Prospects for shale gas production in China: Implications for water demand

Supporting Information (SI) for
Prospects for Shale Gas Production in China: Implications for Water Demand

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1. Schematic diagram for lateral well spacing (*d*) at Fuling Field

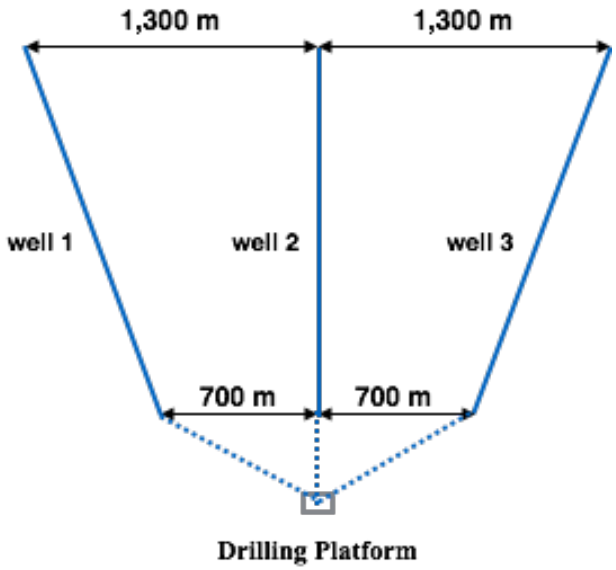

Figure s1. Schematic diagram for lateral well spacing (*d*) adopted in the development of shale gas wells at Fuling Field (from Zhou [s1]).

2. Estimation of temporal water use at Fuling

To estimate the water use from 2015 to 2020, we employ equations (1) and (2) to connect water use with the number of new wells required to achieve the annual production goal set by Sinopec.

$$Pgas_n = \sum_{t=1}^{n} Nt_{f\,n-t+1} \quad (1)$$

$$WU_n = Nn \times L \times I \quad (2)$$

Pgas(n): total production of shale gas production in n^{th} year since 2014; *Nn*: the number of new wells developed in n^{th} year since 2014;

L: the average lateral length of wells developed in China, 80 m;

I: water intensity estimated for shale plays in China

$f(n-t+1)$: a function defines the production of shale gas varies with the operating years of the shale wells. It is expressed as $fx=0.0011x4-0.07x3+1.7x2+17.9x+79.6$.

It is assumed that the function follows a declining curve as in Figure s1. The production curve for shale-gas wells in Fuling was drawn according to the data supplied by Sinopec's managers. Fuling shale gas wells generally reach their maximum output during the first two years after completion, with production declining by a factor of 2 in each of the following three years and decreasing more slowly during later years. This is described by a four order polynomial function shown in Figure s2. We estimate the number of new wells required to achieve production goals using equation (1). Results are shown in Figure s3. Finally, we can calculate the water use over time.

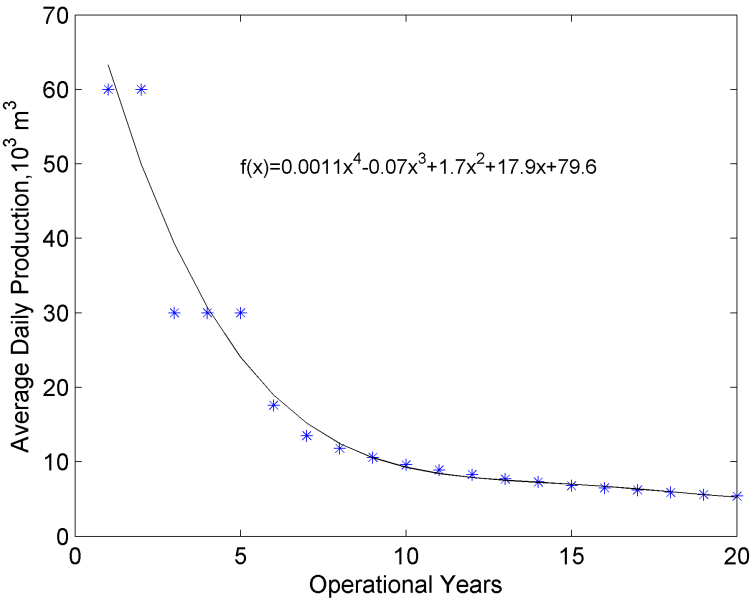

Figure s2. Production curve of a single shale gas production well at Fuling Field

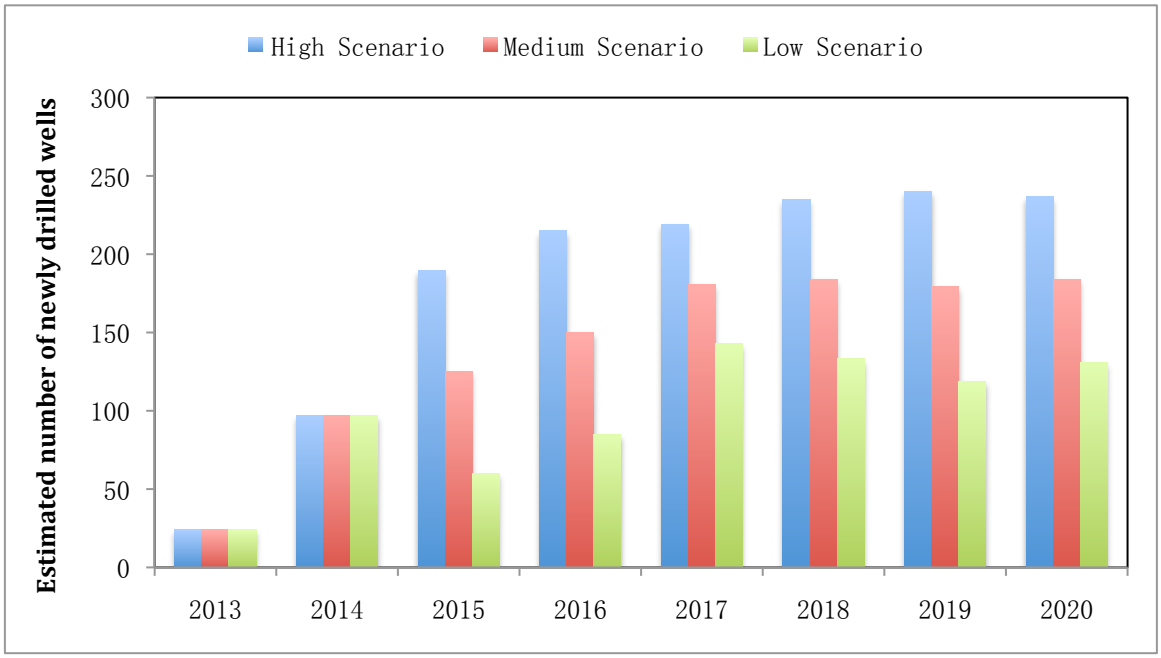

Figure s3. Estimation of the number of newly drilled wells

3. China's Seven Most Promising Shale Gas and Shale Oil Basins

According to EIA/ ARI's assessment report [s2], seven shale basins are most promising in China in terms of both shale gas and shale oil, i.e., Jianghan, Junggar, Sichuan, Songliao, Subei, Tarim, and Yangtze Platform. The geologic properties of these seven basins are sumarized in Table s1. The other three potential shale basins, Turpan, Qaidam and Ordos, are not included in this paper due to lack of data.

Table s1. The geologic properties of China's seven most prospective shale basins (Source: EIA/ARI report, 2013 [s2])

Shale Basin	Gross Area (km^2)	Prospective Area (km^2)	Average Depth (km)	Thickness (m)	Risked Recoverable (tcm)
Greater Subei	142,450	48,325	3.4	175	1.4
Junggar	160,839	41,440	3.3	250	1.1
Sichuan	192,933	97,047	3.5	184	18.8
Jianghan	27,400	18,156	3.1	165	0.8
Tarim	606,578	163,792	3.9	108	6.5
Yangtze platform	279,720	17,871	1.7	305	0.5
Songliao	1,582,490	21,458	3.8	229	4.5

4. National analyses: estimation of total water demand and temporal water use

Applying the low (high) well spacing, high (low) water intensity and the prospectivity (*p*) values to equation 2 in section 2.2 for all plays, we derive an estimate of projected total water use for all major shale-gas basins in China upon full development (Figure s4).

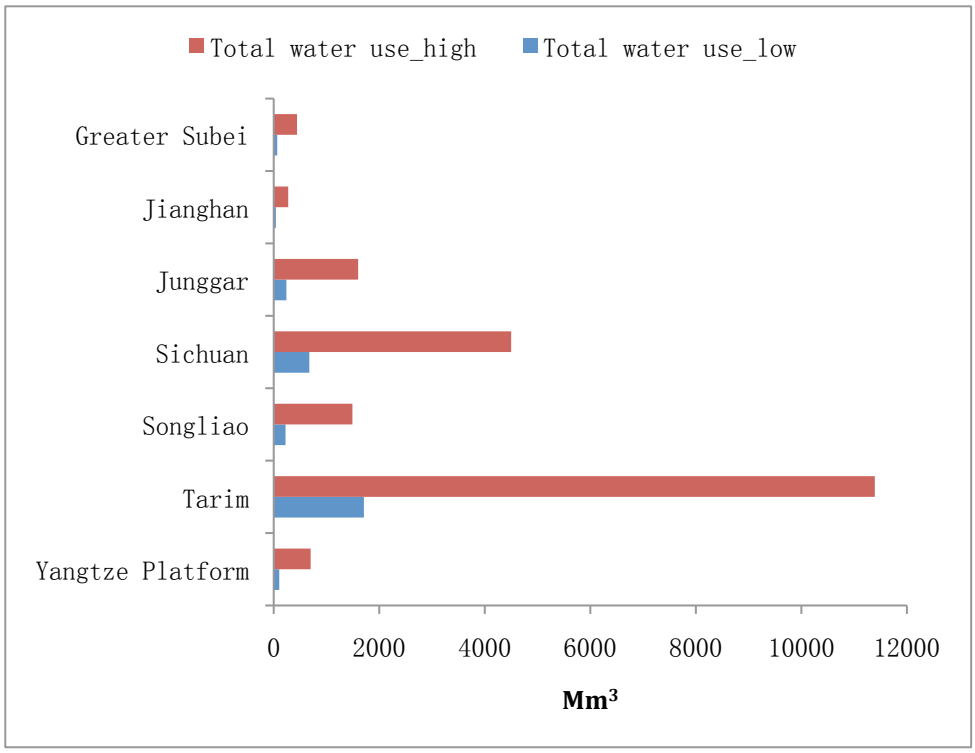

Figure s4. Projections of total fracking water use for 7 Chinese shale-gas basins

The differences in water demands for the different basins relate primarily to geographic size, as basins with larger prospective areas – namely the Tarim, Sichuan, Junggar and Songliao basins – are likely to have more wells at full development and thus greater demand for water.

Based on the national shale-gas production goal of 30 bcm by 2020 [s3], we define high, medium, and low scenarios for nationwide shale-gas production and associated water consumption through 2020, as summarized in Table s2.

Table s2. Shale-gas production and water consumption scenarios for China

	Scenarios	Parameters
Medium	Meet the planned production goal in 2020, with medium water intensity (i.e., at the historical rate of decline from 2013 to 2014, 6.5%)	Production goals in 2020: 30 bcm Rate of decline of water intensity: 6.5%
High	Exceed the planned production goal by 30% in 2020, with high water intensity (i.e., at a lower rate of decline, 2%, than the historical value assumed in the Medium Scenario)	Production goals in 2020: 21 bcm Rate of decline of water intensity: 2%
Low	Fall below the planned production goal by 30% in 2020, with low water intensity (i.e., at a higher rate of decline, 8%, than the historical value assumed in the Medium Scenario)	Production goals in 2020: 39 bcm Rate of decline of water intensity: 8%

We assume that the Sichuan Basin will account for 26 bcm of the 30 bcm national production goal for 2020, with 15 bcm and 11 bcm from Sinopec and PetroChina respectively, consistent with their announced plans. It is assumed that the rest of the target (4 bcm) will be met from the other six basins in proportion to their technically recoverable resources (TRR) as reported in the EIA/ARI's assessment report [s2], and that all of this production will increase from zero in 2014, again subject to the constraint of a smooth drilling trajectory from 2014 to 2020 for practical logistical and financial reasons. The estimated production and number of new wells required in the seven shale basins are shown in Figure s5 and s6 respectively.

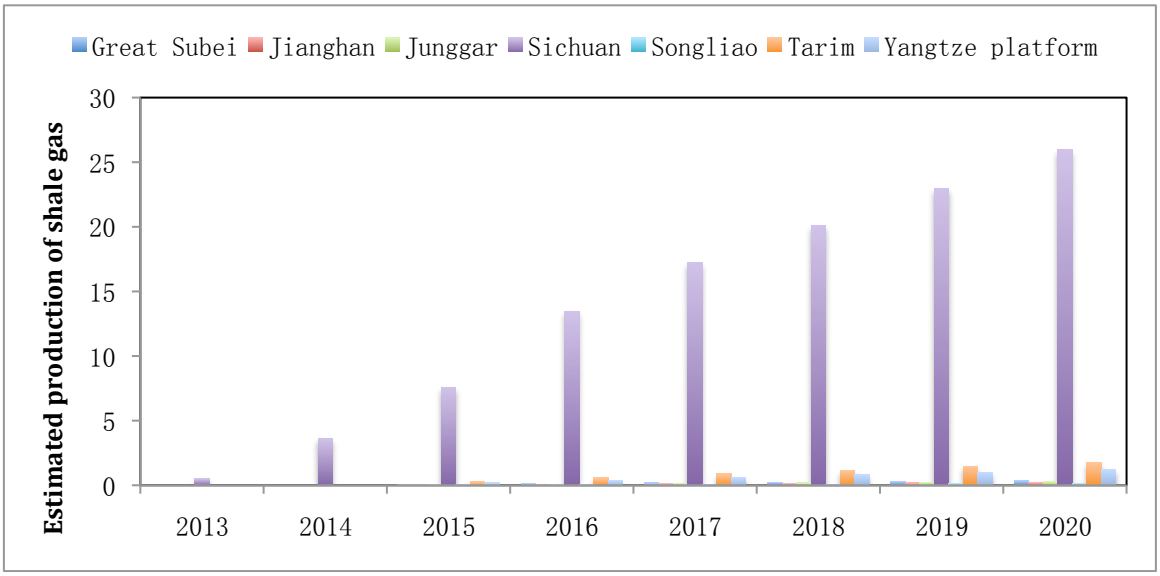

Figure s5. Estimation of shale gas production in China's shale gas basins

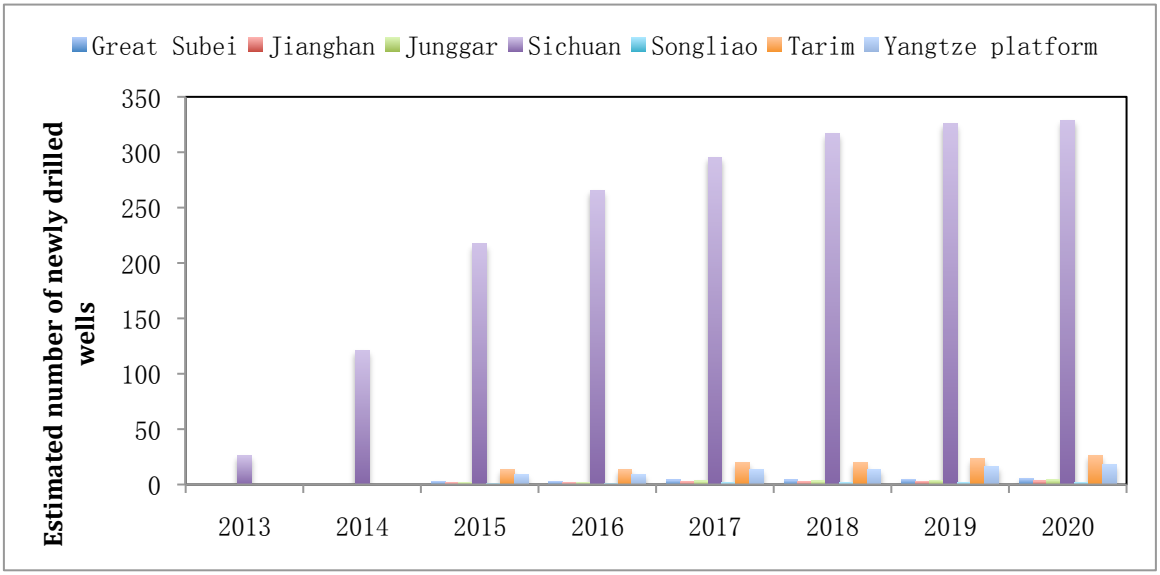

Figure s6. Estimation of newly drilled well number

References:

[s1] Zhou X. Drilling and Completion Techniques Used in Shale Gas Horizontal Wells in Jiaoshiba Block of Fuling Area. Petroleum Drilling Techniques. 2013;41(5):26-30.

[s2] U.S. Energy Information Administration. Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. Washington, DC: U.S. Department of Energy, 2013.

[s3] The State Council. China's Energy Development Strategy Action Plan (2014-2020) 2014 [cited (accessed November 2014)]. Available from: http://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm.