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**Domestic Biogas Production and Use in Nepal – A  
Simple, Reliable, Clean and Cost-Effective Solution  
to Provide Energy Security to the Rural Households**

**A thesis presented in partial fulfilment  
of the requirements for the degree of  
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**MASSEY UNIVERSITY**  
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## Abstract

Nepal is rich in natural resources with a high potential for energy supply, but it is facing an energy crisis. Electricity supply is unreliable and often in short supply. LPG and kerosene are imported, and therefore expensive and less accessible. Biogas is starting to be used for cooking but only at 17% of the total potential households. Most of the fuel used for cooking in rural areas is traditional fuelwood. It takes time and hardship to collect especially for women, emits unhealthy smoke and can lead to deforestation. As an alternative, biogas, mostly methane, has good potential for cooking and heating. It can be produced in a simple plant digester by anaerobic decomposition of biodegradable organic wastes. Cattle dung and human excreta are the main feedstocks used in domestic biogas plant in Nepal. Biogas can be a highly efficient and low carbon emission fuel as it can replace the excessive use of traditional biomass and reduce the associated adverse impacts on social, health and environmental conditions. Biogas development is one of the government's priority programmes in Nepal to provide reliable, clean and low cost energy supply particularly to rural households. However, the replication of the technology is still slow. Biogas production is lower than its full capacity and cannot cover the energy demand of a typical household all year round, especially during winter. Hence, this study aims to explore the potential solution to increase domestic biogas production and use so that its benefits for energy security and environmental emission reduction can be optimised.

Both quantitative and qualitative research approach were applied. Surveys of biogas households in Nepal were conducted to collect household-level information. Key informant interviews, informal discussions and observations were undertaken to gain insight into the context of overall renewable energy technologies, the production and use of biogas technology, and constraints and opportunities for its wider replication, especially to rural poor households.

Users' socioeconomic conditions, feedstock availability, plant design and cost are the major influencing factors for biogas production. The poor households cannot afford to purchase the system, or own fewer cattle, so less dung is available to feed the plant. Others who have enough cattle for dung are also not feeding the required quantity of dung to produce biogas but use it for field manure. Hence, the plants are under-performing in terms of their technical potential mainly due to the insufficient feedstock used. Agricultural residues are easily available, but do not realise their use with dung for co-digestion to increase biogas production.

This research thus analysed the effect of co-digestion of dung with agricultural residues to increase biogas yield. The cost effectiveness of co-digestion technology is also checked out by using financial analysis. The impacts of improved biogas production on the cost of energy, energy consumption and associated greenhouse gas (GHG) emissions reduction were obtained by using the Long-range Energy Alternative Planning (LEAP) system model.

Co-digestion of dung with crop residues could improve biogas production by approximately 50-150% and would meet most of the household cooking energy demand throughout the year. The increased availability of biogas could help address strategic gender needs by utilising the saved time more than 3.2 hours/day for fuelwood collection and cooking in traditional stoves. From the cost-effective perspective, an average total annual cost of energy after co-digestion is up to 37% cheaper than the existing biogas production condition, and even up to 45% cheaper than the energy cost of non-biogas households. Furthermore, a co-digested biogas plant has the potential to reduce average annual energy consumption by 46-57 gigajoules and GHG emissions, mainly from avoiding deforestation, by 16.7-19.3 tCO<sub>2</sub>e per household depending on region, compared to a non-biogas household.

This study, however, pointed out some important issues that are to be addressed to make this research outcome more applicable. Mainly, the design of a biogas digester should be suitable for co-digestion and the government subsidy needs to be revised accordingly to cover any potential increase in the cost of the modified plant design. The utilisation of saved time to achieve strategic gender needs can also be a priority. In summary, this study analysed all three impacts together: *energy consumption; cost of energy; and corresponding GHG emissions*, of co-digestion technology. This has not previously been reported in the literature. This study's findings can also be relevant to other developing countries where biogas can be a part of the solutions to provide energy security, gender equality and climate change mitigation.

***The recent earthquake in Nepal (on 25/4/2015 a 7.9 magnitude earthquake devastated much of the country along with subsequent aftershocks) has left extremely adverse effects on all social, economic, environment and energy supply conditions. At the time of printing the scale of damage and loss of life is still being estimated, but this is clearly an extremely damaging event. It will take a long time and huge funds and a massive pace of infrastructure development to get the situation back to normal. Nonetheless, let's hope this study's outcome will also add further importance to the biogas development to uplift the current vulnerable energy supply situation in poor rural households.***

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## Abbreviations and Acronyms

|                   |  |
|-------------------|--|
| ADB/N             | Agricultural Development Bank Nepal                                |
| AEPC              | Alternative Energy Promotion Centre                                |
| APCAEM            | Asia and Pacific Centre for Agricultural Engineering and Machinery |
| APEREC            | Asia Pacific Energy Research Centre                                |
| BANZ              | Bioenergy Association of New Zealand                               |
| BMP               | Biochemical methane production                                     |
| BSP-Nepal         | Biogas Support Programme- Nepal                                    |
| C/N               | Carbon-Nitrogen ratio  |
| CBS               | Central Bureau of Statistics                                       |
| CDCF              | Community Development Carbon Fund                                  |
| CDM               | Clean Development Mechanism  |
| CES               | Centre for Energy Studies  |
| CFC               | Chlorofluorocarbon   |
| CH <sub>4</sub>   | Methane  |
| CO <sub>2</sub>   | Carbon dioxide   |
| CO <sub>2</sub> e | Carbon dioxide equivalent  |
| COD               | Chemical Oxygen Demand   |
| CRTN              | Centre for Rural Technology, Nepal                                 |
| CSPP              | Climate-Smart Planning Platform                                    |
| DDC               | District Development Committee                                     |
| DFRS              | Department of Forest Research and Survey                           |
| ENPEP             | Energy and Power Evaluation Program                                |
| FAO               | Food and Agriculture Organization of the United Nations            |
| FIRR              | Financial Internal Rate of Return                                  |
| GDI               | Gender Development Index   |
| GDP               | Gross Domestic Product   |
| GEF               | Global Environmental Facility                                      |
| GGC               | Gobar Gas Company  |
| GHG               | Greenhouse gas   |
| GJ                | Gigajoule  |
| GMP               | Greenhouse Gas Mitigation Potential                                |
| GoN               | Government of Nepal  |
| GPOBA             | Global Partnership for Output-Based Aid                            |

|                  |  |
|------------------|--|
| GW               | Gigawatt   |
| GWP              | Global Warming Potential                               |
| HDI              | Human Development Index                                |
| HOMER            | Hybrid Optimization Model for Electric Renewables      |
| IDE              | International Development Enterprises                  |
| IEA              | International Energy Agency                            |
| IPCC             | Intergovernmental Panel on Climate Change              |
| IPP              | Independent Power Producers                            |
| IRADe            | Integrated Research and Action for Development         |
| IUCN             | International Union for Conservation of Nature         |
| KfW              | Kreditanstalt fuer Wiederaufbau                        |
| KVIC             | Khadi Village Industries Commission                    |
| kWel             | Kilowatt electric                                      |
| kWh              | Kilowatt hour  |
| LAPA             | Local Adaptation Plan for Action                       |
| LEAP             | Long Range Energy Alternative Planning                 |
| LPG              | Liquefied Petroleum Gas                                |
| MAED             | Model for Analysis of Energy Demand                    |
| MARKEL           | Market Allocation Model                                |
| MDG              | Millennium Development Goal                            |
| MEDEE            | Modèle d'Evolution de la Demande d'Energie             |
| MESAP            | Modular Energy System Analysis and Planning            |
| MJ               | Megajoule  |
| MSTE             | Ministry of Science, Technology and Environment        |
| Mtep             | Million tonne equivalent of petroleum                  |
| MUHEC            | Massey University Human Ethics Committee               |
| MW               | Megawatt   |
| N <sub>2</sub> O | Nitrous oxide  |
| NAMA             | Nationally Appropriate Mitigation Actions              |
| NAPA             | National Adaptation Programme of Action                |
| NEA              | Nepal Electricity Authority                            |
| NEMS             | National Energy Modelling System                       |
| NPC              | National Planning Commission                           |
| NRs              | Nepalese Rupees  |
| OECD             | Organisation for Economic Co-operation and Development |
| PASA             | Practical Action South Africa                          |
| PJ               | Petajoule  |



|                    |   |
|--------------------|---|
| POLES              | Perspective Outlook on Long-term Energy System                    |
| PPM                | Parts per million   |
| PPP                | Purchasing power parity   |
| PVC                | Polyvinyl Chloride  |
| QDA                | Qualitative Data Analysis   |
| REDD               | Reducing Emission from Deforestation and forest Degradation       |
| RETs               | Renewable Energy Technologies                                     |
| RERL               | Renewable Energy for Rural Livelihood                             |
| RESGEN             | Regional Energy Scenario Generator                                |
| RET                | Renewable Energy Technology                                       |
| SD                 | Sustainable Development   |
| SDGs               | Sustainable Development Goals                                     |
| SNV                | Netherlands Development Organisation                              |
| STP                | Standard temperature and pressure                                 |
| tCO <sub>2</sub> e | Tonnes carbon dioxide equivalent                                  |
| TJ                 | Terajoule   |
| toe                | Tonnes of oil equivalent  |
| tCO <sub>2</sub> e | Tonnes of carbon dioxide equivalent                               |
| TPES               | Total Primary Energy Supply                                       |
| TS                 | Total Solid   |
| UMN                | United Mission to Nepal   |
| UN                 | United Nations  |
| UNDP               | United Nations Development Programme                              |
| UNEP               | United Nations Environment Programme                              |
| UNESCO             | United Nations Educational, Scientific and Cultural Organizations |
| UNFCCC             | United Nations Framework Convention on Climate Change             |
| US\$               | United States dollar  |
| VDC                | Village Development Committee                                     |
| VER                | Voluntary Emission Reduction                                      |
| VFA                | Volatile Fatty Acids  |
| VMP                | Volumetric Methane Production                                     |
| VS                 | Volatile solid  |
| WECS               | Water and Energy Commission Secretariat                           |
| WEM                | World Energy Model  |
| WHO                | World Health Organization   |
| WWF                | World Wildlife Fund   |