Supplementary Material

# Supplementary Tables

## Water withdrawal and consumption factor

The factors of average water withdrawals during 2007-2012 came from 2011 Environmental Statistics Database for Hebei. Factors of water withdraw we use the ratio of water withdrawal/ consumption in the study for Hebei (Shang et al., 2016; Zhang et al., 2013; Zhou et al.,2016). The intensity of water consumption and consumption of solar power generation refer to the coefficient of China solar photovoltaic power generation (Liao et al., 2013), the intensity of hydropower water withdrawal and consumption (Zhou et al., 2016), the intensity of thermal power generation cooling technology (Zhang et al., 2016),meanwhile the intensity of water withdrawal and consumption of Hebei will reduced gradually in different phases ,as the development trend of China (Table S1).

**Table S1.** The predict intensity of water withdrawal and consumption of Hebei in 2010-2050.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Energy types** | | | | **Withdrawal** | **Consumption** |
| **2015-2020** | **coal**（m3/t） | mining | | 0.84 | 0.21 |
| washing | | 0.23 | 0.13 |
| coking | | 0.6 | 0.48 |
| **oil**（m3/t） | exploitation | | 0.38 | 0.06 |
| refining | | 3.56 | 2.81 |
| **gas**（m3/1000m3） | extraction | | 0.22 | 0.03 |
| **heat**（m3/GJ） | heating | | 0.45 | 0.08 |
| **electricity**（m3/Mwh） | thermal | once | 103.1 | 0.343 |
| cycle | 2.75 | 1.89 |
| air | 0.334 | 0.334 |
| nuclear | | 0 | 0 |
| Wind | | 0 | 0 |
| Solar | | 0.02 | 0.02 |
| hydro | | 0 | 12.96 |
| biomass | | 3.19 | 3.19 |
| **2021-2030** | **coal**（m3/t） | mining | | 0.675 | 0.17 |
| washing | | 0.21 | 0.10 |
| coking | | 0.50 | 0.39 |
| **oil**（m3/t） | exploitation | | 0.31 | 0.05 |
| refining | | 2.88 | 2.25 |
| **gas**（m3/m3） | extraction | | 0.18 | 0.025 |
| **heat**（m3/GJ） | heating | | 0.40 | 0.06 |
| **electricity**（L/kwh） | thermal | once | 85.05 | 0.30 |
| cycle | 2.23 | 1.53 |
| air | 0.28 | 0.28 |
| nuclear | | 0 | 0 |
| hydro | | 0.00 | 10.37 |
| Wind | | 0 | 0 |
| Solar | | 0.02 | 0.02 |
| biomass | | 2.55 | 2.55 |
| **2031-2040** | **coal**（m3/t） | mining | | 0.55 | 0.13 |
| washing | | 0.17 | 0.06 |
| coking | | 0.45 | 0.38 |
| **oil**（m3/t） | exploitation | | 0.26 | 0.03 |
| refining | | 2.33 | 1.83 |
| **gas**（m3/m3） | extraction | | 0.14 | 0.02 |
| **heat**（m3/GJ） | heating | | 0.36 | 0.04 |
| **electricity**（L/kwh） | thermal | once | 68.90 | 0.26 |
| cycle | 1.84 | 1.24 |
| air | 0.22 | 0.22 |
| nuclear | | 0 | 0 |
| hydro | | 0.00 | 8.40 |
| Wind | | 0 | 0 |
| Solar | | 0.01 | 0.01 |
| biomass | | 2.03 | 2.03 |
| **2041-2050** | **coal**（m3/t） | mining | | 0.45 | 0.09 |
| washing | | 0.13 | 0.07 |
| coking | | 0.40 | 0.32 |
| **oil**（m3/t） | exploitation | | 0.22 | 0.02 |
| refining | | 1.88 | 1.49 |
| **gas**（m3/m3） | extraction | | 0.10 | 0.02 |
| **heat**（m3/GJ） | heating | | 0.32 | 0.03 |
| **electricity**（L/kwh） | thermal | once | 55.81 | 0.20 |
| cycle | 1.49 | 0.99 |
| air | 0.18 | 0.18 |
| nuclear | | 0 | 0 |
| hydro | | 0.00 | 6.80 |
| Wind | | 0 | 0 |
| Solar | | 0.01 | 0.01 |
| biomass | | 1.65 | 1.65 |

## Major parameters in scenarios setting

**Table S2.** The major parameters used in sub-sector for REF in the LEAP-Hebei model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Terminal sectors** | **2015** | **2020** | **2030** | **2040** | **2050** |
| **Primary industry a** | Effective energy intensity:  1.32×10-5 (tce/yuan) | The effective energy intensity of the primary industry decreased by 1.5% annually | The effective energy intensity of the primary industry decreased by1.0% annually | The effective energy intensity of the primary industry decreased by 0.8% annually | The effective energy intensity of the primary industry decreased by0.8% annually |
| **Industrial sector b** | Effective energy intensity:  1.57×10-4 (tce/yuan) | The effective energy intensity of the industrial sector decreased by 2% annually | The effective energy intensity of the industrial sector decreased by 1.5% annually | The effective energy intensity of the industrial sector decreased by 1.0% annually | The effective energy intensity of the industrial sector decreased by 0.5% annually |
| **Construct sector c** | Effective energy intensity:  1.69×10-5 (tce/yuan) | The effective energy intensity of the construct sector decreased by 2% annually | The effective energy intensity of the construct sector decreased by 1.5% annually | The effective energy intensity of the construct sector decreased by 1.0 % annually | The effective energy intensity of the construct sector decreased by 0.5 % annually |
| **Transport sector d** | Effective energy intensity:  3.41×10-5 (tce/yuan) | The effective energy intensity of the transport sector decreased by 1.5% annually | The effective energy intensity of the transport sector decreased by 2.5% annually | The effective energy intensity of the transport sector decreased by 2% annually | The effective energy intensity of the transport sector decreased by 1.5% annually |
| **Commercial sector e** | Effective energy intensity:  1.67×10-5 (tce/yuan) | The effective energy intensity of the commercial sector decreased by 1.5% annually | The effective energy intensity of the commercial sector decreased by 2.0% annually | The effective energy intensity of the commercial sector decreased by 2.5% annually | The effective energy intensity of the commercial sector decreased by 1.5% annually |
| **Service sector f** | Effective energy intensity:  1.32E×10-5 (tce/yuan) | The effective energy intensity of the service sector decreased by 1.5% annually | The effective energy intensity of the service sector decreased by 2.5% annually | The effective energy intensity of the service sector decreased by 2.0% annually | The effective energy intensity of the service sector decreased by 1.5% annually |
| **Thermal generation sector g** |  | The thermal power generation efficiency grow to 2% and loss of transmission and distribution decrease by 0.25% annually | The thermal power generation efficiency grow to 5% and loss of transmission and distribution decrease by 0.50% annually | The thermal power generation efficiency grow to 8% and loss of transmission and distribution decrease by 0.5% annually | The thermal power generation efficiency grow to 12% and loss of transmission and distribution decrease by 0.75% annually |
| **Household sector h** | Effective energy intensity of urban sector: 0.31 (tce/person);  Effective energy intensity of rural sector: 0.42 (tce/person) | The per capita energy intensity of urban sector and rural sector decrease by 0.5% annually | The per capita energy intensity of urban sector and decrease by 1% annually and rural sector decrease by 0.7% annually | The per capita energy intensity of urban sector and decrease by 1.2% annually and rural sector decrease by 0.9% annually | The per capita energy intensity of urban sector and decrease by 1% annually and rural sector decrease by 0.75% annually |

**Note:** a-h The parameters are statistic from the Hebei economic yearbook 2016 (The People's Government of Hebei Province, 2017), the "13th Five-Year Plan" Energy Development Plan of Hebei (General Office of Circular of The People's Government of Hebei Province, 2017) and 2050 China Energy and Carbon Report (China energy and Carbon Emission Research Group, 2009).

**Table S3.** The major parameters used in sub-sector for CDS in the LEAP-Hebei model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Terminal sectors** | **2015** | **2016-2020** | **2021-2030** | **2031-2040** | **2041-2050** |
| **Primary industry a** | Effective energy intensity:  1.32×10-5 (tce/yuan). Raw coal and diesel account for 51.79%, natural gas and electricity account for 28.67% | The effective energy intensity of the primary industry decreased by 2% annually. Raw coal and diesel account for 49.20%, natural gas and electricity replace 5% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 1.5% annually. Raw coal and diesel account for 44.02%, natural gas and electricity replace 15% of raw coal and diesel | The effective energy intensity of the primary industry decreased by1.0% annually. Raw coal and diesel account for 36.25%, natural gas and electricity replace 30% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 1.0% annually. Raw coal and diesel account for 31.07%, natural gas and electricity replace 40% of raw coal and diesel |
| **Industrial sector b** | Effective energy intensity:  1.57×10-4 (tce/yuan). Raw coal and coke account for 59.97%, natural gas and electricity account for 15.64% | The effective energy intensity of the primary industry decreased by 3.5% annually. Raw coal and coke account for 53.97%, natural gas and electricity replace 10% of raw coal and coke | The effective energy intensity of the primary industry decreased by 3.0% annually. Raw coal and coke account for 44.97%, natural gas and electricity replace 25% of raw coal and coke | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and coke account for 35.98%, natural gas and electricity replace 40% of raw coal and coke | The effective energy intensity of the primary industry decreased by 2.0% annually. Raw coal and coke account for 29.99%, natural gas and electricity replace 50% of raw coal and coke |
| **Construct sector c** | Effective energy intensity:  1.69×10-5 (tce/yuan). Raw coal and diesel account for 26.93%, natural gas and electricity account for 18.36% | The effective energy intensity of the primary industry decreased by 4.0% annually. Raw coal and diesel account for 24.24%, natural gas and electricity replace 10% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 3.5% annually. Raw coal and diesel account for 21.54%, natural gas and electricity replace 20% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 3.0% annually. Raw coal and diesel account for 18.83%, natural gas and electricity replace 30% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and diesel account for 16.16%, natural gas and electricity replace 40% of gasoline and diesel |
| **Transport sector d** | Effective energy intensity:  3.41×10-5 (tce/yuan). Gasoline and diesel account for 72.72%, electricity account for 11.60% | The effective energy intensity of the primary industry decreased by 2.5% annually. Gasoline and diesel account for 65.45%, renewable energy replace 10% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 2.0% annually. Gasoline and diesel account for 58.17%, renewable energy replace 20% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Gasoline and diesel account for 50.90%, renewable energy replace 30% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 2.0% annually. gasoline and diesel account for 43.63%, renewable energy replace 40% of gasoline and diesel |
| **Commercial sector e** | Effective energy intensity:  1.67×10-5 (tce/yuan). Raw coal and diesel account for 19.50%, natural gas and electricity account for 52.73% | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and diesel account for 16.57%, natural gas and electricity replace 15% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and diesel account for 13.65%, natural gas and electricity replace 30% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and diesel account for 11.70%, natural gas and electricity replace 40% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.0% annually. Raw coal and diesel account for 9.75%, natural gas and electricity replace 50% of raw coal and diesel |
| **Service sector f** | Effective energy intensity:  1.32E×10-5 (tce/yuan). Raw coal, gasoline and diesel account for 41.25%, natural gas and electricity account for 38.10% | The effective energy intensity of the primary industry decreased by 3.0% annually. Raw coal, gasoline and diesel account for 35.06%, natural gas and electricity replace 15% of raw coal and diesel | The effective energy intensity of the primary industry decreased by2.5% annually. Raw coal, gasoline and diesel account for 28.88%, natural gas and electricity replace 30% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal, gasoline and diesel account for 20.63%, natural gas and electricity replace 50% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.0% annually. Raw coal, gasoline and diesel account for 12.38%, natural gas and electricity replace 70% of raw coal and diesel |
| **Thermal generation sector g** | Raw coal account for 81.49%, natural gas account for 0.04% | The thermal power generation efficiency grow to 5% and loss of transmission and distribution decrease by 0.25% annually. Raw coal account for 78.23%, natural gas replaces 4% of raw coal, transmission and distribution losses remain stable | The thermal power generation efficiency grow to 10% and loss of transmission and distribution decrease by 0.50% annually. Raw coal account for 73.34%, natural gas replaces 10% of raw coal, transmission and distribution losses remain stable | The thermal power generation efficiency grow to 15% and loss of transmission and distribution decrease by 0.75% annually. Raw coal account for 69.26%, natural gas replaces 15% of raw coal, transmission and distribution losses remain stable | The thermal power generation efficiency grow to 20% and loss of transmission and distribution decrease by 1.0% annually. Raw coal account for 65.19%, natural gas replaces 20% of raw coal, transmission and distribution losses remain stable |
| **Heating sector h** | Raw coal account for 77.74%, natural gas account for 1.18% | Raw coal account for 72.30%, natural gas replaces 7% of raw coal | Raw coal account for 67.63%, natural gas replaces 13% of raw coal | Raw coal account for 64.52%, natural gas replaces 17% of raw coal | Raw coal account for 60.63%, natural gas replaces 22% of raw coal |
| **Household sector i** | In the urban sector, raw coal and gasoline account for 35.75%, natural gas and electricity account for 27.51%,the effective energy intensity: 0.31 (tce/person); in the rural sector, raw coal and gasoline account for 64.57%, natural gas and electricity account for 18.91%, the effective energy intensity: 0.42 (tce/person). | The per capita energy intensity of urban sector and rural sector increase by 1% annually .In the urban sector, raw coal and gasoline account for 28.60%, natural gas and electricity replace 20% of raw coal; in the rural sector, raw coal and gasoline account for 58.11%, natural gas and electricity replace 10% of raw coal | The per capita energy intensity of urban sector and rural sector increase by 1.5% annually. In the urban sector, raw coal and gasoline account for 21.45%, natural gas and electricity replace 40% of raw coal; in the rural sector, raw coal and gasoline account for 51.65%, natural gas and electricity replace 20% of raw coal | The per capita energy intensity of urban sector and rural sector decrease by 0.5% annually. In the urban sector, raw coal and gasoline account for 14.30%, natural gas and electricity replace 60% of raw coal; in the rural sector, raw coal and gasoline account for 38.74%, natural gas and electricity replace 40% of raw coal | The per capita energy intensity of urban sector and rural sector decrease by 1.0% annually. In the urban sector, raw coal and gasoline account for 7.15%, natural gas and electricity replace 80% of raw coal; in the rural sector, raw coal and gasoline account for 25.82%, natural gas and electricity replace 60% of raw coal |

**Note:** a-i The parameters are statistic from the Hebei economic yearbook 2016 (The People's Government of Hebei Province, 2017), the upgrading energy structure in Hebei Province (Zhou et al., 2017; Zhai and Pang, 2017), 2050 China Energy and Carbon Report (China energy and Carbon Emission Research Group, 2009).

**Table S4.** The major parameters used in sub-sector for SER in the LEAP-Hebei model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Terminal sectors** | **2015** | **2016-2020** | **2021-2030** | **2031-2040** | **2041-2050** |
| **Primary industry a** | Effective energy intensity:  1.32×10-5 (tce/yuan). Raw coal and diesel account for 51.79%, natural gas and electricity account for 28.67% | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and diesel account for 46.61%, natural gas and electricity replace 10% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.0% annually. Raw coal and diesel account for 41.43%, natural gas and electricity replace 20% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 1.5% annually. Raw coal and diesel account for 31.07%, natural gas and electricity replace 40% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 1.5% annually. Raw coal and diesel account for 20.72%, natural gas and electricity replace 60% of raw coal and diesel |
| **Industrial sector b** | Effective energy intensity:  1.57×10-4 (tce/yuan). Raw coal and coke account for 59.97%, natural gas and electricity account for 15.64% | The effective energy intensity of the primary industry decreased by 5.5% annually. Raw coal and coke account for 50.97%, natural gas and electricity replace 15% of raw coal and coke | The effective energy intensity of the primary industry decreased by 6.0% annually. Raw coal and coke account for 41.98%, natural gas and electricity replace 30% of raw coal and coke | The effective energy intensity of the primary industry decreased by 4.5% annually. Raw coal and coke account for 29.99%, natural gas and electricity replace 50% of raw coal and coke | The effective energy intensity of the primary industry decreased by 3.5% annually. Raw coal and coke account for 17.99%, natural gas and electricity replace 70% of raw coal and coke |
| **Construct sector c** | Effective energy intensity:  1.69×10-5 (tce/yuan). Raw coal and diesel account for 26.93%, natural gas and electricity account for 18.36% | The effective energy intensity of the primary industry decreased by 5.0% annually. Raw coal and diesel account for 22.89%, natural gas and electricity replace 15% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 5.5% annually. Raw coal and diesel account for 18.85%, natural gas and electricity replace 30% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 4.5% annually. Raw coal and diesel account for 13.47%, natural gas and electricity replace50% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 3.0% annually. Raw coal and diesel account for 8.08%, natural gas and electricity replace 70% of gasoline and diesel |
| **Transport sector d** | Effective energy intensity:  3.41×10-5 (tce/yuan). Gasoline and diesel account for 72.72%, electricity account for 11.60% | The effective energy intensity of the primary industry decreased by 4.0% annually. Gasoline and diesel account for 58.18%, renewable energy replace 20% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 4.5% annually. Gasoline and diesel account for 43.63%, renewable energy replace 40% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 3.0% annually. Gasoline and diesel account for 29.09%, renewable energy replace 60% of gasoline and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. gasoline and diesel account for 14.54%, renewable energy replace 80% of gasoline and diesel |
| **Commercial sector e** | Effective energy intensity:  1.67×10-5 (tce/yuan). Raw coal and diesel account for 19.50%, natural gas and electricity account for 52.73% | The effective energy intensity of the primary industry decreased by 3.5% annually. Raw coal and diesel account for 16.58%, natural gas and electricity replace 15% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 4.5% annually. Raw coal and diesel account for 13.65%, natural gas and electricity replace 30% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 3.5% annually. Raw coal and diesel account for 7.53%, natural gas and electricity replace 60% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal and diesel account for 3.90%, natural gas and electricity replace 80% of raw coal and diesel |
| **Service sector f** | Effective energy intensity:  1.32E×10-5 (tce/yuan). Raw coal, gasoline and diesel account for 41.25%, natural gas and electricity account for 38.10% | The effective energy intensity of the primary industry decreased by 4.0% annually. Raw coal, gasoline and diesel account for 33.06%, natural gas and electricity replace 20% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 4.5% annually. Raw coal, gasoline and diesel account for 24.75%, natural gas and electricity replace 40% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 3.5% annually. Raw coal, gasoline and diesel account for 16.50%, natural gas and electricity replace 60% of raw coal and diesel | The effective energy intensity of the primary industry decreased by 2.5% annually. Raw coal, gasoline and diesel account for 8.25%, natural gas and electricity replace 80% of raw coal and diesel |
| **Thermal generation sector g** | Raw coal account for 81.49%, natural gas account for 0.04% | The thermal power generation efficiency grow to 10% and loss of transmission and distribution decrease by 0.50% annually. Raw coal account for 74.97%, natural gas replaces 8% of raw coal, transmission and distribution losses remain stable | The thermal power generation efficiency grow to 20% and loss of transmission and distribution decrease by 0.75% annually. Raw coal account for 69.26%, natural gas replaces 15% of raw coal, transmission and distribution losses remain stable | The thermal power generation efficiency grow to 30% and loss of transmission and distribution decrease by 1.00 % annually. Raw coal account for65.19%, natural gas replaces 20% of raw coal, transmission and distribution losses remain stable | The thermal power generation efficiency grow to 40% and loss of transmission and distribution decrease by 1.25% annually. Raw coal account for 61.12%, natural gas replaces 25% of raw coal, transmission and distribution losses remain stable |
| **Heating sector h** | Raw coal account for 77.74%, natural gas account for 1.18% | Raw coal account for69.97%, natural gas replaces 10% of raw coal | Raw coal account for 64.52%, natural gas replaces 17% of raw coal | Raw coal account for 59.86%, natural gas replaces 23% of raw coal | Raw coal account for 54.42%, natural gas replaces 30% of raw coal |
| **Household sector i** | In the urban sector, raw coal and gasoline account for 35.75%, natural gas and electricity account for 27.51%,the effective energy intensity: 0.31 (tce/person); in the rural sector, raw coal and gasoline account for 64.57%, natural gas and electricity account for 18.91%, the effective energy intensity: 0.42 (tce/person). | The per capita energy intensity of urban sector and rural sector increase by 0.5% annually .In the urban sector, raw coal and gasoline account for25.03%, natural gas and electricity replace 30% of raw coal; in the rural sector, raw coal and gasoline account for 51.67%, natural gas and electricity replace 20% of raw coal | The per capita energy intensity of urban sector and rural sector increase by 1.0% annually. In the urban sector, raw coal and gasoline account for 17.88%, natural gas and electricity replace 50% of raw coal; in the rural sector, raw coal and gasoline account for 45.20%, natural gas and electricity replace 30% of raw coal | The per capita energy intensity of urban sector and rural sector decrease by 1.0% annually. In the urban sector, raw coal and gasoline account for10.72%, natural gas and electricity replace 70% of raw coal; in the rural sector, raw coal and gasoline account for 32.29%, natural gas and electricity replace 50% of raw coal | The per capita energy intensity of urban sector and rural sector decrease by 1.5% annually. In the urban sector, raw coal and gasoline account for 3.58%, natural gas and electricity replace 90% of raw coal; in the rural sector, raw coal and gasoline account for 19.37%, natural gas and electricity replace 70% of raw coal |

**Note:** a-i The parameters are statistic from the Hebei economic yearbook 2016 (The People's Government of Hebei Province, 2017), the upgrading energy structure in Hebei Province (Zhou et al., 2017; Zhai and Pang, 2017), 2050 China Energy and Carbon Report (China energy and Carbon Emission Research Group, 2009).

**Table S5.** The related power production structure of REF, CDS and SER used in the LEAP-Hebei model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Power structure a**  **(%)** |  |  | **REF** | | | | | **CDS** | | | | |  | **SER** | | | | |
|  | 2015 | 2016-2020 | 2021-2030 | 2031-2040 | 2041-2050 |  | 2015 | 2016-2020 | 2021-2030 | 2031-2040 | 2041-2050 |  | 2015 | 2016-2020 | 2021-2030 | 2031-2040 | 2041-2050 |
| **Thermal power** |  | 91.94 | 85.02 | 80.12 | 75.64 | 70.34 |  | 91.94 | 81.94 | 72.12 | 61.45 | 50.78 |  | 91.94 | 61.02 | 56.12 | 45.34 | 34.34 |
| **Wind power** |  | 7.45 | 10.15 | 12.32 | 15.26 | 18.92 |  | 7.45 | 11.5 | 16.5 | 20.62 | 26.06 |  | 7.45 | 19.08 | 21.32 | 24.56 | 28.92 |
| **Hydroelectric** |  | 0.43 | 2.32 | 1.87 | 1.39 | 1.25 |  | 0.43 | 2.35 | 2.23 | 2.56 | 2.24 |  | 0.43 | 2.32 | 1.87 | 1.39 | 1.25 |
| **Solar power** |  | 0.17 | 2.47 | 5.60 | 7.65 | 9.42 |  | 0.17 | 4.03 | 9.06 | 15.27 | 20.78 |  | 0.17 | 17.47 | 20.28 | 28.65 | 35.42 |
| **Biomass power** |  | 0.01 | 0.04 | 0.09 | 0.06 | 0.07 |  | 0.01 | 0.18 | 0.09 | 0.1 | 0.14 |  | 0.01 | 0.11 | 0.05 | 0.06 | 0.07 |

**Note:** a The parameters are statistic from the China power yearbook 2016 (China Electric Power Yearbook Editorial Committee, 2016), the research on Hebei electric power consumption forecast (Nie, 2017), the "13th Five-Year Plan" Energy Development Plan of Hebei (General Office of Circular of The People's Government of Hebei Province, 2017) and 2050 China Energy and Carbon Report (China energy and Carbon Emission Research Group, 2009).

**Table S6.** The key baseline variables in the LEAP-Hebei model.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Key Baseline Variables** | **2015** | **2020** | **2030** | **2040** | **2050** |
| **GDP (billion USD)** | 29800 | 6300 | 12700 | 22700 | 35400 |
| **Population (million)** | 7400 | 8000 | 8600 | 9000 | 9800 |
| **Urbanization (%)** | 50 | 65 | 73 | 78 | 83 |

## Energy production and their associated with water withdraw and consumption for Scenarios REF, CDS and SER

**Table S7.** Energy production and their associated with water withdraw and consumption for Scenarios REF, CDS and SER.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario REF** | | **2015** | | | **2020** | | | **2030** | | | **2040** | | | **2050** | | |
| **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** |
| **Coal** | **Coal mining** | 62.47 | 15.62 | 53.12 | 80.18 | 20.04 | 68.18 | 109.08 | 27.27 | 92.76 | 190.18 | 47.55 | 161.72 | 271.28 | 67.82 | 230.69 |
| **Coal washing** | 21.96 | 12.41 | 79.35 | 26.77 | 15.13 | 83.13 | 35.30 | 19.95 | 109.63 | 49.64 | 28.06 | 154.18 | 66.22 | 37.43 | 205.65 |
| **Coking** | 40.47 | 32.38 | 68.18 | 44.38 | 35.50 | 71.85 | 58.07 | 46.45 | 94.01 | 80.77 | 64.61 | 130.76 | 107.06 | 85.65 | 173.33 |
| **Oli** | **Oil exploitation** | 2.19 | 0.35 | 8.25 | 2.78 | 0.44 | 10.46 | 4.45 | 0.70 | 16.72 | 6.81 | 1.08 | 25.60 | 9.97 | 1.57 | 37.49 |
| **Oil refining** | 63.45 | 50.08 | 23.40 | 70.40 | 55.57 | 28.25 | 102.22 | 80.68 | 41.02 | 146.15 | 115.36 | 58.65 | 205.16 | 161.94 | 82.33 |
| **Natural gas** | **Gas extraction** | 0.23 | 0.03 | 1.37 | 0.38 | 0.05 | 2.27 | 0.74 | 0.10 | 4.50 | 1.31 | 0.18 | 7.92 | 1.89 | 0.26 | 11.40 |
| **Heat** | **Heating** | 151.30 | 26.90 | 11.46 | 173.67 | 30.87 | 13.16 | 235.29 | 41.83 | 17.83 | 317.77 | 56.49 | 24.08 | 410.54 | 72.99 | 31.11 |
| **Electricity** | **Thermal generation** | 1606.96 | 299.07 | 28.17 | 1679.80 | 312.62 | 29.45 | 1815.55 | 337.89 | 31.83 | 2119.57 | 394.47 | 37.16 | 2177.17 | 405.19 | 38.17 |
| **Hydropower generation** | 0.00 | 13.92 | 0.13 | 0.00 | 26.36 | 0.25 | 0.00 | 135.85 | 0.34 | 0.00 | 42.18 | 0.40 | 0.00 | 47.45 | 0.45 |
| **Windpower generation** | 0.00 | 0.00 | 2.28 | 0.00 | 0.00 | 3.28 | 0.00 | 0.00 | 4.90 | 0.00 | 0.00 | 7.50 | 0.00 | 0.00 | 10.27 |
| **Solarpower generation** | 0.01 | 0.01 | 0.05 | 0.13 | 0.13 | 0.80 | 0.36 | 0.36 | 2.23 | 0.61 | 0.61 | 3.76 | 0.83 | 0.83 | 5.11 |
| **Biomasspower generation** | 0.08 | 0.08 | 0.00 | 0.26 | 0.26 | 0.01 | 1.04 | 1.04 | 0.04 | 0.78 | 0.78 | 0.03 | 1.04 | 1.04 | 0.04 |
| **Scenario CDS** | | **2015** | | | **2020** | | | **2030** | | | **2040** | | | **2050** | | |
| **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** |
| **Coal** | **Coal mining** | 62.47 | 15.62 | 53.12 | 72.02 | 18.24 | 68.59 | 92.47 | 23.12 | 72.76 | 58.67 | 13.87 | 76.19 | 30.26 | 6.05 | 58.03 |
| **Coal washing** | 21.96 | 12.41 | 79.35 | 27.20 | 15.54 | 92.51 | 35.55 | 16.93 | 70.93 | 30.82 | 10.88 | 129.50 | 22.05 | 11.87 | 121.16 |
| **Coking** | 40.47 | 32.38 | 68.18 | 39.56 | 30.93 | 69.87 | 42.86 | 33.43 | 83.26 | 42.06 | 35.52 | 90.79 | 39.07 | 31.26 | 94.89 |
| **Oli** | **Oil exploitation** | 2.19 | 0.35 | 8.25 | 2.83 | 0.50 | 11.90 | 3.31 | 0.53 | 15.27 | 4.70 | 0.54 | 25.81 | 4.47 | 0.41 | 29.03 |
| **Oil refining** | 63.45 | 50.08 | 23.40 | 68.72 | 54.12 | 30.68 | 88.20 | 68.90 | 43.75 | 111.98 | 87.95 | 68.66 | 122.66 | 97.21 | 93.21 |
| **Natural gas** | **Gas extraction** | 0.23 | 0.03 | 1.37 | 1.10 | 0.15 | 7.30 | 3.31 | 0.46 | 24.49 | 4.11 | 0.59 | 39.03 | 3.41 | 0.68 | 45.38 |
| **Heat** | **Heating** | 151.30 | 26.90 | 11.46 | 160.36 | 26.73 | 13.02 | 203.38 | 30.51 | 17.34 | 221.75 | 24.64 | 21.01 | 231.29 | 21.68 | 24.65 |
| **Electricity** | **Thermal generation** | 1606.96 | 299.07 | 28.17 | 1586.74 | 327.99 | 36.46 | 1493.49 | 357.26 | 47.70 | 944.94 | 276.91 | 49.08 | 418.57 | 163.24 | 40.96 |
| **Hydropower generation** | 0.00 | 13.92 | 0.13 | 0.00 | 99.23 | 1.05 | 0.00 | 124.47 | 1.48 | 0.00 | 139.12 | 2.04 | 0.00 | 99.98 | 1.81 |
| **Windpower generation** | 0.00 | 0.00 | 2.28 | 0.00 | 0.00 | 5.12 | 0.00 | 0.00 | 10.91 | 0.00 | 0.00 | 16.40 | 0.00 | 0.00 | 21.02 |
| **Solarpower generation** | 0.01 | 0.01 | 0.05 | 0.29 | 0.29 | 1.79 | 0.98 | 0.98 | 5.99 | 1.02 | 1.02 | 12.50 | 1.36 | 1.36 | 16.76 |
| **Biomasspower generation** | 0.08 | 0.08 | 0.00 | 1.87 | 1.87 | 0.08 | 1.24 | 1.24 | 0.06 | 1.31 | 1.31 | 0.08 | 1.52 | 1.52 | 0.11 |
| **Scenario SER** | | **2015** | | | **2020** | | | **2030** | | | **2040** | | | **2050** | | |
| **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** | **W** | **C** | **E** |
| **Coal** | **Coal mining** | 62.47 | 15.62 | 53.12 | 70.30 | 19.07 | 61.71 | 74.14 | 18.54 | 70.88 | 33.89 | 8.01 | 44.02 | 16.74 | 3.35 | 26.58 |
| **Coal washing** | 21.96 | 12.41 | 79.35 | 25.91 | 14.81 | 88.14 | 27.07 | 12.89 | 72.08 | 18.53 | 6.54 | 77.85 | 12.06 | 6.50 | 66.28 |
| **Coking** | 40.47 | 32.38 | 68.18 | 35.46 | 32.41 | 65.22 | 39.94 | 31.15 | 77.59 | 32.14 | 27.14 | 69.39 | 25.97 | 20.77 | 63.06 |
| **Oli** | **Oil exploitation** | 2.19 | 0.35 | 8.25 | 3.01 | 0.53 | 12.66 | 3.58 | 0.58 | 16.50 | 3.70 | 0.43 | 20.32 | 2.71 | 0.25 | 17.61 |
| **Oil refining** | 63.45 | 50.08 | 23.40 | 68.32 | 53.80 | 30.50 | 82.63 | 64.56 | 40.99 | 87.71 | 68.89 | 53.78 | 83.08 | 65.84 | 63.13 |
| **Natural gas** | **Gas extraction** | 0.23 | 0.03 | 1.37 | 1.10 | 0.15 | 7.35 | 2.99 | 0.42 | 22.12 | 2.80 | 0.40 | 26.63 | 1.38 | 0.28 | 18.34 |
| **Heat** | **Heating** | 151.30 | 26.90 | 11.46 | 159.84 | 26.64 | 12.98 | 47.23 | 7.09 | 4.03 | 45.31 | 5.03 | 4.29 | 44.87 | 4.21 | 4.78 |
| **Electricity** | **Thermal generation** | 1606.96 | 299.07 | 28.17 | 1590.07 | 334.47 | 37.18 | 1348.52 | 322.59 | 43.07 | 904.21 | 217.78 | 35.31 | 282.55 | 110.20 | 27.65 |
| **Hydropower generation** | 0.00 | 13.92 | 0.13 | 0.00 | 109.05 | 1.15 | 0.00 | 114.96 | 1.36 | 0.00 | 74.01 | 1.08 | 0.00 | 55.69 | 1.01 |
| **Windpower generation** | 0.00 | 0.00 | 2.28 | 0.00 | 0.00 | 7.97 | 0.00 | 0.00 | 15.53 | 0.00 | 0.00 | 20.69 | 0.00 | 0.00 | 24.90 |
| **Solarpower generation** | 0.01 | 0.01 | 0.05 | 0.52 | 0.52 | 3.21 | 2.09 | 2.09 | 12.82 | 1.69 | 1.69 | 20.76 | 2.19 | 2.19 | 26.91 |
| **Biomasspower generation** | 0.08 | 0.08 | 0.00 | 1.27 | 1.27 | 0.05 | 1.36 | 1.36 | 0.07 | 0.77 | 0.77 | 0.05 | 0.76 | 0.76 | 0.06 |

**Note:** W represented water withdraw (million cubic meter), C represented water consumption (million cubic meter), E represented energy products (million tons of standard coal).

# Reference

China Electric Power Yearbook Editorial Committee (2016). China power *yearbook 2016*. Beijing: China Electric Power Press.

China energy and Carbon Emission Research Group (2009). *2050 China Energy and CO2 Emissions Report.* Beijing: Science Press.

General Office of Circular of The People's Government of Hebei Province (2017). *the General Office of the People's Government of Hebei Province on Printing the "13th Five-Year Plan" Energy Development Plan*. <http://info.hebei.gov.cn/eportal/ui?articleKey=6753062&columnId=329982&pageId=1962757>. [Accessed May 2, 2020]

Liao, S., Wang, X.Y., Zhu, L.Z., and Yang, W.H. (2013). Research of water consumption in concentrated solar power system. *Ningxia Electric Power*. 8, 35-40.

Nie, Q. (2017). *Research on Hebei electric power consumption forecast under the coordinated development of Beijing-tianjin-hebei*. Master Dissertation of North China Electric Power University.

Shang, Y., Hei, P.F., Lu, S.B., Shang, L., Li, X.F., Wei, Y.P. et al. (2016). China’s energy-water nexus: Assessing water conservation synergies of the total coal consumption cap strategy until 2050. *Appl. Energy.* 210, 643-660. doi: 10.1016/j.apenergy.2016.11.008

The People's Government of Hebei Province (2017). *Hebei economic yearbook 2016*. Beijing: China Statistics Press.

Zhang, C. and Anadon, L.D. (2013). Life cycle water use of energy production and its environmental impacts in China. *Environ. Sci. Technol.* 47, 14459-14467. doi: 10.1021/es402556x

Zhou, Y.C., Li, H.P., Wang, K., and Bi, J. (2016). China’s energy-water nexus: Spillover effects of energy and water policy. *Global Environmental Change*. 2016, 40, 92-100. doi: 10.1016/j.gloenvcha.2016.07.003

Zhang, C., Zhong, L.J., Fu, X.T., Wang J., and Wu, Z.Y. (2016). Revealing water stress by the thermal power industry in China based on a high spatial resolution water withdrawal and consumption inventory. *Environ. Sci. Technol.* 50, 1642-1652. doi: 10.1021/acs.est.5b05374

Zhou, D., Sun, M., and Li, J. (2017). Upgrading Energy Structure in Hebei Province-Development of Distributed Photovoltaic Power Generation Applications. *Modern Business Trade Industry*. 21, 192-193.

Zhai, C.J., and Pang, R.T. (2017). Research on the Path of Hebei Industrial Structure Transformation and Upgrading From the Perspective of the Integration of Beijing,Tianjin and Hebei. *Journal of Baoding University*. 30, 49-57.