Fact Sheet: Ozone Precursors in the Uinta Basin

What This Study Found

Utah State University researchers measured more than 70 ozone-forming organic compounds across the Uinta Basin during the winters of 2019 and 2020. Concentrations were about eight times higher during temperature inversion episodes than in spring, and the mix differed sharply from place to place: air in oil-producing areas carried far more highly reactive alkenes — mainly ethylene and propylene — than air in gas-producing areas. The likely source is natural gas-fueled engines at oil wells, and official emissions inventories capture almost none of this reactive material.

What are Ozone Precursors?

- Ground-level ozone is not emitted directly: it forms when nitrogen oxides (NO_x) and volatile organic compounds (VOC) react in sunlight — so NO_x and VOC are called ozone precursors.
- In the Uinta Basin, ozone forms in winter. Snow cover and the Basin's bowl-shaped topography create multi-day temperature inversions that trap precursors near the ground, and sunlight reflected off the snow drives the chemistry. Winter ozone here has exceeded 100 parts-per-billion (ppb), well above the 70 ppb federal standard.
- Not all VOC are equal. Alkenes — a family that includes ethylene and propylene — react much faster than most other organic compounds: a given mass of ethylene can produce about 32 times more ozone than the same mass of ethane, a major component of natural gas.

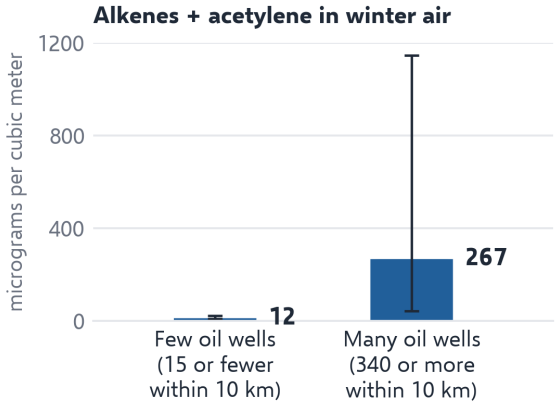
A Basin-Wide Survey of Winter Air

The Bingham Research Center deployed up to 17 portable air sampling stations across the Basin, which contains about 10,000 producing oil and gas wells. Samples collected during a February 2019 inversion held nearly eight times more organic compounds than the same locations in snow-free April: trapped emissions build up day after day.

Oil-Producing Areas Have Different Air

Everywhere in the Basin, slow-reacting alkanes such as propane and butane make up most of the organic mass in air — about 85% on average. The alkene share, however, depends on what is produced nearby. The chart at right shows the contrast: locations with 340 or more producing oil wells within 10 km averaged 267 micrograms per cubic meter (µg/m³) of alkenes plus acetylene, against 12 µg/m³ where there were 15 or fewer. The western Basin produces mostly oil and the eastern Basin mostly natural gas, so this is a geographic divide.

Because alkenes react so quickly, they matter more than their mass suggests: in areas with more than 20

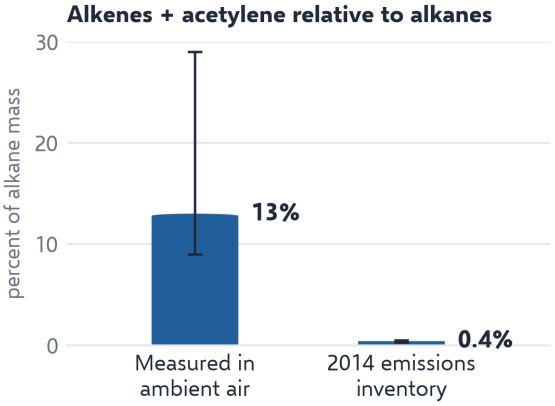


Average alkenes + acetylene in winter air by density of producing oil wells; whiskers are 95% confidence ranges.

oil wells within 10 km, they accounted for 28% (24–33%) of the ozone-forming potential of all measured organics — about twice their share elsewhere (14%).

Engines are the Likely Source — and Inventories Miss Them

Alkenes and acetylene come mainly from combustion, not from leaking equipment. The proportions of individual compounds act as a fingerprint: ethylene and propylene at roughly one-to-one, both high relative to acetylene, match natural gas-fueled engines running lean (with extra air) — not vehicles, flares, or combustors. Most oil wells in the Basin are pumped by natural gas-fueled "artificial lift" engines, while almost no gas wells have them; 98% of the Basin's stationary engines burn natural gas, and 73% are lean-burning two-stroke designs. Later direct exhaust measurements confirmed it (see BRC Fact Sheet 005).



Mass of alkenes + acetylene relative to alkanes: measured in Uinta Basin air versus the 2014 regulatory emissions inventory for the region's oil and gas sources.

The official inventory tells a different story: in measured air, alkenes plus acetylene were 13% (9–29%) of the alkane mass; in the 2014 inventory, only 0.4% (0.3–0.5%) — the chart at right. This helps explain why computer models predict less winter ozone than actually occurs.

What this Means for Air Quality Management

- ✓ **Where emissions occur matters, not just how much.** Oil-producing and gas-producing areas have different precursor mixtures; rules based on one may not transfer to the other.
- ✓ **Inventories need the right composition, not just the right totals.** Raising the reactive share of organics in regulatory inventories would improve the models that guide ozone planning.
- ✓ **Manage the engine NO_x–VOC trade-off deliberately.** Lean-burning engines emit little NO_x but more reactive organics; hotter-burning engines do the reverse. Earlier Basin measurements suggest reducing NO_x lowers winter ozone more effectively, so lean-burn operation may remain the better tactic — but any change should be evaluated for its net effect on ozone.

Limitations

The engine attribution rests on compound ratios and spatial correlation rather than direct exhaust sampling, although later engine measurements support it. Reactivity weightings were developed for summertime urban ozone and are approximate for Basin winters.

More Information

This work was conducted at Utah State University's Bingham Research Center and published as Lyman et al. (2021), "High Ethylene and Propylene in an Area Dominated by Oil Production," Atmosphere, open access at https://dx.doi.org/10.3390/atmos12010001. Additional reports and data are at https://www.usu.edu/binghamresearch/papers-and-reports. Contact us at seth.lyman@usu.edu or visit binghamresearch.usu.edu for more information.