Water for Coal Production in Mongolia

Tomohiro Okadera, National Institute for Environmental Studies, Japan
Qinxue Wang, National Institute for Environmental Studies, Japan
Ochirbat Batkhishig, Institute of Geography, Mongolian Academy of Sciences, Mongolia

The Asian Conference on Sustainability, Energy & the Environment 2014
Official Conference Proceedings
0642

Abstract
Water resources of Mongolia are vulnerable because of low precipitation and melting permafrost by climate changes. Under the situation, its economy is rapidly growing and especially coal production has significantly increased by a rise in its exportation. At the same time, coal requires much water in the production process. For sustainable development of coal production, we analyze water requirement of coal production in Mongolia using a bottom-up approach. We found that 103 million m^3 of water, corresponding to 30% of industrial water withdrawal, is consumed to produce coal for 2013. Additionally, it reveals that impact to domestic water resources increased since the water requirement of 2013 rise to three times of 2007. Furthermore, 65 million m^3 of water is consumed to produce exported coals, so the importing countries indirectly use the water resources in Mongolia. Almost all exported coal (more than 99%) is shipped to China, but water is scarcer in China, whose water stress index (WSI; 0.478) is higher than Mongolia (0.053). Thus, by weighting with the WSIs, stress-weighted water requirements for coal production to export from Mongolia to China estimated as 3 million m^3 in Mongolia, while the value is 31 million m^3 in the case of China. The result suggests that Mongolia may contribute to mitigate water scarcity in China by exportation of its coal.

Keywords: Water-energy nexus, coal mining, Mongolia, water footprint analysis

Introduction

Water resources of Mongolia (the Mongolian People's Republic) are vulnerable because of low precipitation and melting permafrost by climate changes (Wu et al., 2012a; Wu et al., 2012b; Wu et al., 2013). At the same time, Mongolia has rapid economic growth and the annual GDP growth ratio recorded at 25% in 2010 (NSOM, 2011). Especially mining, whose annual growth ratio was 40% for 2010 (NSOM, 2011), has a great contribution to the economic growth. Especially coal production based on gross output, which shares 22% of industrial gross outputs, sharply increased by 115% from the previous year (NSOM, 2011). However, coal production requires much water for mining, beneficiation, delivery and so on (Gleick, 1994). Thus it is important to produce coal under the limitation of vulnerable water resources, for sustainable development in Mongolia. Then we analyze water requirement of coal production in Mongolia. In this paper, we explain a methodology to calculate the water requirements with a summary of the related previous studies. Next, we show the results of water demands of the coal production. Furthermore we discuss the impacts to water resources by coal production.

Methodology

Description of Study Area

Mongolia is a country which has a land area of 1,564,116 km^2 in East Asia that located between Russia (Russian Federation) and China (the People's Republic of China). Mongolia has dry and cold climate, whose annual average temperature recorded from -3.3 to 5.5 degrees C, while annual mean precipitation was 87-324 mm in 2010 (NSOM, 2011). It is estimated that total renewable water resources are 34.8 billion m^3 and per capita has declined to 12,236 m^3/inhabit, 36% of that in 1962, by 2011 (FAO, 2013). 558 million m^3 of water is used for agriculture, industry and daily life (FAO, 2013). There are 2.8 million people and 63% of the people settle in urban areas (NSOM, 2011). The 2010 GDP was 8,255 billion Mongolian Tugrik (4,540 million US dollars) and 22% of that is produced by mining and quarrying sector (NSOM, 2011). 33% of the gross output of mining and quarrying sector is contributed by coal mining, whose gross outputs doubled for one year in 2010 (NSOM, 2011). 66% of coal is exported (NSOM, 2011).

Figure 1 Location of Mongolia

Water for Coal Production

Numerous studies have investigated water requirements to produce energy commodities, which can be categorized into three groups. First is water for bioenergy (Gerbens-Leenes et al., 2009a; Gerbens-Leenes et al., 2009b), whose feedstock production has a big contribution (Gheewala et al., 2011; Gheewala et al., 2013). Second is water for power generation, such as cooling water of thermal power plants (Sovacool, 2009; Sovacool and Sovacool, 2009a; Sovacool and Sovacool, 2009b) and evaporation from reservoirs for hydro power plants (Carrillo and Frei, 2009; Gerbens-Leenes et al., 2009a). Third is water for fossil fuels including coal (Carrillo and Frei, 2009; Gleick, 1994).

Coal production consumes water in the process of mining, beneficiation, slurry pipe control and other plant operation (Gleick, 1994). Water requirement of coal production is calculated by multiplying coal production by water use parameters (water requirements per coal production).

Mongolia, however, has no data of water requirements for the coal production processes. Thus we refers to the results of previous research, water consumption of 136-199 m^3 water /TJ, thus we adopt the average value (0.17 m^3 water/ GJ) (Okadera et al., 2014) for this study,.

Coal production is defined by a coal balance sheet (NSOM, 2011) and energy statistical data (NSOM, 2013) of Mongolia in the last 7 years (2007-2013). The original data are organized using a physical unit (thousand ton), so we convert it to an energy-based unit (GJ) assuming coal's calorific value 21,000 MJ/ ton coal. Finally we calculate water consumption of coal production by multiplying coal production and water intensity to produce coal (Okadera et al., 2014).

Results

In the last 7 years, water consumption of coal production has been increasing, and 103 million m^3 of water, corresponding to three times of the amount of 2007, is consumed to produce coal for 2013 (Figure 1). In 2009, the industrial water withdrawals are estimated as 238 million m^3 (FAO, 2012), thus it is considered that the coal production consumes water corresponding to 30% (51 million m^3) of industrial water withdrawal. Furthermore the water consumption sharply risen from 2010, thus it is considered that more than 30% of industrial water is consumed by coal production.

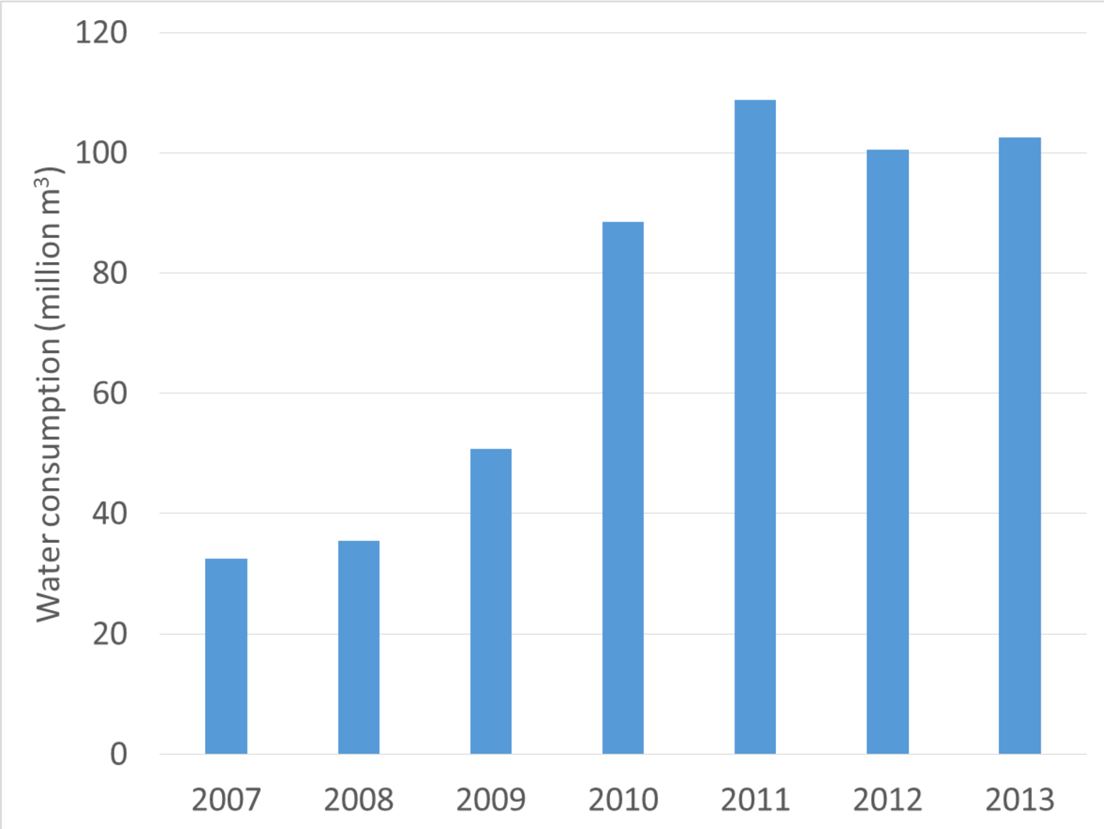

Figure 2 Water consumption for coal production in Mongolia

Discussions

Water for Exported Coal in Mongolia

In 2013, 63% of produced coal is exported (NSOM, 2013), so the importing countries indirectly use the water resources in Mongolia. Then, we estimate water consumption to produce the exported coal in the past 7 years by using data of exported coal in Mongolia (NSOM, 2011: 2013). Figure 2 shows that water amount for the exported coal. The water consumption has significantly risen since 2007 and in 2013 the value is six times larger than 2007, and it reveals that the growth ratio is double of the ratio of water consumption to coal production. At the same time, the percentage of water consumption for the exported coal in that of coal production also has increased. Then 63% of water to produce coal is consumed for exported coal currently whereas that of 2007 was recorded at 35%. Thus we found that the exported coal is a big contributor of water consumption for coal production in Mongolia.

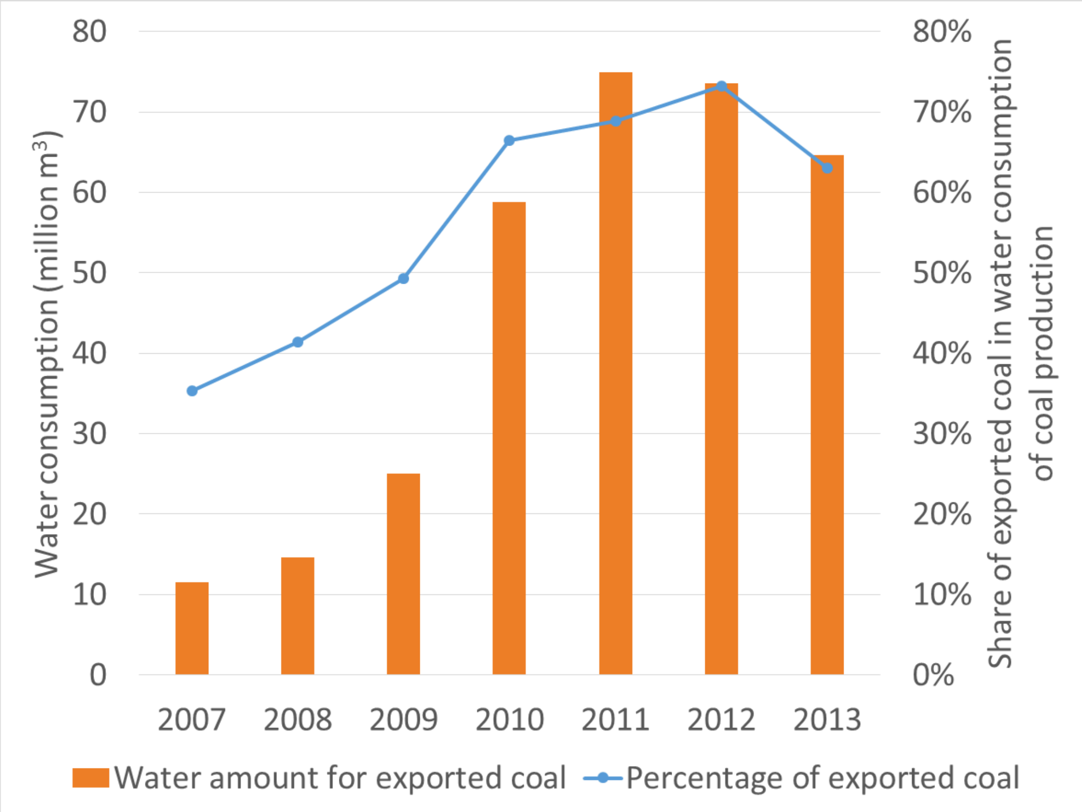

Figure 3 Water for exported coal in Mongolia

Environmental Implication of Coal Exporting System in Mongolia

The exported coal clearly has a big contribution, shown as Figure 2, to the water consumption for coal production in Mongolia. In addition, the coal is exported to China, United Kingdom, Russia, Germany and other countries from 2011 to 2013 (NSOM, 2013). With taking account of the current situation, we should consider the exporting system for an environmental implication, because water capacity differs by regions (Pfister and Hellweg, 2009). Indeed water stress indices (WSI) of the countries which Mongolia has exported from 2011 to 2013 are different by country (Pfister et al., 2009). Especially we focus on the exported coal to China from Mongolia because almost all exported coal is shipped to China (NSOM, 2013).

Then, we summarize the situation of water in Mongolia and China (Table 1). China has 2,526 billion m^3 of renewable water resources and the annual mean precipitation is in the range of 159-1,690 mm. Thus the water supply capacity is larger than Mongolia, whose renewable water resources are 34.8 and annual mean precipitation is 87-324 mm. On the other hand, per capita renewable water resources of China is estimated as 1,918 m^3/inhabit (MWR, 2008) while that of Mongolia accounts as 13,257 m^3/inhabit (FAO, 2013). Furthermore, WSI of China is estimated as 0.478 whereas that of Mongolia is 0.053 (Pfister et al., 2009). Therefore, it is considered that water resources in China are scarcer than Mongolia, although its water supply capacity is better than Mongolia.

Table 1 Water situation in Mongolia and China

	Mongolia	China
Annual mean precipitation (mm)	87-324*	159-1,690**
Renewable water resources (RWR; km^3)	34.8#	2,526**
Per capita RWR (m^3/inhabit)	13,257#	1,918**
Water stress index (WSI)+	0.053	0.478

Notes: *In 2010 (NSOM, 2011); ** In 2007 (MWR, 2008); # In 2007 (FAO, 2013); + Climate normal period 1961-1990 (Pfister et al., 2009)

The fact indicates that the impact to water scarcity by coal production in China is more serious than Mongolia. For taking account of the regional character for water scarcity, we apply a revised approach weighting with the WSIs of Mongolia and China (Ridoutt and Pfister, 2010) and calculate stress-weighted water consumption for coal production to export from Mongolia to China. As the results, the stress-weighted water consumption based on Mongolian WSI estimated as 612 to 3,993 thousand m^3 while the value based on Chinese WSI is 5.5 to 35.8 million m^3 in the last 7 years. The stress-weighted water consumption based on Chinese WSI is 4.9-31.8 million m^3 larger than that based on Mongolian WSI. The result suggests that China acquires coal without increasing domestic water stress by importing from Mongolia. Namely Mongolia contributes to mitigate water stress corresponding to in China by exportation of its coal.

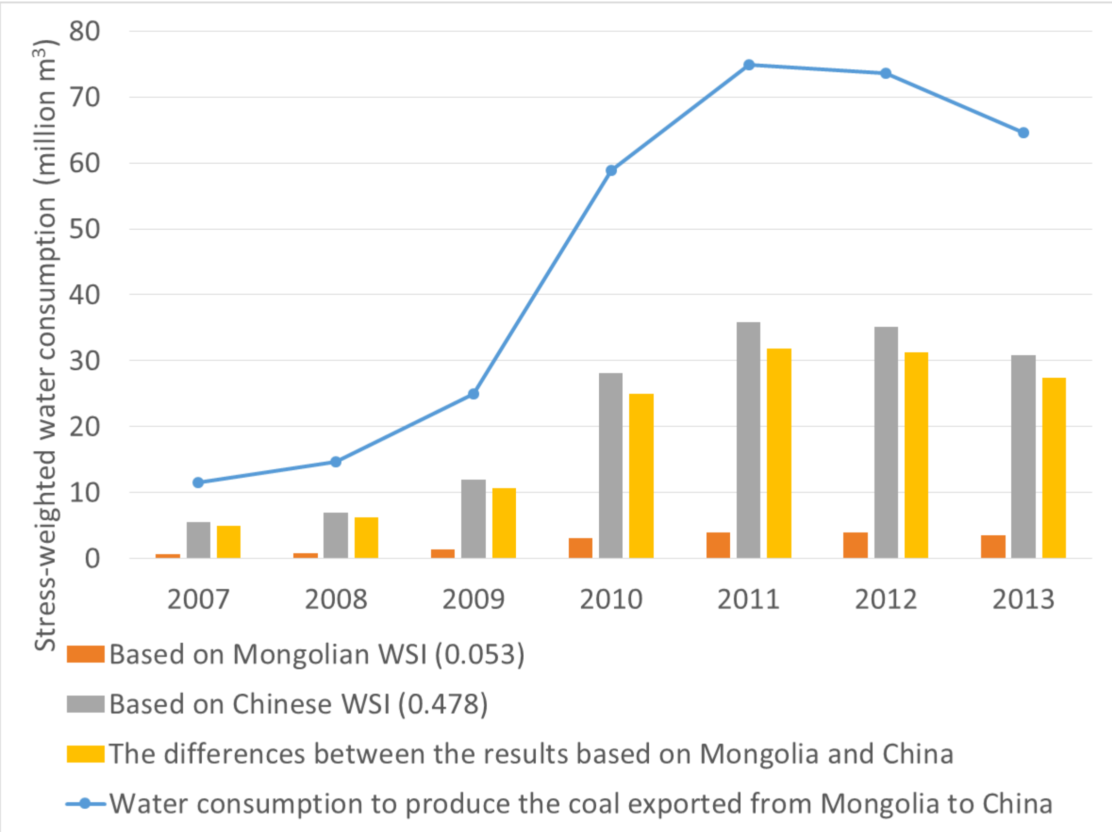

Figure 4 Stress-weighted water consumption of exported coal from Mongolia to China

Conclusion

Water consumption for coal production, which is one of the driving forces for economic growth in Mongolia, has significantly increased and it is considered that more than 30% of industrial water withdrawals of Mongolia are consumed by coal production at the present. Especially exported coals have a big contribution to water consumption of the coal production. Furthermore, we found that the exportation of coals brings a benefit to mitigate water scarcity in China because China can acquire coal without increasing water stress. Nevertheless, we guess that, value to avoid the water scarcity by exporting coal from Mongolia does not include a price of the exported coal. Thus it is important to estimate the value as a future task.

Acknowledgement

This study has been financially supported by the Environment Research and Technology Development Fund (2E-1203) of the Ministry of the Environment, Japan.

References

Carrillo, A.M.R. and C. Frei (2009) Water: A key resource in energy production. *Energy Policy*, 37, 4303-4312.

FAO (2012) AQUASTAT database. http://www.fao.org/nr/water/aquastat/main/index.stm (Accessed December 31, 2012).

FAO (2013) AQUASTAT database. http://www.fao.org/nr/water/aquastat/main/index.stm (Accessed 04/04/2013 5:42, 2013).

Gerbens-Leenes, P.W., A.Y. Hoekstra and T. van der Meer (2009a) The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply. *Ecological Economics*, 68, 1052-1060.

Gerbens-Leenes, W., A.Y. Hoekstra and T.v.d. Meer (2009b) The water footprint of bioenergy. *Proceedings of the National Academy of Sciences of the United States of America*, 106, 10219-10223.

Gheewala, S.H., G. Berndes and G. Jewitt (2011) The bioenergy and water nexus. *Biofuels Bioproducts & Biorefining-Biofpr*, 5, 353-360.

Gheewala, S.H., T. Silalertruksa, P. Nilsalab, R. Mungkung, S.R. Perret and N. Chaiyawannakarn (2013) Implications of the biofuels policy mandate in Thailand on water: The case of bioethanol. *Bioresource Technology*, 150, 457-465.

Gleick, P.H. (1994) Water and Energy. *Annual Review of Energy and the Environment*, 19, 267-299.

MWR (Ministry of Water Resources) (2008) *China water resource bulletin 2007*. Beijing, Ministry of Water Resources.

NSOM (National Statistical Office of Mongolia) (2011) *Mongolian Statistical Yearbook 2010*. Ulaanbatar, National Statistical Office of Mongolia.

NSOM (National Statistical Ofiice of Mongolia) (2013) *Monthly bulletin of statistics (December 2013)*. Ulaanbaatar, National Statistical Ofiice of Mongolia.

Okadera, T., J. Chontanawat and S.H. Gheewala (2014) Water footprint for energy production and supply in Thailand. *Energy*.

Pfister, S. and S. Hellweg (2009) The water "shoesize" vs. footprint of bioenergy. *Proceedings of the National Academy of Sciences of the United States of America*, 106, E93-94.

Pfister, S., A. Koehler and S. Hellweg (2009) Assessing the Environmental Impacts of Freshwater Consumption in LCA. *Environmental Science & Technology*, 43, 4098-4104.

Ridoutt, B.G. and S. Pfister (2010) A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. *Global Environmental Change*, 20, 113-120.

Sovacool, B.K. (2009) Running on empty: The electricity-water nexus and the U.S. electric utility sector. *Energy Law Journal*, 30, 11-51.

Sovacool, B.K. and K.E. Sovacool (2009a) Identifying future electricity-water tradeoffs in the United States. *Energy Policy*, 37, 2763-2773.

Sovacool, B.K. and K.E. Sovacool (2009b) Preventing National Electricity-Water Crisis Areas in the United States. *Columbia Journal of Environmental Law*, 34, 333-393.

Wu, T., Q. Wang, M. Watanabe, J. Chen and D. Battogtokh (2012a) Mapping vertical profile of discontinuous permafrost with ground penetrating radar at Nalaikh depression, Mongolia. *Environmental Geology*, 56, 1577-1583.
Wu, T., Q. Wang, L. Zhao, E. Du, W. Wang, O. Batkhishig, D. Battogtokh and M. Watanabe (2012b) Investigating internal structure of permafrost using conventional methods and ground-penetrating radar at Honhor basin, Mongolia. *Environmental earth sciences*, 67, 1869-1876.
Wu, T., L. Zhao, R. Li, Q. Wang, C. Xie and Q. Pang (2013) Recent ground surface warming and its effects on permafrost on the central Qinghai-Tibet Plateau. *International Journal of Climatology*, 33, 920-930.