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Quantifying Fugitive Methane Emissions from Biodigesters

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Methane to Markets
NEW DELHI, INDIA
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Canada

Agricultural biogas around the world

Country	# of Digesters
Austria	350
Denmark	75
Finland	6
France	4
Germany	3,750
Italy	120
Netherlands	64
Sweden	8
Switzerland	81
United Kingdom	31
Total	4,489

Source: www.iea-biogas.net

Mostly small-scale family or community biogas production for cooking fuel

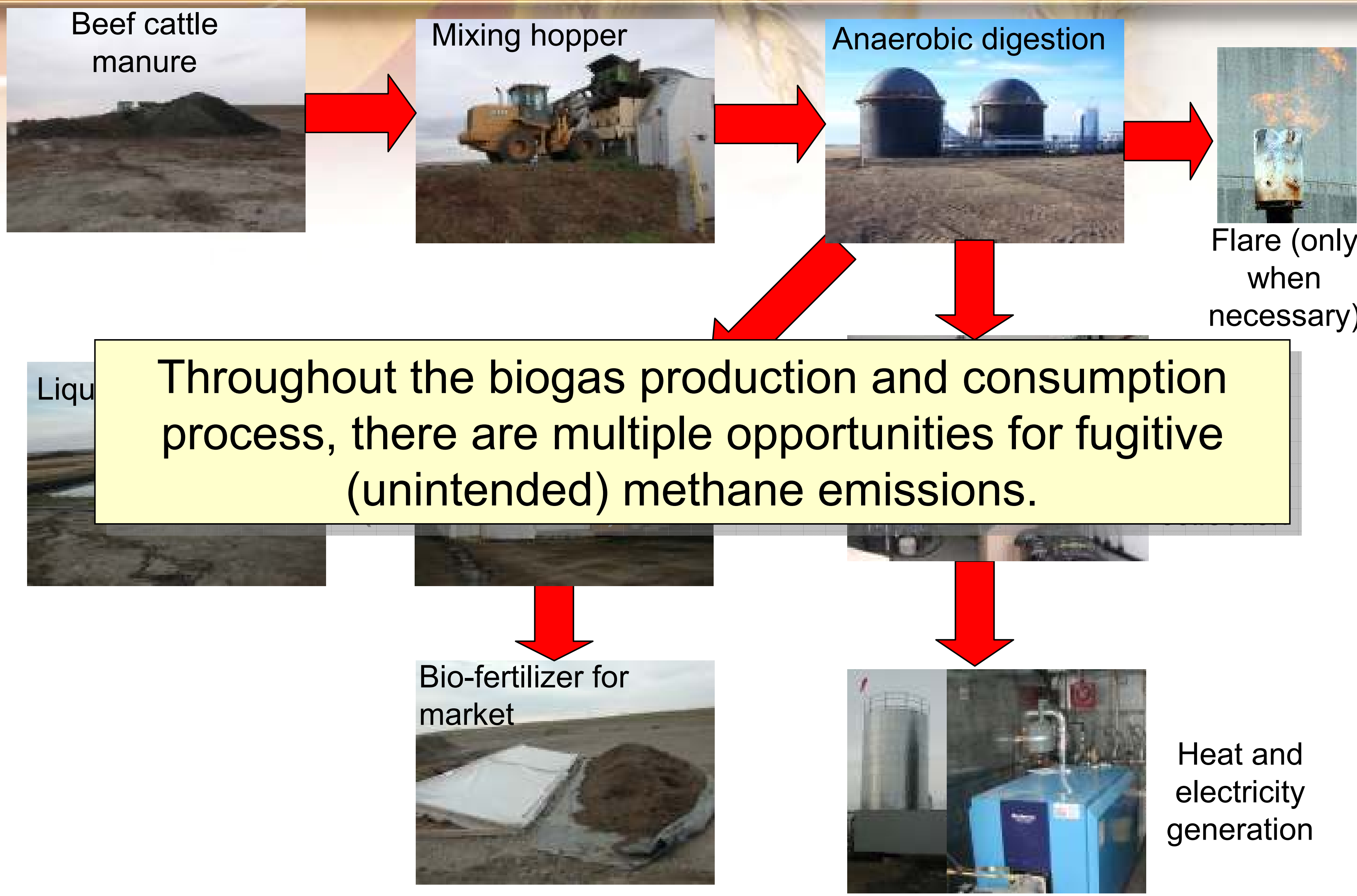
Examples of Biodigesters in Canada

Approximately 16 large-scale biodigesters currently operational in Canada

Integrated Manure Utilization System (IMUS) Biogas Plant

- 1 MW generating capacity
- Manure feedstock from 36,000 head feedlot
- 100 tonnes manure consumed daily (20% of feedlot manure)
- Anaerobic digestion in two concrete tanks
- Internal temperature maintained at 55° C
- 5% new manure added daily -- 5% removed
- Removed digestate separated – liquid to lagoon, solid as fertilizer

The Integrated Manure Utilization System



Throughout the biogas production and consumption process, there are multiple opportunities for fugitive (unintended) methane emissions.

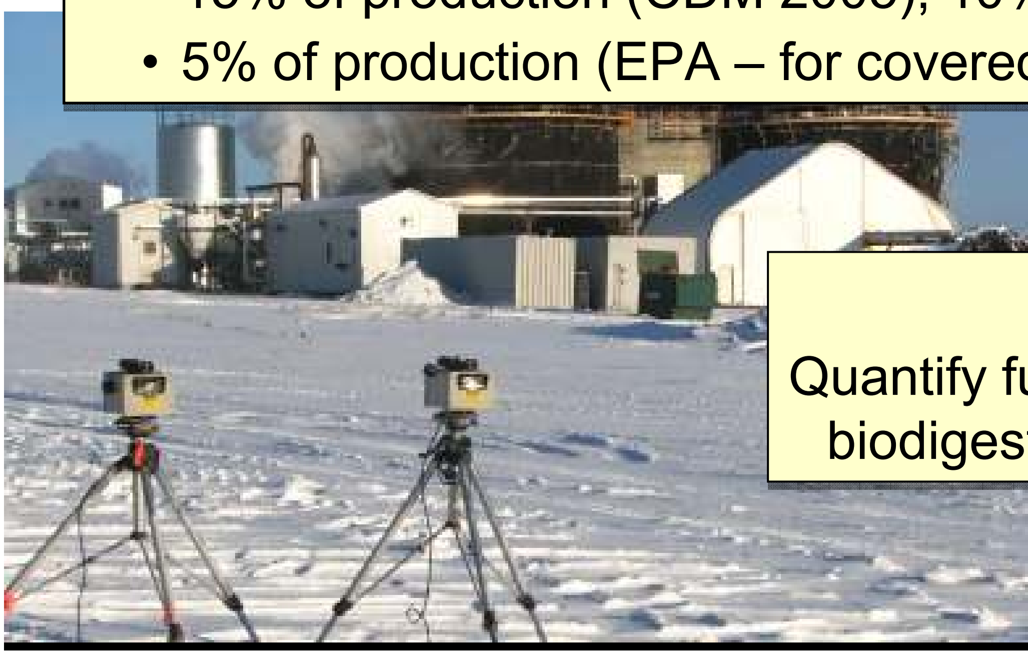
IMUS Biogas Plant Site

Quantifying Fugitive Emissions from Biodigesters

Background

Agricultural biodigesters reduce greenhouse gas (GHG) emissions & generate clean energy. GHG reduction depends on many factors (design, feedstock, etc.), including the amount of fugitive CH_4 emissions. Quantifying fugitive emissions is difficult -- commonly assumed:

- 15% of total CH_4 production (California Climate Action Registry)
- 15% of production (CDM 2005); 10% of production (IPCC 2006)
- 5% of production (EPA – for covered anaerobic lagoons)



Study Objective

Quantify fugitive emissions from a modern biodigester in western Canada

Why are fugitive methane emissions important?

Fugitive methane emissions from biodigestion represents:

•A loss of potential energy, heat and income in the biodigestion process

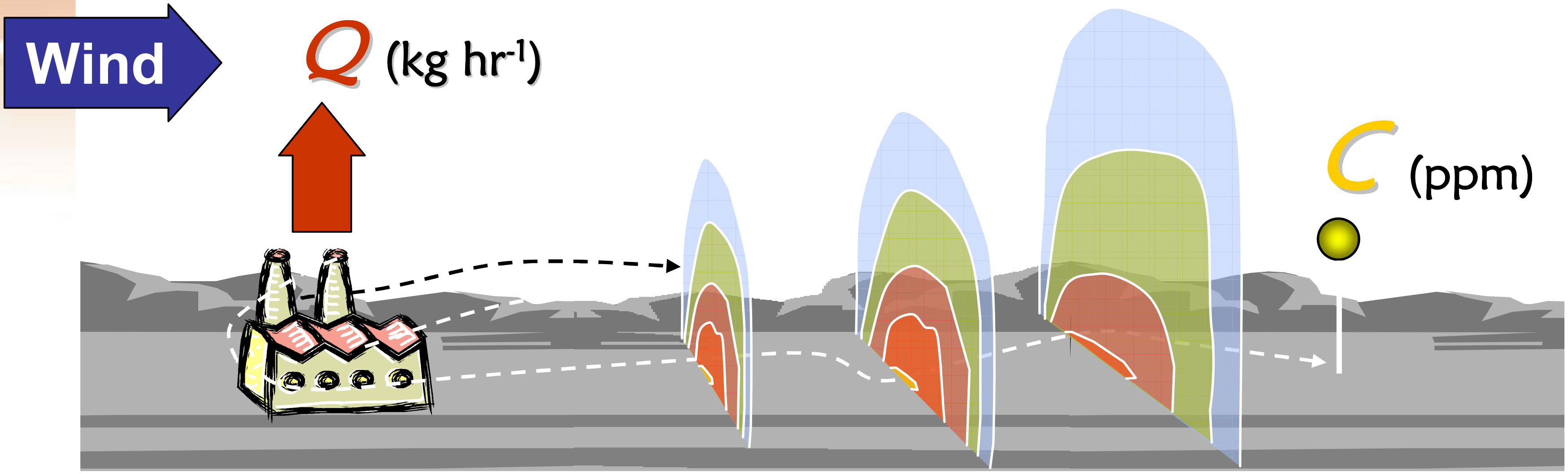
•A negativ … high global wa…

How can we evaluate fugitive emissions from the whole biodigestion system and how can we identify emissions 'hotspots'?

Fugitive m… been estimated to range from 2-15% of biogas production, depending on plant efficiency.

Minimization of fugitive emissions can maximize energy, heat and income, while minimizing environmental impact.

bLS Inverse Dispersion Technique



- Atmospheric dispersion model relates downwind concentration *C* to emission rate *Q* for prevailing winds
- Measurement of *C* then infers *Q*

Advantages

+ simple measurements
+ remote measurement
+ no restrictions on source geometry
+ no management disruption

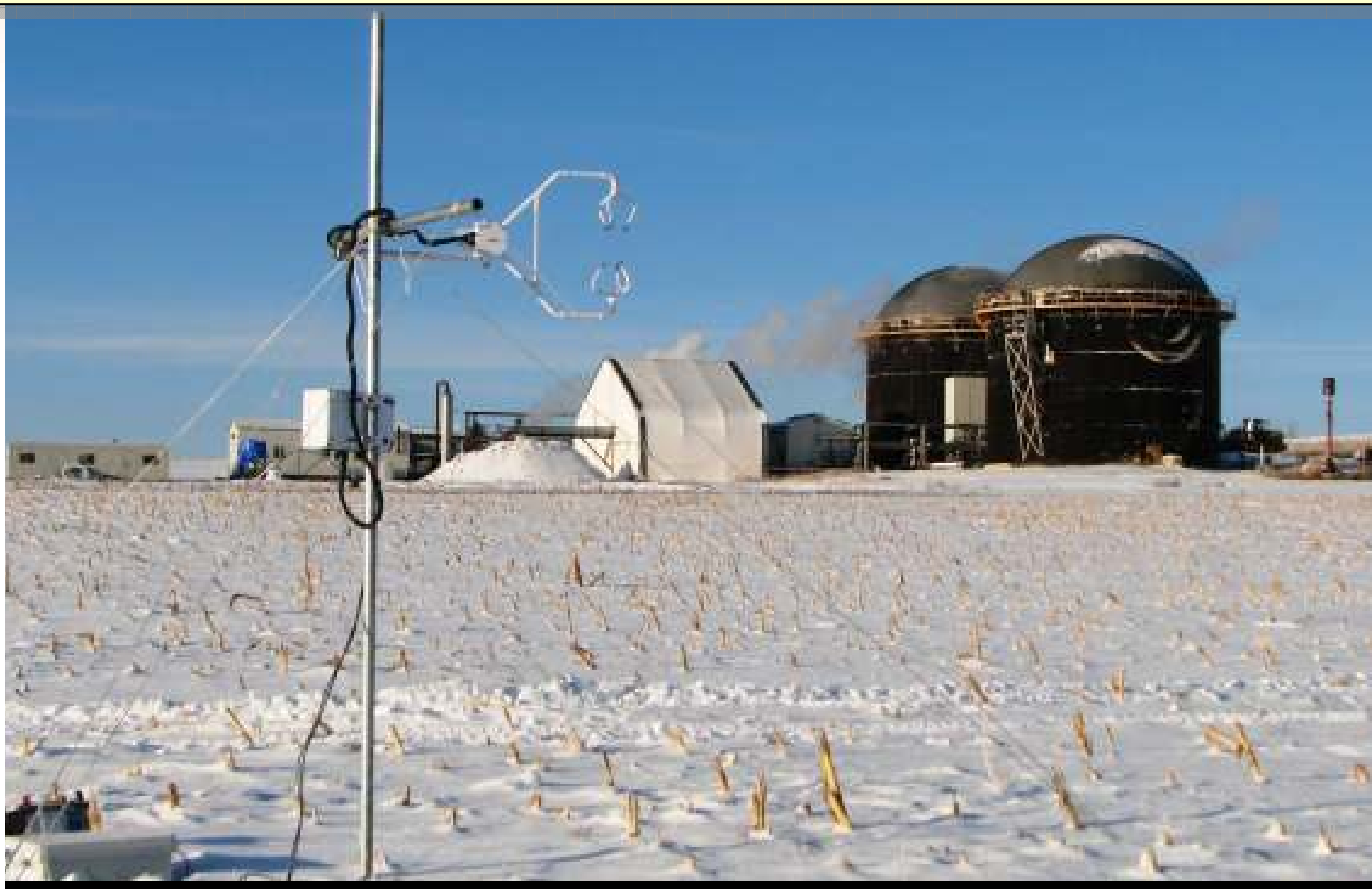
Measuring Methane

5-300 m

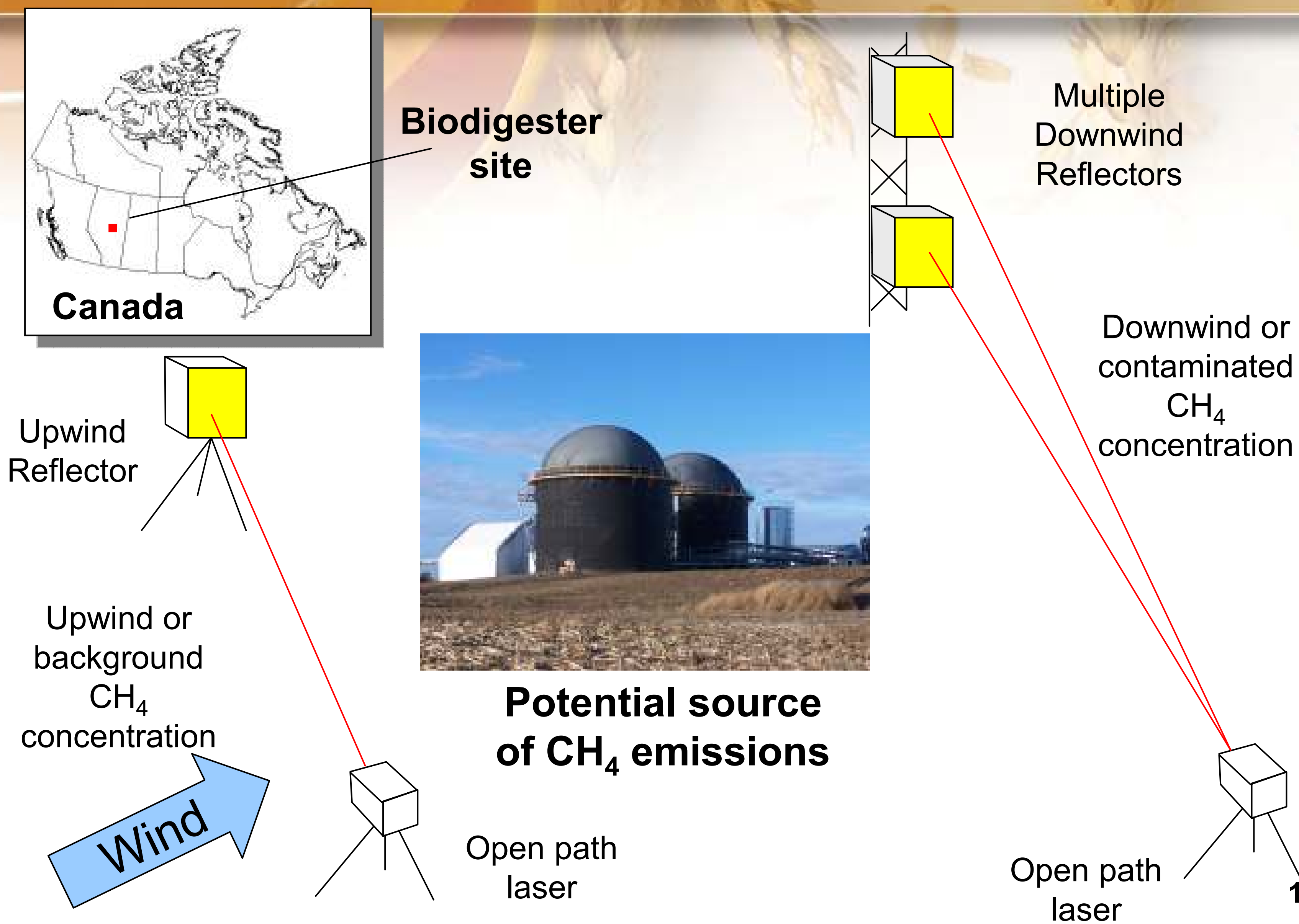
- Open path lasers: laser <-----> reflector

Wind Measurement

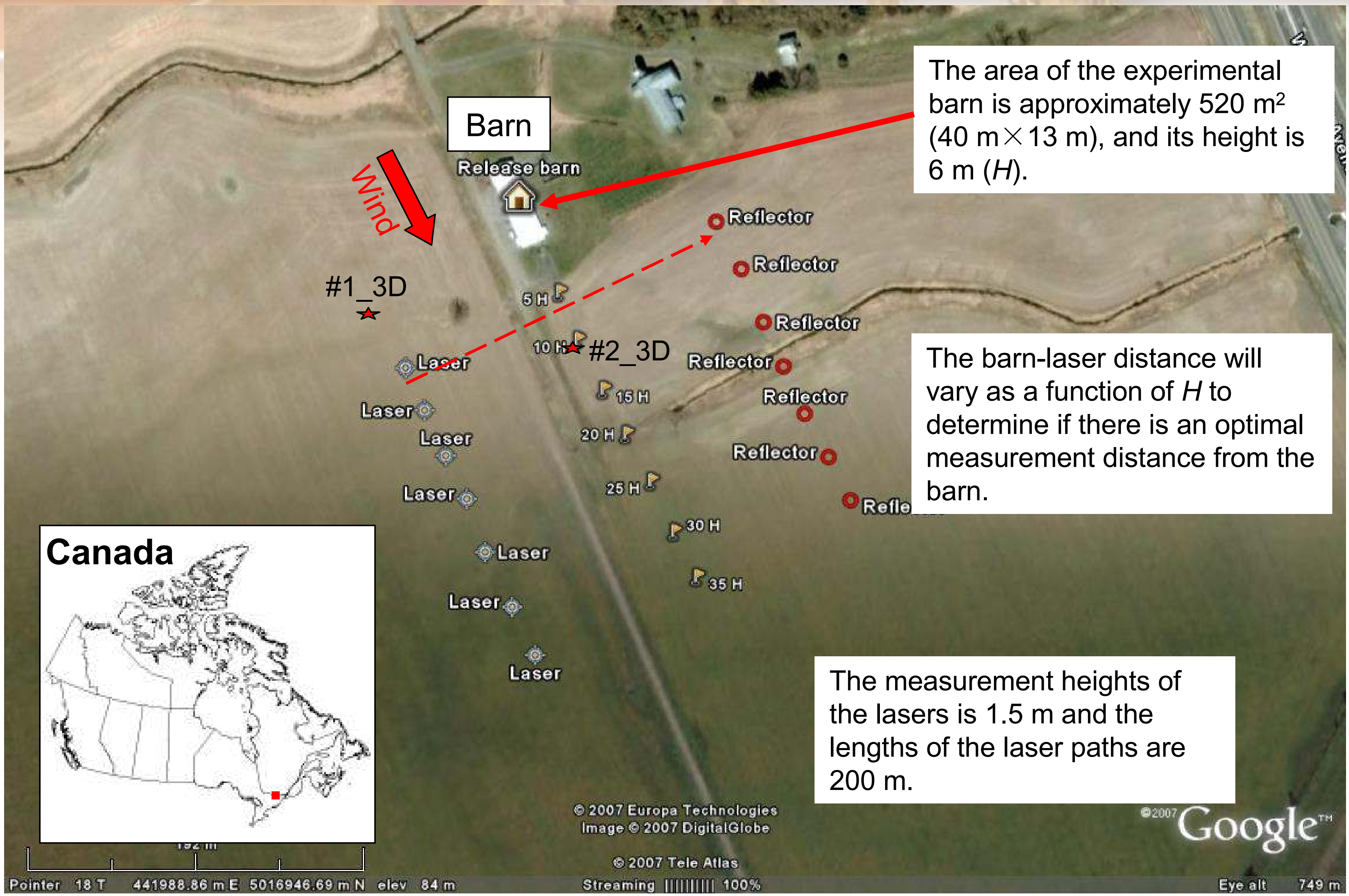
- 3-D Sonic Anemometer
- Gives the average windspeed, direction, and turbulence



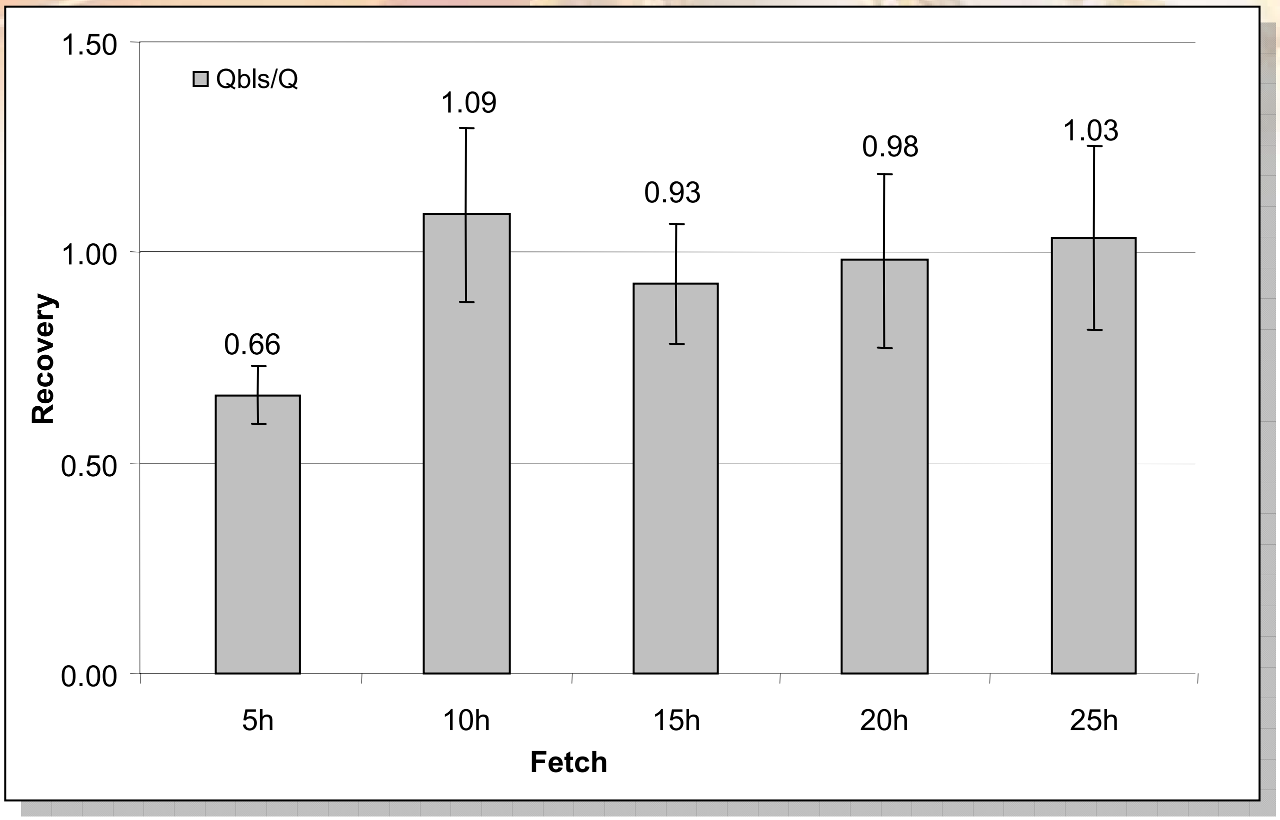
Experimental Set-up to Measure Fugitive CH_4 Emissions



Estimating CH_4 emissions from synthetic barn release



Preliminary results of barn release in 2008



The flux rates from the barn were 60 L/min (140 dairy cows) and 80 L/min.

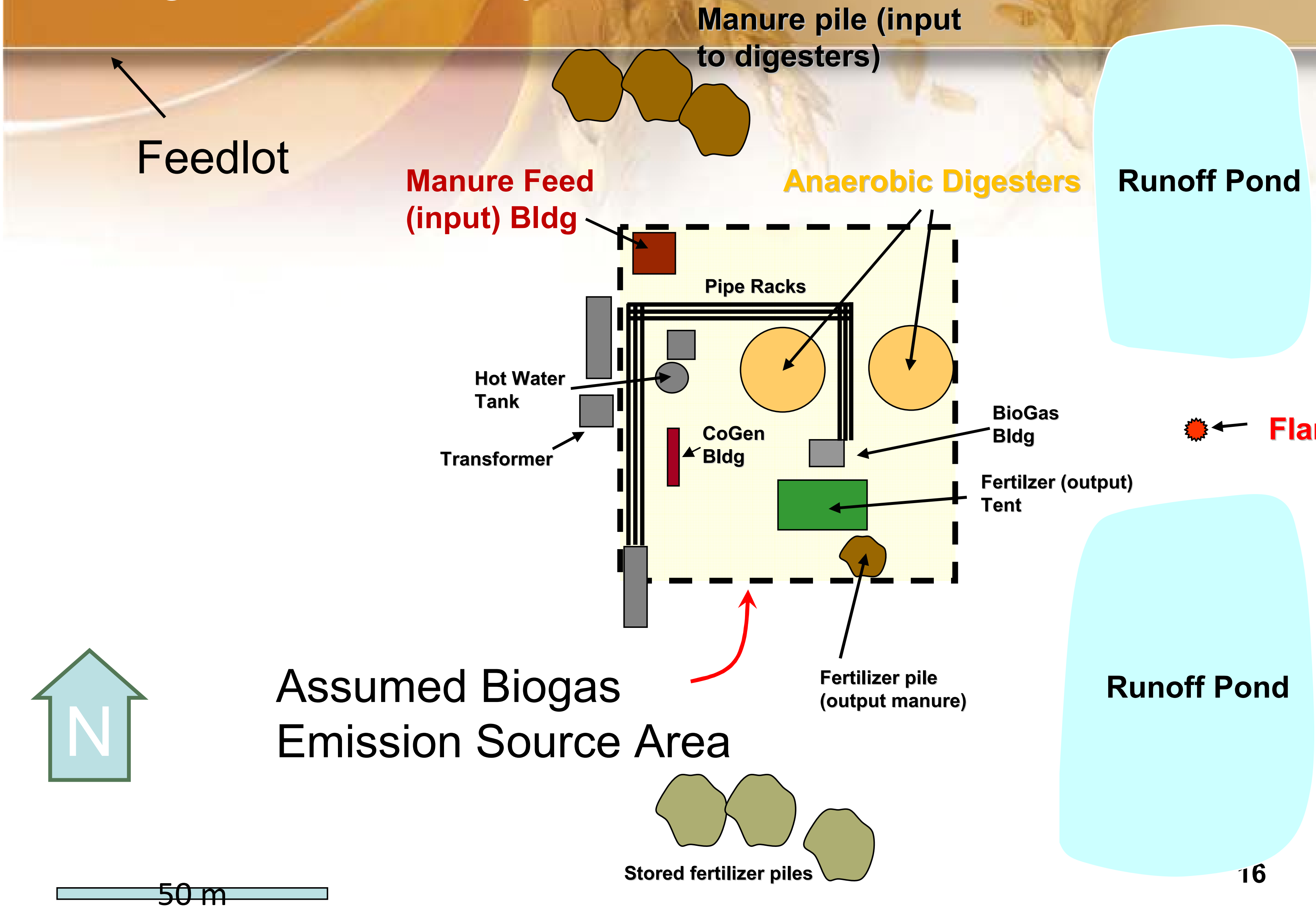
The criteria of the model for u_*, L and z_0 were met.

The barn height h was 6 m.

Use of CH_4 as a tracer gas to validate the bLS technique

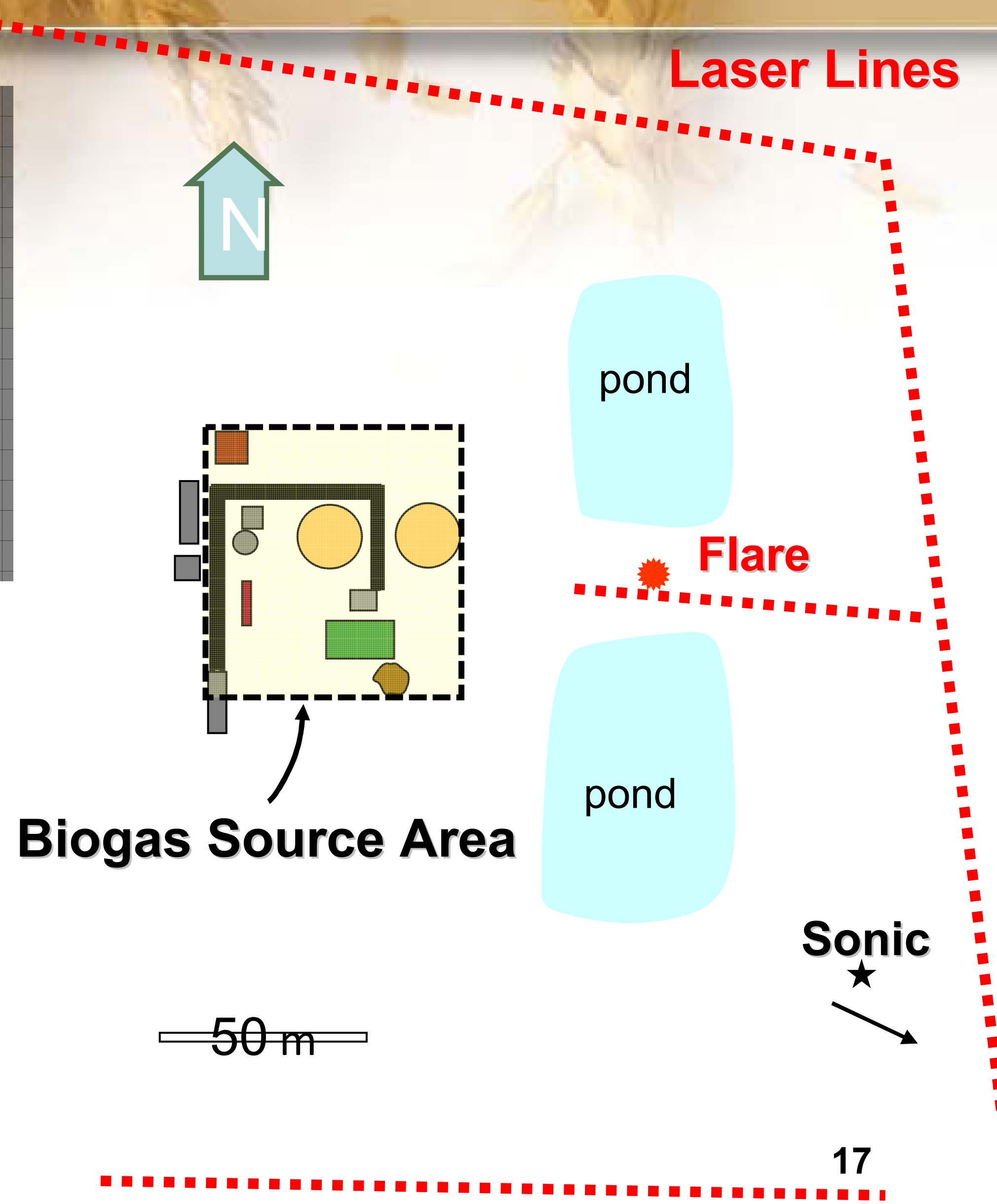
% Recovery of Released CH_4 15 min mean +/- SD	Site Characteristics	Reference
102 ±22	Grass, no obstructions	Flesch et al (2004)
98 ± 20	Grass, obstructions (M>5h from obstructions)	Flesch et al (2005)
107 ± 13	Grass, no obstruction	Harper et al (2006)
106 ± 16	Grass, no obstructions	McBain and Desjardins (2005)
99 ± 20	Grass, obstructions (M>10h from obstructions)	McBain and Desjardins (2005)
86 ± 17	Whole-farm dairy (M>9h from obstructions)	McGinn et al (2006)
102 ±25	Grass, no obstructions	Gao et al (2007)
104 ±29	Grass, no obstructions	Gao et al (2008)

Biodigester Plant Layout

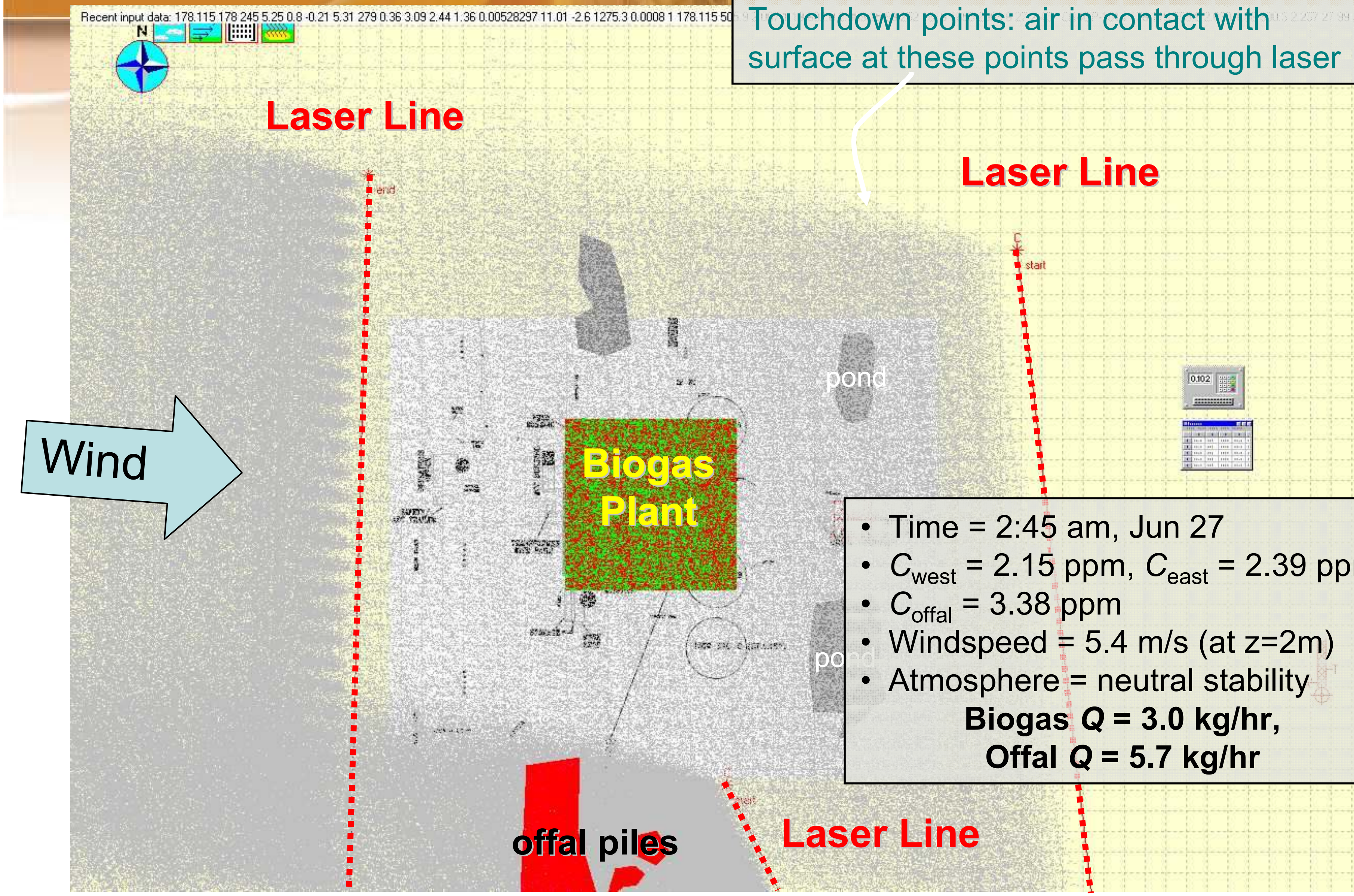


Measurement Layout (Fall 2008)

- Lasers positioned for upwind & downwind CH_4 measurement
- Lasers moved as wind direction changed
- Sonic measured ambient winds
- Estimated pond emissions
- Measurements over 6 days



bLS Dispersion Model – one 15 min interval

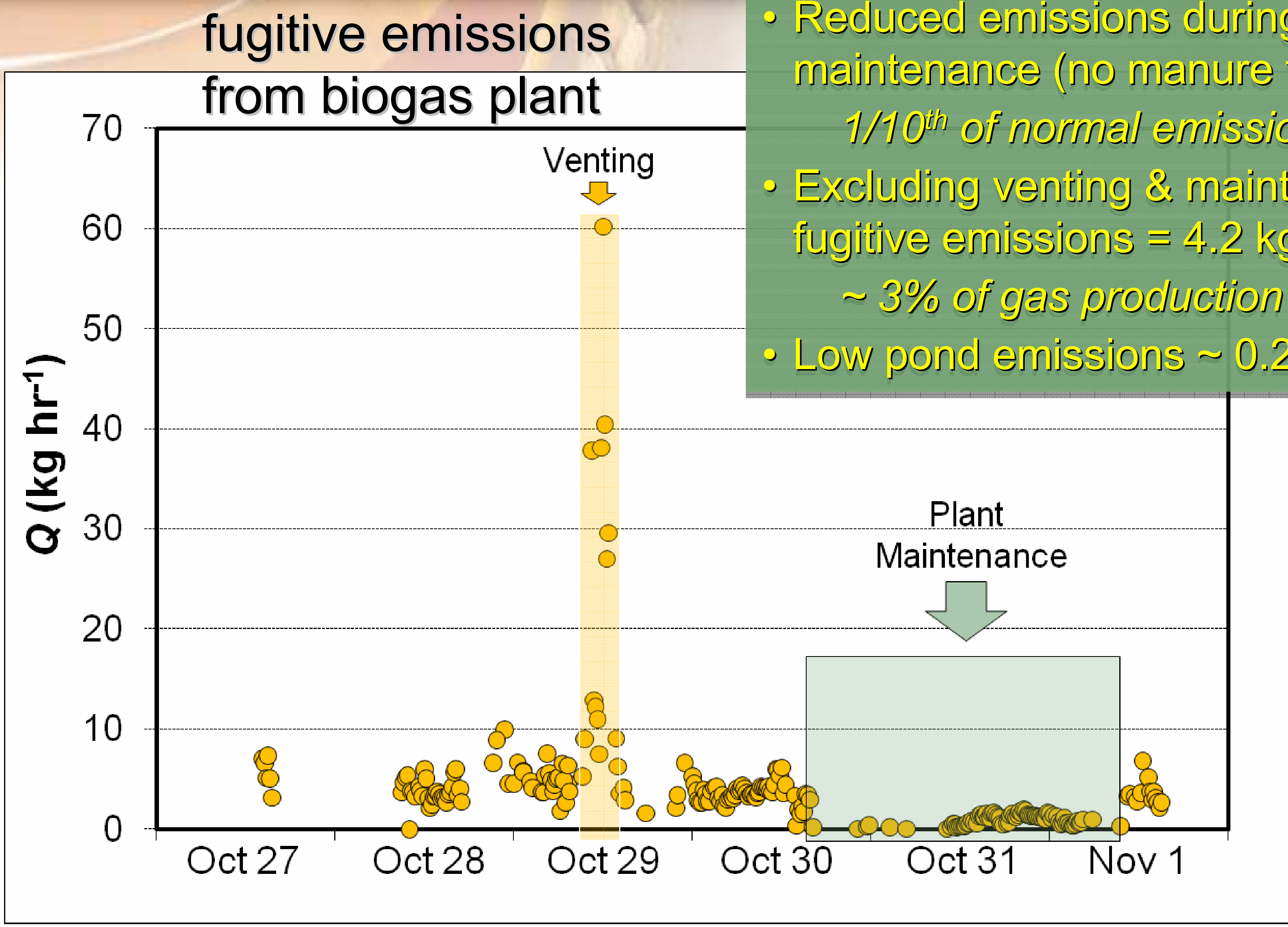


Touchdown points: air in contact with surface at these points pass through laser

- Time = 2:45 am, Jun 27
- C_{west} = 2.15 ppm, C_{east} = 2.39 ppm
- C_{offal} = 3.38 ppm
- Windspeed = 5.4 m/s (at z=2m)
- Atmosphere = neutral stability

Biogas *Q* = 3.0 kg/hr,
Offal *Q* = 5.7 kg/hr

Fall Emissions:

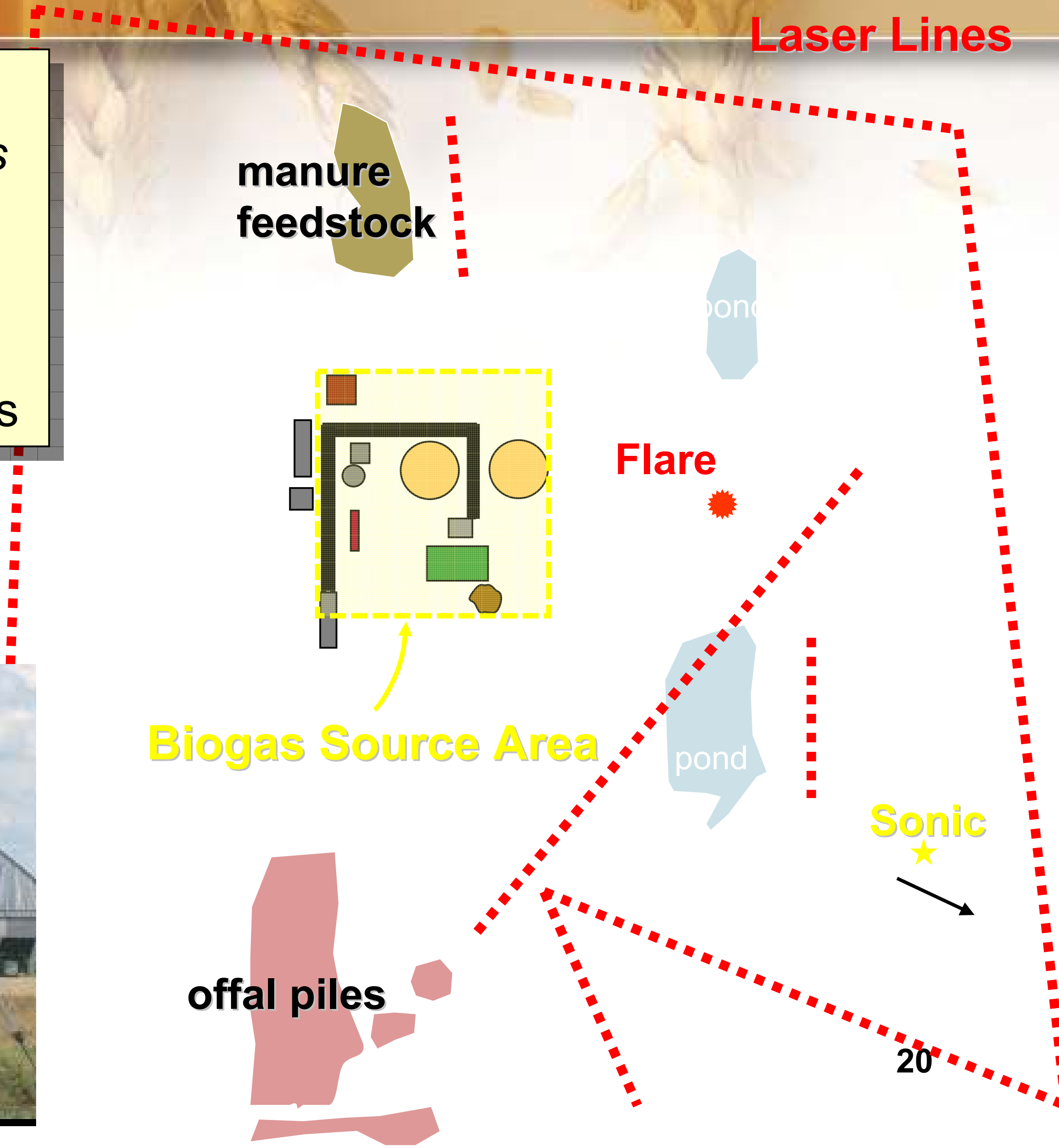


Highlights

- Dramatic venting (→ 60 kg/hr)
- Reduced emissions during maintenance (no manure feeding)
  - *1/10th of normal emissions*
- Excluding venting & maintenance: fugitive emissions = 4.2 kg/hr
  - *~ 3% of gas production*
- Low pond emissions ~ 0.2 kg/hr

Measurement Layout (Summer 2009)

- More laser positions:
  - *biogas plant emissions*
  - *pond emissions*
  - *feedstock emissions*
  - *offal emissions*
- Measurements over 7 days



Summer Emissions:

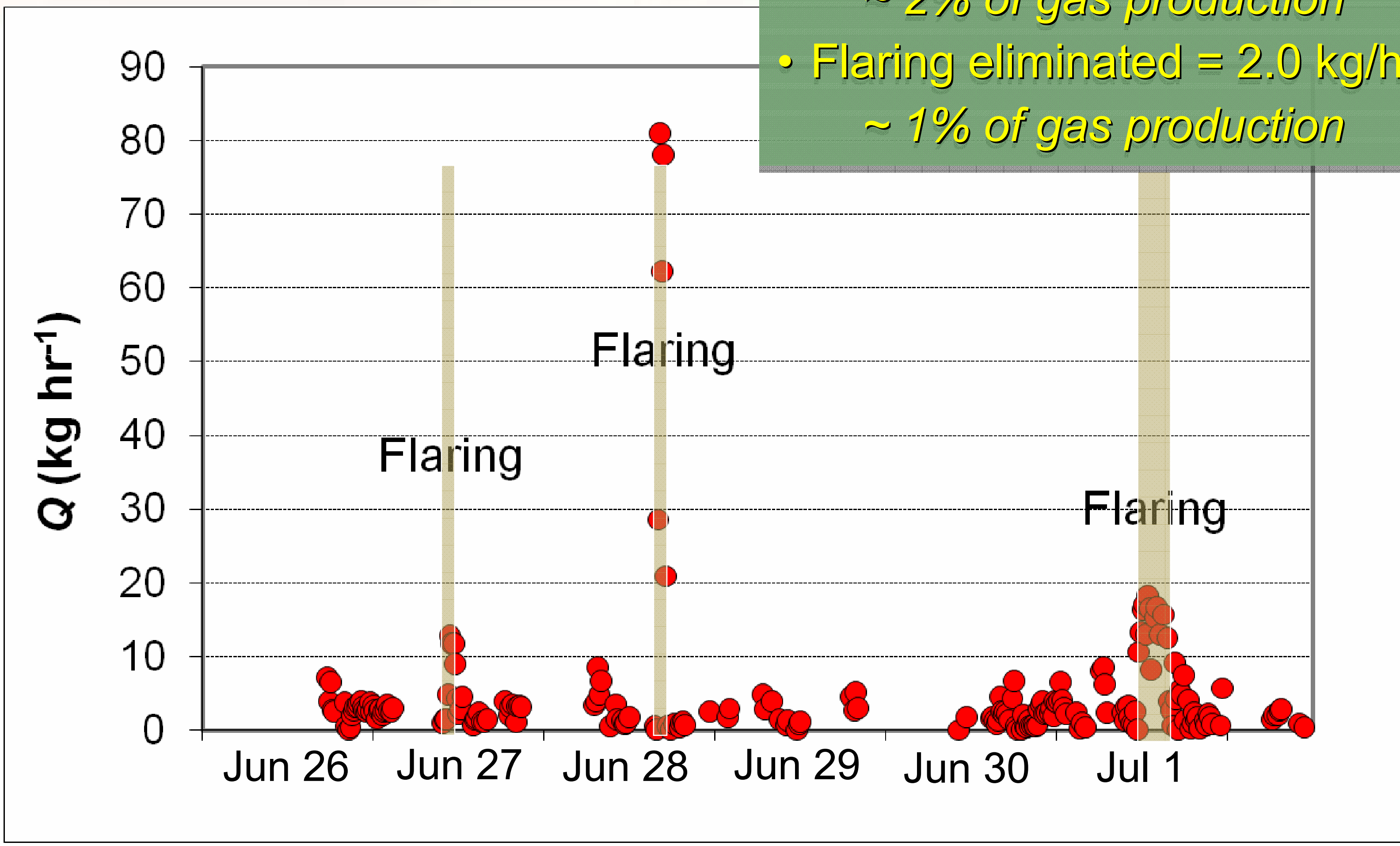
fugitive emissions from biogas plant

Highlights

- High flaring emissions (→80 kg/hr)
- Large variability with time (due to irregular manure feeding?)
- Ave fugitive emissions = 4.0 kg/hr

  ~ 2% of gas production
- Flaring eliminated = 2.0 kg/hr

  ~ 1% of gas production



Observations:

Flare not efficient at burning-off methane in biogas. Flaring occurs when gas cannot be used for electrical generation. Enhanced emissions during flaring is evidence of inefficiency. We estimate flare burning efficiencies as low as 50%.

Manure "hopper" main source of fugitive methane (excluding flare). Manure enters biogas plant at hopper -- warm water mixed with manure & open to air. Suggests reduction in emissions when hopper redesigned to better seal (negative pressure).

Observations:

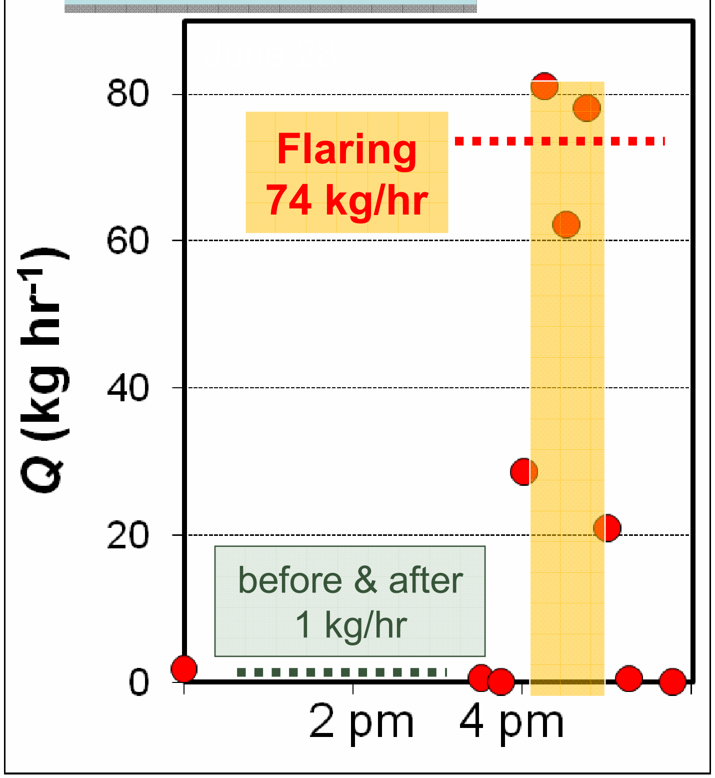
On-site runoff ponds & manure feedstock were minor methane sources. Measurements from runoff pond and feedstock pile indicate they give ~ 10% of fugitive biogas plant emissions. But main effluent pond is off-site (not measured).

In summer stored offal was major methane source. In summer offal (waste from animal slaughter) was stored prior to use as feedstock. This created a CH_4 source equal to the biogas plant.

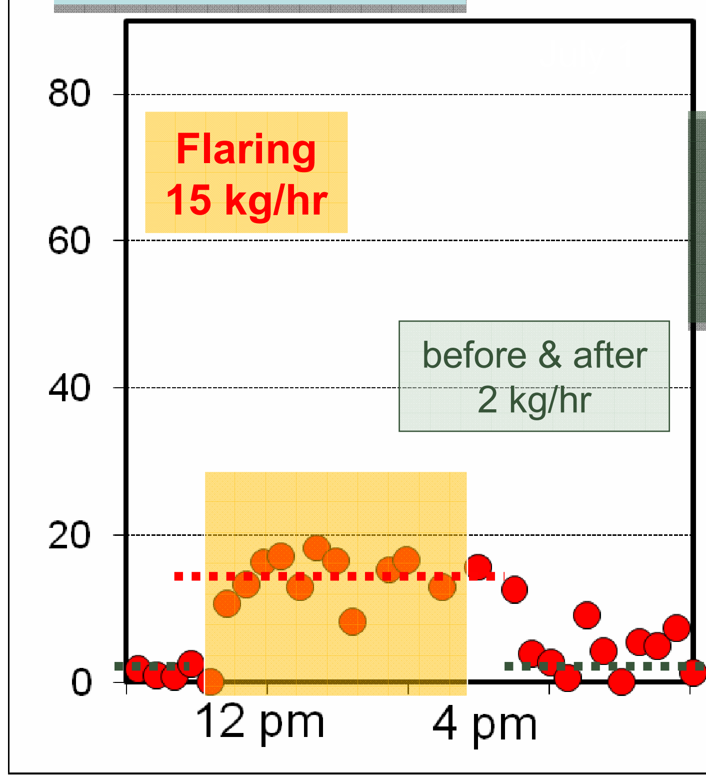
Emissions During Flaring

Gas production during summer was 150 kg CH_4/hr. During flaring we assume production was vented and burned.

Burn Efficiency: 50%



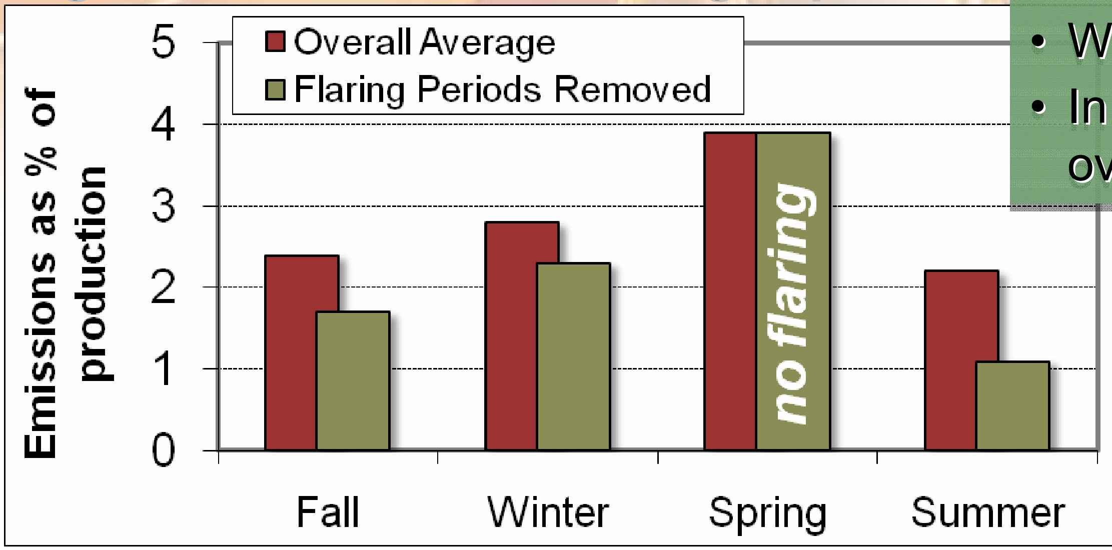
Burn Efficiency: 90%



Flare less efficient than expected

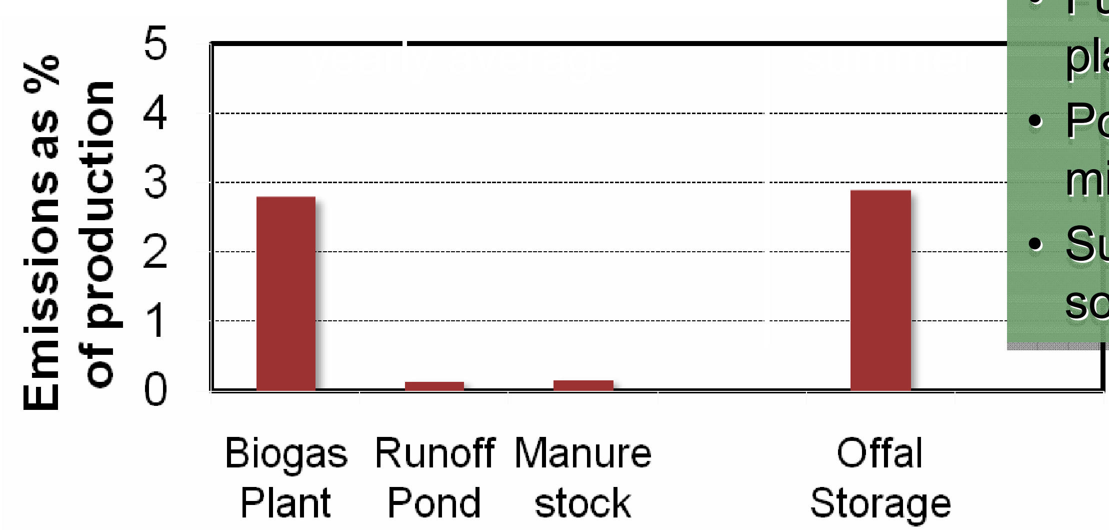
Summary:

- fugitive emissions from biogas plant



- Average = 2.8% of production
- With flaring removed ... 2.3%
- In summer -- flaring doubles overall emissions

- all observed emission sources



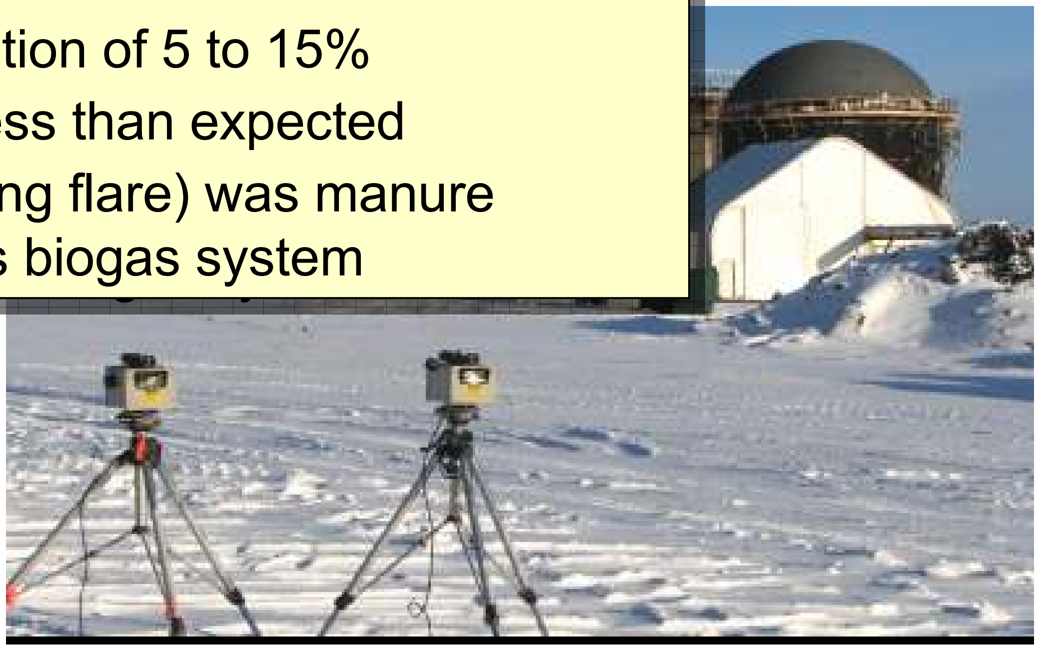
- Fugitive emissions from biogas plant is major source
- Ponds & manure stockpile minor sources
- Summer exception: offal is large source

Conclusions

bLS technique practical for calculating emissions:

- Limited field equipment
- One-man operation
- Can look at different sources at site

- Fugitive emissions 2.8% of total CH_4 production
  - Yearly average
  - Includes periods of flaring & maintenance
  - Lower than typical assumption of 5 to 15%
- Flaring efficiency variable & less than expected
- Main emission source (excluding flare) was manure hopper – where manure enters biogas system



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