Greenhouse gas emission reductions from domestic anaerobic digesters linked with sustainable sanitation in rural China

Supporting Information, 6 pages, including 5 tables and 4 figures

Supporting information contains a map of study sites in Sichuan province, the Global Warming Potentials used to calculate Global Warming Commitments, the emission characteristics of the stoves used in the analysis, an additional figure detailing the observed CH_4 leakage, detailed results of the scenario-based sensitivity analysis, a table calculating uncertainty in GWP associated with variation in stove emissions, and an additional figure summarizing the results of our analysis.

RADHIKA DHINGRA[1], ERICK R. CHRISTENSEN[1], YANG LIU[2], BO ZHONG[2], CHANG-FU WU[3], MICHAEL G. YOST[4], JUSTIN V. REMAIS*[1]

[1]*Department of Environmental Health, Rollins School of Public Health, Emory University, 1518 Clifton Rd. NE, Atlanta, GA 30322 USA. Telephone: (404) 712-8908. Fax: (404) 727-8744. E-mails: rdhingr@emory.edu; erickchristensen@gmail.com; justin.remais@emory.edu*

[2] *Institute of Parasitic Disease, Sichuan Center for Disease Control and Prevention, Chengdu, Sichuan 610041, China Tel.: +1 86 28 8558 89510; Fax: +1 86 28 8558 9563; E-mail: evita_6161@163.com; zhongbo1968@163.com*

[3] *Department of Public Health, National Taiwan University, Room 717, No.17, Xu-Zhou Rd., Taipei 100, Taiwan (R.O.C.) . Tel: (02) 3366-8096; E-mail: changfu@ntu.edu.tw*

[4] *Department of Environmental and Occupational Health Sciences, School of Public Health, University of Washington Box 357234, Seattle, WA 98040 USA. Telephone: (206) 685-7243. E-mails: airion@u.washington.edu*

* Corresponding author. Mailing address: Department of Environmental Health, Rollins School of Public Health, Emory University, 1518 Clifton Rd. NE, Atlanta, GA 30322. Phone: (404) 712-8908. Fax: (404) 727-8744. E-mail: *justin.remais@emory.edu*.

Table S1. Global warming potentials (GWP) relative to CO_2 for selected greenhouse gases for 20, 100 and 500-year time horizons [13].

GHG	Renewable GWP			Non-renewable GWP		
	20 years	100 years	500 years	20 years	100 years	500 years
CO_2	1	1	1	0	0	0
CO	4.5	1.9	1.9	3.5	0.9	0.9
CH_4	72	25	7.6	71	24	6.6
NMHC	12	4.1	2.3	11	3.1	1.3
NO_2	289	298	153	288	297	152

Table S2. Stove/fuel pairings used in the present analysis based on previous work [11].

Fuel Type		ID	Stove Description
Coal	Unprocessed coal – unwashed	1.	Metal stove with flue
		2.	Metal stove without flue
		3.	Brick stove with flue
	Unprocessed coal – washed	4.	Metal stove with flue
	Processed coal – honeycomb briquettes	5.	Metal stove with flue
		6.	Metal stove without flue
		7.	Improved metal stove with flue
	Processed coal – briquettes	8.	Metal stove with flue
		9.	Metal stove without flue
Agricultural waste	Maize	10.	Brick stove with flue
		11.	Improved metal stove with flue
	Wheat	12.	Brick stove with flue
		13.	Improved metal stove with flue
Wood	Fuel wood	14.	Brick stove with flue
		15.	Improved metal stove with flue
		16.	Metal stove without flue *
Biogas	Biogas	17.	Metal stove with flue *

* From India

Table S3. Reported daily energy usage from solid fuels for cooking in 32 surveyed BG and 35 surveyed NB households.

	Wood		Coal		Crop residues		
	Kg (SE)	MJ	kg (SE)	MJ	kg (SE)	MJ	**Total MJ**
BG	4.46 (0.39)	12.15	0	0	0.65 (0.13)	1.34	15.45
NB	8.78 (0.68)	23.93	0.04 (0.003)	0.02	2.61 (0.31)	5.42	29.37
BG before†	6.63 (0.58)	18.06	0	0	5.73 (1.37)	11.90	29.96

† BG households reporting on energy usage before their biogas system was installed

Table S4. GWC per 2 MJ to pot for non-renewable model using 100-yr GWP, with (±SD) associated with the uncertainty in emissions factors reported in the stove emissions database [11].

Stove Distribution	Household GWC			
	Non-biogas	Biogas total[1]	Biogas TSL[2]	Biogas without leak
0% Improved	1631 (52, 3210)	921 (125, 1717)	881 (86, 1676)	810 (14, 1606)
Uniform	1388 (195, 2581)	796 (205, 1387)	755 (164, 1346)	685 (94, 1276)
100% Improved	1075 (421, 1729)	638 (324, 952)	598 (284, 912)	527 (212, 842)

[1] Biogas total: GWC from biogas households including non-adjusted CH_4 leakage data;
[2] Biogas TSL (temperature-sensitive leak): GWC from biogas households including CH_4 leakage adjusted for seasonal ambient temperature change.

S1. Scenario-Based Sensitivity Analysis

To better understand the relative influence of temperature-sensitive methane leakage, renewable/non-renewable resource use and improved stove distribution on GWC of leaking biogas digesters, a scenario-based sensitivity analysis was carried out over the 20 year time horizon. The referent categories were 'Biogas Total' (temperature-independent leakage), 0% improved stoves and non-renewable sourcing of fuel. GWC in leaking BG households was most sensitive to the renewable/non- renewable sourcing status of fuels, which resulted in the largest reductions (32% to 42%) in GWC compared to the reference category (Table S5B). The addition of temperature sensitive leakage produced reductions in GWC of 8 to 15% as compared to Biogas Total (Table S5A). Finally, distribution of 100% improved stoves produced reductions of 17% to 26%; whereas, uniformly distributed improved stoves produced more modest GWC reductions of 7% to 11% (Table S5C). For discussion of these sensitivity results, see the Discussion section of the main manuscript.

Table S5. Scenario-based sensitivity analyses of leaking BG models under a 20 year time horizon.

A. SENSITIVITY TO TEMPERATURE-SENSITIVE LEAKAGE

Stove dist.	Harvesting	Leakage	Household GWC (% reduction in GWC)
0% improved	**Non-renewable**	**Biogas Total†**	1483
		Biogas TSL	1366 (-8%)
	Renewable	**Biogas Total†**	919
		Biogas TSL	801 (-12%)
Uniform	**Non-renewable**	**Biogas Total†**	1329
		Biogas TSL	1212 (-9%)
	Renewable	**Biogas Total†**	855
		Biogas TSL	738 (-13%)
100% improved	**Non-renewable**	**Biogas Total†**	1125
		Biogas TSL	1007 (-10%)
	Renewable	**Biogas Total†**	761
		Biogas TSL	644 (-15%)

B. SENSITIVITY TO RENEWABLE/NON-RENEWABLE RESOURCES

Stove dist.	Leakage	Harvesting	Household GWC (% reduction in GWC)
0% improved	**Biogas Total**	**Non-renewable†**	1483
		Renewable	919 (-38%)
	Biogas TSL	**Non-renewable†**	1366
		Renewable	801 (-41%)
Uniform	**Biogas Total**	**Non-renewable†**	1329
		Renewable	855 (-36%)
	Biogas TSL	**Non-renewable†**	1212
		Renewable	738 (-39%)
100% improved	**Biogas Total**	**Non-renewable†**	1125
		Renewable	761 (-32%)
	Biogas TSL	**Non-renewable†**	1007
		Renewable	644 (-36%)

C. SENSITIVITY TO STOVE DISTRIBUTION

Leakage	Harvesting	Stove dist.	Household GWC (% reduction in GWC)
Biogas Total	**Non-renewable**	**0% improved†**	1483
		Uniform	1329 (-10%)
		100% improved	1125 (-24%)
	Renewable	**0% improved†**	919
		Uniform	855 (-7%)
		100% improved	761 (-17%)
Biogas TSL	**Non-renewable**	**0% improved†**	1366
		Uniform	1212 (-11%)
		100% improved	1007 (-26%)
	Renewable	**0% improved†**	801
		Uniform	738 (-8%)
		100% improved	644 (-20%)

† Reference group for % reduction in GWC calculation
TSL: Temperature-Sensitive Leakage

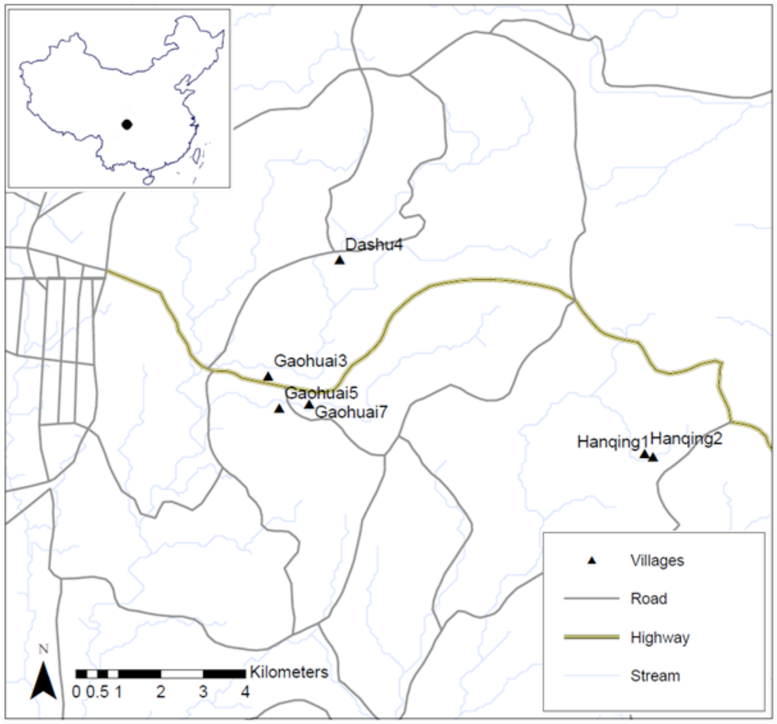

Figure S1. Map of study villages located within China's southwestern province, Sichuan.

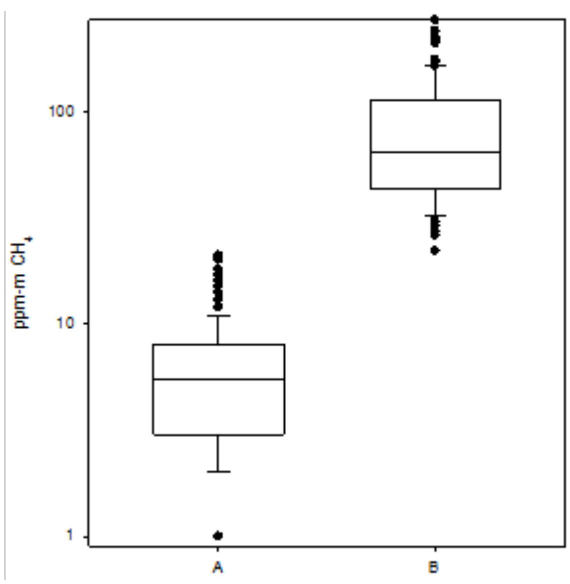

Figure S2. Distribution of RMLD background readings (n=180) taken over 120 seconds in a well-ventilated storage barn (A) and at a leak location indoors in a well-ventilated BG household (B).

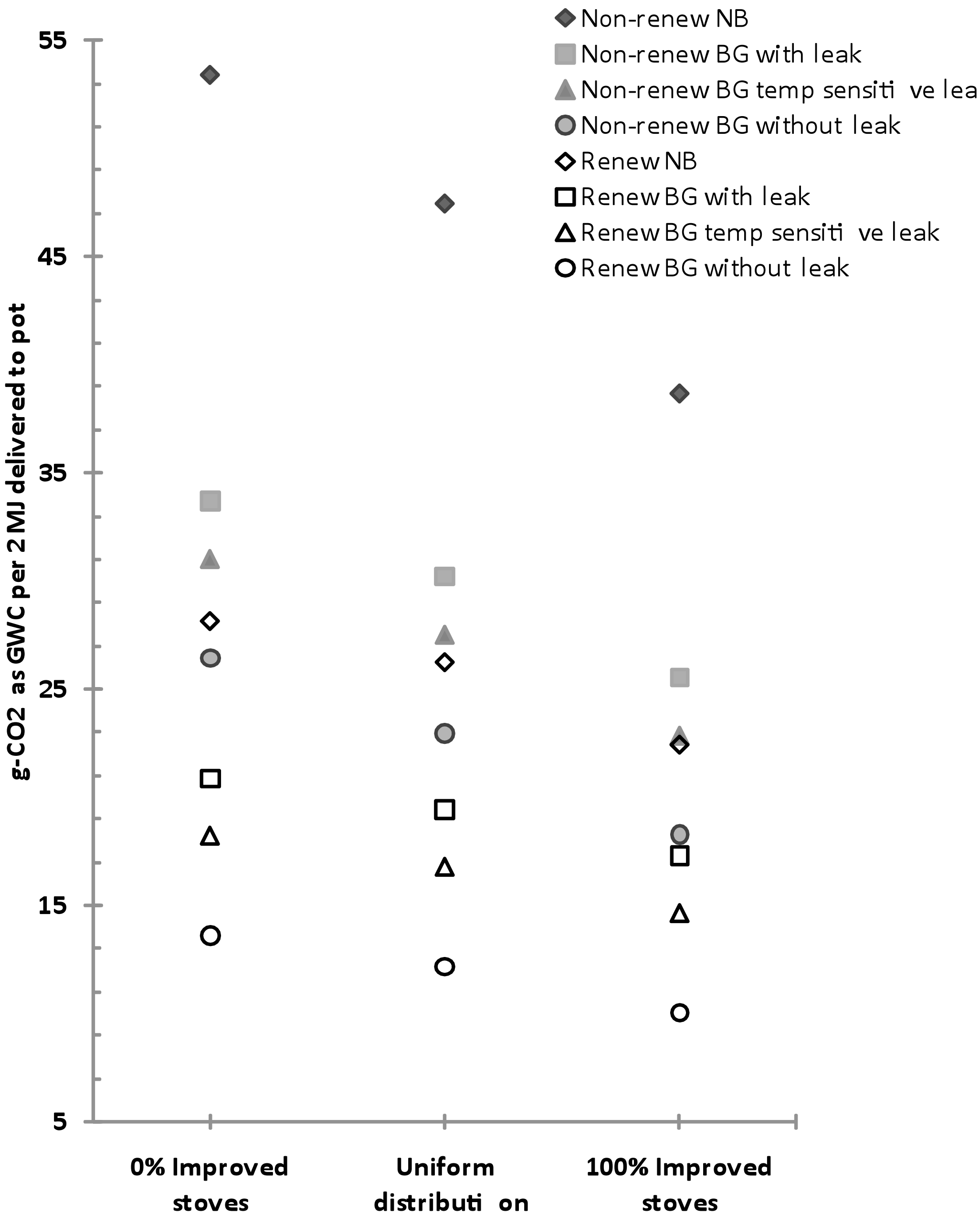

Figure S3. GWC of renewable and non-renewable energy model using 20-year GWP estimates for biogas households (BG) and non-biogas households (NB).

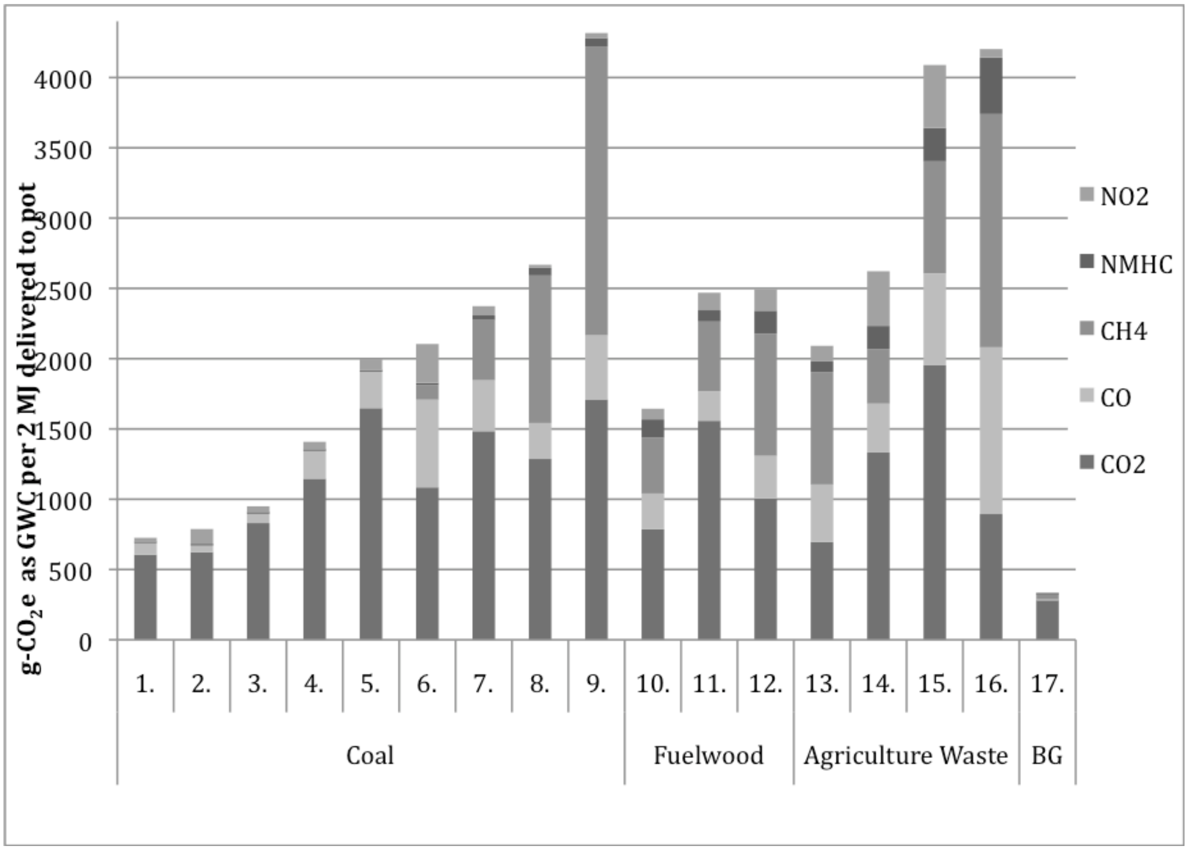

Figure S4. Individual GWC of stoves delivering 2 MJ to pot using non-renewable energy GWP. Stoves are identified by number as described in Table S2.