MEROS — Methane & Emission Reduction Opportunity Study

Methodology Specification

Version 3.0 | Draft for Peer Review

2025

Field	Detail
Supersedes	MEROS Methodology Specification v2.0
Version 3.0 additions	Sections 3.21–3.23, 5.9–5.10, 14.3–14.6 (revised), 15, 16; Annexes F, G; Abbreviations updated
Status	Draft for peer review
Patent	Pending in the United Kingdom

What is new in Version 3.0

Version 3.0 extends the v2.0 specification in five directions:

- Sections 3.21–3.23: Three new terms — Weighted Energy Number (WEN), FlareCO2Scan OOS split classification, and MEROS Foundation Course.
- Section 5.9–5.10: Formalisation of FlareCO2Scan Out of Scope dual-category split (liquid phase and zero combustible content as distinct exclusion reasons).
- Section 14 (revised 14.3–14.6): Baseline and post-project state framework expanded to include stream movement arrows, visual decarbonisation ledger concept, and PFS/UFS colour-coded walk-down route documentation.
- Section 15: MEROS Foundation Course — five-module self-paced online programme with assessment framework and certification pathway.
- Section 16: MEROS Screening Suite — formal definition of MethaneScan, FlareCO2Scan, and EnergyScan (placeholder) as the three free open-source pre-work tools of the MEROS methodology.
- Annex F: EnergyScan methodology placeholder — WEN calculation framework (full specification deferred).
- Annex G: MEROS Periodic Table Register — visual specification updated with movement arrows and dual OOS island.

Foreword

The oil and gas industry spends significant resources detecting and quantifying methane and carbon dioxide emissions using satellite surveillance, aerial surveys, continuous sensor networks, and manual inspection programmes. The predominant paradigm is reactive: emissions are sought after a facility is built and operating, found through measurement, and then addressed through corrective action. This approach has produced real reductions, but it misses the most consequential intervention point — the design stage, when emission sources are created or could be prevented at minimal cost.

MEROS — the Methane and Emission Reduction Opportunity Study — is a structured, facilitated methodology that addresses this gap. It applies a systematic, guideword-based approach to identify emission sources, classify their causes, and generate remediation opportunities, anchored in the plant's engineering design basis rather than in operational measurement. Its pre-work tools derive quantitative priority intelligence from the Heat and Mass Balance, so that a multi-discipline team arrives at a MEROS workshop already knowing which systems carry the greatest emission risk.

The methodology is deliberately modelled on the Hazard and Operability Study (HAZOP) technique, drawing on the institutional familiarity, discipline, and close-out rigour that HAZOP has established over fifty years of practice.

Version 3.0 extends the framework in three significant practical directions: it introduces the MEROS Periodic Table Register as a visual decarbonisation ledger showing stream movements from high to low priority tiers as projects are executed; it formally defines the MEROS Foundation Course as the primary practitioner training pathway; and it establishes the MEROS Screening Suite as the structured family of free pre-work tools. Together these additions complete the practical infrastructure needed to deploy the MEROS methodology at scale.

1 Scope

This document specifies the MEROS methodology for the systematic identification, classification, and reduction of hydrocarbon emissions from oil and gas processing facilities. It defines the purpose, principles, pre-work requirements, workshop process, guideword set, documentation requirements, deliverables, lifecycle maintenance obligations, project portfolio development, emission reduction verification, visual baseline documentation, training programme, and screening tool suite associated with a MEROS study.

MEROS is applicable to:

- New facilities at the Front End Engineering and Design (FEED) stage, where the Heat and Mass Balance (HMB) is available and major design decisions remain open;
- Existing operational facilities undergoing a systematic emission reduction review;
- Facilities subject to a Management of Change (MoC) process where the change has the potential to create new emission sources or materially alter existing ones;
- Post-project verification of emission reductions achieved through implementation of de-carbonisation opportunities identified in a prior MEROS study.

MEROS is not applicable to:

- Facilities for which no Heat and Mass Balance or equivalent process simulation data exists;
- Non-hydrocarbon processing facilities where the release taxonomy defined in this document does not apply;
- Emergency or incident response activities.

2 Normative References

- IEC 61882:2016, Hazard and operability studies (HAZOP studies) — Application guide
- ISO 14064-1:2018, Greenhouse gases — Part 1: Specification with guidance at the organisation level
- ISO 14064-3:2019, Greenhouse gases — Part 3: Specification with guidance for verification and validation
- API RP 754:2016, Process Safety Performance Indicators for the Refining and Petrochemical Industries
- EPA 40 CFR Part 98 Subpart W: Petroleum and Natural Gas Systems (GHGRP)
- EPA AP-42: Compilation of Air Emissions Factors — Chapter 5: Petroleum Industry
- EU Regulation 2024/1787 on the reduction of methane emissions in the energy sector
- OGMP 2.0 Technical Guidance Document: Satellite, Aerial and Ground-based Detection, Carbon Mapper, 2023
- IEA Global Methane Tracker 2025, International Energy Agency
- CCAC Oil and Gas Methane Partnership 2.0 Technical Guidance: Fugitive Emissions

3 Terms and Definitions

Sections 3.1 through 3.20 are unchanged from Version 2.0. They are reproduced below in full. Sections 3.21 through 3.23 are new additions in Version 3.0.

3.1 MEROS study

A structured, facilitated, multi-discipline review of a hydrocarbon processing system, conducted using the MEROS methodology to identify emission sources, classify root causes, and generate ranked reduction opportunities.

3.2 Heat and Mass Balance (HMB)

A process engineering document, typically produced by steady-state simulation software, that specifies the thermodynamic state (temperature, pressure, vapour fraction, molar composition, and flow rate) of every process stream in a facility. The HMB constitutes the primary design-basis input to the MEROS pre-work phase.

3.3 SBEM hierarchy

The System-Based Emission Management five-level classification hierarchy. Levels are: L1 Stream, L2 Equipment, L3 System, L4 Unit, L5 Train. All MEROS analysis is conducted at L3 (System) level.

3.4 MEROS node

The unit of analysis in a MEROS study, corresponding to L3 (System) in the SBEM hierarchy. Each node is a functional grouping of equipment performing a single process duty.

3.5 Weighted Methane Number (WMN)

A dimensionless relative score quantifying the equivalent methane leak rate of a process stream through a standardised 1 mm^2 orifice, calculated using choked-flow orifice equations for gas-phase streams and the Bernoulli equation for liquid-phase streams.

3.6 Weighted Carbon Number (WCN)

A metric quantifying the CO_2 emission consequence of a process stream in two complementary dimensions: (a) Intensity — kilograms of CO_2 produced per standard cubic metre of vapour flared; and (b) Rate — tonnes of CO_2 per hour produced if the entire vapour stream is routed to flare under a blocked-discharge scenario.

3.7 Priority tier

A classification assigned to each MEROS node based on aggregated WMN and WCN scores. Four active tiers are defined: Very High (VH), High (H), Medium (M), and Low (L). Nodes may additionally be classified as Out of Scope (OOS).

3.8 Release point

A specific item of equipment, instrument, or physical connection within a MEROS node from which an emission can originate.

3.9 Release type

A classification of the emission mechanism. Seven release types: Flaring (F), Venting (V), Fugitive Emission (FE), Open Burning (OB), Engine Burning (EB), Fuel Burning (FB), and Other Release (OR).

3.10 Root cause

The underlying condition or event that causes a release to occur at a given release point. A standard taxonomy of fourteen root causes is defined in Section 7.

3.11 SCAMPERO

The structured guideword set: Substitute, Combine, Adapt, Modify, Put to other use, Eliminate, Reverse, Others.

3.12 De-carbonisation opportunity

A remediation action identified through the SCAMPERO guideword process that has the potential to reduce or eliminate an emission. Rated by Impact (High, Medium, Small) and Doability (Very Difficult, Difficult, Easy).

3.13 MEROS leader

The qualified facilitator who leads the MEROS workshop, holding relevant process engineering competence and independent of the design team.

3.14 Evergreen maintenance

The obligation to update and revalidate a MEROS study at defined intervals and in response to Management of Change events.

3.15 WCN driver classification

A sub-classification identifying whether a stream's WCN tier is driven by Rate (R) — high vapour flow under blocked discharge — or Intensity (I) — heavy hydrocarbon composition. Determines the appropriate engineering response.

3.16 Design-Basis Emission and Energy Indicators (DEEI)

The family of HMB-derived stream-level scores: WMN, WCN, and WEN. All share the same calculation philosophy: a standardised reference condition applied to every stream, producing a relative score normalised to the facility peak.

3.17 MEROS Periodic Table Register

A standardised visual representation of the MEROS priority register in which every stream is displayed as an element in a grid. Streams arranged left-to-right in decreasing priority (VH to Low), top-to-bottom by process section. Out of Scope streams displayed in a separate island below, analogous to the lanthanide series.

3.18 MEROS Verified

The independent measurement, monitoring, and verification service confirming actual emission reductions against MAC curve predictions. Constitutes verified evidence for ETS compliance, OGMP 2.0 Level 5, and voluntary carbon markets.

3.19 Marginal Abatement Cost (MAC) curve

A graphical representation of all de-carbonisation opportunities ordered by cost per tonne of CO_2e avoided, with cumulative abatement potential on the horizontal axis.

3.20 Baseline state

The documented condition of a facility's emission profile at T_0, derived from the MEROS workshop output. All subsequent post-project states are measured against the baseline to demonstrate emission reduction.

NEW IN v3.0: *Sections 3.21 through 3.23 are new additions in Version 3.0.*

3.21 Weighted Energy Number (WEN)

A metric quantifying the recoverable energy potential of a process stream in two complementary dimensions: (a) Specific — kJ/kg of recoverable thermal or pressure energy relative to a reference condition (T_ref = 15°C, P_ref = 1.01325 bar); and (b) Rate — kW of recoverable power if the stream's energy content were fully recovered through an idealised process. The WEN is the primary metric of the EnergyScan pre-work tool and determines stream-level energy recovery priority. The WEN calculation methodology is specified in Annex F. NOTE: WEN and the EnergyScan tool are introduced in this version as framework definitions. Full EnergyScan specification is deferred to Version 4.0.

3.22 FlareCO2Scan Out of Scope classification

A dual-category exclusion classification applied to streams that are out of scope for WCN assessment. Two distinct exclusion reasons are formally recognised and shall be documented separately in the MEROS Register:

- Liquid-phase exclusion (OOS-L): streams with vapour fraction ≤ 0.01 at operating conditions. Excluded on the process engineering basis that liquids do not reach the flare tip under normal operations. Represented by blue elements in the Periodic Table Register OOS island.
- Zero combustible content exclusion (OOS-NC): gas-phase or mixed-phase streams containing only N_2, CO_2, H_2S, H_2O, or other non-combustible components that produce no CO_2 upon combustion. Excluded on the chemical basis that combustion produces no additional CO_2. Represented by grey elements in the Periodic Table Register OOS island.

Both exclusion categories shall be formally documented and retained in the MEROS Register as evidence of systematic scope definition.

3.23 MEROS Foundation Course

The primary self-paced online training programme for engineers participating in or commissioning MEROS studies. The MEROS Foundation Course comprises five modules totalling approximately eleven hours of structured learning and constitutes the prerequisite for enrolment in the in-person MEROS Practitioner certification programme. The course structure and assessment requirements are specified in Section 15.

4 Principles of the MEROS Methodology

Sections 4.1 through 4.8 are unchanged from Version 2.0: Design-basis primacy (4.1), Proportionate effort (4.2), Dual-metric assessment (4.3), Systematic guideword discipline (4.4), Multi-discipline ownership (4.5), Living document obligation (4.6), Baseline documentation primacy (4.7), and Evidence chain integrity (4.8). Refer to Version 2.0 for the complete text.

NEW IN v3.0: *Section 4.9 is a new addition in Version 3.0.*

4.9 Visual communication primacy

The MEROS Periodic Table Register is not a summary of the MEROS Register — it is the primary communication artefact of the methodology for non-technical stakeholders. The periodic table format encodes priority (left-to-right position), process grouping (row assignment), and scope status (main table versus OOS island) simultaneously in a single visual that requires no legend to interpret at the tier level. This principle requires that every MEROS study produces a printed Periodic Table Register suitable for display in project offices, control rooms, and management presentations. The register shall be printed at A1 size as a standard MEROS deliverable.

The register serves a second critical function as a decarbonisation ledger: as projects are executed and streams move from higher to lower priority tiers, the Periodic Table Register is updated to show stream movement with directional arrows indicating tier of origin. The visual progression of stream elements from left to right across the tier bands, and from the main table to the OOS island, constitutes the primary visual evidence of the decarbonisation programme's effectiveness.

5 Pre-work: Priority Determination

Sections 5.1 through 5.8 are unchanged from Version 2.0. They govern pre-work purpose, the SBEM hierarchy, WMN calculation, WCN calculation, priority tier assignment, node definition, WCN driver classification, and combined DEEI score for node sequencing. Refer to Version 2.0 for the complete text of Sections 5.1–5.8.

NEW IN v3.0: *Sections 5.9 and 5.10 are new additions in Version 3.0.*

5.9 FlareCO2Scan Out of Scope dual-category assignment

Following WCN calculation, each stream shall be assessed against two sequential exclusion tests before being admitted to the in-scope WCN register:

Test 1 — Phase test: if vapour fraction ≤ 0.01 at HMB operating conditions, the stream is classified OOS-L (liquid-phase exclusion). No further WCN calculation is required. The exclusion basis shall be recorded in the MEROS Register as: "Liquid phase at operating conditions — does not reach flare tip under normal operations."

Test 2 — Combustibility test: if the stream passes Test 1 (gas or mixed phase) but the sum of molar fractions of combustible components multiplied by their respective CO_2 yield coefficients (Annex A) is less than 0.001, the stream is classified OOS-NC (zero combustible content exclusion). The exclusion basis shall be recorded as: "Zero combustible hydrocarbon content — combustion produces no CO_2 beyond that already present in the stream."

Both OOS categories shall be shown as distinct rows in the Out of Scope island of the MEROS Periodic Table Register, with different colour coding (OOS-L in blue; OOS-NC in grey), to allow immediate visual identification of the exclusion basis by engineers reviewing the register without reference to the MEROS Register itself.

NOTE: On the LNG plant validation case (EP BOD Summer, 175 streams), the OOS-L category contains 57 streams and the OOS-NC category contains zero streams, confirming that all non-liquid streams on this facility carry some combustible content. The relative proportions will vary by facility type; refineries and acid gas removal units may exhibit significant OOS-NC populations.

5.10 MethaneScan Out of Scope criteria

For MethaneScan (WMN pre-work), the Out of Scope classification applies to streams where the calculated equivalent methane leak rate is less than 0.1% of the facility peak WMN value, which in practice captures streams with zero or negligible methane mole fraction. These streams are displayed in the MethaneScan Periodic Table Register OOS island in grey. The MethaneScan OOS island represents a single exclusion category (zero methane content), in contrast to the dual-category FlareCO2Scan OOS island. The MethaneScan OOS exclusion basis shall be recorded as: "Zero or negligible methane content — equivalent CH_4 leak rate below 0.1% of facility peak WMN."

6–13 Release Taxonomy, Root Causes, Team Composition, Workshop Process, Documentation, Lifecycle, Regulatory Frameworks, Limitations

Sections 6 through 13 are unchanged from Version 2.0. They govern the release type taxonomy (Section 6), root cause taxonomy (Section 7), team composition and qualifications (Section 8), workshop process (Section 9), documentation and deliverables (Section 10), lifecycle and evergreen maintenance (Section 11), relationship to other studies and regulatory frameworks (Section 12 — including MEROS Projects Section 12.5 and MEROS Verified Section 12.6), and limitations and boundary conditions (Section 13).

NOTE: Section 10 deliverables are extended in Version 3.0 by Sections 15 (MEROS Foundation Course) and 16 (MEROS Screening Suite). The MEROS Periodic Table Register (Section 14) is substantially revised in Sections 14.3 through 14.6.

14 MEROS Periodic Table Register

Sections 14.1 and 14.2 are unchanged from Version 2.0. They govern the purpose and structure of the Periodic Table Register. Sections 14.3 through 14.6 are substantially revised in Version 3.0.

14.1 Purpose

(Unchanged from v2.0) The MEROS Periodic Table Register is a standardised visual representation of the MEROS priority register. It presents every stream in a facility as a discrete element in a structured grid, arranged to communicate priority, process grouping, and scope simultaneously without requiring the reader to interpret a ranked list or data table. The register is designed to be printed at A1 size and displayed in project offices, control rooms, and engineering team workspaces.

14.2 Structure

(Unchanged from v2.0) Main table: streams arranged in a grid with four vertical bands (VH, H, M, L, left to right) and rows corresponding to process sections (SBEM L4 Unit). OOS island below the main table, separated by a visual gap. Element boxes display stream number as the primary identifier. Tier colour coding: VH = red; H = amber; M = blue; L = green; OOS = grey or blue depending on exclusion category.

NEW IN v3.0: *Sections 14.3 through 14.6 are substantially revised or new in Version 3.0.*

14.3 Baseline, in-progress, and post-project states

The Periodic Table Register exists in three formal states, each with a distinct function in the MEROS evidence chain:

- Baseline state (T_0): The initial issue of the register, produced at the time of the MEROS workshop from the facility's design-basis HMB or as-built operational data. This is the "one visible version of truth before any decarbonisation work." It shall be labelled "BASELINE — PRE-PROJECT" and shall include the date of issue, HMB reference, and MEROS study reference. Once issued, the baseline state may only be revised through the evergreen maintenance process (Section 11) or a formal Management of Change update.
- In-progress state: Generated from updated process data as individual projects complete during the decarbonisation programme. Streams that have been addressed show their new (post-project) tier position. Streams awaiting action remain at baseline tier. Each moved stream carries a directional arrow showing its tier of origin, formatted as: [origin tier initial] → [current tier initial] (e.g., VH→M indicates a stream that has moved from Very High to Medium priority as a result of completed project work).
- Post-project state (T_1, T_2, ...): Generated after a defined programme of projects is complete, using measured post-project data validated through MEROS Verified (Section 12.6). Each post-project edition is numbered sequentially and dated. The complete series of editions from T_0 to the current state constitutes the visual decarbonisation ledger for the facility.

The directional movement of stream elements from left to right across the tier bands — from Very High toward Low and Out of Scope — is the primary visual evidence of the decarbonisation programme's effectiveness. A stream that has been permanently eliminated as an emission source (sealed, converted from gas-driven to air-driven, or otherwise fully mitigated) is moved to the OOS island, and its movement arrow shows its origin tier.

14.4 Dual OOS island structure

The Out of Scope island of the Periodic Table Register shall be structured to reflect the dual-category OOS classification defined in Section 5.9 and 5.10:

- MethaneScan register: single OOS row, grey elements, exclusion basis = zero methane content.
- FlareCO2Scan register: two OOS rows. Upper row (blue elements): liquid-phase exclusions (OOS-L). Lower row (grey elements): zero combustible content exclusions (OOS-NC). Each row shall carry a visible label stating the exclusion basis.

Streams that move from the main table to the OOS island as a result of completed projects (e.g., a stream converted from continuous gas bleed to instrument air drive, resulting in zero methane content) shall carry a movement arrow in the OOS island showing their tier of origin.

14.5 PFS and UFS cross-reference (revised)

The stream numbers displayed in the Periodic Table Register shall correspond directly to the stream numbers used in the facility's Process Flow Scheme (PFS) and Utility Flow Scheme (UFS). The PFS/UFS cross-reference workflow is:

- Step 1 — Colour-mark the PFS: Identify all Very High and High priority stream elements in the Periodic Table Register. Locate the corresponding stream numbers on the PFS drawings. Mark those piping runs, vessels, and equipment items in the corresponding tier colour (red for VH, amber for H). This creates a colour-coded PFS that defines the LDAR inspection walk-down route by priority.
- Step 2 — Exclude OOS streams: Identify all Out of Scope stream elements in the Periodic Table Register OOS island. Locate the corresponding stream numbers on the PFS and mark them as excluded from LDAR scope, with reference to the MEROS Register as the documented justification. This formally eliminates those piping runs from inspection routes.
- Step 3 — Issue the Walk-Down Route Document: The colour-coded PFS constitutes the LDAR Walk-Down Route Document. It shall be maintained under formal document control alongside the MEROS Register and updated as the Periodic Table Register evolves through its T_0, in-progress, and post-project states.

The practical value of this cross-reference is that an LDAR inspection contractor can be handed the colour-coded PFS and a copy of the current Periodic Table Register and will immediately understand: where to walk first, how often, and which areas require no methane inspection at all. No additional briefing on the MEROS methodology is required.

14.6 Document control

(Unchanged from v2.0) The Periodic Table Register shall be maintained under the same document control regime as the MEROS Register. Each edition shall carry a revision number, date of issue, and the name of the responsible MEROS leader. Revisions shall be triggered by the same events that trigger MEROS Register updates: periodic revalidation, Management of Change events, and project close-out.

15 MEROS Foundation Course

NEW IN v3.0: *Section 15 is new in Version 3.0.*

15.1 Purpose and position

The MEROS Foundation Course is the primary self-paced online training programme for engineers who will participate in, commission, or interpret MEROS studies. It is not a substitute for the in-person MEROS Practitioner or MEROS Leader certification programmes — it is the prerequisite for both. Engineers who hold a MEROS Foundation certificate have demonstrated sufficient understanding of the methodology to contribute meaningfully to a MEROS workshop as a discipline team member and to interpret MEROS Register outputs without facilitation support.

The course is designed to be delivered on a self-paced online learning platform, either through the MEROS methodology's own platform or through an institutional partner such as IChemE. Completion requires passing a multiple-choice assessment at the end of each module (four out of five questions, unlimited attempts). A certificate of completion is issued upon passing all five module assessments.

15.2 Course structure

The MEROS Foundation Course comprises five modules totalling approximately eleven hours:

Module	Title	Duration	Primary content
1	The Design-Basis Case	~3 hours	The reactive LDAR problem; MethaneScan and FlareCO2Scan approach; WMN and WCN explained; reading a priority register; Out of Scope classification and cost implications; worked example on a 175-stream LNG plant HMB.
2	System Mapping and Node Definition	~2 hours	The SBEM hierarchy (L1–L5); mapping an HMB to MEROS nodes; node boundary rules; P&ID alignment; worked examples from gas processing, LNG, and refinery facility types.
3	Emission Classification	~2 hours	The seven release types (F, V, FE, OB, EB, FB, OR) with worked examples; the fourteen root causes and how they drive different remediation pathways; systematic release point identification; Avoidable vs Unavoidable classification.
4	SCAMPERO Guideword Discipline	~2 hours	Each of the eight guidewords with directing questions and worked examples; anchoring avoidance; facilitation techniques for multi-discipline teams; Impact and Doability rating framework.
5	From Register to Action	~2 hours	Reading and interpreting the MEROS register; action register and management summary; FEED timing and HAZOP relationship; evergreen maintenance obligations; Management of Change triggers; EU Methane Regulation, OGMP 2.0, EPA OOOOa-c, and UK North Sea Transition Deal regulatory alignment.

15.3 Module learning deliverables

Each module produces a downloadable practical deliverable that participants can apply immediately in their workplace:

- Module 1: MethaneScan/FlareCO2Scan priority register interpretation checklist
- Module 2: Node definition template with worked example
- Module 3: Release point identification checklist and root cause prompt card
- Module 4: SCAMPERO facilitation guide with directing questions for each guideword
- Module 5: Action register template and management summary one-pager template

15.4 Assessment

Each module concludes with a five-question multiple-choice assessment drawn from a bank of fifteen questions per module (to prevent rote memorisation on repeat attempts). Pass mark: four out of five correct. Unlimited attempts permitted. Assessments are open-book. The goal is reinforcement of key concepts, not gatekeeping.

A MEROS Foundation certificate of completion is issued upon passing all five module assessments. The certificate displays the candidate's name, completion date, and the MEROS Foundation Course version number. The certificate does not confer the right to lead or independently conduct a MEROS study — that requires MEROS Practitioner or MEROS Leader certification.

15.5 Certification pathway

The MEROS Foundation Course is the entry point of a three-level certification pathway:

Level	Programme	Format	Prerequisite	Certificate
Foundation	MEROS Foundation Course (this section)	Self-paced online, 11 hours	None	Certificate of completion — required for Practitioner enrolment
Practitioner	MEROS Practitioner Course	In-person, 2 days, max 12 participants, workshop simulation	MEROS Foundation certificate	MEROS Practitioner — authorises participation as team member
Leader	MEROS Leader Course + assessment	In-person, 3 days + practical assessment, max 8 participants	MEROS Practitioner certificate + 5 years process engineering experience	MEROS Leader — authorises independent facilitation of MEROS workshops

16 MEROS Screening Suite

NEW IN v3.0: *Section 16 is new in Version 3.0.*

16.1 Definition and purpose

The MEROS Screening Suite is the structured family of free, open-source, HMB-based pre-work screening tools that constitute the entry layer of the MEROS methodology. Each tool converts a plant's Heat and Mass Balance into a quantitative priority register for one dimension of emission or energy risk. All tools in the Suite share the same design philosophy: a standardised reference condition applied uniformly to every stream, producing a relative score normalised to the facility peak, assigned to a tier by percentage threshold. This consistency enables direct comparison of risk profiles across dimensions on the same facility, and comparison of the same dimension across different facilities.

All tools in the MEROS Screening Suite are published as open-source software under the MIT Licence. They are freely available for use by the global engineering community without restriction. The tools run entirely within a web browser — no server-side processing, no data transmission, and no cost. The Heat and Mass Balance is processed locally and permanently scrambled from browser memory after report generation.

16.2 Suite members

Tool	Metric	What it measures	OOS definition	Status
MethaneScan	WMN — Weighted Methane Number	Equivalent CH_4 leak rate (g/s) through a standardised 1 mm² orifice. Ranks streams by fugitive methane potential from design-basis stream conditions.	Zero methane content (CH_4 mole fraction zero or negligible) — single exclusion category	Available — v1.0
FlareCO2Scan	WCN — Weighted Carbon Number (Intensity and Rate)	kg CO_2/Sm³ of vapour flared (Intensity) and t CO_2/hr under blocked-discharge (Rate). Ranks streams by flaring CO_2 consequence from design-basis stream conditions.	Dual-category: OOS-L (liquid phase) and OOS-NC (zero combustible content) — see Section 5.9	Available — v1.0
EnergyScan	WEN — Weighted Energy Number (Specific and Rate)	kJ/kg recoverable thermal or pressure energy (Specific) and kW of recoverable power (Rate). Ranks streams by energy recovery potential from design-basis stream conditions.	Streams at ambient temperature and near-atmospheric pressure with WEN below 0.1% of facility peak	Specification deferred — see Annex F

16.3 Data collection and telemetry

Each tool in the MEROS Screening Suite collects the following anonymised usage data at the time of analysis, subject to explicit user consent via a three-statement consent form presented before use:

- Contact details: name, work email, company, position, telephone, country.

- Analysis statistics: total streams analysed, count of streams in each priority tier (VH, H, M, L), count of Out of Scope streams (by category for FlareCO2Scan).
- Timestamp and tool version.

The following data is explicitly NOT collected: stream numbers, descriptions, or process data; pressure, temperature, or composition values; calculated WMN, WCN, or WEN values; the HMB file itself; plant name, location, or project identifiers. The HMB is processed entirely in the user's browser and permanently overwritten with random data after report generation.

Collected data is used to compile anonymised, aggregated industry statistics on the scale of the methane prioritisation and flaring CO_2 problem across facility types and geographies. These statistics are published periodically by the MEROS methodology team to demonstrate industry impact and inform the methodology's ongoing development.

16.4 Integration with the MEROS workshop

MEROS Screening Suite outputs feed directly into the MEROS workshop pre-work phase (Section 5). The MethaneScan priority register constitutes the WMN pre-work input. The FlareCO2Scan priority register constitutes the WCN pre-work input. Where EnergyScan outputs are available, they constitute the WEN pre-work input for the DEEI combined scoring. The three registers together, when available, constitute the complete DEEI family input to the MEROS workshop node sequencing calculation (Section 5.8).

Annex A — Component Combustion Stoichiometry

(Unchanged from v1.0) Provides the number of moles of CO_2 produced per mole of each HMB component under complete combustion conditions. Used in WCN Intensity calculation. Refer to Version 1.0 for the complete table.

Annex B — Glossary of Abbreviations

> **NEW IN v3.0:** *The following abbreviations are added in Version 3.0. Refer to Version 2.0 for the complete v2.0 glossary.*

Abbreviation	Expansion	Version
EnergyScan	Energy Scan — WEN pre-work tool of the MEROS Screening Suite	3.0 NEW
MEROS Foundation	MEROS Foundation Course — five-module self-paced online training programme	3.0 NEW
MEROS Screening Suite	The structured family of free, open-source HMB-based pre-work tools (MethaneScan, FlareCO2Scan, EnergyScan)	3.0 NEW
OOS-L	Out of Scope — Liquid phase exclusion (FlareCO2Scan)	3.0 NEW
OOS-NC	Out of Scope — No combustible content exclusion (FlareCO2Scan)	3.0 NEW
WEN	Weighted Energy Number — HMB-derived energy recovery potential metric	3.0 NEW
Walk-Down Route Document	Colour-coded PFS/UFS marked up using the Periodic Table Register cross-reference, defining LDAR inspection priority routes	3.0 NEW

Annex C — MEROS Node Record Template

(Unchanged from v1.0) Refer to Version 1.0 for the complete template.

Annex D — MEROS Projects Methodology

(Unchanged from v2.0) Refer to Version 2.0 for the complete text.

Annex E — MEROS Verified Framework

(Unchanged from v2.0) Refer to Version 2.0 for the complete text.

Annex F — EnergyScan Methodology (Placeholder)

> **NEW IN v3.0:** *Annex F is new in Version 3.0 as a methodology placeholder. Full specification in Version 4.0.*

EnergyScan is the third member of the MEROS Screening Suite. It extends the WMN and WCN pre-work framework to the energy recovery dimension, identifying streams with significant recoverable thermal or pressure energy potential from HMB data alone.

The WEN calculation framework addresses three types of energy opportunity derivable from a single HMB:

- Type 1 — Thermal energy recovery: sensible heat content of hot streams above T_ref = 15°C, and cold/cryogenic stream refrigeration loads below T_ref. The pairing of hot sources with cold sinks constitutes the heat integration screening function, analogous to Pinch Analysis but executable from a single-case HMB without specialist software.
- Type 2 — Pressure energy recovery: isentropic expansion work available from gas-phase streams at elevated pressure, and hydraulic turbine power from liquid-phase streams at pressure. Calculated using established orifice flow and turbine equations with standardised efficiency assumptions (η_expander = 0.78, η_hydraulic = 0.82).
- Type 3 — Compression and refrigeration efficiency: gap between actual and theoretical minimum compression or refrigeration work, identifiable from HMB inlet/outlet stream pairs at compressor and refrigeration system boundaries.

Validated on the EP BOD Summer LNG plant HMB (175 streams): total hot stream thermal content 944 MW, total cold/cryogenic load 60 MW, peak pressure recovery potential 61 MW (sour gas inlet at 70 bar). Full WEN calculation specification, tier thresholds, and OOS criteria are deferred to Version 4.0.

Annex G — MEROS Periodic Table Register Visual Specification

NEW IN v3.0: *Annex G is new in Version 3.0.*

The MEROS Periodic Table Register shall be produced to the following visual specification for print and digital distribution:

- Format: A1 landscape (841 × 594 mm), minimum resolution 150 DPI for print output.
- Grid structure: five columns (section label, VH band, H band, M band, L band) and one row per active process section. OOS island below the main grid, separated by a visible gap.
- Element boxes: stream number displayed as the primary identifier in bold monospace font, legible at A1 print scale. Phase (G/L/M) and operating pressure shown in small text within each element.
- Movement arrows (in-progress and post-project editions): streams that have moved tier since T_0 carry a directional badge in the format "[origin tier]→[current tier]" (e.g., VH→L). Streams newly moved to OOS island carry a badge showing tier of origin.
- FlareCO2Scan elements: carry a driver badge (R or I) in the top-right corner of each element, distinguishing Rate-driven streams (orange badge) from Intensity-driven streams (blue badge).
- Colour coding: VH = red (#B91C1C tones); H = amber (#92400E tones); M = blue (#1E40AF tones); L = green (#14532D tones); OOS-L = blue (#1E40AF tones, lighter); OOS-NC = grey (#374151 tones); backgrounds and borders use the same hue family at reduced saturation.
- Labelling: "BASELINE — PRE-PROJECT" for T_0 editions; "IN PROGRESS — [date]" for intermediate editions; "POST-PROJECT — T[n] [date]" for verified post-project editions.

Acknowledgements

The MEROS methodology was developed through applied research in hydrocarbon processing design and the systematic analysis of methane and flaring CO_2 emission sources across oil and gas facility types. The authors acknowledge the foundational contribution of the HAZOP methodology (IEC 61882) as the structural model from which MEROS's workshop discipline, guideword approach, and action close-out process are derived.

The pre-work tools MethaneScan and FlareCO2Scan are published as open-source software under the MIT Licence and are freely available for use by the global engineering community. Both tools have been validated against a real 175-stream LNG plant Heat and Mass Balance (EP BOD Summer case, Appendix 4C), confirming that the methodology produces consistent and physically meaningful priority rankings across a full facility stream population.

The MEROS Periodic Table Register visual format, introduced in Version 2.0 and extended in Version 3.0, draws structural inspiration from the periodic table of elements as a canonical example of a visual communication system that encodes priority, grouping, categorical information, and change over time simultaneously. The use of this format for emission priority communication, including the decarbonisation ledger concept of tracking stream movement across tier bands as projects are executed, is original to the MEROS methodology.

The authors invite peer review, commentary, and challenge from the academic, standards, and practitioner communities. All feedback received will be considered in the preparation of subsequent revisions.

— End of Document —

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