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A lot left over: Reducing CO_2 emissions in the United States' electric power sector through the use of natural gas

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HIGHLIGHTS

- Utilizing recently built natural gas fired power plants can significantly reduce CO_2 emissions in the United States.
- CO_2 emissions from electricity production can be reduced by 23–42 percent.
- U.S. overall CO_2 emissions reduced by 9–17 percent.

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ABSTRACT

As the leading contributor of greenhouse gas emissions, the electricity sector stands to be impacted by policies seeking to curtail emissions. Instead of increasing electricity from renewable resources or nuclear power facilities, an alternative approach to reducing emissions in the electric power sector is changing the dispatch order of fossil fuels. Important differences between fossil fuels, and in the technologies used to burn them, make it possible to substantially reduce emissions from the sector. On average, each gigawatt-year of electricity generation switched from coal to natural gas reduces CO_2 emissions by 59 percent. As a result of significant investments in natural gas fired power plants in the United States between 1998 and 2005, there is an opportunity for electricity producers to take advantage of underutilized capacity. This is the first study to closely examine the new capital additions and analyze the technical potential for reductions in emissions. The analysis finds that 188 GW of capacity may be available to replace coal-fired baseload electricity generation. Utilizing this excess gas-fired capacity will reduce the sector's CO_2 emissions by 23 to 42 percent and reduce overall U.S. CO_2 emissions between 9 percent and 17 percent.

1. Introduction

Emissions of greenhouse gases (GHG), particularly those from anthropogenic sources, will need to be curtailed in order to mitigate the impacts of climate change.[1] In the United States, carbon dioxide (CO_2) is the most prevalent source of GHG emissions from human activities, with gross emissions[2] accounting for 83 percent of overall GHG emissions in 2009 (Fig. 1). Historically, CO_2 has been the fastest growing source of GHG emissions, expanding over 20 percent between 1990 and 2007[3] before falling 10 percent between 2007 and 2009.[4] The net result is that CO_2 emissions increased by 8 percent between 1990 and 2009. Fossil fuel combustion is the primary source of anthropogenic CO_2 emissions, contributing over 94 percent of U.S. emissions in 2009.[5]

Of particular importance when addressing emissions of CO_2 in the U.S. is the electric power sector. Due to the sector's reliance on fossil fuels, the production of electricity is the nation's leading source of CO_2 emissions. In 2009, about 2100 million metric tonnes (Mt) of CO_2 stemmed from the generation of electricity, accounting for 39 percent of overall CO_2 emissions and 42 percent of emissions from fossil fuel combustion in the U.S.[6] (Fig. 2). Thus, the sector will have to play a key role if CO_2 emissions in the U.S. are to be significantly curtailed.

As a result of important differences in fossil fuels and in the technologies used to burn them, significant reductions in CO_2

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[1] Intergovernmental Panel on Climate Change (IPCC) (2007).

[2] Gross emissions of CO_2 do not account for carbon sinks. In 2009, land use, land change, and forestry resulted in 1015 Mt of CO_2 sinks, resulting in net CO_2 emissions in the U.S. of 4490 Mt.

[3] In 2009, approximately 5500 Mt of CO_2 were emitted in the United States, which was approximately 20 percent of global emissions of CO_2.

[4] The recent decline in CO_2 emissions can be attributed to reduced fossil fuel use due to the U.S. economic downturn and the substitution of less carbon intense natural gas for coal resulting from sustained low natural gas prices. This second factor supports the plausibility of the findings in this analysis.

[5] EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2009 (2011). Remaining anthropogenic emissions of CO_2 include iron production, steel production, cement production, and incineration of waste.

[6] ibid.

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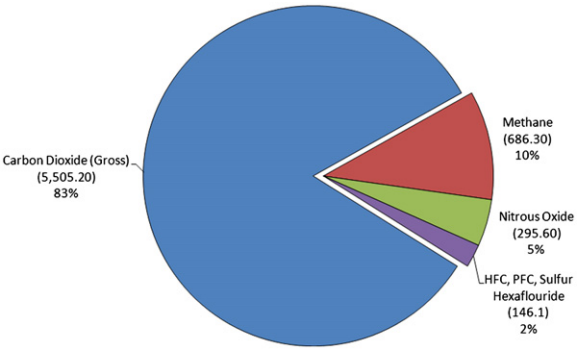

Fig. 1. U.S. greenhouse gas emissions (Million metric tonnes (Mt) CO_2 equivalent) by gas, 2009.

emissions from the electric power sector can be attained through fuel substitution, changing the dispatch order of fossil fuels. Carried out on a large scale, shifting the industry's fuel mix away from coal and towards natural gas has the potential to drastically reduce emissions. One major obstacle to fuel switching is the availability of natural gas generating capacity. However, substantial investments by electric utilities in natural gas fueled generating capacity between 1998 and 2005 allow for the possibility for fuel switching to be carried out very quickly.

A small group of studies examines the potential for emissions cuts that can result from fuel substitution.[7] Sims et al. (2003) use OECD survey data to estimate potential mitigation from the global electricity sector possible from fuel switching, carbon sequestration and storage, and increased use of renewables by 2010 and 2020. Using IEA projections of world electricity generation from capital installed by 2010, they estimate that there is a 15 percent reduction in global emissions of CO_2 that can be achieved by 2020 from all fuel sources. Delarue and D'Haeseleer (2008) and Delarue et al. (2008) investigate the possibility for emissions reductions that would result from substituting gas for coal in several Western European countries under the European Union Emission Trading Scheme. Using a simulation model that considers marginal production costs and the current capital stock in the selected countries, they find that GHG reductions could be as high as 19 percent relative to the reference scenario (price of 0 for European Union Allowance) beginning in 2005.

This study extends the literature by considering the additions of natural gas fired capital in the U.S. electric power sector and presenting a first look at the technical capability of the U.S. electricity sector to cut CO_2 emissions through fuel substitution. Using aggregate level capacity and generation data from the Energy Information Administration (EIA), this paper quantifies the CO_2 reductions that could be achieved by the sector in the short term through altering the use of existing capital. The paper is organized as follows. Section 2 provides an overview of the electricity sector in the U.S., Section 3 illustrates the emissions advantages to using natural gas in place of coal. Section 4 provides estimates of potential emissions reductions. Section 5 concludes.

[7] Fuel substitution in the electric power sector has been an area of interest for researchers in the past. Atkinson and Halvorsen (1976), Joskow and Mishkin (1977), Griffin (1977), Bopp and Costello (1990), and Ko and Bopp (2001) all examine how responsive the choice of fuels by electric utilities is to price changes and provide estimates of interfuel substitutability. While some of these papers discuss the significance of fossil fuel use as it relates to emissions by power plants, none of these studies explicitly considers the potential for emissions reductions by the industry.

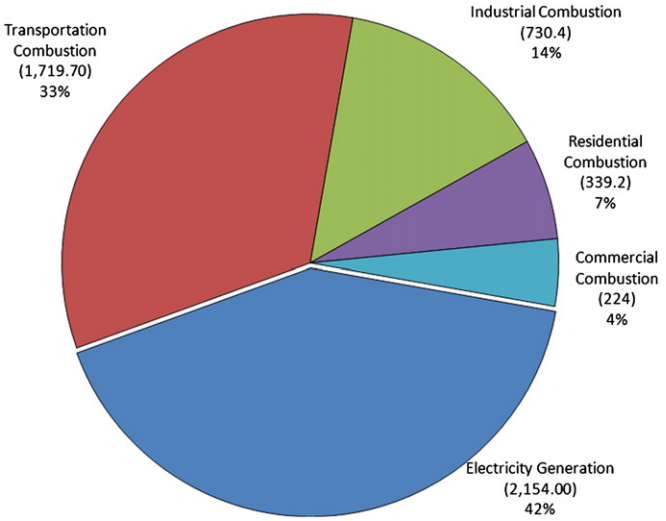

Fig. 2. Sources of U.S. carbon dioxide emissions (Mt) from fossil fuels, 2009.

2. The U.S. electricity sector

2.1. Electricity generation

Electricity generation from the electric power sector in the United States increased nearly 14 fold over the post-war era[8] (Fig. 3). In 2009, about 435 gigawatt years (GW yr) of electricity was produced, compared to slightly less than 33 GW yr in 1949. Per capita generation also grew dramatically over the period, from 2000 kW h per person in 1949 to almost 14,000 kW h per person in 2009. Fossil fuels are currently, and have been historically, the primary input used to generate electricity in the U.S. The predominant fossil fuels used include coal, natural gas, and petroleum. Coal is the leading fossil fuel, and its importance in electricity generation has remained relatively constant over time. In more recent years, most of the electricity generated using petroleum has been replaced with natural gas. In 1949, 68 percent of electricity was generated using fossil fuels, while 32 percent was non-fossil (primarily hydro). Coal was used to generate 46 percent of total electricity, natural gas accounted for 12 percent, and petroleum for 10 percent in 1949.

Fossil fuel use, as a share of the electricity generating mix, peaked from the late 1950s through the mid 1970s at around 80 percent, and declined after nuclear power entered the mix.

In 2009, fossil fuels were used to generate 69 percent of the electricity in the U.S., with 46 percent, 22 percent, and 1 percent of electricity generated from coal, natural gas, and petroleum, respectively (Fig. 4). Nuclear (21 percent) or renewable energy sources (10 percent) were the key inputs used to produce the remaining electricity.

2.2. Infrastructure

Despite the relative stability in the mix of fuels used to produce electricity, there have been significant changes in the composition of the capital stock in the electric power sector, particularly with respect to the relative share of natural gas fired

[8] The primary sources of data for this analysis is the Electric Power Annual and Annual Energy Review published by the Energy Information Administration. The annual data represents the industry over the period from 1949 to 2009 and includes all major classifications of electricity generating capital and fuels (coal, natural gas, petroleum, nuclear, and renewables).