ESTIMATING FLARED NATURAL GAS VOLUMES FOR MAJOR U.S. SHALE PLAYS USING SATELLITE SENSOR DATA

Abstract

Natural gas flaring ("Flaring") is the controlled disposal of excess natural gas from oil and gas wells, gathering facilities, and refineries into the atmosphere. It is estimated that approximately 140 billion cubic meters of natural gas is flared around the globe, resulting in approximately 300 million tons of CO_2 emissions in the atmosphere.[1]

U.S. state and federal agencies often mandate oil and gas companies to self-report the amount of natural gas that they combust monthly ("Reported Flare Volumes"). These same agencies set limitations on the total amount of natural gas that can be flared. Reported Flare Volumes are used by U.S. regulatory bodies to monitor these U.S. greenhouse gas emissions and administer environmental policy. In addition, this data is used by global midstream pipeline companies and investors to identify where gaps in natural gas collection infrastructure exist.

However, studies suggest that these Reported Flare Volumes fail to capture precise flared volumes in a timely fashion.[2] To understand the full extent of domestic emissions within the atmosphere and whether infrastructure shortfalls exist, it is crucial to utilize all available tools and methodologies.

By leveraging publicly available satellite sensor data, the methodology noted within this analysis discusses quantifying flared natural gas volumes at flare stacks and pipes of producing oil and gas wells ("Estimated Flare Volumes") as an alternative to state-government reported sources (i.e. Reported Flare Volumes). For this study, satellite sensor data is sourced from the National Oceanic and Atmospheric Administration's ("NOAA") Visible Infrared Imaging Radiometer Suite ("VIIRS"), synthesized with oil and gas production and well-meta datasets, and then is processed using regression-based statistical models to estimate flared gas volumes. Aggregated Reported Flared Volumes and derivative Estimated Flared Volumes are collected for select U.S. basin and shale plays such as the Permian, Eagle Ford, Denver Julesburg – Niobrara (Colorado only) and Bakken (North Dakota only) ("Tracked Regions").

For the Tracked Regions, Reported and Estimated Flare Volumes were 257 / 253 Bcf in FY 2020, reflecting a 48 / 43% drop from the FY 2019 volumes of 489 / 447 Bcf, respectively. On a CO_2 equivalent ("CO_2e")

basis, natural gas emissions for Tracked Regions, Reported Flaring Volume CO_2e were 14 Megatons ("Mt") and 27 Mt for FY 2020 and FY 2019, respectively.[14] The Permian basin and Bakken shale play were identified as the regions with the highest Reported Flaring Volumes over the FY 2019 and FY 2020 periods. Operators were also ranked by total produced volumes and their proportion of Reported Flare Volumes to total Gas Produced ("Flared Percentages"). For the FY 2019 and FY 2020 periods, Occidental Petroleum (NYSE: OXY), EOG Resources (NYSE: EOG), ConocoPhillips (NYSE: COP), and ExxonMobil (NYSE: XOM) were the top Tracked Region Operators who had the highest Produced Volumes while maintaining the low Flared Percentages (<5%).

The methodologies outlined offer a systematic and objective means of monitoring flaring activity and have the potential to be transferred in other hydrocarbon-producing regions across the world. By analyzing both Reported Flare Volume and derivative Estimate Flare Volume datasets, corporations, governments, and communities can better understand emission levels on a holistic, near real-time basis and more quickly identify where new collection and pipeline infrastructure is required.

Introduction

Natural gas flaring ("Flaring") is the controlled disposal of excess natural gas from oil and gas wells, gathering facilities, and refineries into the atmosphere. The reasons for Flaring include safety and management of excess gas volumes that cannot be efficiently and economically stored or processed by existing midstream infrastructure. A 2015 World Bank Report estimated that approximately 140 billion cubic meters of natural gas is flared around the globe, resulting in approximately 300 million tons of CO_2 emissions in the atmosphere.[1]

U.S. state and federal agencies often mandate oil and gas companies to self-report the amount of natural gas that they flare monthly ("Reported Flare Volumes"). These same agencies set limitations on the total amount of natural gas that can be flared. Reported Flare Volumes are used by U.S. regulatory bodies to monitor these U.S. greenhouse gas emissions and administer environmental policy. However, studies suggest that these Reported Flare Volumes fail to capture precise flared volumes in a timely fashion.[2]

To understand the full extent of domestic emissions within the atmosphere and whether they comply with federal and state-specific limitations, it is important to leverage all available tools and methodologies. An attractive option for monitoring natural gas flares is by estimating the quantity of flared natural gas at individual flare stacks and pipes of producing oil and gas wells ("Estimated Flare Volumes") using infrared signals captured by the National Oceanic and Atmospheric Administration's ("NOAA") Visible Infrared Imaging Radiometer Suite ("VIIRS").[3,4] By synthesizing satellite-sensor data with oil and gas production and well-meta datasets and Reported Flare Volumes, quantifying site-specific estimations of natural gas flare volumes is achievable in a near-real time and systematic fashion.

Methodology

Overview

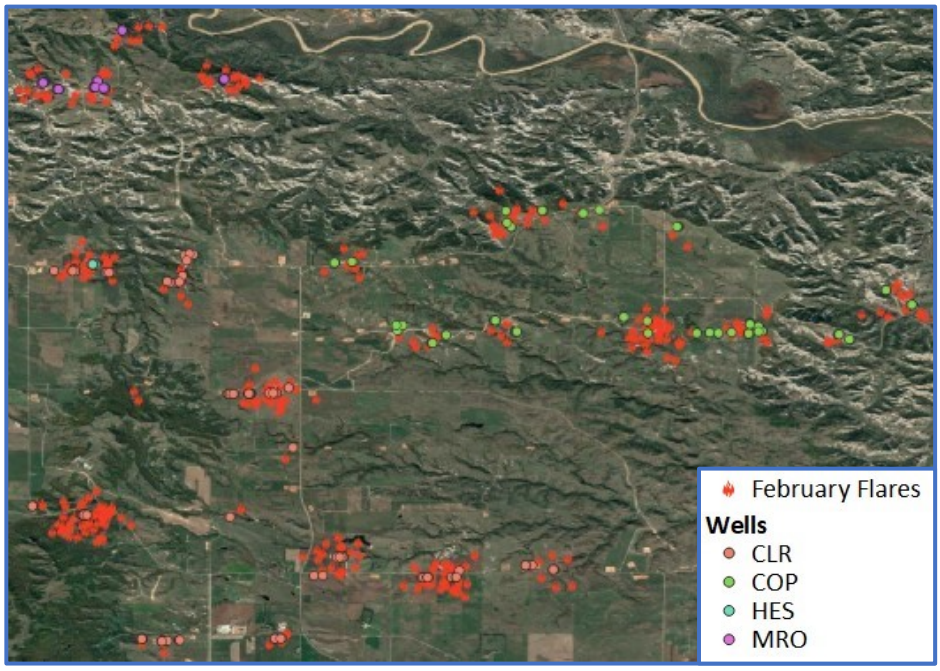
Radiant heat ("RH") measurements from satellite infrared sensors have demonstrated a direct correlation with natural gas flaring volumes, up to an accuracy of ±9.5%.[3,4] VIIRS instruments on the NOAA's Joint Polar Satellite System ("JPSS") and Suomi National Polar-Orbiting Partnership ("NPP") detect and measure radiant emissions from natural gas flares through the collection of shortwave and near-infrared data at night.[8] As part of this collection, these instruments record daily peak radiant emissions from these flares at a moderate resolution. A processed and published version of this data is called the VIIRS Nightfire ("VNF") algorithm. This VNF dataset contains geotagged global radiant heat measurements and other relevant meta data (e.g. flare temperature, area of observed flame and radiant heat intensity, etc.) and is published daily by the Colorado School of Mines.[3,5] The VNF algorithm uses the Wien's Displacement and Stefan-Boltzmann laws to calculate important attributes such as flaring source temperatures and their associated radiant heats.

Aggregated Reported Flared Volumes are collected, and derivative Estimated Flared Volumes are calculated for select U.S. shale plays and basins including: the Permian basin ("Permian"), Eagle Ford shale play ("Eagle Ford"), Denver Julesburg basin – Niobrara – Colorado ("DJ Basin"), and Bakken shale play - North Dakota ("Bakken"), (collectively, "Tracked Regions").

To develop Estimated Flare Volumes using infrared measurements, VNF data is first proximally matched to associated oil and gas production and well meta data within the U.S.

To improve the resolution of VNF detected flares, geotagged satellite flare observations are geospatially matched to clusters of hydrocarbon producing oil and gas wells with a radius of 415 meters. The assumption is that nearby aggregated groups of wells and well pads have a higher probability of flaring from the same source (vs. disparate sources). Flare clusters are then assigned to the nearest well clusters and their corresponding RH values are aggregated by reported operator (See Figure 1).

FIGURE 1. NORTH DAKOTA FLARE CLUSTER WELL ASSIGNMENTS (FEBRUARY 2020)



Statistical regression-based methods are then used to convert aggregated flare cluster radiant heat measurements into Estimated Flaring Volumes.

First, a linear regression model is used to link flare cluster radiant heat measurements to their associated Reported Flaring Volumes. The model's purpose is to calculate operator / basin-specific Conversion Factors (C_f) that directly link flare cluster radiant heat measurements to Reported Flare Volumes.

The model is then optimized to minimize the root mean square error ("RMSE") for these Conversion Factors. Individual statistical models are trained for each basin, shale play, and company-basin/shale play combination to account for unique features in reporting patterns, acreages, atmospheric conditions, flaring protocols and well-pad surface infrastructure.

These calculated Conversion Factors are then used to forecast Estimated Flaring Volumes for the Tracked Regions and the operators within Tracked Regions by multiplying Conversion Factors to geotagged VNF radiant heat measurements (see Detailed Methodology (4)). Natural gas flaring volumes on a CO_2 equivalent ("CO2e") basis is calculated by multiplying the Estimated Flaring Volume with a standard conversion factor published by Environment Protection Agency (EPA)[14].

This process is repeated daily as new VIIRS data is published and allows for near-real time Estimated Flaring Volumes forecasts to be generated.

Detailed Methodology

Theory

Raw short-wave and near-infrared measurements collected by VIIRS instruments are processed using the Nightfire algorithm. The Nightfire algorithm uses six spectral bands to detect and characterize sub-pixel infrared emitters. Using the flare radiances in these spectral bands, heat source temperatures are calculated using Wien's Displacement Law (1):

$$T = b/\lambda_{max} \quad (1)$$

where T is the heat source temperature in kelvin (K), b is the Wien's displacement constant = 2897.8 $K\mu_m$ and λ_{max} is the wavelength of peak radiant emissions (e.g. flare sources).

Using the flare source temperature (T)(1), radiant heat (RH) is calculated using the Stefan-Boltzmann law (2):

$$\mathrm{RH} = \sigma \mathrm{S} \mathrm{T}^4 \quad (2)$$

where RH is radiant heat in megawatts (MW), σ is the Stefan-Boltzmann constant, S is the source area in square meters (m^2), and T is the temperature of heat source in kelvin (K).

Radiant heat measurements have been found to have a direct correlation with natural gas flaring volumes[3], up to an accuracy of ±9.5%[4] as shown in (3) and (4),

$$\mathrm{V} \propto \mathrm{RH} \quad (3)$$

$$\mathrm{V} = \mathrm{C_f RH} \quad (4)$$

where V is the natural gas flaring volume in billion cubic feet (Bcf), $\mathrm{C_f}$ is a conversion factor in Bcf per MW, and RH is radiant heat in megawatts (MW).

By using time-stamped radiant heat and temperature measurements of identified source areas, this methodology calculates a specific conversion factor (either basin or shale play-level or Operator-level), $\mathrm{C_f}$, by benchmarking calculated volumes (V) to their associated, publicly reported natural gas flaring volumes from regulatory sources.

Using these conversion factors, operator and basin-specific Flaring volumes are calculated for Tracked Regions using radiant heat and temperature measurements available from the Nightfire algorithm, often prior to publishing of Reported Flaring Volumes by regulatory agencies.

Processing

These next sections discuss the steps necessary to recreate the methodology in an independent computational environment utilizing VNF Data and Reported Flare Volumes.

VNF Data Processing

VNF data is published by the Colorado School of Mines Earth Observation Group[4], and the following steps are performed to the data set (collectively, "VNF Data"):

1. VNF data series used in this analysis include:
    a. Date_LTZ ("Date-Time"): Observed Flare pixel date-time
    b. Lat_GMTCO ("Flare Latitude"): Flare pixel latitude
    c. Lon_GMTCO ("Flare Longitude"): Flare pixel longitude
    d. Temp_BB ("Temperature"): Flare source temperature assuming blackbody source (derived using Nightfire algorithm (1))
    e. RH ("Radiant Heat"): Flare source radiant heat (derived using Nightfire algorithm (2))
2. Using Flare Latitude and Flare Longitude coordinates, a VNF dataset is filtered to only include observed satellite measurements within Tracked Regions.
    a. Outlines of the Tracked Regions are sourced from the U.S. Energy Information Administration ("EIA") Basin and Shale play shapefiles.[6]
3. Observations with Temperatures less than 1,400 K are then removed from the sample set.
    a. This is done to remove noise from non-Flaring sources like forest fires and biomass, which typically burn at temperatures less than 1,400 K (vs. Flaring sources which burn at over 1,400 K).[4]
4. Remaining observations are then binned on the calendar week for which they were detected using Date-Time.
5. Once binned by week, observations within a 150-meter flare-to-flare distance radius are clustered together ("Flare Clusters").

a. A 150-meter threshold flare-to-flare distance limit was determined by iteratively testing various cluster distance limits across Tracked Regions.
b. To calculate this radius, various lengths were tested and the threshold distance limit was chosen by identifying the radius with the highest average correlation of monthly aggregated Radiant Heat and monthly Reported Flare Volume for all operators.
c. The threshold distance helps account for the decreased precision of detecting repeated flares. The NOAA's satellite resolution is limited to 750 meters and the threshold distance provides a limit on a flare cluster size to account for operators having adjacent acreage positions and idiosyncratic well pad orientations.

6. Once the Flare Clusters are created, Radiant Heat values associated with each Flare Cluster are summed together to calculate total Radiant Heat of individual Flare Clusters ("Total RH").

Well Data Processing

Publicly available, state-reported oil and gas production and meta data are aggregated and the following steps are performed[9]:

1. State-reported oil and gas production and meta data required for this analysis include (collectively, "Well Data"):
    a. Meta data:
        i. API: Unique Identifier given to every permitted Oil and Gas Well in the U.S.
        ii. Operator Name ("Operator"): Name of the current operator of an oil and gas well held on record with the relevant U.S. state regulatory agency
        iii. Latitude Surface Hole ("Well Latitude"): Standardized NAD83/NAD 27 Latitude metric for the Surface Hole location of a wellbore
        iv. Longitude Surface Hole ("Well Longitude"): Standardized NAD83/NAD27 Longitude metric for the Surface Hole location of a wellbore
    b. Production data:
        i. Month of Production ("Production Month"): Month for which the hydrocarbon production is reported
        ii. Oil Volume Produced ("Produced Oil"): Monthly oil production reported by the state regulatory agency for a particular API or lease

iii. Gas Volume Produced ("Produced Gas"): Monthly gas production reported by the state regulatory agency for a particular API or lease

iv. Gas Volume Flared ("Reported Flare Volumes"): Monthly gas flared reported by the state regulatory agency for a particular API or lease

2. Using Well Latitude and Well Longitude coordinates, Well Data is filtered to only include measurements within Tracked Regions.
3. APIs or Leases with no Produced Oil or Produced Gas in the last 6 months are then filtered out of the Well Data subset.
    a. This step helps to eliminate all wells that are either shut-in or temporality abandoned.
4. The remaining well subset is then binned by Production Month and then by Operator
5. Binned Reported Flare Volumes are then clustered using a 300-meter distance limit between wells ("Well Clusters").
    a. This clustering step helps account for multiple wells being collocated on the same well pad or proximally positioned next to other pads utilizing communal flare stacks.
    b. The 300-meter distance limit was derived by averaging a large sample set of oilfield distances including: adjacent pads distances, well to flare stack distances, and well to common tank battery distances. These distances were measured using high-resolution satellite imagery across our Tracked Regions.[7]

Regression Analysis

Processed VNF and Well Data subsets are then synthesized and modeled in the steps below:

1. For a calendar month, Flare Clusters are assigned to the nearest Well Clusters with a maximum geospatial distance of 415 meters.
2. Flare Cluster Total RH values are then tagged to their associated Well Clusters ("Well Cluster RH").
    a. Each Well Cluster can have zero, one, or multiple Flare Clusters associated with them in any given month.
3. Well Cluster RHs are then binned by each basin, shale play, and Operator-basin/shale play combination within Tracked Regions ("Aggregated Well Cluster RH").
4. Conversion factors (C_f) are then calculated for each basin, shale play, and Operator-basin/shale play combination within Tracked Regions.

a. A linear regression model is utilized, setting Reported Flare Volumes as the Y variable and Aggregated Well Cluster RH values as the X variable, as shown in (6).

$$Y = mX + C \quad (5)$$

$$Reported\ Flare\ Volume = C_f * RH \pm Error \quad (6)$$

b. Root mean square error optimizations are executed (6) to calculate basin, shale play, and Operator-specific conversion factors, C_f.

5. These calculated conversion factors, C_f, are then applied to Aggregated Well Cluster RHs to calculate Estimated Flare Volumes using Equation (5), as new Aggregated Well Cluster RHs are made available.
6. To calculate the upper and lower estimate bounds for Estimated Flare volumes, absolute percentage errors between historical Reported Flare Volumes and Estimated Flare Volumes are averaged over all calendar months for which Operator-level Reported Flare Volumes data are available.
7. CO_2 equivalent ("CO_2e") emission quantities are derived by multiplying the Flaring Volume with a standard conversion factor published by the Environment Protection Agency (EPA) as shown in Equation (7)[14]

$$CO_2e, metric\ tons = 0.0548 * Flared\ Volume, mcf \quad (7)$$

Discussion

Reported Flare Volumes and Estimated Flare Volumes were analyzed on a geographic and Operator-level for the Tracked Regions for the following periods: January 1, 2019 to December 31, 2019 ("FY 2019") and January 1, 2020 to December 31, 2020 ("FY 2020").

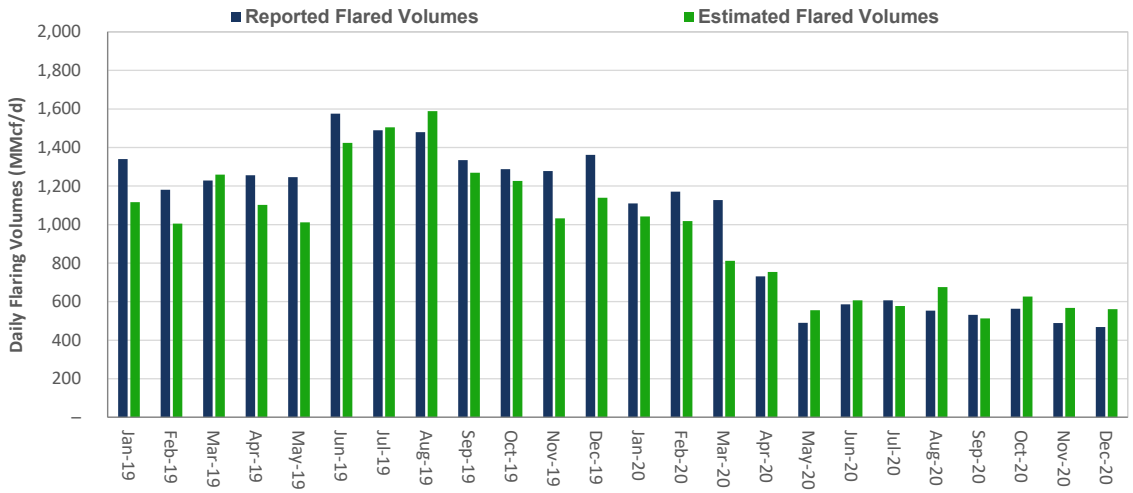
Tracked Regions

For the Tracked Regions, Reported and Estimated Flare Volumes were 257 / 253 Bcf in FY 2020, reflecting a 48 / 43% drop from the FY 2019 volumes of 489 / 447 Bcf, respectively (see Table 1 and Figure 2). On a CO_2e basis, Tracked Region Reported Flaring Volumes were 14 Mt in FY 2020 and 27 Mt in FY 2019. Within the FY 2019 and FY 2020 periods, peak Reported Flare Volumes and Estimated Flare Volumes were observed in June 2019 and August 2019, at 47 Bcf and 49 Bcf, respectively, representing ~5.3% of total Produced Gas in the region for the months (see Table 1). For the FY 2019 and FY 2020 periods, Reported Flare Volumes reflected, 4.5% and 2.3%, of total Produced Gas, representing a 49% decrease year over year.

TABLE 1. TRACKED REGION DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

Period	Rank	Reporting Month	Reported Flared Volumes		Estimated Flared Volumes		Produced Gas Volumes		Flared Percentage
			Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	
FY 2019	5	Jan-19	41.5	1,340	34.6	1,116	852.1	27,487	4.9%
	15	Feb-19	33.1	1,181	28.1	1,005	778.0	27,785	4.3%
	10	Mar-19	38.1	1,229	39.0	1,259	869.9	28,062	4.4%
	11	Apr-19	37.7	1,256	33.1	1,102	848.5	28,283	4.4%
	8	May-19	38.6	1,246	31.3	1,011	900.3	29,042	4.3%
	1	Jun-19	47.3	1,575	42.7	1,423	882.3	29,409	5.4%
	2	Jul-19	46.2	1,490	46.6	1,504	923.2	29,781	5.0%
	3	Aug-19	45.8	1,479	49.3	1,589	947.2	30,554	4.8%
	6	Sep-19	40.0	1,334	38.1	1,268	933.8	31,125	4.3%
	7	Oct-19	39.9	1,288	38.0	1,227	977.3	31,527	4.1%
	9	Nov-19	38.3	1,278	31.0	1,032	963.1	32,104	4.0%
	4	Dec-19	42.2	1,361	35.3	1,140	998.0	32,194	4.2%
FY 2020	13	Jan-20	34.4	1,110	32.3	1,042	1,002.4	32,336	3.4%
	14	Feb-20	34.0	1,171	29.5	1,018	940.1	32,418	3.6%
	12	Mar-20	35.0	1,128	25.2	812	1,014.3	32,719	3.4%
	16	Apr-20	21.9	732	22.6	754	934.6	31,152	2.3%
	22	May-20	15.2	490	17.2	556	845.5	27,275	1.8%
	18	Jun-20	17.6	586	18.2	607	864.0	28,799	2.0%
	17	Jul-20	18.8	606	17.9	577	931.9	30,062	2.0%
	20	Aug-20	17.1	553	21.0	676	954.9	30,802	1.8%
	21	Sep-20	15.9	532	15.4	513	925.6	30,855	1.7%
	19	Oct-20	17.4	563	19.4	626	953.3	30,752	1.8%
	23	Nov-20	14.7	489	17.0	568	917.7	30,591	1.6%
	24	Dec-20	14.5	469	17.4	561	928.4	29,947	1.6%
FY 2019		**Gas (Bcf | MMcf/d)**	**488.8**	**1,339**	**447.2**	**1,225**	**10,873.7**	**29,779**	**4.5%**
		CO_2e (Mt | Kt/d)	**26.8**	**73**	**24.5**	**67**	**595.9**	**1,632**	
FY 2020		**Gas (Bcf | MMcf/d)**	**256.6**	**703**	**253.2**	**694**	**11,212.7**	**30,642**	**2.3%**
		CO_2e (Mt | Kt/d)	**14.1**	**39**	**13.9**	**38**	**614.5**	**1,679**	
		Y/Y Change	**(48%)**	**(48%)**	**(43%)**	**(43%)**	**3%**	**3%**	**(49%)**

FIGURE 2. TRACKED DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

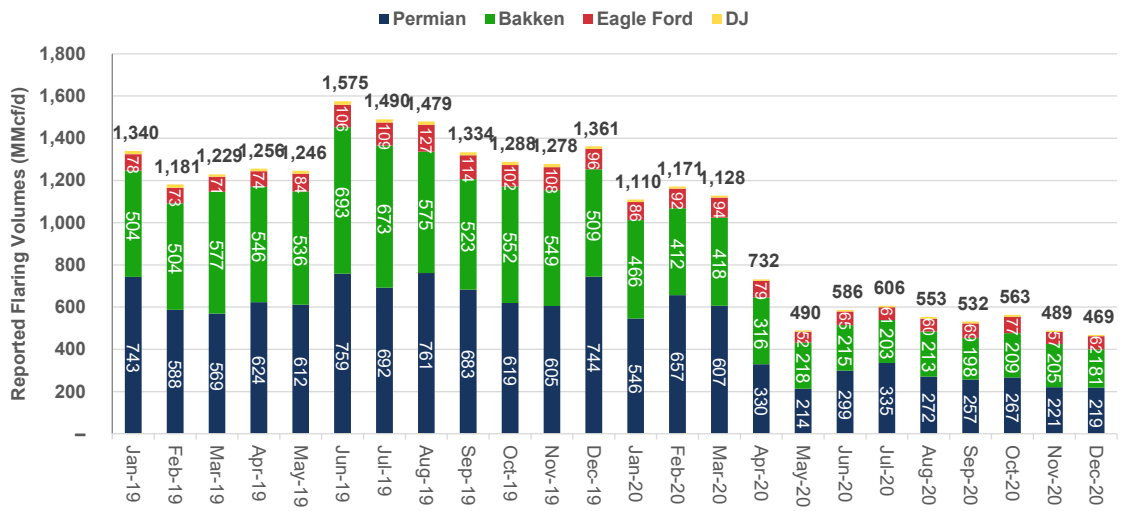


The constituent areas of Tracked Regions were benchmarked by their absolute Reported Flare Volume for the FY 2019 and FY 2020 periods (see Table 2 and Figure 3). The Permian had the highest average Reported Flare Volumes in FY 2019 and FY 2020 of 667 MMcf/d and 352 MMcf/d, respectively. The Bakken had the second highest average Reported Flare Volumes of 562 MMcf/d and 272 MMcf/d, in FY 2019 and FY 2020, respectively. The Eagle Ford had the smallest year over year change (25%) in Reported Flare Volumes between the FY 2019 and FY 2020 periods, while the Bakken had the largest drop of 52%.

TABLE 2. TRACKED REGION BREAKOUT BY AREA - REPORTED FLARING VOLUMES

Period	Rank	Reporting Month	Reported Flared Volumes - Daily (MMcf/d)					Total Produced Gas Volumes (MMcf/d)	Flared Percentage (% of Total)
			Permian	Bakken	Eagle Ford	DJ	Total		
FY 2019	5	Jan-19	743	504	78	15	**1,340**	**27,487**	**4.9%**
	12	Feb-19	588	504	73	16	**1,181**	**27,785**	**4.3%**
	11	Mar-19	569	577	71	11	**1,229**	**28,062**	**4.4%**
	9	Apr-19	624	546	74	12	**1,256**	**28,283**	**4.4%**
	10	May-19	612	536	84	14	**1,246**	**29,042**	**4.3%**
	1	Jun-19	759	693	106	17	**1,575**	**29,409**	**5.4%**
	2	Jul-19	692	673	109	16	**1,490**	**29,781**	**5.0%**
	3	Aug-19	761	575	127	15	**1,479**	**30,554**	**4.8%**
	6	Sep-19	683	523	114	14	**1,334**	**31,125**	**4.3%**
	7	Oct-19	619	552	102	14	**1,288**	**31,527**	**4.1%**
	8	Nov-19	605	549	108	15	**1,278**	**32,104**	**4.0%**
	4	Dec-19	744	509	96	12	**1,361**	**32,194**	**4.2%**
FY 2020	15	Jan-20	546	466	86	12	**1,110**	**32,336**	**3.4%**
	13	Feb-20	657	412	92	10	**1,171**	**32,418**	**3.6%**
	14	Mar-20	607	418	94	9	**1,128**	**32,719**	**3.4%**
	16	Apr-20	330	316	79	7	**732**	**31,152**	**2.3%**
	22	May-20	214	218	52	6	**490**	**27,275**	**1.8%**
	18	Jun-20	299	215	65	7	**586**	**28,799**	**2.0%**
	17	Jul-20	335	203	61	7	**606**	**30,062**	**2.0%**
	20	Aug-20	272	213	60	8	**553**	**30,802**	**1.8%**
	21	Sep-20	257	198	69	8	**532**	**30,855**	**1.7%**
	19	Oct-20	267	209	77	9	**563**	**30,752**	**1.8%**
	23	Nov-20	221	205	57	7	**489**	**30,591**	**1.6%**
	24	Dec-20	219	181	62	7	**469**	**29,947**	**1.6%**
FY 2019		**Gas (MMcf/d)**	**667**	**562**	**95**	**14**	**1,339**	**357,353**	**4.5%**
		CO_2e (Kt/d)	**37**	**31**	**5**	**1**	**73**	**19,583**	
FY 2020		**Gas (MMcf/d)**	**352**	**272**	**71**	**8**	**703**	**367,708**	**2.3%**
		CO_2e (Kt/d)	**19**	**15**	**4**	**0**	**39**	**20,150**	
Y/Y Change			**(47%)**	**(52%)**	**(25%)**	**(44%)**	**(48%)**	**3%**	**(49%)**

FIGURE 3. TRACKED REGION BREAKOUT BY AREA - REPORTED FLARING VOLUMES



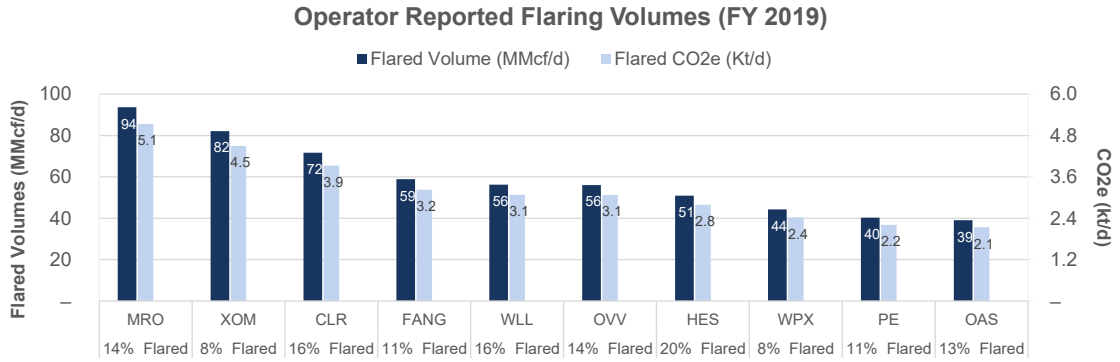
For Tracked Regions, Operators were ranked by their absolute Reported Flare Volumes for the FY 2019 and FY 2020 periods (See Table 3, Figures 4 and 5). Marathon Oil (NYSE: MRO) had the highest average Reported Flare Volumes in FY 2019 and FY 2020 of 94 MMcf/d and 45 MMcf/d, respectively. Oasis Petroleum (NYSE: OAS) was among the top Tracked Region "flarers" by Reported Flare Volumes for the FY 2019 period but was replaced by Endeavor Energy Resources, LP ("Endeavor") for the FY 2020 period. The Top 10 Operators by Reported Flare Volumes comprised 44% of the total FY 2019 Tracked Region Flare Volumes and 40% of the FY 2020 volumes, while accounting for 16 – 17% of the total Produced Gas Volumes.

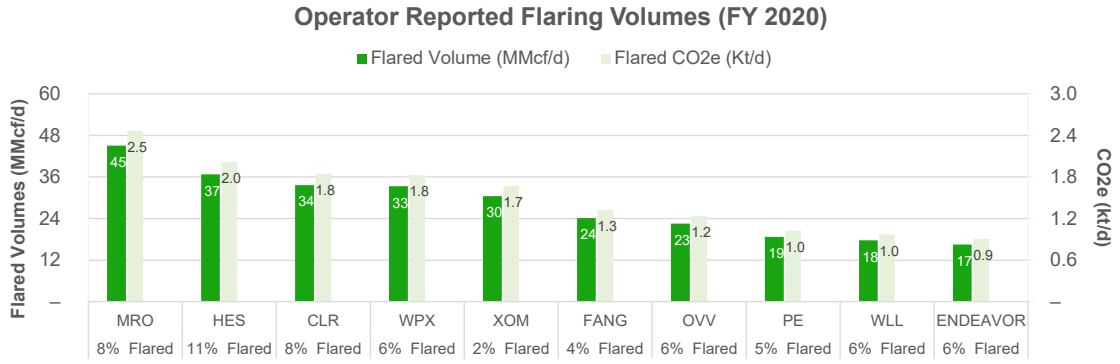
TABLE 3. TRACKED REGION OPERATORS RANKED BY REPORTED FLARED VOLUME (FY 2019 AND FY 2020)

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	MRO	34,199	93.7	1,874.1	5.1	240,570	659.1	14%
	2	XOM	29,976	82.1	1,642.7	4.5	374,396	1,025.7	8%
	3	CLR	26,160	71.7	1,433.6	3.9	160,937	440.9	16%
	4	FANG	21,481	58.9	1,177.2	3.2	202,120	553.8	11%
	5	WLL	20,518	56.2	1,124.4	3.1	129,104	353.7	16%
	6	OVV	20,461	56.1	1,121.3	3.1	146,034	400.1	14%
	7	HES	18,599	51.0	1,019.2	2.8	95,094	260.5	20%
	8	WPX	16,160	44.3	885.5	2.4	194,678	533.4	8%
	9	PE	14,695	40.3	805.3	2.2	132,315	362.5	11%
	10	OAS	14,249	39.0	780.8	2.1	113,734	311.6	13%
	Top 10 Subtotal		**216,498**	**593.1**	**11,864.1**	**32.5**	**1,788,983**	**4,901.3**	**12%**
	Total Tracked Regions		**488,757**	**1,339**	**26,784**	**73**	**10,873,667**	**29,779**	**4%**
	% of Total		*44%*	*44%*	*44%*	*44%*	*16%*	*16%*	

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	MRO	16,435	45.0	900.7	2.5	214,655	588.1	8%
	2	HES	13,422	36.8	735.6	2.0	121,387	332.6	11%
	3	CLR	12,289	33.7	673.4	1.8	146,271	400.7	8%
	4	WPX	12,162	33.3	666.5	1.8	219,625	601.7	6%
	5	XOM	11,128	30.5	609.8	1.7	463,995	1,271.2	2%
	6	FANG	8,801	24.1	482.3	1.3	248,043	679.6	4%
	7	OVV	8,225	22.5	450.7	1.2	141,478	387.6	6%
	8	PE	6,826	18.7	374.1	1.0	141,531	387.8	5%
	9	WLL	6,460	17.7	354.0	1.0	103,327	283.1	6%
	10	ENDEAVOR	6,026	16.5	330.2	0.9	108,646	297.7	6%
	Top 10 Subtotal		**101,774**	**278.8**	**5,577.2**	**15.3**	**1,908,958**	**5,230.0**	**5%**
	Total Tracked Regions		**256,578**	**703**	**14,060**	**39**	**11,212,720**	**30,642**	**2%**
	% of Total		*40%*	*40%*	*40%*	*40%*	*17%*	*17%*	

FIGURES 4 AND 5. TRACKED REGION OPERATORS RANKED BY REPORTED FLARE VOLUME (FY 2019 / 2020)





Within Tracked Regions, Operators were also ranked by their absolute Flared Percentage for the FY 2019 and FY 2020 periods (See Table 4). Gulfport Energy (NYSE: GPOR) and Sandridge (NYSE:SD) had the highest proportion of Reported Flare Volumes to total Gas Produced ("Flared Percentage") within the Tracked Region in FY 2019 and FY 2020 at 89% and 100%, respectively. (See Tables 4 and 5).

Tracked Region Operators who realized a Flared Percentage of less than 5% were also ranked by their total Produced Volumes (MMcfe). For the FY 2019 and FY 2020 periods, Occidental Petroleum (NYSE: OXY), EOG Resources (NYSE: EOG), ConocoPhillips (NYSE: COP), and ExxonMobil (NYSE: XOM) had the highest Produced Volumes while maintaining low Flared Percentages (see Tables 6 and 7).

TABLE 4. TRACKED REGION OPERATORS RANKED BY FLARED PERCENTAGE

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	GPOR	30	0.1	2	0.0	34	0.1	89%
	2	SD	1,796	4.9	98	0.3	2,168	5.9	83%
	3	DEN	210	0.6	12	0.0	478	1.3	44%
	4	USEG	1,076	2.9	59	0.2	2,481	6.8	43%
	5	LLEX	4,586	12.6	251	0.7	10,750	29.5	43%
	6	AXAS	3,926	10.8	215	0.6	15,240	41.8	26%
	7	ERF	4,196	11.5	230	0.6	19,718	54.0	21%
	8	SWN	96	0.3	5	0.0	462	1.3	21%
	9	HES	18,599	51.0	1,019	2.8	95,094	260.5	20%
	10	CLR	26,160	71.7	1,434	3.9	161,031	441.2	16%
	Top 10 Subtotal		**60,674**	**166.2**	**3,325.0**	**9.1**	**307,455**	**842.3**	**20%**

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	SD	1,195	3.3	65.5	0.2	1,195	3.3	100%
	2	DEN	397	1.1	21.8	0.1	446	1.2	89%
	3	LLEX	5,323	14.6	291.7	0.8	8,580	23.5	62%
	4	USEG	862	2.4	47.3	0.1	1,701	4.7	51%
	5	GPOR	15	0.0	0.8	0.0	30	0.1	50%
	6	SWN	81	0.2	4.4	0.0	353	1.0	23%
	7	AXAS	1,420	3.9	77.8	0.2	8,447	23.1	17%
	8	CPG	889	2.4	48.7	0.1	7,346	20.1	12%
	9	SNDE	798	2.2	43.7	0.1	6,812	18.7	12%
	10	HES	13,422	36.8	735.6	2.0	121,387	332.6	11%
	Top 10 Subtotal		**24,404**	**66.9**	**1,337.3**	**3.7**	**156,296**	**428.2**	**16%**

TABLE 5. TRACKED REGION OPERATORS RANKED BY FLARED PERCENTAGE - FLARING CO_2e METRICS

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2019	1	GPOR	2	0	26	0.1	64.5
	2	SD	98	0	1,847	5.1	53.3
	3	DEN	12	0	2,193	6.0	5.2
	4	USEG	59	0	1,749	4.8	33.7
	5	LLEX	251	1	1,485	4.1	169.3
	6	AXAS	215	1	4,509	12.4	47.7
	7	ERF	230	1	15,183	41.6	15.1
	8	SWN	5	0	28	0.1	191.3
	9	HES	1,019	3	44,029	120.6	23.1
	10	CLR	1,434	4	71,971	197.2	19.9
	Top 10 Subtotal		**3,325.0**	**9.1**	**143,018**	**391.8**	**23.2**

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2020	1	SD	65	0	1,130	3.1	57.9
	2	DEN	22	0	1,878	5.1	11.6
	3	LLEX	292	1	1,081	3.0	269.8
	4	USEG	47	0	1,263	3.5	37.4
	5	GPOR	1	0	29	0.1	28.9
	6	SWN	4	0	21	0.1	215.0
	7	AXAS	78	0	2,026	5.6	38.4
	8	CPG	49	0	5,248	14.4	9.3
	9	SNDE	44	0	2,642	7.2	16.6
	10	HES	736	2	50,910	139.5	14.4
	Top 10 Subtotal		**1,337.3**	**3.7**	**66,228**	**181.4**	**20.2**

TABLE 6. TRACKED REGION HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%)

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	OXY	2,198,233	6,023	6,479	17.7	355	1.0	1%
	2	EOG	1,784,358	4,889	6,518	17.9	357	1.0	1%
	3	CXO	980,423	2,686	6,184	16.9	339	0.9	2%
	4	COP	978,513	2,681	11,424	31.3	626	1.7	3%
	5	PXD	894,897	2,452	2,023	5.5	111	0.3	1%
	6	NBL	643,091	1,762	4,480	12.3	246	0.7	1%
	7	APA	631,707	1,731	7,201	19.7	395	1.1	2%
	8	DVN	605,503	1,659	4,006	11.0	220	0.6	1%
	9	CVX	605,161	1,658	2,358	6.5	129	0.4	1%
	10	XEC	603,750	1,654	6,098	16.7	334	0.9	2%
	Top 10 Subtotal		**9,925,637**	**27,194**	**56,772**	**155.5**	**3,111**	**8.5**	**1%**

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OXY	2,128,700	5,832.1	2,507	6.9	137	0.4	0%
	2	EOG	1,654,437	4,532.7	2,031	5.6	111	0.3	0%
	3	XOM	1,222,333	3,348.9	11,128	30.5	610	1.7	2%
	4	CXO	1,021,895	2,799.7	4,338	11.9	238	0.7	1%
	5	PXD	949,472	2,601.3	854	2.3	47	0.1	0%
	6	COP	842,662	2,308.7	4,148	11.4	227	0.6	1%
	7	CVX	768,186	2,104.6	1,748	4.8	96	0.3	1%
	8	FANG	752,918	2,062.8	8,801	24.1	482	1.3	4%
	9	DVN	721,131	1,975.7	907	2.5	50	0.1	0%
	10	APA	598,037	1,638.5	2,305	6.3	126	0.3	1%
	Top 10 Subtotal		**10,659,770**	**29,204.8**	**38,766**	**106.2**	**2,124**	**5.8**	**1%**

TABLE 7. TRACKED REGION HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%) – FLARING CO_2e METRICS

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	OXY	366,372	1,004	355	1.0	1.0
	2	EOG	297,393	815	357	1.0	1.2
	3	CXO	163,404	448	339	0.9	2.1
	4	COP	163,085	447	626	1.7	3.8
	5	PXD	149,150	409	111	0.3	0.7
	6	NBL	107,182	294	246	0.7	2.3
	7	APA	105,285	288	395	1.1	3.7
	8	DVN	100,917	276	220	0.6	2.2
	9	CVX	100,860	276	129	0.4	1.3
	10	XEC	100,625	276	334	0.9	3.3
	Top 10 Subtotal		**1,654,273**	**4,532**	**3,111**	**8.5**	**1.9**

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OXY	354,783	972.0	137	0.4	0.4
	2	EOG	275,740	755.5	111	0.3	0.4
	3	XOM	203,722	558.1	610	1.7	3.0
	4	CXO	170,316	466.6	238	0.7	1.4
	5	PXD	158,245	433.5	47	0.1	0.3
	6	COP	140,444	384.8	227	0.6	1.6
	7	CVX	128,031	350.8	96	0.3	0.7
	8	FANG	125,486	343.8	482	1.3	3.8
	9	DVN	120,188	329.3	50	0.1	0.4
	10	APA	99,673	273.1	126	0.3	1.3
	Top 10 Subtotal		**1,776,628**	**4,867.5**	**2,124**	**5.8**	**1.2**

Permian

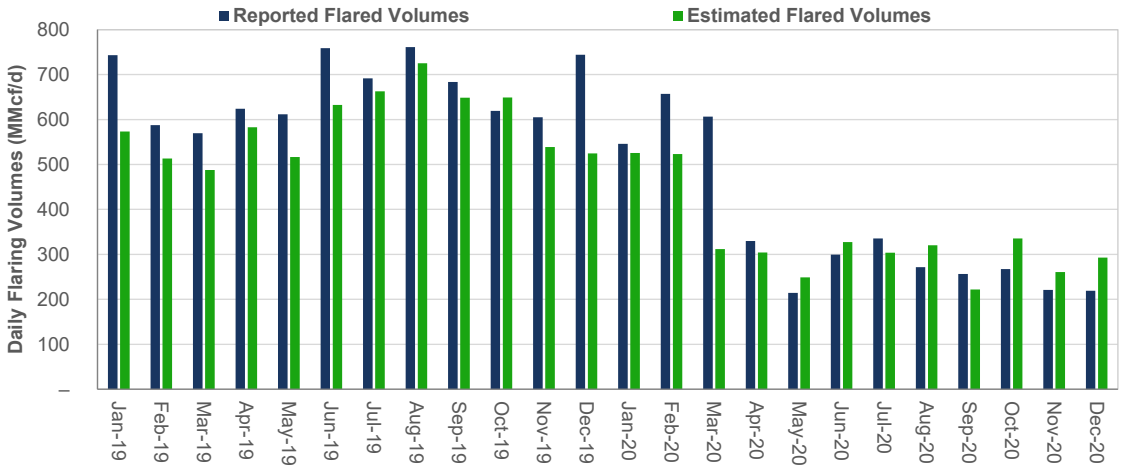
In the Permian, Reported and Estimated Flare Volumes were 129 / 121 Bcf in FY 2020, reflecting a 47 / 44% drop from the FY 2019 volumes of 244 / 215 Bcf, respectively (see Table 8 and Figure 6). On a CO_2e basis, Permian Reported Flaring Volumes were 7 Mt in FY 2020 and 13 Mt in FY 2019.

Within the FY 2019 and FY 2020 periods, peak Reported Flare Volumes and Estimated Flare Volumes were observed in August 2019, at 24 Bcf and 23 Bcf, respectively, representing ~5% of total Produced Gas in the region for the month (see Table 8). For the FY 2019 and FY 2020 periods, Reported Flare Volumes comprised, 4% and 2%, of total Produced Gas.

TABLE 8. PERMIAN DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

Period	Rank	Reporting Month	Reported Flared Volumes		Estimated Flared Volumes		Produced Gas Volumes		Flared Percentage
			Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	
FY 2019	3	Jan-19	23.0	743	17.8	573	409.9	13,224	6%
	15	Feb-19	16.5	588	14.4	513	382.3	13,655	4%
	13	Mar-19	17.7	569	15.1	488	428.8	13,832	4%
	11	Apr-19	18.7	624	17.5	583	414.1	13,802	5%
	9	May-19	19.0	612	16.0	517	448.0	14,452	4%
	4	Jun-19	22.8	759	19.0	632	436.5	14,549	5%
	5	Jul-19	21.4	692	20.5	663	461.5	14,888	5%
	1	Aug-19	23.6	761	22.5	725	480.2	15,492	5%
	6	Sep-19	20.5	683	19.5	649	479.6	15,987	4%
	7	Oct-19	19.2	619	20.1	649	498.8	16,091	4%
	12	Nov-19	18.2	605	16.2	539	492.7	16,423	4%
	2	Dec-19	23.1	744	16.3	524	512.1	16,518	5%
FY 2020	14	Jan-20	16.9	546	16.3	526	519.3	16,750	3%
	8	Feb-20	19.1	657	15.2	523	488.2	16,833	4%
	10	Mar-20	18.8	607	9.7	312	535.2	17,264	4%
	17	Apr-20	9.9	330	9.1	304	492.2	16,408	2%
	23	May-20	6.6	214	7.7	249	458.0	14,774	1%
	18	Jun-20	9.0	299	9.8	327	483.7	16,124	2%
	16	Jul-20	10.4	335	9.4	304	521.7	16,830	2%
	19	Aug-20	8.4	272	9.9	320	529.1	17,067	2%
	21	Sep-20	7.7	257	6.7	222	512.1	17,069	2%
	20	Oct-20	8.3	267	10.4	335	531.8	17,153	2%
	24	Nov-20	6.6	221	7.8	261	511.9	17,063	1%
	22	Dec-20	6.8	219	9.1	293	518.2	16,716	1%
FY 2019		**Gas (Bcf | MMcf/d)**	**243.6**	**667**	**214.8**	**588**	**5,444.6**	**14,917**	**4%**
		CO_2e (Mt | Kt/d)	**13.3**	**37**	**11.8**	**32**	**298.4**	**817**	
FY 2020		**Gas (Bcf | MMcf/d)**	**128.5**	**352**	**121.1**	**332**	**6,101.3**	**16,716**	**2%**
		CO_2e (Mt | Kt/d)	**7.0**	**19**	**6.6**	**18**	**334.3**	**916**	
Y/Y Change			**(47%)**	**(47%)**	**(44%)**	**(44%)**	**12%**	**12%**	**(53%)**

FIGURE 6. PERMIAN DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

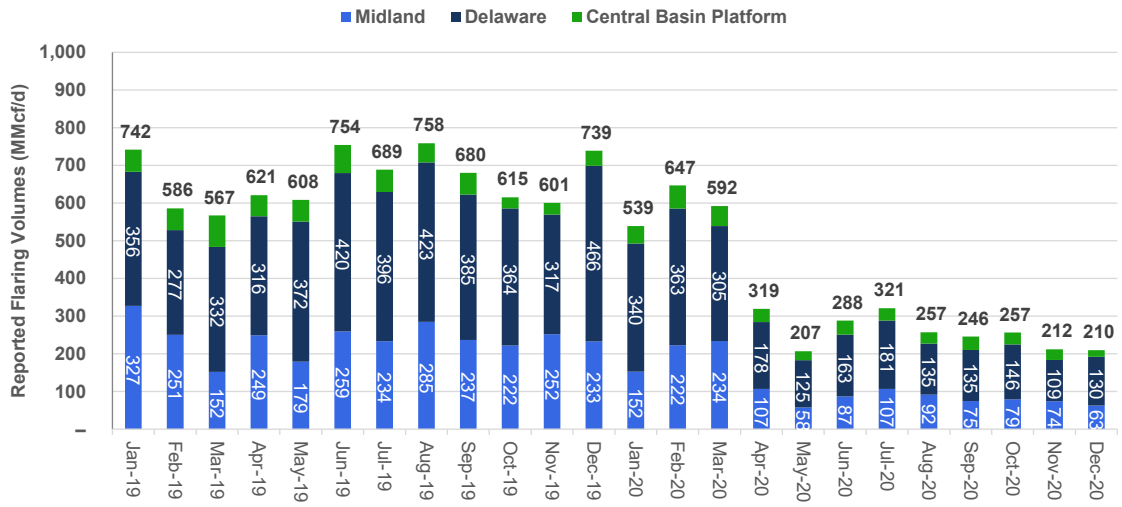


Within the Permian, sub-basins were benchmarked by their absolute Reported Flare Volumes for the FY 2019 and FY 2020 periods (see Table 9 and Figure 7). The Delaware sub-basin had the highest average daily Reported Flare Volume in FY 2019 and FY 2020 of 370 MMcf/d and 193 MMcf/d, respectively. The Midland sub-basin had the second highest average daily Reported Flare Volumes of 240 MMcf/d and 113 MMcf/d in FY 2019 and FY 2020, respectively.

TABLE 9. PERMIAN SUB-BASIN DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

Period	Rank	Reporting Month	Reported Flared Volumes - Daily (MMcf/d)				Total Produced Gas Volumes (MMcf/d)	Flared Percentage (% of Total)
			Midland	Delaware	Central Basin Platform	Total		
FY 2019	3	Jan-19	327	356	59	**742**	**13,224**	**5.6%**
	13	Feb-19	251	277	58	**586**	**13,655**	**4.3%**
	14	Mar-19	152	332	83	**567**	**13,832**	**4.1%**
	8	Apr-19	249	316	56	**621**	**13,802**	**4.5%**
	10	May-19	179	372	58	**608**	**14,452**	**4.2%**
	2	Jun-19	259	420	75	**754**	**14,549**	**5.2%**
	5	Jul-19	234	396	59	**689**	**14,888**	**4.6%**
	1	Aug-19	285	423	51	**758**	**15,492**	**4.9%**
	6	Sep-19	237	385	58	**680**	**15,987**	**4.3%**
	9	Oct-19	222	364	30	**615**	**16,091**	**3.8%**
	11	Nov-19	252	317	32	**601**	**16,423**	**3.7%**
	4	Dec-19	233	466	40	**739**	**16,518**	**4.5%**
FY 2020	15	Jan-20	152	340	46	**539**	**16,750**	**3.2%**
	7	Feb-20	222	363	61	**647**	**16,833**	**3.8%**
	12	Mar-20	234	305	53	**592**	**17,264**	**3.4%**
	17	Apr-20	107	178	35	**319**	**16,408**	**1.9%**
	24	May-20	58	125	24	**207**	**14,774**	**1.4%**
	18	Jun-20	87	163	38	**288**	**16,124**	**1.8%**
	16	Jul-20	107	181	32	**321**	**16,830**	**1.9%**
	19	Aug-20	92	135	30	**257**	**17,067**	**1.5%**
	21	Sep-20	75	135	36	**246**	**17,069**	**1.4%**
	20	Oct-20	79	146	32	**257**	**17,153**	**1.5%**
	22	Nov-20	74	109	29	**212**	**17,063**	**1.2%**
	23	Dec-20	63	130	17	**210**	**16,716**	**1.3%**
FY 2019		**Gas (MMcf/d)**	**240**	**369**	**55**	**663**	**14,917**	**4.4%**
		CO_2e (Kt/d)	**13**	**20**	**3**	**36**	**817**	
FY 2020		**Gas (MMcf/d)**	**107**	**181**	**35**	**323**	**16,716**	**1.9%**
		CO_2e (Kt/d)	**6**	**10**	**2**	**18**	**916**	
Y/Y Change			**(55%)**	**(51%)**	**(37%)**	**(51%)**	**12%**	**(56%)**

FIGURE 7. PERMIAN SUB-BASIN DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)



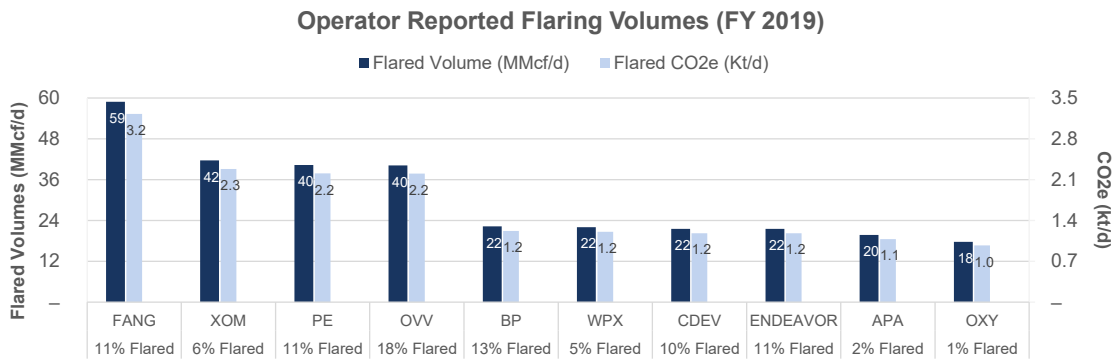
Within the Permian, Operators were ranked by their absolute Reported Flare Volumes for the FY 2019 and FY 2020 periods (See Table 10 and Figures 8 and 9). Diamondback Energy (NYSE: FANG) had the highest average daily Reported Flare Volumes in FY 2019 and FY 2020 of 59 MMcf/d and 24 MMcf/d, respectively. Apache Corp (NYSE: APA) and Occidental Petroleum (NYSE: OXY) were among the top "flarers" by Reported Flare Volumes for the FY 2019 period but were replaced by Lilis Energy (NYSE: LLEX) and Concho Resources (NYSE: CXO) for the FY 2020 period. The Top 10 Operators by Reported Flare Volumes accounted for 46% of the total FY 2019 Permian Flare Volumes and 41% of the FY 2020 volumes.

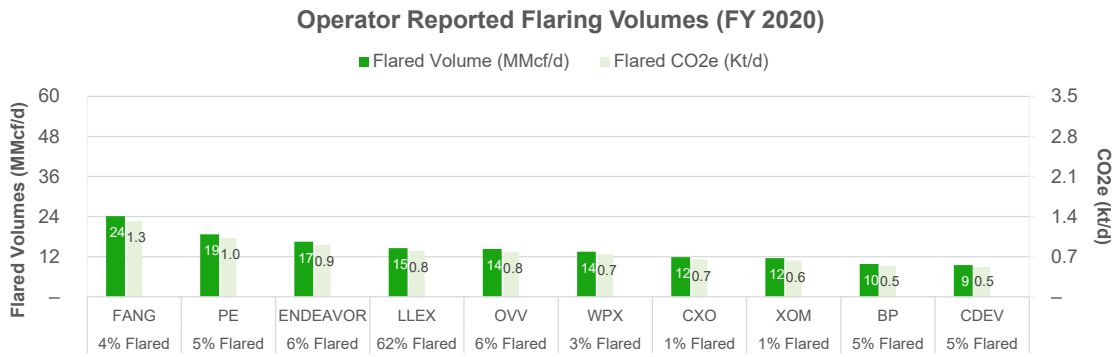
TABLE 10. PERMIAN OPERATORS RANKED BY REPORTED FLARED VOLUME

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	FANG	21,481	58.9	1,177.2	3.2	202,120	553.8	11%
	2	XOM	15,197	41.6	832.8	2.3	241,059	660.4	6%
	3	PE	14,695	40.3	805.3	2.2	132,315	362.5	11%
	4	OVV	14,660	40.2	803.4	2.2	83,025	227.5	18%
	5	BP	8,118	22.2	444.9	1.2	60,597	166.0	13%
	6	WPX	8,038	22.0	440.5	1.2	155,188	425.2	5%
	7	CDEV	7,864	21.5	431.0	1.2	75,541	207.0	10%
	8	ENDEAVOR	7,859	21.5	430.7	1.2	72,338	198.2	11%
	9	APA	7,199	19.7	394.5	1.1	362,673	993.6	2%
	10	OXY	6,473	17.7	354.7	1.0	568,673	1,558.0	1%
	Top 10 Subtotal		**111,584**	**305.7**	**6,114.8**	**16.8**	**1,953,529**	**5,352.1**	**6%**
	Total Permian		**243,555**	**667**	**13,347**	**37**	**5,444,576**	**14,917**	**4%**
	% of Total		*46%*	*46%*	*46%*	*46%*	*36%*	*36%*	

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	FANG	8,801	24.1	482.3	1.3	248,043	679.6	4%
	2	PE	6,826	18.7	374.1	1.0	141,531	387.8	5%
	3	ENDEAVOR	6,026	16.5	330.2	0.9	108,646	297.7	6%
	4	LLEX	5,323	14.6	291.7	0.8	8,580	23.5	62%
	5	OVV	5,229	14.3	286.6	0.8	87,544	239.8	6%
	6	WPX	4,936	13.5	270.5	0.7	170,587	467.4	3%
	7	CXO	4,338	11.9	237.7	0.7	378,701	1,037.5	1%
	8	XOM	4,217	11.6	231.1	0.6	338,993	928.7	1%
	9	BP	3,592	9.8	196.9	0.5	75,058	205.6	5%
	10	CDEV	3,461	9.5	189.6	0.5	70,948	194.4	5%
	Top 10 Subtotal		**52,750**	**144.5**	**2,890.7**	**7.9**	**1,628,630**	**4,462.0**	**3%**
	Total Permian		**128,513**	**352**	**7,043**	**19**	**6,101,253**	**16,716**	**2%**
	% of Total		*41%*	*41%*	*41%*	*41%*	*27%*	*27%*	

FIGURES 8 AND 9. PERMIAN TOP OPERATORS BY REPORTED FLARE VOLUME





Within the Permian, Operators were ranked by their absolute Flared Percentage for the FY 2019 and FY 2020 periods (See Tables 11 and 12). Lilis Energy (NYSE: LLEX) had the highest Flared Percentage within the Permian in FY 2019 and FY 2020 at 43% and 62%, respectively. (See Tables 11 and 12).

Permian Operators who realized a Flared Percentage of less than 5% were also ranked by their total Produced Volumes (MMcfe). For the FY 2019 and FY 2020 periods, Occidental Petroleum (NYSE: OXY), Concho Resources (NYSE: CXO), and Pioneer Natural Resources (NYSE: PXD) had the highest Produced Volumes while maintaining low Flared Percentages (see Tables 13 and 14).

TABLE 11. PERMIAN OPERATORS RANKED BY FLARED PERCENTAGE

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	LLEX	4,586	12.6	251.3	0.7	10,750	29.5	43%
	2	AXAS	870	2.4	47.7	0.1	3,456	9.5	25%
	3	OVV	14,660	40.2	803.4	2.2	83,025	227.5	18%
	4	OAS	801	2.2	43.9	0.1	4,763	13.0	17%
	5	ROSE	2,547	7.0	139.6	0.4	16,146	44.2	16%
	6	BP	8,118	22.2	444.9	1.2	60,597	166.0	13%
	7	REI	488	1.3	26.7	0.1	3,773	10.3	13%
	8	TALO	3,375	9.2	184.9	0.5	28,856	79.1	12%
	9	PE	14,695	40.3	805.3	2.2	132,315	362.5	11%
	10	WLL	97	0.3	5.3	0.0	901	2.5	11%
		Top 10 Subtotal	**50,238**	**137.6**	**2,753.0**	**7.5**	**344,582**	**944.1**	**15%**

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	LLEX	5,323	14.6	291.7	0.8	8,580	23.5	62%
	2	AXAS	1,047	2.9	57.4	0.2	2,201	6.0	48%
	3	WLL	90	0.2	4.9	0.0	794	2.2	11%
	4	OAS	513	1.4	28.1	0.1	5,927	16.2	9%
	5	REI	226	0.6	12.4	0.0	3,508	9.6	6%
	6	OVV	5,229	14.3	286.6	0.8	87,544	239.8	6%
	7	CDEV	3,461	9.5	189.6	0.5	70,948	194.4	5%
	8	PE	6,826	18.7	374.1	1.0	141,531	387.8	5%
	9	BP	3,592	9.8	196.9	0.5	75,058	205.6	5%
	10	QEP	1,751	4.8	96.0	0.3	39,080	107.1	4%
		Top 10 Subtotal	**28,058**	**76.9**	**1,537.6**	**4.2**	**435,169**	**1,192.2**	**6%**

TABLE 12. PERMIAN OPERATORS RANKED BY FLARED PERCENTAGE - FLARING CO_2e METRICS

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2019	1	LLEX	251.3	0.7	1,485	4.1	169.3
	2	AXAS	47.7	0.1	1,410	3.9	33.8
	3	OVV	803.4	2.2	34,368	94.2	23.4
	4	OAS	43.9	0.1	3,045	8.3	14.4
	5	ROSE	139.6	0.4	7,005	19.2	19.9
	6	BP	444.9	1.2	11,232	30.8	39.6
	7	REI	26.7	0.1	5,037	13.8	5.3
	8	TALO	184.9	0.5	21,231	58.2	8.7
	9	PE	805.3	2.2	57,501	157.5	14.0
	10	WLL	5.3	0.0	221	0.6	24.1
		Top 10 Subtotal	**2,753.0**	**7.5**	**142,535**	**390.5**	**19.3**

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2020	1	LLEX	291.7	0.8	1,081	3.0	269.8
	2	AXAS	57.4	0.2	779	2.1	73.7
	3	WLL	4.9	0.0	224	0.6	22.0
	4	OAS	28.1	0.1	3,784	10.4	7.4
	5	REI	12.4	0.0	3,701	10.1	3.3
	6	OVV	286.6	0.8	30,680	84.1	9.3
	7	CDEV	189.6	0.5	18,482	50.6	10.3
	8	PE	374.1	1.0	57,129	156.5	6.5
	9	BP	196.9	0.5	13,216	36.2	14.9
	10	QEP	96.0	0.3	16,096	44.1	6.0
		Top 10 Subtotal	**1,537.6**	**4.2**	**145,173**	**397.7**	**10.6**

TABLE 13. PERMIAN HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%)

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	OXY	1,670,593	4,577	6,473	17.7	355	1.0	1%
	2	CXO	980,423	2,686	6,184	16.9	339	0.9	2%
	3	PXD	893,585	2,448	2,023	5.5	111	0.3	1%
	4	EOG	842,084	2,307	3,406	9.3	187	0.5	1%
	5	APA	624,835	1,712	7,199	19.7	395	1.1	2%
	6	XEC	603,750	1,654	6,098	16.7	334	0.9	2%
	7	CVX	581,225	1,592	2,281	6.2	125	0.3	1%
	8	DVN	318,415	872	3,954	10.8	217	0.6	3%
	9	MEWBOURNE	280,602	769	2	0.0	0	0.0	0%
	10	RDS.A	233,274	639	1,015	2.8	56	0.2	1%
		Top 10 Subtotal	**7,028,788**	**19,257**	**38,635**	**105.8**	**2,117**	**5.8**	**1%**

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OXY	1,603,603	4,393.4	2,500	6.8	137	0.4	0%
	2	CXO	1,021,895	2,799.7	4,338	11.9	238	0.7	1%
	3	PXD	948,346	2,598.2	854	2.3	47	0.1	0%
	4	XOM	912,972	2,501.3	4,217	11.6	231	0.6	1%
	5	EOG	889,336	2,436.5	1,161	3.2	64	0.2	0%
	6	FANG	752,918	2,062.8	8,801	24.1	482	1.3	4%
	7	CVX	745,165	2,041.5	1,640	4.5	90	0.2	0%
	8	APA	591,023	1,619.2	2,304	6.3	126	0.3	1%
	9	XEC	556,432	1,524.5	2,395	6.6	131	0.4	1%
	10	PE	484,305	1,326.9	6,826	18.7	374	1.0	5%
		Top 10 Subtotal	**8,505,995**	**23,304.1**	**35,037**	**96.0**	**1,920**	**5.3**	**1%**

TABLE 14. TRACKED REGION HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%) – FLARING CO_2e METRICS

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	OXY	278,432	763	355	1.0	1.3
	2	CXO	163,404	448	339	0.9	2.1
	3	PXD	148,931	408	111	0.3	0.7
	4	EOG	140,347	385	187	0.5	1.3
	5	APA	104,139	285	395	1.1	3.8
	6	XEC	100,625	276	334	0.9	3.3
	7	CVX	96,871	265	125	0.3	1.3
	8	DVN	53,069	145	217	0.6	4.1
	9	MEWBOURNE	46,767	128	0	0.0	0.0
	10	RDS.A	38,879	107	56	0.2	1.4
	Top 10 Subtotal		**1,171,465**	**3,209**	**2,117**	**5.8**	**1.8**

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OXY	267,267	732.2	137	0.4	0.5
	2	CXO	170,316	466.6	238	0.7	1.4
	3	PXD	158,058	433.0	47	0.1	0.3
	4	XOM	152,162	416.9	231	0.6	1.5
	5	EOG	148,223	406.1	64	0.2	0.4
	6	FANG	125,486	343.8	482	1.3	3.8
	7	CVX	124,194	340.3	90	0.2	0.7
	8	APA	98,504	269.9	126	0.3	1.3
	9	XEC	92,739	254.1	131	0.4	1.4
	10	PE	80,718	221.1	374	1.0	4.6
	Top 10 Subtotal		**1,417,666**	**3,884.0**	**1,920**	**5.3**	**1.4**

Bakken

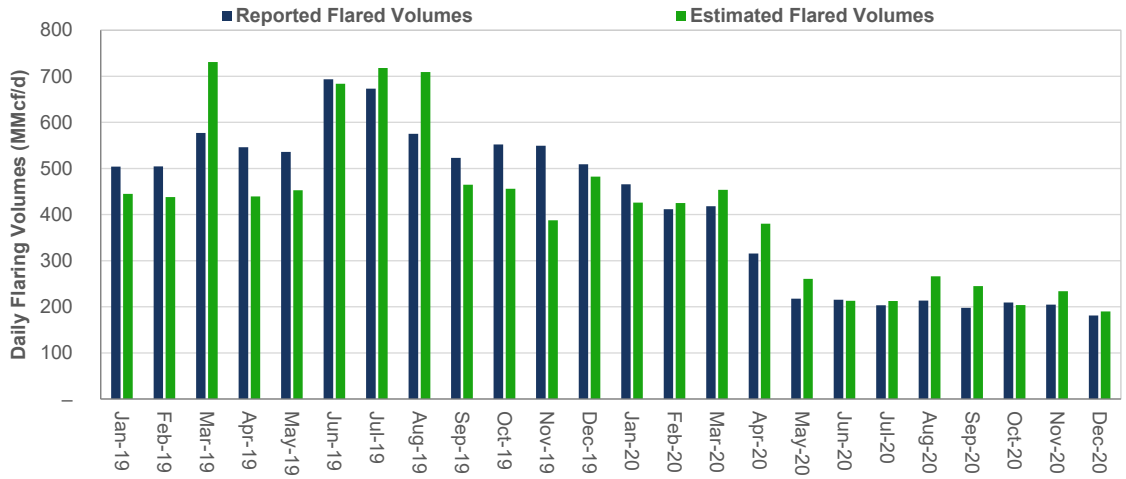
In the Bakken, Reported and Estimated Flare Volumes were 99 / 107 Bcf in FY 2020, reflecting a 52 / 45% drop from the FY 2019 volumes of 205 / 195 Bcf (see Table 15 and Figure 10). On a CO_2e basis, Bakken Reported Flaring Volumes were 5 Mt in FY 2020 and 11 Mt in FY 2019.

Within the FY 2019 and FY 2020 periods, peak Reported Flare Volumes and Estimated Flare Volumes were observed in July and March 2019, at 21 Bcf and 23 Bcf, respectively, representing 23% and 26% of total Produced Gas in the region. For the FY 2019 and FY 2020 periods, Reported Flare Volumes reflected, 19% and 10% of total Produced Gas, respectively.

TABLE 15. BAKKEN DAILY FLARING VOLUMES BY MONTH (REPORTED FLARING VS. ESTIMATED FLARING)

Period	Rank	Reporting Month	Reported Flared Volumes		Estimated Flared Volumes		Produced Gas Volumes		Flared Percentage
			Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	
FY 2019	11	Jan-19	15.6	504	13.8	445	84.0	2,710	19%
	13	Feb-19	14.1	504	12.3	438	73.5	2,625	19%
	3	Mar-19	17.9	577	22.7	731	86.9	2,803	21%
	8	Apr-19	16.4	546	13.2	440	84.8	2,826	19%
	6	May-19	16.6	536	14.0	453	87.3	2,816	19%
	2	Jun-19	20.8	693	20.5	684	86.6	2,887	24%
	1	Jul-19	20.9	673	22.3	718	91.4	2,947	23%
	4	Aug-19	17.8	575	22.0	709	93.5	3,016	19%
	10	Sep-19	15.7	523	14.0	465	88.5	2,950	18%
	5	Oct-19	17.1	552	14.1	456	95.5	3,081	18%
	7	Nov-19	16.5	549	11.6	388	94.3	3,144	17%
	9	Dec-19	15.8	509	15.0	482	95.4	3,077	17%
FY 2020	12	Jan-20	14.4	466	13.2	426	93.7	3,021	15%
	15	Feb-20	11.9	412	12.3	425	90.2	3,112	13%
	14	Mar-20	13.0	418	14.1	454	97.2	3,136	13%
	16	Apr-20	9.5	316	11.4	380	81.9	2,729	12%
	17	May-20	6.7	218	8.1	261	59.9	1,934	11%
	20	Jun-20	6.5	215	6.4	213	59.5	1,982	11%
	21	Jul-20	6.3	203	6.6	212	71.6	2,309	9%
	18	Aug-20	6.6	213	8.2	266	82.0	2,646	8%
	23	Sep-20	5.9	198	7.3	245	84.5	2,816	7%
	19	Oct-20	6.5	209	6.3	204	89.3	2,879	7%
	22	Nov-20	6.1	205	7.0	234	85.5	2,852	7%
	24	Dec-20	5.6	181	5.9	190	88.0	2,839	6%
FY 2019		**Gas (Bcf | MMcf/d)**	**205.2**	**562**	**195.4**	**535**	**1,061.7**	**2,909**	**19%**
		CO_2e (Mt | Kt/d)	**11.2**	**31**	**10.7**	**29**	**58.2**	**159**	
FY 2020		**Gas (Bcf | MMcf/d)**	**99.1**	**272**	**106.9**	**293**	**983.3**	**2,694**	**10%**
		CO_2e (Mt | Kt/d)	**5.4**	**15**	**5.9**	**16**	**53.9**	**148**	
		Y/Y Change	**(52%)**	**(52%)**	**(45%)**	**(45%)**	**(7%)**	**(7%)**	**(48%)**

FIGURE 10. BAKKEN DAILY FLARING VOLUMES BY MONTH (REPORTED FLARING VS. ESTIMATED FLARING)



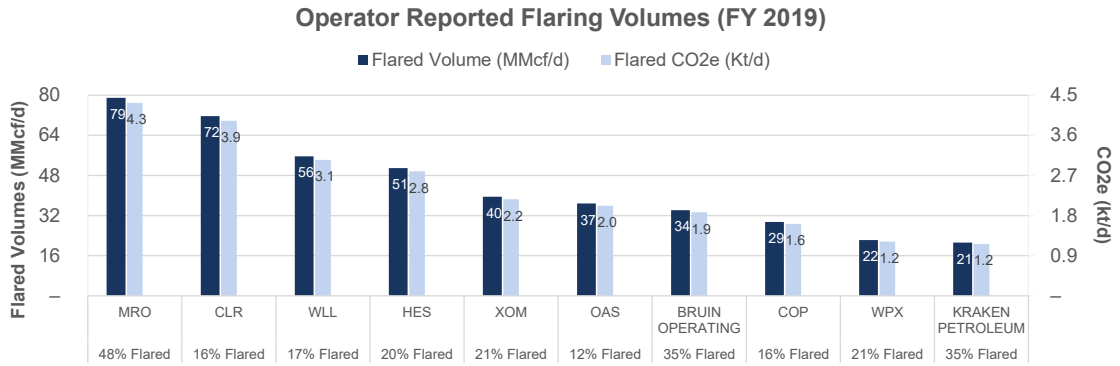
Within the Bakken, Operators were ranked by their absolute Reported Flare Volumes for the FY 2019 and FY 2020 periods (See Table 16 and Figures 11 and 12). Marathon Oil (NYSE: MRO) had the highest average Reported Flare Volumes of 79 MMcf/d for FY 2019 whereas Hess Corporation (NYSE: HES) had the highest volumes of 37 MMcf/d for the FY 2020 period. The Top 10 Operators by Reported Flare Volumes accounted for 78% of the total FY 2019 Bakken Flare Volumes and 74% of the FY 2020 volumes.

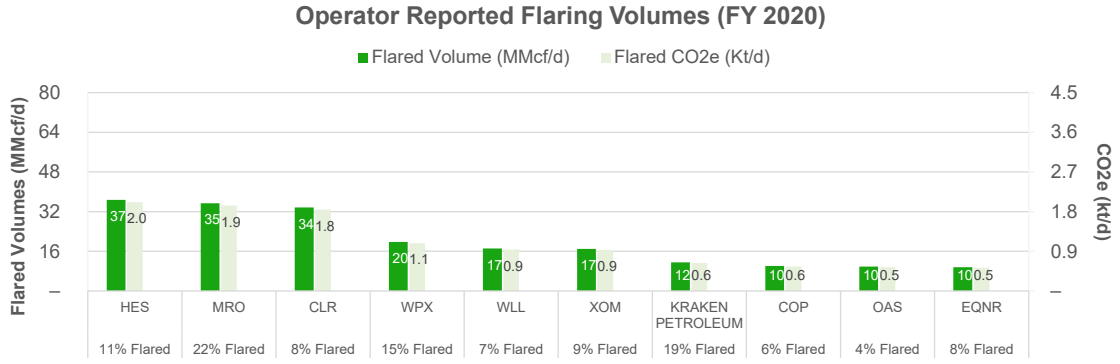
TABLE 16. BAKKEN OPERATORS RANKED BY REPORTED FLARED VOLUME

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	MRO	28,831	79.0	1,579.9	4.3	60,583	166.0	48%
	2	CLR	26,160	71.7	1,433.6	3.9	160,937	440.9	16%
	3	WLL	20,315	55.7	1,113.3	3.1	117,988	323.3	17%
	4	HES	18,599	51.0	1,019.2	2.8	95,094	260.5	20%
	5	XOM	14,423	39.5	790.4	2.2	70,086	192.0	21%
	6	OAS	13,447	36.8	736.9	2.0	108,971	298.6	12%
	7	BRUIN OPERATING	12,478	34.2	683.8	1.9	35,479	97.2	35%
	8	COP	10,746	29.4	588.9	1.6	67,245	184.2	16%
	9	WPX	8,122	22.3	445.1	1.2	39,491	108.2	21%
	10	KRAKEN PETROLEUM	7,745	21.2	424.4	1.2	22,226	60.9	35%
		Top 10 Subtotal	**160,866**	**440.7**	**8,815.5**	**24.2**	**778,099**	**2,131.8**	**21%**
		Total Bakken	**205,197**	**562.2**	**11,244.8**	**30.8**	**1,061,695**	**2,908.8**	**19%**
		% of Total	*78%*	*78%*	*78%*	*78%*	*73%*	*73%*	

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	HES	13,422	36.8	735.6	2.0	121,387	332.6	11%
	2	MRO	12,917	35.4	707.9	1.9	59,713	163.6	22%
	3	CLR	12,289	33.7	673.4	1.8	146,271	400.7	8%
	4	WPX	7,226	19.8	396.0	1.1	49,038	134.4	15%
	5	WLL	6,260	17.2	343.0	0.9	94,280	258.3	7%
	6	XOM	6,183	16.9	338.8	0.9	65,749	180.1	9%
	7	KRAKEN PETROLEUM	4,217	11.6	231.1	0.6	21,798	59.7	19%
	8	COP	3,696	10.1	202.5	0.6	58,027	159.0	6%
	9	OAS	3,588	9.8	196.6	0.5	83,857	229.7	4%
	10	EQNR	3,499	9.6	191.7	0.5	45,129	123.6	8%
		Top 10 Subtotal	**73,297**	**200.8**	**4,016.6**	**11.0**	**745,249**	**2,041.8**	**10%**
		Total Bakken	**99,109**	**271.5**	**5,431.2**	**14.9**	**983,337**	**2,694.1**	**10%**
		% of Total	*74%*	*74%*	*74%*	*74%*	*76%*	*76%*	

FIGURES 11 AND 12. BAKKEN OPERATORS RANKED BY REPORTED FLARED VOLUME





Within the Bakken, Operators were ranked by their absolute Flared Percentage for the FY 2019 and FY 2020 periods (See Tables 17 and 18). Marathon Oil (NYSE: MRO) in FY 2019 and Denbury Resources (NYSE: DEN) in FY 2020 had the highest Flared Percentage within the Bakken at 48% and 89%, respectively.

Bakken Operators who realized a Flared Percentage of less than 5% were also ranked by their total Produced Volumes (MMcfe). For the FY 2019 and FY 2020 periods, EOG Resources (NYSE: EOG), Kaiser Francis Operating Company, and Oasis Petroleum (NASDAQ: OAS) had the highest Produced Volumes while maintaining low Flared Percentages (see Tables 19 and 20).

TABLE 17. BAKKEN OPERATORS RANKED BY FLARED PERCENTAGE

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	MRO	28,831	79.0	1,579.9	4.3	60,583	166.0	48%
	2	DEN	210	0.6	11.5	0.0	478	1.3	44%
	3	LGCY	31	0.1	1.7	0.0	120	0.3	26%
	4	AXAS	3,056	8.4	167.5	0.5	11,784	32.3	26%
	5	ERF	3,955	10.8	216.7	0.6	19,157	52.5	21%
	6	XOM	14,423	39.5	790.4	2.2	70,086	192.0	21%
	7	WPX	8,122	22.3	445.1	1.2	39,491	108.2	21%
	8	HES	18,599	51.0	1,019.2	2.8	95,094	260.5	20%
	9	WLL	20,315	55.7	1,113.3	3.1	117,988	323.3	17%
	10	OVV	4,468	12.2	244.8	0.7	26,808	73.4	17%
	Top 10 Subtotal		**102,010**	**279.5**	**5,590.2**	**15.3**	**441,589**	**1,209.8**	**23%**

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	DEN	397	1.1	21.8	0.1	446	1.2	89%
	2	LGCY	21	0.1	1.1	0.0	85	0.2	24%
	3	MRO	12,917	35.4	707.9	1.9	59,713	163.6	22%
	4	WPX	7,226	19.8	396.0	1.1	49,038	134.4	15%
	5	CPG	889	2.4	48.7	0.1	7,346	20.1	12%
	6	HES	13,422	36.8	735.6	2.0	121,387	332.6	11%
	7	ERF	1,903	5.2	104.3	0.3	20,114	55.1	9%
	8	XOM	6,183	16.9	338.8	0.9	65,749	180.1	9%
	9	QEP	2,292	6.3	125.6	0.3	24,683	67.6	9%
	10	OVV	2,387	6.5	130.8	0.4	27,994	76.7	9%
	Top 10 Subtotal		**47,639**	**130.5**	**2,610.6**	**7.2**	**376,554**	**1,031.7**	**13%**

TABLE 18. BAKKEN OPERATORS RANKED BY FLARED PERCENTAGE - FLARING CO_2e METRICS

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2019	1	MRO	1,579.9	4.3	41,090	112.6	38.5
	2	DEN	11.5	0.0	2,193	6.0	5.2
	3	LGCY	1.7	0.0	155	0.4	11.1
	4	AXAS	167.5	0.5	3,098	8.5	54.1
	5	ERF	216.7	0.6	14,737	40.4	14.7
	6	XOM	790.4	2.2	29,917	82.0	26.4
	7	WPX	445.1	1.2	29,871	81.8	14.9
	8	HES	1,019.2	2.8	44,029	120.6	23.1
	9	WLL	1,113.3	3.1	43,231	118.4	25.8
	10	OVV	244.8	0.7	9,721	26.6	25.2
	Top 10 Subtotal		**5,590.2**	**15.3**	**218,044**	**597.4**	**25.6**

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2020	1	DEN	21.8	0.1	1,878	5.1	11.6
	2	LGCY	1.1	0.0	121	0.3	9.3
	3	MRO	707.9	1.9	36,583	100.2	19.3
	4	WPX	396.0	1.1	31,617	86.6	12.5
	5	CPG	48.7	0.1	5,248	14.4	9.3
	6	HES	735.6	2.0	50,910	139.5	14.4
	7	ERF	104.3	0.3	13,198	36.2	7.9
	8	XOM	338.8	0.9	26,795	73.4	12.6
	9	QEP	125.6	0.3	8,510	23.3	14.8
	10	OVV	130.8	0.4	10,039	27.5	13.0
	Top 10 Subtotal		**2,610.6**	**7.2**	**184,900**	**506.6**	**14.1**

TABLE 19. BAKKEN HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%)

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	EOG	121,920	334	1,537	4.2	84	0.2	5%
	2	KAISER FRANCIS	2,542	7	20	0.1	1	0.0	5%
	3	MISSOURI RIVER RESOURCES	2,166	6	12	0.0	1	0.0	2%
	4	RAMPART ENERGY	1,103	3	4	0.0	0	0.0	3%
	5	BERENERGY	1,078	3	–	–	–	–	0%
	6	CHALLENGER POINT ENERGY	1,034	3	–	–	–	–	0%
	7	PRIMA EXPLORATION	1,022	3	9	0.0	1	0.0	5%
	8	ARMSTRONG OPERATING	945	3	–	–	–	–	0%
	9	BALLARD PETROLEUM	906	2	0	0.0	0	0.0	1%
	10	EMPIRE NORTH DAKOTA	794	2	–	–	–	–	0%
		Top 10 Subtotal	**133,510**	**366**	**1,582**	**4.3**	**87**	**0.2**	**5%**

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OAS	215,192	589.6	3,588	9.8	197	0.5	4%
	2	EOG	90,271	247.3	375	1.0	21	0.1	1%
	3	KAISER FRANCIS	2,067	5.7	14	0.0	1	0.0	4%
	4	BERENERGY	853	2.3	–	–	–	–	0%
	5	RAMPART ENERGY	772	2.1	1	0.0	0	0.0	1%
	6	EMPIRE NORTH DAKOTA	680	1.9	–	–	–	–	0%
	7	ARMSTRONG OPERATING	618	1.7	0	0.0	0	0.0	0%
	8	PHOENIX PETROLEUM	472	1.3	–	–	–	–	0%
	9	CHALLENGER POINT ENERGY	468	1.3	1	0.0	0	0.0	1%
	10	REMUDA ENERGY	195	0.5	–	–	–	–	0%
		Top 10 Subtotal	**311,589**	**853.7**	**3,981**	**10.9**	**218**	**0.6**	**4%**

TABLE 20. BAKKEN HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%) – FLARING CO_2e METRICS

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	EOG	20,320	56	84	0.2	4.1
	2	KAISER FRANCIS	424	1	1	0.0	2.5
	3	MISSOURI RIVER RESOURCES	361	1	1	0.0	1.7
	4	RAMPART ENERGY	184	1	0	0.0	1.2
	5	BERENERGY	180	0	–	–	0.0
	6	CHALLENGER POINT ENERGY	172	0	–	–	0.0
	7	PRIMA EXPLORATION	170	0	1	0.0	3.0
	8	ARMSTRONG OPERATING	158	0	–	–	0.0
	9	BALLARD PETROLEUM	151	0	0	0.0	0.0
	10	EMPIRE NORTH DAKOTA	132	0	–	–	0.0
		Top 10 Subtotal	**22,252**	**61**	**87**	**0.2**	**3.9**

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OAS	35,865	98.3	197	0.5	5.5
	2	EOG	15,045	41.2	21	0.1	1.4
	3	KAISER FRANCIS	344	0.9	1	0.0	2.3
	4	BERENERGY	142	0.4	–	–	0.0
	5	RAMPART ENERGY	129	0.4	0	0.0	0.6
	6	EMPIRE NORTH DAKOTA	113	0.3	–	–	0.0
	7	ARMSTRONG OPERATING	103	0.3	0	0.0	0.1
	8	PHOENIX PETROLEUM	79	0.2	–	–	0.0
	9	CHALLENGER POINT ENERGY	78	0.2	0	0.0	0.7
	10	REMUDA ENERGY	33	0.1	–	–	0.0
		Top 10 Subtotal	**51,931**	**142.3**	**218**	**0.6**	**4.2**

Eagle Ford

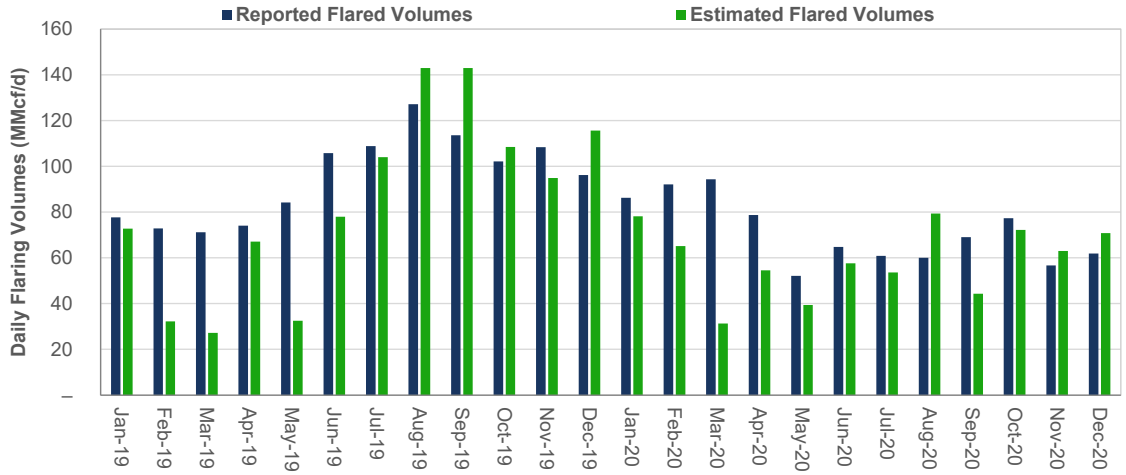
In the Eagle Ford, Reported and Estimated Flare Volumes were 26 / 22 Bcf in FY 2020, reflecting a 25 / 30% drop from the FY 2019 volumes of 35 / 31 Bcf (see Table 21 and Figure 13). On a CO_2e basis, Eagle Ford Reported Flaring Volumes were 1 Mt in FY 2020 and 2 Mt in FY 2019.

Within the FY 2019 and FY 2020 periods, peak Reported Flare Volumes and Estimated Flare Volumes were observed in August 2019, at 3.9 Bcf and 4.4 Bcf, respectively, representing ~1.8% of total Produced Gas in the region for the month. For the FY 2019 and FY 2020 periods, Reported Flare Volumes reflected, 1.3% and 1.1%, of total Produced Gas.

TABLE 21. EAGLE FORD DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

Period	Rank	Reporting Month	Reported Flared Volumes		Estimated Flared Volumes		Produced Gas Volumes		Flared Percentage
			Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	
FY 2019	12	Jan-19	2.4	78	2.3	73	218.4	7,046	1.1%
	18	Feb-19	2.0	73	0.9	32	196.5	7,018	1.0%
	16	Mar-19	2.2	71	0.8	27	216.2	6,976	1.0%
	15	Apr-19	2.2	74	2.0	67	214.0	7,132	1.0%
	11	May-19	2.6	84	1.0	32	224.8	7,251	1.2%
	5	Jun-19	3.2	106	2.3	78	221.3	7,377	1.4%
	3	Jul-19	3.4	109	3.2	104	230.5	7,434	1.5%
	1	Aug-19	3.9	127	4.4	143	232.7	7,506	1.7%
	2	Sep-19	3.4	114	4.3	143	228.4	7,614	1.5%
	6	Oct-19	3.2	102	3.4	108	234.6	7,568	1.4%
	4	Nov-19	3.3	108	2.8	95	228.5	7,616	1.4%
	7	Dec-19	3.0	96	3.6	116	236.8	7,639	1.3%
FY 2020	9	Jan-20	2.7	86	2.4	78	235.6	7,600	1.1%
	10	Feb-20	2.7	92	1.9	65	218.1	7,521	1.2%
	8	Mar-20	2.9	94	1.0	31	230.6	7,439	1.3%
	14	Apr-20	2.4	79	1.6	55	214.9	7,164	1.1%
	24	May-20	1.6	52	1.2	39	186.4	6,014	0.9%
	19	Jun-20	1.9	65	1.7	58	183.5	6,115	1.1%
	21	Jul-20	1.9	61	1.7	54	193.8	6,250	1.0%
	22	Aug-20	1.9	60	2.5	79	197.1	6,359	0.9%
	17	Sep-20	2.1	69	1.3	44	187.9	6,263	1.1%
	13	Oct-20	2.4	77	2.2	72	189.3	6,108	1.3%
	23	Nov-20	1.7	57	1.9	63	181.9	6,064	0.9%
	20	Dec-20	1.9	62	2.2	71	183.1	5,905	1.0%
FY 2019		**Gas (Bcf | MMcf/d)**	**34.8**	**95**	**31.1**	**85**	**2,682.7**	**7,350**	**1%**
		CO_2e (Mt | Kt/d)	**1.9**	**5**	**1.7**	**5**	**147.0**	**403**	
FY 2020		**Gas (Bcf | MMcf/d)**	**26.0**	**71**	**21.6**	**59**	**2,402.2**	**6,581**	**1%**
		CO_2e (Mt | Kt/d)	**1.4**	**4**	**1.2**	**3**	**131.6**	**361**	
		Y/Y Change	**(25%)**	**(25%)**	**(30%)**	**(30%)**	**(10%)**	**(10%)**	**(16.4%)**

FIGURE 13. EAGLE FORD DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)



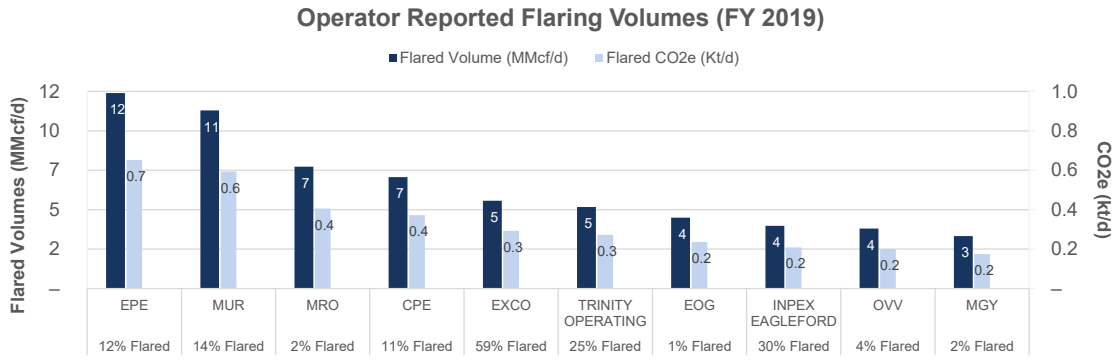
Within the Eagle Ford, Operators were ranked by their absolute Reported Flare Volumes for the FY 2019 and FY 2020 periods (See Table 22 and Figures 14 and 15). EP Energy (NYSE: EPE) had the highest average Reported Flare Volumes of 12 MMcf/d for FY 2019, whereas Trinity Operating, LLC had the highest volumes of 8 MMcf/d for the FY 2020 period. EOG Resources (NYSE: EOG), Ovintiv Inc. (NYSE: OVV) and Magnolia Oil & Gas (NYSE: MGY) were among the top "flarers" by Reported Flare Volumes for the FY 2019 period but were replaced by Treadstone Energy, LLC, Recoil Resources, LLC and U.S. Energy (NYSE: USEG) in the FY 2020 period. The Top 10 Operators by Reported Flare Volumes accounted for 65% of the total FY 2019 Eagle Ford Flare Volumes and 60% of the FY 2020 volumes, while accounting for 9 – 21% of the total Produced Gas Volumes.

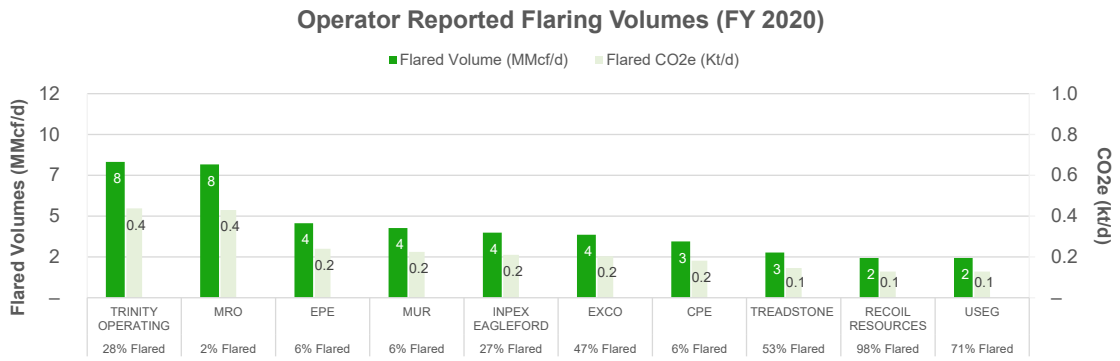
TABLE 22. EAGLE FORD OPERATORS RANKED BY REPORTED FLARE VOLUMES

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	EPE	4,345	11.9	238.1	0.7	37,267	102.1	12%
	2	MUR	3,957	10.8	216.8	0.6	28,032	76.8	14%
	3	MRO	2,707	7.4	148.4	0.4	149,524	409.7	2%
	4	CPE	2,477	6.8	135.7	0.4	23,576	64.6	11%
	5	EXCO	1,952	5.3	106.9	0.3	3,322	9.1	59%
	6	TRINITY OPERATING	1,814	5.0	99.4	0.3	7,140	19.6	25%
	7	EOG	1,575	4.3	86.3	0.2	224,163	614.1	1%
	8	INPEX EAGLEFORD	1,394	3.8	76.4	0.2	4,714	12.9	30%
	9	OVV	1,333	3.7	73.1	0.2	36,201	99.2	4%
	10	MGY	1,166	3.2	63.9	0.2	55,446	151.9	2%
	Top 10 Subtotal		**22,719**	**62.2**	**1,245.0**	**3.4**	**569,385**	**1,560.0**	**4%**
	Total Eagle Ford		**34,776**	**95.3**	**1,905.7**	**5.2**	**2,682,671**	**7,349.8**	**1%**
	% of Total		*65%*	*65%*	*65%*	*65%*	*21%*	*21%*	

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	TRINITY OPERATING	2,915	8.0	159.7	0.4	10,389	28.5	28%
	2	MRO	2,860	7.8	156.7	0.4	126,875	347.6	2%
	3	EPE	1,602	4.4	87.8	0.2	27,771	76.1	6%
	4	MUR	1,496	4.1	82.0	0.2	23,805	65.2	6%
	5	INPEX EAGLEFORD	1,397	3.8	76.6	0.2	5,103	14.0	27%
	6	EXCO	1,354	3.7	74.2	0.2	2,886	7.9	47%
	7	CPE	1,208	3.3	66.2	0.2	21,809	59.8	6%
	8	TREADSTONE	970	2.7	53.2	0.1	1,822	5.0	53%
	9	RECOIL RESOURCES	856	2.3	46.9	0.1	873	2.4	98%
	10	USEG	855	2.3	46.9	0.1	1,207	3.3	71%
	Top 10 Subtotal		**15,514**	**42.5**	**850.2**	**2.3**	**222,541**	**609.7**	**7%**
	Total Eagle Ford		**26,021**	**71.3**	**1,425.9**	**3.9**	**2,402,236**	**6,581.5**	**1%**
	% of Total		*60%*	*60%*	*60%*	*60%*	*9%*	*9%*	

FIGURES 14 AND 15. EAGLE FORD OPERATORS RANKED BY REPORTED FLARE VOLUMES





Within the Eagle Ford, Operators were ranked by their absolute Flared Percentage for the FY 2019 and FY 2020 periods (See Tables 23 and 24). U.S. Energy (NYSE: USEG) had the highest Flared Percentage within the Eagle Ford in FY 2019 and FY 2020 at 75% and 71%, respectively. (See Tables 23 and 24).

Eagle Ford Operators who realized a Flared Percentage of less than 5% were also ranked by their total Produced Volumes (MMcfe). For the FY 2019 and FY 2020 periods, EOG Resources (NYSE: EOG), Chesapeake Energy (NASDAQ: CHK), and ConocoPhillips (NYSE: COP) had the highest Produced Volumes while maintaining low Flared Percentages (see Tables 25 and 26).

TABLE 23. EAGLE FORD OPERATORS RANKED BY FLARED PERCENTAGE

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	USEG	1,075	2.9	58.9	0.2	1,437	3.9	75%
	2	MUR	3,957	10.8	216.8	0.6	28,032	76.8	14%
	3	EPE	4,345	11.9	238.1	0.7	37,267	102.1	12%
	4	SNDE	982	2.7	53.8	0.1	9,014	24.7	11%
	5	CPE	2,477	6.8	135.7	0.4	23,576	64.6	11%
	6	MTDR	252	0.7	13.8	0.0	3,328	9.1	8%
	7	OVV	1,333	3.7	73.1	0.2	36,201	99.2	4%
	8	LONE	398	1.1	21.8	0.1	14,295	39.2	3%
	9	ESTE	30	0.1	1.7	0.0	1,157	3.2	3%
	10	MGY	1,166	3.2	63.9	0.2	55,446	151.9	2%
	Top 10 Subtotal		**16,016**	**43.9**	**877.7**	**2.4**	**209,752**	**574.7**	**8%**

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	USEG	855	2.3	46.9	0.1	1,207	3.3	71%
	2	SNDE	798	2.2	43.7	0.1	6,812	18.7	12%
	3	MTDR	181	0.5	9.9	0.0	2,166	5.9	8%
	4	MUR	1,496	4.1	82.0	0.2	23,805	65.2	6%
	5	EPE	1,602	4.4	87.8	0.2	27,771	76.1	6%
	6	CPE	1,208	3.3	66.2	0.2	21,809	59.8	6%
	7	LONE	301	0.8	16.5	0.0	12,762	35.0	2%
	8	OVV	608	1.7	33.3	0.1	25,941	71.1	2%
	9	MRO	2,860	7.8	156.7	0.4	126,875	347.6	2%
	10	XOM	726	2.0	39.8	0.1	42,158	115.5	2%
	Top 10 Subtotal		**10,635**	**29.1**	**582.8**	**1.6**	**291,305**	**798.1**	**4%**

TABLE 24. EAGLE FORD OPERATORS RANKED BY FLARED PERCENTAGE - FLARING CO_2e METRICS

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2019	1	USEG	58.9	0.2	1,343	3.7	43.9
	2	MUR	216.8	0.6	18,446	50.5	11.8
	3	EPE	238.1	0.7	12,882	35.3	18.5
	4	SNDE	53.8	0.1	3,954	10.8	13.6
	5	CPE	135.7	0.4	17,630	48.3	7.7
	6	MTDR	13.8	0.0	1,434	3.9	9.7
	7	OVV	73.1	0.2	11,843	32.4	6.2
	8	LONE	21.8	0.1	3,491	9.6	6.2
	9	ESTE	1.7	0.0	1,391	3.8	1.2
	10	MGY	63.9	0.2	13,105	35.9	4.9
	Top 10 Subtotal		**877.7**	**2.4**	**85,520**	**234.3**	**10.3**

Period	Rank	Ticker	Reported Flared CO_2e Emissions		Produced Oil Volumes		Carbon Intensity (tons/Mbbl)
			Total (Kt)	Daily (Kt/d)	Total (Mbbl)	Daily (Mbbl/d)	
FY 2020	1	USEG	46.9	0.1	1,034	2.8	45.3
	2	SNDE	43.7	0.1	2,642	7.2	16.6
	3	MTDR	9.9	0.0	872	2.4	11.4
	4	MUR	82.0	0.2	13,503	37.0	6.1
	5	EPE	87.8	0.2	9,115	25.0	9.6
	6	CPE	66.2	0.2	13,958	38.2	4.7
	7	LONE	16.5	0.0	3,423	9.4	4.8
	8	OVV	33.3	0.1	8,238	22.6	4.0
	9	MRO	156.7	0.4	37,815	103.6	4.1
	10	XOM	39.8	0.1	3,885	10.6	10.2
	Top 10 Subtotal		**582.8**	**1.6**	**94,484**	**258.9**	**6.2**

TABLE 25. EAGLE FORD HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%)

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	EOG	820,355	2,248	1,575	4.3	86	0.2	1%
	2	CHK	561,576	1,539	263	0.7	14	0.0	0%
	3	COP	539,289	1,478	212	0.6	12	0.0	0%
	4	MRO	397,807	1,090	2,707	7.4	148	0.4	2%
	5	SN	345,339	946	1,010	2.8	55	0.2	1%
	6	DVN	287,088	787	52	0.1	3	0.0	0%
	7	LEWIS PETROLEUM	270,894	742	–	–	–	–	0%
	8	SM	155,220	425	–	–	–	–	0%
	9	MUR	138,706	380	3,957	10.8	217	0.6	14%
	10	SBOW	134,993	370	540	1.5	30	0.1	0%
	Top 10 Subtotal		**3,651,267**	**10,003**	**10,315**	**28.3**	**565**	**1.5**	**1%**

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	EOG	674,830	1,848.8	494	1.4	27	0.1	0%
	2	CHK	496,797	1,361.1	228	0.6	12	0.0	0%
	3	COP	457,370	1,253.1	70	0.2	4	0.0	0%
	4	MRO	353,764	969.2	2,860	7.8	157	0.4	2%
	5	SN	277,562	760.4	407	1.1	22	0.1	0%
	6	DVN	271,480	743.8	40	0.1	2	0.0	0%
	7	LEWIS PETROLEUM	222,949	610.8	–	–	–	–	0%
	8	BP	149,272	409.0	201	0.6	11	0.0	0%
	9	SM	121,332	332.4	–	–	–	–	0%
	10	MGY	118,048	323.4	633	1.7	35	0.1	1%
	Top 10 Subtotal		**3,143,405**	**8,612.1**	**4,934**	**13.5**	**270**	**0.7**	**0%**

TABLE 26. EAGLE FORD HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%) – FLARING CO_2e METRICS

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	EOG	136,726	375	86	0.2	0.6
	2	CHK	93,596	256	14	0.0	0.2
	3	COP	89,882	246	12	0.0	0.1
	4	MRO	66,301	182	148	0.4	2.2
	5	SN	57,557	158	55	0.2	1.0
	6	DVN	47,848	131	3	0.0	0.1
	7	LEWIS PETROLEUM	45,149	124	–	–	0.0
	8	SM	25,870	71	–	–	0.0
	9	MUR	23,118	63	217	0.6	9.4
	10	SBOW	22,499	62	30	0.1	1.3
	Top 10 Subtotal		**608,545**	**1,667**	**565**	**1.5**	**0.9**

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	EOG	112,472	308.1	27	0.1	0.2
	2	CHK	82,799	226.8	12	0.0	0.2
	3	COP	76,228	208.8	4	0.0	0.1
	4	MRO	58,961	161.5	157	0.4	2.7
	5	SN	46,260	126.7	22	0.1	0.5
	6	DVN	45,247	124.0	2	0.0	0.0
	7	LEWIS PETROLEUM	37,158	101.8	–	–	0.0
	8	BP	24,879	68.2	11	0.0	0.4
	9	SM	20,222	55.4	–	–	0.0
	10	MGY	19,675	53.9	35	0.1	1.8
	Top 10 Subtotal		**523,901**	**1,435.3**	**270**	**0.7**	**0.5**

DJ Basin

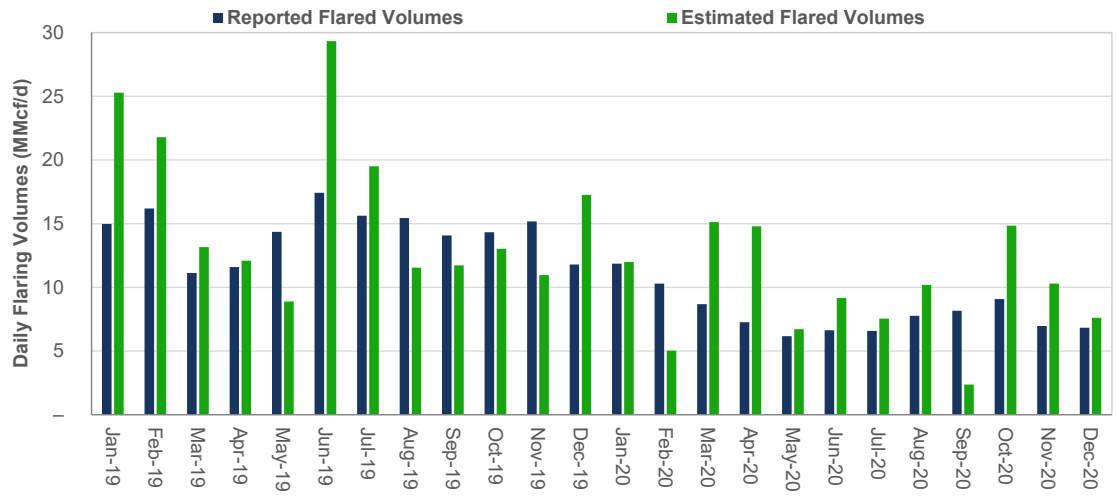
In the DJ Basin, Reported and Estimated Flare Volumes were 2.9 / 3.5 Bcf in FY 2020, reflecting a 44 / 40% drop from the FY 2019 volumes of 5.2 / 5.9 Bcf (see Table 27 and Figure 16). On a CO_2e basis, DJ Basin Reported Flaring Volumes were 0.2 Mt in FY 2020 and 0.3 Mt in FY 2019.

Within the FY 2019 and FY 2020 periods, peak Reported Flare Volumes and Estimated Flare Volumes were observed in June 2019, at 0.5 Bcf and 0.9 Bcf, respectively, representing 0.4% and 0.6% of total Produced Gas in the region for the month (see Table 27). For the FY 2019 and FY 2020 periods, Reported Flare Volumes reflected, 0.3% and 0.2%, of total Produced Gas, respectively.

TABLE 27. DJ BASIN DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)

Period	Rank	Reporting Month	Reported Flared Volumes		Estimated Flared Volumes		Produced Gas Volumes		Flared Percentage
			Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	Total (Bcf)	Daily (MMcf/d)	
FY 2019	4	Jan-19	0.5	15	0.8	25	139.7	4,507	0.3%
	6	Feb-19	0.5	16	0.6	22	125.6	4,487	0.4%
	13	Mar-19	0.3	11	0.4	13	138.0	4,451	0.3%
	12	Apr-19	0.3	12	0.4	12	135.7	4,523	0.3%
	7	May-19	0.4	14	0.3	9	140.2	4,523	0.3%
	1	Jun-19	0.5	17	0.9	29	137.9	4,596	0.4%
	2	Jul-19	0.5	16	0.6	20	139.8	4,511	0.3%
	3	Aug-19	0.5	15	0.4	12	140.7	4,540	0.3%
	9	Sep-19	0.4	14	0.4	12	137.2	4,574	0.3%
	8	Oct-19	0.4	14	0.4	13	148.4	4,787	0.3%
	5	Nov-19	0.5	15	0.3	11	147.6	4,921	0.3%
	11	Dec-19	0.4	12	0.5	17	153.7	4,959	0.2%
FY 2020	10	Jan-20	0.4	12	0.4	12	153.9	4,964	0.2%
	14	Feb-20	0.3	10	0.1	5	143.6	4,952	0.2%
	16	Mar-20	0.3	9	0.5	15	151.3	4,880	0.2%
	19	Apr-20	0.2	7	0.4	15	145.5	4,851	0.1%
	24	May-20	0.2	6	0.2	7	141.1	4,553	0.1%
	23	Jun-20	0.2	7	0.3	9	137.3	4,578	0.1%
	22	Jul-20	0.2	7	0.2	8	144.8	4,672	0.1%
	18	Aug-20	0.2	8	0.3	10	146.6	4,729	0.2%
	17	Sep-20	0.2	8	0.1	2	141.2	4,707	0.2%
	15	Oct-20	0.3	9	0.5	15	143.0	4,612	0.2%
	21	Nov-20	0.2	7	0.3	10	138.4	4,613	0.2%
	20	Dec-20	0.2	7	0.2	8	139.1	4,487	0.2%
FY 2019		**Gas (Bcf | MMcf/d)**	**5.2**	**14**	**5.9**	**16**	**1,684.7**	**4,616**	**0%**
		CO_2e (Mt | Kt/d)	**0.3**	**1**	**0.3**	**1**	**92.3**	**253**	
FY 2020		**Gas (Bcf | MMcf/d)**	**2.9**	**8**	**3.5**	**10**	**1,725.9**	**4,728**	**0%**
		CO_2e (Mt | Kt/d)	**0.2**	**0**	**0.2**	**1**	**94.6**	**259**	
		Y/Y Change	**(44%)**	**(44%)**	**(40%)**	**(40%)**	**2%**	**2%**	**(45%)**

FIGURE 16. DJ BASIN DAILY FLARING VOLUMES (REPORTED VS. ESTIMATED FLARING)



Within the DJ Basin, Operators were ranked by their absolute Reported Flare Volumes for the FY 2019 and FY 2020 periods (See Table 28 and Figures 17 and 18). Sandridge (NYSE: SD) had the highest average Reported Flare Volumes of 4.9 MMcf/d for FY 2019 and of 3.3 MMcf/d for the FY 2020 period. The Top 10 Operators by Reported Flare Volumes accounted for 80% of the total FY 2019 DJ Basin Flare Volumes and 94% of the FY 2020 volumes, while accounting for 3 – 18% of the total Produced Gas Volumes.

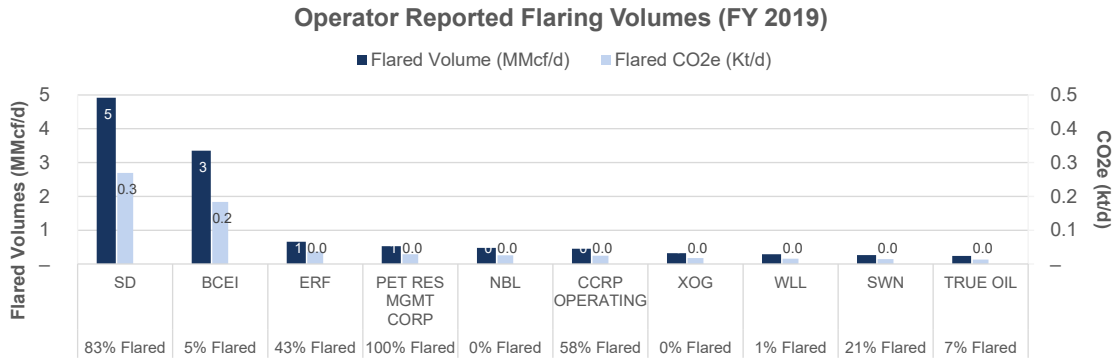
DJ Basin Operators who realized a Flared Percentage of less than 5% were also ranked by their total Produced Volumes (MMcfe). For the FY 2019 and FY 2020 periods, Occidental Resources (NYSE: OXY), PDC Energy (NASDAQ: PDCE), and Noble Energy (NASDAQ: NBL) had the highest Produced Volumes while maintaining low Flared Percentages (see Tables 29 and 30).

TABLE 28. DJ BASIN OPERATORS RANKED BY REPORTED FLARE VOLUMES

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2019	1	SD	1,796	4.9	98.4	0.3	2,168	5.9	83%
	2	BCEI	1,223	3.4	67.0	0.2	23,072	63.2	5%
	3	ERF	241	0.7	13.2	0.0	561	1.5	43%
	4	PET RES MGMT CORP	192	0.5	10.5	0.0	192	0.5	100%
	5	NBL	173	0.5	9.5	0.0	163,187	447.1	0%
	6	CCRP OPERATING	164	0.5	9.0	0.0	283	0.8	58%
	7	XOG	118	0.3	6.4	0.0	108,244	296.6	0%
	8	WLL	106	0.3	5.8	0.0	10,215	28.0	1%
	9	SWN	96	0.3	5.3	0.0	462	1.3	21%
	10	TRUE OIL	87	0.2	4.8	0.0	1,173	3.2	7%
		Top 10 Subtotal	**4,196**	**11.5**	**229.9**	**0.6**	**309,556**	**848.1**	**1%**
		Total DJ	**5,229**	**14.3**	**286.5**	**0.8**	**1,684,725**	**4,615.7**	**0%**
		% of Total	*80%*	*80%*	*80%*	*80%*	*18%*	*18%*	

Period	Rank	Ticker	Reported Flared Volumes		Reported Flared CO_2e Emissions		Produced Gas Volumes		Flared Percentage
			Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	Total (MMcf)	Daily (MMcf/d)	
FY 2020	1	SD	1,195	3.3	65.5	0.2	1,195	3.3	100%
	2	BCEI	1,001	2.7	54.8	0.2	26,217	71.8	4%
	3	WLL	111	0.3	6.1	0.0	8,253	22.6	1%
	4	CVX	107	0.3	5.9	0.0	4,218	11.6	3%
	5	PET RES MGMT CORP	98	0.3	5.4	0.0	98	0.3	100%
	6	SWN	81	0.2	4.4	0.0	353	1.0	23%
	7	VERDAD	74	0.2	4.1	0.0	7,440	20.4	1%
	8	LONGS PEAK RES	36	0.1	2.0	0.0	36	0.1	100%
	9	RENEGADE OIL	32	0.1	1.8	0.0	56	0.2	58%
	10	CCRP OPERATING	28	0.1	1.5	0.0	290	0.8	10%
		Top 10 Subtotal	**2,765**	**7.6**	**151.5**	**0.4**	**48,157**	**131.9**	**6%**
		Total DJ	**2,935**	**8.0**	**160.8**	**0.4**	**1,725,895**	**4,728.5**	**0%**
		% of Total	*94%*	*94%*	*94%*	*94%*	*3%*	*3%*	

FIGURES 17 AND 18. DJ BASIN OPERATORS RANKED BY REPORTED FLARE VOLUMES



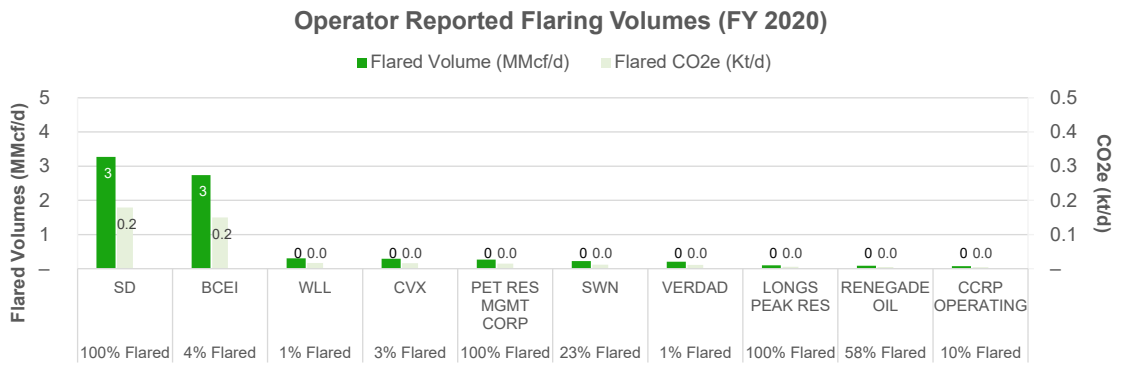


TABLE 29. DJ BASIN HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%)

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	OXY	527,497	1,445	6	0.0	0	0.0	0%
	2	PDCE	400,371	1,097	–	–	–	–	0%
	3	NBL	349,198	957	173	0.5	10	0.0	0%
	4	TEP ROCKY MOUNTAIN LLC	250,535	686	1	0.0	0	0.0	0%
	5	XOG	238,764	654	118	0.3	6	0.0	0%
	6	CAERUS	175,035	480	11	0.0	1	0.0	0%
	7	GREAT WESTERN PETROLEUM	126,931	348	5	0.0	0	0.0	0%
	8	CHALLENGER POINT ENERGY	125,917	345	–	–	–	–	0%
	9	HPR	92,172	253	79	0.2	4	0.0	0%
	10	LARAMIE ENERGY	79,161	217	0	0.0	0	0.0	0%
		Top 10 Subtotal	**2,365,581**	**6,481**	**393**	**1.1**	**22**	**0.1**	**0%**

Period	Rank	Ticker	Produced Volumes		Reported Flared Volumes		Reported Flared CO_2e Emissions		Flared Percentage
			Total (MMcfe)	Daily (MMcfe/d)	Total (MMcf)	Daily (MMcf/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OXY	524,998	1,438	7	0.0	0	0.0	0%
	2	PDCE	380,563	1,043	–	–	–	–	0%
	3	NBL	342,047	937	17	0.0	1	0.0	0%
	4	XOG	243,341	667	0	0.0	0	0.0	0%
	5	TEP ROCKY MOUNTAIN LLC	229,906	630	1	0.0	0	0.0	0%
	6	CAERUS	179,001	490	9	0.0	1	0.0	0%
	7	GREAT WESTERN PETROLEUM	142,091	389	1	0.0	0	0.0	0%
	8	CRESTONE PEAK RESOURCES	117,027	321	–	–	–	–	0%
	9	HPR	79,377	217	0	0.0	0	0.0	0%
	10	BCEI	69,958	192	1,001	2.7	55	0.2	4%
		Top 10 Subtotal	**2,308,310**	**6,324.1**	**1,036**	**2.8**	**57**	**0.2**	**0%**

TABLE 30. EAGLE FORD HIGHEST PRODUCING OPERATORS WITH LOW FLARED PERCENTAGES (<5%) – FLARING CO_2e METRICS

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2019	1	OXY	87,916	241	0	0.0	0.0
	2	PDCE	66,728	183	–	–	0.0
	3	NBL	58,200	159	10	0.0	0.2
	4	TEP ROCKY MOUNTAIN LLC	41,756	114	0	0.0	0.0
	5	XOG	39,794	109	6	0.0	0.2
	6	CAERUS	29,173	80	1	0.0	0.0
	7	GREAT WESTERN PETROLEUM	21,155	58	0	0.0	0.0
	8	CHALLENGER POINT ENERGY	20,986	57	–	–	0.0
	9	HPR	15,362	42	4	0.0	0.3
	10	LARAMIE ENERGY	13,193	36	0	0.0	0.0
		Top 10 Subtotal	**394,263**	**1,080**	**22**	**0.1**	**0.1**

Period	Rank	Ticker	Produced Volumes		Reported Flared CO_2e Emissions		Carbon Intensity (tons/Mboe)
			Total (Mboe)	Daily (Mboe/d)	Total (Kt)	Daily (Kt/d)	
FY 2020	1	OXY	87,500	239.7	0	0.0	0.0
	2	PDCE	63,427	173.8	–	–	0.0
	3	NBL	57,008	156.2	1	0.0	0.0
	4	XOG	40,557	111.1	0	0.0	0.0
	5	TEP ROCKY MOUNTAIN LLC	38,318	105.0	0	0.0	0.0
	6	CAERUS	29,834	81.7	1	0.0	0.0
	7	GREAT WESTERN PETROLEUM	23,682	64.9	0	0.0	0.0
	8	CRESTONE PEAK RESOURCES	19,504	53.4	–	–	0.0
	9	HPR	13,230	36.2	0	0.0	0.0
	10	BCEI	11,660	31.9	55	0.2	4.7
		Top 10 Subtotal	**384,718**	**1,054.0**	**57**	**0.2**	**0.1**

Conclusion

Over the last decade, the application of novel hydraulic fracturing techniques to unconventional shale plays has caused U.S. hydrocarbon production to rapidly grow by over 50% since 2010. Coupled with this increase in exploration and production activity, natural gas flaring volumes have also simultaneously risen.

By leveraging publicly available satellite sensor data, the techniques noted within this analysis demonstrate a means of quantifying these flared volumes in near-real time, as an alternative to state-government reported sources. The methodologies outlined offer a systematic and objective means of monitoring flaring activity in aggregate and have the potential to be transferred in other hydrocarbon-producing regions across the world.

From these methods, it is possible to analyze gas flaring activity on a site-specific basis and identify the levels of combustion on a near-real time basis to better inform local communities of the potential health and environmental impacts of flaring in near real time. This tracking of emissions using alternative sources will increase transparency and communication between Operators, governments, and their local communities and constituents.

Going forward, the coupling of Reported and Estimated Flare Volume datasets will enable the energy industry and its stakeholders to better understand emission levels more holistically and to identify where gaps in midstream infrastructure exist. Equipped with these insights, new capital investment and infrastructure can be implemented to ensure a more sustainable future for all.

Summary Observations

- Tracked Regions:
    - Estimated Flare Volumes were 253 Bcf in FY 2020, reflecting a 43% drop from the FY 2019 volumes of 447 Bcf.
        - For the FY 2020 and the FY 2019 periods, the Permian had the highest Estimated Flare Volumes of 121 Bcf and 215 Bcf, respectively.
        - By contrast, the DJ Basin had the least Estimated Flare Volumes for the FY 2020 and FY 2019 periods of 3.5 Bcf and 5.9 Bcf, respectively.
    - Reporting Flaring Volumes on a CO_2e basis were 14 Mt in FY 2020 and 27 Mt in FY 2019.

- Marathon Oil (NYSE: MRO) had the highest average Reported Flare Volumes in FY 2019 and FY 2020 of 94 MMcf/d and 45 MMcf/d, respectively.
- The Top 10 Operators by Reported Flare Volumes accounted for 40 - 44% of the total FY 2019 / 2020 Tracked Region Flare Volumes, while accounting for 16 – 17% of the total Produced Gas Volumes.
- For the FY 2019 and FY 2020 periods, Occidental Petroleum (NYSE: OXY), EOG Resources (NYSE: EOG), ConocoPhillips (NYSE: COP), and ExxonMobil (NYSE: XOM) were the top Tracked Region Operators who had the highest Produced Volumes while maintaining low Flared Percentages (<5%).

- Permian:
  - The Permian had the highest Reported Flare Volumes for both the FY 2019 and FY 2020 periods of 244 Bcf and 129 Bcf, respectively
    - Reported Flaring Volumes on a CO_2e basis were 7 Mt in FY 2020 and 13 Mt in FY 2019.
  - In the Permian, Diamondback Energy (NYSE: FANG) had the highest average daily Reported Flare Volumes in FY 2019 and FY 2020 of 59 MMcf/d and 24 MMcf/d, respectively.
  - The Delaware sub-basin had the highest daily Reported Flare Volume in FY 2019 and FY 2020 of 370 MMcf/d and 193 MMcf/d, respectively.
  - For the FY 2019 and FY 2020 periods, Occidental Petroleum (NYSE: OXY), Concho Resources (NYSE: CXO), and Pioneer Natural Resources (NYSE: PXD) were the top Permian Operators who had the highest Produced Volumes while maintaining low Flared Percentages (<5%).
- Bakken:
  - The Bakken had the second highest Reported Flare Volumes for both the FY 2019 and FY 2020 periods of 205 Bcf and 99 Bcf, respectively
    - Reported Flaring Volumes on a CO_2e basis were 5 Mt in FY 2020 and 11 Mt in FY 2019.

- In the Bakken, Marathon Oil (NYSE: MRO) had the highest average Reported Flare Volumes of 79 MMcf/d for FY 2019 whereas Hess Corporation (NYSE: HES) had the highest volumes of 37 MMcf/d for the FY 2020 period.
- For the FY 2019 and FY 2020 periods, were also ranked by their total Produced Volumes (MMcfe). For the FY 2019 and FY 2020 periods, EOG Resources (NYSE: EOG), Kaiser Francis Operating Company, and Oasis Petroleum (NASDAQ: OAS) were the top Bakken Operators who had the highest Produced Volumes while maintaining low Flared Percentages (<5%).

- Eagle Ford:
  - On a CO_2e basis, Eagle Ford Reported Flaring Volumes were 1 Mt in FY 2020 and 2 Mt in FY 2019.
  - EP Energy (NYSE: EPE) had the highest average Reported Flare Volumes of 12 MMcf/d for FY 2019 whereas Trinity Operating, LLC had the highest volumes of 8 MMcf/d for the FY 2020 period.
  - The Top 10 Operators by Reported Flare Volumes accounted for 65% of the total FY 2019 Eagle Ford Flare Volumes and 60% of the FY 2020 volumes, while accounting for 9 – 21% of the total Produced Gas Volumes.
  - For the FY 2019 and FY 2020 periods, EOG Resources (NYSE: EOG), Chesapeake Energy (NASDAQ: CHK), and ConocoPhillips (NYSE: COP) were the top Eagle Ford Operators who had the highest Produced Volumes while maintaining low Flared Percentages (<5%).
- DJ Basin:
  - The DJ Basin consistently had the lowest Reported Flare Volumes for both the FY 2019 and FY 2020 periods
    - Reported Flaring Volumes on a CO_2e basis were 0.2 Mt in FY 2020 and 0.3 Mt in FY 2019.
  - In the DJ Basin, Sandridge (NYSE:SD) had the highest average Reported Flare Volumes of 4.9 MMcf/d for FY 2019 and 3.3 MMcf/d for the FY 2020 period.

- For the FY 2019 and FY 2020 periods, Occidental Resources (NYSE: OXY), PDC Energy (NASDAQ: PDCE), and Noble Energy (NASDAQ: NBL) were the top DJ Basin Operators who had the highest Produced Volumes while maintaining low Flared Percentages (<5%).

References

1. The World Bank (n.d.). Zero Routine Flaring by 2030, from https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030, April 2015.
2. Katherine Ann Willyard, Gunnar W. Schade, Flaring in two Texas shale areas: Comparison of bottom-up with top-down volume estimates for 2012 to 2015, Science of The Total Environment, Volume 691, 2019, Pages 243-251
3. Elvidge, C.D.; Zhizhin, M.; Hsu, F.-C.; Baugh, K.E. VIIRS Nightfire: Satellite Pyrometry at Night. *Remote Sens.* **2013**, *5*, 4423-4449. https://doi.org/10.3390/rs5094423
4. Elvidge, C.D.; Zhizhin, M.; Baugh, K.; Hsu, F.-C.; Ghosh, T. Methods for Global Survey of Natural Gas Flaring from Visible Infrared Imaging Radiometer Suite Data. *Energies* **2016**, *9*, 14. https://doi.org/10.3390/en9010014
5. VIIRS Nightfire (VNF). (2020, November 16). Retrieved March 30, 2021, from https://payneinstitute.mines.edu/eog/viirs-nightfire-vnf/
6. Maps: Oil and gas Exploration, resources, and production - Energy Information Administration. (n.d.). Retrieved March 30, 2021, from https://www.eia.gov/maps/maps.htm
7. Planet Labs Inc. (n.d.). Retrieved March 30, 2021, from http://www.planet.com/
8. Suomi NPP Visible infrared IMAGING RADIOMETER Suite (VIIRS). (n.d.). Retrieved March 30, 2021, from https://ncc.nesdis.noaa.gov/VIIRS/
9. Commodity.IO LLC (n.d.). Retrieved March 30, 2021, from https://www.commodity.io/
10. Texas Railroad Commission (TX RRC). (n.d.). Retrieved March 30, 2021, from https://www.rrc.state.tx.us/
11. New Mexico Oil Conservation Division (NM OCD). (n.d.). Retrieved March 30, 2021, from http://www.emnrd.state.nm.us/OCD/ocdonline.html
12. North Dakota Industrial Commission (NDIC). (n.d.). Retrieved March 30, 2021, from https://www.dmr.nd.gov/oilgas/
13. Colorado Oil and Gas Conservation Commission. (n.d.). Colorado Oil and Gas Conservation Commission (COGCC). Retrieved March 30, 2021, from https://cogcc.state.co.us/#/home

14. Environmental Protection Agency. (2021, March 11). Greenhouse Gases Equivalencies Calculator - Calculations and References. EPA. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.