Approaches to Methane Emission Detection and Reduction

Pipeline Transportation: Hydrogen and Emerging Fuels
R&D Public Meeting and Forum
Workgroup 5: Methane Mitigation – Construction and Operations
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METHANE EMISSION MONITORING

CHANGING WHAT'S POSSIBLE

Bridger Photonics is using aerial LiDAR for fugitive methane detection

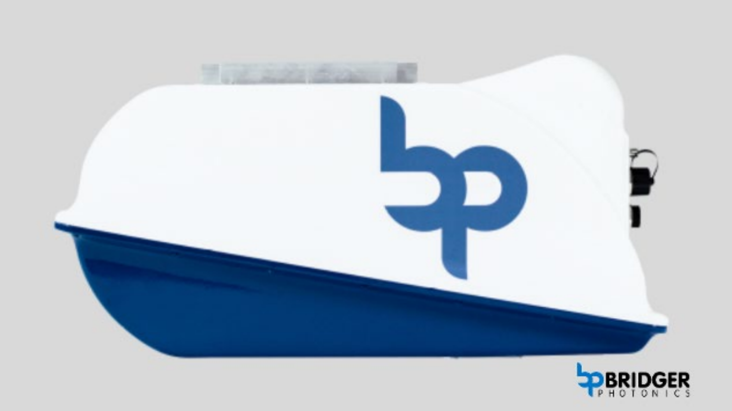
Project Title: Scaling Disruptive Methane Leak Detection and Quantification

Project Overview:

- Originally funded as part of ARPA-E MONITOR program and subsequently awarded $4.5M through the SCALEUP 2019 Program
- Continuous-Wave Laser Absorption LiDAR provides the spectroscopy for methane detection
- Capable of Detecting >90% of Production Basin Emissions (achieves a detection sensitivity of 3 kg/hr (or 161 scfh) with >90% PoD in “typical” conditions)
- Flying major production basins in US and Canada
- SoCalGas signed an $12M agreement in August for helicopter-based scanning of their distribution area
- SCALEUP funding supports efforts to: (1) fully automate job planning, data processing and management, (2) finalize second-generation hardware designs with improved sensitivity and accuracy and scale manufacturing, (3) advance predictive algorithm capabilities, and (4) begin to integrate its technology into customer operations

Technology Overview

Gas Mapping LiDAR sensor, typically attached to an aircraft for aerial scans and an example product of methane plume imaging capability. Data product includes path integrated concentration, GPS leak source location, geo-registered aerial photography, plume imagery, persistency vs. intermittency, and measurement time and date.



Source: https://www.bridgerphotonics.com/, https://arpa-e.energy.gov/technologies/scaleup/scaleup-2019/bridger-photonics

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CHANGING WHAT’S POSSIBLE

LongPath Technologies is one of two ARPA-E SCALEUP 2019 Awardee's focused on fugitive methane detection

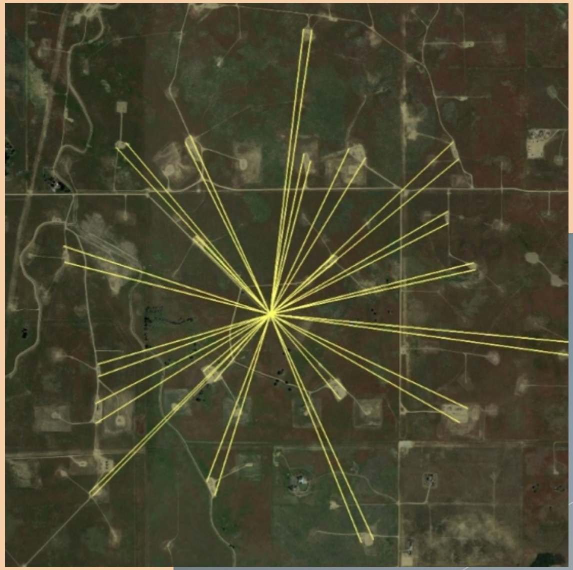
Project Title: **Basin-SCAN: Basin Scale Continuous oil and gas emissions Abatement Network**

Project Overview:

- Originally funded as part of ARPA-E MONITOR program and subsequently awarded $5M through the SCALEUP 2019 Program
- The core laser technology was the basis of Nobel Prize-winning work at the University of Colorado and the National Institute of Standards and Technology
- Eye-safe, long-path laser systems probe the distinct absorption 'fingerprint' of many different molecules (methane, H_2S, CO_2, H_2O, and more) across 50,000+ wavelengths (colors) of light
- Provides parts-per-billion accuracy and precision with no calibration and strong interference rejection over long-distance (2.5+ miles) laser beam paths
- Atmospheric modeling and inversion techniques are used to detect, locate, and quantify emission sources
- SCALEUP funding the proposed largest continuous emissions monitoring network for the oil and gas industry

Technology Overview

LongPath's central laser node, with a dual frequency comb laser technology housed locally on a minimal footprint and tall tower to pitch and catch laser light, provides continuous monitoring of emissions across 20+ square mile areas



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Source: https://www.longpathtech.com, https://arpa-e.energy.gov/technologies/scaleup/scaleup-2019/longpath-technologies

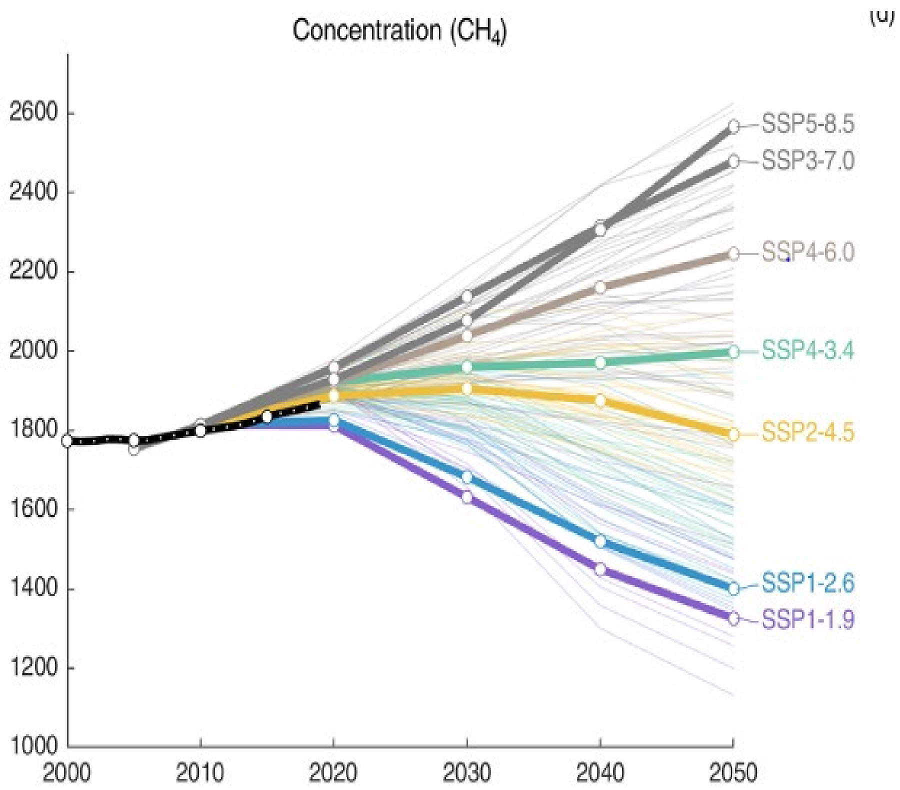
METHANE EMISSION REDUCTION

REMEDY

Reducing Emissions of Methane Every Day of the Year

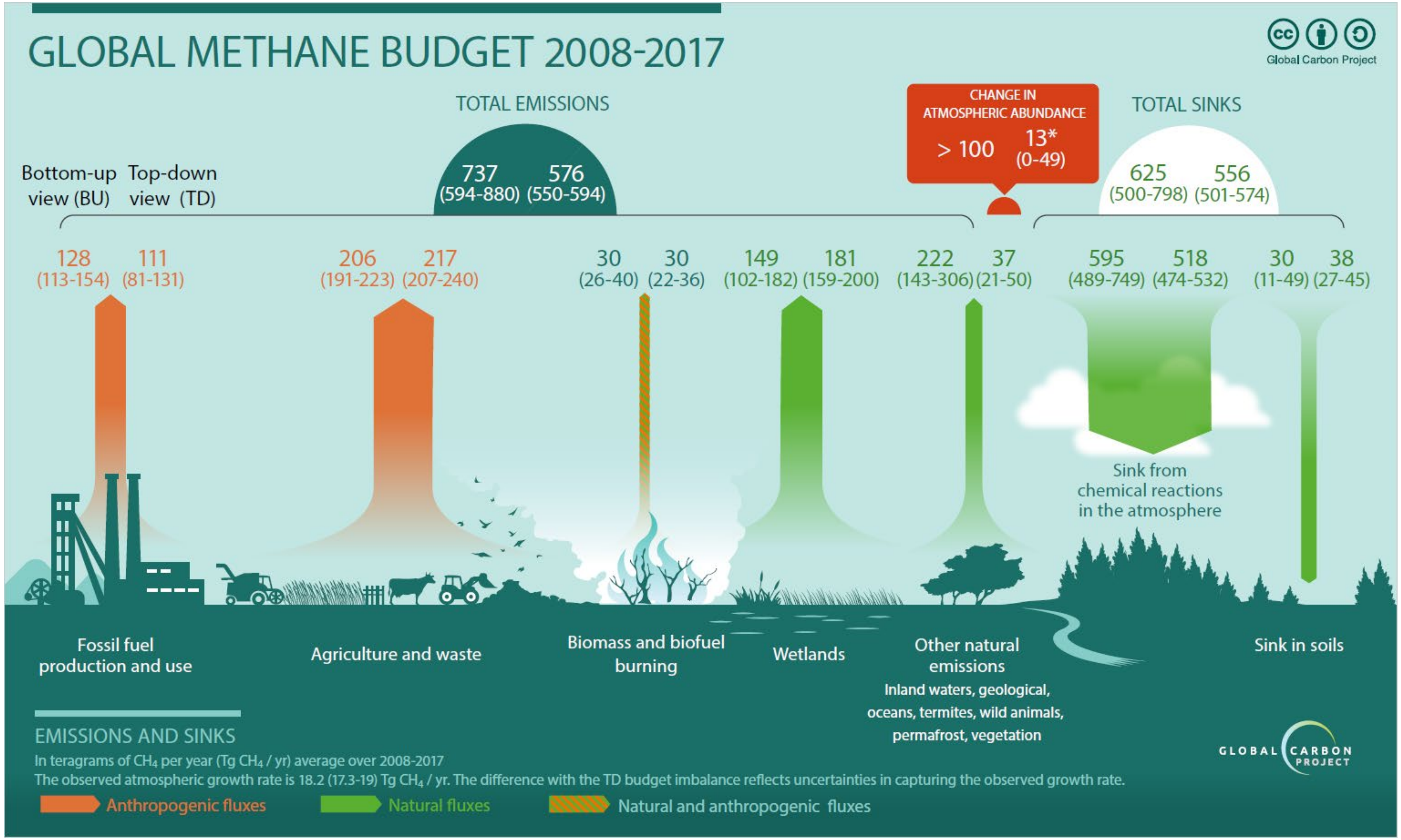
REMEDY will address methane from oil, gas, & coal value chains

- **The Challenge:**
  - The fossil fuels from domestic oil, gas, and coal value chains account for 75% of U.S. primary energy
- **The Answer:**
  - Complete, system-level technical solutions that achieve 99.5% methane conversion from three sources in the oil, gas, and coal value chains that are not addressed by other programs:
    - Exhaust from natural gas engines
    - Flares used in normal operations
    - Coal mine ventilation
  - Results that can be confirmed and validated in a field test or larger, extended-lab-scale test
- **The Impact:**
  - Potential to reduce U.S. methane emissions by at least 60 million tons of CO2e per year



Saunois, et al., Earth Syst. Sci. Data, 12, 1561–1623

Small Reductions Can Lead to Large Impact



Internal Combustion Engines and Pipeline Infrastructure

- Interstate pipelines use compressor stations every ~50 miles to boost pipeline pressures
- The compressors are driven by gas turbines, but more frequently by internal combustion engines
  - Typically, large end of the ICE lean-burn spectrum
- Relatively small number account for disproportionate fraction of the interstate pipeline methane emissions
  - Engine slip
  - Crankcase emissions
  - Rod leak; programs addressing compressor leaks for interstate pipelines

Addressing the Challenge

- Considerations:
  - Methane difficult to remove (i.e., chemistry of molecule, 1700°F spark temperature)
  - Exhaust catalyst does not adequately address the challenge (i.e., light-off temperature)
- How REMEDY is different
- INGAA (Interstate Natural Gas Association of America) and INGAA Foundation estimate the cost to replace engines or turn them to electricity is about $3000/hp

Reducing Emissions of Methane Every Day of the Year

Kickoff Year	2022
Investment	$35M
Duration	3 years

- **REMEDY Goal:** System-level solutions that achieve an overall methane conversion of 99.5%, reduce net greenhouse gas emissions > 87% on a life-cycle basis, have a LCOC < $40/ton CO2e, and address techno-economic issues related to commercialization.

***REMEDY addresses three sources from within the* fossil energy value chain:**

- **Natural gas-fired lean-burn engines**: Exhaust from natural gas-fired lean-burn engines, used to drive compressors, generate electricity, and increasingly, repower ships
- **Flares**: Flares required for safe operation of oil and gas facilities
  - novel open or enclosed combustor designs, likely outside the EPA proscribed operating parameters; additives or catalysts to ensure high combustion efficiency; and
- **VAM**: Coal mine ventilation air methane (VAM) exhausted from operating underground mines
  - systems incorporating novel materials with enhanced properties (high thermal capacity and/or thermal conductivity) and/or catalysts.

REMEDY Technical Performance Requirements

- Technology must meet the performance metrics and address the techno-economic issues:

- **Stage 1 (Lab demonstration)**
  - Economics (per LCCA spreadsheet) • $40-50/ton CO_2e levelized cost of carbon
  - Environmental (per Life Cycle Analysis (LCA) spreadsheet) • 98-99.5% methane conversion efficiency
  - 85-87% LCA CO_2e reduction
  - No adverse environmental impacts

- **Stage 2 (Systems-level solution in field/emulated-field setup)**
  - Economics (per LCCA spreadsheet) • $40/ton CO_2e levelized cost
  - Environmental (per LCA spreadsheet) • 99.5% methane conversion efficiency
  - 87% LCA CO_2e reduction
  - No adverse environmental impacts

Expected Technology Development

- Portfolio of technologies covers span of approaches; progressively more aggressive in nature

Complete aftertreatment system with **MOC (methane oxidation catalyst)**

→

Reducing methane ventilation through the **crankcase gas recirculation**

→

Plasma-based ignition system generates highly reactive intermediate species

→

Non-premixed, mixing-controlled combustion process through an actively fueled prechamber

→

Cylinder replacement to **reduce crevice volume** in engine combustion chambers

THANK YOU

Questions and Discussion:

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Expected Technology Development

- Portfolio of technologies covers span of approaches; progressively more aggressive in nature
  - **Crevice Volume (I)**
    - that will reduce methane slip by reducing the crevice volume in engine combustion chambers.
    - can be retrofitted to a fleet of existing engines with little to no increase in budgeted costs. Emissions of regulated pollutants such as carbon monoxide, volatile organic compounds, and formaldehyde will be reduced, while nitrogen oxides will stay the same.
  - **Catalyst (M)**
    - complete aftertreatment package system for existing lean- and ultra-lean burn natural gas (NG) engines used for power generation.
    - novel methane oxidation catalyst (MOC) formulation capable of high conversion efficiencies at the lower exhaust temperatures in ultra-lean burn engines
    - proposed MOC will use a hydrothermally stable formulation to promote high conversion efficiencies in low-temperature and high-water concentration environments.
  - **Crankcase**
    - technology to reduce methane emissions from lean-burn natural gas engines by reducing methane ventilation through the crankcase. Methane that leaks past the ring and valve seals during compression and combustion enters the crankcase and is usually vented to the atmosphere. The team proposes a system that would capture the crankcase methane, filter it, and reroute it back to the engine intake where it would be re-ingested and combusted
  - **Mixing (MQ)**
    - innovative combustion technology for lean-burn natural gas engines to potentially reduce the amount of methane slip – or methane in the inlet fuel stream that escapes to the atmosphere
    - The best way to reduce methane slip is to avoid premixing the fuel and intake air. The proposed system aims to achieve a non-premixed, mixing-controlled combustion process with natural gas in a lean-burn engine through an actively fueled prechamber. This system could be retrofitted to existing lean-burn engines or as a new engine technology.
  - **Plasma (T)**
    - develop a nanosecond non-thermal plasma-based ignition system capable of generating highly reactive intermediate species (i.e., “radical ions”) that result in rapid self-sustaining combustion, and a cyclic combustion control strategy that predicts and mitigates partial-fire and misfire cycles.
    - plasma ignition system and model-based, feedforward combustion control system that would be transformative for large NG engines