4. FINDINGS

A. *Chinese shale gas production in the next few years will not be substantial. After that, low growth and high growth scenarios are both plausible.*

In our interviews, we found consensus on one point: that Chinese shale gas production in the next few years will not be substantial. We agree with that assessment. Building an industrial supply chain, training personnel, negotiating commercial arrangements and developing technologies to address unique Chinese circumstances will all take time. Implementing reforms that help promote shale gas production, including market-based natural gas pricing, will take time as well. Some observers we spoke with noted that the United States' success with shale gas production did not happen overnight and that China will require several years to put the pieces in place for significant shale gas production.

With respect to the medium and long-term, we found widely divergent views about the prospects for Chinese shale gas development. Some stakeholders were enthusiastic, describing shale gas as an important growth sector with strong prospects for contributing to economic growth, energy security and air quality in China. Others were cautiously optimistic. Many predicted the government's 2015 production target of 6.5 bcm will be met, and some said the 2020 production target of 60–100 bcm will likely be met as well.[1] This is a marked change from one year ago, when most stakeholders in a similar round of interviews expressed considerable skepticism about the prospects for meeting either target.

Nevertheless, we found a significant current of deep skepticism about the medium and long term prospects for shale gas production. Several stakeholders emphasized that, in their view, production of shale gas in China will be far more difficult than in the United States, citing the nature of Chinese source rock, terrain and other factors. Several of these stakeholders highlighted the need for significant technological innovation before shale gas can be produced at a profit in China. Several also noted the lack of data available to shale gas producers in China, contrasting that with publicly available geologic and production in the United States.[2]

These divergent views are reflected in the published literature. Some sources project significant growth in Chinese shale gas production in the years ahead. A Standard Chartered report released in 2013, for example, projects that China will reach its target of 60 bcm (2.118 Tcf) of shale gas production by 2020 and that, by 2030, shale gas will be the largest component of China's domestic gas supply.[3] A paper released by several MIT authors in 2013 is also generally optimistic about long-term prospects for the industry, discussing a model that, under different scenarios, shows shale gas production reaching 140–200

[1] http://www.reuters.com/article/2014/06/13/us-breakingviews-energy-shale-idUSKBN0EO16F20140613 (Sinopec and PetroChina recently announced new shale growth forecasts that would exceed a government target of 6.5 bcm of shale production by 2015). But see Suttikulpanich et al., "China Shale Gas: Potential Unearthed," predicting that the 2015 target will not be met but the 2020 target will be.

[2] Underscoring this skeptical strain, on August 7, 2014, Reuters reported that NEA had cut China's 2020 production target for shale gas to 30 bcm. Aizhu et al., "China Finds Shale Gas Challenging," at note 45. As of this writing, NEA has not issued any official announcement changing its production target.

[3] Suttikulpanich et al., "China Shale Gas: Potential Unearthed," pp. 53–54, at note 30.

bcm/year (13–19 bcf/day) in 2030 and roughly 700–900bcm/year (68–87 bcf/day) in 2050.[4]

Other reports are more skeptical or project slower growth. A 2014 report by the International Energy Agency — while predicting that China will likely reach its 6.5 bcm (229 bcf) target by 2015 — predicts that China will reach only half its 60 bcm (2.12 trillion cubic feet) target by 2020.[5] A Harvard and Rice University joint report from 2013 predicts that the 6.5 bcm-by-2015 production goal will not be met and says "meeting Beijing's 2020 target of 60–100 bcm will be extremely difficult."[6] A 2012 report released by the Oxford Institute for Energy Studies predicts that shale gas development in China is likely to grow quite slowly, reaching 10 bcm/year in 2020.[7] In a 2012 paper, a Peking University study agreed with this projection and predicts 10 bcm/year of China's shale gas production level in 2020 and 60 bcm/year in 2030.[8] BP's Energy Outlook 2030 also projects shale gas production to be around 60 bcm/year by 2030.[9]

As if to highlight these diverging views, on a single day in August 2014 one major Western news organization released a story with the headline "China Drastically Reduces Its Ambitions to Be a Big Shale Gas Producer" and another ran a story with the headline "Chinese Energy Giants Turn Upbeat on Shale Gas."[10]

B. Key barriers to growth include high initial production costs, weak incentives for state-owned enterprises, lack of competition, restrictions on foreign businesses and limited data availability.

Initial production costs at Chinese shale gas sites are high. Those costs are the product of challenging geology (including composition, depth and fracture history), difficult surface

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[4] Sergey Paltsev et al., Shale Gas in China: Can We Expect a Revolution? (April 2013), p. 12, Massachusetts Institute of Technology, https://www.gtap.agecon.purdue.edu/resources/download/6387.pdf.
[5] IEA, Medium-Term Gas Market Report 2014 (June 10, 2014), http://www.iea.org/w/bookshop/add.aspx?id=473 **[needs confirmation]**
[6] Trevor Houser and Beibei Bao, The Geopolitics of Natural Gas — Charting China's Natural Gas Future (October 2013), p. 27, Harvard University's Belfer Center and Rice University's Baker Institute Center for Energy Studies, http://bakerinstitute.org/media/files/Research/07a18d60/CES-pub-GeoGasChina2-103113.pdf.
[7] Gao, Will There be a Shale Gas Revolution, p. 40, in note 77.
[8] Dazhong Dong et al., Experience from Global Shale Gas Development and the Long Term Overview of Developments in China (2012), p. 74, Peking University, http://www.enginsci.cn/chinaes/ch/reader/create_pdf.aspx?file_no=20120419003&year_id=2012&quarter_id=6&falg=1.
[9] BP Energy Outlook 2030, p. 47, January 2013, http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/BP_Energy_Outlook_Booklet_2013.pdf.
[10] "China Drastically Reduces Its Ambitions to Be a Big Shale Gas Producer," Economist (August 30, 2014) (accessed online August 29), http://www.economist.com/news/business/21614187-china-drastically-reduces-its-ambitions-be-big-shale-gas-producer-shale-game; Zhu, "Chinese Energy Giants Turn Upbeat" in note 2.

conditions, limited technical expertise, a young industrial supply chain and other factors. Current shale gas developers are losing money on each well drilled.[11]

High costs are not unusual for new technologies or technologies introduced in new situations. Production costs at Chinese shale gas sites can be expected to decline as expertise improves, the supply chain matures and the industry scales. However, some of the drivers of high costs — including the challenging geology and difficult surface conditions — may require technological innovations unique to the Chinese context. Whether those innovations emerge rapidly enough to spur growth in the industry is an important open question. The pace at which high production costs can be reduced will be a central factor determining the pace of Chinese shale gas development.

In one respect, the dominant role of state-owned enterprises in the Chinese shale gas sector helps to manage the problem of high initial costs.[12] CNPC and Sinopec, in particular, are hugely well-capitalized companies with the ability to absorb substantial losses. Their objectives are broader and more complex than those of public U.S. companies focused primarily on maximizing shareholder return. However, the incentives for SOEs to invest in shale gas operations may be limited. SOEs may do the amount needed to satisfy government mandates, but be reluctant to divert resources from their core business with low likelihood of short- or medium-term profit. The upside for investing risk capital in speculative operations may not seem compelling.

In the United States, the shale gas industry was developed by risk-taking entrepreneurs seeking large returns. In China, potential shale gas entrepreneurs face difficulties gaining access to good acreage and pipelines, among other problems. China's oil and gas resources are mostly controlled by large SOEs, leaving smaller companies with a much narrower range of opportunities in upstream development. Pipelines are held by the large SOEs, with only limited obligations to make them available to others. The extra expense of truck shipment may be required to bring gas to market.

The challenges facing foreign companies are even greater. Foreign companies have expertise, technology and capital that could be enormously helpful in developing China's shale resources, but they face significant restrictions on their ability to participate in the Chinese market. Foreign companies have in practice not been allowed to participate in shale gas bid rounds, for example. To gain access to Chinese acreage, foreign companies must help their NOC partner obtain access to acreage for oil and gas production outside of China, delaying projects and preventing some IOCs from participating in the Chinese shale gas sector.

At present there is a limited global supply of know-how available for shale gas production. Companies with shale gas expertise and technology are able to choose among countries with the most promising returns. In our interviews, we heard little to suggest that the Chinese government or industry sees itself in a competition for the know-how and technology required to develop shale gas. Instead, there tends to be an expectation that foreign businesses that possess such know-how and technology will work to adapt

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[11] According to one estimate, Sinopec and CNPC's short-term losses from shale gas drilling through the end of 2013 are close to $1 billion. See Lei Tian et al., Stimulating Shale Gas Development, p. 4, at note 1.

[12] See discussion in ibid.

themselves to the Chinese context. This orientation may be a barrier to rapid development of shale gas in China, in light of the considerable returns available elsewhere to those who already possess shale gas know-how. One successful U.S. shale gas entrepreneur told us bluntly: "I have no interest in working in China. The business environment there is too uncertain. Why should I deploy capital there instead of the United States?"

Lack of data is also a barrier. In the United States, the public availability of well logs and production data has been important to the shale gas industry's success. In China, there is no obligation to share or disclose such data, most of which is in the hands of state-owned enterprises. Indeed, some oil and gas data have been considered state secrets, creating risks for those working in this area. The lack of data slows the movement of capital and personnel to the best locations, increasing costs and lengthening the time needed for shale gas production.

C. *Government policies will play a central role in determining the growth of the Chinese shale gas sector in the years ahead.*

Geology and policy will be the most important factors shaping the growth of the Chinese shale gas sector. Much about the geology of Chinese shale and its suitability for natural gas production is unknown (and much of what is known is proprietary). An analysis of that issue is beyond the scope of this paper. But whether geologic conditions in China prove to be favorable for shale gas production or more challenging, government policies will play a critical role in the growth of the sector.

As a starting point, the Chinese government of course plays a central role in the country's economy.[13] Although China's transition from a planned to market economy has been dramatic, the government's role in China's economy is still substantial. That is especially so for the energy sector. China's Five-Year Plans establish directions and set targets that shape China's energy industries. State-owned enterprises dominate the energy sector, including in oil and gas. Government ministries set rules concerning land use, foreign partnerships and other matters with far-reaching impacts on the energy sector.

The growth of China's shale gas industry will be shaped by at least three broad factors.

A first factor is the extent of explicit policy support for shale gas. As detailed in Section 3(C) above, the central government currently supports shale gas with production targets, a production subsidy and other policies. The target is rumored to be under revision,[14] and the subsidy expires in 2015. The target has been an important driver of shale gas production in the past year, and the subsidy assists the NOCs with the considerable costs of early-stage shale gas development. How these policies and others are continued during the period of China's 13th Five-Year Plan (2016–2020) will have a material impact on the industry.

A second factor will be the progress and details of economic reforms. President Xi Jinping's ambitious and far-reaching reform agenda includes many elements important to the development of shale gas, including market-based allocation of resources, reform of the

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[13] See generally World Bank, China 2030 (2013), http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/03/27/000350881_20130327163105/Rendered/PDF/762990PUB0china0Box374372B00PUBLIC0.pdf.
[14] Aizhu et al., "China Finds Shale Gas Challenging," at note 45.

state-owned enterprises, land reform and strengthening environmental regulations. The pace of progress and specific details of these reforms will shape development of the shale gas industry in important ways.

A final factor is the commitment to innovation. Growth in China's shale gas sector will require innovation, as technologies and approaches developed in the U.S. context are applied in China. Some of these innovations may be relatively straightforward, such as transport equipment redesigned for mountainous conditions. Others may be more challenging, such as new hydraulic fracturing techniques to respond to China's unique geology. Foreign partners can help contribute to innovation, if given incentives and allowed to do so. The extent to which China creates conditions in which innovations and innovators can thrive will be central to the growth of the Chinese shale gas sector.[15]

D. The environmental impacts of Chinese shale gas production could range from highly positive to highly negative.

Shale gas has the potential to displace coal-fired power generation in China, helping fight global warming and urban smog. Burning shale gas for power reduces carbon emissions (the major cause of global warming) by roughly 50% and particulate emissions (the major cause of China's smog) by more than 99%, as compared to burning coal.[16]

Shale gas also has the potential to displace gasified coal (sometimes called synthetic natural gas or SNG), which could deliver even bigger environmental benefits. Burning SNG for power generates *more* greenhouse gas emissions than a coal plant, on a lifecycle basis. Using SNG as a chemical feedstock or for other purposes also generates high greenhouse gas emissions. China is investing heavily in SNG, with at least nine large-scale SNG plants approved.[17] To the extent that shale gas slows the pace at which SNG plants are built or used in China, the environmental benefits could be significant.

How much carbon reduction could Chinese shale gas deliver? If 100bcm of shale gas (the upper end of the central government's 2020 production target) were all used to displaced coal-fired power generation, carbon emissions would be reduced by approximately 310 million metric tons — roughly 2.5% of China's projected greenhouse gas emissions for that year.[18] These amounts would grow with additional shale gas production.

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[15] On innovation, see Section 5D below. On the role of policy in shale gas development generally, see IHS CERA, Unconventional Frontier — China (2012), p. E-3 ("Government policy is crucial**.** Energy policy will be at least as important as geology in shaping the future of unconventional gas. Rationalization of the regulatory environment is necessary to expedite the takeoff of unconventional gas production."); Beijing Energy Club, Enabling Policy and Regulatory Conditions for Successful Shale Gas Development in China (November 16, 2012) (Reform of policy and regulatory conditions is the key to success for China's shale gas development)

[16] US EIA, Natural Gas 1998 (April 1999) at p.53, http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_trends/pdf/it98.pdf. See also http://naturalgas.org/environment/naturalgas/.

[17] See Chi-Jen Yang and Robert B. Jackson, "China's Synthetic Natural Gas Revolution," Nature Climate Change (October 2013), http://people.duke.edu/~cy42/SNG.pdf.

[18] See Explanatory Note in Attachment D.

Yet the actual situation will be more complicated. Not all shale gas produced in China will be used to replace coal-fired power generation. Indeed, the provinces with the strongest initial prospects for shale gas production — Sichuan and Chongqing — use less coal in power generation than the national average.[19] Shale gas there and elsewhere might be used as a chemical feedstock, for transportation or for other purposes. This could result in larger or smaller carbon reductions than displacing coal-fired power generation, depending on a number of factors, including whether the shale gas is displacing SNG. Further analysis is needed.

With respect to the potential global warming benefits of shale, an important offsetting factor is methane leakage. Methane — the principal component of natural gas — is 34 to 86 times more potent than carbon as a greenhouse gas.[20] Methane emissions from natural gas systems can be significant. Substantial research is currently underway to better understand the nature and extent of methane leakage from U.S natural gas systems, including from upstream shale gas production. While one recent U.S. study found that "system-wide leakage is unlikely to be large enough to negate the climate benefits of coal-to-natural gas substitution," another found methane emissions from a few well pads to be hundreds to thousands of times greater than U.S. EPA estimates.[21] In order for Chinese shale gas production to deliver global warming benefits, fugitive methane emissions must be minimized.

Water pollution is also a concern. Hydraulic fracturing fluids contain proppants (including sand), thickeners, friction reducers, biocides and corrosion inhibitors. Wells also contain water from within the subsurface rock formation, often high in salts, heavy metals and volatile organic compounds such as benzene. Both hydraulic fracturing fluids and water from within the formation flows back to the surface through the well and must be disposed

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[19] In Sichuan, roughly 60% of power production typically comes from coal. In Chongqing, the figure is roughly 45%. See Adam Worthington, "Chinese Power and Energy," (Macquarie, July 17, 2012), pp. 33–42. (Figures based on adding adjusted capacity figures for each fuel, averaged between winter and summer months, and dividing by the total. These percentages will vary, month to month and year to year, depending mainly on hydro resources.)

[20] For time horizons between 20 and 100 years. See IPCC Fifth Assessment Report Working Group 1, Chapter 8: "Anthropogenic and Natural Radiative Forcing" (table 8.7, p. 714) http://www.climatechange2013.org/images/report/WG1AR5_Chapter08_FINAL.pdf.

[21] See A. R. Brandt et al., "Methane Leaks from North American Natural Gas Systems," Science (February 14, 2014) (Official inventories in North America consistently underestimate methane emissions from the overall natural gas system, yet "system-wide leakage is unlikely to be large enough to negate climate benefits of coal-to-NG substitution"); Dana Caulton et al., "Toward a Better Understanding and Quantification of Methane Emissions from Shale Gas Development," PNAS Early Edition (March 2014) (emissions from several shale gas well pads observed from aircraft found to be two to three orders of magnitude greater than U.S. EPA estimates); David Allen et al., "Measurements of Methane Emissions at Natural Gas Production Sites in the United States," PNAS Early Edition (August 2013) (Direct measurement at 190 onshore natural gas production sites in the United States finds total emissions similar to most recent EPA inventory of methane emissions); F. O'Sullivan and S. Paltsev, "Shale gas production: potential versus actual greenhouse gas emissions," Environmental Research Letters (2012) (Fugitive emissions from fracking are likely less than previously thought); Robert Howarth et al., "Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations," Climatic Change (2011) (methane emissions from hydraulic fracturing of shale formations at least 30% greater than from conventional natural gas production).

of. Studies of the Marcellus shale have shown high levels of barium, bromide, radium-228, strontium and salts in flowback and produced waters. [22]

Some of this polluted water can be reinjected into shale wells, with estimates ranging from 10 to 80%.[23] Increased recycling can reduce the volume of polluted effluent requiring treatment and/or disposal (as well as overall water use). However, water recycling also increases the concentration of some pollutants in the water later discharged.

Technologies exist to manage shale gas production with little water pollution. However, there are questions about the extent to which such technologies will be used in China. The United States has a robust system for protection of surface water quality, with standards, permitting requirements and enforcement officials. China's infrastructure for protecting water quality is much more limited. Several recent reports contain recommendations for protecting U.S. water quality in shale gas development, including institutionalizing water risk management within companies, brackish water use and recycling, limiting deep disposal wells and increasing water treatment and developing comprehensive water protection plans and increasing stakeholder engagement.[24] These recommendations are worth examining for potential application in the Chinese context.

Earthquakes are another concern. Hydraulic fracturing does not cause earthquakes, but disposal of produced water (from conventional or unconventional production) in deep underground injection wells has been shown to induce seismicity.[25] Although these earthquakes have been minor, any human-induced seismicity could become extremely controversial in some of the shale-abundant regions in China. Sichuan, the province that is ranked first in terms of shale gas reserve, lies at the edge of the largest continent-continent collision in the world and has suffered two major earthquakes during the past five years.[26] In 2008, Wenchuan city in Sichuan suffered one of the most serious earthquakes in China's history, during which nearly 70,000 people were killed. A study conducted by the Earthquake Administration Bureau of Sichuan, Hebei and Zigong Municipality from 2007 to 2010, found that more than 2,700 seismic events were recorded near an underground injection well in Zigong, Sichuan.[27] At present, seismic vulnerability is not required as part of the standard environment assessment for oil and gas projects.[28] As shale gas production grows in Sichuan, clearer regulation will be needed before the subject becomes increasingly controversial.

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[22] Yusuke Kuwayama et al., "Water Resources and Unconventional Fossil Fuel Development," (Resources for the Future, 2013), pp. 4–5.
[23] Ibid, p. 4.
[24] Monika Freeman, "Hydraulic Fracturing & Water Stress: Water Demand by the Numbers," CERES, February 2014, pp. 38–45.
[25] Nicholas J. van der Elst et al., "Enhanced Remote Earthquake Triggering at Fluid-Injection Sites in the Midwestern United States," Science, July 12, 2013: vol. 341, no. 6142, pp. 164–67, http://www.sciencemag.org/content/341/6142/164.abstract.
[26] Benjamin Haas, "China Fracking Quake-Prone Province Shows Zeal for Gas," August 1, 2013, http://www.bloomberg.com/news/2013-07-31/china-fracking-quake-prone-province-shows-zeal-for-gas.html.
[27] Zhi-Wei Zhang et al., "Study on Earthquakes Induced by Water Injection in Zigong-Longchang Area, Sichuan." Chinese Journal Geophysics, 2012 (5), pp. 1635–45, http://manu16.magtech.com.cn/geophy/CN/abstract/abstract8667.shtml.
[28] Law of the People's Republic of China on Evaluation of Environmental Effects (Order of the President No.77), October 28, 2002, http://english.gov.cn/laws/2005-10/09/content_75327.htm.

At present, there are no specific environmental regulations with respect shale gas in China. An NEA official recently said, "Up to now, China has yet to experience any incident of environmental pollution associated with shale gas exploration and development. We will be actively involved in the development of standards and legislation on shale gas development."[29]

E. Water supply constraints could be a factor in some regions in the medium and long term.

Shale gas production uses large amounts of water. In the United States, shale gas wells use roughly 3 to 4 million gallons of water per well and up to 6 million gallons in deep formations.[30] Water use varies considerably by type of formation: pure gas plays generally involve less water per well than associated gas plays.[31] Horizontal wells use more water than vertical wells on average, partly because such wells may have horizontal sections thousands of feet long.

Shale gas production in China will likely require more water per unit of gas produced than in the United States, because of the depth of China's shale. However China faces substantial challenges in managing its water supplies. On a per capita basis, China's water resources are roughly one-fourth of those in the U.S. and one-third the global average.[32] The recent drought in South China underscores the country's vulnerability to water stress. These factors suggest that water supply could become a constraint on Chinese shale gas development.

Yet water supply is not likely to be a significant constraint on overall Chinese shale gas production in the short term. The regions where most initial shale gas production is taking place — Sichuan and Chongqing — have large water endowments. Water use there is small compared to water availability. One recent study found that current residential, commercial and industrial activities use roughly 10% of Sichuan's available water resources.[33] The same study found that less than 0.1% of water resources in most regions would be needed to meet the demand for water to produce shale gas.[34] Another study found that to produce 40

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[29] Presentation by Xiaolong Li, NEA, July 1, 2014

[30] Suttikulpanich et al., "China Shale Gas: Potential Unearthed," p. 19, at note 30. See also "Draft Plan to Study the Potential Impacts of Hydraulic Fracturing in Drinking Water Resource," U.S. Environmental Protection Agency, Feb. 7, 2011, (table 3, p. 19); Matthew E. Mantel, "Produced Water Reuse and Recycling Challenges and Opportunities Across Major Shale Plays," Chesapeake Energy Corporation, presentation delivered at the EPA Hydraulic Fracturing Study Technical Workshop #4, Mar. 29, 2011, p. 5. According to FracFocus.org, the average U.S. well between January 2011 and May 2013 consumed 2.5 million gallons of water. See Freeman, "Hydraulic Fracturing & Water Stress, in note 120. See generally Water and Shale Gas Development (Accenture 2012), http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-Water-And-Shale-Gas-Development.pdf

[31] Matthew E. Mantel, "Produced Water Reuse and Recycling Challenges and Opportunities," p. 5, in note 126.

[32] Scott Moore, "Water Resource Issues, Policy and Politics in China" (Brookings, February 12, 2013), http://www.brookings.edu/research/papers/2013/02/water-politics-china-moore#_edn2; World Bank, "Renewable internal fresh water resources per capita" 2012, http://data.worldbank.org/indicator/ER.H2O.INTR.PC.

[33] Suttikulpanich et al., "China Shale Gas: Potential Unearthed," p. 41, at note 32.

[34] Ibid., pp. 38, 41.

bcm of shale gas in 2020, China would need 40 billion gallons (150 million cubic meters) of water annually — roughly 0.5% of national water consumption.[35]

In addition, shale gas production uses *less* water per unit of energy than coal mining.[36] Combined-cycle natural gas turbines use less water than coal-fired power plants. (According to one source, one hydraulic fracturing operation uses about the same amount of water as a 1000 MW coal plant uses in 10 hours.)[37] To the extent that shale gas displaces coal production, there may be net savings in water use. Furthermore, China is rapidly developing coal-to-gas plants, which are estimated to consume roughly 60 times as much water as shale gas per unit of natural gas produced.[38] To the extent that shale gas displaces coal — and in particular coal-to-gas plants — shale gas may provide a significant water savings.

However water supply could become a constraint on Chinese shale gas production in the medium or long term. First, water supply in China is unevenly distributed. Some shale-rich regions — including in particular the Tarim Basin — have very limited water supplies. As shale gas production scales up in those regions, water supply will be an important factor. Second, water supply varies from year to year. Droughts could create challenges for shale gas production. Shale gas development plans should reflect large potential inter-annual variation in water supplies.[39]

In addition, water is a highly localized resource. Even in provinces with ample water supplies, a sudden surge in shale gas development in rural areas could overwhelm local water supplies and related infrastructure. Sichuan and Chongqing are highly populous, even in rural areas, and shale production may compete directly with agricultural and residential uses in some locations. Furthermore, water consumption in shale gas production is episodic, not continuous. Some localities may be unprepared for a sudden surge in water consumption at a well.

In both the United States and China, interesting work is underway to minimize water use in shale gas production, as well as to find fluids or gases (such as propane or CO_2) to replace

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35 Gao, Will There Be a Shale Gas Revolution, in note 77.

36 E. Mielke, L. D. Anadon and V. Narayanamurti. "Water Consumption of Energy Resource Extraction, Processing, and Conversion," 2010. See http://www.wri.org/blog/2013/10/china%E2%80%99s-response-air-pollution-poses-threat-water for graph.

37 Lisa Genasci, "Is Fracking the Answer for Water Scarce China" (China Water Risk, October 10, 2012), http://chinawaterrisk.org/resources/analysis-reviews/is-fracking-the-answer-for-water-scarce-china/.

38 Chi-Jen Yang, "China's Synthetic Natural Gas Revolution," Nature Climate Change, vol. 3, October 2013.

39 See Paul Reig et al., Global Shale Gas Development: Water Availability & Business Risks (World Resources Institute, September 2014), http://www.wri.org/sites/default/files/wri14_report_shalegas.pdf. See also http://www.wri.org/sites/default/files/uploads/china_sng_updated.png and http://www.ogj.com/articles/print/vol-110/issue-3/exploration-development/china-vigorously-promoting.html; http://www.circleofblue.org/waternews/2012/world/chinas-water-reserves-and-worlds-warming-atmosphere-wait-for-natural-gas-breakthrough/.

water in hydraulic fracturing. This could be a valuable topic for work by the U.S.-China Clean Energy Research Center.[40]

F. The U.S. and Chinese governments share common interests with respect to shale gas.

The U.S. and Chinese governments work closely together on shale gas. This cooperation has support at the highest levels. On November 17, 2009, in Beijing, Presidents Barack Obama and Hu Jintao announced a new U.S.-China Shale Gas Resource Initiative. The White House fact sheet reported that:

> The two Presidents announced the launch of a new U.S.-China Shale Gas Resource Initiative. Under the Initiative, the U.S. and China will use experience gained in the United States to assess China's shale gas potential, promote environmentally-sustainable development of shale gas resources, conduct joint technical studies to accelerate development of shale gas resources in China, and promote shale gas investment in China through the U.S.-China Oil and Gas Industry Forum, study tours, and workshops.[41]

In the years since, bilateral work has been extensive and wide ranging. The U.S. Department of Energy, U.S. State Department, U.S. Trade and Development Agency and other federal agencies have worked with the National Energy Administration, Ministry of Land and Resources, provincial governments and others on meetings, workshops and delegation visits covering a range of shale gas topics. Topics discussed have included U.S. federal policies and regulations, U.S. state policies and regulations, characterization and assessment of shale gas resources, drilling and completion, cost saving in shale gas development, Production Sharing Contracts, geopolitical issues and more. Private companies and SOEs have been core participants in many of these events.

This joint work is fueled by common interests. The Chinese government gives priority to the development of China's shale gas sector in order to help fight air pollution and reduce reliance on natural gas imports. The U.S. government supports the sustainable development of China's shale gas sector for a range of economic, environmental and geostrategic reasons. First, Chinese shale gas development offers export opportunities for U.S. companies. Second, Chinese shale gas development could deliver global environmental benefits — in particular, lower carbon emissions. (U.S. technical expertise could help reduce fugitive methane emissions at production sites, improving the likelihood of global warming benefits from Chinese shale gas development.) Third, Chinese shale gas could reduce pressure on global gas markets and in the long term reduce China's dependence on both Iran and Russia as energy suppliers.

The two governments share common interests with respect to the U.S. shale gas sector as well. The United States welcomes foreign investment, including in the shale gas sector.

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[40] Peter Marsters, "A Revolution on the Horizon: The Potential of Shale Gas Development in China and Its Impact on Water Resources," in Jennifer Turner et al. (eds.), China Environment Series: Special Water and Energy Issue, Wilson Center, 2012/2013, pp. 40–42. With respect to the US-China Clean Energy Research Center, see http://www.us-china-cerc.org/ and Section 5D below.

[41] "U.S. China Clean Energy Announcements," Office of the Press Secretary, The White House (November 17, 2009), http://www.whitehouse.gov/the-press-office/us-china-clean-energy-announcements

Chinese companies seek opportunities for profitable investments abroad, as part of China's "going out" strategy, as well as technology acquisition. The result has been over $8 billion of Chinese investment in the U.S. shale gas sector.

Not all parts of the U.S.-China energy relationship enjoy such a range of joint activities and common interests. The two governments have sparred over solar trade policies, with disputes adjudicated by the World Trade Organization. Disagreements concerning cyber espionage and intellectual property theft in the energy sector have contributed to broader tensions in the bilateral relationship.

Nor are relationships in the shale gas sector entirely free of discord. The U.S. government has urged the Chinese government to remove restrictions on U.S. companies operating in the Chinese shale gas sector, for example. But in general the U.S.-China shale gas relationship is characterized by productive activities and common interests. In this regard, shale gas is similar to other energy topics on which the U.S. and Chinese governments have often if not always worked productively together in recent years, including civil nuclear programs, strategic petroleum stocks and the U.S.-China Clean Energy Research Center.