

An environmental and economic evaluation of carbon sequestration from pyrolysis and biochar application in China

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Electronic supplementary material (ESM)

APPENDIX

Appendix A presents the simulation results under various prices of gasoline, coal and emissions. The results show that as gasoline price increases, more feedstocks will be used in ethanol production, but the net emission reduction will increase at a slower rate. Conventional co-fire electricity is less competitive compared to pyrolysis-based electricity because its input/output ratio is lower. Fast pyrolysis dominates at high coal prices because it generates more electricity, but slow pyrolysis is preferred when emission price is high.

A.1 Simulation results bioenergy production and GHG offsets under various conditions

	Units						
Gasoline price	(¥ /liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥ /kg)	0.7	0.7	0.7	0.7	0.7	0.7
GHG price	(¥ /ton)	20.0	20.0	20.0	20.0	20.0	20.0
Ethanol production	1000 liter	41 134	348 000	417 600	417 600	417 600	417 600
Electricity production	1000 kWh	6 315 000	3 191 275	1 849 777	1 848 909	1 848 906	1 848 906
Government subsidy	Million ¥	2 473.2	2 449.2	2 516.9	2 516.9	2 516.9	2 516.9
Planted area	1000 ha	235.6	233.3	239.7	239.7	239.7	239.7
Carbon reduction from ethanol	Ton	4 607	38 976	46 771	46 771	46 771	46 771
Carbon reduction from electricity	Ton	4 157 796	3 101 135	1 963 525	1 963 667	1 963 665	1 963 665
Net carbon offset	Ton	4 162 403	2 140 112	2 010 296	2 010 439	2 010 437	2 010 437

	Units						
Gasoline price	(¥ /liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥ /kg)	0.7	0.7	0.7	0.7	0.7	0.7
GHG price	(¥ /ton)	25.0	25.0	25.0	25.0	25.0	25.0
Ethanol production	1000 liter	13 920	348 000	348 000	417 600	417 600	417 600
Electricity production	1000 kWh	6 118 937	2 426 368	2 426 368	2 260 478	2 259 064	2 147 734
Government subsidy	Million ¥	2 428.7	2 431.4	2 431.4	2 532.6	2 532.2	2 594.8

	Units						
Planted area	1000 ha	231.3	231.6	231.6	241.2	241.2	247.0
Carbon reduction from ethanol	Ton	1 559	38 976	38 976	46 771	46 771	46 771
Carbon reduction from electricity	Ton	4 411 850	2 331 199	2 331 199	1 885 769	1 884 973	2 131 885
Net carbon offset	Ton	4 413 409	2 370 176	2 370 176	1 932 540	1 931 744	2 178 656
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.7	0.7	0.7	0.7	0.7	0.7
GHG price	(¥/ton)	30.0	30.0	30.0	30.0	30.0	30.0
Ethanol production	1000 liter	13 920	53 951	348 000	348 000	417 600	417 600
Electricity production	1000 kWh	6 292 752	6 315 000	2 861 799	2 896 885	2 124 640	2 259 456
Government subsidy	Million ¥	2 544.2	2 488.7	2 611.8	2 611.8	2 611.8	2 611.8
Planted area	1000 ha	242.3	237.0	248.7	248.7	248.7	241.4
Carbon reduction from ethanol	Ton	1 559	6 042	38 976	38 976	46 771	46 771
Carbon reduction from electricity	Ton	4 564 124	4 157 796	2 614 551	2 603 737	2 169 013	1 885 241
Net carbon offset	Ton	4 565 683	4 163 838	2 653 527	2 642 713	2 215 784	1 932 013
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.7	0.7	0.7	0.7	0.7	0.7
GHG price	(¥/ton)	35.0	35.0	35.0	35.0	35.0	35.0
Ethanol production	1000 liter	15 098	16 398	38 694	348 000	348 000	348 000
Electricity production	1000 kWh	6 315 000	6 315 000	6 315 000	2 896 771	2 861 842	2 861 842
Government subsidy	Million ¥	2 534.3	2 495.4	2 611.8	2 611.8	2 611.8	2 611.8
Planted area	1000 ha	241.4	237.7	248.7	248.7	248.7	248.7
Carbon reduction from ethanol	Ton	1 691	1 836	4 334	38 976	38 976	38 976
Carbon reduction from electricity	Ton	4 650 978	4 547 020	4 539 875	2 603 799	2 614 575	2 614 575
Net carbon offset	Ton	4 652 670	4 548 865	4 544 209	2 642 775	2 653 551	2 653 551
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.7	0.7	0.7	0.7	0.7	0.7
GHG price	(¥/ton)	40.0	40.0	40.0	40.0	40.0	40.0
Ethanol production	1000 liter	13 920	14 203	35 321	348 000	348 000	348 000
Electricity production	1000 kWh	6 459 044	6 315 000	6 315 000	2 861 942	2 861 942	2 861 950
Government subsidy	Million ¥	2 611.1	2 529.9	2 614.9	2 611.8	2 611.8	2 611.8
Planted area	1000 ha	148.7	240.9	249.0	248.8	248.8	248.8
Carbon reduction from ethanol	Ton	1 559	1 590	3 956	38 976	38 976	38 976
Carbon reduction from electricity	Ton	4 732 067	4 654 891	4 576 507	2 614 631	2 614 631	2 614 636
Net carbon offset	Ton	4 733 626	4 656 482	4 580 463	2 653 607	2 653 607	2 653 612
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.7	0.7	0.7	0.7	0.7	0.7

	Units						
GHG price	(¥/ton)	45.0	45.0	45.0	45.0	45.0	45.0
Ethanol production	1000 liter	13 920	13 920	25 498	37 712	348 000	348 000
Electricity production	1000 kWh	6 457 974	6 457 974	6 315 000	6 315 000	2 896 031	2 896 031
Government subsidy	Million ¥	2 611.8	2 611.8	2 611.8	2 612.0	2 612.0	2 612.0
Planted area	1000 ha	248.7	248.7	248.7	248.8	248.8	248.8
Carbon reduction from ethanol	Ton	1 559	1 559	2 856	4 223	38 976	38 976
Carbon reduction from electricity	Ton	4 735 385	4 735 385	5 667 537	4 549 709	2 604 386	2 604 386
Net carbon offset	Ton	4 736 944	4 736 944	4 670 393	4 553 933	2 643 362	2 643 362
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.4	0.4	0.4	0.4	0.4	0.4
GHG price	(¥/ton)	20.0	20.0	20.0	20.0	20.0	20.0
Ethanol production	1000 liter	348 000	417 600	417 600	417 600	417 600	462 980
Electricity production	1000 kWh	3 174 956	1 654 058	1 654 058	1 654 058	2 434 647	1 473 500
Government subsidy	Million ¥	2 453.4	2 431.2	2 431.2	2 431.2	2 444.4	2 400.9
Planted area	1000 ha	233.7	231.6	231.6	231.6	232.8	228.7
Carbon reduction from ethanol	Ton	38 976	46 771	46 771	46 771	46 771	51 853
Carbon reduction from electricity	Ton	2 090 391	1 896 110	1 896 110	1 896 110	1 602 971	1 420 259
Net carbon offset	Ton	2 129 376	1 942 881	1 942 881	1 942 881	1 649 742	1 472 113
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.4	0.4	0.4	0.4	0.4	0.4
GHG price	(¥/ton)	25.0	25.0	25.0	25.0	25.0	25.0
Ethanol production	1000 liter	13 920	348 000	417 600	417 600	417 600	417 600
Electricity production	1000 kWh	6 532 622	2 431 452	1 659 373	1 659 373	1 659 373	1 841 762
Government subsidy	Million ¥	2 438.7	2 446.5	2 446.7	2 446.7	2 446.7	2 516.4
Planted area	1000 ha	232.3	233.0	233.0	233.0	233.0	239.7
Carbon reduction from ethanol	Ton	1 559	38 976	46 771	46 771	46 771	46 771
Carbon reduction from electricity	Ton	4 301 078	2 368 730	1 933 978	1 933 978	1 933 978	1 965 247
Net carbon offset	Ton	4 302 637	2 407 706	1 980 749	1 980 749	1 980 749	2 012 018
	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.4	0.4	0.4	0.4	0.4	0.4
GHG price	(¥/ton)	30.0	30.0	30.0	30.0	30.0	30.0
Ethanol production	1000 liter	13 920	348 000	348 000	417 600	417 600	417 600
Electricity production	1000 kWh	6 533 993	2 427 200	2 424 039	1 820 912	1 819 522	1 654 978
Government subsidy	Million ¥	2 439.2	2 432.9	2 514.8	2 492.3	2 491.9	2 432.9
Planted area	1000 ha	232.3	231.7	239.5	237.4	237.3	231.7
Carbon reduction from ethanol	Ton	1 559	38 976	38 976	46 771	46 771	46 771
Carbon reduction from electricity	Ton	4 301 981	2 334 623	2 499 667	1 939 269	1 938 486	1 899 787
Net carbon offset	Ton	4 303 540	2 373 599	2 538 643	1 986 040	1 985 258	1 946 558

	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.4	0.4	0.4	0.4	0.4	0.4
GHG price	(¥/ton)	35.0	35.0	35.0	35.0	35.0	35.0
Ethanol production	1000 liter	13 920	13 920	348 000	348 000	417 600	417 600
Electricity production	1000 kWh	6 687 196	6 196 923	2 782 257	2 782 196	2 010 018	2 010 018
Government subsidy	Million ¥	2 521.5	2 448.0	2 611.8	2 611.8	2 611.8	2 611.8
Planted area	1000 ha	240.2	233.2	248.7	248.7	248.7	248.7
Carbon reduction from ethanol	Ton	1 559	1 559	38 976	38 976	46 771	46 771
Carbon reduction from electricity	Ton	4 402 850	4 433 877	2 639 090	2 639 056	2 204 364	2 204 364
Net carbon offset	Ton	4 404 409	4 435 436	2 678 066	2 678 032	2 251 135	2 251 135

	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.4	0.4	0.4	0.4	0.4	0.4
GHG price	(¥/ton)	40.0	40.0	40.0	40.0	40.0	40.0
Ethanol production	1000 liter	13 920	14 203	26 806	348 000	348 000	417 600
Electricity production	1000 kWh	6 457 877	6 315 000	6 315 000	2 782 299	2 751 229	1 978 991
Government subsidy	Million ¥	2 611.8	2 529.9	2 611.8	2 611.8	2 611.8	2 611.8
Planted area	1000 ha	248.7	240.9	248.7	248.7	248.7	248.7
Carbon reduction from ethanol	Ton	1 559	1 590	3 002	38 976	38 976	38 976
Carbon reduction from electricity	Ton	4 735 324	4 654 891	4 654 891	2 639 114	2 648 699	2 213 973
Net carbon offset	Ton	4 736 883	4 656 482	4 657 893	2 678 090	2 687 675	2 260 745

	Units						
Gasoline price	(¥/liter)	4.0	5.0	6.0	7.0	8.0	9.0
Coal price	(¥/kg)	0.4	0.4	0.4	0.4	0.4	0.4
GHG price	(¥/ton)	45.0	45.0	45.0	45.0	45.0	45.0
Ethanol production	1000 liter	13 920	13 920	13 920	26 830	348 000	348 000
Electricity production	1000 kWh	6 457 974	6 457 974	6 457 974	6 315 000	2 751 396	2 751 396
Government subsidy	Million ¥	2 611.8	2 611.8	2 611.8	2 612.0	2 611.8	2 611.8
Planted area	1000 ha	248.7	248.7	248.7	248.8	248.8	248.8
Carbon reduction from ethanol	Ton	1 559	1 559	1 559	3 005	38 976	38 976
Carbon reduction from electricity	Ton	4 735 385	4 735 385	4 735 385	4 654 899	2 648 795	2 648 795
Net carbon offset	Ton	4 736 944	4 736 944	4 736 944	4 657 904	2 687 771	2 687 771

¥ denotes the Chinese yuan, whose exchange rate on October 16, 2014, was 0.1633 to the US dollar