VOC concentration increases near oil and gas well drilling, completion, and production operations

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HEI energy

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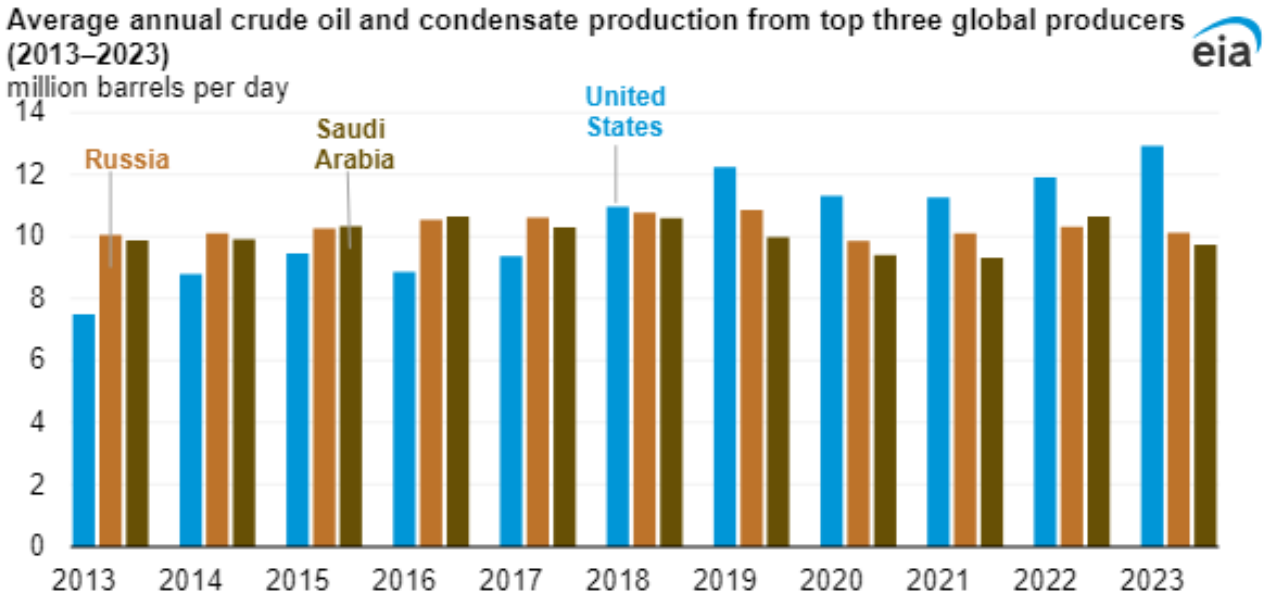
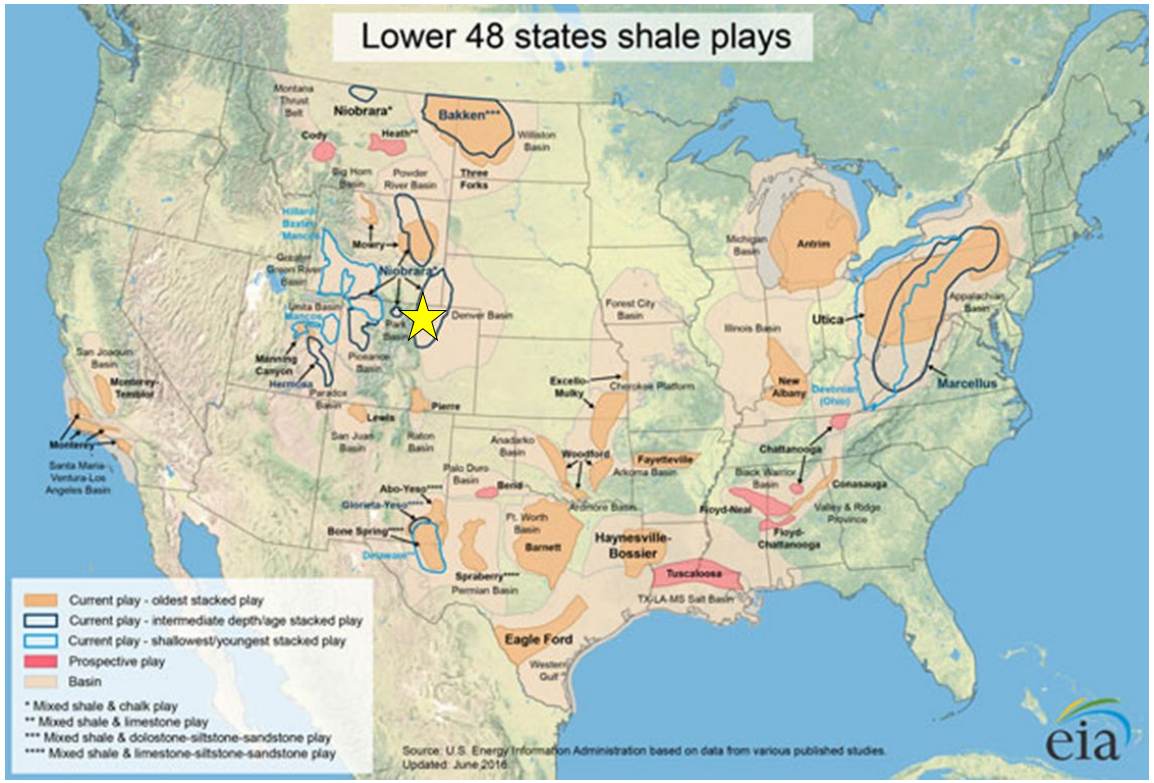
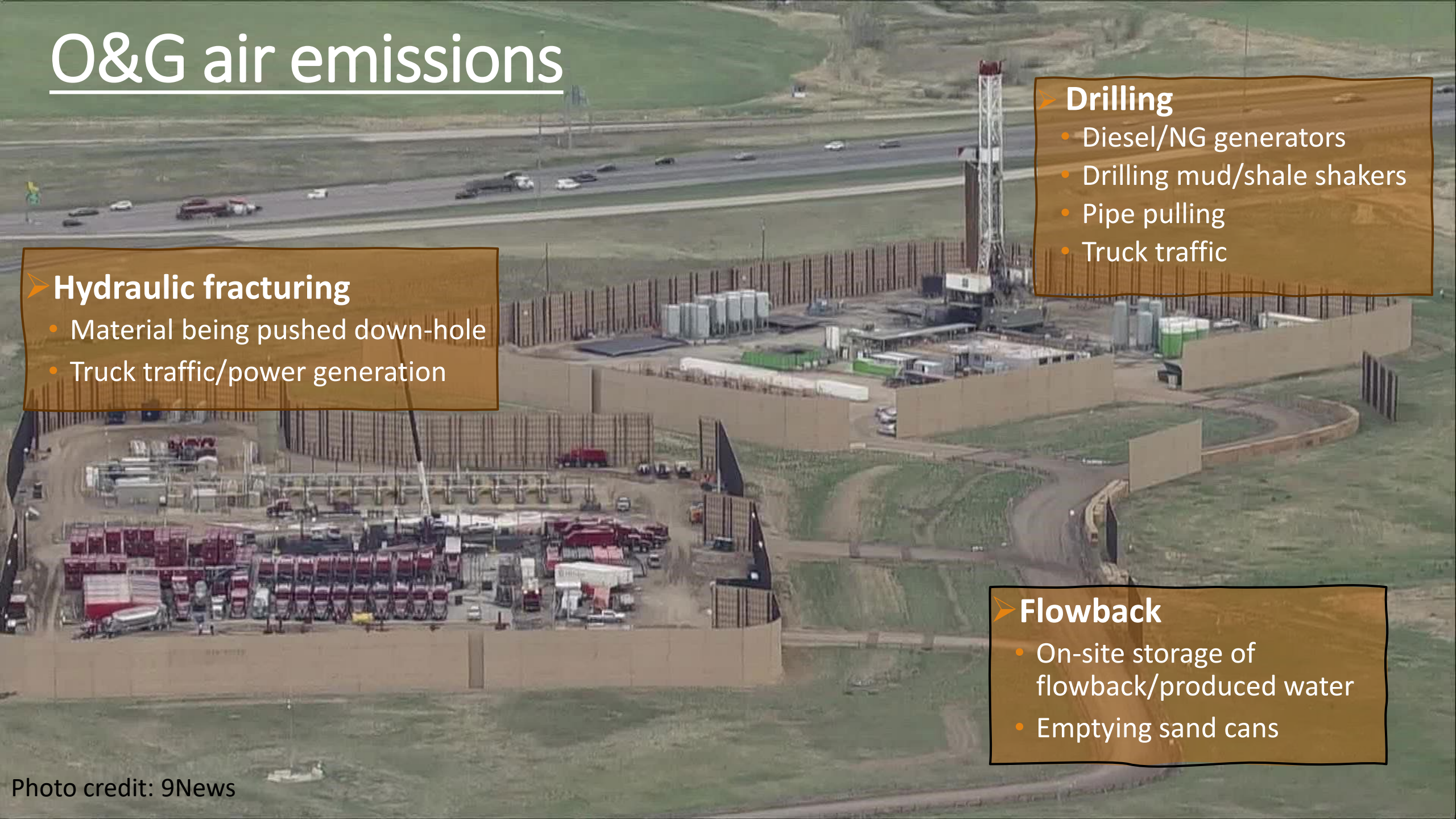
U.S. now world's largest producer of oil & natural gas



Improvements in directional drilling and hydraulic fracturing techniques have made vast new oil and gas reserves economically accessible



O&G air emissions



Drilling
- Diesel/NG generators
- Drilling mud/shale shakers
- Pipe pulling
- Truck traffic

Hydraulic fracturing
- Material being pushed down-hole
- Truck traffic/power generation

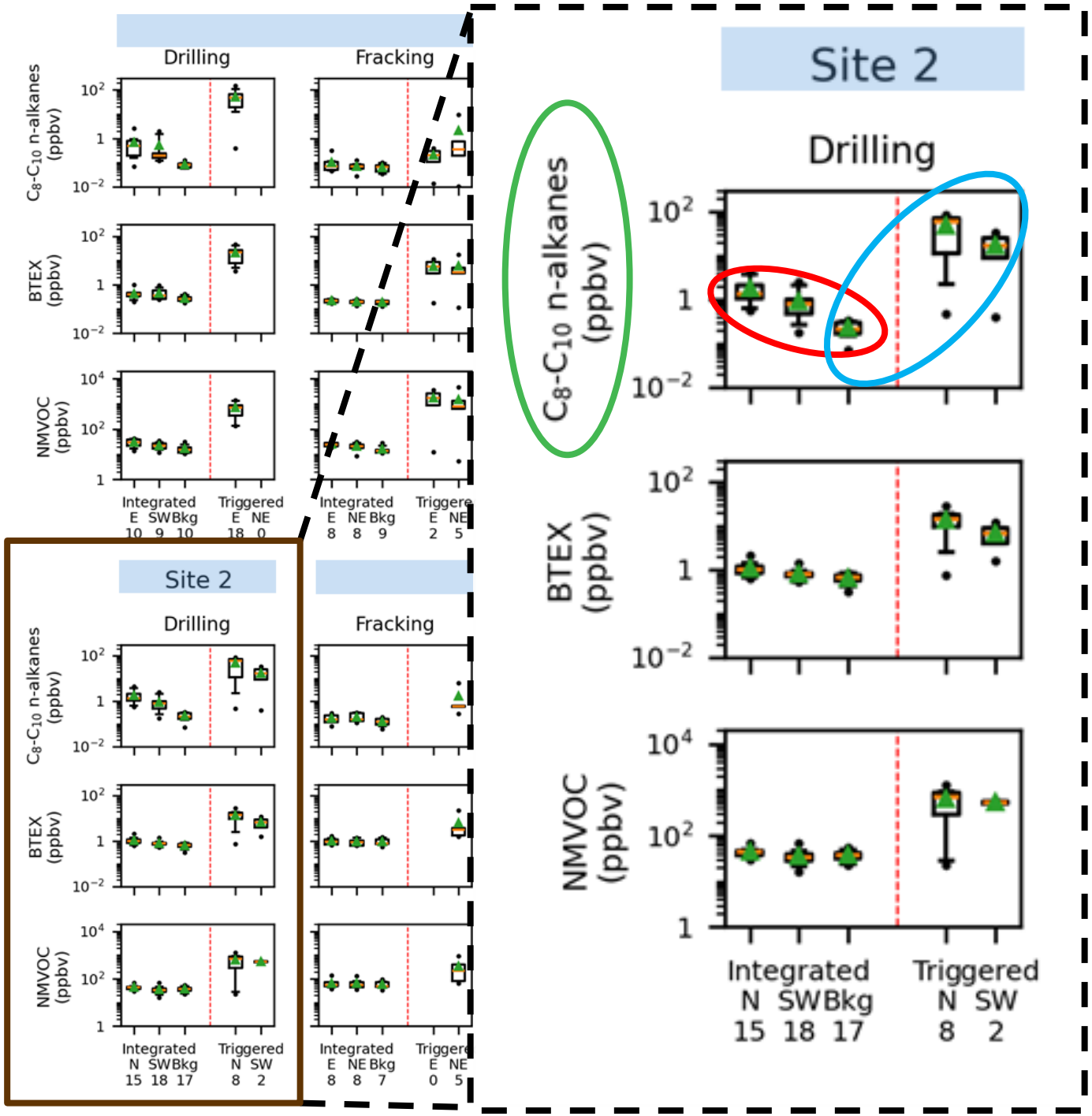
Flowback
- On-site storage of flowback/produced water
- Emptying sand cans

Photo credit: 9News

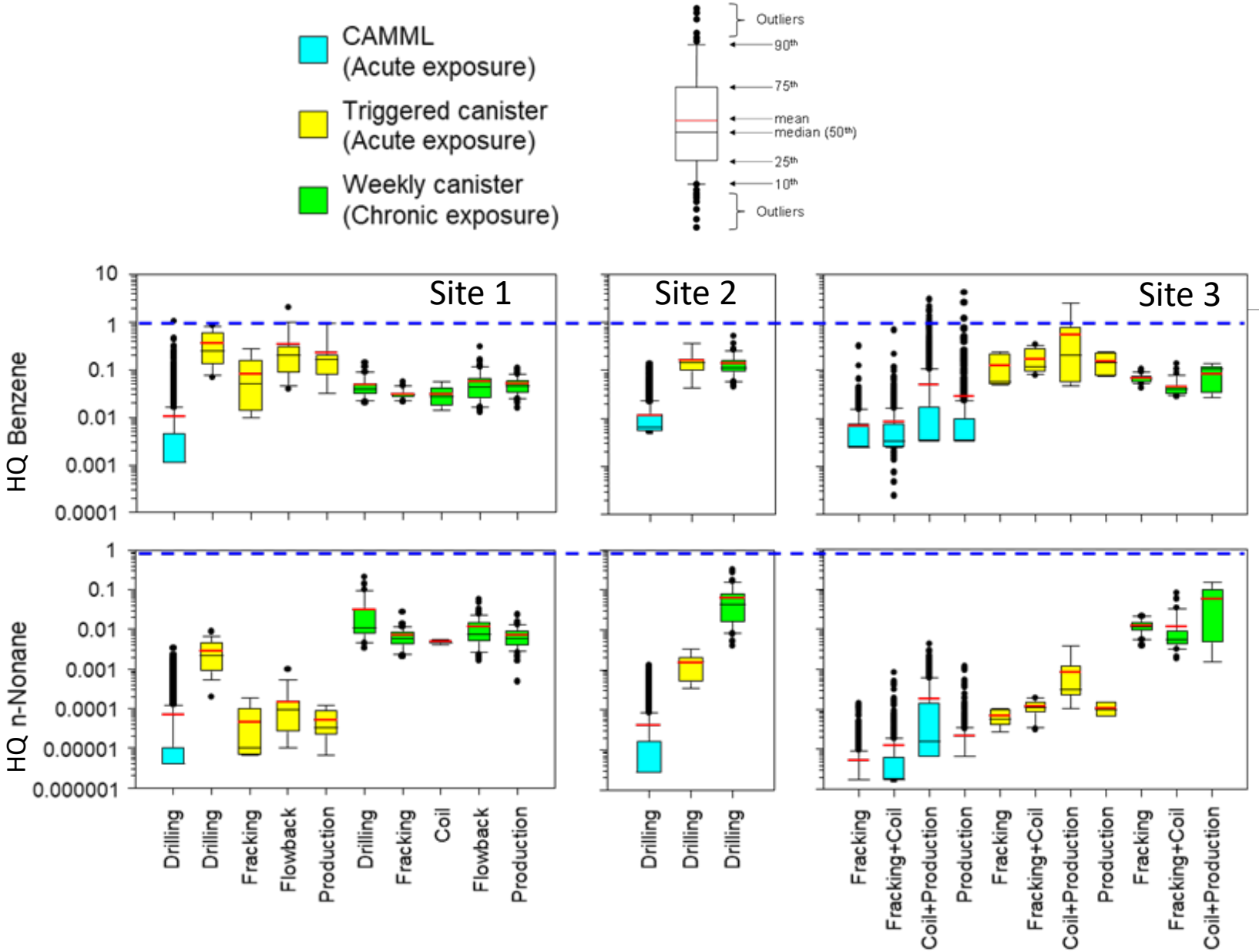
Air monitoring approach

- 3 sites, 4 well pads, 3 O&G operators
- CDPHE CAMML
  - Hourly speciated VOCs, CH_4, NO_x, $PM_{2.5}$
- Weekly integrated VOC canisters
  - 51 speciated VOCs + CH_4
  - 2 near-pad locations plus background reference site
- Continuous PID monitors with event-triggered canister samples
  - 2 near-pad locations
- Mobile measurements
  - CH_4 and VOCs

VOC concentration gradients around well pads



- Weekly and triggered canister VOC concentrations at near-pad and background sites by UOGD operation
- Generally modest increases in weekly average concentrations near pad
- Plume concentrations much higher than weekly averages
- Strong local enhancements of C8-C10 alkanes (from synthetic drilling mud volatilization) during drilling and millout

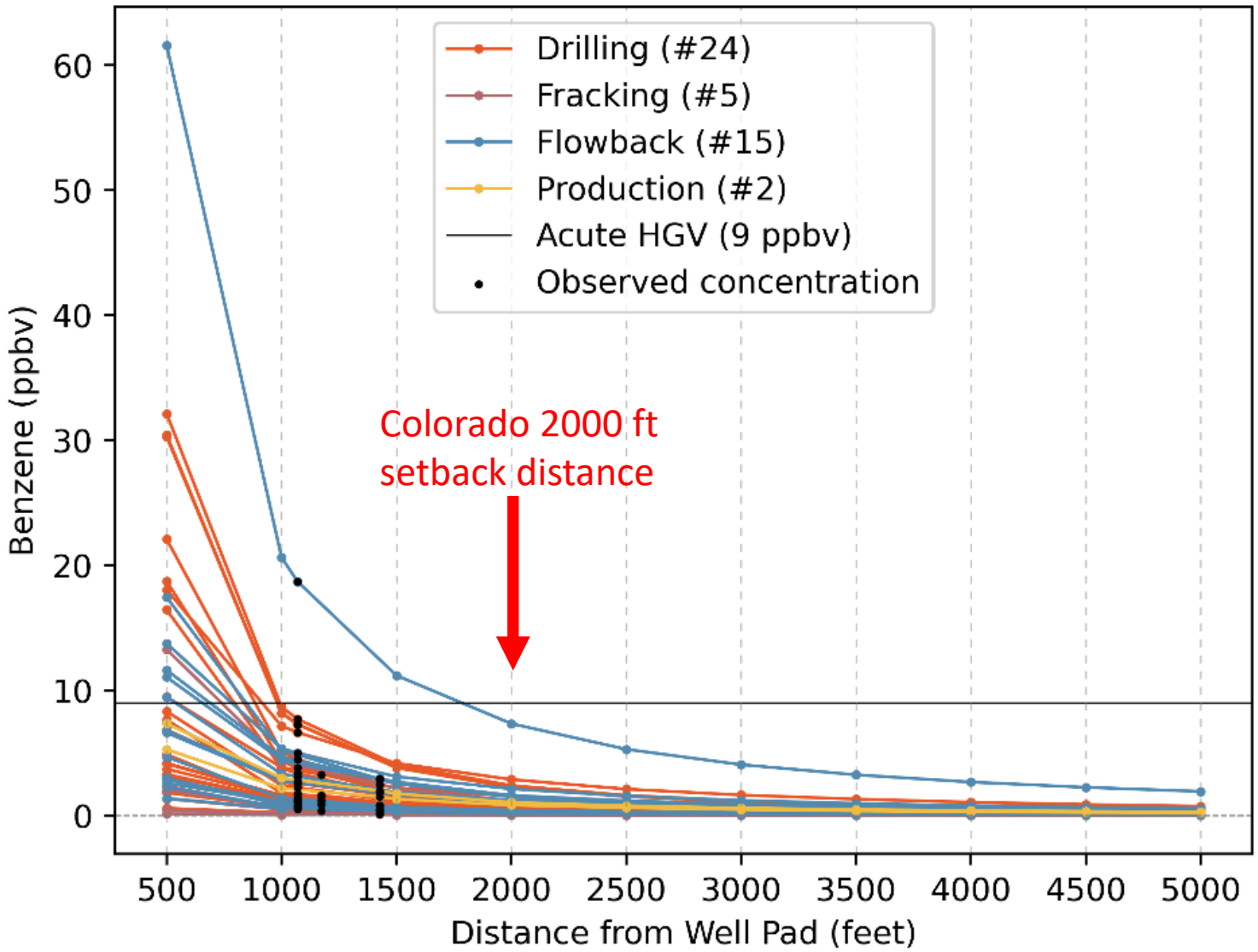


Acute and chronic exposure risk

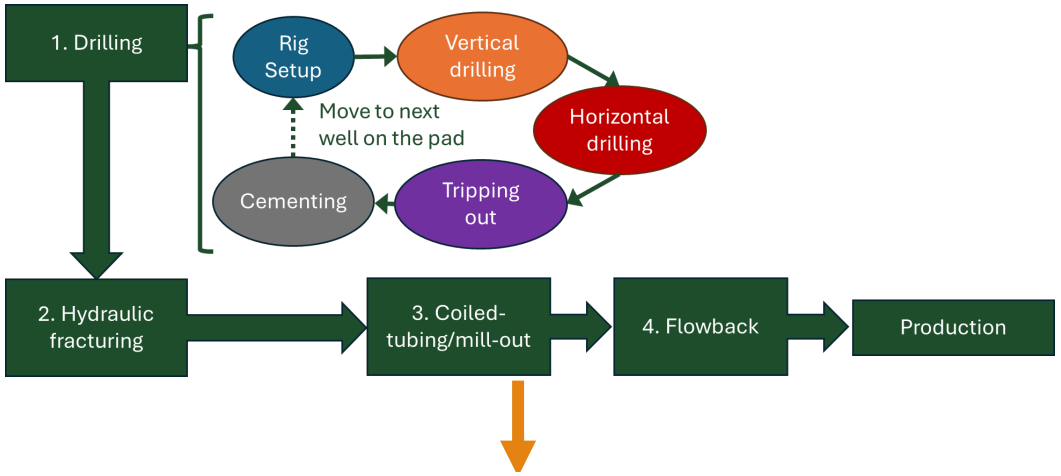
- HQ = Conc/Health Guideline Value
- Chronic exposure HGVs not exceeded
  - Benzene and n-nonane important contributors
- Periods of benzene acute exposure HQ > 1 observed for most UOGD operation types
  - Benzene dominates acute exposure risk

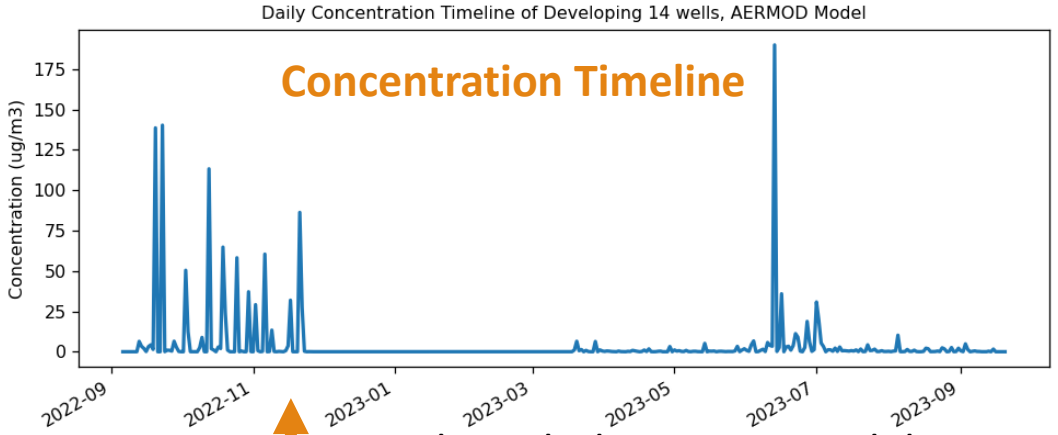
Exposure vs. distance

- Run EPA AERMOD dispersion model for high hourly monitor values
  - Align plume centerline with monitor location
  - Constrain AERMOD emissions to match measured hourly concentration
- Examine hourly concentration as function of distance from 500-5000 feet
  - Method provides a conservative estimate

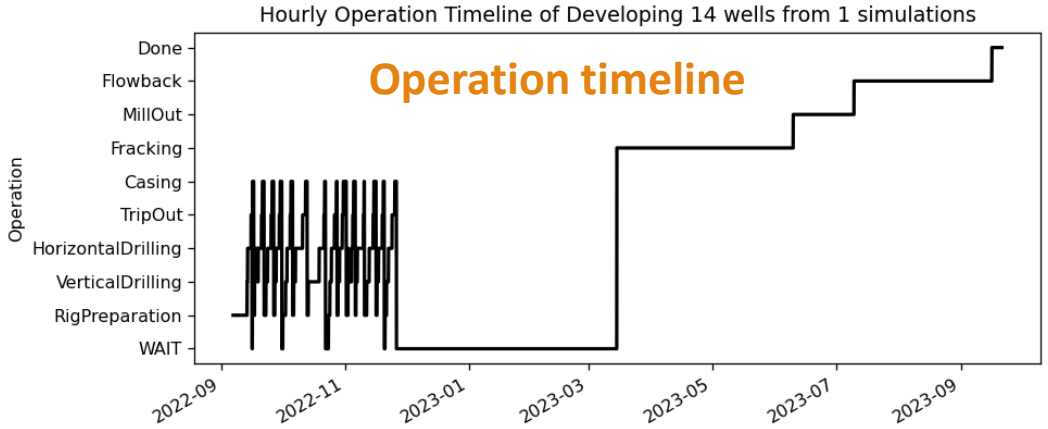


TRACER pre-production model

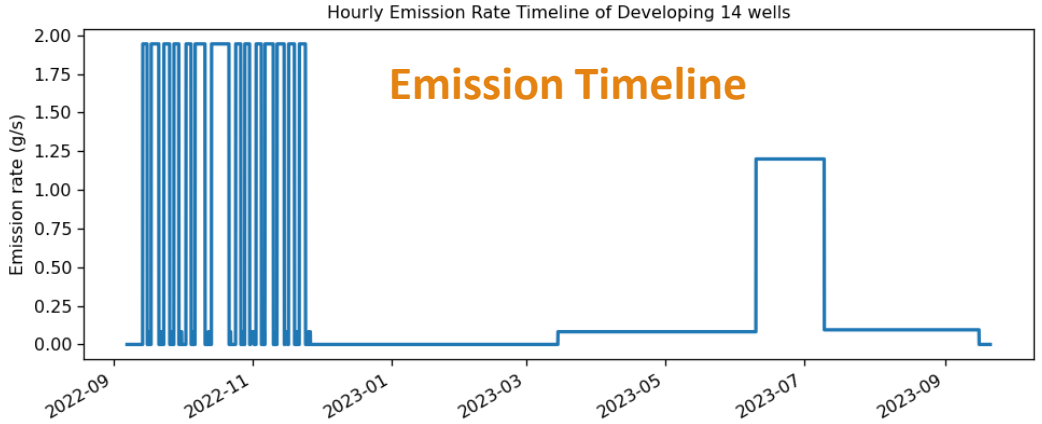




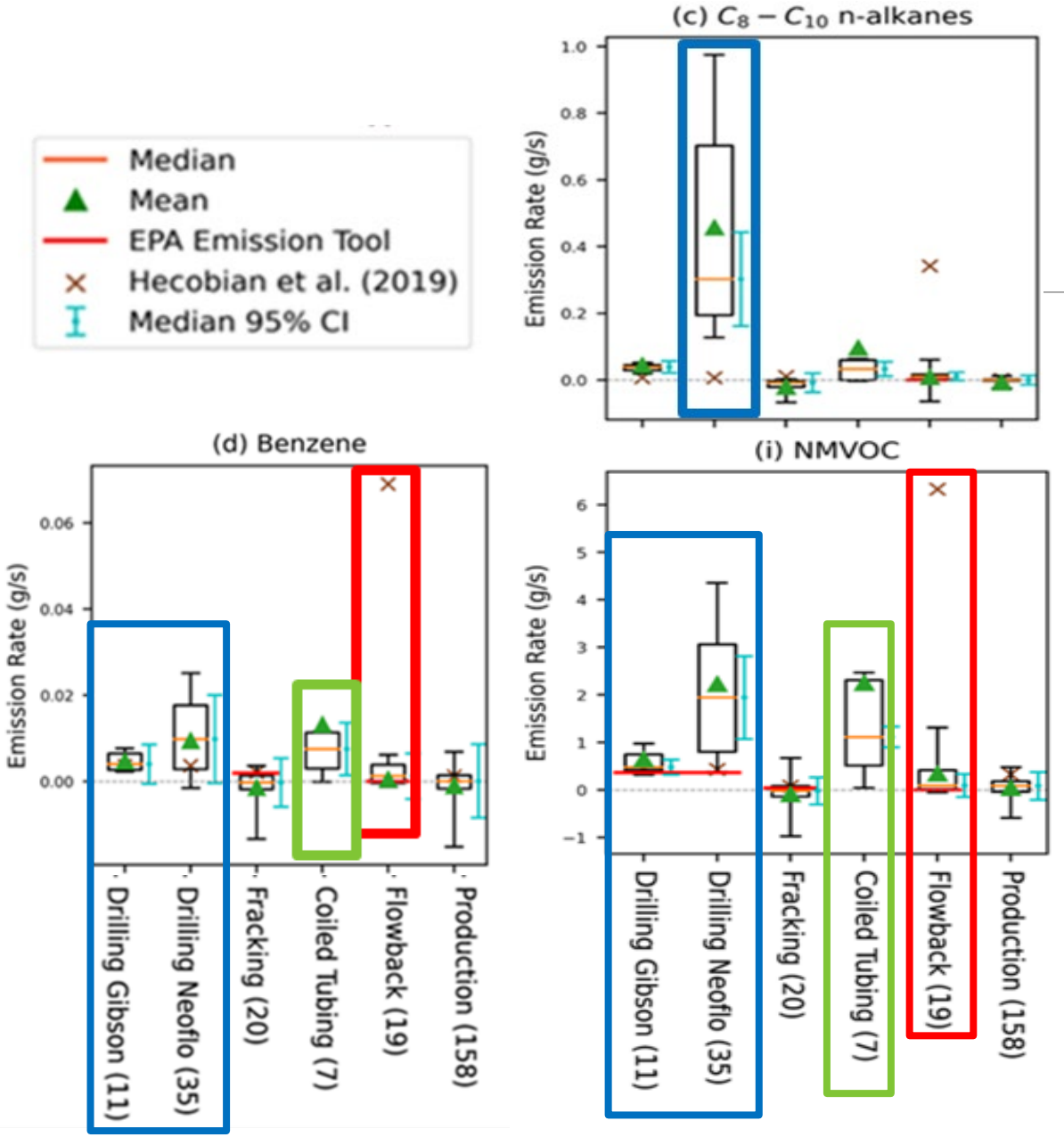
Couple with dispersion model



Select Emission Factor



More details will be presented in Feb. 13 Webinar



Constraining UOGD VOC emission rates

- Utilized extensive VOC observations during development of 6 large well pads in Broomfield, Colorado
- Updated estimates for drilling mud volatilization, including synthetic Neoflo
- First VOC emission estimates for coil tubing/millout operations
- Document >95% reduction in average VOC and benzene emissions from flowback using closed loop, tankless systems vs. other green completions

Study highlights

- Increased VOC concentrations observed near well pads during pre-production operations
  - Transient plumes much more concentrated than weekly samples and dominate non-cancer exposure risk
  - Use of grid-powered electrified drill rigs reduces NO_x and some VOC emissions but outgassing from drilling mud remains major VOC source
  - Closed-loop, tankless flowback systems reduce average flowback VOC emissions >95% but we still see large emission pulses during emptying of sand cans