost of compliance without proportionately reducing flared volumes, a finding that argues for evaluation criteria that are auditable at the well or facility level rather than only at the aggregate reporting level. In the United States, the 2016 New Source Performance Standards for the oil and natural gas sector extended federal control requirements to flaring-related emission points at new and modified facilities, adding a compliance dimension that a recovery-technology screen must now carry alongside its safety and economic criteria (U.S. Environmental Protection Agency, 2016). Comparable regulatory friction has been documented in Russia, where flaring-reduction policy momentum weakened during a period of economic insecurity even though the underlying gas-utilization infrastructure remained technically available (Loe & Ladehaug, 2012). For power-generation or reinjection system, the decision model must represent ignition and radiation exposure, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects. Implementation risk review supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience to update the decision rather than remaining in a separate record (Mbonu & Oluoha, 2018) (Mbonu et al., 2018; Mbonu et al., 2019). (Shaimardanova & Shagieva, 2019; Strizhenok & Korelskiy, 2019; Ubani & Onyejekwe, 2013)

II. THEORETICAL FRAMEWORK

The framework developed in this paper rests on a risk-based theoretical foundation that treats safety, reliability, and economic performance as properties of a single decision system rather than as separate evaluation exercises. Kaplan and Garrick's (1981) definition of risk as a set of scenarios, each with an associated likelihood and consequence, supplies the basic unit of analysis used throughout the paper: every flare-gas recovery decision is framed as a scenario-consequence-likelihood triplet rather than a single point estimate. Reason's (1997) organizational accident model extends this scenario-based view by showing how weaknesses in successive organizational and technical defenses align to produce loss events, which is why the framework developed later treats barrier performance, not barrier existence, as the relevant evidence. Hazard and operability studies supply one of the systematic techniques through which such barriers are first identified during design, before their in-service performance can be assessed at all (Kletz, 2018). The Center for Chemical Process Safety's (2007) risk-based process safety guidelines translate these ideas into an implementable management structure built around defined risk criteria, competence, and continuous improvement, and ISO 31000:2018 supplies the generic risk management process, principles, and vocabulary that keep the framework's terminology consistent with recognized international practice (Kaplan & Garrick, 1981; Reason, 1997; Center for Chemical Process Safety, 2007; International Organization for Standardization, 2018) (Mbonu & Uzoka, 2020a; Sanni & Atima, 2020c; Khan & Abbasi, 1998) (Mbonu et al., 2020; Mbonu et al., 2020; Obogo et al., 2019). (Wood et al., 2012; Yeboah & Ike, 2020; Zulhairun et al., 2019)

A second theoretical strand concerns how safeguards are defined and evaluated once a risk-based structure is in place. Sklet (2006) proposes a barrier taxonomy that separates prevention, detection, control, and mitigation functions and, critically, separates a barrier's documented existence from its demonstrated performance in service; this distinction underlies the framework's insistence, developed in later sections, that acceptance be tied to observable performance measures rather than to completion of a design or inspection record. Where a barrier is implemented as a safety instrumented function, its required performance is not a matter of engineering judgment alone: IEC 61511-1:2016 specifies the safety integrity level targets and verification requirements that such functions must meet across the process industry sector (Sklet, 2006; International Electrotechnical Commission, 2016). Read together with Fabiano and Currò's (2012) analysis of near-miss reporting in downstream oil operations, these sources indicate that barrier-performance evidence and precursor-event evidence should be reviewed jointly rather than in separate management systems. Read together, these sources give the paper a common vocabulary for comparing safeguards across the different flare-gas recovery interfaces examined later, independent of which vendor or configuration is used (Obogo & Obriki, 2020c; Obogo & Obriki, 2020b; Sunday & Oluokun, 2019) (Obogo et al., 2020; Obogo et al., 2020; Ogbuefi et al., 2020). (Okojie & Abioye, 2020)

A third strand situates these safety and barrier concepts inside a broader asset management perspective. ISO 55000:2014 defines an asset management system around the coordinated activity of an organization to realize value from its assets, and it identifies alignment between organizational objectives and asset decisions, leadership accountability, and assurance of performance as core principles (International Organization for Standardization, 2014). This perspective is the conceptual bridge between the technical decision functions developed later in the framework and the governance and performance measurement requirements discussed alongside them: a recovery technology choice is not merely a process engineering result but an asset decision that must be aligned with organizational objectives, resourced, and verified over the asset's operating life (International Organization for Standardization, 2015; Okoruwa & Abolaji, 2020; Orise & Niniola, 2020) (Obogo et al., 2019; Eyetsemitan et al., 2020; Akpe et al., 2020).

The fourth strand supplies the technical vocabulary and governing mechanisms against which these safety, barrier, and asset management principles are applied. Gas purification and treating chemistry follows the equilibrium and rate limits described in Kohl and Nielsen (1997), and the equipment modules used to implement compression, dehydration, and liquids recovery follow the design basis set out in Campbell (1992) and in the Gas Processors Suppliers Association engineering data book (2012). Facility-level layout, header sizing, and separator arrangements follow the surface-facility design treatment in Arnold and Stewart (1999), and Mokhatab, Poe, and Speight (2006) provide the integrated process-facility perspective that connects these unit operations into a single gas-handling system (Kohl & Nielsen, 1997; Campbell, 1992; Gas Processors Suppliers Association, 2012; Arnold & Stewart, 1999; Mokhatab et al., 2006). These references establish the definitions and governing mechanisms that the detailed framework in the next section applies to specific flare-gas recovery equipment and decisions (Arumosoye & Obriki, 2019; Arumosoye & Obriki, 2018) (Arumosoye & Obriki, 2019; Arumosoye & Obriki, 2018).

Together, these four strands, namely risk-based process safety, barrier performance theory, asset management principles, and gas processing engineering fundamentals, form the conceptual lens through which this paper reviews the flare-gas recovery literature and builds its decision framework. None of the four is sufficient alone: a risk-based structure without barrier-performance evidence cannot demonstrate that a safeguard actually works, and technical process knowledge without an asset management perspective cannot connect a sound engineering choice to organizational accountability and funding. The methodology described next applies this combined lens to select and code the literature synthesized in the remainder of the paper (Okonkwo & Mayo, 2019; Akomolafe & Agu, 2019c; Akomolafe & Agu, 2019a) (Aneke & Adesemoye, 2019; Aneke & Adesemoye, 2020; Akpe et al., 2020).

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

III. METHODOLOGY

The review draws on four literatures that are rarely combined in a single flare-gas recovery assessment: process safety and risk management, gas processing and treating engineering, satellite-based flaring measurement, and flaring policy and economics. Baseline process descriptions for compression, dehydration, and liquids recovery follow the equipment-level treatment in the Gas Processors Suppliers Association engineering data book and the process-facility design guidance in Mokhatab, Poe, and Speight (2006), both of which remain reference texts practitioners use to size and specify the equipment discussed in this paper (Gas Processors Suppliers Association, 2012; Mokhatab et al., 2006). Membrane-based acid-gas separation supplies an alternative gas-treating pathway whose materials and module design are reviewed by Zulhairun et al. (2019), and amine-blend selection for acid-gas removal has itself been shown to materially change treating-unit performance under associated-gas compositions specific to Nigerian operations (Erayanmen, 2010). For flare header and knockout drum, the decision model must represent unstable flare-header pressure, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects. Performance monitoring supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience to update the decision rather than remaining in a separate record (Atta & Adenuga, 2020; Adeyelu, 2018; Amayo & Oshevire, 2015) (Adeyelu, 2018; Adeyelu, 2020).

Sources were retained where they addressed at least one of the eight decision functions directly, using publication venue, citation pattern, and correspondence with recognized standards as quality screens rather than journal ranking alone. Gas-treating chemistry and dehydration performance limits, for example, were checked against the acid-gas and glycol-dehydration treatment in Kohl and Nielsen (1997) and the equipment-module design basis in Campbell (1992), both long-standing references for the gas conditioning and processing decisions represented in the compression train and gas treating and dehydration unit interfaces (Kohl & Nielsen, 1997; Campbell, 1992). Process-level technical and economic evaluations of triethylene glycol regeneration (Neagu & Cursaru, 2017) and field estimates of the hydrocarbon emissions such regeneration units release (Thompson et al., 1993) extend these baseline references into the specific dehydration-unit performance limits used later in this paper. For compression train, the decision model must represent liquid carryover, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects. Continuous optimization supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience to update the decision rather than remaining in a separate record (Amayo & Popoola, 2017b) (Gbadamosi & Obogo, 2013).

Coding proceeded thematically against the eight decision functions rather than chronologically, so that an early combustion-efficiency field study and a contemporary techno-economic evaluation could be placed in the same evidence category when they addressed the same decision. Facility-level gas-handling design conventions, including the header sizing and separator arrangements referenced throughout this review, follow Arnold and Stewart (1999), whose surface-facility design treatment underlies much of the equipment-level discussion in later sections (Arnold & Stewart, 1999). Process simulation of a back-up condensate stabilization unit demonstrates that recovery-train redundancy, not primary unit capacity alone, determines whether liquids specification is maintained during upset conditions (Rahmanian, Ilias, & Nasrifar, 2015), a finding consistent with the facility-level design logic reviewed above. For gas treating and dehydration unit, the decision model must represent compressor surge, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects. Source measurement and compositional characterization supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience to update the decision rather than remaining in a separate record.

IV. FINDINGS AND DISCUSSION

The Proposed Framework

System Definition and Functional Requirements. Because routine flaring and upset flaring both burn away gas that could have been sold, add to the combustion-emissions inventory, and expose any shortfall between production output and the capacity of the gas-handling system, defining the system boundary correctly is one of the first tasks this framework asks the reviewer to complete. The analysis should identify physical, information, utility, organizational, and market interfaces. Offshore production platforms carry an additional layer of interface requirements, since basic surface safety systems there are governed by a dedicated analysis, design, and testing framework rather than by onshore practice alone (American Petroleum Institute, 2001). Vapor recovery from crude-oil stock tanks, a closely related source of otherwise-vented hydrocarbon, was documented using comparable low-pressure compression principles as early as the 1970s (Griswold & Ambler, 1978). Piping that connects the flare header, knockout drum, and compression train across these interfaces is itself subject to a governing mechanical design code that fixes allowable stress, material, and inspection requirements independent of the process decision being evaluated (American Society of Mechanical Engineers, 2016). Cheremisinoff (2013) provides a comprehensive survey of flare types, combustion mechanisms, and mitigation practice that supplies much of the equipment-level vocabulary used throughout this review. Applied to the natural gas liquids recovery section, the boundary must extend far enough to capture acid-gas corrosion, from the conditions that initiate it through the limits of its detection, the safeguards in place, the time needed to recover from an excursion, and what happens downstream if it is not caught in time. Flare network hydraulic analysis contributes part of the case here, though no single dataset is enough on its own to prove the system is technically sound. What keeps the assessment honest is a record of where each input came from: the date it was collected, the operating mode in force at the time, its measurement uncertainty, the model version it fed, and who is accountable for it. Without that record, a tidy-looking number can hide assumptions nobody has actually tested. Keeping the record open, rather than closing it out as a one-time exercise, also means that whatever operations learns later can feed back into the same decision instead of sitting in a separate file (Sunday & Oluokun, 2020) (Ogunnowo et al., 2020).

The same boundary-setting logic applies wherever the system touches export or storage infrastructure: gas that flares, scheduled or not, is lost revenue, added emissions, and a sign that production and handling capacity are not well matched. The analysis should identify physical, information, utility, organizational, and market interfaces. Where recovered natural gas liquids or condensate are stored or transferred at the export pipeline interface, flammable-liquid storage and handling requirements under the applicable fire code become an additional functional boundary that the system definition must carry forward into later screening (National Fire Protection Association, 2015). A cryogenic process that recovers natural gas liquids from oil-field associated gas using imported liquefied natural gas cold energy illustrates one route by which the natural gas liquids recovery section can be integrated with an existing import terminal rather than built as a stand-alone cryogenic plant (Bian, Xu, Li, & Qian, 2011). At the export pipeline interface specifically, the boundary needs to reach off-specification gas as a scenario in its own right, tracking how it starts, how soon it would be caught, what safeguards intervene, how long recovery takes, and what it would affect further downstream. Technology-screening work covers part of that ground, but it was never meant to be the sole basis for declaring the interface technically adequate. Recording where each data point came from, under what operating mode, with what measurement uncertainty, against which model version, and under whose ownership is what stops a clean-looking output from masking untested assumptions. Kept live rather than filed away, that same record lets later field experience revise the boundary definition instead of leaving it fixed at the original study (Mbonu & Uzoka, 2020b) (Mbonu et al., 2020).

At the power-generation or reinjection end of the system, the same principle holds: whatever is flared, whether during normal running or an excursion, is unsold gas, avoidable emissions, and a visible mismatch between what production sends forward and what the downstream equipment can absorb. The boundary work here needs to identify the physical, information, utility, organizational, and market interfaces that connect this equipment to the rest of the network. Ignition and radiation exposure is the scenario that boundary must be drawn wide enough to cover, from its early warning signs through detection, the safeguards that respond, the time a recovery takes, and the effects that ripple downstream if it is missed. Availability and turndown modelling is one useful input to that picture, but it is not, by itself, proof that the interface is technically sound. The value of tracking each figure's source date, operating mode, uncertainty band, model version, and owner is that it keeps an apparently clean result from disguising assumptions that were never actually checked, and it leaves the door open for operating experience gathered afterward to revise the boundary rather than being filed away separately from it (Dogbatsey & Oyeleye, 2019).

Technology and Process Fundamentals: Process Configuration and Governing Mechanisms. Every cubic foot that goes to flare, whether on a routine day or during an upset, is gas the operation did not sell, emissions it did not avoid, and a reminder that production and gas-handling capacity are not fully in step, which is why this subsection works through the equipment mechanisms themselves rather than taking them for granted. The analysis should explain governing mechanisms, equipment functions, constraints, and failure modes. Flare header and knockout drum sizing, and the pressure-relieving devices that protect them, follow established relieving-system design practice: API Standard 521 sets the basis for determining relieving loads and flare-tip performance under fire, blocked-outlet, and control-valve-failure scenarios (American Petroleum Institute, 2014), API Standard 537 specifies the mechanical and combustion-performance requirements for the flare tip, pilot, and ignition system itself (American Petroleum Institute, 2008), and API Recommended Practice 520 covers the sizing and selection of the pressure-relieving devices that deliver gas to the header in the first place (American Petroleum Institute, 1990). These three standards, read together, define the governing mechanism this subsection describes: the header must accept the largest credible simultaneous relief load while the flare tip maintains stable, smokeless combustion across the resulting turndown range. Practical design experience compiled from operating emergency flare systems corroborates these standard-based sizing rules, with field-observed exceptions worth carrying into the screening stage (Boix, 1985). Unstable flare-header pressure is the failure mode the model needs to carry for the header and knockout drum, and carrying it well means tracking how the instability starts, how quickly it would be detected, what safeguards limit it, how long a return to normal takes, and what else it disturbs on the way. Economic-evaluation figures add to that picture without settling it; nothing produced by a single study is sufficient proof of technical adequacy on its own. Logging the source date, operating mode, measurement uncertainty, model version, and accountable owner behind each input is what keeps a precise-looking answer from hiding assumptions that were never actually tested, and it means that whatever operations subsequently learns can be folded back into the same decision rather than parked in a separate record (American Petroleum Institute, 2016; American Petroleum Institute, 2016) (Adewoyin et al., 2020).

Operating Constraints and Failure Modes. Flaring, whether it happens on a normal day or in response to an upset, always carries the same three costs: gas that goes unsold, emissions the site did not avoid, and evidence that production is outrunning gas-handling capacity, so this part of the analysis stays focused on how the equipment actually behaves rather than how it is meant to behave. The analysis should explain governing mechanisms, equipment functions, constraints, and failure modes. Combustion efficiency, not recovery-system design alone, sets the environmental performance baseline against which a recovery investment is judged: controlled field studies dating to the early 1980s found that flare combustion efficiency falls sharply outside a fairly narrow window of exit velocity, heating value, and steam or air assist

DOI: https://doi.org/10.64388/IREV4I1-1723154

rate (McDaniel, 1983; Pohl & Soelberg, 1985), and subsequent Alberta field surveys confirmed that a meaningful share of operating flares run outside that window during routine service (Strosher, 1996). A compression train that reduces flared volume therefore also improves the combustion performance of whatever residual flow remains, because it can keep the flare closer to its efficient operating range rather than cycling between near-zero and peak flow. Liquid carryover is the compression-train failure mode this model has to account for, meaning its triggers, how soon it would be caught, the safeguards that intervene, the time needed to recover, and its knock-on effects need to be spelled out rather than assumed away. A risk review of the implementation plan contributes useful evidence toward that, though it cannot on its own certify the design as technically sound. Recording where each source figure came from, the operating mode it reflects, its measurement uncertainty, the model version it informed, and who owns it is what stops an apparently precise conclusion from masking assumptions nobody has actually stress-tested, and it keeps the finding open to revision as real operating experience accumulates rather than closing it out as a one-off study.

The same equipment-behavior focus carries into wind effects on combustion. The analysis should explain governing mechanisms, equipment functions, constraints, and failure modes. The University of Alberta flare research program extended the early combustion-efficiency work into a crosswind-specific parametric model, showing that ambient wind speed relative to exit velocity is often a stronger predictor of unstable combustion and visible smoking than fuel composition alone (Johnson & Kostiuk, 2002; Kostiuk et al., 2004). Independent atmospheric-dispersion assessments reached a consistent conclusion using a different measurement approach, reporting that theoretical combustion-efficiency assumptions commonly used in emissions inventories overstate actual field performance under low-flow, high-crosswind conditions (Leahey et al., 2001). Computational fluid dynamics simulations of steam-assisted and air-assisted flare combustion corroborate these field findings by reproducing the same narrow efficient-operating window from first principles rather than from empirical correlation alone (Castiñeira & Edgar, 2006), building on earlier flare efficiency studies that first identified the practical limits of steam-assist ratio in refinery service (Davis, 1983). Compressor surge is the counterpart failure mode at the gas treating and dehydration unit, and modelling it properly means capturing what sets it off, how detection limits are set, what safeguards are triggered, how long the unit takes to recover, and what happens further downstream while it does. Ongoing performance monitoring adds evidence to that case without being sufficient on its own to call the model technically adequate. What makes the difference is discipline in recordkeeping, source date, operating mode, measurement uncertainty, model version, and named owner, since that is what keeps a tidy result from hiding untested assumptions and lets subsequent operating experience feed back into the decision instead of sitting apart from it (Okonkwo & Okeke, 2020) (Okonkwo et al., 2020).

Data and Measurement Architecture. Whether gas goes to flare on a routine basis or because of an upset, the result is the same lost sale, added emissions, and a signal that production and gas-handling capacity are out of balance, which is exactly the kind of gap a well-built measurement architecture is meant to expose. The analysis should define variables, quality rules, reconciliation, uncertainty, and traceability. Applied to the flare header and knockout drum, that architecture has to be able to see unstable flare-header pressure coming: what triggers it, where the limits of detection sit, which safeguards respond, how long recovery takes, and what it affects downstream. A round of technology screening contributes part of the picture, but no single dataset closes the case on its own. The reason to log source date, operating mode, measurement uncertainty, model version, and an accountable owner for every input is that doing so keeps a clean-looking number from concealing assumptions that were never actually checked, and it means later operating experience can revise the decision instead of being filed away on its own.

Data quality problems are where the cost of flaring, in lost gas, added emissions, and mismatched capacity, is easiest to lose track of, which is why the measurement architecture needs to define its variables, quality rules, reconciliation steps, uncertainty, and traceability up front rather than after the fact. Emissions data quality is a particular concern because standard emission-factor approaches, including the industrial-flares chapter of the United States emission-factor compilation, were developed primarily from steady, high-heating-value test conditions and can misstate performance at the low-flow, variable-composition conditions typical of associated-gas flaring (U.S. Environmental Protection Agency, 2018). Direct field measurement work by Conrad and Johnson (2017) shows that black carbon yield from a given flare varies by more than an order of magnitude with fuel composition and combustion condition, which means a single default yield factor cannot substitute for asset-specific measurement wherever black carbon or particulate performance is a decision input. Multispectral nighttime satellite observations of Russian flaring sites corroborate the persistence pattern reported for other producing regions, while also showing measurable year-to-year variation tied to specific field developments (Matveev, Zhizhin, & Poyda, 2020). At the flare header and knockout drum, this means representing unstable flare-header pressure directly, its onset, the point at which it becomes detectable, the safeguards that engage, the time to recover, and what it touches downstream, rather than assuming the header behaves the same way every time. Technology-screening data feeds into that picture, but on its own it does not settle the question of technical adequacy. Keeping a record of each figure's source date, operating mode, measurement uncertainty, model version, and owner is what stops a seemingly exact number from hiding untested assumptions, and it is also what lets later operating experience revise the decision instead of sitting outside it.

Good measurement design needs a dataset broad enough to defend, and this is where one already exists. The Texas Commission on Environmental Quality flare study program supplies one of the more complete low-flow measurement datasets available for this purpose, combining ground-based and airborne sampling to characterize destruction and removal efficiency across a wide range of steam-assist and flow conditions rather than relying on a single design-basis test point (Allen & Torres, 2011; Torres et al., 2012). Process-level optimization of triethylene glycol circulation rate and reboiler duty further tightens the water-dew-point specification that a gas treating and dehydration unit must meet under variable feed conditions (Chebbi, Qasim, & Abdel Jabbar, 2019). A measurement architecture built around this kind of dataset can support the compression-train turndown decisions addressed later in this paper without assuming that combustion performance is constant across the operating envelope. Turboexpander-based energy recovery at a gas city-gate station follows comparable feasibility logic, converting pressure-letdown energy that would otherwise be wasted into usable power rather than assuming a constant recovery envelope (Zabihi & Taghizadeh, 2016). Liquid carryover at the compression train needs the same treatment: its initiating conditions, the point where it becomes detectable, the safeguards involved, the time to recover, and its downstream consequences all belong in the model rather than being left implicit. Availability and turndown modelling supplies useful evidence toward that end, though no single dataset is enough by itself to call the system technically adequate. Recording the source date, operating mode, measurement uncertainty, model version, and accountable owner behind each figure is what keeps a precise-sounding result honest about the assumptions underneath it, and it is also how later operating experience gets folded back into the decision rather than staying in a separate file.

Framework Development and Validation. A model built to guide flare-gas recovery decisions is only as good as its ability to keep assumptions, calibration evidence, sensitivity testing, and acceptance limits separate from one another rather than blended into a single number. Unstable flare-header pressure at the flare header and knockout drum is the scenario that separation needs to be tested against: what starts it, how it is detected, what safeguards catch it, how long recovery takes, and what it disturbs further along the system. Source measurement and compositional characterization contributes part of that evidence base, but it was never meant to carry the full weight of proving the model adequate on its own. What makes the difference is whether each input is traceable back to a source date, an operating mode, a stated measurement uncertainty, a model version, and a named owner, since that is what stops a confident-looking output from hiding assumptions that were never actually tested, and it is also how field experience gathered afterward gets folded back into the model rather than left to sit in a separate file (Amayo & Popoola, 2017a).

A validated model needs its assumptions, calibration evidence, sensitivity testing, and acceptance limits kept visibly distinct rather than folded together into a single confident-sounding conclusion. Acceptance limits for a flare-gas recovery model should be anchored to management-system requirements the organization already carries, rather than invented for the study alone: environmental performance criteria can be drawn from an existing ISO 14001 environmental management system (International Organization for Standardization, 2015a), and safety-critical assumptions about operator competence and change control follow the same process-safety-management logic already codified in United States hazardous-chemical process safety regulation (Occupational Safety and Health Administration, 1992). The unstable flare-header pressure scenario at the flare header and knockout drum is where this discipline gets tested in practice, requiring a clear account of what initiates it, how detection limits are set, what safeguards respond, how long recovery takes, and what downstream effects follow. Source measurement and compositional characterization is one input to that account, not the whole of it, since no single dataset can carry the full burden of proof. Tracking the source date, operating mode, measurement uncertainty, model version, and accountable owner behind every figure is what keeps an apparently precise result from concealing assumptions nobody actually tested, and it is what lets operating experience gathered later update the model instead of being kept apart from it (Mbonu & Uzoka, 2020) (Mbonu et al., 2019).

The same separation of assumptions, calibration evidence, sensitivity testing, and acceptance limits applies at the gas treating and dehydration unit, where compressor surge is the scenario the model has to represent explicitly: its triggers, the limits of detection, the safeguards that respond, the time needed for recovery, and the effects that follow downstream. Technology-screening evidence adds to the case for that representation without being sufficient proof on its own that the model is technically adequate. The habit that closes the gap is recording, for every figure used, its source date, operating mode, measurement uncertainty, model version, and accountable owner, because that record is what prevents a clean-looking number from hiding untested assumptions and what allows later operating experience to revise the model rather than being logged separately from it.

Screening and Decision Criteria. Ranking sources, assets, technologies, or interventions only works if the criteria behind the ranking are made explicit rather than left implicit in whoever is doing the scoring. Acid-gas corrosion is the scenario the natural gas liquids recovery section needs represented in that ranking, meaning its initiating conditions, the limits of its detection, the safeguards that respond, the time a recovery takes, and its downstream effects all need to be accounted for rather than assumed away. A review of implementation risk supplies part of the evidence for that accounting, though it cannot by itself settle whether the case is technically adequate. Logging each input's source date, operating mode, measurement uncertainty, model version, and accountable owner is what stops a confident-looking score from concealing assumptions that were never actually tested, and it also means that operating experience gathered afterward can revise the ranking instead of being kept in a separate record (Dagodzo, 2018).

At the export pipeline interface, the same ranking exercise has to include off-specification gas as a named scenario, tracking what triggers it, how quickly it can be detected, the safeguards that respond, how long recovery takes, and what it affects further along the line. Performance-monitoring data feeds into that ranking, but it does not, by itself, establish that the interface is technically adequate. What earns that confidence is a habit of recording each figure's source date, operating mode, measurement uncertainty, model version, and accountable owner, since that record keeps a precise-looking rank from concealing weak assumptions and gives later operating experience a way back into the decision instead of staying separate from it.

For the power-generation or reinjection system, ignition and radiation exposure is the scenario that has to be built into the ranking criteria, complete with its initiating conditions, the limits of detection, the safeguards involved, the time a recovery takes, and the downstream effects that follow. Continuous-optimization data supports that ranking without being sufficient on its own to prove the system technically adequate. Recording the source date, operating mode,

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

measurement uncertainty, model version, and accountable owner for each input is what prevents an apparently precise ranking from masking assumptions nobody actually tested, and it also lets later operating experience revise the ranking instead of sitting apart from it in a separate record. Table 1 summarizes the eight decision stages, together with the primary question, required evidence, and decision output associated with each stage across the flare header and knockout drum, compression train, gas treating and dehydration unit, natural gas liquids recovery section, export pipeline interface, and power-generation or reinjection system interfaces.

Figure 1 maps flare-gas sources through conditioning to distinct product routes and outcomes. Table 1 instead compares the technical, commercial, and environmental indicators used to select among recovery options.

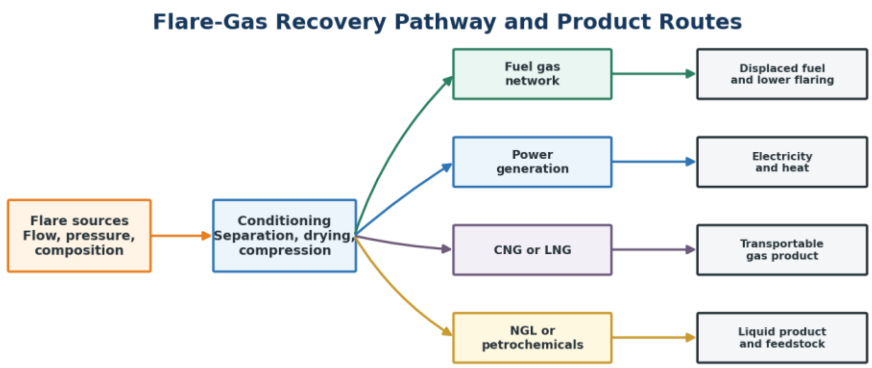

Figure 1. Flare-gas recovery pathway from source characterization to product-route selection.

Table 1. Technical and Economic Indicators for Comparing Flare-Gas Recovery Options

Evaluation dimension	Primary indicator	Why it matters	Decision use
Recoverable supply	Standard volume per day	Defines practical project scale	Size recovery equipment
Flow variability	P10, P50, and P90 flow	Shows turndown and storage needs	Select flexible capacity
Gas quality	Heating value and composition	Controls product route and treatment	Screen end-use options
Available pressure	Header pressure profile	Sets compression requirement	Estimate compression stages
Contaminants	H2S, CO2, water, and liquids	Determines pretreatment duty	Define conditioning system

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

Evaluation dimension	Primary indicator	Why it matters	Decision use
Energy demand	kWh per recovered unit	Affects cost and net emissions	Compare equipment trains
Commercial value	Netback per product route	Measures revenue after delivery costs	Rank monetization pathways
Environmental result	Verified emissions avoided	Confirms reduction beyond baseline	Report project performance

Risk, Reliability, and Environmental Assessment. Loss scenarios only become useful for decision-making once they are tied back to reliability, safety, emissions, and resource outcomes rather than treated as a stand-alone hazard list. At the natural gas liquids recovery section, acid-gas corrosion is the scenario that connection has to run through: what sets it off, how it is detected, which safeguards intervene, how long recovery takes, and what it affects downstream. Data from continuous-optimization efforts contributes to that assessment, though no single dataset is enough to call the case technically adequate by itself. Keeping a record of source date, operating mode, measurement uncertainty, model version, and accountable owner behind each figure is what stops a precise-looking result from hiding assumptions that were never tested, and it is also what allows later operating experience to feed back into the assessment rather than being logged apart from it. Quantitative risk methods developed for pipeline systems, including ditch-laid pipeline risk assessment models that combine failure-frequency and consequence data into a single ranking, offer a transferable template for scoring loss scenarios across the flare network in the same way (Zhang et al., 2019) (Akomolafe & Agu, 2018).

The export pipeline interface calls for the same connection between loss scenarios and reliability, safety, emissions, and resource outcomes, with off-specification gas as the scenario in question: its initiating conditions, the point at which it becomes detectable, the safeguards that respond, the time to recover, and its downstream effects all need representing rather than assuming away. Source measurement and compositional characterization contributes evidence toward that picture, but it cannot alone certify the interface as technically adequate. Keeping track of each input's source date, operating mode, measurement uncertainty, model version, and owner is what prevents a seemingly exact result from concealing untested assumptions, and it also lets whatever operations learns afterward feed back into the assessment instead of remaining separate from it.

For the power-generation or reinjection system, ignition and radiation exposure is the loss scenario that needs to be tied explicitly to reliability, safety, emissions, and resource outcomes, covering how it starts, where detection limits sit, which safeguards engage, how long recovery takes, and what it affects downstream. Flare network hydraulic analysis is one contributor to that picture, not a substitute for it, since no single dataset establishes technical adequacy on its own. The discipline of recording source date, operating mode, measurement uncertainty, model version, and accountable owner for each figure is what keeps an apparently precise conclusion from hiding assumptions nobody tested, and it also gives later operating experience a route back into the assessment rather than leaving it as a closed, separate record.

Operating-Envelope Integration: Safe and Reliable Operating Envelope. Design and model assumptions are only useful to shift-level operators once they have been translated into daily limits and a defined response to excursions, which is the job this integration step performs. For the natural gas liquids recovery section, that means representing acid-gas corrosion directly, its initiating conditions, how it is detected, the safeguards available, the time a recovery takes, and what it affects downstream, inside the operating envelope rather than treating it as an occasional footnote. Availability and turndown modelling supplies part of the supporting evidence, though no single dataset is enough to prove the envelope technically sound. The reason to record each figure's source date, operating mode, measurement uncertainty, model version, and accountable owner is that doing so stops a precise-looking limit from hiding assumptions that were never actually tested, and it lets operating experience gathered later revise the envelope rather than sitting outside it.

Excursion Management and Model Updating. The export pipeline interface needs the same translation of design and model assumptions into working daily limits and a defined excursion response, built around off-specification gas as the scenario that limit has to guard against, its onset, the point of detection, the safeguards that respond, the time to recover, and its downstream effects. Economic-evaluation data contributes to setting that limit without being able to prove, on its own, that it is technically adequate. What closes that gap is tracking source date, operating mode, measurement uncertainty, model version, and accountable owner for every input, since that traceability is what keeps a confident-sounding limit from concealing untested assumptions and what lets field experience update the limit later instead of leaving it fixed.

The power-generation or reinjection system needs its own daily limits and excursion response, translated from the same design and model assumptions, this time built around ignition and radiation exposure: what triggers it, where the detection limits fall, which safeguards respond, how long recovery takes, and what downstream effects follow. A review of implementation risk supplies part of the evidence behind that limit, though it does not by itself prove the envelope technically adequate. Recording source date, operating mode, measurement uncertainty, model version, and accountable owner for each input is what stops an apparently precise limit from concealing weak assumptions, and it is also what allows later operating experience to update that limit rather than leave it as a fixed, separate record.

Barrier and Safeguard Assurance: Barrier Functions and Performance Standards. Assuring a barrier means checking its prevention, detection, control, isolation, mitigation, and emergency layers individually rather than assuming that the presence of a barrier is the same thing as a working one. At the flare header and knockout drum, unstable flare-header pressure is the scenario that assurance work has to cover, including how it starts, how it is picked up, which safeguards act on it, how long recovery takes, and what it affects downstream. Performance-monitoring records add to that picture, though no single dataset is enough on its own to declare the barrier set technically adequate. The value of logging source date, operating mode, measurement uncertainty, model version, and accountable owner for each input is that it keeps a reassuring-looking conclusion from hiding assumptions that were never actually verified, and it lets later operating experience revise the assurance case instead of leaving it closed. A barrier taxonomy that distinguishes prevention, detection, control, and mitigation functions, and that separates a barrier's existence from its demonstrated performance, gives this evaluation a common vocabulary across asset interfaces (Sklet, 2006); where a barrier is implemented as a safety instrumented function, its target performance should be specified and verified against the safety integrity level requirements set out in IEC 61511-1:2016 (International Electrotechnical Commission, 2016). Non-destructive measurement techniques for assessing accumulated corrosion damage supply one route to that verified evidence at pipeline and vessel interfaces, where a barrier depends on remaining wall thickness rather than on instrumentation alone (Kania & Carroll, 1998) (Amayo, 2017; Sanni & Atima, 2020a) (International, 2009).

Testing, Impairment, and Assurance. The compression train's prevention, detection, control, isolation, mitigation, and emergency layers need the same individual scrutiny, this time against liquid carryover as the scenario in play, tracking what sets it off, how it is detected, the safeguards it activates, how long recovery takes, and what happens downstream. Continuous-optimization data contributes part of the picture without settling, by itself, whether the barrier set is technically adequate. Recording each input's source date, operating mode, measurement uncertainty, model version, and accountable owner is what stops a confident assurance conclusion from concealing assumptions that were never actually

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

tested, and it also lets operating experience gathered afterward revise the assurance case rather than leaving it filed away separately. The prevention, detection, control, isolation, mitigation, and emergency layers evaluated at each interface correspond closely to the layered-defense treatment of process hazards in Lees' Loss Prevention in the Process Industries, which remains a standard reference for identifying which layer a given barrier actually occupies (Mannan, 2012). Reliability-centered maintenance programs targeted at the specific wear components of reciprocating compressors have been shown to reduce unplanned downtime in comparable industrial service (Liang et al., 2012), and documented safety issues in reciprocating compressor design, operating practice, and maintenance reinforce why barrier performance, not nameplate capacity, should anchor the compression-train acceptance criteria discussed later in this paper (Upreti et al., 2013).

At the gas treating and dehydration unit, the same review of prevention, detection, control, isolation, mitigation, and emergency layers has to be carried out against compressor surge, working through its triggers, the limits of its detection, the safeguards that respond, how long recovery takes, and what it affects downstream. Source measurement and compositional characterization adds part of the evidence for that review, but no single dataset is sufficient to call it technically adequate on its own. Recording the source date, operating mode, measurement uncertainty, model version, and accountable owner behind each figure is what keeps an apparently precise assurance case from hiding assumptions that were never tested, and it also allows later operating experience to update that case instead of leaving it closed off.

Techno-Economic and Resource Evaluation. An economic case for flare-gas recovery is only as strong as the links it draws between capital, operating cost, downtime, recovery, emissions, and uncertainty. Emissions accounting conventions matter to this evaluation because they determine which avoided emissions a recovery project can claim credit for: the American Petroleum Institute's greenhouse gas emissions methodology compendium and the Intergovernmental Panel on Climate Change's national inventory guidelines both specify flaring-related emission factors and reporting boundaries that a techno-economic case must use consistently if its avoided-emissions claim is to be auditable (American Petroleum Institute, 2009; Intergovernmental Panel on Climate Change, 2006). Sustainability-linked procurement criteria increasingly shape how operators select vendors and contractors for recovery-system installation, and Okojie et al. (2020) show how ESG-integrated supply chain models embed environmental performance requirements directly into contracting decisions of this kind. For the natural gas liquids recovery section, acid-gas corrosion has to enter that economic picture directly, its initiating conditions, the point of detection, the safeguards in place, the time a recovery takes, and its downstream effects. Flare network hydraulic analysis supplies part of the underlying evidence, though no single dataset is enough by itself to prove the case technically adequate. Tracking source date, operating mode, measurement uncertainty, model version, and accountable owner for each input is what stops an apparently precise economic result from concealing weak assumptions, and it also lets later operating experience revise the case rather than leaving it as a closed, separate record (Aminu-Ibrahim & Ambali, 2019) (Aminu-Ibrahim et al., 2019; Aminu-Ibrahim et al., 2018; Aminu-Ibrahim et al., 2020).

The export pipeline interface needs the same links drawn between capital, operating cost, downtime, recovery, emissions, and uncertainty, with off-specification gas as the scenario the model has to carry: what sets it off, where detection limits lie, which safeguards respond, how long recovery takes, and what it affects downstream. Technology-screening evidence supports that economic picture without being able to prove it technically adequate on its own. Recording the source date, operating mode, measurement uncertainty, model version, and accountable owner for each figure is what keeps a precise-looking result from hiding untested assumptions, and it also lets later operating experience revise the economic case instead of sitting apart from it.

For the power-generation or reinjection system, ignition and radiation exposure is the scenario that the economic model has to connect back to capital, operating cost, downtime, recovery, emissions, and uncertainty, covering how it starts, how it is detected,

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

what safeguards respond, how long recovery takes, and its downstream effects. Availability and turndown modelling contributes part of the evidence for that case, but it cannot alone prove the case technically adequate. What matters is recording the source date, operating mode, measurement uncertainty, model version, and accountable owner behind each figure, since that is what keeps a confident-sounding result from hiding assumptions never actually tested, and it is what allows later operating experience to update the case rather than leaving it as a stand-alone record.

V. APPLICATION ACROSS ASSET CLASSES

Source and Composition Characterization. Source and composition characterization begins with a decision statement for flare headers and knockout drums. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to unstable header pressure, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority (Kaplan & Garrick, 1981; Center for Chemical Process Safety, 2007) (Center for Chemical Process Safety, 2007).

Validation of source and composition characterization should use independent evidence from gas-treating and dehydration units wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include acid-gas corrosion and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions.

Flare-Network Hydraulic Assessment. Flare-network hydraulic assessment begins with a decision statement for compression trains. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to liquid carryover, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority.

Validation of flare-network hydraulic assessment should use independent evidence from liquids-recovery systems wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include off-specification product and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions (Dosunmu & Ogundele, 2019).

Technology and Product-Route Screening. Technology and product-route screening begins with a decision statement for gas-treating and dehydration units. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to compressor surge, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority.

Validation of technology and product-route screening should use independent evidence from export interfaces wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include loss of emergency disposal capacity and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions (Kaplan & Garrick, 1981; Center for Chemical Process Safety, 2007) (Center for Chemical Process Safety, 2008).

Compression and Treatment Design. Compression and treatment design begins with a decision statement for liquids-recovery systems. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to acid-gas corrosion, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority (Kaplan & Garrick, 1981; Center for Chemical Process Safety, 2007). Green corrosion-inhibitor formulations offer one mitigation option for the acid-gas corrosion addressed at this interface, while non-destructive-testing-based integrity management and corrosion-risk assessment provide the monitoring evidence needed to confirm that the mitigation remains effective over time. Field-proven inhibitor programs for top-of-line corrosion in sour gas gathering pipelines document how continuous chemical treatment and periodic coupon monitoring together sustain the corrosion allowance assumed in the original design basis (Martin, 2009) (Center for Chemical Process Safety, 2016).

Validation of compression and treatment design should use independent evidence from power-generation and reinjection systems wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include unstable header pressure and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions (Ogbete et al., 2019).

Availability and Turndown Analysis. Availability and turndown analysis begins with a decision statement for export interfaces. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to off-specification product, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority.

Validation of availability and turndown analysis should use independent evidence from flare headers and knockout drums wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include liquid carryover and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions.

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

Safety and Operability Assurance. Safety and operability assurance begins with a decision statement for power-generation and reinjection systems. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to loss of emergency disposal capacity, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority.

Validation of safety and operability assurance should use independent evidence from compression trains wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include compressor surge and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions (Kaplan & Garrick, 1981; Center for Chemical Process Safety, 2007) (Obriki & Arumosoye, 2019) (Obriki & Arumosoye, 2019).

Techno-Economic Evaluation. Techno-economic evaluation begins with a decision statement for flare headers and knockout drums. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to unstable header pressure, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority (Kaplan & Garrick, 1981; Center for Chemical Process Safety, 2007) (Center for Chemical Process Safety, 2010).

Validation of techno-economic evaluation should use independent evidence from gas-treating and dehydration units wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include acid-gas corrosion and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions.

Performance Verification. Performance verification begins with a decision statement for compression trains. The team must specify what evidence will support the decision, which operating modes are included, and which assumptions require later confirmation. For flare-gas recovery, this stage should recover associated gas without destabilizing production or compromising flare-system safety. The analysis should represent normal operation, startup, shutdown, turndown, maintenance, and credible upset conditions. Particular attention should be given to liquid carryover, because a locally acceptable condition may create a wider process, safety, environmental, or commercial consequence. Input records should identify source, timestamp, units, uncertainty, configuration, and accountable owner. A decision threshold should be approved before the final ranking is viewed. This reduces hindsight bias and prevents a favorable economic result from overriding mandatory safety or legal constraints. The resulting record should state the selected option, rejected alternatives, evidence gaps, interim controls, and residual-risk authority.

Validation of performance verification should use independent evidence from liquids-recovery systems wherever feasible. Acceptance should depend on observable performance rather than completion of a report or work order. Suitable measures include availability, detection coverage, response time, product compliance, avoided loss, energy intensity, maintenance burden, and verified risk reduction. The team should test sensitivity to uncertain supply, composition, equipment condition, utility availability, market conditions, and model error. A credible adverse case should include off-specification product and the loss of one important safeguard or dependency. Differences between predicted and observed performance should trigger model review, not informal adjustment of the acceptance limit. Management of change should capture revised drawings, procedures, training, spares, software versions, alarm settings, and inspection requirements. This verification loop converts flare-gas recovery from a one-time study into a controlled operating capability. It also supplies comparable evidence for future investment and risk decisions.

VI. IMPLEMENTATION ROADMAP AND GOVERNANCE

Source Measurement and Compositional Characterization. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving flare header and knockout drum. Record assumptions about unstable flare-header pressure, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response (Ogbete et al., 2018).

Flare Network Hydraulic Analysis. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving compression train. Record assumptions about liquid carryover, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response.

Technology Screening. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving gas treating and dehydration unit. Record assumptions about compressor surge, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response.

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

Availability and Turndown Modelling. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving natural gas liquids recovery section. Record assumptions about acid-gas corrosion, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response.

Economic Evaluation. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving export pipeline interface. Record assumptions about off-specification gas, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response.

Implementation Risk Review. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving power-generation or reinjection system. Record assumptions about ignition and radiation exposure, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response (Adeyelu, 2019) (Adeyelu, 2019; Mgbame et al., 2020).

Performance Monitoring. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving flare header and knockout drum. Record assumptions about unstable flare-header pressure, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response.

Continuous Optimization. Establish scope, accountable roles, minimum evidence, approval criteria, and a documented output. Apply the phase first to high-consequence scenarios involving compression train. Record assumptions about liquid carryover, test the decision with sensitivity analysis, and assign closure evidence. Advance to the next phase only when unresolved uncertainty has an explicit treatment and owner. Review interfaces with operations, maintenance, inspection, process safety, environmental management, commercial planning, and emergency response.

Governance and Organizational Requirements. A flare-gas recovery decision needs clear ownership, decision rights, change control, competence, and assurance behind it, or it risks becoming a study that nobody is accountable for acting on. At the flare header and knockout drum, unstable flare-header pressure is the scenario governance has to be built around: what triggers it, where detection limits sit, which safeguards respond, how long recovery takes, and what it disturbs downstream. Economic-evaluation figures inform that governance structure without being able to prove it adequate on their own. Assigning a source date, operating mode, measurement uncertainty, model version, and named owner to each input is what keeps an apparently solid governance case from resting on assumptions nobody tested, and it also means later operating experience can be brought back into the decision rather than staying outside it.

The compression train needs the same assignment of ownership, decision rights, change control,

© JUL 2020 | IRE Journals | Volume 4 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV4I1-1723154

competence, and assurance, built around liquid carryover as the scenario governance is meant to manage: how it starts, how it is detected, the safeguards that respond, how long recovery takes, and its downstream effects. An implementation risk review contributes part of the evidence for that governance structure, though no single dataset is enough to declare it technically adequate. Recording source date, operating mode, measurement uncertainty, model version, and accountable owner for every input is what keeps a governance case that looks solid on paper from resting on untested assumptions, and it is also what lets later operating experience feed back into that governance rather than remaining separate from it.

At the gas treating and dehydration unit, ownership, decision rights, change control, competence, and assurance need to be assigned against compressor surge specifically, covering its triggers, the limits of detection, the safeguards involved, the time to recover, and its downstream effects. Ongoing performance monitoring adds to the evidence supporting that governance arrangement, though it does not by itself prove the arrangement technically adequate. The habit of recording source date, operating mode, measurement uncertainty, model version, and accountable owner for each input is what keeps a seemingly well-governed decision from resting on assumptions that were never actually checked, and it is also what allows operating experience gathered later to update the governance rather than leaving it fixed.

Performance Measurement and Organizational Learning. Leading and lagging measures, each with its own update threshold, are what turn a one-time flare-gas recovery decision into something the organization can keep learning from. For the natural gas liquids recovery section, that learning loop has to include acid-gas corrosion explicitly: its initiating conditions, the limits of its detection, the safeguards that respond, the time recovery takes, and its downstream effects. Data from continuous optimization contributes to that picture, but no single dataset is enough to call it technically adequate on its own. Recording the source date, operating mode, measurement uncertainty, model version, and accountable owner behind each figure is what stops an apparently precise measure from hiding assumptions that were never tested, and it also gives later operating experience a way to update the measure rather than leaving it fixed in a separate record.

At the export pipeline interface, the leading and lagging measures defined for this purpose need to reach off-specification gas directly, tracking what triggers it, how it is detected, what safeguards respond, how long recovery takes, and what it affects downstream. Source measurement and compositional characterization supplies part of the evidence behind those measures, though it cannot alone prove them technically adequate. Recording each input's source date, operating mode, measurement uncertainty, model version, and accountable owner is what keeps a confident-looking measure from concealing untested assumptions, and it also lets field experience gathered later update the measure instead of leaving it as a closed record.

For the power-generation or reinjection system, the same leading and lagging measures need to be defined against ignition and radiation exposure, covering how it starts, where its detection limits sit, which safeguards respond, how long recovery takes, and what downstream effects follow. Flare network hydraulic analysis contributes part of the evidence base for those measures, but no single dataset is sufficient to establish their technical adequacy alone. The reason to record source date, operating mode, measurement uncertainty, model version, and accountable owner for each figure is that doing so prevents an apparently precise measure from hiding assumptions nobody tested, and it lets later operating experience revise the measure rather than leaving it in a separate, closed record.

Sector evidence on pipeline surveillance, thermofluid analysis, human factors, and industrial safety extends the general risk literature (Adewoyin et al., 2020). Read against the wider flare-gas recovery literature synthesized in this paper, three gaps stand out. First, combustion-efficiency evidence and recovery-system economics are almost always reported by separate research communities, so a techno-economic case rarely carries an explicit combustion-performance assumption that a reviewer could check against field measurement (McDaniel, 1983; Pohl & Soelberg, 1985; Johnson & Kostiuk, 2002; Conrad & Johnson, 2017). Second, policy and regulatory evaluations of flaring outcomes, including the Bakken, Russian, and Nigerian experience, are conducted at the jurisdiction level and rarely connect back to the asset-level decision that produced the measured result (Anomohanran, 2012; Ejiogu, 2013; Lade & Rudik, 2020). Third, satellite-derived flaring inventories establish that the problem persists at scale but are not designed to diagnose why a specific asset continues to flare (Elvidge et al., 2009; Elvidge et al., 2016). Compressor and ejector technology choices for the compression train are similarly reported mainly as isolated equipment case studies. Screw compressor units were among the earliest recovery technologies documented in the field literature (Ibragimov & Shaikhutdinov, 2000), reciprocating compressor trains have since recovered flare gas successfully at individual gathering stations (Sitorus, Sitaresmi, & Oetomo, 2018), liquid ring and dry screw compressor combinations have been applied at acid-gas-bearing flare headers (Ramasamy, 2018), and hybrid screw compressors have been proposed for offshore vapor-recovery and flare-elimination service where deck space and weight are constrained (Fujimatsu, 2009). Ejector-based systems have since been advanced as a lower-maintenance alternative to rotating equipment at some facilities (Ainge, 2019), with computational performance analysis of ejector geometry supporting that design choice (Sonawat & Samad, 2014). The decision framework developed in this paper is intended to close these gaps by carrying combustion-performance, economic, and regulatory-compliance evidence inside one traceable structure rather than leaving them in separate literatures (Ilodigwe & Adesemoye, 2019b; Obriki & Arumosoye, 2020; Ogbete & Ambali, 2019) (Arumosoye & Obriki, 2020; Ogbete et al., 2020; Obriki & Arumosoye, 2020).

VII. LITERATURE SYNTHESIS

Flare-gas recovery projects sit between process design, equipment availability, project delivery, and operating discipline. Aifuwa et al. (2020) show that forecasting-model accuracy directly affects the inventory-management inefficiency that undermines availability and turndown performance in comparable industrial supply chains. Facility-level energy efficiency and cost optimization assessments at an operating processing terminal reach a related conclusion from the operations side, showing that terminal-wide energy accounting, not unit-level tuning alone, identifies the largest recoverable savings (Kukadiya & Gajendran, 2017).

Technical feasibility alone does not establish sustained recovery. Thermofluid analysis supports heat and energy integration choices in recovery trains (Adewoyin, Ogunnowo, & Ezeugwa, 2020). Waste heat recovered from the compression train itself represents a complementary energy source at this interface: a systems-level analysis of United States natural gas compressor stations estimates the scale of this recoverable waste heat nationally (Tavakkoli, Lokare, Vidic, & Khanna, 2016), an early field installation demonstrated that a waste heat recovery system can be retrofitted onto an existing gas-turbine-driven compressor station (Tateosian & Roland, 1983), and trigeneration schemes that combine power, heating, and cooling from turbine exhaust waste heat further improve compression-train energy efficiency at an integrated gas processing plant (Popli, Rodgers, & Eveloy, 2012). Gas-to-wire conversion of stranded associated gas has been evaluated directly for Niger Delta production, where in-situ electricity generation was shown to displace an equivalent volume of otherwise-flared gas (Kerunwa, Ekwueme, & Obibuike, 2020), and a parallel review of flare-gas electricity potential in Iran reaches a similar conclusion using national flaring-inventory data (Pourmalek, Amanpour, Kuprat, & Schwarz, 2020). Field demonstration of oilfield flare-gas-to-electricity systems earlier established the basic feasibility of this power-generation route at the wellsite scale

(Henderson & Fickes, 2007). These sources support the proposed stage gates for operability, assurance, and lifecycle performance (Dagodzo, 2018a) (Dagodzo, 2018; Adewoyin et al., 2020; Dagodzo, 2018).

Research Propositions

Proposition Development. Turning the relationships in this framework into testable empirical statements means starting from a concrete scenario, and for the flare header and knockout drum that scenario is unstable flare-header pressure, with its initiating conditions, detection limits, safeguards, recovery time, and downstream effects all needing to be specified before a proposition can be tested. Technology-screening evidence contributes part of the basis for such a proposition, though no single dataset is enough to establish it as technically proven. Recording source date, operating mode, measurement uncertainty, model version, and accountable owner for each input is what keeps a proposition that looks well supported from resting on assumptions nobody actually tested, and it is what allows later operating experience to refine the proposition instead of leaving it fixed.

Empirical Testing Priorities. Liquid carryover at the compression train is the natural test case for converting this framework's relationships into a testable statement, since it has a clear set of initiating conditions, detection limits, safeguards, recovery time, and downstream effects that a study could actually check against. Availability and turndown modelling supplies part of the supporting evidence for that test, but it is not, on its own, sufficient to establish technical adequacy. What a testing program should insist on is recording the source date, operating mode, measurement uncertainty, model version, and accountable owner behind every figure it uses, since that record is what keeps an apparently conclusive test from resting on assumptions nobody checked, and it is what lets later operating experience update the proposition rather than leaving it closed.

At the gas treating and dehydration unit, compressor surge offers a similarly concrete basis for a testable proposition, one built around its initiating conditions, detection limits, safeguards, recovery time, and downstream effects rather than around the unit's design intent alone. Economic-evaluation data supplies part of the evidence for that proposition, though no single dataset is sufficient to establish it as technically proven. Recording the source date, operating mode, measurement uncertainty, model version, and accountable owner for each figure is what stops a seemingly solid proposition from concealing assumptions that were never actually tested, and it also allows later operating experience to revise the proposition instead of treating it as settled.

Testable Propositions:

- P1: Greater maturity in source measurement and compositional characterization improves the traceability and effectiveness of flare-gas recovery decisions when data quality and organizational context are controlled.
- P2: Greater maturity in flare network hydraulic analysis improves the traceability and effectiveness of flare-gas recovery decisions when data quality and organizational context are controlled.
- P3: Greater maturity in technology screening improves the traceability and effectiveness of flare-gas recovery decisions when data quality and organizational context are controlled.
- P4: Greater maturity in availability and turndown modelling improves the traceability and effectiveness of flare-gas recovery decisions when data quality and organizational context are controlled.
- P5: Greater maturity in economic evaluation improves the traceability and effectiveness of flare-gas recovery decisions when data quality and organizational context are controlled (Sanni & Atima, 2020b).

- P6: Greater maturity in implementation risk review improves the traceability and effectiveness of flare-gas recovery decisions when data quality and organizational context are controlled.

VIII. LIMITATIONS AND FUTURE RESEARCH

Scope and Evidence Limitations. Being honest about this framework's limits means stating its evidence, transferability, model, and implementation boundaries plainly rather than leaving them implied. Three limits deserve explicit statement. The conceptual synthesis draws heavily on North American and Russian field and regulatory evidence because that is where controlled flare-efficiency measurement has been concentrated (McDaniel, 1983; Pohl & Soelberg, 1985; Strosher, 1996; Kostiuk et al., 2004); transferring its acceptance limits to associated-gas compositions and ambient conditions outside that range should be treated as a hypothesis requiring local verification, not an established result. Computational fluid dynamics studies of gas or liquid separator internals reinforce this same transferability caution for liquid carryover specifically, showing that carryover from a flare knockout drum is sensitive to inlet momentum and droplet coalescence behavior rather than to vessel volume alone (Lu, Greene, & Agrawal, 2009), a mechanism further illustrated in a documented flare drum carryover case investigated with the same modelling approach (Lewis & Deddis, 2011). Satellite-based flaring estimates carry their own detection-threshold and cloud-cover uncertainty, so volumetric baselines drawn from that literature should be treated as directional rather than exact at the single-asset level (Elvidge et al., 2009; Elvidge et al., 2016). Adsorbed natural gas technology has similarly been evaluated as a technically feasible utilization route at smaller flare-gas volumes where pipeline connection is not economic, though its performance has mainly been demonstrated at pilot rather than commercial scale (Muharam, Giffari, & Mahendra, 2018). Finally, the framework itself has not yet been tested against a documented case history; the propositions in the next section are offered specifically to make that test possible. Acid-gas corrosion at the natural gas liquids recovery section is a further case in point: representing it properly means specifying its initiating conditions, the limits of its detection, the safeguards available, the time recovery takes, and its downstream effects, and a review of implementation risk only supplies part of that picture rather than the whole of it. Until each figure carries its own source date, operating mode, measurement uncertainty, model version, and accountable owner, an apparently precise conclusion here risks resting on assumptions nobody has actually tested, and without that record, later operating experience has no clear route back into revising the analysis.

Priority Research Directions. Future work on the export pipeline interface should prioritize off-specification gas as a scenario worth its own dedicated study, one that specifies initiating conditions, detection limits, safeguards, recovery time, and downstream effects clearly enough to be checked rather than assumed. Performance-monitoring data offers part of what such a study would need, but it is not a substitute for the study itself, since no single dataset can establish technical adequacy alone. Research in this area should insist on recording source date, operating mode, measurement uncertainty, model version, and accountable owner for every figure used, because that is what would keep a future finding from resting on untested assumptions and what would let later operating experience revise it rather than leaving it fixed.

The power-generation or reinjection system deserves similar research priority, with ignition and radiation exposure as the scenario future work should target directly: its initiating conditions, detection limits, safeguards, recovery time, and downstream effects all need clearer evidence than currently exists. Continuous-optimization data would supply part of that evidence, though, as elsewhere in this framework, no single dataset would be enough to settle the question alone. Any future study here should still record source date, operating mode, measurement uncertainty, model version, and accountable owner for each figure, since that is what keeps a seemingly conclusive result honest about its underlying assumptions and what allows later operating experience to revise it instead of treating it as final.

Published energy studies support integrating flare recovery with production planning, compression limits, and facility reliability (Li et al., 2016; Allen et al., 2017; U.S. Environmental Protection Agency., 2016; Yuhua et al., 2005; Alvarez et al., 2018; Younsi et al., 2017; Zavala-Araiza et al., 2015; Cao, 2012; Favre, 2007; Gvakharia et al., 2017; Petron et al., 2014; Ravikumar et al., 2020; Vaughn et al., 2018; Umukoro et al., 2017).

Resource-efficiency research links recovery performance to measurement quality, equipment availability, and operating discipline (Johnson et al., 2017; Lavoie et al., 2017; Mitchell et al., 2015; Ben Seghier et al., 2020; Korppoo, 2018; Zavala-Araiza et al., 2017; Zimmerle et al., 2015; Ossai, 2012; Remeljej et al., 2006; Peischl et al., 2016; Kemp, 2007; Robertson et al., 2020; Balcombe et al., 2017; Yazdi et al., 2017).

Oil and gas infrastructure evidence emphasizes lifecycle cost, environmental exposure, and continuity of supply in technology selection (Lyon et al., 2016; Mehrotra et al., 2017; NACE International et al., 2015; Askari et al., 2019; Yu et al., 2018; Omara et al., 2016; Howarth, 2014; Anderson et al., 2004; Heath et al., 2015; Nesic, 2007; Wang et al., 2020; Bell et al., 2017; Ayasse et al., 2016).

Process-engineering studies support scenario analysis across feed variability, utility demand, and downstream product constraints (Allen et al., 2015; Robertson et al., 2017; Brantley et al., 2014; Fang et al., 2019; Zavala-Araiza et al., 2018; Roscioli et al., 2015; Lee et al., 2013; Oil and Gas Methane Partnership 2.0., 2020; Lamb et al., 2015; Campbell, 2004; Adegboye et al., 2019; Kanshio et al., 2017).

Field evidence strengthens the case for monitoring recovery systems through transparent technical and economic indicators (Marchese et al., 2015; Zimmerle et al., 2017; Beavers et al., 2006; Oakley, 2019; Yang et al., 2017; Subramanian et al., 2015; Lewis, 2013; U.S. Environmental Protection Agency., 2020; McKain et al., 2015; Manning et al., 1991; Elbashir, 2018; Ravikumar et al., 2017).

Additional infrastructure evidence links recovery performance to maintenance readiness and efficient project delivery (Nwafor et al., 2019b; Adaramola et al., 2018).

Ewim and colleagues provide relevant thermofluid evidence for pressure-drop, condensation, heat-transfer, and equipment-screening decisions in gas-recovery systems (Meyer & Ewim, 2018; Ewim et al., 2018; Ewim & Meyer, 2019; Adelaja et al., 2019; Ewim et al., 2020a; Ewim et al., 2020b). The related findings also strengthen the paper's treatment of performance verification and model uncertainty (Adelaja et al., 2020).

IX. CONCLUSION

This paper set out to address a persistent and well-measured problem: satellite and field evidence agree that gas flaring continues at a large scale despite decades of engineering and policy attention, and the underlying reason is rarely a missing technology but a missing decision architecture that connects safety, reliability, product route, emissions, and economics for a specific asset. International experience outside Nigeria reinforces this diagnosis: studies of associated-gas utilization projects at Russian oil fields document their technical and ecological justification, while the near-elimination of routine flaring achieved on the Norwegian continental shelf through mandatory utilization requirements shows the same pattern, evidence that the missing element is typically decision architecture and policy commitment rather than available technology. The paper's contribution is that architecture: eight linked decision functions, applied consistently across the flare header and knockout drum, compression train, gas treating and dehydration unit, natural gas liquids recovery section, export pipeline interface, and power-generation or reinjection system interfaces, with Table 1 summarizing the evidence and decision output expected at each stage (Adegbite & Ahmed, 2020; Sunday & Omoegun, 2018; Atta & Adenuga, 2018) (Obogo et al., 2019).

The synthesis behind that architecture draws on four literatures that are rarely combined in a single flare-gas recovery assessment: process safety and risk management, gas processing and treating engineering, combustion and emissions field measurement, and flaring policy and economics. Bringing these literatures into one traceable framework, rather than treating them as separate studies reconciled informally after the fact, is what allows the framework to move from a general risk-management template to a decision tool specific to flare-gas recovery. Where recovered gas is routed to power generation, the integration lessons documented for large-scale solar deployment, including phased commissioning and grid-interconnection sequencing, offer a transferable programmatic template for staging flare-gas-to-power projects, and comparable statistical estimation methods developed for daily solar radiation in renewable energy planning illustrate how site-specific resource data, rather than generic design assumptions, should also inform the sizing of flare-gas-to-power alternatives (Obriki & Arumosoye, 2018; Agbabiaka & Okeke, 2019; Obogo & Ozobu, 2019) (Obogo et al., 2020; Obriki & Arumosoye, 2018; Agbabiaka et al., 2019).

Conclusions is central to flare-gas recovery because routine and non-routine flaring wastes saleable hydrocarbons, creates combustion emissions, and signals weak integration between production and gas-handling capacity. The analysis should summarize the contribution and practical implications. For gas treating and dehydration unit, the decision model must represent compressor surge, including initiating conditions, detection limits, safeguards, recovery time, and downstream effects. Technology screening supplies part of the evidence, but no single dataset establishes technical adequacy. The reviewer should record source date, operating mode, measurement uncertainty, model version, and accountable owner. This traceability prevents an apparently precise result from concealing weak assumptions. It also allows later operating experience to update the decision rather than remaining in a separate record. The paper's specific contribution is a source-to-market decision framework that treats safety, recovery reliability, product route, emissions, and economics as linked design variables. Future work should test the propositions with operating data and report both successful and unsuccessful applications (Badmus & Ozowara, 2019a).

Offshore field evidence strengthens the case for treating flare recovery as part of integrated production surveillance, resource recovery, and lifecycle optimization (Babadagli, 2005; Bresnen et al., 2003; Clayton et al., 1998; Faseemo et al., 2009; Perrin et al., 2005).

Declarations

Ethics approval and consent to participate: The flare-recovery review examined technical literature and did not recruit people or use animals.

Consent for publication: Not applicable.

Availability of data and materials: All technical evidence used for the flare-recovery assessment appears in the cited literature; no field dataset was collected.

Competing interests: The author declares no competing interests.

REFERENCES

[1] Adaramola, T. S., Fadero, S., & Gideon, E. N. (2018). Predictive maintenance and condition monitoring in critical power and energy infrastructure. Iconic Research and Engineering Journals, 2(5), 454-477. https://doi.org/10.64388/IREV2I5-1722489

[2] Adegbite, M. P., Adebayo, A., & Ahmed, M. O. (2020). Securing operational technology networks in electric utilities: A systematic review of NERC CIP compliance and architectural threat mitigation. International Journal of Engineering and Modern Technology, 6(3), 103-146. https://doi.org/10.56201/ijemt.vol.6.no3.2020.pg103.146

[3] Adegboye, M. A., Fung, W. K., & Karnik, A. (2019). Recent advances in pipeline monitoring and oil leakage detection technologies: Principles and approaches. Sensors, 19(11), 2548. https://doi.org/10.3390/s19112548

[4] Adelaja, A. O., Ewim, D. R. E., Dirker, J., & Meyer, J. P. (2019). Heat transfer, void fraction and pressure drop during condensation inside inclined smooth and microfin tubes. Experimental Thermal and Fluid Science, 109, 109905.

[5] Adelaja, A. O., Ewim, D. R. E., Dirker, J., & Meyer, J. P. (2020). An improved heat-transfer correlation for condensation inside inclined smooth tubes. International Communications in Heat and Mass Transfer, 117, 104746.

[6] Adewoyin, M.A., Ogunnowo, E.O., Fiemotongha, J.E., Igunma, T.O. & Adeleke, A.K., 2020. A Conceptual Framework for Dynamic Mechanical Analysis in High-Performance Material Selection. Iconic Research and Engineering Journals, 4(5), pp.137-155.

[7] Adewoyin, M.A., Ogunnowo, E.O., Fiemotongha, J.E., Igunma, T.O. & Adeleke,

A.K., 2020. Advances in Thermofluid Simulation for Heat Transfer Optimization in Compact Mechanical Devices. Iconic Research and Engineering Journals, 4(6), pp.116-133.

[8] Adeyelu, O. O. (2018). A predictive compliance monitoring framework for detecting systemic safety risks through aviation consumer complaint data. Iconic Research and Engineering Journals, 1(8), 250-276. https://doi.org/10.64388/IREV1I8-1718478

[9] Adeyelu, O. O. (2019). An adaptive safety management system implementation model for aerodromes in developing economy contexts. Iconic Research and Engineering Journals, 3(4), 628-654. https://doi.org/10.64388/IREV3I4-1718479

[10] Adeyelu, O.O., 2020. An Artificial Intelligence-Driven Conceptual Model for Wildlife Strike Risk Quantification and Aircraft Airworthiness Impact Assessment at High-Traffic African Airports. Iconic Research and Engineering Journals, 4(1), pp.339-368. DOI: 10.64388/IREV4I1-1718482.

[11] Agbabiaka, J., Okonkwo, C. S., Ogunwole, O., Mayo, W., & Okeke, O. T. (2019). Supply chain risk management model for EPC and gas processing projects. Iconic Research and Engineering Journals, 3(2), 968-980. https://doi.org/10.64388/IREV3I2-1713124

[12] Aifuwa, S. E., Oshoba, T. O., Ogbuefi, E., Ike, P. N., Nnabueze, S. B., & Olatunde-Thorpe, J. (2020). Predictive analytics models enhancing supply chain demand forecasting accuracy and reducing inventory management inefficiencies. International Journal of Multidisciplinary Research and Growth Evaluation, 1(3), 171-181. https://doi.org/10.54660/.IJMRGE.2020.1.3.171-181

[13] Ainge, P. (2019). Ejector technology for flare gas recovery as an alternative to rotating equipment. Abu Dhabi International Petroleum Exhibition and Conference. https://doi.org/10.2118/197909-ms

[14] Akomolafe, O., & Agu, M. U. (2018). A conceptual model for enhancing internal audit quality through technology-enabled risk assessment frameworks. Iconic Research and Engineering Journals, 1(9), 458-475.

[15] Akomolafe, O., & Agu, M. U. (2019a). A conceptual framework for developing risk-based internal control models in the insurance and banking sectors. Iconic Research and Engineering Journals, 2(8), 335-354.

[16] Akomolafe, O., & Agu, M. U. (2019c). Advances in financial resilience through integrated governance and compliance strategies. Iconic Research and Engineering Journals, 2(10), 607-620.

[17] Akpe, O.E.E., Ogeawuchi, J.C., Abayomi, A.A., Agboola, O.A.A. & Ogbuefi, E., 2020. A Conceptual Framework for Strategic Business Planning in Digitally Transformed Organizations. Iconic Research and Engineering Journals, 5(4), pp.310-325.

[18] Akpe, O.E.E., Swoade, S., Ubanadu, B.C., Daraojimba, A.I. & Gbenle, T.P., 2020. A Conceptual Model for Cross-Functional Collaboration Between IT and Business Units in Cloud Projects. Iconic Research and Engineering Journals, 4(6), pp.99-115.

[19] Allen, D. T., & Torres, V. M. (2011). TCEQ 2010 flare study final report. University of Texas at Austin.

[20] Allen, D. T., Cardoso-Saldana, F. J., & Kimura, Y. (2017). Variability in spatially and temporally resolved emissions and hydrocarbon source fingerprints for oil and gas sources in shale gas production regions. Environmental Science & Technology, 51(20), 12016-12026.

[21] Allen, D. T., Pacsi, A. P., Sullivan, D. W., Zavala-Araiza, D., Harrison, M., Keen, K., Fraser, M. P., Hill, A. D., Sawyer, R. F., & Seinfeld, J. H. (2015). Methane emissions from process equipment at natural gas production sites in the United States: Pneumatic controllers. Environmental Science & Technology, 49(1), 633-640. https://doi.org/10.1021/es5040156

[22] Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., Davis, K. J., Herndon, S. C., Jacob, D. J., Karion, A., Kort, E. A., Lamb, B. K., Lauvaux, T., Maasakkers, J. D., Marchese, A. J., Omara, M., Pacala, S. W., Peischl, J., Robinson, A. L., Shepson, P. B., Sweeney, C., Townsend-Small, A., Wofsy, S. C., & Hamburg, S. P. (2018).

Assessment of methane emissions from the U.S. oil and gas supply chain. Science, 361(6398), 186-188. https://doi.org/10.1126/science.aar7204

[23] Amayo, E. B. (2017). Multi algorithm of loss objective function of a single phase induction motor. International Journal of Development Research, 7(5), 12805-12810.

[24] Amayo, E. B., & Popoola, T. T. (2017a). Multi algorithm of weight objective function of a single phase induction motor. International Journal of Trend in Research and Development, 4(2), 184-188.

[25] Amayo, E. B., & Popoola, T. T. (2017b). Scientific study of telecommunication deployment in achieving quality network. International Journal of Trend in Research and Development, 4(5), 311-314.

[26] Amayo, E. B., Ubeku, E., & Oshevire, P. (2015). Multi algorithm of a single objective function of a single phase induction motor. Journal of Multidisciplinary Engineering Science and Technology, 2(12), 3400-3403.

[27] American Petroleum Institute. (1990). API Recommended Practice 520, Part I: Sizing, selection, and installation of pressure-relieving devices in refineries (6th ed.). API.

[28] American Petroleum Institute. (2001). API Recommended Practice 14C: Analysis, design, installation, and testing of basic surface safety systems for offshore production platforms (7th ed.). API.

[29] American Petroleum Institute. (2008). API Standard 537: Flare details for general refinery and petrochemical service (1st ed.). API.

[30] American Petroleum Institute. (2009). Compendium of greenhouse gas emissions methodologies for the oil and natural gas industry. API.

[31] American Petroleum Institute. (2014). API Standard 521: Pressure-relieving and depressuring systems (6th ed.). API.

[32] American Petroleum Institute. (2015). API Recommended Practice 1173: Pipeline safety management systems. API.

[33] American Petroleum Institute. (2016). API Recommended Practice 580: Risk-based inspection (3rd ed.). API.

[34] American Petroleum Institute. (2016). API Recommended Practice 581: Risk-based inspection methodology (3rd ed.). American Petroleum Institute.

[35] American Petroleum Institute. (2016). API Standard 580: Risk-based inspection (3rd ed.). American Petroleum Institute.

[36] American Society of Mechanical Engineers. (2016). ASME B31.3: Process piping. ASME.

[37] Aminu-Ibrahim, A. Y., Ogbete, J. C., & Ambali, K. B. (2018). Developing sustainable diagnostic laboratory infrastructure models for emerging and resource constrained health systems. Iconic Research and Engineering Journals, 1(8), 118-132. https://doi.org/10.64388/IREV1I8-1713586

[38] Aminu-Ibrahim, A. Y., Ogbete, J. C., & Ambali, K. B. (2019). Capital project delivery models for high risk healthcare infrastructure in developing national health systems. Iconic Research and Engineering Journals, 2(10), 626-649. https://doi.org/10.64388/IREV2I10-1713588

[39] Aminu-Ibrahim, A.Y., Ogbete, J.C. & Ambali, K.B., 2020. Infrastructure Driven Expansion of Diagnostic Access Across Underserved and Rural Healthcare Regions. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), pp.691-706. DOI: 10.54660/IJMRGE.2020.1.5.691-706.

[40] Anderson, S., & Newell, R. (2004). Prospects for carbon capture and storage technologies. Annual Review of Environment and Resources, 29, 109-142. https://doi.org/10.1146/annurev.energy.29.082703.145619

[41] Aneke, O.B. & Adesemoye, A.C., 2019. Toward an Integrated Conceptual Framework for Traceability and Chain-of-Custody Integrity in Pharmaceutical Distribution. Iconic Research and Engineering Journals, 3(4), pp.655-672.

[42] Aneke, O.B. & Adesemoye, A.C., 2020. A Conceptual Framework for Risk-Based Decision-Making in Good Manufacturing Practice Environments. Iconic Research and Engineering Journals, 4(6), pp.325-341.

[43] Anomohanran, O. (2012). Determination of greenhouse gas emission resulting from gas

flaring activities in Nigeria. Energy Policy, 45, 666-670.

[44] Arnold, K., & Stewart, M. (1999). Surface production operations, Volume 2: Design of gas-handling systems and facilities (2nd ed.). Gulf Professional Publishing.

[45] Arumosoye, O. M., & Obriki, O. D. (2018). Development of an integrated heat stress risk conceptual model for industrial operations in extreme environments. Iconic Research and Engineering Journals, 1(12), 141-160. https://doi.org/10.64388/IREV1I12-1714415

[46] Arumosoye, O. M., & Obriki, O. D. (2019). Systematic review of near-miss and hazard observation data utilization in industrial safety management. Iconic Research and Engineering Journals, 3(2), 981-999. https://doi.org/10.64388/IREV3I2-1714417

[47] Arumosoye, O. M., & Obriki, O. D. (2020). A governance-oriented conceptual model for contractor safety performance in multi-contract industrial projects. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 728-740. https://doi.org/10.54660/.IJMRGE.2020.1.5.728-740

[48] Askari, M., Aliofkhazraei, M., & Afroukhteh, S. (2019). A comprehensive review on internal corrosion and cracking of oil and gas pipelines. Journal of Natural Gas Science and Engineering, 71, 102971. https://doi.org/10.1016/j.jngse.2019.102971

[49] Atta, S., Asomani, E., & Adenuga, O. M. (2018). A systematic review of green corrosion inhibitors from agricultural extracts for mild steel protection in acidic and alkaline media. International Journal of Engineering and Modern Technology, 4(1), 64-97. https://doi.org/10.56201/ijemt.vol.4.no1.2018.pg64.97

[50] Atta, S., Tofah, P., Kankam, M. A., & Adenuga, O. M. (2020). A critical review of NDT-based integrity management and corrosion risk assessment strategies for refinery process equipment. International Journal of Engineering and Modern Technology, 6(2), 19-46. https://doi.org/10.56201/ijemt.vol.6.no2.2020.pg19.46

[51] Ayasse, C., & Ayasse, R. (2016). Using small-scale gas to liquids technology for flare gas mitigation. In Abu Dhabi International Petroleum Exhibition & Conference. Society of Petroleum Engineers. https://doi.org/10.2118/183161-MS

[52] Babadagli, T. (2005). Mature field development: A review. SPE Middle East Oil and Gas Show and Conference. Society of Petroleum Engineers. https://doi.org/10.2118/93884-MS

[53] Badmus, O., Dosunmu, A. A., & Ozowara, D. E. (2018). A systematic review of CI/CD pipeline strategies in Salesforce DevOps: Tools, practices, and deployment outcomes. Iconic Research and Engineering Journals, 2(6).

[54] Badmus, O., Dosunmu, A. A., & Ozowara, D. E. (2019a). A conceptual model for ETL design and data integration in Salesforce-centric enterprise architectures. Iconic Research and Engineering Journals, 3(5).

[55] Balcombe, P., Anderson, K., Speirs, J., Brandon, N., & Hawkes, A. (2017). The natural gas supply chain: The importance of methane and carbon dioxide emissions. ACS Sustainable Chemistry & Engineering, 5(1), 3-20. https://doi.org/10.1021/acssuschemeng.6b00144

[56] Beavers, J. A., & Thompson, N. G. (2006). External corrosion of oil and natural gas pipelines. In ASM handbook, Vol. 13C: Corrosion: Environments and industries (pp. 1015-1024). ASM International.

[57] Bell, C. S., Vaughn, T. L., Zimmerle, D., Herndon, S. C., Yacovitch, T. I., Heath, G. A., Petron, G., Edie, R., Field, R. A., Murphy, S. M., Robertson, A. M., & Soltis, J. (2017). Comparison of methane emission estimates from multiple measurement techniques at natural gas production pads. Elementa: Science of the Anthropocene, 5, 71. https://doi.org/10.1525/elementa.266

[58] Ben Seghier, M. E. A., Keshtegar, B., Tee, K. F., Zayed, T., Abbassi, R., & Trung, N. T. (2020). Prediction of maximum pitting corrosion depth in oil and gas pipelines. Engineering Failure Analysis, 112, Article

104505. https://doi.org/10.1016/j.engfailanal.2020.104505

[59] Bian, H., Xu, W., Li, X., & Qian, Y. (2011). A novel process for natural gas liquids recovery from oil field associated gas with liquefied natural gas cryogenic energy utilization. Chinese Journal of Chemical Engineering, 19(3), 452-461. https://doi.org/10.1016/S1004-9541(11)60006-2

[60] Boix, J. A. (1985). Emergency flare system: Some practical design features. Plant/Operations Progress. https://doi.org/10.1002/prsb.720040407

[61] Brantley, H. L., Thoma, E. D., Squier, W. C., Guven, B. B., & Lyon, D. (2014). Assessment of methane emissions from oil and gas production pads using mobile measurements. Environmental Science & Technology, 48(24), 14508-14515.

[62] Bresnen, M., Edelman, L., Newell, S., Scarbrough, H., & Swan, J. (2003). Social practices and the management of knowledge in project environments. International Journal of Project Management, 21(3), 157-166. https://doi.org/10.1016/S0263-7863(02)00090-X

[63] Campbell, J. M. (1992). Gas conditioning and processing, Volume 2: The equipment modules. Campbell Petroleum Series.

[64] Campbell, J. M. (2004). Gas conditioning and processing, volume 2: The equipment modules (8th ed.). Campbell Petroleum Series.

[65] Cao, W. (2012). Natural gas liquefaction process for small-scale LNG project. In 2012 International Conference on Computer Distributed Control and Intelligent Environmental Monitoring. IEEE. https://doi.org/10.1109/CDCIEM.2012.110

[66] Castiñeira, D., & Edgar, T. F. (2006). CFD for simulation of steam-assisted and air-assisted flare combustion systems. Energy and Fuels, 20(3), 1044-1056. https://doi.org/10.1021/ef050332v

[67] Center for Chemical Process Safety. (2007). Guidelines for risk based process safety. John Wiley & Sons.

[68] Center for Chemical Process Safety. (2008). Guidelines for hazard evaluation procedures (3rd ed.). John Wiley & Sons.

[69] Center for Chemical Process Safety. (2010). Guidelines for process safety metrics. John Wiley & Sons.

[70] Center for Chemical Process Safety. (2016). Guidelines for implementing process safety management systems (2nd ed.). John Wiley & Sons.

[71] Chebbi, R., Qasim, M., & Abdel Jabbar, N. (2019). Optimization of triethylene glycol dehydration of natural gas. Energy Reports, 5, 723-732. https://doi.org/10.1016/j.egyr.2019.06.014

[72] Cheremisinoff, N. P. (2013). Industrial gas flaring practices. Wiley. https://doi.org/10.1002/9781118671078

[73] Clayton, C. A., et al. (1998). Ubit field rejuvenation: A case history of reservoir management of a giant oil field, offshore Nigeria. SPE Annual Technical Conference and Exhibition. Society of Petroleum Engineers. https://doi.org/10.2118/49165-MS

[74] Conrad, B. M., & Johnson, M. R. (2017). Field measurements of black carbon yields from gas flaring. Environmental Science and Technology, 51(3), 1893-1900.

[75] Coyle, D., Durr, C., & Shah, P. (2003). LNG: A proven stranded gas monetization option. SPE Annual Technical Conference and Exhibition. https://doi.org/10.2118/84251-ms

[76] Dagodzo, D. & Ahiaeke Patrick, M.C., 2020. UAV-Based Pipeline and Corridor Monitoring: A Review of Current Practices and Emerging Technologies. IRE Journals, 3(10), pp.574-597. DOI: 10.64388/IREV3I10-1716084

[77] Dagodzo, D. (2018a). A conceptual framework for UAV integration into national power grid inspection programs. Iconic Research and Engineering Journals, 2(5), 391-412. https://doi.org/10.64388/IREV2I5-1716082

[78] Dagodzo, D., 2018. A Review of UAV Applications in Electrical Transmission Line Inspection: Methods, Technologies, and Challenges. IRE Journals, 2(6), pp.234-254. DOI: 10.64388/IREV2I6-1716083

[79] Dagodzo, D., 2018. Hydrothermal Alteration Interpretation of LANDSAT and ASTER Data.

Saarbrücken, Germany: Lambert Academic Publishing. ISBN: 978-3-330-02903-3.

[80] Davis, B. C. (1983). Flare efficiency studies. Plant/Operations Progress. https://doi.org/10.1002/prsb.720020316

[81] Dogbatsey, E. A., & Ebhojie, O. (2018). Budget compliance and statutory reporting in Sub-Saharan Africa: A systematic review of frameworks, gaps, and reform pathways. Zenodo. https://doi.org/10.5281/zenodo.20446859 \[Originally numbered 2(6); journal name not captured in source.\]

[82] Dogbatsey, E. A., Ebhojie, O., & Oyeleye, A. O. (2019). Reconciliation control and financial workflow redesign in emerging market organizations: A conceptual framework. Zenodo. https://doi.org/10.5281/zenodo.20447103 \[Originally numbered 3(5); journal name not captured in source.\]

[83] Dosunmu, A. A., & Ogundele, P. O. (2019). Security audit and enterprise risk assessment frameworks for resilient information systems. Iconic Research and Engineering Journals, 3(5), 434-447. https://doi.org/10.64388/IREV3I5-1713225

[84] Ejiogu, A. R. (2013). Gas flaring in Nigeria: Costs and policy. Energy and Environment, 24(6), 983-999.

[85] Elbashir, N. O. (2018). Introduction to natural gas monetization. In Natural gas processing from midstream to downstream (pp. 1-14). Wiley. https://doi.org/10.1002/9781119269618.ch1

[86] Elvidge, C. D., Baugh, K. E., Tuttle, B. T., Sutton, P., Ghosh, T., Ziskin, D., Erwin, E. H., & Zhizhin, M. (2009). A fifteen year record of global natural gas flaring derived from satellite data. Energies, 2(3), 595-622.

[87] Elvidge, C. D., Zhizhin, M., Baugh, K., Hsu, F. C., & Ghosh, T. (2016). Methods for global survey of natural gas flaring from visible infrared imaging radiometer suite data. Energies, 9(1), 14.

[88] Erayanmen, W. A. (2010). Optimizing acid gas removal from natural gas using amine mixtures. SPE Nigeria Annual International Conference and Exhibition. https://doi.org/10.2118/140746-ms

[89] Ewim, D. R. E., & Meyer, J. P. (2019). Pressure drop during condensation at low mass fluxes in smooth horizontal and inclined tubes. International Journal of Heat and Mass Transfer, 133, 686-701.

[90] Ewim, D. R. E., Adelaja, A. O., Onyiriuka, E. J., Meyer, J. P., & Huan, Z. (2020b). Modelling of heat transfer coefficients during condensation inside an enhanced inclined tube. Journal of Thermal Analysis and Calorimetry. https://doi.org/10.1007/s10973-020-09930-2

[91] Ewim, D. R. E., Mehrabi, M., & Meyer, J. P. (2020a). Modelling of heat transfer coefficients during condensation at low mass fluxes inside smooth horizontal and inclined tubes. Heat Transfer Engineering. https://doi.org/10.1080/01457632.2020.1723844

[92] Ewim, D. R. E., Meyer, J. P., & Noori Rahim Abadi, S. M. A. (2018). Condensation heat transfer coefficients in an inclined smooth tube at low mass fluxes. International Journal of Heat and Mass Transfer, 123, 455-467.

[93] Eyetsemitan, R. A., Ambali, K. B., Oyeleye, A. O., & Fadayomi, O. (2020). Multi-stakeholder governance alignment in joint venture operations: A conceptual framework for coordinating business processes in highly regulated environments. Iconic Research and Engineering Journals, 4(4), 418-441. https://doi.org/10.64388/IREV4I4-1716955

[94] Fabiano, B., & Currò, F. (2012). From a survey on accidents in the downstream oil industry to the development of a detailed near-miss reporting system. Process Safety and Environmental Protection, 90(5), 357-367. https://doi.org/10.1016/j.psep.2012.06.005

[95] Fang, W., Wu, J., Bai, Y., Zhang, L., & Reniers, G. (2019). Quantitative risk assessment of a natural gas pipeline in an underground utility tunnel. Process Safety Progress, 38(4), e12051. https://doi.org/10.1002/prs.12051

[96] Faseemo, O., Massot, J., Essien, N., Healy, W., & Owah, E. (2009). Multidisciplinary approach to optimising hydrocarbon recovery from conventional offshore Nigeria: OML100 case

study. SPE Nigeria Annual International Conference and Exhibition. Society of Petroleum Engineers. https://doi.org/10.2118/128889-MS

[97] Favre, E. (2007). Carbon dioxide recovery from post-combustion processes: Can gas permeation membranes compete with absorption? Journal of Membrane Science, 294(1-2), 50-59. https://doi.org/10.1016/j.memsci.2007.02.007

[98] Fujimatsu, K. (2009). Hybrid screw compressor suitable for offshore vapor recovery or flare gas elimination application. Offshore Technology Conference. https://doi.org/10.4043/20246-ms

[99] Gas Processors Suppliers Association. (2012). GPSA engineering data book (13th ed.). GPSA.

[100] Gbadamosi, I.T. & Obogo, S.F., 2013. Chemical Constituents and In Vitro Antimicrobial Activities of Five Botanicals Used Traditionally for the Treatment of Neonatal Jaundice in Ibadan, Nigeria. Nature and Science, 11(10), pp.130-135. Available at: http://www.sciencepub.net/nature.

[101] Griswold, J. A., & Ambler, T. C. (1978). A practical approach to crude oil stock tank vapor recovery. SPE Rocky Mountain Regional Meeting. https://doi.org/10.2118/7175-ms

[102] Gvakharia, A., Kort, E. A., Brandt, A., Peischl, J., Ryerson, T. B., Schwarz, J. P., Smith, M. L., & Sweeney, C. (2017). Methane, black carbon, and ethane emissions from natural gas flares in the Bakken Shale, North Dakota. Environmental Science & Technology, 51(9), 5317-5325.

[103] Heath, G., Warner, E., Steinberg, D., & Brandt, A. (2015). Estimating U.S. methane emissions from the natural gas supply chain: Approaches, uncertainties, current estimates, and future studies. Joint Institute for Strategic Energy Analysis.

[104] Henderson, R., & Fickes, R. (2007). Oilfield flare gas electricity systems (OFFGASES project). U.S. Department of Energy. https://doi.org/10.2172/936728

[105] Hinderaker, L., & Njaa, S. (2010). Utilization of associated petroleum gas (APG): The Norwegian experience. SPE Russian Oil and Gas Conference and Exhibition. https://doi.org/10.2118/136316-ms

[106] Howarth, R. W. (2014). A bridge to nowhere: Methane emissions and the greenhouse gas footprint of natural gas. Energy Science & Engineering, 2(2), 47-60. https://doi.org/10.1002/ese3.35

[107] Ibragimov, E. R., & Shaikhutdinov, R. N. (2000). Use of screw compressor units for flare gas recovery. Chemical and Petroleum Engineering, 36(5), 290-291. https://doi.org/10.1007/bf02463382

[108] Ilodigwe, L., & Adesemoye, A. C. (2019b). From molecules to health systems: A conceptual model explaining why scientific innovation fails to improve patient outcomes without effective healthcare delivery infrastructure. International Journal of Health and Pharmaceutical Research, 5(2), 56-79. https://doi.org/10.56201/ijhpr.vol.5.no2.2019.pg56.79

[109] Intergovernmental Panel on Climate Change. (2006). 2006 IPCC guidelines for national greenhouse gas inventories, Volume 2: Energy. IPCC.

[110] International Electrotechnical Commission. (2009). IEC 61511-1: Functional safety: Safety instrumented systems for the process industry sector. IEC.

[111] International Electrotechnical Commission. (2016). IEC 61511-1:2016, Functional safety: Safety instrumented systems for the process industry sector, Part 1. IEC.

[112] International Organization for Standardization. (2014). ISO 55000:2014, Asset management: Overview, principles and terminology. ISO.

[113] International Organization for Standardization. (2015). ISO 9001:2015 Quality management systems: Requirements. ISO.

[114] International Organization for Standardization. (2015a). ISO 14001:2015, Environmental management systems: Requirements with guidance for use. ISO.

[115] International Organization for Standardization. (2015b). ISO 15156, Petroleum, petrochemical and natural gas industries: Materials for use in H2S-containing environments in oil and gas production. ISO.

[116] International Organization for Standardization. (2016). ISO 14224:2016 Petroleum, petrochemical and natural gas industries: Collection and exchange of reliability and maintenance data for equipment. ISO.
[117] International Organization for Standardization. (2018). ISO 31000:2018, Risk management: Guidelines. ISO.
[118] Ismail, O. S., & Umukoro, G. E. (2012). Global impact of gas flaring. Energy and Power Engineering, 4(4), 290-302.
[119] Johnson, M. R., & Kostiuk, L. W. (2002). A parametric model for the efficiency of a flare in crosswind. Proceedings of the Combustion Institute, 29(2), 1943-1950.
[120] Johnson, M. R., Tyner, D. R., Conley, S., Schwietzke, S., & Zavala-Araiza, D. (2017). Comparisons of airborne measurements and inventory estimates of methane emissions in the Alberta upstream oil and gas sector. Environmental Science & Technology, 51(21), 13008-13017. https://doi.org/10.1021/acs.est.7b03525
[121] Kania, R., & Carroll, L. B. (1998). Non-destructive techniques for measurement and assessment of corrosion damage on pipelines. Proceedings of the 1998 2nd International Pipeline Conference. https://doi.org/10.1115/ipc1998-2037
[122] Kanshio, S., Agogo, H. O., & Chior, T. J. (2017). Techno-economic assessment of mini-GTL technologies for flare gas monetization in Nigeria. In SPE Nigeria Annual International Conference and Exhibition. Society of Petroleum Engineers. https://doi.org/10.2118/189120-MS
[123] Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. Risk Analysis, 1(1), 11-27.
[124] Kemp, I. C. (2007). Pinch analysis and process integration: A user guide on process integration for the efficient use of energy (2nd ed.). Butterworth-Heinemann.
[125] Kerunwa, A., Ekwueme, S. T., & Obibuike, U. J. (2020). Utilization of stranded associated flare gases for electricity generation in situ through gas-to-wire in the Niger Delta. International Journal of Oil, Gas and Coal Engineering, 8(1), 28.
[126] Khalilpour, R., & Karimi, I. A. (2009). Evaluation of LNG, CNG, GTL and NGH for monetization of stranded associated gas with the incentive of carbon credit. International Petroleum Technology Conference. https://doi.org/10.2523/iptc-14083-ms
[127] Khan, F. I., & Abbasi, S. A. (1998). Techniques and methodologies for risk analysis in chemical process industries. Journal of Loss Prevention in the Process Industries, 11(4), 261-277.
[128] Kletz, T. (2018). Hazard and operability studies (Hazop). In Hazop and Hazan. CRC Press. https://doi.org/10.1201/9780203752227-2
[129] Kohl, A. L., & Nielsen, R. B. (1997). Gas purification (5th ed.). Gulf Publishing.
[130] Komi, N. M., & Adeniji, I. O. (2020). Co-optimizing technical performance and community affordability in smart solar microgrids for underserved regions. International Journal of Engineering and Modern Technology, 6(3), 173-212. https://doi.org/10.56201/ijemt.vol.6.no3.2020.pg173.212
[131] Korppoo, A. (2018). Russian associated petroleum gas flaring limits: Interplay of formal and informal institutions. Energy Policy, 116, 232-241. https://doi.org/10.1016/j.enpol.2018.02.005
[132] Kostiuk, L. W., Johnson, M. R., & Thomas, G. P. (2004). University of Alberta flare research project: Final report. Alberta Environment.
[133] Kukadiya, K. N., & Gajendran, B. (2017). Energy efficiency and cost optimization assessments in Mangala processing terminal. SPE Oil and Gas India Conference and Exhibition. https://doi.org/10.2118/185385-ms
[134] Lade, G. E., & Rudik, I. (2020). Costs of inefficient regulation: Evidence from the Bakken. Journal of Environmental Economics and Management, 102, 102336.
[135] Lamb, B. K., Edburg, S. L., Ferrara, T. W., Howard, T., Harrison, M. R., Kolb, C. E., Townsend-Small, A., Dyck, W., Possolo, A., & Whetstone, J. R. (2015). Direct measurements show decreasing methane emissions from natural gas local distribution systems in the United States. Environmental Science & Technology, 49(8), 5161-5169.

[136] Lavoie, T. N., Shepson, P. B., Gore, C. A., Stirm, B. H., Kaeser, R., Wulle, B., Lyon, D., & Rudek, J. (2017). Assessing the methane emissions from natural gas-fired power plants and oil refineries. Environmental Science & Technology, 51(6), 3373-3381.

[137] Leahey, D. M., Preston, K., & Strosher, M. (2001). Theoretical and observational assessments of flare efficiencies. Journal of the Air and Waste Management Association, 51(12), 1610-1616.

[138] Lee, J., Antara, D. S., & Kim, J. (2013). Economic small scale LNG plant implementation with cluster LNG technology. In SPE Asia Pacific Oil and Gas Conference and Exhibition. Society of Petroleum Engineers. https://doi.org/10.2118/165752-MS

[139] Lewis, M. J., & Deddis, C. R. (2011). Application of CFD to a flare drum carryover issue. Offshore Technology Conference. https://doi.org/10.4043/21776-ms

[140] Lewis, P. E. (2013). Gas to liquids: Beyond Fischer Tropsch. In SPE Asia Pacific Oil and Gas Conference and Exhibition. Society of Petroleum Engineers. https://doi.org/10.2118/165757-MS

[141] Li, X., Chen, G., & Zhu, H. (2016). Quantitative risk analysis on leakage failure of submarine oil and gas pipelines using Bayesian network. Process Safety and Environmental Protection, 103, 163-173. https://doi.org/10.1016/j.psep.2016.06.006

[142] Liang, W., Pang, L., Zhang, L., & Hu, J. (2012). Reliability-centered maintenance study on key parts of reciprocating compressor. 2012 International Conference on Quality, Reliability, Risk, Maintenance, and Safety Engineering. https://doi.org/10.1109/icqr2mse.2012.6246265

[143] Loe, J. S. P., & Ladehaug, O. (2012). Reducing gas flaring in Russia: Gloomy outlook in times of economic insecurity. Energy Policy, 50, 507-517. https://doi.org/10.1016/j.enpol.2012.07.049

[144] Lu, Y., Greene, J., & Agrawal, M. (2009). CFD characterization of liquid carryover in gas/liquid separator with droplet coalescence due to vessel internals. SPE Annual Technical Conference and Exhibition. https://doi.org/10.2118/124205-ms

[145] Lyon, D. R., Alvarez, R. A., Zavala-Araiza, D., Brandt, A. R., Jackson, R. B., & Hamburg, S. P. (2016). Aerial surveys of elevated hydrocarbon emissions from oil and gas production sites. Environmental Science & Technology, 50(9), 4877-4886. https://doi.org/10.1021/acs.est.6b00705

[146] Mannan, S. (Ed.). (2012). Lees' loss prevention in the process industries (4th ed.). Butterworth-Heinemann.

[147] Manning, F. S., & Thompson, R. E. (1991). Oilfield processing of natural gas. PennWell Books.

[148] Marchese, A. J., Vaughn, T. L., Zimmerle, D. J., Martinez, D. M., Williams, L. L., Robinson, A. L., Mitchell, A. L., Subramanian, R., Tkacik, D. S., Roscioli, J. R., & Herndon, S. C. (2015). Methane emissions from United States natural gas gathering and processing. Environmental Science & Technology, 49(17), 10718-10727. https://doi.org/10.1021/acs.est.5b02275

[149] Martin, R. L. (2009). Control of top-of-line corrosion in a sour gas gathering pipeline with corrosion inhibitors. CORROSION 2009. https://doi.org/10.5006/c2009-09288

[150] Matveev, A. M., Zhizhin, M. N., & Poyda, A. A. (2020). Variations in gas flaring in Russia observed using multispectral nighttime remote sensing. Sovremennye Problemy Distantsionnogo Zondirovaniya Zemli iz Kosmosa, 17(6), 37-44. https://doi.org/10.21046/2070-7401-2020-17-6-37-44

[151] Mbonu, I. S., Aliliele, C., Iwuanyanwu, U., & Oluoha, O. M. (2018). A conceptual framework for legal and ethical risk modeling in enterprise data protection governance systems. Iconic Research and Engineering Journals, 2(2), 207-226. https://doi.org/10.64388/IREV2I2-1714911

[152] Mbonu, I. S., Aliliele, C., Iwuanyanwu, U., & Uzoka, E. (2020). A review of identity and access management integration strategies in hybrid and multi cloud environments. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 795-

810. https://doi.org/10.54660/.IJMRGE.2020.1.5.795-810

[153] Mbonu, I. S., Iwuanyanwu, U., Aliliele, C., & Uzoka, E. (2020a). A conceptual framework for agile supply chain digital transformation with embedded IT risk and ISO compliance controls. Iconic Research and Engineering Journals, 3(11), 566-593. https://doi.org/10.64388/IREV3I11-1714916

[154] Mbonu, I. S., Iwuanyanwu, U., Aliliele, C., & Uzoka, E. (2020b). Advances in infrastructure as code governance for secure terraform based enterprise cloud deployments. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 811-828. https://doi.org/10.54660/.IJMRGE.2020.1.5.811-828

[155] Mbonu, I.S., Aliliele, C., Uzoka, E. & Oluoha, O.M., 2019. A Review of Comparative Data Protection Regulations and Secure Cloud Implementation Strategies Across Jurisdictions. Iconic Research and Engineering Journals, 2(9), pp.482-501. DOI: 10.64388/IREV2I9-1714912.

[156] Mbonu, I.S., Iwuanyanwu, U., Uzoka, E. & Oluoha, O.M., 2019. Advances in Enterprise Log Analytics and Automated Incident Response Architectures Using Python and SIEM Platforms. Iconic Research and Engineering Journals, 3(2), pp.1000-1019. DOI: 10.64388/IREV3I2-1714915.

[157] McDaniel, M. (1983). Flare efficiency study (EPA-600/2-83-052). U.S. Environmental Protection Agency.

[158] McKain, K., Down, A., Raciti, S. M., Budney, J., Hutyra, L. R., Floerchinger, C., Herndon, S. C., Nehrkorn, T., Zahniser, M. S., Jackson, R. B., Phillips, N., & Wofsy, S. C. (2015). Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts. Proceedings of the National Academy of Sciences, 112(7), 1941-1946.

[159] Mehrotra, S., Faloona, I., Suard, M., Conley, S., & Fischer, M. L. (2017). Airborne methane emission measurements for selected oil and gas facilities across California. Environmental Science & Technology, 51(21), 12981-12987.

[160] Meyer, J. P., & Ewim, D. R. E. (2018). Heat transfer coefficients during the condensation of low mass fluxes in smooth horizontal tubes. International Journal of Multiphase Flow, 99, 485-499.

[161] Mgbame, A.C., Akpe, O.E.E., Abayomi, A.A., Ogbuefi, E. & Adeyelu, O.O., 2020. Barriers and Enablers of BI Tool Implementation in Underserved SME Communities. Iconic Research and Engineering Journals, 3(7), pp.211-226.

[162] Mitchell, A. L., Tkacik, D. S., Roscioli, J. R., Herndon, S. C., Yacovitch, T. I., Martinez, D. M., Vaughn, T. L., Williams, L. L., Sullivan, M. R., Floerchinger, C., Omara, M., Subramanian, R., Zimmerle, D., Marchese, A. J., & Robinson, A. L. (2015). Measurements of methane emissions from natural gas gathering facilities and processing plants: Measurement results. Environmental Science & Technology, 49(5), 3219-3227.

[163] Mokhatab, S., Poe, W. A., & Speight, J. G. (2006). Handbook of natural gas transmission and processing. Gulf Professional Publishing.

[164] Muharam, Y., Giffari, F., & Mahendra, M. (2018). Techno-economic feasibility of flare gas utilization using adsorbed natural gas. IOP Conference Series: Earth and Environmental Science, 105(1), Article 012022. https://doi.org/10.1088/1755-1315/105/1/012022

[165] NACE International, & International Organization for Standardization. (2015). NACE MR0175/ISO 15156: Petroleum, petrochemical and natural gas industries: Materials for use in H2S-containing environments in oil and gas production. NACE International.

[166] National Fire Protection Association. (2015). NFPA 30: Flammable and combustible liquids code. NFPA.

[167] Neagu, M., & Cursaru, D. L. (2017). Technical and economic evaluations of the triethylene glycol regeneration processes in natural gas dehydration plants. Journal of Natural Gas Science and Engineering, 37, 327-340. https://doi.org/10.1016/j.jngse.2016.11.052

[168] Nesic, S. (2007). Key issues related to modelling of internal corrosion of oil and gas

pipelines: A review. Corrosion Science, 49(12), 4308-4338.

[169] Nwafor, M. I., Uduokhai, D. O., Ifechukwu, G. O., Stephen, D., & Aransi, A. N. (2019b). Developing an analytical framework for enhancing efficiency in public infrastructure delivery systems. Iconic Research and Engineering Journals, 2(11), 657-670.

[170] Oakley, M. (2019). Flare gas monetization. In SPE Gas & Oil Technology Showcase and Conference. Society of Petroleum Engineers. https://doi.org/10.2118/198533-MS

[171] Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020b). Conceptual risk management model for heavy lifting and crane installation engineering operations. Shodhshauryam, International Scientific Refereed Research Journal, 3(4), 122-144. https://doi.org/10.32628/SHISRRJ214441

[172] Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020c). Critical review of occupational safety management systems in oil and gas maintenance projects. Shodhshauryam, International Scientific Refereed Research Journal, 3(4), 145-166. https://doi.org/10.32628/SHISRRJ214442

[173] Obogo, S. F., Uduokhai, D. O., & Ozobu, C. O. (2019). Systematic review of hazard identification and risk control practices in urban construction projects. Iconic Research and Engineering Journals, 2(12), 666-681. https://doi.org/10.64388/IREV2I12-1715496

[174] Obogo, S.F., Arumosoye, O.M. & Obriki, O.D., 2020. Advances in Internal QHSE Audit Systems for Industrial Engineering Operations. Iconic Research and Engineering Journals, 4(4), pp.399-417. DOI: 10.64388/IREV4I4-1715499

[175] Obogo, S.F., Ozobu, C.O. & Uduokhai, D.O., 2019. Advances in Leadership Driven Safety Culture Transformation in Large Construction Workforces. Iconic Research and Engineering Journals, 3(5), pp.507-523. DOI: 10.64388/IREV3I5-1715497

[176] Obogo, S.F., Ozobu, C.O. & Uduokhai, D.O., 2019. Development of a Construction Safety Risk Governance Model for Multi Contractor High Rise Projects. Iconic Research and Engineering Journals, 2(9), pp.502-522. DOI: 10.64388/IREV2I9-1715495

[177] Obriki, O. D., & Arumosoye, O. M. (2018). Conceptual modeling of data-driven occupational safety risk control in large-scale energy infrastructure projects. Iconic Research and Engineering Journals, 1(7), 169-189. https://doi.org/10.64388/IREV1I7-1714414

[178] Obriki, O. D., & Arumosoye, O. M. (2019). A conceptual framework linking management safety walkthrough frequency and coverage to safety culture outcomes in mega projects. Iconic Research and Engineering Journals, 2(8), 355-374. https://doi.org/10.64388/IREV2I8-1714416

[179] Obriki, O. D., & Arumosoye, O. M. (2020). Conceptual framework for human error causation in high-risk construction and industrial activities. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 715-727. https://doi.org/10.54660/.IJMRGE.2020.1.5.715-727

[180] Occupational Safety and Health Administration. (1992). Process safety management of highly hazardous chemicals, 29 CFR 1910.119. U.S. Department of Labor.

[181] Odejobi, O. D., & Ahmed, K. S. (2018). Statistical model for estimating daily solar radiation for renewable energy planning. IRE Journals, 2(5), 1-12.

[182] Ogbete, J. C., Aminu-Ibrahim, A. Y., & Ambali, K. B. (2019). Regulatory compliant design systems for molecular and pathology laboratories in highly controlled environments. Iconic Research and Engineering Journals, 3(4), 607-631. https://doi.org/10.64388/IREV3I4-1713589

[183] Ogbete, J. C., Aminu-Ibrahim, A. Y., & Ambali, K. B. (2020). Sustainable materials selection and energy efficiency strategies for modern medical laboratory facilities. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 674-690. https://doi.org/10.54660/IJMRGE.2020.1.5.674-690

[184] Ogbete, J.C., Aminu-Ibrahim, A.Y. & Ambali, K.B., 2018. Optimizing Laboratory Spatial

Planning Strategies to Improve Diagnostic Accuracy, Safety, and Clinical Throughput. Iconic Research and Engineering Journals, 2(1), pp.87-113. DOI: 10.64388/IREV917-1713587.

[185] Ogbuefi, E., Swoade, S., Ubanadu, B.C., Daraojimba, A.I. & Akpe, O.E.E., 2020. Advances in Role-Based Access Control for Cloud-Enabled Operational Platforms. Iconic Research and Engineering Journals, 4(2), pp.159-176.

[186] Ogunnowo, E.O., Adewoyin, M.A., Fiemotongha, J.E., Igunma, T.O. & Adeleke, A.K., 2020. Systematic Review of Non-Destructive Testing Methods for Predictive Failure Analysis in Mechanical Systems. Iconic Research and Engineering Journals, 4(4), pp.207-222.

[187] Oil and Gas Methane Partnership 2.0. (2020). Reporting framework. United Nations Environment Programme and Climate and Clean Air Coalition.

[188] Okojie, J. S., & Abioye, R. F. (2020). Reconciling chemical safety with circular-economy targets: A decision framework for post-consumer recycled polymers in consumer-goods packaging balancing REACH compliance, lifecycle GHG footprint, and regulatory risk. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 992-1006.

[189] Okojie, J. S., Filani, O. M., Ihwughwavwe, S. I., & Sakyi, J. K. (2020). Sustainable procurement practices: ESG-integrated supply chain models for corporate responsibility and environmental performance. IRE Journals, 4(2).

[190] Okonkwo, C. S., Agbabiaka, J., Ogunwole, O., Mayo, W., & Okeke, O. T. (2020). Model for demurrage elimination and port logistics efficiency in emerging economies. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 552-562. https://doi.org/10.54660/IJMRGE.2020.1.5.552-562

[191] Okonkwo, C. S., Ogunwole, O., & Okeke, O. T. (2018a). Framework for strategic procurement optimization in oil and gas operations. Iconic Research and Engineering Journals, 1(7), 153-168. https://doi.org/10.64388/IREV1I7-1713119

[192] Okonkwo, C. S., Ogunwole, O., & Okeke, O. T. (2018b). Model for inventory availability and plant uptime improvement in energy facilities. Iconic Research and Engineering Journals, 2(4), 160-172. https://doi.org/10.64388/IREV2I4-1713120

[193] Okonkwo, C. S., Ogunwole, O., Okeke, O. T., & Mayo, W. (2019). Conceptual framework for cost reduction through contract negotiation and vendor governance. Iconic Research and Engineering Journals, 2(9), 468-482. https://doi.org/10.64388/IREV2I9-1713121

[194] Okoruwa, P. O., Fadayomi, O., Akeju, B., Edivri, J., Ogbole, J. I., & Abolaji, T. O. (2020). Conceptual model for privacy-centric security engineering in digital and cloud computing systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(5), 371-389.

[195] Omara, M., Sullivan, M. R., Li, X., Subramanian, R., Robinson, A. L., & Presto, A. A. (2016). Methane emissions from conventional and unconventional natural gas production sites in the Marcellus Shale Basin. Environmental Science & Technology, 50(4), 2099-2107. https://doi.org/10.1021/acs.est.5b05503

[196] Orise, C., & Niniola, S. (2020). Data-informed digital learning platforms: A conceptual framework for evidence-based educational technology in healthcare and STEM environments. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 1078-1089. https://doi.org/10.54660/.IJMRGE.2020.1.5.1078-1089

[197] Osiki, O. M. (2018). Gas flaring and environmental issues in the Niger Delta, 1956-2007. Journal of Energy and Natural Resource Management, 1(2), 127-131. https://doi.org/10.26796/jenrm.v1i0.28

[198] Ossai, C. I. (2012). Advances in asset management techniques: An overview of corrosion mechanisms and mitigation strategies for oil and gas pipelines. ISRN

Corrosion, 2012, Article 570143. https://doi.org/10.5402/2012/570143

[199] Patrick, M.C.A., Okonkwo, C.S., Mayo, W. & Okeke, O.T., 2020. A GIS Enabled Framework for Modern ERP Procurement Processes. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), pp.499-508. DOI: 10.54660/IJMRGE.2020.1.5.499-508.

[200] Peischl, J., Karion, A., Sweeney, C., Kort, E. A., Smith, M. L., Brandt, A. R., Yeskoo, T., Aikin, K. C., Conley, S. A., Gvakharia, A., Trainer, M., Wolter, S., & Ryerson, T. B. (2016). Quantifying atmospheric methane emissions from oil and natural gas production in the Bakken Shale region of North Dakota. Journal of Geophysical Research: Atmospheres, 121(10), 6101-6111.

[201] Perrin, M., Zhu, B., Rainaud, J.-F., & Schneider, S. (2005). Knowledge-driven applications for geological modelling. Journal of Petroleum Science and Engineering, 47(1-2), 89-104. https://doi.org/10.1016/j.petrol.2005.03.001

[202] Petron, G., Karion, A., Sweeney, C., Miller, B. R., Montzka, S. A., Frost, G. J., Trainer, M., Tans, P., Andrews, A., Kofler, J., Helmig, D., Guenther, D., Dlugokencky, E., Lang, P., Newberger, T., Wolter, S., Hall, B., Novelli, P., Brewer, A., . . . Schnell, R. (2014). A new look at methane and nonmethane hydrocarbon emissions from oil and natural gas operations in the Colorado Denver-Julesburg Basin. Journal of Geophysical Research: Atmospheres, 119(11), 6836-6852.

[203] Pohl, J. H., & Soelberg, N. R. (1985). Evaluation of the efficiency of industrial flares: Test results (EPA-600/2-85-106). U.S. Environmental Protection Agency.

[204] Popli, S., Rodgers, P., & Eveloy, V. (2012). Trigeneration scheme for energy efficiency enhancement in a natural gas processing plant through turbine exhaust gas waste heat utilization. Applied Energy, 93, 624-636. https://doi.org/10.1016/j.apenergy.2011.11.038

[205] Pourmalek, M., Amanpour, S., Kuprat, M., & Schwarz, H. (2020). A review on flare gas potentials for electricity generation in Iran. 2020 7th International Conference on Renewable Energy: Generation and Applications (REEPE). https://doi.org/10.1109/reepe49198.2020.9059165

[206] Rahmanian, N., Ilias, I. B., & Nasrifar, K. (2015). Process simulation and assessment of a back-up condensate stabilization unit. Journal of Natural Gas Science and Engineering, 26, 730-736. https://doi.org/10.1016/j.jngse.2015.06.058

[207] Ramasamy, B. (2018). ADNOC gas processing experience in hydrocarbon and acid gas flare recovery utilizing liquid ring compressor and dry screw compressors. Abu Dhabi International Petroleum Exhibition and Conference. https://doi.org/10.2118/192892-ms

[208] Ravikumar, A. P., Roda-Stuart, D., Liu, R., Bradley, A., Bergerson, J., Nie, Y., Zhang, S., Bi, X., & Brandt, A. R. (2020). Repeated leak detection and repair surveys reduce methane emissions over scale of years. Environmental Research Letters, 15(3), 034029. https://doi.org/10.1088/1748-9326/ab6ae1

[209] Ravikumar, A. P., Wang, J., & Brandt, A. R. (2017). Are optical gas imaging technologies effective for methane leak detection? Environmental Science & Technology, 51(1), 718-724. https://doi.org/10.1021/acs.est.6b03906

[210] Reason, J. (1997). Managing the risks of organizational accidents. Ashgate.

[211] Remeljej, C., & Hoadley, 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

[212] Robertson, A. M., Edie, R., Field, R. A., Lyon, D., McVay, R., Omara, M., Zavala-Araiza, D., & Murphy, S. M. (2020). New Mexico Permian Basin measured well pad methane emissions are a factor of 5-9 times higher than U.S. EPA estimates. Environmental Science & Technology, 54(21), 13926-13934. https://doi.org/10.1021/acs.est.0c02927

[213] Robertson, A. M., Edie, R., Snare, D., Soltis, J., Field, R. A., Burkhart, M. D., Bell, C. S., Zimmerle, D., & Murphy, S. M. (2017).

Variation in methane emission rates from well pads in four oil and gas basins with contrasting production volumes and compositions. Environmental Science & Technology, 51(15), 8832-8840.
[214] Roscioli, J. R., Yacovitch, T. I., Floerchinger, C., Mitchell, A. L., Tkacik, D. S., Subramanian, R., Martinez, D. M., Vaughn, T. L., Williams, L. L., Zimmerle, D., Robinson, A. L., Herndon, S. C., & Marchese, A. J. (2015). Measurements of methane emissions from natural gas gathering facilities and processing plants: Measurement methods. Atmospheric Measurement Techniques, 8(5), 2017-2035. https://doi.org/10.5194/amt-8-2017-2015
[215] Sanni, J. O., Ajiga, D., & Atima, M. E. (2020a). Analytical models addressing measurement challenges of marketing return on investment in regulated services. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 636-648. https://doi.org/10.54660/IJMRGE.2020.1.5.636-648
[216] Sanni, J. O., Ajiga, D., & Atima, M. E. (2020b). Data driven brand positioning frameworks resolving differentiation challenges in regulated professional markets. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 649-660. https://doi.org/10.54660/IJMRGE.2020.1.5.649-660
[217] Sanni, J. O., Ajiga, D., & Atima, M. E. (2020c). Systematic review of product management strategies in mobile network rollouts across emerging markets. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 661-673. https://doi.org/10.54660/IJMRGE.2020.1.5.661-673
[218] Shaimardanova, G. R., & Shagieva, G. A. (2019). Efficient utilization of associated petroleum gas in Russia. Oil and Gas Business (OGBUS), 3, 237-250. https://doi.org/10.17122/ogbus-2019-3-237-250
[219] Sitorus, T., Sitaresmi, R., & Oetomo, H. (2018). Flare gas recovery system using integrated reciprocating compressor in gathering station C. Journal of Earth Energy Science, Engineering, and Technology, 1(2). https://doi.org/10.25105/jeeset.v1i2.3946
[220] Sklet, S. (2006). Safety barriers: Definition, classification, and performance. Journal of Loss Prevention in the Process Industries, 19(5), 494-506.
[221] Sonawat, A., & Samad, A. (2014). Performance analysis of an ejector for flare gas recovery. Geosystem Engineering, 17(3), 169-177. https://doi.org/10.1080/12269328.2014.957788
[222] Strizhenok, A. V., & Korelskiy, D. S. (2019). Ecological and economic justification of the utilization of associated petroleum gas at small oil fields of Russia. Journal of Physics: Conference Series, 1384, Article 012053. https://doi.org/10.1088/1742-6596/1384/1/012053
[223] Strosher, M. (1996). Investigations of flare gas emissions in Alberta. Environment Canada and Alberta Research Council.
[224] Subramanian, R., Williams, L. L., Vaughn, T. L., Zimmerle, D., Roscioli, J. R., Herndon, S. C., Yacovitch, T. I., Floerchinger, C., Tkacik, D. S., Mitchell, A. L., Sullivan, M. R., Dallmann, T. R., & Robinson, A. L. (2015). Methane emissions from natural gas compressor stations in the transmission and storage sector: Measurements and comparisons with the EPA Greenhouse Gas Reporting Program protocol. Environmental Science & Technology, 49(5), 3252-3261. https://doi.org/10.1021/es5060258
[225] Sunday, E. A., & Omoegun, G. O. (2018). Integrating solar power solutions in small-scale manufacturing industries in Nigeria. International Journal of Scientific Research in Science, Engineering and Technology, 4(8), 832-853.
[226] Sunday, E. A., Omoegun, G. O., Essien, M. A., & Oluokun, O. A. (2019). Thermodynamic efficiency and control strategies in residential air conditioning systems. International Journal of Scientific Research in Civil Engineering, 3(3), 52-76.
[227] Sunday, E. A., Omoegun, G. O., Essien, M. A., & Oluokun, O. A. (2020). Transitioning from

reactive to predictive maintenance in mechanical systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 6(6), 425-447.

[228] Tateosian, C. J., & Roland, G. K. (1983). Installation of a waste heat recovery system at a gas turbine-driven compressor station. ASME 1983 International Gas Turbine Conference and Exhibit. https://doi.org/10.1115/83-gt-157

[229] Tavakkoli, S., Lokare, O. R., Vidic, R. D., & Khanna, V. (2016). Systems-level analysis of waste heat recovery opportunities from natural gas compressor stations in the United States. ACS Sustainable Chemistry and Engineering, 4(7), 3618-3626. https://doi.org/10.1021/acssuschemeng.5b01685

[230] Thompson, P. A., Berry, C. A., Espenscheid, A. P., Cunningham, J. A., & Evans, J. M. (1993). Estimating hydrocarbon emissions from triethylene glycol dehydration of natural gas. Proceedings of the SPE/EPA Exploration and Production Environmental Conference. https://doi.org/10.2523/25952-ms

[231] Torres, V. M., Herndon, S., Kodesh, Z., & Allen, D. T. (2012). Industrial flare performance at low flow conditions. 1. Study overview. Industrial and Engineering Chemistry Research, 51(39), 12559-12568.

[232] U.S. Environmental Protection Agency. (2016). Oil and natural gas sector: Emission standards for new, reconstructed, and modified sources, 40 CFR Part 60, Subpart OOOOa. Federal Register.

[233] U.S. Environmental Protection Agency. (2016). Oil and natural gas sector: Emission standards for new, reconstructed, and modified sources. 40 CFR Part 60, Subpart OOOOa. Federal Register, 81(107), 35824-35942.

[234] U.S. Environmental Protection Agency. (2018). AP-42: Compilation of air emissions factors, Chapter 13.5, Industrial flares (5th ed.). EPA.

[235] U.S. Environmental Protection Agency. (2020). Greenhouse Gas Reporting Program: Subpart W, petroleum and natural gas systems, technical support document. U.S. EPA.

[236] Ubani, E. C., & Onyejekwe, I. M. (2013). Environmental impact analyses of gas flaring in the Niger delta region of Nigeria. American Journal of Scientific and Industrial Research, 4(2), 246-252. https://doi.org/10.5251/ajsir.2013.4.2.246.252

[237] Umukoro, G. E., & Ismail, O. S. (2017). Modelling emissions from natural gas flaring. Journal of King Saud University: Engineering Sciences, 29(2), 178-182. https://doi.org/10.1016/j.jksues.2015.08.001

[238] Upreti, K. C., Dev, A., Prasad, T. V., & Pundarikaksha, B. (2013). Safety issues with reciprocating compressor design, operating practices and maintenance. ASME Turbo Expo 2013: Turbine Technical Conference and Exposition. https://doi.org/10.1115/gt2013-94533

[239] Vaughn, T. L., Bell, C. S., Pickering, C. K., Schwietzke, S., Heath, G. A., Petron, G., Zimmerle, D. J., Schnell, R. C., & Nummedal, D. (2018). Temporal variability largely explains top-down/bottom-up difference in methane emission estimates from a natural gas production region. Proceedings of the National Academy of Sciences, 115(46), 11712-11717. https://doi.org/10.1073/pnas.1805687115

[240] Wang, X., & Song, C. (2020). Carbon capture from flue gas and the atmosphere: A perspective. Frontiers in Energy Research, 8, 560849. https://doi.org/10.3389/fenrg.2020.560849

[241] Wood, D. A., Nwaoha, C., & Towler, B. F. (2012). Gas-to-liquids (GTL): A review of an industry offering several routes for monetizing natural gas. Journal of Natural Gas Science and Engineering, 9, 196-208.

[242] World Bank Global Gas Flaring Reduction Partnership. (2004). Regulation of associated gas flaring and venting: A global overview and lessons from international experience (Report No. 3). World Bank Group.

[243] World Bank Global Gas Flaring Reduction Partnership. (2015). GTL is a commercial reality for flaring reduction: Associated gas monetization via mini-GTL (Report III). World Bank Group.

[244] World Bank Global Gas Flaring Reduction Partnership. (2019). Mini-GTL technology bulletin. World Bank Group.

[245] World Bank. (2015). Zero routine flaring by 2030 (ZRF) initiative. World Bank Group.

[246] Yang, M., & You, F. (2017). Modular methanol manufacturing from shale gas: Techno-economic and environmental analyses of conventional large-scale production versus small-scale distributed, modular processing. AIChE Journal, 64(2), 495-510. https://doi.org/10.1002/aic.15958

[247] Yazdi, M., & Kabir, S. (2017). A fuzzy Bayesian network approach for risk analysis in process industries. Process Safety and Environmental Protection, 111, 507-519. https://doi.org/10.1016/j.psep.2017.08.015

[248] Yeboah, B. K., & Ike, P. N. (2020). Programmatic strategy for renewable energy integration: Lessons from large-scale solar projects. International Journal of Multidisciplinary Research and Growth Evaluation, 1(3), 306-315. https://doi.org/10.54660/.IJMRGE.2020.1.3.306-315

[249] Younsi, K., & Smati, A. (2017). Intrinsic availability assessment of aged gas transmission pipeline using Bayesian update and stochastic process modeling. Journal of Natural Gas Science and Engineering, 45, 659-669. https://doi.org/10.1016/j.jngse.2017.06.012

[250] Yu, W., Song, S., Li, Y., Min, Y., Huang, W., Wen, K., & Gong, J. (2018). Gas supply reliability assessment of natural gas transmission pipeline systems. Energy, 162, 853-870. https://doi.org/10.1016/j.energy.2018.08.039

[251] Yuhua, D., & Datao, Y. (2005). Estimation of failure probability of oil and gas transmission pipelines by fuzzy fault tree analysis. Journal of Loss Prevention in the Process Industries, 18(2), 83-88.

[252] Zabihi, A., & Taghizadeh, M. (2016). Feasibility study on energy recovery at Sari-Akand city gate station using turboexpander. Journal of Natural Gas Science and Engineering, 35, 152-159. https://doi.org/10.1016/j.jngse.2016.08.054

[253] Zavala-Araiza, D., Alvarez, R. A., Lyon, D. R., Allen, D. T., Marchese, A. J., Zimmerle, D. J., & Hamburg, S. P. (2017). Super-emitters in natural gas infrastructure are caused by abnormal process conditions. Nature Communications, 8, 14012. https://doi.org/10.1038/ncomms14012

[254] Zavala-Araiza, D., Herndon, S. C., Roscioli, J. R., Yacovitch, T. I., Johnson, M. R., Tyner, D. R., Omara, M., & Knighton, B. (2018). Methane emissions from oil and gas production sites in Alberta, Canada. Elementa: Science of the Anthropocene, 6, 27. https://doi.org/10.1525/elementa.284

[255] Zavala-Araiza, D., Lyon, D. R., Alvarez, R. A., Davis, K. J., Harriss, R., Herndon, S. C., Karion, A., Kort, E. A., Lamb, B. K., Lan, X., Marchese, A. J., Pacala, S. W., Robinson, A. L., Shepson, P. B., Sweeney, C., Talbot, R., Townsend-Small, A., Yacovitch, T. I., Zimmerle, D. J., & Hamburg, S. P. (2015). Reconciling divergent estimates of oil and gas methane emissions. Proceedings of the National Academy of Sciences, 112(51), 15597-15602. https://doi.org/10.1073/pnas.1522126112

[256] Zhang, P., Qin, G., & Wang, Y. (2019). Risk assessment system for oil and gas pipelines laid in one ditch based on quantitative risk analysis. Energies, 12(6), 981.

[257] Zimmerle, D. J., Williams, L. L., Vaughn, T. L., Quinn, C., Subramanian, R., Duggan, G. P., Willson, B., Opsomer, J. D., Marchese, A. J., Martinez, D. M., & Robinson, A. L. (2015). Methane emissions from the natural gas transmission and storage system in the United States. Environmental Science & Technology, 49(15), 9374-9383. https://doi.org/10.1021/acs.est.5b01669

[258] Zimmerle, D., Bell, C. S., Vaughn, T. L., Roscioli, J. R., Yacovitch, T. I., & Herndon, S. C. (2017). Comparison of methane emission estimates at oil and gas facilities in the Fayetteville Shale region of Arkansas. Environmental Science & Technology, 51(16), 9127-9135.

[259] Zulhairun, A. K., Yusof, N., Salleh, W. N. W., Aziz, F., & Ismail, A. F. (2019). Advanced membrane materials for CO2 separation from

natural gas. In Membrane technology for CO2 sequestration and separation. CRC Press. https://doi.org/10.1201/b22409-6