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# Energy Transition in the Power Sector in China: State of Affairs in 2016

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Review on the Developments in 2016 and an Outlook

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**ANALYSIS**

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25.1\*

\*RES-Share on power consumption

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## IMPRINT

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Review on the Developments in 2016 and an Outlook

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# Preface

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Dear readers,

Last year, China overtook Germany as the world's leader for installed solar capacity. In 2016 alone, 34 GW solar PV were installed in China, while Germany merely added a single GW. This is not China's only distinction. China has also started an energy transition with its own dynamics and characteristics. However, this transition resembles what we have already observed in Germany and Europe.

While it is true that China is still the largest energy consumer and emitter of greenhouse gases, its rapid surge of coal-fired power plants has slowed, and the increase in emissions has come to a halt. Furthermore, the government has begun a rapid expansion of renewable energy. In the diplomatic arena, the Chinese government has reiterated its commitment to

the Paris climate agreement, despite the USA's recent volte-face.

In this annual review, we provide a more comprehensive picture of the latest development of China's power system. The review focuses on recent data regarding the supply and demand of power from renewable and conventional sources.

Your feedback is more than welcome. We hope you enjoy reading this review.

**Wang Zhongying**

China National Renewable Energy Centre

**Patrick Graichen**

Director Agora Energiewende

## Key findings

1

**Total electricity generation increased by five per cent in 2016, or by about 300 TWh.** At 65 per cent, coal provides the largest share of total generated electricity. Renewables account for 25 per cent. Consumption increased by 283 TWh, comparable to the entire consumption of Spain.

2

**However, there is a clear trend towards renewable energy.** Since 2010, the share of renewables in the power mix has increased by 8 percentage points, while coal has decreased by 11 percentage points.

3

**Curtailement of renewable energy is high, averaging 17 per cent.** Some provinces, like Gansu and Xinjiang, plan to slow down wind capacity expansion in the coming years. Furthermore, the government is encouraging expansion of the transmission grid.

4

**Use of conventional power plants is decreasing.** Full load hours for coal plants decreased from more than 5,000 hours in 2013 to 4,165 hours in 2016, and energy-related emissions have stagnated at 2013 levels. However, the government is reviewing its plans for new coal plants, and another 200 GW of coal-fired power plants are under construction and are expected to go online by 2020.

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## Data and Methodology

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Compiling an annual review within the first half of a following year always comes with certain obstacles – this is true for Germany, Europe and even more so globally. Reliable and recent data sources are sometimes hard to find, and even if reliable sources exist, some compromises regarding completeness of data have to be made. For this review, we have asked Energy Brainpool to compile the most appropriate data to provide a comprehensive and consistent picture of the Chinese power system in 2016.

If not indicated otherwise, data are sourced from the annual electricity statistics provided by the China Electricity Council. Many of the data sources used in this report are Chinese language policy documents or statistics. They have been sourced from China Energy Portal, a website that collects Chinese policy documents, news, and statistics, and offers [partial] translations of these.<sup>1</sup> Over the years the annual electricity statistics (2009-2016) changed slightly in their composition and degree of detail. English translations of the annual electricity statistics can be found on the China Energy Portal.<sup>2</sup> Furthermore, no detailed or consistent information on capacities and generation by oil, geothermal, waste, biomass, offshore wind and concentrated solar power are available. Generation denoted as "other" is not defined in the data source. In this report, it denotes energy generation from oil, geothermal, waste and biomass.

Whenever an exchange rate is used for conversion from Chinese Yuan to Euro we refer to the exchange rate of April 3, 2017 of 1 CNY = 0.136108 EUR.

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1 [chinaenergyportal.org/en/](http://chinaenergyportal.org/en/)

2 [chinaenergyportal.org/en/2010-detailed-electricity-statistics/](http://chinaenergyportal.org/en/2010-detailed-electricity-statistics/)

# 1. Power generation

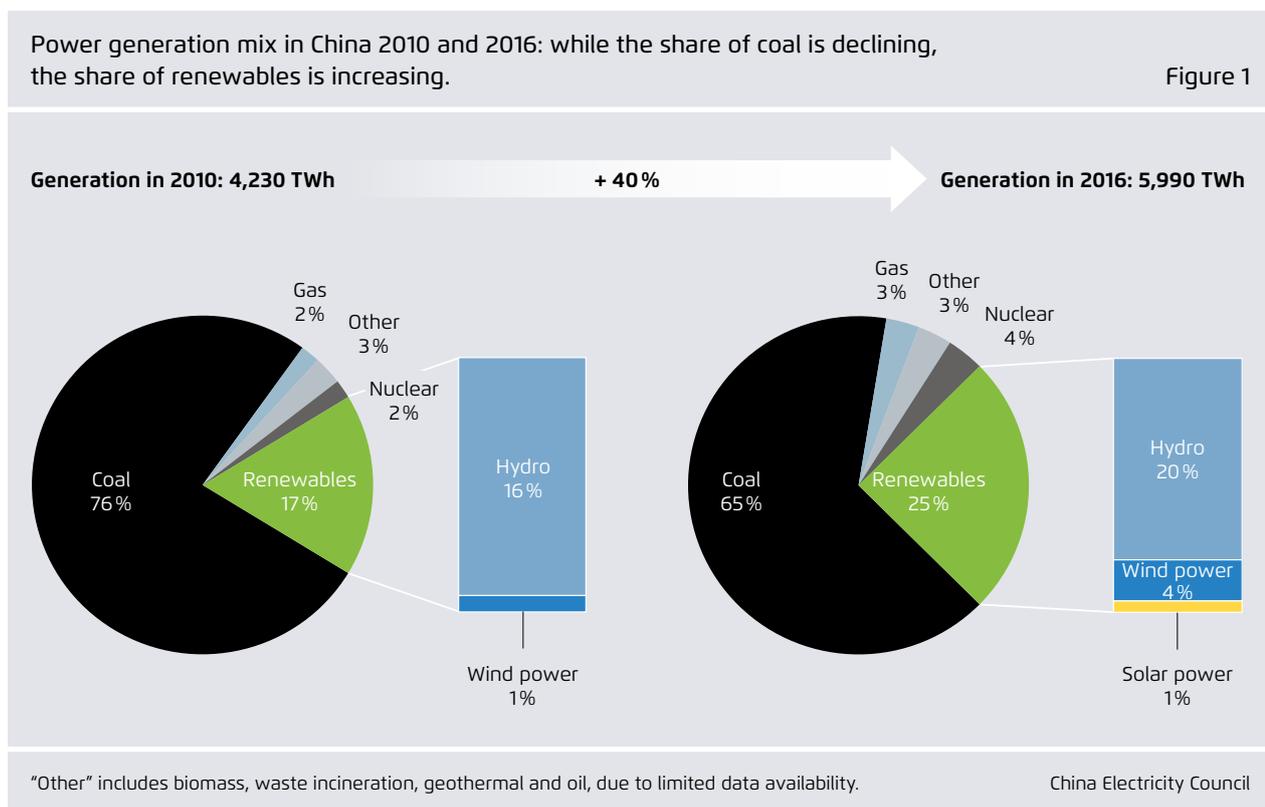
In 2016, Chinese power generation increased by more than 5 per cent, or 296 terawatt hours, compared to 2015, reaching a total of 5,990 terawatt hours (European Union: 3,211 terawatt hours). In 2016, the bulk of Chinese electricity was produced by thermal power plants, mainly coal, which accounted for 65 per cent (or 3,906 terawatt hours) of the country's total power generation.

This is an increase of more than 40 per cent, or 1,761 terawatt hours, compared to 2010. Of this total, fossil fuel power plants generated an additional 870 terawatt hours (mainly coal, with 680 terawatt hours). Wind contributed 190 terawatt hours of the additional electricity, solar PV 66 terawatt hours, nuclear 140 terawatt hours, and hydro power almost another 500 terawatt hours. In relative shares, renewable

energy (excluding biomass)<sup>3</sup> grew by 8 percentage points, from 17 to 25 per cent, while coal-fired generation declined 11 percentage points.

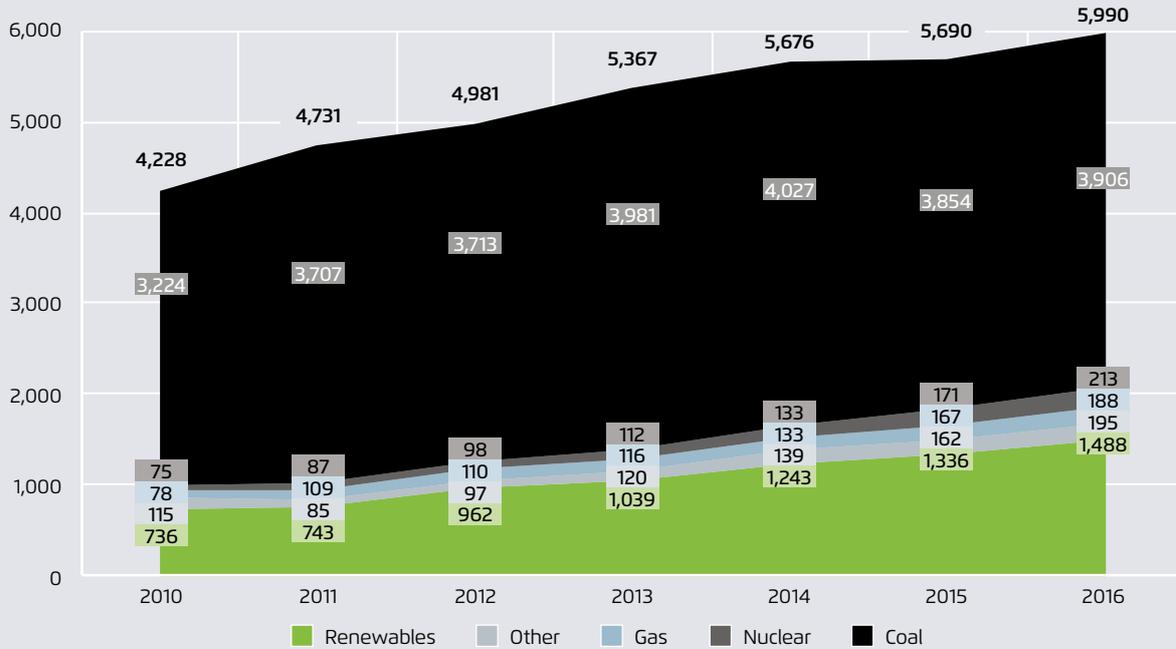
In 2016, the share of renewable energy in power generation amounted to 24.8 per cent, or 1,488 terawatt

3 In general, renewable energy includes: hydro (run-of-river and pumped storage), wind (onshore and offshore), PV and biomass. However, detailed data are not available for onshore and offshore wind. Also, no data are available on concentrated solar power. Therefore, data on hydro in this report contains both run-of-river and pumped hydro, data on wind includes onshore, and probably offshore, and data on solar only includes PV. Data on power from biomass are not consistent. Therefore, no separate biomass statistics are considered in this report. Along with oil, geothermal, and waste, biomass is considered as "other" generation in this report. Biomass is also not considered in the capacity data in this report. Biomass capacity stood at about 15 GW at the end of 2016.



Annual power generation by energy source in 2010–2016: the share of power generation from renewables is growing faster than total power generation.

Figure 2



China Electricity Council

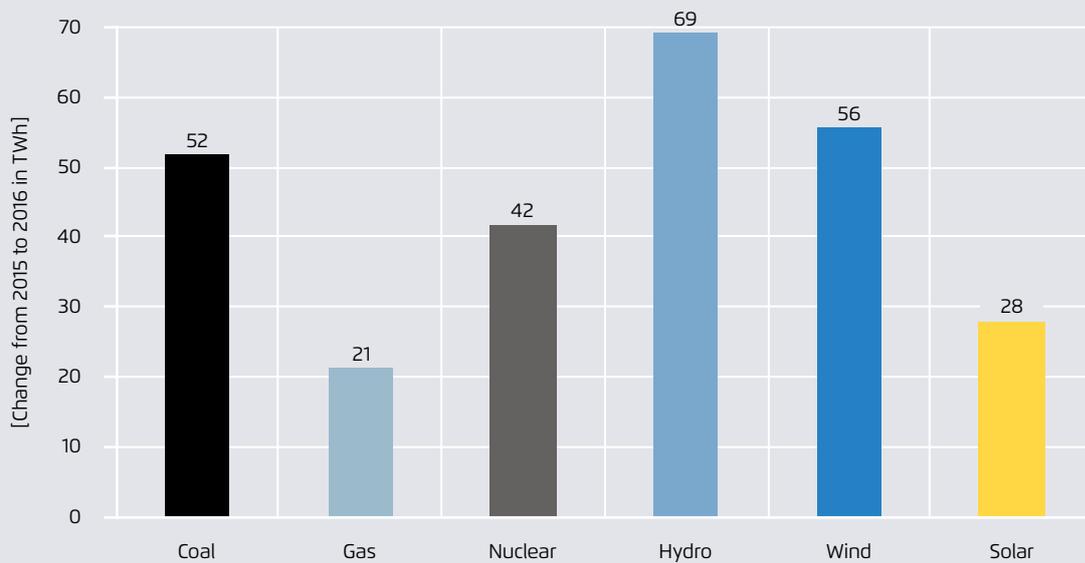
hours. To put this into perspective: In Europe, renewable energy accounted for 29.6 per cent of total power generation, and only 23.8 per cent if biomass is excluded.<sup>4</sup>

Year-over-year, all generating technologies produced more electricity than in the previous year. However, there are stark differences between the individual technologies. In 2015-2016, the lowest increase on a year-over-year basis came from coal-fired generation, which only grew 1.3 per cent, while wind grew by 30 per cent, solar PV by 72 per cent, nuclear by 24 per cent, and gas by 13 per cent. Hence, new generation from wind and solar outstripped new generation from coal- and gas-fired thermal power plants, the latter of which grew by 84 and 73 terawatt hours, respectively. Including hydro, new generation from renewable sources was higher than the addi-

tional generation from all conventional power plants, including nuclear. Electricity production by nuclear power plants grew by 42 terawatt hours compared to 2015.

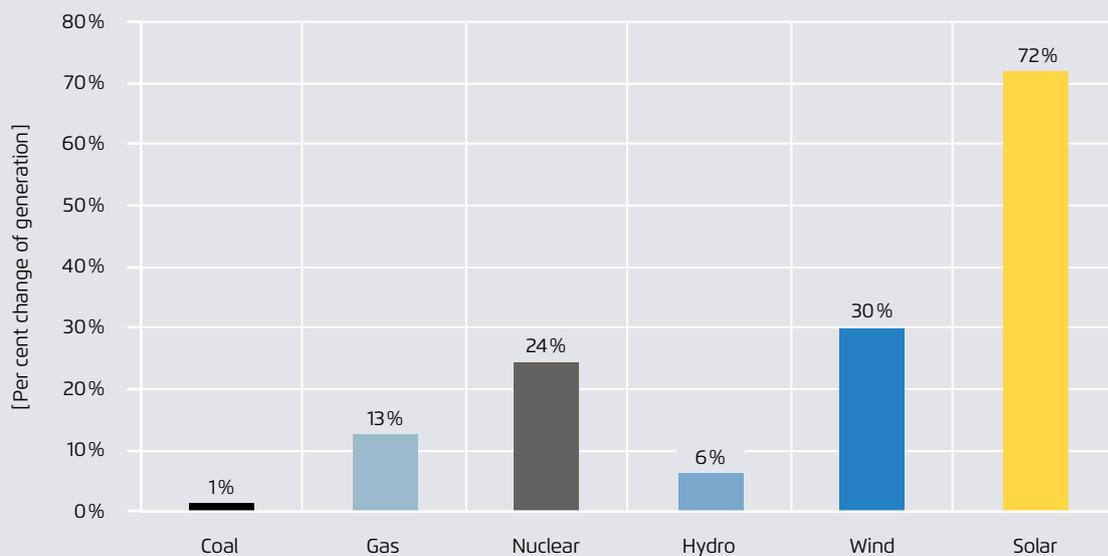
4 Agora Energiewende and Sandbag, 2017.

Year-on-year increase (2015 to 2016) of generation from all technologies in terawatt hours: new generation from renewable energy outstripped new generation from conventional generation. **Figure 3**



China Electricity Council

Year-on-year increase (2015 to 2016) of generation from all technologies in per cent: while new generation growth from coal was low, new generation growth from wind and solar, as well as nuclear, were considerably high. **Figure 4**



China Electricity Council

## 2. Power consumption

Since 2010, China's net power consumption grew by 1,720 terawatt hours, roughly half of Europe's total electricity consumption in 2015.<sup>5</sup> Consumption grew in all sectors<sup>6</sup>, but the manufacturing industry (secondary sector) is clearly dominating, with demand increasing by 1,060 terawatt hours since 2010. The biggest percentage increase between 2010 and 2016 however took place in the services industry (tertiary sector) with 78 per cent, which indicates the sectoral shift the Chinese economy is undergoing. Households increased consumption by 58 per cent. Over the years, the absolute growth of electricity consumption gradually levels off. While total consumption grew by 12 per cent from 2010 to 2011, the year-on-year

increase from 2015 to 2016 only stood at 5 per cent and even stagnated the previous year.

While China's economic growth and energy consumption are closely linked, China's economy is becoming less dependent on energy consumption to fuel GDP growth. The adoption of energy efficiency technologies, particularly within energy intensive industries, and the growth of China's service sector, are lessening the energy intensity of GDP, as Figure 6 shows.<sup>7</sup>

In its 13<sup>th</sup> Five-Year Plan (2016-2020)<sup>8</sup>, the Chinese government aims to achieve GDP growth of at least 6.5 per cent to 92.7 trillion Yuan in 2020. Along

5 ENTSOE, 2016.

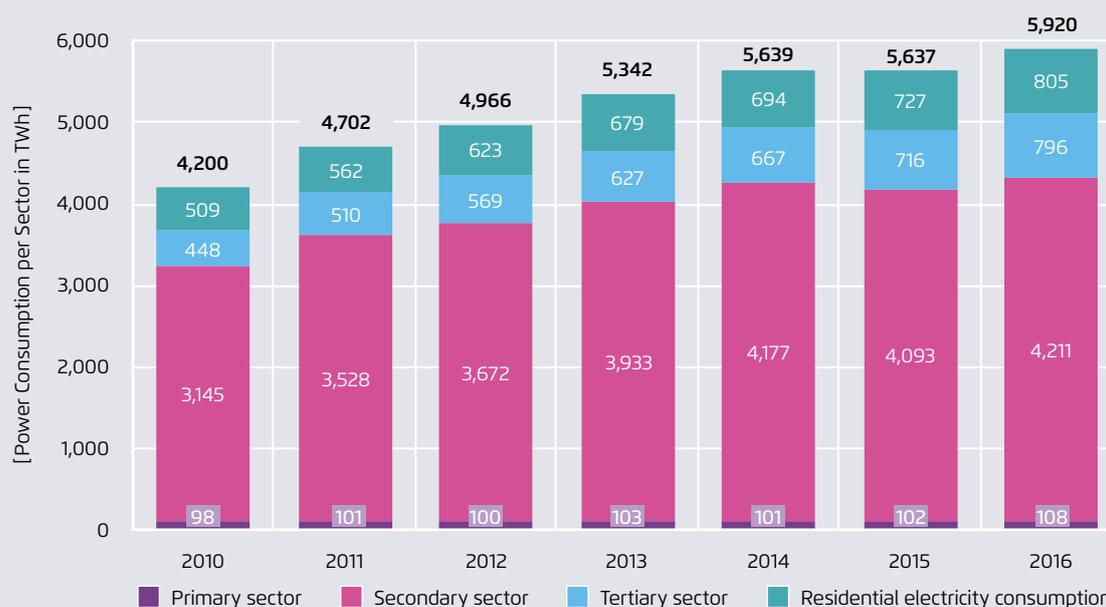
6 Primary industry: Agriculture; Secondary industry: Mining, manufacturing, construction; Tertiary industry: Service, knowledge, retail

7 IEA, 2016; Financial Times, 2016; KPMG, 2016.

8 Central Committee of the Communist Party of China, 2016.

Chinese sectoral power consumption, 2010–2016. From 2010 to 2016 the share of the tertiary and the residential power consumption grew faster than total power consumption.

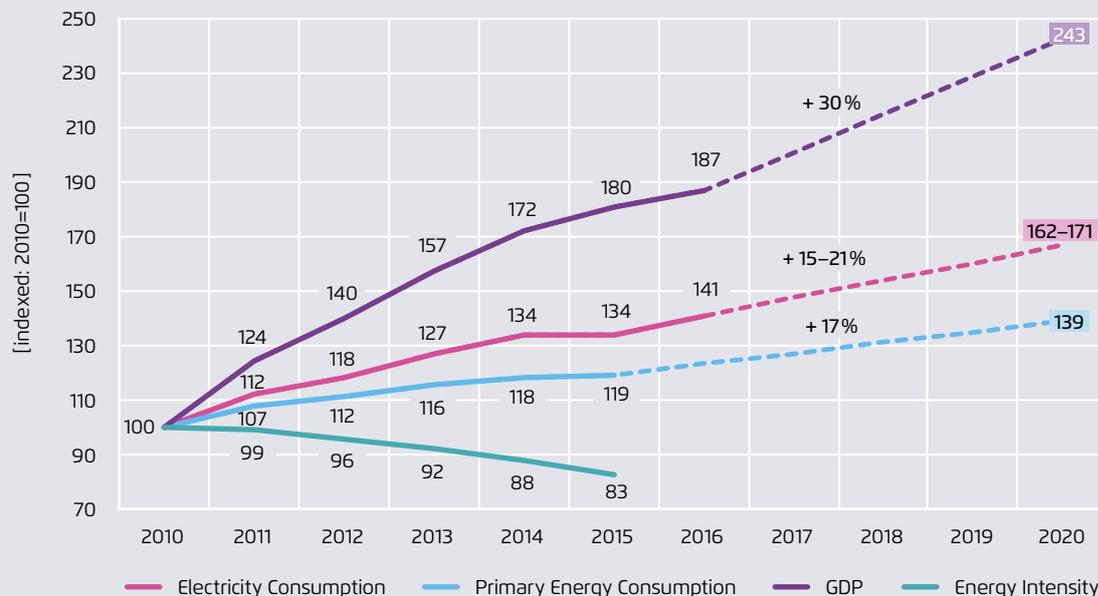
Figure 5



China Electricity Council

GDP, primary energy consumption, electricity consumption and energy intensity of GDP (at constant purchase power parity) 2010 to 2016 with goals for 2020 (indexed, 2010 = 100).

Figure 6



Dotted lines are linear projections based on 2020 targets. Percentage increase for GDP and Electricity Consumption from 2016 to 2020, for Primary Energy Consumption from 2015 to 2020. Data on energy intensity of GDP (at constant purchase power parity) only available up to 2015 from Enerdata 2017.

China Electricity Council, National Development and Reform Commission (13<sup>th</sup> FYP), Enerdata and own calculations.

with the target, that 80 per cent of the energy supply is supposed to be covered domestically, and energy consumption will increase accordingly. China also seeks to limit the growth of total primary energy consumption to 3 per cent, or, at most, 5 billion Standard Coal Equivalents (40,700 terawatt hours). Electricity consumption is expected to increase by 3.6 to 4.8 per cent to 6,800 to 7,200 terawatt hours until 2020.<sup>9</sup>

9 National Development and Reform Commission, 2016a.

### 3. Development of renewable energy

In 2016, renewable energy generated 24.8 per cent of China’s total electricity, and covered about 25.1 per cent of the country’s power consumption. The share of renewables in power consumption was 1.1 percentage points higher compared to 2015, and 7.6 percentage points higher compared to 2010.

The targets of the 12<sup>th</sup> FYP, covering the period 2010–2015, with 290 GW for hydropower, 100 GW for wind and 21 GW for PV, were exceeded by 30 GW for hydropower, 30 GW for wind and more than 20 GW for PV.<sup>10</sup> From 2010 to 2016, about 115 GW of hydro power, almost 120 GW of wind power, and more than 77 GW of solar power were connected to the Chinese power grid.

10 National Development and Reform Commission, 2016b.

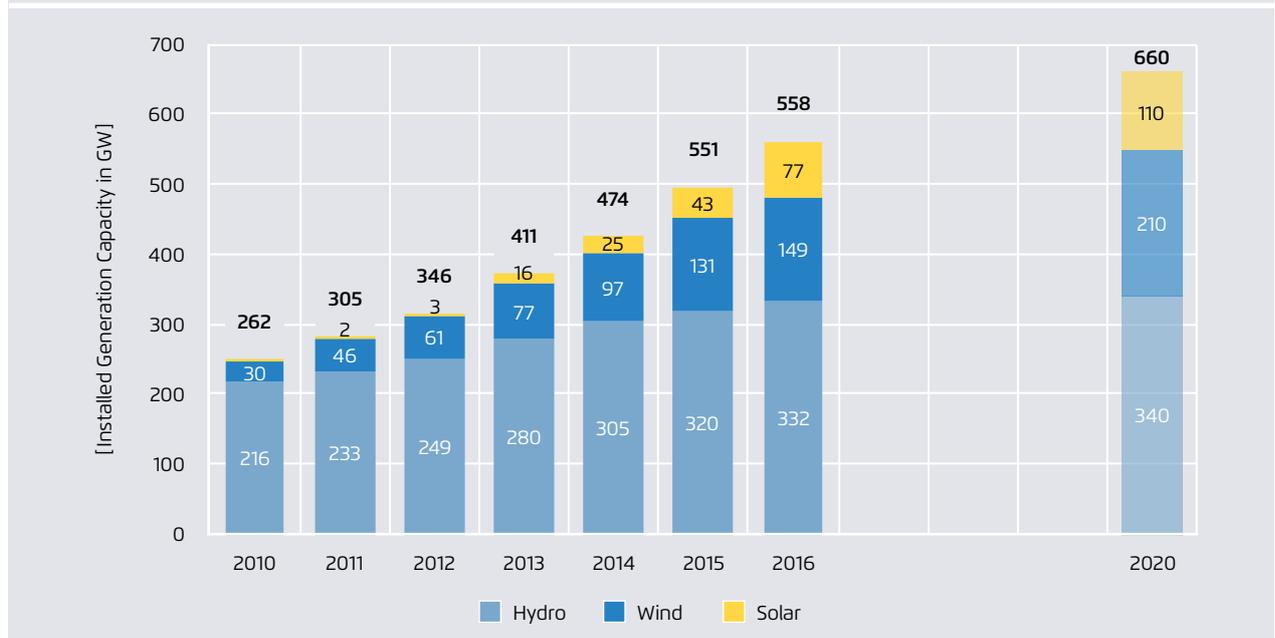
In terms of electricity generated, hydro power contributed the most to renewable generation, with 1,180 terawatt hours in 2016 (80 per cent of the total renewable electricity). Wind turbines generated 241 terawatt hours (16 per cent of the total renewable generation), and solar energy 66 terawatt hours (4 per cent of the total renewable generation).<sup>12</sup> Electricity output from hydropower fluctuates due to its strong dependence on precipitation patterns, as only 1–2 per

11 2020 targets include 5 GW of concentrated solar power and 5 GW of offshore wind power.

12 Biomass is not included in renewable generation here due to data integrity and consistency. If it were included, its share in renewable generation in 2016 would have been in par with PV, standing at roughly 4 per cent.

Renewable generating capacity from 2010 to 2016 and targets for 2020<sup>10</sup>: very moderate capacity additions for hydropower are expected when compared to wind and solar.

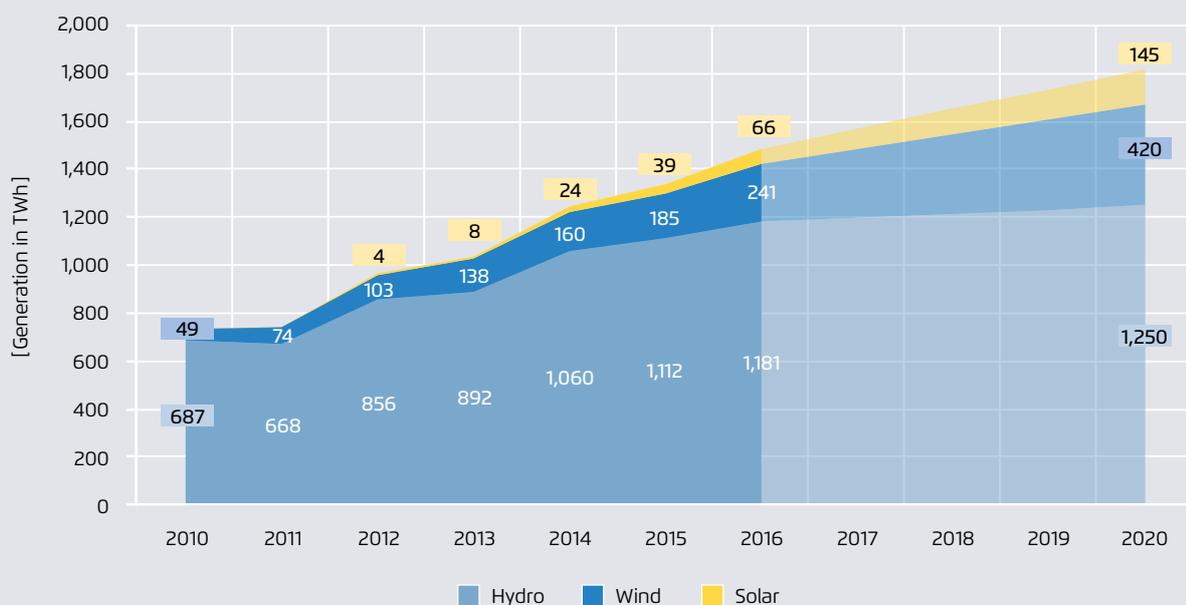
Figure 7



China Electricity Council, National Development and Reform Commission (13<sup>th</sup> FYP)

Power generation from renewable energies (hydro, wind, and solar) from 2010 to 2016 and targets for 2020: accordingly, the share of wind and solar in total renewable power generation is projected to grow from 20 per cent in 2016 to 30 per cent in 2020.

Figure 8



China Electricity Council, National Development and Reform Commission (13<sup>th</sup> FYP).

cent of China's hydro power generation comes from pumped-hydro stations<sup>13</sup>.

The 13<sup>th</sup> FYP for Renewable Energy<sup>14</sup> includes generation targets for solar power (at least doubling today's generation), wind (almost doubling today's generation) and hydro (only a slight increase).

Wind and solar power in China are being supported by a feed-in tariff (FiT), which is differentiated according to so-called geographical resource types or

categories.<sup>15</sup> Depending on solar irradiation or wind speed, the feed-in tariff is adjusted to create similar economic conditions across the country. The feed-in tariff is guaranteed for a period of 20 years for PV. For wind onshore, projects have to be approved by a tendering process before getting a FIT granted.

With 34 GW newly installed PV capacity, China set a new world record in 2016. Triggered by a reduction of the FIT in the second half of the year, 22 GW were installed in the first six months.<sup>16</sup> These astonishing installation rates were possible due to a strong growth

13 Hydro data includes all types of hydro power: dam hydro, run-of-river and pumped hydro. The generation share of pumped-hydro during 2010–2016 was in the range of 2 per cent of the entire hydro generation. The capacity share of pumped-hydro stands at 7 per cent of the total hydropower generating capacity (deviation between capacity and generation due to different production patterns of run-of-river and pumped-hydro).

14 National Development and Reform Commission, 2016b.

15 The area of Tibet is not included in these resource areas, but specific rules apply for Tibetan projects.

16 China Electricity Council, 2016a; Projects that have been approved until the end of 2015 and built before the 30th of June 2016 could still apply for the 2015 feed-in tariffs. Projects where construction was finished after June 30, 2016 fell under the new feed-in tariff regime.

in PV module fabrication that drove down prices for PV panels. In the second half of 2016, new module fabrication capacity of 12 GW was constructed.<sup>17</sup> For 2017, new PV feed-in tariffs ranging from 0.65–0.85 Yuan/kWh (0.09–0.12 Euro/kWh) are in place. Figure 9 depicts the development of the feed-in tariff for PV from before 2016 until 2017 for the three different resource categories.<sup>18</sup>

Similarly, feed-in tariffs for wind power have also been lowered over the years, as displayed in Figure 10.

The location of renewable generation capacity has increasingly become an issue in China. Most of the wind and solar capacities are located in the north-western provinces. The electricity then has to be transported to China's load centres. However, due to

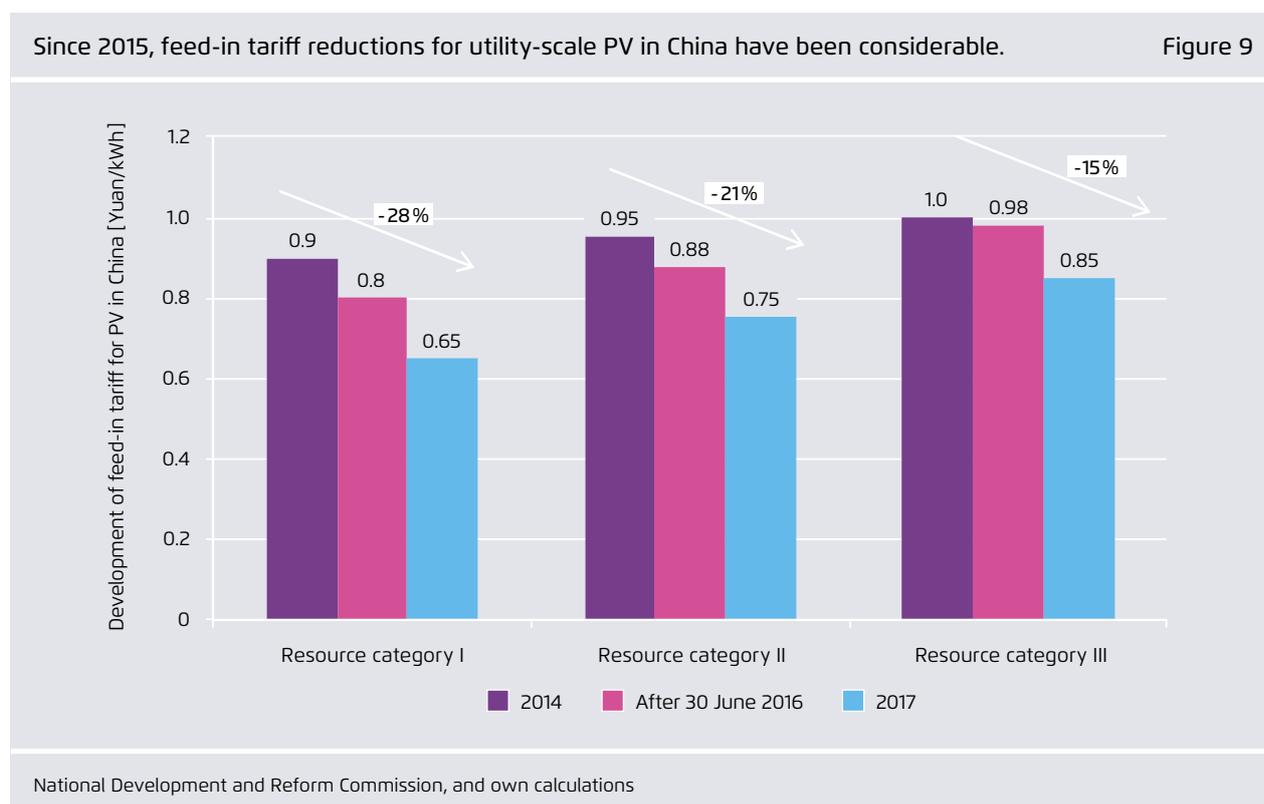
grid bottlenecks and the guaranteed full load hours for coal-fired power plants that are part of China's central dispatch model, curtailment of renewable generation has become significant. In 2016, 17 per cent, or 49.7 terawatt hours, of China's wind power generation was curtailed, as figure 11 displays.<sup>19</sup>

Figure 12 shows the state of curtailment of wind power as a percentage of its generation across the country's provinces. Curtailment is mainly a problem in China's northwestern provinces, especially Gansu and Xinjiang. China's central government has worked to alleviate curtailment by encouraging the construction of ultra-high voltage direct current power lines from the West to the East, and halted wind power

17 China Electricity Council, 2016b; China Electricity Council, 2016c.

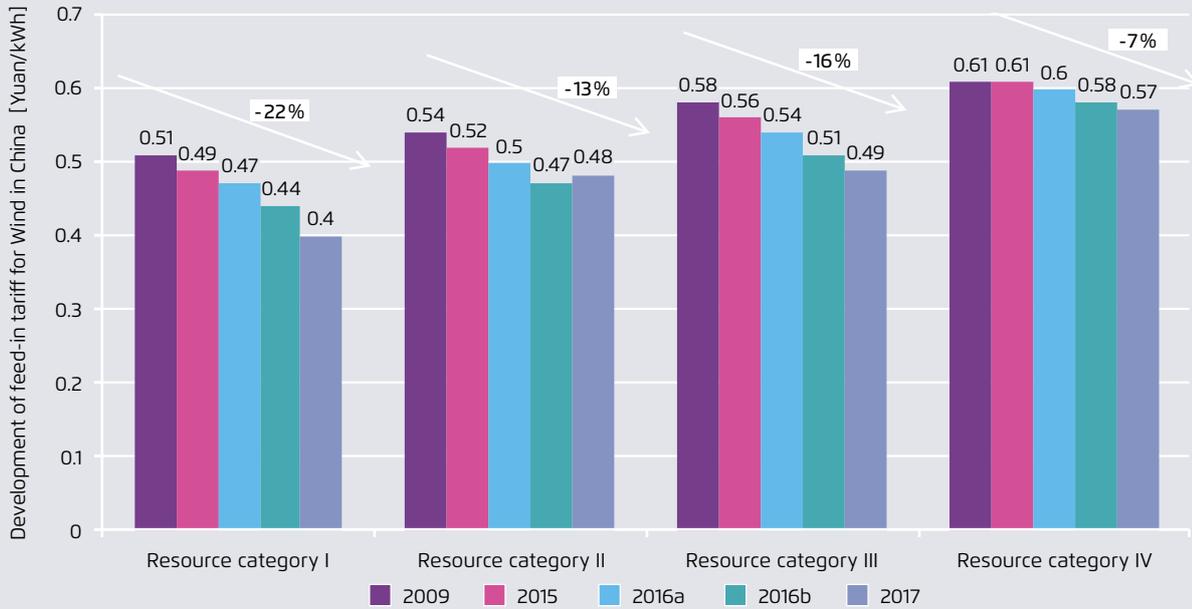
18 National Development and Reform Commission, 2016c.

19 Wind Power Monthly, 2013; China Wind Power Center, 2014; National Energy Administration, 2014; National Energy Administration, 2015; National Energy Administration, 2016a; National Energy Administration, 2017a.



Feed-in tariff reductions for onshore wind power in China have been lower than those for PV since 2009.

Figure 10

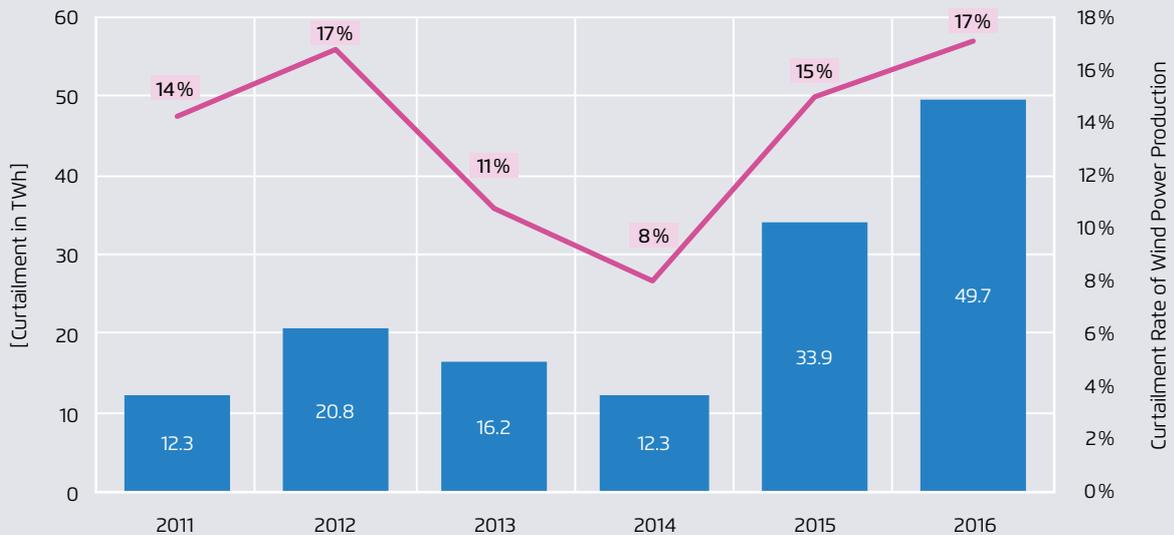


Years denote the effective date of the feed-in tariff.

National Development and Reform Commission and own calculations<sup>19</sup>

The wind power curtailment situation in China showed improvement until 2014, but worsened again during the past two years.

Figure 11



National Energy Administration

expansion in six provinces, Xinjiang, Ningxia, Gansu, Heilongjiang, Jilin and Inner Mongolia.<sup>21</sup>

Full load hours for hydro power fluctuated between 3,000 and 3,700 hours per year. Wind turbines had an average of 1,740 hours, and PV power plants just

above 1,100 hours in 2016. Figure 13 shows a clear downward trend for full load hours of wind and solar PV, a trend that is explained by curtailment rates and increasing capacity deployment in less resource-rich locations.<sup>22</sup> Solar irradiation values across China reach about 1,500 kWh per m<sup>2</sup> (Germany: ~1,050 kWh/m<sup>2</sup>). However, China possesses a large number of sites with very good resources. For example, Beijing is located further south than Madrid and considerable PV capacities are installed in areas as far south as Northern Africa and the Mediterranean Sea. Thus, full load hours of PV are significantly higher than Germany's 980 hours per year.<sup>23</sup>

20 For projects that have been approved since the start of 2016, or approved before 2016, but where construction has not commenced by the end of 2017, the 2016a feed-in tariff applies. For projects that will be approved after the beginning of 2018, the 2016b feed-in tariff is valid. For projects that will be approved from beginning of 2018 or before 2018, but where construction has not commenced by the end of 2019, the 2017 feed-in tariff applies.

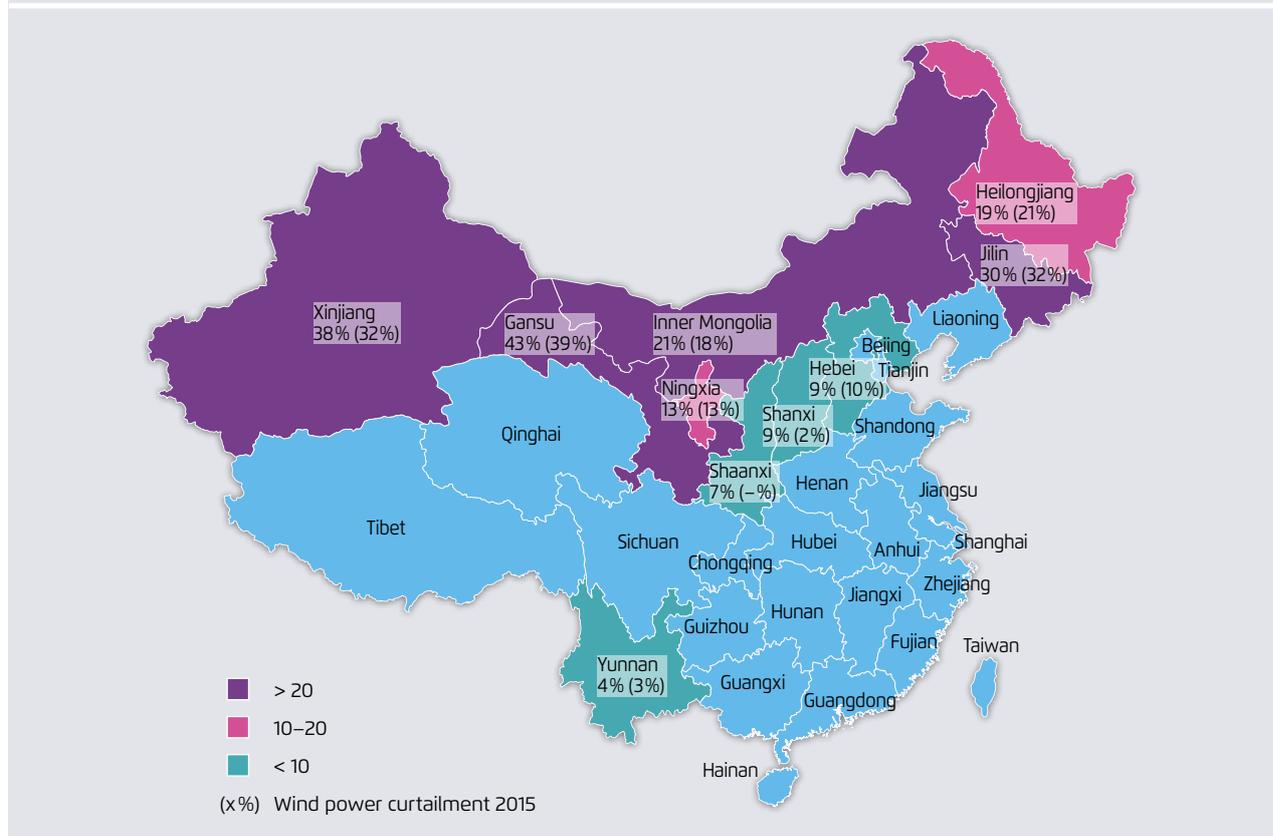
21 Central Committee of the Communist Party of China, 2010 (12th Five-Year-Plan), State Grid Corporation of China, 2017; National Energy Administration, 2017b.

22 National Energy Administration, 2016b.

23 Solargis, 2017.

Curtailment rates for wind power in different Chinese provinces in 2016.

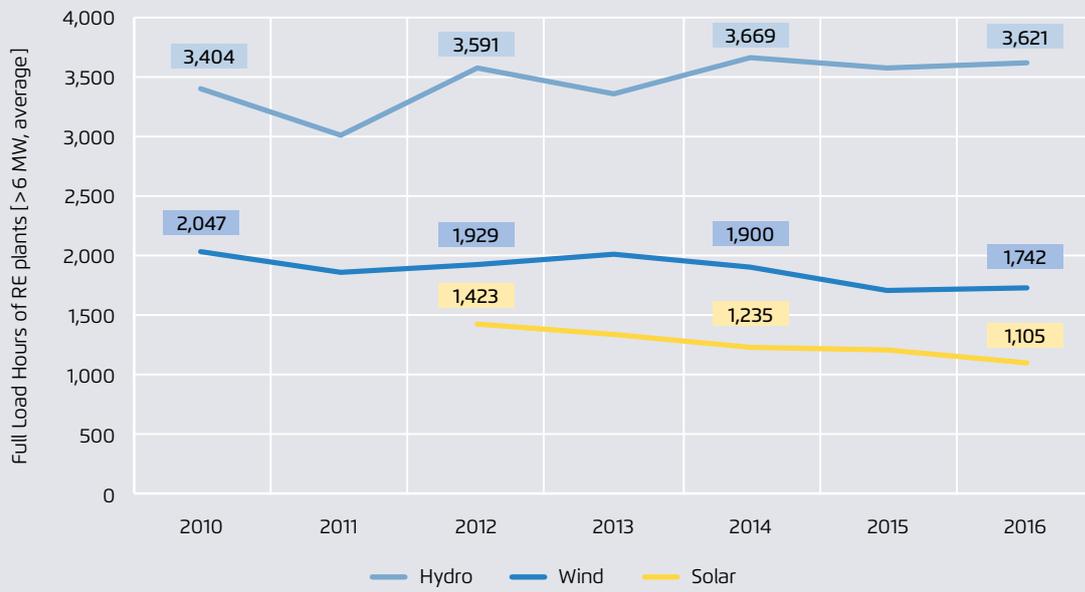
Figure 12



own illustration

Full load hours of hydro, wind and solar power from 2010 to 2016.

Figure 13



Full load hours already include curtailment; theoretically, full load hours are higher; for PV, no accurate data is available prior to 2012. China Electricity Council

## 4. Development of conventional energy

Despite the tremendous growth in Chinese renewable energy, the country's power system is based on conventional thermal generation. In 2016, China's conventional power generating capacity stood at about 1,050 GW, which represents an increase of more than 40 per cent (equivalent to 300 GW) over the last seven years. With 943 GW of installed capacity in 2016, coal-fired power plants clearly dominate the picture. Figure 14 shows the capacity build-up from 2010 to 2016, including the targets of last year's 13<sup>th</sup> Five-Year Plan for energy for 2020.<sup>24</sup>

While coal capacity has witnessed steady growth in recent years, the generation of electricity from coal-fired power plants has been stagnate since 2013 (at between 3,900 and 4,000 terawatt hours).

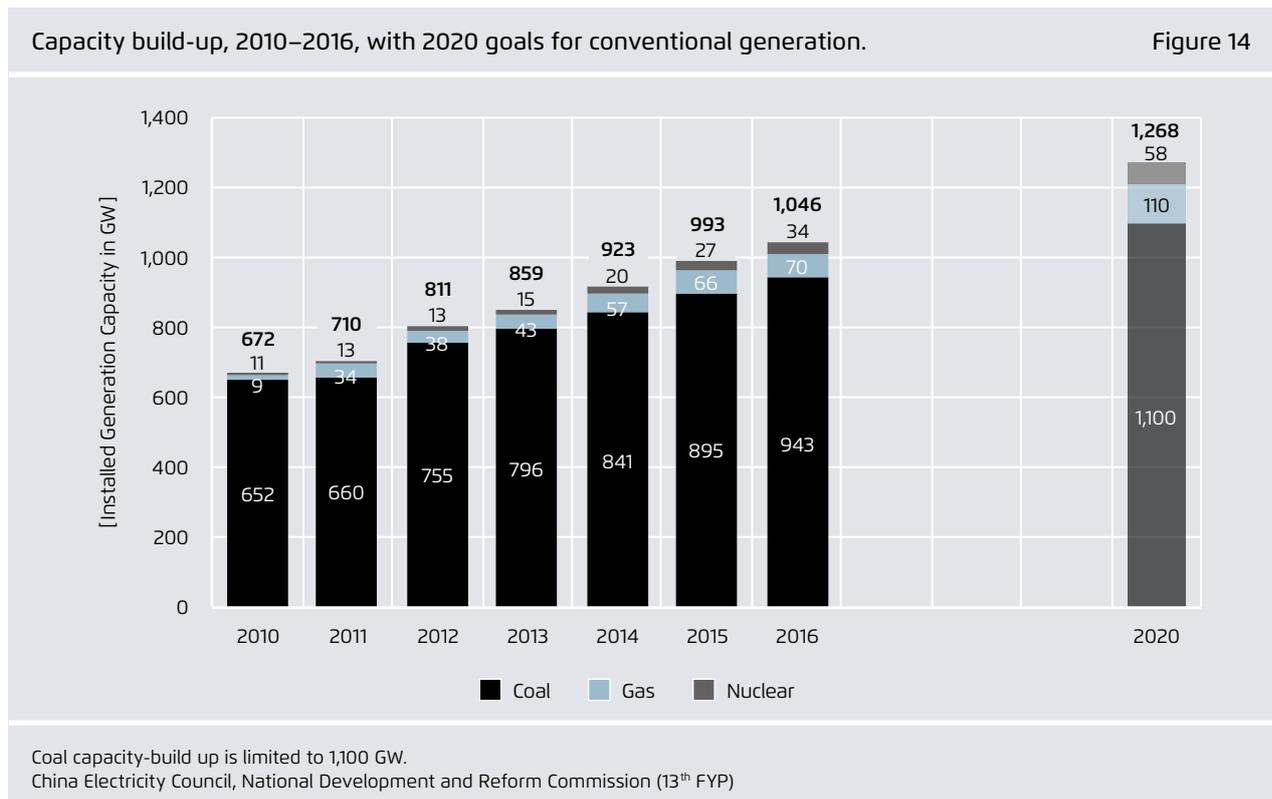
Accordingly, and due to increased capacity, the full load hours of thermal power plants decreased by almost 1,000 hours.<sup>25</sup> With about 4,160 full load hours in 2016, Chinese plants experienced their lowest level of full-load operation in the past three decades (see figure 16).

Although China's electricity system is oversupplied, load centres on the East coast experience situations with tight supply during peak load times. This is mainly due to the re-location of coal plants away from consumption centres to reduce air pollution. In order to tackle power imbalances between the generation bases in less populated areas and the load centres, China is expanding its transmission system.<sup>26</sup>

<sup>25</sup> Liu, J. Zhang, J., Tian F., Mi, Z., 2017; IHS Markit, 2016; China Electricity Council, 2016d.

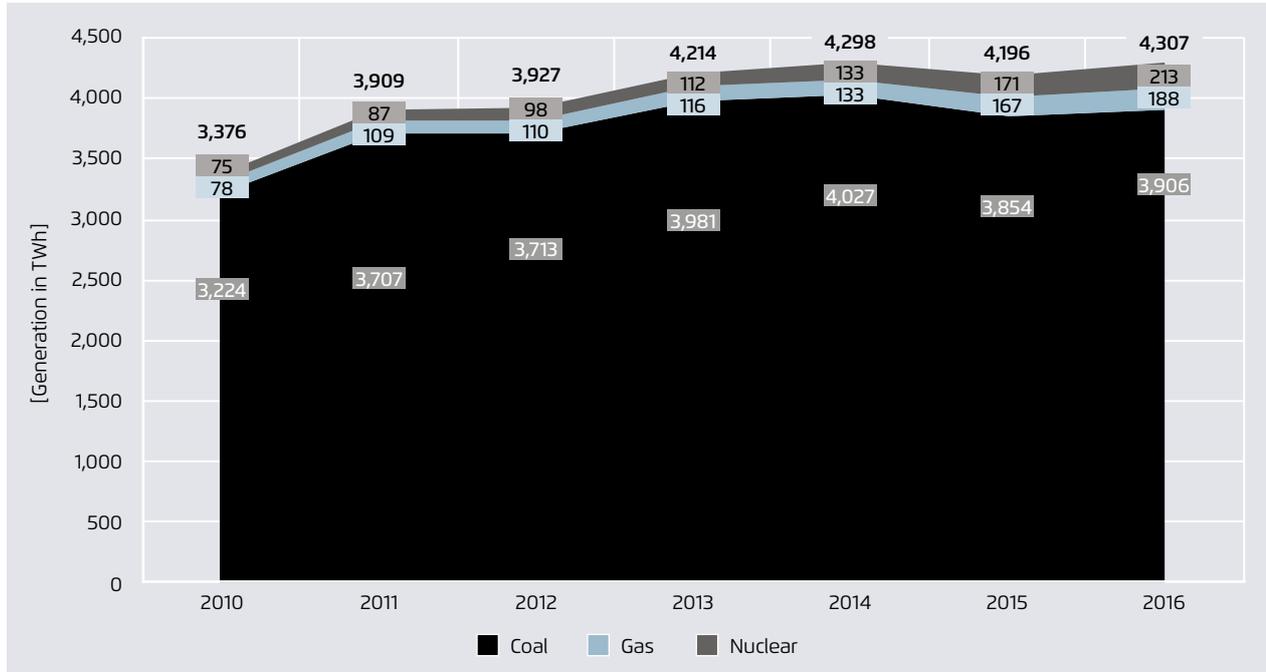
<sup>26</sup> China Electricity Council, 2015,

<sup>24</sup> National Development and Reform Commission, 2016a.



Power generation in thermal power plants in China, 2010–2016: thermal power generation has remained on a similar level since 2013.

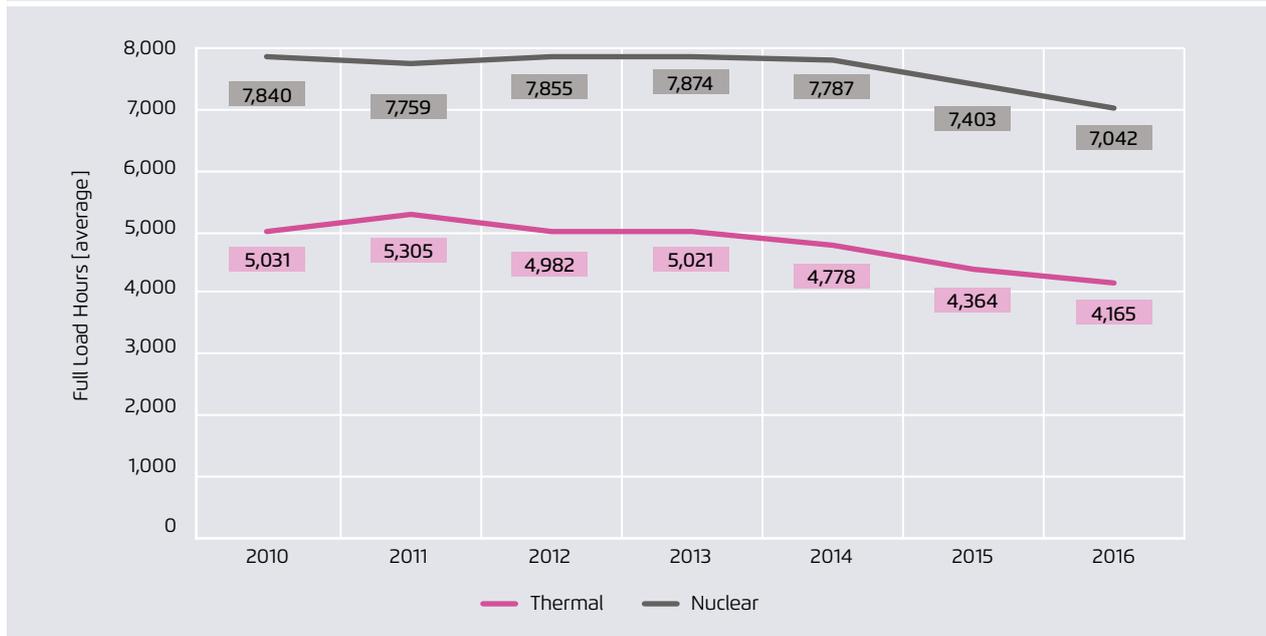
Figure 15



China Electricity Council

Full load hours of thermal power plants are at a decade low, due to overcapacities in the thermal sector and increased generation from renewables.

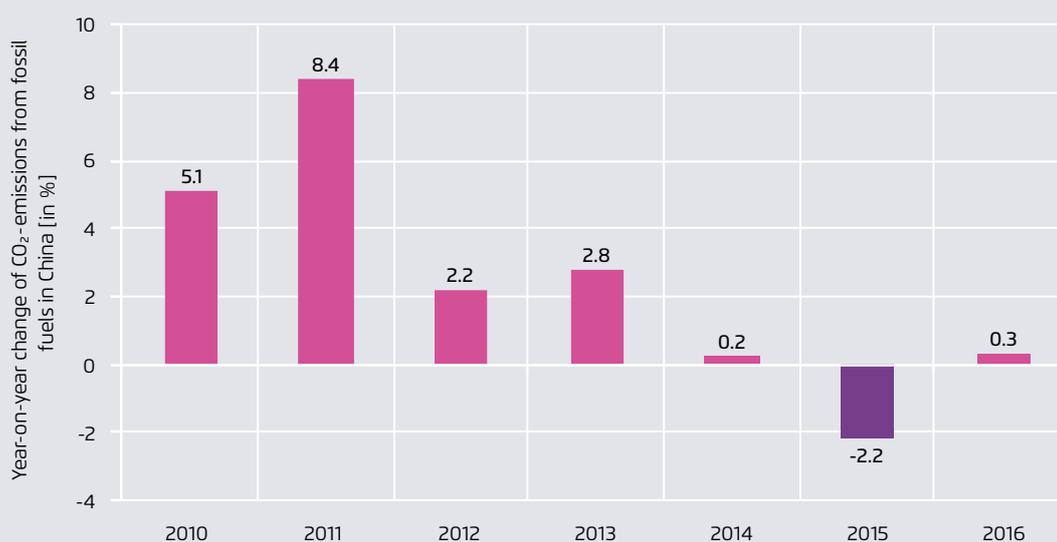
Figure 16



China Electricity Council

Year-on-year percentage changes of CO<sub>2</sub>-emissions of China's fossil fuels, 2010–2016: emissions remained on a similar level since 2014 and have even decreased in 2015.

Figure 17



Greenpeace

The central government has started a number of initiatives regarding coal-fired power plants. The 13<sup>th</sup> Five-Year Plan for Energy calls for a two-year moratorium on the approval of new coal-fired power stations in provinces with a power surplus, which will be reviewed after three years. Furthermore, 20 GW of less efficient capacity will be shut down until 2020, while old coal-fired power plants are required to undergo strict efficiency upgrades, and the construction of new ones will be limited to a total capacity addition of 200 GW up to 2020.<sup>27</sup>

<sup>27</sup> National Development and Reform Commission, 2016a.

The stagnating electricity generation from coal-fired power plants, and the government's initiatives, has had a strong impact on the country's CO<sub>2</sub> emissions while also stirring hopes that China's carbon emissions could peak earlier than envisioned by the Chinese government. A Greenpeace analysis shows that Chinese energy-related carbon emissions have not risen since 2014.<sup>28</sup>

<sup>28</sup> Greenpeace: Energydesk, 2017.

## 5. Outlook

The 13<sup>th</sup> FYP calls for a further shift toward innovation and aims at balancing economic growth with environmental protection. The Chinese government has established targets for the country’s energy and power sector.<sup>29</sup> By 2020 China aims to have an installed power generating capacity of about 2,000 GW, an increase of more than 300 GW from 2016 levels.

Coal-fired power plants should at most make up 200 GW of newly installed capacity. At the same time, investment into renewables will amount to approximately 340 billion euros up to 2020. By that time,

total wind and solar power capacities are forecasted to reach at least 210 and 110 GW, respectively.<sup>30</sup>

The reform of China’s power market that was initiated in March 2015 has already impacted the country’s power sector. The reform’s influence will only grow in years to come, especially due to the introduction of power trading, as a surge in long-term power trading platforms was seen last year, and a pilot spot market is planned for 2018.<sup>31</sup>

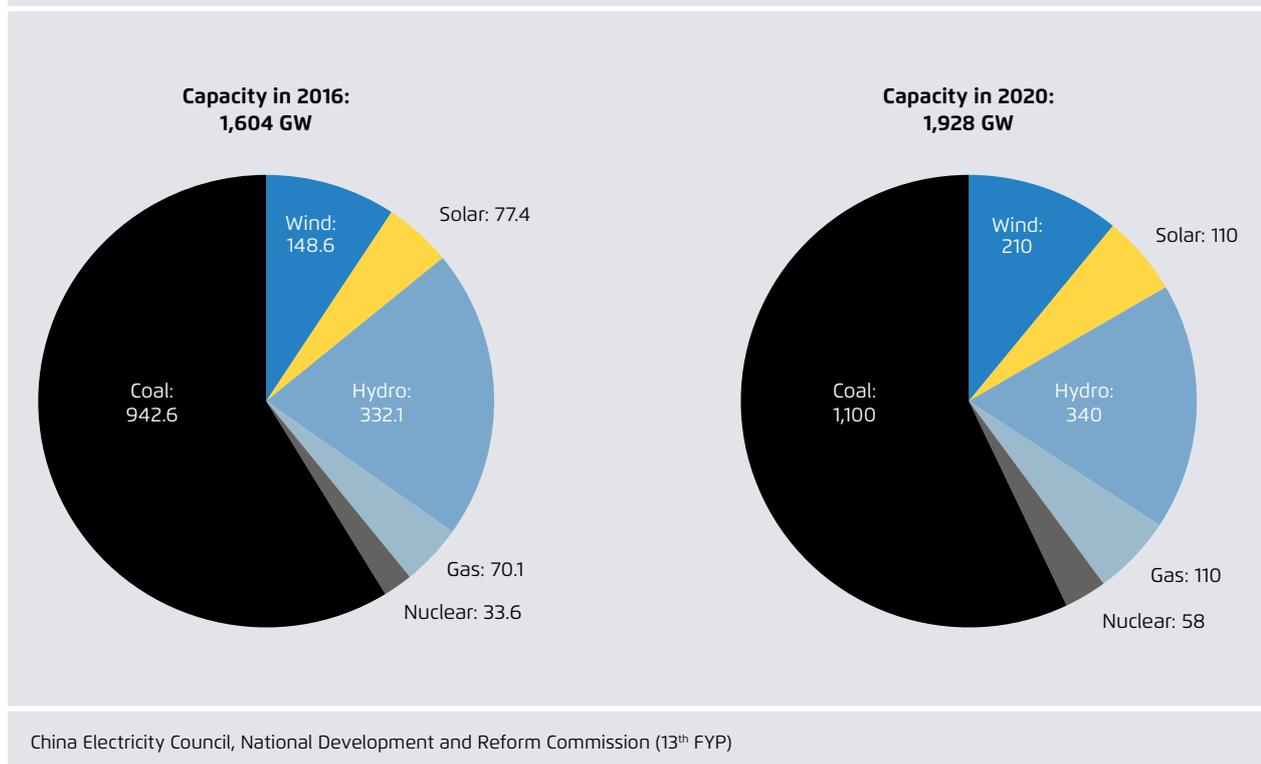
29 National Development and Reform Commission, 2016a.

30 National Development and Reform Commission, 2016b.

31 China Electricity Council, 2016e.

Installed generating capacity of China’s power sector in 2016 and 2020 in GW: a capacity increase of more than 20 per cent, or more than 300 GW, is planned.

Figure 18



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