Appendix I The main data indicators and symbols are explained in this paper

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Symbol | Description | Formula | Unit | Explanation |
|  | Total carbon emissions |  | 10,000 tCO2 | Total carbon emissions = Carbon emissions from primary industry (C1) + Carbon emissions from secondary industry (C2) + Carbon emissions from tertiary industry (C3) |
|  | Carbon emissions from agriculture and forestry consumption sectors |  | 10,000 tCO2 | Total carbon emissions from the agriculture and forestry consumption sectors |
|  | Secondary carbon emissions |  | 10,000 tCO2 | Total carbon emissions from the secondary industry |
|  | Carbon emissions from the energy supply sector |  | 10,000 tCO2 | Carbon emissions from the energy supply sector this year |
|  | Carbon emissions from the industrial consumption sector |  | 10,000 tCO2 | Carbon emissions from the industrial consumption sector this year |
|  | Carbon emissions from tertiary industries |  | 10,000 tCO2 | The total carbon emissions of the tertiary industry are composed of the carbon emissions of the transportation consumption department and the construction consumption department. |
|  | Carbon emissions from transportation consumption sector |  | 10,000 tCO2 | Carbon emissions from the transportation consumption sector this year |
|  | Carbon emissions from the building consumption sector |  | 10,000 tCO2 | Carbon emissions from the construction consumption sector this year |
|  | Carbon emissions from residential consumption |  | 10,000 tCO2 | Carbon emissions from residents’ consumption this year |
|  | Carbon emissions intensity (Energy structure intensity) |  | 10,000 tCO2 / 10,000 tce | Also known as carbon emission factor, indicates the amount of CO2 emissions per unit of energy consumption. A lower value indicates a higher proportion of non-fossil energy consumption and lower greenhouse gas emissions from energy consumption. |
|  | Carbon emission growth rate |  | % | Growth rate of carbon emissions compared to the previous year |
|  | Total population |  | 10,000 people | Total population of the region |
|  | Population growth rate |  | % | Growth rate of population compared to the previous year |
|  | Gross Domestic Product (GDP) |  | 100 million yuan | GDP equals the sum of the production values of the primary, secondary, and tertiary industries |
|  | GDP growth rate |  | % | Growth rate of GDP compared to the previous year |
|  | Agriculture and forestry consumption sector GDP |  | 100 million yuan | Agricultural and forestry consumption sector GDP |
|  | Secondary GDP |  | 100 million yuan | The total GDP of the secondary industry consists of the GDP of the energy supply sector and the industrial consumption sector. |
|  | Energy supply sector GDP |  | 100 million yuan | Energy supply sector GDP |
|  | Industrial consumption sector GDP |  | 100 million yuan | Industrial consumption sector GDP |
|  | GDP of the three industries |  | 100 million yuan | The total GDP of the tertiary industry is composed of the GDP of the transportation consumption sector and the construction consumption sector. |
|  | Transportation consumption sector GDP |  | 100 million yuan | Gross domestic product of transportation consumption sector this year |
|  | Construction consumption sector GDP |  | 100 million yuan | Gross domestic product of the construction consumption sector this year |
|  | Total energy consumption |  |  | Total energy consumption includes consumption in agriculture and forestry sectors, energy supply sectors, industrial consumption sectors, transportation sectors, building consumption sectors, and residential consumption sectors |
|  | Energy consumption growth rate |  | % | Growth rate of energy consumption compared to the previous year |
|  | Energy consumption in agriculture and forestry consumption sectors |  | 10,000t ce | Energy consumption in agriculture and forestry consumption sectors this year |
|  | Secondary energy consumption |  | 10,000 tce | The energy consumption of the secondary industry consists of the energy consumption of the energy supply sector and the industrial consumption sector. |
|  | Energy consumption in the energy supply sector |  | 10,000 tce | Energy consumption in the energy supply sector this year |
|  | Energy consumption in industrial consumption sector |  | 10,000 tce | Energy consumption in the industrial consumption sector this year |
|  | Energy consumption of tertiary industries |  | 10,000 tce | The energy consumption of the tertiary industry consists of the energy consumption of the transportation consumption department and the construction consumption department. |
|  | Energy consumption in transportation consumption sector |  | 10,000 tce | Energy consumption in the transportation consumption sector this year |
|  | Energy consumption in building consumption sector |  | 10,000 tce | Energy consumption in the building consumption sector this year |
|  | Residential energy consumption |  | 10,000 tce | Energy consumption in regional residents this year |
|  | Carbon emissions per unit GDP |  | 10,000 tCO2 / 100 million yuan | Amount of CO2 emissions per unit GDP |
|  | Per capita GDP (Economic development effect) |  | 100 million yuan / 10,000 people | Ratio of total GDP to total population |
|  | Energy consumption per unit GDP |  | 10,000 tce / 100 million yuan | Also known as energy consumption intensity, it is an important indicator of regional energy utilization efficiency. Lower energy consumption per unit GDP indicates higher energy utilization efficiency. |

Appendix II-1 2010-2020Annual carbon emissions and four factors statistical table

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| years | carbon emission | Population size effect (10,000 people) | economic development effect(100 million yuan/10,000 people) | energy consumption intensity(10,000 tce/100 million yuan) | Energy structure intensity |
| (10,000 t) | (10,000 tCO2/10,000 tce) |
| 2010 | 165497.1626 | 7869.34 | 5.258874315 | 0.568804088 | 7.030670458 |
| 2011 | 98963.94523 | 8022.99 | 5.727621498 | 0.584515274 | 3.684432246 |
| 2012 | 42742.90149 | 8119.81 | 6.239086875 | 0.552686687 | 1.526574825 |
| 2013 | 212584.0207 | 8192.44 | 6.784317004 | 0.507431602 | 7.537610704 |
| 2014 | 190861.1998 | 8281.09 | 7.288826712 | 0.466712588 | 6.775213815 |
| 2015 | 193663.3449 | 8315.11 | 7.883479593 | 0.442909569 | 6.670316155 |
| 2016 | 201352.8776 | 8381.47 | 8.431182934 | 0.423797878 | 6.723421757 |
| 2017 | 192746.0507 | 8423.5 | 8.992960348 | 0.404871223 | 6.284537472 |
| 2018 | 190867.2477 | 8446.19 | 9.569724566 | 0.388148147 | 6.083781506 |
| 2019 | 189362.0091 | 8469.09 | 10.10216374 | 0.376682582 | 5.87578861 |
| 2020 | 163002.0678 | 8477.26 | 10.46130644 | 0.354497722 | 5.184874371 |

Appendix II-2 Year-by-year LMDI decomposition results of regional carbon emission factors

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| years | Δp | Δg | Δe | Δc | ΔC | C\_j-C\_(j-1) |
| 2011 | 2502.05 | 11047.93 | 3525.53 | -83608.73 | -66533.22 | -66533.22 |
| 2012 | 803.29 | 5727.79 | -3749.51 | -59002.62 | -56221.04 | -56221.04 |
| 2013 | 942.84 | 8870.36 | -9045.01 | 169072.93 | 169841.12 | 169841.12 |
| 2014 | 2169.01 | 14455.36 | -16857.44 | -21489.75 | -21722.82 | -21722.82 |
| 2015 | 788.21 | 15078.25 | -10064.37 | -2999.94 | 2802.15 | 2802.15 |
| 2016 | 1569.79 | 13264.49 | -8710.78 | 1566.03 | 7689.53 | 7689.53 |
| 2017 | 985.5 | 12708.65 | -9001.28 | -13299.7 | -8606.83 | -8606.83 |
| 2018 | 515.96 | 11923.05 | -8090.72 | -6227.1 | -1878.8 | -1878.8 |
| 2019 | 514.75 | 10293.74 | -5700.41 | -6613.33 | -1505.24 | -1505.24 |
| 2020 | 169.56 | 6143.2 | -10674.44 | -21998.26 | -26359.94 | -26359.94 |
| total | 10960.97 | 109512.83 | -78368.42 | -44600.47 | -2495.09 | -2495.09 |

Appendix III-1 Logistic Regression prediction results of slow population growth

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| years | Projected population | years | Projected population | years | Projected population | years | Projected population |
| 2021 | 85395956 | 2031 | 86661901 | 2041 | 86949510 | 2051 | 87013945 |
| 2022 | 85620210 | 2032 | 86713328 | 2042 | 86961056 | 2052 | 87016525 |
| 2023 | 85814173 | 2033 | 86757642 | 2043 | 86970996 | 2053 | 87018745 |
| 2024 | 85981823 | 2034 | 86795819 | 2044 | 86979554 | 2054 | 87020657 |
| 2025 | 86126647 | 2035 | 86828705 | 2045 | 86986921 | 2055 | 87022302 |
| 2026 | 86251689 | 2036 | 86857031 | 2046 | 86993262 | 2056 | 87023718 |
| 2027 | 86359604 | 2037 | 86881426 | 2047 | 86998721 | 2057 | 87024937 |
| 2028 | 86452705 | 2038 | 86902433 | 2048 | 87003421 | 2058 | 87025986 |
| 2029 | 86532998 | 2039 | 86920523 | 2049 | 87007466 | 2059 | 87026889 |
| 2030 | 86602226 | 2040 | 86936099 | 2050 | 87010948 | 2060 | 87027666 |

Appendix III-2 Model prediction results for time series models

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| years | Forecast GDP | years | Forecast GDP | years | Forecast GDP | years | Forecast GDP |
| 2021 | 93413.149 | 2031 | 140712.49 | 2041 | 188011.84 | 2051 | 235311.2 |
| 2022 | 98143.084 | 2032 | 145442.43 | 2042 | 192741.77 | 2052 | 240041.1 |
| 2023 | 102873.02 | 2033 | 150172.36 | 2043 | 197471.71 | 2053 | 244771.1 |
| 2024 | 107602.95 | 2034 | 154902.3 | 2044 | 202201.64 | 2054 | 249501 |
| 2025 | 112332.89 | 2035 | 159632.23 | 2045 | 206931.58 | 2055 | 254230.9 |
| 2026 | 117062.82 | 2036 | 164362.17 | 2046 | 211661.51 | 2056 | 258960.9 |
| 2027 | 121792.76 | 2037 | 169092.1 | 2047 | 216391.45 | 2057 | 263690.8 |
| 2028 | 126522.69 | 2038 | 173822.03 | 2048 | 221121.38 | 2058 | 268420.7 |
| 2029 | 131252.62 | 2039 | 178551.97 | 2049 | 225851.31 | 2059 | 273150.7 |
| 2030 | 135982.56 | 2040 | 183281.9 | 2050 | 230581.25 | 2060 | 277880.6 |

Appendix III-3 Least squares linear regression prediction results

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| years | Forecast total energy consumption | years | Forecast total energy consumption | years | Forecast total energy consumption | years | Forecast total energy consumption |
| 2021 | 32441.18885 | 2031 | 34892.28 | 2041 | 36349.46 | 2051 | 37579.93 |
| 2022 | 32785.51033 | 2032 | 35061.02 | 2042 | 36477.69 | 2052 | 37699.05 |
| 2023 | 33099.05904 | 2033 | 35222.54 | 2043 | 36604.29 | 2053 | 37817.81 |
| 2024 | 33385.87608 | 2034 | 35377.82 | 2044 | 36729.49 | 2054 | 37936.25 |
| 2025 | 33649.5043 | 2035 | 35527.73 | 2045 | 36853.47 | 2055 | 38054.42 |
| 2026 | 33893.03562 | 2036 | 35673.01 | 2046 | 36976.42 | 2056 | 38172.36 |
| 2027 | 34119.16778 | 2037 | 35814.3 | 2047 | 37098.46 | 2057 | 38290.1 |
| 2028 | 34330.25006 | 2038 | 35952.14 | 2048 | 37219.74 | 2058 | 38407.67 |
| 2029 | 34528.32063 | 2039 | 36087.02 | 2049 | 37340.35 | 2059 | 38525.09 |
| 2030 | 34715.15044 | 2040 | 36219.34 | 2050 | 37460.38 | 2060 | 38642.37 |

Appendix III-4 Summary table of LSTM model prediction of future carbon emissions results from 2021 to 2060

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| years | Forecasting carbon emissions | years | Forecasting carbon emissions | years | Forecasting carbon emissions | years | Forecasting carbon emissions |
| 2021 | 195874.7 | 2031 | 189549.4 | 2041 | 164910 | 2051 | 134580.2 |
| 2022 | 196922.3 | 2032 | 187563.9 | 2042 | 162041.6 | 2052 | 131397.1 |
| 2023 | 197460.8 | 2033 | 185437.3 | 2043 | 159127 | 2053 | 128194.7 |
| 2024 | 197553 | 2034 | 183185.7 | 2044 | 156170.7 | 2054 | 124974.6 |
| 2025 | 197254.1 | 2035 | 180823.3 | 2045 | 153176.5 | 2055 | 121738 |
| 2026 | 196612.1 | 2036 | 178362.2 | 2046 | 150147.7 | 2056 | 118485.8 |
| 2027 | 195668.9 | 2037 | 175813.2 | 2047 | 147087.3 | 2057 | 115219.3 |
| 2028 | 194461.2 | 2038 | 173185.7 | 2048 | 143998.2 | 2058 | 111939.2 |
| 2029 | 193020.7 | 2039 | 170488 | 2049 | 140882.5 | 2059 | 108646.5 |
| 2030 | 191375.4 | 2040 | 167727.3 | 2050 | 137742.6 | 2060 | 105341.9 |

Appendix IV Original data: The original data has been uploaded to github

<https://github.com/HongWu-122/Prediction-and-Path-Planning-Framework>