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Ensuring benefits from North American shale gas development: Towards a research agenda

M. Bazilian [c,e,*], A.R. Brandt [a], L. Billman [b], G. Heath [b], J. Logan [b], M. Mann [b], M. Melaina [b], P. Statwick [c], D. Arent [c], S.M. Benson [a,d]

[a] Department of Energy Resources Engineering, Stanford University, CA, USA
[b] National Renewable Energy Laboratory (NREL), CO, USA
[c] Joint Institute for Strategic Energy Analysis (JISEA), CO, USA
[d] Global Climate and Energy Project (GCEP), and Precourt Institute for Energy (PIE), Stanford University, CA, USA
[e] Columbia University, NY, USA

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ABSTRACT

The North American shale gas "revolution" provides tremendous opportunities, but our scientific understanding of this transition and its potential near- and long-term social, economic, and environmental impacts lags behind the rapid pace of change. Investors, policy makers, and other stakeholders need greater clarity to make robust decisions in today's dynamic natural gas sector. A comprehensive, interdisciplinary research agenda can help inform these decisions.

This short paper discusses elements of a long-term interdisciplinary research effort that is required to ensure social, economic, and environmental benefits of the North American unconventional natural gas "revolution." Natural gas produced from hydraulic fracturing of gas-bearing shales has taken a significant share of the North American natural gas market and driven down the wellhead gas price (JISEA, 2013; MIT, 2011; EIA, 2013). It is the only region in the world with this level of development, as a result, this paper focuses on the North American market. The effects of this rapid shale gas expansion have been far reaching: electricity fuel shares have undergone their most significant change in decades (JISEA, 2013); facilities built in the last decade to import liquefied natural gas are now planning to become export terminals (FERC, 2013; Ratner et al., 2011); industries are contemplating significant expansion of energy-intensive primary manufacturing in the U.S. (Dow, 2012; ACC, 2011); European and Asian gas markets are being impacted. (Bazilian et al., 2013a) and infrastructure for natural gas vehicles is expanding (Lee et al., 2012). This shale gas "revolution" provides tremendous opportunities, but our scientific understanding of this transition and its potential near- and long-term climate and societal impacts lags far behind the rapid pace of change.

Investors, policy makers, and other stakeholders need greater clarity to make robust decisions in today's dynamic natural gas sector. A comprehensive, interdisciplinary research agenda can help inform these decisions. The agenda would: (1) determine relevant indicators across the economic, environmental, and social dimensions of natural gas; (2) develop data collection, analysis, and modeling capabilities to better understand these indicators and their future trajectories; and (3) create interactive, engaging, and transparent means of communicating the tradeoffs and opportunities of different options. This research effort must necessarily include and integrate the economic, environmental, and social impacts of gas development.

First, there are significant economic opportunities and challenges associated with relatively low-cost, abundant natural gas. Although low-cost natural gas has the potential to provide economic benefits to North America in the future, how this windfall is obtained and distributed will greatly impact the realized benefits of this new gas resource. The current debate over whether to export liquefied natural gas (LNG), and if so, how much, exemplifies these crosscutting questions (Ebinger et al., 2012; NERA, 2012). Even basic economic and financial questions associated with the recent rapid expansion of shale gas – driven by, *inter alia*, "take or pay" leasing requirements – do not provide a clear picture of where a new equilibrium price for natural gas might settle (Joskow, 2012; EIA, 2013) (see Fig. 1A).

* Corresponding author at: Joint Institute for Strategic Energy Analysis (JISEA), CO, USA. Tel./fax: +1 303 275 3000.
E-mail address: Morgan.Bazilian@nrel.gov (M. Bazilian).

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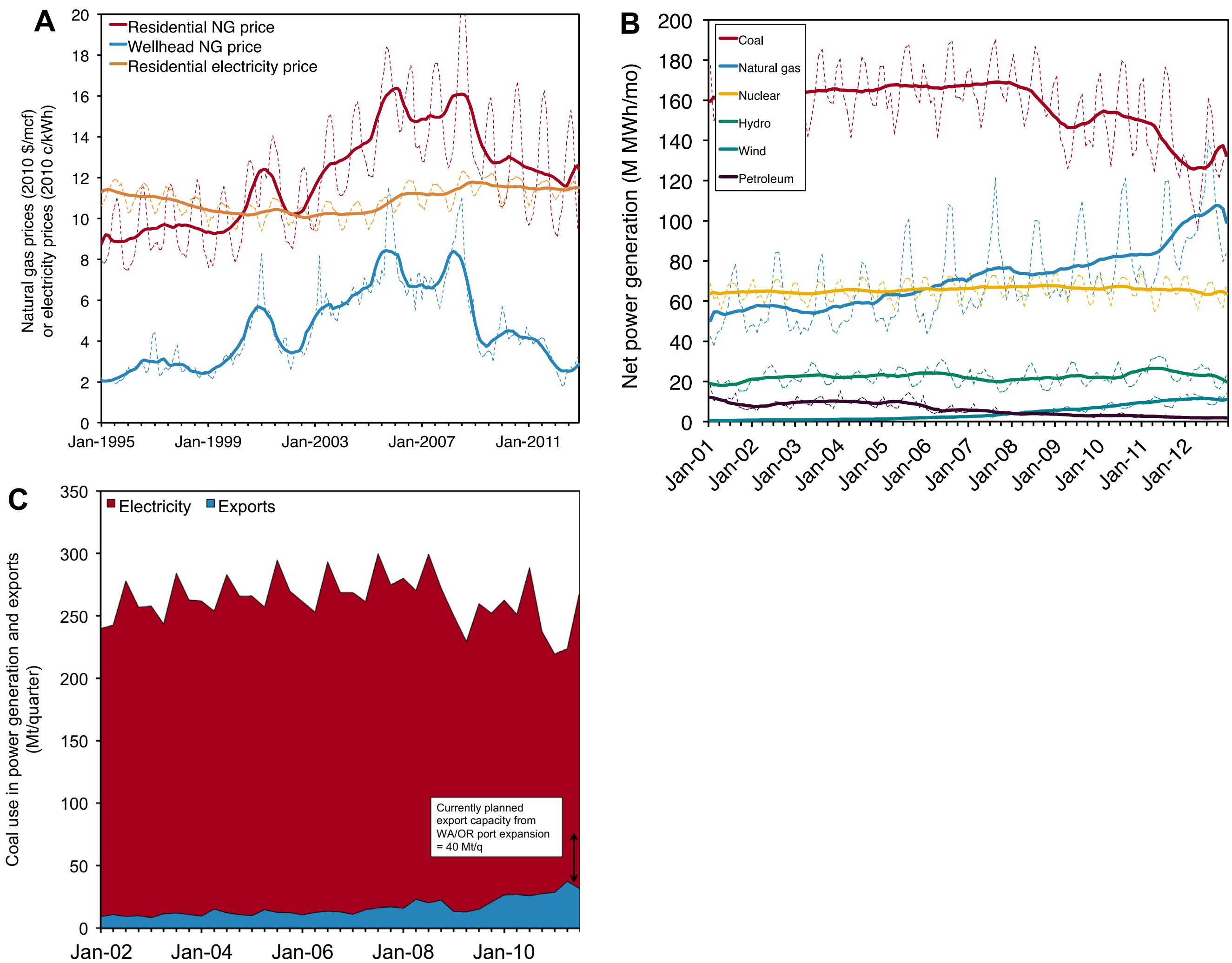

Fig. 1. (A) Declining real wellhead NG prices since 2008 (decline to 30% of peak 12-month rolling average) have not translated into commensurate changes in consumer natural gas prices or residential electricity prices. (monthly data in dashes, 12-month rolling averages in solid) (B) Lower natural gas prices have lead to a surge in natural gas fired power generation. Coupled with growth in wind power output, this has caused coal-fired generation to decline significantly. (C) Coal exports increase as demand for coal in electricity generation falters. Planned export capacity from 5 planned terminals is approximately 160 M short tons per year.

Utility decision makers struggle to maximize advantage from today's low-cost gas while minimizing risk of an over-exposed gas portfolio in the future. Improved indicators that quantify and qualify the advantages and disadvantages of gas-rich electricity generation portfolios will allow decisionmakers to arrive at more resilient answers. Frameworks for interaction and possible synergies between natural gas and renewable energy have been developed (Lee et al., 2012), but further work on considering business models and specific regulation is required.

Second, environmental impacts associated with the unconventional gas surge are poorly understood. The potential climate benefits of shale gas development are large. As an example, fuel switching from coal to gas that occurred in the U.S. power sector between 2008 and 2012 (see Fig. 1B) likely led to a reduction of life-cycle CO_2 emissions of approximately 300 million tons, or nearly 13% of that sector's emissions in 2008 (JISEA, 2013; Cathles et al., 2012). On the other hand, the emissions intensity of natural gas production, processing, and consumption are the subject of significant ongoing debate (Howarth et al., 2012; Levi, 2012; Petron et al., 2012; Harrison et al., 2011). Estimates of fugitive emissions were, until recently, based on outdated and incomplete assessments that were not reflective of current conditions. Recent measurement campaigns suggest the potential for higher methane leakage rates than were previously expected, though the methods and results have not been universally accepted (Harrison et al., 2011; Tollefson, 2013; Brandt et al., 2014).

Likewise, our understanding of the implications of hydraulic fracturing and shale development on water is incomplete. The risks associated with water withdrawal, use, and disposal are not well characterized because of a lack of robust data. The tradeoffs associated with different classes of risk are also not well understood. Still, information on water use by well (JISEA, 2013) and lifecycle water use (Meldrum et al., 2013) is emerging. Certain resources – such as the State Review of Oil and Natural Gas Environmental Regulations (STRONGER) and FracFocus – have greatly increased public access to information about risks of hydraulic fracturing. In addition, activities by the U.S. Environmental Protection Agency help address some of these data shortcomings (Broderick and Anderson, 2012), but again, the pace of shale development has moved ahead of the ability to produce timely, sound, analytically-supported regulations and even best management practices in the field. The literature suggests that further water-related study is required to, *inter alia*: Quantitatively assess the magnitude of the impacts of contamination pathways; quantitatively assess the probability that risks will occur, based on existing industry practices; and evaluate in detail wastewater recycling practices, including estimates of current recycling rates, estimates of total potential freshwater savings resulting from recycling, and a life cycle assessment (in terms of energy inputs, emissions, and costs) to identify thresholds for deciding whether to dispose of or recycle wastewaters.

Realizing global, long-term environmental benefits of a large-scale transition to gas rich portfolios depend on how it is used and how effective it is at displacing and working in synergy with other energy sources. In a world with growing energy demand and increasingly integrated global energy markets, assessing the implications of large-scale fuel switching is critical. For example, U.S. coal consumption for power generation dropped by nearly 250 million tons (Mt) since 2008, largely due to natural gas fuel switching, but coal exports have increased by 50 Mt over the same time period, offsetting some of this benefit (EIA, 2012; Stern, 2008). Planned expansion of coal export facilities could increase this offsetting trend (see Fig. 1C).

Also, long-term, climate-relevant emissions trajectories are heavily dependent on system inertia, positive feedbacks, and path dependencies. Near-term shale gas exports from North America could push Asia onto a more natural-gas-dependent development path, reducing emissions for decades to come. But this will only occur after building gas-consuming infrastructure, training engineers in non-steam turbine technology, and building confidence in shale gas production techniques for local conditions. Or conversely, low-cost gas could hamper renewable power development, foregoing learning-by-doing and the associated future opportunities associated with lower cost renewables.

Another possible environmental benefit of low-cost natural gas is a further shift in electricity investment towards a low-emission, flexible grid comprised of renewable generators coupled with gas turbines for firming. Indeed, such gas-based firming, coupled with new operational improvements and demand management, is likely to remain one of the more cost-effective options for the foreseeable future (Wolak, 2012). If natural gas is to be a "bridge" to a sustainable future, new policies that support the synergistic development of natural gas and renewables will be required that explicitly address the nature of the bridge.

These examples show that environmental benefits from natural gas are a property not just of technologies, conversion efficiencies, and leakage rates, but of the interaction of natural gas with the rest of the energy system and the broader social and political system. These "bigger picture" questions are fundamental – not incidental – to realizing societal benefits from gas.

Third, the shale gas expansion raises a number of political and social questions. Current debates include a discussion of whether gas should be used in domestic industries or exported. The impacts of either choice are complex and can only be forecast with great uncertainty (Theodori, 2012). Using low-cost gas to drive domestic chemical, plastic and primary metal production could bring jobs and stability to communities hard hit by the offshoring trends of recent decades (ACC, 2011). How should these benefits be weighed against the profits available by selling gas in international markets? The political implications of this are not limited to North America, and depend greatly on the dynamics of the various regional gas markets and their growing interconnectedness. For example, might significant gas exports from North America result in a de-linking of oil and LNG market prices and contracts, resulting in greater access for importing regions such as Asia? Or, could gas exports to Europe affect the complex political and economic relationship between Western Europe and Russia?

The social acceptability of gas development in North America is also in question in many locations. Shale gas development has moved into regions previously insulated from traditional natural resource extraction. This has resulted in increased attention to the local safety and economic benefits of gas development. When affected communities perceive a lack of monetary benefits, or that benefits accrue to a limited number of resource owners while costs are perceived to be incurred broadly, resentment to gas development builds (Alvarez et al., 2012).

Lastly, numerous tradeoffs exist between these economic, environmental, and social impacts. For example, development of natural gas fueling infrastructure for heavy- and light-duty transport could have numerous benefits: it would reduce reliance on liquid petroleum products; improve transport fuel price stability; reduce balance of payments deficits; and improve air quality near

Fig. 2. A variety of challenges surrounding natural gas development require sophisticated decision support tools. These support tools should illuminate complex tradeoffs between options in a user-friendly manner.

shipping hubs. On the contrary, natural-gas-based transportation pathways are not necessarily beneficial from a climate perspective, especially when considering that increased demand in the transport sector could increase gas prices beyond which fuel switching from coal to gas is favored (O'Sullivan, 2013). How can investors, policymakers, consumers, industry planners, or other decision makers navigate this tangle of interconnections, complexities, and uncertainties?

The global geopolitical, energy security and environmental implications of the U.S. shale experience have not yet been well quantified and are outside the scope of this paper. Still, they have undeniably caused wide-reaching shifts in energy dynamics across gas markets of the world. Three areas where global ramifications are, or might, manifest are: impact on LNG markets and trade (FERC, 2013; Ratner et al., 2011; Ebinger et al., 2012; NERA, 2012); impact on European markets and trade with Russia (Bazilian et al., 2013a; O'Sullivan, 2013; Goldthau et al., 2012); and impact on plant siting and jobs in the U.S. industrial sector (Dow, 2012; ACC, 2011). Additionally, the developments around shale gas in China are being closely watched (Bazilian et al., 2013b).

Making broadly beneficial choices about natural gas futures will be challenging without greatly improved decision support tools (see Fig. 2). We propose a comprehensive research agenda focused in three areas: (a) increased empirical research into environmental impacts from natural gas, including fugitive emissions of methane and water contamination issues (both surface and subsurface); (b) comprehensive and integrated economic, environmental, and social research in order to understand tradeoffs and interactions between different sectors and impacts; and (c) development of decision support tools to convey results of integrated modeling to decision makers in an engaging and informative fashion. Given the scale of possible benefits and impacts from natural gas development, there is no time to waste in clarifying these choices.

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