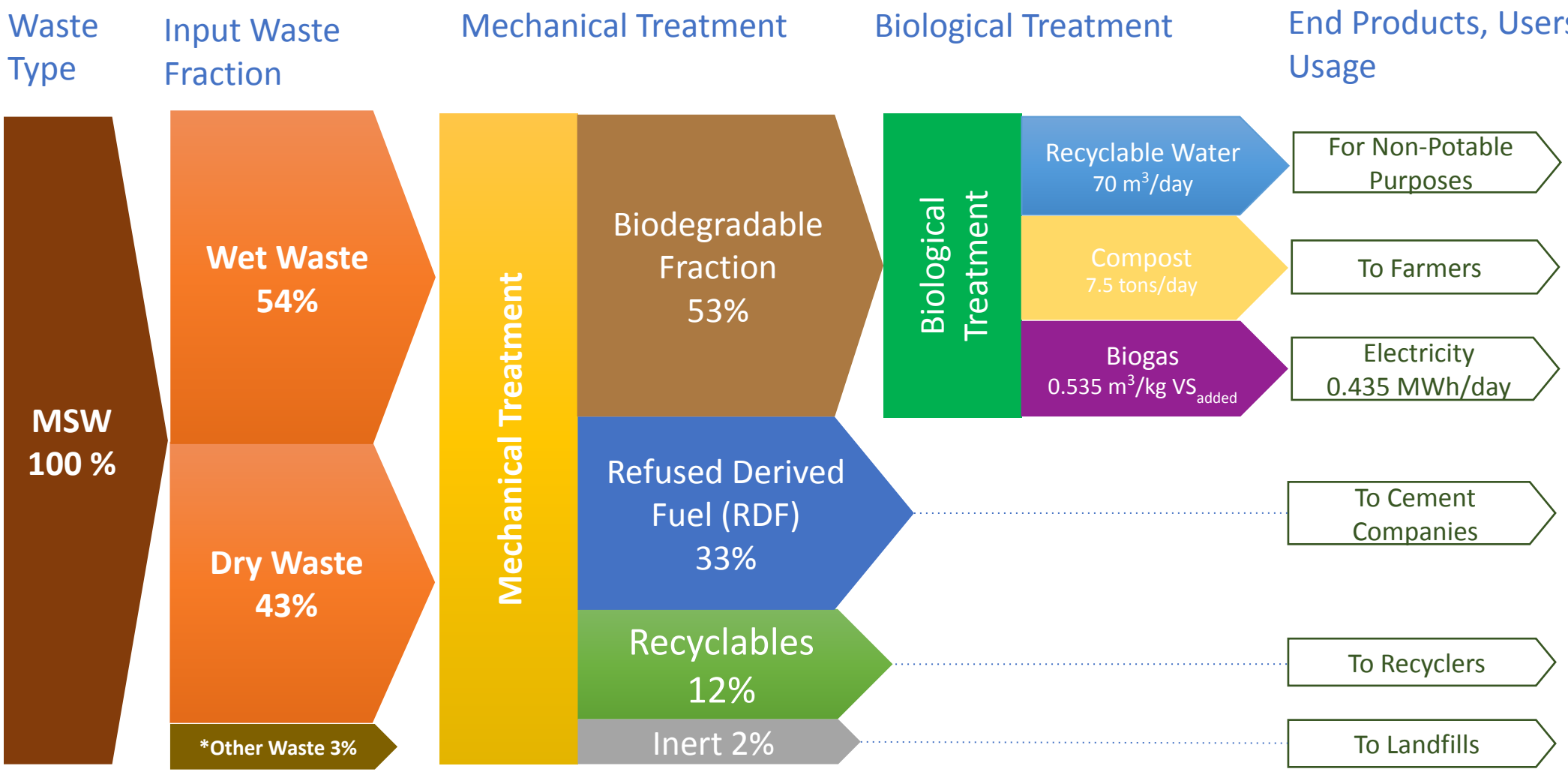
Municipal Solid Waste Biorefinery: Case study of 100 TPD Mechanical-Biological Treatment Plant

Dr. Vinay Kumar Tyagi
Scientist D

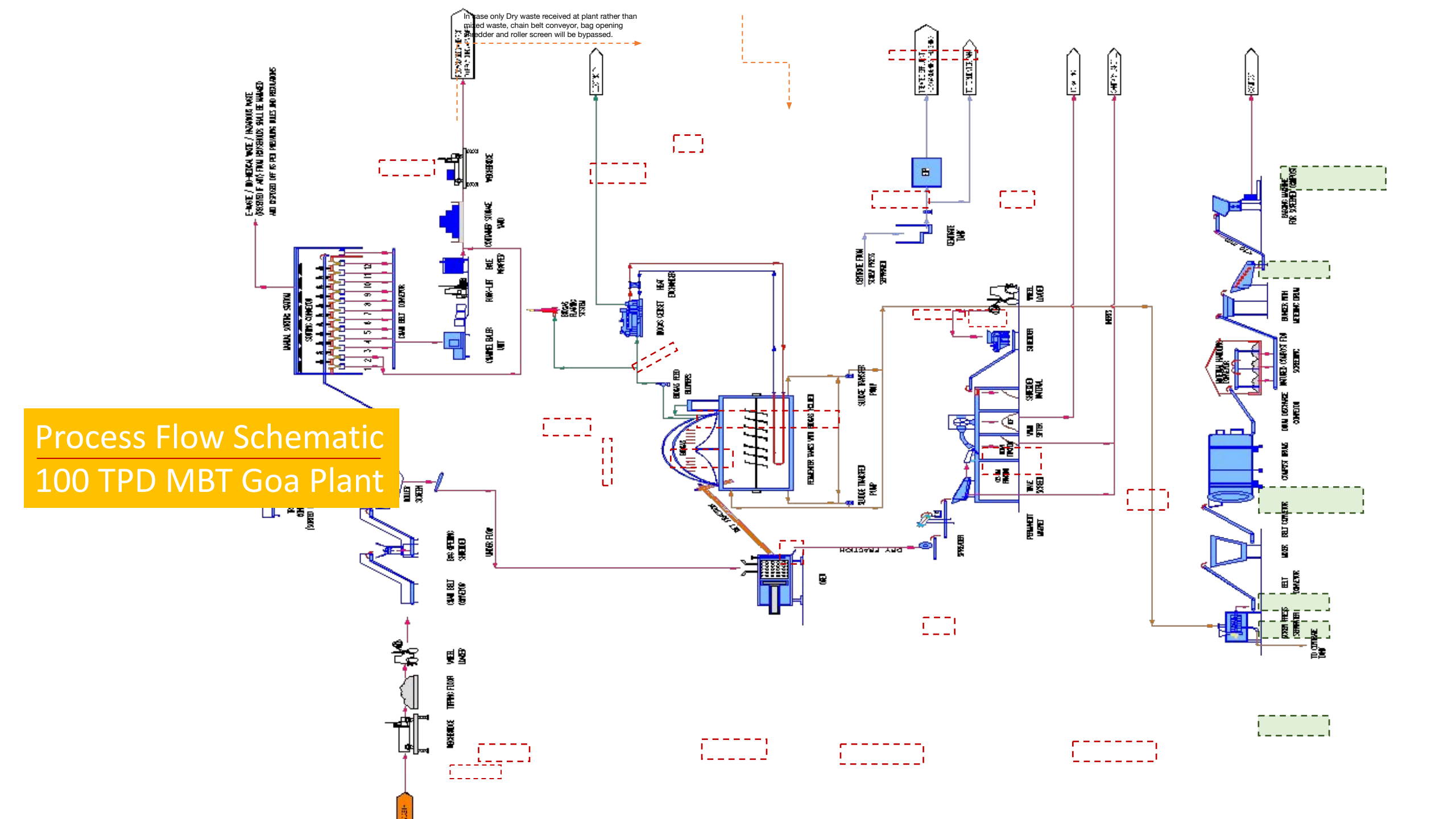
Environmental Hydrology Division
National Institute of Hydrology Roorkee

Overview: Waste Processing and Recoverable



*Mixed & Mulched tree waste

Process Flow Schematic
100 TPD MBT Goa Plant



Process Flow Schematic
100 TPD MBT Goa Plant

Input waste Tipping Floor

Bag opening shredder

Roller Screen

Overflow

Dry fraction

Manual sorting station

Bale Wrapper

Recyclables and RDF to Recycling Vendors

Underflow

Wet fraction

Biogas after purification (H_2S, moisture removal)

Biogas genset

Electricity

Biopress/ Orex

Organics extrusion

Wet fraction

Organic pulped slurry

Thermophilic Anaerobic Digester

Heat Exchanger

Digestate

Wind shifter

Plastic, card board, paper, wood

RDF

Dry fraction

Plastics, papers, cellulosic material, inert, sand, grit, stones, & other debris

Wave screen

Inert: inert, sand, grit, stones, & other debris

Landfill

Digestate from AD

Screw press separator

Dewatered solids

Rotary drum composter

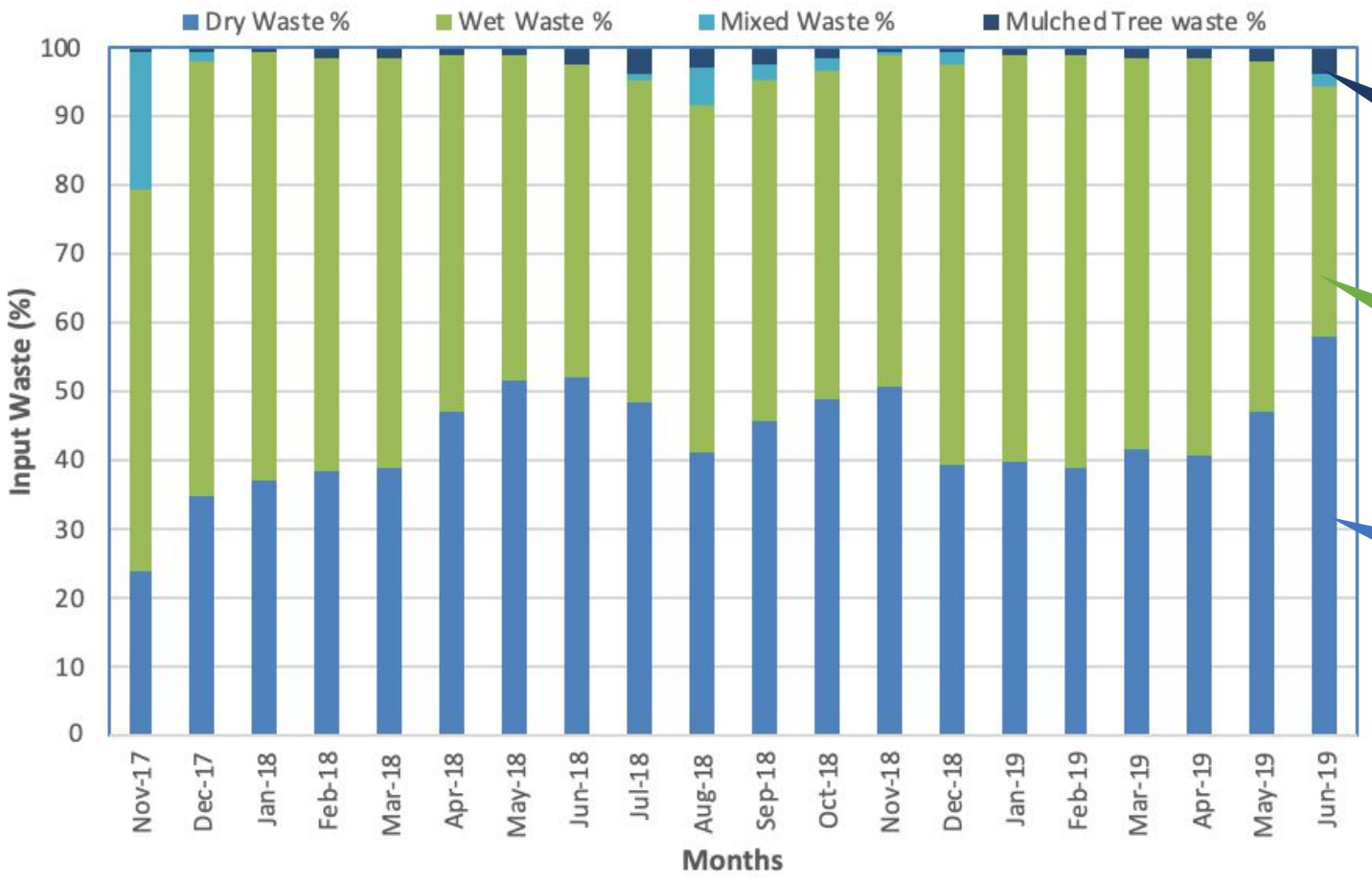
Compost

Centrate

Effluent treatment plant (MBR+RO)

Treated effluent for gardening/flushing

Input Waste Fractionization



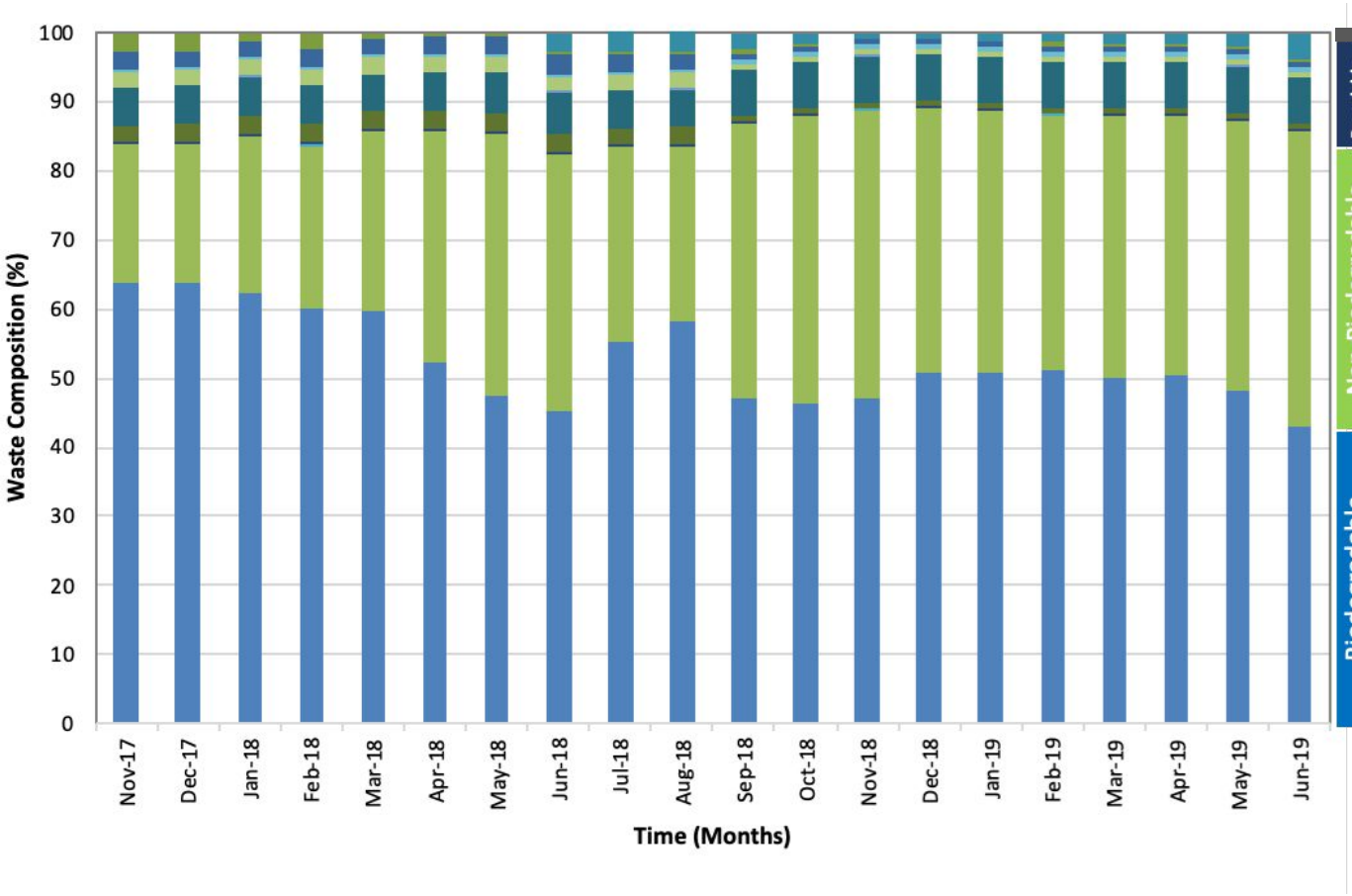
Mixed waste: 4 tons/day
- 3% of Input Waste

Wet waste: 80 tons/day
- 54% of Input Waste

Dry waste: 64 tons/day
- 43% of Input Waste

Waste Input:
Avg. 148 tons/ day
(130-173 tons/ day)

Waste Characterization



Inert – 1 to 3% (avg. 2%)

Stone, grit, sand, construction debris

recyclables – 10 to 14% (avg. 11%)

Paper, plastic, metal, glass, rubber, textile

Inorganics/RDF – 20 to 35% (avg. 32%)

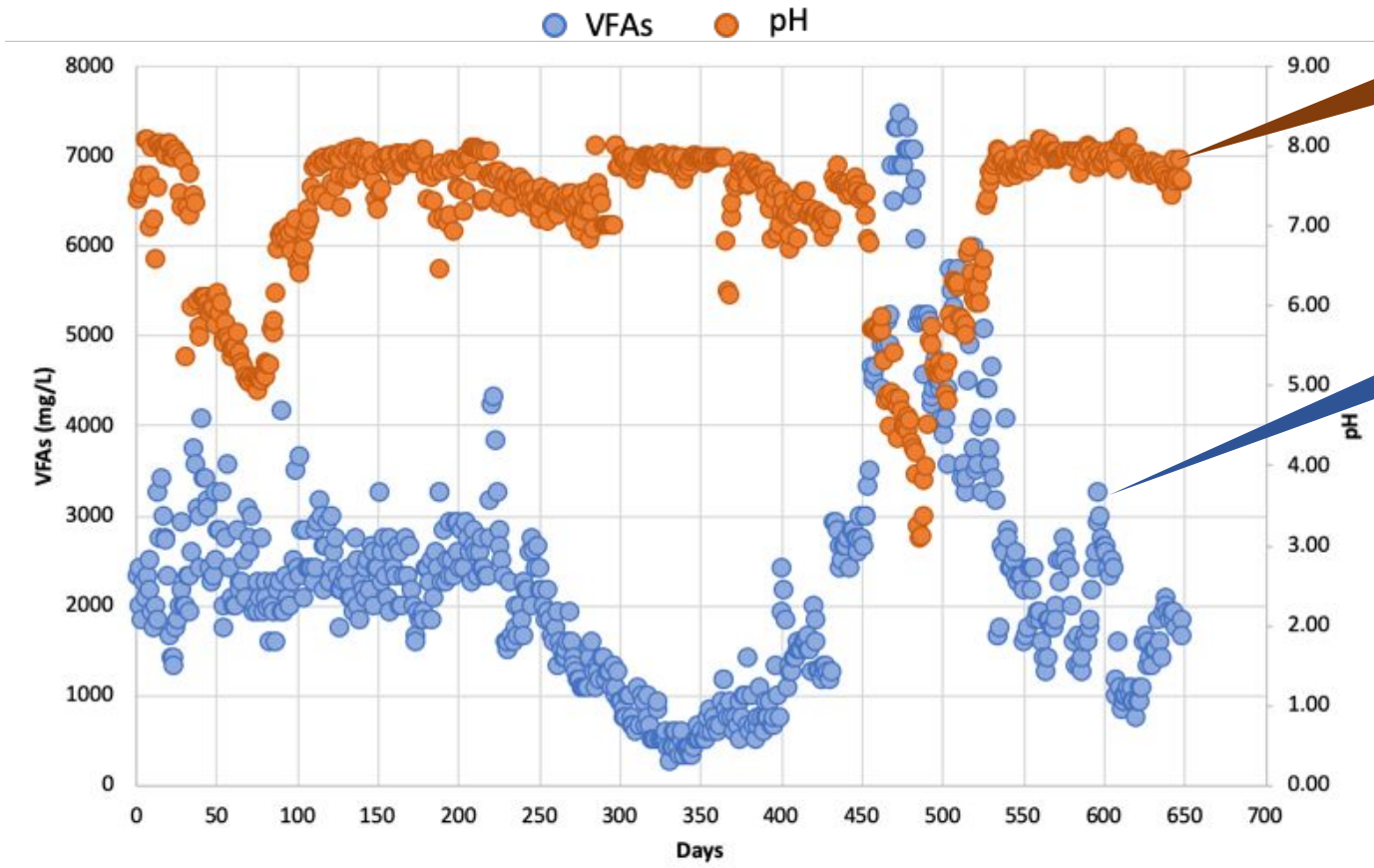
Non-recyclable material: thin micron plastic bags, crushed paper, textile, cloth, rags, wood

Organics or bio-waste – 45 to 60% (avg. 54%)

Food, vegetable, yard, and slaughterhouse waste

Anaerobic Digestion (AD)

pH-VFA profile & VFA/Alkalinity ratio



pH: 3.10- 8.40 (Avg. 7.15)

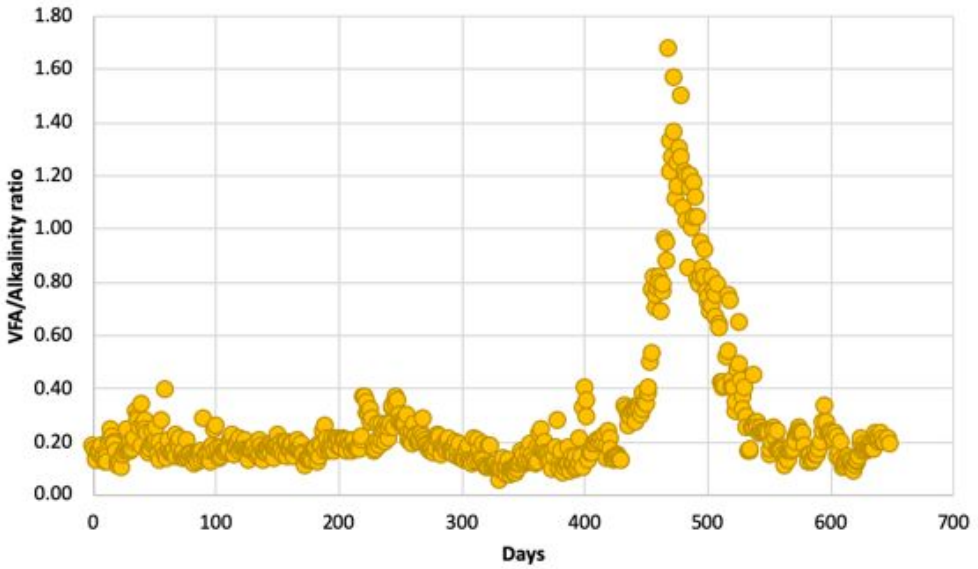
- 17% occasions: pH 3.00 to <6.50, due to VFAs buildup in the digester.
- Mostly, pH 6.5 to 8.4 (Avg. 7.40).

VFA: 250-7500 mg/L (Avg. 2300 mg/L)

- VFAs: 3500 to 7500 mg/L VFAs (avg. 5200 mg/L) from Days 45—530. Corresponding pH: 3.00 to 6.20 (avg. 5.12).

Why Low pH & High VFAs?

High OLR: 4.65 kg VS/m^3.day, i.e., 2.25 times higher than average operating OLR (1.82 kg VS/m^3.day, range: 0.28 to 2.77 kg VS/m^3.day)



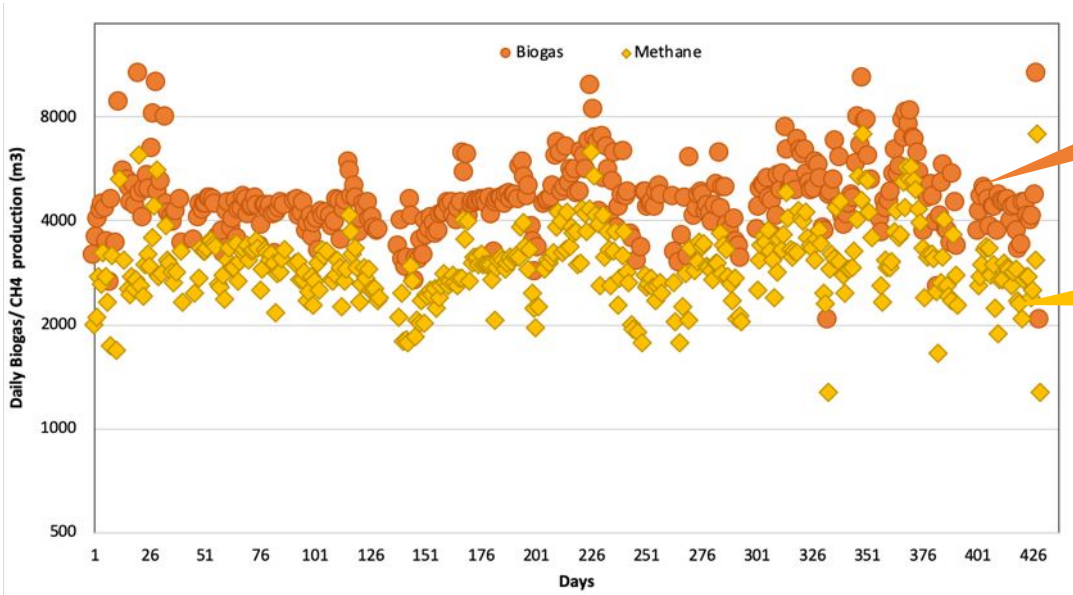
VFA to alkalinity ratio: average VFA/alkalinity ratio was 0.27

- less than 0.35 (0.1 to 0.35) indicates a stable operational condition or a well-operated digester
- **Ratio exceeding 0.35** is an indication of organic and hydraulic overloading conditions

During the event of **digester disturbance**, the average VFA/alkalinity ratio (0.85) and the ratio spectrum (0.42 to 1.68) was significantly higher than the optimum one

Anaerobic Digestion (AD)

Biogas generation and Yield



Biogas: Avg. 5000 m3/day
[2100- 10750 m^3/day]

Methane: Avg. 3250 m^3/day
[1300- 7250 m^3/day]

Biogas
- 50%: 4000-5000 m^3/day
- 25%: 5000-10000 m^3/day

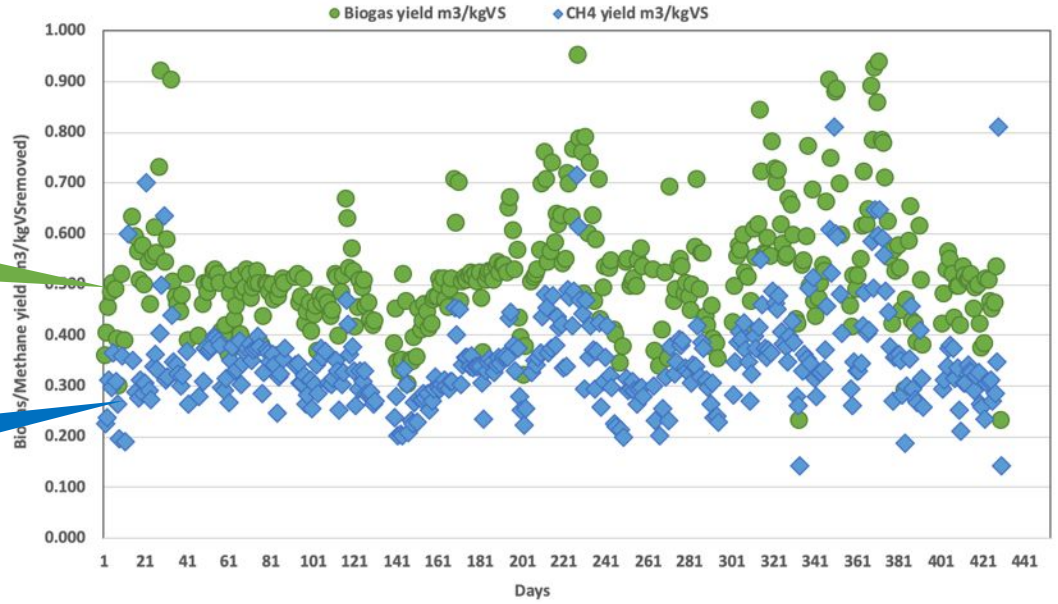
Methane
- 60%: 2000-4000 m^3/day
- 10%: 4000- 7000 m^3/day

Biogas
- 70%: 0.400 -0.700 m^3/kgVS
- 11%: 0.700 to 1.200 m^3/kgVS

Biogas: Avg. 0.535 m3/kg VS
[0.235 - 1.200 m^3/kgVS]

Methane
- 60%: 0.300 and 0.500 m^3/kgVS
- 5%: 0.500 to 0.800 m^3/kgVS

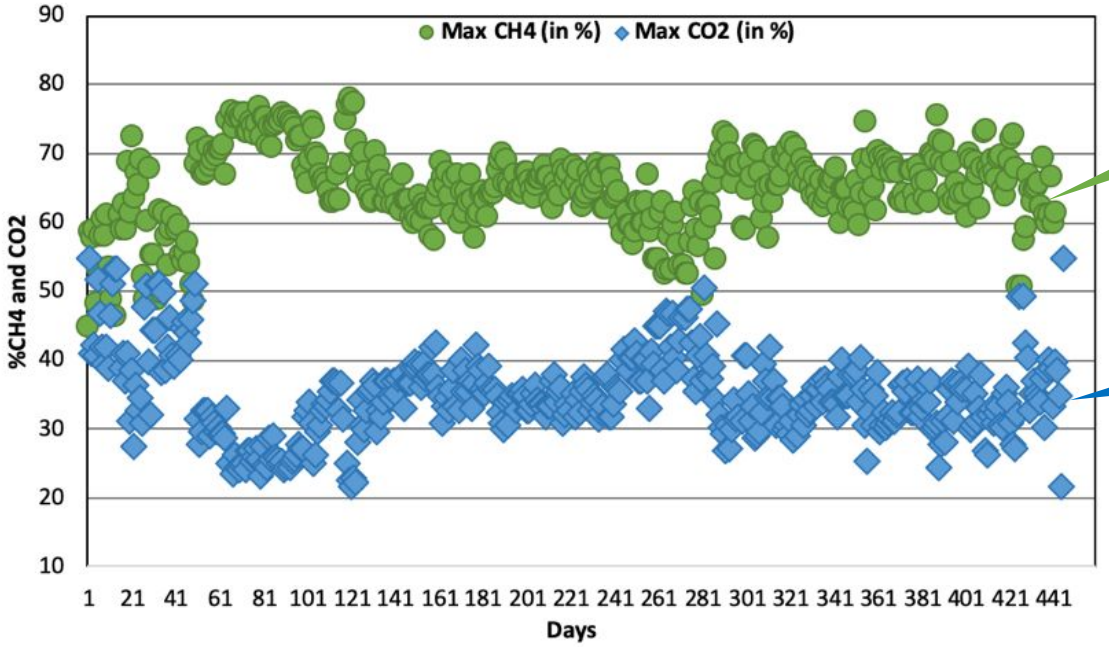
Methane: Avg. 0.350 m^3/kgVS
[0.150- 0.800 m^3/kgVS]



Efficient biogas generation: Effective preliminary treatment of MSW; Good quality of substrate obtained through the extraction and pulping unit; low OLR (1.60 kgVS/m^3.day); Good buffering conditions (optimum VFA/alkalinity ratio); Thermophilic digestion.

Anaerobic Digestion (AD)

Biogas Composition and VS removal



- 64% CH_4 (Avg.) [Range: 45-80%]

CH_4 percentage of 60-80% were noticed on 85 % occasions

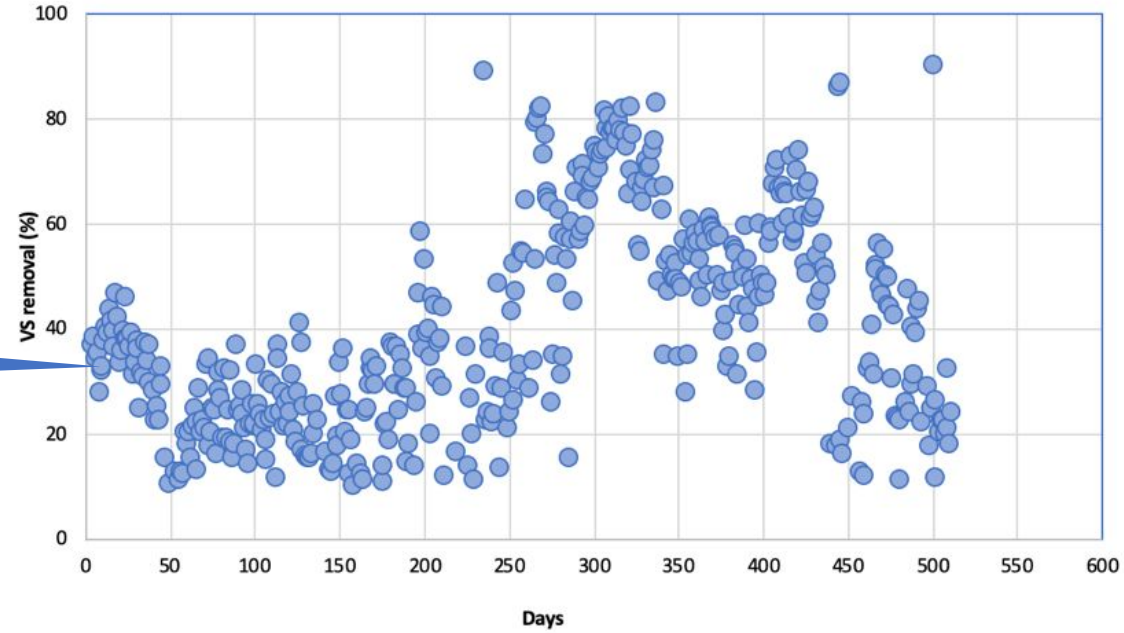
- 35% CO_2 (Avg.) [Range: 25-55%]

CO_2 percentage of 30-40% were noticed on 70% occasions

- **H_2S concertation** in biogas: less than 10 ppm

- Average VS fraction in feedstock was 0.65 (of TS) with a min. to max. range of 0.50 to 0.85

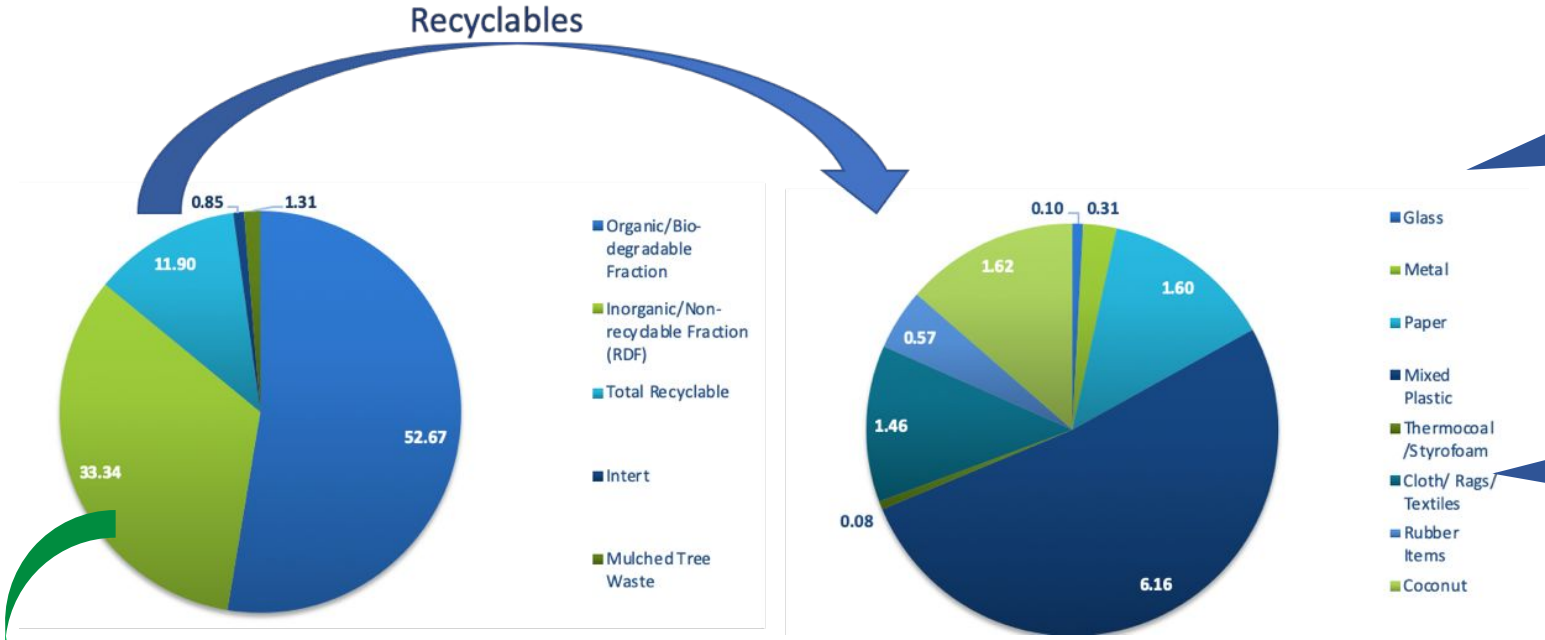
40% (Avg.) VS removal



- VS removal varies from 20-70% during 90% times of the study.

Material Recovery, Recycle, Revenue

Recyclables



11.90% recyclables: Glass- 0.10%; metal- 0.31%; paper- 1.60%; plastic- 6.16%; thermocol- 0.08%; cloth- 1.46%; rubber- 0.57%; coconut- 1.62%.

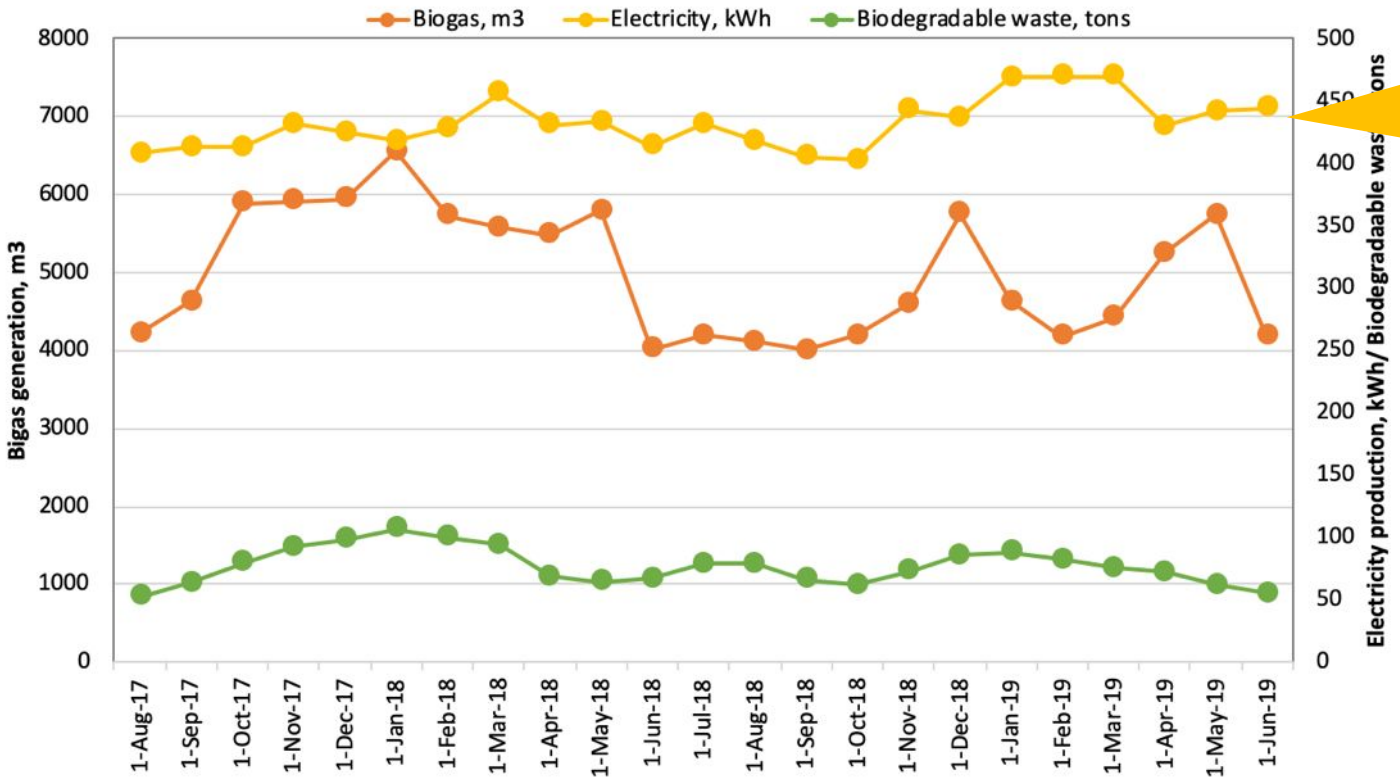
Plastic waste (mixed plastic, PET bottles, cups, food packets, coated plastics) added the **highest fraction of recyclables**.

RDF

- RDF composition: waste plastic, textiles, wood, paper, etc.,
- Raw waste comprised avg. 33% (49.10 tons) RDF
- Calorific value: 4500 to 5500 Kcal/kg
- **RDF used in Cement industries:**
  - burns RDF at temperature > 1,200°C and uses RDF as fuel for co-processing
  - In India, typically cement industry blends 5-8% RDF with pet coke and uses it.

Material Recovery, Recycle, Revenue

Electricity Generation



- **Average electricity generation**: 435 kWh or 0.435 MWh/day from corresponding biodegradable waste treated of 77 tons (avg.) and 5,000 m^3 biogas (avg.) produced

- Two **gas engines** of 170 kWh capacity each installed at the plant site.
- Smaller size gas engines operate at lower electrical efficiency of 26 to 28%, which is much higher for larger sized engines (>40%). So larger sized engine could help to increase the electrical output.

- **Higher energy** could be recovered from biogas purification and utilization over electricity production from biogas (30-40% only). overall energy yield from biogas purification is 2.5 times higher the biogas electricity production.

Material Recovery, Recycle, Revenue

Revenues

	Waste quantity		148 TPD			
S.No.	Item	%	Quantity	Unit Rate	Amount	
			TPD	US$/kg or unit	US$/day	US$/ Year
A	**Income Source**					
1.	Recyclables	11.90	17.60	0.015	264	96,360
2.	Electricity[1]	MWh	0.435	0.07	731	266,815
	Net Revenue				995	**363,175**
					6.72 US$/ Ton.day	**≈0.36 milion US$/ year**
3.	Inert to Landfill	2.0	2.96	-	-	-

- **Recyclables** are traded at 0.015 US$ per kg, making the per day revenue of **US$ 264**
- **Electricity:** Government of Goa procures electricity **(**0.435 MWh for $ 0.071 per unit). Add $731 in revenue generated from per day electricity feed to the power grid.
- **Compost** is mostly taken free of cost by farmers, whereas **RDF** has a disposal cost.

- **Total income: US$ 995** per day for 148 tons MSW processed, **≈ $ 6.72** per ton of waste processed per day at MBT plant
- 0.36 million US$ per year

Operation and Maintenance Expenses (OPEX)

- **OPEX main heads**: electricity*, manpower, diesel, RDF disposal, spares, chemicals, and miscellaneous
- **OPEX**: $ 3,552 per day/148 ton waste treated ≈ **US$ 24 /ton**
- **Total OPEX** (US$ 24 /ton) —Total revenue generation (US$ 6.72/ton)= **Net OPEX US$ 17/ ton**

- **RDF** (apprx. 48 tons/day) transportation cost to cement factory (200-500 km away from MBT plant): US$ 9.3 per ton.
- **RDF** used by local industries could reduce OPEX to: **US$ 24 /ton - US$ 9.3 per ton**= ≈ **US$ 14 /ton**

- **Compost as a source of revenue:** US$ 0.03/ kg, i.e., 7.5 tons/day compost @ 0.03US$= 225 $/ day.
- US$ 1.52 (225 $/148 tons) adding to total revenue 6.72 US$= **US$ 8.24/ ton (**Net revenue).
- As per SWM rules 2016, the Department of Fertilizers, Ministry of Chemicals and Fertilizers could offer market development support on compost and ensure campaign of co-marketing of compost with chemical fertilizers in the ratio of 3 to 4 bags: 6 to 7 bags by the fertilizers firms to the extent compost is made accessible for marketing to the firms.

- **Gross OPEX is 24 US$/ton** making the **net OPEX of 17 US$/ton** (minus revenue), which could be considered as the **excellent OPEX for MSW based MBT plants as per global benchmarks.**

Life Cycle GHGs Emission

- As per LCA study, the **total GHG emissions** have been calculated to be **-25.68 tons CO_2 eq./100 tons MSW**.
- **Negative emissions** result from the **export of electricity, compost, and RDF** as well as **recycling of paper and plastic products**.

Socio-Economic Perspective

- **Waste management infrastructure like Goa MBT** can be successful by adopting a co-operative and participatory approach.
- **Effective involvement of** peoples, urban local bodies (ULBs), and stakeholders in waste management is a requisite
- **Government incentives** like feed-in tariffs, long-term financing, capital grants, viability gap funding, and tipping fee for waste collection and handling are needed.

- **In order to ensure MBT plants are sustainable to install and operate**, government is urgently required to **allocate substantial funds towards capital as well as OPEX** for MBT based solid waste management plants **to fill up the difference between revenue generation and the OPEX**, as this technique has been evaluated to be **most suitable for Indian waste**.

Summary

- Long term performance of first successful 100 tons/d MBT plant in India was studied
- 12% recyclable, 33% RDF, 5% compost, 70 m^3/d water recovered. 0.435 MWh/d electricity generation
- Biogas production were 5,000 m3/day with a CH4 content of 65%. Biogas and methane yield were 0.535 and 0.350 $m^3/kgVS_{added}$ (65%CH_4), 40% VS removal
- Less than 3% (inert) of total waste received at the plant was subjected to landfill disposal.
- MBT plant has OPEX of US$ 24/ton and revenue of $6.72/ton; net OPEX of US$ 17/ton.
- LCA study revealed the negative GHG emission of -41.45 tons CO2 eq./100 tons MSW.
- MBT plant plays a significant role in averting the GHG emissions associated with untreated MSW

Acknowledgement

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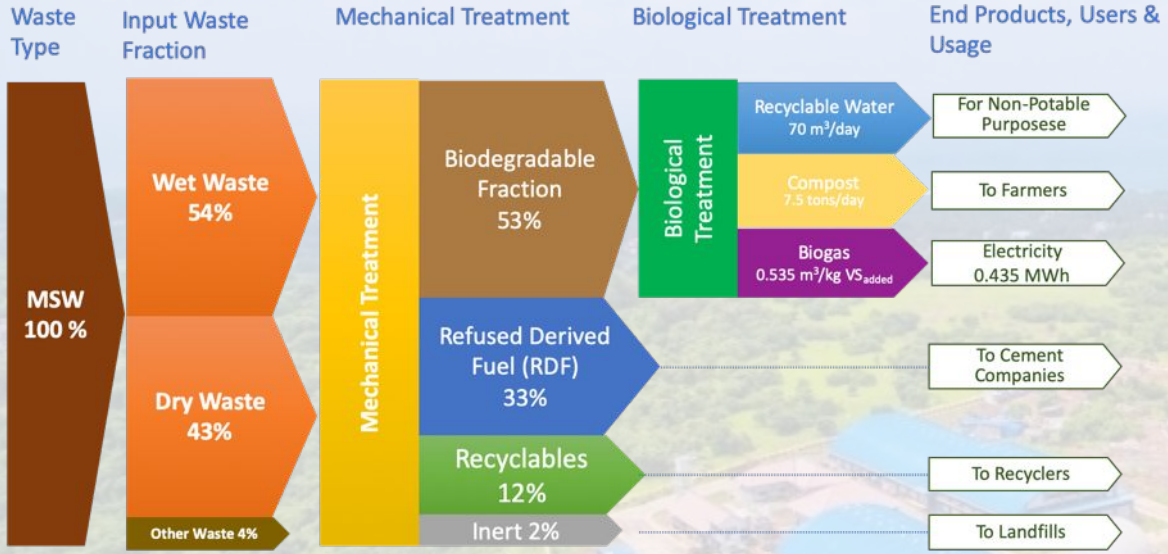
Thank you for your attention

100 TPD Goa MBT Plant for MSW Treatment: A Case Study



Highlights of the Study

- 12% recyclable, 33% RDF, 0.435 MWh/d power, 5%compost, 70 m^3/d water were recovered
- Apprx. 2% (inert) of total waste was subjected to landfill disposal.
- Biogas production were 5000 m3/day with a CH4 content of 65%.
- Biogas and methane yield were 0.535 and 0.350 $m^3/kgVS_{added}$ (65%CH_4), 40%VS removal
- MBT plant has OPEX of US$ 24/ton and revenue of $6.72/ton (995 US$ per day/ 148 tons); net OPEX of US$ 17/ton. Use of RDF in local industries could significantly reduce the OPEX to US$ 14/ ton. Adding revenue from compost would further make the net operating cost at US$12.5/ton
- LCA study revealed the negative GHG emission of -41.45 tons CO_2 eq./100 tons MSW.