Reducing Well Pad Air Emissions

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Topics Discussed

- **O&G Emissions Overview**
- **Emission Sources**
- **Flash vapor control methods**
  - Flaring
  - Gas recovery using a vapor recovery tower
  - Recovery directly from atmospheric storage tanks
- **Emissions Reductions**
- **Sample Economics**

Regulated Air Emissions

Well Pad Emission Sources	***Regulated Emissions (Permit Limited Conditions)***	***Regulated Emissions (Reporting Requirements)***
Condensate Tank (flash emissions)	VOCs and HAPs	GHG (CH_4, N_2O and CO_2)
Fixed Roof Tank, Condensate, working+breathing+flashing losses	VOCs HAPs NOX, CO	
Fugitive Emissions	VOCs and HAPs	
Truck Load Out Emissions	VOCs and HAPs	
Natural Gas Fired Heaters, VRUs	VOCs, HAPs, NOX, CO, SO2	
Flare & Combustor Emissions	VOCs, HAPs, NOX, CO, SO2, PM10, PM2.5	
Produced Water Tank Emissions	VOCs HAPs NOX, CO	
Emergency Tank Vent	VOCs and HAPs	

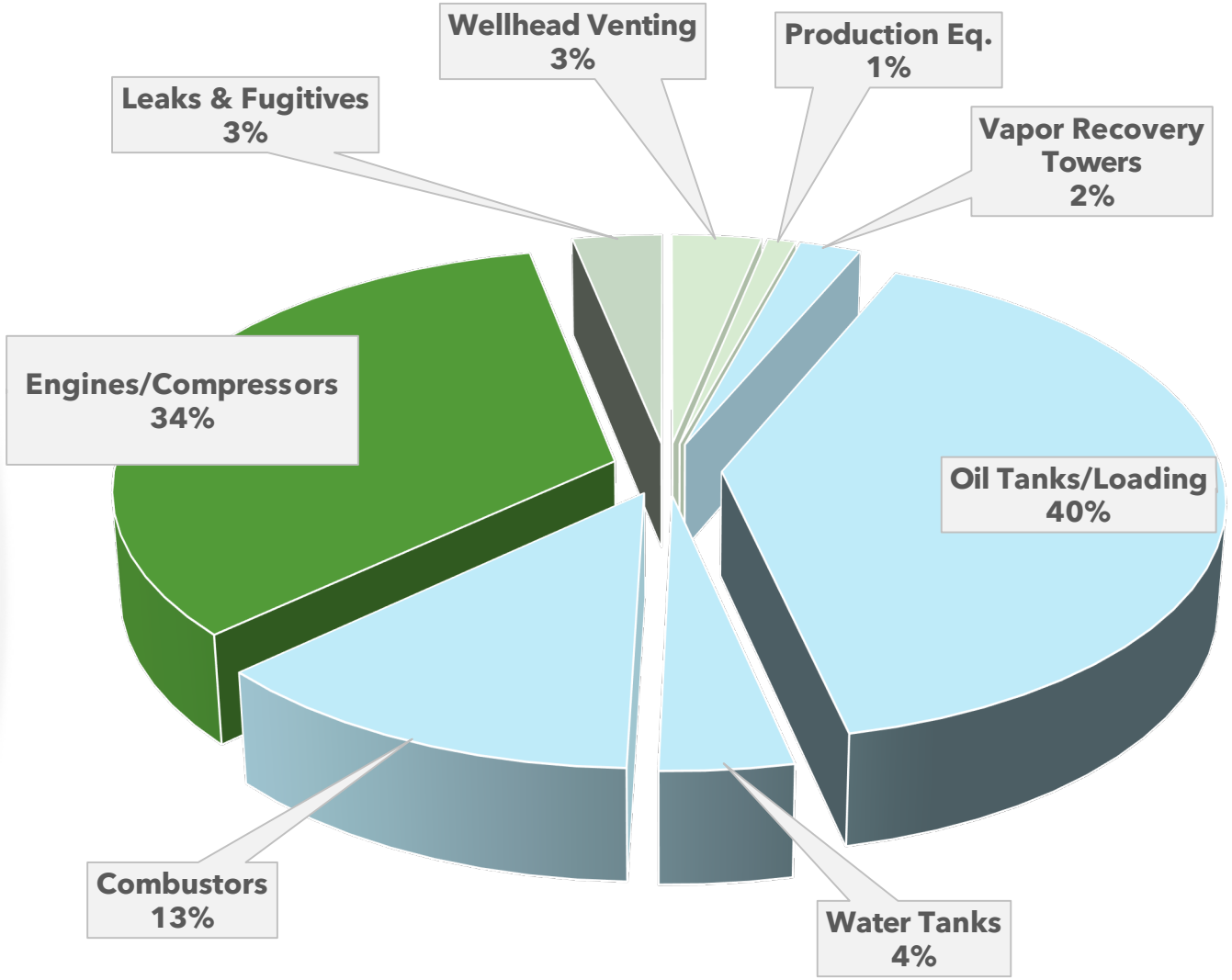
HAPs: Benzene, Toluene, Ethylbenzene, Xylene, n-hexane, 224 TMP

Criteria Pollutants

- The Clean Air Act requires EPA to set National Ambient Air Quality Standards (NAAQS). The standards are set at a level that protects public health with an adequate margin of safety. These pollutants are Federally Regulated and measured and managed by State Agencies.

  ✓Carbon Monoxide (CO)
  ✓Ozone (O3)
  ✓Nitrogen Dioxide (NO2)
  ✓Particulate Matter (PM-10 and PM 2.5 microns)
  ✓Sulfur Dioxide (SO2)
  ✓Lead (Pb)

VOC & NOx Emissions from O&G Facilities

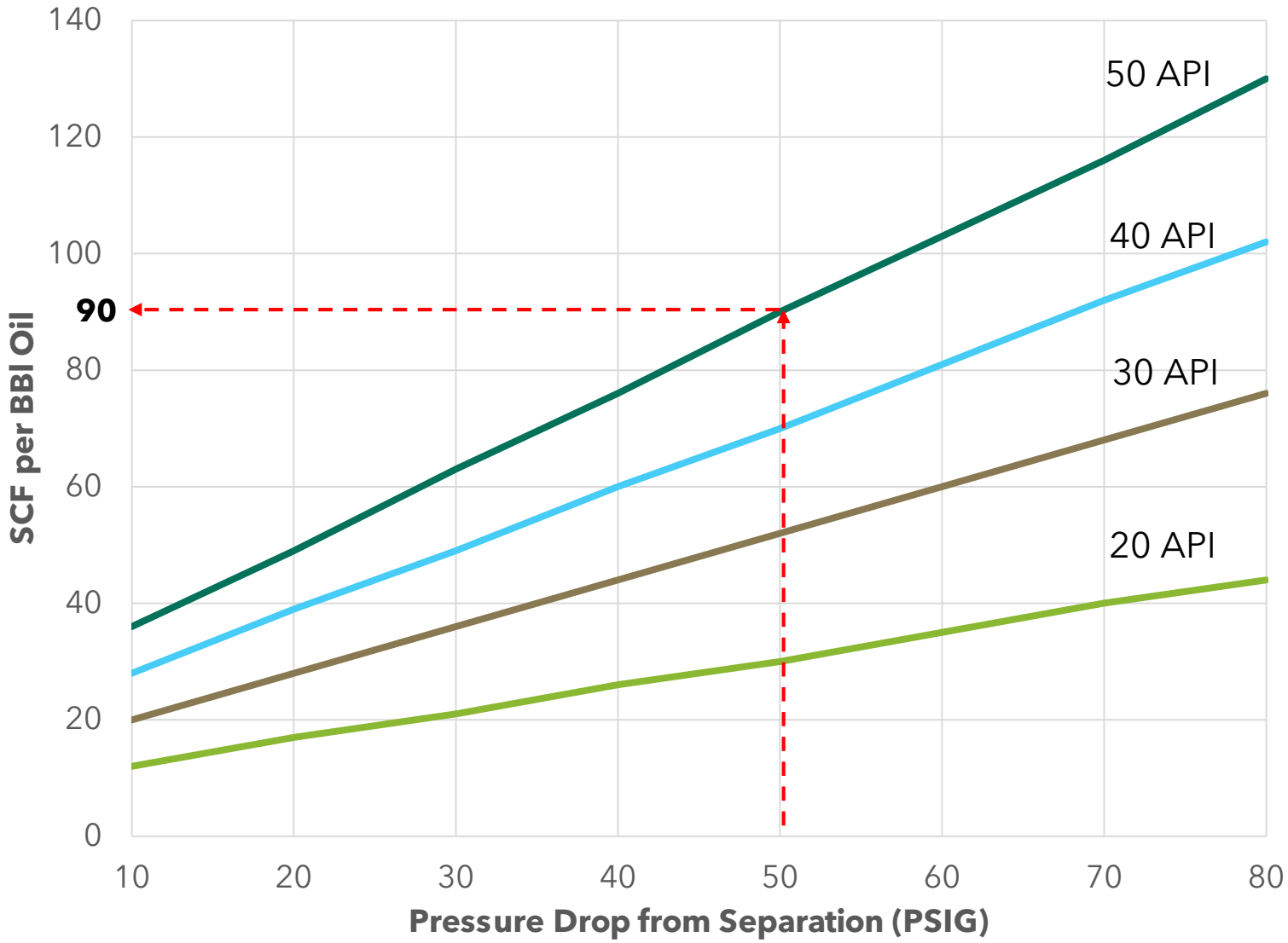


Roughly 60% of all site emissions related to flash vapor

Source: Colorado Dept. of Public Health & Environment

Recommended practice is to <u>add 50% to 100%</u> to these volumes due to variability in production volume & composition

Estimating Flash Vapor Potential



90 SCF/BBL * 2,000 BOPD
= 180 MCFD
Add 75% ~ 300 MCFD

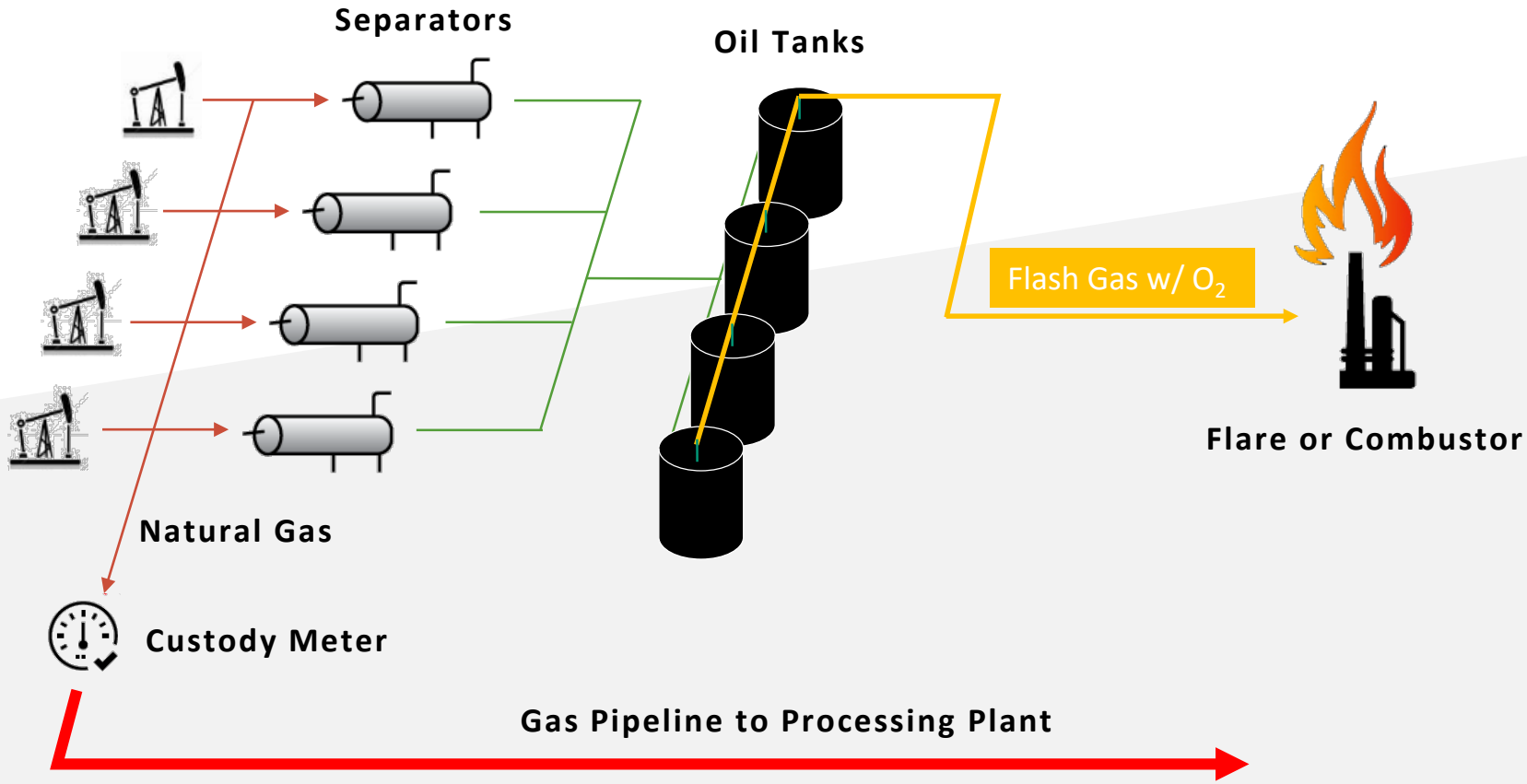
Source: Griswold, SPE 7175 (1978); 50 API data extrapolated

Option 1 - Flaring

Common issues:

- Matching flare capacity to variable production
- Keeping hatches/reliefs closed – no tank pressure control
- TCEQ: most common finding is open hatches & flare pilot failure

- *All gas flared*
- *300 Mscfd = 120 bpd oil energy equivalent*
- *Relatively low OPEX, high opportunity cost* [1]
- *High VOC, NOx, GHG emissions*



[1] *300 mscfd at $1.50/mcf plus 2x Btu premium ($3/mcf) = $328,000 annually*

Reasons For Flaring

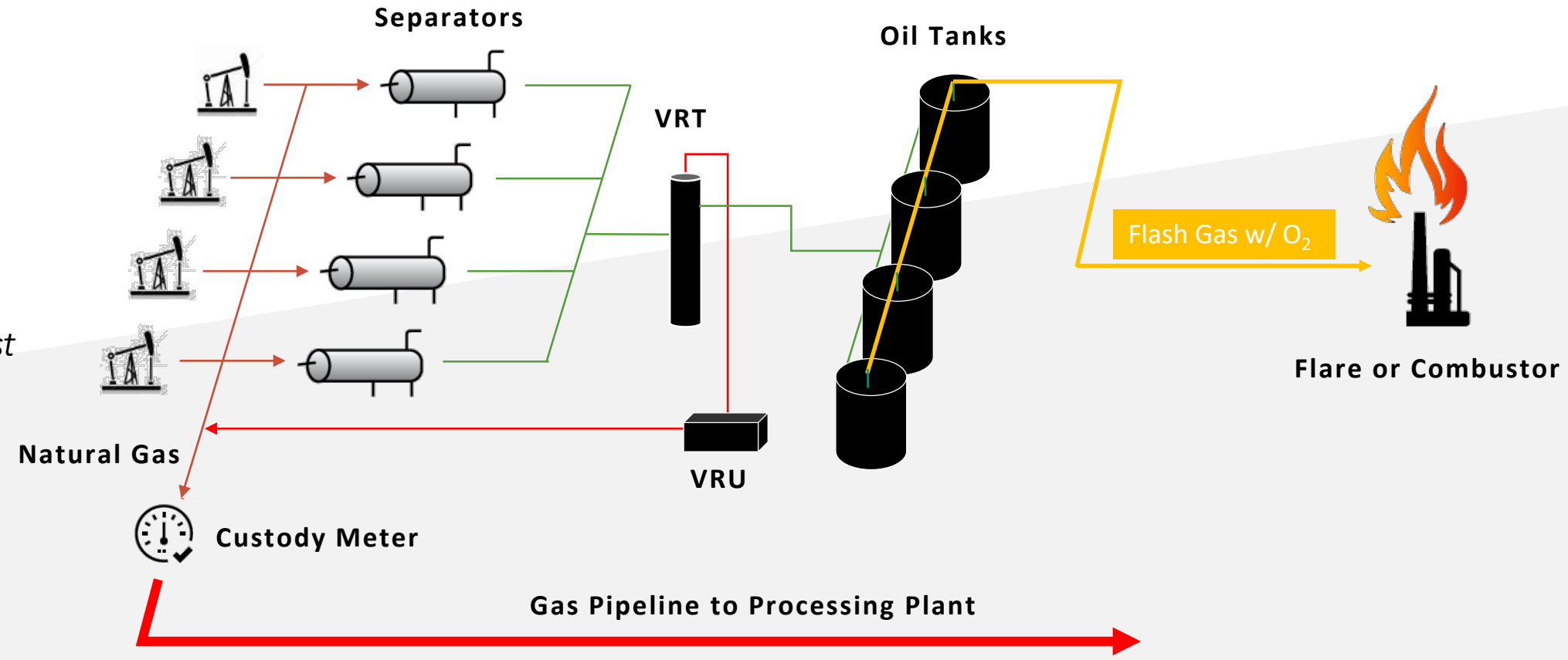
- No gas pipeline access (e.g. Bakken)
- Pipeline access, but no/limited takeaway capacity (e.g., parts of Permian)
- Pipeline with open capacity, but contaminants in recovered gas stream (e.g., typical 10 ppm O_2 limits)
- Low gas value
- Liquids focus, or cost-driven operation
- Unfamiliarity with options

Option 2 – Partial Vapor Recovery

Common issues:

- Matching flare capacity to variable production
- Keeping hatches/reliefs closed – no tank pressure control
- VRT efficiency
- VRT maintenance (paraffin loading, gas outlet freezing)
- VRU uptime

- *VRT captures 60-80% of vapor*
- *Lower oil sales $$*
- *Still flaring with lost revenue + VOC & NOx emissions*



VAPOR RECOVERY TOWERS

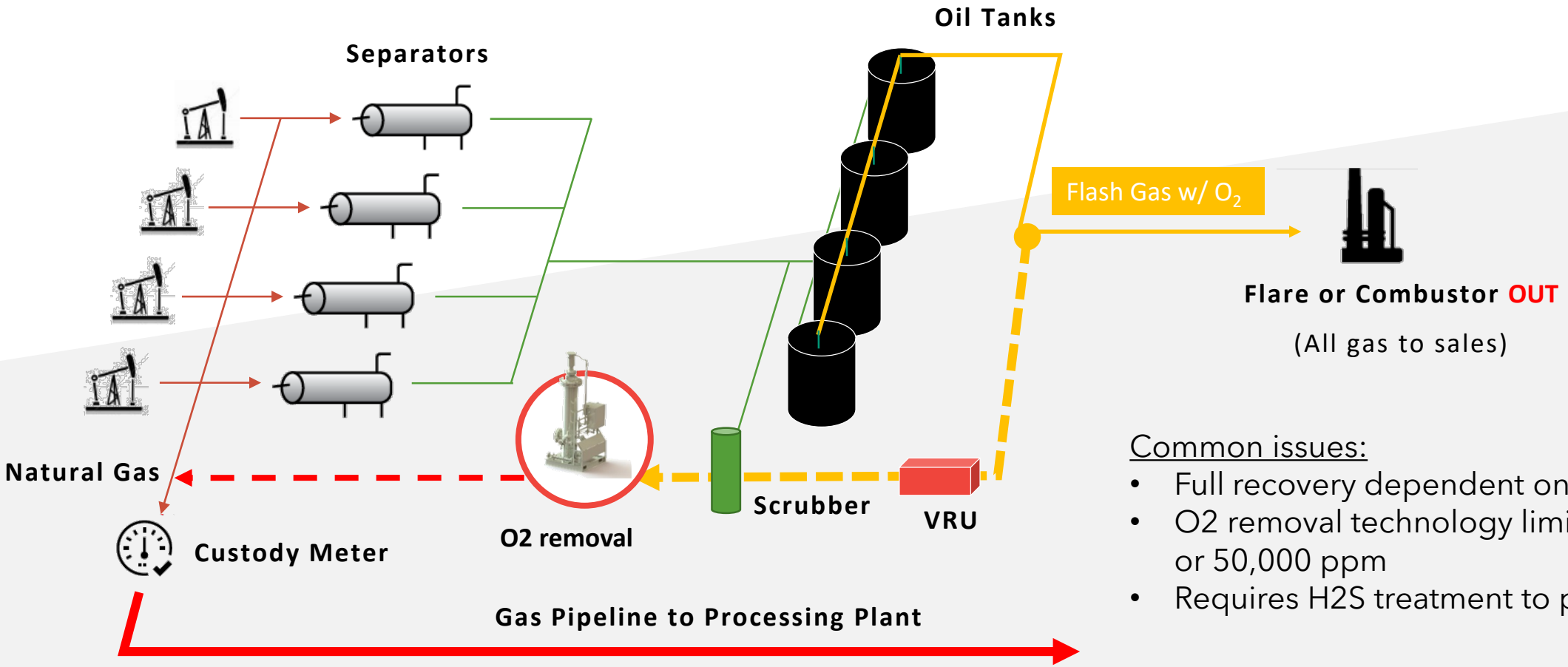
- Primary function is to degas produced oil from separation before atmospheric storage, where oxygen is present

- Immediately downstream of separation with flashing occurring at or near heated separator temperatures
  - Lower RVP
  - Lost oil sales

- Efficiency typically 60% to 80%
  - Inadequate pressure control & remaining pressure drop
  - Sizing & standardization
  - Variable oil production volume
  - Installation and maintenance issues

Option 3 – Full Vapor Recovery

- *No VRT*
- *All vapor captured for sale*
- *Increased oil sales $$*
- *Flaring occurs when VRU is not operating*

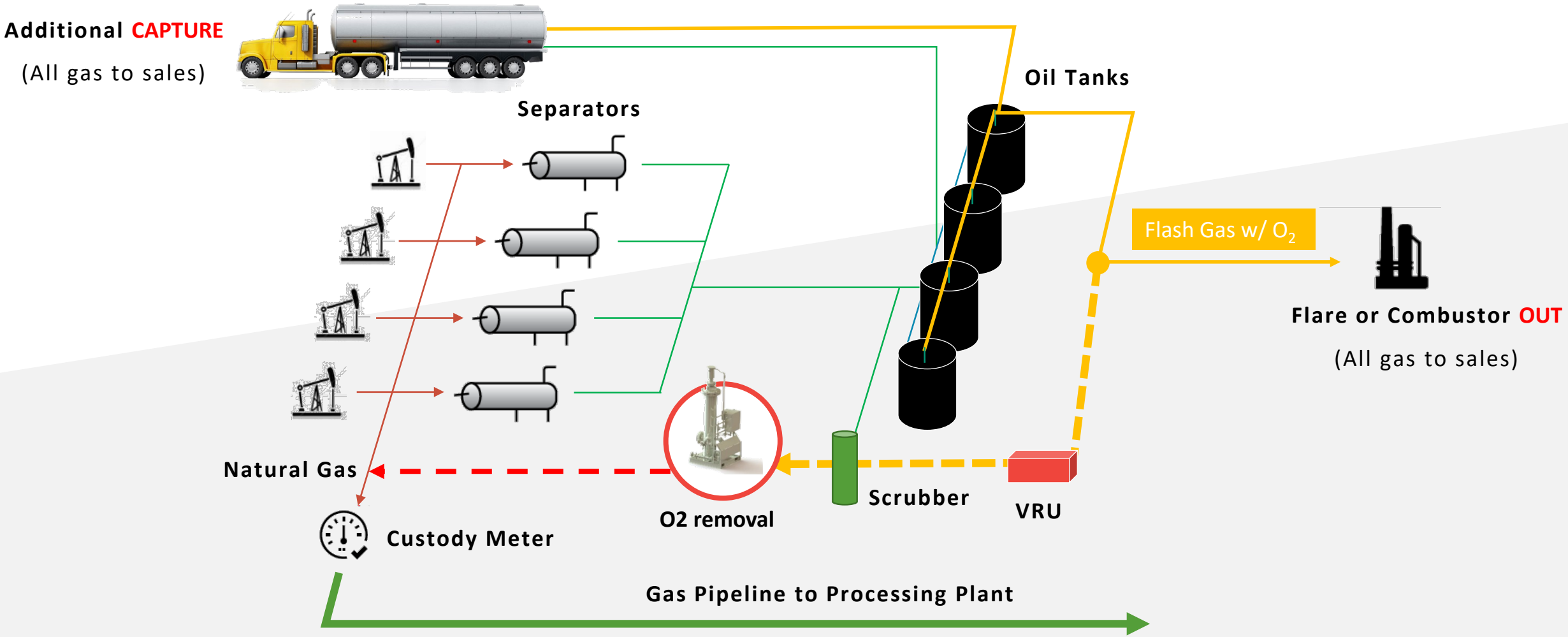


Common issues:

- Full recovery dependent on VRU uptime
- O2 removal technology limited to 5% O2 or 50,000 ppm
- Requires H2S treatment to protect catalyst

Truck Loading

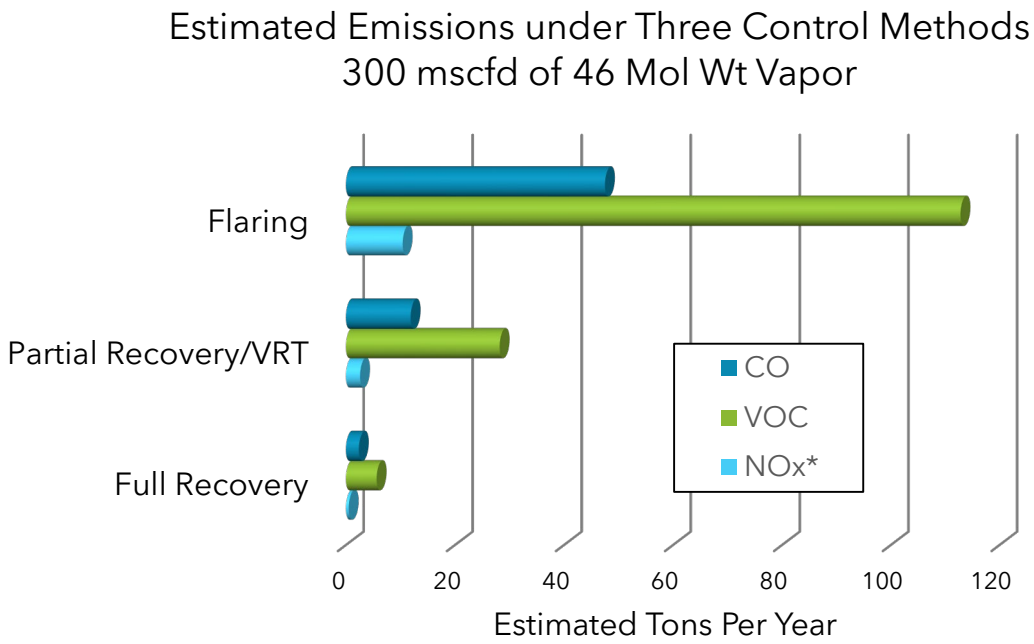
High O2 in truck vapor can require addition of produced gas to dilute O2 content for removal



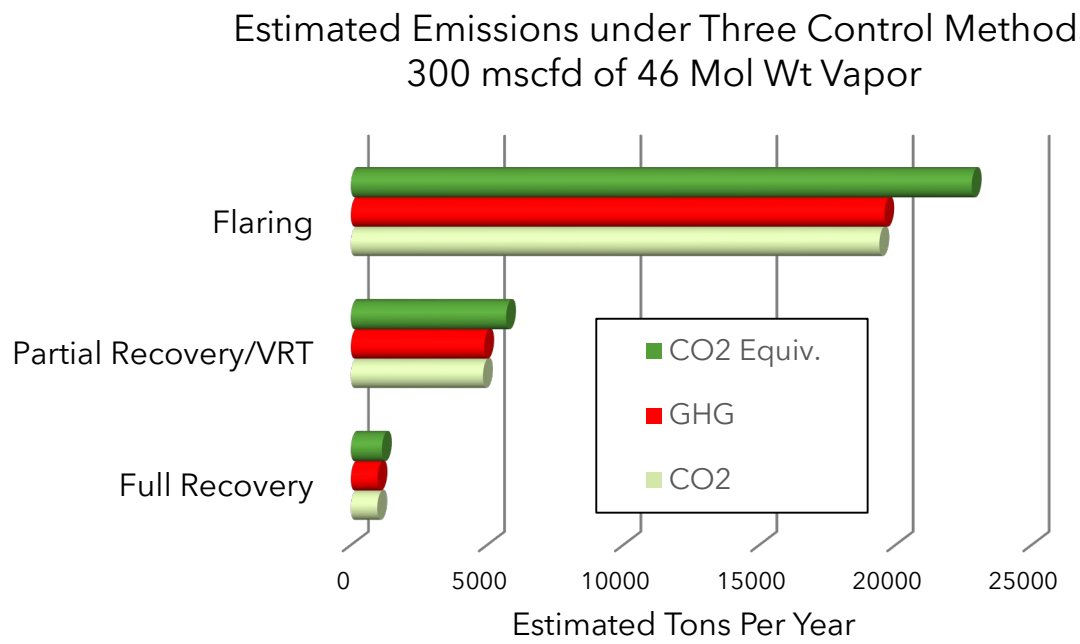
AIR EMISSIONS

- Comparison of three vapor control methods
- Based on actual 46 mol weight tank vapor sample
- 75% VRT efficiency, 95% VRU uptime, 98% flare VOC destruction rate

CO, VOC & NOx



GHGs



Emission Factors:

NOx, VOC, and CO: AP 42, Section 13, Table 13.5

GHG - CH4 and CO2 densities: 40 CFR 98 Subpart W, Section V

GHG = Methane, N_2O, & CO_2

Example from a Colorado O&G Permit

Condensate Tank Flashing and Combustor Emissions

Criteria Pollutants	*Requested Permit Limits Uncontrolled (tons/year)*	*Requested Permit Limits Controlled (tons/year)*
VOC	2815.08	28.16
PM10	0.14	0.14
PM 2.5	0.14	0.14
NOX	2.52	2.52
CO	5.23	5.23

***2,786.92 tons of VOC Reduction**

- Emissions from the condensate tanks are routed to an enclosed combustor when the Ecovapor and/or VRU skid is not operating.
- Requested overall VOC & HAP control efficiency is 99% annually.
- VRU minimum operational hours are 7,008.
- Combustor maximum operational hours are 1,752 (represents 20% VRU possible down time at 95% VOC & HAP control) .
- Data from a well pad within the DJ Basin with EcoVapor Equipment.
- Emissions represented by site specific emission factors.

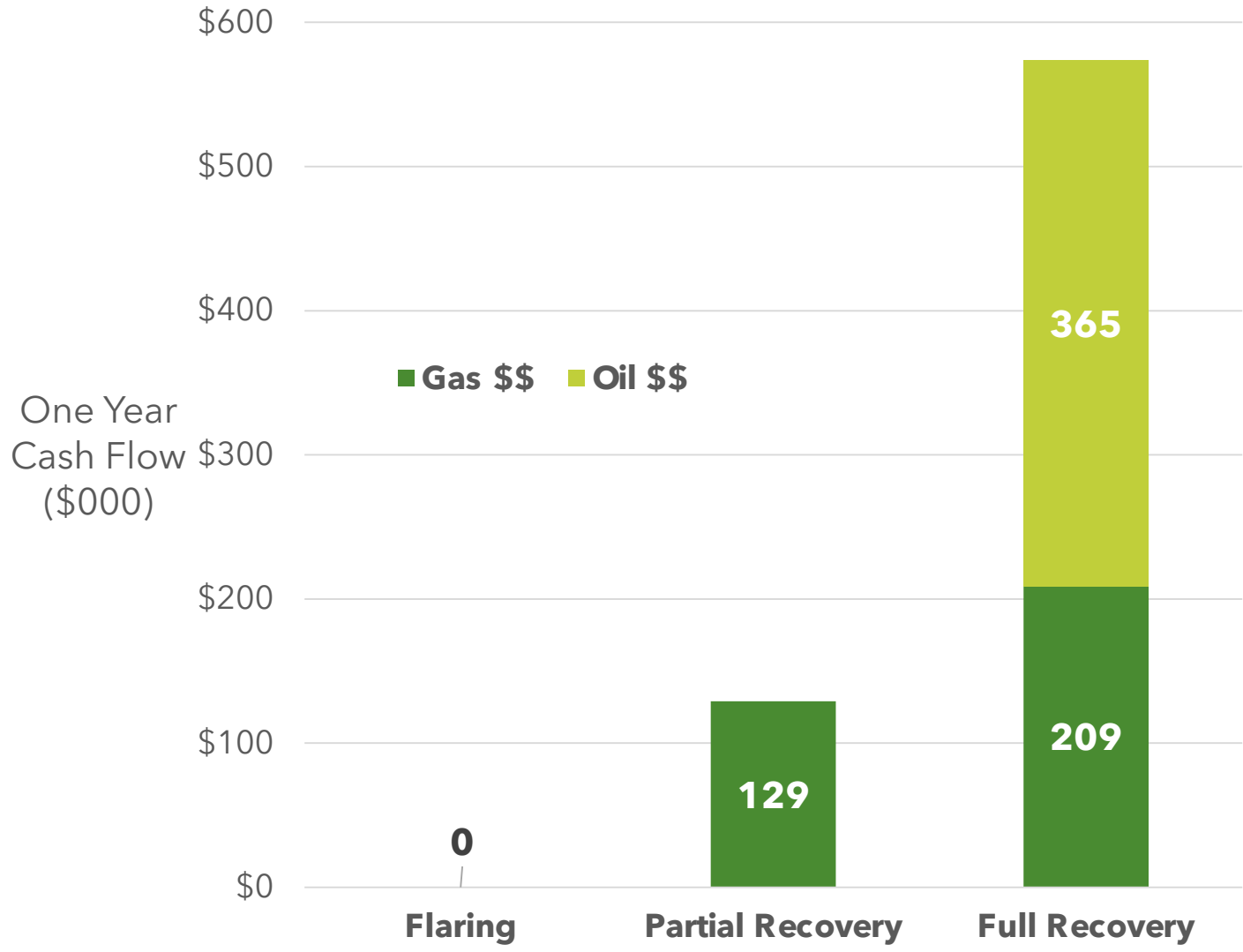
Sample Economics

- Year One View
- 300 mscfd vapor
- VRT 75% efficient
- VRU 95% Uptime
- $1.50/mcf gas, 2x bonus
- 2,000 BOPD - $50/bbl oil

		Flaring	Partial Recovery	Full Recovery	Notes
	Price/Each				
Combustors	*$30,000*	*$90,000*	*$90,000*	*$90,000*	*Three 100 mscfd*
Installation	*$3,000*	*$9,000*	*$9,000*	*$9,000*	
Maintenance		*$4,000*	*$4,000*	*$4,000*	
Dual Inlet Flare	*$28,000*	*$28,000*	*$28,000*	*$28,000*	*Hi-Low Flare*
Installation	*$3,000*	*$3,000*	*$3,000*	*$3,000*	
Maintenance		*$2,500*	*$2,500*	*$2,500*	
Vapor Rec Tower	**$45,000**	$0	$45,000	$0	48" x 30', 75% efficiency
Installation	$5,000	$0	$5,000	$0	
Maintenance	$5,000	$0	$5,000	$0	
Vapor Compressor	$3,750/mo	$0	$ 45,000	$ 45,000	95% Uptime, Maintenance Lease
Installation	$5,000	$0	$5,000	$5,000	
Maintenance	$0	$0	$0	$0	
O2 Removal	$4,000/mo	$0	$0	$ 48,000	
Installation	$4,000	$0	$0	$4,000	
Maintenance	$600			$600	
Equipment Cost		$0	$105,000	$102,600	Excluding flaring
Total Vapor (mscfd)		300	300	300	
Gas Sold		0	214	285	$1.50/mcf + 2x premium
Total Revenue		$0	$ 234,056	$ 312,075	
Cash Flow - Gas Only		$0	**$129,056**	**$209,475**	
Add: 1% increase in Oil		$0	$0	$ 365,000	Data from field trials
Potential Cash Flow		$0	$129,056	$574,475	2,000 BOPD, $50 WTI

One Year Cash Flow under Three Options

300 Mscfd vapor
VRT 75% efficient
VRU 95% Uptime
$1.50/mcf gas, 2x bonus
2,000 BOPD - $50/bbl oil



Conclusions

- Flash vapor resulting from the pressure drop from separation is the primary source of VOC, NOx & GHGs
- There are options in controlling these emissions; each option has advantages and disadvantages
- State & Federal regulations, and the priorities of each operator will largely determine the approach
- Vapor recovery, by itself, will not determine a project's economics