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Life cycle greenhouse gas emissions from Barnett Shale gas used to generate electricity

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ABSTRACT

This paper presents research findings on life cycle greenhouse gas (GHG) emissions associated with natural gas production in the Barnett Shale play in Texas. The data sources and approach used in this study differ significantly from previous efforts. The authors used inventories from the year 2009 tracking emissions of regulated air pollutants by the natural gas industry in the Barnett Shale play. These inventories were collected and screened by the Texas Commission on Environmental Quality (TCEQ). These data cover the characteristics and volatile organic compound (VOC) emissions of more than 16,000 individual sources in shale gas production and processing. Translating estimated emissions of VOCs into estimates of methane and carbon dioxide emissions was accomplished through the novel compilation of spatially heterogeneous gas composition analyses. Life cycle greenhouse gas emissions associated with electricity generated from Barnett Shale gas extracted in 2009 were found to be very similar to conventional natural gas and less than half those of coal-fired electricity generation.

Introduction

According to the latest U.S. Greenhouse Gas (GHG) Emissions Inventory (EPA, 2013), the natural gas industry[4] represents nearly a quarter of total methane emissions in the United States in 2011, the largest single category, and is also the fourth largest contributor of CO_2 emissions. The United States Environmental Protection Agency (EPA), which produces the U.S. GHG inventory, has significantly changed its estimate of GHG emissions from natural gas systems since the 2008 reporting year. These changes result from alterations to methods more than changes in natural gas sector activity. For any change in method, the EPA adjusts estimates of GHG emissions from all years (i.e., backcasts the changes). For instance, for the calendar year 2008, the inventory published in 2011 more than doubled their estimates of year 2008 emissions, whereas the inventory published in 2013 decreased 2008 emissions by approximately 25% (EPA, 2010, 2011a, 2012a, 2013). EPA acknowledges what is well understood: the estimates of GHG emissions from the natural gas sector are highly uncertain, with a critical lack of empirical data to support GHG emission assessments (EPA, 2011b). This uncertainty is especially acute for production of unconventional gas resources. Data gathering to support re-assessment of the EPA's U.S. GHG inventory and potential regulations is underway.

An emerging body of scientific literature, described below, has attempted to estimate GHG emissions from unconventional natural gas production, based on the limited available information. Measurement of GHGs in the atmosphere, if they could be reliably attributed to specific sources, would be an ideal methodological approach. However, such measurements are expensive, attribution is challenging, and the few existing studies (e.g., Petron et al., 2012) have assessed few locations at specific times such that an understanding of systemwide emissions is still lacking. The state of the practice employs engineering-based estimation methods, based on as much empirical information as is possible to assemble. Much of this emerging literature is guided by the methods of life cycle assessment (LCA), which in this context aim to estimate all GHG emissions attributable to natural gas used for a particular function: electricity, transportation, or primary energy content (e.g., heat). Attributable emissions are those from any activity in the process chain of producing the natural gas—from exploration and well pad preparation to drilling and completion—processing it to pipeline quality, transporting it to the location of end use, and combus-

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4 For purposes of the GHG inventory, the natural gas industry includes exploration, production, processing, transmission, storage, and distribution of natural gas to the end user (EPA, 2011b).

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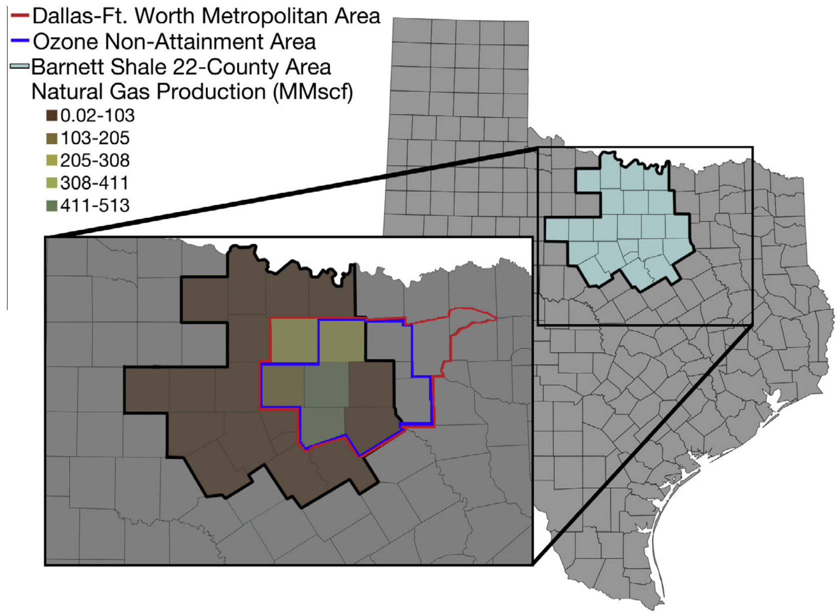

Fig. 1. Counties with non-zero gas production from the Barnett Shale formation in 2009, and other demarcations of the Barnett Shale area in Texas (based on data from the Texas Railroad Commission (TRRC) (2012)).

tion. In addition, the construction, operation and maintenance, and end-of-life decommissioning of the end use technology are also considered.

LCAs are typically performed to compare the results of one system to another.[5] The focus of this article is to advance understanding of life cycle GHG emissions from the production and use of shale gas in the context of use by the electric power sector as compared to generation of electricity from conventionally produced natural gas.[6] Natural gas once processed for pipeline transmission is a homogenous product, undifferentiated by source. End-use combustion of the natural gas has, by far, the largest contribution to life cycle GHG emissions (as is true for any fossil-fueled combustion technology); but is not a point of differentiation between conventional and unconventional natural gas. Therefore, this study focuses on the activities associated with production of natural gas because they are the points of potential differentiation between unconventional and conventional natural gas.

We additionally focus on emissions from natural gas processing, given current regulatory and scientific attention to emissions from the natural gas industry and opportunity provided by the unique data sources employed in this study. Furthermore, we rely on the multitude of previously published LCAs of conventionally produced natural gas, updated for recent changes in understanding (EPA, 2011b, 2012b, 2013) and harmonized to obtain methodological consistency, as reported in O'Donoughue et al. (2014), for comparison to the results of this study. We also compare our results to those for coal-fired electricity generation based on a systematic review and harmonization of that LCA literature, because coal has been the largest source for electricity in the United States over the last 50-plus years (Whitaker et al., 2012 and its corrigendum).

Prior research comparing life cycle GHG emissions of electricity generated from shale gas to conventional gas has been inconclusive and remains highly uncertain. Both the magnitude and direction of difference reported in these publications vary (Howarth et al., 2011; Burnham et al., 2012; Jiang et al., 2011; Skone et al., 2011; Stephenson et al., 2011; Hultman et al., 2011). These differences occur despite their reliance on very similar data sources (mostly EPA's GHG emission inventory and supporting documentation). The present study addresses some of the weaknesses of previous LCAs in terms of lack of empirical data on which to base emissions estimates.

Methods and data

We present results from a new method of estimating life cycle GHG emissions from shale gas that takes advantage of unusually detailed and rarely produced empirical data specific to a shale gas play and year. Broadly, we use the methods of air quality engineering, life cycle assessment, and energy analysis to estimate GHG emissions attributable to the generation of electricity from shale gas produced from the Barnett Shale play in Texas in 2009, the latest year with available data. There are several unique aspects of this research as compared to previous natural gas life cycle assessments:

1. Highly resolved estimates of GHG emissions from shale gas production and processing developed at site (facility) and source (equipment and practices) levels.
2. Use of industry-supplied and regulator quality-assured data regarding equipment, practices, and emissions developed with very high operator participation rates.
3. Development of a geospatial database of county-level, extended gas composition analyses of produced (raw) gas demonstrating wide variability of methane and VOC content within the Barnett Shale formation.

It is critical to note that the new results reported here are not necessarily applicable to other plays or years. However, they are discussed in the context of other published literature, where the broad outlines of consistency found within this literature increases

[5] For interested readers, many texts describe LCA principles and methods, such as Horne et al. (2009) and Vigon et al. (1993).

[6] Defined as any non-stimulated well. This article follows EPA (2011b) in recognizing "that not all unconventional wells involve hydraulic fracturing, but some conventional wells are hydraulically fractured, which is assumed to balance the over-estimate."