Supplementary Material

# Supplementary Figure



Figure S1. Location of the five northwestern provinces of China.

1. **Scenario Setting**

To achieve the target of energy saving and emission reduction, three scenarios are designed: the baseline scenario, the policy scenario and the green scenario.

Under the baseline scenario, the energy demand and CO2 emissions evolve naturally based on existing policies. A future development plan is set every five years in China to guide economic development. In the 14th(2020-2025) Five-Year Plan (FYP), the average annual economic growth rates of the five northwestern provinces are 6% ([Shaanxi](#five1sx)), 6.5% ([Gansu](#five2gansu)), 6% ([Ningxia](#five3nx)), 5.5% ([Qinghai](#five4qh)), and 6.1% ([Xinjiang](#five5xj)), respectively ([Figure S1](#_Supplementary_Figure)). We take the average value of 6.02% as the overall economic growth rate of the region. The energy intensity of the region in the 14th FYP all implement the target issued by the country, namely, the cumulative reduction of energy intensity is set by 13.5%. In addition, the plan states that the share of non-fossil energy will increase to 20% by 2025 ([NDRC, 2021](#ndrc)).

The policy scenario is a relatively energy-saving scenario. Based on “China Energy and Electricity Development Planning Study 2030 and Outlook 2060” and the 14th FYP, we assume that during the 14th FYP, the economy of the region will grow at the average annual rate of 5.5%, and the proportion of clean energy such as non-fossil energy and natural gas will reach 22.03% by 2025.%. At the same time, based on the 10th to 13th FYP period, the energy intensity of the five northwestern provinces not only completed the national targets, but also exceeded the established targets by about 2-3%. Therefore, we assume that energy intensity will be reduced cumulatively by 16% in policy scenario. It is predicted by “Global Energy Internet Development Cooperation Organization” that the share of the secondary industry in China will drop to 37% by 2030, while the tertiary industry will increase to 57% ([GEIDCO, 2021](#geidco)). Combining with the status quo of the relative backwardness in northwest China, we assume that the share of the secondary industry will drop to 37.96% by 2030, and the tertiary industry will increase to 52.9%.

The green scenario is a more ideal scenario of energy saving and emission reduction. It is assumed that China will formulate more energy-efficient policies in the future and further improve the technology level. After several attempts at parameter setting, we assume that the average annual growth rate of the region's economy will be 5.41% in the 14th FYP, energy intensity will be reduced cumulatively by 17.75%, and the share of non-fossil energy and natural gas will rise to 25.85% by 2025. At the same time, basing on “Global Energy Internet Development Cooperation Organization”, and combining with the actual situation in northwest China, we assume that the proportion of secondary industry will decrease to 36.79% by 2030, while that of tertiary industry will rise to 54.08% ([GEIDCO, 2021](#geidco)).

The energy conversion module of this study includes three sectors: the thermal power, the oil refining, and the coking. The energy conversion efficiency is estimated based on historical data. We also make a lower (the baseline scenario) and a higher expectation (the green scenario) for the estimated values. Electricity includes thermal power and renewable energy generation. It is estimated that the installed thermal power capacity is expected to decrease to 27.6% in 2030 ([GEIDCO, 2021](#geidco)). However, considering the current large share of thermal power generation in the five northwestern provinces (69.20% in 2019), we assume that this share of installed thermal power capacity decreases to 40% in 2030 and 28.78% by 2040 under the policy scenario, for which the baseline and green are lower and higher expectations. The specific parameter settings are shown in the following table.

# Supplementary Tables

**Table S1.** Economic output by different sector under different scenarios (1×109 CNY).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Year | Agriculture | Industry | Construction | Transportation | Commerce | Other industries |
| Baseline  | 2025 | 741.2 | 2566.5 | 658.4 | 428.5 | 569.0 | 3036.7 |
| 2030 | 940.2 | 3108.2 | 863.4 | 561.9 | 689.0 | 4115.9 |
| 2040 | 1320.2 | 4191.6 | 1342.4 | 828.8 | 929.0 | 6272.5 |
| Policy  | 2025 | 747.6 | 2400.7 | 651.0 | 408.6 | 550.0 | 3074.1 |
| 2030 | 941.39 | 3017.4 | 849.8 | 514.3 | 672.4 | 4202.0 |
| 2040 | 1252.1 | 3858.2 | 1258.1 | 691.2 | 880.7 | 6278.2 |
| Green | 2025 | 747.6 | 2324.7 | 643.0 | 399.9 | 540.1 | 2982.7 |
| 2030 | 900.9 | 2819.9 | 812.6 | 498.3 | 660.3 | 4180.4 |
| 2040 | 1153.2 | 3634.0 | 1180.2 | 680.9 | 843.4 | 5563.5 |

**Table S2.** GDP share by different sector under different scenarios (%).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Year | Agriculture | Industry | Construction | Transportation | Commerce | Other industries |
| Baseline  | 2025 | 9.26 | 32.05 | 8.21 | 5.34 | 7.12 | 38.02 |
| 2030 | 9.14 | 30.24 | 8.4 | 5.46 | 6.72 | 40.04 |
| 2040 | 8.86 | 28.2 | 9.0 | 5.57 | 6.24 | 41.47 |
| Policy | 2025 | 9.54 | 30.65 | 8.31 | 5.22 | 7.0 | 38.9 |
| 2030 | 9.13 | 29.62 | 8.34 | 5.04 | 6.6 | 41.26 |
| 2040 | 8.8 | 27.13 | 8.84 | 4.86 | 6.19 | 44.15 |
| Green | 2025 | 9.77 | 30.43 | 8.41 | 5.23 | 7.07 | 39.04 |
| 2030 | 9.12 | 28.56 | 8.23 | 5.05 | 6.69 | 42.34 |
| 2040 | 8.83 | 27.8 | 9.04 | 5.22 | 6.46 | 42.62 |

**Table S3.** Energy intensity by different sector under different scenarios (tonnes/104 CNY).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scenario | Year | Agriculture | Industry | Construction | Transportation | Commerce | Other industries |
| Baseline  | 2025 | 0.162 | 1.73 | 0.108 | 0.913 | 0.275 | 0.058 |
| 2030 | 0.131 | 1.53 | 0.088 | 0.712 | 0.24 | 0.047 |
| 2040 | 0.091 | 1.25 | 0.058 | 0.455 | 0.21 | 0.03 |
| Policy | 2025 | 0.16 | 1.69 | 0.107 | 0.913 | 0.27 | 0.056 |
| 2030 | 0.127 | 1.485 | 0.084 | 0.703 | 0.24 | 0.043 |
| 2040 | 0.087 | 1.18 | 0.052 | 0.436 | 0.2 | 0.026 |
| Green | 2025 | 0.156 | 1.65 | 0.107 | 0.91 | 0.265 | 0.056 |
| 2030 | 0.124 | 1.42 | 0.076 | 0.69 | 0.232 | 0.043 |
| 2040 | 0.082 | 1.08 | 0.048 | 0.395 | 0.19 | 0.026 |

**Table S4.** Energy consumption structure by different sector under different scenarios (%).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Energy Structure Percentage (%) | Year | Coal | Coke | Oils | Natural gas | Electricity |
|  | Baseline | 20302040 | 38.1434.5 |  | 26.9324.36 | 4.497.53 | 30.4433.62 |
| Agriculture | Policy | 20302040 | 36.0831.02 |  | 25.4721.90 | 3.459.08 | 3538 |
|  | Green | 20302040 | 34.1127.87 |  | 24.0919.68 | 6.814.45 | 3538 |
|  | Baseline | 20302040 | 51.4642.04 | 3.734.2 | 5.275.27 | 12.5416.86 | 27.0131.61 |
| Industry | Policy | 20302040 | 48.6437.76 | 3.734.2 | 4.994.74 | 13.2318.66 | 29.4236.64 |
|  | Green | 20302040 | 41.0127.27 | 3.734.2 | 4.934.64 | 15.525.24 | 34.8338.64 |
|  | Baseline | 20302040 | 16.4414.87 | 15.6213.09 | 40.4636.66 | 8.2314.11 | 19.2521.27 |
| Construction | Policy | 20302040 | 15.5513.37 | 14.3712.01 | 39.7135.13 | 10.0415.90 | 20.3323.59 |
|  | Green | 20302040 | 14.7012.01 | 13.5210.03 | 39.1034.80 | 11.6818.06 | 21.0025.10 |
|  | Baseline | 20302040 | 9.197.67 |  | 59.6855.61 | 12.3314.83 | 18.8021.89 |
| Transportation | Policy | 20302040 | 8.586.42 |  | 58.1649.97 | 13.9718.47 | 19.2925.14 |
|  | Green | 20302040 | 5.783.02 |  | 54.6440.29 | 16.7223.90 | 22.8632.79 |
|  | Baseline | 20302040 | 21.3618.36 |  | 15.6214.13 | 38.8142.87 | 24.2124.64 |
| Commerce | Policy | 20302040 | 20.6517.22 |  | 14.7712.70 | 38.8142.87 | 25.7627.20 |
|  | Green | 20302040 | 18.0413.30 |  | 14.2911.91 | 38.8142.87 | 28.8631.91 |
|  | Baseline | 20302040 | 30.2427.35 |  | 14.3814.38 | 17.1018.89 | 38.2839.38 |
| Other industries | Policy | 20302040 | 30.2427.35 |  | 12.8711.64 | 18.0620.96 | 38.8340.05 |
|  | Green | 20302040 | 27.0422.10 |  | 12.8711.64 | 18.0620.96 | 42.0345.30 |

**Table S5.** Energy processing conversion efficiency by different sector under different scenarios (%).

|  |  |  |  |
| --- | --- | --- | --- |
|  | Baseline scenario | Policy scenario | Green scenario |
| 2025 | 2030 | 2040 | 2025 | 2030 | 2040 | 2025 | 2030 | 2040 |
| Thermal Power | 44.91 | 48.31 | 56.12 | 45.91 | 49.31 | 56.12 | 46.91 | 50.31 | 57.12 |
| Coking | 87.76 | 88.63 | 91.37 | 89.76 | 90.63 | 92.37 | 91.37 | 92.63 | 93.37 |
| Oil Refining | 89.82 | 92.25 | 93.38 | 91.82 | 93.25 | 95.38 | 93 | 94.25 | 95.44 |

**Table S6.** Exogenously specified capacity (Million KW).

|  |  |  |  |
| --- | --- | --- | --- |
|  | Baseline scenario | Policy scenario | Green scenario |
| 2025 | 2030 | 2040 | 2025 | 2030 | 2040 | 2025 | 2030 | 2040 |
| Thermal Power | 179.6 | 198.3 | 241.7 | 171.3 | 181.8 | 204.8 | 169.3 | 177.9 | 196.5 |
| Renewable Power | 206.7 | 271.4 | 468 | 211.4 | 282.9 | 506.7 | 212.6 | 285.9 | 516.8 |

1. **Trend extrapolation expression**
2. **Agriculture**

**Baseline**

Economic output: y = 0.2535x2−991.93x+969891 (R2=0.9983)

Energy intensity: y = −1E-09x3+7E-06x2−0.0148x+10.017 (R2=0.9767)

**Policy**

Economic output: y = 0.1591x2−611.76x+587179 (R2=0.9976)

Energy intensity: y = −1E-09x3+7E-06x2−0.0144x+9.7876 (R2=0.9879)

**Green**

Economic output: y = 0.0273x2−81.39x+53533 (R2=0.996)

Energy intensity: y =−1E-09x3+7E-06x2−0.0145x+9.8805 (R2=0.9877)

1. **Industry**

**Baseline**

Economic output: y=108.34x−216822 (R2=0.9925)

Energy intensity: y=1E-08x2−5E-05x+0.0533 (R2=0.983)

**Policy**

Economic output: y =96.212x−192464 (R2=0.9953)

Energy intensity: y =4E-08x2−0.0002x+0.1881 (R2=0.9969)

**Green**

Economic output: y = 96.206x-192450 (R2=0.996)

Energy intensity: y = 5E-08x2-0.0002x+0.2206 (R2=0.9982)

1. **Construction**

**Baseline**

Economic output: y=0.4987x2−1981.5x+ (2E+06) (R2=0.9925)

Energy intensity: y=1E+35e-0.046x (R2=0.9643)

**Policy**

Economic output: y =0.3992x2−1581x+ (2E+06) (R2=0.9982)

Energy intensity: y =4E+36e-0.047x (R2=0.9959)

**Green**

Economic output: y = 0.302x2−1190.2x+ (1E+06) (R2=0.9973)

Energy intensity: y =2E+39e-0.05x (R2=0.9974)

1. **Transportation**

**Baseline**

Economic output: y=0.2899x2−1150.4x+ (1E+06) (R2=0.9982)

Energy intensity: y=3E+38e-0.048x (R2=0.9941)

**Policy**

Economic output: y =0.0173x2−57.19x+32988 (R2=0.9989)

Energy intensity: y =2E+39e-0.049x (R2=0.995)

**Green**

Economic output: y =0.0207x2-65.435x+47900 (R2=0.9991)

Energy intensity: y =1E+41e-0.051x (R2=0.9961)

1. **Commerce**

**Baseline**

Economic output: y=24x−48031 (R2=0.9944)

Energy intensity: y=5E+12e-0.02x  (R2=0.9534)

**Policy**

Economic output: y =22.462x-44941 (R2=0.9962)

Energy intensity: y =9E+13e-0.021x  (R2=0.995)

**Green**

Economic output: y =21.649x-43308 (R2=0.9991)

Energy intensity: y =5E+15e-0.023x (R2=0.9674)

1. **Other industries**

**Baseline**

Economic output: y=2.7033x2−10759x+ (1E+07) (R2=0.9971)

Energy intensity: y=−2E-09x3 +(1E-05)x2−0.0202x+13.649 (R2=0.9875)

**Policy**

Economic output: y =2.6928x2−10715x+ (1E+07) (R2=0.9964)

Energy intensity: y =−2E-09x3 +(1E-05)x2−0.0195x+13.17 (R2=0.9884)

**Green**

Economic output: y =1.7724x2−7011.6x+ (7E+06) (R2=0.9929)

Energy intensity: y =8E-09x2−(3E-5)x+0.0331 (R2=0.9674)

**Reference**

Gansu Provincial Development and Reform Commission. (2021). Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of Gansu Province and the Vision 2035. <http://fzgg.gansu.gov.cn/> (accessed June 8, 2022)

Global Energy Internet Development Cooperation Organization (GEIDCO). (2021). China Energy and Electricity Development Planning Study 2030 and Outlook 2060. <https://shupeidian.bjx.com.cn/html/20210319/1142781.shtml/> (accessed June 12, 2022).

National Development and Reform Commission of the People's Republic of China (NDRC). (2021). Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Vision 2035. <https://www.ndrc.gov.cn/> (accessed May 3, 2022).

Ningxia Hui Autonomous Region Development and Reform Commission. (2021). Outline of the Fourteenth Five-Year Plan for National Economic and Social Development and the 2035 Vision for Ningxia Hui Autonomous Region. <http://fzggw.nx.gov.cn/> (accessed June 8, 2022)

Qinghai Provincial Development and Reform Commission. (2021). Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of Qinghai Province and the Vision 2035. <http://fgw.qinghai.gov.cn/> (accessed June 8, 2022)

Shaanxi Provincial Development and Reform Commission. (2021). Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of Shaanxi Province and the Vision 2035. <http://sndrc.shaanxi.gov.cn/> (accessed June 8, 2022)

Xinjiang Uygur Autonomous Region Development and Reform Commission. (2021). Outline of the Fourteenth Five-Year Plan for National Economic and Social Development and Vision 2035 of Xinjiang Uygur Autonomous Region. <http://xjdrc.xinjiang.gov.cn/> (accessed June 8, 2022)