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Exploring the impact of energy efficiency as a carbon mitigation strategy in the U.S.

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ABSTRACT

As temperatures across the globe hit record highs and extreme climate events multiply, interest in least-cost CO_2 mitigation pathways is growing. This paper examines the pros and cons of strengthening demand-side options in strategies to reduce carbon emissions from the U.S. electricity sector. To date, demand-side management in the U.S. power sector has received overly simplistic treatment in energy models. To help fill this gap, we develop a customized version of the National Energy Modeling System to assess a range of demand- and supply-side policy scenarios. This enables four research hypotheses to be tested, related to mitigation costs, investment in new natural gas plants, carbon leakage, and local air pollution.

We conclude that the clean power transformation can be made more affordable by improving the efficiency of energy utilization. By downscaling the expansion of natural gas plants, energy efficiency can also avoid legacy impacts. While strong energy-efficiency policies lower overall CO_2 emissions, coal plant retirements can be delayed, postponing associated local air quality benefits. Thus, we illustrate a limitation of single-pollutant policies while also demonstrating the value of co-optimizing demand- and supply-side carbon mitigation options.

1. Introduction

The U.S. electricity sector is in a period of unprecedented change. Natural gas is now generating as much electricity as coal, wind and solar systems are generating as much electricity as hydropower, and energy efficiency is moderating the demand for electricity (US EIA, 2016). As a result, carbon pollution from electricity generation in the U.S. has declined in recent years while the economy has continued to grow. While historic in magnitude, it is unclear that this pace of change can be sustained and ultimately accelerated to achieve the ambitious mid-century climate mitigation goals of the Paris Agreement, to “prevent dangerous anthropogenic interference with the climate system” as specified by the United Nations Framework Convention on Climate Change. Feng et al. (2015) documents that the CO_2 emission reductions between 2007 and 2013, were largely a result of economic recession with changes in fuel mex playing a relatively minor role. The U.S. Energy Information Administration (US EIA, 2015a) estimates that as the U.S. economy expands, its CO_2 emissions will exceed 2012 levels by 7% in 2030 and by 8% in 2040.

This paper examines the role that energy efficiency could play as a U.S. carbon mitigation strategy. We accomplish this by characterizing strong demand-side policies that are then competed against supply-side options using least-cost energy modeling. This approach expands the comprehensiveness of mitigation modeling by assessing both demand- and supply-side options in the U.S., in contrast to the cursory and simplified analysis that energy efficiency has typically received to date.

Section 2 describes the shortcomings that have pervaded the modeling of energy efficiency as a demand-side option in carbon mitigation pathways. Section 3 then presents four hypotheses about the potential impacts of strong energy-efficiency options, that we subsequently test. These relate to compliance costs, investments in new natural gas plants, carbon leakage, and local air pollution. Section 4 describes our research methodology and provides an overview of the modeling tool used to test our hypotheses. Results are presented in Section 5, and the paper ends with conclusions and a discussion of policy implications in Section 6.

2. A gap in the literature: shortcomings in prior modeling of energy efficiency

Over the past several years, energy efficiency has been inadequately assessed in models of U.S. mitigation pathways, relative to the treatment of supply-side compliance options. There are at least three reasons for this.

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First, much of the recent modeling of mitigation pathways has focused on ways to meet the requirements of the U.S. Environmental Protection Agency (EPA)'s Clean Power Plan (CPP), which aimed to accelerate the current pace of electricity decarbonization by cutting CO_2 emissions from the electric sector 32% below 2005 levels by 2030 (US EPA, 2015). After issuing proposed rules in 2014, EPA issued final guidelines limiting CO_2 emissions from existing fossil-fueled electric generating units (EGUs) in 2015.[1] Energy efficiency was a building block in EPA's calculation of state-specific CO_2 caps in the proposed rule, but it was removed from the calculation of limits in the final rule, while remaining an eligible compliance option. This complicated treatment created misunderstandings among analysts and policy-makers, some of whom erroneously assumed that end-use energy efficiency was no longer an eligible compliance mechanism (Bushnell, et al., 2017).

Second, stakeholders raised concerns that energy-efficiency carbon allowances and emission rate credits might be difficult to qualify in trading systems because of rigorous monitoring and verification requirements. While energy efficiency as a CO_2 compliance strategy is well honed in some regions where cap and trade systems have operated, other regions have limited experience with it (Chesney, et al., 2016).

Third, most least-cost utility modeling tools are not able to adequately represent energy efficiency. As a result, some studies have ignored energy efficiency entirely when examining CO_2 mitigation options (Peters and Hertel, 2016). Others simply assume an exogenous reduction of energy demand, associated with a step-curve of costs possessing little granularity. Such short cuts are necessary when modeling platforms do not compete energy supply and demand resource options, as is the case with the Integrated Planning Model (IPM) used by EPA (2015a), Bradley et al. (2016), and the Bipartisan Policy Center (BPC, 2016), the Haiku model used by Resources for the Future RFF (2016), US-REGEN used by the Electric Power Research Institute, EPRI (2016), FACETS-ELC used by Wright and Kunudia (2016), and the MARket ALlocation (MARKAL) model used by Shearer et al. (2014). While the IPM used by EPA borrows forecasts of peak load and regional electricity consumption from the EIA's National Energy Modeling System (NEMS), the IPM possesses none of the detailed level of demand-side energy modeling offered by NEMS. After applying an exogenous electricity load forecast, the power sector and its fuel supplies are then modeled. For example, EPA's Regulatory Impact Analysis (RIA) externally imposes state estimates of energy efficiency as load reductions, assuming that the first 0.5% increment of energy efficiency would cost $1100/MWh (in $2011) decreasing to a cost of $660/MWh for an increment of 1% (EPA, 2015b, Table 27). BPC (2016) and RFF (2016) assume that the supply of incremental energy efficiency is half the rate of the EPA's RIA. BPC (2016) uses a 3-step cost curve ranging from $230 to $320/MWh,[2] while RFF (2016) assumes a single undiscounted lifetime cost of $400/MWh.

By treating energy efficiency as an exogenous resource, models cannot reflect interactions such as when supply-side investments elevate electricity prices and make demand-side management more economically attractive. Superior modeling approaches are needed, with highly articulated specifications of end-use technologies embedded in a least-cost optimization algorithm that allows demand- and supply-side energy resources to compete head-to-head.

3. Development of hypotheses

Given the shortcomings of prior least-cost mitigation scenario modeling, it becomes clear that improved modeling could exposit new knowledge about the role of energy efficiency. To structure our inquiry and refine expectations, we propose four research hypotheses.

Hypothesis 1 derives from the large body of literature documenting the low levelized cost of saving electricity (Brown and Wang, 2015). Thus, it postulates that strong energy-efficiency policies would make CO_2 mitigation more affordable. Energy efficiency is seen as the least-cost energy resource with the potential to dominate as a bridge between the Paris Accord and the deeper CO_2 cuts needed to achieve a 2 °C maximum threshold for global warming (IEA, 2016). So why aren't most U.S. utilities taking advantage of this opportunity? In addition to the fact that energy prices do not fully reflect the cost of significant negative externalities such as climate change (National Research Council, 2009), many utilities are still locked into conventional business models with throughput incentives that favor resource expansion over energy efficiency. Policymakers tend to correlate expansion of supply-side resources with economic and employment growth, and utilities focus on expanding generation and transmission resources so that systems are not caught short. Energy efficiency, on the other hand, is seen as a customer service and in standard U.S. utility accounting practice it is categorized as an "operations and maintenance expense." Analysts increasingly argue that utilities should use least-cost resource planning that considers demand- and supply-side options in a single integrated approach (Brown and Wang, 2015, 2017).

The second hypothesis derives from historical experience documenting how energy-efficiency policies and programs influence the nation's electricity fuel mix by curtailing the construction of new generating units that would otherwise be required to meet a more rapidly growing demand. Since natural gas combined cycle (NGCC) plants are the least-cost source of new generation (National Academies, 2016), Hypothesis 2 postulates that strong energy-efficiency policies would reduce the magnitude of natural gas plant investments and capacity expansions. This hypothesis is critical for several reasons. First, the benefits of natural gas over coal could be mitigated by its potential to delay the adoption of near-zero carbon technologies such as renewables (Hausfather, 2015). Second, evidence suggests that without carbon capture and storage, natural gas power plants could thwart the achievement of deep CO_2 emission reductions. With system-wide U.S. fugitive methane emissions of 2–4% of natural gas production or more (Brandt et al., 2014), gas plants could produce greater near-term warming potential than similarly sized coal plants (Zhang et al., 2014).

Hypothesis 3 addresses carbon leakage – the shift of emissions within a state from covered to uncovered fossil generators. Leakage is motivated when compliance designs cause existing steam units and NGCC plants to face compliance costs that new NGCC plants do not, as is the case when mitigation focuses on existing units. Rather than curbing emissions by exploiting low-carbon resources such as renewables, nuclear and energy efficiency, electricity generation may be dispatched less from existing fossil plants and more from new natural gas units (Litz and Murray, 2016). Since strong energy-efficiency policies curb demand growth and the need for new NGCC plants, Hypothesis 3 postulates that they would mitigate carbon leakage.

Hypothesis 4 postulates that strong energy-efficiency policies would reduce the emission of local air pollutants such as SO_2, NOx, and mercury. Utilizing energy efficiency in pathways of compliance with CO_2 caps is expected to deliver greater pollution abatement because energy efficiency is one of the cleanest forms of meeting energy service requirements.

4. Methodology

To fill the gap in the literature described in Section 2, we evaluate mitigation pathways using the Georgia Tech version of NEMS. GT-NEMS has a highly articulated representation of end-use technologies

[1] 40 CFR Part 60 "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units" (80 Fed. Reg. 64662, Oct. 23, 2015).

[2] 2.3–3.2 cents/KWh represents only 55% of the total resource cost of energy-efficiency investments, assumed to be the utility portion of ratepayer funded EE; the assumed total resource cost is 4.2–5.8 cents/KWh.