CHAPTER II
REVIEW OF LITERATURE

The literature reviewed during research work considering objectives has been discussed thoroughly in this section. The reviews are divided under following heads:

(i) Performance evaluation of biogas plant
(ii) Energetics of biogas plant
(iii) Life cycle assessment of biogas plant

2.1 Performance evaluation of biogas plant

Kanwar and Guleri (1994) evaluated the performance of a 2 m$^3$ rubber-balloon biogas plant under hilly conditions and compared with a fixed-dome type Deenbandhu biogas plant of the same capacity. The daily average (over one year) biogas production was found 33.7% lower in rubber-balloon plant than Deenbandhu plant. The effect of changes in ambient temperature was observed more in the rubber-balloon plant than conventional plant. In the experiment conducted it was found that there was a reduction of about 77% in rate of biogas production in case of rubber-balloon plant during winter months as compared to production during the summer months; while for Deenbandhu biogas plant it was only 16%. The methane contents of the biogas of both the plants were almost identical. It was concluded that the rubber-balloon plant was not generally suitable for hilly areas but may be suitable in coastal areas where the winters were not severe or in water-logged soil where building of a fixed-dome plant may be difficult.

Singh and Sooch (2004) studied the comparative economics of three prevalent models, viz. KVIC, Janta and Deenbandhu family size biogas plants with capacity from 1 to 6 m$^3$ for state of Punjab, India, where the hydraulic retention time is 40 days,. They have given table for number of persons that may be served by and animals required for different capacity and calculation of cost of construction and installation of KVIC, Janta and Deenbandhu model biogas plants. Comparison of the economics revealed that the cost of installation and annual operational cost of each capacities varying from 1 to 6 m$^3$, were found higher for the KVIC model, followed by the Janta and then the Deenbandhu model.

Vani (2007) designed pilot biogas plants based on KVIC and Deenbandhu design operative on solid state fermentation of dairy cattle waste. It was observed that biogas production with undiluted cattle dung has option on the per unit volume of
digester. In both the solid-state biogas plants total solid content of effluent slurry was found about 10% which had quite sufficient liquidity to flow and no problem occurred at outlet. In case of solid state Deenbandhu & KVIC total volatile solids removal efficiency was varied between 11.11 to 27.41% and 19.69 to 34.03% respectively while biogas production was found 0.173 & 0.182 m³/kg dm (yearly average). They were also designed larger size solid state KVIC (8 to 85 m³) & Deenbandhu biogas plants (3 to 10 m³).

Hakimuddin et al. (2010) designed and evaluated the performance of a commercial size fixed dome cattle dung feed biogas plant of 25 m³ capacity, based on solid-state fermentation. The plant was designed and constructed with brick masonry without using RCC. The shape of the designed plant was of capsule structure. Feeding was carried out with fresh cattle dung having moisture content of 16 percent. The average total solids (TS) content at inlet was 17.21% and at outlet was 9.92% while the volatile solids were 84% and 66.5% respectively. The gas yield over the period varied from 19.56 to 22.45 m³/day with methane content varying between 56.2 and 61.8 per cent. It was stated that the commercial size fixed dome biogas plant generated biogas in the month of May, which was highest amongst all months of testing. Average gas production was 0.14 m³/kg of dry matter during the study period with the least gas production in the months of November and December. The digested slurry contained 1.78% nitrogen, 1.24% phosphorus and 1.02% potash, and was high grade organic manure.

Agrahari and Tiwari (2011) designed and tested the performance of a portable floating type biogas plant of volume capacity 0.018 m³ for outdoor climatic condition of New Delhi, India under the monsoonal season. The plant digester was made by aluminium having 30 kg slurry capacity for batch system. The slurry has been added once to the digester for whole duration of the process. The range of slurry and ambient temperature of atmosphere recorded during the observed period have been found as 26 to 42°C and 30 to 40°C respectively. They suggested that aluminium made biogas plant can use for biogas production because of more durable, less prone to corrosion, light in weight and more heat absorbing capacity comparative to iron made biogas plant, so it maintains sufficient temperature inside the digester which increases the rate of production of biogas. Increase the slurry temperature inside the digester by coat a black paint on the surface of aluminium made biogas chamber.
Chandra et al. (2012) was carried out experimental study on anaerobic digestion of jatropha (Jatropha curcas) and pongamia (Pongamia pinnata) oil seed cakes in a 20 m³/d capacity floating drum biogas plant under mesophilic temperature condition. They have measured of ambient temperature and substrate temperature (°C) by using K-type thermocouple. Substrate temperature was measured by inserting a thermocouple into the digester of the biogas plant at a depth of 1.0 m. The daily biogas production (m³) at standard temperature and pressure (STP) was measured. It was concluded that these oil seed cakes have low non-volatile solids content, higher content of hydrogen and carbon as compared to the cattle dung.

Dioha et al. (2013) studied on effect of carbon to nitrogen ratio on biogas production. It was stated that various parameters such as concentration of slurry, pH, moisture, total solids, temperature, and C/N ratio are among the main parameters affecting biogas production. Production of biogas will enhance clean environment through the killing of the pathogens, during anaerobic digestion and thus producing fertilizer very rich in NPK. The results of the comparative studies of cumulative yields of biogas from cow dung, clean poultry droppings, rice husks, neem tree leaves and sugar cane bagasse at the temperature of 33-42°C showed that cow dung gave the highest cumulative yield of biogas followed by the poultry droppings.

Desai et al. (2013) evaluated the performance of cattle dung in solid-state in fixed dome type biogas plant under water scarce region. The average gas production per day for the retention period from third week to seventh week was observed to be 0.38 m³/m³/day. On an average 0.202 m³ of biogas/kg dry matter was produced with an average methane content of 60%. The results also showed that the nitrogen, phosphorous and potassium contents of digested slurry were higher than that of fresh cattle dung, which indicated that solid-state digestion of cattle dung results in rich nutrient fertilizer. The benefit-cost ratio of biogas plant worked out to be 1.49:1.

Kumar et al. (2014) has conducted an experimental study on biogas production in pre-fabricated FRP floating drum digester in the month of February. It was found that the production of biogas is dependent on the global radiation, slurry temperature, ambient temperature and various other parameters. During morning and evening the slurry temperature were observed low where as it raised significantly from 10:00 am to 04:00 pm up to 34°C. During morning and evening the global radiations were low where as it raised significantly from 10:00 am to 01:00 pm to about 824 W/m². The ambient temperature increased from 10:00 am to a maximum
value of 30°C. In the month of February, the volume of the biogas was on an average 2399.85 mm$^3$ at 12:00 noon to 01:00 pm and 1592.78 mm$^3$ at 05:00 pm. It was concluded that pressure of the biogas and volume showed a direct proportionality with changes in the global radiation, slurry temperature and ambient temperature.

Pham et al. (2014) studied the factors affecting process temperature and biogas production in small-scale rural biogas digesters in winter in Northern Vietnam. Four composite digesters (two insulated and two uninsulated) were buried underground to measure their internal temperature (°C) at a depth of 140 cm and 180 cm, biogas production and methane (CH$_4$) concentration in biogas from August to February. In parallel the temperature of the air (100 cm above ground), in the slurry mixing tank and in the soil (10, 100, 140, and 180 cm depth) was measured by thermocouple. It was observed that time of the year significantly influenced temperatures in the air, the slurry mixing tank, the soil and the digesters. Consequently during the winter biogas production was found much lower than during the summer. It was suggested that slurry from the mixing tank should add at 14:00 h because it has been found that there was a significant relationship between digester temperature and the temperature of the slurry in the mixing tank. Therefore, it will increase the temperature in the digester and thus increase potential biogas production.

Kumar et al. (2015) studied and summarized nutrient potential of digested biogas slurry (DBGS) and relation with synthetic fertilizers in India, as a potential source. Biogas slurry has potential to provide a considerable amount of both macro and micro nutrients besides appreciable quantities of organic matter. Along the richness in nutrients it also has very low amount of heavy metals as compared to synthetic fertilizers. Biogas slurry (Dry-DBGS & Wet-DBGS) is environmental friendly, has no toxic or harmful effects and can easily reduce the use of chemical fertilizers up to 15-25%. It was concluded that biogas slurry provide a beneficial way for farmer’s community, reduce fertilizer burden on economy of country and improve sustainability of field.

Matulaitis et al. (2015) did the experiment to quantify of methane production from pig and cattle manure in Lithuania. Manure was stored for a period of up to 70 days at constant 35±1°C temperature. The methane production from the total volatile solids (VS) for both pig and cattle manure was found in the range of 0.41-0.46 m$^3$ kg$^{-1}$ CH$_4$ VS. During the storage period, up to 64% of total manure volatile solids and up to 89% of easily degradable volatile solids had decomposed. The methane production
for dairy cattle liquid and solid manure, also non dairy cattle solid manure reached 0.20-0.21 m³ kg⁻¹ CH₄ VS.

Ali et al. (2016) studied the biogas production from various organic biomass materials by anaerobic batch fermentation. They conducted the experiment by combining various organic biomass materials such as ground pine needle, ground oak, vermi compost of pine needle and cow urine treated pine needle and pine needle treated with NaOH, lime, urea and Trichoderma spp., Pseudomonas spp. combinations in batch mode anaerobic fermenter of 4 litre capacity polymer reagent bottle at mesophilic temperature of 35±1°C. The process parameters such as pH, total alkalinity, TS and VS were measured and analyzed. It was observed that the highest biogas production of 0.696 l/g TS destroyed was observed for vermi composed pine and it was lowest 0.106 l/g TS for pine treated with cow urine.

### 2.2 Energetics of biogas plant

Rubab and Kandpal (1995) studied the energetic of household biogas plants in India. They determined energy yield ratio by calculating embodied energy and total energy output throughout the useful life of three biogas plant viz. KVIC, Deenbandhu and Janta. It was observed that energy yield ratio was maximum for the Deenbandhu biogas plant and minimum for a KVIC plant. The energy yield ratio increases with daily gas production capacity for all designs and retention times. It was concluded that large size biogas plants provide more energy output per unit energy input in comparison to the smaller ones. For all design and size, energy yield ratio decreases with an increase in retention time.

Arif and Chandra (2008) analyzed biogas system based on energy, economic and environmental factor by estimated embodied energy from the building materials used in construction of various type of biogas plants, energy payback time and potential carbon dioxide (CO₂) mitigation using renewable energy and different biomass for domestic cooking in India. Analysis of money payback time has also been carried out. It was concluded that EPBT and MPBT decreased as the biogas plant size increases. It was stated that biogas is non-commercial and environment friendly renewable source of energy (fuel) and pollution emitted was comparatively very low as compared to other biomass fuels.

Kumar and Tiwari (2009) analyzed life cycle cost of single slope hybrid (PV/T) active solar still based on the annual performance at 0.05 m water depth.
Effects of various parameters, namely interest rate, life of the system and the maintenance cost have been taken into account. Total energy required for construction of solar still were determined by adding embodied energy of each material.

Bhagade (2015) evaluated the performance of prefabricated portable floating drum type biogas plant installed at DREE, CTAE Udaipur. The established plant was a floating drum type biogas plant based on cattle dung which was made of High density polyethylene (HDPE) material for anaerobic digestion process. The experiment was carried out for 90 days period of operation and the results were compared with traditional KVIC biogas plant having same capacity. The energy efficiency analysis of installed plant was observed that the total energy input of the biogas plant provided for the construction and operation, total energy output from the plant, and energy yield ratio for the biogas plant were found 7526.45 MJ, 124100 MJ, and 16.48 MJ respectively. The energy yield ratio was found higher than unity and it increases with daily gas production capacity. It was concluded that the energy yield ratio was in favour to biogas technology.

Mali and Waghmare (2016) reviewed the embodied energy audit of residential building. Total life cycle energy use in a building consists of two components: embodied and operational energy. Energy required for various materials was calculated and energy efficient alternatives were suggested.

### 2.3.1 Life cycle assessment of biogas plant

Berglund and Borjesson (2006) studied the assessment of energy performance in the life-cycle of biogas production based on 8 different raw materials. The analysis was based on published data and relates to Swedish conditions. The results showed that the energy input into biogas systems (i.e. large-scale biogas plants) overall corresponds to 20-40% of the energy content in the biogas produced. It was observed that large variations exist in energy efficiency among the biogas systems studied which depends on both on the properties of the raw materials studied and on the system design and allocation methods chosen. Also found that operation of the biogas plant was generally the most energy-demanding process in the biogas systems, corresponding to approximately 40-80% of the net energy demand.

Ishikawa et al. (2006) studied on evaluation of a biogas plant from life cycle assessment (LCA). In this study two evaluation methods were used. First, LCA used to estimate how global warming gas was influenced by BGP systems, and it was
found that production of CO$_2$ at the time of biogas combustion was much lesser than it required at the time of introduction i.e. accounts for about 80% of the whole. The second evaluation method was made by comparing fossil energy input to BGP with energy output and found energy output higher than input. It was also observed that digested slurry plays important positive role to reduce energy pay-back time.

Bayer et al. (2010) provided guidelines to help architects understand and use LCA methodology as part of the design process by identifying scenarios for the use of LCA in the design process and providing a set of proposed guidelines for the conductance of whole-building LCA.

Stucki et al. (2011) investigated the life cycle assessment of biogas production from different substrates: maize silage, sugar beets, fodder beets, beet residues, molasses, and glycerine. Furthermore, biogas from a grass refinery was analysed. The life cycle inventory data required for such an LCA were collected according to the ecoinvent v2.0 quality guidelines. It was stated that the use of biogas from non-waste substrates as vehicle fuels instead of using conventional fuels has some benefits regarding the consumption of non-renewable energy resources and regarding carbon footprint.

Poeschl et al. (2012) carried out a study on attributional Life Cycle Assessment (LCA) of multiple biogas production and utilization pathways in order to identify areas where further mitigation of potential environmental impacts could be realized to enhance environmental sustainability of biogas deployment. The LCA of pre-defined small (<500 kW$_{el}$) and large-scale (≥ 500 kW$_{el}$) biogas systems was conducted in accordance with the ISO 14040 standards, using SimaPro 7.2 computer software. The analyses quantified the impacts of feedstock type (both single feedstock and co-digestion), biogas utilization pathways, and the digestate processing and handling unit processes. Analyses also considered the replacement of fossil fuels and chemical fertilizer with equivalent energy value of the biogas and nutrient content of the digestate, respectively.

Singh et al. (2013) studied on the importance of life cycle assessment (LCA) of renewable energy sources and they overviewed of LCA methodological steps. It was stated that LCA is a tool that can be used effectively in evaluating various renewable energy sources for their sustainability and can help policy makers choose the best energy source for specific purpose.
Mezzullo et al. (2013) investigated the LCA of a small-scale anaerobic digestion plant from cattle waste. In this investigation SimaPro software was used and EcoInvent primary databases used. For this study the EI 99 method was adopted using the hierarchical data in the impact assessment. It was observed that environmental and energy impact of the plant manufacture contributes very little to the whole life cycle impacts. Also the results found that compared with alternative energy supply the production and use of biogas was beneficial in terms of greenhouse gases and fossil fuel use due to the replacement of the alternative, kerosene, and from fertiliser production from the AD process. The use of the AD plants created emissions which appeared significant impacts towards human respiratory systems and acidification/eutrophication issues within ecosystems. These were found to be a result of ammonia emissions during the production phase of the biogas and suggested that these damages can be significantly reduced if further emission control measures are undertaken. The study concluded that it is essential to cover the digestate storage tank as biological reactions are still occurring thus emitting, methane, ammonia and carbon dioxide.

Garfi et al. (2014) worked on the technical, economic and environmental assessment of household biogas digesters for rural communities. The fixed dome and plastic tubular digester in terms of biogas production, cost and environmental impact, using the life cycle assessment methodology were compared. The LCA showed how the plastic tubular digester caused the highest impact; as a result of the relatively short lifespan of plastic materials and geomembrane. In the fixed dome model, most environmental impact corresponded to concrete and bricks. It was concluded that the main advantage of the plastic tubular digester was its ease of implementation and handling, and lower investment cost compared to the fixed dome digester, which appeared to be more environmentally friendly.

Hahn et al. (2015) comparatively assessed the environmental performance of biogas plant configurations for a demand-oriented biogas supply for flexible power generation. They compared those configurations indicate an increased energy demand to operate the operational enhancements to conventional biogas plants supplying biogas for baseload power generation. The results found that in contrast to an alternative supply of power generators with natural gas, biogas supplied on demand by adapted biogas plant configurations saves greenhouse gas emissions by 54-65 g CO$_2$-eq MJ$^{-1}$ and primary energy by about 1.17 MJ MJ$^{-1}$. 

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