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Abstract

Coal combustion to power China's factories, generate electricity, and heat buildings has increased continually since energy use statistics were first published in 1981. From 2013 until 2015, however, this trend reversed and coal use continued to decline from 2,810 million metric tons of coal equivalent (Mtce) to 2,752 Mtce, leading to a levelling off of China's overall CO₂ emissions. Some analysts have declared that China's coal consumption may have peaked, but preliminary data indicate that coal consumption increased in 2017. This recent growth, combined with our analysis of projected increases in electricity demand that cannot be met by other fossil-fuel or non-fossil-fuel electricity sources, along with projected increases in coal use in light manufacturing, other non-industrial sectors, as well as in coal use for transformation, indicates potential future growth of China's coal use to levels of 2,908 Mtce to 3,060 Mtce in 2020, with associated increases in energy-related CO₂ emissions.

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Introduction

China is currently the world's largest consumer of coal as well as the largest emitter of energy-related carbon dioxide (CO₂). China's 13th Five Year Plan, covering 2016-2020, aims to limit coal-fired power generation capacity to less than 1,100 gigawatts (GW) and gas-fired power generation capacity to 110 GW in 2020 (NDRC and NEA, 2016a; NDRC and NEA, 2016b). By 2020, China also aims to cap coal consumption to 4,100 million metric tons (Mt) (NDRC and NEA, 2016a) and total primary energy consumption to under 5,000 million tonnes of coal equivalent (Mtce) (State Council, 2016), while increasing the share of non-fossil energy consumption to 15% of total primary energy use (NDRC and NEA, 2016a). China has pledged internationally "to achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early" as a key element of its Nationally Determined Contributions (NDCs) for the Paris Agreement (NDRC, 2016).

Nearly 80% of China's annual energy-related CO₂ emissions are from combustion of coal and coal-derived products, followed by 17% from oil-based products, and 4% from natural gas (NBS, 2017a; IPCC, 2006). In 2013, China's coal consumption reached about 2,810 Mtce and then declined to 2,793 Mtce in 2014 and further decreased to 2,752 Mtce in 2015 (NBS, 2017a), with the decline continuing into early 2016 (NBS, 2017b), which has been primarily driven by a marked drop in heavy industrial and manufacturing activity.

Some analysts have declared that this recent decline could mark the peak of China's coal consumption and perhaps of its CO₂ emissions (Tollefson, 2016). Green and Stern (Green and Stern, 2016) review past trends, future targets, and economic drivers to conclude that China's CO₂ emissions may have peaked in 2014, but acknowledge some future growth risks that could result in relatively flat emissions with a peak highly likely by 2025. Qi et al. (2016) describe the conditions that support their argument that "China's coal consumption has indeed reached an inflection point much sooner than expected [2013 or 2014] and will decline henceforth — even though coal will remain the primary source of energy for the coming decades."

Preliminary data for 2017, however, shows an increase in China's production of coal as well as increases in some other key indicators such as thermal power production, production of crude steel, aluminum, and coking (NBS, n.d.). The analysis presented in this paper seeks to understand the critical factors shaping China's near-term (to 2020) coal consumption to assess whether it has peaked and will plateau or decline or whether the trends in key drivers of coal demand will lead once again to near-term growth in coal use and hence in China's energy-related CO₂ emissions. We focus our analysis on the use of coal for electricity production and in

the industrial sector, since these two uses represent 87% of the coal consumed in terms of primary energy.

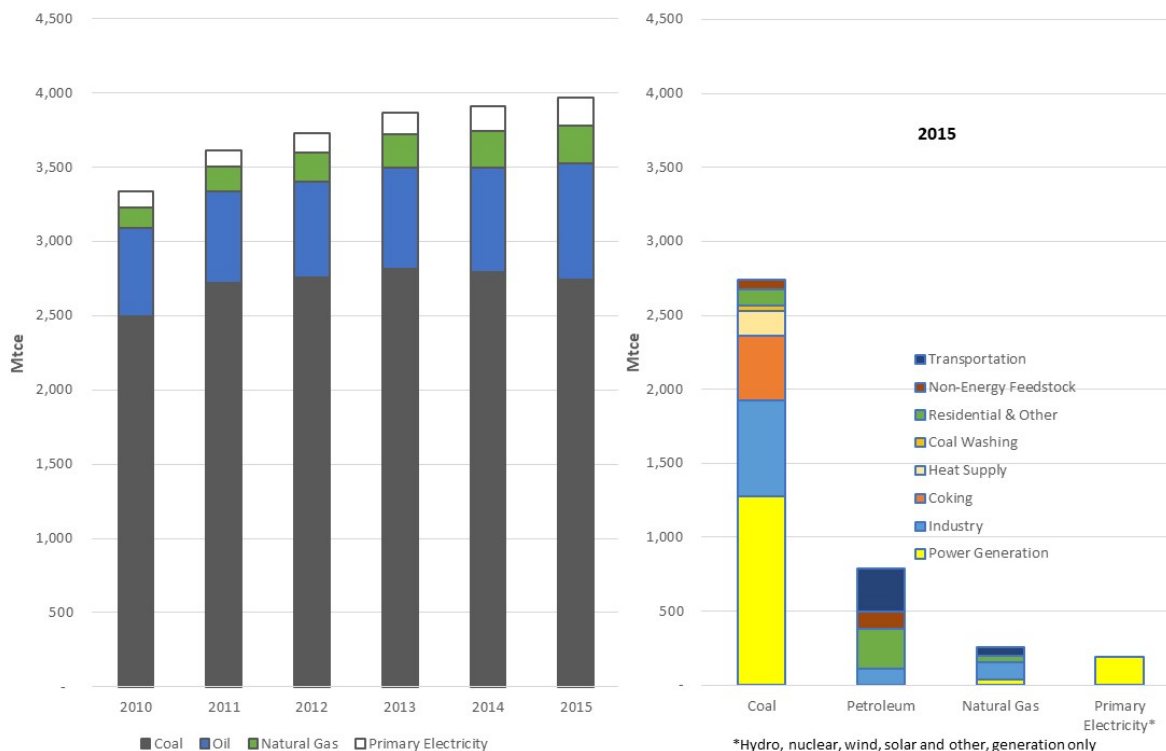


Figure 1. China's primary energy consumption by fuel, 2010-2015, and by end-use 2015.

Left: primary energy consumption by energy form from 2010 to 2015. Primary electricity is converted from TWh to Mtce based on the direct equivalent method. Right: breakdown of primary energy consumption in 2015 by energy form and major end-use sectors (NBS, 2017a). The "other" category includes commercial buildings, construction, agriculture, and consumption of the public sector. Primary electricity is gross generation.

Methods

Data

Energy data are from the *China Energy Statistical Yearbook* (CESY) published by the National Bureau of Statistics (NBS) of China annually (NBS, 2017a). In the CESY, energy data are reported in both physical energy units and standard energy units. China's standard conversion from metric tons of coal to metric tons of coal equivalent (tce) is 1 metric ton = 0.713 tce (1 tce is approximately equivalent to 29.3 gigajoules, GJ). NBS classifies the energy-consuming end-use sectors as: agriculture, industry, construction, transport, commercial, and residential. The industrial sector consists of three major categories: 1) mining and quarrying, 2) manufacturing, and 3) electric power, gas, and water production and supply. The manufacturing sector is further disaggregated by NBS. At the two-digit level of the manufacturing sector, there are 30

subsectors such as manufacturing of food, beverages, textiles, chemicals, ferrous and non-ferrous metals, non-metallic metals, and machinery and transport equipment.

In the latest CESY, total energy is reported under two different standardization approaches, i.e., the direct equivalent method as adopted by the Intergovernmental Panel on Climate Change (IPCC), and followed in this paper, and China's power-plant coal equivalent method. The differences and the implications of the standardization methods are further discussed in Lewis et al., 2015.

CO₂ emissions were estimated based on reported energy data multiplied by IPCC default carbon emissions factors (NBS, 2017a; IPCC, 2006). We used the reported physical consumption units multiplied with reported low heating values by source. NBS annually publishes lower heating values for fuels, such as crude oil and raw coal, and these values normally do not change much over time. However, for some fuels, such as coke oven gas and other gas, NBS provides a range of lower heating values. To determine the exact lower heating values, conversion factors are calculated by dividing the standard coal equivalent value by the physical unit value, based on the reported values in the *China Energy Statistical Yearbook*. After calculating the energy consumption data from physical quantities and low heating values, the carbon coefficients reported in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* are used for the CO₂ emissions calculation, assuming 100% carbon release from combustion.

Historical industrial production data and thermal power generation data from NBS (NBS, 2015; NBS, 2016) were used to evaluate the CO₂ emission reduction contributions of key industrial products. Expert judgements on future industrial production (Fan, 2016; Baosteel, 2015; PetroChina, 2016; Xiao, 2017) were used to compare with the results from this analysis.

Historical energy intensity data and fuel mix data by industrial subsector are from the *China 2050 Demand Resources Energy Analysis Model (DREAM)* developed by Lawrence Berkeley National Laboratory (Zhou, 2011) and described further below. Table 1 presents a summary of data and data sources in this paper.

Table 1. Data Sources

Data	Data sources	Notes
China energy data	<i>China Energy Statistical Yearbook</i> (NBS, 2017a)	Includes both physical and standard energy use data
Heating content by fuel source	<i>China Energy Statistical Yearbook</i> (NBS, 2017a) and National Bureau of Statistics National Data	Based on China’s reported physical and standardized energy consumption by fuel
Oxidation factor by fuel source	IPCC, 2006	Adopted the IPCC default values
Emission factor by fuel source	IPCC, 2006	Adopted the IPCC default values
Industrial production and power generation data	<i>China Statistical Yearbook</i> (NBS, 2015); <i>2015 Statistical Communique of National Economic and Social Development</i> (NBS, 2016); industry experts forecast (Fan, 2016; Baosteel, 2015; PetroChina, 2016; Xiao, 2017)	2005-2014 data 2015 data 2016 data
Energy intensity and fuel mix by industrial subsector	Zhou et al., 2011	Application of the China 2050 DREAM model

China 2050 Demand Resources Energy Analysis Model (DREAM)

The China 2050 DREAM has a demand module consisting of five demand subsectors (residential buildings, commercial buildings, industry, transport, and agriculture) and a transformation module consisting of energy production and conversion, transmission, and distribution subsectors. Using the Long-range Energy Alternatives Planning (LEAP) platform, the China 2050 DREAM model captures diffusion of end-use technologies and macroeconomic and sector-specific drivers of energy demand as well as the energy required to extract fossil fuels and produce energy and a power sector with distinct generation dispatch algorithms.

Within the energy-demand sectors, key drivers of energy use include activity drivers (total population growth, urbanization, building and vehicle stock, and commodity production), economic drivers (total GDP and income), and energy-intensity drivers related to energy-using equipment and appliances (Zhou et al., 2011). These factors in turn are affected by changing consumer preferences, settlement patterns, infrastructure, and technologies. We use published energy sector statistics to prepare a time-series database representing primary energy use that takes supply-side losses into account. After the model was built from the bottom up, sector and fuel-specific consumption data were calibrated by comparing the end-use energy results with the reported data for the base year.

The China 2050 DREAM reference scenario was developed to represent a pathway in which the Chinese economy continues a moderate pace of “market-based” improvement in all sectors

and adopts all announced policies and goals related to efficiency improvement, non-fossil energy production, fuel switching, technology adoption, and economic restructuring. Unlike a frozen scenario, which is unrealistic given China’s commitments to energy and carbon intensity reductions, the reference scenario reflects the direction in which China is heading and thus serves as the baseline for measuring changes from alternative policy conditions.

Industrial Sector Analyses

Two projections of output for heavy industrial commodities in 2020 were examined. The first projection is based on Chinese sector expert opinions, and the second is derived from the physical drivers in the China 2050 DREAM reference scenario. 2015 actual output and that in 2020 for the two scenarios are summarized in Table 2. Using the China 2050 DREAM, both output scenarios were run for 2020 to calculate the total amount of coal and coke consumed in each sector on a final energy basis. In both projections, total coal and coke consumption in these sectors declines from the 2015 levels (see Table 3). The China 2050 DREAM projections of coal and coke use in the “other industry” and non-industrial end-use sectors are extracts of model results. No sensitivity analyses or alternative scenario projections were undertaken.

Table 2. Physical output projections of key industrial commodities in China to 2020

(Mt)	2015 Actual	2020 DREAM 2050	2020 Expert	References
Cement	2,394	2,229	2,550	<i>Liu et al., 2015</i>
Steel	781	799	700	<i>Zhou et al., 2011</i>
Ethylene	17	22	30	<i>Li and Gao, 2016</i>
Ammonia	58	54	53	<i>Li and Gao, 2016</i>
Soda Ash	26	28	32	<i>NBS, 2016</i>

Table 3. Projection of coal and coke consumption in major energy-intensive sectors in China, 2015-2020

(Mtce)	Actual		Expert Judgement		DREAM 2050 model	
	2015	2020	2020	Growth	2020	Growth
Cement	240	245	245	5	214	(30)
Iron & Steel	437	362	362	(75)	413	(11)
Ethylene	2	4	4	2	3	1
Ammonia	82	74	74	(8)	76	(9)
Soda ash	11	13	13	2	12	1
Total	2,787	2,718	2,718	(74)	2738	(49)

The analysis of the sectoral change in energy-related CO₂ emissions of key industrial sectors between 2014 and 2015 was based on calculation of a weighted average of final energy intensity for each sector (crude steel, cement, aluminum, ammonia, caustic soda, soda ash, ethylene, and thermal power generation) which was derived from the shares of key

technologies in a sector (e.g. shares of blast furnace/basic oxygen furnace and electric arc furnace in steel industry), the specific energy intensity of technologies, the sector-specific fuel mix, and IPCC CO₂ emissions factors (using 100% oxidation factors) combined with the changes in key commodity production between 2014 and 2015 (IPCC, 2006; Liu et al., 2015; Zhou et al., 2011; NBS, 2015; NBS, 2016).

To understand the short-term outlook for CO₂ emissions from China's industrial sector, we projected physical output and related coal and coke consumption of the five largest-emitting heavy industrial commodities in 2020 using the physical driver-based output of the China 2050 Demand Resources Energy Analysis Model (DREAM) reference case¹ and compared the results with Chinese sector expert opinions (Fan, 2016; Baosteel, 2015; PetroChina, 2016; Xiao, 2017).

Estimating Ranges of Electricity Generation in 2020

To project non-fossil electricity supply, we calculated the maximum potential generation under two scenarios of capacity factors: existing and improved. The existing capacity factors derive from the trend of the past 5 years, while the improved capacity factors assume an increase of 5 percentage points for both thermal power and wind power utilization from their relatively low current averages. Both generation scenarios, 13th FYP-low and 13th FYP-high, assume that China fully achieves its 2020 targets for solar, wind, hydro, and nuclear power generation.

For 2020, NDRC and NEA target generation capacities (NDRC and NEA, 2016b) were adopted as the basis for power sector modeling (see Table 4). Historical capacity factors were calculated based on year-end total generation capacity and annual generation. Consequently, both full-year generation and part-year generation from new installations are included, resulting in a lower average capacity factor than would be achieved by full-year generators alone (see Table 5). Transmission and distribution (T&D) losses are deducted from generation in order to calculate final availability. In 2015, T&D losses averaged 5.5% and were assumed to decline to 5% in 2020.

The calculation of the growth rate that would allow for complete elimination of additional coal-powered generation is based on 2015 actual consumption plus the incremental available generation net of T&D losses from all other non-coal sources in 2020 under the two capacity factor scenarios.

¹ The China 2050 DREAM model has a demand module consisting of five demand subsectors (residential buildings, commercial buildings, industry, transport, and agriculture) and a transformation module consisting of energy production, transmission, and distribution subsectors. Using the Long-range Energy Alternatives Planning (LEAP) platform, the China 2050 DREAM model captures diffusion of end-use technologies and macroeconomic and sector-specific drivers of energy demand as well as the energy required to extract fossil fuels and produce energy and a power sector with distinct generation dispatch algorithms. See: <https://china.lbl.gov/tools/dream>

Table 4. Summary of China’s 2020 capacity targets

Generation Type	GW
Thermal	1,210
Coal	1,100
Natural Gas	110
Hydro	380
Nuclear	58
Wind	210
Solar	110
Other	32
Total	2,000

Source: NDRC and NEA, 2016b.

Table 5. Capacity Factors

	2010	2011	2012	2013	2014	2015	Avg 2010-15	Low Scenario	High Scenario
Thermal	54%	57%	54%	56%	53%	48%	54%	50%	55%
Hydro	39%	35%	40%	37%	40%	40%	38%	40%	40%
Nuclear	78%	91%	88%	87%	75%	72%	82%	90%	90%
Wind	17%	17%	18%	21%	18%	16%	18%	20%	25%
Solar	5%	4%	12%	6%	11%	11%	8%	12%	12%

Source: NBS, n.d.

China’s Recent Coal Consumption Trends

Between 2010 and 2015, the share of coal use in China’s total primary energy consumption slowly dropped from 75% to 69% (Fig. 1). This decline, however, was offset by a continued rise in the consumption of natural gas and oil, shares of which grew from 4% to 6% and 18% to 20%, respectively. Non-fossil primary energy (nuclear, hydro, solar, wind, and other renewables) increased slightly from 3% to 5% (NBS, 2017a). In 2015, coal use was responsible for almost 80% of China’s energy-related CO₂ emissions, still within the 79%-84% range it has experienced since 1981.

In 2015, 47% of China’s total primary energy consumption was coal used to produce electricity. Industrial uses of coal – including both direct use and as feedstock for coking and for non-energy products such as ammonia, accounted for 40% of China’s primary energy use that year. Coal is also an input fuel and feedstock in several transformation sectors, including district heating, combined heat-and-power, coal liquefaction (CTL), coal gasification (CTG, synthetic natural gas production), methanol production, and coal gas production. The remainder is used for coal washing, in residential and commercial buildings, by construction equipment, and in agriculture.

As the single largest consumer of coal in China, power generation expanded steadily from 4,207 terawatt hours (TWh) in 2010 to 5,650 TWh in 2014 at a 7.6% annual average increase but faltered in 2015 when China's industrial production slowed and power generation grew just 0.1% to 5,657 TWh, with thermal generation - and thermal coal use - falling by nearly 1% (NBS, n.d.). Figures for 2016 indicate a rebound to a 5.2% growth rate in overall power generation, with thermal generation growing at 2.4% (CEC, 2017). The share of power generation from fossil-fuel sources dropped from 79% in 2010 to 76% in 2015 and preliminarily to 74% in 2016 (NBS, 2017a; NBS, 2017b; NBS, n.d.). In 2010, 96% of thermal generation was from coal and it dropped to 94% in 2015 as the use of natural gas expanded (NBS, 2017a; NBS, n.d.). Increasing the use of natural gas and non-fossil resources to generate electricity has less impact on overall coal demand in China than it does in countries such as the U.S. where the power sector accounts for nearly 100% of coal use.

The decline in coal consumption in 2014 and 2015 was primarily driven by a decline in production of heavy industrial commodities. The industrial sector of the economy, including industry's share of electricity consumption, accounts for the bulk of China's CO₂ emissions, at 72% in 2014 (NBS, 2017a; IPCC, 2006). Our analysis of the contribution of key heavy industrial sectors - crude steel, cement, aluminum, ammonia, caustic soda, soda ash, and ethylene, as well as thermal power generation - to China's year-on-year changes in energy-related CO₂ emissions shows declines in coal combustion for production of cement, crude steel, and for thermal power generation were primarily responsible for the drop in CO₂ emissions between 2014 and 2015 (Fig. 2) (IPCC, 2006; Liu et al., 2015; Zhou et al., 2011; NBS, 2015; and NBS, 2016).

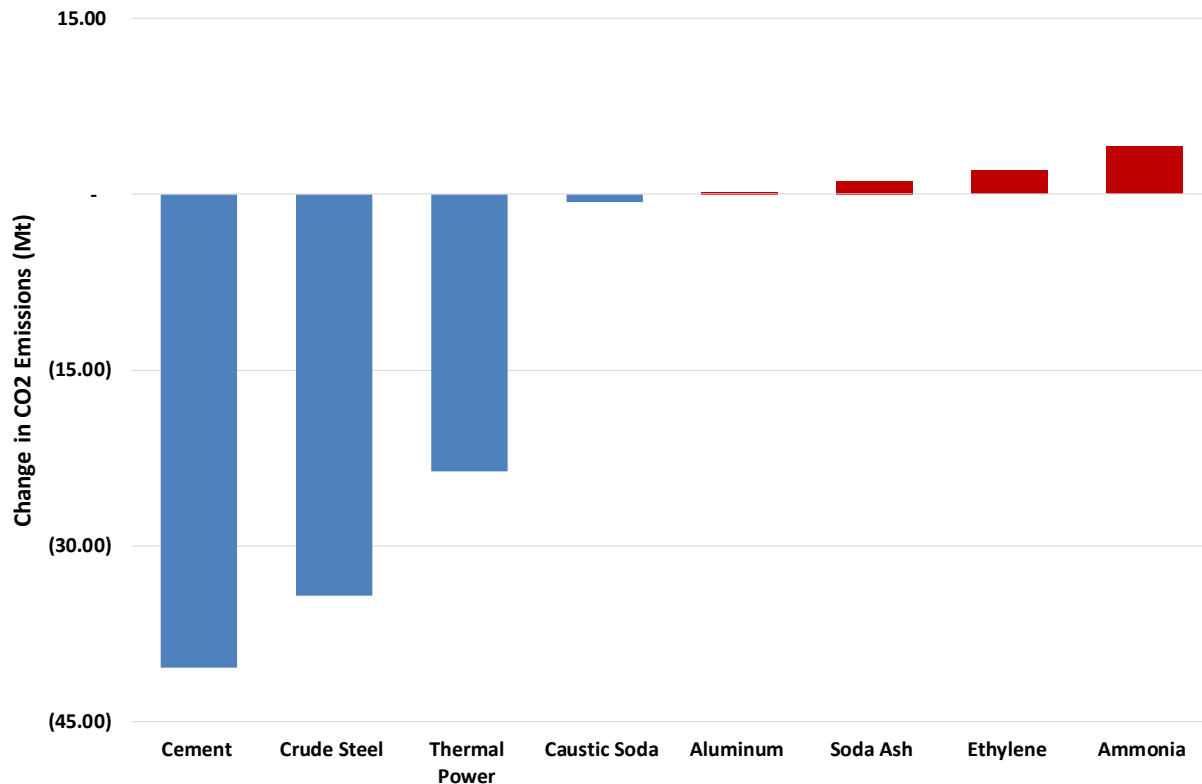


Figure 2. Analysis of the changes in CO₂ emissions from combustion of fossil fuels for the production of crude steel, cement, aluminum, ammonia, caustic soda, soda ash and ethylene, as well as for thermal power generation in China, 2014-2015.

Calculated weighted average final energy intensity for each sector based on the shares of key technologies in a sector (e.g. shares of blast furnace/basic oxygen furnace and electric arc furnace in steel industry), the specific energy intensity of technologies, the sector-specific fuel mix, and Intergovernmental Panel on Climate Change CO₂ emissions factors (using 100% oxidation factors) were combined with the changes in key commodity production between 2014 and 2015 (IPCC, 2006; Liu et al., 2015; Zhou et al., 2011; NBS, 2015; and NBS, 2016).

Outlook for Coal Use in China

The China 2050 DREAM model projects 2020 coal and coke final energy use to decline 49 Mtce, or 6.3%, from 2015 levels in three heavy industrial sectors (cement, iron & steel, and ammonia) furthering a 36 Mtce decline in 2015 over 2014, offset by a slight 0.2% projected increase in coal use in soda ash and ethylene production. Given that these five sectors account for 70% of total coal and coke consumption in China's industrial sector, this projected decline is sufficient to accommodate a rise in other less coal- and energy-intensive manufacturing sectors such as machinery, transport equipment, and electric/electronic equipment manufacturing where commodity production is not projected to decline between 2015 and 2020. The projected

increased coal consumption by these less energy-intensive manufacturing sectors nearly offsets the projected decline from coal use for the energy-intensive manufacturing sectors.

The near-term outlook for coal use in power generation to 2020 depends on the overall rate of demand growth for electricity, the growth of non-fossil generation, and the increase in natural gas use for fossil-powered generation. For the 13th Five Year Plan (2015-2020), China's National Energy Administration (NEA) projects low and high electricity demand growth rates of 3.6% and 4.8% per year, respectively, from 2016 to 2020 (NDRC and NEA, 2016b). (See Table 4.)

Based on these targets, we calculated the maximum potential generation from these non-fossil sources under two capacity factor scenarios: existing and improved. The existing capacity factors derive from the trend of the past 5 years, while the improved capacity factors assume an increase of 5 percentage points for both thermal power and wind power utilization from their relatively low current averages based on China's effort to reduce curtailment – which has reached as high as 20 to 30% in some Northeastern and Western provinces—of its solar and wind generation. Both generation scenarios, 13th FYP-low and 13th FYP-high, assume that China fully achieves its renewable electricity 2020 targets for solar, wind, hydro, and nuclear power generation. Transmission and distribution losses are then subtracted to derive available supply.

NEA's low- and high-power demand growth forecasts to 2020 result in total electricity demand of 6,475 to 6,860 TWh, or a growth of 1,050 to 1,430 TWh over the 2015 level. When compared against the maximum incremental generation available from non-fossil sources in 2020 compared to 2015, a gap of 240 TWh to 710 TWh remains that will require the use of additional thermal power generation (Fig. 3).

This gap, however, will not necessarily be filled completely by coal power. Currently, China consumes about 79 Mtce of other fossil fuels—nearly all natural gas—as inputs to thermal power generation, and these non-coal inputs have been growing at 8.8% a year since 2008. The NEA has also established a capacity target for natural gas power generation in 2020 of 110 GW (NDRC and NEA, 2016a), up from 66 GW in 2015, and under conservative assumptions of 40% generation efficiency and 40-52% average capacity factor, the incremental capacity could generate between 150 and 200 TWh, insufficient to fill the gap between projected 2020 demand and non-fossil power supply, but enough to reduce the demand for additional coal generation significantly in a low-demand-growth, improved capacity factor scenario.

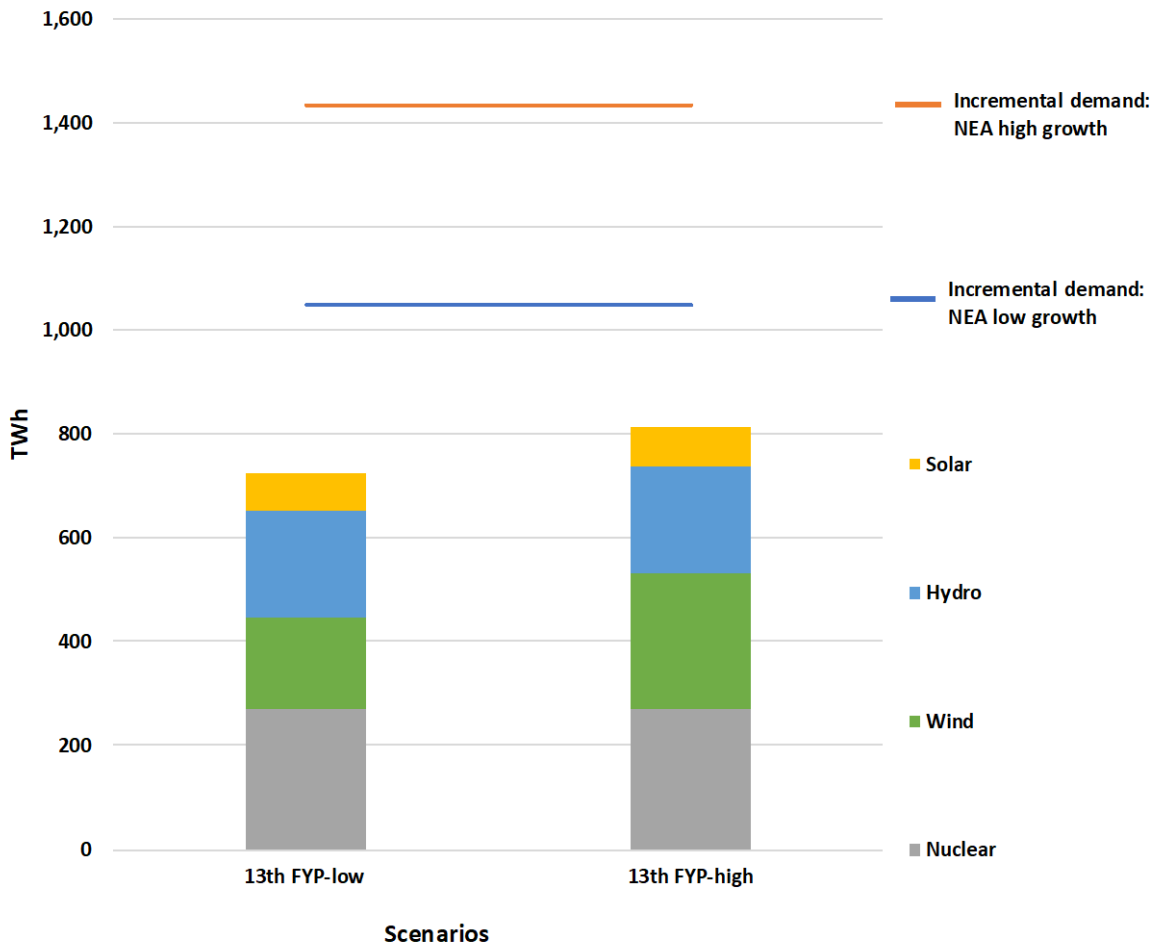


Figure 3. Gap between incremental non-thermal power generation and China's forecasted incremental electricity demand in 2020.

Orange line shows high (4.8% per year 2016-2020) and blue line show low (3.6% per year 2016-2020) 2020 forecasted incremental electricity demand (NDRC and NEA, 2016a). 13th FYP-low and 13th FYP-high scenarios show generation by non-thermal sources in 2020 if 13th FYP targets are achieved, using low (existing) and high (improved) generation capacity factors. Improved capacity factors assume an increase of 5 percentage points for both thermal power and wind power utilization from their relatively low current averages. The gap of 240 TWh to 710 TWh will need to be filled with thermal power generation sources.

Findings

Our analysis finds that China's 2020 coal consumption is projected to be higher than the 2015 coal consumption level. Fig. 4 combines the above analyses to show the various contributions to our projection of China's 2020 coal consumption. The first two bars show the drop in coal consumption from 2,810 Mtce in 2013 to 2,752 in 2015⁵. Looking forward to 2020, our China 2050 DREAM model analysis identified an expected decrease in coal use in heavy industry of 49

Mtce and a very minor decrease in coal use in transport of 0.01 Mtce. These declines are offset by expected increases in coal used for electricity generation of 34 Mtce in the 13th FYP-low scenario and 185 Mtce in the 13th FYP-high scenario. Using the China 2050 DREAM model, we further project additional coal use of 54 Mtce in selected light industries (transport equipment manufacturing, rubber and plastics, other non-metal minerals, machinery and metal products, and other manufacturing), as well as 24 Mtce in the residential and commercial buildings, agriculture, and construction sectors. Among non-industrial end-use sectors, growth in demand in commercial buildings accounts for over 70% of the increase.

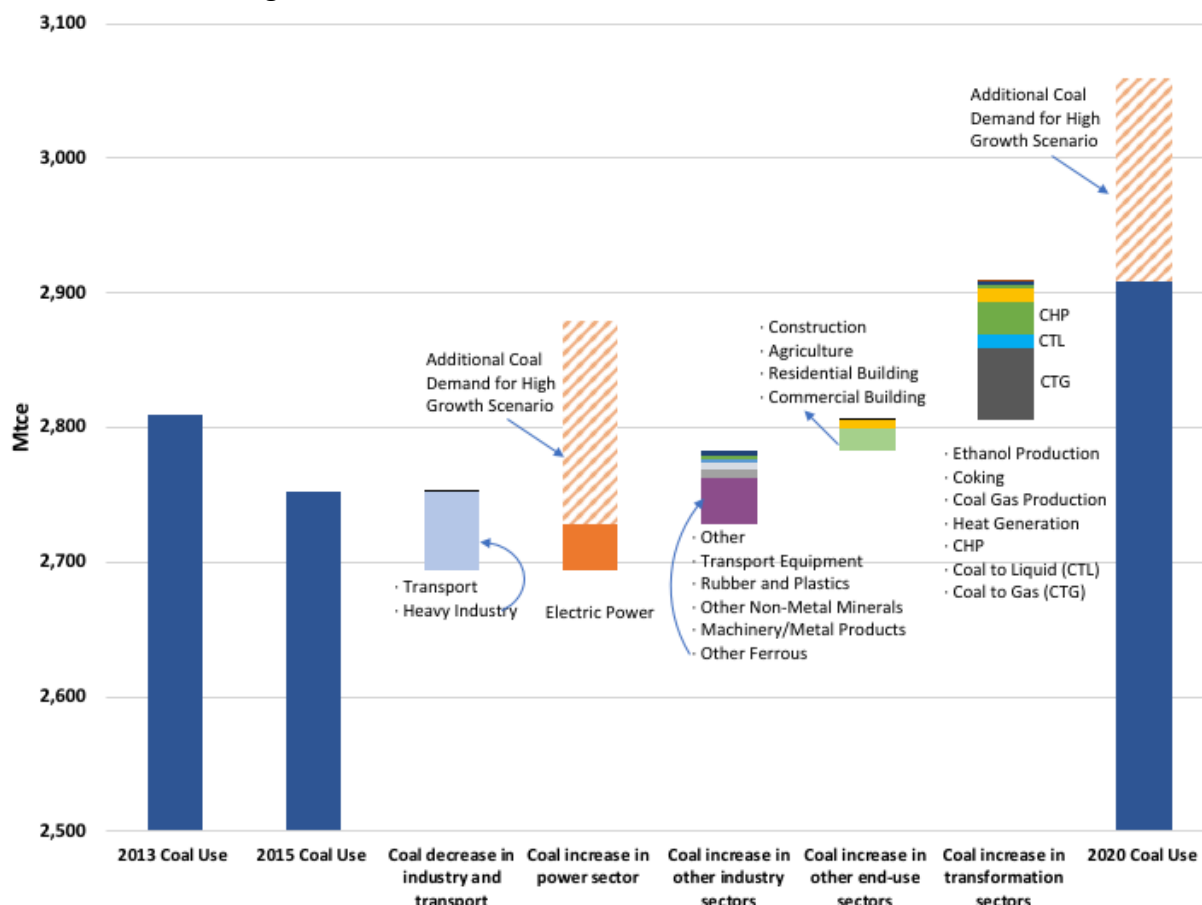


Figure 4. Components of China's coal demand in 2020 compared to China's coal consumption in 2013 and 2015. Coal use in 2013 and 2015 are actuals

Source: NBS, 2017a

The decline in transport and heavy industrial use are as projected in the DREAM 2050 model based on projections of physical activity in the heavy industrial sectors. The increase in electric power consumption of coal derives is calculated from the gap between maximum non-fossil generation and the increase in natural gas generation compared to demand forecasts from NEA, assuming 306 grams of coal equivalent (gce) heat rate of generation and capacity factors in the two capacity factors scenarios. The increases in other industrial sector consumption as well as for conversion use in biofuels and coal liquefaction (CTL) and coal gasification (CTG) processes is from the DREAM 2050 model.

Based on the China 2050 DREAM model reference case projection, demand for coal in the transformation sectors, including district heating, combined heat-and-power, CTL, CTG, coking, ethanol production, and coal gas production, will increase between 2015 and 2020. The largest source of demand growth is seen in the coal gasification sector. Although lifecycle CO₂ emissions from the consumption of synthetic natural gas are 260-330% higher than consumption of conventional natural gas in power generation (Li and Gao, 2016), 50 plants have been proposed, and capacity of at least 20 billion cubic meters is currently in operation or under construction in China. By 2020 completion and operation of the plants currently in operation or under construction increases coal demand by 53 Mtce, accounting for more than half of the increase from the non-power transformation sectors.

Overall, we projected that China's coal use in 2020 will range from a low of 2,908 Mtce based on the 13th FYP-low power demand projection to a high of 3,060 Mtce based on the 13th FYP-high power demand projection. The low demand case is 98 Mtce higher in 2020 than 2013 and 156 Mtce higher than in 2015, with the major sources of the net increase being power generation, CTG and CTL. Indeed, without growth in these three sectors, demand in 2020 would be essentially the same as it was in 2013.

This relative plateauing of coal demand between 2015 and 2020 disappears in the 13th FYP-high power demand case. Under these conditions, coal demand in 2020 is 250 Mtce higher than in 2013 and 308 Mtce higher than in 2015. Even without additional growth in CTG and CTL coal use, demand rises 186 Mtce. In this case, thermal power generation becomes the primary driver of coal demand in the short term, with increases sufficient to offset even further reductions in other end-use sectors.

Discussion

Using Chinese government projections for the 13th FYP for economic and electricity demand growth, our analysis shows that coal demand has not reached a final peak, despite declines recorded in 2014, 2015, and preliminarily, for 2016 (NBS, 2017a; NBS, 2017b). Key to the future growth in coal use are the need for additional coal-based power generation to supplemental the rapid, but insufficient, growth in non-fossil generation, plans for coal gasification to expand gas supplies to improve urban air quality, and additional coal liquefaction to offset China's current high oil import dependency. Even without CTG and CTL expansion, perhaps owing to the growing concern over the emissions and water impacts of these plants, growth in coal demand in the power sector would result in a slight rise over the 2013 level of coal demand.

Additional coal use in China's power sector can only be completely avoided with lower rates of electricity demand growth. Based on the expansion of natural gas-based power generation and the expansion of non-fossil generation, additional coal-based thermal power would not be necessary if demand growth fell to 2.2% to 3.5% per year to 2020, below the NEA's current projection of 3.6% to 4.8%, but this lower rate would likely be a consequence of a decline in economic activity below the government's forecast. One consequence of the structural shift

that China is experiencing is the move from reliance on high-energy-intensive and high-coal-intensive sectors to lower energy-intensive and higher electricity-intensive sectors. This shift underpins a continued strong rate of electricity demand growth which will partially be met by coal-based power generation.

Projected growth of coal consumption in non-heavy-industrial sectors is subject to a range of policy uncertainties, including accelerated fuel switching from coal to natural gas, mandatory coal consumption quotas, constraints on commercial building floor space expansion, and further industrial restructuring in addition to other potential impacts such as a decline in trade as a result of external trade policy changes. Current policies on urbanization, for example, favor expansion.

Even if a plateau in coal consumption persists, China's CO₂ emissions will rise in conjunction with the continued growth in oil and natural gas consumption. An absolute sustained decline in coal demand is required to offset the increasing CO₂ emissions from these fuels. At 2015 levels of demand, a 1% decline in coal consumption would fully offset the CO₂ emissions associated with a 3% rise in oil demand along with a 6% rise in natural gas demand, lower than the actual rates of growth recorded in recent years.

Thus, while China's coal consumption has recently declined slightly, projected trends to 2020, including projected increases in electricity demand that cannot be met by other fossil-fuel or non-fossil-fuel based electricity sources combined with projected increases in coal use in light manufacturing, construction, agriculture, and buildings as well as projected increases in coal use for transformation (e.g. CHP, CTL, CTG, etc.) lead us to conclude that China's coal use – and associated CO₂ emissions – have not peaked and will continue to grow at least until 2020.

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References

- Baosteel, 2015. "Harder path may be ahead for the steel industry during the 13th Five-Year Plan." July 22. <http://www.baosteel.com/group/contents/4701/91034.html>
- China Electricity Council (CEC). 2017. *2016 National Power Industry Statistical Bulletin*. <http://www.cec.org.cn/guihuayutongji/tongjixinxi/niandushuju/2017-01-20/164007.html>
- Fan, Yongbin. 2016. *Achieving Coal Cap Goals in the Cement Industry over the 13th Five-Year Plan*. November. <http://www.china5e.com/download/20161101-nrdc/1101-FanYongbin.pdf>
- Green, F. and Stern, N. 2016. "China's changing economy: implications for its carbon dioxide emissions", March 16. *Climate Policy*. <http://dx.doi.org/10.1080/14693062.2016.1156515>
- Intergovernmental Panel on Climate Change (IPCC). 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf
- Lewis, J., D. Fridley, L. Price, H. Lu, and J. Romankiewicz. 2015. "Understanding China's non-fossil energy targets". *Science* 27, November. Vol. 350, Issue 6264, pp. 1034-1036. DOI: 10.1126/science.aad1084
- Li, Sheng and L. Gao. 2016. "Greenhouse gas emissions from synthetic natural gas production". *Nature Climate Change*, 6, 220–221 (2016). DOI:10.1038/nclimate2887
- Liu, Z., D. Guan, W. Wei, S. Davis, P. Ciais, J. Bai, S. Peng, Q. Zhang, K. Hubacek, G. Marland, R. Andres, D. Crawford-Brown, J. Lin, H. Zhao, C. Hong, T. Boden, K. Feng, G. Peters, F. Xi, J. Liu, Y. Li, Y. Zhao, N. Zeng, and K. He. 2015. "Reduced carbon emission estimates from fossil fuel combustion and cement production in China." *Nature* 524, August. DOI:10.1038/nature14677
- National Bureau of Statistics (NBS). 2016. *2015 Statistical Communique of National Economic and Social Development*, February 29.
- National Bureau of Statistics (NBS). 2017b. *Statistical Communiqué of the People's Republic of China on the 2016 National Economic and Social Development*, February 28. http://www.stats.gov.cn/english/PressRelease/201702/t20170228_1467503.html
- National Bureau of Statistics of China (NBS). 2015. *2015 China Statistical Yearbook*. China Statistics Press. Beijing, China.
- National Bureau of Statistics of China (NBS). 2017a. *2016 China Energy Statistical Yearbook*. China Statistics Press. Beijing, China.
- National Bureau of Statistics of China (NBS). n.d. *Coal Consumption by Sector* (a searchable database). <http://data.stats.gov.cn/easyquery.htm?cn=A01>
- National Development and Reform Commission (NDRC) and National Energy Administration (NEA). 2016a. *13th Five-Year Plan of Energy Development*. <http://www.ndrc.gov.cn/zcfb/zcfbghwb/201701/W020170117350627940556.pdf>

National Development and Reform Commission (NDRC) and National Energy Administration (NEA). 2016b. *13th Five-Year Plan of Power Sector Development*.

<http://www.sdpc.gov.cn/zcfb/zcfbghwb/201612/P020161222570036010274.pdf>

National Development and Reform Commission (NDRC). 2016. *Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions*.

<http://www4.unfccc.int/Submissions/INDC/Published%20Documents/China/1/China's%20INDC%20-%20on%2030%20June%202015.pdf>

PetroChina, 2016. *13th Five-Year Plan of Petroleum and Chemicals Industry*, April 13.

http://www.360doc.com/content/16/0413/17/5507330_550330945.shtml

Qi, Y., N. Stern, T. Wu, J. Lu, and F. Green. 2016. "China's post-coal growth". July 25. *Nature Geoscience*. doi:10.1038/ngeo2777

State Council of China. 2016. *13th Five-Year Plan on Energy Conservation and Emission Reduction*, December 20.

http://www.gov.cn/zhengce/content/2017-01/05/content_5156789.htm

Tollefson, 2016. "China's carbon emissions could peak sooner than forecast", March 21. *Nature*.

<http://www.nature.com/news/china-s-carbon-emissions-could-peak-sooner-than-forecast-1.19597>

Xiao, Hui. 2017. "Development status, trends, and market overview of China's soda ash industry." October 27. <http://www.niuniu.com/mobile/news/176611?fontSize=2>

Zhou, N., D. Fridley, M. McNeil, N. Zheng, J. Ke, and M. Levine. 2011. *China's Energy and Carbon Emissions Outlook to 2050*. Lawrence Berkeley National Laboratory (LBNL-4472E). Berkeley, CA.

<https://china.lbl.gov/sites/all/files/lbl-4472e-energy-2050april-2011.pdf>