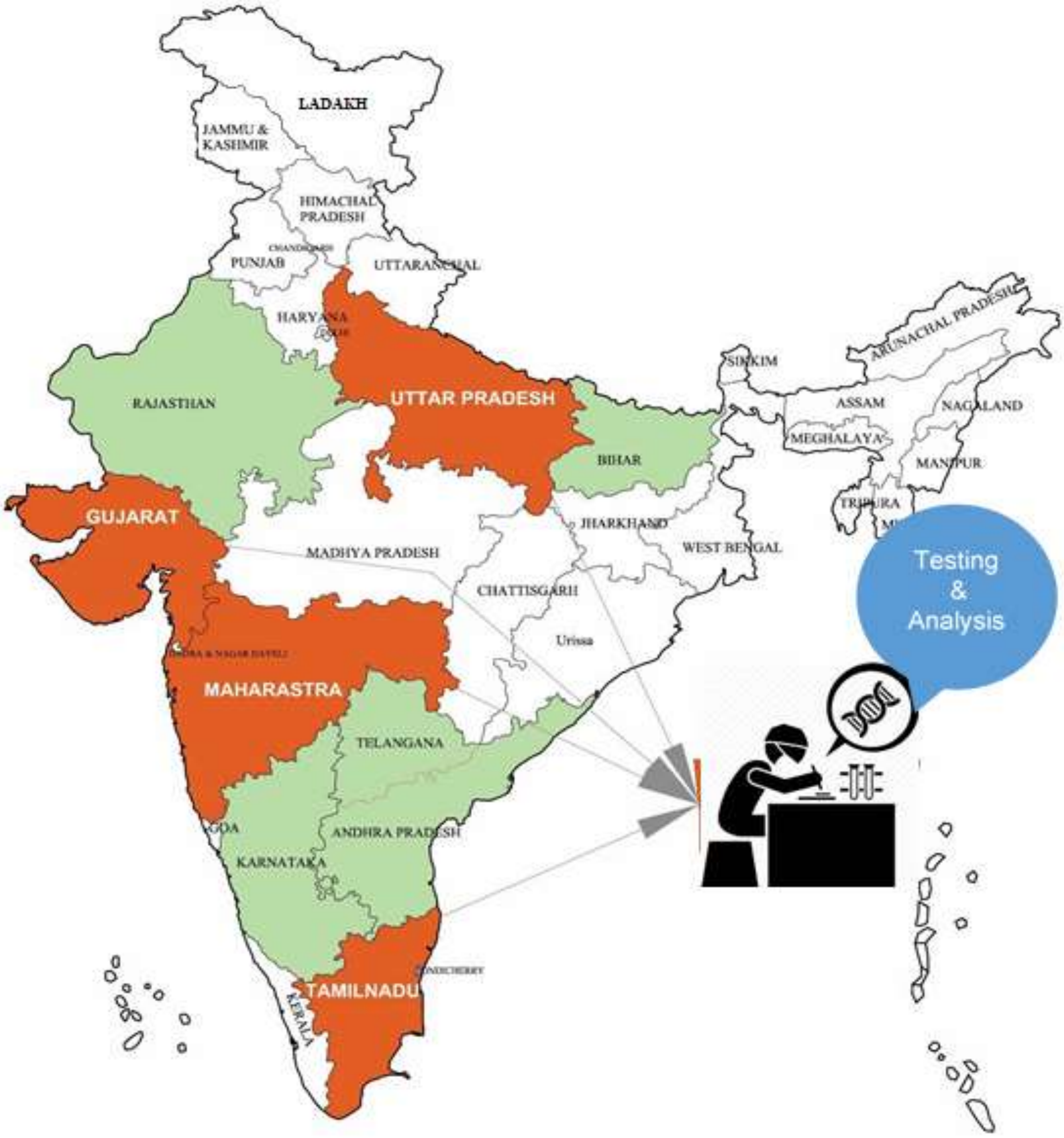
Stage: Fourth Progress Report

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION



FOURTH PROGRESS REPORT – COLLECTION AND CHARACTERIZATION OF VARIOUS SAMPLES OF INDUSTRIAL ORGANIC WASTE ACROSS THE SELECTED STATES

Mapping the available urban and industrial organic waste in various locations in India

PREFACE

United Nations Industrial Development Organisation (UNIDO) is implementing a GEF supported project "Organic Waste Streams for Industrial Energy Applications in India" jointly with the Ministry of New and Renewable Energy (MNRE), Government of India. The project aims to contribute to its climate change strategic objective namely, promoting investment in renewable energy technologies by transforming the market for using organic waste for SME industrial energy applications in India; and focusses on supporting different technological and commercial innovations in the application of bio-methanation technology (Biogas or Anaerobic Digestion).

A study for mapping the urban and industrial organic waste availability across India is being carried out by UNIDO, also to determine energy generation potential from different organic wastes. A comprehensive and integrated "Bio-Resource Map" of the organic waste from four targeted sectors will be developed using GIS applications. A complete study will have following outcome reports.

Part-I	Identification of Organic Waste Streams in India
Part-II	Identification of Potential States for Energy Generation Using Organic Waste from the Targeted Industries
Part-III	Availability, Utilisation Pattern and Price of Organic Waste from Targeted Industries in Potential States
Part-IV	Characterisation of Organic Waste from Targeted Industries in Potential States.
Part-V	A Comprehensive Map (GIS) of the Organic Waste from Targeted Industries in Potential States

The current report presents and analyses the results of the waste sampling and characterization survey undertaken from various industrial organic waste generating plants in India i.e. poultry farm, cattle farm, sugar industry and fruit & vegetable processing units. 16 samples of industrial organic waste were collected from the 4 selected sectors from each of the 4 selected states showing high potential of feedstock availability. The samples were tested in a NABL accredited Lab for physiochemical parameters like pH, total & volatile solids, C/N ratio, COD and Biomethane potential; parameters affecting the biogas production and design of a biomethanation plant based on anaerobic digestion technology. A decision-making matrix has been developed further in the report for strategically selecting the locations for Biomethanation plants considering the key decision criteria including the locations with maximum possibilities of Mixed/ Multi- feedstock and seasonality variations.

CONTENTS

List of Tables

List of Photos

Abbreviations

AD	:	Anaerobic Digestion
AIFPA	:	All India Food Processors' Association
AIWPA	:	All India Wine Processing Association
APEDA	:	The Agricultural and Processed Food Products Export Development Authority
ASI	:	Annual Survey of Industries
BDTC	:	Biogas Development and Training Centres
B&H	:	Buswell and Hatfield 1936
BMP	:	Biomethane Potential
BOD	:	Biological Oxygen Demand
BPGTP	:	Biogas Power (Off-grid) Generation and Thermal Application Programme
BTDC	:	Biogas Training and Development Centre
CBG	:	Compressed Biogas
CERC	:	Central Electricity Regulatory Commission
CFTRI	:	Central Food Technological Research Institute
CFA	:	Central Financial Assistance
CLRI	:	Center Leather Research Institute
CNG	:	Compressed Natural Gas
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
DADF	:	Department of Animal Husbandry Dairying & Fisheries
DPR	:	The Directorate of Poultry Research
DWSC	:	District Water Sanitation Committee
ETP	:	Effluent Treatment Plant
F&V	:	Fruits and Vegetable
GCMMF	:	Gujarat Cooperative Milk Marketing Federation Ltd.
GEDA	:	Gujarat Energy Development Agency
GEF	:	Global Environment Facility
GERC	:	Gujarat Electricity Regulatory Commission
GoI	:	Government of India
GOBAR Dhan	:	Galvanizing Organic Bio-Agro Resources Dhan
HPMC	:	Himachal Pradesh Horticulture Produce Marketing and Processing Corporation Ltd
IARPMA	:	Indian Agro & Recycled Paper Mills Association
IBA	:	Indian Biogas Association
ICAR	:	Indian Council of Agriculture Research
IISR	:	Indian Institute of Sugarcane Research
INR	:	Indian Rupees
ISMA	:	Indian Sugar Mill Association
IWA	:	Indian Wine Academy
KLD	:	Kilo liters day
KVIC	:	Khadi and Village Industries Commission
LPG	:	Liquefied Petroleum Gas
MAIDC	:	Maharashtra Agro Industries Development Corporation Ltd
MEDA	:	Maharashtra Energy Development Agency
MERC	:	Maharashtra Electricity Regulatory Commission

MNRE	:	Ministry of New & Renewable Energy
MOAFW	:	Ministry of Agriculture & Farmers Welfare
MOSPI	:	Ministry of Statistics and Program Implementation
MPEDA	:	Marine Products Export Development Authority
MSME	:	Micro, Small and Medium Enterprises
MSW	:	Municipal Solid Waste
MT	:	Metric Ton
MW	:	Mega Watt
NAPCC	:	National Action Plan on Climate Change
NABL	:	National Accreditation Board for Testing and Calibration Laboratories
NDDB	:	National Dairy Development Board
NEDA	:	Non-conventional Energy Development Agency
NHB	:	National Horticulture Board
NNBMMP	:	New National Biogas and Manure Management Program
OLR	:	Organic Loading Rate
ORS	:	Organic Recycling System
O&M	:	Operation and Maintenance
PESO	:	Petroleum Explosive Safety Organization
PPG	:	Project Preparation Grant
Qt	:	Quintal
RE	:	Renewable Energy
SEA	:	Solvent Extractors Association
SERC	:	State Electricity Regulatory Commission
SNA	:	State Nodal Agency
TCD	:	Tons of cane crushed per day
TEDA	:	Tamil Nadu Energy Development Agency
TPD	:	Ton Per Day
TNERC	:	Tamil Nadu Electricity Regulatory Commission
TS	:	Total Solids
UNDP	:	United Nations Development Program
UNIDO	:	United Nations Industrial Development Organization
UP	:	Uttar Pradesh
UPERC		Uttar Pradesh Electricity Regulatory Commission
VS	:	Volatile Solid
VSI	:	Vasantdada Sugar Institute
WTE	:	Waste to Energy

1. Introduction

A study was conducted under the Project Preparation Grant (PPG) by Global Environment Facility (GEF) - United Nations Industrial Development Organization (UNIDO), in consultation with Ministry of New & Renewable Energy (MNRE) entitled “Organic Waste Streams for Industrial Renewable Energy Applications in India”. During this study, based on discussion with relevant stakeholders and officials from Government of India (GoI), it was decided that Bio-methanation - Anaerobic digestion would be one of the most suitable technology for treatment of industrial organic waste. The history of India’s first digestion plant date back to the year 1859 when the first digestion plant was established in leper colony in Mumbai. The Government of India already has a well-developed policy framework for encouraging plants based on organic waste and anaerobic digestion.

The first progress report for the project included state wise assessment of the urban and industrial organic wastes in India, which included identification of waste sources, estimation of waste generation quantities and estimation of energy potential for urban and industrial organic waste streams in India.

The second progress report was an extension of first progress report and provides detail matrix on estimated waste generation and energy potential of urban and industrial organic waste. This report also provides detail assessment of four key sectors such as poultry industry, sugar industry, fruit & vegetable processing industry and cattle farming, priorities and shortlisting of states and districts / regions based on the waste generation/ availability and other parameters. The selected top four states with maximum energy potential were Uttar Pradesh, Maharashtra, Tamil Nadu and Gujarat. The potential region in each of the four states was identified for detailed analysis and field investigations.

The third progress report provided details about the primary survey, site visits and stakeholder consultation for each identified sector and the states based on which a “Consolidated Matrix on Availability, Utilization and Pricing of Industrial Organic Waste” was developed for the four states based on the data obtained from primary survey and validation of secondary data based on stakeholder consultations. Primary survey was carried out by conducting site visits in the industries generating organic waste from the selected four sectors

The major objective of this fourth progress report is to develop a decision-making matrix to strategically select locations for Bio-methanation plants with maximum possibilities of Mixed/Multi- feedstocks and seasonality variations. The decision making matrix has been developed in this report with due consideration to the availability of the selected industrial organic waste categories across the 4 states in India including industrial organic waste characterization, seasonal variations in availability, current usage of the waste, existing market for the waste and possibilities of usage of mixed multi feedstock in biomethanation plants.

As part of this deliverable, the industrial organic waste sampling and characterization survey was carried out to access the maximum biomethane potential (BMP) from the four selected sectors. The other parameters being analysed apart from BMP are pH, total solids, volatile solids, C/N ratio and COD. The current report presents and analyses the results of the waste sampling and characterization survey undertaken from various industrial organic waste generating plants in India i.e. poultry farm, cattle farm, sugar industry and fruit & vegetable processing units. 16 samples of industrial organic waste were collected from the 4 selected sectors from each of the 4 selected states showing high potential of feedstock availability. The samples were tested in a NABL accredited Lab. The results from the lab and their analysis will help the developers in designing of their plant in terms of maximum biogas potential and usage of mixed/multi feedstocks.

2. Waste Sampling and Testing

This chapter discusses the sampling plan & methodologies, testing & analytical parameters and test results for the collected samples. The selection of potential region and potential sectors has been described in detail in the second and third stage of the report. Waste samples were collected from 16 identified regions in India with high potential for availability of feedstock; tested & analysed for their suitability to support the setting up of new Biomethanation plant.

2.1. Waste Sampling Plan

Plan was developed to collect four samples each of press mud, cattle dung, poultry litter and fruit & vegetable waste respectively from each of the four high potential states i.e. Gujarat, Maharashtra, Tamil Nadu and Uttar Pradesh. Since, the number of samples to be collected for the project were limited, due care was taken to ensure that the selected sample is the representative of all the operating and proposed plants in the region. The sample locations were finalised prior to the field visit and after careful assessments of the plant operation status, sample availability, operating capacity and location. The methodology adopted for sampling location finalization, collection & transfer of organic waste samples from industries to the laboratory and testing of the samples is discussed in detail in the following section:

1. Samples to be collected from actively operating plants in the potential region
2. Sample collected should be the representative sample of the type of industrial organic waste in the region.
3. Identification of NABL (National Accredited Board for Testing and Calibrated Laboratories) accredited laboratory for analysis of industrial organic waste samples.
4. Prior confirmation on the date for sampling to be obtained from the respective plant operator.
5. Travel plan to be formulated for transportation of the samples from the plant to the laboratory in minimum time possible.
6. Sampler to be appraised of the required health & safety protocols to be followed during visit to plants for collection of samples.
7. Tamper proof containers to be procured to ensure the samples collected from the respective locations are free from any contamination.
8. Sample collection containers to be labelled with type & location
9. Only fresh industrial organic waste samples to be collected from the end of the processing line.
10. Each identified sample of industrial organic waste to be mixed uniformly.
11. Collection of samples in designated tamper proof container to prevent any contamination during handover of samples to lab.
12. Indicate the date and time after collection of samples on sample collection containers to ensure that the sample does not get exchanged with another sample.
13. Chain of custody form to document evidence confirming that a sample has not been exchanged with another sample, contaminated, or tampered with in any manner.
14. Photographic evidence of waste sampling for record and references.
15. Waste sample testing by the lab as per the approved methodologies.

2.2. Sample Collection

Based on the sampling plan and methodology, the samples were collected from the respective industries/farms. Sample collection details for each sector are presented in the following section

Press mud

During field visit it was observed that press mud was available with and without spent wash from the sugar processing industries; therefore, it was decided after consultation with UNIDO to collect & analyse 2 samples of press mud with spent wash and 2 samples without spent wash.

Samples were collected from plants with average crushing capacity ranging from 4000 TCD to 14000 TCD generating an average of 150 to 500 tonnes of press mud every day. Press mud availability is a seasonal and is available from October to February in the states of Uttar Pradesh, Gujarat and Maharashtra. Press mud availability in Tamil Nadu is split into two seasons, one from November to February and the other from May to September. The sample collection from the respective states were planned accordingly.

Gujarat

Press mud sample was collected from Shree Ganesh Khand Udyog Sahkari Mandli Ltd on 8th February 2019. The press mud from the plant is composted within the plant premises using distillery spent wash. The sample for analysis was collected from the windrow platform prior to mixing with the distillery spent wash.

Photo 2-1 : Press Mud Sample Collection, Bharuch, Gujarat

Maharashtra

Press mud sample blended with distillery spent wash was collected from Ajinkyatara sugar processing plant,Satara on 8th February 2019.

The plant has a distillery unit which generates around 150 cubic meters of spent wash per day. The spent wash from distillery unit is sprayed on press mud for composting. Sample collected from the plant is the press mud blended with the spent wash.

Photo 2-2 : Ajinkyatara sugar processing plant,Satara

Tamil Nadu

Press mud sample was collected on 29th January 2019 from Sakthi sugars plant situated at Bhavani, Erode district of Tamil Nadu. The average processing capacity of the plant is 7000 TCD and 8 lakh tons of sugarcane was crushed and approximately, 28,000 tons of press mud (filter cake) generated in the year 2018-19.

The plant is having a distillery unit generating approximately 1200 KLD of spent wash. The raw spent wash from distillery unit is processed to concentrate the spent wash from 1200 KLD to 300 KLD. The final concentrated spent wash is transferred to the solar evaporation ponds and utilised for composting the press mud. The press mud generated from the plant is collected and shifted to windrow platform for further composting. Sample collected for analysis include fresh press mud sample unloaded on the windrow platform prior to mixing with the spent wash.

Photo 2-3 : Press mud sampling, Sakthi Sugars, Erode

Press mud sample blended with distillery spent wash was collected on 23rd January 2019 from Dhampur sugar mills ltd which is located at Bijnor district of Uttar Pradesh. The sugarcane crushed in the year 2016-17 was 22.83 lakh tons with an installed crushing capacity of 14,000 TCD. The sugar plant was composting press mud using spent wash from their facility through windrow composting. The press mud sample collected from the site was one week old and was blended with spent wash.

Photo 2-4 : Press Press Mud Sample Collection – Uttar Pradesh

Cattle Dung

Fresh Cattle dung samples were directly collected from the cattle farm for further analysis. The cattle farm selected were of different sizes with animals ranging from 20 to 150 animals.

Gujarat

The sample of cattle dung was collected on 8th February 2019 from Punit Bharwad cattle farm.

Photo 2-5 : Cattle Dung Sample Collection, Vadodara

Maharashtra

Cattle dung sample was collected on 8th February 2019 from Govardhan Trust gaushala, situated at Wai, Satara district of Maharashtra. Goshala has 24 cows generating 10 Kg of cattle dung per animal per day. Cattle dung is manually collected and stored at stock yard for further usage. Fresh sample from the stockyard was collected for analysis.

Photo 2-6 : Govardhan Trust, Wai, Satara, Maharashtra

Tamil Nadu

The cattle dung sample was collected from Excel dairy farm on 29th January 2019..Approximate quantity of cattle dung generation is 10 Kg per animal per day. Cattle dung from the farm is manually collected and shifted to stock yard on daily basis. The cattle dung is stored in the open yards and allowed for sun drying for a period of 2 to 3 months. The demand for dried cattle dungs as organic manure is high in the region. For the current analysis, fresh samples from the dairy farm was collected.

Photo 2-7 : Cattle dung sampling at Excel dairy farm, Namakkal, Tamil Nadu

Uttar Pradesh

The sample of cattle dung was collected on 23rd January 2019 from Lal Bahadur Singh cattle farm. Fresh samples from cattle farm was collected for the current analysis.

Photo 2-8 : Cattle Dung Sample Collection, Bijnour, Uttar Pradesh

Poultry Litter

Poultry litter samples was collected from the poultry farm with an average bird population ranging from 20000 to 55000 birds. Sample was collected from three-layer type farm and one broiler farm. Layer farm are the farms where the droppings of birds directly fall into the pit constructed under the cages of birds; whereas in the broiler farm the droppings from the broiler birds gets mixed with paddy husk, food gains and therefore collection of poultry litter separately from the broiler farms is not possible.

Gujarat

Poultry litter sample for analysis was collected on 8th February 2019 from Hafiz poultry farm having an average litter generation of 12 Kg per bird per annum. Poultry litter from the farm is used as organic manure. Fresh sample was collected directly from the poultry litter storage area of the farm.

Photo 2-9 : Poultry Litter Sample Collection, Vadodara Gujarat

Maharashtra

The sample of poultry litter was collected from Ajinkyatara poultry farm. Layer birds were developed in cages; the poultry litter from these birds fell into the pits constructed below the cages in the farm. Poultry litter from the farm is manually collected and shifted to stock yard after allowing the material to dry for

Photo 2-10 : Ajinkyatara poultry farm, Satara, Maharashtra

2 to 3 months. The demand for dried litter as organic manure is high in the region. The sample of poultry litter for current analysis was collected from the litter collection pit.

Tamil Nadu

The poultry sample was collected on 30th January 2019 from Kumar poultry farm This farm is a layer farm; poultry litter from birds was collected in the pit constructed below the cages of layer birds. Poultry litter was manually collected, shifted and stored in open stock yards allowing sun drying for a period of 2 months. After complete drying, material is loaded manually in trucks/tractors and transported for further utilization. Sample for testing and analysis was collected directly from the pit under the cage of the birds

Photo 2-11 : Kumar poultry farm, Namakkal, Tamil Nadu

Uttar Pradesh

Poultry litter was collected on 24th January 2019 from Dinesh poultry farm situated in Shamli district of Uttar Pradesh. Shamli district in Uttar Pradesh has the highest poultry bird population in the state. The number of birds present in the farm was 24,000 and the farm generates approximately 360 tonnes of

Photo 2-12 : Poultry Litter Sample Collection, Shamli district , Uttar Pradesh

poultry litter with an average generation of 15 Kg per bird annually. Currently, poultry litter is utilized as organic manure by farmers. The poultry farm visited was broiler type and the poultry litter sample was collected from the farm contained poultry litter along with feeding material, husk etc.

Fruit and vegetable processing waste

Fruit and vegetable processing plants are operational only during the respective seasons. The waste samples were collected from the plants operational during the field visit.

Gujarat

Raw potato peel waste was collected from Fine Taste Food Pvt Ltd on 7th February 2019. Approximately 0.6tonne of waste is generated per day from the plant. Potato waste from the processing facility is manually collected and stored at the stocking yard within the

Photo 2-13 : Vegetable Processing Industry Waste Sample Collection, Ahmedabad, Gujarat premises. The organic waste is sold to Green Earth Bio Energy Plant located a distance of 100 Km in Surendranagar district.

Maharashtra

Strawberry waste sample was collected from the fruit processing unit of Mapro Private Limited located at Satara in Maharashtra. This plant was established in 1956 and is in continuous operation. 15 different types of fruits such as pineapple, guava, oranges, tamarind, strawberry, mango, black plum etc. are processed in the plant based on seasonal availability. Mapro facility is in operation for the entire year except two months of shut down period. The processing capacity of the plant is 10 tons/day and 2-3 tons of organic waste is generated per day. The waste is manually collected from the plant and transported to Maharashtra Industrial Development Corporation (MIDC) composting plant.

Photo 2-14 : Pine apple waste generation at Mapro, Maharashtra

Tamil Nadu

The papaya waste was collected on 30th January 2019 from Sakthi Fruits Pvt Ltd . The fruit processing plant was established in the year 1997. The installed and operational capacity of the plant is 2 tons per day. Papaya, mango and pineapple are the major fruits processed in the plant. Approximate waste generation is 40% from papaya, 30% from mango and pineapple. Waste from the plant was collected manually in handcarts and loaded in auto tippers and tractors for subsequent transportation for final utilization.

Photo 2-15: Sakthi Fruits Pvt Ltd, Erode, Tamil Nadu

Uttar Pradesh

Carrot waste was collected on 13th February 2019 from Bharat Agro Tronica City. Fruits processed in the plant include pineapple, papaya and guava. Quantity of raw material handled per day is 5 tons per day with an approximate waste generation of 200 Kgs per day. All types of fruit wastes were utilized as cattle feed in nearby farms of the processing facility.

Fresh waste sample was collected directly from the plant for the current analysis.

Photo 2-16 : Bharat Agro Tronica City, Loni, Ghaziabad

The summary of the locations for sample collection with date and plant is presented in following **Table 2-1**

Table 2-1: Sampling locations and other details

Sample	State	Sample Collection date	Plant location	Plant details
Press Mud	Maharashtra	08.02.2019	Ajinkyatara sugar processing plant, Shendre Taluk, Satara District	4000 TCD/140 TPD

Sample	State	Sample Collection date	Plant location	Plant details
	Gujarat	08.02.2019	Shree Ganesh Khand Udyog Sahkari Mandli Ltd., Vataria	4,000 TCD/140 TPD
	Tamil Nadu	29.01.2019	Sakthi Sugar, Bhavani, Erode district	7000 TCD/245 TPD
	Uttar Pradesh	23.01.2019	Dhampur sugar mills ltd, Bijnor district	14,000 TCD/490 TPD
Cattle dung	Maharashtra	08.02.2019	Govardhan Trust, Wai, Satara district	Average cow dung generation -10 Kg / animal /day Average cow dung generation in plant - 240 kg/day
	Gujarat	08.02.2019	Punit Bharwad cattle farm	Average CD generation -11 Kg / animal /day Average cow dung generation -11 Kg / animal /day Average cow dung generation in plant - 1650 kg/day
	Tamil Nadu	29.01.2019.	Namakkal district	Average cow dung generation -10 Kg / animal /day Average cow dung generation in plant - 400 kg/day
	Uttar Pradesh	23/01/2019	Lal Bahadur Singh cattle farm situated in Bijnor district	Average cow dung generation -16 Kg / animal /day Average cow dung generation in plant - 960 kg/day
Poultry farm	Maharashtra	08.02.2019	Ajinkyatara poultry farm, Shendre Taluk, Satara District	Litter generation -12 to 15 Kg/bird/annum Annual litter generation– 600000 Kg

Sample	State	Sample Collection date	Plant location	Plant details
	Gujarat	08.02.2019	Hafiz poultry farm situated in Vadodara district	12 Kg/bird/annum Litter generation -12 Kg/bird/annum Annual litter generation – 660000 Kg
	Tamil Nadu	30.01.2019	Kumar poultry farm, outskirts of Namakkal district	Litter generation -15 Kg/bird/annum Annual litter generation – 300000 Kg
	Uttar Pradesh	24.01.2019	Dinesh poultry farm situated in Shamli district	Litter generation -15 Kg/bird/annum Annual litter generation – 360000 Kg
Fruit and Vegetable waste	Maharashtra	08.02.2019	Mapro Pvt Ltd located at Satara	10 tons/day
	Gujarat	07.02.2019	Fine Taste Food Pvt Ltd. Bavla in Ahmedabad district	5.4 tons/day
	Tamil Nadu	30.01.2019	Sakthi Fruits Pvt Ltd, Vettuvapalayam, Nasiyanur (PO), Erode district	2 Tons/Day
	Uttar Pradesh	13.01.201	Bharat Agro Tronica City situated in Loni at Ghaziabad district	5 tons per day

All the collected samples were sent to Shriram Institute for Industrial Research (SRI) for further physiochemical analysis. SRI is one of the key testing facility in India and accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL), a, constituent board of Quality Council of India (QCI) as per ISO/IEC: 17025.

2.3. Waste Analysis and Test Results

The physiochemical parameters analysed for the waste samples included pH, COD, C/N ratio, Total Solids (TS)%, Volatile Solid (VS)% and Biochemical Methane Potential. All the analytical determinations were performed according to the standard methods and are listed in Table 2-2:

Table 2-2: Testing methods for various physiochemical parameters of waste

SN	Particular	Testing method
1	pH	BIS 9040 C method for pH determination
2	COD	APHA 23rd Ed, Method no. 5220

3	C:N	ASTM D 5373 guidelines
4	TS% (on received basis)	ASTM D 7348 guidelines
5	VS% (on dry basis)	ASTM D 7348 guidelines
6	Biomethane Potential	Buswell and Hatfield method , 1936

2.4. Analysis of test results

The analysis of the test results is discussed in this section of the report.

pH of the waste samples

For anaerobic digestion to take place profoundly, pH value of the composition of the waste is significant. The biogas generation is highly affected by the pH value range. It has been experimentally proved that the biogas production yield and the degradation efficiency is said to be higher for the substrates having an optimum range value of pH 7 comparing with other pH range values; and the biomethanation process maintains optimum pH value between 7.5 to 8 during digestion, to obtain higher yield of biogas.

The pH values for the waste samples was analysed and the result are presented below

Table 2-3: pH for studied waste type in potential state

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	6.6	8	7.8	6.8	7.3
Cattle Dung	8.3	8.2	8.6	7.9	8.3
Poultry Litter	8.8	7.9	6.7	8.2	7.9
Fruit & Veg	4.7	4.2	5.9	4.2	4.8

Source: Arcadis field survey, Jan- Feb 2019 and tested by Shriram Institute for Industrial Research

Sample analysis indicate that both poultry and cattle dung waste are slightly basic with pH ranging from 6.7 to 8.8 for poultry waste (average 7.90) and pH ranging from 7.9 to 8.6 for cattle dung (average 8.25). During the biomethanation process a starting basic pH normally favoured the production of biomethane, as it reduced the lag-time while increasing the production rate[1]. The laboratory results for pH suggests that the manure and poultry litter being naturally basic substrate, can start the digestion process without any alteration in the pH[2] of the substrate.

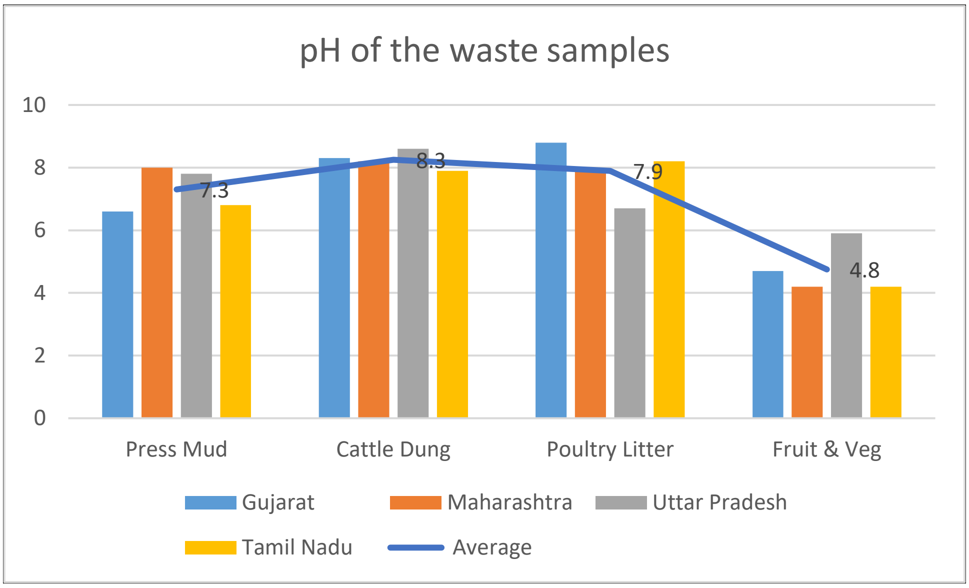
Press mud sample tested from field showed the pH in the range of 6.6 to 8 and have an average value of 7.3. However fast acidification is a problem identified during biogas production from press mud. There are few biogas plants, based on press mud, are in operation, their performance is not satisfactory due to the presence of wax and problem of fast acidification[3].

Fruit and vegetable waste have relatively low pH and also lack the anaerobic bacteria required for digestion; normally an inoculum is used to start and continue the biomethanation process using fruit and vegetable waste. The pH of the four fruit and vegetable waste samples was observed in the range of 4.2 to 5.9. The average value of 4.75 is considerably lower than the optimal pH range of any healthy AD reactor therefore such acidic wastes may require feed perpetration to adjust their pH before feeding into the digester. Alternatively, they can be also blend proportionally with some other basic organic wastes having high pH.

[1] Temperature and pH Effect on Methane Production from Buffalo Manure Anaerobic Digestion; Claudia Carotenuto et al ,2016

[2] Temperature and pH Effect on Methane Production from Buffalo Manure Anaerobic Digestion; Claudia Carotenuto et al ,2016

[3] Optimization of Biogas Generation from Press Mud in Batch Reactor, M. A. Rouf et al (available at www.banglajol.info)



Chemical Oxygen Demand (COD)

In anaerobic digestion, COD typically reflects the organics strength of the waste sample .The efficiency of anaerobic digestion can also be evaluated using COD; COD reduction can be reflective of the amount of degradation taking place within an anaerobic digester, as it reflects the consumption of organics. Methane production can be estimated from the chemical oxygen demand (COD) based on the fact that 1 kg COD destroyed produced 0.35m^3 CH_4 at standard temperature and pressure.[4].

COD is dependent on the climatic conditions, type of feed in case of cattle dung & poultry litter, type of housing system in case of poultry litter.

Table 2-4: COD for studied waste type in potential state

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	163	132	136	151	145.5
Cattle Dung	192	136	138	136	150.5
Poultry Litter	135	187	127	135	146.0
Fruit & Veg	60	75	40	87	65.5

Source: Arcadis field survey, Jan- Feb 2019 and tested by Shriram Institute for Industrial Research
COD values are in gm/kg

Following section analyses the COD values obtained on physiochemical analysis of the waste sample.

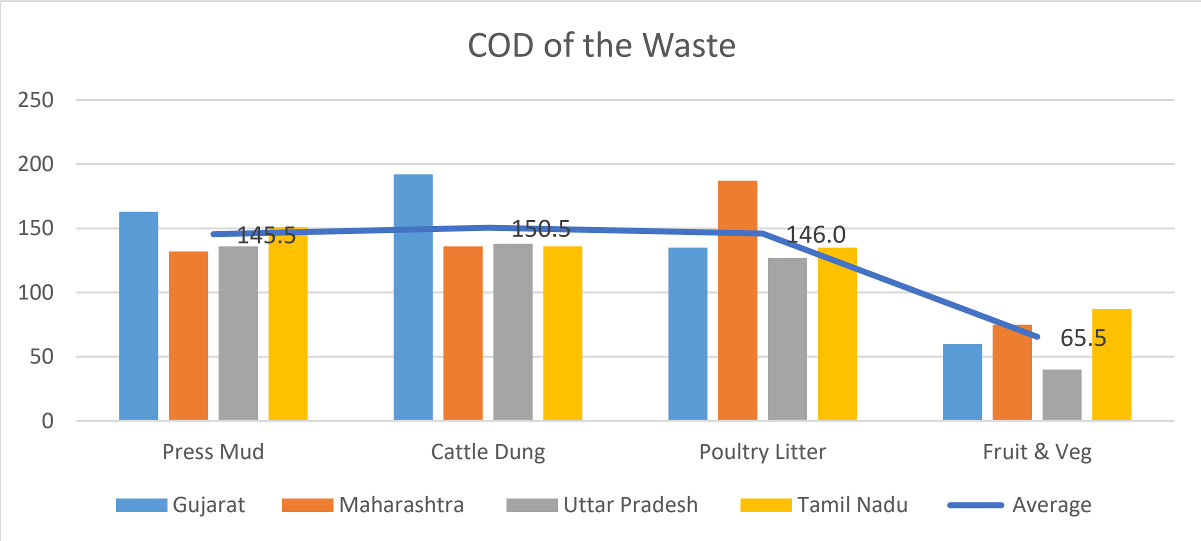
- Press mud samples showed COD values in the range of 132 to 163 gm/kg and an average value of 145.5 gm/ kg. This is comparable to the results from other secondary sources where COD values for press mud were observed in the range of 80 to 152gm/litre[5].
- COD values for cattle dung from waste samples ranges from 136 to 192 gm/kg, with an average value of 150.5 gm/kg. Selected references from secondary sources indicated COD value for cattle dung in the range of 128gm/kg to 160.86 gm/kg[6].

4 Angelidaki, I.; Sanders, W. Assessment of the Anaerobic Biodegradability of Macropollutants. Rev. Environ. Sci. Biotechnol. 2004

5 i) Anaerobic Codigestion of Sugarcane Press Mud with Food Waste: Effects on Hydrolysis Stage, Methane Yield, and Synergistic Effects (https://www.hindawi.com/journals/ijce/2018/9351848/tab2/)

6i) Li, J. & Jha, ajay kumar & He, J. & Ban, Qiaoying & Chang, S. & Wang, P.. (2011). Assessment of the effects of diy anaerobic codigestion of Cow Dung with waste water sludge on biogas yield and biodegradability. International Journal of Physical Sciences. 6. 3679-3688.

- COD results for poultry waste from the collected samples were in the range of 127 to 187, whereas secondary sources provided COD in the range of 80 to 241 gm/kg[7].
- COD result obtained from laboratory analysis of fruit and vegetables (40-87gm/kg) were observed in line with the numbers reported from secondary sources (60-90 gm/kg) [8] .



Total Solid (TS%)

Total solids (TS) is a measurement of dry matter in a waste sample, irrespective of its organic or inorganic nature; TS indicates the dry matter content, usually expressed as percentage of total weight, of the prepared feedstock. The TS content is determined by the drying of a waste sample at 103–105ºC in succession until no further change in weight is observed. Along with being an evaluator of influent, TS is an important attribute of digester operation and performance. Common digesters use feedstock/ manure that has TS between 1% and 13% solids.[9] Increase in TS concentration from 10% to 25% leads to reduction in the total methane generation[10]. High TS levels in the digestor can cause digestate acidification and inhibition of methanogens, which reduces methane generation.

Table 2-5: Percentage of TS in the Waste Sample

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	26.7	39	21.1	26.6	**28.4**
Cattle Dung	23.4	19.3	16.4	26.2	**21.3**
Poultry Litter	69	32.8	36.9	33.1	**43.0**
Fruit & Veg	13.3	8.3	14.8	10.8	**11.8**

Source: Arcadis field survey, Jan- Feb 2019 and tested by Shriram Institute for Industrial Research
TS samples were tested on 'As Received' basis

ii) Biochemical methane potential and biodegradability of complex organic substrates Rodrigo A. Labatut ⇑ , Largus T. Angenent, Norman R. Scott Biological and Environmental Engineering, Riley-Robb Hall, Cornell University, Ithaca, NY 14853, United States (http://www.fao.org/fileadmin/user_upload/affris/docs/NewCommonCarp/carpT3-1.pdf

7 i) Chemical Characteristics of and Methane Production from Turkey Manure DAVID J. HILLS

ii) Effect of poultry species and housing type on the poultry waste physiochemical characteristics (www.ajol.info › index.php › gjer › article › download

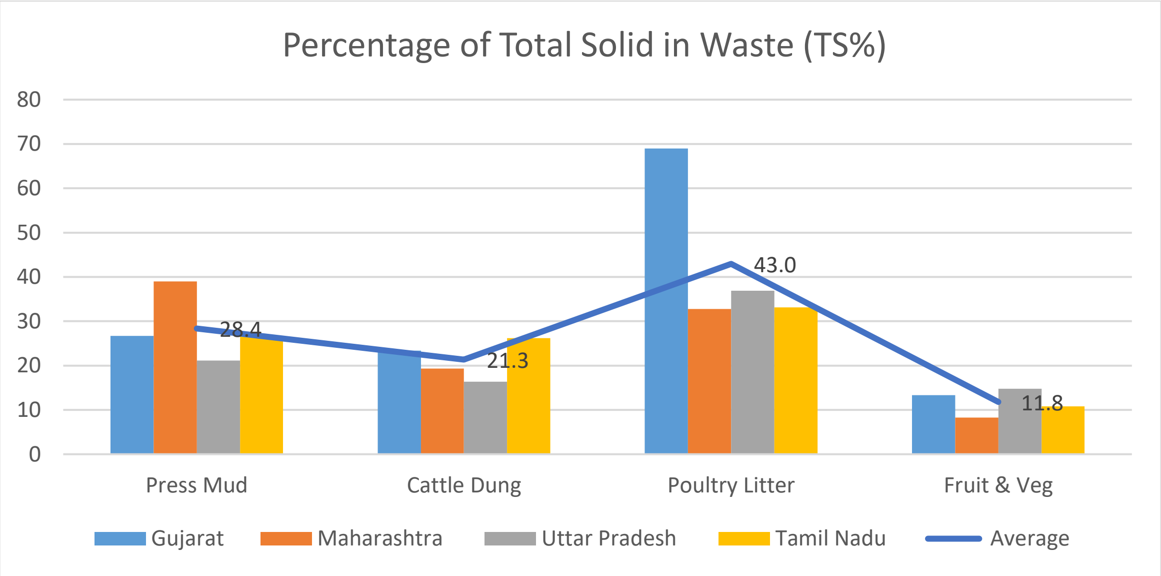
[8] "Extracting Energy from Poultry Waste and Fruit and Vegetable Waste through Anaerobic Digestion Technology" Gary L. Hawkins, Ph.D. University of Georgia Biological and Agricultural Engineering Department (http://eeer.org/journal/view.php?number=730)

[9] Biomethane from Dairy Waste, A Sourcebook for the Production and Use of Renewable Natural Gas in California;2005

[10] https://www.sciencedirect.com/science/article/abs/pii/S0960852412002258

Analysis of the results on TS obtained for waste sample collected from field indicates that:

- Press mud samples collected from field indicated a TS % in the range of 21% to 39%. Review of selected secondary sources indicates the TS % in the samples approximately 25%[11].
- TS for cattle dung sample collected from field survey ranges from 16.4% to 26.2 %. The results are in line with the values provided in various secondary sources. TS for cattle dung from selected sources are indicated in range from 12% to 22.15%[12].
- TS for Poultry Litter from the field survey ranges from 32.8% to 69%, which is in line with the values obtained from secondary sources (32.28% to 78%)[13]. The relatively high TS value for poultry litter in a Maharashtra may be on account of sample being mixed with the stock yard. Poultry waste being a mixture of litter, bird bedding, waste feed is a heterogenous waste and may exhibit more variations in physiochemical characteristics not only from one region to another also from other studied waste like cattle dung, press mud and fruit and vegetable waste.
- TS for fruit and vegetable waste from field survey was in the range from 8.3% to 14.8% with an average value of 11.8%, which is comparable to the number observed from the secondary sources. TS values for Fruit & Vegetable waste taken from selected sources[14] indicate a range of 4.85% to 44.98%.



11 TS -22% (Roufa, M.A., Bajpaib, P., & Jotshic, C.K. (2011); TS 23.8 Optimization of Biogas Generation from Press Mud in Batch Reactor.

12 i) TS of cattledung -12% (Douglas W. Hamilton, Ph.D., P.E.Anaerobic Digestion of Animal Manures: Methane Production Potential of Waste Materials BAE-1762. Oklahoma Cooperative Extension)

ii) TS of Cattle dung -22.15%.Yadav N, Kumar R, Rawat L, Gupta S (2014) Physico-Chemical Properties of Before and After Anaerobic Digestion of Jatropha Seed Cake and Mixed With Pure Cow Dung. J Chem Eng Process Technol 5: 186. doi: 10.4172/2157-7048.1000186

13 i) Ts of poultry waste indicated as 32.28% (Barooah, Manas & Borah, Abhijit & Dutta, M.. (2015). Enhancing anaerobic digestion of poultry litter in field digestors by incorporating in-line pre-digestor assembly. Carbon : Science and Technology. 7. 122-129.
ii)TS of Poulty litter indicated as 66% (Source: Douglas W. Hamilton, Ph.D., P.E.Anaerobic Digestion of Animal Manures: Methane Production Potential of Waste Materials BAE-1762. Oklahoma Cooperative Extension)

iii) Ts of poultry broiler litter 78% (https://www.clemson.edu/extension/camm/manuals/poultry/pch3b_00.pdf)

14 TS reported for Fruit and Vegetable waste range from 4.85% to 44.98% (*Characterisation of fruit and vegetable waste for maximizing the biogas yield AB Mane Bakul Rao and Anand B Rao)*

For effective digestor operation, TS in the range of 10-15% is preferred, where the feedstock is in the slurry form. The mixing and pumping of the digestate become difficult in case the TS value exceed this limit. Feedstock with higher TS requires solid treatment and dilution.

However, there also exist working examples of anerobic digestors with higher TS concentration. It normally works with the anaerobic digestion with smaller digester sizes and lower heating needs.

Volatile Solid (VS%)

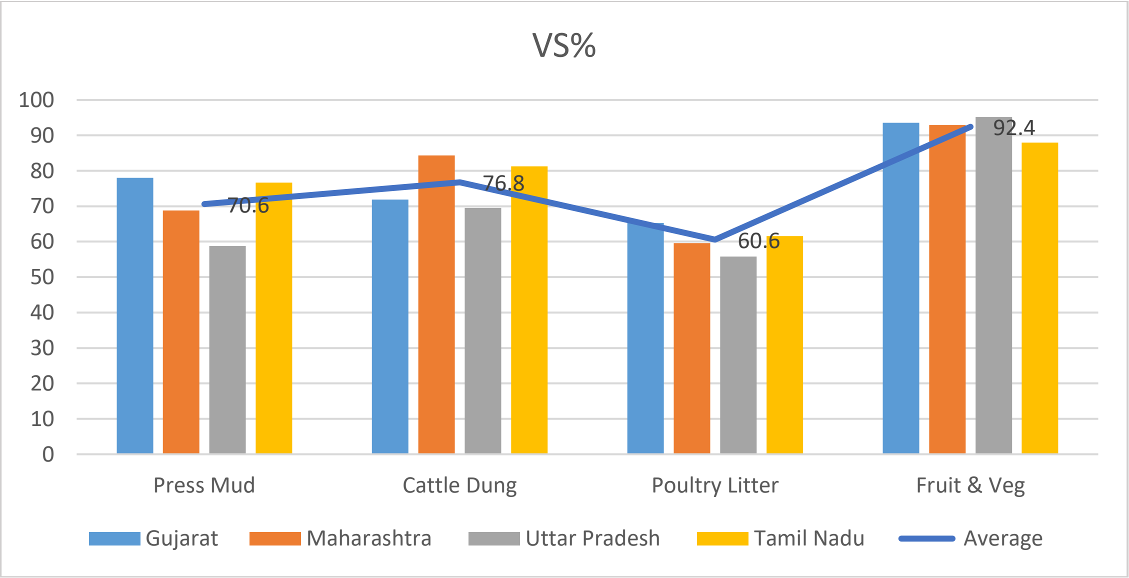
Volatile solids (VS%) is generally treated as a measurement of the organic fraction of total solids; although a more accurate description would be the amount of a matter in the waste sample that is lost on ignition. The VS content is determined by the igniting the remaining solids produced from total solids measurement at 550˚C, though some volatilization may have already occurred during the measurement of the total solids. Like COD, VS can be treated as a measurement of organics in waste sample, although the former is a more accurate measure. Nonetheless, both measurements can be used as a basis for determining the organic loading rate of a digester. The volatile solids loading rate is a key design parameter that is used to size digester tanks.

Table 2.6 provides details of the Volatile Solid percentage (dry basis) for different waste samples collected during field survey.

Table 2-6: Percentage of Volatile Solid in the sample waste

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	78	68.8	58.8	76.7	70.6
Cattle Dung	71.9	84.3	69.5	81.3	76.8
Poultry Litter	65.3	59.6	55.8	61.6	60.6
Fruit & Veg	93.6	92.9	95.2	88	92.4

Source: Arcadis field survey, Jan- Feb 2019 and tested by Shriram Institute for Industrial Research



Following section present the details of the results obtained from field investigation and provides a comparison against the values observed from selected secondary sources

- VS in the press mud sample from field survey ranges from 58.8% to 78%, with an average value of 70.6%. References values of VS of press mud obtained from secondary sources shows a range of 76% to 77%[15].
- VS result for Cattle dung from field survey ranges from 69.5 % to 84.3% , with an average value of 76.8%. VS for cattle dung from secondary sources range from 77.20% to 84.85%[16].

- VS for Poultry litter ranges from 55.8% to 65.3%, with an average value of 60.6%. Results obtained from research paper indicates VS for Poultry Litter in the range of 61% to 83.30%[17].
- VS from fruit and vegetable waste from field survey range from 88% to 95%, with an average value of 92.4%. VS values for Fruit & Vegetables waste obtained from secondary sources[18] showed a wide range from 78.69 % to 93.63%.

The VS percent observed from our field investigation was comparable to the VS results obtained from secondary sources. However, it may also be noted that volatile solids get lost with time, so during actual project implementation, care should be taken to reduce the time lag between generation and collection of waste from the stock yards and avoid mixing of old waste with the fresh waste.

It has been observed that for cattle manure the biogas yield is very low after about 30 days due to considerable loss of VS[19]. Though VS is an important parameter, it is important to note here that not all of the VS component of a feedstock is digestible[20]

Carbon Nitrogen Ratio

The waste materials were analysed for their carbon to nitrogen ratio, as the relationship between the organic carbon and nitrogen ratio is crucial for production of biogas.

During the biomethanation process on an average the carbon consumption is 30 times faster than the nitrogen consumption. A carbon/nitrogen ratio (C/N) of 30 (30/1 or 30 times as much carbon as nitrogen) permits digestion and gas production to proceed at the best possible rate, if other conditions such as temperature are favourable. In case of high C/N ratio of the feedstock, the nitrogen gets consumed completely before the carbon and the rate of biogas generation slow down due to lack of nitrogen required for residual carbon. If there is too much nitrogen (C/N of 10), the carbon will soon be all used up, digestion will slow down, and the remaining nitrogen will be lost as ammonia gas which smells bad but does not burn. In addition to a lower biogas production rate, the loss of the nitrogen decreases the quality of the fertilizer[21].Substrates with high C/N ratios have poor buffering capacity and produce excessive amounts of VFAs during fermentation. In contrast, substrates characterized by low C/N ratios have high buffer capacity and the increased concentration of ammonia in the fermentation process leads to microbial growth inhibition[22]

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[15] VS reported 76.6% (Roufa, M.A., Bajpaib, P., & Jotshic, C.K. (2011). Optimization of Biogas Generation from Press Mud in Batch Reactor.

[16] VS of cattledung - 84% (Douglas W. Hamilton, Ph.D., P.E.Anaerobic Digestion of Animal Manures: Methane Production Potential of Waste Materials BAE-1762. Oklahoma Cooperative Extension)

[17] VS of Poultry Litter Miah, Mohammad & Rahman, A K M & Akanda, Muhammad Rajibul & Pulak, Abdullah & Rouf, Md. (2015). Production of bio-gas from poultry litter mixed with the co-substrate cow dung. Journal of Taibah University for Science. 10. 497-504. 10.1016/j.jtusci.2015.07.007.
https://www.researchgate.net/publication/334989021_Characterisation_of_Poultry_Litter_and_Evaluation_Of_Its_Biochemical_Methane_Potential

[18] VS reported for Fruit and Vegetable 78.69% to 93.63% (*Characterisation of fruit and vegetable waste for maximizing the biogas yield AB Mane Bakul Rao and Anand B Rao)*

[19] Biomethane from Dairy Waste, A Sourcebook for the Production and Use of Renewable Natural Gas in California;2005

[20] Biomethane from Dairy Waste, A Sourcebook for the Production and Use of Renewable Natural Gas in California;2005

[21] Source : The biogas/biofertilizer business handbook

22 (A Review on Anaerobic Co-Digestion with a Focus on the Microbial Populations and the Effect of Multi-Stage Digester Configuration, Anahita Rabii et al, 2019

Optimum C/N ratios in anaerobic digesters are between 20 – 30. Optimum C/N ratios of the digester materials can be achieved by mixing materials of high and low C/N ratios, such as organic solid waste mixed with sewage or animal manure.

The carbon and nitrogen ratio for different waste type obtained from different states has been summarised in the following table

Table 2-7: Carbon to Nitrogen Ratio for Waste Samples

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	21.9	16	17.4	21.4	19.2
Cattle Dung	29.3	64.8	24	48.2	41.6
Poultry Litter	6.4	11.3	13.5	20.7	13.0
Fruit & Veg	27.8	21.1	19.8	10.9	19.9

Source: Arcadis field survey, Jan- Feb 2019 and tested by Shriram Institute for Industrial Research

Analysis of the C/N results obtained from physiochemical testing of waste samples is provided in the following section

- C/N ratio calculated from the analysis of cattle dung sample collected during field investigation ranges from 24 to 64.8 and average value is 42. However, as per different secondary sources, C/N ratio in cattle dung was found in the range between 17 – 25[23]. C/N ratio from few of our samples is higher than the range specified in various studies. This may be on account of mixing of cattle dung with cow fodder as husk etc during collection, which has a relatively high C/N ratio (Wheat straw: 150, corn stalk: 53 and rice straw: 51). Since cattle waste during collection get mixed up with the fodder (containing wheat straw, rice straw etc) with normally high carbon content, under practical scenario, the values arrived from our analysis have not been ignored and considered for further analysis. Also, the C/N ratio depends on animal feed, age and other environmental factors.
- C/N for poultry litter ranges from 6.4 to 20.7 with an average C/N value of 13; this is in line with the C/N ratio for Poultry litter indicated in the secondary sources (poultry litter has C/N ratio of approximately 10 to 15)[24]. Thus, potential feedstock with higher carbon content is required for optimal digestion.
- C/ N ratio for press mud ranges from 16 to 21.9 with an average value of 19. Comparison of the C/N with some of the published data from different secondary sources indicated a C/N ranges from 14 to 26.[25] Few selected references from secondary sources also indicates C/N ratio range for press mud till 35. it important to note that the chemical composition of press mud also depends on the cane variety, soil conditions, nutrients applied in the field, process of clarification adopted and other environmental factors.
- C: N for food and vegetable waste ranges from 10.9 to 27.8 with an average value of 20.

[23] i) C/N ratio of cattle dung is 25 (reference: https://www.sciencedirect.com/topics/engineering/c-n-ratio);

ii) C/N ratio of Cow dung is indicated as 19.9 (https://energypedia.info/wiki/Nitrogen-content_and_C/N-ratio_of_Organic_Substrates)

iii) C/N of cattle dung reported as 17-25(https://www.ag.ndsu.edu/manure/documents/nm1478.pdf).

[24] https://certifiedorganic.bc.ca/programs/osdp/I-050%20Compost%20Factsheet.pdf

[25] i) C/N of press mud reported as 14 (Optimization of Biogas Generation from Press Mud in Batch Reactor M. A. Roufa , P. K. Bajpaib and C. K. Jotshic)

ii) The *C/N* ratio of raw pressmud from study 25.95 (https://www.irjet.net/archives/V5/i6/IRJET-V5I6480.pdf),

iii) C/N range of 20–35 for press mud (source: https://www.sciencedirect.com/science/article/abs/pii/S0956053X08002420)

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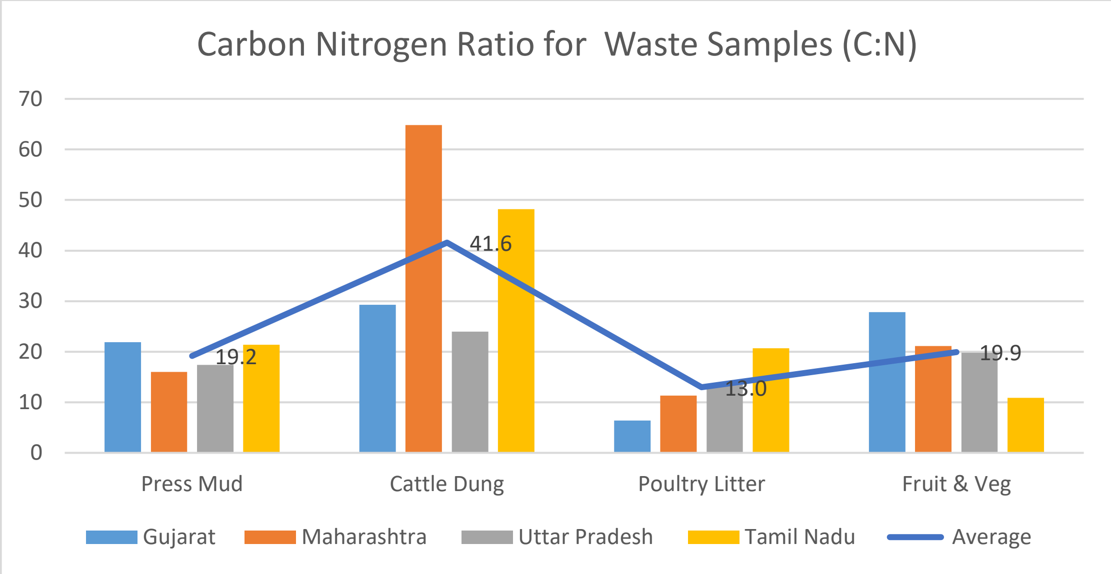


Bio methane Potential (BMP)

BMP often defined as the maximum volume of methane produced per gm of VS substrate provides an indication of the biodegradability of a substrate and its potential to produce methane via Anaerobic Digestion (AD). BMP test is a method of establishing a baseline for performance of AD. BMP data are useful for designing AD parameters in order to optimise methane production.

The biochemical methane potential for the samples was done by chemical substrate composition derived by elementary analysis using Buswell & Hatfield (1936) equation. With the knowledge of the chemical composition of waste, quantity of methane can be predicted from the stoichiometric formula developed by Buswell and Hatfield (B&H),1936. This formula calculates the maximum biogas yield and methane potential using the elementary analysis(C,H,O) of the feed stock.

The stoichiometric formula developed by B&H is as follows:

$$C_xH_yO_z + \left(x - \frac{y}{4} - \frac{z}{2}\right)H_2O \rightarrow \left(\frac{x}{2} + \frac{y}{8} - \frac{z}{4}\right)CH_4 + \left(\frac{x}{2} - \frac{y}{8} + \frac{z}{4}\right)CO_2$$

Boyle further modified the above formula to include nitrogen and sulphur; the following modified formula has been used for assessment of BMP for various samples collected during the field study.

$$C_aH_bO_cN_dS_e + \left(a - \frac{b}{4} - \frac{c}{2} + \frac{3d}{4} + \frac{e}{2}\right)H_2O \rightarrow \left(\frac{a}{2} + \frac{b}{8} - \frac{c}{4} - \frac{3d}{8} - \frac{e}{4}\right)CH_4 + \left(\frac{a}{2} - \frac{b}{8} + \frac{c}{4} + \frac{3d}{8} + \frac{e}{4}\right)CO_2 + dNH_3 + eH_2S$$

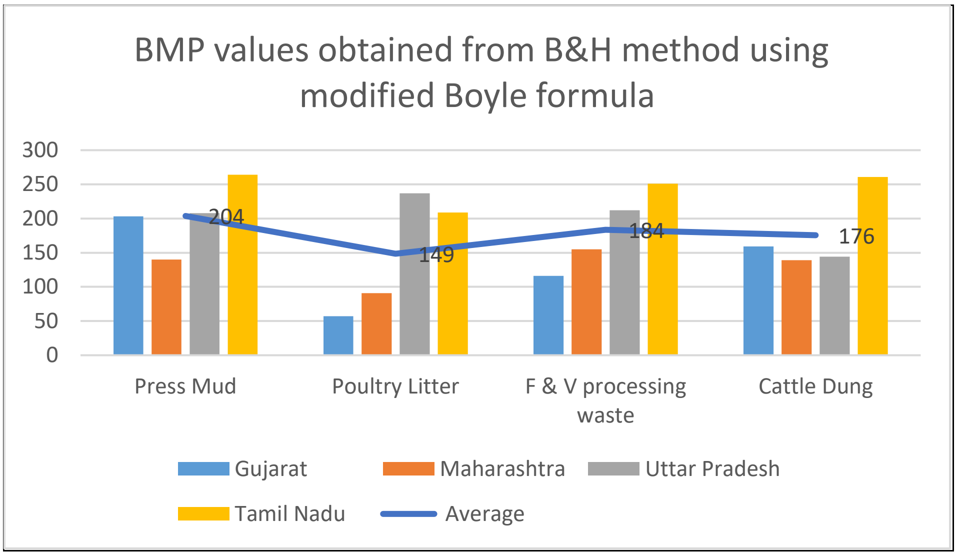
The biomethane potential for various samples obtained from B&H method are provided in **Table 2-8** :

Table 2-8: Biomethane potential (CH_4 gm/kg)

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	203	140	208	264	204
Poultry Litter	57	91	237	209	149
Fruit & Vegetable processing waste	116	155	212	251	184
Cattle Dung	159	139	144	261*	147

Source: Arcadis field survey, Jan- Feb 2019 and tested by Shriram Institute for Industrial Research
Above calculation of BMP has been done using B&H method using modified Boyle formula

**BMP of cattle dung sample from Tamil Nadu appear to be abnormally high compared to the other three samples. The implausible output of the BMP analysis may be the result of imperceptible adulteration in the sample before collection and therefore it may be overlooked.*



The results obtained from B&H methods are too optimistic and are usually seen as maximum methane potential for a feedstock. The BMP does not exactly replicate conditions in a continuously feed AD system and therefore the BMP result cannot be viewed as an absolute value. Secondary sources also confirmed that the methane yield obtained in continuous experiments or in full-scale plants is lower compared to the value obtained in a BMP test (Holliger et al., 2017)[26].

[26] Holliger, C., Fruteau de Laclos, H., and Hack, G. (2017). Methane production of full-scale anaerobic digestion plants calculated from substrate's biomethane potentials compares well with the one measured on-site. *Front. Energy Res.* 5:12. doi: 10.3389/fenrg.2017.00012

Sample BMP calculation using B&H method (using Boyle modified formula) for Fruit & Vegetable waste sample collected from Gujarat

Elementary analysis of the feedstock was conducted and percentage composition for C, H, N, S and O was derived from laboratory analysis. The results from the elementary analysis are presented below

Parameter	I %	II %	Average Composition (X)	Atomic Mass (Y)	Molar Mass (X*Y) in gm/mole
Carbon %	41.81	41.56	**41.7 (a)**	12.0107	501.11
Hydrogen %	5.949	5.934	**5.9 (b)**	1.0079	5.95
Oxygen %	100-(CHNS+ASH)		**46.6 (c)**	15.999	745.70
Nitrogen %	1.471	1.523	**1.5 (d)**	14.0067	21.01
Sulphur %	0.327	0.301	**0.3 (e)**	32.065	9.62
	49.6	**49.3**			**1283.39**

Loss of ignition has been computed and ash content has been assessed as 4% by mass for the samples.

Methane calculation has been done using the following Stoichiometric formula developed by Buswell and Hatfield, which was further modified by Boyle

$$C_aH_bO_cN_dS_e+\left(a-\frac{b}{4}-\frac{c}{2}+\frac{3d}{4}+\frac{e}{2}\right)H_2O \rightarrow \left(\frac{a}{2}+\frac{b}{8}-\frac{c}{4}-\frac{3d}{8}-\frac{e}{4}\right)CH_4 +\left(\frac{a}{2}-\frac{b}{8}+\frac{c}{4}+\frac{3d}{8}+\frac{e}{4}\right)CO_2+dNH_3+eH_2S$$

Following values has been derived

Parameter		Computation using B&H method
Carbon	a	a/2 = 20.85
Hydrogen	b	b/8 = 0.74
Oxygen	c	c/4 = 11.65
Nitrogen	d	3d/8 = 0.56
Sulphur	e	e/4 = 0.08

22400 ml of gas = 1 g mol = 16 g

1 ml of gas =0.000714286 g

162 ml of gas =0.115714286 g

BMP g CH4/kg vs = 116 g/kg

Biogas Potential (BP)

Based on the biomethane potential provide in **Table 2-8**; the biogas potential for various samples has been calculated and provided in **Table 2-9**:

Table 2-9: Biogas* Potential (m^3/ton VS)

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Press Mud	103.6	92.1	63.3	132.0	97.7
Poultry Litter	62.9	43.6	119.6	104.4	82.7
Fruit & Vegetable processing waste	35.4	29.3	73.2	58.5	49.1

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Average
Cattle Dung	65.6	55.4	40.2	136.3#	53.7

**Assuming a methane content of 60% in biogas and methane density of 0.68 kg/m3*

 # Biogas potential of cattle dung sample from Tamil Nadu appear to be abnormally high compared to the other three samples. The implausible output of the BMP/Biogas analysis may be the result of imperceptible adulteration in the sample before collection and therefore it may be overlooked.

The biogas potential obtained are on slightly on the higher side (except press mud) compared to the some of the secondary sources[27] due to the results obtained in BMP.

Conclusion

Physiochemical tests were conducted for the parameters impacting the anaerobic digestion process and conclusion observed from the same have been summarised in the following section.

- Poultry and cattle dung waste samples were slightly basic in nature with an average pH of 7.9 and 8.25. During the biomethanation process a starting basic pH normally favoured the production of biomethane; hence, cattle dung and poultry litter can start the digestion process without any alteration in the pH of the substrate; whereas Fruit and vegetable waste has considerably lower pH (average 4.75) than the optimal pH required for healthy anaerobic digestion and may require pH adjustment or blending proportionally with some other basic organic wastes having high pH before feeding into the digester.
- COD value for all the samples analysed under the project was in line with the values obtained from other secondary sources. COD reduction during anaerobic digestion process is an indicator of bacterial activity and decomposition.
- Poultry waste may exhibit more variations in physiochemical characteristics due to heterogeneity of composition due to mixing of litter, bird bedding, waste feed. Variations from standard value may be observed from one region to another as compared to other studied waste type like cattle dung, press mud and fruit and vegetable waste.
- TS concentration from all the waste samples though were comparable with the results obtained from other sources, seemed slightly higher than as required for Anaerobic digestion and requires TS adjustment during feeding the same to the digestor.
- VS analyses for the selected samples showed sufficient degradation potential, and were in line with the VS values observed from other secondary sources.
- The ideal C/N for Anaerobic digestion is around 30; it permits digestion and gas production to proceed at the best possible rate, if other conditions such as temperature are favourable. C/N ratio for cattle dung was observed within the range or slightly higher for some samples, whereas C/N ratio for poultry, press-mud and fruit and vegetable waste was observed on the lower side. The variation in the results for different samples may be on account of soil condition, variety (type), nutrients applied and other environmental factors in case of plant waste; and animal feed, age and other factors in case of animal waste.
- For low C/N ratio as in case of poultry waste, potential feedstock with higher carbon content is required for optimal digestion of poultry waste.
- BMP analysis was done based on the elementary analysis of the feedstock using Buswell and Hatfield method with modified Boyle formula. The results obtained using this formula give the maximal biogas potential and are usually seen as maximum methane potential for a feedstock. BMP test do not exactly replicate conditions in a continuously feed AD system.

[27] Biogas potential from Press mud is around 100m^3/ton (http://www.iitmandi.ac.in/ireps/images/Presentation%20%20Waste%20to%20energy%20for%20IIT%20Mandi%2016th%20Ma y.pdf)
Biogas potential from poultry litter is around 58 m^3/ton (*http://urpjournals.com/tocjnls/38_13v3i1_3.pdf)*

Biogas potential from cattle dung is around 34m^3/ton (http://urpjournals.com/tocjnls/38_13v3i1_3.pdf)

The further section on decision making support matrix has been conceptualised based on the above results obtained from physiochemical investigations as well as the results from the Primary field investigations and consultation with stakeholders conducted by the field team.

3. Decision Making Support Matrix

Selection of the most suitable location for setting up a waste to energy (biomethanation) facility is a key strategic decision and needs to be taken cautiously as it involves considerable investment and commitment. The overall feasibility, performance and success of a biomethanation plant to a large extents depends on the location in terms of availability & cost of raw material, market for finished products, policies of state supporting the installation and operation, competitive performance/ usage, etc.

The selection of the most suitable location for setting up a biomethanation facility with the identified waste streams has been done using a decision-making matrix. The matrix allows a transparent assessment of the candidate site/regions against the selected decision criteria. The key objective of the decision-making matrix for the project are the following:

- Identification of the Key Criteria for setting up a biomethanation plant (waste to energy facility) for the four key sectors studied as part of the project.
- Compare the suitability of potential regions identified within the shortlisted four states for setting up the waste to energy facility for different framework conditions.
- To offer a first orientation on the region feasibility to host a new biomethanation Plant for the selected waste streams and strategically select locations for bio-methanation plants with maximum possibilities.

The decision making matrix will identify the areas with maximum availability of waste, areas with multi / mixed feedstock and will also analyse various other factors which directly or indirectly influence the availability of waste in a region and influence setting up a new bio methanation plant. The outcome of decision-making matrix will support the potential investor in selection of the region having maximum potential to set up a biomethanation plant from the selected four sectors.

3.1. Identification of Decision Criteria

The key criteria considered for the analysis and development of decision-making matrix include:

- Availability of waste
- Availability of multi feed stock
- Energy Potential
- Test Results & Waste characteristics
- Alternate utilisation practices
- Seasonal variation and waste availability
- Cost of raw material
- Market for final product and offtake arrangements
- Operating plants in the vicinity
- Institutional arrangement and state government initiatives
- Power tariff in the state

It is important to note that the current decision criteria select the most suitable region from the list of potential regions already identified in second stage report. The site level criteria like availability of land, land acquisition, land cost, site utilities & surrounding infrastructure, real estate framework, and site due diligence are still required to be performed. Site level criteria are equally important parameters for finalisation of plant location within any region along with the decision criteria discussed above.

3.2. Decision Criteria Analysis

This step involves detailed analysis of the Decision Criteria and establish the relative importance of each for the selection region. To fully assess the importance of each decision criteria, it is necessary to consider not only the absolute importance of the Decision Criteria, but also the significance of the difference between the highest and lowest rated options. Ranking of each decision criteria for the potential region was done after analysis of all the related parameters. This section provides an example of the ranking of the decision criteria for the potential region identified for the project. And may be used for broadly identifying the region most suitable for establishment of biomethanation plant based of the selected waste type.

Availability of waste

Waste availability is one of the key factors identified for setting up a new waste to energy facility. Waste availability is to be determined considering that the feedstock of required quality and quantity is available for longer term and is sustainable.

For the current assessment, waste availability has been analysed at two levels, the state level and at the potential region level. Based on the waste availability data for the state and the potential region, a comprehensive matrix for both the state level and potential region has been derived for each identified sector considering the individual and sectoral weightage.

The weightage based on availability for the identified sectors (Poultry, Press Mud, Fruit and vegetable, Cattle Dung) for all the shortlisted states is presented in the following table along with the ranking of the state.

Table 3-1 : State level weightage* and ranking based on waste availability

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Poultry Litter (TPA)	3,06,600	8,46,800	3,28,500	28,25,100	43,07,000
Weightage	**0.005**	**0.015**	**0.006**	**0.050**	**0.08**
Press Mud (TPA)	3,52,776	33,34,100	38,91,650	2,87,000	78,65,526
Weightage	**0.01**	**0.06**	**0.07**	**0.01**	**0.14**
Fruit & Vegetable (TPA)	0	20,000	0	1,61,290	1,81,290
Weightage	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Cattle Dung (TPA)	92,66,952	67,38,121	2,35,35,455	50,48,878	4,45,89,406
Weightage	**0.16**	**0.12**	**0.41**	**0.09**	**0.78**
Total Waste (TPA)	**99,26,328**	**1,09,39,021**	**2,77,55,605**	**83,22,268**	**5,69,43,222**
Total Weightage	**0.174**	**0.192**	**0.487**	**0.146**	**1.00**
Rank	3	2	**1**	4	

*1) *Weightage has been calculated for individual sectors by dividing the waste available for a sector in a state with the total waste of all the four potential sectors in all the four potential states.*

A similar exercise is conducted for the potential region based on the waste availability data and weightage and is presented in the **Table 3-2**. The finalisation of potential region (based on district level analysis) under each potential state has been done in the stage two report of this assignment. The potential region was primarily finalised based on two key factors, first is availability of multi-sector waste together in one region and another is maximum energy potential concentrated in a region for one or more sectors. The details of districts included in the Potential Region in the four states is provided below for ready reference (detail selection criteria provided in stage 2 report):

- *Tamil Nadu: Vellore, Krishnagiri, Tiruvannamalai, Dharmapuri, Salem, Erode and Namakkal*
- *Maharashtra: Sangli, Satara, Ahmednagar, Pune, Kolhapur, Nasik, Raigarh, Ratnagiri*
- *Gujarat : Surat, Bharuch, Navsari, Vadodara, Anand, Gandhinagar, Kheda, Panchmahal*

- *Uttar Pradesh: Aligarh, Bijnor, Bulandshahr, Ghaziabad, Meerut, Moradabad, Muzaffarnagar, Saharanpur, Sambhal, and Samli*

Table 3-2 : Weightage and ranking for Potential region based on waste availability

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Poultry Litter (TPA)	1,46,000	7,11,312	40,406	16,06,000	25,03,718
Weightage	**0.01**	**0.04**	**0.00**	**0.09**	**0.14**
Press Mud (TPA)	3,01,021	3,02,403	13,27,831	70,000	20,01,255
Weightage	**0.02**	**0.02**	**0.07**	**0.00**	**0.11**
Fruit & Vegetable (TPA)	0	20,000	0	1,61,290	1,81,290
Weightage	**0.00**	**0.00**	**0.00**	**0.01**	**0.01**
Cattle Dung (TPA)	33,49,999	34,08,642	50,10,287	19,51,029	1,37,19,957
Weightage	**0.18**	**0.19**	**0.27**	**0.11**	**0.75**
Total Waste	**37,97,020**	**44,42,357**	**63,78,523**	**37,88,319**	**1,84,06,219**
Total Weightage	**0.21**	**0.24**	**0.35**	**0.21**	**1.00**
Rank	3	2	**1**	3	

Note:

1)*Waste availability for the potential region taken based on the number derived from various sources during field investigation*

2) Weightage has been calculated for individual sectors by dividing the waste available for a sector in a potential region with the total waste of all the four sectors in all the four potential region.

2) For UP and Maharashtra, PM waste details for potential region was not available; assessment for waste done based on ratio of crushing capacity available for the region

3) Poultry waste details for potential region UP and Maharashtra not available from field survey. Computed based on district level data from secondary sources.

Above table indicates that among the four selected sectors, cattle dung has the largest share of waste (approximately 78%). The high cattle population in Uttar Pradesh state and also in the selected potential region of state makes it the most suitable location, based on decision criteria corresponding to availability of waste. The state of Maharashtra is second; and the states of Tamil Nadu and Gujarat are both placed at third position.

It is further emphasized here that the potential region selected for the setting up the biomethanation plant is also very large and may need to be divided into smaller subregions to reduce the cost associated with transportation of feed stock and make the projects more economically viable. The cost of the transportation of feedstock is one of the major cost associated affecting the economic viability of the project and reduction in the transportation cost had been a major challenge for the biogas industry. One of the study (done for Assam) have taken the travel distance of approximately 10 km radius or travel time of 30 minutes as the potential area for getting the feedstock for the biomethanation plant for economic viability[28]. However, this would surely vary with the local onsite conditions including terrain, road network, mode of transportation, travel speed and other factors and this may increase up to 25 to 30 km for relative plain area having good network of roads.

Considering the above logic, there may be several sub potential zones available within the identified potential zone for setting up a pilot biomethanation plant.

[28] GIS based planning of a biomethanation power plant in Assam, India, Antara Brahma et al, 2016

Availability of Multi feed stock vs single feedstock

One of the decision criteria considered for selection of potential region is availability of multi feedstock for setting up new biomethanation facility based on co digestion. This is in line with the number of researches which have indicated that anaerobic co digestion with two or more feed stock is more beneficial in terms of its economic viability, increased methane yield and its capability to alleviate some of the problems emerging in single feedstock digestion. The advantages of co-digestion over single feedstock digestion are increase in system stability, increased biogas yield, and solids reduction. Co-digestion also offers benefits such as dilution of toxic compounds, increased odour and pathogen reduction, enhanced nutrients balance, synergistic effect of microorganisms and increased weight of biodegradable organic substance (Sosnowski et al, 2008). Some of research finding indicating the advance of co digestion of multiple feedstocks on single feedstock digestion are provided below for ready reference

- *Press mud when mixed with cow dung, biomethanation process became more stable (Rouf, 2010)[29].*
- *The results showed that co-digestion of animal wastes with fruit wastes and inoculums (additives) increased biomethane yield and reduced the start-up time for biomethane generation as compared to animal wastes alone. In addition, cumulative biomethane yield increased with increase in pH while it decreased with increase in TS content.[30]*
- *Progressive studies of the C/N ratio (carbon to nitrogen ratio) optimization cases during co-fermentation conducted by Hassan et al. (2016), where co-digestion had enhanced the methane production from 31.49% to 85.11%.*
- *Rahman et al. (2017) showed that the best quality and a greater quantity of biogas can be produced as a result of the optimal selection of the C/N ratio of the complex substrate. Organic agricultural wastes have a large content of carbon and animal manure has a high content of nitrogen. Proper co-digestion of these two components increases biogas yield and improves the methane content (Bagudo et al., 2011; Rahman et al., 2017)[31].*
- *Co-fermentation of various substrates showed a better effect than mono- fermentation. Typically, each organic substrate rich in nutrients is required for anaerobic and aerobic bacteria growth. Nevertheless, the nutrient level differences are correlated with material age, species, and growth conditions (Divya et al., 2015).*
- *Co-digestion of different feedstocks with animal manure can increase biogas production from 25% to 400% compared to the mono-digestion of the same substrates[32].*
- *The co digestion of vegetable and fruit waste with cow dung takes less to time to digest. Because cow dung increases the methanogenic activity the digestion period decreased. The Co digestion depends upon the amount CD added with VW or FW. The gas varies with CD added to the FW and VW and The Co digestion reduces the HRT (Hydraulic Retention Time).[33]*
- *Co-digestion of different feedstocks with animal manure can increase biogas production from 25% to 400% compared to the mono-digestion of the same substrates*

[29] Optimization of Biogas Generation from Press Mud in Batch Reactor, M. A. Rouf et al (available at www.banglajol.info)

[30] Enhancement of animal waste biomethanation using fruit waste as co-substrate and chicken rumen as inoculums O. O. Ogunleye,

[31] Effect of different composition on anaerobic co digestion of cattle manure and agro industrial by product, K MeiramKulova et.al), (https://www.researchgate.net/publication/322629178_Effect_of_different_compositions_on_anaerobic_co-digestion_of_cattle_manure_and_agro-industrial_by-products)

[32] A Review on Anaerobic Co-Digestion with a Focus on the Microbial Populations and the Effect of Multi-Stage Digester Configuration, Anahita Rabii et.al, 21 March 2019 . https://webcache.googleusercontent.com/search?q=cache:PvmC3iWQWUgJ:https://www.mdpi.com/1996-1073/12/6/1106/pdf+&cd=1&hl=en&ct=clnk&gl=in

[33] (Biomethanation of Vegetable And Fruit Waste in Co-digestion Process Earnest Vinay Prakash1 , Dr. L. P. Singh2, 2013)

Based on the above researches, it is recommended to consider composite feedstock for development of biomethanation based pilot project under the project. This will not only ensure round the year availability of waste, increase the biogas production rates and sustainability of the plant in long run.

Evaluation of the four potential region was done for availability of multi feed stock and setting up a co-digestion facility.

Table 3-3 : Feed stock availability in the Potential Region

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
Feed stock availability in the potential region	Gujarat has high percentage of cattle dung, followed by press mud, poultry litter and fruit &vegetable processing waste Cattle Dung - 19% Press mud -2% Poultry Litter-0.8% Fruit & Vegetable- 0%	Maharashtra has high percentage of cattle dung, followed by poultry litter, press mud and small quantity of Fruit & vegetable processing Cattle Dung - 19% Poultry Litter - 2.5% Press mud -1% Fruit & Vegetable - 0.1%	UP has high percentage of cattle dung and Press mud; whereas the availability of poultry litter is relatively low and negligible fruit and vegetable processing waste . Cattle Dung - 29% Press mud -5% Poultry Litter - 0.1% Fruit & Vegetable - 0%	TN has approximately maximum poultry litter among all states and has approximately 11% of cattle dung. Cattle Dung -11% Poultry Litter – 9.1 % Fruit & Vegetable – 1% Press mud - 0.4%
Rank	**4**	**1**	**3**	**1**

Note:

1) The percentage of different waste type in this section is calculated on the quantity of waste available in the potential region against the total feedstock available. Refer **Table 3-2** for actual quantities.
2) Ranking is based on availability of maximum type of feedstock for co-digestion, not on the quantity of percentage availability of single feedstock.

On the basis of availability of multiple feedstock, Maharashtra and Tamil Nadu are the top states, followed by Uttar Pradesh and Gujarat.

Currently number of successful Co-digestion plant are in operation globally with animal manures, agricultural waste, and food processing wastes. Selected international and Indian case studies for successful Co – digestion are listed below for ready reference.

International Successful Case Studies on Co-Digestion

Case Study I : Groene Stroom Lievens– G.S.L. Belgium: *The biogas plant is operational since September 2009, and currently operates at 85% load. The Anaerobic Digestion plant processes annually 27,000 tons: 3,000 tons manure, 11,500 tons agricultural related products (especially corn) and 12,500 tons organic bio-waste. The manure, energy crops and organic biological waste are co-digested to converted to biogas through anaerobic digestion. The biogas is used for the production of electricity in a gas engine (CHP, 1.1 MW).*

Start of operation	*September 2009*
Engineering/construction	*BiogasTec, Trevi*
Operator	*BiogasTec, Wim Lievens*
Amount of gas produced	*4 Mio m^3 per year*
Cost	*4 Mio Euros*
Electric power of the engine	*1131 kW*
Thermal power of the engine	*1311 kW*
Generated electricity	*8,4 Mio kWh per year*
Power consumption of the biogas plant	*1,3 Mio kWh per year*
Delivery of electricity to the grid	*7,1 Mio kWh per year*

Case Study II: Bieleveld Bio energy BV In Heeten, The Netherlands

Plant successfully demonstrate 2 MW co-digestion including the treatment of digestate, resulting in commercially interesting end products. The digestate is transformed into commercially interesting products, such as liquid replacement for artificial fertilizer. The installation has been built by Certified Energy (biogas installation) and VP Kasag (digestate treatment). The installation has been running since 2007.

On a yearly basis, the installation is fed ***with 43.500 m^3 pig manure, 5.000m^3 cow manure, 7.000 m^3 poultry manure and 22.500 tons of maize****. The biogas is consumed by a 1.965 kW CHP-installation, which leads to a yearly production of 9.700.000 kWh. The digestate is transformed into commercially interesting products. The first step is mechanically separating the solid fraction from the liquid fraction. The solid fraction is then dried, using the heat from the CHP. The liquid fraction is processed by means of ultrafiltration and reversed osmosis. The resulting products are a liquid replacement for artificial fertilizers, and water.*

The investment amount for the installation was € 6.000.000. The installation produces 9,7 GWh of electricity each year. The production is CO_2 neutral, leading to an annual saving of almost 5.500 tons of CO_2.

. Source: *Implementation Plan for Bio Energy Farm, Description of best Examples, Intelligent Energy Europe (IEE)*[34]

During the field visit, some of the successful co-digestion-based plants were visited in India. The discussion with the plant developers and operator highlighted the benefits of co-digestion as increased gas generation, availability of feedstock throughout the year, increased system stability. Selected cases from the field visit and secondary sources are presented for reference.

[34] https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/bioenergy_farm_description_of_best_case_examples_en.pdf

Indian Successful Case studies on Co-Digestion

Case Study I: Bharat Biogas, Anand Gujarat

Bharat biogas plant was established in the year 2014 with an installed capacity of 14000 cubic metres. The plant operates on cattle dung along with potato waste and press mud and generates biogas and CNG, which is supplied to the industries and bulk consumer in Anand, Halol and Vadodara. The current operating capacity of the plant is approximately 12000 m^3. The CNG from the plant is supplied at the rate of INR 45 to 47 per Kg and manure from the plant is sold locally and also transported to Senegal in Africa.

Case Study II: Grid-Connected Biogas-Based Power Plant, Haryana

1.2 MW Grid connected biogas-based power plant has been commissioned in village Morkhi of Jind district in Haryana in March 2020. The plant has been set up by M/s Mor Bio Energy Private Limited and supported by MNRE. It is a first grid connected biogas-based power plant in the state of Haryana. The estimated annual power generation from the plant will be 85 lakh units. The plant will operate on CSTR technology and have 14500m^3 capacity digesters to produce biogas.Total cost of the plant is about INR 14 crore.
Poultry litter and cow dung is the main feed material of this plant and around 180 tonnes of organic waste will be utilized per day. The plant will produce nearly 15 tonnes per day of organic fertilizer, which will be sold to nearby farmers and mushroom cultivators.

There are technical areas regarding the mix ratio, processing monitoring and controls which need to be addressed for a mixed feedstock and a successful co-digestion. These issues have not been discussed as part of this report and need to be addressed prior to actual planning of the biomethanation plant.

Energy Potential

Energy potential for each sector and over all energy potential for potential region of the state has been considered as one of the key decision-making criteria. Energy potential is directly related to waste availability and characteristics of waste and is the baseline data for establishing the economic feasibility of setting up plant at any location.

Although, there are many factors which control biogas and methane yield during anaerobic digestion which include type of feedstock, digestion technology and operating parameters like temperature, pH , Organic loading ratio (OLR), C:N ratio, Hydraulic retention time and inoculums. The biogas generation from any anaerobic digestor is based on how effectively these factors are controlled to get maximum yield. Keeping the standard operating parameter, an average biogas yield and the total waste availability has been considered to calculate the energy potential for the selected potential region. Table 3.4 provides details of expected energy potential from different waste for the selected potential region of the selected states.

Table 3-4 : Energy Potential of the Potential Region (MW)

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Poultry	2.14	6.45	0.22	23.54	**32.35**
PM	7.35	3.83	22.87	1.71	**35.77**
F&V	0.00	0.16	0.00	1.30	**1.46**
CD	28.64	29.14	42.84	16.68	**117.31**
Composite	**38.14**	**39.59**	**65.93**	**43.23**	**186.89**
Rank	4	3	1	2	

1) *Energy potential has been calculated from the waste available in the potential area and the bio gas potential for each waste.*
2) *Biogas potential for poultry litter has been considered as 60 m^3/tonne; press mud as 100 m^3/tonne; Cattle dung as 35m^3/tonne and fruit and vegetable as 33 m^3/ tonne.*

The total expected energy potential from the potential region is 187 MW; the state of Uttar Pradesh leads with 66 MW, followed by Tamil Nadu, Maharashtra and Gujarat.

Test Results & Waste characteristics

The result of the physiochemical analysis of the waste samples have already been discussed in detail in the earlier chapter.

C/N

C/N ratio derived from collected samples from each states are more or less within the range and does not exhibit an any special criteria that can contribute on giving higher weightage to a particular state/ region. All the states and potential regions have been given equal weightage on account of this parameter.

pH Analysis

An ideal pH for optimising the fermentation process and gas production during biogas generation process is close to 7 (neutral). Several studies have proved that biogas yield and degradation efficiency were substantially higher for the substrate of pH 7 compared to other pH values. The methane and carbon-di-oxide composition in the biogas produced with pH 7 was much higher than lower pH condition. However, there is a different optimum pH range for each group of micro-organisms and bacteria during different stages of biomethanation. The methanogenic Archaea bacteria (responsible for methanogenesis) are very sensitive to pH and the optimum range for them is between 6.5 and 7.2. The fermentative microorganisms are relatively less sensitive and can tolerate a wider range of pH between 4.0 and 8.5. During the input of the feedstock the pH balancing is done to maintain the optimal conditions and as the process proceeds the system balances itself.

Since pH can be controlled during the biomethanation process through physical and chemical means and does not have direct bearing on selection of potential region, we have given equal weightage to all the potential region.

TS & VS

Although TS and VS loading rate is a key design parameter for biogas production in AD systems, TS and VS are inherent characteristics of the waste; and may not be directly responsible for the selection of potential region so similar weightage has been given to all states for this parameter.

Table 3-5 : Ranking of Potential Region based on Waste Characteristics

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
Rank	1	1	1	1

Alternate Utilisation Practices

Alternate utilisation practices of waste will reduce the diversion of waste to the biogas or waste to energy facility. Almost all the waste streams identified for the current study have alternate utilisation pattern. The scoring for alternate utilisation has been done on the level of utilisation current being practiced in the potential region. This analysis also consider the case if the current alternate utilisation will continue after the development of proposed waste management facility (for e.g. as in the case of press mud being utilised by sugar factories for treatment of spent wash); this will restrict diversion of the waste to the proposed waste management facility.

Multiple utilisation pattern for the selected waste type was observed, which has been summarised below:

1) Cattle dung is primarily used as manure in farm fields (approx. 85%), and a small quantity of dung is diverted to waste to energy plants (13%) and used as fuel as cow dung cake (2%).
2) Poultry litter is primarily used as organic manure (approx. 92%) and only 8% of the poultry farms were selling the litter to bio-methanation plants for energy generation.
3) Major contribution of fruit and vegetable waste is from mango processing plants. The waste from mango processing plants was utilized as boiler fuel and the remaining quantum of waste from other fruit and vegetable processing plants was utilized as cattle feed and for producing compost. The statistical data from the selected 4 states shows; 70% utilized as boiler fuel, 22% as cattle feed and the remaining 8% for composting.
4) Sugar plants with distillery facilities are using press mud for composting by spraying distillery spent wash. The plants without sugar plants are selling the press mud directly to farmers to be utilized as organic fertilizer or to distilleries to be used for treatment of spent wash. 60% share of raw press mud was directly utilized as fertilizer in agriculture. Sugar processing plants with distillery facilities were composting press mud by using spent wash from their distillery facilities. Some sugar processing plants without distillery facilities were selling press mud to standalone distillery facilities.

Competitive utilisation for each waste type in the potential region is summarised based on the findings of the field survey in Table 3-6

Table 3-6 : Current utilisation of the waste in the various state and Ranking

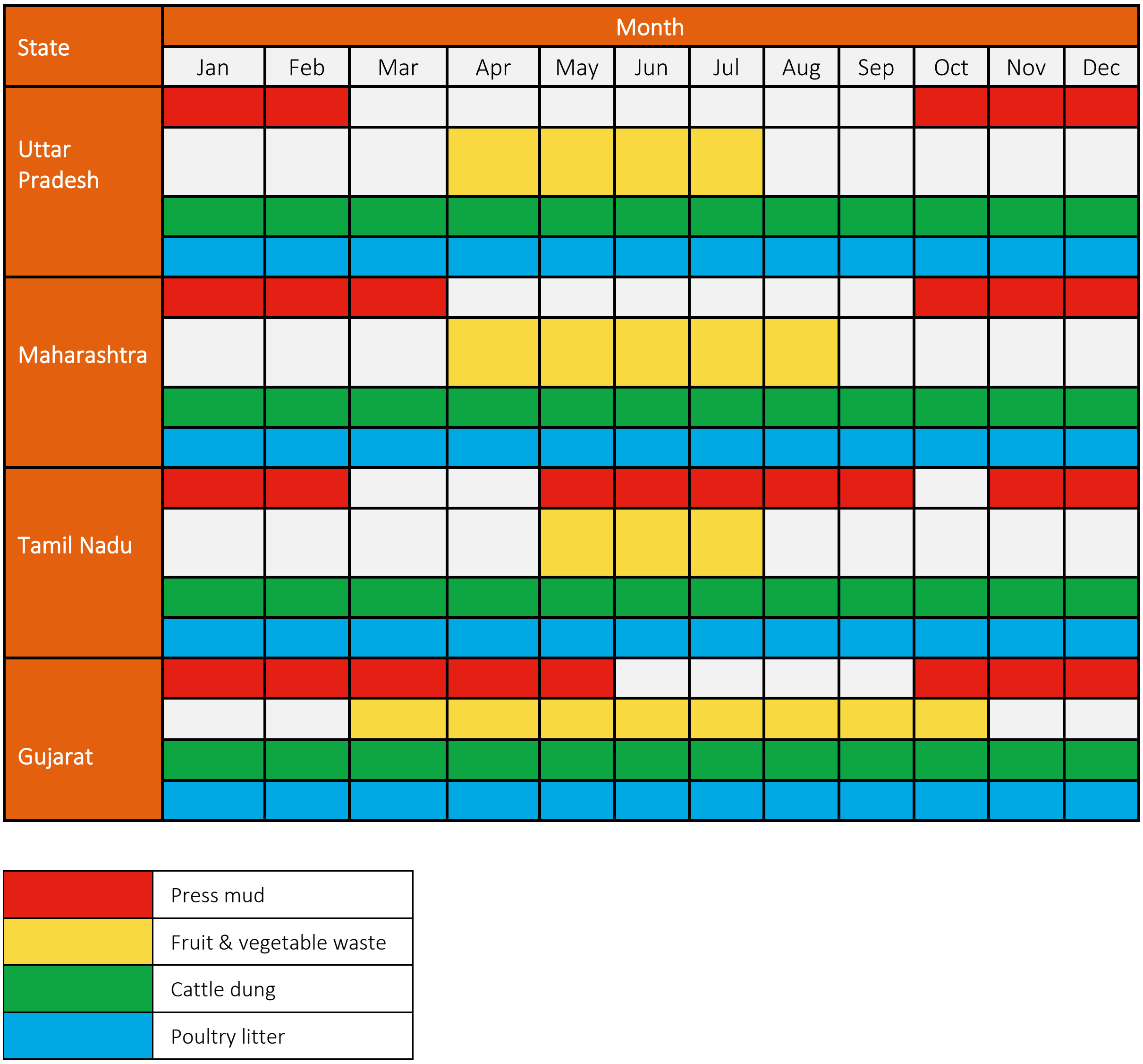
Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
Poultry Litter	Poultry litter is mainly used as fertilizer or supplied to the biogas plant	The waste is sold to the farmers at a price of INR 2000 to INR 2500 per tractor trolley.	The waste is used in own agriculture land	Used as fertilizer in farm fields.
Press Mud	Press mud is used for making of compost using spent wash or directly sold to farmers	Composting of press mud was being practiced using spent wash from distillery unit. Raw press mud is normally not sold. Only compost is sold to farmers at the rate INR 900/- per ton.	Press mud is used for making of compost and compost sold to local farmer (@ INR 1500/- per ton)	Press mud sold to registered farmers and at other farmers.
Fruit & Vegetable	Organic waste was sold at a rate of INR 1000/- per cubic meter to farmers And also being supplied to biogas plant	Mango waste was processed through pit composting in open lands. Also, mango waste is utilized by briquette industries for manufacturing biomass briquettes	Send to cattle farm as feed stock free of cost.	Waste sold to seed industry and briquette industries.
Cattle Dung	Almost 90% of the cattle dung is sold to farmers which is used as an organic manure	Currently utilized as organic manure in farms and previously used in preparation of dung cake.	Most of the dung is sold to farmers as organic fertilizer and some utilised for preparation of dung cake.	Used as fertilizer in farm fields.
Rank	1	1	1	1

All the states have competitive usages /utilisation practice for waste, hence similar ranking has been provided to each state under this decision-making criterion.

Seasonal Variation & waste availability

The impact of the seasonal variation on waste availability has been analysed for each waste type and for each state. This is relevant to access the fluctuations in the feedstock supply, which can hamper the gas production efficiency of the biomethanation plant. It was observed that out of the four studied sectors, the animal waste will be available throughout the year, whereas agriculture-based waste like press mud and fruit & vegetable processing waste will be available only during the harvesting season. Among the fruit and vegetable, it was observed that majority of the fruit processing plant are for Mango, which is available only for selected months (May to July). The following chart shows the seasonal availability of waste.

Table 3-7 : Seasonal availability of waste



Biomethanation plant based on press mud and fruit and vegetable processing waste may be crippled by insufficient feedstock during non-season; or may require huge storage facilities for storage of feedstock during the non-season. However, it may be noted that fresh feed stock has higher methane generation potential due to retention of volatile solids. Storage of feedstock reduces the methane generation potential. Hence composite plant with wide array of feedstock may be the right choice.

State wise analysis of the seasonality criteria shows minor variation. This is primarily due to availability of press mud in Tamil Nadu for relatively longer duration than other states. Table 3-8 provides the weightage of each sector and ranking of the state based on the total weightage.

Table 3-8 : Seasonal availability of waste

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Poultry Litter based on availability in months	12	12	12	12	12

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Weightage based on availability in months	1	1	1	1	
Press Mud	5	5	5	9	12
Weightage based on availability in months	0.42	0.42	0.42	0.75	
F&V Processing	4	4	0	4	12
Weightage based on availability in months	0.33	0.33	0.00	0.33	
Cattle Dung	12	12	12	12	12
Weightage based on availability in months	1	1	1	1	
Total Weightage	**2.75**	**2.75**	**2.42**	**3.08**	
Rank	2	2	4	1	

Above table indicates that considering the seasonality aspect, the state of Tamil Nadu holds the first rank followed by Maharashtra and Gujarat as second and Uttar Pradesh on fourth rank .

Cost of the Raw Material

Cost of the raw material was collected during the field survey for all type of waste material. The variation in the cost of raw material for a sector across different state was very less.

Table 3-9 : Raw material cost in potential region of different States

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Poultry Price (Rs per ton)	500- 800	700- 800	700- 800	750- 900	
Score	0.03	0.03	0.03	0.03	0.13
PM Price (Rs per ton)	600- 800	300- 500	220- 500	500- 800	
Score	0.03	0.02	0.01	0.03	0.08
F&V-Price (Rs per ton)	900- 1000	800- 1000	600- 800	800- 1000	
Score	0.00	0.00	0.00	0.00	0.01
CD Price (Rs per ton)	600- 700	600- 700	500- 800	600- Rs 800	
Score	0.19	0.19	0.19	0.21	0.78
Total Score	**0.250**	**0.242**	**0.238**	**0.270**	**1.00**
Ranking	**3**	**2**	**1**	**4**	

Above table indicates that average cost of raw material is least in the potential region of Uttar Pradesh, hence is most favourable for development of biomethanation plant followed by the state of Maharashtra.

It may be noted that in addition to the cost of raw material mentioned above, other cost related to handling and transportation of waste will be the associated input cost for project development.

Market for the Final Product and Off take arrangement

The location identification also corelates with the possibility of marketing the final product, off take arrangement, distribution and end use of energy and other product produced. The potential region selected in each state was analysed for the existing and the potential energy offtake arrangement in the vicinity as final output of the process are economically feasible on transportation over short distances. The final output of the process includes heat generated from the process, biogas or electricity and manure.

Biogas can be supplied directly after purification for domestic, commercial consumption or can be directly feeded to the gas grid; biogas can also be upgraded (by removing hydrogen sulfide, moisture, and carbon dioxide with methane content more than 95%). compressed and used as Bio CNG in vehicles; or converted to electricity. Setting up the Bio CNG plant in the vicinity of the CNG station will reduce the cost of compression and ensure easy offtake of bio CNG. In case the biogas is converted to electricity, then the offtake arrangement and distance to the electric grid is the key assessment criteria, as the transmission of electricity in the low voltage range might result in a reduction of the economic yield because of significant line losses.

The digestate/ manure (residual matter) obtained from the biomethanation plant, has a commercial value and can be sold in the market; the presence of distribution area and the market for the same in the vicinity is one of the key criteria.

Evaluation of the market for the final product and offtake arrangement can be summarised based on utilisation potential of key outputs from the biogas generation process. Key output from the process for which market and offtake has been analysed include i) Electricity offtake ii) Biogas containerisation and consumption by large domestic, Industrial and commercial consumer iii) Bio CNG – which is proven vehicle fuel iv) Manure obtained post digestion. The selected potential region in the four states have been qualitatively analysed for the possibility of existing and potential market in the region and ranking has been done based on the same.

Table 3-10 : Assessment of the market for the final product and offtake arrangement

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
Electricity offtake and existing scenario	No grid connected plant from agriculture, industrial and urban effluent waste in the state.	3 plant grid connected 9.59 MW capacity from agricultural industrial or urban effluent Clear cut policy from the state government on electricity generated through biomethanation route provides better marketing scenario for the same	No grid connect plant from agriculture, industrial and urban effluent in the state	3 plants with capacity of 6.4 MW in the state agriculture, industrial and urban effluent
Rank	**3**	**1**	**3**	**2**
Biogas	No of off grid biogas plant installed are 4 with installed capacity of 24800 m3/ day Industries visited in the potential region of Gujarat are already buying gas from the existing biogas plant. e.g. Bharat biogas is	10 number of off grid biogas plant with installed capacity 109636 m3/ day. Sufficient biogas demand in the state	22 number of off grid biogas plant with installed capacity 62320 m3/ day. Sufficient biogas demand in the state	28 number of off grid biogas plant with installed capacity 150218 m3/ day. Sufficient biogas demand in the state

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
	supplying biogas to Amul dairy plant, furness Industry at Halol & Savli in Vadodara & Panchmahal district (up to 50 km radius). But, number of such industries is limited and since not many plants are operational in the state demand cannot be assessed			
Rank	**4**	**3**	**2**	**1**
Bio CNG	Gujarat 5 plants with installed capacity 28338 kg /day	Maharashtra has 4 operating plant with installed capacity of 27723 kg /day Existing market and Acceptability level is high in the state Selling price of Bio CNG – 45 to 50 rupees.	Uttar Pradesh has 1 plant with total installed capacity of 2000 kg /day. The plant is at Hardoi and is not operating	Tamil Nadu has one plant with installed capacity of 400 kg per day– Mahindra world city where Bio CNG is used to convert as automotive fuel. (MNRE standing committed on electricity report does not mention about the plant)
	1	**2**	**4**	**3**
Manure	The demand for organic manure is high in the potential region. Manure is sold in the open market in India & also exported The plants visited in Gujarat are exporting the manure to Senegal in Africa. The selling price for manure in potential region was INR 400 to 600 per tonne	Compost selling price in the potential region 500 -900 Per tonne There is a high demand of organic fertiliser in the sugar cane belt of the state, which also happens to be the selected potential region of the state for the project	Potential area in UP is the key agricultural zone and have large scale sugar cultivation. The demand for organic manure is the region is high. Compost from the manure is sold at Rs 1500 per tonne.	
Rank	3	2	1	4
Overall score	11	8	10	10
Rank	**3**	**1**	**2**	**2**

Source of biogas and bioCNG plant: Standing Committee on Energy 2019-20, MNRE

As per MEDA (2018) -11 Waste to Energy projects and 5 Bio-CNG projects are operational in Maharashtra.

Analysing the market potential and offtake arrangements, Maharashtra occupies first rank followed by Uttar Pradesh, Gujarat and Tamil Nadu.

Its important to note here that there are no central or state level regulations for use of biogas as transport fuel or injecting the same in the gas grid. Hence, a number of approvals and permissions are required from various government department prior to use of biogas for transportation or offloading to the gas grid. All these processes and permissions from government agencies without transparent legal guidelines for setting up new plants, consume lot of time and deters the development of bio gas plants in India.

Operating Plants in the Potential Region

The total number of sustainably operating plant in the state and the potential region was analysed for the competitor analysis and evaluate the sustainability of the new biomethanation plant in the long term. More the number of operating plant in the area of influence of the proposed biomethanation plant, lesser the possibility of getting raw material and feed stock due to competing uses. Though this analysis is done and presented in the report to get better details on sustainability operating plants potential area, this information cannot be considered as the bench mark for selection of location for the new biogas plant. The reason being the area of the selected potential region is also very vast and have potential to accommodate to accommodate more number of plant with separate sphere of influences for collection of raw material.

Following table provides details on the number of biogas plant from agricultural, urban, industrial effluent both at the state level and also at the level of potential region identified for the states.

Table 3-11 : Operational waste to energy plants in the selected state and Potential Region

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	Total
Plants in state (capacity)	14	42	34	25	**101**
Rank	**1**	**4**	**3**	**2**	
Potential region	13	28	15	19	62
Rank	**1**	**4**	**2**	**3**	

Based on the plant availability details, maximum waste to energy plants are available in the Maharashtra state as well as the potential region of the state. The state of Gujarat has least number of plants both at the state level as well as in the potential region, making it the best choice for setting up a new biomethanation based plant, followed by potential region of Uttar Pradesh.

Institutional Arrangement and State Government Incentives

Existing state government policies on promotion of agriculture and animal based biogas plant including the licensing policies, institutional finance, Government subsidies and benefits associated with establishing a unit in the urban areas or rural areas are significant for deciding on the location of the proposed plant.

Most of the shortlisted state government followed the central government assistance and incentive pattern provided by Ministry of New and Renewable energy (MNRE) and have limited state level assistance or benefits for project from urban , industrial and agricultural waste. In this section we plan to compare institutional arrangement and policy level support provided by the state government in addition to the central schemes. Although details on some of the central schemes have been already been covered in 3rd stage report , the same has been covered here to address the changes in policy from then, completeness of the document and comparison with the state schemes. Key central government policies for promotion of biogas include:

- Revised Guidelines of Waste to Energy programme – Programme on Energy from Urban, Industrial, Agricultural Waste / Residue and Municipal Solid Waste , Feb 2020
- New National Biogas and Manure Management Program (NNBMMP),
- Biogas Power (Off-grid) Generation and Thermal Application Programme (BPGTP)
- Gobar Dhan
- National policy on bio fuels

Revised Guidelines of Waste to Energy programme

The Ministry of New and Renewable Energy (MNRE) formulated 'Revised Guidelines of Waste to Energy programme – Programme on Energy from Urban, Industrial, Agricultural Waste / Residue and Municipal Solid Waste 'in February 2020. This program intends for recovery of energy in the form of biogas/ Bio-CNG/ enriched biogas/ power from urban, industrial and agricultural wastes; captive power and thermal use through gasification in Industries. The scheme provides Central Financial Assistance in the form of capital subsidy and Grants-in-Aid for the following activities:

I. Biogas production from industrial waste, sewage treatment plants, urban & agricultural Waste/residue through bio-methanation.

II. Power generation or production of Bio-CNG/enriched biogas from biogas produced from industrial waste, sewage treatment plants, urban & agricultural waste/residue.

III. Installation of biomass gasifier-based projects in industry for producing electricity to meet the unmet demand of captive power and thermal needs of rice mills and other industries and villages for lighting, water pumping and micro-enterprises.

IV. Promotional activities including R&D, resources assessment, technology up gradation and performance evaluation, etc.

The Central Financial Assistance (CFA) for Biogas project as provided in the revised MNRE guidelines, includes:

- CFA of INR 1.0 crore (approximately USD 150,000) per 12,000 m^3 biogas/day for biogas projects
- INR 4.0 crore (USD 600,000) per 4,800 kgs of bio-CNG/day generated from 12,000 m^3 biogas/day. The maximum for any project is INR 10.0 crore (USD 1.5 million). The CFA will be INR 3.0 crore/ MWeq if bio-CNG is generated from an existing biogas plant.
- For power plants based on biogas, the CFA will be INR 3 Cr per MW, with maximum limit of 10 crore per project. The CFA will be 2 crore per MW for the already existing biogas plant setting up power generation unit.
- For gasifier based project CFA varies from INR 6.67 lakh per MW to INR 1.5 crore per MW depending upon type and usage of gasifier.

New National Biogas and Manure Management Programme (NBMMP)

New National Biogas and Manure Management Programme (NBMMP) from MNRE is for development of small biogas plant in rural and semi urban areas, which help beneficiaries in converting cattle dung and organic waste into useful clean gaseous fuel for cooking and lighting. The programme is implemented through State Rural Development Departments (SRDDs) and Khadi & Village Industries Commission (KVIC). The CFA under NNBOMP is provided in the form of central subsidy for setting up biogas plant of capacity 1-25 m^3 biogas per day. The subsidy ranges from INR 7,500/- per plant of 1 m^3 to INR 35,000/- per plant of 20-25 m^3 depending upon the size of plants, location States or regions, category, etc. Besides this, financial support is also provided for turnkey job fee for construction, supervision, etc.

Biogas Power (Off-grid) Generation and Thermal Application Programme (BPGTP)

The Biogas based Power Generation and Thermal Application Programme (BPGTP) is implemented through the Agriculture and Rural Development Departments of the States, Dairy Co-operatives, State Nodal Agencies (SNAs), Biogas Development and Training Centres (BDTCs), Khadi and Village Industries Commission (KVIC) and National Dairy Development Board (NDDB) from the year 2018-19. The scheme promotes biogas generation for decentralized applications in the capacity range 3 kW to 250 kW and also for thermal energy applications having biogas generation capacity in the matching size range of 30 m^3 to 2500 m^3 per day.

The CFA under the programme being provided in the range of INR 25,000 /- per kW to INR 40,000 per kW for power generation and INR 12,500 /- per kW to INR 20,000 /- per kWe for thermal applications respectively. The CFA rates vary depending upon the category of beneficiaries and location /region for the projects installed.

Gobar Dhan

GOBAR DHAN (Galvanizing Organic Bio-Agro Resources Dhan) scheme by department of Drinking Water and Sanitation, Ministry of Jal Shakti, Government of India under Swachh Bharat Mission (Gramin) in February 2018. The scheme supports biodegradable waste recovery and conversion of waste into resources such as cattle dung and solid waste in farms to bio-slurry, biogas, bio-CNG and compost. Rural India is one of the areas where a big thrust can be made to push the usage of Biofuels and reduce dependency on fossil fuels.

The scheme intends for development of cleaner villages through solid waste management, increased rural income and reduced environmental impact and to make villages self-reliant in clean energy by harnessing bio-waste to generate bioenergy and thereby reduce burning and dependence on forests. The program will be funded under SLWM (Solid Liquid Waste Management) component of SBM-G. The total assistance provided for SLWM component of SBM-G is based on total number of households in each Gram Panchayat (GP) subject to maximum of INR 0.7 million for GP having up to 150 households, INR 1.2 million up to 300 households, INR 1.5 million up to 500 households and INR 2 million for GPs with more than 500 households. Funds will be provided by Central and State government in the ratio of 60:40.

National Policy on Biofuels

The National Policy on Biofuels, 2018, emphasized on active promotion of advanced biofuels, including bio-CNG. The Indian oil marketing companies are venturing into bio-CNG plants with projected investments upto INR.100,000 million to encourage the use of a clean fuel, reduce dependency on fossil fuels and reduce the oil import bill.

Other Support measures and incentives

Other support measures and incentives available for a promoter / developer to set up a Biomethanation based waste to energy plant as indicated by MNRE include

i. Preferential Tariff for sale of electricity generated by biogas plant by the CERC /SERC;
ii. Fiscal incentives and concessions
    - Concession in Custom Duty and GST at rate of 5% for initial setting up of grid connected projects for power generation or production of Bio-CNG from wastes;
    - Accelerated Depreciation
    - Exercise duty for RE devices
    - Income tax benefits
iii. Energy Buyback, Wheeling & Banking;
iv. Open access to electricity grid for the power from biogas plant
v. Captive generation decontrolled
vi. RE Power Obligations for Transmission Companies

vii. Policy framework for pumping upgraded Biogas into gas grids and for price fixation for Bio-CNG – work in progress

viii. According to the amended Tariff Policy: Distribution Licensee(s) shall compulsorily procure 100% power produced from all the Waste-to-Energy plants in the State, in the ratio of their procurement of power from all sources including their own, at the tariff determined by the Appropriate Commission under Section 62 of the Act.

The state of Gujarat and Maharashtra has waste to energy policy for the state. Gujarat Waste to Energy Policy, 2016. includes industrial non-hazardous waste along with the municipal waste, whereas Maharashtra has a 'Comprehensive Policy for Grid connected Power Projects based on New and Renewable Energy Sources(2015)' and it addresses the power generation from Industrial waste. The other two State of UP and Tamil Nadu has no specific policy which addresses the biogas production from Agriculture, industrial and urban effluent.

In terms of state level policies on renewable energy, Maharashtra is the most progressive state and has comprehensive policies for development of waste to energy facility from New & Renewable (Non-Conventional) Energy sources. Under the umbrella of comprehensive policy on connection of grid connected power plant projects , Maharashtra state government is encouraging the power generation from industrial waste and have targeted 200 MW of Industrial Waste-based Power Projects along with other renewable sources to meet the total state target of 14,400 MW capacity power projects based on new and renewable energy sources.

The ranking for the current analysis have been made considering the qualitative fact on clear cut policy directions at the state level on waste to energy from renewable sources, availability of methodology for setting up the facility and other policy level support and incentives provided by the state government to promote the sector.

Table 3-12 : Institutional policy status on biogas generation in selected states

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
State level Institutional policies for biogas generation	Gujarat State Waste to Energy Policy, 2015 The state policy for Gujarat includes both waste to energy and Non hazardous industrial waste Policy on determination of tariff does not take into account animal based or the non-biomass waste stream. No financial assistance in the state for setting up biogas or biogas based power plant	Comprehensive Policy for Grid connected Power Projects based on New and Renewable (Nonconventional) Energy Sources – 20th July 2015 The policy for Maharashtra is more specific and includes only Non-renewable (Non-conventional) energy sources The targets for development of power from industrial waste specified. It provides detail on, methodology for setting up the project including	No state level policy to promote biogas plant or biogas-based power plant was identified for the state. Or no policy to encourage waste to energy from organic waste was mentioned by the stakeholders during the discussions	No Specific state government policy for biogas plant or biogas-based waste to energy plants TN department of Industries and commerce provides capital subsidy of 25% on plant and machinery for micro enterprise i.e. investment < INR 25 lakhs. Also providing 25% subsidy to medium scale enterprises with investment <INR 10 crores which are established in the identified backward blocks in Tamil Nadu.

Particular	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
		evacuation arrangements and all the relevant formats for application under the project Provision for Financial assistance upto a maximum of INR 1 crore per project from Green Cess fund from MEDA, by way of reimbursement has been made for the project developer, setting up the evacuation arrangement at own expense.		Our potential region contain number of backward blocks in TN
Rank	**2**	**1**	**3**	**3**

In terms of state level policies on renewable energy, Maharashtra is the most progressive state and has policy for Grid connected Power Projects based on New and Renewable (Nonconventional) energy sources and includes power from industrial waste. Also, the state provides financial assistance to the developer for making the power evacuation arrangement. On the state level policy initiatives and support, the state of Maharashtra occupies first rank followed by the state of Gujarat which has a state waste to energy policy and includes the energy generated from Industrial waste. Tamil Nadu and UP are at third rank with no major policy initiatives in the sector.

Power Tariff

Central Electricity Regulatory Commission (CERC) has specified the normative capital cost for Biogas based power projects to be INR 1185.76 lakhs/MW for FY 2019-20. After taking into account capital subsidy of INR 300.00 lakhs/MW, net project cost is INR 885.76 lakhs/MW for FY 2019-20. Normative O&M expenses for biogas for the FY 2019- 20 is as INR 59.05 Lakhs per MW, which is escalated at the rate of 5.72% per annum over the tariff period. CERC has also fixed a levelized tariff of INR 7.64 for biogas-based power project for the financial year 2019-20. However, there had been a non-alignment in the central policy and state policy on the feed in tariff, as electricity is the concurrent list. Most of the states do not have any clear directives and mandates on the biogas-based power and have not declared the feed in tariff for biogas-based power project. In absence of the fixed generic tariff, it is difficult to assess the project viability at the pre-investment assessment stage due to unpredictability related to the power purchase agreement prices determined by the SERCs[35].

Following section compares the initiative taken up by selected states for promotion of biogas-based power projects and feed in tariff status in the selected states

[35] Barriers to biogas dissemination in India, Shivika Mittal et. Al, 2017

Table 3-13 : State level initiative for promotion of biogas based power and feed in Tariff

Decision Criteria	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	CERC
Policy status and power tariff	None of GERC policies and orders are specific for biogas based power and donot specify the generic tariff for for biogas based power plant. The RPO target specified in GERC (Procurement of Energy from Renewable Sources) (Second Amendment) Regulations, 2017 of 0.5% from other energy sources,(i.e. biomass, bagasse, small hydro power projects etc.) during FY 2017-18 to FY 2020-21 out of total RPO percentages specified for the year do not include biogas based power plant	MERC (Terms and Conditions for determination Renewable Energy Tariff) Regulations, 2019. The power generated from the projects based on organic degradable waste will be sold by the project developer/project holder primarily to the distribution licensee for the fulfilment of Renewable Purchase Obligation. After fulfilment of RPO, the power can be used for captive consumption or sold to third party within and outside state. The power can also be sold by way of Renewable Energy Certificates. The in-organic degradable/organic degradable waste based power projects will be eligible to execute power purchase agreement or to seek open access approval or to sell energy through Renewable Energy Certificates only upon obtaining Infrastructure Clearance from MEDA.	UPERC (Captive and renewable energy generation plants) regulation 2019 – Biogas project as approved by MNRE are considered under eligible for renewable energy generating plants are governed by the regulation Thought the regulation recognises the biogas based plant but tariff fixation for biogas plant is similar to Bagasse and is applicable for the projects which do not claim any subsidy from MNRE. No Applicable tariff for the bio gas plant fixed by the state and Procurement of power through biogas based power plant commissioned on or after 1st April 2019 is to be done through a competitive bidding process on technologies approved by MNRE and plants not	TNERC has fixed generic tariff for the procurement of power from various renewable energy sector including bagasse, biomass and municipal solid waste projects. However, the Tariff rate from biogas based power generation has not been established.	CERC has fixed the applicable tariff rate for the financial year 2019-20 as Rs 7.83 and accelerated depression of 0.19 which gives the net levelized tariff of Rs 7.64

Decision Criteria	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu	CERC
			availing subsidy [36]		
Rank	**3**	**1**	**2**	**3**	

Based on the clarity on policy level initiatives on purchase of biogas-based power, the state of Maharashtra occupies the first rank followed by the state of Uttar Pradesh and Gujarat and Tamil Nadu.

Its important to note here that biogas based power is slightly more expensive than power from other renewable sources like solar , hydro and wind and requires support from Government in form of fixed feed-in tariffs and renewable power obligations. In the absence of same, the development and progress in the sector will be limited. A 'Report on subgroups on challenges for biomass and WTE power project' from Forum of Regulators indicated that due to high cost of biomass based energy generation and decrease in prices of power of wind and solar projects, discoms are not willingly procuring power from RE projects such as biomass and delaying payments by 3-4 month which is pushing biomass projects to shut down.[37] In the absence of electricity purchase/selling mandate and guaranteed feed in tariff for the biogas based plants, it would be difficult to sustain these plants in long run and generate continuous revenue. This also discourages the private investment in the sector. Bio gas should be looked as clean energy and associated benefits of reduced environmental impacts should be taken into consideration in comparison to other conventional sources of energy while fixing the feed in tariff for bio gas based power generation.

Composite Ranking

Based on the individual ranks assigned to each decision making criteria a composite scoring table is developed along with the final rank for each state.

Table 3-14 : Composite ranking of the states based on key decision criteria

Decision Criteria	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
Availability of Waste- State Level	3	2	1	4
Availability of Waste- Potential Region	3	2	1	3
Multi Feedstock Availability	4	1	3	1
Test Results and Waste Characteristics	1	1	1	1
Energy potential – Potential Region	4	3	1	2
Alternate utilisation practices	1	1	1	1
Seasonal Variations	2	2	4	1
Cost of Raw material	3	2	1	4
Market for Final Product	3	2	1	4
Operating plants in the state	1	4	3	2
Operating plants in the potential region	1	4	2	3

36 UPERC (Captive and renewable energy generation plants)regulation 2019

37 Report on subgroups on challenges for biomass and WTE power project by Forum of Regulators , October 2018 (http://www.forumofregulators.gov.in/Data/Reports/Report%20of%20SubGroup%20on%20addressing%20challenges%20for%20Biomass%20WTE.pdf)

Decision Criteria	Gujarat	Maharashtra	Uttar Pradesh	Tamil Nadu
Institutional support and state policies	2	1	3	3
Power tariff in the state	3	1	2	3
Total Score	**29**	**21**	**21**	**28**
Composite Rank	**4**	**1**	**1**	**3**

Composite scoring and ranking indicate that the selected potential region in the state of Uttar Pradesh and the state of Maharashtra have maximum potential for development of new biomethanation based plant with four selected waste types (poultry waste, cattle dung, fruit and vegetable processing and press mud) The potential region identified in the state of Gujarat is third in rank followed by potential region in the state of Tamil Nadu which occupies fourth place.

The above analysis can be seen as an example and can be used for broadly identifying the region most suitable for establishment of biomethanation plant based of selected four waste type.

It is important to note that the current decision criteria select the most suitable region. The site level criteria like availability of land, land acquisition, land cost, site utilities & surrounding infrastructure, real estate framework, and site due diligence are still required to be performed. Site level criteria are equally important parameters for finalisation of plant location within any region along with the decision criteria discussed above.

ANNEXURE

SHRIRAM INSTITUTE FOR INDUSTRIAL RESEARCH

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Date	: 24-11-2020
Job No	: 1901-1-421-3410
Booking No	: RG1819/1/12212
Booking Date	: 24-01-2019
Customer Ref No.	: PO : ARCADIS/PO/457/2018-19
Customer Ref Dt.	: 05-12-2018

Sample Particulars:
One sample marked as Press Mud Blend with Spent Wash, ID: UP/PMSW/1, Date of Collection: 23.01.2019 was received. (Revised report to report No. C1/0000162538 dated 21.02.2019)

Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	7.8	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	21.1	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	58.8	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	17.1	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	136	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	208	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 25.01.2019
DOC: 21.02.2019

RKSharma

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Date : 24-11-2020
Job No : 1901-1-421-3411
Booking No : RG1819/1/12212
Booking Date : 24-01-2019
Customer Ref No. : PO : ARCADIS/PO/457/2018-19
Customer Ref Dt. : 05-12-2018

Sample Particulars:
One sample marked as Cattle Dung, ID: UP/CD/1, Date of Collection: 23.01.2019 was received.
(Revised report to report No. C1/0000162539 dated 21.02.2019)

Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	8.6	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	16.4	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	69.5	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	23.0	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	138	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	144	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 25.01.2019
DOC: 21.02.2019

RKSharma

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Date	: 24-11-2020
Job No	: 1901-1-421-3529
Booking No	: RG1819/1/12255
Booking Date	: 25-01-2019
Customer Ref No.	: PO : ARCADIS/PO/457/2018-19
Customer Ref Dt.	: 05-12-2018

Sample Particulars:
One sample marked as Poultry Litter, ID: UP/PL/1, Date of Collection: 24.01.2019 was received.
(Revised report to report No. C1/0000162540 dated 21.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	6.7	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	36.9	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	55.8	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	13.5	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	127	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	237	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 25.01.2019
DOC: 21.02.2019

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NOIDA
UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date	: 24-11-2020
Job No	: 1902-1-421-237
Booking No	: RG1819/1/12611
Booking Date	: 02-02-2019
Customer Ref No.	: -
Customer Ref Dt.	: 02-02-2019

Sample Particulars:
One sample marked as Poultry Litter, ID: TNPL, Date of Collection: 30.01.2019 was received.
(Revised report to report No. C1/0000162998 dated 25.02.2019)

Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	8.2	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	33.1	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	61.6	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	20.7	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	135	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	209	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 02.02.2019
DOC: 25.02.2019

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Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-238
Booking No : RG1819/1/12611
Booking Date : 02-02-2019
Customer Ref No. : -
Customer Ref Dt. : 02-02-2019

Sample Particulars:
One sample marked as Cattle Dung, ID: TNCD, Date of Collection: 29.01.2019 was received.
(Revised report to report No. C1/0000163003 dated 25.02.2019)

Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	7.9	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	26.2	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	81.3	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	48.2	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	136	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	261	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 02.02.2019
DOC: 25.02.2019

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TEST CERTIFICATE NO : C1/0000162999

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NOIDA
UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-239
Booking No : RG1819/1/12611
Booking Date : 02-02-2019
Customer Ref No. : -
Customer Ref Dt. : 02-02-2019

Sample Particulars:
One sample marked as Press Mud ID: TNPM, Date of Collection: 29.01.2019 was received.
(Revised report to report No. C1/0000162999 dated 25.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	6.8	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	26.6	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	76.7	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	21.4	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	151	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	264	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 02.02.2019
DOC: 25.02.2019

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UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-240
Booking No : RG1819/1/12611
Booking Date : 02-02-2019
Customer Ref No. : -
Customer Ref Dt. : 02-02-2019

Sample Particulars:
One sample marked as Fruit & Vegetable Processing Waste ID: TNFP, Date of Collection: 30.01.2019 was received.
(Revised report to report No. C1/0000163000 dated 25.02.2019)

Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	4.2	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	10.8	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	88.0	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	10.9	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	87	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	251	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 02.02.2019
DOC: 25.02.2019

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PLOT NO. 5, SECTOR-127
NOIDA
UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-1491
Booking No : RG1819/1/12972
Booking Date : 11-02-2019
Customer Ref No. : -
Customer Ref Dt. : 11-02-2019

Sample Particulars:
One sample marked as "Fruit & Vegetable Processing waste" sample ID: GJ/FV/1, Date Collected: 07.02.2019, Arcadis project no.10003135, Project name: Mapping the availability of urban and industrial organic waste across various locations in India was received.
(Revised report to report no. C1/0000163838 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	4.7	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	13.3	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	93.6	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	27.8	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	60	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4, gm/kg	116	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

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UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-1492
Booking No : RG1819/1/12972
Booking Date : 11-02-2019
Customer Ref No. : -
Customer Ref Dt. : 11-02-2019

Sample Particulars:
One sample marked as "Press Mud" sample ID: GJ/PM/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received.
(Revised report to report no. C1/0000163844 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	6.6	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	26.7	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	78.0	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	21.9	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	163	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	203	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

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UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-1493
Booking No : RG1819/1/12972
Booking Date : 11-02-2019
Customer Ref No. : -
Customer Ref Dt. : 11-02-2019

Sample Particulars:
One sample marked as "Cattle Dung" sample ID: GJ/CD/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received.
(Revised report to report no. C1/0000163847 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	8.3	BIS 9040 C method for pH Determination
2.	Total Solids, % by mass (on received basis)	23.4	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	71.9	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	29.3	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	192	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	159	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

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UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 01-12-2020
Job No : 1902-1-421-1494
Booking No : RG1819/1/12972
Booking Date : 11-02-2019
Customer Ref No. : -
Customer Ref Dt. : 11-02-2019

Sample Particulars:
One sample marked as "Poultry Litter" sample ID: GJ/PL/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received.
(Revised report to report no. C1/0000163848 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	8.8	BIS 9040 C method for pH Determination
2.	Total Solids, % by mass (on received basis)	69.0	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	65.3	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	6.4	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	135	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	57	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

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UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date	: 24-11-2020
Job No	: 1902-1-421-1495
Booking No	: RG1819/1/12972
Booking Date	: 11-02-2019
Customer Ref No.	: -
Customer Ref Dt.	: 11-02-2019

Sample Particulars:
One sample marked as “Fruit & Vegetable Processing Waste” sample ID: MH/FV/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received.
(Revised report to report no. C1/0000163918 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	4.2	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	8.3	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	92.9	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	21.1	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	75	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	155	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

DS Chatterjee

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UTTAR PRADESH-201304
Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-1496
Booking No : RG1819/1/12972
Booking Date : 11-02-2019
Customer Ref No. : -
Customer Ref Dt. : 11-02-2019

Sample Particulars:
One sample marked as "Press Mud Blended with Spent Wash" sample ID: MH/PMSW/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received.
(Revised report to report no. C1/0000163919 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	8.0	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	39.0	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	68.8	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	16	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	132	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	140	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

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Date	: 24-11-2020
Job No	: 1902-1-421-1497
Booking No	: RG1819/1/12972
Booking Date	: 11-02-2019
Customer Ref No.	: -
Customer Ref Dt.	: 11-02-2019

Sample Particulars:
One sample marked as "Cattle Dung" sample ID: MH/CD/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received. (Revised report to report no. C1/0000163920 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	8.2	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	19.3	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	84.3	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	64.8	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	136	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	139	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

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Kind Attn: MR. ABHISHEK GHOSH

Date : 24-11-2020
Job No : 1902-1-421-1498
Booking No : RG1819/1/12972
Booking Date : 11-02-2019
Customer Ref No. : -
Customer Ref Dt. : 11-02-2019

Sample Particulars:
One sample marked as "Poultry Litter" sample ID: MH/PL/1, Date Collected: 08.02.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various locations in India was received. (Revised report to report no. C1/0000163922 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

Results Table

S. No.	Tests	Results	Protocol/Test Method
1.	pH	7.9	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	32.8	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	59.6	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	11.3	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	187	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	91	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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Kind Attn: MR. ABHISHEK GHOSH

Date : 01-12-2020
Job No : 1902-1-421-1791
Booking No : RG1819/1/13074
Booking Date : 13-02-2019
Customer Ref No. : -
Customer Ref Dt. : 13-02-2019

Sample Particulars:
One sample marked as "Fruit & Vegetable Processing waste" sample ID: UP/FV/1, Date Collected: 30.01.2019, Arcadis project no.10003135, Project Name: Mapping the availability of urban and industrial organic waste across various location in India was received.
(Revised report to report no. C1/0000163923 dated 28.02.2019)
Note: The sampling was not carried out by Shriram Institute for Industrial Research. The sample details provided in the test certificate are based on the declaration by sponsor.

S. No.	Tests	Results	Protocol/Test Method
1.	pH	5.9	BIS 9040 C method for pH determination
2.	Total Solids, % by mass (on received basis)	14.8	ASTM D 7348 guidelines
3.	Volatile Matter, % by mass (on dry basis)	95.2	ASTM D 7348 guidelines
4.	C: N Ratio, % by mass (on dry basis)	19.8	ASTM D 5373 guidelines By Calculation
5.	Chemical Oxygen Demand (as COD), gm./kg	40	APHA 23rd Ed. Method no. 5220
6.	Bio Methane Potential (BMP), CH_4 gm./kg	212	Buswell and Hatfield, 1936 Formula Developed for calculating Theoretical Biogas Potential

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DOR: 11.02.2019
DOC: 28.02.2019

RKSharma

AUTHORISED SIGNATORY
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