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US liquefied natural gas (LNG) exports: Boom or bust for the global climate?

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Highlights

- US LNG exports could have large GHG impacts.
- Positive or negative depending on replacement scenarios.
- Domestic and international market impacts critical.

Abstract

Due to surging natural gas production, the United States is now a growing exporter of liquefied natural gas (LNG) to overseas destinations. However, the potential greenhouse gas implications from increased US natural gas remain unclear. Through a hybrid lifecycle energy strategy analysis, we investigate potential greenhouse gas scenarios of US LNG exports to Asia, the largest source of global LNG demand. We find that the climate impacts of US exports to China, Japan, India, and South Korea could vary tremendously. Annual global lifecycle emissions range from−32 to+63 million metric tons CO_2e per billion cubic feet (Bcf) per day of exports. Despite this range, emissions are not likely to decrease and may increase significantly due to greater global energy consumption, higher emissions in the US, and methane leakage. However, international climate obligations are a critical uncertainty underlying all emissions estimates. Our results indicate the need for further research into quantifying the climate impacts of LNG exports, and energy exports more generally.

Introduction

Natural gas production in the United States has increased significantly in the last decade due to the shale revolution [1]. Originally faced with the prospect of having to import massive amounts of liquefied natural gas, the US is now becoming a large net exporter. Dry natural gas production increased by more than 35% since 2006 and is projected to grow further through 2020 [2]. Natural gas prices have fallen significantly, with major economic and emissions benefits domestically [3].

The shale revolution is now on the verge of rippling across the world. Rapidly increasing domestic natural gas production in the United States is leading to mounting pressure from industry and legislators to export domestic natural gas to other countries. The Department of Energy (DOE) has received applications for projects with a cumulative natural gas export capacity of more than 40 Bcf/day for permission to construct facilities to liquefy natural gas for export to countries without Free Trade agreements [4]. Exports from the first of these terminals recently began, with more under construction or under regulatory consideration.

Recently, many studies investigated the environmental implications of the domestic natural gas boom in the US, which has largely replaced coal for electricity generation. Natural gas is methane, which is itself a powerful greenhouse gas. Natural gas can leak out of its infrastructure and into the atmosphere during normal production and transportation operations, leading to greenhouse gas emissions greater than combusting the natural gas. Accordingly, despite having lower combustion emissions than coal, Howarth argued that leakage of natural gas undermined the lifecycle greenhouse gas advantages of natural gas [5]. Subsequent research found that while methane leakage may be higher than official inventories, natural gas remains better than coal for electricity generation for domestic uses [6], [7], [8], [9]. This is due to the relative efficiency of the US natural gas fleet, relative inefficiency of the coal fleet, coal mine leakage, and because natural gas has replaced primarily coal instead of other fuel sources [9].

However, relatively few studies have examined the global greenhouse gas implications of expanded US LNG exports. To date, the DOE and the Federal Energy Regulation Commission (FERC), the federal agencies responsible for approving LNG export projects, have not comprehensively examined the impacts of export approvals on global greenhouse gas emissions. The only study conducted by DOE thus far was limited to examining the replacement of coal with natural gas for electricity generation, had key methodological shortcomings, and did not account for several aggravating factors [10].

A similar study by Abrahams et al. was more comprehensive, including a first order consequential lifecycle analysis, which is better able to capture replacement effects. Nevertheless, this study also only examined, natural gas replacing coal, did not fully examine domestic and international markets impacts, and did not analyze how energy strategies of importing countries could affect emissions from LNG [11].

This lack of inquiry into emissions and LNG is unfortunate, as the energy and carbon intensity of its conversion could be significant. The liquefaction and transportation processes are very energy intensive, as are the end uses (and displaced uses) of exported LNG.

Critically, the emissions impacts of expanded LNG exports can be difficult to determine because they impact activities in two or more country's energy markets: the exporter and the importer. Accordingly, analyses that look narrowly at only one replacement scenario (i.e. coal to LNG) are incomplete looks of global market effects.

This study more accurately and comprehensively assesses the greenhouse gas emissions of US LNG exports by developing a bounded hybrid lifecycle – energy strategy analysis. This new approach combines lifecycle emissions uniquely normalized to an export metric with an analysis of domestic and international energy markets. By investigating four of the largest LNG importers in 2013 (China, Japan, India, and South Korea), we identify eleven potential uses of US LNG in Asia, the most likely destination. Through developing individual lifecycle emissions for these uses, we bound potential changes in greenhouse gas emissions per 1 Bcf/day of exports. Further, this study measures how methane leakage, export-driven changes in domestic emissions, and energy demand growth affect global greenhouse gas emissions from exports. Integrating analysis of key energy concerns in each country with lifecycle profiles of individual technologies more fully captures the dynamics at play in international fuel switching scenarios.

Section snippets

Identifying the potential uses of exported LNG in Asian countries

The countries that are likely to import LNG from the United States face energy challenges that are somewhat distinct from those in the United States and Europe. The nuclear accidents at Fukushima generally soured public opinion on nuclear power in Asia, leading to calls to permanently close existing nuclear reactors and stop construction of new ones [12], [13], [14], [15]. As such, heavy dependence on imported fossil fuels in Japan and South Korea create significant energy security concerns. In …

Normalizing emissions and selecting end-uses

Two central tenants underlie the technology portion of our hybrid lifecycle – energy strategy analysis: emissions normalization and the breadth of technologies examined.

First, normalization is necessary because the cumulative global climate impact of US LNG exports will depend on the magnitude of exports and how LNG is used. However, decision making for LNG exports is currently made on a project-by-project basis. This paper normalizes the potential positive or negative lifecycle emissions from…

Calculating normalized lifecycle emissions changes from LNG

In the United States, recent studies have found that natural gas infrastructure leaks more methane than previously estimated by the US Environmental Protection Agency (EPA) [5], [6]. As methane is a more potent greenhouse gas than carbon dioxide, methane leakage potentially undermines the climate benefits of coal to natural gas fuel switching domestically and abroad. Despite increased scrutiny, substantial uncertainty remains as to the amount of methane that is leaking. To test the impacts of…

The aggravating factors: lost displacement and additionality

On a bounded technological LCA basis, our results indicate a spectrum of potential global net emissions outcomes of exporting LNG. However, the actual impacts are going to depend on natural gas impacts domestic and international energy markets. In domestic markets, LNG exports could lead to higher natural gas prices decreasing total natural gas consumption in the United States. In international markets, primarily the countries in this study, LNG exports could lower LNG prices and lead to…

Conclusion and policy implications

Our hybrid lifecycle-energy strategy analysis, based on both emissions estimates and likely market effects, indicates that exporting LNG is likely to increase global greenhouse gas emissions. While uncertainty remains, methane leakage, additional energy demand, and decreased domestic coal displacement have the very real potential to undermine any prospective climate benefit in the long term. LNG exports lead to increased short-term climate emissions in most scenarios. Only with favorable…

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Why are methane emissions from China's oil & natural gas systems still unclear? A review of current bottom-up inventories

2022, Science of the Total Environment

> *Citation Excerpt :*
> …Referring to the processing segment, Chen et al. (2017) provided the smallest EFs through the measurements of separator, desulfurizing and compressor. For the transmission and storage segment, except for natural gas pipelines, LNG stations and transmissions should also be included, as LNG facilities were massive in China (Gilbert and Sovacool, 2017). Höglund-Isaksson (2017) adopted throughput-based EFs for transmission from literature.…

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…Another concern is due to methane leakage associated with both natural gas international trade and domestic usage. Based on a hybrid lifecycle energy strategy analysis, Gilbert and Sovacool (2017) argue that global greenhouse gas (GHG) emissions are expected to increase due to rising energy demand and methane leakage. Excess dependence on natural gas may delay the energy transition to a low-carbon economy.…

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2019, Energy

Citation Excerpt :

…Furthermore, the regasification of LNG, that results in large amounts of energy being generated, has led to the development of new technologies and processes to exploit available cold energy [11–15]. Nevertheless there remain some concerns about the environmental impact of such a large increase in LNG trading [16]. LNG is industrially stored in highly insulated tanks at cryogenic temperatures below −160 °C, which corresponds to the LNG boiling point at the operating pressure.…

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Energy demand of liquefaction and regasification of natural gas and the potential of LNG for operative thermal energy storage

2019, Renewable and Sustainable Energy Reviews

Citation Excerpt :

…Ulvestad and Overland [29] state that a single LNG facility became the fourth major producer of greenhouse gases in Norway. Gilbert and Sovacool [44] analysed the climate impact exporting LNG from the USA to Asia. Methane - the main component of NG - is a powerful greenhouse gas.…

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