Emissions Mitigation in Industrial Gas Flares

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Introduction

Objective: Develop a whitepaper on industrial gas flares, including a detailed technology assessment and proposed R&D roadmap

- Flares are devices used to dispose of gases not processed and sold as part of normal operations
- Flaring represents an attractive alternative to venting
- Global Warming Potential (GWP): CH_4~30, CO_2=1, N_2O~273
- **Main reasons for flaring:**

Non-Routine	Routine
Operational/safety – diversion, disposal of gas influx during drilling, gas production during well testing, flow-back gas during completion, maintenance.	Economic reasons – lack of gathering, compression, sales infrastructure or capacity, oil vs. gas monetization (associated petroleum gas – APG).

U.S. vs. Global Trends

- Largest flaring volumes (in order): Russia, Iraq, Iran, United States, Algeria, Venezuela, Nigeria
- Globally – main source of emissions large, continuous flares
- U.S. – unconventional basins, small gas volumes, large number of individual wells/flares

Regulations and Oversight

- Flaring regulated at state and federal level
  - Federal: 40 CFR Part 60, Subparts OOOO/OOOOa
  - State: varies considerably – see DOE fact sheets
- EPA requires GHG reporting for >25,000 metric tons CO_{2e} per year
- Data reported to DOE EIA under process emissions
- Assumed flare destruction efficiency (DE) of 98%

$$DE = \left(1 - \frac{CH4_{exhaust}}{CH4_{flare\ feed\ gas}}\right) \times 100$$

- Independent measurements indicate under-reporting, highlight significant impact of unlit/poorly performing flares
- Average DE ~91%
- NEW OOOOb/c flaring regulations adopted December 2023
- Major reductions in routine flaring
- Addresses unlit/poorly performing flares
- Increased monitoring and verification

Image from https://doi.org.10.1126/science.ade2315

Gas Flare Technology Review

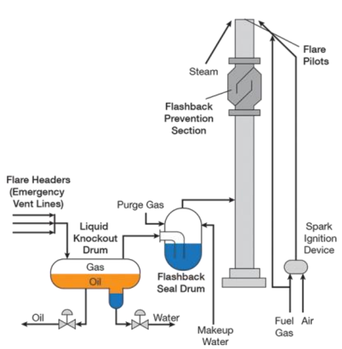
- **Main gas flare categories:**

Ground	Elevated
Array-style, often staged, can be enclosed providing radiation shielding and promoting natural draft.	Isolate noise, heat, flame emission from process and personnel. Most common, handle highest gas volumes.

Enclosed Combustor (ECD)

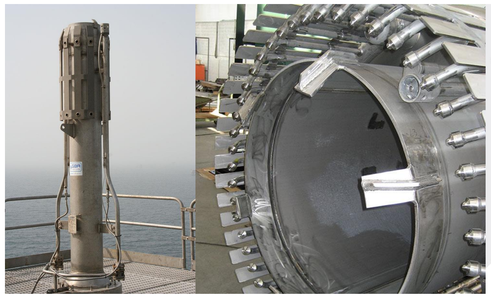
Include a direct method to control air, can be natural draft or forced, and are capable of >99.9% DE. Not considered flares, must adhere to stricter Tier 4 emissions requirements.

- **Main components of a flare system:** knockout drum, flashback mitigation device(s), pilots and ignition system, and the flare tip



Images from https://www.aiche.org, https://encorecombustion.com/, https://www.thermoeng.it/

- **The flare tip is largely responsible for emissions performance**
- Most are self-aspirated - largest challenge is achieving sufficient air entrainment/mixing with low flare gas supply pressure
- Many flares utilize support media to achieve smokeless operation
- Steam is most prevalent due to increased air entrainment
- Air blowers (oxidizer), high-pressure air/gas injection (entrainment) also used
- Low-pressure (utility) tips most common, high-pressure affords greater sophistication (sonic/Coanda/staged)



Images from https://www.gba.com/, https://www.zeeco.com/

Flaring Alternatives

- **Alternative techniques critical to eliminating routine flaring**
- Currently available technologies include direct compression and sale, utilization to produce compression energy, electrical power (IC engine, SOFC, or other), or combined heat and power, small-scale gas-to-methanol or gas-to-liquids conversion plants, or production of other fuels (ex. hydrogen), chemicals (ex. benzene/ethylene) or products (carbon).
- Ongoing DOE FECM and ARPA-E projects to advance the TRL of these and other technologies

Technology Needs and R&D Recommendations

- **Economics remain the largest inhibitor to adoption of advanced gas flare technologies**
- R&D recommendations focus on low-cost retrofittable/modular solutions supporting the NEW OOOOb/c regulations

	2023	2024	2025	2026	2027
Information Gathering	Gas flare tech. whitepaper	Gas flare tech. operator RFI	Operator tool for flare tech. selection		
Gas Flare Technology R&D		Monitoring and re-light technologies to address unlit and poorly performing flares			
		Measurement, reporting, and verification technologies for OOOOb/c compliance, data consistency			
				Retrofit technologies for >98% DE (field-verified)	
					NEW technologies for 99.5%+ DE
Flaring Alternatives R&D	Identify, develop, and demonstrate alternatives to routine flaring				

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Link to Full Report

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