The Cost Effectiveness of Mitigating Liquids Unloading Emissions Using Flares

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This analysis examines the 107 liquids unloading wells measured by Allen et al.[1] and evaluates the cost-effectiveness of deploying flares to reduce methane and VOC emissions at those wells. Rigorous, well-designed standards for liquids unloading should directly regulate methane emissions. As set forth in the tables below, direct regulation of methane produces the lowest cost-effectiveness numbers.

Because the Allen dataset shows that most emissions come from a discrete set of wells, this memo analyzes the effectiveness of reducing emissions only at wells above various emission thresholds. Moreover, the analysis focuses on flaring technology, despite the existence of other highly cost-effective technologies, because flares can be applied at all wells. Operators should nonetheless be able to deploy other technologies, where feasible, to meet a performance standard. Because these other technologies often result in capture of natural gas that would otherwise be wasted, they could enhance cost-effectiveness beyond the numbers presented here.[2]

For this analysis, we evaluate the use of either mobile or stationary flares depending on well type, and for each, assess the cost-effectiveness of both rental and purchase.[3] The results set forth below represent a preliminary assessment of the cost-effectiveness of deploying flares above certain venting thresholds, and accordingly, rely on assumptions from existing literature concerning the cost and effectiveness of flaring technology.

Summary Results.

These preliminary results suggest that a requirement to mitigate liquids unloading emissions from wells that emit above certain annual thresholds would be cost-effective and yield significant emission reductions. In the Allen study, wells that vented at least 250 Mcf per year of methane represented approximately 16% of the projected well population, but accounted for 95% of the total measured

[1] David T. Allen et al., Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Liquids Unloading, 49 J. Environ. Sci. & Tech. 641 (2014), *available at* http://pubs.acs.org/doi/abs/10.1021/es504016r.

[2] For instance, IFC estimates that the cost effectiveness of deploying plunger lifts at uncontrolled wells is approximately $75/ton methane reduced.

[3] Where a producer determines other more cost-effective technologies can effectively reduce emissions, however, producers should be afforded latitude to deploy those technologies.

emissions in the study.[4] If flares with a combustion efficiency of 98% were deployed at this subset of wells, total measured emissions from all wells in the dataset would be reduced by 93%. The average cost-effectiveness of these reductions would be $140-$260 per ton of methane reduced (approximately $6-$10 per ton of CO_2-e, using a methane global warming potential of 25) and $940-$1,800 per ton of VOC reduced.[5] The distribution of emissions for the different well types is shown in Figure 1, below, for wells with liquids unloading emission rates greater than 250 Mcf per year.

Figure 1. Distribution of Emissions by Well Type for Emission Rates > 250 Mcf.
Based on 107 wells measured by Allen et al. (2013)

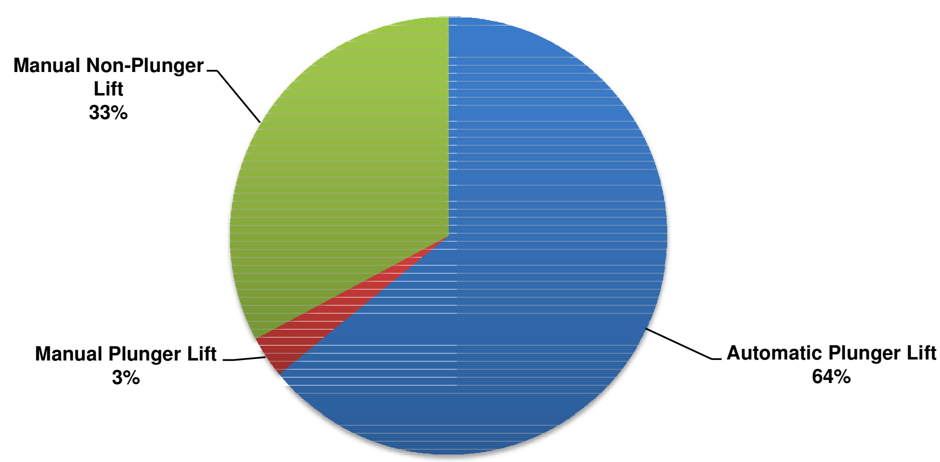

Table 1 summarizes the cost-effectiveness of deploying flares to reduce emissions from each well type (automatic plunger lift, manual plunger lift, manual non-plunger lift wells) at the 107 analyzed wells. For each, as described more fully below, the analysis assumes deployment of flaring technologies (mobile vs. stationary; and rented vs. purchased) according to certain well characteristics and provides a range of estimates for both methane and VOC cost

[4] Note, the Allen study only measured wells that vent for liquids unloading, not all wells with liquids loading activity. An API/ANGA study (Characterizing Pivotal Sources of Methane Emissions from Natural Gas Production: Summary and Analysis of API and ANGA Survey Responses) based on an industry survey of over 40,000 wells reports than only 21.1% of wells equipped with plunger lifts vent. Therefore, the estimated number of wells that vented at least 250 Mcf of methane per year assumes 78.9% of plunger lift wells do not vent.

[5] For comparison, EPA's NSPS Subpart OOOO analysis determined measures associated with costs of $4,360 per ton of VOC reduction to be cost effective (for LDAR at processing plants for connectors). *See* EPA NSPS Subpart OOOO Background Technical Support Document for Proposed Standards, EPA-453/R-11-002 July 2011, pp. 3-2, 3-3 and 8-29.

effectiveness.[6]

TABLE 1. Cost Effectiveness of Flares for Liquids Unloading.
The analysis is based on 107 wells measured by Allen et al. 2013.

Annual Emissions Limit (Mcf methane)	Automatic Plunger Lift Wells				Manual Plunger Wells and Manual Non-Plunger Wells				All Wells				
	Stationary Flare				Mobile flare for wells venting less than 20 times per year and stationary flare for wells venting more than 20 times per year				Weighted Average Cost Effectiveness of Stationary Flares at Automatic Plunger Wells and a Combination of Mobile and Stationary Flares at Manual Plunger/Non-Plunger Wells				% of Total Emissions Reduced by Flaring
	CH_4 LOW [$ / ton]	CH_4 HIGH [$ / ton]	VOC LOW [$ / ton]	VOC HIGH [$ / ton]	CH_4 LOW [$ / ton]	CH_4 HIGH [$ / ton]	VOC LOW [$ / ton]	VOC HIGH [$ / ton]	CH_4 LOW [$ / ton]	CH_4 HIGH [$ / ton]	VOC LOW [$ / ton]	VOC HIGH [$ / ton]	
1600	$67	$120	$460	$810	$77	$140	$530	$930	$71	$120	$480	$850	82%
1450	$71	$130	$490	$860	$77	$140	$530	$930	$73	$130	$500	$880	83%
1300	$71	$130	$490	$860	$77	$140	$530	$930	$73	$130	$500	$880	83%
1150	$71	$130	$490	$860	$86	$150	$590	$1,000	$77	$130	$520	$920	85%
1000	$71	$130	$490	$860	$86	$150	$590	$1,000	$77	$130	$520	$920	85%
850	$71	$130	$490	$860	$86	$150	$590	$1,000	$77	$130	$520	$920	85%
700	$71	$130	$490	$860	$100	$180	$720	$1,300	$85	$150	$590	$1,000	86%
550	$81	$140	$560	$980	$150	$260	$1,000	$1,800	$110	$200	$780	$1,400	90%
400	$81	$140	$560	$980	$150	$280	$1,000	$1,900	$120	$210	$810	$1,500	91%
250	$100	$180	$700	$1,200	$170	$350	$1,200	$2,400	$140	$260	$940	$1,800	93%
AVERAGE	$76	$130	$520	$910	$110	$190	$730	$1,300	$91	$160	$620	$1,100	

NOTES:

All flares:

Emissions reductions are based on a 98% flare efficiency

% emissions reductions are based on measured emissions from all wells measured and at all emission rates (not the subset of emissions above 100 Mcf)

Stationary Flare:

Low cost estimates are based on EPA annualized capital costs for completion combustion based on a 15 year equipment life and 7% interest plus annual operating cost estimates from CDPHE for pilot fuel and maintenance. See EPA NSPS Subpart OOOO RIA at 3-12 and TSD at 7-6 (April 2012).
See Colorado Department of Public Health and Environment, Cost-Benefit Analysis, Submitted per § 24-4-103(2.5), C.R.S., at 7 (2014)

High cost estimates are based on ICF data for capital costs for venting flares annualized, for consistency, based on EPA's assumptions of 15 year equipment life and 7% interest. Operating costs are also based on ICF estimates. See ICF International, "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries" at 3-22 (March 2014)

Mobile Flare (rented):

Cumulative annual costs for all reported venting events are calculated based on mobile flare rental costs ranging from $250 - $850/day and labor costs of $100/hr. The number of rental days is assumed to equal the reported number of venting events. Estimated labor time is based on min/max reported average sampled event duration. See ICF International Memo from Don Robinson, Joel Bluestein, Hemant Mallya, Tarang Mehta, and Mike Polchert, ICF International, to Peter Zalzal and Tomas Carbonell, EDF, June 13, 2014

VOC Cost Effectiveness:

Calculated based on ratios derived from EPA's NSPS Subpart OOOO. For liquids unloading the calculated VOC:methane ratio is 0.146.
See CATF, NRDC, Sierra Club "Waste Not: Common Sense Ways to Reduce Methane Pollution from the Oil and Natural Gas Industry" (January 2015)
See EPA NSPS Subpart OOOO RIA at Table 3-3 (April 2011)

<u>Automatic Plunger Lift Wells</u>.

Due to the greater frequency of unloading events at wells with automatic plunger lifts, a stationary flare is the most cost-effective flaring technology available to reduce emissions from such wells.

[6] The Allen study reported methane emissions from the sampled wells, but not VOC emissions. Accordingly, VOC cost effectiveness estimates in this analysis are calculated based on ratios of VOC:methane derived from EPA's NSPS Subpart OOOO (2011 RIA at Table 3-3). For liquids unloading the calculated VOC:methane ratio is 0.146. *See* CATF, NRDC, Sierra Club "Waste Not: Common Sense Ways to Reduce Methane Pollution from the Oil and Natural Gas Industry" (January 2015).

In estimating the cost effectiveness of stationary flares, this analysis assumes: (1) the “low cost” estimates are based on EPA data for annualized capital costs for completion combustion devices based on a 15 year equipment life and 7 percent interest rate, plus annual operating costs estimated for Colorado’s oil and gas rules, which include cost estimates for pilot fuel and maintenance;[7] and (2) the “high cost” estimates are based on ICF International data for capital costs for completion and venting flares annualized – for consistency – based on EPA's assumptions of a 15 year equipment life and 7% interest rate, plus annual operating cost estimates from ICF International.[8]

As shown in Table 1, based on the wells in the Allen et al. dataset, the average cost effectiveness of employing a stationary flare at wells with automatic plunger lifts, across all emission thresholds assessed, ranges from \$76-\$130 per ton of methane reduced (\$3 to \$5 per ton CO_2-e, using a methane GWP of 25), and \$520-\$910 per ton of VOC reduced. The cost effectiveness of employing a stationary flare to reduce emissions at wells with automatic plunger lifts with emissions above 250 Mcf methane ranges from \$100-\$180 per ton of methane reduced, and \$700-\$1,200 per ton of VOC reduced. At the 250 Mcf methane threshold for automatic plunger lift wells, deploying stationary flares would reduce total measured emissions from all wells in the dataset by 60%.

<u>Manual Plunger Lifts and Non-Plunger Wells</u>.

For wells in the data set with manual plunger lifts and manually vented wells without plunger lifts, this analysis assumes the use of either a mobile flare or a stationary flares, based on the frequency of unloading events reported at the wells. For manually vented wells, vented methane emissions in the dataset are generally lower than the other measured wells, averaging around 100 Mcf per year for wells with manual plunger lifts and 1,000 Mcf per year for wells without plunger lifts compared with an average of 2,500 Mcf per year for wells using automatic plunger lifts. Well venting also occurs relatively infrequently at these wells, with an average of as few as 10 reported venting events per year for wells with manual plunger lifts and 30 per year for wells without plunger lifts compared with automated plunger lift wells (which reported over 2,000 events per year). This analysis assumes mobile flares would be deployed at manual plunger wells when the number of annual venting events is low—less than 20—and stationary flares would be deployed at wells when annual venting events exceed 20.

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[7] Annualized capital costs = \$3,523 and annual operating costs = \$3,000. *See* EPA NSPS Subpart OOOO RIA at 3-12 and TSD at 7-6 (April 2012). *See* Colorado Department of Public Health and Environment, Cost-Benefit Analysis, Submitted per § 24-4-103(2.5), C.R.S., at 7 (2014).

[8] Annualized capital costs = \$5,490 and annual operating costs = \$6,000. *See* ICF International, "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries" at 3-22 (March 2014).

In estimating the cost effectiveness of flares at wells with manual plunger lifts, we relied on the stationary flaring assumptions set forth above. For mobile flares deployed at wells with fewer than 20 venting events per year, we assume: (1) cumulative annual costs for all reported venting events are calculated based on mobile flare rental costs ranging from $250/day - $850/day and labor costs of $100/hour;[9] (2) the number of rental days is assumed to equal the reported number of venting events (*i.e.*, a mobile flare only serves one well at a time and one event per day); and (3) estimated labor time is based on the minimum and maximum reported average sampled event duration rounded up to the next hour (labor costs are then calculated at a rate of $100/hour).[10]

As shown in Table 1, the average cost effectiveness of employing a combination of stationary and mobile flares at wells with manual plunger lifts and at wells without plunger lifts, across all emission limits assessed, ranges from $110-$190 per ton of methane reduced and $730-$1,300 per ton of VOC reduced. The cost effectiveness at this same subset of wells with emissions above 250 Mcf ranges from $170-$350 per ton of methane reduced and $1,200-$2,400 per ton of VOC reduced. For wells with manual plunger lifts and without plunger lifts whose emissions exceed 250 Mcf per year, deploying this combination of mobile and stationary flares would reduce total measured emissions from all wells in the dataset by 33%.[11] The majority of these emission reductions are associated with manually vented wells without plunger lifts, which generally have higher liquids unloading emissions than wells equipped with manual plunger lifts. Accordingly, cost-effectiveness of achieving emission reductions at manually vented wells without plunger lifts is also greater than at wells with manual plunger lifts.

[9] We note that purchasing mobile flares could further enhance cost-effectiveness for wells that unload more frequently.

[10] *See* ICF International Memo from Don Robinson, Joel Bluestein, Hemant Mallya, Tarang Mehta, and Mike Polchert, ICF International, to Peter Zalzal and Tomas Carbonell, EDF, June 13, 2014.

[11] Calculated reductions are based on measured emissions from all wells measured and at all emission rates (not the subset of emissions above 100 Mcf).