The LDAR Simulator
Flexible simulation of realistic LDAR programs

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Equivalence framework

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<th>Stage</th>
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<td>Field testing</td>
<td>Methods are independently evaluated at testing facilities</td>
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<td>Simulation modeling</td>
<td>An empirical leak simulator is used to estimate mitigation</td>
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<td>Piloting</td>
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<td>Full approval</td>
<td>Regulatory LDAR may be discontinued</td>
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Draft equivalence framework

**Stage**

1. **Field testing**
   - Methods are independently evaluated at testing facilities
   - Performance metrics established

2. **Simulation modeling**
   - An empirical leak simulator is used to estimate mitigation
   - Regulator grants probationary approval

3. **Piloting**
   - Program is implemented and validated in the field
   - Regulator grants full approval

**Why model?**

Simulation is fast, cheap, and reaches across space/time
LDAR-Sim is a flexible modeling framework

Real space, real time, real assets, real producers, real weather

Equivalence demonstration should not only answer: ‘Is it theoretically possible?’
Demonstration should also answer: ‘Is it practically possible?’

**LDAR effectiveness depends on context**
- Is my facility accessible by truck?
- Is this valley too cloudy for satellite?
- How many OGI cameras are available?
- Can we ignore the one facility far from the others?
What can LDAR-Sim do?

• Emissions mitigation equivalence
• Evaluate and compare policy and regulation
• Identify areas of research
• Estimate costs of programs or policies
• Estimate required cost/performance of new tech
• Produce geospatial visualizations of LDAR regions

• Multi-stakeholder interest and use (regulators, researchers, producers, technology developers, consultants, etc.)
How does LDAR-Sim work?

Multiple companies doing LDAR at once

Each able to deploy multiple agents (crews)

Build world
• Methods
• Agents
• Sites
• Leaks
• Program
How does LDAR-Sim work?

For each day of the simulation...

- Deploy screening methods
- Flag high-emitting sites for follow-up
- Deploy close-range methods
- Conduct repairs
- Tag leaks for repair
- Identify sites to visit
- Add new leaks

Build world
- Methods
- Agents
- Sites
- Leaks
- Program

Reporting
What has LDAR-Sim revealed?
Timing can matter more than sensitivity

Triannual surveys at 500 sites

Method 21 (high sensitivity, slower)

OGI (less sensitive, faster) ⇐ lower emissions!!
Screening follow-up protocols affect outcomes

**Protocol 1:**

Choose a constant threshold. Always follow up when emissions are above that value.

*e.g. all facilities emitting over 5 kg/hour*

**Protocol 2:**

Choose a percentage highest emitting facilities to receive follow-up, even if emissions are low.

*e.g. top 5% of highest emitting facilities*
Protocol 1: Strict threshold

Protocol 2: Top emitters

Screening follow-up protocols affect outcomes
Facility-scale screening can be expensive... 
... especially when venting is present!

Cost at equivalence with **annual** OGI

- Truck program costs
- Aircraft program costs

Follow-up surveys required to achieve equivalence

Annual OGI: $547

Facility-scale screening can be expensive, especially when venting is present!
Sensitivity depends on program and unknowns

Program 1: OGI
- Max precipitation
- Max wind
- Detection limit
- Min survey interval
- Min temperature
- Number of crews
- Reporting delay
- Required surveys
- Survey time

Program 2: MGL
- Follow-up ratio
- Follow-up threshold
- Max precipitation
- Max wind
- Detection limit
- Min survey interval
- Min temperature
- Number of crews
- Reporting delay
- Required surveys
- Survey time

Global parameters

Program
- Max workday
- Time offsite (O)
- Time offsite (S)
- Repair delay
- Leak counts (O)
- Leak counts (S)
- Leak production rate
- Leak rates (O)
- Leak rates (S)

Binary
- Daylight
- Operator
- Venting

Conditional
- Operator bonus
- Operator strength
- Site rates (O)
- Site rates (S)
Final notes & take-aways

• Emerging hypotheses
  • Context is essential; No solution is universal
  • Explicit equivalence targets can improve clarity
  • Vented emissions may be a big problem under current regs
  • Screening + follow-up (two-visit programs) can be expensive

• Many large uncertainties remain
  • Areas of research: leak lifecycle, method performance in context
  • More data is needed! Enable producers to share anonymously?

LDAR-Sim going public soon... use it and be in touch!