

1. Project Summary

This project aims to develop and deploy an integrated monitoring system through creating a comprehensive plan. The plan will consider various monitoring strategies at different scales, including in-situ and remotesensing observations, as well as both bottom-up and top-down modeling.

2. Project Objectives

- Gathering data from companies or solution providers involved in methane emission monitoring,
- Analyze and evaluate the data collected in the database,
- Review and evaluate modern methane sensor technologies,
- Classification and technical assessment of monitoring platforms,
- Classification of methane sensors based on cost.

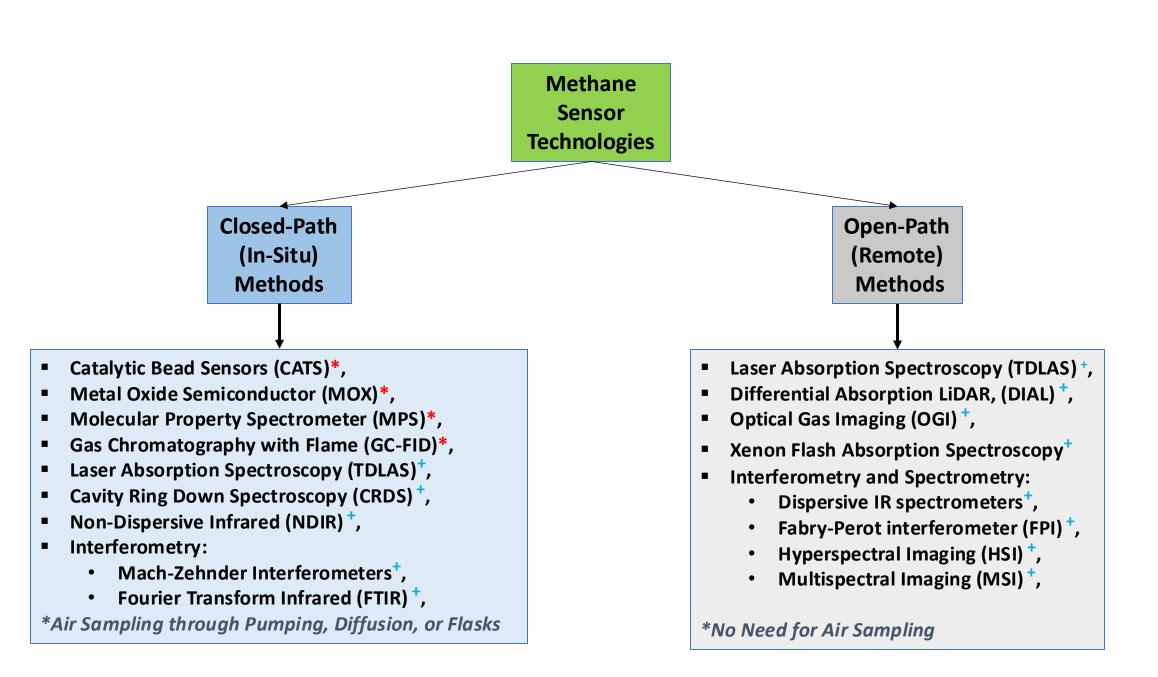
3. Analyses and Results

Data from 106 providers was surveyed, collected, and stored in a database,

Company		C	Country (HQ)			Product Names				Service Type			Detection Technology			-	Sensor Type		Monitor Platform			San Me	
Sens or D		-	A	ccura	асу		Resc	olut	ion			pon: le T9			C	ost		Monit Pictur		M	Vebsi	tes	Pro W
A	Cometry	c	N/A D i	E F Detection Technology		H Monitor Platform	l J Sampling Method®	K Spectral Versiliest		M N Detector Type	0 Detection Range ^{##}	P Q Sensitivity/ or Detection Limit ***	R Accuracy	S Resolution	T Response time or T90	U V T Cost Assessment	√ × Monitor Picture	∨ ¥ebsites	2 Notes	AA Product Veight	AB AC	AD Represent	AE AF
SMP Robotics	US	S6 series	Robotic, Drone	LAS, OGI	TDLAS, Thermal camera	Auto Mobile	Viewing, Sniff	1.2 to 2.5	Near-IR	InGaAs	Locate methane 33 yard away	*	*	*	*	*	*	https://smprobotics.com/			CATS	Catalytic type gas senso	
LICHENS	France	Cranberry, Mulberry	Detection of environmental gases	Non-Dispersive IR	NDIR	Stationary/ Portable	Sniff/ Diffusion	3.3	IR	MEMS IR micro- source	05% vol.	claimed: 1 ppm	±0.1% vol. or ±5% of concentr	0.05% vol.	30 sec	¢	5 *	https://www.elichens.com/			СМ	Continuous Monitoring	
Arolytics	Canada	AroFEMP. AroVIZ	Software, Analytics	N/A	N/A	N/A Hang Held,	N/A	NłA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	https://www.arolytics.com/			CRDS	Cavity Ring-Down Spectroscopy	
SENSIT Technologies	US	GAS-TRAC FMD, SENSIT- VMD, TBAK-IT	LDAR	LAS	TDLAS	Stationary (FMD), Portable (PMD, VMD)	Open Path, Sniff	1.65	Near-IR	InGaAs	VMD: 1 to 1000 ppm-m, HH: 0- 50000ppm- m up to 50ft	Open Path: 5ppm-m ≤50ft, Sniffing: 200ppb with MPCell	10% 0.5ppm min	FMD:200ppb, VMD and PMD; 0.1ppm	FMD:<10 sec, HH:<0.1 sec	PMD:\$13,381, VMD:\$31,515, HH:\$14000, FMD:\$9700.,	4 4 4	https://gasleaksensors.com/		PMD:3.1 Ib, HH:0.7Ib, FMD: 15Ib	FP Interfro	Fabry-Perot Interfrometer	
Champion X	US	SOOFIE, MIR Camera, AURA OGI,	LDAR, Aerial Analytics	Metal Oxide, OGI	MOX, Camera	Aerial, Stationarg, Handheld	Viewing, Sniff	3.0-5	Mid-IR	N/A	÷	÷	¢	÷	¢	¢	The	https://www.championx.com/			GC	Gas Chromatography	
Purway Innovation Technologies	China	CH-4 UAV Laser Methane Leak Detector II	LD, UAV	LAS	TDLAS, Camera	Aerial	Open Path, Viewing	1.65	Near-IR	InGaAs	5 to 300 m, 0 99999 ppm	5ppm-m,	±10% (100~50000 ppm*m)	5 ppm	5ms, 10ms	\$28,900	*	https://purway-innovate.com/		730gr	GHG	Greenhouse Gases	
Bridger Photonics	US		LD, Aerial, LiDAR Tech., Analytics, Dual Imaging method	LAS	LIDAR	Aerial, Portable	Open Path, Gas mapping	1.65	Near-IR	InGaAs	500 to 700 ft	In production sector:3 kg/hour with a >90% Probability of	*	*	*	>\$150 K based on no. of sites		sww.bridgerphotonics.com/	PoD>0.9		LAS	Laser Absorption Spectroscopy	
Qube Technologies	Canada	Azon	LDAR, CM, Analytics	Metal Oxide	мох	Stationary/ Portable	Sniff	NłA	N/A	N∕A	÷).2 kg/hr @ 100m, %100 detection at 1kg/hr	1ppm	<1ppm	¢	focused on low-	1	www.qubeiot.com/	PoD>0.5		LD	Leak Detection	
Olythe	France	OCIEngine PRO Methane	R&D, Infrared optics	Non-Dispersive IR	NDIR	Stationary/ Portable	Sniff, 0.1 to 1.5 L/min	3.3	Mid-IR	*	0-5000ppm	0.5% full scale	20 ppm • 5% of reading,	*	1s at a flow rate of 1 L/min	\$1,650	Terrate	www.olythe.io	Confid.		LDAR	Leak Detection and Repair	
MFE Inspection Solutions	US	MFE OGI CAMERA, (by Sierra- Olympia)	Environmental Inspection, LD, UAV	OGI	Camera	Hand Held, Robots, Drone	Viewing	3.2-3.42	Mid-IR	HOT MVIR, Focal Plane Array	ф	ф	÷	640x512 pixel, and 8MP	÷	MSRP: \$110k to \$120k	1	https://mfe-is.com/	Run Time: 4 hr	2.2 lb	LEL	Lower Explosive Limit	
Jonah Energy	US	Konica Minolta GMP02	Gas Leak Visualization	OGI	Camera	Hand Held	Viewing	3.2-3.42	Mid-IR	÷	4ft to 328 ft	÷	÷	÷	÷	ф	8.5	https://www.konicaminolta.co m/us-en/gas/		5.5 lb	LIDAR	Light Detection and Ranging	
GHGSat	Canada	GHGSAT	Emission monitoring, Satellite-based imaging	Fabry-Perot Interferometer	Interferom eter	11 Satellites	Remote- Sensing of GHGs	1.65	Near-IR	÷	FOV: 12X12km	100 kg/hr	÷	Spectral Res: 0.3m , Spatial Res:25m	¢	÷		https://www.ghgsat.com/en/			мох	Metal Oxide Semiconductor	infoqualitaq malligle, equiperala equiperala etaqle allian
PICARRO	US	G2000 Platform	High-precision and low-drift measurements	Time-based technique	CRDS	Aerial, Stationary	Sniff	1.65	Near-IR	InGaAs	0-20 ppm	<0.5 ppb for CH4	÷	÷	÷	ф		https://www.picarro.com/	~20 km pathlength	60 lb	MPS	Molecular Property Spectrometer™	
PROJECT	US	Canary X designed for methane	Emissions data platform, risk assessments and emission profiles	LAS, OGI, LiDAR, Metal Oxide	TDLAS, MOX, Camera, Lidar	Aerial, Stationary,	Remote- Sensing, Sniff, Open Path, Gas mapping	1.65	Near-IP	InGaAs	Methane: 0.2ppm - 100ppm	TDLAS: <1ppm, MOX:<5ppm, LiDAP: 10kg/hour	Precision: 0.001ppm; Accuracy: ~0.2ppm [~2o]	÷	ф	*		https://www.projectcanary.cor	a		NDIR	Non-Dispersive Infrared	
Aeris Technologies	US	MIRA Pico, Strato, Mobile LDS	A Project Canary Company, LD	LAS, Direct absorption mid- IR spectroscopy in the 3	TDLAS with sonic anemomet ry	Portable, Handheld, UAV	Sniff, Gas mapping, 0.3-0.5 lpm	2.5-4.5, 3.3 for Methane	Mid-IR	¢	1ppb level to % concentrati on levels.	<2 ppb/s	1-2ppb drift long-term	Ф	÷	\$29,500, Advanced LDS cost: \$36,500		https://aerissensors.com/		6.7kg with drone	OA-ICOS	Off-axis Integrated Cavity Output Spectroscopy	y
LGR-ICOS	US	ABB LGR-ICOS	Laser gas analyzing	LAS	OA-ICAS	Hand Held, Stationary, UAV	Sniff	1.65	Near-IR	InGaAs	÷	ppt/ppb-levels	÷	÷	÷	¢		https://global.abb/group/en	***	26 kg	ogi	Optical Gas Imaging	
Aerial Production Service	US	ICI-OGI camera	LD, Analytics	OGI	Camera	UAV (Drone)	Viewing	2.5-4.5	Mid-IR	ф	ф	0.75 g i hour	¢	÷	ቀ	ф	A	www.flyaps.io/			PoD	Probability of Detection	
lubo Sphere	SWTZ		LD, Detect, locate and quantify methane emissions	LAS, CH4sensor cartridge with Near-IR spectroscopy	TDLAS	Stationary	Sniff	1.65	Near-IR	InGaAs	÷	1.2 kg/h	98.10%	¢	÷	Ф	Contraction of	https://sensition-connected.c	PoD: 0.8kg/h		TDLAS	Tunable Diode Laser Absorption Spectroscopy	
Opgal	US	MWIH: EYECGAS2or EyeCGas Pro, LWIR: EyeCGas Mini or	LDAR	OGI-cameras	Camera	Hand Held	Viewing	3.2-3.4	Mid-IR	MWIR: Cooled MCT, FPA, LWIR: Uncooled	ф	0.35 g/hr	¢	÷	÷	ф	-	www.opgal.com			UAV	Unmanned Aerial Vehicle	ź

*The link to this database will be available at the end of the project,

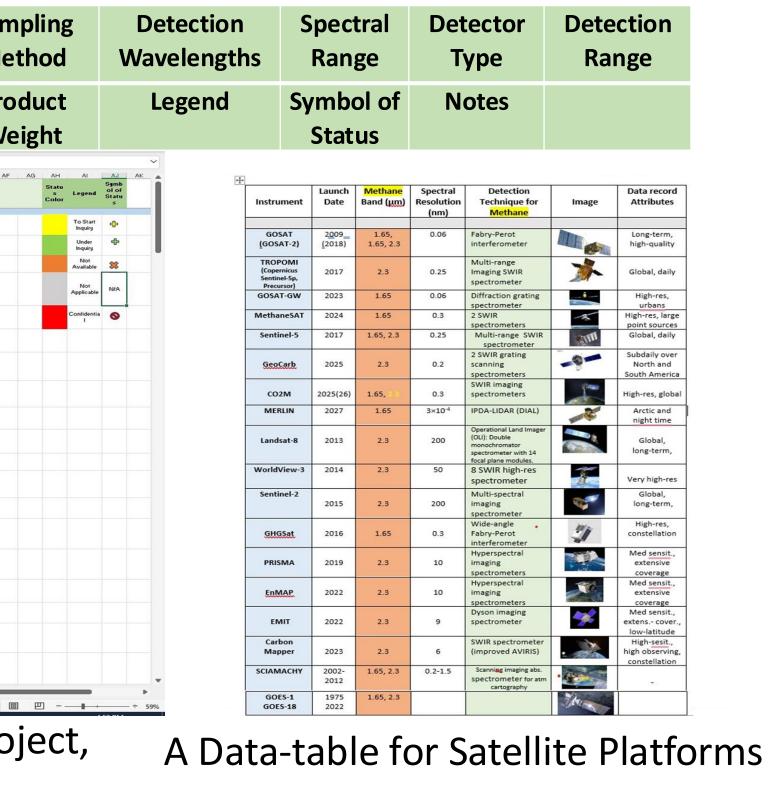
4. Dividing Methane Sensors



*CATS, MOX, MPS, and GC-FID are chemical reaction methods used for methane sensing, based on Changes in Resistance or Conductivity. ⁺ Infrared optical methods for methane sensing rely on Changes in Spectral Response.

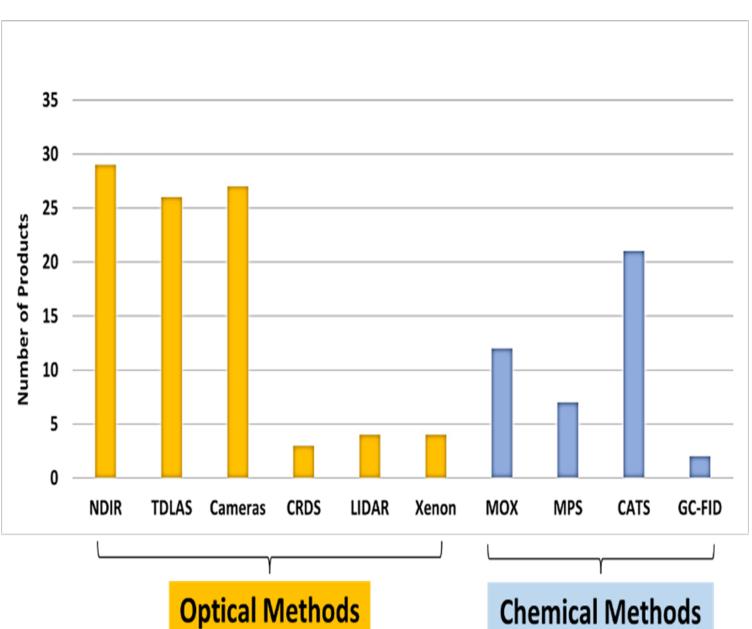
A Comprehensive Survey of Methane Detection Technologies

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Measuring Methane Emissions.

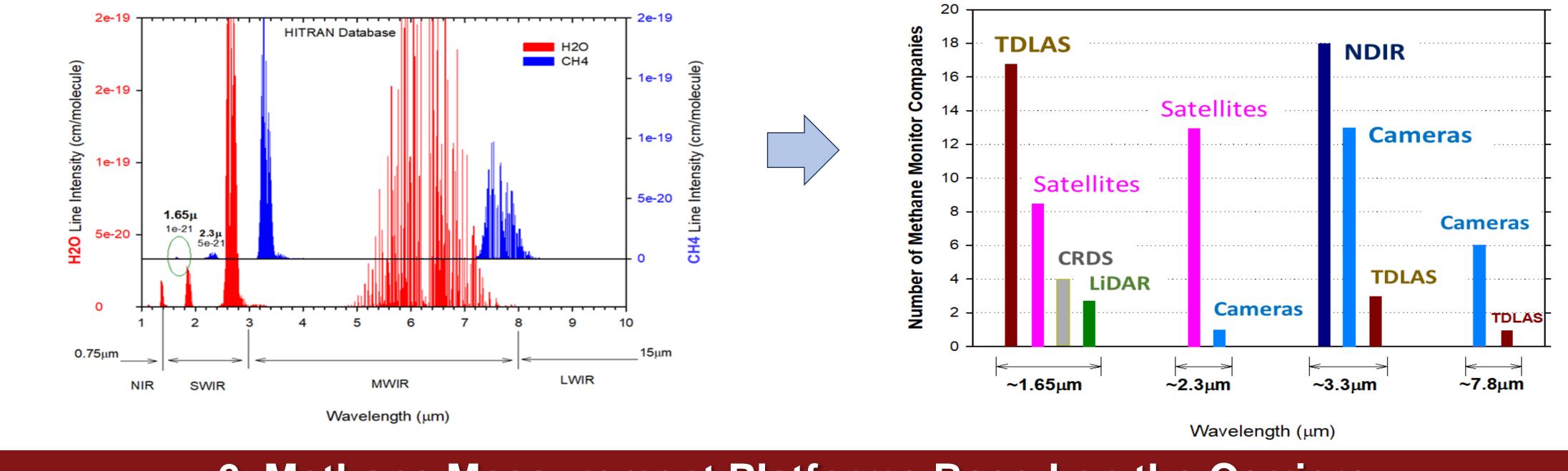
Distribution of CH⁴ Sensor **Technologies in the Database:**



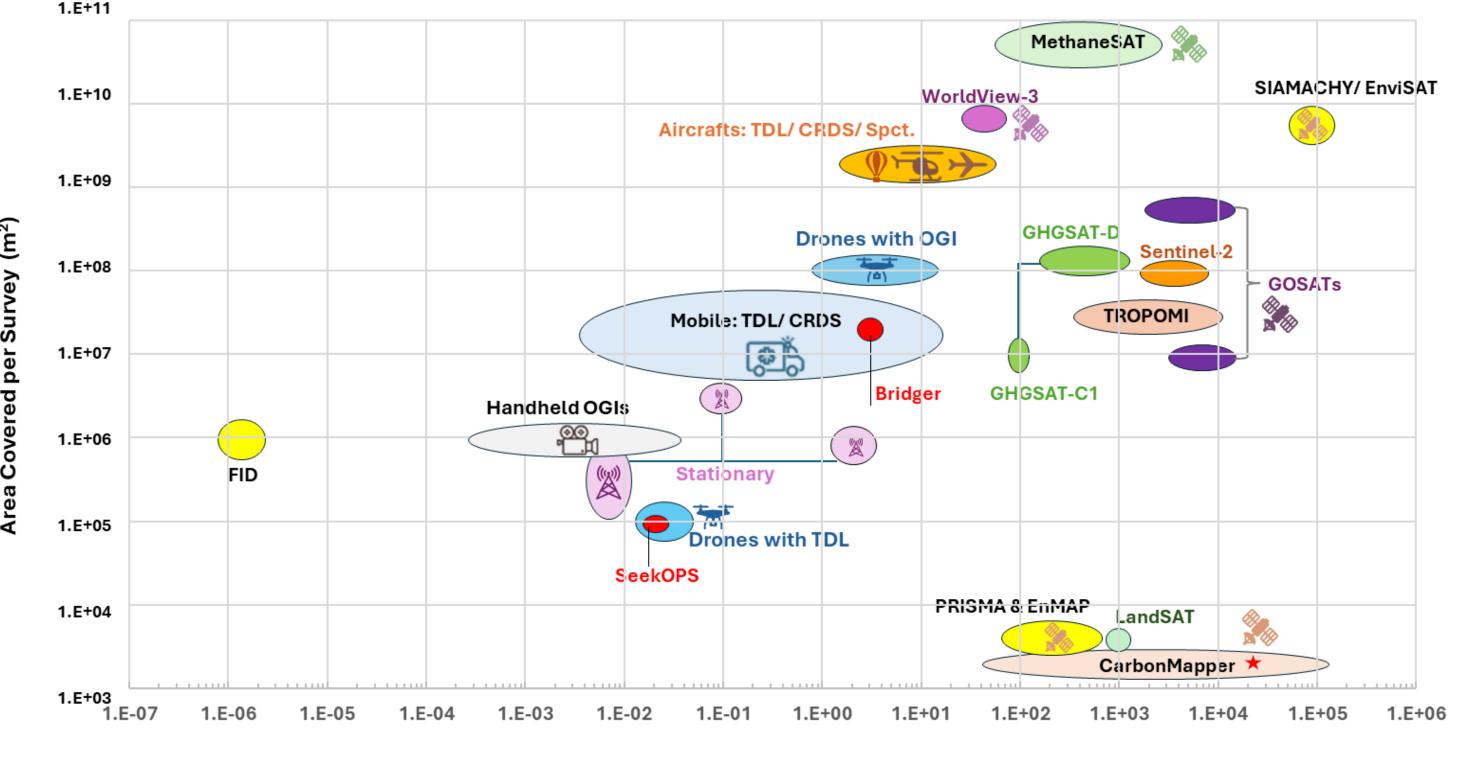
> MOX vs TDLAS:

Comparison	Metal Oxide Sensors (MOX)	Laser Absorption Spectroscopy (TDLAS)					
factors							
Sensitivity	Lower sensitivity	Higher sensitivity					
Detection Limits	Higher detection limits	Lower detection limits					
Selectivity	Cross-sensitivity to other gases	Highly selective					
Response Time	Moderate response time,	Fast response times,					
	a few seconds to minutes	milliseconds to seconds					
Stability	Affected by changes in temperature, humidity,	More stable across different environmental					
	and pressure	conditions					
Cost	Cheaper, suitable for cost-sensitive	Higher cost, its complexity ensures high accuracy					
	applications	and reliability					
Applications	Portable methane gas detectors,	Leak detection in pipelines,					
	where cost is a critical factor	where high precision and fast response needed					
Maintenance	Regular calibration and maintenance	Less frequent calibration and maintenance					

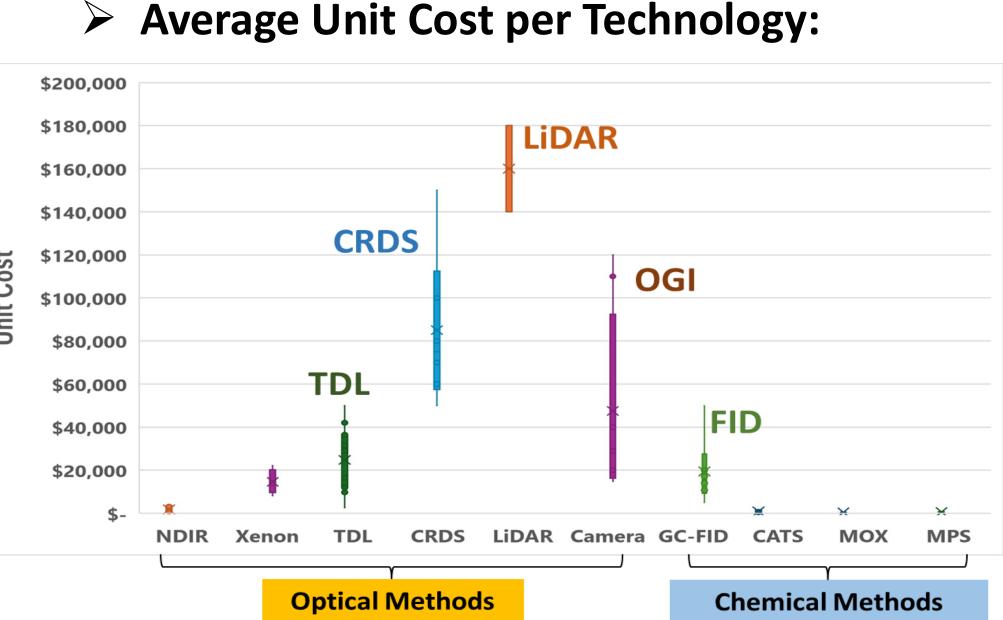
Comparing Methane Absorption Bands with Water Vapor Interferences in IR-Based Sensor Technologies :



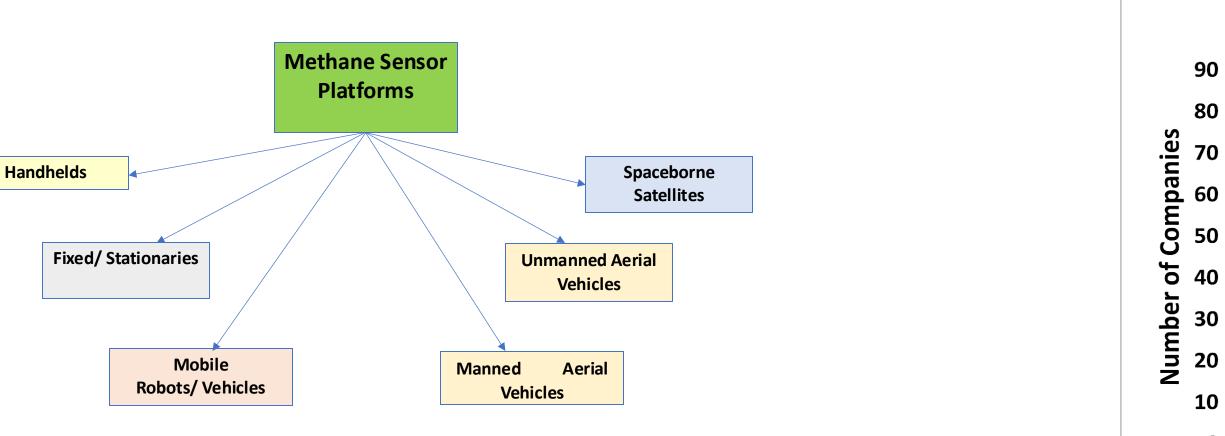
Approximate Coverage Area vs Methane Detection Limits on Platforms:



5. Examples of Technologies Comparison



6. Methane Measurement Platforms Based on the Carriers



Rate-Based Minimum Detection Limit (kg CH₄/hr)



Distribution of IR-based Methane Sensor Technologies by Spectral Response:

Distribution of Platforms in Database *Satellites were not included 20 10 Mobile Handheld Stationary Aerial

Proposed Points in Choosing a Methane Monitoring System:

