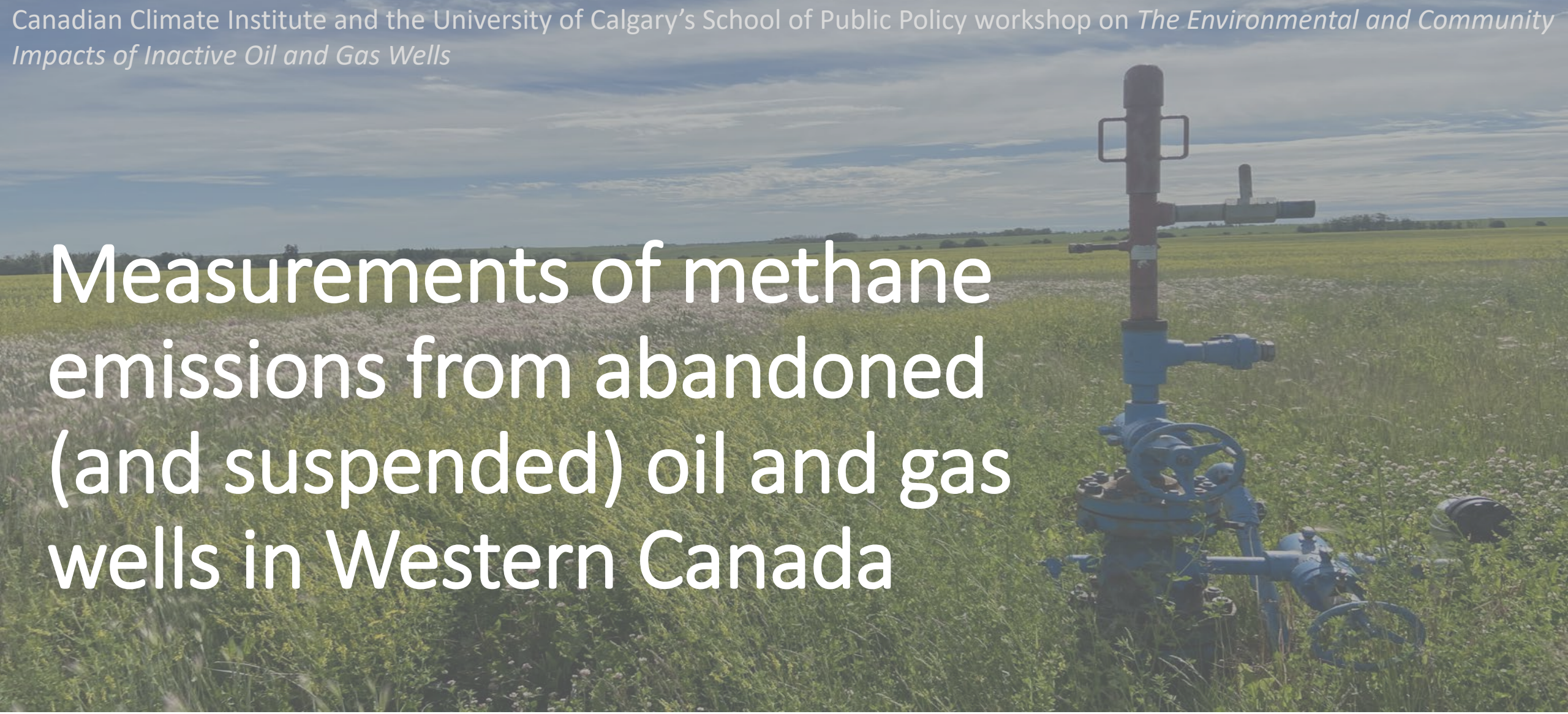
Canadian Climate Institute and the University of Calgary's School of Public Policy workshop on *The Environmental and Community Impacts of Inactive Oil and Gas Wells*



Measurements of methane emissions from abandoned (and suspended) oil and gas wells in Western Canada

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March 31, 2023

McGill

Overview

- Introduction
  - Definitions of abandoned oil and gas wells
  - Surface casing vent flow and gas migration
  - Number and distribution of wells
- Methane emissions
  - National estimates, Geographical variations, High emitters
- Upcoming June 2023 field campaign
- Other environmental impacts

Definition of “abandoned oil and gas wells” varies among states/provinces/territories

The definition by the U.S. Environmental Protection Agency in the U.S. Greenhouse Gas Inventory (2019):

The term "abandoned wells" encompasses various types of wells:

- *Wells with no recent production, and not plugged. Common terms (such as those used in state databases) might include: inactive, temporarily abandoned, shut-in, dormant, and idle.*
- *Wells with no recent production and no responsible operator. Common terms might include: orphaned, deserted, long-term idle, and abandoned.*
- *Wells that have been plugged to prevent migration of gas or fluids.*

Well status definitions

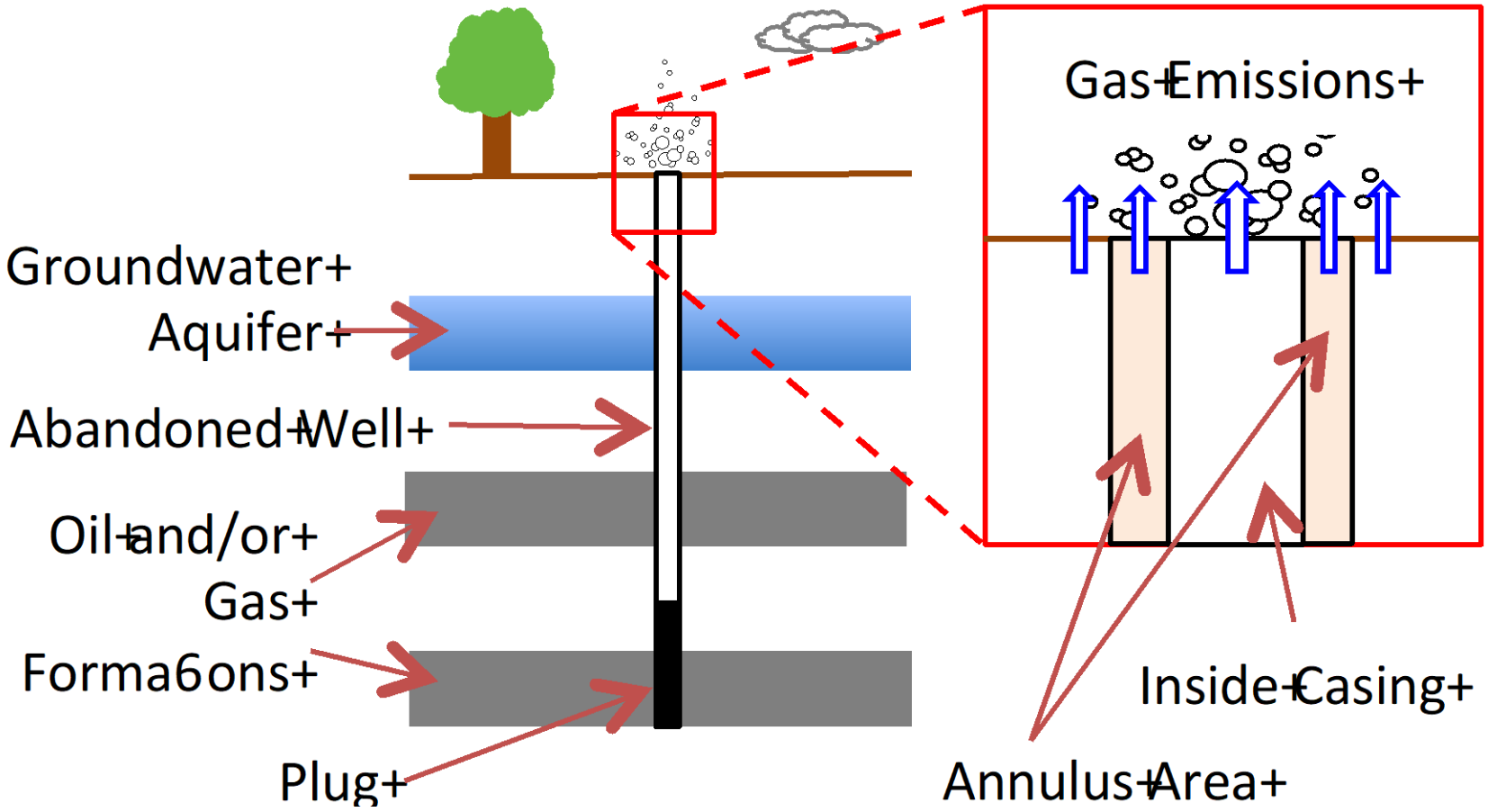
Alberta (Directive 013) [11]

- **Inactive well:** *An inactive well is defined as follows:*
  - *Critical sour wells (perforated or not) that have not reported any type of volumetric activity (production, injection, or disposal) for six consecutive months.*
  - *All other wells that have not reported any type of volumetric activity (production, injection, or disposal) for 12 consecutive months.*
- **Suspended well:** *A well whose initial suspension has been completed and reported as per Directive 013 requirements.*
- **Abandoned well:** *A well that has been downhole abandoned, surface abandoned and the well license status is "abandoned."*

Saskatchewan (Directive PNG015) [12]

- **Downhole Abandonment:** *When all wellbores and completions are permanently plugged in accordance with this Directive.*
- **Wellbore Abandonment:** *When a wellbore is permanently plugged to prevent migration of fluids within the stratigraphic units and the wellbore. "Wellbore abandonment" is only relevant in relation to multi-bore horizontal wells. If the wellbore abandonment results in all wellbores being abandoned, then the operation is a downhole abandonment.*

Abandoned oil and gas wells: methane emissions and groundwater contamination



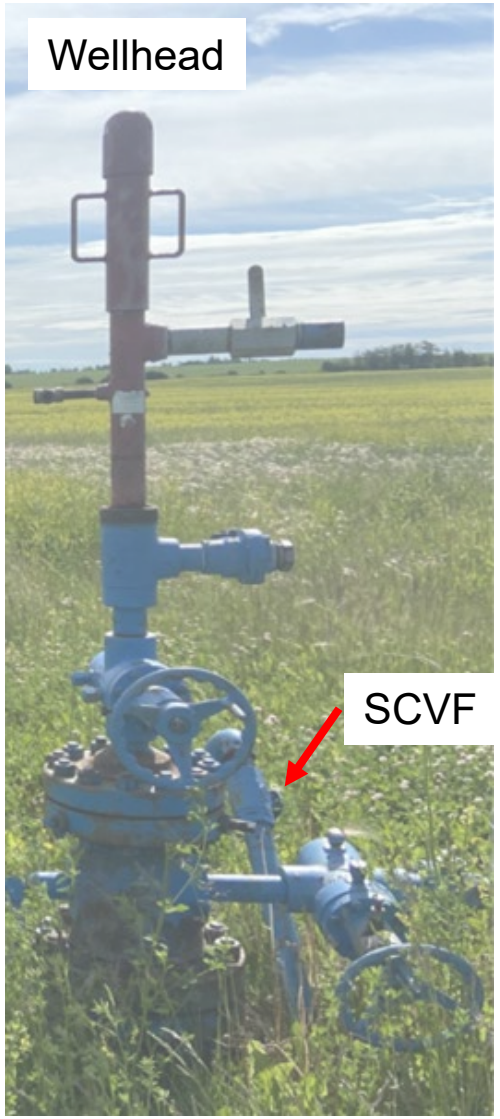
Kang *et al.* (2015)

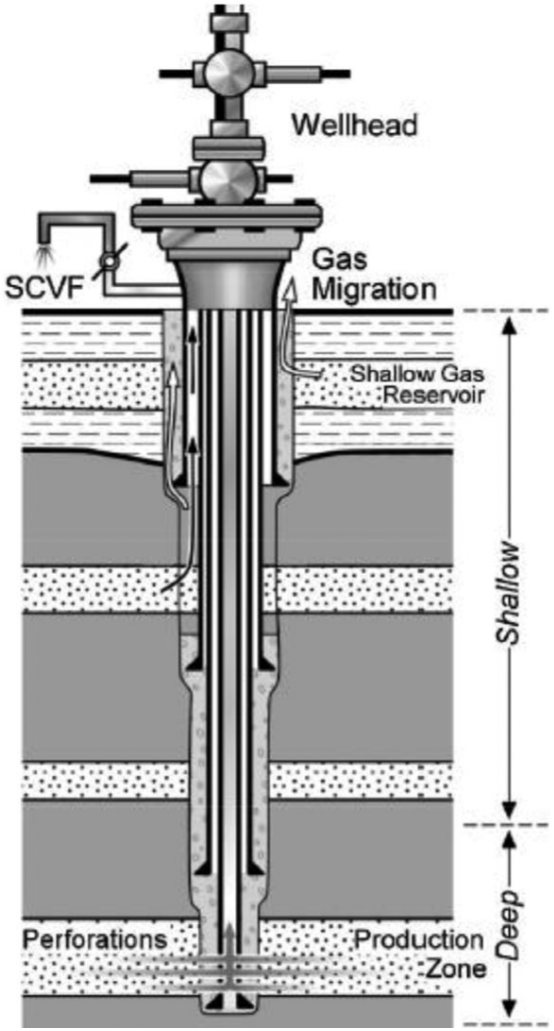
Surface Casing Vent Flow and Gas Migration

Definitions (Directive PNG015) [12]

- **Surface Casing Vent Flow (SCVF):** Refers to the surface release of fluids and/or gas in any combination or volume between the production casing and surface casing.

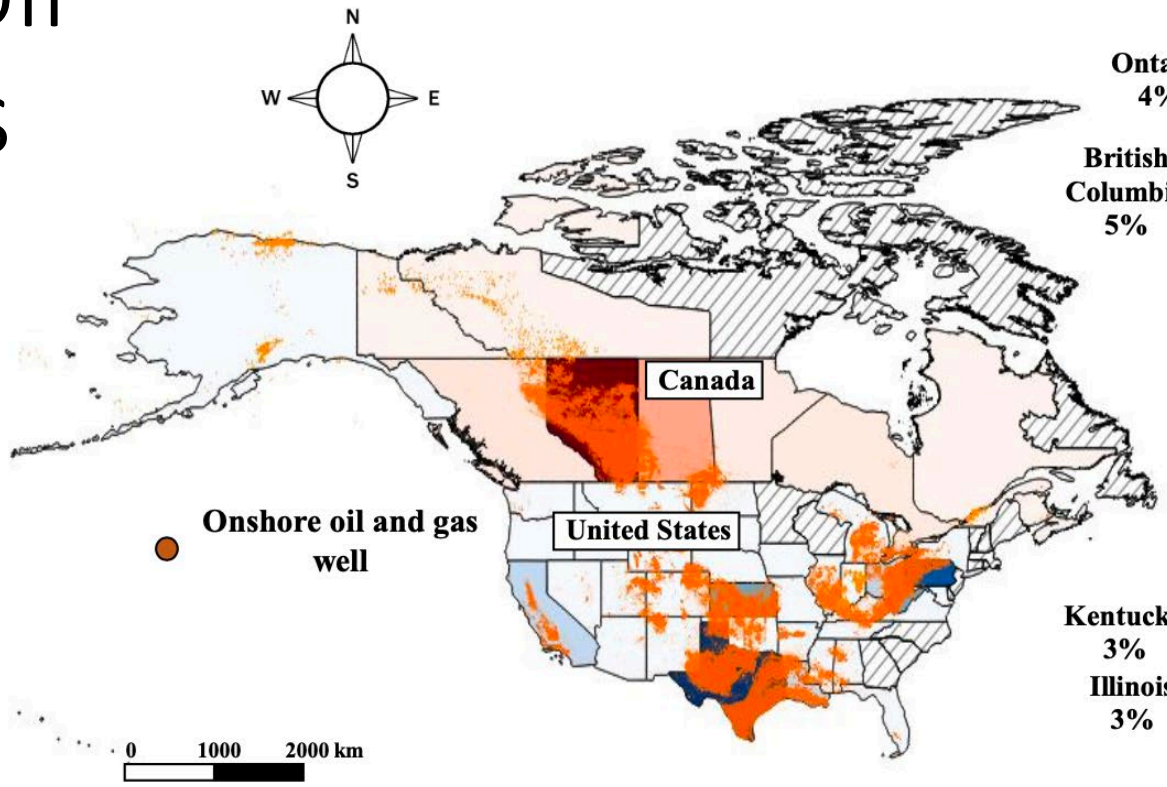
- **Gas Migration (GM):** Refers to situations where gas from stratigraphic units penetrated by the well is present at surface in soils around the outermost string of well casing.

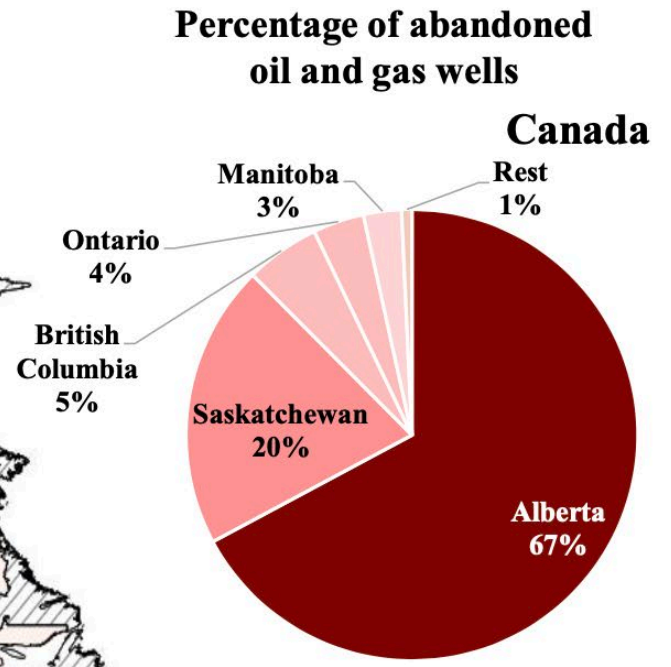


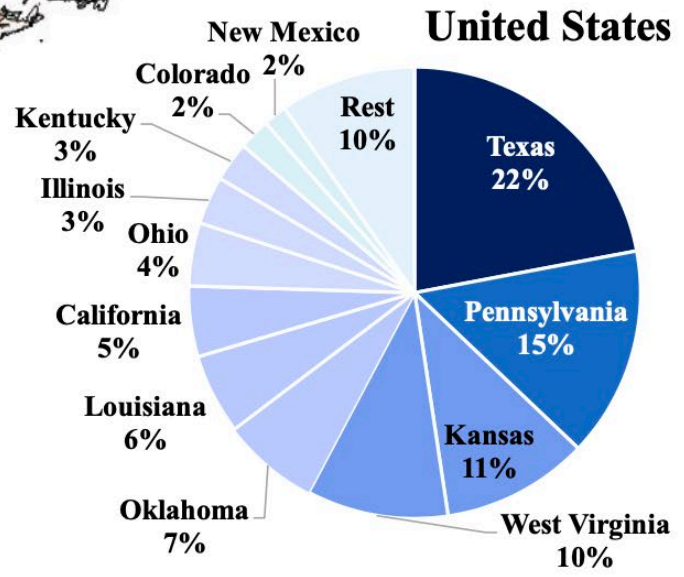


Watson and Bachu, 2008

> 370,000 abandoned oil and gas wells in Canada alone



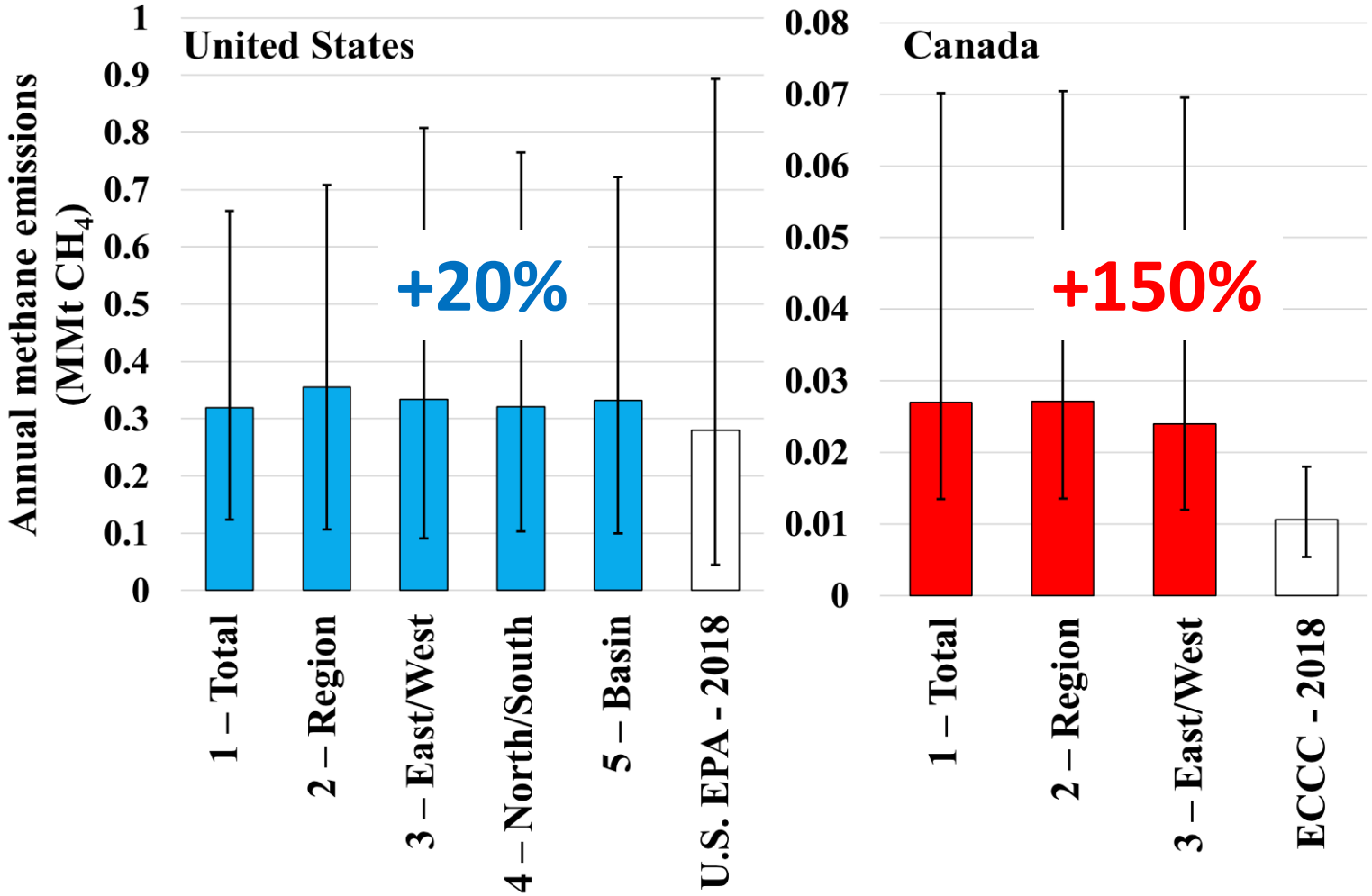




Williams, Regehr, and Kang, ES&T, 2021

Methane emissions from abandoned oil and gas wells are underestimated

Based on 598 direct measurements in Canada and the US, which is very small relative to the number of abandoned wells (> 370,000 in Canada alone)



Williams, Regehr, and Kang, ES&T, 2021

Estimates based on plugging status, well type, and geographical variation

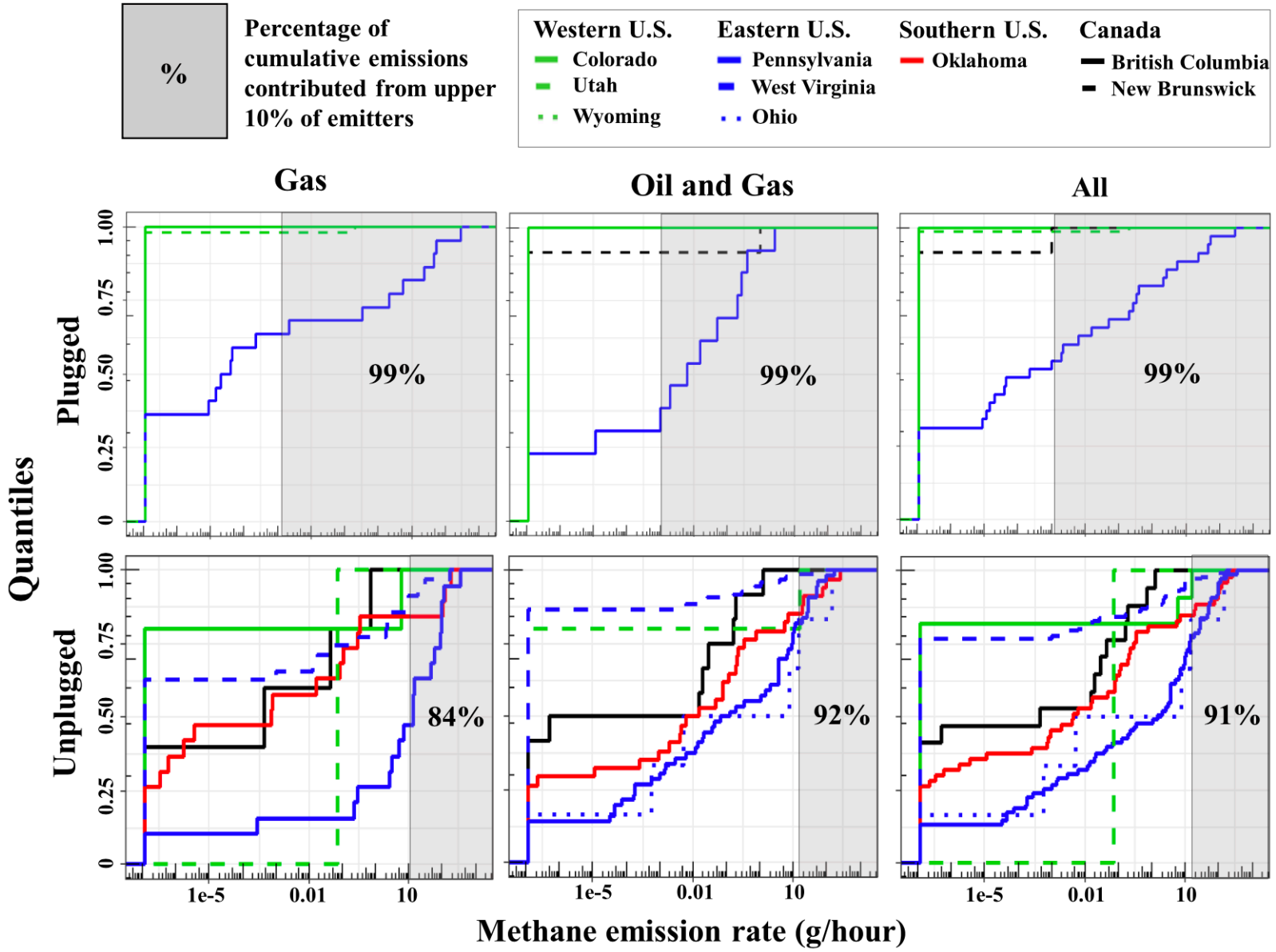
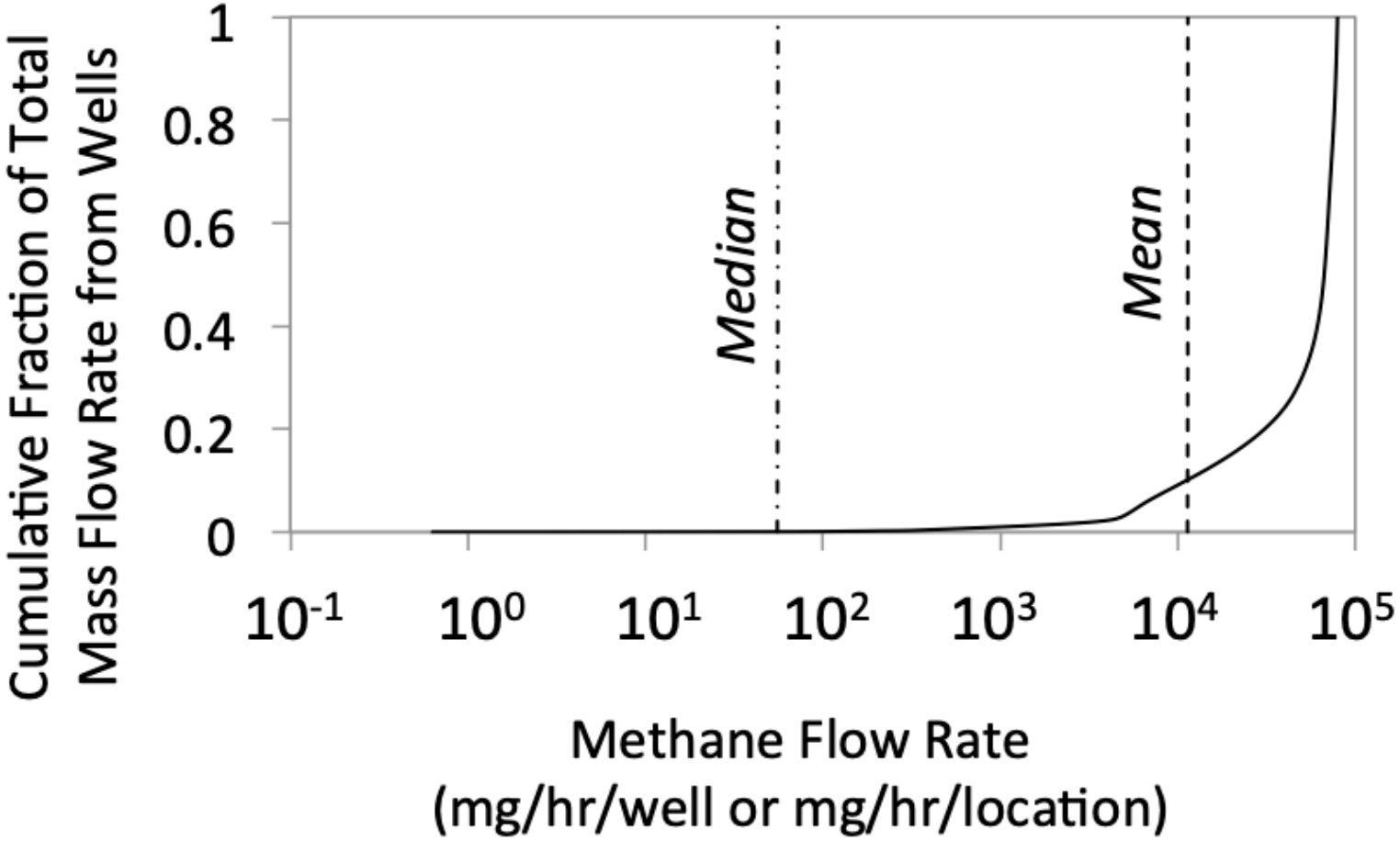


Figure 1. Empirical cumulative distributions of measured methane flow rate from unplugged (top) and plugged (bottom) AOG wells in the U.S. and Canada. Each curve represents a state/province. Blue and green curves represent eastern and western states in the U.S., respectively. Red curves represent Oklahoma, which is in the southern U.S. Black curves represent Canadian provinces. Shaded regions in each plot represent the 90–100th percentile of methane emission rates for that group, with the annotation showing the percentage of cumulative emissions, the top 10% of AOG wells.

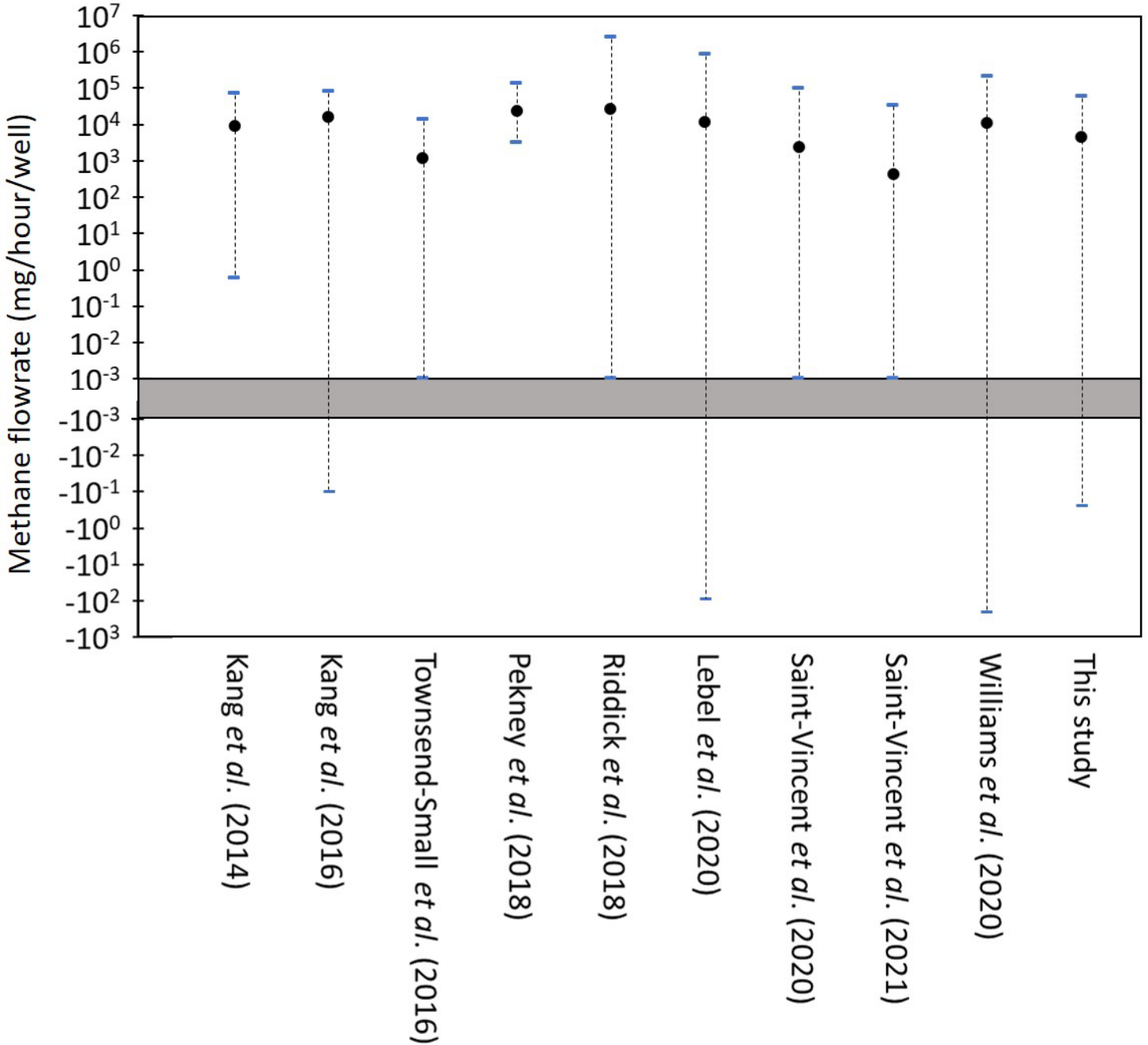
Williams, Regehr, Kang, 2021

High emitters govern emission factors and total emissions



Kang *et al*., *PNAS*, 2014

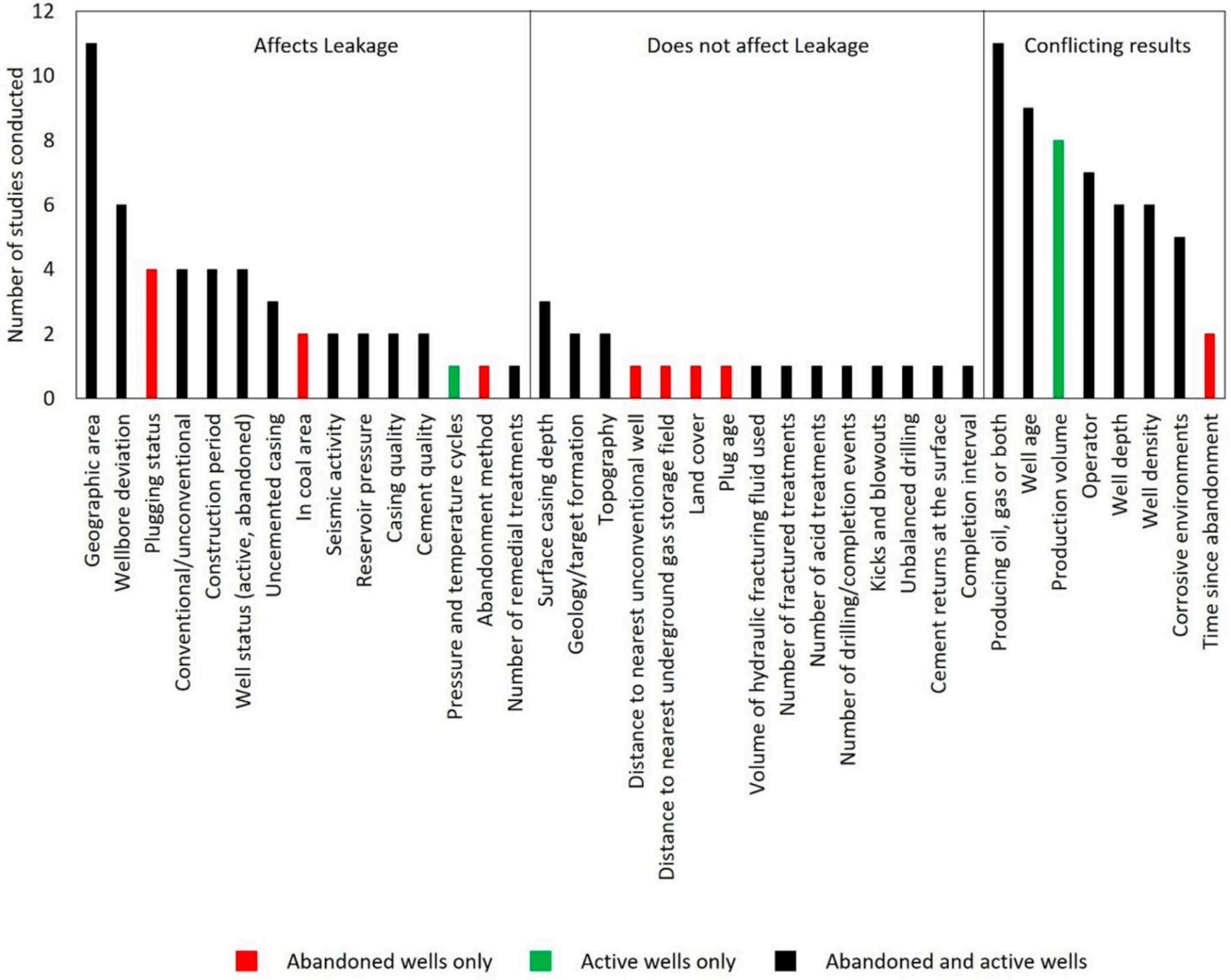
High emitters are in the 10^4 to 10^6 mg/hr/well range



El Hachem and Kang (2022)

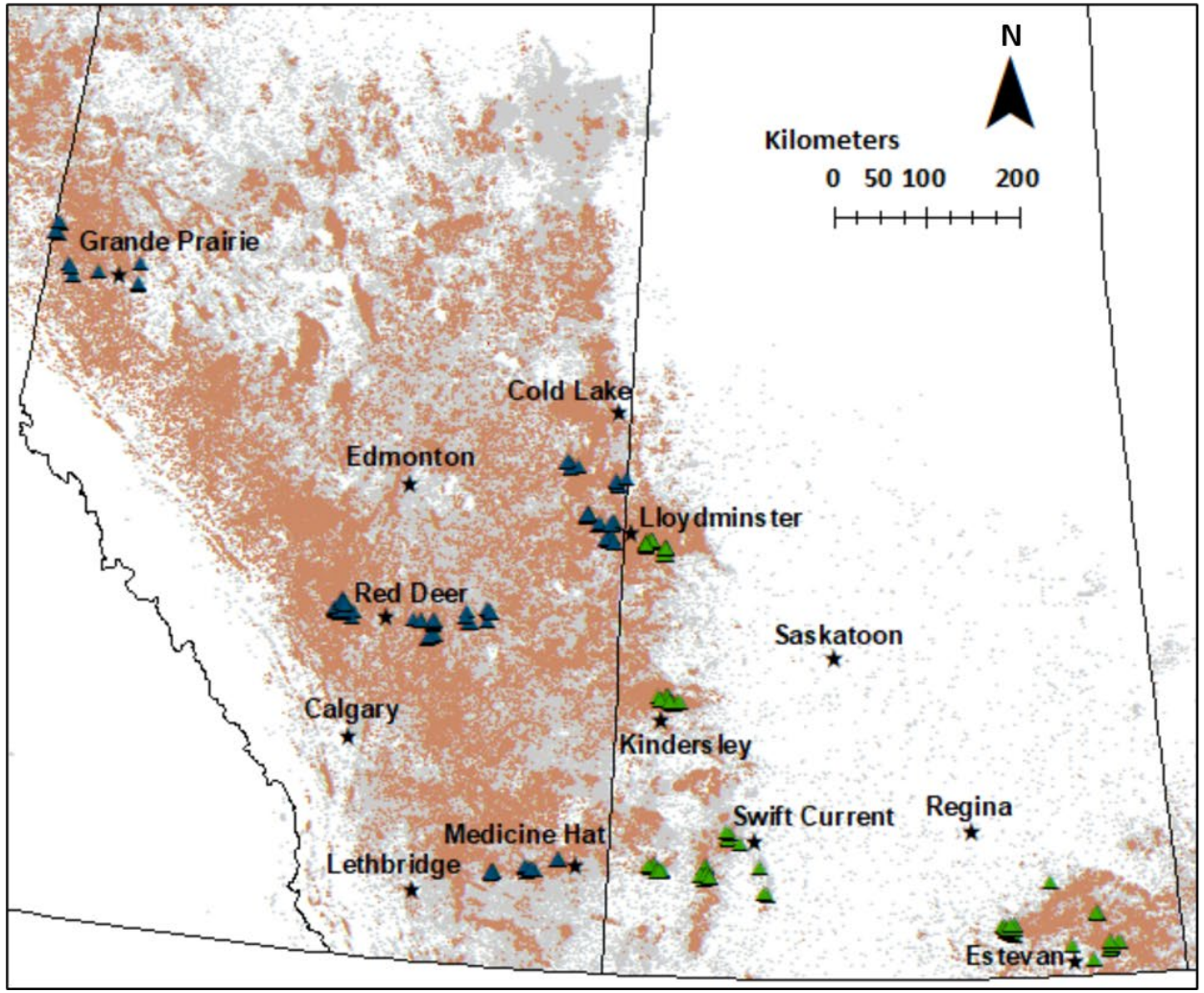
So far, geographical area is a key predictor.

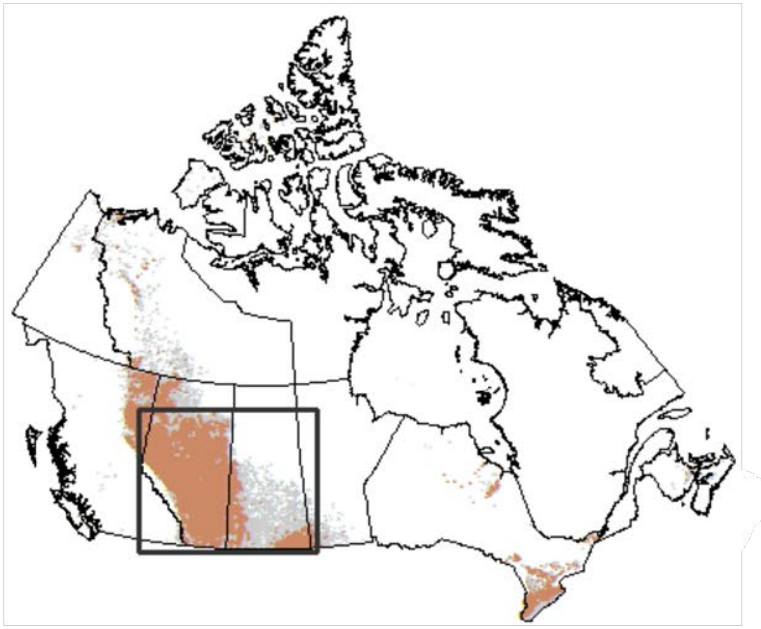
Measurements needed in previously-unmeasured areas



El Hachem and Kang (2023)

Measured methane emissions from 238 abandoned / suspended wells in Alberta and Saskatchewan





Abandoned (Plugged) Wells

Suspended (Unplugged) Wells

Measured Well Sites Saskatchewan

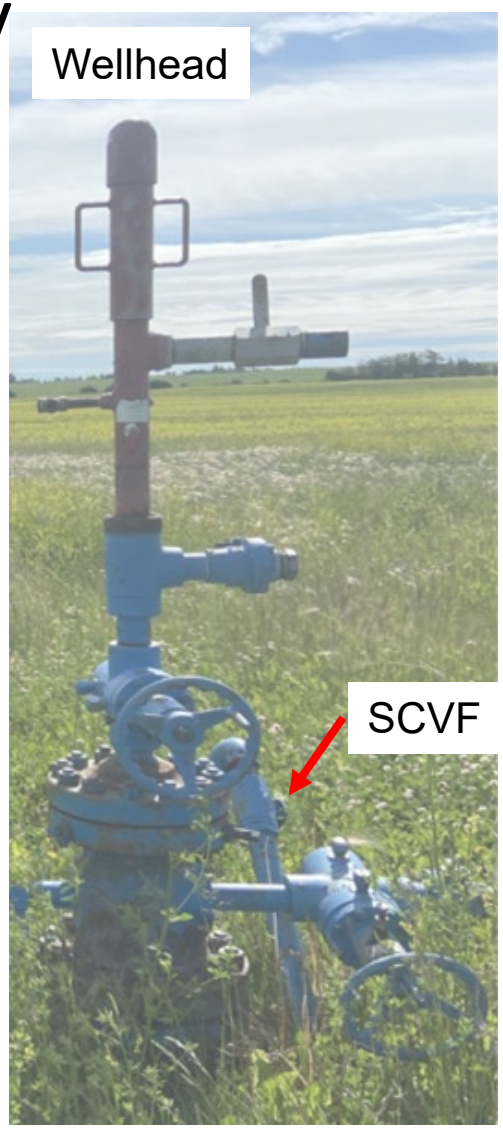
Measured Well Sites Alberta

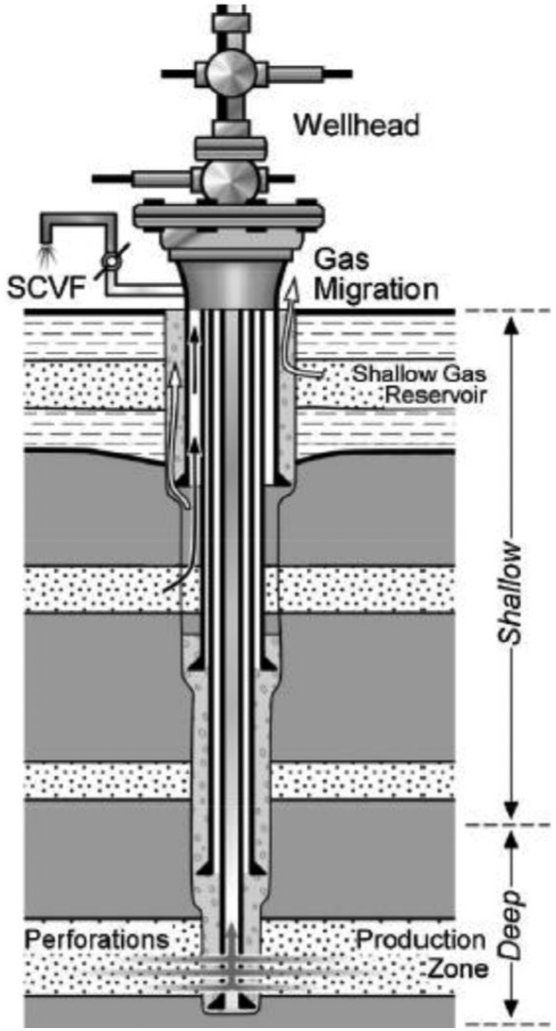
Bowman, El Hachem, and Kang, In Prep

Measured surface casing vent (SCV) and non-SCV emissions separately

- Important to separate SCV and non-SCV emissions for
  - Canada's National Inventory Report
  - Mitigation

- Analysis of emission trends and geochemistry of emitted gases from SCV and non-SCV emission in progress.





Watson and Bachu, 2008

Limitations of measurements made in Alberta and Saskatchewan so far

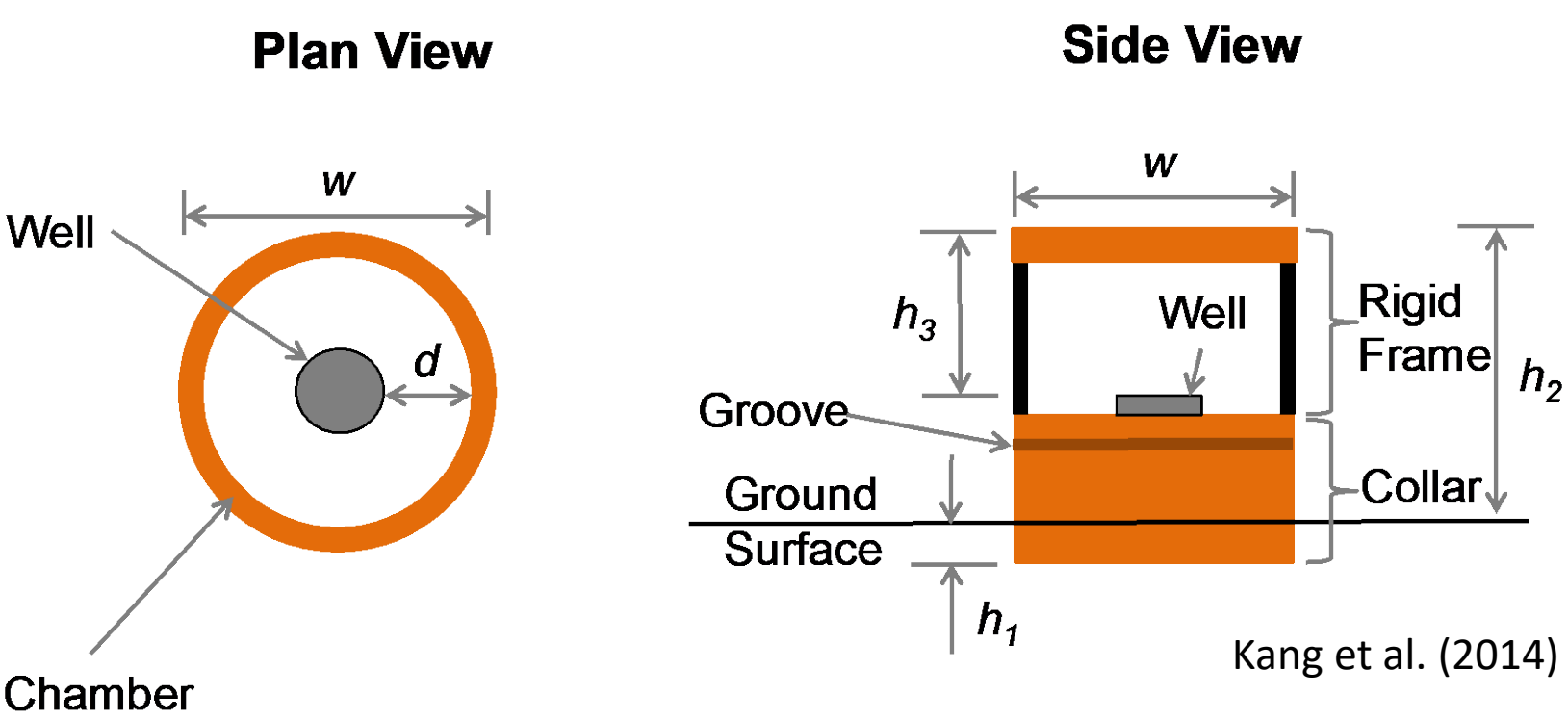
- 238 abandoned wells is a small number (>350,000 abandoned wells in Canada with 87% in Alberta and Saskatchewan).
- A representative sample of measurements not available for all sub-provincial areas.
- Measurements only provide a snapshot in time, although industry reports substantial temporal variations are likely.

Objectives of upcoming June 2023 field campaign

- Measure methane emissions from ~50 abandoned oil and gas wells in Alberta and Saskatchewan
    - Re-measure some previously measured wells (10 to 30) to capture temporal variability
    - Measure SCV and non-SCV emissions separately
    - Focus on improving representativeness of the measurement dataset

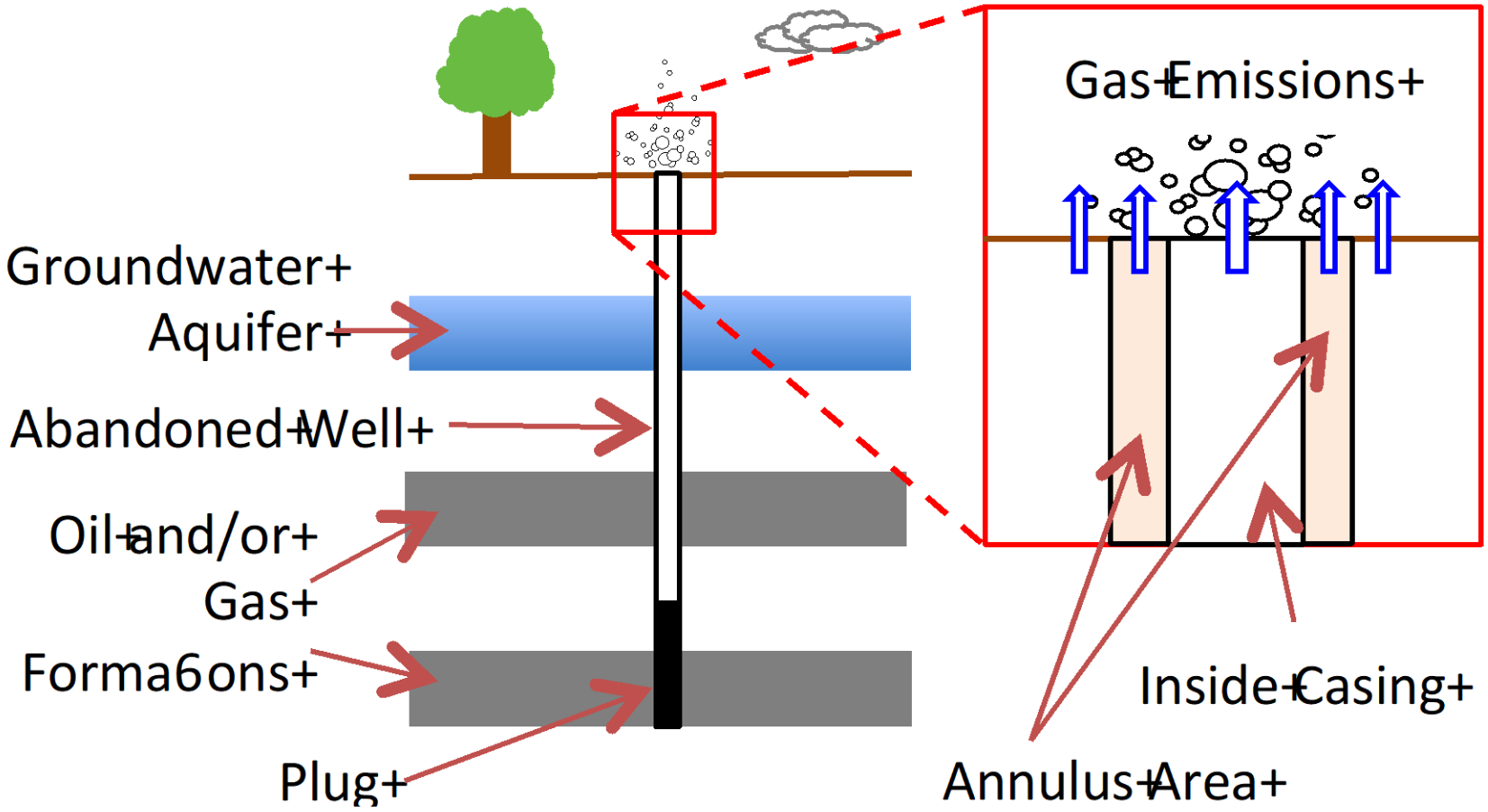
Field Measurements

- Chamber methodologies to determine methane (mass) flow rate
- Picarro G4301 Gas Scouter and Sensit Portable Methane Detector (PMD) used for concentration analysis in the field
- Gas sampling for geochemical analysis (using GC-FID, GC-IRMS, CRDS)



Kang et al. (2014)

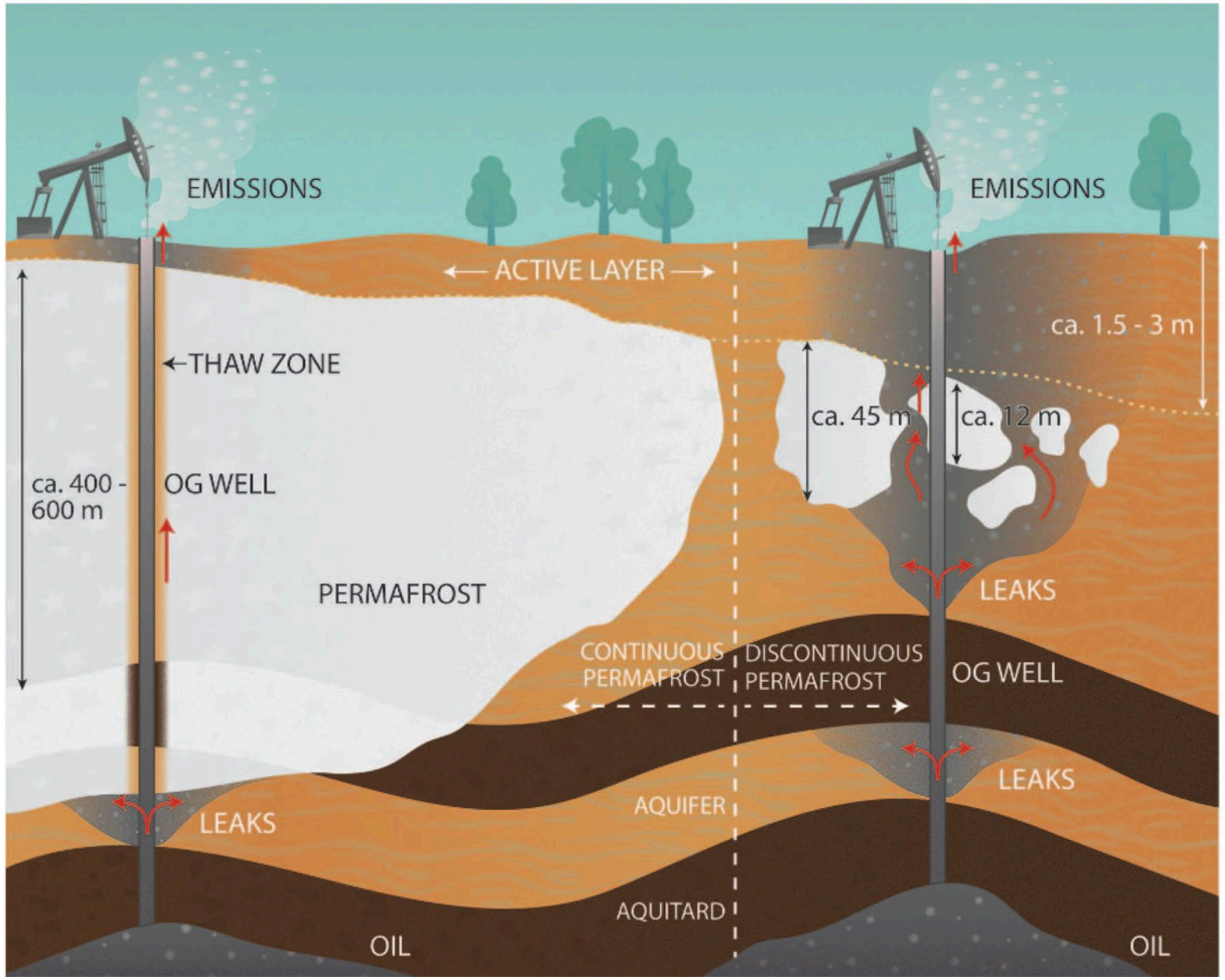
Abandoned oil and gas wells: methane emissions and groundwater contamination



Kang *et al.* (2015)

Environmental component	**Availability of direct measurements**	**Strategies to reduce environmental impacts**	**Ability of plugging and site restoration to reduce impacts**
Surface water	Wen et al. (2019)	Plugging; Site restoration; Dilution/mixing	Depends on interactions with groundwater.
Groundwater	Kell (2011); McMahon et al. (2018); Wen et al. (2019)	Plugging; Groundwater remediation; Natural attenuation	Unclear.
Air	Lebel et al. (2020)	Plugging; Dilution/mixing	Assumed to reduce emissions.
Climate (Methane emissions)	Kang et al. (2014, 2016); Townsend-Small et al. (2016); Boothroyd et al. (2016); Pekney et al. (2018); Riddick et al. (2019); Saint-Vincent et al. (2020); Lebel et al. (2020); Williams, Regehr, and Kang (2021)	Plugging; Flaring; Gas usage	Appears to reduce emissions.
Ecosystems	Nallur et al. (2020)	Plugging; Site restoration; Natural attenuation	Site restoration to pre-development conditions likely to reduce impacts. Plugging may reduce impacts depending on reliance on groundwater and sensitivity to air quality.
Human health	Not available	Plugging; Site restoration; Natural attenuation	Depends on reliance on groundwater. Depends on air pollutant and exposure limits.

Oil and gas wells and permafrost interactions in the subsurface



Klotz et al. (2023)

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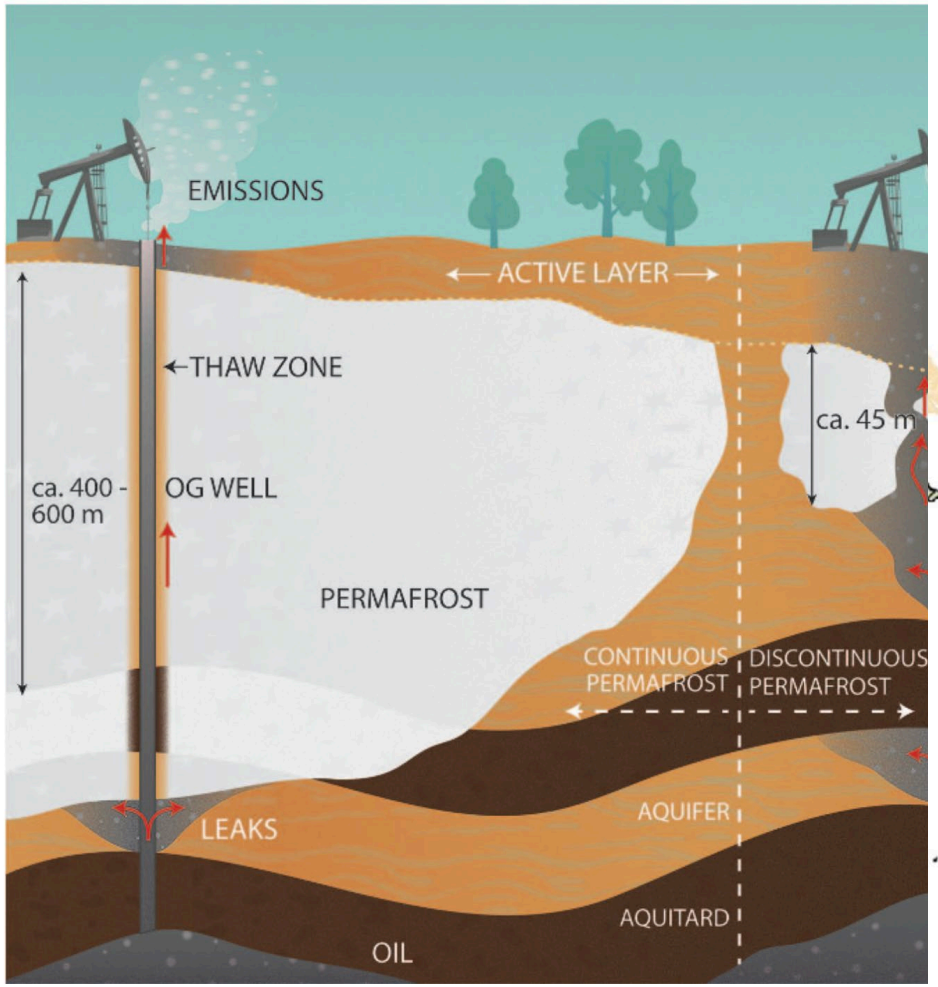

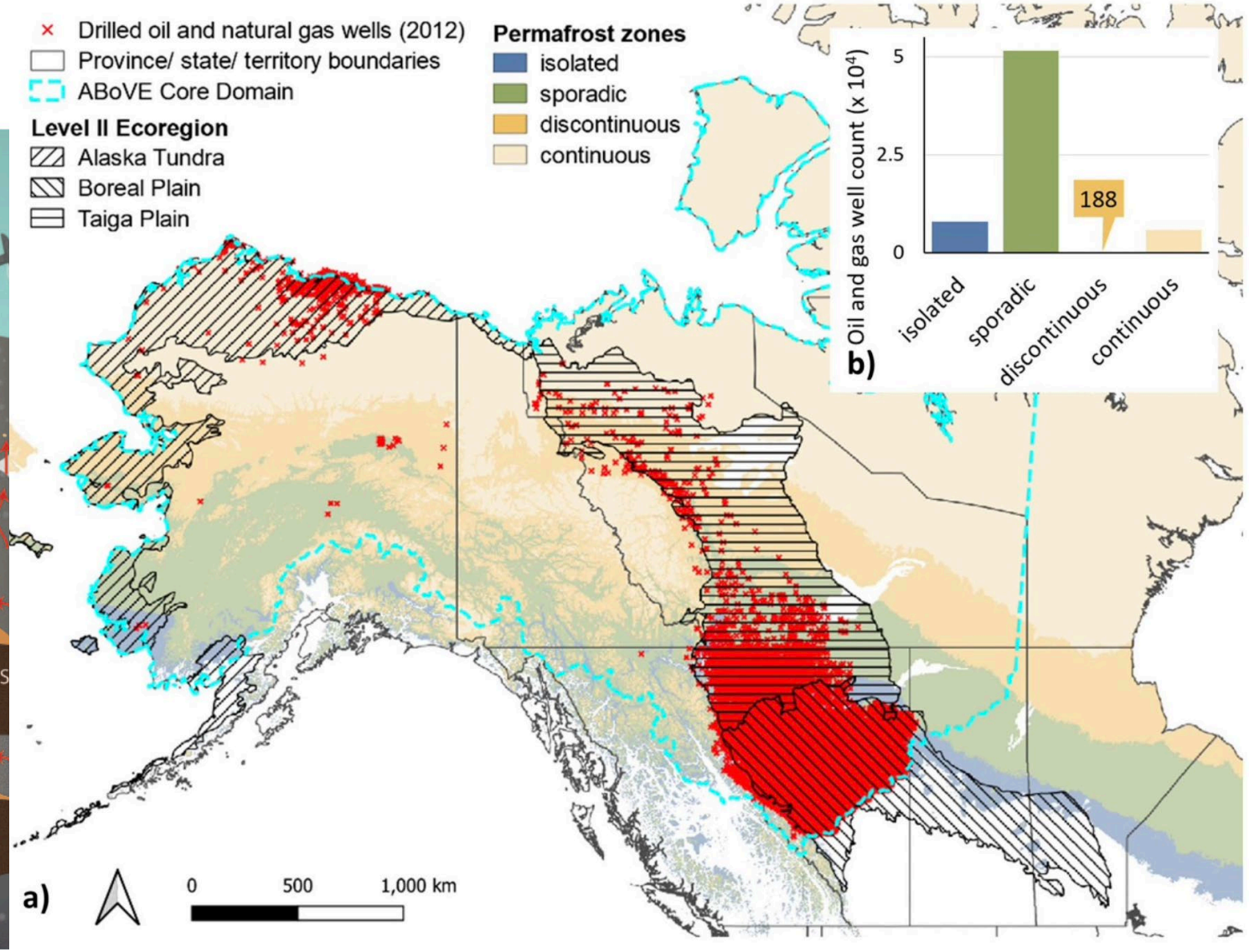

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Thank you!

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