UNNAT BHARAT ABHIYAN

Compendium on Rural Energy Systems

Rural Energy

Improved Cookstoves / Biogas/ Solar System/CBG/Biodiesel

Prepared by the Subject Expert Group on Rural Energy Systems

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FOREWORD

Unnat Bharat Abhiyan, the flagship programme of the Ministry of Education, Government of India, was initiated in 2014 with a vision of bringing transformational change in rural development processes by leveraging knowledge institutions to help build the architecture of an Inclusive India. The idea behind this ambitious programme is to involve the higher educational institutions (technical / non-technical / public / private) of the country in the process of indigenous development of self-sufficient and sustainable village clusters.

Through Unnat Bharat Abhiyan, the educational institutions in the country will be able to help in the overall development of the nation by adopting villages. The educational institutions will also be able to understand and participate in the development process by employing technologies in the rural areas and in turn students of the academic institutions and faculty members will enrich themselves.

In order to provide the knowledge and technology support to improve livelihoods in rural areas and to upgrade the capabilities of both the public and private organizations in the society, 12 Subject Expert Groups (SEGs) were created under Unnat Bharat Abhiyan. Indian Improved Biomass Cook stoves / Biogas/ Solar Light /Solar System and Implementation of Various Govt. Schemes headed by the Centre of Rural Development and Technology (CRDT) is one of those Subject Expert Groups where the focus is levied on building the capacity of the rural sector through various technologies, creating opportunities through convergence, and to disseminate right information and application of the government schemes at the grassroots level.

I see great potential in this SEG Compendium designed and drafted deliberately while holding dexterity of various experts at one single platform. This compendium will help the rural energy technology in creating a foundation for how they can improvise their livelihood in villages under Rural Energy System, Strategy for Convergence and Implementation of Various Govt. Schemes SEG.

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PREFACE

Unnat Bharat Abhiyan (UBA) aims at enabling Higher Education Institutions (HEI) to work with the people of rural India in identifying development challenges and evolving appropriate solutions for accelerating sustainable growth. Thus, it aims at creating a virtuous cycle between society and an inclusive academic system by providing knowledge and practices for emerging professions and to upgrade the capabilities of both the public and the private sectors in responding to the development needs of rural India.

UBA demands a connection between HEI and local communities in order to address the development challenges through appropriate technologies/management models and so on. Actually, there are several universities and science & technological institutions that already have community service as an integral component of their academic programmes. Nevertheless, sometimes it ends up as an NSS camp in the surrounding villages, where students clean up village streets - when the villagers look on; or arrange games and play with local school children etc.

Possibly, this is because of a lack of understanding about what community engagement is all about; or what are the modes through which meaningful community engagement can be taken up by Universities and Science & Technology Institutions. This handbook provides the approaches and strategies HEI's can put to use so to get started with meaningful community engagement in the neighbourhood.

September 2020

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INTRODUCTION

Cook stoves are commonly used for cooking and heating food in rural households which can run with locally available biomass. Cook stoves are super clean, efficient, affordable and low cost means of renewable rural energy and are greatly adopted by people in rural areas as they require low maintenance and are suitable for average and large household.

Biogas has emerged as a reliable and efficient energy asset in the development and quality of life of peoples of rural areas. Biogas is a type of biofuels that is naturally produced from the decomposition of organic waste such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste and can be used as a fuel for transportation, cooking and the leftover from biogas plant can be used as fertilizer for plants and crops. The production and utilization of biogas from AD provides environmental and socioeconomic benefits for the society as a whole as well as for the involved farmers.

The use of solar energy and its utilization has been gaining attention and is a long lasting source of energy. Solar power is energy from the sun that is converted into thermal or electrical energy. Solar energy is the cleanest and most abundant renewable energy source available. Solar energy can be used for cooking food with the help of solar cooker, lighting purpose with help of solar street lights and solar heating systems for hot water purpose. Thus solar energy system plays a very important role in providing basic facilities such as light, food and warm water and helps in providing better life to the peoples of especially rural areas.

Thus, cook stoves, biogas, solar cooker, solar heating system and solar lights are the efficient tools which can proof as a boom to the life of rural areas peoples. Still there are many villages or rural areas which are still far away from basic facilities of life such as electricity, fuel for cooking and are helpless to live their life in darkness. By using these renewable energy resources, we can easily help them improving their life so that they can get gas for cooking from biogas, lighting facilities from solar lighting system etc., which is the basic aim of the rural development. Therefore, by efficient utilization of these renewable energy sources, can be a great aid to the quality of life of rural peoples, so that they can get their basic requirements of life easily such as light, cheap fuel, warm water, making their life easier and convenient.

“Appropriate utilization of renewable resources is a key for sustainable energy for rural development”

Chapter 1

1. Improved biomass cookstoves

1.1 Impmetal TERI SPFM_0414 E&N

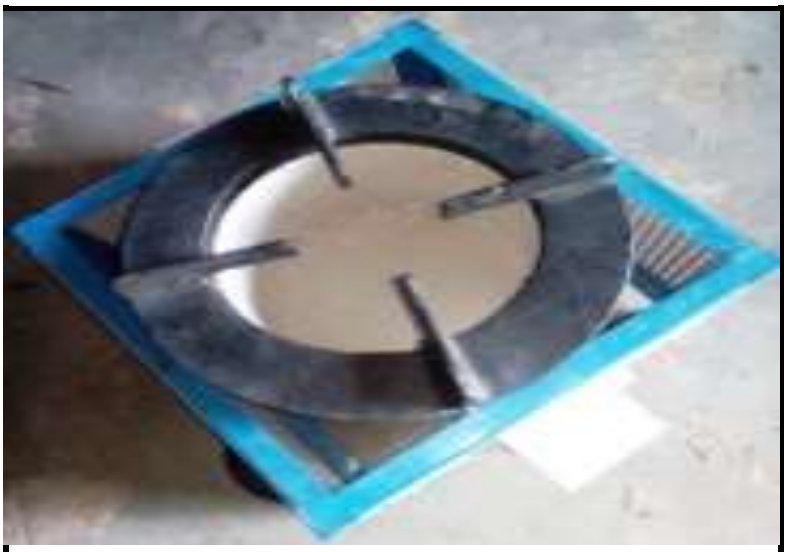

Fig. 1.1 Impmetal TERI SPFM_0414

1.1.1. Key features

- Super Clean and efficient
- Affordable and low cost
- Run with locally available biomass mix
- Need based and user friendly
- Side feed/ front loaded
- Refractory material based combustion chamber (K type- 1600®C)
- Draft regulation knob
- Qualify to Tear-4 and 5
- Robust and portability option
- Low maintenance
- Suitable for average and Large HH (12-15 Persions)

1.1.2. Details of cook stove

Table 1.1 Details of cook stove

Stove type	Front loaded force draft-Medium size
Efficiency	35.52%
Co	3.63mg/MJd
PM	107.56 g/MJd

Power output	4.36 KW
Fuel consumption	1.70-2.3 kg/h
Power supply	12V DC
Fan type and details	DC 92*92*25mm 12V,3.6W
Approximate Cost (With 12V, 1.0A AC-DC Adapter)	Rs. 2000.00
Stage of development	Full developed
Approving body	MNRE
Developed by	IIT+TERI
Contact detail of developer	Prof. R. Prasad, Biomass cookstove laboratory, IIT Delhi
Contact detail of supplier	Pheonix Udyog Pvt. Ltd. Ms.Rajvi Saboo Email rajvi@rbsgroup.in Phone +919350193026
Disseminated in field (Region and Numbers)	More than 5000 nos

1.1.3. Drawing and dimensions

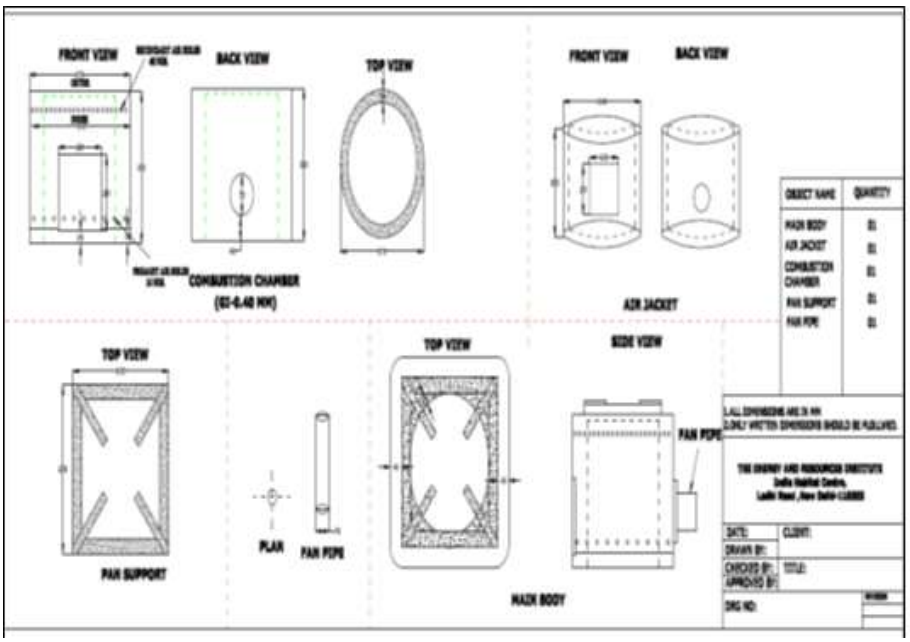

Fig. 1.1.2 Drawing and Dimensions of Model SPFM-0414

1.2. Thermoelectric generator (TEG) Impmetal TERI-IIT SPFR_0143

Fig. 1.2.1 TEG Cookstove

1.2.1. Key features

- Super Clean and efficient
- Affordable and low cost
- Run with locally available biomass mix
- Need based and user friendly
- Side feed/ front loaded
- Refractory material based combustion chamber (K type- 1600®C)
- Draft regulation knob
- Qualify to Tear-4 and 5
- Robust and portability option
- Low maintenance
- Suitable for average and Large HH (4-6Persions)
- USB output for mobile charging

1.2.2. Technical specification

Table 1.2 Technical specification

Stove type	Front loaded force draft-Regular size
Efficiency	35.63 %
Co	2.8 g/MJd
PM	151.71 mg/MJd,
Power output	1.52kW

Fuel consumption	1.0-1.2 kg/h
Power supply	12V DC
Fan type and details	DC 80*80*25mm 12V, 1.44W
Approximate Cost (With 14W TEG and battery sets and USB LED light)	Rs. 7000.00
Stage of development	Full developed
Approving body	MNRE
Developed by	IIT+TERI
Contact detail of developer	Prof. R. Prasad, Biomass cookstove laboratory, IIT Delhi
Contact detail of supplier	Pheonix Udyog Pvt. Ltd. Ms. Rajvi Sahoo, Email: rajvi@rbsgroup.in Phone +919350193026
Disseminated in field (Region and Numbers)	More than 100 nos

1.2.3. Drawing and dimensions

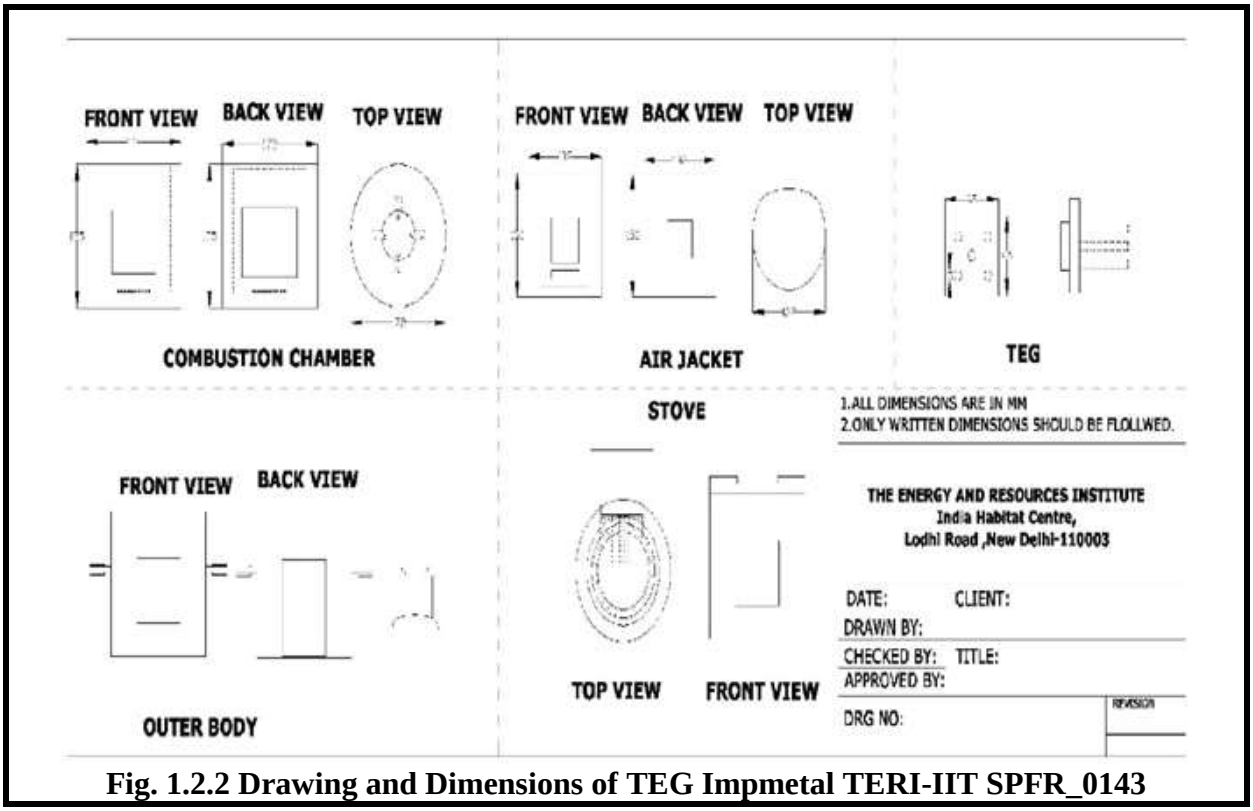

Fig. 1.2.2 Drawing and Dimensions of TEG Impmetal TERI-IIT SPFR_0143

1.3. Impmetal TERI SPFR_0413

Fig. 1.3.1 Impmetal TERI SPFR_0413

1.3.1. Key features

- Super Clean and efficient
- Affordable and low cost
- Run with locally available biomass mix
- Need based and user friendly
- Side feed/ front loaded
- Refractory material based combustion chamber (K type- 1600®C)
- Draft regulation knob
- Qualify to Tear-4 and 5
- Robust and portability option
- Low maintenance
- Suitable for average and Large HH (8-10Persions)

1.3.2. Technical specification

Table 1.3 Technical specification

Stove type	Front loaded force draft-Regular size
Efficiency	36.77%
Co	1.28 mg/MJd
PM	100.94 g/MJd
Power output	3.06KW

Fuel consumption	1.2-1.5 kg/h
Power supply	12V DC
Fan type and details	DC 92*92*25mm 12V,3.6W
Approximate Cost (With 12V, 1.0A AC-DC Adapter)	Rs. 1750.00
Stage of development	Full developed
Approving body	MNRE
Developed by	IIT+TERI
Contact detail of developer	Prof. R. Prasad, Biomass cookstove laboratory, IIT Delhi
Contact detail of supplier	Pheonix Udyog Pvt. Ltd. Ms. Rajvi Sahoo, Email: rajvi@rbsgroup.in Phone +919350193026
Disseminated in field (Region and Numbers)	More than 100 nos

1.3.3. Drawing and dimensions

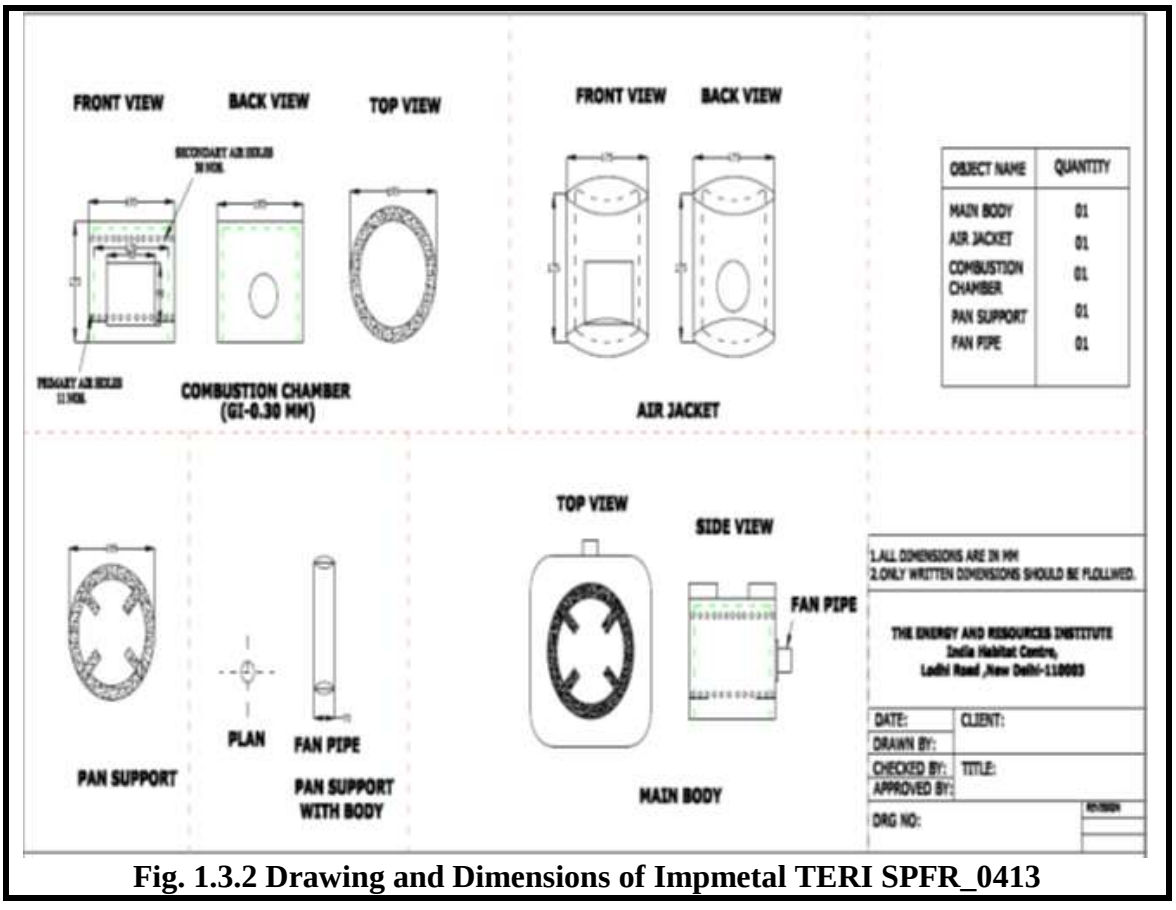

Fig. 1.3.2 Drawing and Dimensions of Impmetal TERI SPFR_0413

Chapter 2

2. BIOGAS

2.1. Introduction

For long time, the rural peoples of our country uses biomass and woods for cooking and other energy purpose. Animals are also the part of their life and the dung collected from them are dried properly and used for energy. This way of utilizing dung emits harmful pollutants upon burning and negatively impacts the health of women around the cook stoves. There exists another to utilize the dung, which can be converted into the biogas via anaerobic digestion process. Anaerobic digestion of dung produce biogas and digested material as sludge. Biogas is mixture of methane and carbon dioxide mainly as well as traces of hydrogen sulphide, ammonia, oxygen, hydrogen, water vapour etc. depending upon the feed materials and other conditions. Methane produces energy upon burning and the digested materials can be used in the farms to enrich the soils.

Biogas is generated by fermentation of cellulose rich organic matter under anaerobic conditions (oxygen controlled environment) because in anaerobic conditions, the methane producing bacteria are more active. The production and utilization of biogas from AD provides environmental and socioeconomic benefits for the society as a whole as well as for the involved farmers. Utilization of the internal value chain of biogas production enhances local economic capabilities, safeguards jobs in rural areas and increases regional purchasing power. It improves living standards and contributes to economic and social development.

Organic matter + anaerobic bacteria ---- CH_4 + CO_2 + H_2S+ NH_3 + other end products (bio-fertilizer) + energy

Table 2.1.1 Potential gas production from different feed stocks

S. No.	Type of feed stock	Gas yield per kg (m^3)
1	Cow Dung	0.036
2	Buffalo Dung	0.036
3	Camel Dung	0.056
4	Horse Dung	0.045
5	Sheep Dung	0.042
6	Human Excreta	0.40

Biogas is one of the renewable sources of energy receiving popularity in rural areas and has successfully met the cooking energy needs of families. The optimum utilization depends upon the successful physical installations, which in turn depends upon plant design and its selection. Biogas is zero waste model and perfect for people reliable on the agriculture. Biogas is non-poisonous and non-toxic gas, upon mixing with air gives blue colour flame without any foul smell and soot. The slurry is rich in nitrogen (N), phosphorous (P), Potassium (K) and humus materials. N, P, and K are major nutrients required in soil for agricultural applications.

2.2. Composition of biogas and slurry

The composition of biogas is as below:

a) Methane (CH_4): 55-70% by volume
b) Carbon Dioxide (CO_2): 30-45% by volume
c) Hydrogen Sulphide: 500-30000 ppm by volume
d) Nitrogen (N_2): 1-2% by volume
e) Water vapour: up to 5% by volume
f) Hydrogen (H_2): in traces by volume

As it can be seen from above methane and carbon dioxide are main components in which, methane is flammable and produces energy upon burning. H_2S has foul smell but presented in very less quantity in dung based biogas.

Biogas plants are primarily operated on 10% of total solid content, that means the solid content in the feeding materials should 10 kg in 100 kg. Generally, animal dung consists around 20% of total solid materials in wet condition, Further, to make it 10% solid content material which ultimately enters into the digester we have to dilute the material using water. The ideal way to dilute animal dung is mixing equal amount of water and thus making pest like solution before feeding into the digester. Uniformly mixed and total solid content is very important for efficient production of biogas. Mass transfer of microorganism community in the digester is solely depends upon viscosity if the solution inside the digester which yields best with 10% of the total solid content.

Composition of slurry – the composition of biogas slurry is presented below:

a) Nitrogen (N_2): 1.5%
b) Phosphorous (P_2O_5): 0.4%
c) Potash (K_2O): 2.2%

In India, we have huge amount of cattle and animals and almost all the agricultural families own them having. 3-4 numbers of cattle are enough to have small biogas plant. Various applications and quantity of biogas required are:

Table 2.2.2 Application of biogas

S. No.	Use	Specification for application	Quantity of gas required
1	Cooking	2'' Burner, 0.33 m^3/h	0.3 m^3 per day per person
		4'' Burner, 0.47 m^3/h	
		6'' Burner, 0.64 m^3/h	
2	Coal	6930	0.15 m^3 per h
3	LPG	1088	0.50 m^3 per bhp hour

2.3 Types of biogas plants-

The common types of Biogas plants in India are as follows:

(a) KVIC floating drum type

(b) Janata fixed dome type

(c) Deenbandhu fixed dome type

(d) Shramik Bandhu biogas plant

(e) Flexible balloon type biogas plant

(a) KVIC floating dome type – This is most common type of biogas plants in India. Gas in this type of plant is stored in a metallic drum which is inverted upside down on the digester and moves according to the quantity of gas stored in it. This type of biogas plant is best suitable for rural areas, and does not requires much skill in its operation. The gas delivery pressure is 10 millibar and remains constant. However, the cost of plant is high. This type of plant is best suited for household uses.

(b) Janata fixed dome type – this is fixed dome type plant. It has inlet tank, outlet tank and the digester is closed with concrete and cement material due to which the dome is fixed and does not move with gas amount. Thus, the pressure of the gas is not constant and varies with gas amount. The cost of the plants is relatively less compared to the KVIC plant.

(c) Deenbandhu biogas plant – Fixed dome plant developed by action for Food Production, New Delhi. Principle of working is same as Janata type, except for the configuration of inlet entrance and digester with lower cost.

(d) Shramik bandhu biogas plant – developed by NIGO to reduce the construction cost by using locally available low cost material. Plant design and working principle was same as deenbandhu plant.

(e) Flexible balloon type biogas plant: A flexible balloon is used as anaerobic digestion and gas holder in this type of biogas plant. The gas delivery pressure is very less and does not remains constant. The cost of plant is minimum.

Fig. 2.1 Floating Dome type biogas Plant at IIT Delhi

2.4. Selection of size and type of biogas plant

For selection of size of biogas plants, there are two factors:

(a) Quantity of material available: This is the main factor for selecting the size of the materials available which can be converted to biogas. 25 kgs of dung is required for the production of 1 m^3 of biogas on daily basis, considering 40 days of retention time of material in the digester. Same amount of water is required for the efficient gas production.

(b) Consumption of biogas: When availability of biogas is more and requirement is less, then consumption of biogas is calculated and size is decided.

(c) Retention time: Generally referred as hydraulic retention time (HRT) of the materials inside the digester is also going determine the size of the digester. HRT is dependent up on the mean temperature in the particular area. If the mean temperature of the area is 50 °C which corresponds to 30 days of HRT. Similarly, for 40 °C it will be 40 days and 30 °C for 55 days. Shorter HRT require a lesser volume of digester and vice versa.

The type of biogas plants available in India are floating drum and fixed dome mainly. There are certain conditions which are to be considered before selecting the type of plant:

(a) Technical Considerations: the level of skill required, quality of building material available locally, suitability of site and gas consumption pattern influences the selection of particular design of plant. The fixed dome requires skilled training and good quality building material whereas KVIC floating drum can be constructed easily.

(b) Climate conditions: the climate, specifically temperature affects the fermentation and therefore production of biogas. If the mean temperature is more than 20 °C in

the winter, then any type can be chosen. In case, if the mean temperature is less than 20 °C, then fixed dome is preferred.

(c) Geographic conditions: the fixed dome type plants should be constructed underground completely. It should be constructed in raised platform to achieve automatic flow of slurry.

(d) Economic considerations: the cost of fixed dome the lesser compare to floating drum. Based on the economic considerations of beneficiary selection should be made.

2.5. Cost estimation of biogas plants

Table 2.5.1 Tentative cost of biogas plants construction

Size of Plant (m^3)	Amount of dung (kg)	Amount of water (lit)	Cost*(Rs)
1	25	25	15,000
2	50	50	24,000
3	75	75	32,000
4	100	100	45,000
6	150	150	60,000

*total cost varies as cost of material and daily wagers changes

Table 2.5.2 Materials requirement for construction

Materials	**Size of plant (m^3)**				
	1	**2**	**3**	**4**	**6**
Bricks (standard size)	800	1100	1500	1900	2500
Cement (50 kg bag)	9	15	19	25	33
Stone Chips (m^3)	1	1.27	1.55	1.98	2.54
Sand (m^3)	2	3.5	4.5	6	8
PVC Pipe (1” & ¾” dia)	2	2	2.3	2.6	2.6
Stove and gas valve set	1	1	1	1	1
Pent	1	1.5	1.5	2.5	3
Labour days	20	24	32	40	60
Construction days	10	12	16	20	30

2.6. Basic structure of biogas plants

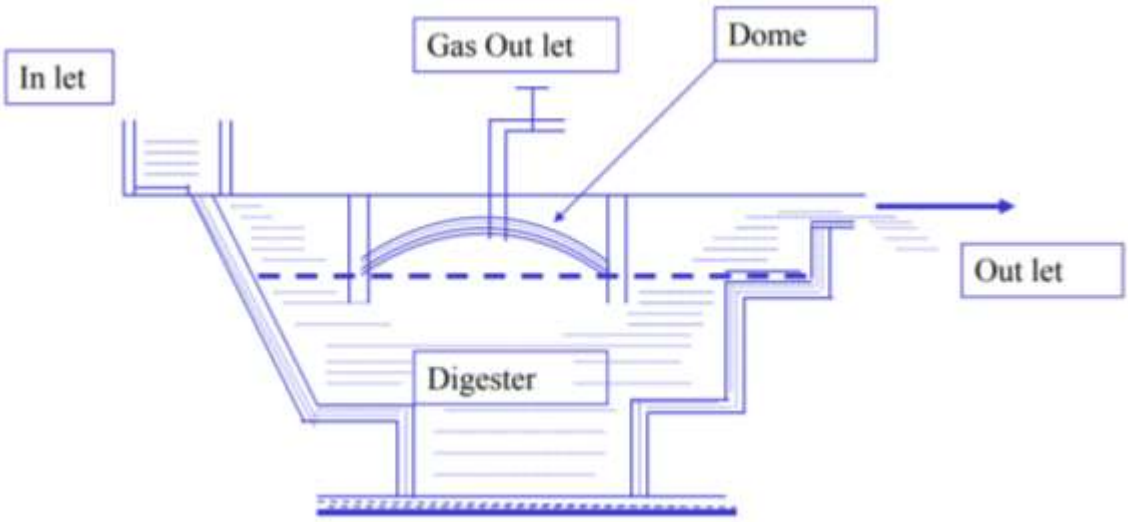

Fig. 2.2 Basic structure of fixed dome biogas plants.

2.7. National Biogas and Manure Management Programme

The main objectives of the scheme were to provide clean bio-gaseous fuel mainly for cooking purposes; for reducing use of Liquified Petroleum Gas (LPG) and other conventional fuels; and to provide bio-fertilizer/ organic manure to reduce use of chemical fertilizers. NBMMP provides for grant of central subsidy to the plant; turn-key job fee linked with five years' free maintenance warranty; financial support for repair of old non-functional plants; training of users, staff, entrepreneurs, etc. and publicity and communication.

(a) Objective of the scheme: (i) availability and accessibility of clean fuel in rural areas.
(ii) Bio fertilizer for the agricultural purpose
(iii) Reducing dependence on the woods
(iv) Alternate source generation for lighting and pumping
(v) Environment Protection

(b) Eligibility for subsidy: (i) Availability of 50 m^2
(ii) Daily availability of water
(iii) Ability of 15,000-20,000 rupees investment

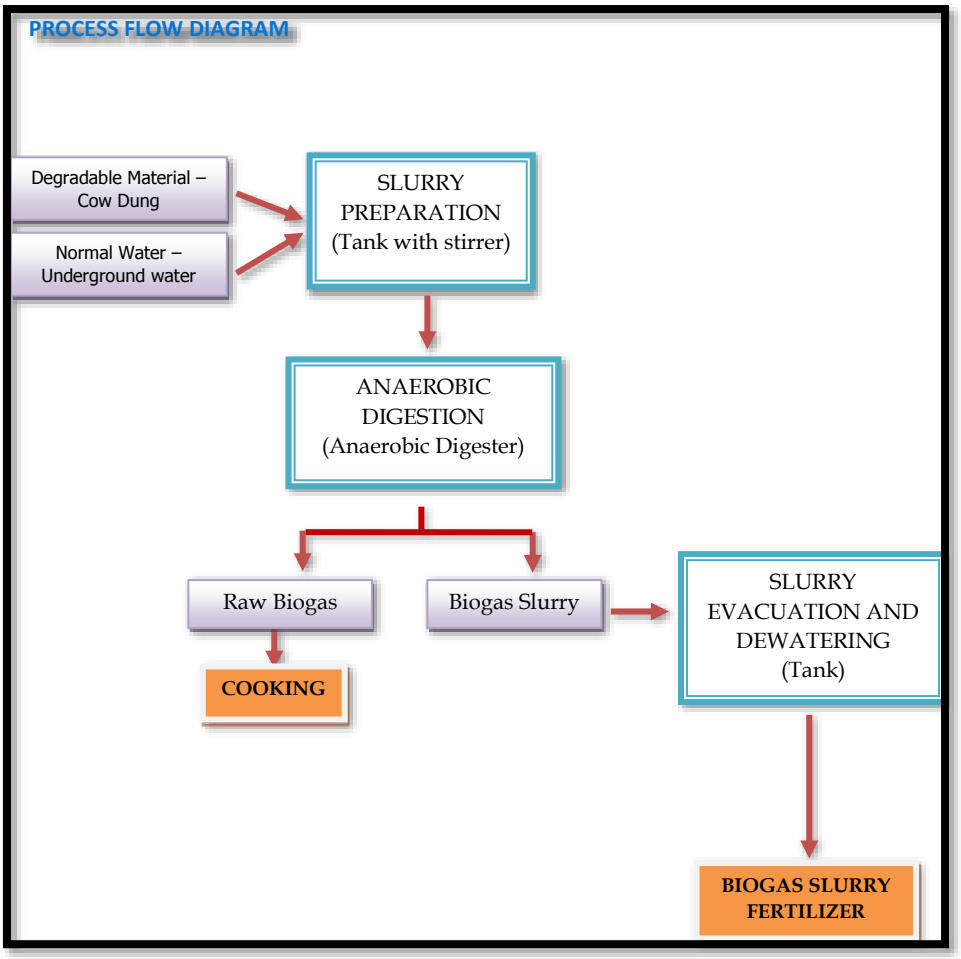

Fig. 2.3 Flow diagram for uses of biogas and digestate

2.8 Benefits of Biogas Digested Slurry

Biogas digested slurry produced through anaerobic digestion is a nutrient-rich material generally directly applied after production on agricultural land as a fertilizer, thereby replacing manmade artificial fertilizers and/or soil conditioners.

- **Enhanced soil quality**
- **Increased crop yields**

Chapter 3

3. Compressed Biogas (CBG)

Fig. 3.1 Compressed biogas uses and bottling

3.1 Introduction

Compressed Biogas (CBG) is an enriched form of biogas containing more than 90% methane (CH_4) (v/v), carbon dioxide (CO_2) up to 4% (v/v) and other traces of gases such as hydrogen sulphide (H_2S), moisture, oxygen (O_2), and nitrogen (N_2). It is produced through a series of processes like the compression of raw biogas, removal of impurities (CO_2, H_2S), and storage of purified gas in a high-pressure vessel at around 200–250 bars for the transport application. Currently, 32 million tonnes of CBG potential is estimated in the country; though, of the total estimated potential, only 0.06% CBG is being produced currently on an annual basis (The details are depicted in Table 1). The research on biogas purification and its utilization as a vehicular fuel and power production are getting more concern from the government bodies. A huge scope of setting up of CBG plants is available in India.

3.2 The Process of CBG Production in the Country

Biogas is produced through anaerobic digestion of biodegradable materials with methane (55%–65%) and carbon dioxide (25%–35%) as major constituents along with some traces of other gases like hydrogen, hydrogen sulphide, ammonia, oxygen, and water vapor. Except for methane and hydrogen, all are accounted as impurities, which reduce the calorific value of the

fuel and corrodes the engine parts. The process of removal of the impurities from the raw biogas is known as biogas cleaning and the adjustment of carbon dioxide to enhance the calorific value to an optimal level is called biogas purification which increases the methane concentration up to 80%–99% in the gas mixture. There are various technologies, such as water scrubbing, chemical absorption, pressure swing adsorption (PSA), membrane separation, cryogenic separation, and biological filtration method, used for CBG production worldwide. Though in India, water scrubbing and PSA systems are most prominently used for the same.

3.3 Water Scrubbing Technology

Fig. 3.2 Mobile & fix unit of Water scrubbing technology for biogas upgradation plant

The working principle of water scrubbing is based on the solubility of different gaseous components present in raw biogas. In this process, water is used as an absorbent, because the solubility of CO_2 in water is much higher than that of CH_4, and is almost 25–26 times higher at 25 °C and atmospheric pressure. Simultaneously, H_2S can also be removed since it is more soluble in water than that of CO_2. This technology consists of a vertical column, where water and pressurized gas, almost at around 9–10 bars is allowed to flow counter-currently. The water is supplied at the top of the column while the pressurized raw biogas is allowed to pass from the bottom as shown in Figure 3.3. The column is filled with the packing materials to provide more surface contact area and retention time. Consequently, CO_2 and H_2S get absorbed in the water and CH_4 with some traces of other gases along with moisture left the purification column at the top. On the other hand, the impurities which are soluble in water leave the column at the bottom and sent to the regeneration tank, where water is depressurized, and CO_2 released. The regenerated water is recirculated back to the scrubbing column, and CO_2 is collected whereas the purified biogas is stored in a cylindrical gas storage vessel. The purified biogas is

compressed in a high-pressure compressor at around 200–240 bars to produce CBG for vehicular application and subsequently stored in a high-pressure cylindrical vessel as same as CNG. The purification efficiency of this technology ranges from 88.9%–96% with less than 2% CH4 loss.

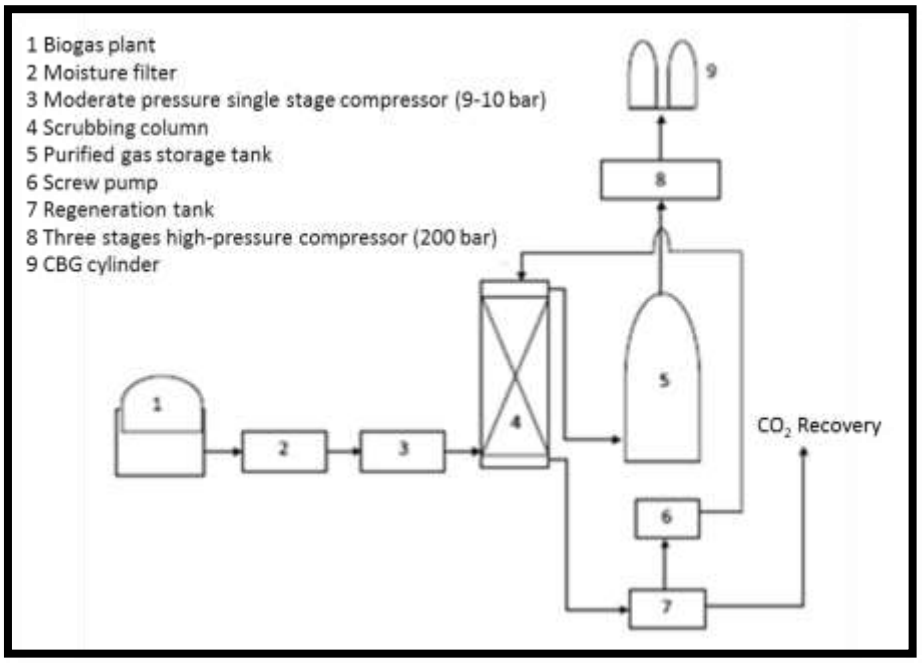

Figure 3.3: Schematic flow diagram of Water Scrubbing Technology

3.4 Pressure Swing Adsorption (PSA) Technology

The separation of impurities of the biogas is based on the adsorption of the different molecules in a solid surface as per the molecular size. This method is particularly used to remove N_2, O_2, CO_2, and water vapour present in raw biogas. The purification process is completed in four sequential steps, viz., adsorption, depressurization, desorption, and pressurization. The dry biogas (after moisture removal) enters at the bottom of the adsorption column as shown in Figure 3.4, where the impurities are adsorbed, and CH_4 leaves at the top. When the adsorbent material gets fully saturated the pressure is released to desorb the CO_2, and the raw biogas is sent to another vessel, in which the regeneration is already done. The CO_2 is sent to the off-stream channel after desorption. Pressurization is done by equalizing the pressure with the depressurizing vessel. Activated carbon, activated charcoal, natural and synthetic zeolites or alumina, synthetic resins, silica gel, carbon molecular sieve, etc., are commonly used as an adsorbent material. This technique employs biogas purification up to 96%–98% methane concentration with 2%–4% CH_4 loss.

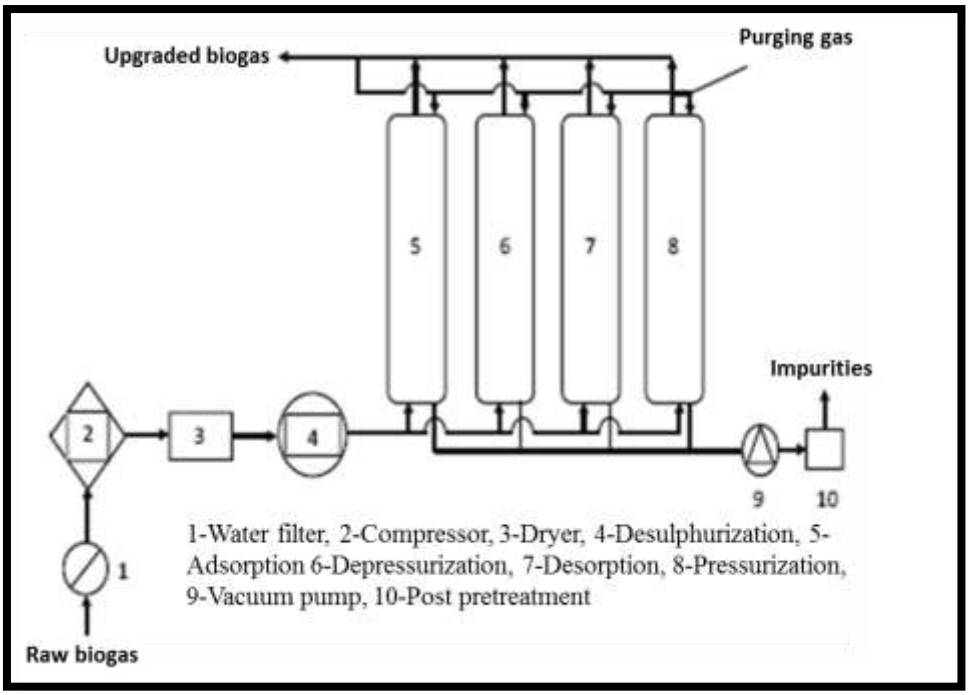

Figure 3.4: Schematic diagram of biogas purification through PSA technique

3.5 Potential of raw materials for CBG

Biogas can be produced using any biodegradable biomass. India has a huge potential of these biodegradable materials for the production of CBG. The details are depicted in Table 3.1.

Table 3.1: The potential of CBG in India

S.N.	Source of biogas	Potential in India ($year^{-1}$)	Biogas potential (Million m^3 $year^{-1}$)	CBG (Million kg $year^{-1}$)
1.	Agricultural waste	234 MT	16,717.0	7,522.65
2.	Cattle waste	-	18,240.0	8,208.00
3.	Dairy waste		80.1	36.05
4.	Distilleries effluent	34.6 million m^3	1,048.4	471.60
5.	Food waste/ kitchen waste	110.4 MT	5,780.0	2,601.00
6.	Human excreta	176.7 MT	15,019.5	6,758.78
7.	MSW	90 MT	8,550.0	3,847.50
8.	Poultry waste	-	159.9	71.96
9.	Pulp and Paper Industries	1.07 MT	150.5	67.73
10.	Slaughter house	194.8 million m^3	545.4	245.43

11.	Sugar Factory	-	846.8	381.06
12.	Vegetable market waste	50 MT	4,000.0	1,800.00
	Total		**~71,138**	**32,011.76**

3.6 An Overview of CBG Plants in India

In India, the water scrubbing and PSA-based purification systems are common. Presently, there are 12 commercial CBG plants installed in the country with a cumulative CBG production capacity of 18,461.7 tonnes per year, which is only 0.06% of the total potential. The details of the CBG plants are shown in Table 3.2.

Table 3.2: Commercial Compressed Biogas (CBG) plants in India

Sr. No.	Company & Location	Raw material for biogas	Plant capacity (m3 day-1)	Biogas Enrichment Technology		CBG production (kg day-1)
1.	Spectrum Renewable Energy Ltd. Kakodi, Kolhapur (Maharashtra)	Pressmud (100 TPD)	20,000	For H_2S removal	Adsorbent Bed	8000
				CO_2 removal	Water Scrubbing	
2.	Mahindra Group's Vehicles @Mahindra World City, Near Chennai (Tamil Nadu)	Food & Kitchen waste (8,000TPD)	1000	--		400
3.	Primove Engineering, Pirangut, Pune (Maharashtra)	Agricultural waste & plants materials (AgroGasTM)	--	Modified PSA		100(Existing) 5000 (Target)
4.	Amul, Vadodara, Anand (Gujarat)	Dairy effluent	1,000	MPSA		--
5.	Brajdham Power Pvt. Ltd., Jaipur (Rajasthan)	Sludge from waste water treatment plant (JMC)	8,400	LPSA		3,780
6.	Manas Agro Industries and Infrastructure Limited, Nagpur (Maharashtra)	Molasses sludge	21,600	Planning to set-up the CBG		--
7.	Tajpur Dairy Complex, Ludhiana (Punjab)	Cattle dung	12,000	--		4,000
8.	M/s. Bharat Biogas Energy Ltd., Ahmedabad (GJ)	MSW	14,000	PSA		6,538

9.	M/s Arc Bio Fuel Pvt. Ltd, Barnala, Punjab		5,000	PSA	1,842
10.	M/s. NRB Bio-Energy,Hanumangarh, Rajasthan	Cattle Manure	2500	MPSA	1,000
11.	M/s Green Elephant India Pvt. Limited, Satara (MH)	Distillery effluents	19,200	PSA	7,920
12.	Noble Exchange Environment Solution Pvt. Ltd., Pune-India	Food waste	350 TPD	--	17,000

TPD: Tonnes per day; PSA: Pressure swing adsorption; MPSA: Medium pressure swing adsorption; LPSA: Low-pressure swing adsorption

Chapter 4

4. Solar Lighting System

Fig 4.1 Solar light (LED)

4.1. Feature of the solar lighting system

a) Battery 12v 7 Ah
b) Mobile charger with an optional fan
c) Operation 3-4 hours
d) Autonomy 2 days
e) Temperature compensation for the best battery charging for various terrain and climatic conditions
f) Short circuit protection on the load side
g) Multi-level overload safeguard
h) Deep discharge fortification and efficient over charge
i) Battery reverses the polarity protection with the fuse
j) 3/4 LED indication systems
k) Low battery cut

4.2. Benefits of the system

1. **Economical:-** Since the sun gives energy without any charge, one can enjoy thirty percent power savings on the electricity bills as well as a long backup lighting system at no running cost.
2. **Non-Polluting:-** Powered by the renewable energy of the sun, this system is a clean source of illumination.
3. **No Maintenance:-** Solar home lighting system includes some moveable parts that reduce the danger of breakage. After it is installed, the system lasts for a long span of time and needs negligible attention.

4.3. Kit of the system includes

a) **Solar Panels: –** These panels are the solid semi-conductor devices, which convert the solar energy into electricity directly.

b) **LED Lamps: –** This system is equipped with two LED lamps comprising of eighteen LEDs in every lamp. Each LED lamp consumes almost 1.5 Watt nominal power and is found to be much more luminous than the CFL. These lamps last for almost 10,000 hours.

c) **External Charger or the Grid: –** In absence of the sunlight, the system can be charged with the help of this external charger, which can be connected to the primary electric supply directly.

d) **Control Unit: –** The compact system has a controller for protecting the battery from getting overcharged.

e) The **Solar** Home Lighting System is used at several locations besides homes like the verandahs, walkways, balcony, and in the non-electrified areas.

4.4. Advantages of solar energy

1. Solar energy is truly renewable energy source. It can be harnessed in all areas of the world and is available every day.
2. Solar energy helps to reduce electricity bills.
3. Solar energy can be used for diverse purposes. We can generate electricity (photovoltaics) or heat (solar thermal). Solar energy can be used to produce electricity in areas without access to the energy grid, to distill water in regions with limited clean water supplies.
4. Solar energy systems generally don't require a lot of maintenance.
5. Technology in the solar power industry is constantly advancing and improvements will intensify in the future.

4.5. Drawing and dimension of solar lighting system

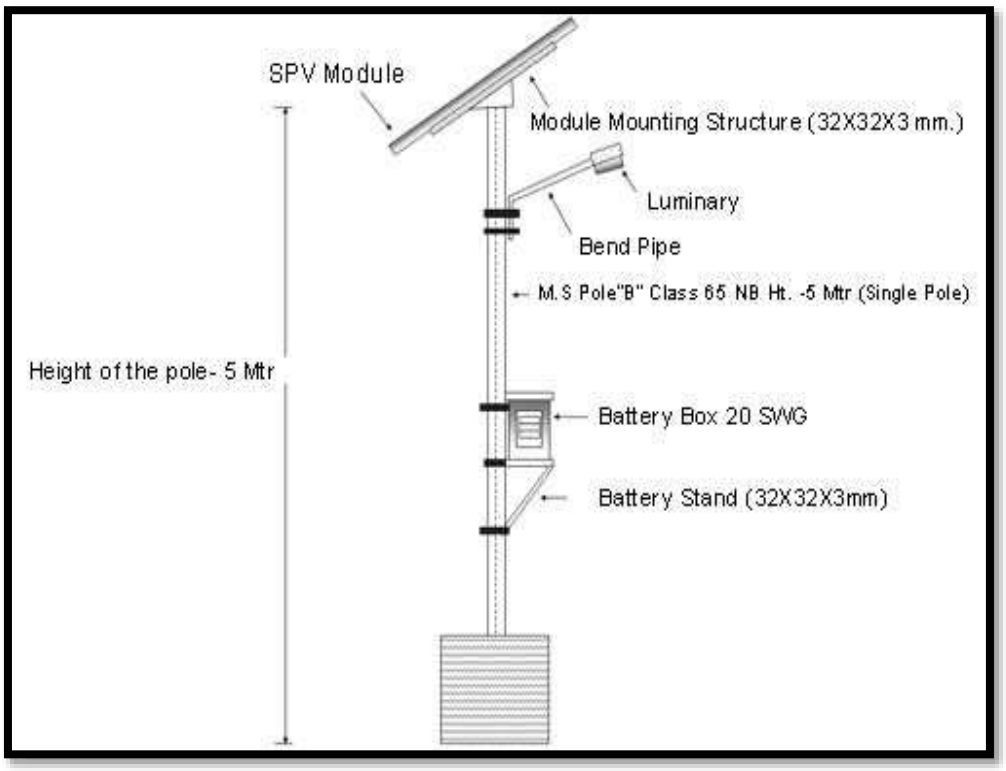

Fig. 4.2 Drawing and dimension of solar lighting system

4.6. Details of the solar street light

RECW provides complete solar street lighting system with installation, proper designing and technique. We design the system with our own in-house solar DC luminary, pole and other accessories.

Table 4.1 Basic models of solar street lights

Model	Solar Panel	Battery	Operation Time	Autonomy
RBFNSL-9W	40 Watt	40 Ah	12 Hrs	2 days
RBFNSL-12W	50 Watt	60 Ah	12 Hrs	2 days
RBFNSL-18W	75 Watt	80 Ah	12 Hrs	2 days

S.No	Item	Description	Unit
1	Luminary	Led technology Dusk to dawn	1
2	Pole	GI or MS	1
3	Battery	dry Battery maintenance free	1
4	Battery Box	MS, GI	1
5	Solar panel	Polycrystalline panel	1
6	Wire cable	2 core Dc cable	As per requirement

As per as requirements, solar street lights can be modified as given below:

Fig. 4.3 Modified solar street lights

Chapter 5

5. Solar Cooker

Fig. 5.1 Basic model of solar cooker

5.1 Working principle

Solar cooking is done by means of the suns UV rays. A solar cooker lets the UV light rays in and then converts them to longer infrared light rays that cannot escape. Infrared radiation has the right energy to make the water, fat and protein molecules in food vibrate vigorously and heat up.

5.2 Benefits of solar cooker

1. Using clean, renewable, and readily available solar energy as fuel.
2. Preserving natural resources by not requiring the use of wood or other biomass fuels to cook.
3. Not producing dangerous emissions which pollute local environments and contribute to climate change.
4. Solar cooking is free.
5. Solar cooking is quick and easy.
6. Food cooked with a solar cooker is healthy.
7. Solar cookers make no noise.
8. Cooking with sunshine is kind to the environment.
9. Solar cooking ovens are portable.
10. Cooking with the sun empowers you to be more self-sufficient.

5.3 Advantages of solar cooker

1. No requirement of cooking gas or kerosene, electricity, coal or wood.
2. No need to spend on fuel, as solar energy is available free.
3. Food cooked in solar cooker is nutritious. About 10-20% of protein retention is more as compared to that in conventional cooking .Vitamin thiamine retention is about 20 to

30% more whereas vitamin A is retained 5 to 10% more when food is cooked in solar cooker.

4. Solar cooking is pollution free and safe.
5. Solar cookers come in various sizes. Based on the number of family members, the size of the cooker can be chosen.
6. All cooking activities (like boiling, roasting) can be done using a solar cooker.
7. There are government schemes which offer subsidies to purchase solar cookers.

5.4 Disadvantage of solar cooker

- Adequate sunshine is required for cooking.
- Takes longer time to cook food than the conventional cooking methods

5.5 Types of solar cooker

There are two basic types of solar cookers –

1. Box solar cookers.
2. Concentrator type solar cookers

Each of these basic types of solar cookers meets a specific need and specific type of cooking.

5.5.1 Box solar cookers

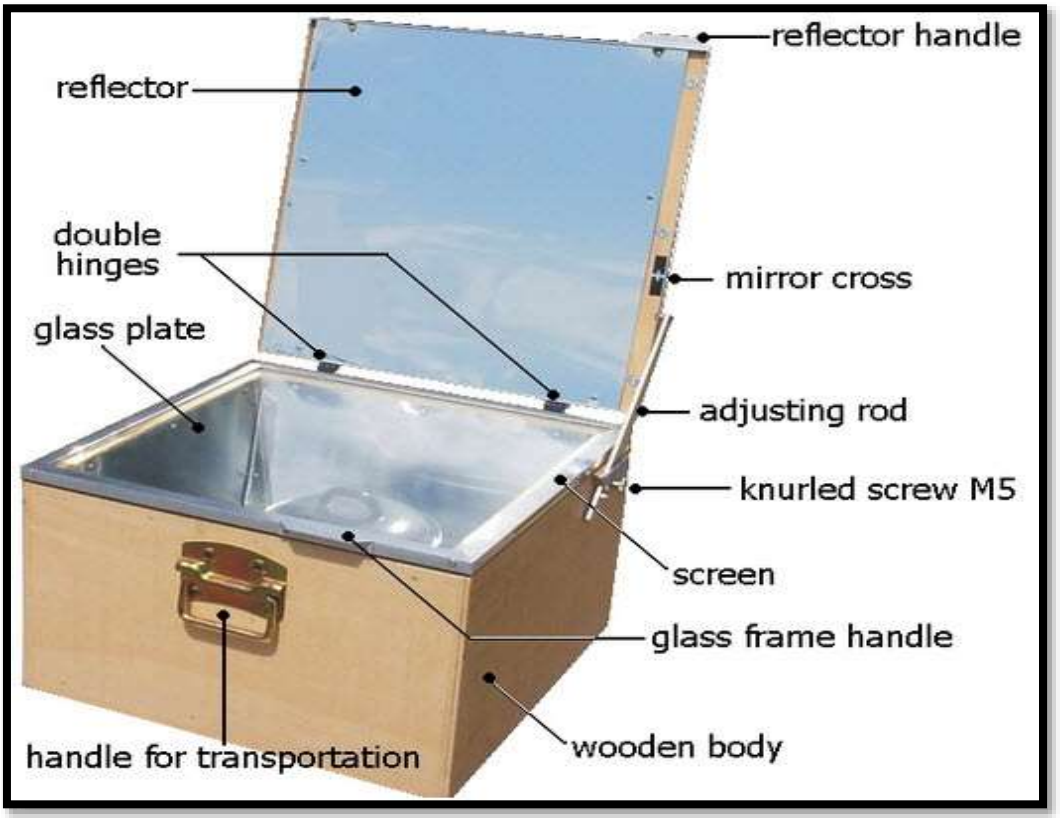

Fig. 5.2 Box type solar cooker

5.5.1.1 Working of box type solar cooker

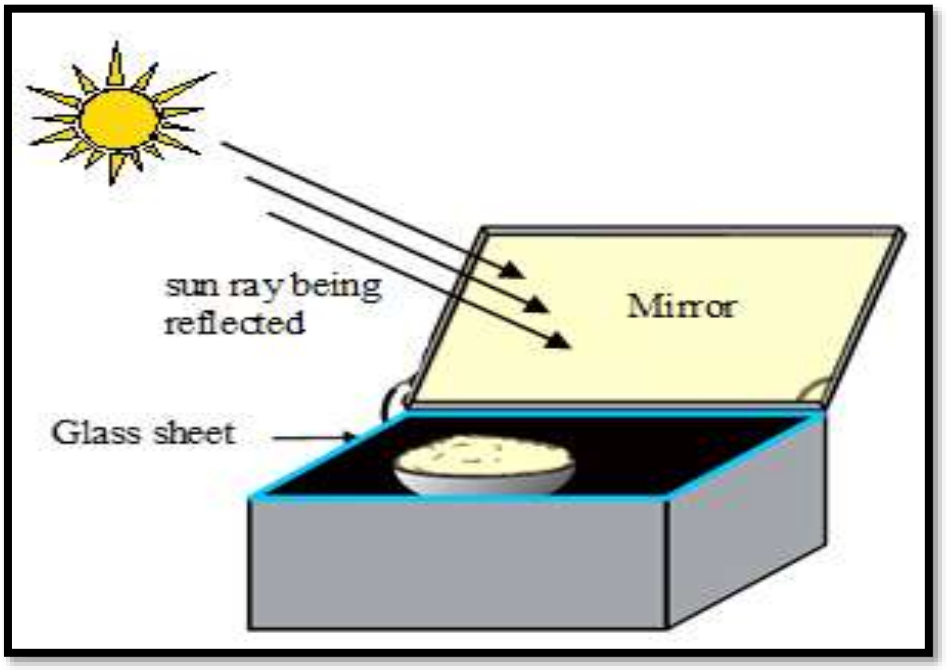

Fig. 5.3 Working model of box type solar cooker

5.5.1.2 Components of a box type solar cooker

1. **Outer Box:** The outer box of a solar cooker is generally made of G.I. or aluminum sheet or fiber reinforced plastic.
2. **Inner Cooking Box** (Tray): This is made from aluminum sheet. The inner cooking box is slightly smaller than the outer box. It is coated with black paint so as to easily absorb solar radiation and transfer the heat to the cooking pots.
3. **Double Glass Lid:** A double glass lid covers the inner box or tray. This cover is slightly larger than the inner box. The two glass sheets are fixed in an aluminum frame with a spacing of 2 centimeters between the two glasses. This space contains air which insulates and prevents heat escaping from inside.
4. **Thermal Insulator:** The space between the outer box and inner tray including bottom of the tray is packed with insulating material such as glass wool pads to reduce heat losses from the cooker. This insulating material should be free from volatile materials.
5. **Mirror:** Mirror is used in a solar cooker to increase the radiation input on the absorbing space and is fixed on the inner side of the main cover of the box.
6. **Containers:** The cooking containers (with cover) are generally made of aluminum or stainless steel. These vessels are also painted black on the outer surface so that they also absorb solar radiation directly

5.5.1.3 Cost of a box type solar cooker

- Cost ranges between Rs 2500 to 4,000. It varies based on the size and model.

5.5.2 Concentrator type solar cooker

5.5.2.1 Working principle

It works on the principle of solar energy concentration using a Reflecting Parabolic Solar Concentrator. A parabolic solar concentrator is used for concentrating solar radiation on a focal area where the cooking vessel is placed.

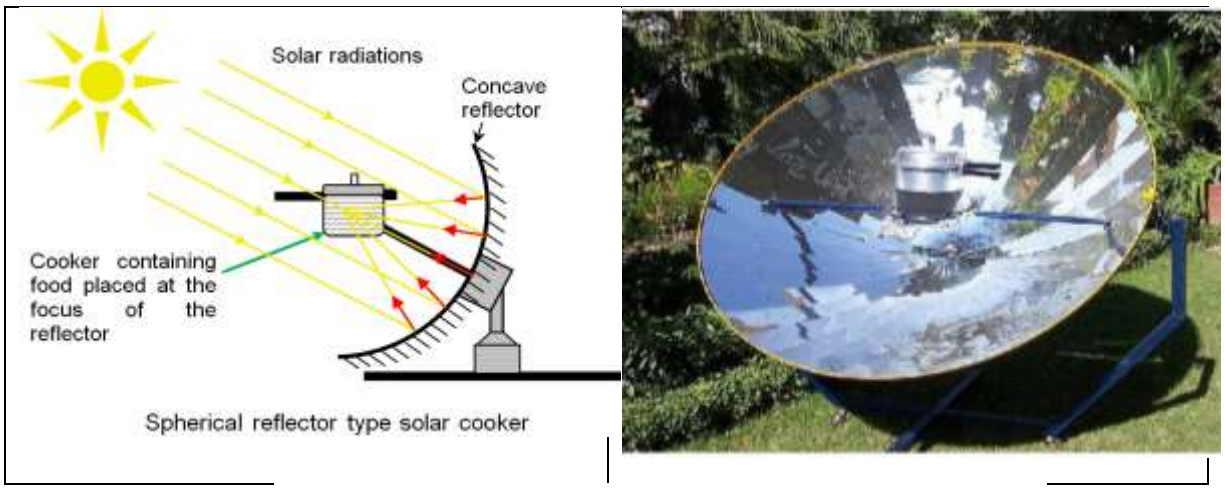

Fig. 5.4 Reflecting parabolic solar concentrator (RPSC) solar cooker

5.5.2.2 Parts of concentrator type solar cooker

1. **Solar Concentrating Disc** - The disc which helps in concentrating solar energy to a focal point
2. **Automatic Tracking System** - With the help of a simple automatic mechanical tracking system the solar disc rotates in the direction of the movement of the Sun to give continuous and accurate solar energy concentration.
3. **Secondary Reflector** -This is provided opening in the north-facing wall of the kitchen or the cooking place just below the cooking vessel. This reflector receives the concentrated solar radiation and reflects it on to the bottom of the cooking vessel.
4. **Cooking vessels**

5.5.2.3 Cost

It ranges from Rs 7000 - Rs 50, 0000 depending upon the size and the model.

5.6. Designing Solar Cooker

Simple things which are readily available around the house can be used to create a solar cooker.

5.6.1 Material required

- **Two reasonably large cardboard boxes** - a size that can hold two large bowls with some room to spare. One box should fit into the other.

- **Straw / Old newspapers** – Collect and crush a few old newspapers, better still if you can get some straw. These will be used for insulation.
- **A transparent glass cut to the dimensions of the top of the box** – to be used as the lid of the inner box.
- Aluminum foil
- Black acrylic paint
- Packing tape
- Scissors
- Glass sheet
- 2 aluminum bowls with metal lids

5.6.2 Methodology

- **The inner Box**: Clean out the box; tape up all the sides except the top. Ensure that the box is sturdy. With a pair of sharp scissors cut off the top four top flaps of the inner box. Tape up the rough edges. Now, paint the inside of the box a very very dark black - preferably using acrylic paint. Leave the box to dry.
- **The outer box**: Clean out the box; tape up all the sides except the top. Ensure that the box is strong. With the scissors cut out large pieces of aluminum foil - the kind that is used to wrap food. Paste the pieces on the inner side of the four top flaps. Leave the box to dry.
- **The insulation**: Use materials that are poor conductors of heat - rolled up newspaper, straw, husk etc. Place a layer of this material at the bottom of the big box and then place the smaller box on top. Next, fill out the gaps between the four sides of the boxes tightly with insulation material. Once this is done the two boxes should become one unit.
- **The glass top**: Place the glass top on the inner box.
- **The meal**: Select two non-reflective bowls with lids. In one bowl put half a cup of washed rice and pour two cups of water. In the other bowl mix your favorite vegetable with a spoonful of oil, salt to taste, a pinch of turmeric and green chilies. Place both bowls carefully in your solar cooker and set it out in the sun. Wait for two hours, and the delicious food is ready, cooked only with the pure goodness of nature.

Chapter 6

6. Solar Water Heater

Fig. 6.1 Basic model of solar water heater

6.1 Parts of solar water heating system

- A solar water heating system consists of a flat plate solar collector, a storage tank kept at a height behind the collector, and connecting pipes.
- The collector usually comprises copper tubes welded to copper sheets (both coated with a highly absorbing black coating) with a toughened glass sheet on top and insulating material at the back. The entire assembly is placed in a flat box.
- In certain models, evacuated glass tubes are used instead of copper; a separate cover sheet and insulating box are not required in this case.

A solar thermal device captures and transfers the heat energy available in solar radiation which can be used for meeting the requirements of heat in different temperature ranges.
Three main temperature ranges used are

- Hot water - 60°C to 80°C
- Medium temperature Drying - 80°C to 140°C
- High temperature Cooking & power generation - > 140°C

6.2. Working of solar water heating system

- The system is generally installed on the roof or open ground, with the collector facing the sun and connected to a continuous water supply.
- Water flows through the tubes, absorbs solar heat and becomes hot.
- The heated water is stored in a tank for further use.

- The water stored in the tank remains hot overnight as the storage tank is insulated and heat losses are small.

6.3 Advantages of solar heating system:

- **Choice of size**: Proper sizing is essential, as homeowners must have enough storage to meet 90 to 100 percent of their hot water needs. Storage volume is also a consideration. A 50- to 60-gallon storage tank is fine for up to three people, an 80-gallon tank for up to four people, and a larger one for as many as six people.
- **Less space**: Solar thermal panels are usually less space-intensive than photovoltaic panels. Fewer are required to heat water than in an array used to produce sufficient power for a home.
- **High efficiency**: About 80 percent of the sun's radiation is turned into the heat energy needed to obtain hot water at home.
- **Cost savings**: The cost of two or three panels is cheaper than larger domestic installations. You also save on fuel bills for supplying gas heating systems.
- **Low maintenance**: After installation, little maintenance is required, and a solar water heater can run for up to 20 years.
- **Lower carbon footprint**: A home can be eco-friendlier, plus tax incentives may be available for using renewable energy.

6.4 Disadvantages of solar water heating system

- Corrosion is main concern. In open loop hydronic solar systems, oxygen can rust any iron or steel part.
- Compared to photovoltaic panels, solar thermal panels only heat water.
- Solar heaters require sufficient roof space to accommodate them.
- Solar water heaters require direct sunlight to function.
- The system does not function on cloudy, rainy, or foggy days.
- Annual maintenance is recommended to check the pump and antifreeze.
- Installation requires the use of a new hot water cylinder.

6.5 Configuration

Solar water heating system is a device which supplies hot water at 60°C to 80°C using only solar thermal energy without any other fuel. It has three main components:

1. Solar Collector
2. Insulated hot water storage tank
3. Cold water tank with required insulated hot water pipelines and accessories.

6.6 Working principle

In a typical solar water heater, water is heated by the solar thermal energy absorbed by the collectors. The hot water with lower density moves upwards and cold water with

higher density moves down from the tank due to gravity head. A bank of collectors can be arranged in a series – parallel combination to get higher quantity of hot water. A typical 100 liters insulated tank with a $2m^2$ collector area, will supply water at a temperature of 60 - 80°C

6.7 Types of solar heating systems:

6.7.1 Flat plate collectors solar water heaters

The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water.

Fig. 6.2 Flat plate collectors solar water heaters

These are the most widely used type of collector for domestic solar water heating. Flat plate collectors are shallow rectangular boxes with glass lids and usually aluminum for the body. Typically, 1-1.5 meters wide by 2-2.5 meters long.

6.7.2 Evacuated tube solar water heaters

Evacuated Tube Collectors collect the heat through a number of annealed glass tubes that each have their own heat-absorbing plate inside. There are loads of different designs, but the basic principle is the same for all designs. Basically each tube is like a little greenhouse that traps sunlight inside the glass tube which is used to heat either the water directly, or a special heat transfer fluid that transfers the heat to the water.

Fig. 6.3 Evacuated tube solar water heaters

6.8 Capacity of solar water heating systems

Table 6.1 Capacity of solar water heating systems

CAPACITY (liters)	AREA (m^2) ETC TYPE	AREA (m^2) FPC TYPE
100	**1.5**	**2**
200	**3**	**4**
250	**3.75**	**5**
300	**4.5**	**6**
350	**7.5**	**10**

6.9 Cost of solar water heater

- The total cost of a solar water heating system is dependent upon many things. These include, the capacity, the kind of back-up used, the materials used for the inner and outer tanks, the length of distribution piping required to take hot water to the bathrooms, and not insignificantly, the brand value.
- Typically, for an Indian make system with single BIS approved flat plate collector of 2 sq. m area, the current market costs are reported to be in the range of Rs. 15,000-20,000, excluding the distribution piping. However, this range is indicative, and could vary from manufacturer to manufacturer.

Table 6.2 Details for cost of solar water heater

Capacity (liters)	Cost of ETC type((Rs)	Cost of FPC type(Rs)
100	**15000**	**22000**
200	**28000**	**42000**
250	**34000**	**50000**
300	**40000**	**58000**
350	**62000**	**85000**

Chapter 7

7. Toilet linked biogas plant

Fig. 7.1 Toilet link biogas plant

7.1 Introduction

Since 1900's, anaerobic biogas digester had been applied successfully in Asian countries like India, Nepal and China, treating cow manure, pig excreta, organic waste or a combination of them, providing not only biogas, which is used as source of energy, but also slurry used as soil conditioner.

During last 20 years in India, different government and private institutions promoted the use of toilet linked biogas plants (TLBPs) especially in rural area. TLBP is a modification of the household-size anaerobic biogas digester which includes toilet effluent connection through a pipeline. This system not only generates biogas and slurry, but also offers a new option for wastewater disposal and treatment. However, little is known about the slurry's properties, and previous research studies recommended a post-treatment of TLBPs effluent, prior its use as soil amendment. One of the options are sludge treatment wetlands (STWs).

Recycling and reuse of human excreta for biogas generation is an important way to get rid of health hazards from human excreta. Energy Sources, Govt. of India, for its implementation through state nodal agencies. Human excreta contain a full spectrum of pathogens. Most of

these pathogens are eliminated due to anaerobic condition inside the digester. Besides using biogas for different purposes, biogas plant effluent can also be used as manure or discharged safely into any river or water body without causing pollution. Thus biogas technology from human wastes has multiple benefits – sanitation, bioenergy and manure. Human excreta based biogas technology remained unnoticed for long due to the fact that the available technology was not socially acceptable, as it required manual handling of human excreta, which contains a full spectrum of pathogens. The design of digester does not require manual handling of human excreta and there is complete recycling and resource recovery from the wastes. The Digester is built underground into which excreta from public toilets flows under gravity. Inside the digester biogas is produced due to anaerobic fermentation by the help of methanogenic bacteria. The biogas, thus produced, is stored in inbuilt liquid displacement chamber. One cubic foot biogas is produced from the human excreta of per person per day. Human excreta based biogas contains 65-66% methane, 32-34% carbon dioxide and, rest the hydrogen sulphide and other gases in traces.

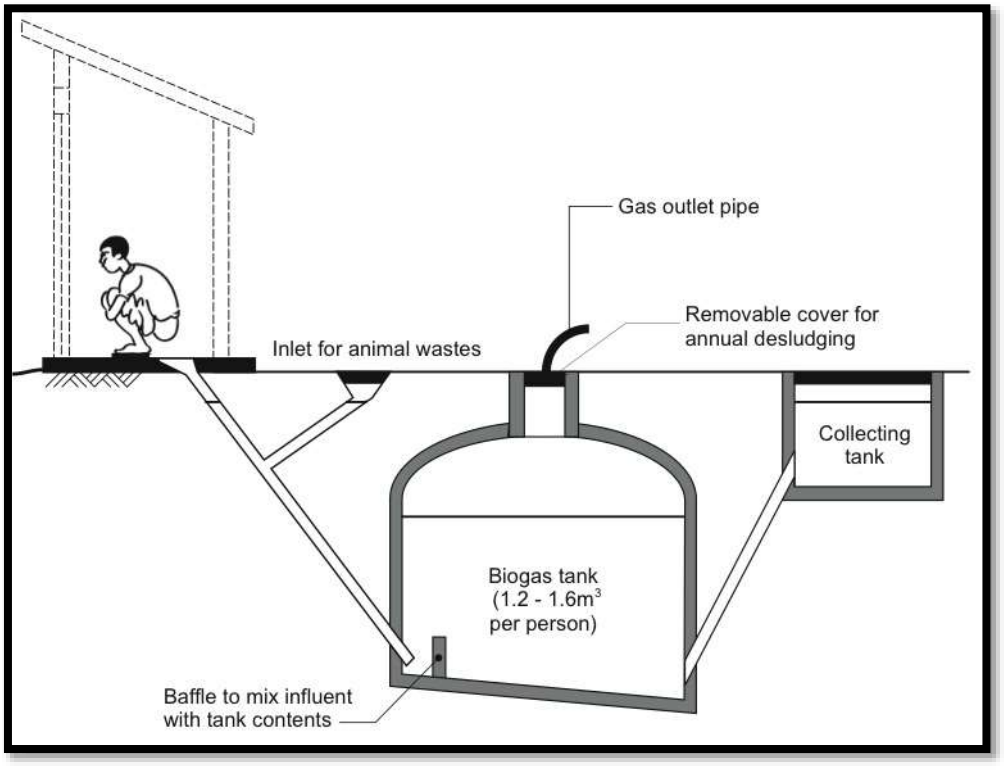

Fig.7.2 Schematic diagram of toilet link biogas production

Methane is the only combustible constituent, which is utilized in different forms of energy. Its calorific value is 24 MJ/cum or about 5000 Kcal/cum. A one thousand cft. (30 cum) of biogas is equivalent to 600 cft. of natural gas, 6.4 gallons of butane, 5.2 gallons of gasoline or 4.6

gallons of diesel oil. Biogas is utilized for cooking, lighting through mantle lamps, electricity generation and body warming during winter. Cooking is the most efficient use of biogas. Biogas burners are available in a wide ranging capacity from 8 cft to 100 cft biogas consumption per hour. It burns with a blue flame and without soot and odour. The biogas mantle lamp consumes 2-3 cft per hour having illumination capacity equivalent to 40 W electric bulbs at 220 volt. Motive power can be generated by using biogas in dual fuel internal combustion (IC) engine. Air mixed with biogas is aspirated into the engine and the mixture is then compressed, raising its temperature to about 350°C, which is the self-ignition temperature of diesel. Biogas has a high (600°C) ignition temperature. Therefore, in order to initiate combustion of the charge, a small quantity of diesel is injected into the cylinder just before the end of compression. The charge is thus ignited and the process is continued smoothly.

At optimum condition only 20% diesel is required, rest (80%) is substituted by biogas. Biogas consumption by engine is 15 cft/BHP/hour. A public convenience used by about 2000 persons per day would produce approximately 60 cum of biogas which can run a 10 KVA genset for 8 hours a day, producing 65 units of power. It is a new method to make biogas based electricity generation sustainable.

7.2 Advantages and limitations of biogas sanitation systems

Human excreta based biogas system has multiple advantages; improves sanitation, makes availability energy, bio fertilizer and reduces green-house effect.

- Generation of clean energy for household use: after an initial investment in the system, there is less or no need to spend money on fuel, and no more smoke from wood or charcoal in the kitchen.
- Cooking on biogas is quicker and easier than cooking with firewood.
- Destruction of bacteria, viruses and helminth eggs in human and animal excreta. A farm with a biogas system is a cleaner and safer place.
- Production of safe fertilizers for use on the farm containing plant nutrients in an easy absorbable liquid form.
- Support the fight against global warming by facilitating to burn methane from organic waste, instead of escaping into the atmosphere where it adds to the greenhouse effect; supports also efforts to restrict deforestation.
- Cost effectiveness: Biogas septic tanks have at least the same investment as a conventional septic tank, and capture the biogas for further use. Operation and

maintenance expenses (energy and supplies) are low and require only low skilled labour. For financial consideration the energy source that is replaced by biogas is important (wood, kerosene, LPG).

- Low-tech system: Anaerobic technology does not rely on complex machines and processes (such as aeration systems); systems, such as the anaerobic pre-treatment units (settler, baffled reactors or filters) of a complex decentralized wastewater treatment system, require low but adequate maintenance.
- Low space requirement: underground construction does not occupy valuable space especially in urban areas; only 0.5-1m^2 per m^3 daily flow are needed, compared to25-30 $m^2/m^3/d$ flow in aerobic ponds and constructed wetlands.
- The space above a biogas plant could also be built on as parking area, as long as the system remains accessible.

7.3 Key factors

For the successful and sustainable implementation of biogas sanitation schemes it's crucial to:

• Create awareness amongst future users (sanitation related problems in general and value of wastewater in particular);

• Participatory planning and decision making;

• Training of users on how to operate and maintain the wastewater system;

7.4 Slurry collection, treatment and application

The slurry, i.e. the fermented sludge, may be directly applied as liquid soil amendment to agricultural land or collected and further processed in so called sludge drying beds for dewatering.

7.4.1 Direct application of the slurry

The slurry is directly applied to agricultural plots using a trench or pipe system for distribution.

7.4.2 Advanced treatment of slurry in sludge drying beds

If the slurry is not used directly used, it may be collected and treated in sludge drying beds. The simplest way of providing for sludge drying beds is to partially dig up the ground and pile up the excavated soil to earthen bunds. These perimeter bunds will also help in keeping surface run-off water from entering the sludge drying beds.

Fig. 7.3 View of simple sludge drying beds

It is recommended to provide for at least 2 beds, which are used alternately. One bed receives slurry on a daily basis while the other lays idle or provides for additional resting period. The volume of each drying bed should allow for collection of slurry produced within a period of one month. Thus taking care on reduced infiltration and evaporation rates during rainy season.

Construction details and other important information

• The location of the sludge drying beds should be safe from flooding.

• If available, natural slope avoids the need for pumps.

Chapter 8

8. Bio-diesel

Fig.8.1 Biodiesel production plant

8.1 Introduction

Biodiesel is a renewable, biodegradable fuel manufactured domestically from vegetable oils, animal fats, or recycled restaurant grease. Biodiesel meets both the biomass-based diesel and overall advanced biofuels requirement of the Renewable Fuel Standard.

Unlike the vegetable and waste oils used to fuel converted diesel engines, biodiesel is compatible with existing diesel engines and distribution infrastructure.

8.2 Physical properties

Table 8.1 Biodiesel's Physical Characteristics

Biodiesel's Physical Characteristics	
Specific gravity	0.88
Kinematic viscosity at 40°C	4.0 to 6.0
Cetane number	47 to 65
Higher heating value, Btu/gal	˜127,960
Lower heating value, Btu/gal	˜119,550
Density, lb/gal at 15.5°C	7.3

Carbon, wt%	77
Hydrogen, wt%	12
Oxygen, by dif. wt%	11
Boiling point, °C	315-350
Flash point, °C	100-170
Sulfur, wt%	0.0 to 0.0015
Cloud point, °C	-3 to 15
Pour point, °C	-5 to 10

8.3 Bio-diesel production

Biodiesel is produced from vegetable oils, yellow grease, used cooking oils, or animal fats. The fuel is produced by transesterification—a process that converts fats and oils into biodiesel and glycerin (a co product). Approximately 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol (usually methanol) in the presence of a catalyst (usually sodium hydroxide [NaOH] or potassium hydroxide [KOH]) to form 100 pounds of biodiesel and 10 pounds of glycerin (or glycerol). Glycerin, a co-product, is a sugar commonly used in the manufacture of pharmaceuticals and cosmetics.

Raw or refined plant oil, or recycled greases that have not been processed into biodiesel, are not biodiesel and should not be used as vehicle fuel. Fats and oils (triglycerides) are much more viscous than biodiesel, and low-level vegetable oil blends can cause long-term engine deposits, ring sticking, lube-oil gelling, and other maintenance problems that can reduce engine life.

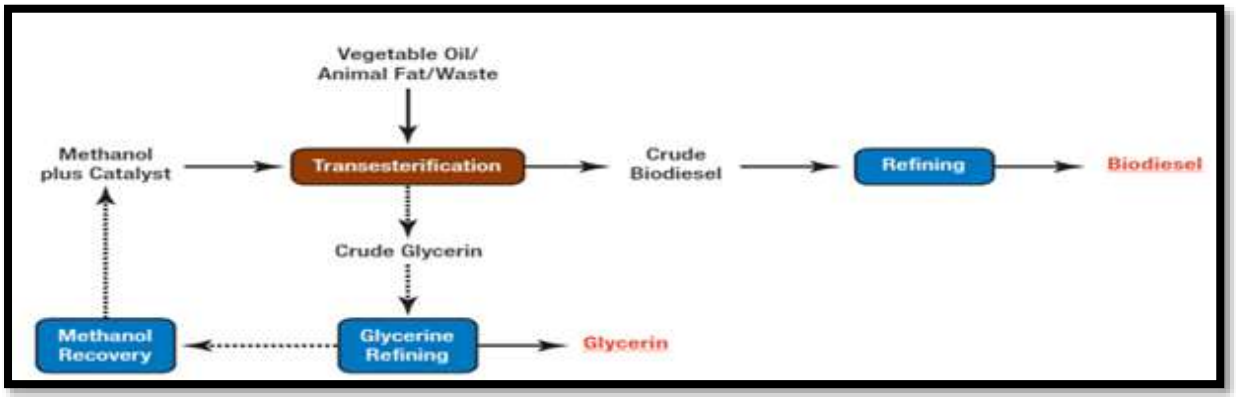

Fig. 8.2 Schematic of biodiesel production path

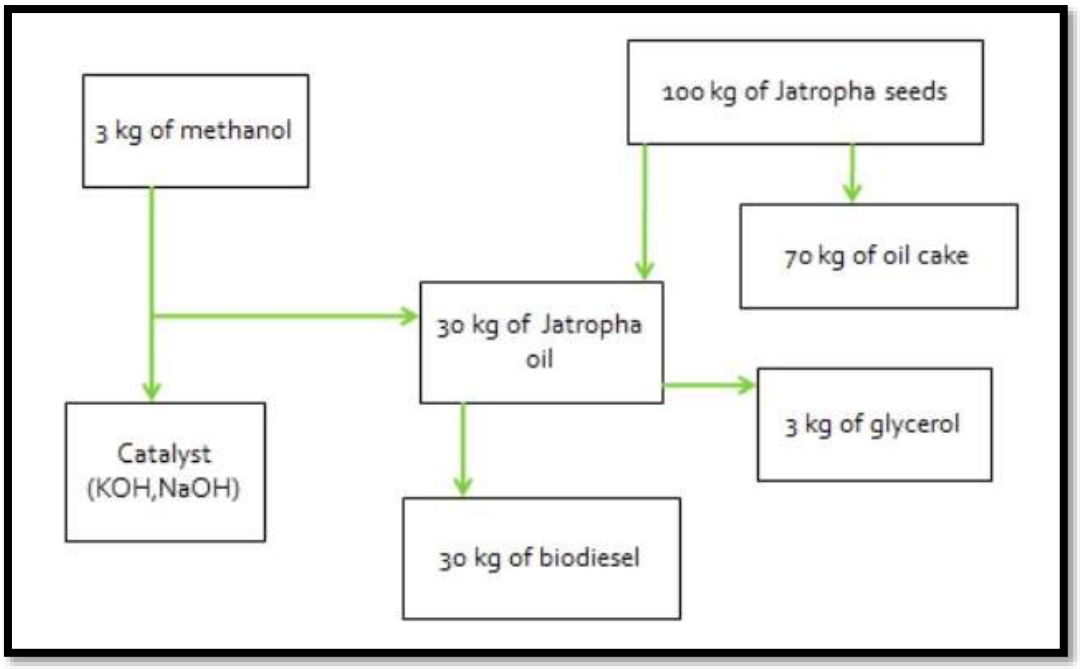

Fig. 8.3 Flow diagram for Conversion of Jatropha seeds to biodiesel

8.4 Biodiesel benefits and considerations

Biodiesel is a domestically produced, clean-burning, renewable substitute for petroleum diesel. Using biodiesel as a vehicle fuel increases energy security, improves air quality and the environment, and provides safety benefits.

a) **Energy Security and Balance:** Using biodiesel and other alternative fuels and advanced technologies to reduce fuel consumption continues to strengthen national security and reduce transportation energy costs for businesses and consumers.

b) **Air Quality:** Using biodiesel reduces life cycle emissions because carbon dioxide released from biodiesel combustion is offset by the carbon dioxide absorbed from growing soybeans or other feedstock's used to produce the fuel.

c) **Engine Operation:** Biodiesel improves fuel lubricity and raises the cetane number of the fuel. Diesel engines depend on the lubricity of the fuel to keep moving parts from wearing prematurely.

d) **Safety:** Biodiesel in its pure, unblended form causes far less damage than petroleum diesel if spilled or released to the environment. It is safer than petroleum diesel because it is less combustible. The flashpoint for biodiesel is higher than 130°C, compared with about 52°C for petroleum diesel. Biodiesel is safe to handle, store, and transport.

8.5 Why bio-diesel?

There are several reasons in the support of using biodiesel as an alternative fuel-

- Biodiesel reduces exhaust smoke (particulates) emissions by up to 75% so the usual black cloud associated with a diesel engine can be eliminated.
- Biodiesel is much less dangerous to put in vehicle fuel tank as its flash point is ± 150°C (300°F) as opposed to petroleum diesel ± 70°C (150°F).
- Biodiesel provides significant lubricity improvement over petroleum diesel fuel so engines last longer, with the right additives engine performance can also be enhanced**.**
- It is biodegradable, nontoxic and produces fewer pollutants when burnt completely. It can be used in pure form (B100) or blended with petroleum diesel. Most of the common blend includes B2 (2% biodiesel, 98% diesel), B5 (5% biodiesel, 95% petrodiesel) or B20 (20% biodiesel, 80% petrodiesel).
- It has reduced exhaust emissions as compared to petroleum diesel fuel and also it has lower toxicity as compared to the petroleum diesel fuel.
- If we compare biodiesel with petroleum diesel, it is safer to handle and its quality is governed by ASTM D 6751 quality parameters.
- There were will be a major reduction in all types of pollutants adding to global warming and smog because it burns clean
- It is the only alternate fuel, which has been approved by the Environment Protection Agency (EPA). It has also passed every Health – Effects Test of the Clean Air Act and meets the necessities of the California Air Resources Board (CARB)
- Biodiesel is much more economical than petrol and diesel since recycling materials such as vegetable oil or animal feces are much cheaper than fossil fuel. And also petrol prices may increase with time as natural resources shrink
- One of the most important advantages of using biodiesel is that it burns clear than fossil fuels and hence does not produce sulfur or any other harmful chemicals and also there is no unpleasant smell associated with burning biodiesel
- Other advantages of biodiesel fuel are that it can also be blended with other energy resources and oil. Biodiesel fuel can also be used in existing oil heating systems and diesel engines without making any alterations
- It can also be distributed through existing diesel fuel pumps, which is another biodiesel fuel advantage over other alternative fuels. The lack of sulfur in 100% biodiesel extends

the life of catalytic converters and also the lubricating property of the biodiesel may lengthen the lifetime of engines.

8.6 Biodiesel utilization

8.6.1 Bio diesel pumps

Fig. 8.4 Bio-diesel pump for fuels filling station

Biodiesel has emerged as a fuel with no harm to the environment and which is safe to burn. As an alternative fuel similar to petrol and fossil diesel, biodiesel is an advance form of biofuel produced from an animal or vegetable fat based renewable fuel. Even, used cooking oil (UCO) could be effectively used to produce biofuel and of great use in diesel vehicles. This revolution is helping several countries overcome their dependence on diesel, as biodiesel has the combustion properties which are very similar to those of petroleum diesel. Pollution is increasing day by day and one the major reasons behind this is automobile pollutants, which come out due to the use of petrol or diesel based automobiles. Biodiesel can act as excellent alternative, which least harms the environment.

8.6.2 Bio diesel vehicles

Fig. 8.5 Biodiesel filling in vehicles on filling station

Biodiesel can be used as fuel in tractors for farming specially in rural areas which will be great aid to the farmers as they can get cheap fuel and they don't have to run for cities for fuel as petroleum fuels are not easily available in rural areas. This will be a boom in the crop production and will be advantage for the farmers. Biodiesel provides better fuel economy then the petroleum based products and can be used in existing diesel engines with little or no modifications at all and can replace fossil fuels to become the most preferred primary transport energy source.

Biodiesel can work as an alternative form of fuel and can reduce our dependence on foreign suppliers of oil as it is produced from domestic energy crops. It is produced in local refineries, which reduce the need to import expensive finished products from other countries.

8.6.3 Bio-diesel irrigation pumps

Fig. 8.6 Biodiesel engine for utilization of irrigation propose

In rural areas load shedding, shortage of petroleum and diesel fuel and in some places frequent loss of power is the major problems our farmers are facing in the modern India. Use of bio diesel can be a boom for the farmers. By use of biodiesel in irrigation pumps there is no rust formation in the engine and it emits little noise during operation. In fact the engine running on the oil emits less smoke unlike the diesel operated one.

GUIDELINES FOR SUBMISSION OF SEG PROPOSALS

The Subject Expert Groups are institutions which have been appointed by the NCI for providing operational expertise sought by the institutions engaged in the rural works. They evaluate and approve the technical solutions / customization proposed by the Participating Institutions (PIs) and provide guidance for implementation of the projects.

Following points must be taken into consideration while submitting the project proposals under the subject expert group of Rural Energy Systems.

1. The proposal submitted by Participating Institutions should have direct impact on the beneficiaries in the adopted villages.

2. PIs must clearly have explained the plan of action, technology to be used and how it will be implemented?

3. Where could be the technology installed, who will manage and maintain? How the system would be maintained after implementation of the project?

4. What are the funds required for and breakup of expenditure in details?

5. Is the machine/device is available in the market or is it designed by Participating Institution.

6. The duration of the project should be limited to a maximum of 6 months.

7. The cost of the project should be mentioned as per UBA norms (Rs. 1.0 Lakh for Technology Development and Rs. 0.50 Lakh for customization of technology).

8. Awareness/ campaign (Health, Safety, Plastic free etc.) based Proposals should not be considered.

9. Basic research and development project proposals should not be considered instead if technology is available, UBA may provide fund for implementation of the technology in the adopted villages.