Increasing the Potential for Biogas to Satisfy Household Cooking Needs in Nepal

This policy brief highlights key findings from a recent research study: *Maximizing the Health Benefits of Clean Household Energy in Peri-Urban Nepal*. In related briefs, we examined the pathways and potential rewards of transitioning to electric cookstoves. However, it is clear from our surveys that while electricity is a promising national strategy to meet clean cooking and other household energy needs, economic and infrastructure barriers limit electricity access in many communities in the short term. While these broader electrification efforts continue, we also need to meet household cooking needs cleanly today. Biogas produced in anaerobic digesters is a widely adopted clean cooking fuel used by households across Nepal and can help bridge the clean cooking fuel transition.

Key messages

- Biogas is a widely accepted clean energy source that is used for household cooking in Nepal.
- However, at least 25% of the biogas digesters examined in a recent study exhibited performance issues due to broken components. Gas production was further limited by digesters not being maintained properly to ensure digester health, due in part to households having no way to check chemical composition of digester slurry and feedstocks.
- Service contracts for repairs and routine maintenance, combined with educational materials for owners, could help avoid nearly all of the identified issues.

- With this support, and the promotion of new designs appropriate for higher altitudes, biogas can be scaled up as a viable, clean fuel alternative for many families in Nepal.

Introduction

Biogas is used by tens of thousands of Nepalese households. Biogas systems consist of a biogas-producing anaerobic digester, and a gas-burning stove, connected by piping. Households generate and collect feedstocks locally, and freely, so systems generally have low operating costs and are not reliant on external distribution networks. Although upfront installation costs are still prohibitively high for many households, subsidy programs backed by the Government of Nepal have led to promising rates of uptake over the last 30 years. The welfare benefits of optimizing biogas systems could be significant, by providing households with an additional clean, reliable, and affordable source of cooking fuel to supplement electricity and to displace the use of petroleum gas (LPG) and biomass.

This brief summarizes the results from surveys administered in the Kavre district of Nepal to assess the conditions of household biogas systems. The most common performance issues observed are described and potential measures to mitigate their impacts and expand use of biogas are discussed.

Box 1. Overview of study design and methods

Assessments of 374 household biogas digesters and stoves were performed in 10 Wards of Panchkhal and Mandandeupur municipalities in Kavre district, to examine operational characteristics and potential maintenance issues affecting the performance of the biogas systems. Informed by the assessment results, project staff made repairs to digesters in 345 households.

Feedstock slurry samples were collected from the inlet chamber of 20 digesters to conduct a physical and chemical analysis. Measurements of chemical oxygen demand, pH, total solids, volatile solids, ammonia, and the C:N ratio were performed on 108 slurry samples. Sample analysis used the modified Walkley and Black method.[1] Stove flame and feedstock input practices were observed in 292 of the 374 households.

To measure stove use, temperature sensors were placed on biogas and traditional cooking stoves of enrolled households for up to one year. In the average home, stove use was measured at 10- to 20-minute intervals for more than 300 days.

[1] Motsara M.R. and Roy R.N. *Guide to laboratory establishment for plant nutrient analysis in Fertilizer and Plant Nutrition Bulletin.* Food and Agriculture Organization of the United Nations, Editor. 2008, FAO: Rome.

Assessments of the biogas systems revealed that a large fraction of these systems had structural damage and suboptimal composition of feedstock material.

Findings and implications

Biogas stoves are widely used, but not performing up to their potential. Most biogas stoves monitored as part of the study were used daily, confirming their acceptance by the local community. However, assessments of the biogas systems revealed that a large fraction of these systems had structural damage and suboptimal composition of feedstock material, which likely were reducing the performance of the system. Visual inspections of the structural components of the biogas stoves and digesters identified the common issues shown in table 1.

Table 1. Common issues found on inspection of biogas stoves and digesters.

COMPONENT	FINDING	IMPLICATION
Mechanical mixer	55% of mixer mechanisms were nonfunctional. This inlet chamber mechanism mixes feedstock material in the digester, which stimulates bacterial activity and gas production by improving contact between microorganisms and the substrate.	Non-functioning mixers can negatively affect the health of digesters and their gas production rates.
Main valve	30% of digesters had a damaged main valve, of which 3% were leaking.	Damage to the main valve can influence the general functioning of the stove and lead to gas leaking out before it reaches the stove.
Water trap	26% of digesters did not have functioning water traps; traps were either jammed as a result of rust or completely buried under rubble.	Moisture buildup in gas lines can lead to decreased gas flow to the stove.
Inlet and outlet sludge pipes	18% of digesters did not have a functioning inlet pipe, and 17% had structural damage to outlet pipes. Functioning inlet and outlet pipes allow the proper transfer of slurry to the digester.	Malfunctioning pipes disrupt the appropriate transfer of slurry into the digester, reducing both gas production and the ability to access bio-slurry for use as fertilizer.
Gas valve	30% of gas taps required replacement or had faulty gasket rings.	This can cause gas to leak out before reaching the stove.[1]
Stove burner knobs and movable check nuts	29% of stove burner knobs and 18% of movable check nuts showed signs of damage or were nonfunctional.	This can affect the ability to modify the stove's power setting.
Stove and flame	During an assessment of the flames in a subset of 239 stoves, 15% were classified as "too small."	Small flames can reduce the stove's power and require more time to complete cooking tasks.

1 In one case, owners replaced a missing gas valve with a water faucet. While this is a clever work-around, and not particularly dangerous since biogas isn't pressurized, having a proper valve would prevent leakage of methane gas.

To maximize gas production owners must maintain the digester environment, which requires regular agitation and loading with proper quantities and ratios of feedstock. The surveys revealed that most system owners understood that proper feedstock was important for the health of digesters. However, the analysis of feedstocks and digester slurry suggested that compositions were often suboptimal for gas production, exhibiting the following problems:

- **Water-manure ratio.** The average water-to-waste ratio was 1:1, but the liquid included a substantial amount of animal urine, which can negatively affect pH. The average weight of daily feedstock material was 33 kilograms, of which dung comprised 47%, animal urine 38%, and water 15%. The ideal mix of dung and water is 1:1 by weight.
- **Carbon to nitrogen (C:N) ratio.** The chemical analysis of feedstock material collected from the inlet pipe indicated that 95% of samples were not within optimal C:N ratios. The ratios ranged from 5:1 to 24:1, with only 4 of 108 samples measuring greater than 20:1 (ideal conditions are 20:1 to 30:1).[1]
- **pH.** The average pH of the feedstock was 7.7, which is slightly higher than the optimal range of 7.0 to 7.2.[2]

Variety in digester design options may help expand the use of biogas. Exploring system modifications and new digester designs may provide opportunities for expanding biogas in new regions of Nepal. The current model of digester system, with a small fixed dome, has been successfully deployed for almost 30 years and works well at altitudes as high as 1,500 meters or in areas with temperatures favorable for methanogenic microorganism growth (30–400 C).[3] Exploring new designs and modifications that are more adaptive to colder climates may improve service in some areas where systems are deployed, and expand biogas into colder climate regions of the country.[4] Potential retrofits to current designs could include thermal insulation, by covering the biogas system with a greenhouse,[5] or blacking and glazing the ground above the fixed-dome digester.[6] Assessments are needed of how existing and new biogas systems are being used to satisfy households' cooking needs, to determine which tasks continue to be performed on open fires, and what additional stove designs may be needed to maximize clean cooking.

A broken gas valve pictured next to a new valve for comparison.

Summary and Calls to Action

Biogas is a widely used and accepted cooking fuel in Nepal that has the potential to be scaled up. The ability to generate gas using local feedstocks and its low operating cost make it an important complement to electric cooking appliances and other clean cooking solutions, especially in remote regions and for families that are unable or unwilling to purchase cooking fuels. However, there are barriers that limit biogas from reaching its full potential as a clean cooking fuel for households in Nepal. Based on the findings of this study, the research team developed the following calls to action:

Table 2. Calls to action

CHALLENGE	ACTIONS
The majority of biogas-producing anaerobic digesters surveyed showed structural damage.	Standardizing and supporting service contracts for repairs and routine maintenance could help sustain the performance of biogas systems.
Owners are not able to evaluate the issues that could be negatively impacting the performance of their system, and make appropriate changes. These include suboptimal composition of feedstock and physical chemical composition of the digester contents.	Assessments should be conducted of whether poor composition is due to a lack of proper feedstock or to operating practices by owners. Supporting service contracts that educate users and help them maintain the health of their digesters could help maximize gas production.
Subsidies support installation of a limited range of digester designs and do not support maintenance.	Expanding subsidies to support newer digester models and establishing service and repair contracts could help optimize systems for households and sustain their benefits over time.
The extent to which biogas could meet household cooking needs and displace biomass and/or LPG is unclear, which makes it difficult to assess the full value of improving the performance of biogas systems.	Assessments should be conducted that measure how much LPG and biomass is used as a result of inadequate biogas fuel supply, and that evaluate design and behavioral measures aimed at increasing biogas supply.

Notes

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cleancookingalliance.org

@cleancooking

@cleancookingalliance

@cleancookingalliance

info@cleancookingalliance.org