

Trade and Sustainable Energy Series



The Shale Gas Revolution

Implications for Sustainable Development and International Trade

By **Thomas L. Brewer**, Senior Fellow, ICTSD

ICTSD Global Platform on Climate Change, Trade and Sustainable Energy



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ICTSD welcomes feedback on this document. These can be forwarded to Joachim Monkelbaan, jmonkelbaan@ictsd.ch

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LIST OF ABBREVIATIONS AND ACRONYMS

BTUs	British thermal units
CEM	Clean Energy Ministerial
CH ₄	Methane
Cif	Cost plus insurance plus freight
CO ₂	Carbon dioxide
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FTA	Free-trade agreement
FX	Foreign exchange
GHGs	Greenhouse gases
GWP	Global warming potential
ICTSD	International Centre for Trade and Sustainable Development
IEA	International Energy Agency
ISO	International Standards Organization
LNG	Liquefied natural gas
M&As	Mergers and acquisitions
MEF	Major Economies Forum on Energy and Climate
MRV	Monitoring, reporting, and verifying
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing power parity
PwC	PricewaterhouseCoopers
SETIs	Sustainable energy trade initiatives
TPP	Trans-Pacific Partnership
TTIP	Transatlantic Trade and Investment Partnership
UK	United Kingdom
UNFCCC	UN Framework Convention on Climate Change
US	United States
WTO	World Trade Organization

FOREWORD

Shale gas has rapidly gained an important spot on domestic and international agendas. Some countries are experiencing a true shale gas ‘revolution,’ owing to the way in which shale gas is changing industrial competitiveness, relative energy prices, and geopolitics. Meanwhile, other countries have banned the exploration of shale gas (using ‘fracking’ technology), which is a sign of the continued controversy that shale gas brings with it. These bans are mostly related to concerns about health, safety, and the environment. Shale gas exploration can, in particular, affect water resources and greenhouse-gas emissions (in both positive and negative ways). While the impacts of fracking are not yet fully known, it is clear that we need to know more about shale gas in order to inform sound policymaking.

This paper, authored by Thomas Brewer, a senior fellow with the International Centre for Trade and Sustainable Development (ICTSD), offers improved knowledge of shale gas and its trade and sustainable development aspects, in particular. It offers an overview on the nature of shale gas. As the paper is not meant to provide a final judgment on the desirability of shale gas exploration, it argues that the actual impacts of shale gas will depend on how different stakeholders respond to the sustainable development issues that come along with it. These issues are directly relevant to ICTSD’s agenda, in particular, where they have linkages with trade. The paper places these concerns in a wider context, which takes the impacts of natural gas beyond shale gas into account.

The paper focuses on the sustainability aspects specific to shale gas: methane leakages that contribute to global climate change, increases in international trade in natural gas, increases in international trade in coal, and reductions in investment in renewable energy sources.

In response to these issues, different stakeholders are called upon to actively address both the opportunities and the challenges that shale gas represents. One important approach could be based on the goals of sustainable development and international cooperation. The findings of this paper can facilitate such an approach and contribute to the establishment of deeper research agendas, as it identifies major knowledge gaps.

This analysis is timely, as several countries are planning to explore shale gas in the midst of both public criticism and industrial enthusiasm.

As always, your comments and input on this paper are most welcome.



Ricardo Meléndez-Ortiz
Chief Executive, ICTSD

EXECUTIVE SUMMARY

Shale gas has become a highly contentious multi-dimensional topic in many countries. Although shale gas has the potential to make important contributions to sustainable development, it also can cause significant harm, including to climate change mitigation efforts. The actual impacts of shale gas, therefore, will depend on how industry, governments, international agencies, and non-governmental organisations (NGOs) respond to sustainable development issues. This paper addresses issues that are directly relevant to the International Centre for Trade and Sustainable Development (ICTSD). However, issues concerning sustainable development and international trade arise in addition to local issues related to health, safety and quality of life. Based on current trends, we conclude:

Increases in methane leakages that contribute to global climate change.

Methane emissions are highly potent greenhouse gases (GHGs), and they are inherently global in terms of their consequences. Therefore, they require global solutions. The UN Framework Convention on Climate Change (UNFCCC) processes and institutions should establish mechanisms for more comprehensive and precise monitoring, reporting, and verifying (MRV) of methane emissions.

Increases in international trade in natural gas, including shale gas, through pipelines and as liquefied natural gas (LNG) on specially outfitted ships.

Importers should be required to certify methane emissions levels, based on exporters' declarations, with the exporting government's confirmation and independent third-party verification. International standards of emissions for pipelines and LNG transport ought to be developed and implemented. The requirements could be established by international standard-setting bodies, with the involvement of the UNFCCC, industry associations, and NGOs. The IEA and the OECD should be mobilized in this effort.

Increases in international trade in coal, as exports replace production for domestic consumption.

The UNFCCC, other international agencies, and national governments should refine their reporting and analyses on sources of carbon dioxide (CO₂) emissions and their allocation of these emissions to producing-exporting countries and importing-consuming countries.

Reductions in investment in wind and solar and other renewable energy sources.

The World Trade Organization (WTO) should explicitly recognize the use of subsidies to address the positive externalities associated with renewable energy sources as legitimate economic efficiency-enhancing measures, with guidance about the limits and conditions of the subsidies and with a red-yellow-green-light system for screening such subsidies.

In view of these issues, 'business as usual' in industry, governments, international agencies, and among other stakeholders will not be adequate to address effectively the shale gas agenda. That agenda requires new approaches to developing practices and policies that are effective in addressing climate change and other environmental problems and that are politically viable at all levels of government, as well as economically efficient. It is a daunting but 'doable' agenda.

1. CONTEXT AND ORGANIZATION OF THE PAPER

The topic of shale gas has become an object of much hype and hyperbole in public commentaries by politicians and business leaders. This paper goes beyond the hype and hyperbole—and beyond the special pleadings of various groups—to address key facts and their implications for policy.

Shale gas has become not only an energy exploration and production issue wherever it is or might be located, but also a macroeconomic issue for national economies, a microeconomic issue for energy-intensive industry sectors, a global environmental issue for local communities, a public safety and health issue wherever there is exploration or production, and an energy independence and national security issue in countries that are dependent on oil imports and/or gas imports.

Moreover, while North America has thus far been the leader in developing and producing shale gas, there are significant reserves in a wide range of countries, including many emerging economies, such as Argentina, China, and South Africa. Shale gas is, therefore, already an international issue in several respects. Indeed, there is truly global interest in it, as it has attracted attention in countries that have it and want to exploit it; in countries that have deposits but have decided not to exploit it, owing to public health, environmental, and other concerns; in countries that would like to know more about how much they have and where it is; and in countries that don't have it, but want to import it.

Exports of shale gas have become a trade issue in the United States (US). In particular, there are questions about whether the US government should allow shale gas exports in

the form of LNG- and, if so, to whom and under what conditions. This trade policy question is also of considerable economic and political significance in Japan, currently the leading importer of natural gas (mostly from the Asia-Pacific region, but in increasing quantities from the US as well). This has, of course, taken on greater urgency in Japan, as it searches for a new national energy strategy in the aftermath of the Fukushima nuclear accident.

As production and trade of shale gas have increased, sustainability issues have multiplied—particularly the climate change implications of 'fugitive' methane emissions during shale gas exploration, recovery, and distribution. The impact of abundant and cheap shale gas on the future development of wind, solar, and other renewable energy sources is also a concern.

This issue paper addresses these concerns in the following sections: Section 2 presents basic information about shale gas, including a primer for any readers who are not familiar with the geology of its location, the technology of its exploration and extraction, and its relationship to other forms of unconventional gas. Section 3 addresses sustainable development concerns, with an emphasis on the implications of the prospective widespread development of shale gas resources for climate change. Section 4 considers international trade, including trade patterns and trends as well as trade policies. The implications of shale gas trade include, for instance, its effects on trade balances and currency exchange rates; there are thus macroeconomic implications as well as effects on the energy industry and other industries. Section 5 summarizes gaps in the literature, and it offers recommendations for policymaking, with an emphasis on sustainable development and trade.

2. SHALE GAS PRIMER

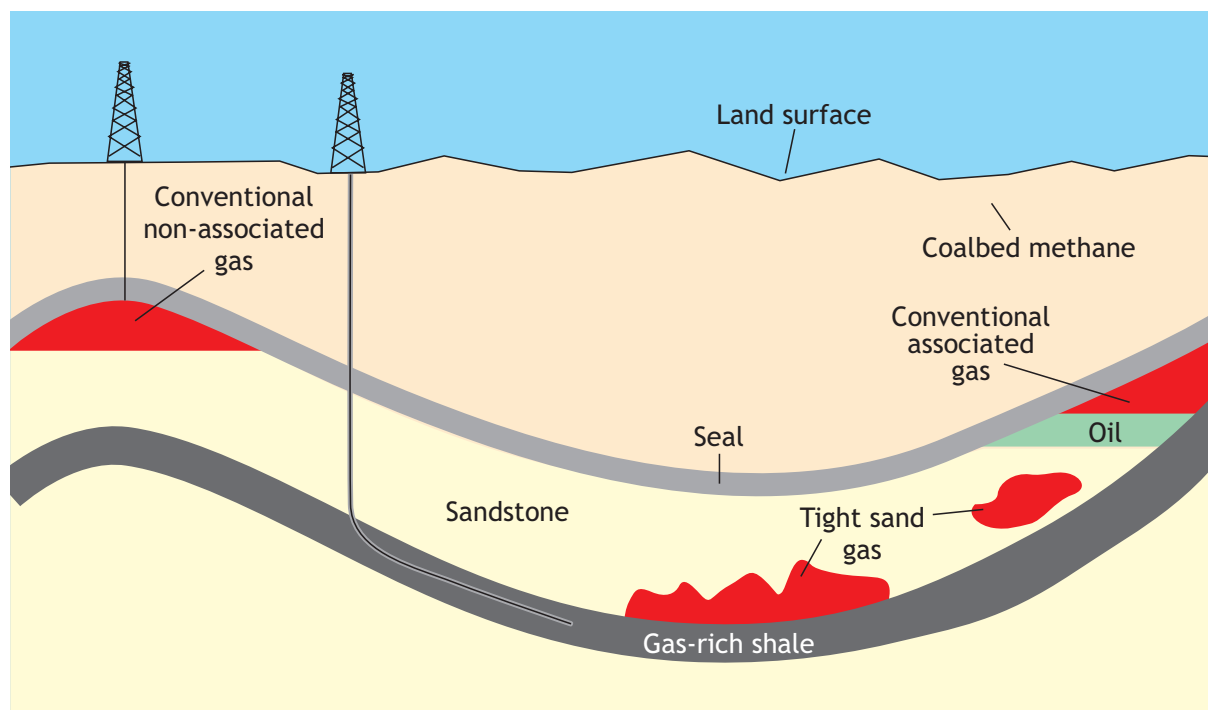
2.1 What is Shale Gas?

Shale gas is an ‘unconventional’ natural gas that is defined by its location, namely shale rock formations that include clay, quartz, and other minerals. Such formations—and hence shale gas deposits—can be found in both on-shore and off-shore locations.

Figures 1 and 2 depict the basics of the geology of location and the technology of extraction. Figure 1 provides a simple summary

picture of how shale gas is different from conventional sources of gas and oil—and from other unconventional sources of gas and oil. As the figure suggests, shale gas is relatively deeply located compared with other sources of natural gas, including both ‘conventional’ and ‘unconventional’ sources. The latter includes ‘tight gas,’ which is located in sand formations, and methane from coal beds, as well as shale gas. Shale gas is interspersed in deep rock formations, usually thousands of meters deep that are millions of years old.

Figure 1: Sources of Gas and Oil



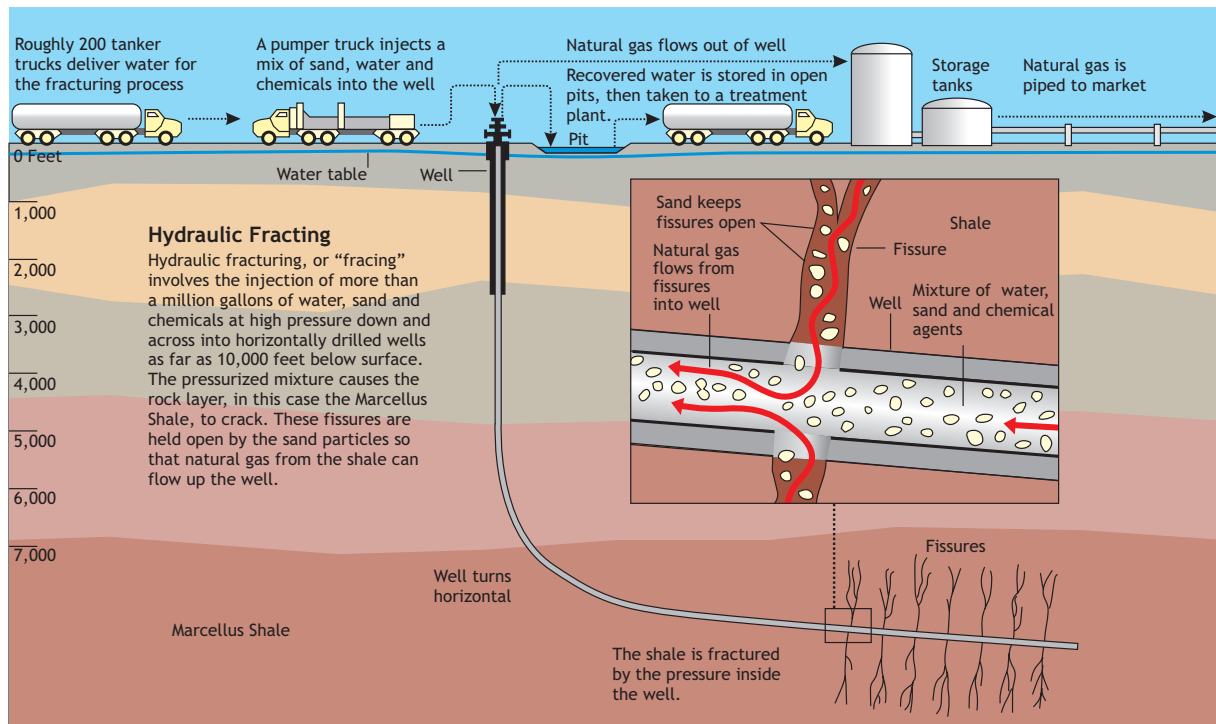
Source: US Energy Information Administration, *World Shale Gas Resources, 2011*; the report was prepared by Advanced Resources International.

The basics of the geology of shale gas deposits have been known for more than half a century, so there is no revolution in the sense of a sudden and unexpected discovery of the existence of shale gas. The technological challenge has been to extract it at commercially viable costs from rock formations that are deep underground or deep under bodies of water. In this respect, the relatively recent development of two extraction technologies—hydraulic fracturing

and horizontal drilling—have made recovery economically feasible. In that sense there have been very specific technological developments, which have combined to comprise a kind of technological revolution.

Figure 2 depicts the combination of deep horizontal drilling with hydraulic fracturing of the shale that has made the exploitation of shale gas commercially feasible.

Figure 2: Illustrative Shale Gas Well Cross Section



Source: US Energy Information Administration, *World Shale Gas Resources, 2011*; the report was prepared by Advanced Resources International.

Recent developments in shale gas exploration and recovery techniques have created the potential for a shift away from current fracking methods (see, for instance, Bullis 2013).

2.2 How Is It Used?

Like all forms of natural gas, when extracted shale gas is mostly methane (CH₄), although several chemically distinct gases (e.g. propane and ethane) are derived from natural gas during refining. Methane and the other gasses are used in many economic sectors, including:

- in electric power plants and combined power-heat plants
- for heating residential and commercial buildings
- for motor vehicles (including cars, trucks, busses, and trains)
- as feed stock in industrial processes, such as the production of plastics.

Thus far, in the US, most shale gas—like natural gas in general—has been going to electric power plants. Therefore, much of the discussion about sustainable development has focused on the implications for GHG emissions of the substitution of shale gas—and natural gas from other sources—for coal in electric power plants. The issue, as discussed below, concerns especially the amounts of reductions in CO₂ emissions relative to the amounts of increases in methane emissions. In some other countries, where there is proportionately much more use of natural gas for combined power and heat in cogeneration facilities, those issues are of course different than in the US, where cogeneration facilities are relatively rare. A large amount of natural gas in the US also goes directly into commercial and residential buildings for heating.

To date, the use of natural gas in the transport sector has been rather limited and concentrated in municipal bus systems and large, long-haul trucks. These patterns of use are beginning to change, however; there is increasing use in locomotives, corporate and government fleets of

small trucks and automobiles, and individuals' private automobiles. Although the numbers are generally still small for these uses, over time they could become quite large; in that context, a key sustainable development issue will be the relative amounts of GHG emissions of shale gas and other sources of natural gas compared with gasoline and diesel fuels on a complete cycle basis.

The use of natural gas as a feedstock in several industries poses different issues, including sustainability issues. These gases have different global warming potentials compared with methane. The most economically significant use is in the production of plastics. The international competitiveness implications of relatively inexpensive shale gas in the petrochemical industry have received a lot of attention.

In sum, the direct and the indirect consumers of natural gas include individuals and firms, using it as a fuel in the electric power, heating, and transportation sectors, as well as producers

and consumers of a wide array of petrochemical products. In short, shale gas is potentially pervasive in many economies.

2.3 Who Produces and Distributes It?

The basics of shale gas not only include its geology, technology and uses, but also industry structure and practices. It is a rapidly growing industry, where there is a strong tendency toward consolidation in which large firms, including major international oil and gas firms are acquiring smaller, more specialised 'independents.' This trend could have significant implications for the sustainability issues discussed below if there are differences in the two types of firms' approaches to health, safety, and environmental issues.

Several detailed reports by the consulting firm PricewaterhouseCoopers (PwC) are useful for understanding the increasing concentration. The levels of recent mergers and acquisitions (M&As) in the US are noted in Table 1.

Table 1: Mergers and Acquisitions in the Shale Sector and Total Oil and Gas Industry

	2010	2011
Value of shale sector M&As ^a (USD bil.)	68.9	107
Value of oil & gas industry total M&As (USD bil.)	138.5	186.5
Shale as % of total	49.7	57.4
Number of shale transactions	85	68
Number of total transactions	196	191
Shale as % of total	43.4	35.6

^a Based on individual deals over USD 50 million

Sources: Compiled by the author from data in PwC, U.S. Oil & Gas deals highlighted by shale plays, foreign investment, and robust private equity interest. February 8, 2012, accessed at www.pwc.com on 1 May 2013;

PwC. M&A deal volume in the U.S. Oil & Gas industry reaches highest level in ten years during fourth quarter 2012. Accessed at www.pwc.com on 1 May 2013. Also see PwC. Shale Oil: The Next Energy Revolution. February 2013. Accessed at www.pwc.com on 1 May 2013.

In Box 1, there are several summary statements about recent tendencies, including the importance of acquisitions by major oil and gas firms and the role of international investments. For instance, Statoil of Norway owns substantial drilling rights in the largest shale gas basin the

US, namely the Marcellus Basin. It has been noted that "Large international oil companies are expected to continue to increase their positions in the unconventional plays in North America."¹ (At the same time, however, Shell has reduced its shale gas interests.)

Box 1: Commentaries on Recent Merger and Acquisition Levels and Trends

“The industry continued to make a paradigm shift to shale in 2011 with virtually every major oil and gas company taking a position in unconventional plays....” (PwC 2012).

“The total value of US oil and gas mergers and acquisitions (M&A) increased significantly in 2011 due to continued investment in US shale plays and related infrastructure....” (PwC 2012).

“M&A activity in the US oil and gas sector was extremely active in 2011 as shale plays continued to attract the large multinational energy companies, foreign buyers, and private equity firms....” (PwC 2012).

In the third quarter of 2011 “the high gas content in ... [the four transactions totaling USD 3.6 billion, in the Marcellus Shale, and four in the Utica Shale, totaling USD 3.1 billion] revealed continued interest in natural gas....” (Financial Times 2011).

“... the drop in gas prices had made small independents that hold shale acreage in the US more willing to sell.... The buyers tend to be the majors or national oil companies, with deep enough pockets to outlast the low gas prices.”

“International players invested heavily in US shale plays through joint ventures in 2011 - and we believe a trend to watch out for in 2012 is for foreign buyers to look to acquire entire companies that operate in shale plays so they can take more control of the assets through operatorship....” (PwC 2012).

Sources: Financial Times, Shale gas drives US energy group mergers. By Sheila McNulty. 26 October 2011. Accessed at www.ft.com on 29 March 2013; PwC, U.S. Oil & Gas deals highlighted by shale plays, foreign investment, and robust private equity interest. February 8, 2012, accessed at www.pwc.com on 1 May 2013;

PwC. M&A deal volume in the U.S. Oil & Gas industry reaches highest level in ten years during fourth quarter 2012. Accessed at www.pwc.com on 1 May 2013.

A strategic assumption of firms that are investing in shale gas is that...

utilities will increasingly switch from coal-fired power plants to gas-fired [in order] to reduce carbon emissions and the US transportation industry will increasingly turn to gas-powered vehicles and plug-ins to [meet new fuel standards and consumer preferences].... Beyond that, buyers want to learn the tools of the trade to extract resources from shale globally.... To that end, foreign buyers accounted for ... 76 percent of the value of [shale gas] deals [in the third quarter of 2011].²

In other words, access to technology is a significant driver of foreign direct investment in the US shale gas industry.

2.4 How Much Is There and Where Is It?

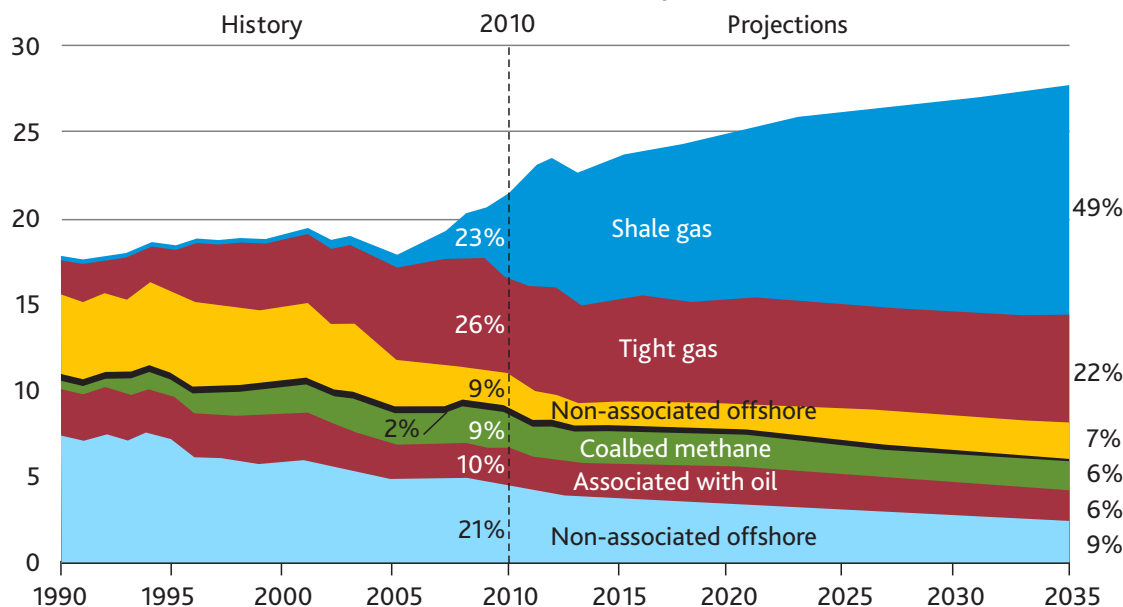
The estimation of shale gas deposits from geologic data in many countries and the increasing use of on-site exploratory drilling have significantly expanded the number of countries where deposits are evident. However, because of variations in the sizes and the costs of extraction and distribution at individual sites, there is also much variation and uncertainty in the commercial potential of individual countries' production. It has been mostly the expected economic consequences of the prospective increases in the exploitation of shale gas, mainly in the US and in many other countries around the world that have led commentators to refer to the “Shale Gas Revolution” or sometimes “Game Changer” or “Bonanza.” What, then, are some of the key

numbers that have led to such exclamations? The following series of questions and associated data help answer this question.

official US Energy Information Administration (EIA) projections in Figure 3 indicate that by 2035, annual shale gas production could be between 10 and 15 trillion cubic feet—or about half of total US gas production. Meanwhile, all other forms of natural gas would remain at about their recent levels or decline in absolute as well as relative terms.

Figure 3 shows increases in shale gas production over the 20-year period from 1990, when it was virtually 0, to 2010, when it was 23 percent of total US natural gas production. As for the future, the

Figure 3: US Natural Gas Production: Historical and Projected



Sources: U.S. Energy Information Administration. Annual Energy Outlook 2012 (June 2012).

Of course, actual production levels depend in part on the levels of the reserves still left and the costs of recovery and distribution. Thus, projections of reserves become an important element of almost any forecasting/projecting exercise. Estimates of ‘resources’ and ‘reserves’ are inevitably much more challenging and less reliable than estimates of production.

In their estimates of ‘reserves’ and ‘resources,’ both the International Energy Agency (IEA) and the EIA use similar categories. They refer to ‘proven’ (IEA) or ‘proved reserves’ (US EIA), while the IEA uses ‘technically recoverable resources,’ and the EIA uses ‘technically recoverable reserves’ (see Box 2).

Box 2: Definitions of Reserves and ResourcesPanel A: International Energy Agency (IEA) Definitions

“...proven gas reserves, *i.e.* volumes that have been discovered and can be produced economically with existing technology at current gas prices.”

“... recoverable gas resources, *i.e.* volumes that analysts are confident will be discovered or technology developed to produce them...”

Panel B: US Energy Information Agency (EIA) DefinitionsProved Reserves

“Proved reserves are those volumes of ... natural gas that geologic and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions. Reserves estimates change from year to year as new discoveries are made, existing fields are more thoroughly appraised, existing reserves are produced, and as prices and technologies change.”

Technically Recoverable Resources (TRR)

TRR estimates consist of “proved reserves” and “unproved resources.”

Source: IEA, *FAQs: Natural Gas*, accessed at <http://www.iea.org/aboutus/faqs/gas/> on 24 March 2013.

Source: US IEA, *U.S. Crude Oil, Natural Gas, and NG Liquids Proved Reserves*, accessed at <http://www.eia.gov/naturalgas/crudeoilreserves/index.cfm> on 24 March 2013.

Source: US IEA, *Geology and technology drive estimates of technically recoverable resources*, accessed at <http://www.eia.gov/todayinenergy/detail.cfm?id=7190> on 24 March 2013

There are many substantive issues about such projections beyond the definitional semantics. In fact, as Table 2 indicates, as exploration has proceeded, there have been significant changes in estimates of US ‘proved reserves.’ Over a period of four years, the total estimated ‘proved reserves’ in the US increased by a factor of more than four.

Clearly, it is important to keep in mind such variability in estimates and to be aware that the estimates can go down as well as up over time. Countries where estimated resources were reduced from a 2011 report (US EIA, 2011) to a 2013 report (US EIA, 2013) included China, Mexico, Norway, Poland, and South Africa.

Table 2: Changes in Estimates of US Proved Reserves (billion cubic feet as of end of the year)

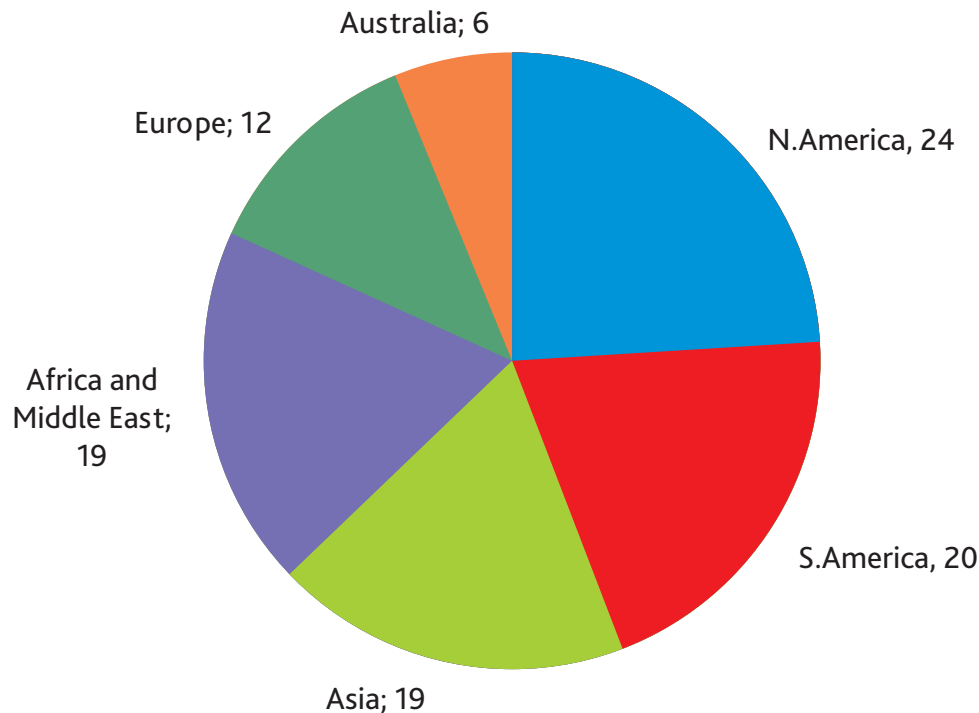
Year	Billions of cubic feet (Bcf)	Percent change from previous year	Percent change from 2007
2007	23,304	NA	NA
2008	34,428	47.7	47.7
2009	60,644	76.1	160.2
2010	97,449	60.9	381.6
2011	131,616	35.1	464.8

Source: Computed by the author from data in US EIA, *Shale Gas, Proved Resources as of December 31*, accessed on 8 September 2013 at http://www.eia.gov/dnav/ng/ng_enr_shalegas_a_EPG0_R5301_Bcf_a.htm

Figure 4 presents preliminary estimates for selected countries' 'technically recoverable resources.' These are widely used numbers produced by a consulting firm for the EIA in the

2013 report. The study identified the top 10 countries, which collectively account for more than 80 per cent of all the countries included in the study.

Figure 4: Estimated Shares of Shale Gas Technically Recoverable Resources (Percentages of World Total)



Notes:

North America includes Canada, Mexico and US (which uses EIA estimate of 665 tcf in Table 1)

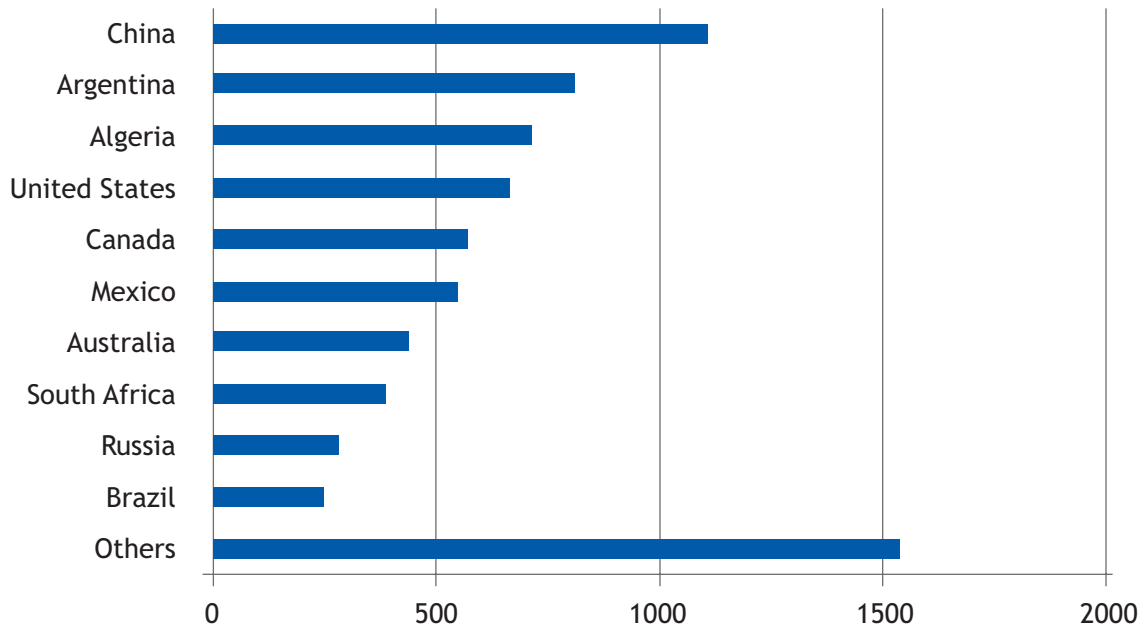
Europe includes Russia

Source: Compiled by the author from data in US Energy Information Administration, Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States, June 2013; Tables 1 and 2A.

Despite their preliminary nature for many countries, the data in Figures 4 and 5 are useful for present purposes. They are indicative of countries' approximate rankings as major source countries, and they are being widely used to form preliminary impressions of countries'

prospects. It is reasonable to suppose that many—not necessarily all, by any means—of these countries will become major producers of shale gas over the next decade or two and that some within that group will become major exporters.

Figure 5: Preliminary Estimates of Selected Countries' Technically Recoverable Shale Gas Resources^a (trillion cubic feet)



^a These are preliminary estimates that are subject to significant revision, either upward or downward.

Source: Compiled by the author from data in US Energy Information Administration, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States*, June 2013; Table 6, page 10

Several factors could limit the production and/or exports of any of the countries. Some, like France, may decide not to allow production, owing to concerns about health, safety, the environment, or other problems. Some may turn out to have smaller resources than previously estimated, as seems to be the case with respect to Norway and Poland, for instance. Some may limit distribution to domestic markets and prohibit exports. Yet, another limiting factor may be the rate at which production from individual wells declines. Most current projections are relying on production experience gained from conventional gas deposits; but, shale gas is known to behave differently, and long-term projections are consequently less reliable. So, again, this is a preliminary list that should be used with caution.

What then do the figures reveal? Figures 4 and 5 indicate a regionally dispersed pattern with substantial amounts in most regions. In North America, Canada as well as the US and Mexico seem to have substantial resources, making North America apparently quite rich in shale gas. In South America, Brazil may join Argentina as a regionally significant source. Algeria and Libya in North Africa are likely to be significant sources. Thus far, China seems to have the greatest amounts.

These patterns—plus the relatively small levels (or perhaps absence) of shale gas in some major economies (e.g. Japan)—combine with growing energy demand to yield the likely trade patterns discussed in section 4.

3. SUSTAINABLE DEVELOPMENT ISSUES

3.1 Local Safety, Air Quality, Water Quality, and Quality of Life Concerns

Exploration, production, and trade of shale gas have become highly controversial around the world, especially in light of concerns about the health effects of chemical additives that may seep into aquifers and ground water as well as concerns about micro-earthquakes and disruptions of daily life in local communities. These and other concerns—whether based on real or imagined risks—may impose significant constraints on the long-term exploitation of shale gas, especially in some countries in Europe and perhaps in some states in the US.

Such concerns have led to moratoria and other limitations on exploration and recovery of shale gas in parts of the US and other countries. Some countries (e.g. France) have imposed prohibitions; yet others (e.g. Denmark) are allowing carefully controlled exploration, but without any decisions yet on extraction. Within the US, some states imposed temporary moratoria while collecting more information and then subsequently allowed drilling; some states are still waiting for more conclusive information about local conditions; some towns and counties (e.g. in Colorado) have imposed local bans, within the limits of state laws, even as the state has been allowing drilling to proceed in other parts of the state. It seems highly likely that there will be many law suits in the US; therefore, it may be several years before it is clear whether or not shale gas exploitation will proceed in some areas and the conditions under which it will be allowed. It is not an exaggeration, therefore, to suggest that the future of the global industry will be determined in part by attitudes and actions at the local level. This may be true not only in the US, but also in other countries.

Of course, some countries (e.g. China) have embarked on ambitious exploration operations in the hope of subsequent large-scale extraction operations, though inadequate water supplies may constrain exploitation of the deposits

there. There are some states in the US, such as North Dakota, where exploration and production are moving ahead rapidly.

Although these concerns are not explicitly climate change issues, they are potentially significant, because they could substantially reduce production of shale gas and thus limit its impacts on GHG emissions—i.e. reductions of CO₂ but increases in methane. It would be far beyond the scope of this study to address the specific local safety, health, and other concerns in detail, but interested readers can learn about them in other sources.⁴

3.2 The Methane Emissions Problem and Climate Change

An attractive feature of shale gas from the standpoint of climate change mitigation is that, like natural gas in general, GHG emissions from shale gas *consumption* are much lower than those from coal, for instance in electric power plants (about 40-50 per cent lower). However, there are serious questions about GHG emissions, in particular, methane, during exploration, extraction, and transport.

Methane has long been known to be a much more potent GHG than CO₂; in fact, methane's global warming potential (GWP) is more than 20 times greater than CO₂'s GWP at 100 years and more than 70 times greater at 20 years. Methane, thus, has particularly strong short-term effects (UN FCCC, 2013; US EPA, 2012).

As of early February 2014, the range of estimated methane leakage rates in the US was from less than 1 per cent to as much as 19 per cent. Table 3 lists some of the individual estimates, which it should be noted are based on different estimation methods and different stages in the full cycle from exploration to final use. Important studies by large teams of experts with diverse backgrounds reported in Brandt et al. (2014a; 2014b) and in Miller et al. (2013) have found that US EPA estimates of national methane fugitive emissions are too low. Also see Climate Central (2013), Jenkins

(2014) and Romm (2013). A study by Allen et al. (2013; also see Song and Morris 2013) and in a series of ongoing studies sponsored by the Environmental Defense Fund and nine energy companies, methane emissions rates were measured directly at more than 500 wells nationwide. Because the nine energy firms participating in the study were voluntary funders, the study was not based on a randomly selected, representative sample of firms. However, based on the results from the wells that were studied, plus estimates for other wells not in the study, the total national methane fugitive emissions rate for natural gas was estimated to be 0.42 per cent, slightly less than the previous US Environmental Protection Agency (EPA) estimate of 0.47 per cent. However, for certain stages of shale gas

production, in particular, the results for well completions were lower than previous EPA estimates, but higher than EPA estimates for valves and equipment leaks. In sum, the study has added significant new data to ongoing discussions about methane emissions, but many more studies will be needed before there is a consensus on the methane leakage rates from the shale gas segment of the industry and from the industry as a whole. There are many other estimates and studies in progress, as well as secondary analyses of existing data, aimed at developing more conclusive estimates. The continuing projects of the World Resources Institute (e.g. Bradley et al., 2013) and of the Environmental Defense Fund (2013) are especially important (see the 0.71-2.25 short review by Tollefson, (2013).

Table 3: Estimates of Methane Leakage Rates

Estimate of leakage rate %	Reference gas	Stages included	Location	Reference
19	Shale Gas	Well production	US	Freedman (2013)
6.2-11.7 [Mean = 8.95]	Shale Gas	Wells and distribution, not including consumer	Unitah Basin, US	Karion et al. (2013)
3.6-7.9 [Mean = 5.75]	Shale Gas	Production, transport, storage, distribution	US	Howarth, Santoro and Ingraffea (2011)
1.9	Shale Gas	Well completion	US	Howarth, Santoro and Ingraffea (2011)
0.01	Conventional Gas	Well completion	US	Howarth, Santoro and Ingraffea (2011)
1.7-6.0 [Mean = 3.85]	Conventional Gas	Production, transport, storage, distribution	US	Howarth, Santoro and Ingraffea (2011)
2.25	All Natural Gas	National	US	US EPA (2013)
More than US EPA est.	All Natural Gas	National		Miller et al. (2013)
More than US EPA est.	All Natural Gas and Other Sources	National	US and Canada	Brandt et al. (2014a; 2014b)

Source: Compiled by the author from the sources listed in the reference column and Other Sources

The total climate change impact is, of course, a function of the volume of emissions as well as the GWP of each molecule. Estimates of the volumes of methane emissions from a single exploratory well or a single production well vary depending on local geological conditions, the equipment used, the policies of the firms, the operational practices of the crews in the field, and many other aspects of the exploration, production, and transportation processes. Although much has been learned about the emissions of methane at various points in its life cycle, there are still gaps in the data, which are being addressed by several organizations (Bradbury et al., 2013).

There are cost-effective technological fixes available for the fugitive methane emissions problem, but their effective implementation will require changes in industry practices. The large-scale flaring of gas from shale oil deposits in the US in the same areas where there are also shale gas deposits is a related issue.³

3.3 Impact on Investments in Renewable Energy Sources

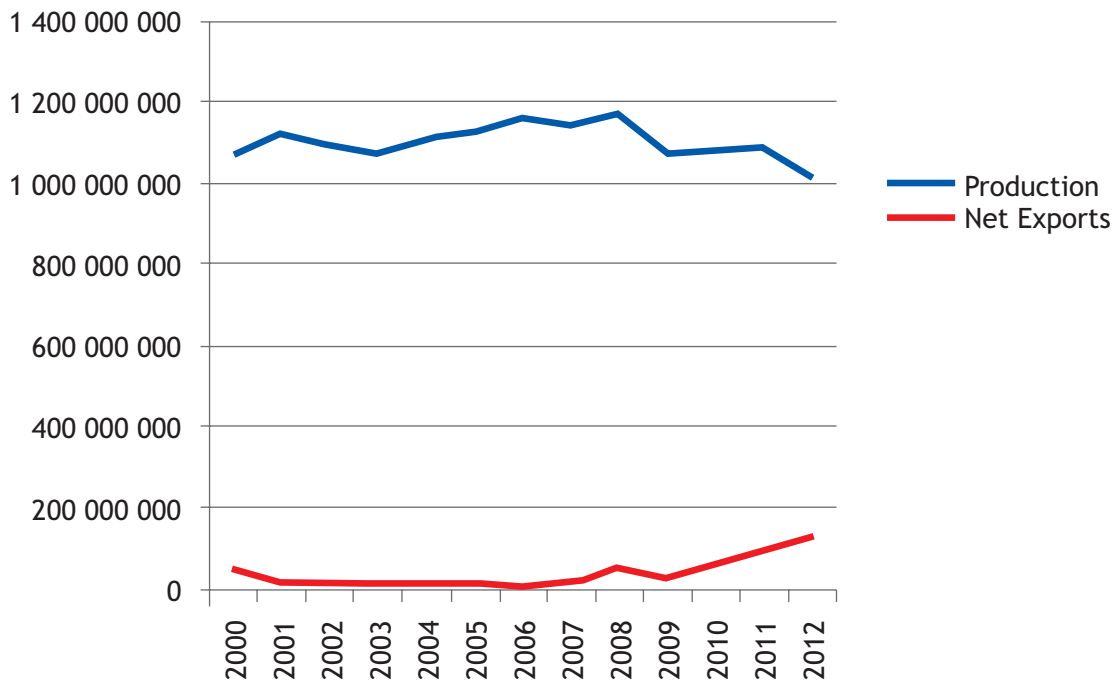
Over the longer term, a key issue is whether cheap, abundant shale gas will undermine investment in renewable energy sources. Already in the US, with the significant decrease in the price of natural gas and a consequent decline in electricity prices produced in natural gas-fired power plants, the competitive position

of wind, solar, and other renewable energy sources has been weakened. The future shares of those technologies in the energy mix are thus also undermined. In some scenarios, therefore, while the substitution of shale gas for coal to produce electricity may yield a net reduction in GHG emissions in the short run, the increasing share of shale gas and concomitant smaller share of renewables may yield a net increase in emissions by deferring deployment of low-carbon energy sources. Yet, cheap natural gas may also indirectly support investment in renewables by lowering the overall price of electricity and thus reducing opposition to renewable subsidy costs (Baron, 2013).

3.4 Coal Production and Consumption

Thus far in the US, there has been a significant decline in coal consumption for electricity power plants (see Figure 6). At the same time, domestic consumption and production of coal have declined. However, exports have increased. Although exports remain a small portion of total production, they have increased substantially in recent years, as shale gas has become an increasingly common substitute for coal in domestic electricity production. Net coal exports increased from about 13 million tons in 2006 to 117 million in 2012 (126 million tons of exports minus 9 million tons of imports). Therefore, 2012 was a record-setting year looking at the last half century since 1950. During the first half of 2013, exports were at about the same level as in the first half of 2012.

Figure 6: Trends in US Coal Production, Domestic Consumption and Exports (Short tons)



Source: Computed by the author from data in US Energy Information Agency, *Coal, Annual Energy Review*, 27 September 2012 and *Monthly Energy Review*, 27 August 2013 (accessed at www.eia.gov on 10 September 2013).

The implication for climate change, of course, is that declining consumption of coal in the US and thus declining CO₂ emissions are at least partially offset by increasing consumption of exported coal and thus increasing CO₂ emissions outside the US. In 2011 and 2012—the two most recent complete years for which data are available—consumption declined by 113 million tons, but production declined by only 80 million tons. Since exports increased by 19 million tons, export increases offset about 17 per cent of the consumption decline in the US market. (There were also changes in stocks on hand and imports as well as unaccounted for changes.)

Such data are consistent with the recognition that global CO₂ emissions do not decline in direct proportion to declines in domestic consumption of coal. To some extent, the emissions are increasing in other (importing) countries even as they are decreasing in the exporting country. Of course, these data are only illustrative, as they are based on one country and two years. Much more extensive analysis will be needed to determine the magnitude of the phenomenon as a global climate change issue.

4. TRADE ISSUES

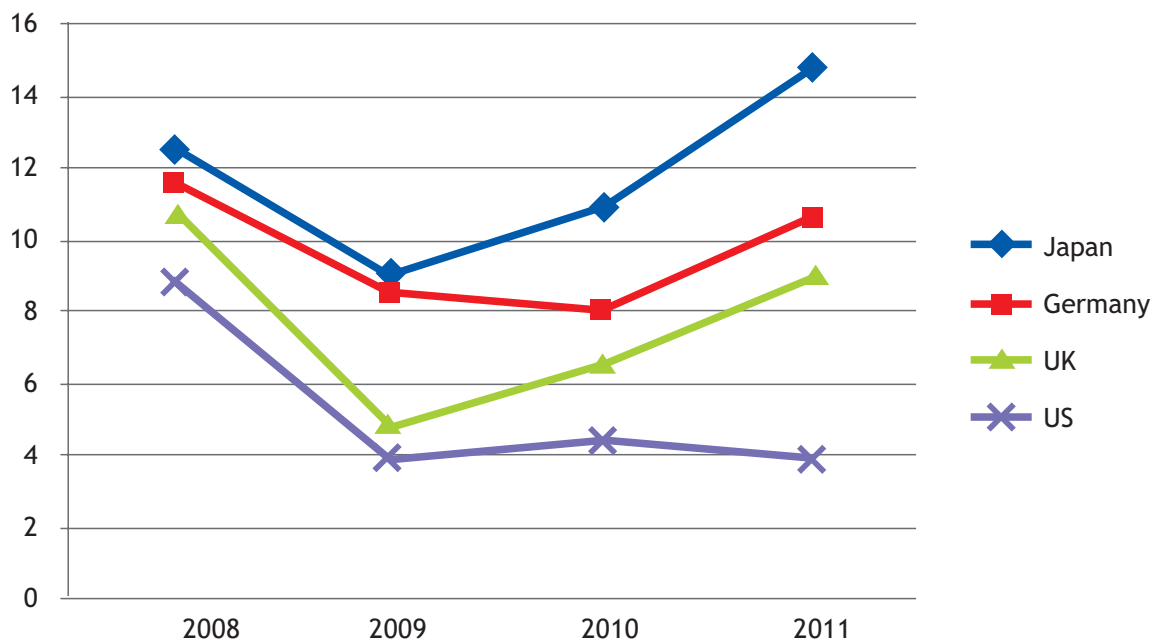
International price differences, in combination with likely geographic patterns of production versus consumption, are indicative of a significant potential for international trade in LNG derived from shale gas and in pipelines where feasible. Already, there is much interest, for instance, in US exports to Europe and Australian exports to Japan, among many other possible trading relationships. Of course, there are a variety of constraints on the potential trade, including not only transport costs, but also the costs of LNG export and import processing facilities. In any case, the US Obama administration announced approval in May 2013 of a large LNG export facility, and there are many more applications for additional such facilities pending.

4.1 International Price Differences and Competitiveness Issues

The costs of extraction and distribution obviously vary according to the location of the deposits. In the US, some of the large deposits are close to highways and population centres, while others are not. Some are close to petrochemical facilities where natural gas is a feed stock. Some are close to natural gas pipelines for distribution to ports for conversion into LNG and shipment to international customers. Even more basic, some deposits are under the seabed in many parts of the world. So, it is obviously prudent to

beware of simple generalisations about the cost of shale gas compared with natural gas from other sources or with other fossil fuels, or even with renewable energy sources for that matter.

Yet, it is true that the prices of shale gas produced in the US in recent years have been strikingly lower than previous natural gas prices, and it is also true that shale gas prices have become a serious competitive threat to coal prices in the US. Based on the widely used Henry Hub benchmark price in the US, Figure 7 and Table 4 present international comparative price data for recent years, during which the increases in the extraction of low-cost US shale gas have driven down overall natural gas prices (the recession has also been a contributing factor). After generally increasing during the previous decade and more—albeit with much fluctuation around the trend—the US benchmark Henry Hub price peaked in 2008. From 2008 to 2012, the spot price of 1 million British thermal units (BTUs) declined 75 per cent from approximately USD 12 to about USD 3. See Baron (2013: Fig. 14) for additional international comparative price data. Although shale gas prices may increase over time (depending obviously on the path of demand relative to supplies), they are, nevertheless, widely expected to keep natural gas prices in total at relatively low levels in the US—low relative to their previous levels and low relative to other energy sources.

Figure 7: Natural Gas Prices: International Comparisons (USD per million BTU)^a

^a These are nominal US dollars and do not reflect PPP adjustments. However, these adjustments would not significantly change the patterns and trends over this short, recent time period (see discussion in the text).

Source: Compiled by the author from BP, *Statistical Review of World Energy 2012*; accessed at http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2012.pdf on 29 April 2013. Also see Baron (2013: Fig. 14).

What of the rest of the world? Figure 7 indicates clearly that prices have gone back up in Japan, Germany, and the United Kingdom (UK), which are all major natural gas users and importers, while US prices have remained low. In Table 4, which shows ratios of the cross-national differences, the dramatic shift in relative prices for Japan, in particular, is evident. While the US dollar price of Japanese imports in 2008 was about 40 per cent higher than the US domestic price, by 2011 it was nearly four times higher. Not surprisingly,

there is much interest in Japan in increasing imports of low-priced shale gas from the US; indeed, the largest Japanese electric utility TEPCO has signed a contract for exports from the US. Although the relative price changes for Germany and the UK have not been so great, they have, nevertheless, been enough to cause concern about shifts in the international competitiveness of major industries, such as chemicals, that are highly dependent on natural gas feed stocks in their production processes.

Table 4: Ratios of Natural Gas Prices in Japan, Germany, and the UK to US Prices^a

Year	2008	2009	2010	2011
Japan ^b	1.4	2.3	2.5	3.7
Germany ^c	1.3	2.2	1.8	2.6
UK ^d	1.2	1.2	1.5	2.3

^a These ratios are computed from the nominal US dollars in the data source. See Figure 5. The US reference price is the Henry Hub price.

^b Average import price, cif

^c Average import price

^d Heren NBP Index

Source: Compiled by the author from BP, *Statistical Review of World Energy 2012*; accessed at http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2012.pdf on 29 April 2013

These international comparative price data need three further refinements to convey more precisely the international competitiveness implications. Transport costs need to be taken into account. For the Japanese and German data, these are import prices, including cost plus insurance plus freight (CIF), but for the UK, they are domestic prices. Thus, for the UK, the cost of international transport needs to be added in comparisons with domestic prices to determine the competitive relationship between domestic gas and imported gas. The approximate cost of LNG international transportation is about USD 3 per million BTUs, which is less than the US-UK domestic price differences and thus the basis for international trade. In fact, a UK firm has signed a long-term contract for imports from the US.

In order to understand more clearly the international competitiveness impacts and the potential for international trade from the increasing production of shale gas, it is necessary to disaggregate further the international price differences to focus specifically on the international differences in the costs of production. Because shale gas production on a commercial basis has thus far occurred only in the US, it is not yet possible to make international comparisons on the basis of actual production data. However, the shale gas deposits in the US appear to be generally less deep and therefore cheaper to extract than those in Europe.⁴ Also, its greater experience with production and distribution, the more advanced state of the exploration and production technology, and the rapidly developing infrastructure are all likely to give the US a cost advantage for many years. Even if shale gas deposits in other countries turn out to be as great as or even greater than current estimates, it will be as much as a decade or more before the entire gamut of facilities and skills will make many countries' shale gas internationally competitive with the US.

There is yet another factor to take into account in analysing international price differences and their trade and competitiveness implications, namely changes in exchange rates and their relationship to cross-national differences in

inflation rates. If we consider, for instance, the data in Figure 7 and Table 4 above, which are based on the *BP Statistical Review of World Energy*, it is important to note that the prices are expressed in nominal US dollars.⁶ But, of course, foreign exchange (FX) rates and domestic prices changed over the three-year period represented. For these countries, therefore, we can adjust the comparisons taking into account three sets of purchasing power parity (PPP) data for the three currencies and national economies, relative to the US. If we compare 2011 with 2008, we find that, for Germany, the PPP FX EUR-USD conversion rate changed from 0.844 to 0.833 or only 1.3 per cent, and the GBP-USD PPP shifted only 2.2 per cent. Meanwhile, the JPY-USD PPP shifted 8.5 per cent (because of the yen's appreciation in real terms over the period). These are all quite small compared with the percentage increases in US dollar-denominated relative prices for natural gas compared with the US over the same period—namely 100 per cent for Germany, 92 per cent for the UK, and 164 per cent for Japan. After adjusting for the PPP and FX changes, the relative price of imported natural gas in Japan increased by about 155 per cent.

In sum, even after taking into account foreign exchange rate changes and cross-national differences in inflation rates as well as international transportation costs, the basic trend and pattern in the substantial decline in US relative prices of natural gas, compared with these three countries and many others over the past several years mark fundamental changes in the international gas markets. Moreover, they have significant implications for international competitiveness.

As for the future, although there are not sufficient data yet about the actual relative costs of shale gas production in different countries, there are reasons to think that the US will continue to be a low-cost supplier for many years and, therefore, that some industries will experience significant shifts in international patterns of competitiveness. A large-scale study commissioned by the US Department of Energy concluded that although

there would be some price increases for a few industries, such as chemicals, there would not be significant macroeconomic effects on the national economy.⁷ (Those results are being disputed, however, and there are likely to be additional studies.)

4.2 Producing, Consuming and Trading Countries

There are many questions about the future of trade in natural gas. Will Australia be a principal source of internationally traded natural gas in the Asia-Pacific region, especially through exports to China, India, and Japan? Will Argentina, Brazil, and Mexico become major exporters? To whom? Will the US become an important shale gas exporter? What impact will US shale gas use have on the international

competitive positions of firms in industries, such as chemicals, steel, and aluminium in the US and other countries? Will European dependence on natural gas imports from Russia and Qatar decline? Even though this is not an exhaustive list of questions, it is sufficient to convey the diversity and importance of potential trade patterns emerging over the next many years (perhaps decades).

The data presented in Table 5 make it possible to develop a simple outline of the basic patterns of recent international trade in natural gas, from whatever sources. Although the data implicitly include shale gas and other 'unconventional' forms, it is essentially a table of trade in 'conventional' natural gas, since the unconventional forms have hardly begun to emerge as traded commodities.

Table 5: International Trade in Natural Gas: Principal Countries (billions of cubic metres)

Regions/Countries ^a	Exports	Imports	Net
North America	4624	5161	-537
Canada	3108	1053	2055
United States	1507	3469	-1962
Central & South America	1374	921	453
Europe	7193	16381	-9188
France	23	1671	-1648
Germany	695	3085	-2389
Italy	4	2485	-2481
Netherlands	1972	813	1160
Norway	3436	0	3436
Spain	60	1253	-1193
Turkey	25	1551	-1525
United Kingdom	574	1876	-1302
Eurasia	8770	6250	2521
Russia	7808	1494	6314
Turkmenistan	0	1628	-1628
Ukraine	0	1582	-1582
Middle East	5213	1147	4066
Qatar	4015	0	4015
Africa	3557	214	3343
Algeria	1837	0	1837
Nigeria	917	0	917
Asia & Oceania	4241	9077	-4836
Australia	958	230	728
China	113	1108	-995
Indonesia	1366	0	1366
Japan	0	4113	-4113
Korea, South	0	1654	-1654
Malaysia	1169	70	1099
Subtotal of countries above (% world total)	29588 (85%)	35383 (90%)	
World^b	34972	39149	

^a Only countries with either exports or imports in excess of 1000 billion cubic feet have been included in order to highlight the principal trading countries and simplify the table. Nigeria was included because it is generally considered a principal exporter, though its 2011 exports were slightly below the 1000 cut-off point.

^b The discrepancy in world exports and imports is a result of differences in

Source: Compiled by the author from data in US Energy Information Administration, World Shale Gas Resources, 2011; the report was prepared by Advanced Resources International.

The trade patterns are highly—although not perfectly—regionalized. In Europe, there is some intra-Western European trade, consisting of exports from the Netherlands and Norway, but imports from Russia, Northern Africa, and Qatar are major sources. The major importers are obviously the large economies: Germany, Italy, France, Spain, and the UK. In the Asia-Pacific region, exports from Australia, Indonesia, and Malaysia mostly go to Japan, South Korea, and China. In the Western Hemisphere, natural gas

trade is dominated by imports to the US from Canada and Mexico.

Within these broad trade patterns, there are specific relatively large pairs of trading partners, which are earmarks of the natural gas trading system. They are displayed in Table 6, where the importance of pipeline trade between Canada and the US is evident, as are the pipeline shipments from Eastern Europe to Western Europe, especially Germany.

Table 6: Major Natural Gas Trading Partners^a (billion cubic metres, 2011)

Exporter	Importer	Amount ^b	Mode
Canada	US	88	Pipeline
Russia	Ukraine	41	Pipeline
Russia	Germany	31	Pipeline
Norway	Germany	28	Pipeline
US	Canada	27	Pipeline
Netherlands	Germany	24	Pipeline
Russia	Turkey	24	Pipeline
Norway	UK	22	Pipeline
Qatar	UK	22	LNG
Algeria	Italy	21	Pipeline
Malaysia	Japan	20	LNG
Australia	Japan	19	LNG
Qatar	UAE	17	Pipeline
Russia	Belarus	18	Pipeline
Qatar	Japan	16	LNG
Norway	France	15	Pipeline
Russia	Italy	15	Pipeline
Indonesia	Japan	13	LNG
Qatar	India	13	LNG
US	Mexico	14	Pipeline
Indonesia	South Korea	11	LNG
Kazakhstan	Russia	11	Pipeline
Qatar	South Korea	11	LNG
Bolivia	Brazil	10	Pipeline
Russia	Japan	10	LNG
Russia	Turkmenistan	10	Pipeline

^a Pairs of countries with 10 billion cubic metres or more (collectively 53 percent of total world trade)

^b Rounded to nearest billion from original source

Source: Compiled by the author from BP, *Statistical Review of World Energy 2012*; accessed at http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2012.pdf on 29 April 2013.

These patterns are relevant to the future of international trade in several respects. First, they are indicative of countries that already have in place the physical infrastructure and associated skills for importing or exporting. Individual LNG gasification facilities for export and de-gasification facilities for imports cost on the order of USD 10 billion to construct. Of course, they will need to be scaled up if there is significant additional trade in natural gas. Moreover, the differences between pipeline transport and LNG maritime shipping will be crucial determinants of the types of scaling up required. Second, the current patterns of trade provide benchmarks against which new shale gas trade levels can be compared to gain a better perspective on the energy and economic significance of absolute magnitudes of trade.

Japan is by far the biggest importer of LNG, since it has virtually no natural gas of its own and no pipelines for transport of imports. More than half of its imports are from Australia, Indonesia, and Malaysia. The Asia-Pacific region as a whole, including South Korea, China, India, Taiwan, and other countries in the region, in addition to Japan, gets about half of its LNG imports from Qatar, which is the world's biggest LNG exporter. Qatar also exports LNG to Europe, especially the UK. Algeria and Nigeria are also significant LNG exporters, particularly to France and Spain.

In sum, the international gas market has consisted to a great extent of three regions—Europe, North America, and increasingly, the Asia-Pacific region—with a great deal of intra-regional trade within them, but with some significant inter-regional trade as well, especially exports from North Africa, the Middle East, and West Africa.

These regionalised pipeline and LNG patterns—plus regional differences in pricing practices—have combined to create a regionally 'balkanized' world trade system in natural gas, with pipeline trade in Europe and North America physically separated from each other and the rest of the world. In that system, there have been large inter-regional differences in prices. However, a trend that will perhaps transform the system into a more nearly globally integrated system is in progress.⁵ Natural gas prices have

traditionally been set in long-term (i.e. 10-20 year) contracts, in which gas prices have been linked to oil prices.

In sum, the rapid increases in US production of low-cost shale gas, the prospect of eventually significant production of shale gas in other countries and exports of it in other countries, the potential for large-scale shipments of LNG at great distances, and the continuing growth in energy demand in Asia are all creating pressures toward more inter-regional trade.

4.3 International Trade Policies

US government policies concerning LNG exports are now under increased scrutiny after having been the concern for decades of a limited circle of industry specialists.

The Canada-US Free Trade Agreement (FTA) included a chapter on energy trade that guaranteed open access to bilateral imports and exports of oil, gas, and uranium. Exports of natural gas are generally subject to authorization on a case-by-case basis by the Department of Energy under the Natural Gas Act. However, after the FTA, the US exempted Canada from this requirement. This treatment was extended to 17 partners in later FTAs, including Australia, Bahrain, Chile, Colombia, Dominican Republic, El Salvador, Guatemala, Honduras, Jordan, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, Republic of Korea, and Singapore.⁷ There has been some discussion of the possibility of loosening these restrictions.

Domestic chemical firms and other manufacturers that use natural gas have put pressure on the government to limit exports in order to maintain the current relatively low price of natural gas, which is an important feedstock in their production processes. Some key members of the US Congress—including the Chairman of the Senate Energy Committee, Senator Ron Wyden—have also called for restrictions on exports. In May 2013, however, President Obama approved the construction and operation of a new export LNG facility to be developed by Exxon in Texas at a cost of about USD 10 billion.⁸

5. CONCLUDING REMARKS

5.1 Gaps in the Literature

It should be noted that, as this paper was being completed in October 2013, there was a rapidly expanding body of relevant studies and of course periodic updating of data. Observations about gaps in the literature may therefore have an unusually short half-life.

As of this writing, there are five topics that need further attention.

Advancing existing knowledge about the sources and levels of methane emissions—and the associated measurement methods, monitoring, and reporting systems—is essential to understand the full extent of the methane leakage problem. Research in progress in several organisations will surely be helpful, but a truly massive and ongoing effort is required. The continuing projects of the Environmental Defense Fund (2013) and World Resources Institute (e.g. Bradley et al., 2013) are especially important.

Also essential are technologies that could reduce or perhaps even eliminate the sources and levels of those emissions. The cost-effectiveness of the technologies, industry experience with them, and government regulatory policy options for addressing them are all open questions. Again, some progress is being made, but much more needs to be done to develop and apply the technologies.

Econometric studies on the impact of shale gas on investments in renewables, including solar and wind, as well as full-cycle comparisons of those alternatives for producing electricity are needed.

Also, as domestic consumption of coal declines in the US there will need to be studies on increases in US coal exports - and the extent to which CO₂ emissions in other countries offset or exceed decreases in the US. Trade in coal, like trade in natural gas, creates a need for more internationalised studies, including, in particular, a more precise understanding of

the shifting patterns of the GHG emissions in coal producing-exporting countries and coal consuming-importing countries.

We also need a better understanding of patterns and trends in the structure of the extracting, refining, and transporting industries, including, in particular, international mergers and acquisitions, and their implications for international technology transfer.

5.2 Policy Recommendations

The paper has addressed a wide variety of issues concerning shale gas. Among them, a few stand out as being particularly noteworthy and within the scope of ICTSD special concerns related to sustainable development and international trade. The following measures should, therefore, be undertaken:

- **Methane leakages**

Because fugitive emissions of methane, as a potent GHG, are inherently global in their consequences, they require global solutions. Therefore, there should be more comprehensive and precise MRV of methane emissions within the context of the UNFCCC.

- **International trade in natural gas, including shale gas**

There should be a comprehensive, worldwide system of verifying the levels of natural gas emissions associated with any international trade transactions in natural gas. Importers should be required to certify methane emissions levels, based on exporters' declarations, with the exporting government's confirmation and independent third-party verification. International standards of emissions for pipeline and LNG transport ought to be developed and implemented. This will probably require the involvement of two sets of industries, governmental agencies and international agencies—one set concerned with pipelines and the other with maritime shipping.

- **International trade in coal**

As production of coal for export replaces production for domestic consumption—in some countries at least—the challenges of computing, analysing, and reporting the sources of CO₂ emissions and the allocation of them to producing-exporting countries and importing-consuming countries become more pressing. Thus, there is a need to refine the MRV systems of the UNFCCC as well as other international agencies' reports and databases and in national government reports of emissions.

- **Investment in wind and solar and other renewable energy sources**

Subsidies can be legitimate means to address the positive externalities associated with renewable energy sources and enhance economic efficiency. While local content requirements attached to subsidies may be problematic, non-discriminatory subsidies are in a different category. Better understanding is needed concerning whether and how WTO rules would conflict with the use of non-discriminatory subsidies for renewable energy.

5.3 Venues for Dialogue and Action

These and other issues can be addressed in a broad array of existing venues with the expertise and the authority to consider them and take action.

Among international agencies, clearly the IEA and the Organisation for Economic Co-operation and Development (OECD) both have important roles to play, as they have already demonstrated in their conferences and publications, and their activities should be well funded. The IEA's work on the formulation of good industry practices and government policies to facilitate the development of a responsible and sustainable shale gas industry is especially noteworthy.

The Major Economies Forum on Energy and Climate (MEF) ought to play an important role as a policy discussion forum, and the associated Clean Energy Ministerial (CEM) should include shale gas issues in its activities.

Trade issues ought to be addressed at all levels of intergovernmental policymaking—bilateral, regional, plurilateral, and multilateral. The initiatives in these institutional contexts ought to be linked to the increasing interest in sustainable energy trade initiatives (SETIs). The negotiations for a Trans-Pacific Partnership (TPP) and a Transatlantic Trade and Investment Partnership (TTIP) are obvious venues for international cooperation on natural gas trade, investment, and technology transfer questions.

The expertise of the secretariat of the Energy Charter Treaty on topics associated with international trade through pipelines and in the form of LNG—and its work more generally on international trade and investment issues in natural gas—should enable it to make additional contributions to the understanding of technical issues associated with pipeline and LNG trade.

The International Standards Organization (ISO) should address standards and certification issues about fugitive methane releases.

In Europe, the combination of regional-level EU discourse and policymaking, plus the diverse array of the EU's national members and non-members as natural gas exporters and importers, offers a rich opportunity for developing approaches to industry practices and government policies that are sensitive to intercultural differences in attitudes toward sustainable development and to modes of international cooperation.

At the national level, because the US is where the technology, exploration, production, and infrastructure (and perhaps the policy discourse in some respects) are relatively advanced, it also has a special role to play; this should be the case, for instance, concerning international technology transfer practices and policies. As with all participants in the CEM, there are of course some technologies in which each country is a leader and others for which it is a laggard. There are, therefore, many opportunities for fruitful international learning processes.

At the local level, key questions about shale gas are largely about the implications of exploration and production for local public safety, health, employment, and quality of life. These questions ought to be addressed in local political processes to decide according to local priorities, within relevant subnational and national political-legal frameworks. At the same time, where there are nationwide concerns about these problems, national policymaking processes ought to be engaged. There should also be international arenas where such concerns and measures to address them can be discussed and coordinated.

In fact, where shale gas basins transcend international boundaries, safety, health, and environmental concerns are truly both local and international.

NGOs with expertise in health, safety, environmental, and/or trade issues ought to be involved in dialogs in multiple arenas, including in the design and implementation of health, safety, and environmental standards. For instance, they could be used for independent third-party verification that exports/imports meet such standards regarding exploration, extraction, and transport.

ENDNOTES

- 1 MITeI, IEA Outlook forecasts upheaval in worldwide energy system, 5 December 2012 (accessed at www.mitei.mit.edu on 10 September 2013).
- 2 PwC, “US Oil & Gas Deals Highlighted by Shale Plays, Foreign Investment, and Robust Private Equity Interest As Total Deal Value Increases 35%,” 2012, www.pwc.com (accessed on March 29, 2013); PwC, “M&A Deal Volume in The U.S. Oil & Gas Industry Reaches Highest Level in Ten Years During Fourth Quarter 2012, 2013,” www.pwc.com (accessed on March 19, 2013).
- 3 PwC, “PwC Says Fundamentals are Strong for U.S. Mergers & Acquisitions Activity in 2013, 2013 (accessed at www.pwc.com on 29 March 2013).
- 4 For a useful introduction to shale gas in an international context, see *Global Energy Assessment - Toward a Sustainable Future*. Cambridge, UK, and New York, NY, USA, Cambridge University Press, and Laxenburg, Austria, the International Institute for Applied Systems Analysis, 2012. For wide-ranging analyses of shale gas issues, see Bipartisan Policy Center, *Shale Gas: New Opportunities, New Challenges* (Washington, DC: Bipartisan Policy Center, 2012); International Energy Agency [IEA], *Are We Entering a Golden Age of Gas? World Energy Outlook 2011*, Special Report (Paris: IEA, 2011); International Energy Agency [IEA]. *Golden Rules for a Golden Age of Gas. World Energy Outlook 2012*, Special Report (Paris: IEA, 2012); Henry D. Jacoby, Francis M. O’Sullivan, and Sergey Paltsev, “The Influence of Shale Gas on U.S. Energy and Environmental Policy,” *Economics of Energy & Environmental Policy*, Vol. 1, (2012); Michael A. Levi, *The Power Surge: Energy, Opportunity, and the Battle for America’s Future* (New York: Council on Foreign Relations, 2013); and MIT, *The Future of Natural Gas* (Cambridge, Mass: MIT, 2012). For a focused presentation on exploration and drilling techniques, see Mark K. Boling, “Balancing Environmental, Social and Economic Impacts of Shale Gas Development Activities,” webinar presentation for The Yale Center for Environmental Law and Policy, (accessed at www.vimeo.com/58162903 on February 10, 2013).
- 5 Methane issues are discussed in James Bradbury, et al., *Clearing the Air: Reducing Upstream Greenhouse Gas Emissions from U.S. Natural Gas Systems* (Washington, DC: World Resources Institute, 2013); R.A Alvarez and others, “Greater focus needed on methane leakage from natural gas infrastructure,” *Proceedings of the National Academy of Sciences* 109 (2012): 6435-6440; Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, “Methane and the Greenhouse-Gas Imprint of Natural Gas from Shale Formations,” *Climatic Change*, vol. 106 (2011); Ajay Makan and Ed Crooks, “Shale gas boom now visible from space,” *Financial Times*, January 27, 2013; Daniel P. Schrag, “Is Shale Gas Good for Climate Change?,” *Daedalus* (2012); Wigley, Tom M.L., “Coal to Gas: The Influence of Methane Leakage,” *Climatic Change* vol. 108 (2011).
- 6 BP, *Statistical Review of World Energy, 2012*, http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2012.pdf (accessed on April 29, 2013).
- 7 NERA Consulting, *Macroeconomic Impacts of LNG Exports from the United States*. Report for the US Department of Energy (Washington, DC: US Department of Energy, 2012), www.energy.gov (accessed on April 30, 2013). Costa Rica and Israel have FTAs with the US but did not seek to have such energy provisions apply to them.

- 8 Two key documents concerning the shale gas policies of the current US administration are US President's Council of Advisors on Science and Technology, untitled letter to the president, March 2013 (accessed at www.whitehouse.gov/sites/default/files/microsites/ostp/pcast/pcast_energy_and_climate_3-22-13_final.pdf on 25 March 2013); and US Department of Energy, Secretary of Energy Advisory Board Subcommittee Releases Shale Gas Recommendations, August 11, 2011 (accessed at www.energy.gov on 27 July 2013).

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