

# Mitigating the Impacts of Natural Gas Flaring

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## Abstract

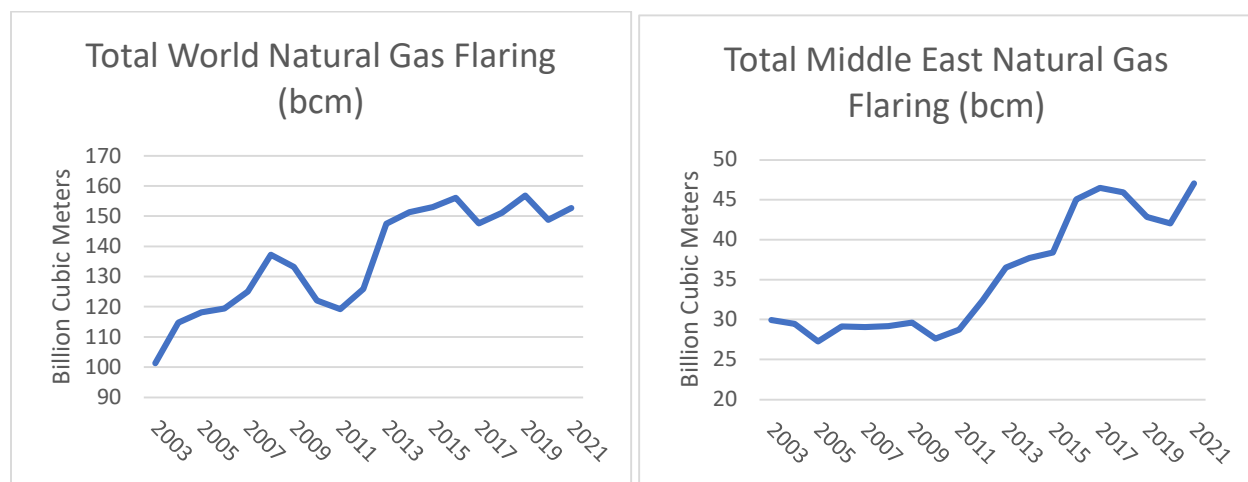
Flaring, the controlled combustion of natural gas, is carried out to dispose of excess gas associated with oil production and preserve safe working conditions. It is associated with several negative environmental and health impacts due to the harmful emissions it releases. Solutions to mitigating these impacts include bringing more gas to market and implementing technological solutions to improve onsite intake of associated gas. This paper aims to determine the economic drivers of flaring. Utilizing a LASSO regression model, we identify gas reserves, gas consumption, and refinery capacity as significant contributors to changes in flaring. Due to the insignificance of price effects, we conclude that supply-focused onsite gas utilization technologies are likely to have a greater impact on flaring than market-focused solutions.

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## Background and Motivation

Flaring is the controlled combustion of volatile hydrocarbons during the process of extracting and processing oil and natural gas. It is often carried out to reduce the risk of gas ignition or dispose of associated gas that is unsuitable for commercial use (Michelussi, 2014). Considerations of worker safety, operational efficiency, and economic feasibility play a role in making the decision to flare gas. A large motivator behind flaring is a lack of direct market access for gas owing to the isolated nature of oil processing plants and the expense associated with constructing pipelines (U.S. Department of Energy, 2019). These transportation expenses mean that the price of natural gas is a major determinant of the choice to flare it rather than sell it (U.S. Government Accountability Office, 2004).

While flaring can help preserve workplace safety on refinery sites, it is associated with negative environmental consequences in the form of harmful emissions. Emitted carbon dioxide contributes to global warming and more harmful chemicals such as sulfur oxides and nitrogen oxides comprise acid rain, damaging vegetation, water bodies, and agriculture. Further, exposure to flared gas is known to cause chronic health issues in humans, ranging from skin diseases to lung damage and cancer (Ajugwo, 2015).



Natural Gas Flaring, 2003-2021. Source: BPSR 2022

Over the decade of 2011-2021, the worldwide volume of gas flared (in billion cubic meters) has grown by 2.5%, causing emissions of 308.3 million tons of carbon dioxide in 2021 (British Petroleum Statistical Review of World Energy, 2022). With the Middle East and Africa comprising 30.8% and 19.8% of all gas flared in 2021 respectively, these regions are the largest contributors

of flared gas (BPSR, 2022). Flared gas represents a large opportunity cost in terms of wasted energy that could be instead used to power these regions.

Flaring trends have been volatile and tend to be influenced by energy regulations. The harmful effects of flaring have necessitated the development of mitigation mechanisms that are manifold in their approaches: market solutions involve the incentivization of gas processing and development of pipeline infrastructure, while technological solutions are more focused on increasing onsite usage of gas. These include extraction of natural gas liquids from flare gas, small-scale electricity generation, and reinjection of flare gas into the ground to increase pressure for oil extraction. The capital and operational costs of these interventions are often not fully offset by the gains from the gas or gas liquids captured (U.S. Department of Energy, 2019), disincentivizing oil producers from implementing them. However, some regions have shown successful results, and research in accelerated development of modular, inexpensive flaring reduction technologies is being undertaken.

This paper seeks to explore some of the economic motivations behind flaring, and in doing so, identify stages in the oil production process where flaring reduction mechanisms can be targeted towards. We aim to utilize explanatory variables relating to the consumption (demand) and production (supply) of gas and oil to determine if market solutions would be more effective than non-market technological solutions. Specifically of interest is the impact of gas prices, oil prices, and gas consumption on quantity of gas flared. Our hypothesis is that gas prices and consumption will be negatively correlated with flaring, owing to greater incentives for producers to process and distribute gas rather than flare it, and oil prices will be positively correlated with flaring owing to greater incentives for producers to shift away from gas production and towards oil production.

## **Data and Methodology**

British Petroleum's Statistical Review of World Energy, 2022 (referred to in this paper as BPSR) documents developments in global energy and emissions. The data used in this paper have been obtained from their cumulative dataset spanning till 2021. Our regions of interest are the Middle East and Africa, as defined in the BPSR dataset, as they are the largest contributors of flared gas as described above. Data from North America was considered in the preprocessing stage but was

excluded due to large volatility in flaring owing to political administration shifts that changed energy regulations frequently. The Middle east and Africa have not implemented as much legislation on flaring, freeing the data of exogenous policy shocks and enabling a more objective analysis of market effects on flaring. Data from some countries of these regions were removed due to excessive missing observations. The final dataset used contains 333 observations and can be found in the Appendix.

As our goal was interpretability of results, we utilized a linear regression model. Due to the low number of observations, we applied the L1 penalty using LASSO to rein in overfitting. Since it reduces sufficiently small coefficients to zero, this would also allow us to narrow down on the variables that significantly impacted flaring. We chose variables from the BPSR dataset that we felt would help explain the variation in flaring, explaining our hypotheses as follows:

1. Oil Refining Capacity: In the absence of data on gas refining capacity, oil refining capacity was chosen as a proxy for a country's capacity to process gas products. We expect a negative relationship between this variable and flaring, as larger capacity could imply an increased ability to process gas rather than flare it.
2. Oil Production: We expect a positive relationship with flaring; associated gas is a byproduct of oil extraction, so an increase in oil production could imply a greater amount of gas to be flared.
3. Oil Price: We expect a positive relationship with flaring; higher oil prices could incentivize producers to increase oil production, thereby increasing the amount of associated gas produced. Further, the cross-price elasticity between oil and gas could make the processing of gas less economically viable than that of oil.
4. Gas Price: We expect a negative relationship with flaring; higher gas prices could make processing gas more economically viable and incentivize producers to bring more natural gas to market, reducing the amount of gas flared.
5. Gas Consumption: We expect a negative relationship with flaring; higher gas consumption could represent a greater demand for natural gas and could incentivize producers to bring more gas to market.

6. Gas Reserves: We expect a positive relationship with flaring; larger reserves could indicate lower rates of consumption and demand for natural gas, leading producers to increase flaring.
7. Gas production: We expect a negative relationship with flaring; an increase in natural gas production would indicate an intentional step by producers to take advantage of economically feasible gas capture, leaving less gas to be flared.

These variables are represented by the following names in our dataset and code:

refcap_kbd	Refinery Capacity in thousands of barrels per day
oilprod_kbd	Oil Production in thousands of barrels per day
gasreserves_tcm	Gas reserves in trillions of cubic meters
gasprod_bcm	Gas Production in billions of cubic meters
gascons_bcm	Gas Consumption in billions of cubic meters
oil_price	Oil Prices in dollars, adjusted for 2021 inflation
gas_price	Gas prices in dollars

The large discrepancies in units of measurement between variables led us to normalize the data to avoid unfairly penalizing larger coefficients.

## Results

The LASSO regression yielded a mean squared error of 0.02941 and the following coefficients for each of the explanatory variables:

(Intercept)	0.1648176
refcap_kbd	-0.4127130
oilprod_kbd	0.2502223
gasreserves_tcm	0.8507129
gasprod_bcm	0.1319856
gascons_bcm	-0.5132083
oil_price	0.0000000
gas_price	0.0355837

The variable with the largest coefficient is Gas Reserves, which was novel since greater focus had been placed on prices and production. A possible mechanism behind this is that larger reserves indicate less active utilization of gas, incentivizing producers to increase flaring rather than processing it. Gas consumption has a large negative coefficient, in line with our hypothesis that greater demand for gas would disincentivize flaring over processing. Refinery capacity also has a large negative coefficient, agreeing with our hypothesis that greater capacity would reduce the amount of gas that needs to be flared out of a lack of processing ability. Oil production and gas production both have small positive coefficients; the former lines up with our hypothesis but the latter does not. The effect is rather small, and one possible interpretation is that increased gas production could cause more gas to escape from the ground, necessitating flaring to maintain safety. Of note is the coefficients of the price variables. The coefficient of Oil Price is zero, indicating that it is not an important feature for the model. This implies that the cross-price elasticity between oil and gas likely does not factor into the decision to flare. The coefficient of Gas Price is slightly positive, contrary to our hypothesis. It is exceedingly small, however, and can be interpreted to have no significant impact on flaring.

## Discussion and Conclusion

The regression results indicate that prices, our initial focal point, do not have a significant impact on the variation in natural gas flaring. Instead, it seems to be primarily driven by gas reserves, refinery capacity, and gas consumption. This informs us that market-focused solutions such as commercial gas processing incentives may not be highly effective, as flaring is not very sensitive to prices. A more efficient way to tackle the issue of flaring would be to increase focus on the development and implementation of non-market solutions - technologies that improve onsite gas utilization. In 2019, the U.S. Department of Energy identified avenues for research into two promising technologies: multi-functional catalysts that would boost conversion of methane gas to useful liquid petrochemicals, and modular equipment designs that would allow producers to selectively scale their capacity to process flare gas. Policymakers must consider the underlying economic activity surrounding oil and gas trade to implement targeted solutions that will help reduce the wastage and harmful emissions associated with flaring. Through policy action, energy producers must be made to realize that the costs of implementing flaring reduction methods may pale in comparison to the environmental and humanitarian costs of not implementing them.

It is important to take note of the limitations of this analysis. After cleaning the data, we were left with 333 observations from countries in the Middle East and Africa. Incomplete data limited our ability to include more regions and datapoints, which leaves room for improvement in the accuracy of our regression model. Further, without producer-reported data on flaring, it is difficult to ascertain the non-market drivers behind flaring. Thus, cultural context and collaboration with energy producers is vital in making any policy decisions regarding flaring reduction. Finally, since our focus was on model interpretability, we selected LASSO as our regression method. Other machine learning methods could be applied with potentially interesting results – XGBoost would, to some extent, circumvent the issue of incomplete data to obtain a high prediction accuracy at the cost of some interpretability.

## References

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## Appendix

All data and R Code utilized in this analysis can be found at this GitHub repository.

[Code and Data for Natural Gas Flaring Analysis](#)  
([https://github.com/abhamidi03/flaring\\_econ484/tree/main](https://github.com/abhamidi03/flaring_econ484/tree/main))