REMEDY Reducing Emissions of Methane Every Day of the Year

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What problem are we trying to solve?

- Reverse methane accumulation in atmosphere
  - Prevent methane emissions
  - Reduce methane emissions at source
  - Remove methane from air
- Decreasing atmospheric methane concentration is possible with 10-30% reduction in anthropogenic CH$_4$ emissions, due to natural methane sinks
- Addressing methane emissions complements CO$_2$ capture/sequestration programs, and may be faster/cheaper

Saunois, et al., Earth Syst. Sci. Data, 12, 1561–1623
Decreasing the Atmospheric Methane Inventory

REMEDY
Reducing Emissions of Methane Every Day of the Year

- Develop integrated systems that
  - Eliminate methane emissions
    - Oxidizing to CO₂ is acceptable
    - Capture for use or conversion to higher-value products is allowed, but not a focus
    - Must ensure no harmful products are produced (e.g., formaldehyde)
  - Quantify inlet and outlet methane fluxes
    - Needed for control, since many sources have variable methane flow rates and/or concentration
    - Required to quantify methane reductions in future carbon credit programs

- Seek flexible and robust processes
  - Many approaches will be required, given diversity of methane sources
  - Multi-step processes allowed
  - Need to define emission space where proposed technology could work

- Interested in novel biological, chemical, and/or mechanical approaches; equipment designs, and/or process configurations

- Economics predicated on carbon reduction, not making a salable product
Why is this hard?

- **Sources**
  - Millions of point sources; many diffuse sources (e.g., landfills)
  - Concentrations range over >4 orders of magnitude
    - Concentration of most sources below LEL – won’t “burn”
    - Ambient concentration 1.9 ppm; CO₂ 410 ppm
  - Flow rates range over >6 orders of magnitude
  - Concentration and/or flow rate can vary with time, esp for high-impact point sources

- **Methane chemistry**
  - Symmetric, and consequently stable, molecule
    - Activation energy 359 kJ/mol in air; heat of combustion 889 kJ/mol
    - Auto-ignition temperature 540 °C (theoretical), 600 °C (experimental) at ambient pressure;
      390 °C at 1100 bar
    - Flammable (explosive) limits 4.4% (LEL) – 17% (UEL) vol% in air

- **No “Silver Bullet”**
  - Wells/mines – millennium time scales, numerous subsurface geologies
  - Oxidation – Temperature; catalysts (photocatalysts, NEMCA effect); reactants (H₂, ethane, oxygen, ozone, hydroxyl radicals); mechanical designs (engines, flares, reactors); and combinations
  - Biology – consortia populations; nutrients; poisons; enzyme stabilization
Sources—Diverse and Numerous

- Many bottom up/top down studies
  - New and improved detection tools/quantification methods
  - “Super-emitters” following log-normal distributions
- Ruminants – 100 MM cattle
- Oil and gas examples
  - Sources across supply chain
    - “Orphaned” and leaking “plugged and abandoned” wells – 0.5-2MM
    - Gas-fired compressors – 30K
    - Methane slip from flares – >50K
- Coal – Operating and abandoned mines – >3K
- Landfills – >1000 operating; >5000 closed

Example Potential Approaches

*Not Intended to Limit or Direct*

- **Ruminants**
  - Novel genetics, nutrients, enteric consortia modification

- **Wells/mines**
  - New abandonment/plugging techniques; novel pliable, chemical resistant materials
  - Downhole biological intervention to prevent methane emissions

- **Post-combustion methane slip (gas-fired engines, flares)**
  - New hardware designs; recuperation; catalysts; additives

- **“Geo-engineering”**
  - Accelerate tropospheric reactions
  - Accelerate soil/methanotroph reactions
Evaluation Criteria

- Disruptive, transformative technologies
  - Novel biology, chemistry, mechanical approaches; not incremental advances
- Systems Engineering Solution
  - Core prevention/abatement technology
  - Integrated detection/quantification sensors/measurement protocol
  - Control system with feedback to the prevention/abatement technology
  - Measurement protocol consistent with carbon credit markets
- Team
  - Diverse and complementary skills
  - Commercialization plan, and ideally partner
- End goal
  - De-risk proposed system with relevant lab-scale, or ideally field test
Contacts/More information

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- Maruthi Devarakonda, Tech SETA, Booz Allen Hamilton, Support Contractor to ARPA-E maruthi.devarakonda@hq.doe.gov
- Link to October 20th workshop - https://arpa-e.energy.gov/events/preventing-abating-anthropogenic-methane-emissions-workshop
- Teaming Partner List – https://arpa-e-foa.energy.gov/#FoaId93b90253-21d8-414a-a110-0facd1518f83
- Contract questions - ARPA-E-CO@hq.doe.gov