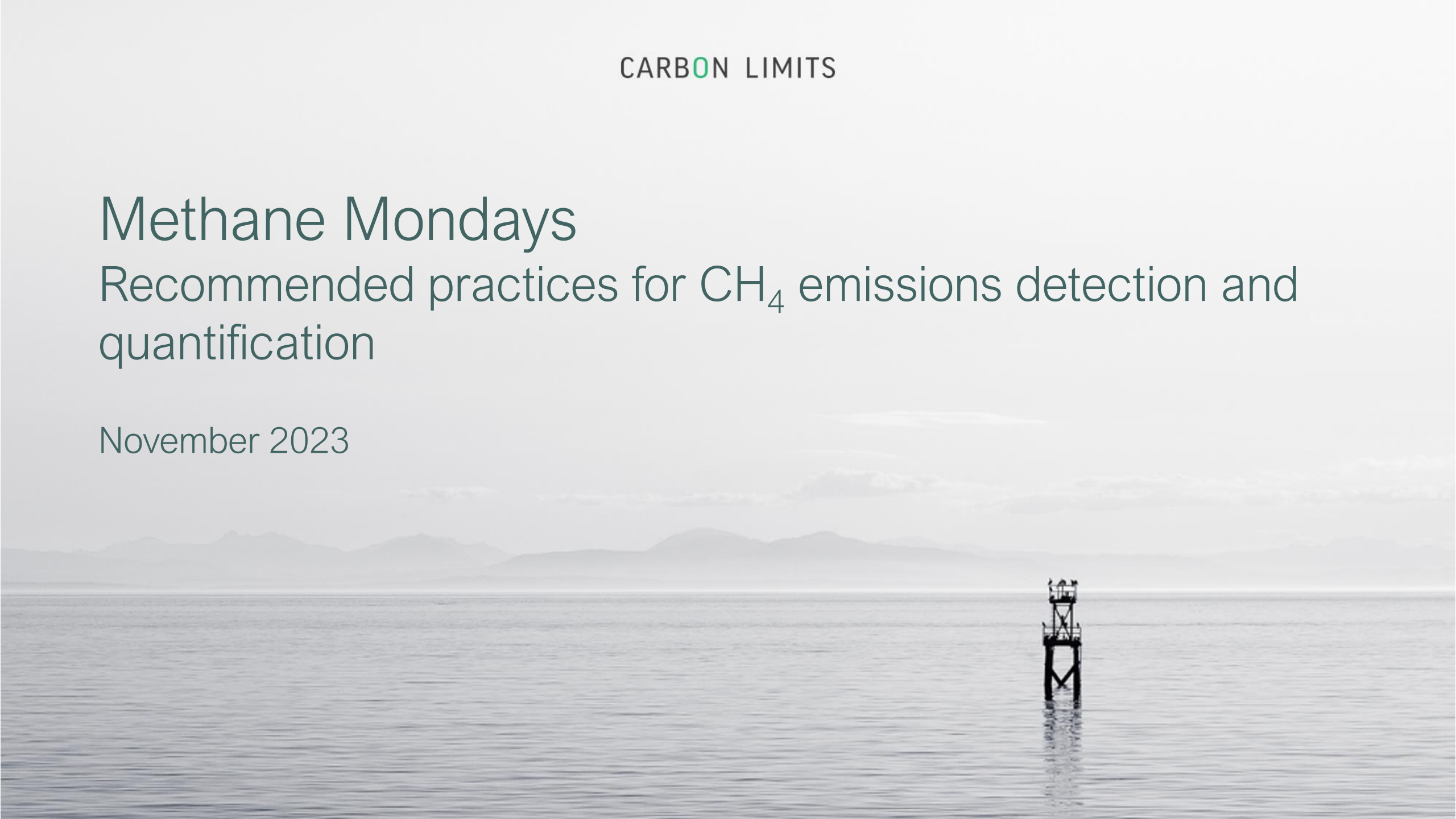
CARBON LIMITS

Methane Mondays

Recommended practices for CH_4 emissions detection and quantification

November 2023



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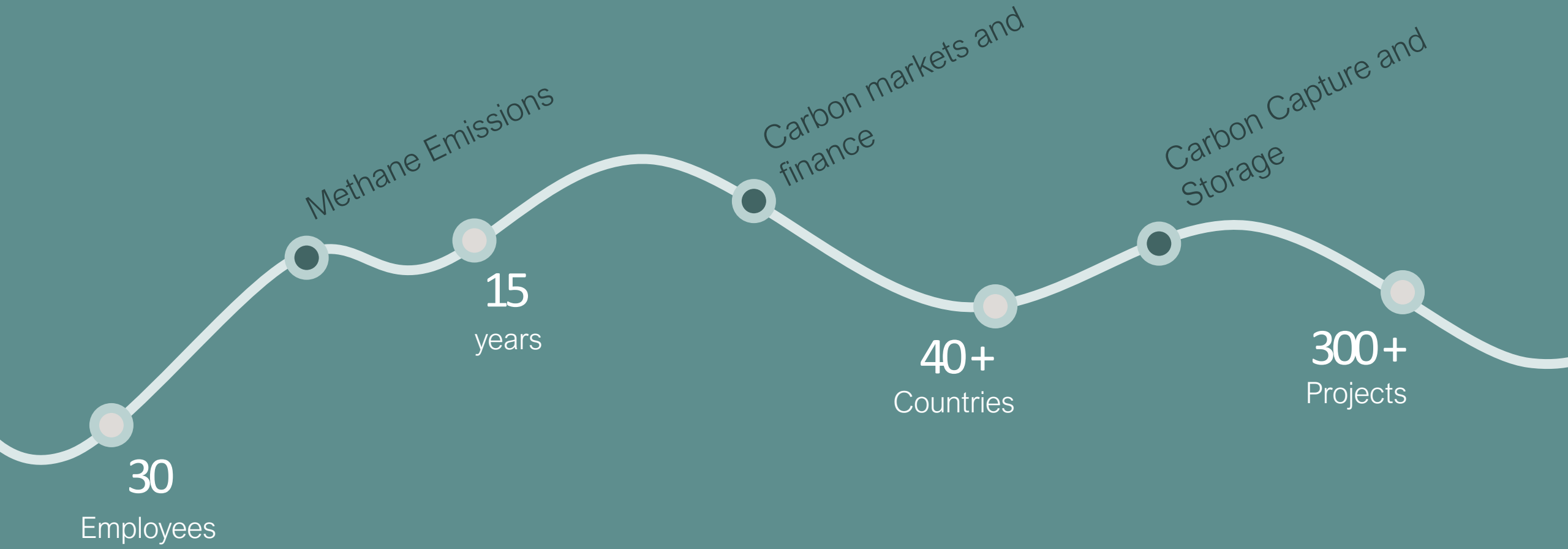
Meeting people where they are on their climate journey



WORLD BANK GROUP · AKER CARBON CAPTURE · UN environment programme · Northern Lights · TotalEnergies · European Commission · European Bank for Reconstruction and Development · GASSNOVA · Norwegian Ministry of Petroleum and Energy · GMP Oil And Gas Methane Partnership 2.0

Agenda

1. OGCI, IOGP and Ipieca Recommended Practices Overview
2. Recommended Practices Structure
3. Decision Trees
4. Technology Datasheets
5. Technology Filtering Tool
6. Conclusions and Summary
7. Case Study

Recommended Practices Document - Objectives

Provides the user with a framework for:

- Provides criteria that operators can consider in selecting technology
- Guidance on technology deployment
- Combinations of measurement, detection, and quantification technologies
- Facilitate improved methane management and emissions reporting.

https://www.iogp.org/bookstore/product/recommended-practices-for-methane-emissions-detection-and-quantification-technologies-upstream/
https://www.ipieca.org/resources/methane-detection-quantification-technologies-upstream

Recommended Practices Document - Project Structure

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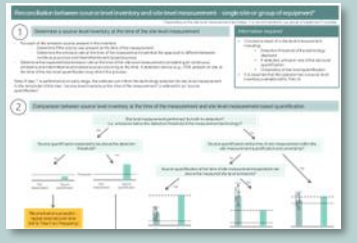
- Carbon Limits Analysis
- Technology Providers
- Industry/Researcher Input
- Project Task Force
- Scientific Publications

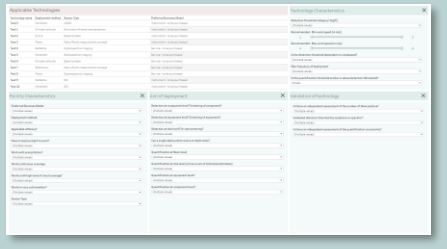
Decision trees

Allow the users to navigate the different objectives and situations Help them narrow down the purpose of technology deployment



Technologies database

Operators can narrow down suitable technologies for their purpose and given their site conditions

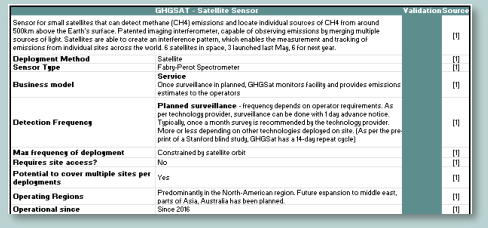


Technologies Datasheets

Factsheet for each technology to provide more details on the technology and validation of results for the operator's reference

Technologies

51



GHGSAT - Satellite Sensor		Validation Source
Sensor for small satellites that can detect methane (CH4) emissions and locate individual sources of CH4 from around 500km above the Earth's surface. Patented imaging interferometer, capable of observing emissions by merging multiple sources of light. Satellites are able to create an interference pattern, which enables the measurement and tracking of emissions from individual sites across the world. 6 satellites in space, 3 launched last May, 6 for next year.		
Deployment Method	Satellite	[1]
Sensor Type	Fabry-Perot Spectrometer	[1]
Business model	**Service** Once surveillance in planned, GHGSat monitors facility and provides emissions estimates to the operators	[1]
Detection Frequency	**Planned surveillance** - frequency depends on operator requirements. As per technology provider, surveillance can be done with 1 day advance notice. Typically, once a month survey is recommended by the technology provider. More or less depending on other technologies deployed on site. (As per the pre-print of a Stanford blind study, GHGSat has a 14-day repeat cycle)	[1]
Max frequency of deployment	Constrained by satellite orbit	[1]
Requires site access?	No	[1]
Potential to cover multiple sites per deployments	Yes	[1]
Operating Regions	Predominantly in the North-American region. Future expansion to middle east, parts of Asia, Australia has been planned.	[1]
Operational since	Since 2016	[1]

Recommendations for operators

Decision trees

How can technologies be deployed to meet the objectives?

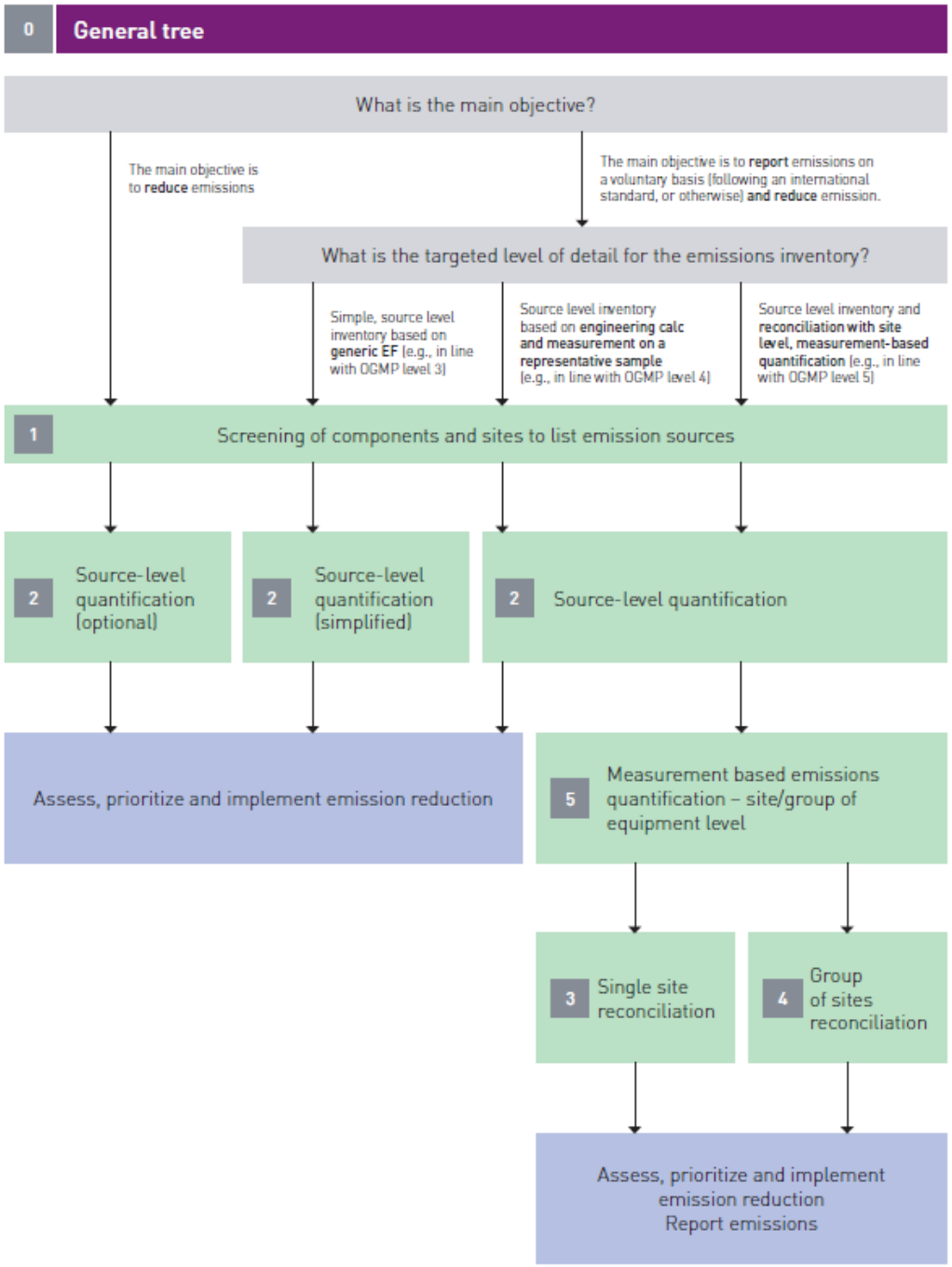
Main objectives

- Reduce emissions
- Report and reduce emissions

Practical approach through a series of guided questions – narrow down situation and purpose

Network of trees

1. Overview
2. Site and source screening
3. Source quantification
4. Site quantification
5. Single site reconciliation
6. Group of sites reconciliation



Technology Datasheets

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Structured compilation of data

- General Information
- Tech. Specifications
- Environmental Conditions
- Location Conditions
- Deployment Information
- Links to Additional information

GHGSAT - Satellite Sensor		Validation	Source
Sensor for small satellites that can detect CH_4 emissions and locate individual sources of CH_4 from around 500 km above the Earth's surface. Patented imaging interferometer, capable of observing emissions by merging multiple sources of light. Satellites can create an interference pattern, which enables the measurement and tracking of emissions from individual sites across the world. 6 satellites in space, 3 launched last May, 6 for next year.			[3]
Deployment Method	Satellite		[3]
Sensor Classification and Type	Visual Product, Remote sensor type Fabry-Perot Spectrometer		[3]
Business model *(Instrument or data to be purchased?)*	Data Product – Once surveillance in planned, GHGSat monitors facility and provides emissions estimates to the operators.		[3]
Frequency – *for technology deployment*	Periodic Monitoring Planned surveillance: frequency depends on operator requirements. As per technology provider, surveillance can be done with 1-day advance notice. Typically, once a month survey is recommended by the technology provider: more or less depending on other technologies deployed on site. As per Sherwin et al (2022) [pre-print], GHGSat has a 14-day repeat cycle.		[3]
Sampling frequency during operation	1 image per visit. Revisit time is 14 days for a single satellite, or 1 to 7 days when considering the satellite constellation.		[1] [5]
Requires access to site?	No		[3]
Potential to cover multiple sites per deployments	Yes		[3]
Operating Regions	Worldwide		[3]
Operational since	>5 years (2016)		[3]
Detection			
Detection Level	At Site level – Yes At equipment level - No At component level – No An independent test performed stated that GHGSat can narrow down key zones of emissions, with no individual source identification		[2], [3]

Kuva Systems – Kuva camera		Validation	Source
Kuva Systems provides a camera based, stationary, continuous monitoring system for methane (can alse be tuned for other VOC emissions). It includes a cloud platform that provides emissions data and image-based alerts via web portal, email or API.			[3]
Deployment Method	Stationary		[3]
Sensor Classification and Type	Visual Product, Remote sensor type Shortwave infrared (SWIR)		[3]
Business model *(Instrument or data to be purchased?)*	Instrument can be purchased or rented Data Product – cloud monitoring services are offered		[5]
Frequency – *for technology deployment*	Continuous monitoring Technology measures during daylight hours. Currently testing a system for day and night-operation (under development).		[5]
Sampling frequency during operation	Not specified		[5]
Requires access to site?	Yes		[5]
Potential to cover multiple sites per deployments	No		[5]
Operating Regions	North America as of November 2022, deployments planned in other continents		[3]
Operational since	>5 years (founded in 2015)		[5]
Detection			
Detection Level	At Site level – Yes At equipment level – Yes At component level – Maybe		[3] [5]
Detection Threshold / Precision	1-10 kg/h In field conditions (METEC ADED testing), lower under lab conditions		[3]
Detection Threshold validation	Validated by fully blinded tests performed with third party By METEC, ADED, Alt-FEMP approved	(b), (d)	[1], [2], [3]

Technology Datasheet Development

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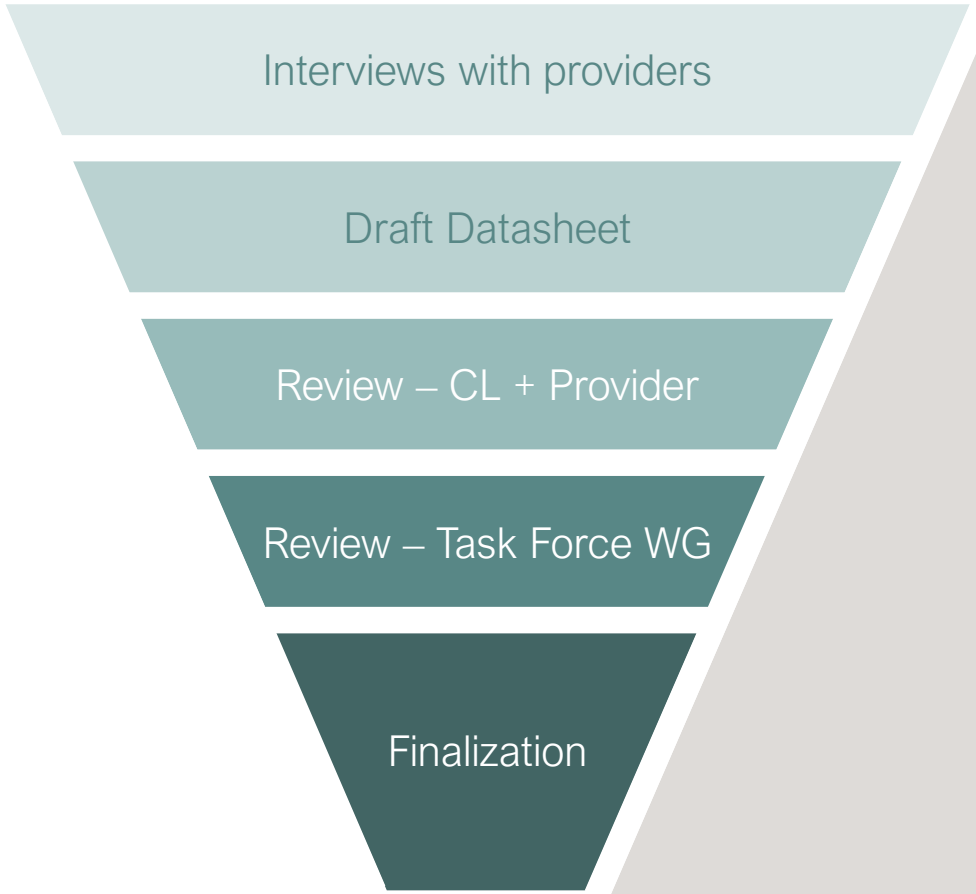

Integrate feedback from various stakeholders:

- Technology Providers
- Independent research
- & academic literature
- Industry Feedback

Link to Technology Filtering Tool

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Methane detection and quantification technology filtering tool

This database has been developed for oil and gas operators looking to deploy methane detection and quantification technologies at their facilities. The choice of technology depends largely on the area's characteristics, aim of deployment, and operator preferences, matched against technology specifications.

The list of applicable technologies was developed using research from academia, independent third-party assessments, and interviews with technology providers.

To see the list of eligible technologies based on the selected preference, scroll to the end of the page.

Please note that this list is not exhaustive and will be periodically updated and expanded.

Preliminary Preferences → Area Characteristics → Aim of Deployment → Technology Characteristics → Technology Validation

https://www.iogp.org/workstreams/environment/environment/methane-emissions-detection-and-quantification/methane-detection-and-quantification-technology-filtering-tool/tool/

Key Points

- Criteria for technology selection presented in the online database and Technology Data Sheets
  - Operator Preferences
  - Area Characteristics
  - Aim of Deployment
  - Technology Characteristics and Validation
- Decision trees and “Forest” explanations
  - General Tree
  - Site screening
  - Source & site level measurements
  - Reconciliation (single and group of sites)
- 6 case studies of combining technologies from:
  - Operators
  - Peer reviewed papers
- Other recommendations and overarching elements
  - Uncertainty
  - Data management and security
  - Internal practices, standards
  - Interpretation of test results

Report

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International Association of Oil & Gas Producers | ipieca | OGCI | REPORT 661 | SEPTEMBER 2023

Recommended practices for methane emissions detection and quantification technologies – upstream

Recommended Practices – Next steps

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Keeping Recommended Practices «Evergreen»

Flare Technologies

Decision Trees to reflect new Voluntary Initiatives (e.g., GTI Veritas Protocols)

Datasheet Updates as technologies and availability evolves

Project Scope

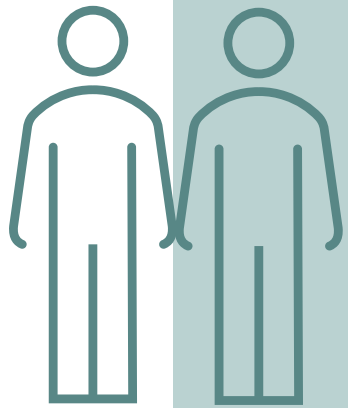
OIL AND GAS CLIMATE INITIATIVE

International Association of Oil & Gas Producers

ipieca

energy institute

Recommended Practices for CH_4 emissions detection and quantification technologies



Recommended Practices for CH_4 emissions detection and quantification technologies – flare efficiency

- Technologies for the measurement of flaring destruction/combustion efficiencies are not covered as part of the existing recommended practices for methane emissions detection and quantification

- Build on recommended practices to include flare technologies
- Ensure stakeholders are adequately informed of techniques and technologies to measure and quantify methane emissions
- Project is currently ongoing
- Expected to be made publicly available in Oct/Nov 2023

Recommended Practices for flares

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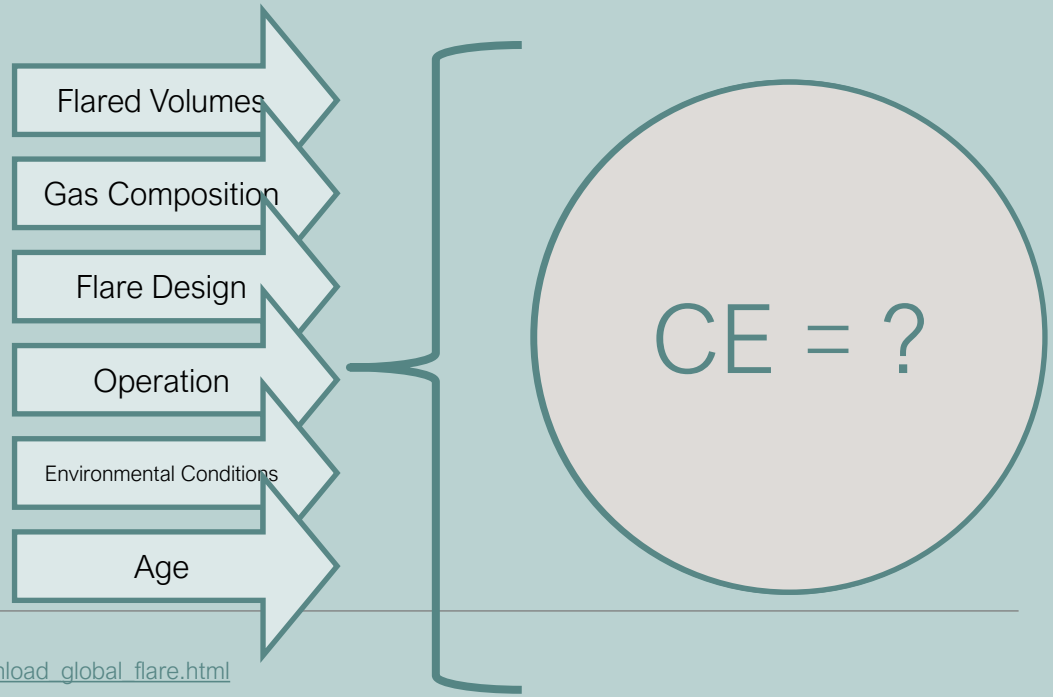
Background

- Flaring: burning undesirable or surplus gas in an open-atmosphere flame
- Flaring converts flared gases (including methane) into carbon dioxide.
- GWP of CH_4 82.5/29.8 times greater than CO_2 over a 20/100 year period
- 152 billion m^3 of gas was flared in 2020
- Motivation for initiatives such as ZRF program



Colorado School of Mines. Global Gas Flaring Observed from Space: https://eogdata.mines.edu/download_global_flare.html

Techniques and applicability for Flare CE/DRE measurement

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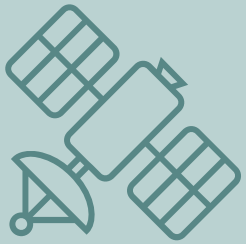
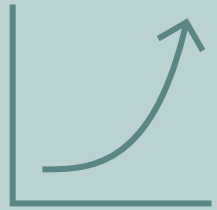


Satellites

Aircraft

Drones

Fixed Sensors



Numerical Models

Predictive Measurements

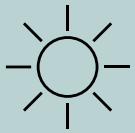
Technology Datasheets

Key elements – examples

CARBON LIMITS

General Information

Tech. Specifications specific to flares



Environmental Conditions

Location Conditions

Deployment Information

Links to Additional information

Report

CARBON LIMITS

Introduction	• Background on Flaring
Technology Review	• Technology to measure flare emissions • Overview of past and current research
Documentation	• Datasheet and Database Instructions • Documentation for Technology Filtering Tool
Analysis	• Availability of technologies

Use of Datasheets in Decision Trees

Key elements – examples

Use of datasheets with Decision Trees part of initial OGCI, IOGP and Ipieca project Scope

- Emission Source Screening
- Either as part of source level quantification
- Follow-up after reconciliation
- Continuous improvement of emission inventory

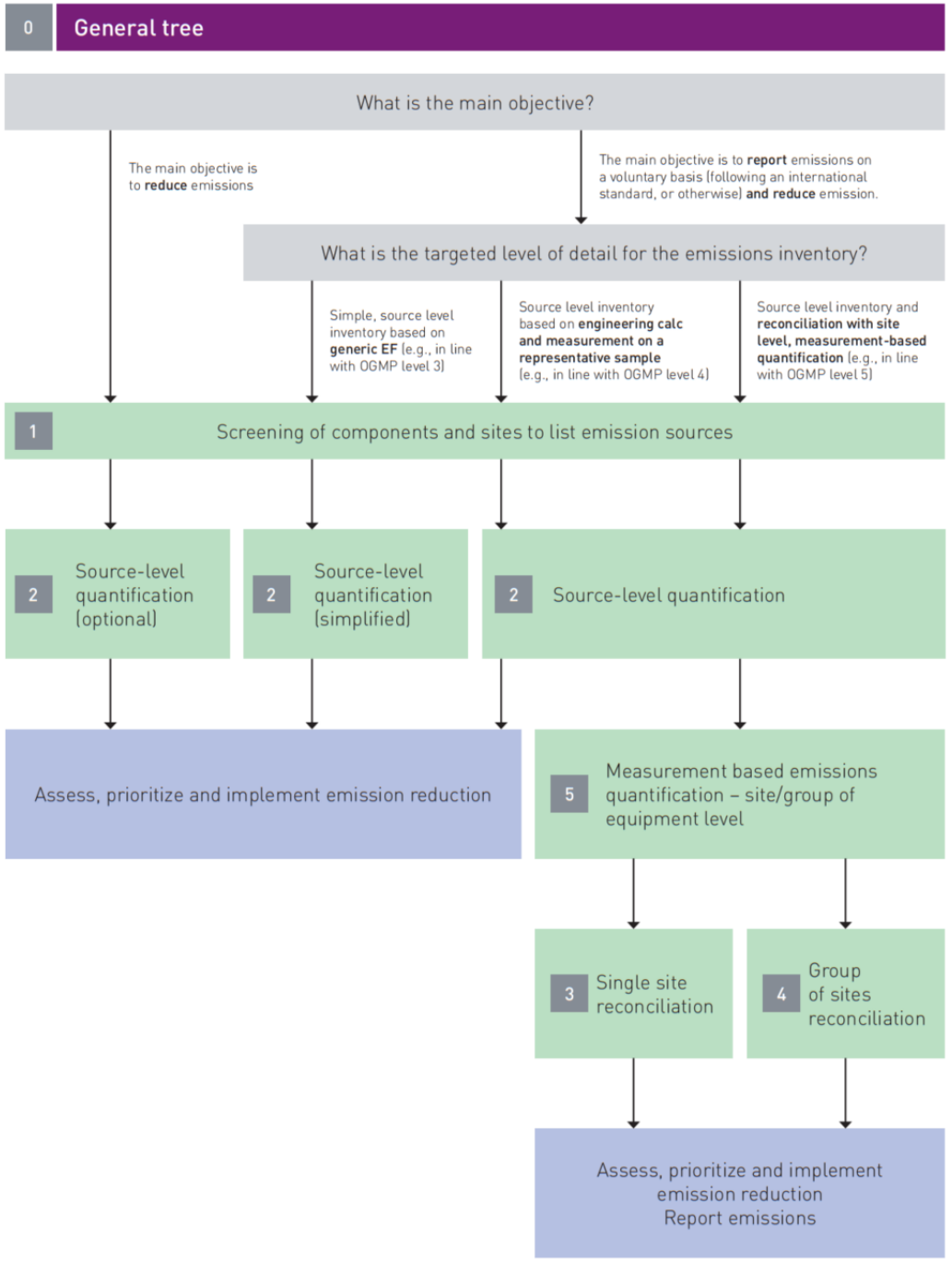


Figure 6: General tree

Recommended Practices for flares

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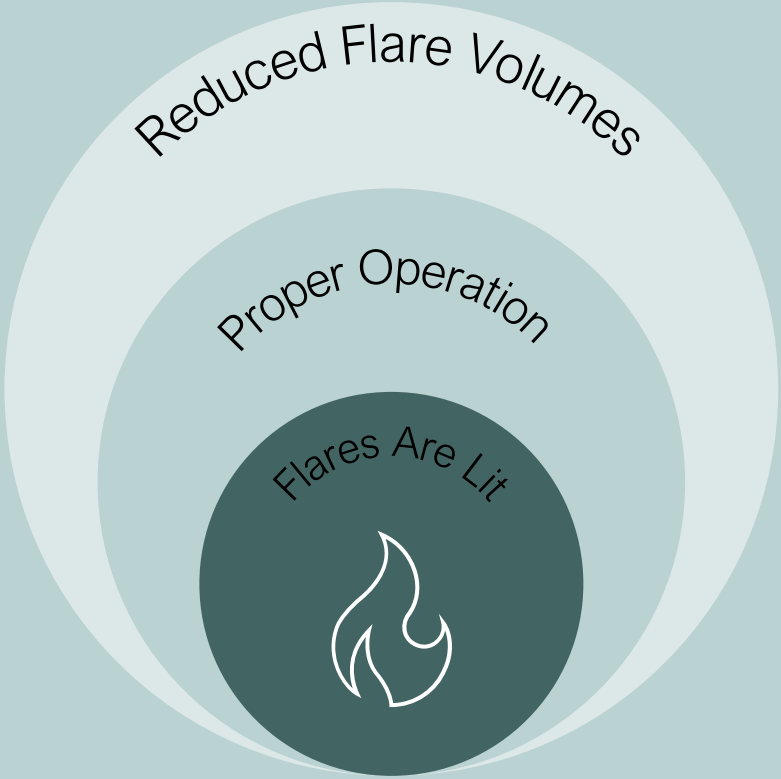
Relevance

- Ongoing Industry Effort
  - Offshore Norge DIAL measurements of flares
  - bp flare efficiency Study using Flare.IQ
  - CFD testing at offshore platforms in the UK North Sea
  - Experimental Testing & Modelling @ Carleton University
- Great to measure
- Focus on mitigation
- Work is complementary to OGCI, IOGP and Ipieca RP, Methane Flaring Toolkit, World Bank ZRF Initiative



Project and report ongoing and expected to be made available later this year

Recommended Practices Document – Integration of Flare Technologies

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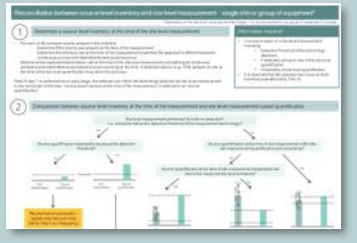
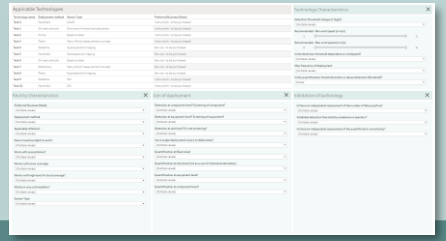
Decision trees

Allow the users to navigate the different objectives and situations Help them narrow down the purpose of technology deployment



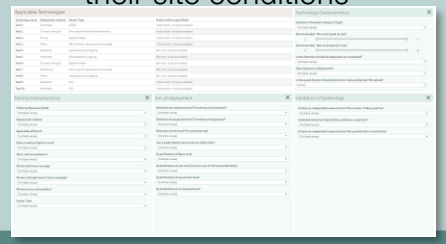
CH_4 Technologies database

Operators can narrow down suitable CH_4 technologies for their purpose and given their site conditions



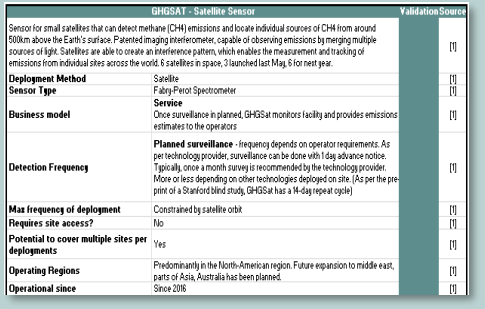
Flare Technologies database

Operators can narrow down suitable flare technologies for their purpose and given their site conditions



Technologies Datasheets

Datasheet for each technology to provide more details on the technology and validation of results for the operator's reference



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Operational since	Since 2016	[1]

CH_4 Technologies	Flare Technologies
51	8

Recommendations for operators

Case – how this project could be used by operators

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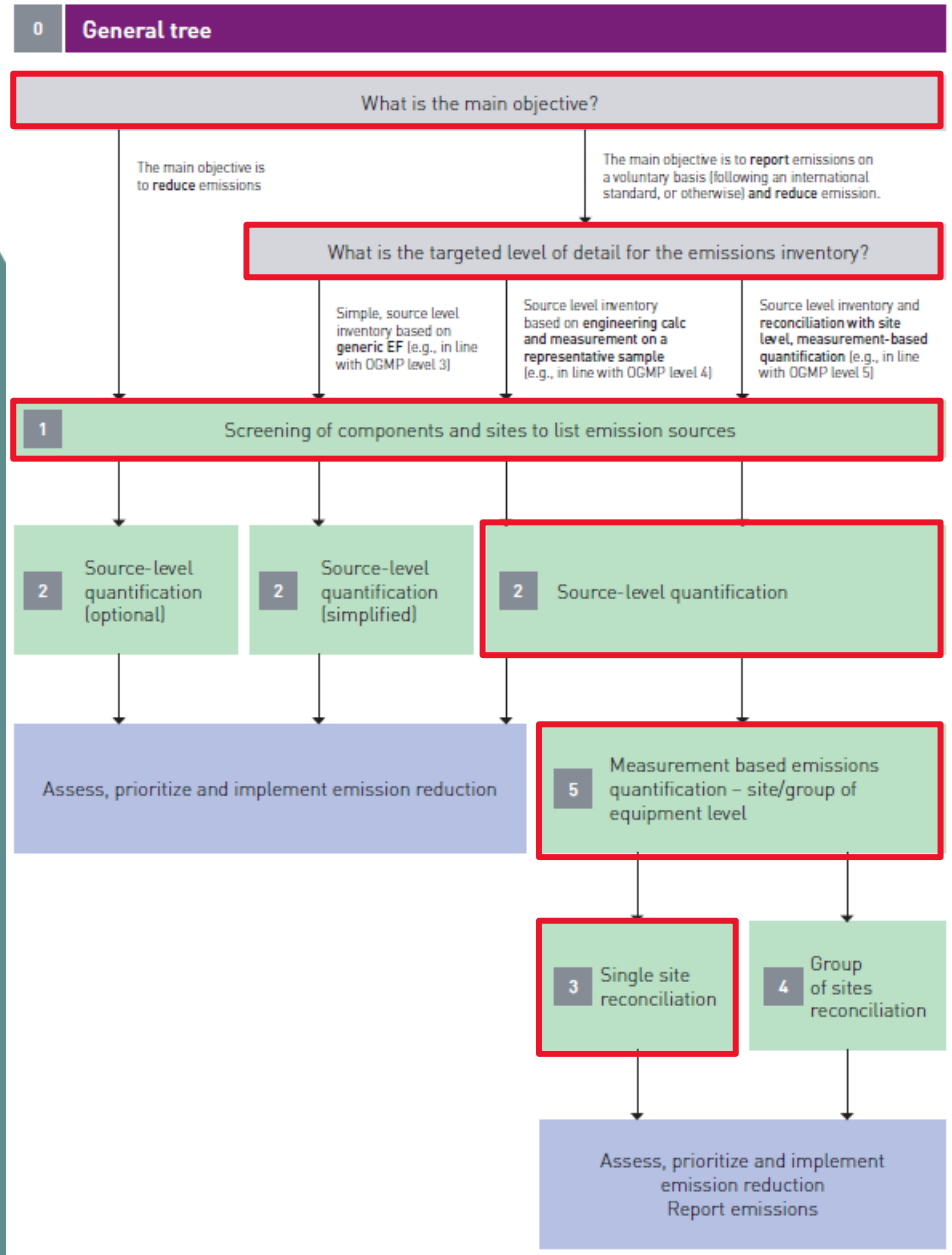

- Objective/starting point
- Report emissions on a voluntary basis and reduce emissions
  - E.g., reporting to OGMP
  - Reach OGMP Gold Standard
- Screening
- Source Level
- Site Level
- Reconciliation

Screening

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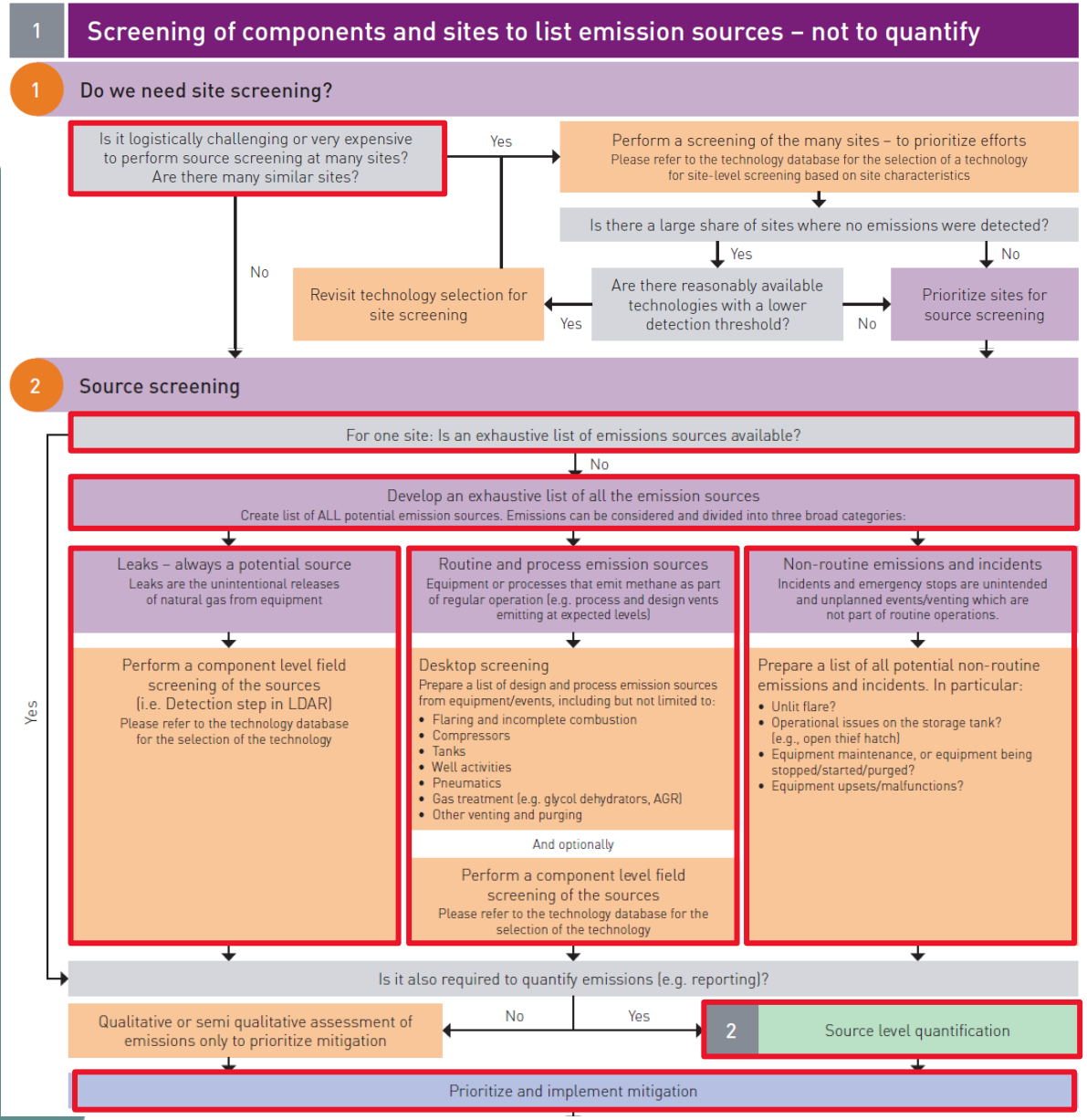

- Not many sites
- For a site, first time screening (next time skip to below)
- Develop list of all sources
  - Leaks
  - Routine/Process emission sources
  - Non-routine emission sources
- Goal OGMP reconciliation, so quantify source level emmissions

Screening

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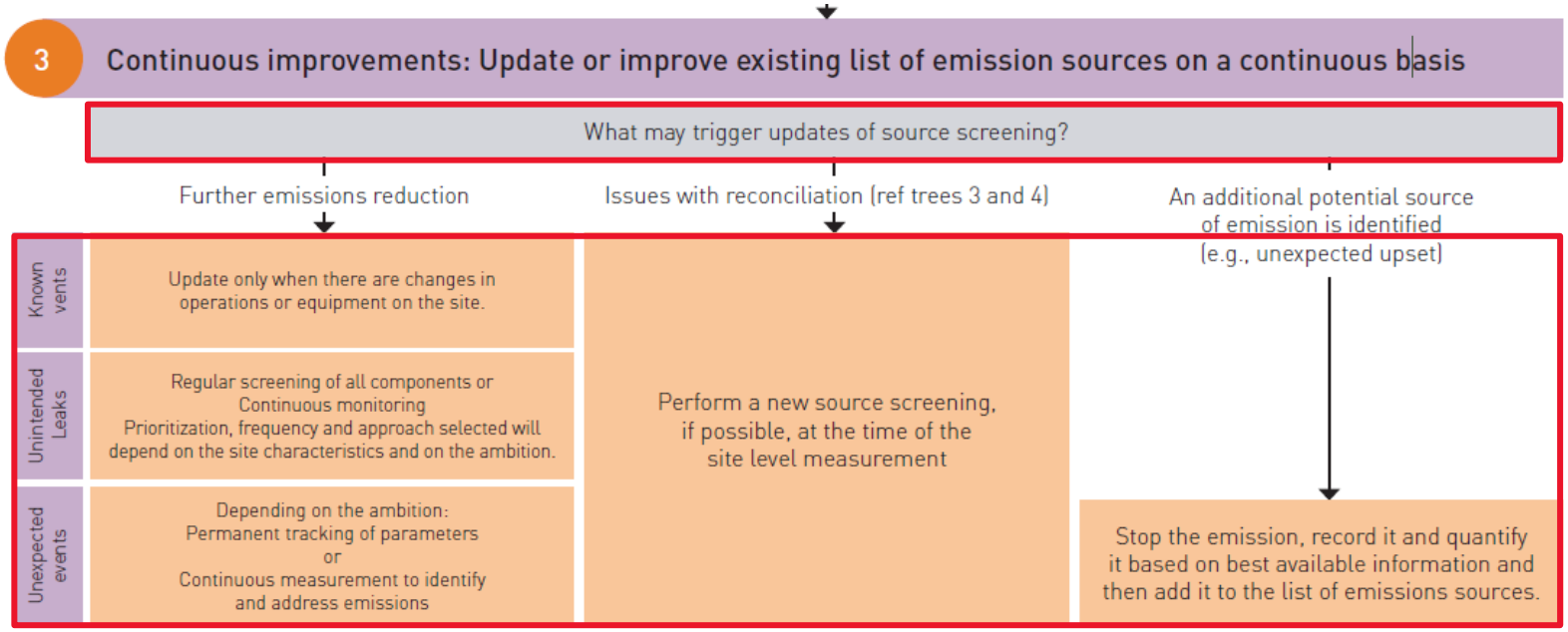
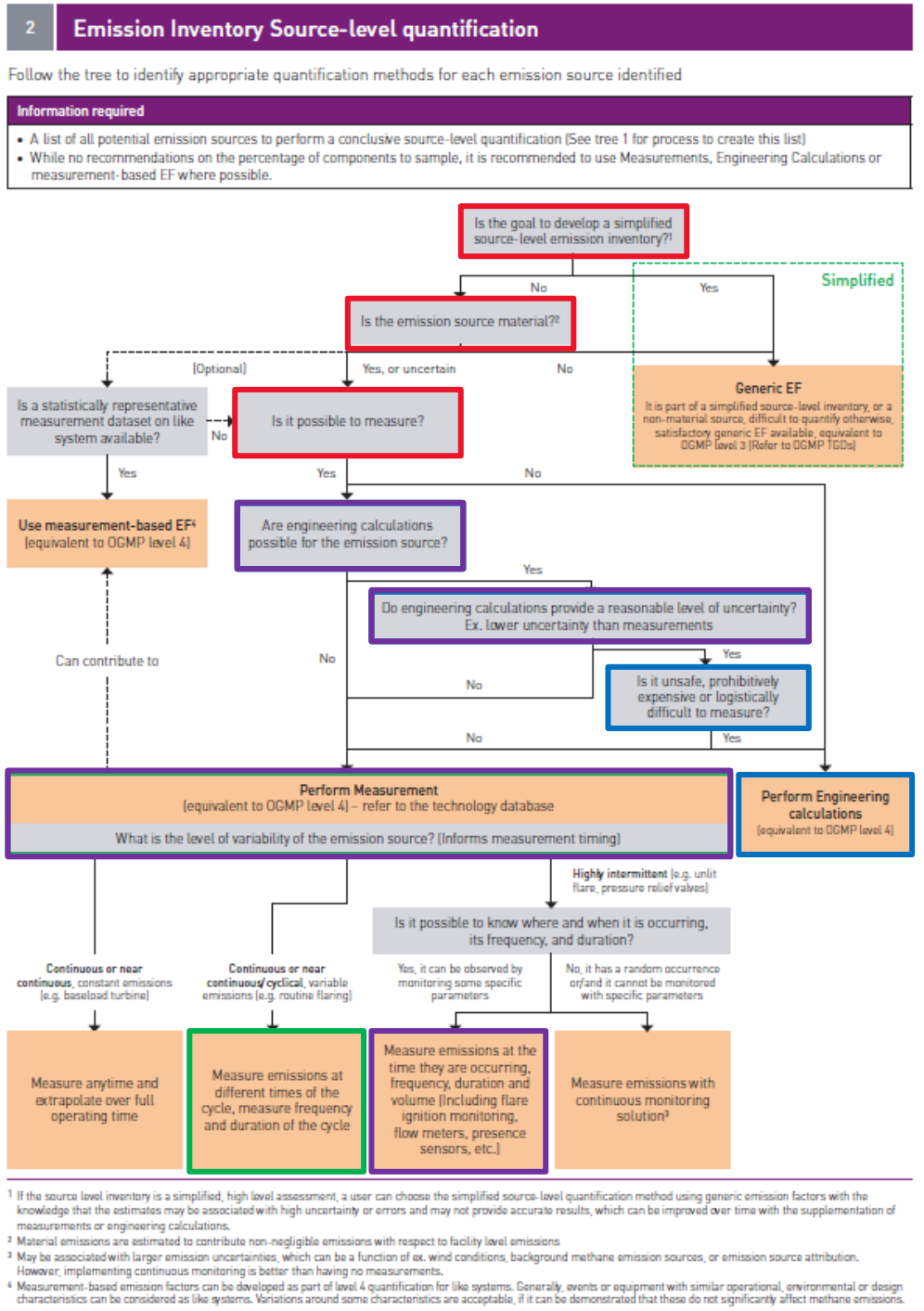


- Continuous Improvements: depending on results of reconciliation
- Continuous follow-up

Source Level quantification

- Goal to develop extensive inventory
- Materiality
- Repeat this process for all identified emission sources



Site Level quantification

CARBON LIMITS

3 Site-level quantification measurement

The main tool for selecting site-level quantification technology is the technology database. The different aspects present in this document are to be considered simultaneously (as filters) rather then sequentially.

Information required
• Information on site characteristics (location, environmental conditions, other co-located industrial activity ...) • Objective of site level quantification (reconciliation with source-level inventory, screening assessment for anomalous emissions...) • Source-level assessment of total emission rates (in different operational mode, if possible) – is recommended to be done prior to site-level measurements, including knowledge of both routine and non routine emission sources – ref Tree 2

- Understand site characteristics
- Understand source level emissions

Site Level quantification

CARBON LIMITS

What is the objective of the site-level quantification?			
	Inform inventory / validation / reconciliation (equivalent to OGMP level 5)	Monitor and address potential super emitters / unexpected sources	Build understanding of temporal variability – continuous
Threshold	Select a technology with a threshold well below expected emission rate determined by source-level inventory – within reasonable costs, logistical and labor efforts with regards to the absolute level of emissions. Very high probability of detection required for the threshold target.	Select a technology with a threshold higher than the total of continuous source, and in line with either super emitter definition for your site or proportionately large emission sources. Very high probability of detection required for the threshold target.	Select technology with quantification threshold (or alarm threshold) that does not generate alarm fatigue (i.e quality degradation due to repetition). Detection threshold can be slightly higher than the total of the continuous sources.
Uncertainty	Technologies with documented uncertainties that consider uncertainty of the sensor and of the method depending on environment conditions.	Requirement on the uncertainty of the quantification depends on whether the quantification will directly be used for inventory or whether the measurement will be combined with other estimation methods.	NA - Currently high to very high uncertainty for all technologies assessed.

- Covered in part in Datasheets
  Use this to make informed decision

Site Level quantification

CARBON LIMITS

- Covered in part in Datasheets
- Use this to make informed decision

Technology Constraints to consider when selecting site-level quantification technology:

Validation
Documented, transparent validation of emissions (third party testing, public availability of information, controlled release testing in representative conditions).

Safety
Technologies that respect company and local safety requirements, e.g. ATEX certification, civil aviation requirements, IOGP/company aviation requirements.

Source Localization
Selection of technologies that can attribute emissions to desired level (e.g. site or equipment level) and that are appropriate with respect to the facility characteristics (e.g. small/large, congested/ geographically dispersed assets).

Availability
Import/export, commercial availability in-country and other restrictions and logistical constraints for technologies.

Operational data
Ensure field data collection at the time of monitoring (operational mode, events, ...) to improve the understanding of operational factors and correlate them to measured levels of emissions.

Environment
Technologies may be impacted by environmental conditions (e.g. cloud cover, snow, precipitation) that undermine their ability to monitor emissions at desired frequency.

Location offshore may also make some technologies not applicable.

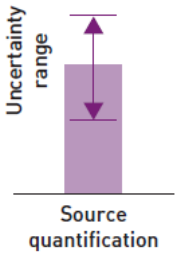
Reconciliation

CARBON LIMITS

4 Reconciliation between source level inventory and site level measurement – single site or group of equipment[1] for a single point in time

1 Determine a source level inventory at the time of the site level measurement

- For each emission source present in the inventory:
  - To the best ability, determine if the source was present at the time of the measurement.
  - Determine the emission rate at the time of the measurement (note that the approach is different between continuous sources and intermittent/event-based sources)
  - A detection device (e.g., OGI) present on site at the time of the site level quantification may inform if an emission source was emitting when the measurement was performed.
- Determine the expected total emission rate at the time of the site level measurement considering all continuous emissions and intermittent/event-based sources occurring at the time.

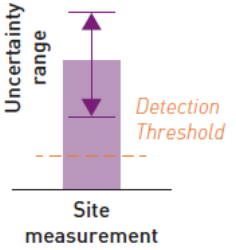


Notes:

- If step 1 is performed at an early stage, the estimate can inform the technology selection for site level measurement
- If it is not possible to determine a source level inventory at the time of the site level measurement (e.g. if inventory is limited to annual reporting), it is possible to skip and go directly to step 2. However, caution should be taken as this may result in larger uncertainties on the reconciliation performed .

Information required

- Source level inventory (refer to Tree 2)
- Conclusive result of a site level measurement including:
  - Detection threshold of the technology deployed
  - If detected, emission rate of the site level quantification
  - Uncertainty of site level quantification
  - Consideration of weather conditions and geographical site setup

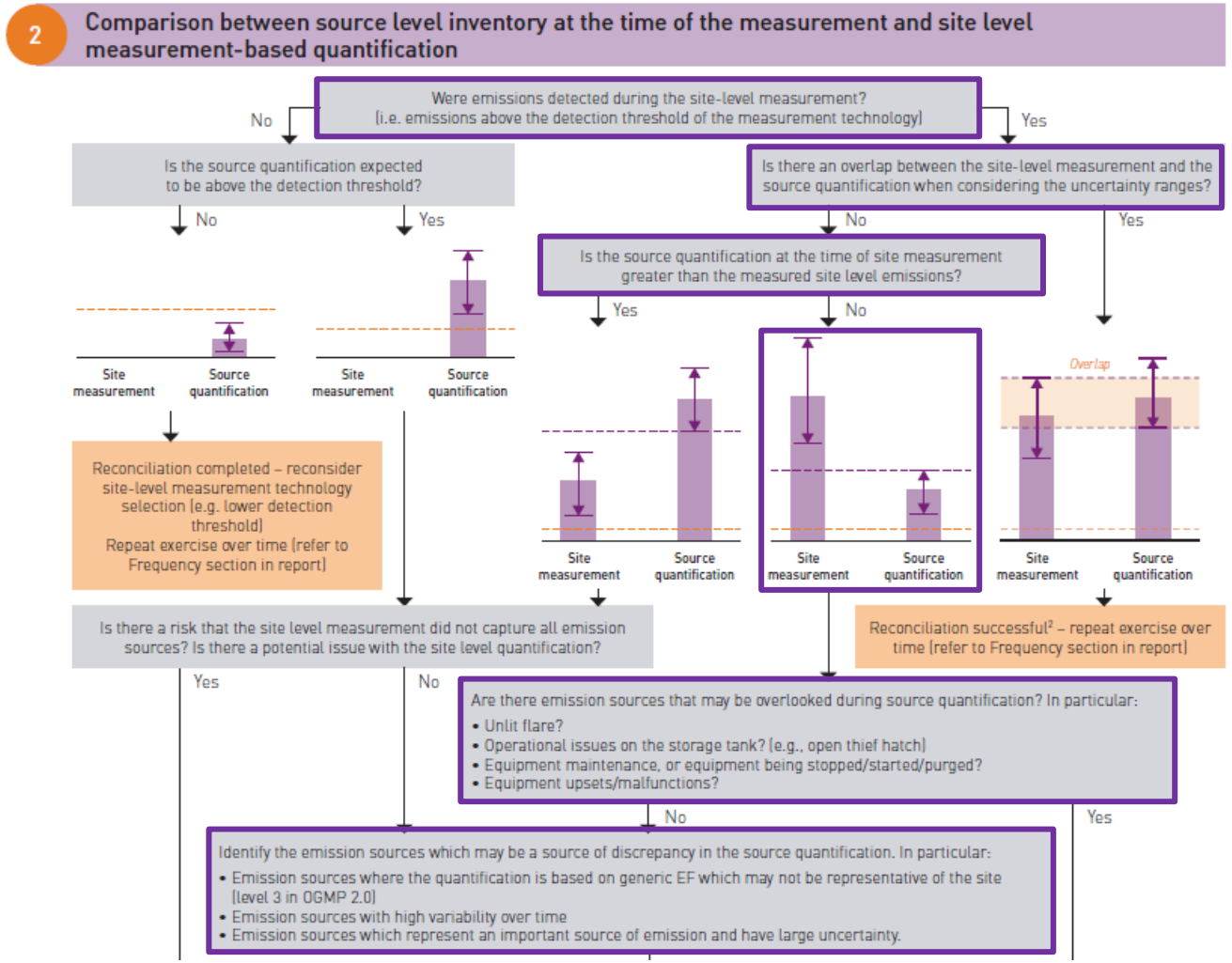


- Build on source level
- If possible to have detection device to inform this
- Site level inventory, where possible knowing detection threshold, total emission rate, uncertainty and weather or geogrpahical site setup

Reconciliation

CARBON LIMITS

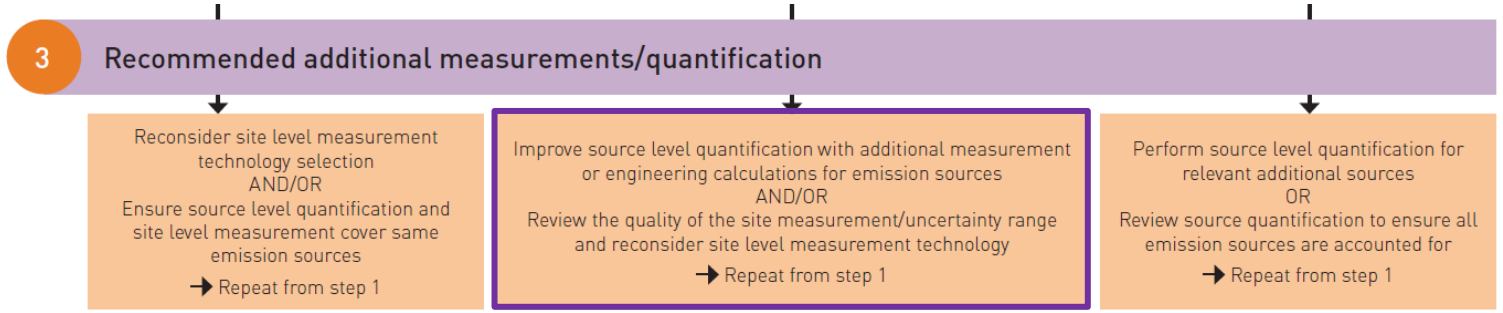
- Emissions deteccted
- No overlap
- Site level higher than source level
- Emssion sources not overlooked during source level
- Identify sources of discrepancy



Reconciliation

CARBON LIMITS

- Emissions detected
- No overlap
- Site level higher than source level
- Emssion sources not overlooked during source level
- Identify sources of discrepancy
- Improve source level quantification
- Review quality of site measurement



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