

Supplementary Material

Table S1. Main parameters and data sources of SD model

Type	Factor	Unit	Value/Equation	Data sources
Stocks	Gross domestic product (GDP)	10 ⁸ yuan	INTEG(GDPG,9497.7)	Statistical yearbook of Beijing, Tianjin and Hebei
	Total population (POP)	10 ⁴ people	INTEG(POPG,7871.2)	Statistical yearbook of Beijing, Tianjin and Hebei
	Conventional energy consumption (CEC)	10 ⁴ tce	INTEG(CECG,15917.9)	Statistical yearbook of Beijing, Tianjin and Hebei
	Renewable energy consumption (NEC)	10 ⁸ kWh	INTEG(NECG + NETP,33.74)	China Energy Statistical Yearbook
	Subsidy intensity (SI)	10 ⁸ yuan	INTEG(-SI*SDR,0.0028)	[1]
Flows	GDP growth per year (GDPG)	10 ⁸ yuan	GDP*GGR	Endogenous
	Population growth per year (POPG)	10 ⁴ people	PGR*POP	Endogenous
	Conventional energy consumption growth per year (CECG)	10 ⁴ tce	CEGR * CEC *(1/ RFET ₀)	Endogenous
	Renewable energy consumption growth per year (NECG)	10 ⁸ kWh	NEC * NEGR * RFET ₀	Endogenous
	Subsidy decline rate (SDR)	10 ⁸ yuan	((STEP(0.0092, 49)+STEP(0.0026, 73)))	[1]
Constants	Proportion of environmental protection investment (PEI ₀)	%	1.1	[2]
	Proportion of R&D (PRI ₀)	%	0.5	China Statistical Yearbook on Science and Technology
	Coefficient of environmental	Mt CO ₂ /10 ⁸ yuan	0.02432	China Energy Statistical

	protection investment (CEI_0)			Yearbook; [3]
	Environmental capacity coefficient (ECC_0)	-	0.08	Expert estimation method
	Standard coefficient of renewable energy ($SCNE_0$)	10^4 t ce/ 10^8 kWh	1.129	China Energy Statistical Yearbook
	Economic benefit per unit renewable energy ($EBNE_0$)	10^8 yuan/ 10^4 tce	0.45	[4]
	Regulatory factors of energy tax ($RFET_0$)	-	1	[4]
Variables	GDP growth rate (GGR)	-	WITH LOOKUP (Time ([(2000,0)-(2050,0.5)], (2000,0.125), (2001,0.308), (2002,-0.008), (2003,0.188), (2004,0.159), (2005,0.151), (2006,0.217), (2007,0.167), (2008,0.087), (2009,0.173), (2010,0.173), (2011,0.096), (2012,0.082), (2013,0.062), (2014,0.056), (2015,0.08), (2016,0.089), (2017,0.082), (2018,0.071), (2020,0.07), (2030,0.045), (2040,0.035), (2050,0.025))	Statistical yearbook of Beijing, Tianjin and Hebei; [5]
	Population growth rate (PGR)	-	WITH LOOKUP (Time ([(2000,0)-(2019,0.03)], (2000,0.021), (2001,0.006), (2002,0.009), (2003,0.008), (2004,0.009), (2005,0.011), (2006,0.013), (2007,0.014), (2008,0.016), (2009,0.015), (2010,0.029), (2011,0.011), (2012,0.011), (2013,0.01), (2014,0.009), (2015,0.006), (2016,0.005), (2017,0.005), (2018,0.002), (2019,0.004), (2027,0), (2030,-0.001))	Statistical yearbook of Beijing, Tianjin and Hebei; [6]
	Conventional energy growth rate ($CEGR$)	-	WITH LOOKUP (Time ([(2000,0.01)-(2019,1)], (2000,0.14), (2001,0.06), (2002,0.083), (2003,0.11), (2004,0.13), (2005,0.11), (2006,0.094), (2007,0.08), (2008,0.03), (2009,0.05), (2010,0.056), (2011,0.07), (2012,0.035), (2013,0.039), (2014,-0.02), (2015,0.04), (2016,0.006), (2017,0.012), (2018,0.009), (2019,0.015), (2030,0.005), (2040, 0.003), (2050, 0.001))	Statistical yearbook of Beijing, Tianjin and Hebei
	Renewable energy growth rate ($NEGR$)	-	WITH LOOKUP (Time ([(2000,0)-(2019,0.3)], (2000,0.001), (2001,0.006), (2002,0.039), (2003,0.072), (2004,0.003), (2005,0.005),	China Energy Statistical Yearbook

			(2006,0.084), (2007,0.009), (2008,0.054), (2009,0.101), (2010,0.124), (2011,0.103), (2012,0.065), (2013,0.077), (2014,0.061), (2015,0.131), (2016,0.201), (2017,0.125), (2018,0.148), (2020,0.112), (2025,0.042), (2030,0.025), (2035,0.005), (2040,0.001), (2045,0))	
	Renewable energy tax factor (NETF)	-	WITH LOOKUP (Time ([(2010,0.1)- (2050,0.125)]), (2010,0.1), (2011,0.11), (2012,0.11), (2013,0.11), (2014,0.11), (2015,0.12), (2016,0.125), (2017,0.125), (2018,0.125), (2019,0.125), (2030,0.12), (2040,0.11))	[4]
	Environmental protection investment (EPI)	10 ⁸ yuan	GDP* PEI ₀	Endogenous
	CO ₂ reduction by environmental protection investment (CEPI)	Mt CO ₂	EPI * CEI ₀	Endogenous
	Factors of CO ₂ reduction policies (FCRP)	-	0.005495+0.001365*SIN(3.14*(Time-2020))	[2]
	CO ₂ reduction by policies (CRP)	Mt CO ₂	EC * FCRP	[4]
	CO ₂ emissions (TCE)	Mt CO ₂	CEC *0.02475*(1/ RFET ₀)+ SNEC *0-(CRP + CEPI)	[2]
	Renewable energy incentive factors (NEIF)	10 ⁸ yuan/Mt CO ₂	TCE *10 ⁻⁷	Expert estimation method
	Investment proportion of renewable energy industry (IPNE)	-	0.003* NEIF	Expert estimation method
	Investment of renewable energy industry (INEI)	10 ⁸ yuan	GDP* IPNE	Endogenous
	R&D investment in renewable energy industry (RINE)	10 ⁸ yuan	INEI + PRI ₀ *GDP	Endogenous
	Technological progress coefficient (TPC)	10 ⁴ tce/10 ⁸ yuan	RINE *1.004	Expert estimation method
	Added value of	10 ⁴ tce	TPC *0.0498	China Energy

	renewable energy brought by technological progress (NETP)			Statistical Yearbook
	Standard renewable energy consumption (SNEC)	10^4 tce	$NEC * SCNE_0$	China Energy Statistical Yearbook
	Economic benefit of renewable energy (EBNE)	10^8 yuan	$SNEC * EBNE_0$	Endogenous
	Output value of renewable energy (OVNE)	10^8 yuan	$EBNE * (1 - NETF) + SI + INEI$	[4]
	Total energy consumption (TEC)	10^4 tce	$CEC + SNEC$	Endogenous
	Energy consumption per capita (ECP)	tce /person	TEC / POP	Endogenous
	Carbon emission per capita (CEP)	Mt CO ₂ /person	TCE / POP	Endogenous
	Energy pollution coefficient (EPC)	-	$(CEC * 0.78 + SNEC * 0) / TEC$	[4]
	Environmental capacity (EC)	-	$TEC * ECC_0 * (1 / EPC)$	[4]
	Energy consumption structure (ECS)	-	$CEC / SNEC$	[5]
	Energy intensity (EI)	tce/ 10^4 yuan	TEC / GDP	[7]

Reference

- [1] Cheng Y.; Mu D. Study on optimal subsidy strategy in new energy vehicle supply chain based on SD game model. *China Popul., Resour. Environ.* **2018**, *28*(12):29–39. (in Chinese)
- [2] Zhou X.; Xu Z.; Xi Y. The system dynamic model and policy optimized simulation of energy conservation and emission reduction in China. *Systems Eng. Theory Pract.* **2018**, *38*(06), 1422–44. (in Chinese)
- [3] Ye F.; Fang X.; Li L.; Li Y.; Chang C. Allocation of carbon dioxide emission quotas based on the energy-economy-environment perspective: Evidence from Guangdong Province. *Sci. Total. Environ.* **2019**, *669*, 657–667.
- [4] Huang G.; Xu C. Analysis on the influencing factors and dynamic characteristics of new energy industry development under the low carbon perspective. *J. Chongqing Univ. Technol. (Nat. Sci.)*. **2020**, *34*(12), 206–17. (in Chinese)
- [5] Yang H.; Li X.; Ma L.; Li Z. Using system dynamics to analyse key factors influencing China's

energy-related CO₂ emissions and emission reduction scenarios. *J. Clean. Prod.* **2021**, *320*, 128811.

- [6] Zhang F.; Deng X.; Xie L.; Xu N. China's energy-related carbon emissions projections for the shared socioeconomic pathways. *Resour. Conserv. Recy.* **2021**, *168*, 105456.
- [7] Zhang F.; Deng X.; Phillips F.; Fang C.; Wang C. Impacts of industrial structure and technical progress on carbon emission intensity: Evidence from 281 cities in China. *Technol. Forecast. Soc.* **2020**, *154*, 119949.