# Whose Development Counts? Adoption of Biogas in the Rural Communities of India- A Review

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**Abstract-** In developing countries like India, biogas technology is a clean and sustainable renewable energy for rural people. The Government of India encourages and supports disadvantaged groups of people in rural areas by launching various schemes to construct biogas plants to fulfil their energy needs and reduce energy poverty at a very low cost. Caste-based inequalities are one of the major social factors, especially in rural areas leading to low biogas utilization. This paper highlights the Indian scenario with 2000 households from the various districts of West Bengal, exploring the caste-based inequalities over the access of utilization of biogas plants. Analysis was performed on the access and utilization of biogas by different castes. The results demonstrate that the general caste households have adopted 60% of biogas plant and have controlled over the biogas than the marginalized or underprivileged caste of the society. The study found that needy and disadvantaged groups are deprived for several socio-economic barriers of the access and utilization of biogas due to a lack of consideration of caste inequalities. The households belonging to scheduled caste and scheduled tribe communities have poorer access to biogas energy than the general caste. The higher caste people benefitted more by accessing biogas energy, whereas lower caste people still lack access to modern energy like biogas. It also exposes that caste inequalities still dominate the access to modern energy in the society of developing countries.

**Keywords** Caste, underprivileged or marginalized, social group, inequalities, biogas.

## 1. Introduction

Energy is one of the essential requirements for the development of any nation. Energy plays a fundamental role in sustained and inclusive growth, which is highly correlated between development and energy consumption [1], [2]. UN report of 2017 projected that India is the 2nd largest population in the world and also the fastest growing population country and will overtake China by 2027. According to International Energy Agency (IEA) statistics stated that India is the 3rd biggest electricity consumer globally, and per capita, energy consumption is 106th positions in 2017, which is one-third of the world's energy consumption [3], [4]. According to the world resource institute report 2017, globally India ranked 4th;

responsible for nearly 6.65% of total global carbon emissions in the world [5]. The emissions from burning fossil fuels are the main factor of increasing energy crisis and greenhouse gas leading to global warming [6]. Biogas technology is a very cheap alternative energy and can reduce environmental problems such as soil degradation, deforestation, $CO_2$ emissions, and indoor air pollution. This will be helping the rural people by providing cooking fuel and improving living conditions and health benefits of the people [7].

Biogas is vital renewable energy, reducing the demand and cost of fossil fuels and reducing greenhouse gas emissions. Biogas is renewable energy resulting from the biological breakdown of organic components like leaf, human, and animal excreta and biodegradable waste in a biogas plant, [8]. A biogas plant generates 50-70% of methane gas with 24-44% of $CO_2$ that can be used as cooking fuel and generates electricity [9], [10]. It also generates byproducts as output from that biogas plant called 'slurry', one of the good quality organic fertilizers; it can increase crop and soil quality [11].

Sustainable development can ensure access to affordable, reliable, and modern energy for people through sustainable energy. In a developing country like India, rural people face many problems regarding accessing modern and clean sustainable energy. The service of supply sustainable, affordable and reliable clean energy source is one of the emerging priorities for developing country including India, to promote energy security [2]. The Government of India, with the fulfilment of the objective of SDG-7, "Ensure access to affordable, reliable, sustainable and modern energy", is to provide energy security towards people [12], [13]. The Government of India has taken several policy initiatives towards the disadvantages of the social group to access sustainable, reliable, modern, and clean energy towards rural people. Improvement of access to energy services can play a significant role in health improvement, poverty reduction, economic growth promotion, and social inequality following gender and caste [2], [9]. In many developing countries like South Africa, India; the Government felt the need for renewable energy to promote social equality [14]. The significant barriers to sustainable development are social inequalities that block rapid economic development from access to clean and modern energy technologies [4]. In India, social stratifications play a dominant role in distributing social opportunities and resources. Generally, the scheduled caste (SC) and scheduled tribe (ST) populations are considered deprived and backward classes due to economic and social discrimination. At the same time, the Government has encouraged and provided support to those groups of people by launching various schemes for their socio-economic development, like policies to adopt biogas plants. This paper discusses the problems associated with adopting biogas among disadvantaged communities, i.e. scheduled caste.

## 2. Energy Access Scenario of India

According to Soubghya Dashboard, Govt of India (2019), almost 99% of households have electricity connections [15], whereas only 65% of rural people are covered under governmental electrification schemes. According to Ministry of New and Renewable Energy (MNRE, 2017), almost 70% of the population depends on traditional biomass and 32% of primary energy is derived from the traditional biomass of India [16]–[18]. According to World Bioenergy Association (WBA) statistics of 2016, globally, India is the 2$^{nd}$ largest country using biomass after China [19]–[21]. According to the NSSO report of 66$^{th}$ round, 76% of rural households use traditional biomass, 15% use LPG as their primary energy source, and very few use biogas for cooking energy. A recent study conducted by Council on Energy, Environment And Water (CEEW) observed that 54% of households still use traditional biomass along with LPG connection because of the high cost of refilling [22]. According to the IEA report of 2020, more than 2.6 billion are still dependent on solid biomass fuels (like fuelwood, crop residues, charcoal, coal, and dung cake) for cooking [15], [23], [24]. According to World Energy Outlook (WEO), a 2017 report indicate that almost 770 million populations still do not have access to electricity [15], [25]. Globally it is estimated that over two-thirds (772 million) of countries population still use traditional biomass for cooking which is accounted for 30% of total global biomass users [26], [27]. Globally, India is the largest producer of fuelwood, about 307 million tons in 2015 [19].

However, biogas can potentially reduce the use of firewood and promote the regeneration of degraded forests [28]–[30].

## 3. Caste System in India

The Indian caste system is very complex and one of the oldest forms of social stratification. In India, social stratification begins with the social group. The caste system is one of the oldest social institutions, which gives a distinct identity and structure to Indian society [31]. Caste is a social stratification that is exclusive and exhaustive; still, it is prevalent in Hindu societies worldwide [32]. Its roots are based on the theological model of Hindu scriptures from the ancient period, classified into four hierarchically ranked castes called *Varna's*. They were identified and classified according to their occupation in their society. The *Brahmin's*, are usually nominated as priests and scholars who are the hierarchically top of society based on caste [33]. Next are *Kshatriyas*, who are mainly warriors and rulers. They are followed by the *Vaishya*, who are the merchants or traders. Lastly, *Sudras* are considered the lower group of society and their main occupation is to serve the upper caste people. Sudras are generally known as 'Untouchables' in society. Besides these four Varnas, the fifth category of people was considered tribal [33], [34], native or aboriginal people.

Caste is pre-set hierarchical social identities determined by birth and categories through occupations. In modern India, caste describes as *Jati* or *Varnas*. After Independence, the constitutions of India abolished the practice of untouchability and identified *Sudras* as 'Scheduled Castes' (SC). Apart from the scheduled caste, many of the population lived in forests, mountains far away from the main populations called *Adivasi* or Tribes. Indian Government constitutionally recognizes them as 'Scheduled Tribes' (ST) [34]. Traditionally these are the two groups that were the most deprived in the society. The *Brahmins* and *Kshatriyas* have traditionally enjoyed the advantages of high status and esteem those who are referred to as the 'general caste'. Besides the top three castes (*Brahmin*, *Kshatriya* and *Vaishya*), the Indian Government also recognized other backward Classes (OBC) classified as socially and educationally disadvantaged groups of people compared to the general caste, but they are vastly heterogeneous and have a high range of backwardness. Thus the Indian societal structure seems a pyramid based on caste hierarchically, representing that general caste are top of the society followed by other backward classes (OBC), and the SCs and STs are the bottoms of this pyramid [35]–[40].

According to the census 2011 of India, 121 crore people lived in the country [41]. At the same time, 83.3 crores (68.86%) people and 37.7 crores (31.14%) live in rural and urban areas, respectively [42], [43]. The number of literate people in India is 778.5 million (73%) (Rural areas 493 million about 67.8% and urban areas 285.4 million about 84.1% people) [44]. Presently the number of villages in India is about 6.4 lakh [45]–[47]. The Scheduled Caste and Scheduled Tribe population is 16.5% and 8.6% respectively of the total countries population in India [48]. According to the Ministry of Social Justice & Empowerment report, almost 76% Scheduled caste and 90% Scheduled Tribes people lived in rural areas of India [49], [50]. As per census 2011, it is estimated that 1284 and 757 groups of people were notified as Scheduled Caste (SC) and Scheduled tribe (ST) respectively among all over India.

## 4. The Emergence of Biogas Technology In India

Biogas is a sustainable, renewable, and environmentally friendly source of energy which is an excellent opportunity for us to reduce greenhouse gas and deforestation to save the planet from the current climate-change situation [58]. Biogas technology is considered economically and technically affordable and accessible among poor people of rural areas, providing clean energy and improving agricultural activity [2]. Biogas technology is one of the alternative vehicles to reduce rural poverty and meet the energy needs of rural people of India [53]. In India, according to census 2011, nearly 70% of the population lives in rural areas [28], [54], [55]; those who primarily depend on firewood and chips as their primary source of cooking fuel around 67.3% [56].

Biogas technology in India has a long historical experiment on digesters. Biogas in India was introduced in the early 1930s for research on sewage purification at Mumbai undertaken by Prof. N.V. Joshi of Indian Agriculture Research Institute (IARI), New Delhi [57], [58]. But the plants were costly, and they could not supply enough gas for a small family [59]. Then after a few years, Jashbhai Patel developed, designed and made small scale biogas for the farmers. The design was adopted and promoted nationwide by Khadi and Village Industry Commission (KVIC) in 1961 called Gramalakshmi. The first family type is the floating Dome biogas plant in rural India [27], [60], [61]. The Planning Research and Action Division (PRAD) took more initiatives by establishing a research station at Ajitmal in Uttar Pradesh, known as Gobor Gas research Centre, in 1977. They developed the Janata Fixed Dome plant model, which is similar to China. It is well designed with maximum gas pressure and outlet of the slurry system. This plant is 30% cheaper to construct and maintain as compere to KVIC floating Dome Model [62]–[64]. The Indians cannot adopt the model because, during that time, the relationship between China and India is not cordial. So the Indian Government felt the need for biogas technology as an alternative energy source that could be beneficial for the rural people to solve the energy crisis [65], [66]. So, the Janta model was introduced in 1978. This model failed to provide rural people service [67]. It had some disadvantages like a short circulating path of outlet for slurry, production of less amount of gas due to the undigested slurry [68]. The Government of India felt the need for biogas energy and launched National Project on Biogas Development (NPBD) under the 6$^{th}$ five-year plan in 1981; it was the first national policy for promoting biogas plants [69], [70]. The Department of Non-Conventional Energy Source (DNES) undertook the programme, established in 1981 under the Ministry of Power [71], [72]. In 1984 AFPRO developed the fixed dome biogas design called the Deenbandhu model approved by NPBD in 1986 [63], [73]. It was more crack-proof and consumed less material for construction than the Janta Model [74], which is 30% cheaper than the Janata biogas model and 45% cheaper than KVIC floating dome model [75]. During this time, the Deeenbandhu model became popularised toward the rural people in India. In the Himalayans regions, this model becomes ideal because of the underground digestion chamber, providing good biogas during colder climates. The energy-using pattern in hilly areas is an average of 1.49 kg fuelwood per capita per day [76]. The demand for fuelwood of tribal communities is five times higher [77]. In hilly regions, 90% of rural households use firewood for cooking [78], [79]. In 1992, Department of Non-conventional Energy Sources (DNES) transformed into Ministry for Non-conventional Energy Source (MNES) [80]–[82]. MNES took many initiatives to develop access energy in rural areas like improved Chullas extension, biogas research and development, hydro and solar photovoltaic power through various nodal agencies such as IREDA (Indian Renewable Energy Development Agency) [81]. The National Project on Biogas Development (NPBD) was renamed National Biogas and Manure Management Programme (NBMMP) in 2003. This programme is a Central Financial Assistance (CFA) for ensuring subsidies for the construction of family type biogas plants [54], [83]. During the twelfth five year plan (2012-2017), the Government of India set a target to set up 6.5 lakh biogas plants under the National Biogas and Manure Management Program (NBMMP) project across the nations [29], [58], [84]–[86]. The installation of these biogas plants could produce per day 1-6 meters of biogas and 4745 lakh cubic meter biogas generated annually [3], [87].

These projects (NBMMP) are carried out by the State Nodal Department and Agencies (such as WBREDA), Energy Development Agency at the state level. At the district level, Khadi and Village Industries Commissions (KVIC), and Biogas Development and Training Centre's (BDTCs), District Rural Development Agency (DRDA) collaboratively work with the Government and in the ground level Panchayet, Agents and NGOs implementing the biogas plant towards the rural households [88]. The NBMMP provides family types of biogas plants mainly for rural households. The schemes provide capital subsidies up to 5500 rupees and 7000 rupees for the general category and SC/ST category, respectively, to set up one cubic meter biogas plant. Whereas for setting up 2-6 cubic meter biogas plant subsidies are given 9000 rupees for

general caste and 11000 rupees SC/ST categories, respectively. The main objective is to provide clean and cheap cooking fuel by reducing the use of traditional biomass and LPG for financially assisting the poor people and increasing the use of biofertilizer to reduce chemical fertilizer.

## 5. India's Biogas Scenario: Reality and Potential

According to the estimation of the Government, India is the 4th worldwide largest country for renewable energy installation capacity [89]. India efforts to increase renewable energy capacity from 42,489 MW to 175000 MW by 2022 [90]–[92]. India has set up the 2nd largest number of bio-gas plants after China [93]. According to a recent estimation of the MNRE Government of India, the total number of biogas plants installed in India was around 47.5 lakh till March 31, 2014 [5], [94]–[99]. Less than 1% of households in India use biogas for cooking [100]. During the 12th five year plan, MNRE estimated that 3.22 lakh plants would have been installed by December 2015 [91], [101]. It will generate about 6.46 Lakh cubic meter biogas per day [102], an equivalent of 70.90 lakh LPG cylinders, 8.20 lakh tonnes of firewood that can reduce 615000 tons of $CO_2$ annually [10]. However, the NSSO report shows that biogas plants have increased from 0.20% in 2000-2001 to 0.25% in 2012-13 [103]. According to Mr Piyush Goyal, Ministry in charge of New and Renewable Energy in 2015 reported that about 20,700 lakh cubic meters of biogas are produced in India, equivalent to 5% of total LPG consumption during the year 2014-15 [3], [104], [105]. It was estimated that the total annual production of biogas is about 40734 $mm^3$ by other organic waste in India. India can install about 12 million household type biogas plants [8] whereas about 4.75 million, which is 40% of the total potential of biogas plants established in the year 2015, which has increased by 1.27 million in 1990 [106]. Biogas can generate 17000 MW powers which are about 10% of the country's energy requirement [107], [108]. If India achieves the target to install 12 million family sizes biogas plant, it will reduce about 120 million $CO_2$ every year [92], [109], [110], which will be able to produce 8.75 billion cubic meters of biogas, and generate 11.67 GWh renewable energy for India by 2022 [92].

According to the report of MNRE, 2017 estimated that 49.6 Lakh Biogas plants have been constructed against the potential of 2.1 crore biogas plant by March 2017 [10]. The Comptroller and Auditor General of India or CAG (2015) evaluated 429 NBMMP systems across 13 states and highlighted that 74% of installed biogas plants were functioning [111]. While biogas offers a great opportunity of accessing clean energy with minimum cost, the MNRE reported that only 55% target had been archived by NBMMP for 2016-17 [112], awareness and satisfaction of using biogas plant is the central to sustained use of biogas plants as per the report of ACCESS, only 36% of households surveyed aware of biogas as cooking fuel. The study also revealed that almost 50% of biogas users are satisfied with their plants [16], [29], [112], [113]. In India, biogas production is estimated at 20,757 lakhs cubic meters in 2014-15 [114], [115]. It is equivalent to 6.6 crores domestic LPG cylinders [59], [116]. The average cost of a two cubic meter Biogas plant is about Rs. 17,000, which will be accounted for 10000 by government subsidies under NBMMP (MNRE, 2009). The cost is 6.25% of the annual household's income of 1,60,000 rupees [88], [92].

Biogas is used as cooking fuel; it is very economical and convenient. One cubic meter ($1m^3$) of biogas energy is equivalent to 1.1 liters of gasoline, 1.7 liters of bioethanol and 0.97 $m^3$ Natural gas [74], [98], [117]–[120], equivalent to about 4700 kcal energy [75], [121], [122]. It is also equal to lighting 60-100 watt bulb for 6 hours or cooking three meals per day for 5-6 persons [123], [124]. However, a 2 $m^3$ biogas plant would be the appropriate size for family types biogas plants to fulfil the daily energy requirement of 8 members of the family, which is monthly equivalent to 740 kg animal dung, 37 litres of kerosene or 88 kg of charcoal, 210 kg Fuelwood, and 26 kg LPG which is about two standers of cylinders save (700/cylinders x 2pc = 1400/month x 12 months) Rs 16800 annually [10], [104], [125], [126]. A family type biogas plant can mitigate global warming by an estimated 9.7 tons $CO_2$ equivalent [39]. Biogas technology is very effective in rural areas to enhance energy requirements at a low price [127].

## 6. West Bengal Biogas Potential and Scenario

West Bengal is the second-highest rural biogas density in India [128], [129]. West Bengal Renewable Energy Development Agency (WBREDA) is the state nodal agency established in 1993 to promote and improve renewable energy in West Bengal [129]. Santanu Basu, Director in Charge of WBREDA, stated that the MNRE, Government of India, aims to install 175 GW of grid-connected renewable energy by 2022 [130]–[132]. WBREDA targeted to install 18000 numbers of domestic types of biogas plants in West Bengal by 2011-12 [133], whereas approximately 11000 biogas plants were installed by December 2011. West Bengal can install an estimated 695000 no of family type's biogas plant of which the NPBD programme installed 355960 biogas plants till 2016 (Fig. 1). The annual growth rate of the family type biogas plant was 5.95% in West Bengal, which is higher than the country's annual growth rate of 3.3% during 2011-12 [133]. The Agency for Non-Conventional Energy and Rural Technology (ANERT) collaboratively works with MNRE to set up 1100 biogas plants with particular consideration for the households of Scheduled Caste (SC) and Scheduled tribes (ST) in the district of Kolkata, West Bengal.

West Bengal is the top cattle population, followed by Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra. The biogas plant is most popular and technically known for digesting animal waste [106]. The animal dung yield per cattle is about 4.5 kg/day, and a buffalo is about 10.2 kg/day [106], [134], [135]. Cow dung generated from 3-5 cattle is 9-15 kg dung/day [116], [136], which can run 8-10 $m^3$ biogas plant, it will produce 1.5-2 $m^3$ biogas per day, that can be sufficient for 2-3 times cooking for 6-8 persons [116]. It is estimated that 7818.24 MT dung will be produced annually, generating biogas about 15083 $mm^3$ annually [106]. It also generates 13.87 metric tons of organic fertilizer per year, used as bio-fertilizer [116], [137].

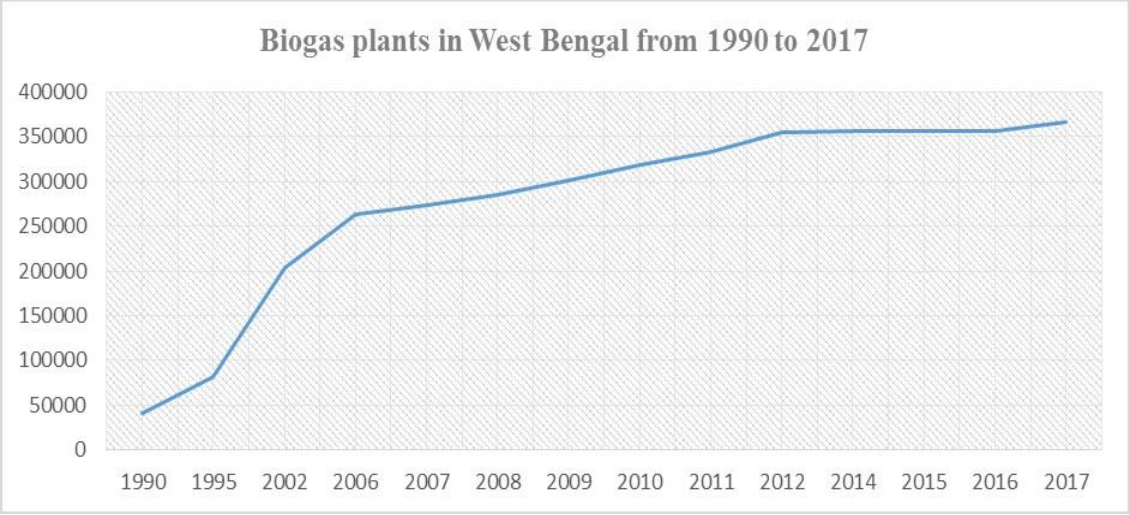


**Fig 1**: Distribution of biogas plants in West Bengal from the period 1990 to 2017 [79]

According to the livestock census 2019 of GoI, West Bengal is the fourth highest livestock population of 37.4 million in India, of which the cattle population was about 19 million. The higher availability of cow dung cakes is becoming extensively used along with firewood in West Bengal in rural areas, about 102 kg/month than 64 kg/month in urban areas. Cooch Behar (170 kg/month) and Murshidabad (147 kg/month) consume the highest cow dung cake from all districts of West Bengal. According to the latest NSSO 72 round, 42.8% of people have LPG connections in rural areas of West Bengal. Saubhagya scheme of the Government of India (GoI) reported that West Bengal had already achieved 100 per cent village electrification by 2017. Petroleum Planning and Analysis Cell (PPAC) in 2016 estimated that per capita electricity consumption was increased from 515 kW·h in 2010 to 660 kW·h in 2016 with a 4.24% annual average rate

of West Bengal. Biomass use is highest (125 kg/month), about 63% to cook in West Bengal. Rural households use biomass about 35.7% due to its higher availability in rural areas. Districts located in forest areas with a high tribal population such as Cooch Behar, Jalpaiguri have reported high rates of firewood consumption, about 150 kg/month for cooking. Biomass used as fuel over 90% of households in CoochBehar, Murshidabad (201 kg/month) and East Medinipur (137 kg/month) of West Bengal due to large family, low income and available biomass from forest and agricultural land is plenty.

## 7. Role Of Caste Inequality in Energy Access in India

Structural inequalities and discriminations are the key factor of the caste system in society. Social stratification, according to caste, determines social hierarchy and people's access to fundamental human rights. Inequality and discrimination are central to the agenda of SDG 2030 "emphasis equality of opportunity and reducing inequality of outcomes, the elimination of discriminations in law, policy and social practice and socio-economic inclusion of all under the banner goal to leave nobody behind'' [138]. Many international human rights organizations proposed that worldwide 260 million people suffer from discrimination based on caste, which is around 25% of the world's population and 17% of the SC population of India [139]–[141]. India is the largest population of scheduled caste in the world. Now the constitution of India formally termed Dalits as scheduled caste; over 76.4% of SC lives in rural areas while 23.6% of SC lives in urban areas [142]. The upper caste, like the general caste and the lower caste, like disadvantaged groups of society like SC and ST, participate as wages labourers in the economy (Mosse, 2018). V. Saxena highlights in his research that lower caste (SC) and tribal households have 10-30% of less access to electricity and clean cooking fuel energy [143]. According to Census 2011, The Scheduled caste and Scheduled Tribes comprise about 17% and 9%, respectively, from the Hindu group of the Indian population. Muslims in India comprises about 14% of the Indian population. These social groups are still belonging the lowest level of social scale from energy deprived people of India. As per NSSO initial research conducted by V.Saxena in 2017, the households belonging from upper caste have access to LPG 55%, which is a far difference among the three disadvantaged social groups of Muslims households 45% Scheduled Caste 39% and Scheduled Tribes 34% households [143]. This highlights that upper caste people have better LPG access than SC, ST and Muslim households.

According to WHO, 2018 reported that globally, 1.3 million people in India die prematurely from indoor air pollution because of lack of access to modern energy. The dependency rate of solid fuel is higher in rural areas with 72.22% than 21.43% in urban areas [144]. Households belonging from socially and economically marginalized & disadvantaged groups of society are more dependent on solid fuels for cooking, like Scheduled Caste (SC) 64% and Scheduled Tribe (ST) 71% [144]. Similarly, those households where solid fuel is used as a primary source of cooking, like Scheduled Caste (SC) and Scheduled Tribe (ST), they are a chance of suffering 17-60% more from various respiratory diseases [144]. So the Government provided subsidies for the disadvantaged groups of people for widely used clean cooking fuel is Liquefied Petroleum Gas (LPG) by launching Pradhan Mantri Ujjwala Yojana (PMUY) in 2016 and distributed 8 million LPG connections to the poor women at free of cost (CAG report, 2019) with aimed to safeguard the health of women and children of the country. Council on Energy, Environment and Water (CEEW) estimated that about 94% of Indian households would have LPG connections by April 2019 [145]. As per National Family Health Survey-5 (NFHS-5), only 23% of rural households used LPG as primary cooking fuel. But the illegal and informal uses and high cost of LPG by the advantages group often prioritize the distribution of cylinders for the economic purpose of black marketing[143]. As a result, only 48.3% of rural households have access to LPG in rural areas as per The of 76$^{th}$ round report NSSO [146], [147]. There is a lack of demand for LPG due to the high cost, huge availability with free of cost of biomass, which is the problem encountered by the marginalized groups of people [78], [148]. The solution to this problem is that the Government should

focus on renewable energy like biogas technology can be used as an alternative source of energy access, which will be affordable and accessible for the poorer people in rural India. Basically, in rural areas of India, SC and ST people are do not live together with the other communities of the villages. The SC residence will be away from the village, while ST villages are in the forest or remote areas that will be very far from the main village, making it difficult to access electricity and gas supply [17], [18]. Equal energy access is essential determinants of human capital. Suppose the Government wants to develop culturally and economically, then it must reduce inequality to access safe cooking fuel and electricity among all social groups. To reduce inequality, government policies must pay attention to the disadvantaged and marginalized populations.

Many studies related to biogas adoption and utilization have been done in India. Still, very few research has been taken place on the energy consumption inequality based on caste. At the same time, none of the research dwelled on the impact of caste on biogas adoption in rural areas. The adoption of biogas technology differs and vary based on the different social group in other regions. This article aims to present the caste factor in adopting and utilizing biogas technology at the community level of rural West Bengal in India and discuss the variables influencing the adoption of biogas technology. The goal is to highlight and discuss the impact of caste inequalities among different social groups on promoting biogas adoption to strengthen access to sustainable energy in rural Bengal.

## 8. Study Area and Methodology

West Bengal is an agricultural based state in India. It is the fourth most populous state. The state of West Bengal covers 88,752 $m^2$/km, which is 2.7% of the geographical area of India. The state has 19 districts. Among 12 districts are tribal districts, and one is a hill district. West Bengal is the third-highest population living in rural areas of India. According to the 2011 census, the population of West Bengal is 91.28 million, and the proportionate rural and urban population constitutes 6.21 million (68.13%) and 2.91 million (31.87%), respectively. The Scheduled Caste and Scheduled Tribe population is 27.5% and 7.8%, respectively, in West Bengal. West Bengal is the second-highest number of scheduled caste populations in India, about 23% all over West Bengal. It is estimated that 60 and 40 groups of people were notified as Scheduled Caste (SC) and scheduled tribe (ST) respectively among all over West Bengal.

The present data used in this paper is a large scale representative of rural areas from districts of West Bengal. The article focuses on biogas adoption among the rural areas of fifteen various districts from West Bengal of Eastern India. Every biogas plant size is two cubic meters, fixed dome Deenbandhu Models installed by KVIC in all districts. Since it is impossible to study the entire population, secondary data was collected through KVIC of West Bengal from 2009 to 2011. The initial research was carried out in 15 districts of West Bengal with 2000 households as sample constructed biogas from 2009, 2010 and 2011. The households are mainly caste-wise social stratified into four social groups as per the GoI constitutions: General, Scheduled Caste, Scheduled Tribe, and Minorities.

## 9. Result And Discussion

### *9.1. The Pattern of District Wise Biogas Plants in West Bengal*

Livestocks manuare are one of the main organic wastes and it was the best feedstock for biogas production [149]. Among all the livestock waste, cattle and buffalo dung are mainly and widely used as feedstock for Biogas in rural India. But in India, people mainly use cow dung as direct burning cooking fuel in rural and urban areas [116], [126]. The conversation of 25 kg fresh dung to biogas yields 55% efficiency rate that is much higher than direct burning, about 10% [92].

**Table 1**: distribution of biogas plant in districts of West Bengal

| Districts | Rural Households (In Lakh) | Rural Cattle 2019 (In Lakh) | Per Household Cattle Population | Biogas Plants | Biogas plants ( Per Lakh/ households) |
|---|---|---|---|---|---|
| North 24 Parganas | 9.9 | 6.50 | 0.65 | 175 | 17.7 |
| Bankura | 7 | 5.18 | 0.74 | 70 | 10.0 |
| Burdwan | 10.71 | 14.83 | 1.38 | 132 | 12.3 |
| Birbum | 7.15 | 11.69 | 1.64 | 237 | 33.1 |
| Medinipur East | 9.88 | 10.56 | 1.07 | 40 | 4.0 |
| Hoogly | 7.81 | 8.65 | 1.11 | 152 | 19.5 |
| Howrah | 3.91 | 2.18 | 0.56 | 57 | 14.6 |
| Jalpaiguri | 6.25 | 7.19 | 1.15 | 335 | 53.6 |
| Malda | 7.34 | 10.33 | 1.41 | 47 | 6.4 |
| Mursidabad | 12.86 | 11.67 | 0.91 | 214 | 16.6 |
| Nadia | 8.8 | 7.93 | 0.90 | 321 | 36.5 |
| Purulia | 4.95 | 9.08 | 1.83 | 68 | 13.7 |
| Uttar Dinajpur | 5.32 | 10.72 | 2.01 | 2 | 0.4 |
| Medinipur West | 11.42 | 16.97 | 1.49 | 35 | 3.1 |
| Darjeeling | 2.36 | 1.99 | 0.84 | 115 | 48.7 |
| Total | 115.66 | 135.47 | 1.17 | 2000 | 17.29 |

Source: 20th Livestock Census as on October, 2019 http://www.darahwb.org/stasticstics_census.php;

Livestock plays a crucial role in Indian society. According to UN-FAO, the world has 1.4 billion cattle [150]. According to the 20$^{th}$ livestock census 2012, India is the highest livestock population, about 535.78 million [151]–[155] Uttar Pradesh is the highest livestock population with 67.8 million, followed by Rajasthan (57.7 million), Madhya Pradesh (36.3 million) and West Bengal (30.3 million) [153]. About 20.5 million people depend on livestock in India, which provides two third livelihood opportunities for rural communities [156]–[158]. The cattle estimated around 191 million, which is 36% of total livestock in the country followed by goats accounted 28% around 135 million, buffaloes accounted 20.45% about 109 million, sheep accounted 14% about 65 million and the pig is significantly less accounted 1.7% about 10 million livestock population India [153]. Table 1, it can be observed that almost every district except Uttar Dinajpur has benefited through biogas facilities in rural areas of West Bengal. Jalpaiguri district is the highest 335 households using biogas, followed by Nadia 321 households, Birbhum 237 households. The lowest number of biogas users district in Uttar Dinajpur just two households followed by Medinipur West 35 household and Medinipur East 40 households. Table 1 shows that Uttar Dinajpur is the highest because eevergy households have more than 2 cattle and the second highest is purulia where evergy households have 1.83 cattle population on the other side it stated that Jalpaiguri district is the highest followed by Darjeeling and Birbhum interms of per households bogas adoption since 2009 to 2011 financial year.

*9.2. Yearly Adoption of Biogas Plants in West Bengal*

Ministry of New and Renewable Energy (MNRE) launched Biogas Distributed/Grid Power Generation Programme (BGPG) in 2006 to produce electricity by biogas

plants. The main objectives of this programme is aim to developed at community and village level organization or institution to produce electricity and sold to the village

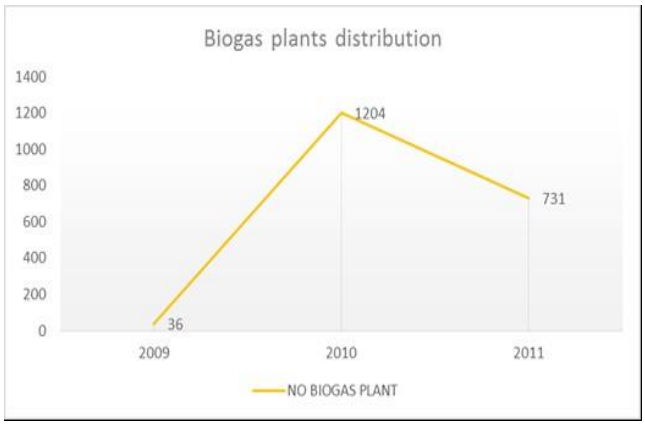


**Fig 2**: Yearly adoption of biogas plant in West Bengal

people at a minimum value[159]. The MNRE report shows that during that time 73 projects are ongoing with total capacity of 461 kW. S. Hazra in his study conducted in Bangladesh find out that lower rate of electricity use is significantly negatively associated with the ownership of working biogas plant[26]. This schemes helps to people converted to the faith on the renewable energy source. In 2nd December 2009, MNRE launched National Biomass Cookstove Programme (NBCP) implemented in the 12th Five year Plan. The programme aims to enhance the use of improved cookstove and switching towards the modern energy access for domestic cooking. The prommmage helps the people to moving from use of traditional fuel to modern fuel. The Improved biomass cookstove directly benefitted towards the weaker and vulnerable people of the society. Similarly Biogas stove also perform better to enhance the efficiency around 50%. So during that time the adoption of biogas plant is also increased side by side due to emphasis on the access of modern fuel. Fig. 2, it can be observed that there was slide increase in biogas adoption from 2009 to 2010 and slide decrease in 2011. Because the reason behind the access of biogas adoption is totally is the time era to moving towards the modern energy source. The government also takes several indicatives to moving forward the changing pattern of access of cooking pattern.

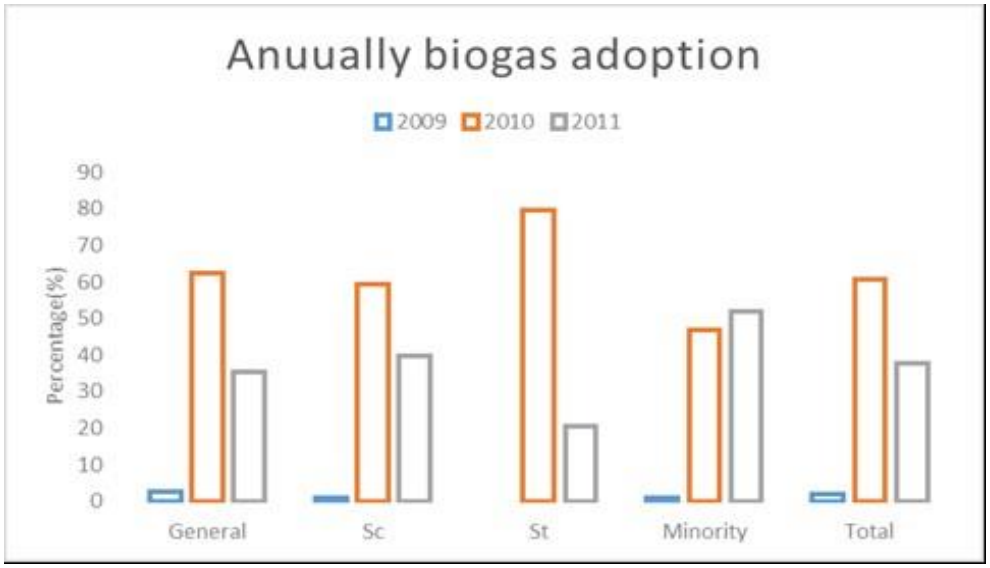


**Fig 3**: Caste wise adoption of biogas plants every year

*9.3. Caste Wise Distribution of Biogas Plant Annually*

Households from Scheduled Caste and Scheduled Tribes are still deprived of LPG access and lower electricity consumption than upper-caste households, especially in rural areas [143]. Fig 3, It can be noted that most of the biogas plants were adopted in 2011. The general caste has adopted every year biogas plant. Besides that other three social groups mainly adopted biogas in the year 2011. ST groups of households are the lowest in the case of adopting biogas plants every year. The 'SC' group of households adopts biogas plants more or less every year except the year 2009 after general caste. In 2011, minority community households adopted more biogas plants than in 2010.

Fig 4 represents the percentages of caste wise adoption of a biogas plant in the rural areas of various districts of West Bengal. The study revealed that 60% of General category households adopted biogas facilities. 27% of households from the SC category and 10% from the minority community adopted biogas plants. The ST community households adopted the lowest number of biogas plants viz. 3%. The study finds that the needy and poor people still depend on traditional biomass and lack access to modern energy. It shows in that most disadvantaged case to access the biogas plant; upper-caste still dominates them for social inequalities. The graph shows that caste inequalities are the factor of accessing modern energy towards disadvantaged people.

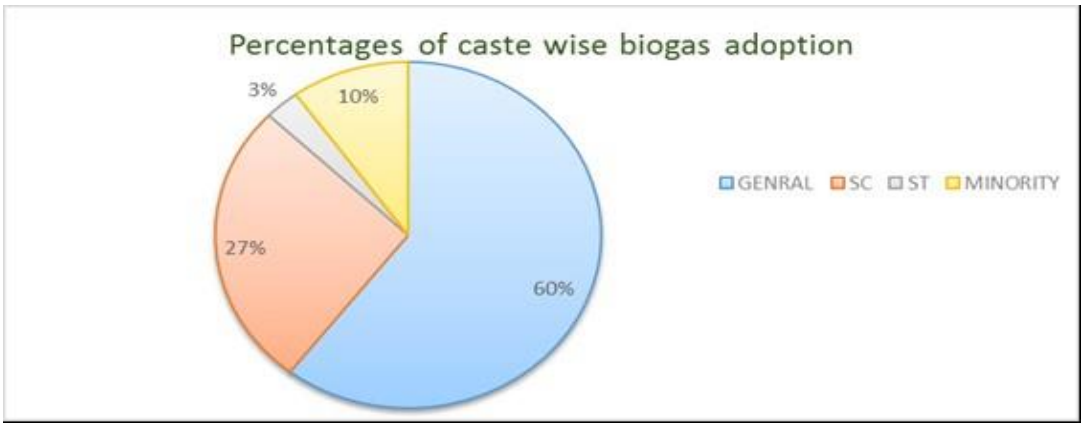


**Fig 4**: Percentages biogas adoption plants by different social groups

*9.4. Proportion of Biogas Plants Adoption Among Caste in West Bengal*

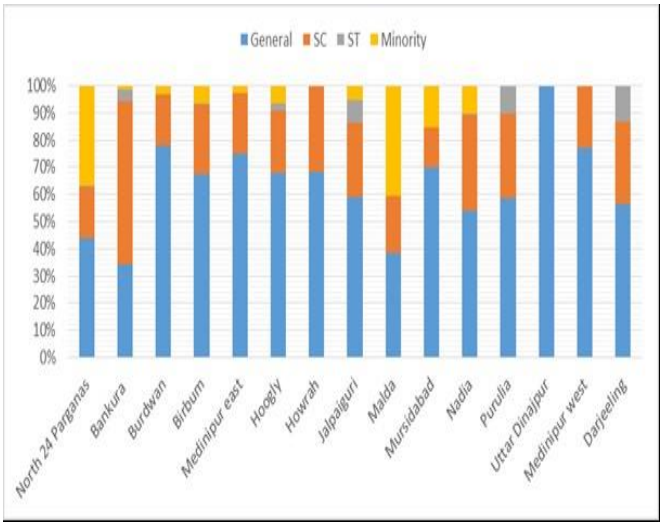


**Fig 5**: Caste wise percentage of biogas adoption in different districts of West Bengal

Fig 5 illustrates that in 2009-2011, most households belonging from general categories in all the districts adopted over 50% biogas plants except Bankura, Malda, and North 24 Parganas. Besides that, Bankura district is the highest, about 60% of households adopted biogas plant by Scheduled Caste community followed by Nadia (35%), Purulia (31%). Scheduled Tribes groups of communities lowest in case of adopting biogas plants, whereas Darjeeling is the highest with about 14% of the population adopting biogas plant, followed by Purulia (10%). Lastly, Nadia is the highest percentage (40%) of the minorities' communities adopting biogas plants, followed by North 24 Parganas, Murshidabad district. There were some barriers influencing the biogas adoption mostly for the lower caste people.

*9.5. Barriers For Biogas Adoption*

Historically, caste based discrimination has widely experienced distributed among rural India households. Scheduled Caste (SC) and Scheduled Tribe (ST) people mostly known as social and economic disadvantage and marginalized groups of the society in India. Other backwards caste (OBCs) s also known as socially and educationally disadvantage groups of the society. The key barriers identified based on literature review which is summaries in the Fig **6** on the factor of caste to biogas adoption in rural societies in India.

*9.5.1. Socio-cultural Factors*

There are several socio cultural barriers influence by the caste system in terms of adoption of biogas technology in rural areas. First, backward classes faced many challenges in accessing education due to discrimination by the other forward caste people especially in rural society. Second, in rural areas lower caste people mainly lived from outskirts of the main village areas and the tribal lived in forest and remote areas for that reason this community people lagged behind from late access of the several upliftment schemes or information. Because households living nearby to the market have high probability of switching towards clean cooking fuels for cooking [160]. So the service providers have lack penetration in rural and remote areas [161]. So lack of information become is one of the factor of inequality of caste system. Third, disadvantages and marginal groups of people have cultural and social stigma regarding the biogas plants so the adoption rate of biogas plant is higher among forward caste than the lower caste.

*9.5.2. Economic Factors*

Economic condition is one of the key barriers to adoption of biogas technology for the rural people. While caste system is also dominating on the economic sector as well. The cost of biogas construction, labour and equipment is very high for the marginalized caste groups of the society such as Scheduled Caste (SC), Scheduled Tribe (ST) and Other Backward Class (OBC). These group of people earn less than national household's income. On the other hand upper caste households earn nearly 47% more than the national average annual households income [162]. So the wealth inequality is one of the factor in terms of adoption of biogas technology because it has a high capital cost which is quite high for the lower caste people. Mittal in study indicates that the installation of a family type households biogas plant is significantly higher than monthly households expenditure of low income households in rural India [8]. This makes difficultly for the rural low level income households to adopt biogas technology even after receiving very lower

amount of subsidies. Moreover lack of access of credit for installing biogas plant and the burden of low subsidies from the government is influencing the lower rate of biogas plant adoption among the lower caste people of the society.

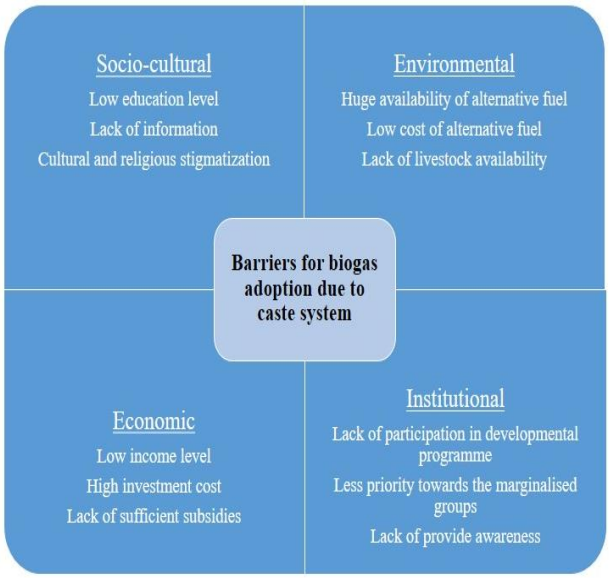


**Fig 6**: Barriers for biogas adoption due to caste system in India

*9.5.3. Environmental Barriers*

Environmental factor affecting the biogas adoption in rural areas of developing countries. The adoption choice of biogas technology as cooking fuel among rural households substantially influenced by huge availability of biomass fuel nearby their location. Most of the marginal and disadvantages caste groups mainly collect and gathering biomass fuel due to social stigma of structural hierarchy and well as low income level than the forward caste people. ST people are the main forest dwellers they mainly used traditional fuel due to greater accessibility of firewood at a free of cost [161]. V.Saxena in his study shows that in rural India 55% general caste population people use LPG as modern fuel whereas only 34% and 39%, SC and ST people used LPG as their primary fuel respectively [143]. Lack of feedstock among the lower income and lower caste people is one of another problem. The NSSO report shows less than 2 per cent (2.7 million) rural households depend on livestock for their livelihood, it also shows that General (1.67%) and OBC (2.17%) caste have more livestock than the SC (1.50%) and ST (0.75%) people of total population due to availability of huge amount of farming land and higher income source. So the lack of availability of feed stock is also another important problem for adoption of biogas technology for the lower caste people of the rural Indian society.

*9.5.4. Institutional Barriers*

NBMMP programme initiated by central government of India for top-down approach of biogas adoption. The programme mainly targeted towards the 2-3 cattle ownership households as their one of the major criteria of gain capital for subsidies to install biogas plants [8], [163]. But this amount of cattle does not provide reliable substrate for biogas plant. Since majority of rural households with low-income and lower caste does not have 2-3 cattle, so it very difficult to gain capital subsidies and also installing biogas plant [8]. Therefore those section of rural people still depend on biomass for cooking. Thus it seems to that government provide less consideration among those marginalized and disadvantages groups of society as they were some amount of subsidies for SC and ST people but still the amount is very less to install a biogas plant. Lack of awareness about the technology is one of the reasons for low adoption of biogas plant in rural area. Feedstock is the main issues for the lower caste people of rural areas. People are not aware about the alternative feedstock for biogas plants [8], [164]. Multiple developmental agencies are involved in planning and implementing schemes regarding adoption of biogas plant but there have been lack of participation and research on the poor performances and lower adoption of biogas plants in rural areas.

## 10. Conclusion

Social stratification plays a dominanting role in the different social groups in the distribution of social opportunities and resources in India. However, the SC and ST are more deprived and backward than the other social group. So the government

biogas dissemination schemes nominate these backward groups of people to get more advantages than the other group of people to fulfil their energy needs. Similarly, religious factored may also affect the choice of biogas adoption. The study's main purpose is that the decision to adopt biogas technology is also significantly influenced by socio-demographic characteristics of a household where caste factors play a vital role in rural India. The general group is more likely to adopt biogas plants than the other social group in society, whereas the lower caste is still deprived in society. This reflects that the subsidies programmes implemented by MNRE for dissemination could not appear to this marginalized social group [9]. So they should get the most priority to adopting the biogas facilities to fulfil their energy requirements. Thus biogas technology adoption is positively associated with caste identity and social status. India is the highest livestock population with enormous quantities of cow dung that can be transformed into renewable energy to fulfil the energy requirement of households in rural areas. Biogas technology effectively enhances energy supply to enable people to meet their energy needs during the time of difficult access to commercial fuels in rural areas [106]. The situation in India, such as resource availability, suitable climate, hands-on operation, etc., encourages biogas generation and utilization in rural people [165]. The study also emphasizes the strategies to reduce energy inequality among different social groups and encourage adopting biogas technology for energy consumption.

Thus it conclude that the study recommends that the government policy measures be targeted at the poor and backward section of society. Inequality in every country is one of the greatest issues, but caste inequalities are more glaring in India than in other countries. Therefore policies should remodify according to the focus on the deprived section of the society.

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