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The potential role of natural gas flaring in meeting greenhouse gas mitigation targets

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ABSTRACT

In this paper, we compare 2015 satellite-derived natural gas (gas) flaring data with the greenhouse gas reduction targets presented by those countries in their nationally determined contributions (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. Converting from flaring to utilization is an attractive option for reducing emissions. The analysis rates the potential role of reduction of gas flaring in meeting country-specific NDC targets. The analysis includes three categories of flaring: upstream in oil and gas production areas, downstream at refineries and transport facilities, and industrial (e.g., coal mines, landfills, water treatment plants, etc.). Upstream flaring dominates with 90.6% of all flaring. Global flaring represents less than 2% of the NDC reduction target. However, most gas flaring is concentrated in a limited set of countries, leaving the possibility that flaring reduction could contribute a sizeable portion of the NDC targets for specific countries. States that could fully meet their NDC targets through gas flaring reductions include: Yemen (240%), Algeria (197%), and Iraq (136%). Countries which could meet a substantial portion of their NDC targets with gas flaring reductions include: Gabon (94%), Algeria (48%), Venezuela (47%), Iran (34%), and Sudan (33%). On the other hand, several countries with large flared gas volumes could only meet a small portion of their NDC targets from gas flaring reductions, including the Russian Federation (2.4%) and the USA (0.1%). These findings may be useful in guiding national level efforts to meet NDC greenhouse gas reduction targets.
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1. Introduction

There is wide consensus in the scientific community that anthropogenic greenhouse gas emissions have begun to impact the earth's climate, and that large reductions in those emissions is required to constrain the adverse impacts of climate change. Worldwide, the largest source of emissions comes from the burning fossil fuels, widely consumed for electricity, heat, and transportation. Fossil fuels widely consumed include coal, petroleum, and natural gas.

The Paris Climate Agreement, developed under the United Nations Framework Convention on Climate Change (UNFCCC), came into force on November 4, 2016. Under the Agreement, countries have presented specific actions and targets to reduce greenhouse gas emissions. These commitments are referred to as Nationally Determined Contributions (NDCs). There are two types of NDC targets. Unconditional targets are those that countries have volunteered with no expectation for external financial and technical assistance. Conditional targets are reductions that a country lists as possible with external assistance.

One of the methods for meeting NDC targets is the reduction of natural gas flaring. Flaring is a widely-used practice to dispose of natural gas in situations where there is insufficient infrastructure to use the gas locally or move it to market. The admissibility of gas flaring reductions to meet emission reduction targets traces back to the Kyoto Protocol's Clean Development Mechanism [1].

There are gas flares at oil and gas exploration and production facilities, refineries, liquid natural gas terminals, and industrial sites such as coal mines and landfills. A recent study [2] found that 90%

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of the global flared gas volume occurs at upstream exploration and production facilities. This is referred to as "associated gas", a byproduct of oil extraction, arising in part due to the change in pressure from deep underground reservoirs to the earth's surface. Natural gas dissolved in the oil at depth is released at the surface. Much of this associated gas is utilized or conserved because governments and oil companies have made substantial investments to capture it; nevertheless, some of it is flared because of technical, regulatory, or economic constraints. As a result, thousands of gas flares at oil production sites around the globe burn approximately 140 billion cubic meters (bcm) of natural gas annually, resulting in nearly 300 million tons of carbon dioxide (CO_2) to be emitted to the atmosphere. In terms of global warming potential, methane is 28–36 times stronger than CO_2. Therefore, flaring results in less warming impact than venting, the direct release of natural gas into the atmosphere.

Methods for reducing gas flaring include transport as gas to a market, conversion to a liquid fuel similar to gasoline, on-site utilization for heat or electric power, and reinjection into underground strata. Reductions in gas flaring are an attractive option for stepping down greenhouse gas emissions because the gas is a marketable commodity. Utilization of the gas displaces other fossil fuels, thus reducing greenhouse gas emissions.

The World Bank supports a "zero routine flaring by 2030" initiative [3]. However, regulations on gas flaring are set at national and sub-national levels. There is wide variation regarding the permissibility of flaring, conditions under which flaring is allowed, and reporting requirements. Russian law requires the utilization of 95% of associated gas. Gas flaring is illegal in Nigeria. Flaring is prohibited in Equatorial Guinea, though the government can grant exemptions. Still, flaring is legal in the USA, with state regulations setting conditions and reporting requirements.

There is a relatively limited recent literature on satellite detection of gas flaring [4–8]. There is a somewhat wider literature looking at the air pollution and emission impacts of flaring [9–17]. And a further set of research focuses on alternatives to flaring [18–23]. NOAA's Earth Observation Group operates the only global satellite remote sensing program focused on gas flaring [2]. EOG produces global flare detection data on 24 h increments using nighttime data collected by the Visible Infrared Imaging Radiometer Suite (VIIRS) data. This is the VIIRS Nightfire (VNF) product [24], which was recently used to conclude that Islamic State oil production levels have been substantially lower than previously reported [25]. EOG distills full years of VNF data to estimate flared gas volumes for individual flaring sites [2].

In this paper, we compare 2015 VIIRS-derived gas flaring estimates with the submitted NDC greenhouse gas reduction targets. The analysis is conducted for three types of flaring: upstream in oil/gas production, downstream at oil/gas processing and refineries, and industrial. The industrial category is defined as natural gas flaring detected outside of the upstream and downstream sets, including flaring at coal mines, landfills, water treatment plants, and ephemeral flaring in oil exploration areas. The results indicate the potential role of gas flaring reduction in meeting country-specific targets. Section 2 describes the methods employed to source the data. Section 3 presents results. Section 4 discusses elements of those results, and Section 5 concludes.

2. Methods

In this study, we use gas flaring estimates from 2015 derived from data collected by the U.S National Oceanic and Atmospheric Administration's (NOAA) Visible Infrared Imaging Radiometer Suite (VIIRS). The satellite collects both global daytime and nighttime data at near 1 km^2 resolution every 24 h. Nighttime VIIRS data are particularly well suited for detecting and measuring the radiant emissions from natural gas flares due to the collection of shortwave infrared (1.61 μm) data at night. This wavelength coincides with peak radiant emissions from gas flares and lies in one of the clearest atmospheric windows worldwide, ensuring a high degree of transmission from the flare to the satellite. Temperature, source size and radiant heat are calculated using physical laws [24]. Gas flares can be separated from other IR emitters based on temperature and persistence. Biomass burning and non-flaring industrial sites have temperatures in the 600–1500 K range in VIIRS Nightfire (VNF) data. Flares have temperatures ranging from 1300 to 2200 K. If temperature ever exceeded 1600 K the site is labeled as a gas flare. If a site falls in the flaring temperature range and has two or more detections per year it is also deemed to be a gas flare. This persistence test filters out biomass burning, which can reach into the low temperature range of gas flares.

Flares were divided into three categories. Upstream sites were defined as flaring sites in or near oil and gas fieldmaps from the Peace Research Institute Oslo (PRIO) [26]. Downstream flaring was labeled primarily based on refinery and gas processing sites listed by the Oil and Gas Journal for 2015 [27]. The remaining operational flaring sites were provisionally assigned to the industrial category, which includes gas flares at coal mines, landfills, water treatment facilities and other industrial sites. This labeling was confirmed through visual assessment of the high spatial resolution google earth images (Fig. 1). The labels for the initial set of sites in the industrial category were modified and finalized based on this visual inspection. The 2015 analysis identified 13,605 flaring sites worldwide, with 12,227 upstream sites, 861 downstream sites and 517 industrial sites.

A calibration has been developed for estimating flared gas volumes in terms of methane equivalents [2] based on national level estimates of flared gas volumes from Cedigaz [28]. The conversion factor is derived assuming all flares have combustion efficiency of 100%. Therefore, all carbon atoms in a methane (CH_4) molecule are converted to CO_2 molecule. Under standard environment, which is 1 atm and 25° Celsius (298 K), 1 BCM of CH_4 gas is converted to 1800.62 kilotons (kt) of CO_2 molecules. These estimates are listed as CO_2 emission equivalents, the same reporting units as the NDC targets.

NDC greenhouse gas emission targets were extracted from the summaries extracted from two sources: the World Resources Institute CAIT Climate Data Explorer [29] and the World Bank's Nationally Determined Contributions (NDCs) web site [30].[1] The NDCs indicate both unconditional and conditional greenhouse gas emission reduction targets in terms of a percentage relative to a year in the past or a business-as-usual projection for a future year. If the NDC listed the reference quantity, this number was used in our analysis. If the NDC did not list the reference quantity, the analysis is based on greenhouse gas emission quantities from EDGAR (Emission Database for Global Atmospheric Research) [31]. In either case, the target percentage was multiplied by the reference quantity to yield the target reduction quantity in kilotons of CO_2e. We are then able to compare the 2015 flaring versus the target reduction quantities. This was performed for both the unconditional NDC targets and the total (unconditional plus conditional) targets. For countries with flaring that do not have NDC targets, we performed an analysis of flaring versus total greenhouse gas emissions.

[1] Note that the CAIT and World Bank NDC data sets are now in a combined NDC Partnership tool: Climate Watch on: https://www.climatewatchdata.org/.

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