ARPA-E Workshop
Methane Emissions Prevention and Abatement

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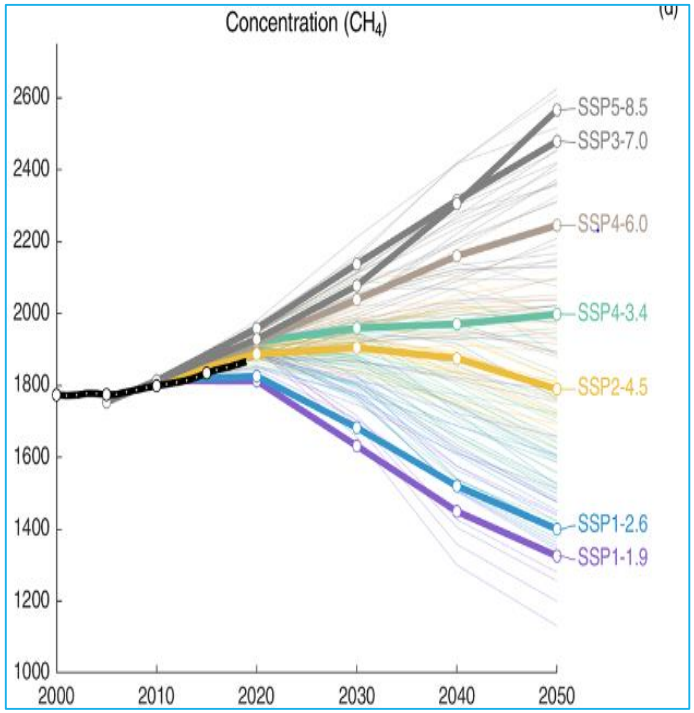
What problem are we trying to solve?

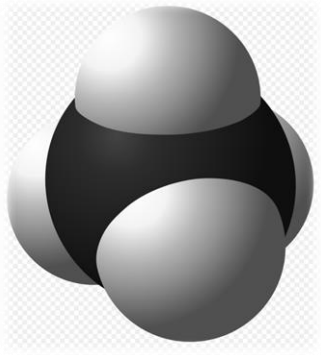
- Reverse anthropogenic methane accumulation in atmosphere
  - Prevent methane emissions
  - Reduce methane emissions at source
  - Remove methane from air
- Decreasing atmospheric methane concentration is possible with 10-30% reduction in anthropogenic CH_4 emissions, due to natural methane sinks
- Addressing methane emissions complements CO_2 capture/sequestration programs, and may be faster/cheaper



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

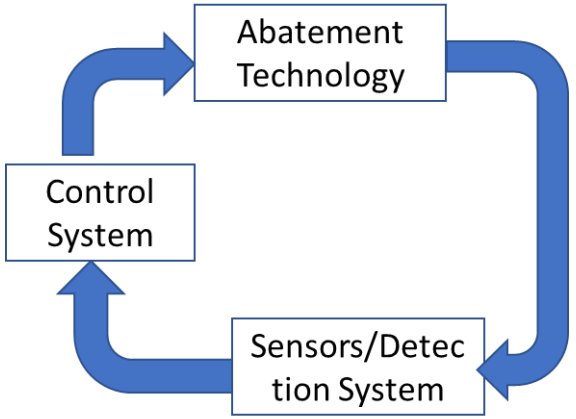
Why is this problem ARPA-E hard?

- Sources
  - Millions of point sources; thousands of 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
  - 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

- Seeking system-level 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



- No "Silver Bullet"
  - Diversity of sources will require diverse set of solutions
  - Which tools to take from the toolsbox?

Today's Goal: Refine the Problem Statement

- Need to identify if/where ARPA-E should invest
  - High impact
  - Transformative/Disruptive approach
  - Too risky for private sector
- Inputs
  - Conversations with industry and experts *(ongoing)*
  - Request for Information *(>40 responses)*
  - Workshop Breakout session discussions *(today)*
- Outputs
  - Program Director internal pitch focused on high ranking concepts, if any
  - Funding Opportunity Announcement, if approved

Example:
Biological approaches to methane mitigation

Sources (need to quantify)	Recent science/ technology advances	Advantages/ limitations	Unresolved issues/ Gaps	Integrated System requirements	Ideal team
Above ground point sources (leaky wells, feedlots, flares, AD effluent, etc.)	New biofilter designs Biomimic catalytic enzymes	Lower cost/only works for medium flows	Models indicate it could work, but it's never been tried	Core technology Ability to quantify reductions Control system/sensors	You People you know People you need to meet
Below ground point sources (inside wells & coal mines, landfills)	Recently isolated methanotrophs	High activity/undefined consortia requiremetns	Data for this idea in this application	Ability to quantify reductions	Someone you know People they know People they need to meet
Ambient mitigation in soil	New agricultural tilling practices	Piggyback on ag/ Viability on field	Promising short-term data, no long-term data	Control system/sensors	
Ambient mitigation in air	Concepts from direct air capture	Low opex/limited geographies			

- Impact - mass of sources; degree of methane reduction; cost
- Disruptive – new technologies or combinations; translated ideas from another sector
- Risk – what ideas do you have that no one will fund

Workshop Overview

- Morning Sessions: Sources
  - Breakouts by emission source types
  - Emission sources and characteristics
  - State-of-Art for preventing/abating emissions
  - Gaps: why hasn't the problem been solved?
  - What new approaches could be used?

- Afternoon Sessions: Tools
  - Breakouts by technical approaches
  - Biological, chemical/catalytic, mechanical, materials approaches
  - Combination of approaches should be considered!
  - Which emission sources could these approaches address?
  - Who/What/How Much will it take to build a system?

- Wrap-up/Happy Hour "fast pitch" and networking
  - Find a partner, or many!
  - Create a team