Supplementary:

In this analysis, Global warming potential (GWP) of firewood and biogas is determined. A comparison was made between substitute fuel and biogas to determine the GHG emission from biogas production and application. A comparison was made between substitute fuel and biogas to determine the GHG emission from biogas production and application. Consequently, a comparison was also made between the combustion of biogas and substituted firewood to calculate the GWP of CH_4, CO_2, N_2O, and CO emissions. The amount of methane that must be produced per unit of energy supplied to heat water was calculated using equation 1 [1]

$$M_p(f_l) = \frac{1}{SEC_{CH4}*0.57(1-f_l)} \quad (1)$$

$$= \frac{1}{59*0.57(1-0.4)}$$

=0.05

Here,

$M_p(f_l)$ −amount of methane that is required to be generated per unit of energy supplied to heat water (kg MJ^{-1});

f_l −fraction of biogas lost through intentional releases or leakages;

SEC- specific energy content of CH4 (59 MJ/kg)

Value of 0.57 -biogas stove efficiency

It was reported that from small-scale biogas plants, 40% biogas can be lost through leakage[1–3]. This study also considered this worst case and took 40% as reference.

Subsequently the amount of lost CH_4 per unit of energy delivered is as follows:

$M_l(f_l) = f_l M_p(f_l)$ (2)

=0.4*0.05

=0.02

After that, the method from Bruun et al. was followed to calculate the GWP per unit energy delivered (g CO_2-eq. MJ^{-1}), highlighted in equation 3[1,2].

$$IPB_{GW}(f_l) = M_l(f_l)CF_{CH_4} + ECB_{CH_4}CF_{CH_4} + ECB_{N_2O}CF_{N_2O} + ECB_{CO}CF_{CO} + ECB_{CO_2}CF_{CO_2} \quad (3)$$

Here, ECB - (g GHG) GHG emissions during fuel combustion. The corresponding ECB value can be found in Table 1.

CF -(g CO_2-eq. g^{-1}) characterization factor of CO_2, CH_4, N_2O and CO. For CO, CO_2, N_2O, and CH_4, the values are 1.9 g CO_2-eq. g^{-1}, 1 g CO_2-eq. g^{-1}, 295 g CO_2-eq. g^{-1}, and 25 g CO_2-eq. g^{-1} respectively[1,2].

Sample Calculation:

$IPB_{GW}(f_l)$==0.02×25+25×57×10^{-3}+5.4×10^{-3} × 295+81.5×1+1.9×1

=85.208g

Equation (4) was employed to estimate the impact potential of emissions from the replaced fuels (g CO_2-eq. MJ^{-1}) since the GWP emissions of substituted fuel (wood) are not linked to the losses of CH_4 of biogas plants:

$$IPR_{GW} = ECR_{CH_4}CF_{CH_4} + ECR_{N_2O}CF_{N_2O} + ECR_{CO}CF_{CO} + ECR_{CO_2}CF_{CO_2} \quad (4)$$

Here,

CF -(g CO_2-eq. g^{-1}) characterization factor of CO_2, CH_4, N_2O and CO

ECR- (g GHG) GHG emissions during replaced fuel combustion

Sample Calculation:

IPR_{GW}= 600×10^{-3}×25+4.3×10^{-3} ×295+532×1+14×1.9

=574.8685

Then, relation 5 is utilized to measure the emission prevented due to the use of biogas instead of firewood.

Avoided GHG emissions

$=\frac{\text{GHG emissions of firewood}-\text{GHG emissions of biogas}}{\text{GHG emissions of firewood}} \times 100$ (5)

$=\frac{574.8685-85.208}{574.8685} \times 100$

$=0.851 \times 100$

=85.1

Table S1. Emission of GHG gas during the combustion of wood and biogas [1].

Emission of gas during per MJ of supplied energy	g CO	g CO_2	mg N_2O	mg CH_4
Biogas	0.1	81.5	5.4	57
Wood	14	532	4.3	600

Number of households:

Total number of populations in 2025 is 907011.

Number of households will be (907011 ÷6.6) =137426,

Cost for 13 m^3 digester:

For 10 m^3, cost is 392 USD

For 13 m^3, cost is 392*13/10=510

Cooking energy demand:

To replace the consumption of firewood, biogas energy required

$$e_{biogas} = \frac{(12\, m_f LHV_f)\eta_f}{\eta_{biogas}} \times 10^{-9}$$

$=\frac{12*198*16.4*10^6*0,044}{0.57} \times 10^{-9}$

$=3.008 \, \frac{TJ}{Household-year}$

The average energy $\left(\frac{TJ}{year}\right)$ required to meet up the BSC at the refugee community

$$E_{elect} = BSC * 12 * 3600 * H_{we} * 10^{-9}$$

$=109941*100*12*3600*10^{-9}$

$=474.94 \, \left(\frac{TJ}{year}\right)$

LPG reduction potential:

For camp 1, biogas potential is 8683610 m^3/year

Considering 29 m^3 biogas equivalents 1 LPG Cylinder, the number of LPG cylinders will be replaced= 8683610/29

=299435

Previous literature:

We have used mathematical model to project the biogas potential. The result was taken from our previous literature which was published in Energy journal of Elsevier. Case 1 has higher population which results in a higher generation of waste. From this waste, higher amount of biogas can be produced. Please check the below text from our previous literature:

Researchers identified that income plays a vital role in MSW generation. With the increase of income, the total MSW increases up to a certain value, and then stabilizes. The correlation between GDP per capita and waste generated per capita per day can be determined from Equation 1[4].

$$GR_t = \frac{GR^*}{1+e(\alpha+\beta*GDPPC_t)} \quad (1)$$

GR_t is waste generated per capita per day in given year t, and it largely depends on the income level.

Equation 2 was used to calculate municipal solid waste generation of the camp [4]

$$OPMSW_t = GR_t * OF_t * UPOP_t * 365 \quad (2)$$

Equation 3 was used to estimate recoverable biogas resource potential [4]

$$BP = OPMSW_t * DM * BY * CF_{t,S} \quad (3)$$

Nomenclature:

BP - Biogas potential from substrate k (organic wastes in MSW)

BY-Biogas yield.

CF - Collection efficiency (%)

DM - Percentage of Dry Matter in the gross weight of organic municipal waste (%)

GR - Waste generated per capita per day in given year t (kg/day)

GDPPC - GDP per capita in year t.

GR* - Saturation value

OFMSW - Organic fraction of municipal solid waste generated (Mt)

OF - Percentage of organic matter in MSW (%)

$UPOP_t$ - Urban Population

Population Projection:

The projected population was taken from our previous study which was conducted on Rohingya refugees. We used mathematical modelling and code to project the Rohingya population up to 2025. We have provided the information for your kind consideration. The following formula is used to project the population in refugee camps [4].

$$N_t = Pe^{rt}$$

N_t refers to the number of people at a future date t, P represents present population, r depicts the rate of increase divided by 100.

References:

1. Bruun, S.; Jensen, L.S.; Khanh Vu, V.T.; Sommer, S. Small-Scale Household Biogas Digesters: An Option for Global Warming Mitigation or a Potential Climate Bomb? *Renewable and Sustainable Energy Reviews* 2014, *33*, 736–741.

2. Roubík, H.; Barrera, S.; van Dung, D.; Phung, L.D.; Mazancová, J. Emission Reduction Potential of Household Biogas Plants in Developing Countries: The Case of Central Vietnam. *Journal of Cleaner Production* **2020**, *270*, doi:10.1016/j.jclepro.2020.122257.

3. Lemma, B.; Ararso, K.; Evangelista, P.H. Attitude towards Biogas Technology, Use and Prospects for Greenhouse Gas Emission Reduction in Southern Ethiopia. *Journal of Cleaner Production* **2021**, *283*, doi:10.1016/j.jclepro.2020.124608.

4. Chowdhury, H.; Chowdhury, T.; Miskat, M.I.; Hossain, N.; Chowdhury, P.; Sait, S.M. Potential of Biogas and Bioelectricity Production from Rohingya Camp in Bangladesh: A Case Study. *Energy* **2021**, *214*, doi:10.1016/j.energy.2020.118837.

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