SI: Environmental payoffs of LPG cooking in India

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1. Data

We use the Indian national censuses (2001 and 2011) and the Indian National Sample Survey (NSS) Organization socio-economic surveys (round 55 and round 68) to estimate the amount of fuelwood displaced due to an increase in liquefied petroleum gas (LPG) access. The Indian national census is a complete enumeration of all Indian households and is a publicly available primary data source at the village and town level (Census of India, 2016). The NSS is India's largest organization conducting regular nationwide sample surveys relating to various socio-economic topics since 1950 (MOSPI, 2011). Both datasets contain socio-cultural and demographic data including population characteristics, economic activity, education, household size, and type of cooking fuels. While the census provides information for all households in India on the primary fuel used for various household activities (e.g. cooking, heating etc.), it ignores the actual quantities of fuel used. Conversely, the NSS does contain information on the quantities and expenditures of various household fuels, but is limited in that it does not cover the entire population (it is a sampled population that is representative of the total). Thus, to obtain the best possible estimate for fuelwood and LPG use in India, we utilized both sources.

To calculate the net emissions impact we utilized the emissions factors as reported in Table S1 of Freeman & Zerriffi (2014) for various climate forcing emissions. Averages reported for W-Tr-U were taken as the emissions factors for a traditional open fire and those for LPG-U were taken for estimates of LPG stoves. Table S2 of Freeman & Zerriffi (2014) provided the 100-year global warming potential (GWP_{100}) values used in our analysis. The conservative value of 0.3 for fraction of non-renewable biomass (fNRB) was based on the estimates from Bailis et al 2015.

2. Method Overview

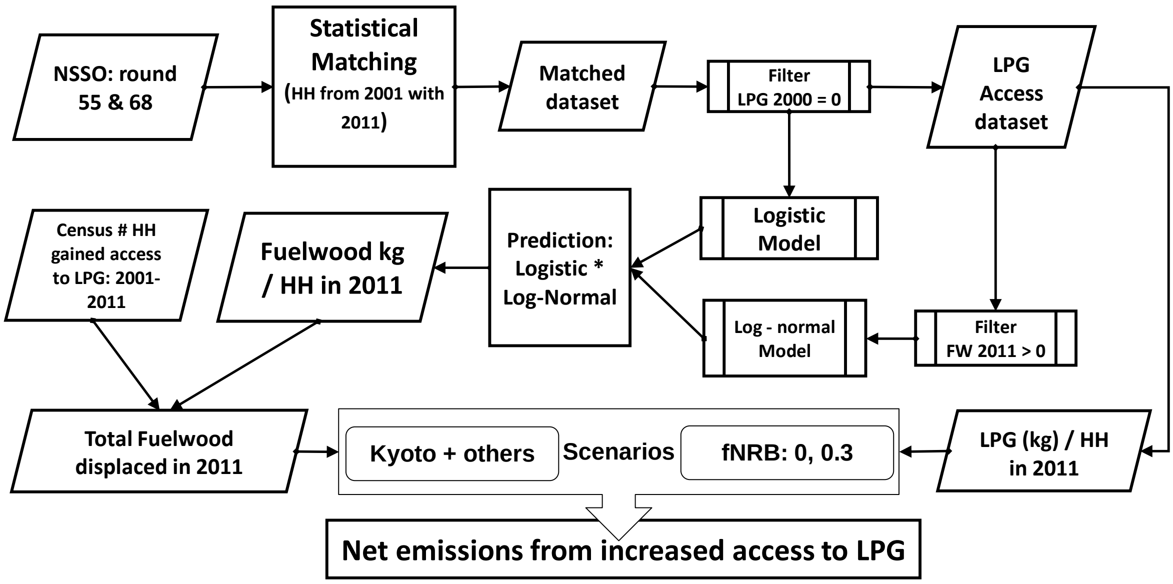

Figure 1. Flowchart showing the method for arriving at net emissions impact.

3. Statistical Matching

We applied statistical matching techniques to assess the number of households that gained access to LPG between 2000 and 2011. Households from the NSS rounds 55 and 68 were 'matched' on the basis of State, urban/rural, and caste for a total of 109,507 observations in the synthetic dataset. The mixed procedure was utilized in the R StatMatch package to match 2011 households with those in 2000. The R-code with explanations for statistical matching is given below:

```
# Load the NSS rounds 55 and 68 combined file.
survey <- read.csv ("C:\\Users\\Devyani\\NSS.SurveysCombined.csv",
                    header=T)
# split the NSS survey data by years 2000 and 2011
survey2000 <- subset (survey, year==2000)
survey2011 <- subset (survey, year==2011)
# now rename LPG quantities for each year
colnames (survey2000) [16] <- "lpg_q2000"
colnames (survey2011) [16] <- "lpg_q2011"
# make modely = year 2011 and modelz = year 2000 variables
lm.modely <- lm (lpg_q2000 ~ firewood_q * income * employment_type
                 * HHsize * caste * kerosene_q, data=survey2000)
summary (lm.modely)
lm.modelz <- lm (lpg_q2011 ~ firewood_q * income * employment_type
                 * HHsize * caste * kerosene_q, data=survey2011)
summary (lm.modelz)
# Now calculate predicted values znew and ynew
# ynew is the predicted value of lpg2000 based on 2011 model
ynew <- predict (lm.modely, survey2011, interval="none")
length (ynew)
# znew is the predicted value of lpg2011 based on 2000 model
znew <- predict (lm.modelz, survey2000, interval="none")
length (znew)
# rename lpg_q variables to match one another
# this is required to run StatMatch code
survey2000$lpg_q2011p <- znew
survey2011$lpg_q2000p <- ynew
survey2000$lpg_q2000p <- survey2000$lpg_q2000
survey2011$lpg_q2011p <- survey2011$lpg_q2011
survey2000yz <- subset (survey2000, select = c (lpg_q2000p, lpg_q2011p))
survey2011yz <- subset (survey2011, select = c (lpg_q2000p, lpg_q2011p))
# create the group of matching variables
group.v <- c ("state2000", "urban", "caste")
# used states in 2000 for consistency between datasets
# as some of the states were split up in India between 2000-2011
X.mtc <- c ("lpg_q2000p","lpg_q2011p")
out.nnd <- NND.hotdeck (data.rec = survey2000, data.don = survey2011,
             match.vars = X.mtc, don.class = group.v)
summary (out.nnd$dist.rd)
summary (out.nnd$noad)
# Create a fused dataset with 2011 variables in the matched file
# this matched file uses HH from 2000 as base
fused.nnd <- create.fused (data.rec = survey2000, data.don = survey2011,
              mtc.ids=out.nnd$mtc.ids,
              z.vars = c(8, 9, 11:14, 16, 18:20))
# add 2011 variables to fused dataset: HHsize, weights, employment_type,
        caste, income, firewood_q, kerosene_q, charcoal_q, and coal_q
summary (fused.nnd)
matched <- fused.nnd # rename file to matched to be used in tobit model
```

4. **Tobit Model**

The statistically matched synthetic dataset was utilized to estimate the amount of fuelwood displaced due to LPG access in 2011. We used a three step Tobit model, based on the technique used by Green (2003):

1. Logit transformation (i.e., a logistic model): this model estimated the probability of a household using fuelwood in 2011 as a function of household size, urbanization and LPG use in 2011.

$$Prob\ (fuelwood\_q2011 > 0) = \beta_0 + \beta_1 * lpg2011 + \beta_2 * HHsize2011 + \beta_3 * Urban2011$$

2. Log-normal transformation: this model predicted the quantity of fuelwood consumed by a household using fuelwood in 2011.

$$fuelwood\_q2011 = \beta_0 + \beta_1 * lpg2011 + \beta_2 * HHsize2011 + \beta_3 * Urban2011$$

3. Step 3 = logit transformation * log-normal transformation: this final step predicted the quantity of fuelwood used by all households considering the probability of them using fuelwood in 2011.

We used the Tobit model by Greene (2003) because the existence of zeros for fuelwood use in the synthetic dataset was more than one would expect from a binomial distribution, however, it is expected to be the case for households gaining access to LPG. A Tobit model models the zero's and the non-zero as separate processes (Greene 2003). Thus, we first determined whether a household uses fuelwood in 2011 ('participation' equation to model probabilities), and if so, then how much is being used on average (conditional consumption equation).The R-code for analysis was based on the gamma hurdle biological model by Anderson (2014) and is given below:

```
##### Read in data – the matched dataset.
matched <- read.csv ("C:\\Users\\Devyani\\Matched.csv", header = T)
# Filter the data where only those HH with no access in 2000 are included
lpg_access <- matched %>%
   filter(lpg_q2000 == 0)
# Add in urban2011.f to be recognized as factor.
lpg_access$urban2011.f <- as.factor (lpg_access$urban2011)
# get the non zero file for lognormal model to be used in step 2
lpg_access_nozeros <- lpg_access %>%
  filter (firewood_q2011 > 0)
```

Step 1: Logistic model

```
#Logit transformation this model estimates the probability of a household using fuelwood in 2011 as a result of the x-variables
## Set up the binomial y variable.
lpg_access$firewood_q_2011yes <-
                                ifelse (lpg_access$firewood_q2011 <=0.0, 0,1)
# fit the null model with no x variables.
logistic.null <- glm (lpg_access$firewood_q_2011yes ~1,
                                family=binomial(link = "logit"),data=lpg_access,
                                weights=Weight2011)
summary(logistic.null)
# now fit the best model (details given later in SI)
logistic.M1 <- glm (lpg_access$firewood_q_2011yes  ~ lpg_q2011
                                + urban2011.f + HHsize2011
                                + lpg_q2011 * urban2011.f
                                + HHsize2011 * urban2011.f,
                        data = lpg_access, weights = Weight2011)
summary (logistic.M1)
AIC(logistic.null); AIC(logistic.M1)
```

```
logLik(logistic.null);logLik(logistic.M1)
pred.logit.M1 <- fitted (logistic.M1)
pred.prob.M1 <- (exp(pred.logit.M1)) / (1+(exp(pred.logit.M1)))
```

 # Step 2: Log-normal distribution for non-zero firewood.

```
#Log-normal transformation: this model predicts the quantity of fuelwood
#consumed by a household using fuelwood in 2011.
normal.null <- glm (firewood_q2011 ~ 1,
                data = lpg_access_nozeros,
                family = gaussian (link = log), weights=Weight2011)
normal.M1 <- glm (firewood_q2011 ~ lpg_q2011 + urban2011.f
                          + HHsize2011 + lpg_q2011 * urban2011.f
                                    + HHsize2011 * urban2011.f,
                                    data = lpg_access_nozeros,
                                    family = gaussian (link = log), weights=Weight2011)
summary (normal.M1)
AIC(normal.null); AIC(normal.M1)
logLik(normal.null);logLik(normal.M1)
# predicted values for the normal model.
# get the Beta and the X matrix and use that to get predicted y values
n <- length (lpg_access$firewood_q2011)
# coefficients as a matrix.
Beta.M1 <- normal.M1$coefficients
Betamat.M1 <- as.matrix (Beta.M1) # convert to a matrix.
dim (Betamat.M1)
# X matrix for the model for data without zeros
Xmat.M1.no0 <- model.matrix ( ~ lpg_q2011 + urban2011.f
                         + HHsize2011 + lpg_q2011 * urban2011.f
                         + HHsize2011 * urban2011.f,
                                               lpg_access_nozeros)
# head (Xmat.M1.no0)
dim (Xmat.M1.no0)
yhat.M1.no0 <- exp (Xmat.M1.no0%*% Betamat.M1)
head (yhat.M1.no0)
length (yhat.M1.no0)  # yhats using > 0 data.
resid_b_nM1.no0 <- lnfirewood_q2011 - lnyhat.M1.no0
## Predicted values using both models on all data.
##     yhat given firewood>0  times Prob (firewood>0)
n <- length (lpg_access$firewood_q2011)
# coefficients as a matrix.
Beta.M1 <- normal.M1$coefficients
Betamat.M1 <- as.matrix (Beta.M1) # convert to a matrix.
dim (Betamat.M1)
# X matrix for the model.
Xmat.M1 <- model.matrix ( ~ lpg_q2011 + urban2011.f
                       + HHsize2011 + lpg_q2011 * urban2011.f
                       + HHsize2011 * urban2011.f, data = lpg_access)
head (Xmat.M1)
dim (Xmat.M1)
yhat.M1 <- exp (Xmat.M1%*% Betamat.M1) # same as predict prob. in step 1
                                                      but here multiply matrix
head (yhat.M1)
length (yhat.M1)  # yhats for all data using model built > 0 data.
```

 # MAIN STEP – Step 3

*#Step 3 = logit transformation * log-normal transformation:*
#predicts the quantity of fuelwood used by all households considering the
#probability of them using fuelwood in 2011.
#This part of model was based on p. 821 of Greene, Econometric Analysis.

```
lpg_access$pred_b_nM1 <- yhat.M1 * pred.prob.M1
head (lpg_access$pred_b_nM1)
```

We tested a combination of x-variables (urban/rural, LPG quantity, household size, income, caste, employment, and religion) and selected the 'best model' based on AIC and logLIK to predict firewood use in 2011 (Table 1). The AIC and LogLik for the various combinations of x-variables is given below (for both the logistic and log-normal models). To avoid complexity in the model for the sake of minor gains in model fit, we chose LPG quantity consumed (lpg_q2011), urban/rural (urban2011.f), and household size (HHsize) as the variables to use in the tobit model (Model 3).

Table 1. X-variable selection using AIC and LogLIK for the logistic and log-normal models.

	X-variable combinations	**AIC (logistic)**	**logLik (logistic)**	**AIC (log-normal)**	**logLik (log-normal)**
0	Null	40386121	-20193059	79660	-39828
1	lpg_q2011	30752	-15373	79012	-39503
2	lpg_q2011 + urban2011.f + lpg_q2011 * urban2011.f	27468	-13729	78862	-39426
3	**lpg_q2011 + urban2011.f + HHsize2011 + lpg_q2011 * urban2011.f + HHsize2011 * urban2011.f**	**25676**	**-12831**	**77978**	**-38982**
4	lpg_q2011 + urban2011.f + HHsize2011 + caste2011 + lpg_q2011 * urban2011.f + HHsize2011 * urban2011.f + lpg_q2011 * caste2011 + HHsize2011 * caste2011	24995	-12841	77883	-38925
5	lpg_q2011 + urban2011.f + HHsize2011 + caste2011 + income2011 + lpg_q2011 * urban2011.f + HHsize2011 * urban2011.f + lpg_q2011 * caste2011 + HHsize2011 * caste2012 + income2011 * caste2011 + income2011 * urban2011.f	24837	-12397	77759	-38858
6	lpg_q2011 + urban2011.f + HHsize2011 + caste2011 + income2011 + employment_type2011 + lpg_q2011 * urban2011.f + HHsize2011 * urban2011.f + lpg_q2011 * caste2011 + HHsize2011 * caste2012 + income2011 * caste2011 + income2011 * urban2011.f + lpg_q2011 * employment_type2011 + Hhsize2011 * employment_type2011 + income2011 * employment_type2011	23593	-11747	77347	-38624

Selection of these variables also makes sense from an economic viewpoint. Urban regions tend to use more LPG due to better access and distribution facilities. Additionally larger households require more energy for cooking thus consuming more quantity, on average, of fuelwood. Regression results below confirm this, where less fuelwood is consumed with an increase in LPG use, and urban regions tend to use less fuelwood, while a larger household size shows an increase in fuelwood consumed.

R code and output for the logistic and log-normal model using the selected variables is:

Step 1: Logistic Model

```
> logistic.M1 <- glm (lpg_access$firewood_q_2011yes  ~ lpg_q2011 + urban2011.f +
                + HHsize2011 + lpg_q2011 * urban2011.f
                + HHsize2011 * urban2011.f,
                data = lpg_access, weights = Weight2011)
> summary (logistic.M1)

Call:
glm(formula = lpg_access$firewood_q_2011yes ~ lpg_q2011 + urban2011.f +
```

```
    HHsize2011 + lpg_q2011 * urban2011.f + HHsize2011 * urban2011.f,
    data = lpg_access, weights = Weight2011)

Deviance Residuals:
    Min        1Q     Median      3Q       Max
-162.810    1.270    6.104     11.719   80.479

Coefficients:
                             Estimate     Std. Error    t value    Pr(>|t|)
(Intercept)                   0.7738594   0.0031141     248.50     <2e-16 ***
lpg_q2011                    -0.0250164   0.0007478     -33.45     <2e-16 ***
urban2011.f1                 -0.3772846   0.0079502     -47.46     <2e-16 ***
HHsize2011                    0.0155226   0.0005660      27.43     <2e-16 ***
lpg_q2011:urban2011.f1       -0.0246765   0.0010491     -23.52     <2e-16 ***
urban2011.f1:HHsize2011       0.0568233   0.0016386      34.68     <2e-16 ***
---
Signif. codes:  0 '***'  0.001 '**'  0.01 '*'  0.05 '.'  0.1 ' '   1
(Dispersion parameter for gaussian family taken to be 561.2585)

    Null deviance: 54488717  on 84494  degrees of freedom
Residual deviance: 47420169  on 84489  degrees of freedom
AIC: 138580
Number of Fisher Scoring iterations: 2

> Anova (logistic.M1, type='III')
Analysis of Deviance Table (Type III tests)
Response: lpg_access$firewood_q_2011yes
                             LRChisq     Df    Pr(>Chisq)
lpg_q2011                    1119.22     1     < 2.2e-16 ***
urban2011.f                  2252.09     1     < 2.2e-16 ***
HHsize2011                   752.12      1     < 2.2e-16 ***
lpg_q2011:urban2011.f        553.29      1     < 2.2e-16 ***
urban2011.f:HHsize2011       1202.60     1     < 2.2e-16 ***
---
Signif. codes:  0 '***'  0.001 '**'  0.01 '*'  0.05 '.'  0.1 ' '  1
```

 # Step 2: Log-normal distribution for non-zero firewood.

```
> normal.M1 <- glm (firewood_q2011 ~ lpg_q2011 + urban2011.f +
               + HHsize2011 + lpg_q2011 * urban2011.f
               + HHsize2011 * urban2011.f,
                data = lpg_access_nozeros, family = gaussian (link = log),
                weights=Weight2011)
> summary (normal.M1)

Call:
glm(formula = firewood_q2011 ~ lpg_q2011 + urban2011.f + HHsize2011 +
    lpg_q2011 * urban2011.f + HHsize2011 * urban2011.f,
    family = gaussian(link = log),
    data = lpg_access_nozeros, weights = Weight2011)

Deviance Residuals:
   Min       1Q     Median     3Q       Max
-21740    -1922       -348     1416     99651
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.2548902	0.0066301	641.752	< 2e-16 ***
lpg_q2011	-0.0368756	0.0025980	-14.194	< 2e-16 ***
urban2011.f1	-0.4667261	0.0337133	-13.844	< 2e-16 ***
HHsize2011	0.0715726	0.0009737	73.505	< 2e-16 ***
lpg_q2011:urban2011.f1	-0.0197092	0.0074869	-2.632	0.00848 **
urban2011.f1:HHsize2011	0.0365373	0.0046711	7.822	5.28e-15 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 26169678)

Null deviance: 1.8412e+12 on 64970 degrees of freedom

Residual deviance: 1.7001e+12 on 64965 degrees of freedom

AIC: 797883

Number of Fisher Scoring iterations: 6

5. Fuelwood Displacement

Coefficients of the tobit model helped predict the amount of fuelwood displaced in a year by for three household sizes (small, average, medium) that gained access to LPG in 2011 (Table 2). The household sizes were selected by quartiles (0.25, 0.5, and 0.75) from the matched LPG access dataset. Average LPG quantity consumed was also calculated from the LPG access matched dataset. Using the census number of households who gained access to LPG between 2000 and 2011 we estimated the total fuelwood displaced in 2011 by the various household sizes. Figure 2 shows the amount of fuelwood displaced by various households at varying levels of LPG consumption.

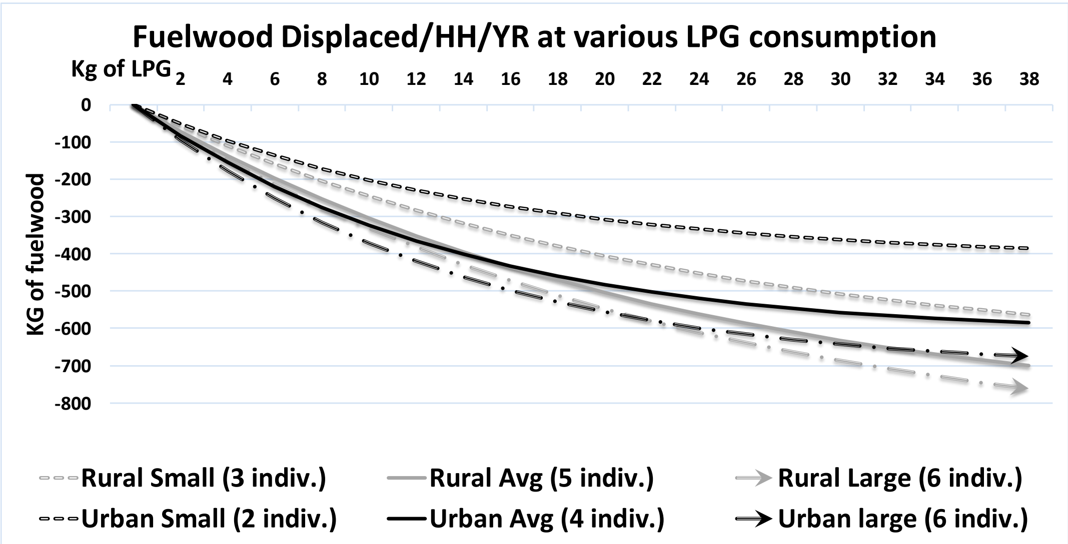

Figure 2. Fuelwood displaced by the households at varying levels of LPG consumption.

Table 2. Fuelwood displacement calculation for the various household sizes.

		Rural, small house		Urban, small house		Rural, Avg. house		Urban, Avg. house		Rural, large house		Urban, large house	
Logistic Model (all HH)	**Estimate**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**
(Intercept)	0.7739	1	1	1	1	1	1	1	1	1	1	1	1
lpg_q2011	-0.0250	0	2.452	0	7.414	0	2.452	0	7.414	0	2.452	0	7.414
urban2011.f1	-0.3773	0	0	1	1	0	0	1	1	0	0	1	1
HHsize2011	0.0155	3	3	2	2	5.105	5.105	4.340	4.340	6	6	6	6
lpg_q2011:urban2011.f1	-0.0247	0	0	0	7.414	0	0	0	7.41	0	0	0	7.414
urban2011.f1:HHsize2011	0.0568	0	0	2	2	0	0	4.340	4.340	0	0	6	6
Pred.logit		0.820	0.759	0.541	0.173	0.853	0.792	0.711	0.342	0.867	0.806	0.831	0.462
Probability of a HH using fuelwood		0.694	0.681	0.632	0.543	0.701	0.688	0.671	0.585	0.704	0.691	0.696	0.614
Lognormal Model (non 0 fw HH)	**Estimate**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**	**No Access**	**Access**
(Intercept)	4.2549	1	1	1	1	1	1	1	1	1	1	1	1
lpg_q2011	-0.0369	0	2.452	0	7.414	0	2.452	0	7.414	0	2.452	0	7.414
urban2011.f1	-0.4667	0	0	1	1	0	0	1	1	0	0	1	1
HHsize2011	0.0716	3	3	2	2	5.105	5.105	4.340	4.340	6	6	6	6
lpg_q2011:urban2011.f1	-0.0197	0	0	0	7.41428	0	0	0	7.414	0	0	0	7.414
urban2011.f1:HHsize2011	0.0365	0	0	2	2	0	0	4.340	4.340	0	0	6	6
Pred.lnfirewood		4.470	4.379	4.004	3.585	4.620	4.530	4.257	3.838	4.684	4.594	4.437	4.017
Pred.firewood (how much wood non0 FW HH use)		87.322	79.774	54.838	36.048	101.521	92.746	70.623	46.424	108.237	98.881	84.506	55.550
Predicted firewood (All HH)		**60.630**	**54.339**	**34.664**	**19.578**	**71.188**	**63.829**	**47.355**	**27.145**	**76.212**	**68.345**	**58.858**	**34.082**
		Rural, small house		**Urban, small house**		**Rural, Avg. house**		**Urban, Avg. house**		**Rural, large house**		**Urban, large house**	
Difference (FW kg/HH/mth)		**-6.29**		**-15.09**		**-7.36**		**-20.21**		**-7.87**		**-24.78**	
Fuelwood Displaced	**in KG / HH / yr**	**-75.50**		**-181.03**		**-88.32**		**-242.52**		**-94.40**		**-297.31**	
# HH Gained LPG access (FROM Census)													
Urban	25,533,895												
Rural	11,294,825	**Rural, small house**		**Urban, small house**		**Rural, Avg. house**		**Urban, Avg. house**		**Rural, large house**		**Urban, large house**	
TOTAL Fuelwood displaced (kg/yr) in 2011		**-852,729,197**		**-4,622,417,567**		**-997,523,945**		**-6,192,501,148**		**-1,066,246,892**		**-7,591,409,912**	

The estimates used in table 2 are a result of the logistic and log-normal regressions. No access households were described as lpg_q2011 = 0 and the average quantity for LPG access households was the average from the matched synthetic dataset. The difference in predicted firewood use between the access and no access households gave us the amount of fuelwood displaced for the year by each household. Then using the number of households that gained access to LPG from the census of India (which states only primary users of LPG, and thus a conservative estimate of households), we estimated the total fuelwood displaced in by an average household in urban regions to be 6,192,501,148 kg.

6. Net Emissions

The net impact on emissions in 2011 was calculated using the estimates of fuelwood displaced due to increased LPG access in 2011. We calculated the net emissions reduction (in million metric tons of carbon dioxide equivalent or $MtCO_2e$) utilizing the emissions factors and hundred year global warming potentials (GWP_{100}) from Freeman & Zerriffi (2014) for a traditional open fire and an LPG stove. Freeman and Zerriffi (2014) include the uncertainty associated with estimates of the emission factor based on reported stove testing results. For the fuelwood renewability assumptions, the case of fully renewable biomass, and a conservative estimate of 0.3 for non-renewable biomass, based on research by Bailis et al., 2015 was applied.

Table 3. Emissions factors (with uncertainty expressed as one standard deviation) from Table S1 of Freeman & Zerriffi (2014) for a traditional wood stove and LPG stove.

Stove	CO2	CO	CH4	NMHC	OC	BC	SO_2 (g/kg)	$PM_{2.5}$ (g/kg)	Production+
W-Tr-U	382.28 ± 13.77	20.67 ± 1.67	2.92 ± 0.68	3.65 ± 0.44	2.15 ± 0.59	1.10 ± 0.25	0.27 ± 0.30	2.78 ± 0.60	N/A
LPG-U	842.06 ± 22.28	3.69 ± 0.85	0.22 ± 0.35	7.35 ± 2.04	0.07 ± 0.06	0.07 ± 0.06	N/A	0.52 ± 0.45	96.78

* in gC/kg unless otherwise noted.

Table 4. Table S2 of Freeman & Zerriffi (2014) for GWP_{100} values for species included in the study.

Species	CO_2	CO	CH_4	NMHC	OC	BC	SO_2
GWP_{100}	1	1.9	25	3.4	-35	455	-76

Fuelwood displaced under each model was multiplied by the emissions factors and GWP_{100} for a traditional wood stove to get the $MtCO_2e$ reduction in 2011. The climate forcers considered were carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), non-methane hydrocarbons (NMHC), organic carbon (OC), black carbon (BC), and sulphur dioxide (SO_2). $MtCO_2e$ from increased access to LPG was then calculated for each of these. The net emission impact is the difference between the $MtCO_2e$ from LPG stoves and the $MtCO_2e$ of fuelwood displaced for each model.

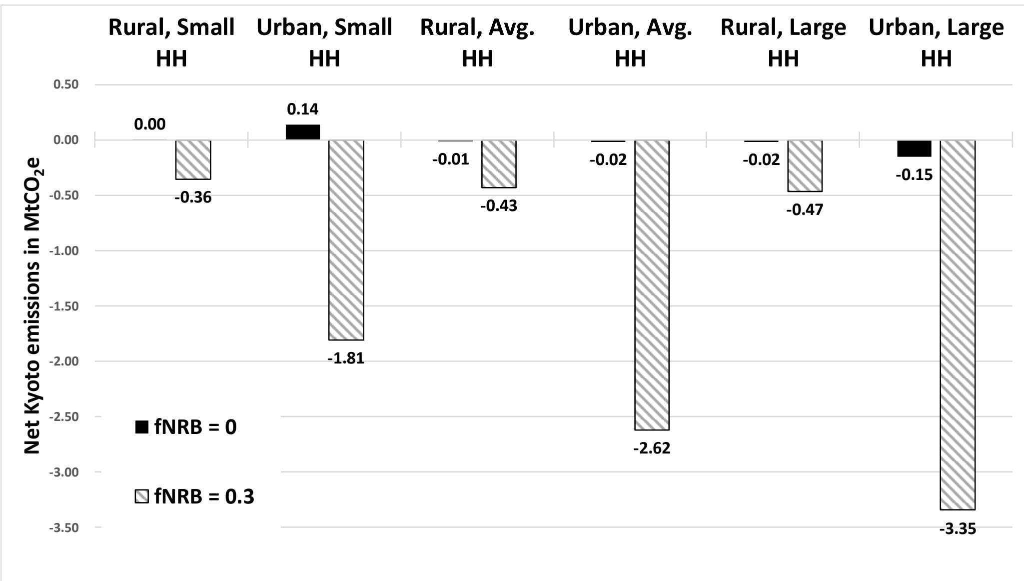

Figure 3. Changes in net Kyoto emissions due to changes in fNRB for average sized households.

Emissions reductions were calculated in the case of fNRB = 0 and fNRB = 0.3. When fNRB = 0 is assumed, the CO_2 emissions from wood are zero as it is presumed to be reabsorbed into the ecosystem cycle during tree growth. However, when fNRB > 0, a fraction of the CO_2 emissions from wood gets accounted for, such as in the case of fNRB=0.3 where 30% of the CO_2 emissions are included in total emissions. However, other emissions do not change with the fNRB, as they would be emitted from burning of wood whether or not the wood is sustainably extracted.

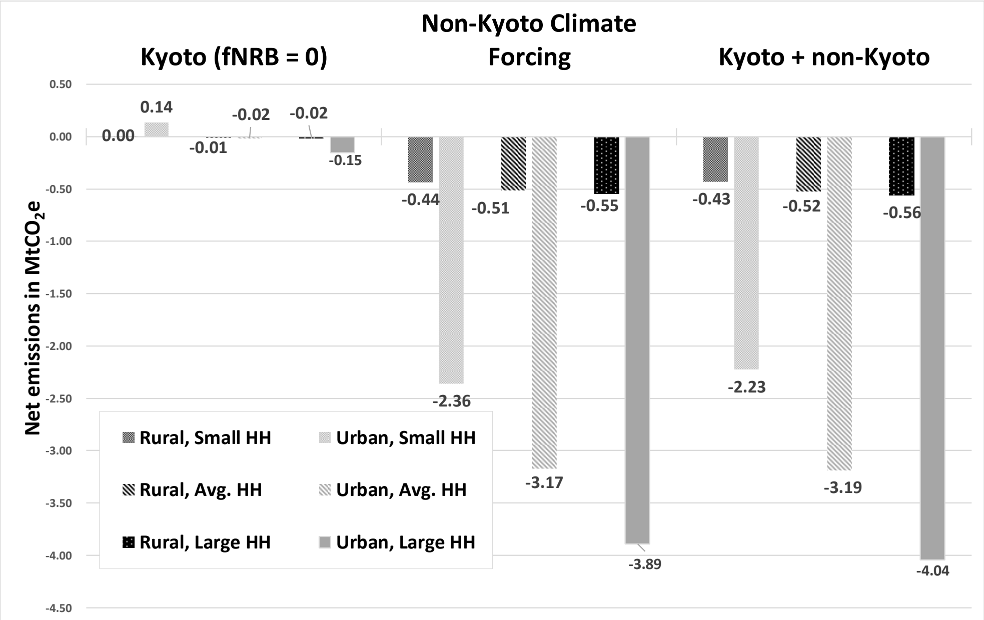

Figure 4. Net emissions from increased LPG access at fNRB = 0.

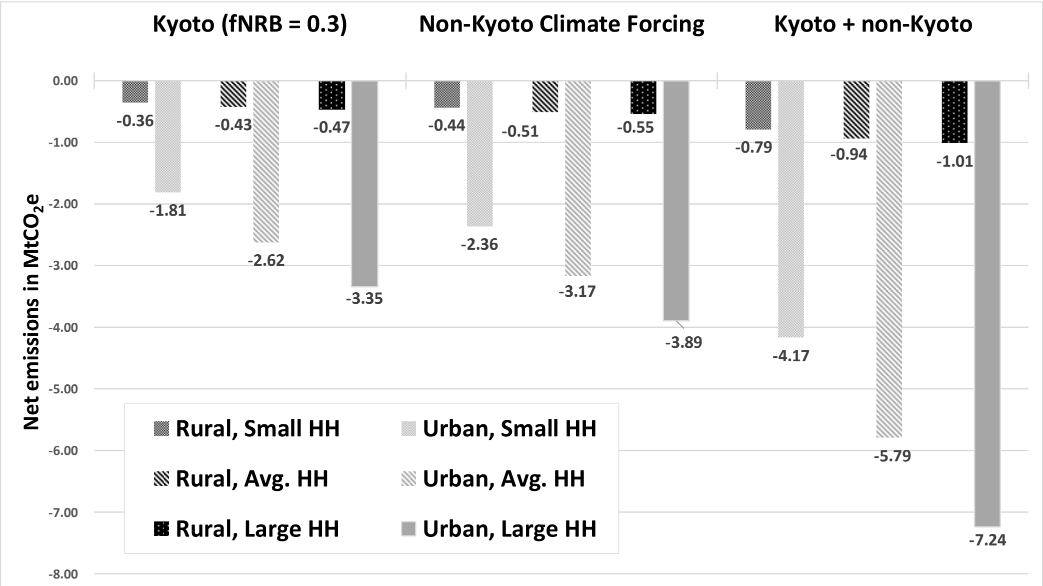

Figure 5. Net emissions from increased LPG access at fNRB = 0.3.

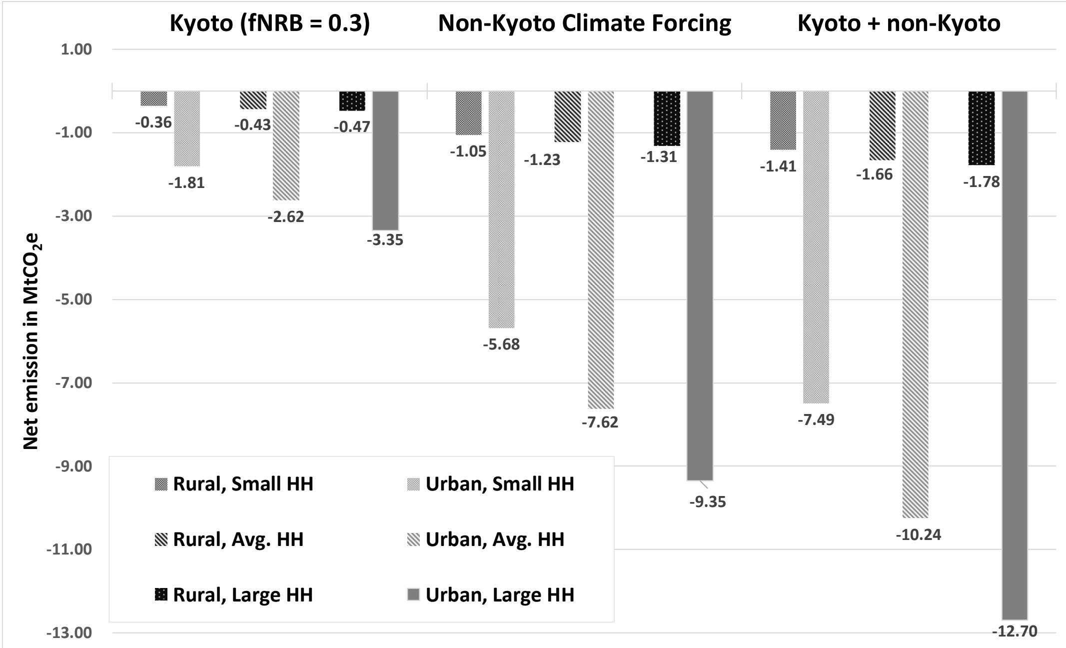

Figure 6. Net emissions from increased LPG access at black carbon GWP_{100} = 1110.

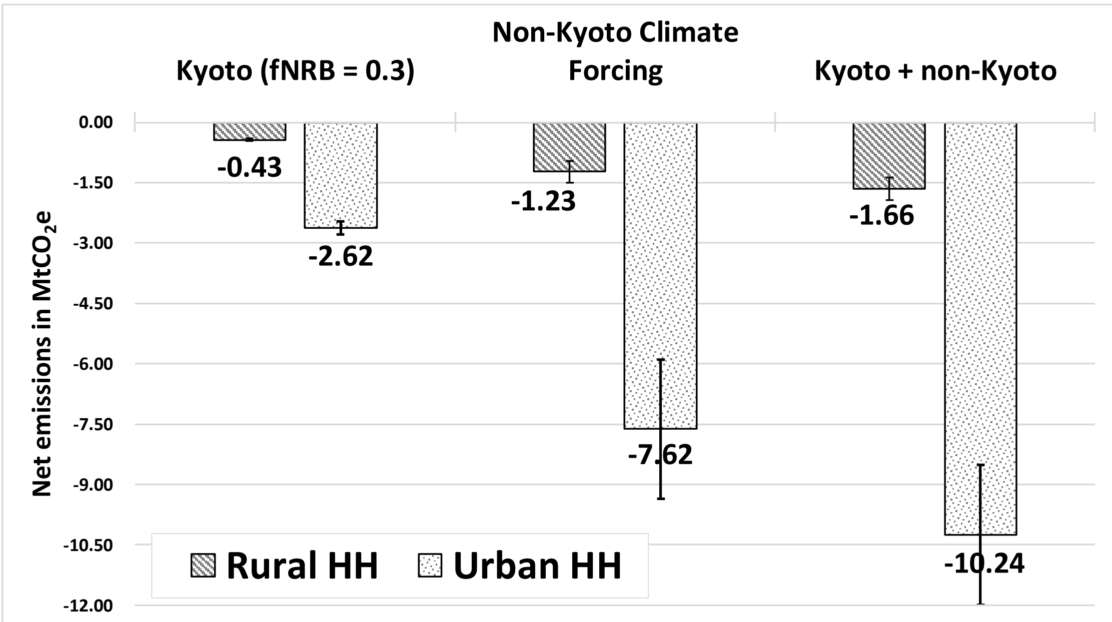

Figure 7. Net emissions (& associated uncertainties) from increased LPG access at black carbon GWP_{100} = 1110 for average sized households.

7. References

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