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EXPLORING THE SCOPE OF RENEWABLE ENERGY TECHNOLOGIES IN DAIRY SECTOR

Prof. R. H. Yadav*, Mr. V. V. Jadhav, Mr. G. A. Chougule

* Assistant Professor, Department of Mechanical Engineering, Dr. J. J. Magdum College of Engineering, Jaysingpur, India

PG Scholar, Department of Mechanical Engineering, Dr. J. J. Magdum College of Engineering, Jaysingpur, India

PG Scholar, Department of Mechanical Engineering, Dr. J. J. Magdum College of Engineering, Jaysingpur, India

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ABSTRACT

It is unavoidable that in the long run the fuel reserves, currently being used so intensively, will be exhausted. Therefore industries will have to employ alternative energies. Major developments in this field will, however, take a long time to reach a commercially feasible level. However, there have been recent developments that indicate a growing trend towards the use of renewable energies for its potential to contribute to reductions in GHG emissions, electricity generation and application in process heating. Dairies have considerable advantages in that as they are high energy users with a relatively constant demand for electricity and heat throughout the year. Wind energy and geothermal energy are in general only suitable as a supplement to a collective supply, which is an electricity grid or a district heating system. The conditions and the costs are often too prohibitive for individual dairies to even consider using them as alternative energies. More adaptable to the dairy is the use of solar energy and biomass energy which can be effectively and directly utilized both as alternatives and supplements to the existing energy supply.

KEYWORDS:Dairy Industry, Energy Conservation, Renewable Energy, Solar Energy, Biomass.

INTRODUCTION

Energy is a critical input for the production activities in the dairy. In addition to land, labor and capital, energy is the four factors for the production of dairy product in dairy industry. The cost of energy is having a vital impact on the cost of the manufactured dairy products, transport, cost of storage and associated comfort in dairy industry. In view of widening gap between demand and supply in energy sectors energy conservation and efficient use of energy is important. Energy conservation is not the suppression of demand for energy use in dairy industry, but efficient use of more and more energy and steep rejection of its wastage. Processing of milk and milk products require considerable amount of energy in the terms of the heat and electricity. A major amount of electricity is used for running motors, fan, blowers, and lighting the plant building. Heat energy needs is met by the combustion of fossil fuels to generate steam and hot water for evaporative and heating processes. Typically, in dairy plant, 80 per cent cost is of milk and remaining 20 percent comprises of the other variable and fixed costs. The energy cost reflects to nearly 4 per cent of the expenditure. Hence, any attempt to efficiently manage the energy costs will influence the processing costs. Renewable energy offers a good opportunity for dairies to reduce their carbon footprint and at the same time reducing energy costs. There are a number of renewable energy technologies with potential for use in dairies. In particular these are anaerobic digestion, wind, and solar (both in the generation of heat and electricity) which can help in cutting energy costs in addition to reducing the carbon footprint. There are also capital allowance and capital funding schemes available which can make the introduction of some of these more financially attractive.

MATERIALS AND METHODS

ENERGY USE IN DAIRY:

Energy plays a major role in processing milk and milk products. In a dairy, primary energy sources such as furnace oil, etc are used in boiler for generating steam which in turn is used for heating applications like pasteurization, evaporation, drying of milk. Electricity is another major energy input, which is utilized for refrigeration, and motive loads. The cost of energy in processing milk in a dairy is substantial. Nearly 30% of overall manufacturing cost is spent on purchase of furnace oil, electricity. The dairy sector consumes a significant amount of energy in its heating, cooling and processing activities. Typical dairy plants derive about 70% of their energy requirements in the form of thermal energy and the remaining 30% is consumed in the form electricity. The energy consumption and savings assessed in term of equipments used and its functional purpose. Investing to improve the energy efficiency of a dairy industry provides an immediate and relatively predictable cash flow resulting from lower energy bills.

Typical utility and service demands for dairy processing plants are summarized in Table 1. The importance of the different utilities can vary between processes, as indicated. Utility requirements can also vary to some extent between different plants producing the same product.

Table 1 Summary of Utilities & Service Demands

Utility	Service Demand
Electrical	
Compressed Air	Valve Actuations Air Blows Packaging
Refrigeration	Milk & Product Cooling Chilling Cold Storage
Thermal	
Steam	Pasteurize Heating Dryer Air Heating Evaporation Water Heating
Water	
Cold Water	Recirculation Cooling, Product Cooling
Hot Water	Recirculation Heating CIP

ELECTRICAL ENERGY CONSUMPTION BREAK DOWN:

The specific energy consumption of the dairy is as given in graph below. The graph indicates that major amount of electrical energy *i.e.* 32% is utilized by utilities in the dairy. These utilities involve pumps, and various product manufacturing equipments. Followed to this almost same amount of energy consumption is for refrigeration and cold storage. Lighting shares smallest amount of electrical energy of total share – 5%

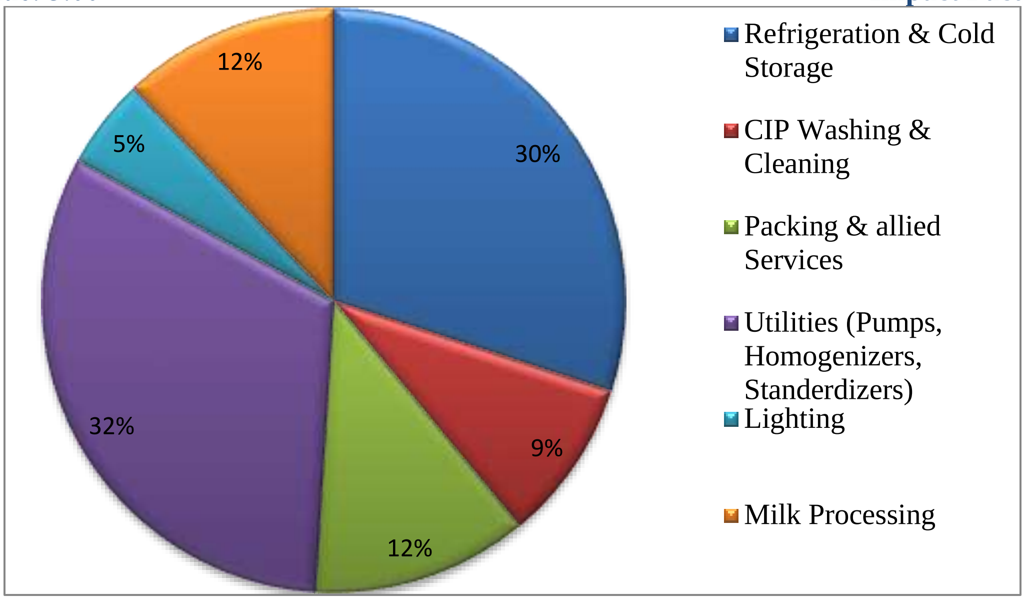

Figure 1 Process Wise Electrical Energy Consumption Profile

THERMAL ENERGY CONSUMPTION BREAK DOWN:

The total amount of heat energy generated by boiler is divided into various processes as per requirement. The process wise thermal energy consumption is represented in pie chart below. Maximum amount of thermal energy generated is consumed for chilling and cold storage. Followed to this sterilization and spray drying consumes equal amount of energy. Chemical processes carried out at dairy requires smallest amount of energy of total energy generated.

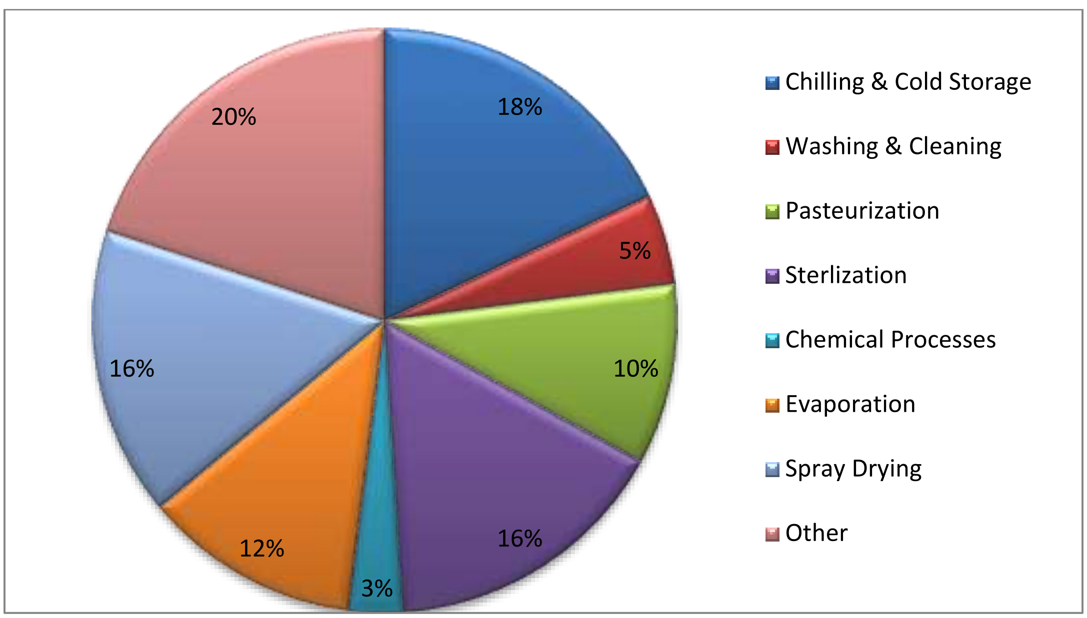

Figure 2 Process Wise Thermal Energy Consumption

SCOPE FOR RENEWABLE ENERGY IN DAIRY

SOLAR ENERGY:

Both solar thermal and photovoltaic systems utilise the energy of the sun to generate heat and electricity respectively. An ideal location is on a building as close to due south as possible to maximise radiation capture. Both solar thermal and PV systems are ideally suited to Gokul dairy where large roof space is generally not a limiting factor. Solar thermal can be used to pre-heat the water before it enters the main tank for final heating by a back-up system to achieve the temperature of >85oC generally required for CIP. A PV system can act in isolation mode where a battery system can provide a storage facility or can be connected to the grid with the potential to export electricity when not required on site. Various solar energy operated techniques have been developed to carry out various operations in dairy. These techniques can be used for cooling purpose, for water heating, for steam generation, for solar drying, for pumping dairy fluid, for lighting and for electric fencing

BIOMASS ENERGY:

Biogas is a combustible fuel which is produced through the anaerobic digestion process. Anaerobic means "in the absence of oxygen". In the right set of circumstances, the organic fraction of liquid or solid biomass is converted into valuable fuel. Biogas consists of roughly 40% – 70% methane, with the rest being CO2 and trace amounts of H2O, H2S, H2 and NH3 produced by the microbiological process. The amount of methane in the biogas is largely a function of the organic input menu.

Organic wastes from dairy processing units are ideally suited as inputs to a biogas plant. Biogas, when utilized in a combined heat and power (CHP) unit produces electrical energy for consumption and heat energy for further ues. The heat produced by the CHP is used to heat the digestion process to improve biogas yield. Biogas can also be cleaned up for injection into boiler as a fuel substitute for conventional fuel.The remaining byproduct of the digestion process is digestate which is a fermented organic material which may be used as high quality fertilizer. Biogas has a key role in supporting a diverse energy portfolio as a flexible, dispatchable fuel source.

WIND ENERGY:

Wind generators are a possible future source of alternative energy for those companies that have a constant source of 'clean wind' (i.e. wind coming from a constant direction and not made turbulent by nearby obstacles).A wind turbine captures wind energy and converts it into electrical energy. As the wind passes over the blades it causes them to rotate which turns a generator to produce electricity which is fed into an inverter which converts the power to mains power.Wind turbines generate direct current (DC) electricity and off-grid systems require battery storage and an inverter to convert the DC electricity generated to AC (alternating current) which is mains electricity. Ideally a controller is also beneficial to divert power to another useful source (e.g. space and/or water heaters) when the battery is fully charged. Within the controller will be a meter recording the amount of electricity produced and another to record how much electricity is exported to the grid. The grid connection means that no battery storage is required as surplus can be exported to the grid and sold to an electricity supply company.

HEAT PUMP:

Heat pumps can take heat from the environment or from waste heat streams and supply it to dairy applications without the need to burn any fuel. In applications where the pumping energy input is in the form of electricity produced from renewable energy sources, heat pumps are a fully renewable energy technology. Where the electricity is generated from fossil fuels, only part of the energy output of heat pumps can be regarded as renewable. So, for example, if the electricity comes from fossil fuel generation with an efficiency of 40%, the coefficient of performance12 of the heat pump needs to be higher than 2.5 if the pump is to save primary energy and be considered as providing renewable heat. The amount of useful heat provided must be higher than the primary energy consumed.

RESULTS AND DISCUSSION

ENERGY SAVING BY PROVIDING SOLAR WATER HEATER FOR BOILER WATER PREHEATING & HOT WATER REQUIREMENTS:

BACKGROUND:

Milk processing plants require process heat in the form of hot water or steam in the lower and middle temperature range. Hot water is required for both process & for cleaning purpose.

Low Temperature Processes <80°C:

Bottle washing 60°C
Pasteurization 70°C
CIP (Cleaning-in-Place) 70-80°C

High Temperature Processes >100°C:

Bottles sterilization 115-120°C
Multiple stage evaporation 110°C
Spray drying 100-110°C

Process heat in this range can be generated without risk by solar energy. For temperatures of 70°C (to possibly 100°C) flat collector systems which do not concentrate radiation are suitable. Solar hot water system, do not have any costly maintenance along with literally lowest operation cost. Solar heating is unlikely to find application in any factories which evaporate or dry milk or whey, as it will be in direct competition with sources of recovered heat which are likely to be cheaper. The solar system can be effectively utilized for post heating hot water obtained from de-super heater to heat the water up to 85 ºC so that most of the fuel requirement for boiler can be saved.

DESIGN OF PROPOSED SYSTEM:

A central solar system consists of the following parts:

i. **Collector:** This is where solar radiation is absorbed and converted into heat.
ii. **Tank:** This is a thermal storage container for the storage of the collected thermal energy.
iii. **Pump:** This is a device which allows the circulation of the thermal transfer fluid (antifreeze liquid or air) through heat collectors and heat exchangers.
iv. **Control Systems:** these are devices (thermostats, valves etc.) which ensure the efficient and/ or optimal operation of the system.

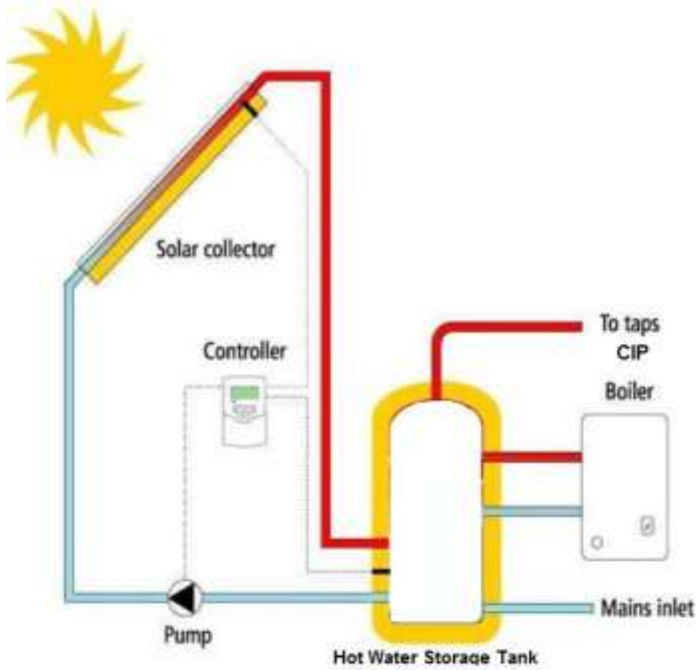

Figure 3 Solar Thermal System

PRINCIPLE OF HEATING WATER THROUGH SOLAR:

i. Thermo-siphon action: Is based on a simple principle that hot water is less dense and hence tends to rise above colder water.
ii. Black body absorption: It is a well known fact that a black body absorbs heat which can be used to heat water.
iii. The Sun's rays heats the black powder coated copper fins (larger surface area) which in turn heats the cold water in the copper tubes. The heated water slowly rises in the copper pipes thro thermo-siphon action and eventually gets stored in the hot water storage tank.

BENEFITS OF PROPOSAL:

i. **Improvement in working environment:** Use of Solar Water Heater in Dairy Industry reduces the energy consumption, and also improves efficiency of unit and reduces CO2 generation.
ii. **Improvement in workers skill:** Technical skills of persons will definitely be improved. As the training will be provided by equipment suppliers which improve the technical skills of manpower required for operating of the equipment and also the technology implementation will create awareness among the workforce about energy efficiency and energy saving.
iii. **Reduction in GHG emission:** Implementation of this technology will reduce the CO_2 emissions. Reduction in CO_2 emissions will be possible due to Energy saving.
iv. **Fuel Saving:** This will help to save fuel required for water heating purpose.
v. **Reduction in other emissions like SO_X:** Amount of SO_X will be reducing due to improved efficiency of the power plants due to better plant load factor.

COST BENEFIT ANALYSIS:

Table 2 CBA for Energy Savings by Solar Water Heater System

Sr. No.	Particulars		Amount	Unit
1	Fuel used currently for hot water generator	=	FO	

2	Heat Captured by Providing Solar Water Heater (10000 ltrs/day capacity providing hot water at 70°C from ambient water temperature from 27°C)	=	430000	Kcal/day
3	Calorific Value of currently used fuel	=	10350	kCal/kg
5	Expected Saving of Currently Used Fuel Considering Hot Water Generator	=	41	Kg/day
6	Expected Saving of Fuel per Annum (Considering effective full working day for solar system to be 300 days only)	=	12300	Kg/annum
7	Cost of Fuel	=	25	Rs./kg
8	Expected Saving in Rs/annum	=	307500	Rs./annum
9	Expected Investment for Solar Heating System with Insulated Storage Tank, Pipe lines and associated insulation	=	1187000	Rs./Machine
10	Simple Payback Period	=	3.86	Yrs
			46	Months

ELECTRICITY GENERATION USING SOLAR PV CELL:

- ***BACKGROUND:***
  Photovoltaic (PV) means electricity from light. Photovoltaic systems use daylight to power a range of equipment from calculators and watches, to garden lighting through to domestic scale roof top systems of 2-3kW and also including larger commercial buildings supplying several hundred kW.

- ***DESIGN OF PROPOSED SYSTEM:***

Figure 4 Solar Photovoltaic System Configuration

A solar PV system consists of the following parts:

i. **Solar** PV Panels: Converts sunlight into DC electricity.
ii. Solar Charge Controller**:** Regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life.
iii. Inverter**:** Converts DC output of PV panels or wind turbine into a clean AC current for AC appliances or fed back into grid line.
iv. **Battery:** Stores energy for supplying to electrical appliances when there is a demand.
v. **Load: It** is electrical appliances that connected to solar PV system such as lights, computer, fans etc.

PRINCIPLE OF ELECTRICITY GENERATION THROUGH SOLAR:

A PV cell consists of two or more thin layers of semi-conducting material (conducts electricity when sunlight falls on it) most commonly silicon encased between sheets of glass or plastic. When the silicon is exposed to light, electrical charges are generated and this can be conducted away by metal contacts as direct current (DC). This DC is carried through wiring to an inverter which converts the current to alternating current (AC) so that it can be connected into an electricity distribution board for on-site use or can be exported to the grid. It may include a storage facility (e.g. battery bank) to allow electricity to be provided during the night or at times of poor sunlight levels. The electrical output from a single cell is small, so multiple cells are connected together and encapsulated (usually behind glass) to form an array of generally about 1m x 1m. The PV array is the principle building block of a PV system and any number of arrays can be connected together to give the desired electrical output.

BENEFITS OF PROPOSAL

i. The equipment in a PV system has no moving parts and as a result requires minimal maintenance.
ii. Its operation is virtually silent.
iii. It generates electricity without producing emissions of greenhouse or any other gases.
iv. Electricity produced by solar cells is clean and silent. Because they do not use fuel other than sunshine, PV systems do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health.
v. Photovoltaic systems are quiet and visually unobtrusive.
vi. Small-scale solar plants can take advantage of unused space on rooftops of existing buildings.
vii. A PV system can be constructed to any size based on energy requirements.

COST BENEFIT ANALYSIS:

Units Generated Annually (in Kwh) = System Size in kW * CUF * 300 * 8 (1)
= 100 X 0.19 X 300 X 8
= 45600 kWh/annum

Table 3 CBA for Energy Savings by Solar PV System

Sr. No.	Particulars		Amount	Unit
1	Electricity Generated per day	=	152	kW/day
2	Electricity Units Generated per Annum (Considering Effective Full Working Day for Solar System to be 300 Days Only)	=	45600	kW/annum
3	Cost of Electricity	=	7.21	Rs./kWh
5	Expected Saving in Rs/annum	=	328776	Rs./annum

6	Expected Investment for Solar PV System with Battery, Inverter	=	10000000	Rs.
7	Net cost after reducing subsidy and tax benefit on depreciation	=	5040000	Rs.
8	Simple Payback Period	=	15.32	Yrs
			184	Months

Capacity Utility Factor (CUF) For India, it is typically taken as 19%

Table 4 Final Cost of 100kW Solar PV System

Particulars	**Rs.**
Cost of a 1 kW rooftop solar plant	10000000
MNRE Subsidy @ 30%	3000000
Net cost after subsidy	7000000
Accelerated depreciation @80%	5600000
Tax rate	35%
Tax saved through depreciation	1960000
Net cost after both AD and Subsidy	5040000

METHANE CAPTURE FROM EFFLUENT & UTILIZATION AS FUEL FOR BOILER / HOT AIR GENERATOR TO SAVE ENERGY:

BACKGROUND:

Effluents of typical dairy contain high COD & BOD contain. This results in suitable case for anaerobic methane capture. Currently aerobic ETP treatment is carried using various mechanical equipments which consume energy. Capture of methane results in energy saving & benefit to environment.

BENEFITS OF PROPOSAL:

The bio-degradable effluent have high COD which results in liberation of methane gas in to atmosphere which is not desirable. Conventional ETP method both consumes high energy along with liberation of methane in the atmosphere. By various latest techniques such as anaerobic digestion and various other processes, this methane can be captured as fuel to be utilized either in boiler or hot air generator. Along with saving environment, considerable energy can also be saved.

i. 99% of the Methane gas generated is destroyed.
ii. Greenhouse gas emissions from grid electricity are offset by the electricity generated.
iii. Untreated effluent is no longer going into atmosphere or water sources.
iv. Waste treatment now fully complies with Victoria's Environment Protection Authority requirements.

DESIGN OF PROPOSED SYSTEM:

Generally biogas plant structure remains same for all type of industries excluding end use of it. Some industries utilize biogas for Power Generation with CHP only while some uses for Process Heat only. Few organizations adopt both options. Typical layout of Biogas Plant is shown below in Fig. 3

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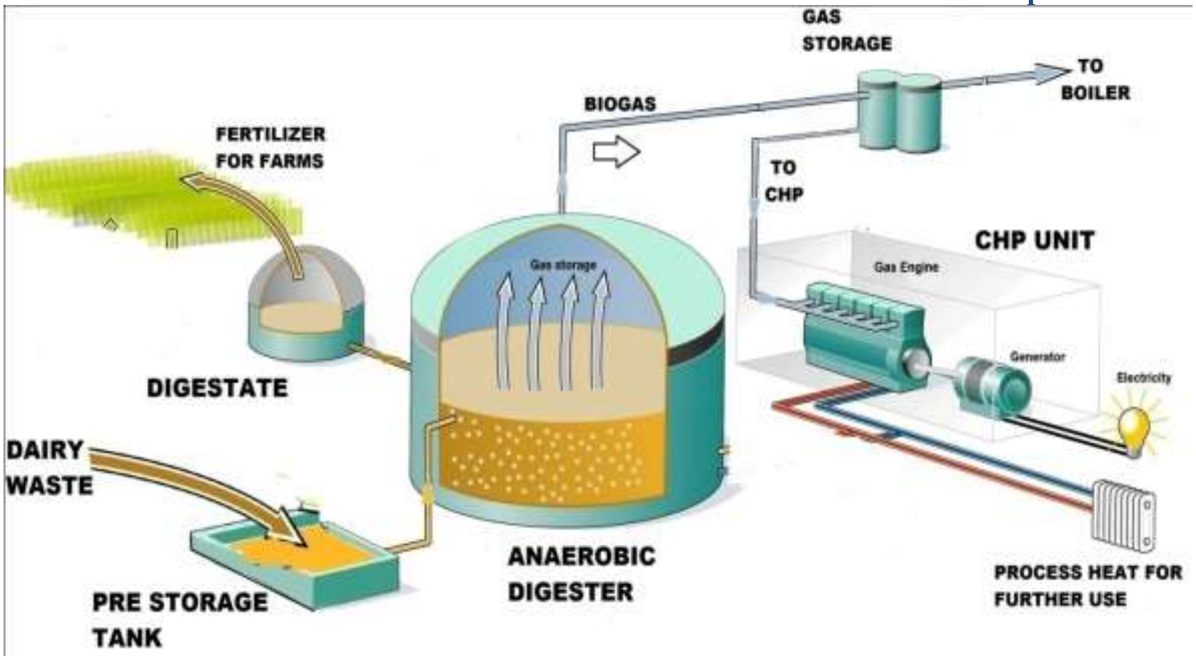

Figure 5 Biogas Plant Layout

A Biogas plant consists of:

i. **Pre Storage Tank:** It is a collection tank for waste coming from dairy. All the organic waste is collected in this tank.

ii. **Anaerobic Digester:** It is the heart of the system. In absence of Oxygen, bacteria break down the organic matter and converts it into to biogas. The Digester is continuously stirred using submersible mixers in the anaerobic digester.

iii. **Biogas Storage:** The resulting biogas is stored in storage units for further use. Further it can be supplied to boiler for burning as a fuel and heat generation or it can be supplied to the CHP unit for Electricity as well as Heat generation.

iv. **Digestate:** In addition to biogas, the anaerobic digester produces digestate as an end-product. It is a high value fertilizer which can be used in farms. Using separator, solid digest can be used as bedding for cattle.

Table 5 Untreated Effluent Data for Typical Dairy

Sr. No.	Particulars		Amount	Unit
1	BOD	=	2500	Mg
2	COD	=	5000	Mg
3	Effluent Quantity (1 kg=1000000 mg & Considering for ETP, 1kg=1Ltr)	=	41666	Ltrs/hr

COST BENEFIT ANALYSIS:

Table 6 CBA for Energy Saving By Methane Capture from Effluent

Sr. No.	Particulars	Amount	Unit

1	COD Load per Day	=	5000	Kg/day
2	COD Reduction Percentage Considered	=	80	%
3	Actual Reduced COD Load	=	4000	Kg/day
4	Bio-gas Generated	=	0.5	m^3/kg of Reduced COD Load
5	Actual Bio-Gas Generated	=	2000	m^3/day
6	Calorific Value of Bio-Gas	=	4900	kCal/m^3
7	Total Heat that can be generated from Bio-gas	=	9800000	kCal/day
8	Calorific Value of FO	=	10350	kCal
9	FO Equivalent of Bio-gas Generated	=	947	kg/day
10	Cost of FO	=	25	Rs.
11	Saving from Bio-gas Generation	=	24350	Rs./day
12	No. of Working Days/annum	=	360	Days
13	Total Expected Saving per Annum	=	8887750	Rs./annum
14	Expected Investment for Civil Work, Mechanical Works, electrical works etc	=	22500000	Rs.
15	Simple Payback Period	=	5.53	Yrs
			30	Months

CONCLUSION

The objective of this study is to explore the scope of renewable energy technologies in dairies to reduce dependence on conventional energy sources. This study will help dairy processing facility managers to understand the importance of renewable energy in their facility and uncover opportunities to significantly reduce facility energy consumption. Applying these good management practices will reduce energy costs. It is known that renewable energy sources are one of the most comprehensive sources to achieve energy savings by reducing fossile fuel energy consumption. The implementation of renewable energy technologies programme at Gokul industry will need investment of of Rs. 2,87,27,000. These measures will help to save 45600 kWh of electricity per annum and 353220 kg of FO per annum.

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