WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

# Applying the Clean Development Mechanism AMS-III.R Methodology to Pig Manure Management: A Case Study of Dharan, Nepal

*Sandesh Rai [a], Jeet Chand [b]*

[a] Department of Applied Sciences and Chemical Engineering, Pulchowk Campus, Lalitpur, Nepal
[b] National Agriculture Modernization Program, Khumaltar, Lalitpur, Nepal
Email: jeetchand06@yahoo.com

**ABSTRACT**

Emissions of greenhouse gases are one of the most severe global externalities and the production of methane in managing livestock manure activities is one of the leading contributors since it has global warming potential of 27.2 times more than $CO_2$. The least developed countries such as Nepal have the highest susceptibilities to the effects of climate change, but may also offer potential climate-related mitigation through low-cost sustainable efforts. The Clean Development Mechanism is a system that was introduced in Kyoto Protocol to give a window in reducing emissions and at the same time promoting sustainable development. Through its methodologies, AMS-III.R gazes particularly at avoiding methane by better manure handling on livestock. This paper uses AMS-III.R approach to pig manure management in the city of Dharan Sub-Metropolitan, Nepal. Farming goes hand in hand with the livestock, but unmanaged manure poses huge methane emissions. The calculation of the baseline indicated that the households provided with biogas digesters had 2.160 $tCO_2e$ emission per household annually as compared to 0.20486 after they were installed leading to a net reduction of 1.955 $tCO_2e$ per household. The benefit to 4,000 households shows a total of 7,820.56 $tCO_2e$ avoided annually hence signifying the mitigation potential of the climate. It proves economically viable of the project through economic analysis. By investing an amount of Nrs. 80,000,000, annual revenues of Nrs. 14,000,000 will give a simple payback period of 5.71 years. Internal Rate of Return (IRR) is higher than the discount rate, and Net Present Value is NPR 455,882,120 with the Benefit-Cost Ratio being 2.34, which means that the benefits will be tremendous in the long run. In sum, the aggregation of biogas digesters within the clean development mechanism does not only limit the GHG emissions but also contributes toward the establishment of local energy security, fossil fuel offset, and sustainable development of Nepal. Expansion of such programs may bring forth models that can be replicated by other LDCs that encounter similar problems.

**Keywords:** AMS-III.R, Biogas Digester, Clean development mechanism, Greenhouse gas emissions

## 1. Introduction

Emission of greenhouse gases (GHG) is one of the most staggering externalities in the whole world and they are vastly considered as the biggest market failure in human history. Compared to traditional localized externalities, the emissions of GHGs have no borders of national jurisdiction and affect the cost of populations distant to the site of emission. Although the causes of these emissions are generated by each individual and sector, their effects are felt around the globe and therefore cause devastating effects (Stern, 2008).

Climate change denotes a shift in the status quo of the climate, over a long period of time where the mean or variation of the character of the climate alters (IPCC, 2007). Over the last century, drastic warms in global temperatures and precipitation fluctuations have been largely caused by the human activity which contributes to the concentration of greenhouse gases (GHG) in the atmosphere. Burning fossil fuel like coal, petroleum, and natural gas as well as massive cutting down of trees are major causes. It is estimated that further emissions of GHGs especially carbon dioxide will increase global temperatures at the surface by between 1.4 to 5.8 ºC at the end of the 21st century (Intergovernmental Panel on Climate Change (IPCC). Climate change is extensive both in its impacts that include biodiversity, food security, water resource and general productivity particularly in the vulnerable geographical areas(Kotsompolis et al., 2023). The Least Developed Countries (LDCs) experiences a higher risk level since limited resilience and adaptive capacity in comparison to other developing countries are experienced. Africa itself is believed to be among the most vulnerable continents due to the high exposure to the impacts of climate as well as the low adaptive capacity. The susceptibility is mostly associated with the low levels of economic development, poor institutional support, and poor financial as well as technical resources. As a result, LDCs have unequal exposure to climate changes especially because of their reliance on agriculture and lack of flexibility to adjust to climate change.

Thus, UNFCCC have put forth clean development mechanisms in alleviating effects of climate change because of the two kinds of development work in our society. An estimate by Point Carbon (2008) placed the 2007 level of Clean Development Mechanism (CDM) projects producing Certified Emission Reductions (CERs) that can be traded in international carbon markets at the level of 12 billion Euro. China alone provided 62 percent of CERs that year, whereas China, Indonesia, Brazil and India provided 85 percent of the world total in joint efforts. Other developing countries on the other hand had very low participation. It has been argued that this underrepresentation has been due to numerous barriers facing CDM including high cost of transactions connected to creation of CDM projects, poor awareness and information regarding the carbon market, complicated and lengthy procedural requirements and an inadequate estimation in terms of CDM potentials in most countries (Cosbey et al., 2005; Silayan, 2005).

Nepal is accorded the opportunity to voluntarily join the Clean Development by ratifying the Kyoto Protocol in September 16, 2005. The mechanism (CDM) set out in Article 12. This kind of participation helps parties that are not in Annex I such as Nepal in their course of attaining sustainable development and by offering contribution to the end result of the United Nations Framework Convention on Climate Change (UNFCCC), to avoid total destruction of climate change; and helps parties under Annex I, which consist mainly of the developed countries, to meet compliance of their quantified article 3 commitments on emission limitation and reduction (UNFCCC, 1998).

Among various CDM methodologies, AMS-III.R targets methane avoidance through the treatment of livestock manure, making it particularly relevant for countries like Nepal, where livestock farming is integral to rural livelihoods. Methane from unmanaged pig manure contributes significantly to GHG emissions, with a global warming potential (GWP) 21 times higher than $CO_2$ over a 100-year horizon (IPCC, 2006). By applying controlled anaerobic digestion, biogas systems not only mitigate methane release but also generate renewable energy and organic fertilizer. Such co-benefits align with CDM's dual mandate of reducing emissions and promoting sustainable rural development (Michaelowa et al., 2003). This study aims to motivate Sub metropolitan city Office to make a initiation on applying this project for reducing GHG emission and utilizing it in a proper way to uplift the people's health, economic sector and make a sustainable life.

The main objective of this study is to calculate the baseline emission of the project and calculate the emission reduction by using biogas digester. The primary objectives are to do the economic analysis of investment for this project.

## 2. Methods

### *2.1 Study Area*

Dharan Sub Metropolitan City, located in the Sunsari District of Koshi Province. The city sits at an altitude of 349 meters (1148 feet) on the foothills of the Mahabharat Range. The Dharan is located at approximately 26.8167º latitude and 87.2833º longitude. As of the 2021 Nepal census, Dharan has an estimated city population of 1,66,531 and 42,396 households. In Dharan the total % of population according to the cast are Rai (19.4%), Limbu (13.01%), Newar (11.1%), Chhetri (10.7%), Tamang (7.3%), Hill Brahmin (7.1%), Kami (6.2%) and other Ethnic Groups (25.2%).

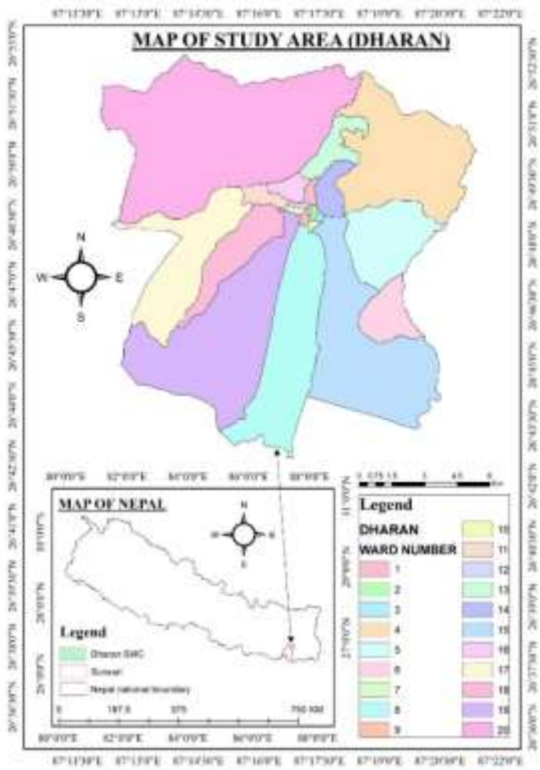


*Figure 1: - Figure of Study Area.*

### *2.2 Clean Development Mechanism*

Clean Development Mechanism (CDM) is among the flexibility mechanisms that were introduced through the Kyoto Protocol (1997) to help in attaining the target of reducing greenhouse gas (GHG) emission. It enables the industrialized countries (Annex I Parties with binding commitments to reduce emission) to invest in, or finance, emission-reduction projects in the developing countries (non-Annex I Parties). Such projects need to use clean, sustainable technologies and bring sustainable development to the country where the project is located. As a payback, the investing country gets Certified Emission Reductions (CERs) each worth one tonne of CO2 that they can utilize to fulfil their Kyoto Protocol commitments (Naik et al., 2014). By 17 April 2025, there were 1,388 registered Project Activities (CPAs), which had requested transition to the post-Kyoto framework under the CDM portfolio. The first Parties accepted up to a sub-set of these CDM activities which included 17 PAs, 18 PoAs, 187 CPAs hosted in Bangladesh, Bhutan, Dominican Republic, Ghana, Myanmar and Uganda according to the UNEP Copenhagen Climate Centre. The methodology used for this project is AMS-III.R. which helps in Recovery and destruction of methane from manure and wastes from agricultural activities through: Installation of a methane recovery and combustion system to an existing source of methane emissions; or, change of the management practice of an organic waste or raw material in order to achieve controlled anaerobic digestion that is equipped with methane recovery and combustion system.

The manure produced by a pig is collected from the sample of seven houses with the average pigs kept is 3.

*Table 1: - Sample taken from 7 houses.*

| Name of House owner | No of Pigs | Kg/day waste produced by Pigs |
|---|---|---|
| Ram Kumar Rai | 2 | 0.38 |
| Siddhartha Rai | 3 | 0.39 |
| Dinesh Limbu | 3 | 0.28 |
| Roshan Limbu | 4 | 0.30 |
| Iksha Limbu | 2 | 0.40 |
| Suchan Ramtel | 3 | 0.38 |
| Samir Khapung | 4 | 0.35 |
| Average | 3 | 0.354 |

Daily volatile solid excretion per head of pig (VS)= 0.354 Kg/hd/day.

Maximum methane producing capacity of manure ($B_0$)= 0.29 $m^3$ $CH_4$ / kg VS From IPCC 2006 on Agriculture Sector Page no 332. (Matulaitis et al., 2015) (Eggleston et al., 2006)

Baseline $CH_4$ emission from baseline manure management system in city, $tCO_2$ e/yr is calculate using the below formula.

$EF_i$= (VS* 365) *($B_o$*$D_{CH4}$*$MCF_i$*MS%) ---------------------------------------------------------(1)

MS=Under the baseline condition all the manure will be collected and stored as Liquid/Slurry in a deep pit, tanks natural earthen ponds outside the animal housing (without natural crust cover), cesspit enclosed below animal confinement facility or household toilet for about 3-6 months, the MS=1.

$D_{CH4}$= Conversion factor of $m^3$ $CH_4$ to kilograms $CH_4$, 0.67 (IPCC, 2006)

$MCF_i$= 0.46 according to the temperature of Dharan 21.6 $^0$C (Amon et al., 2021)

GWP global Warming Potential (GWP) of $CH_4$= 27.2 from Assessment Report 6 (Ruane, 2024).

### *2.3 Baseline Emissions Calculation*

A baseline scenario is the scenario that sensibly captures how much greenhouse gas (GHG) emissions would have taken place had the proposed project activity not taken place. The estimated GHG emissions under such scenario are referred to as the baseline emissions. Emission cuts by the project are obtained by subtracting the baseline project emissions and the new project emissions following the implementation of the project.

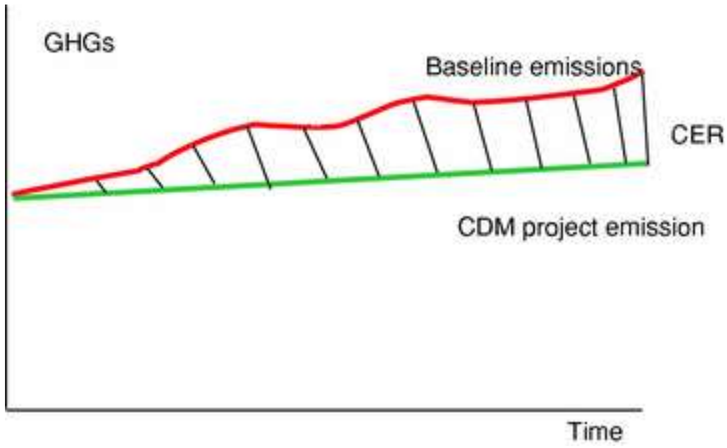


*Figure 2:- Baseline and Project Emissions Under a CDM project Activity(Bhattacharyya, 2011).*

The total baseline emission is obtained from adding (i) methane ($CH_4$) from pig manure management and (ii) Carbon dioxide ($CO_2$) from coal combustion.

$BE_{total}$= $BE_{CH4}$ + $BE_{CO2,coal}$-------------------------------------------------------------------------------(2)

### *2.4 Baseline emission from each pig manure management*

$BE_{CH4}$=$GWP_{CH4}$*(1/1000) *LN*EF-------------------------------------------------------------------(3)

$BE_{CH4}$=Baseline $CH_4$ emission from baseline manure management system in city, $tCO_2$ e/yr.

GWP=GWP global Warming Potential (GWP) of $CH_4$

LN= Average pig population for household before the installation of biogas digester in City

EF= $CH_4$ emission factor for baseline pig manure management in city, kg $CH_4$. Pig-1 yr-1

### *2.5 Baseline $CO_2$ emission from coal combustion*

$BE_{CO2}$= ($EGt_{hermal}$*$EF_{FF}$, $CO_2$)/ $\eta_{BL, thermal, coal stove}$-------------------------------------------------(4)

$BE_{CO2}$= Baseline $CO_2$ emission from coal combustion for household before the installation of digester in city, $tCO_2$e $yr_{-1}$ for each household

$EG_{thermal}$ = The net quantity of heat supplied for household by the project activity, TJ

$EF_{FF, CO2}$=Emission factor of baseline fuel (raw coal), $tCO_2$e/TJ

$\eta_{BL, thermal, coal stove}$=Efficiency of the baseline cooking stove

$EG_{thermal}$ =k $W_{thermal}$ *$H_{stove}$*DI

k $W_{thermal}$=The manufacturers rated thermal capacity of the biogas stove for household

$H_{stove}$=Average Operating hours of the stoves for household

DI= Discount factor equal to the rate of average thermal capacity of the biogas stove rated capacity.

### *2.6 Project Methane Emission*

$PE_{CH4,y}$=$LF_{AD}$*[$GWP_{CH4}$*$B_0$*$D_{CH4}$*$VS_{m,y}$*Average pig *365]/1000----------------------------(5)

$LF_{AD}$- Livestock Fraction of manure handled in Anaerobic Digestion (fraction from IPCC Guidelines), Unit No Dimension

$GWP_{CH4}$= Global Warming Potential of $CH_4$ over 100 years, $tCO_2e$ / $tCH_4$

$B_0$= Maximum methane producing capacity of manure, $m^3$ $CH_4$ / kg VS

$D_{CH4}$= Density of methane, kg $CH_4$ / $m^3$ $CH_4$

$VS_{m,y}$= Average volatile solids excreted per pig per day, kg VS / pig / day

### *2.7 Emission Reduction*

The total emission reduction after the implementation of this project is calculated by:-

$BE_{total}= BE_{CH4} + BE_{CO2,coal}- PE_{CH4,y}$------------------------------------------------------------------(6)

### *2.8 Economic Analysis*

For economic analysis the project life time is taken as 10 years, discount rate is 0.1%, Project Investment Cost is 8,00,00,000 Nrs, Repair and maintenance cost is 320,0,000 Nrs/yr (4% of investment), Operation Cost is 3,65,00,000 Nrs/year, Average annual utilities cost is 12,00,000 Nrs/year, Inflation rate of maintenance cost is 7 percent, Electricity cost is 5.16/kwh, energy generated is 9329400 kwh in year and Inflation rate of energy cost is 3 percent.

The benefits would be from Revenue by substituting firewood, coal, LPG etc is 80,00,000 Nrs per year, from Health Care Expenses 80,00,000 Nrs per year, Energy Saving Cost is 9,32,94,000 Nrs in first year and by fertilizer use of 60,00,000 Nrs per year.

Economic analysis is conducted to analyze the costs and benefits of a venture to find out the feasibility of the venture, how efficient it will be and the impact. The most accepted ones are Cost Benefit Analysis (CBA), Cost-Effectiveness Analysis (CEA), and Net Present Value (NPV). In this analysis, we have used CBA and IRR method. Benefit Cost(B/C) Ratio B/C Ratio is the use of present value benefits to costs ratio to show economic feasibility when a ratio greater than 1 is achieved. It is derived as:

$$B/C\ Ratio = \frac{\sum_{t=0}^{n}\frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n}\frac{C_t}{(1+r)^t}} \text{-----------------------------------------------------------------------------------(7)}$$

Where: -

$B_t$= Benefits in year t

Ct= Costs in year t

R= Discount Rate

T= Time periods (years)

N= Total Project Lifespan

The Internal Rate of Return (IRR) is the discount rate (r) at which the Net present Value (NPV) of the all-cash flows (both inflows and outflows) become zero. In our study, the IRR was calculated using the trail-and-error approach, applying the following formula:

$$NPV = \sum_{t=0}^{n}\frac{C_t}{(1+r)^t} = 0 \text{---------------------------------------------------------------------------------(8)}$$

Where $C_t$ is the net cash flow in year t. The IRR was determined using the trail-and-error methods.

### **3. Results and Discussion**

By using the equation 1 the $EF_i$ the value is 11.55 $KgCH_4$/hd/yr which is shown in the Table 2.

*Table 2: - $EF_i$ Calculation Table.*

| City | Average Temperature 2021 | Average Temperature 2022 | Average Temperature 2023 | Average value of 3 years | VS | $B_o$ | $MCF_i$ | $EF_i$ |
|---|---|---|---|---|---|---|---|---|
| Unit | ºC | ºC | ºC | ºC | Kg/hd/day | $M^3$CH4/kg VS | % | Kg CH4/hd/yr. |
| Dharan | 21.6 °C | 21.6 °C | 21.6 °C | 21.6 °C | 0.354 | 0.29 | 0.46 | 11.55 |

For the calculation of the baseline emission from each pig management ($BE_{CH4}$) using the equation 3 without implementing the project is 0.94248 $tCO_2$ e/yr. The total calculation in shown in table 3.

*Table 3 : - $BE_{CH4}$ Calculation Table.*

| City | $EF_i$ | Average pig population without biogas digesters | $GWP_{CH4}$ | Baseline emission from each pig manure management system |
|---|---|---|---|---|
| Dharan | 11.55 | 3 | 27.2 | 0.94248 |

Before the project is implemented the people of Dharan uses the Coal for the cooking of food and others. The baseline $CO_2$ emission for the coal combustion using equation 4 is calculated to be 1.217 $tCO_2$e/yr/household which is shown in table 4.

*Table 4: - $BE_{CO2}$ calculation table.*

| Data | Value | Unit | Data source |
|---|---|---|---|
| $EF_{FF, CO2}$ | 94600 | Kg CO2/TJ | (Eggleston et al., 2006) |
| $\eta_{BL,thermal,coal\ stove}$ | 55 | % | https://energypedia.info/wiki/Biogas_Stoves |
| k $W_{thermal}$ | 1-5=3 | kW | (Singh et al., 2019) |
| $H_{stove}$ | (3.6*350)=1260 | h/yr | By survey with people |
| DI | 52 | % | Referenced value from technical evaluation estimated by biogas stove manufacture |
| $EG_{thermal}$ | (3*1260*52*3600)=707616000 | KJ | Calculations |
| $BE_{CO2}$ | =1.217 | tCO2 e/yr/household | Calculated |

Adding the value of baseline emission from each pig manure management system and baseline emission from coal combustion in each household is 2.160 $tCO_2e$/yr./household. Since the total biogas digestor installed is on 4000 household. So, the total baseline GHG emission is 8640.881 $tCO_2e$/yr.

Using the equation 5 the GHG emission under project activity ($PE_y$) is calculated and the value is 0.20486 $tCO_2e$/yr per household. The calculation is shown in table 5. The total GHG emission under project activity for the total 4000 household is calculated as 820 $tCO_2e$/yr.

*Table 5 : - GHG emission under project activity ($PE_y$).*

| City | $LF_{AD}$ | $B_o$ | VS | $D_{CH4}$ | $GWP_{CH4}$ | Average pig population for each household | Methane emission from each anaerobic digester |
|---|---|---|---|---|---|---|---|
| Unit | % | $M_3CH_4$/kg VS | kgVS/yr. | $Kg/m^3$ | $kgCO_2/kgCH_4$ | hd | $tCO_2e$/yr. |
| Dharan | 0.10 | 0.29 | 0.354 | 0.67 | 27.2 | 3 | 0.20486 |

After implementing the project of 4000 Biogas Digester in Dharan the reduction of GHG emission is calculated to be 7820.56 $tCO_2e$/yr./household. The total Calculation is shown in Table no 6 below.

*Table 6 : - Total GHG reduction by project activity.*

| City | Baseline GHG emission from each household | Project emission from each household | GHG emission reduction from each household | Expected number of biogas digester to be installed | Total GHG emission reduction by project activity |
|---|---|---|---|---|---|
| Unit | $tCO_2$ e/yr./household | $tCO_2$ e/yr./household | $tCO_2$ e/yr./household | Household | $tCO_2$ e/yr./h |
| Dharan | 2.160 | 0.20486 | 1.95514 | 4000 | 7820.56 |

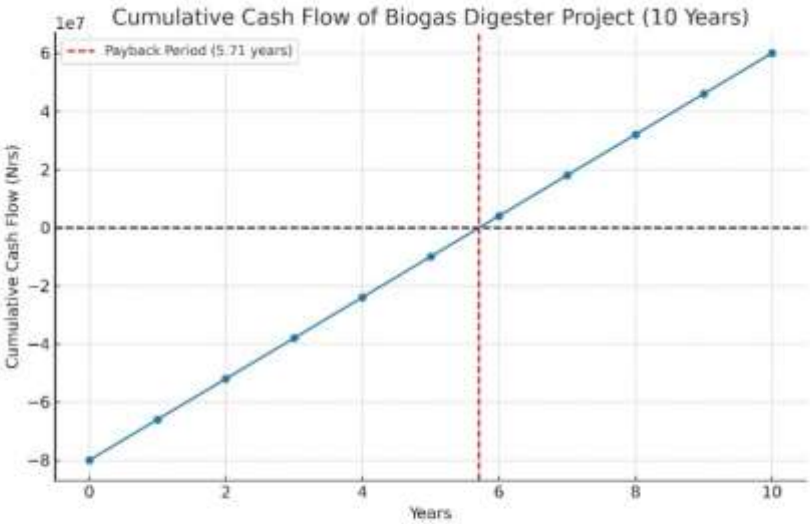


*Figure 3 : - Cumulative cash flow of the biogas digester project over 10 years, with the payback period marked at 5.71 years.*

The suggested biogas digester project is fairly sound in terms of financial feasibility as per the conventional markers. The Nrs. 80,000,000 installed capital cost would provide Nrs. 14,000,000 annual revenues through replacement of conventional fuels namely firewood, coal and LPG. This replacement does not only save monetary costs, but never makes us dependent on the non-renewable sources. The simple payback calculated to be 5.71 years shows that it will take the project a short operating time to repay the initial investment prompting the project to be more attractive to the investors. Moreover, the Internal Rate of Return (IRR) of 0.73 is higher than the discounted rate used assuming that the project is profitable. In a long run financial view, the potential returns (Nrs. 796,658,820) in terms of present value of benefits are exceedingly above the present value of costs (Nrs. 340,776,699). This implies that the project has a favorable net present value (NPV) of Nrs. 455,882,120 which indicates sound economic benefits when the time value of money is considered. The Benefit-Cost Ratio (B/C) is 2.34 which is above unity hence validating those benefits heavily outweigh the costs. This ratio simply means that, on every rupee invested in the project one earns above two returns. In sum, the findings demonstrate that the project on the biogas digester is economically viable and sustainable with pleasant returns, acceptable payback period, high benefit and cost ratio. These results attract the effect that the project has as a trustworthy clean energy source as well as saving resources and emissions.

## 4. Limitation and Future Recommendations

The household survey had to be conducted on only seven households out of the total 4000 households in the area of study; this was due to time constraints. On the one hand, the sample is useful, but on the other hand, it cannot help to take into consideration the variability and representativeness of the whole population. Future research ought to thus have a bigger and more representative sample to enhance reliability of the observation. A biogas digester in the study area costs between Nrs. 20,000-60, 000 as the size, design and differences in local markets impact the prices. As part of this analysis, we have taken the small-scale cost of a lower boundary of Nrs. 20,000 as initial investment. Such conservative assumption might count underside of the financial load of a few households. A range of future research positions should also include the complete range of costs and assess the economic feasibility for a variety of household incomes. Secondly, transportation fee and miscellaneous expenses connected with the field of study were not covered by the present research because of budget and time limitations. All these can play an important role in the total cost of implementation. It is suggested that in the future studies the following cost items be added in order to come up with a more geared projection on project feasibility. The limitation noted addresses these issues and thus in future studies a more accurate and comprehensive predictive assessments of conformity of economic and environmental impacts of household biogas digester benefits policies can be done.

## 5. Conclusion

This paper determines the environmental and economic impacts of biogas digesters used within the household of Dharan, Nepal. The baseline scenario showed that in every household, 2.160 $tCO_2e$ can be produced on the annual basis both in pig manure management and coal combustion. Emissions drop further by 70 percent to 0.20486 $tCO_2$ e per household per annum to a net figure of about 1.955 $tCO_2$ e once the digesters are installed. The total amount of emission cut calculated on the proposed 4,000 households lies at 7,820.56 $tCO_2e$/ year, which is an indication that the project contributes heavily to the mitigation of climate changes as well as enhancement of air quality. The financial feasibility was also validated in the economic analysis. Its installed capital cost is Nrs. 80,000,000 and the system is turning in annual revenues of Nrs. 14,000,000 by replacing firewood, coal, and LPG. The short simple payback period of 5.71 years is indicative of the fast recoup of the invested amount whereas the Internal Rate of Return (IRR) of 0.73 is more than the given discount rate of 0.60, which reaffirms its profitability. The long-term potential of the project is quite high as Net Present Value (NPV) of the project is Nrs. 455,882,120 with Nrs. 796,658,820 of benefits exceeding costs of Nrs. 340,776,699. The Benefit Cost Ratio (2.34) evidences the fact that each rupee invested returns more than two in benefits and fortifies evidence of its adoption.

To sum up, the project of a biogas digester in Dharan not only proves to be environmentally friendly but also appealing in terms of economics. It provides a flexible way of decreasing the amount of greenhouse gas emissions, improve energy security and lessen the use of non-renewable fuels. Such efforts should be expanded to help Nepal become sustainable and resilient in energy systems.

***Acknowledgement***

The authors owe their heartfelt gratitude to the locals of Dharan, the local people, who supported, cooperated and engaged with the study unendingly. The absence of reservations against sharing their information and practical experiences helped a great deal in increasing the accuracy and actuality of research findings.

**References**

Amon, B., Çinar, G., Anderl, M., Dragoni, F., Kleinberger-Pierer, M., & Hörtenhuber, S. (2021). Inventory reporting of livestock emissions: The impact of the IPCC 1996 and 2006 Guidelines. Environmental Research Letters, 16(7), 075001.

Bhattacharyya, S. C. (2011). The Clean Development Mechanism. In S. C. Bhattacharyya, *Energy Economics* (pp. 623–645). Springer London. https://doi.org/10.1007/978-0-85729-268-1_27

Cosbey, A., Parry, J. E., Browne, J., Babu, Y. D., Bhandari, P., Drexhage, J., & Murphy, D. (2005). Realizing the development dividend: Making the CDM work for developing countries. International Institute for Sustainable Development, 72.

Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). 2006 IPCC guidelines for national greenhouse gas inventories.

IPCC (2006) Emissions from livestock and manure management. In '2006 IPCC guidelines for national greenhouse gas inventories. Agriculture, forestry and other land use'. Vol. 4. pp. 10.1–10.87. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.htm [Verified 3 December 2007]

Kotsompolis, G., Konstantakis, K. N., Xidonas, P., Michaelides, P. G., & Thomakos, D. D. (2023). Climate change economics and the determinants of carbon emissions' futures returns: A regime-driven ARDL model. *Finance Research Letters*, *58*, 104485. https://doi.org/10.1016/j.frl.2023.104485

Matulaitis, R., Juškienė, V., & Juška, R. (2015). Measurement of methane production from pig and cattle manure in Lithuania. *Zemdirbyste-Agriculture*, *102*(1), 103–110. https://doi.org/10.13080/z-a.2015.102.013

Michaelowa, A., Stronzik, M., Eckermann, F., & Hunt, A. (2003). Transaction costs of the Kyoto Mechanisms. *Climate Policy*, *3*(3), 261–278. https://doi.org/10.3763/cpol.2003.0332

Naik, M. R., Singh, A., Unnikrishnan, S., & Naik, N. (2014). Role of the Clean Development Mechanism (Cdm) in the Development of National Energy Industries. *Energy & Environment*, *25*(2), 325–342. https://doi.org/10.1260/0958-305X.25.2.325

Ruane, A. C. (2024). Synthesis report of the IPCC sixth assessment report (AR6).

Silayan, A. (2005). *Equitable Distribution of CDM Projects Among Developing Countries*. https://doi.org/10.22004/AG.ECON.26098

Singh, G., Verma, S., & Baredar, P. (2019). A Review on Performance of Biogas Stove From Different Design of Burner. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3442426

Stern, N. (2008). The Economics of Climate Change. *American Economic Review*, *98*(2), 1–37. https://doi.org/10.1257/aer.98.2.1

UNFCCC. (1998). The Kyoto Protocol to the United Nations Framework Convention on Climate Change. [Online] Avaliable: http://unfccc.int/resource/docs/convkp/kpeng.pdf. (2 August 2010)