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Supporting Information for

Experimental evidence on promotion of electric and improved biomass cookstoves

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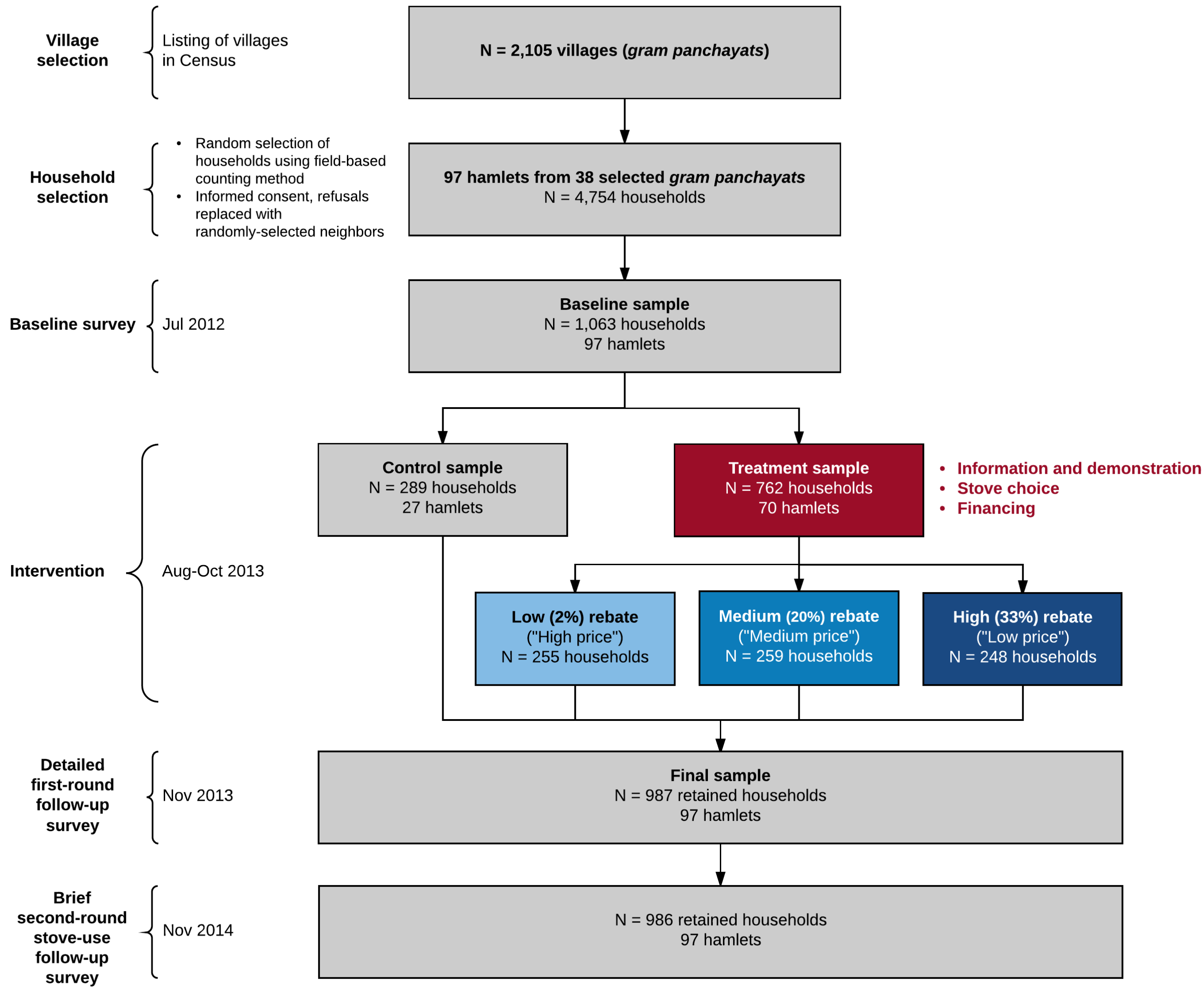

Fig. S1. Study design and timeline.

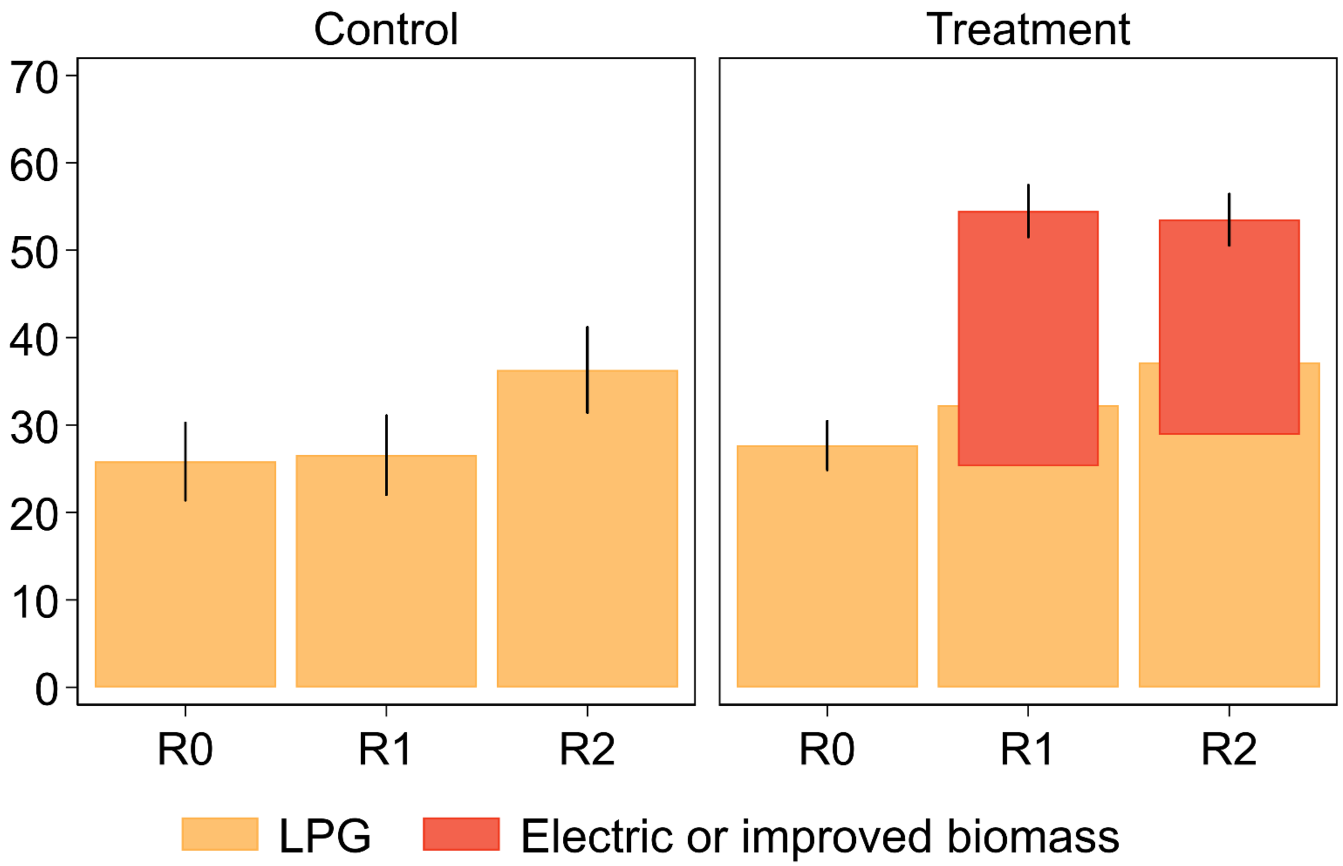

Fig. S2. Stove use (% of households) by treatment group. LPG = liquefied petroleum gas. Household-level use is derived from a binary (yes/no) survey question about whether the device in question was used in the past week. Baseline (R0) surveys conducted during the summer of 2012. Intervention occurred during the summer of 2013. Detailed first-round (R1) follow-up surveys occurred approximately three months after the intervention. Second-round (R2) follow-up surveys to evaluate continued use occurred approximately 15 months after the intervention. Error bars indicate 90% confidence intervals.

(A) Location of Uttarakhand within India

(B) Distribution of study sites within Uttarakhand

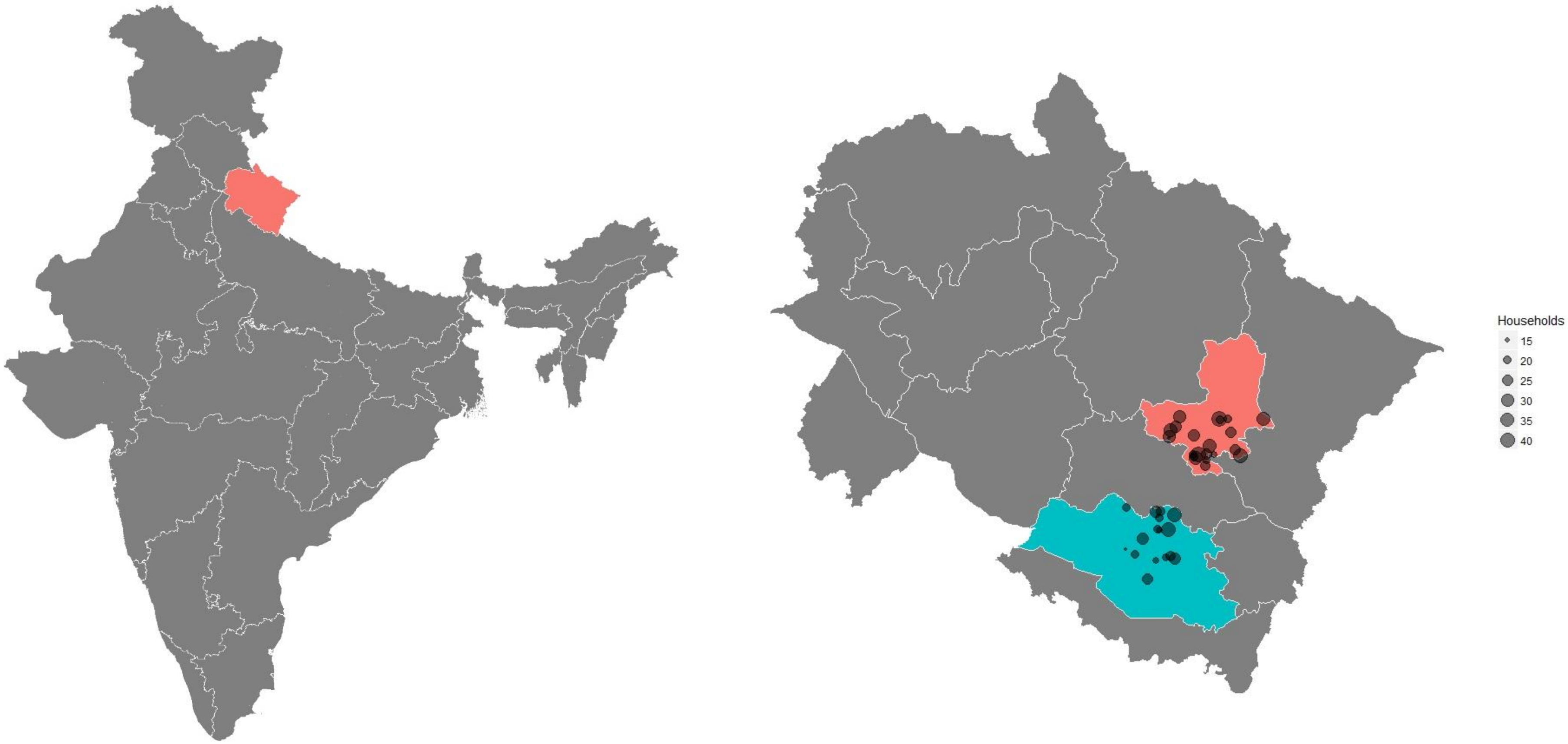

Fig. S3. Study area. The union territories of Andaman and Nicobar Islands and Lakshadweep not shown in panel (A). Bageshwar district indicated in red and Nainital district indicated in blue in panel (B).

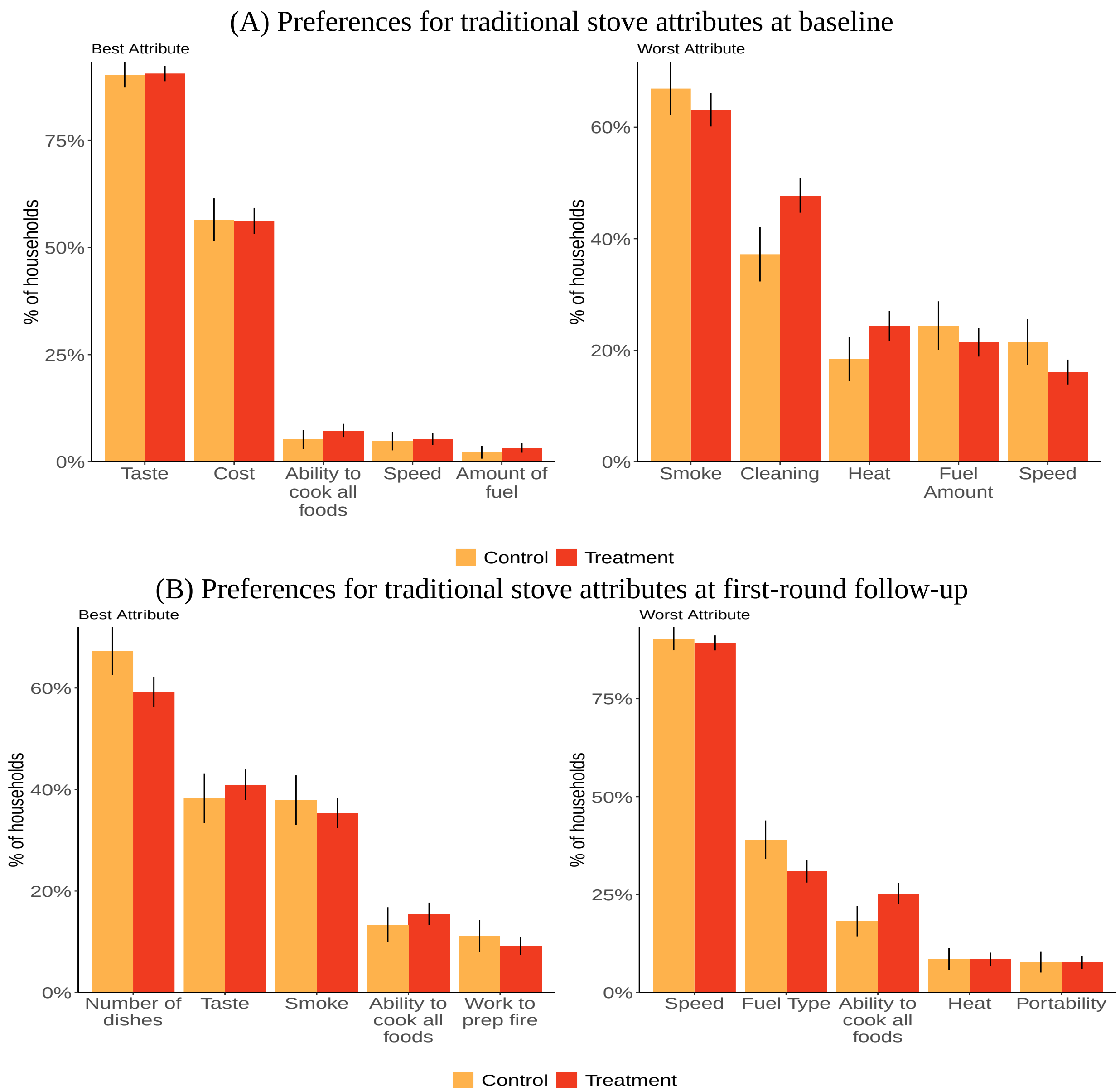

Fig. S4. Preferences for traditional stoves. Panel (A) presents the five most frequently chosen best and worst attributes of traditional stoves by respondents at baseline (summer of 2012). Panel (B) presents the five most frequently chosen best and worst attributes of traditional stoves by respondents during first-round follow-up surveys (around November 2013, three months after the intervention). Error bars represent 90 percent confidence intervals.

	(1)	(2)	(3)	(4)
	CONTROL	TREATMENT	(TREATMENT – CONTROL)	
STOVE PURCHASE AND OWNERSHIP				
Own LPG stove (%)	28.4	33.0	4.55	(6.27)
Own traditional stove (%)	98.9	96.8	-2.11*	(1.15)
Purchased an intervention stove (%)	0	52	52.0***	(2.90)
Purchased G-Coil (electric) stove at intervention (%)	0	41.6	41.6***	(2.61)
Purchased Greenway (improved biomass) stove at intervention (%)	0	15.9	15.9***	(2.16)
Own G-Coil stove at first-round follow-up (%)	0	34.2	34.2***	(2.64)
Own Greenway stove at first-round follow-up (%)	0	13.7	13.7***	(1.98)
STOVE USE				
Used improved stove in past week (%)	26.6	54.5	27.9***	(5.56)
Used LPG stove in past week (%)	26.6	32.3	5.70	(5.90)
Used intervention stove in past week (%)	0	29.2	29.2***	(2.44)
Time spent cooking on traditional stoves (minutes per day)	272.2	231.6	-40.6***	(14.3)
Aware of stoves that produce less smoke (%)	75.9	82.4	6.48	(4.30)
FUEL USE				
Use clean fuels (%)	29.4	57.3	28.0***	(6.07)
Weighed 24-hour biomass fuel used (kg)†	14	12	-2.07**	(0.95)
Self-reported daily biomass fuel use (kg)	12.7	11.6	-1.16*	(0.63)
FUEL COLLECTION				
Total fuel collection time (minutes per day, natural log)‡	4.4	4.23	-0.17	(0.13)

Table S1. Summary of stove purchase and ownership, use, and fuel-related outcomes. Column 3 shows the differences between treatment and control based on results measured in follow-up surveys conducted in November-December 2013. Standard errors on differences, show in parentheses in column (4), are clustered at the hamlet level. 1 US dollar ≈ INR 65. *** p<0.01; ** p<0.05; * p<0.1. †Only a subsample of households had fuel weighed over a 24-hour period during the baseline survey. ‡This variable was log transformed because of the skewness in the distribution of collection times. There is no meaningful difference across groups on the untransformed measure.

	(1) TREATMENT × FOLLOW-UP	(2) STD ERROR	(3) N
STOVE PURCHASE AND OWNERSHIP			
Own LPG stove (%)	2.12	(3.72)	1,974
Own traditional stove (%)	-4.77***	(1.72)	1,974
Purchased an intervention stove (%)	52.0***	(2.90)	1,974
Purchased G-Coil (electric) stove at intervention (%)	41.6***	(2.61)	1,974
Purchased Greenway (improved biomass) stove at intervention (%)	15.9***	(2.16)	1,974
Own G-Coil stove at first-round follow-up (%)	34.2***	(2.64)	1,974
Own Greenway stove at first-round follow-up (%)	13.7***	(1.98)	1,974
STOVE USE			
Used improved stove in past week (%)	26.1***	(4.04)	1,974
Used LPG stove in past week (%)	3.87	(3.57)	1,974
Used intervention stove in past week (%)	29.2***	(2.44)	1,974
Time spent cooking on traditional stoves (minutes per day)	-15.6	(14.6)	1,974
Aware of stoves that produce less smoke (%)	3.92	(6.51)	1,973
FUEL USE			
Use clean fuels (%)	28.7***	(5.22)	1,974
Weighed 24-hour biomass fuel used (kg)[†]	-1.95**	(0.91)	792
Self-reported daily biomass fuel use (kg)	-1.58**	(0.67)	1,928
FUEL COLLECTION			
Total fuel collection time (minutes per day, natural log)[‡]	-0.39	(0.27)	1,941

Table S2. Difference-in differences estimates of intervention impacts on stove purchase and ownership, use, and fuel-related outcomes. Column (1) shows the coefficient on an interaction between the treatment group indicator and an indicator for the follow-up period. The regression controls for baseline differences in the two groups using household fixed-effects and a binary indicator for the time period. Standard errors are clustered at the hamlet level. *** p<0.01; ** p<0.05; * p<0.1. [†]Only a subsample of households had fuel weighed over a 24-hour period during the baseline survey. [‡]This variable was log transformed because of the skewness in the distribution of collection times. There is no meaningful difference across groups on the untransformed measure.

	(1)	(2)	(3)	(4)	(5)	(6)
	TREATMENT		TREATMENT × REBATE		N	ADJ R-SQ
STOVE PURCHASE AND OWNERSHIP						
Own LPG stove (%)	12.34	(8.39)	-0.042	(0.026)	987	0.002
Own traditional stove (%)	-2.73*	(1.48)	0.0033	(0.0047)	987	0.00082
Purchased an intervention stove (%)	24.6***	(3.87)	0.14***	(0.014)	987	0.33
Purchased G-Coil (electric) stove at intervention (%)	18.7***	(3.36)	0.12***	(0.015)	987	0.24
Purchased Greenway (improved biomass) stove at intervention (%)	5.56***	(2.33)	0.05***	(0.011)	987	0.08
Own G-Coil stove at first-round follow-up (%)	16.4***	(3.18)	0.094***	(0.015)	987	0.18
Own Greenway stove at first-round follow-up (%)	3.83*	(2.14)	0.052***	(0.011)	987	0.075
STOVE USE						
Used improved stove in past week (%)	23.6***	(7.43)	0.022	(0.025)	987	0.078
Used LPG stove in past week (%)	15.19**	(7.45)	-0.05**	(0.023)	987	0.004
Used intervention stove in past week (%)	10.3***	(2.64)	0.100***	(0.013)	987	0.17
Time spent cooking on traditional stoves (minutes per day)	-44.9**	(20.2)	0.023	(0.054)	987	0.025
Aware of stoves that produce less smoke (%)	4.12	(5.99)	0.013	(0.022)	986	0.0028
FUEL USE						
Use clean fuels (%)	23.3***	(8.63)	0.024	(0.015)	972	0.074
Weighed 24-hour biomass fuel used (kg)†	-2.15*	(1.26)	0.00039	(0.0030)	387	0.033
Self-reported daily biomass fuel use (kg)	-1.48	(0.92)	0.0018	(0.0019)	965	0.0036
FUEL COLLECTION						
Total fuel collection time (minutes per day, natural log)‡	-0.28	(0.17)	0.00061	(0.00049)	981	0.0048

Table S3. Effect of rebate level on stove purchase and ownership, use and fuel-related outcomes. All estimates are obtained using OLS regression. The coefficient for the treatment shown in column (1) corresponds to the effect of treatment status on the outcome as represented by a binary indicator. The coefficient on the Treatment × Rebate interaction term in column (3) shows the effect of a one-rupee increase in the rebate on the outcome. Standard errors—in parentheses in columns (2) and (4), respectively—are clustered at the hamlet level. *** $p<0.01$; ** $p<0.05$; * $p<0.1$. † Only a subsample of households had fuel weighed over a 24-hour period during the baseline survey. ‡ This variable was log transformed because of the skewness in the distribution of collection times. There is no meaningful difference across groups on the untransformed measure.

	(1)	(2)	(3)	(4)	(5)	(6)
	TREATMENT × FOLLOW-UP		TREATMENT × REBATE × FOLLOW-UP		N	ADJ R-SQ
STOVE PURCHASE AND OWNERSHIP						
Own LPG stove (%)	11.3**	(5.61)	-0.049*	(0.025)	1,974	0.02
Own traditional stove (%)	-7.40**	(3.56)	0.014	(0.012)	1,974	0.01
Purchased an intervention stove (%)	24.6***	(3.86)	0.14***	(0.014)	1,974	0.58
Purchased G-Coil (electric) stove at intervention (%)	18.74***	(3.36)	0.12***	(0.015)	1,974	0.47
Purchased Greenway (improved biomass) stove at intervention (%)	5.56**	(2.33)	0.05***	(0.011)	1,974	0.19
Own G-Coil stove at first-round follow-up (%)	16.4***	(3.18)	0.094***	(0.015)	1,974	0.38
Own Greenway stove at first-round follow-up (%)	3.83*	(2.14)	0.052***	(0.011)	1,974	0.17
STOVE USE						
Used improved stove in past week (%)	21.8***	(5.06)	0.022	(0.026)	1,974	0.19
Used LPG stove in past week (%)	13.41***	(4.85)	-0.05**	(0.023)	1,974	0.02
Used intervention stove in past week (%)	10.3***	(2.63)	0.100***	(0.013)	1,974	0.35
Time spent cooking on traditional stoves (minutes per day)	-16.0	(25.1)	0.0010	(0.096)	1,974	0.09
Aware of stoves that produce less smoke (%)	-0.034	(8.56)	0.022	(0.033)	1,973	0.48
FUEL USE						
Use clean fuels (%)	25.5***	(7.25)	0.016	(0.029)	1,944	0.11
Weighed 24-hour biomass fuel used (kg) †	0.20	(1.27)	-0.011**	(0.0047)	792	0.20
Self-reported daily biomass fuel use (kg)	-1.66	(1.20)	0.00037	(0.0051)	1,928	0.25
FUEL COLLECTION						
Total fuel collection time (minutes per day, natural log) ‡	-0.74**	(0.32)	0.0019**	(0.00079)	1,941	0.01

Table S4. Difference-in differences estimates of intervention impacts on stove purchase and ownership, use, and fuel-related outcomes, as a function of the rebate level. Column (1) shows the coefficient on an interaction between the treatment group indicator and an indicator for the follow-up period. Column 3 is the coefficient for the three-way interaction of indicators for the treatment, follow-up period, and the rebate level. The regression controls for baseline differences in the two groups using household fixed-effects and a binary indicator time period. Standard errors on differences are clustered at the hamlet level. *** p<0.01; ** p<0.05; * p<0.1. †Only a subsample of households had fuel weighed over a 24-hour period during the baseline survey. ‡ This variable was log transformed because of the skewness in the distribution of collection times. There is no meaningful difference across groups on the untransformed measure.

Stove Attribute	Electric Stove (%)	Improved Biomass Stove (%)
The cost of the stove	1.6	0.8
The smoke produced by the stove	11.6	17.4
The speed of cooking	29.4	12.4
The ability to cook all foods	9.7	4.6
The taste of the foods	1.5	1.3
The number of dishes that can be prepared with the stove	2.3	2.9
The number of people that the stove can feed	1.7	1.6
The amount of fuel required	2.6	25
The type of fuel required	0.4	1.2
The maintenance of the stove, including repair cost / Sturdiness	1.2	2.2
The cleaning requirement	4.9	3.1
The portability of the stove	12.1	17.9
Stove gives off heat	1.8	1.4
Attractiveness of the stove	15.8	4.8
Availability of fuel	0.7	2.6
The work required to prepare fire before cooking	1	0.1
Electrical shocks	0.4	0
The ability to use electricity	0.5	0
Cost of fuel or electricity bill	0.2	0.1
Other	0.5	0.6

Table S5. Best attributes of electric and biomass ICS. Post-intervention surveys asked respondents to select the top two best attributes of the intervention stoves (electric G-Coil and Greenway natural draft biomass). Each column presents the percent of respondents that ranked each attribute in their top two (first column shows results for the electric stove, second column shows results for the biomass stove). Sample was restricted to respondents who had heard of each stove.

VARIABLE	(1) MEAN: CONTROL	(2) MEAN: TREATMENT	(3) NORMALIZED DIFFERENCE	(4) p-VALUE
STOVE- AND FUEL-USE CHARACTERISTICS				
Own LPG stove (%)	26.2	28.6	-0.039	0.7
Own traditional stove (%)	95.9	98.6	-0.12	0.12
Used LPG stove in past week (%)	25.8	27.7	-0.029	0.77
Time spent cooking on traditional stoves (minutes per day)	309.7	284.8	0.12	0.072
Use clean fuels (%)	38.3	36.7	0.023	0.81
Weighed 24-hour biomass fuel used (kg)	9.61	9.47	0.02	0.85
Self-reported daily biomass fuel use (kg)	6.73	7.01	-0.032	0.59
Total fuel collection time (minutes per day, natural log)†	4.18	4.37	-0.11	0.31
SOCIOECONOMIC AND DEMOGRAPHIC CHARACTERISTICS				
Below poverty line (%)	60.8	56.4	0.062	0.36
Accessed loan services in the past year (%)	12.2	16.5	-0.087	0.16
Report that it is possible to save money (%)	24.4	26	-0.026	0.73
Relative wealth rating (six-point scale)	2.13	2.12	0.0079	0.91
Scheduled Caste or Tribe (%)	22.1	26.1	-0.066	0.61
Household size	5.04	4.8	0.081	0.36
Female-headed household (%)	32.7	24.0	0.14	0.015
Age, household head (years)	54.2	53.9	0.012	0.82
Education, household head (years)	6.11	6.21	-0.016	0.77
Education, primary cook (years)	4.66	4.62	0.005	0.93
Electricity supply (hours per day)	17.9	17.1	0.077	0.25
At least one household member with cold/cough in past week (%)	19.9	23	-0.054	0.35
Aware stoves that produce less smoke (%)	23.6	26.3	-0.043	0.55
Believes cooking smoke is unsafe (%)	46.7	50.7	-0.057	0.29
COMMUNITY-LEVEL CHARACTERISTICS				
Time to nearest bus stop (minutes)	41.2	34.9	0.11	0.62
Distance to nearest doctor (km)	15.1	9.6	0.27	0.12
Bank facility in village (%)	36.5	39.1	-0.038	0.83
Households lost to attrition (%)	7.19	7.13	0.0016	0.97

Table S6. Balance tests comparing control and treatment households/communities at baseline. Attrition percentages are based on pre-intervention sample; other balance test use the final follow-up sample ($N = 987$). p-values are adjusted for clustering at the hamlet level. 1 US dollar ≈ INR 65. †This variable was log transformed because of the skewness in the distribution of collection times. There is no meaningful difference across groups on the untransformed measure.

VARIABLES	(1) Δ (LOW REBATE – CONTROL) ("High price")	(2)	(3) Δ (MEDIUM REBATE – CONTROL) ("Medium price")	(4)	(5) Δ (HIGH REBATE – CONTROL) ("Low price")	(6)
STOVE- AND FUEL-USE CHARACTERISTICS						
Own LPG stove (%)	-0.56	(6.52)	3.31	(6.61)	4.47	(7.00)
Own traditional stove (%)	2.78	(1.80)	3.24*	(1.74)	1.96	(1.96)
Used LPG stove in past week (%)	-0.62	(6.45)	2.86	(6.49)	3.16	(6.83)
Time spent cooking on traditional stoves (minutes per day)	-20.4	(16.8)	-26.9*	(14.7)	-27.5*	(15.0)
Use clean fuels (%)	-1.29	(7.17)	-2.34	(7.08)	-1.11	(7.33)
Weighed 24-hour biomass fuel used (kg)	-0.75	(0.97)	-0.47	(0.73)	0.78	(0.84)
Self-reported daily biomass fuel use (kg)	0.54	(0.66)	0.0080	(0.56)	0.29	(0.66)
Total fuel collection time (minutes per day, natural log)†	0.25	(0.19)	0.14	(0.19)	0.18	(0.19)
SOCIOECONOMIC AND DEMOGRAPHIC CHARACTERISTICS						
Below poverty line (%)	-5.31	(5.25)	-3.45	(5.18)	-4.25	(5.90)
Accessed loan services in the past year (%)	-0.64	(3.04)	4.22	(3.42)	9.25**	(4.41)
Report that it is possible to save money (%)	-1.70	(5.29)	3.51	(5.22)	2.96	(5.08)
Relative wealth rating (six-point scale)	-0.035	(0.092)	-0.038	(0.096)	0.044	(0.099)
Scheduled Caste or Tribe (%)	0.082	(7.86)	6.55	(8.22)	5.17	(8.16)
Household size	-0.10	(0.28)	-0.37	(0.27)	-0.24	(0.29)
Female-headed household (%)	-4.27	(4.24)	-14.5***	(4.25)	-7.18*	(4.15)
Age, household head (years)	-1.03	(1.42)	-0.95	(1.30)	1.26	(1.23)
Education, household head (years)	0.16	(0.41)	0.27	(0.42)	-0.12	(0.42)
Education, primary cook (years)	-0.21	(0.43)	0.25	(0.43)	-0.15	(0.43)
Electricity supply (hours per day)	-0.051	(0.82)	-1.35*	(0.74)	-0.83	(0.70)
At least one household member with cold/cough in past week (%)	1.55	(4.20)	3.39	(4.25)	4.51	(3.89)
Aware stoves that produce less smoke (%)	0.74	(4.97)	1.79	(4.64)	5.38	(5.07)
Believes cooking smoke is unsafe (%)	5.04	(5.08)	2.10	(4.55)	5.01	(5.19)
COMMUNITY-LEVEL CHARACTERISTICS						
Time to nearest bus stop (minutes)	-6.43	(12.7)	-5.97	(12.3)	-6.24	(12.3)
Distance to nearest doctor (km)	-6.35*	(3.43)	-4.96	(3.62)	-5.15	(3.60)
Bank facility in village (%)	6.20	(12.7)	0.76	(12.4)	0.86	(12.4)
Households lost to attrition (%)	-1.73	(2.57)	-4.18*	(2.44)	-5.93***	(2.13)

Table S7. Balance tests comparing control and treatment households/communities across rebate levels at baseline. The values reported in columns (1), (3) and (5) are for the difference between the households in the specific rebate group and the control households, as estimated using an OLS regression with an indicator variable for each rebate group; corresponding standard errors are clustered at the hamlet level, and reported in columns (2), (4) and (6), respectively. Attrition percentages are based on pre-intervention sample; other balance test use the final follow-up sample ($N = 987$). 1 US dollar ≈ INR 65. *** p<0.01; ** p<0.05; * p<0.1. †This variable was log transformed because of the skewness in the distribution of collection times. There is no meaningful difference across groups on the untransformed measure.

Appendix S1: Self-reported stove use

Self-reports can be imprecise (Ramanathan et al., 2016; Simons et al., 2017), but we are confident about this metric for three reasons. First, we used a simple indicator—households stated whether they had used an ICS in the week prior to the survey visit. Compared to difficulty of reporting the minutes spent using each device (which can be erroneous), it is easier to accurately report whether you did or did not use the stove. Second, where possible, survey enumerators visually observed clues of recent use (e.g., ash on the biomass stove, location of electric stove next to electricity sockets, food spills on ICS) without invading the privacy of homes and kitchens. They found that among households who bought stoves and where we could complete such inspections, most households were using the intervention devices.[1] Third, this indicator triangulates with fuelwood quantity, which was objectively measured using a 24-hour fuel weighing protocol. If this self-reported use indicator was error-ridden, there would be no correlation with this measure. Nonetheless, we underscore that almost no household exclusively used the intervention ICS. Indeed, the data clearly show that there is widespread ownership and use of traditional stoves and solid fuels (SI Appendix, Table S3), consistent with evidence on stove and fuel stacking in other settings (Masera et al., 2000).

[1] Such enumerator observation during follow-up surveys occurred for 90 percent of all study households, and included all household stoves. Approximately 85 percent of households that had purchased an intervention ICS were inspected in this way; enumerators judged that 65 percent of all intervention ICS exhibited signs of recent use. Observed use was positively correlated with self-reported use ($p < 0.01$), and observed use rates for non-intervention stoves were similar.

Appendix S2: Costs and benefits of the intervention

Costs of the "supply chain" intervention

In conducting careful pre-intervention demand and supply assessments and then facilitating convenient access to two improved cooking technologies without a corresponding increase in their price, the research and supply chain intervention provided an implicit subsidy to households. This subsidy included the costs of:

- Phase 1 and 2 demand and supply assessments (through baseline surveys and then intervention piloting);
- Transportation and delivery of stoves;
- Production and explanation of social marketing and promotional materials by trained sales people; and
- A relatively low interest rate equivalent for financing (which added INR 60 to the cost of each stove, or roughly 6% to its cost).

Importantly, the financing aspect required two additional visits to villages, although these also provided opportunities to households not purchasing a stove during the first visit, to catch up and adopt a stove by paying several installments at once, during a later visit.

In order to estimate the full costs of implementation of the learning and subsequent "supply chain" interventions, we first separated costs into three distinct categories: a) stove costs (for purchase of the electric and biomass ICS from manufacturers); b) non-stove intervention costs (for transportation and delivery to households, administration of the intervention, training and salaries of sales personnel, and production of promotional materials); and c) research costs (which included, among other things, all costs associated with conducting baseline and follow up surveys in the field). Due to the distinct timing of the research and implementation activities, this separation of costs was generally straightforward with the exception of administration costs, since personnel working for the implementing NGO were responsible for both intervention and research aspects. For these shared aspects, which include program managers and NGO overheads but not researchers' time, we assumed 50% of the cost was borne by the intervention, and that the other half covered research-related aspects (including demand assessments).

We next specified the "supply chain" intervention costs to be those comprising the second category of non-stove intervention costs listed above. It is likely that these are high, because a) the NGO was conducting the intervention for the first time; b) implementation costs were likely increased due to the fact that the intervention was part of a rigorous research study, which entailed additional management (even though researchers' time was not included); and c) administrative effort by the NGO was skewed towards research rather than implementation, because the research study took much longer than the actual intervention.

For the learning costs, we parceled out the full research costs in the following manner. First, we only included the field costs of the baseline studies, which were largely about measuring demand and preferences for ICS. In doing so, we assigned half of the NGO labor devoted to research (since the other half was for the follow-up impact studies). Second, we reasoned that a real intervention would not be targeted specifically at a sample of households within intervention villages, as ours was, but rather at the entire population for which those samples were representative. Thus, we computed an adjusted per household cost on the basis of the total village population as obtained from 2011 Census data, adjusted for population growth.

We summarize the various categories of learning and implementation expenses below in Table A1, as well as the implied per-household cost.

Table A1. Program and learning costs for the intervention

Category	Description	Amount (USD)
<u>Program/implementation</u>		
Salaries and field expense: Sales team	Salaries for all members of the sales team, training and promotion materials costs; food expenses in the field; and transportation costs	$6551.30
Lodging: Sales team	Lodging for sales team in the field	$763.70
Salaries: NGO Admin	Salary cost-share (50%) for NGO managers	$442.42
Payment recovery	Payment recovery costs	$750.24
Repairs	Replacement of defective stoves	$802.92
Overhead	NGO overhead cost-share (50%) for intervention	$1041.90
Total program cost		**$10352.48**
Program cost per household	Intervention targeted 771 households	**$13.43**
<u>Learning</u>		
Salaries: Field managers	Compensation for fieldwork management staff	$921.27
Salaries and field expense: Survey team	Salaries for members of the survey team, training and promotion materials costs; transportation costs; food and lodging for survey teams in the field	$6075.75
Data entry: Survey team	Cost of data entry	$1963.80
Survey/travel costs	Additional travel and survey costs incurred by Delhi-based research personnel	$3184.45
Stationary	NGO overhead cost-share (25%) for baseline research	$177.54
Total demand research cost		**$12322.81**
Demand assessment cost per household	Scaled up intervention would have targeted 3379 households	**$3.65**
Total cost per household		**$17.08**

Notes. All program costs were converted to USD by using the 2014 exchange rate of INR 61.03 = USD 1; research costs were converted using a 2012 exchange rate of INR 52.50 INR = USD 1.

Benefits of the intervention

We further applied a published cost-benefit methodology (Jeuland et al. 2018), to carry out illustrative cost-benefit calculations using a) the cost data discussed above plus the cost of the stoves and b) the estimates of impacts presented in the main paper. The calculations were carried out from both a private (for those adopting ICS only) and social perspective (for the overall population and therefore accounting for limited adoption of ICS). On the cost side of the ledger, only the portion of stove costs paid by households was included in the private perspective, while the social calculation adds to these private costs the subsidy costs, in addition to the program and demand assessment costs presented above. For benefits, the private perspective included fuel and time savings, and health benefits from reduced household air pollution, while the social perspective added to these health spillovers (reduced contribution of household air pollution to ambient air pollution), reduced climate forcing emissions, and forest quality benefits.

Here it must be noted that these calculations rest on a number of assumptions about a range of parameters that were not measured in our field site, but that were obtained from the literature as discussed in Jeuland et al. (2018). The following key assumptions were not measures and were thus set to the base case numbers presented in Jeuland et al. (2018):

- Emissions of different climate forcing pollutants (CO_2, CO, CH_4, NO_2, black carbon, and organic carbon) – for electric stoves, emissions from the national electricity-generation sector in India were applied,
- Emissions of health harming particulate matter ($PM_{2.5}$),
- Relative stove thermal efficiencies,
- Health benefits valuation parameters (namely cost-of-illness and value of a statistical life), and
- Private and social discount rates. Importantly, we assume a much higher private discount rate than social discount rate, which explains why capital costs are higher in the private perspective, despite the inclusion of stove subsidies.

Meanwhile, several assumptions were modified from the base case in Jeuland et al. (2018):

- Use rates (these are based on the ICS-specific uptick in use of clean stoves as described in the main paper),
- Stove lifespan (assumed to be only 3 years in our case, down from 3.8 years in the base model),
- The private ($0.033/kW-hr) and social ($0.062/kW-hr) cost of electricity, obtained from Uttarakhand government data (Pinto 2016),
- Disease prevalence and mortality parameters for acute lower respiratory illness, chronic obstructive pulmonary disease, ischemic heart disease, and lung cancer, which were set to average prevalence rates in India according to the Global Burden of Disease,
- Unskilled wage rate, for which we use the minimum wage in Uttarkhand at the time (US$0.27/hr), and
- Fraction of non-renewable biomass harvesting, for which we use the India average of 23.7% from Bailis et al. (2015).

The results of this analysis are presented in Table A2.

Interpretation

As shown through these calculations, the private benefits from adoption of the two promoted ICS were positive. Given the large implicit subsidy that was provided by the intervention (as summarized in Table A1), this is not surprising and is consistent with the revealed preference (i.e., the adoption and use of the intervention ICS) that we observed in the field. Also consistent with our field results is the fact that the electric ICS delivers higher private benefits on average, given the design of the intervention. The difference between the electric and natural draft biomass ICS is driven by each of the three categories of benefits – time savings, health benefits, and fuel savings – but nearly two thirds of the effect is due to fuel savings (~$1.3/household-month), and is directly related to the low consumer price of electricity in Uttarkhand (as is made evident by the much smaller social benefit from fuel savings, ~$0.05/household-month). It is important to note that much of this fuel savings benefit is a nonmarket benefit, in the sense most households in the sample (73%) save on the time spent collecting biomass fuel rather than on money for purchase of such fuels.

Table A2. Summary of benefits and costs of the different technologies deployed in the intervention (All costs and benefits are reported in US$/household-month)

	Natural-draft biomass stove	Electric coil stove
Private costs		
Stove cost	$0.99	$0.76
Private learning cost	$0.03	$0.03
Private benefits		
Cooking time savings	$0.36	$0.63
Health benefits	$0.23	$0.49
Fuel savings	$0.73	$2.01
Net private benefits (rounded to nearest $0.1/household-month)	**$0.30**	**$2.30**
Social costs		
Stove cost	$0.09	$0.18
Program and learning cost	$0.51	$0.51
Private learning cost	$0.00	$0.01
Social benefits		
Cooking time savings	$0.05	$0.25
Health benefits	$0.07	$0.42
Fuel savings	$0.11	$0.05
Climate benefits	$0.25	$0.49
Forest benefits	$0.01	$0.07
Net social benefits (rounded to nearest $0.1/household-month)	**-$0.10**	**$0.60**

The social benefits deviate from the private calculations in four main ways. First, as discussed above, costs are driven up by inclusion of the full costs of the program intervention, including the elements included to allow learning about supply and demand, as well as the stove subsidies. Second, and pushing against the first effect, costs are considerably lower due to application of a discount rate (3.5%) that is much lower than private rates that are commonly observed in such low-income settings. Third, the main benefits in the social perspective are climate and health benefits. All of the climate benefits are spillovers that do not directly benefit those adopting the ICS, and some portion of the health benefits are as well, owing to the contribution of household air pollution to ambient air pollution in this setting. Moreover, both of these are largely nonmarket benefits. The final major difference in the private and social calculations comes from the social perspective's accounting for partial adoption within the community; that is, costs are incurred for the program and learning costs across the entire population, many members of who do not adopt the technology. This last effect explains the much lower per household benefits in the social perspective, relative to the private perspective that only pertains to those acquiring stoves. In addition, given the low revealed preference for natural draft stoves in our setting, the low adoption rate for that ICS explains its negative net social benefits.

In concluding, we emphasize that an estimate of the overall social benefit of the intervention can be obtained by adding the two stove-specific numbers in the final row of Table A2, because these explicitly account for the adoption rates (a similar calculation is not appropriate in the private calculation which only pertains to those actually acquiring the stoves). This yields a value of net benefits that is positive and equal to $0.5/household-month. This value is clearly sensitive to a large number of assumptions, and should therefore be interpreted with caution.

SI References

Bailis, R., Drigo, R., Ghilardi, A., & Masera, O. (2015). The carbon footprint of traditional woodfuels. *Nature Climate Change* 5(3), 266.

Jeuland, M., Soo, J. S. T., & Shindell, D. (2018). The need for policies to reduce the costs of cleaner cooking in low income settings: Implications from systematic analysis of costs and benefits. *Energy Policy* 121, 275-285.

Masera, O., Saatkamp, B., & Kammen, D. (2000). From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model. *World Development*, *28*(12), 2083-2103.

Pinto, A. (2016). A Hard Bargain? A cost benefit analysis of an improved cookstove program in India. Masters Thesis; Duke University Sanford School of Public Policy. http://hdl.handle.net/10161/12495.

Ramanathan, T., Ramanathan, N., Mohanty, J., Rehman, I., Graham, E., & Ramanathan, V. (2016). Wireless sensors linked to climate financing for globally affordable clean cooking. *Nature Climate Change*, *7*(1), 44-47.

Simons, A., Beltramo, T., Blalock, G., & Levine, D. (2017). Using unobtrusive sensors to measure and minimize Hawthorne effects: Evidence from cookstoves. *Journal of Environmental Economics and Management*, *86*, 68-80.