Synergetic pathways of water-energy-carbon in ecologically vulnerable regions aiming for carbon neutrality: A case study of Shaanxi, China

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1. Data and Calculations in the IG module

When the total production volume of a product and the proportion of each technology corresponding to the product are given, the energy demands can be obtained as

$$TED_n = \sum_{\mathrm{i}} \sum_{\mathrm{j}} TSV_{\mathrm{i,j}} \times EI_{n,\mathrm{i,j}} \qquad (1)$$

where TED_n is the total energy demands of fuel type n(tce), $TSV_{n,i,j}$ is the technical service volume of technology j in sector i(unit), and $EI_{n,i,j}$ is the energy intensity of fuel type n through technology j in sector i(tce/unit). The detailed calculations for the sectors are shown in Table A1. The model data is quoted from statistical yearbooks (NBS,2021;SXBS,2021),urban planning(Shaanxi,2018;Shaanxi,2021a;Shaanxi,2021b;Shaanxi,c) and related reports(ERI,2017; Tsinghua University, 2019;AECOM,2022; IRENA,2021).

CO_2 emissions is calculated as follows according to non-energy emission and energy emission:

$$CE_i = \sum_{\mathrm{j}} \sum_{\mathrm{n}} ED_{\mathrm{j,n}} \times CF_{j,\mathrm{n}} + \sum_{\mathrm{i}} \sum_{\mathrm{j}} PD_{\mathrm{i,j}} \times cf_{i,\mathrm{j}} \qquad (2)$$

where CE_i is the CO_2 emission of sector i(t), $ED_{j,n}$ is the energy demands of fuel type n about technology j in sector i(tce), $CF_{i,j}$ is the CO_2 emission factor of fuel type n about technology j(t/tce), $PD_{j,k}$ is the product output of technology j in sector i(unit), $cf_{i,j}$ is the CO_2 emission factor of technology j in sector i(t/unit).

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Table A1 The calculations of the energy system

Sectors	Formula	Notes	Data sources
The agriculture sector	$E_n = \sum_i Area_i \times Intensity_{i,n}$	E_n: the energy demands(tce) $Area_i$: the area of agricultural production activity(m^2) $Intensity_{i,n}$: the energy intensity of production activity i (tce/ m^2)	1)Statistical yearbooks ➢ Shaanxi Statistical Yearbook ➢ China Energy Statistical Yearbook ➢ China Statistical Yearbook ➢ Urban statistical yearbook 2)City plans ➢ Shaanxi Province Low-carbon Pilot Work Implementation Plan and Shaanxi Province Climate Change Plan ➢ Shaanxi Province Comprehensive Transportation Development Plan", "Four Major Defense Battle 2020 Work Plan ➢ Shaanxi Province" 14th Five-Year "High Quality Development Plan of Manufacturing Industry ➢ Shaanxi Province Iron hand to control haze to win the Blue Sky Battle ➢ The 14th Five-Year Plan for the National Economic and Social Development of Shaanxi Province and the Outline of the Long-range Goals to 2035 3)Reports ➢ Earliest peaking carbon emission in China (ERI, 2017) ➢ Annual development report of building energy efficiency in China (Tsinghua University, 2019)
The residential life sector	$E_n = \sum_n F \times H_n \times P_n$	H_n: the energy intensity of household appliance n(tce/ unit) P_n: household appliance ownership rate (%) F: Household number (unit)	
The public buildings sector	$E_n = \sum_j A_i \times P_{i,n} \times Intensity_{i,n}$	A_i: the building area (m^2) $P_{i,n}$: penetration rate of terminal energy (%) $Intensity_{i,n}$: the energy intensity (tce/ m^2)	
The industry sector	$E_n = \sum_i Product_i \times Intensity_{i,n}$	$Product_i$: output of industrial product (t) $Intensity_{i,n}$: the energy intensity (tce/ t)	
The transportation sector	$E_n = \sum_i Turnover_i \times Intensity_{i,n}$	$Turnover_i$: transportation turnover (p·km or t·km) $Intensity_{i,n}$: the energy intensity (tce/ p·km or tce/ t·km)	

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