Supplementary Information for

Industrial Ecosystems and Food Webs: An Ecological-Based Mass Flow Analysis to Model the Progress of Steel Manufacturing in China

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S1. Flow data used in models

Flow from	Flow to	Future	Current	Historical	Units	Historical source
Blast furnace slag	Cement plant	0.3481	0.0000	1.3140	ton/ton-cs	CISY 1989
Washery coal	Coking plant	0.6173	0.6173	1.4450	ton/ton-cs	CISY 1989
Water	Coking plant	0.8592	0.8592	4.4834	ton/ton-cs	**
Hot rolled sheet	Cold rolling plant	0.2096	0.2096	0.0500	ton/ton-cs	CISY 1989
Water	Cold rolling plant	0.0286	0.0286	0.1494	ton/ton-cs	**
Basic oxygen furnace slag	Construction material plant	0.1250	0.0000	0.0085	ton/ton-cs	Yin 2009
Slab & plate	Deep-processing industrial park *	0.3846	0.0000	0.0000	ton/ton-cs	—
Water	Entire	4.1200	4.1200	21.5000	ton/ton-cs	CISY 1998
Flume emissions	Environment	0.0003	0.0003	1.2000	ton/ton-cs	Price et al. 2001 for year 1988
Dust emissions	Environment	0.0009	0.0009	0.0017	ton/ton-cs	***
SO_2 emissions	Environment	0.0012	0.0012	0.0024	ton/ton-cs	***
NO_x emissions	Environment	0.0016	0.0016	0.0033	ton/ton-cs	***
Effluent	Environment	0.1300	0.1300	2.2081	ton/ton-cs	CISY 1989
Slab & plate	Equipment manufacturing *	0.1442	0.0000	0.0000	ton/ton-cs	—
Con. cast slab	Hot rolling plant	0.7096	0.7096	0.3464	ton/ton-cs	CISY 1989
Water	Hot rolling plant	0.9249	0.9249	4.8263	ton/ton-cs	**
Pellet	Iron plant	0.3904	0.3904	0.0000	ton/ton-cs	Rosst and Feng 1990
Lump ore	Iron plant	0.0981	0.0981	1.7920	ton/ton-cs	CISY 1989
Coal	Iron plant	0.2019	0.2019	0.5890	ton/ton-cs	CISY 1989
Sinter ore	Iron plant	1.2365	1.2365	1.6020	ton/ton-cs	Sun et al. 2013 for year 1990
Coke	Iron plant	0.3173	0.3173	0.6320	ton/ton-cs	Sun et al. 2013 for year 1990
Oxygen blast	Iron plant	0.0012	0.0012	0.0000	tce/ton-cs	—
Water	Iron plant	0.6722	0.6722	3.5076	ton/ton-cs	**
Lime & dolomite stone	Lime plant	0.2942	0.2942	0.0000	ton/ton-cs	—
BFG	Lime plant	0.0067	0.0067	0.0000	tce/ton-cs	—
COG	Lime plant	0.0076	0.0076	0.0000	tce/ton-cs	—
Wide & heavy plate products	Market	0.2692	0.2692	0.6927	ton/ton-cs	CISY 1989
Cold rolling products	Market	0.1923	0.1923	0.2131	ton/ton-cs	CISY 1989
Hot rolled plate products	Market	0.4827	0.4827	1.4762	ton/ton-cs	CISY 1989
COG	Outside park power plant	0.0036	0.0036	0.0000	tce/ton-cs	—
BFG	Power plant	0.0477	0.0477	0.0000	tce/ton-cs	—
BOFG	Power plant	0.0289	0.0289	0.0000	tce/ton-cs	—
COG	Power plant	0.0013	0.0013	0.0000	tce/ton-cs	—
Water	Power plant	0.2510	0.2510	0.0000	ton/ton-cs	—
Cold rolling scrap/scale	Scrap/scale	0.0173	0.0173	0.0080	ton/ton-cs	CISY 1988
Hot rolling scrap/scale	Scrap/scale	0.0173	0.0173	0.0556	ton/ton-cs	CISY 1989
Wide & heavy plate scrap/scale	Scrap/scale	0.0212	0.0212	0.0176	ton/ton-cs	CISY 1989

Slab & plate	Ship building *	0.0135	0.0000	0.0000	ton/ton-cs	—
Lime plant	Sinter plant	0.0635	0.0635	0.0635	ton/ton-cs	
Iron ore powder	Sinter plant	1.1538	1.1538	1.1538	ton/ton-cs	
Lime (raw material yard)	Sinter plant	0.0346	0.0346	0.0346	ton/ton-cs	
Anthracite	Sinter plant	0.0025	0.0025	0.0000	ton/ton-cs	—
Coke powder	Sinter plant	0.0538	0.0538	0.0680	ton/ton-cs	CISY 1989
Scrap/scale	Sinter plant	0.0154	0.0154	0.0000	ton/ton-cs	—
Water	Sinter plant	0.0927	0.0927	0.4835	ton/ton-cs	**
Lime & dolomite	Steel plant	0.0808	0.0808	0.0000	ton/ton-cs	Rosst and Feng 1990
Oxygen	Steel plant	0.0260	0.0260	0.0530	tce/ton-cs	*Estimate based on US Prod.
Hot liquid iron	Steel plant	1.0096	1.0096	1.0000	ton/ton-cs	CISY 1989
Scrap/scale	Steel plant	0.0962	0.0962	0.0950	ton/ton-cs	CISY 1989
Water	Steel plant	0.1146	0.1146	0.5978	ton/ton-cs	**
Crude steel	To plate, HR, CR, and construction	1.0000	1.0000	0.5589	ton/ton-cs	Sun et al. 2013 for year 1990
Effluent	Water-treatment plant	0.1250	0.1250	0.1250	ton/ton-cs	—
Con. cast heavy slab	Wide & heavy plate plant	0.2904	0.2904	0.1625	ton/ton-cs	CISY 1989
Water	Wide & heavy plate plant	0.9249	0.9249	4.8263	ton/ton-cs	**

BFG: blast furnace gas; COG: coke oven gas; BOFG: basic oxygen furnace gas.

* Estimate.

** Using ratios from current time and assuming 210 m^3 per metric ton of crude steel.

*** Using 2 × the current values as estimate.

S2. Historical data from steel statistical yearbook

Anshan Iron and Steel Group Corporation 1988 (*Steel Statistical Yearbook 1989*)						
Output (10^4 metric tons)	Finished rolled steel	Steel-making pig iron	Blast furnace slag	Iron ore	Metallurgy coke	
	5943	756.4	395.02	2507.22	408.55	
Energy consumption (10^4 metric tons)	Coking coal	Fuel coal	Coke	Electricity	Heavy oil	Natural gas (10^6 m^3)
	642.15	247.82	429.36	42.61	102.96	1.09
Fuel consumption (10^4 metric tons)	Sinter & pellet	Iron-making	Steel-making and rolling	Machinery repairing and power plant		
	65.67	55.89	—	100.69		
Electricity consumption (10^8 kW·h)	Mining and mineral processing	Sintering and pelleting	Iron-making	Steel-making	Steel rolling and forging	Machinery repairing and power plant
	11.7	3.19	0.85	1.7	4.51	14.55
Process-level statistics (10^4 metric tons)	Coke	Wet coal consumption	1445			
		Yield ratio (%)	76.44			
	Sinter	Ratio of good sinter (%)	99.56			
		Fuel consumption	68			
	Iron	Ratio of good pig iron (%)	100			
		Fuel consumption	589			
		Coal injection	72			
		Coke	490			
		Iron ore	1792			

	Steel	Pig iron and scrap	1116
		Pig iron	1021
		Scrap	95
		Alloy additive	19.3
		Ratio of good steel	10.69
	Rolling	Ratio of good rolled steel (%)	99.68
		Equivalent coal consumption for rolling	164
		Composite yield (%)	83.94
	Slabbing	Yield ratio (%)	89.16

S3. Flow matrices used in model

Historical Configuration		From																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Exports	Respiration
To	0 *Imports*	0	0	1.4450	0	0	0	0	0	2.3810	0.0981	0	0	0	0	1.4407	0.0867	21.5000	0	0	0	0	0	0
	1 *Cement Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2 *Coking Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.4834	0	0	0	0	0	4.4834
	3 *Cold Rolling Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0500	0.1494	0	0	0	0	0.0420	0.1494
	4 *Construction Material Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 *Deep Processing Industrial Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6 *Equipment Manufacturing Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7 *Hot Rolling Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3464	5.2485	0	0	0	0	0.3464	5.1929
	8 *Iron Plant*	0	0	1.3770	0	0	0	0	0	0	0	0	0	0	0	1.6020	0	3.5076	0	0	0	0	0	7.8676
	9 *Lime Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0024
	10 *Grid*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11 *On-Site Power Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12 *Scrap/Scale*	0	0	0	0.0080	0	0	0	0.0556	0	0	0	0	0	0	0	0	0	0.0176	0	0	0	0	0
	13 *Ship Building Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14 *Sinter Plant*	0	0	0.0680	0	0	0	0	0	0	0.0957	0	0	0	0	0	0	0.4835	0	0	0	0	0	0.4859
	15 *Steel Plant*	0	0	0	0	0	0	0	0	1.0000	0	0	0	0.0812	0	0	0	0.5978	0	0	0	0	0	1.2068
	16 *Water Treatment Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2038
	17 *Wide & Heavy Plate Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1625	4.8260	0	0	0	0	0.1625	4.8084
	18 *Oxygen Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	19 *Wetlands*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20 *Pyrolysis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Current Configuration		From																					
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Exports	Respiration
To	0 *Imports*	0	0	0.6173	0	0	0	0	0	0.6904	0.2942	0.0709	0	0	0	1.0123	0	4.1200	0	0	0	0	0	0
	1 *Cement Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2 *Coking Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6173	0	0	0	0	0	0.8510
	3 *Cold Rolling Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0562	0	0	0	0.1950	0.0286	0	0	0	0	0.1923	0.0702
	4 *Construction Material Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5 *Deep Processing Industrial Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6 *Equipment Manufacturing Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7 *Hot Rolling Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0936	0	0	0	0.5600	0.9249	0	0	0	0	0.4827	1.0227
	8 *Iron Plant*	0	0	0.3173	0	0	0	0	0	0	0	0	0	0	0	1.2365	0	0.6722	0	0.0171	0	0	0	1.8695
	9 *Lime Plant*	0	0	0.0076	0	0	0	0	0	0.0067	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1642
	10 *Grid*	0	0	0.0036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11 *On-Site Power Plant*	0	0	0.0013	0	0	0	0	0	0.0477	0	0.0745	0	0	0	0	0	0.2510	0	0	0	0	0	0
	12 *Scrap/Scale*	0	0	0	0.0173	0	0	0	0.0731	0	0	0	0	0	0	0	0	0	0.0212	0	0	0	0	0
	13 *Ship Building Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14 *Sinter Plant*	0	0	0.0538	0	0	0	0	0	0	0.0635	0	0	0.0154	0	0	0	0.0927	0	0	0	0	0	0.0012
	15 *Steel Plant*	0	0	0	0	0	0	0	0	1.0096	0.0808	0	0	0.0962	0	0	0	0.1146	0	0.0260	0	0	0	0.3272
	16 *Water Treatment Plant*	0	0	0	0	0	0	0	0	0	0	0	0.1498	0	0	0	0	0	0	0	0	0	0	1.5685
	17 *Wide & Heavy Plate Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0318	0	0	0	0.2450	0	0	0	0	0	0.2000	0.0556
	18 *Oxygen Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0431	0	0	0	0	0	0	0	0	0	0	0
	19 *Wetlands*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20 *Pyrolysis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

EIP Configuration			From																					
			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Exports	Respiration
To	0	*Imports*	0	0	0.6173	0	0	0	0	0	0.6904	0.2942	0.0709	0	0	0	1.0123	0	4.1200	0.0171	0	0	0	0	0
	1	*Cement Plant*	0	0	0	0	0	0	0	0	0.3481	0	0	0	0	0	0	0	0	0	0	0	0	0.3481	0
	2	*Coking Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6173	0	0	0	0	0	0.8510
	3	*Cold Rolling Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0562	0	0	0	0	0.0286	0	0	0	0	0.0675	0
	4	*Construction Material Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1250	0	0	0	0	0	0.1250	0
	5	*Deep Processing Industrial Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2000	0	0	0	0.2000	0
	6	*Equipment Manufacturing Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1142	0	0	0	0.1142	0
	7	*Hot Rolling Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0936	0	0	0	0.6000	0.9249	0	0	0	0	0.4827	1.0627
	8	*Iron Plant*	0	0	0.3173	0	0	0	0	0	0	0	0	0	0	0	1.2365	0	0.6722	0	0.0012	0	0	0	1.5055
	9	*Lime Plant*	0	0	0.0076	0	0	0	0	0	0.0067	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1642
	10	*Grid*	0	0	0.0036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	*On-Site Power Plant*	0	0	0.0013	0	0	0	0	0	0.0477	0	0.0745	0	0	0	0	0	0.2510	0	0	0	0	0	0
	12	*Scrap/Scale*	0	0	0	0.0173	0	0	0	0.0731	0	0	0	0	0	0	0	0	0	0.0212	0	0	0	0	0
	13	*Ship Building Plant*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0135	0	0	0	0.0135	0
	14	*Sinter Plant*	0	0	0.0538	0	0	0	0	0	0	0.0635	0	0	0.0154	0	0	0	0.0927	0	0	0	0	0	0.0012
	15	*Steel Plant*	0	0	0	0	0	0	0	0	1.0096	0.0808	0	0	0.0962	0	0	0	0.1146	0	0.0260	0	0	0	0.3022
	16	*Water Treatment Plant*	0	0	0	0	0	0	0	0	0	0	0	0.1498	0	0	0	0	0	0	0	0	0	0	1.5685
	17	*Wide & Heavy Plate Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0318	0	0	0	0.3000	0	0	0	0	0	0	0
	18	*Oxygen Plant*	0	0	0	0	0	0	0	0	0	0	0	0.0431	0	0	0	0	0	0	0	0	0	0	0.0159
	19	*Wetlands*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	*Pyrolysis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0