Effect of co-digestion on energy economics in anaerobic digestion of rice straw and dairy manure

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Contents

Introduction

- Notable surge in the generation of organic wastes
- Uncontrolled dumping - greenhouse gas emissions and climate change.

Municipal waste dumping yard Madikonda, Waranal, India

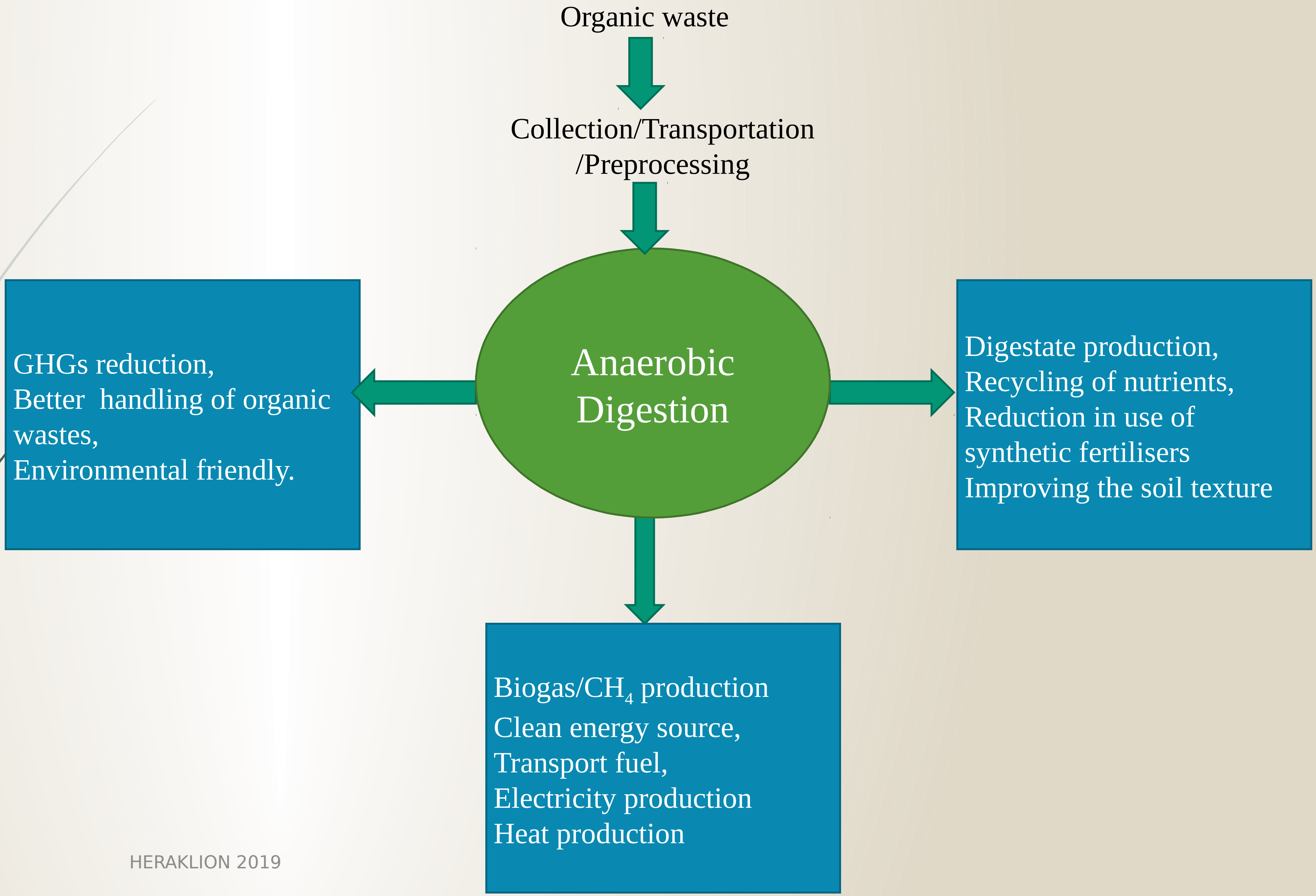
Introduction

- Emissions due to uncontrolled anaerobic digestion and open burning

Introduction

- Conventional landfilling and incineration can no longer be used because of their detrimental environmental effects.
- Adopting a technology with energy & nutrient recovery will be an environmentally sound option.
- Anaerobic digestion can be used to manage the several organic wastes including animal manure.

Introduction



Anaerobic Digestion

- Anaerobic digestion is conventionally used to manage the **cattle dung** and has been popular in India for a long period.
- Partially answers "energy-nutrient-environmental pollution" crisis.
- ***3.8 million*** anaerobic digestion plants installed so far in India against the potential of ***12.4 million*** anaerobic digestion plants (in the capacity range of 1-6 m^3).
- Technical, institutional, policy and financial barriers preventing to use at optimal capacities.
- Need for transformation of "**highly potential**" technology to "**highly performing**" technology.

Research gaps & Objectives

- Research gaps
  - Net energy balance in involved in anaerobic digestion in comparison of mono-digestion and co-digestion of organic wastes is limited.
  - The economics of the anaerobic digestion of dairy manure, rice straw is limited.
- Objectives
- To evaluate net energy production in anaerobic mono and co-digestion of rice straw and dairy manure.
- To evaluate economic feasibility in anaerobic mono and co-digestion of rice straw and dairy manure.

Materials & Methods

Energy Economics

- The large scale anaerobic digestion plant was assumed to produce 80 % of the cumulative methane generated at laboratory scale (B. Ruffino 2015 et al).
- The plant was assumed to be equipped with **combined heat and power system** (CHP) to convert biogas to electrical and thermal energy.
- The lower heating value (LHV) of methane is 39.62 MJ/m^3 (E. A. Scano 2014 et al)
- The standard electrical efficiency of the **CHP** system was considered to be **35 %** and **thermal efficiency** was considered to **be 50 %** (E. A. Scano 2014 et al).

- **Shredding**
  - In the current study, the energy consumption 207 MJ/t for shredding was assumed.
- **Conveyance**

Two series connected screw conveyors between the silo and feed tank, each with a motor capacity of 5 KW was considered.

- **Pumping system**.
  - The pump (0.5 kW) will be able to deliver manure to the bioreactor with a capacity of 10 m^3/h
  - Its efficiency is assumed to be 0.5.
- **Heat Energy**
  - Heat Energy is required for two reasons
  - To heat the feeding substrate ,
  - To maintain the temperature against heat losses from the digester wall

Energy Economics

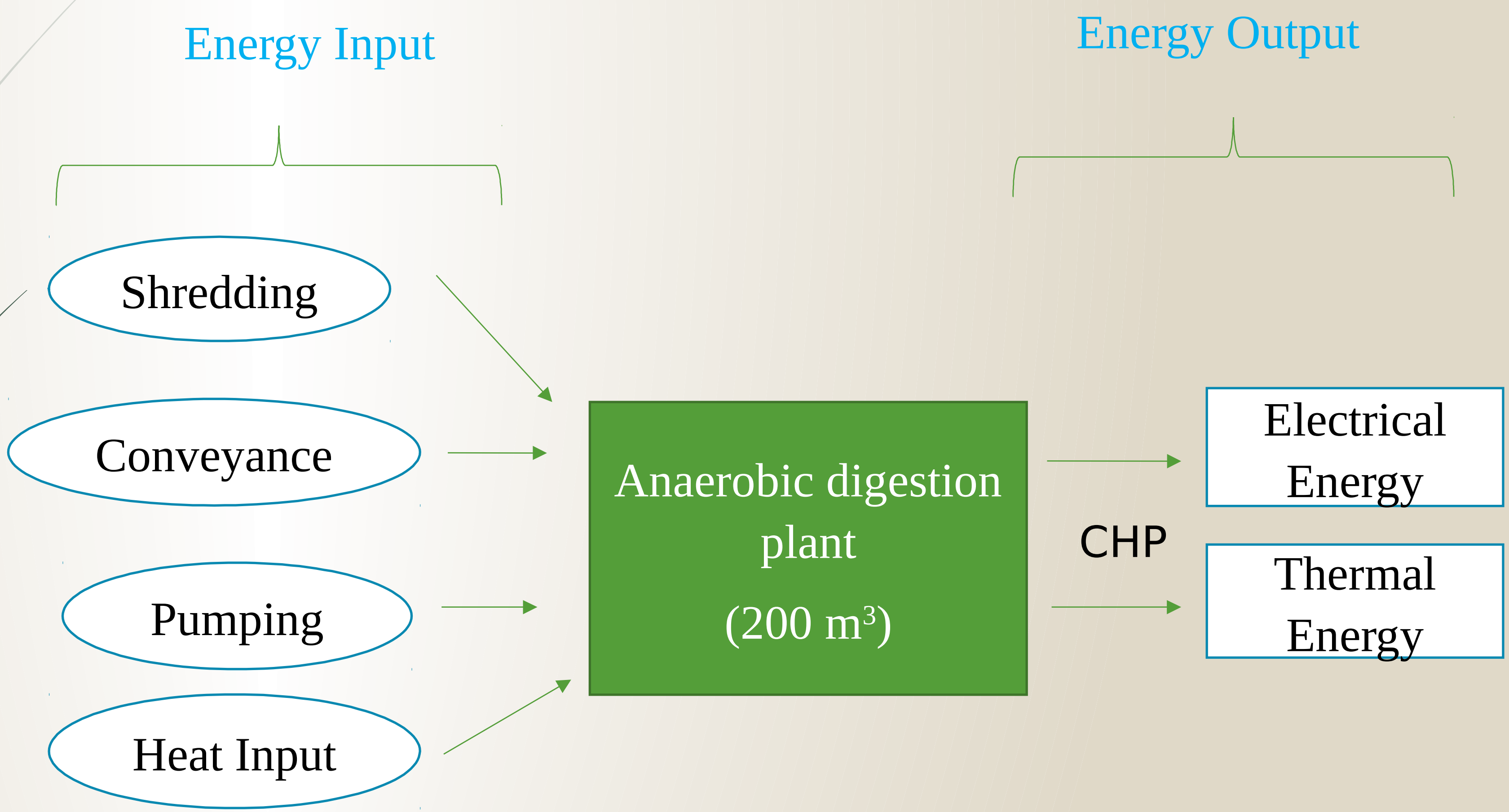


Figure: Energy balance of anaerobic digestion

Energy Economics

- Evaluated the cost of unit electrical energy produced through anaerobic digestion of organic waste mixes

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- $Cost\ of\ energy = \frac{(Total\ capital\ cost * Capital\ charge\ rate) + O\&M\ cost}{Electricity\ produced\ in\ a\ year (kWh)}$

- Assumptions (eficio et al 2014)

  Total capital cost of 200 m^3 anaerobic digestion plant= Rs. 20,00,000/-

  Capital charge rate= 11.8 %

  Operating life = 20 years

  Annual O & M cost= 10% of Total capital cost

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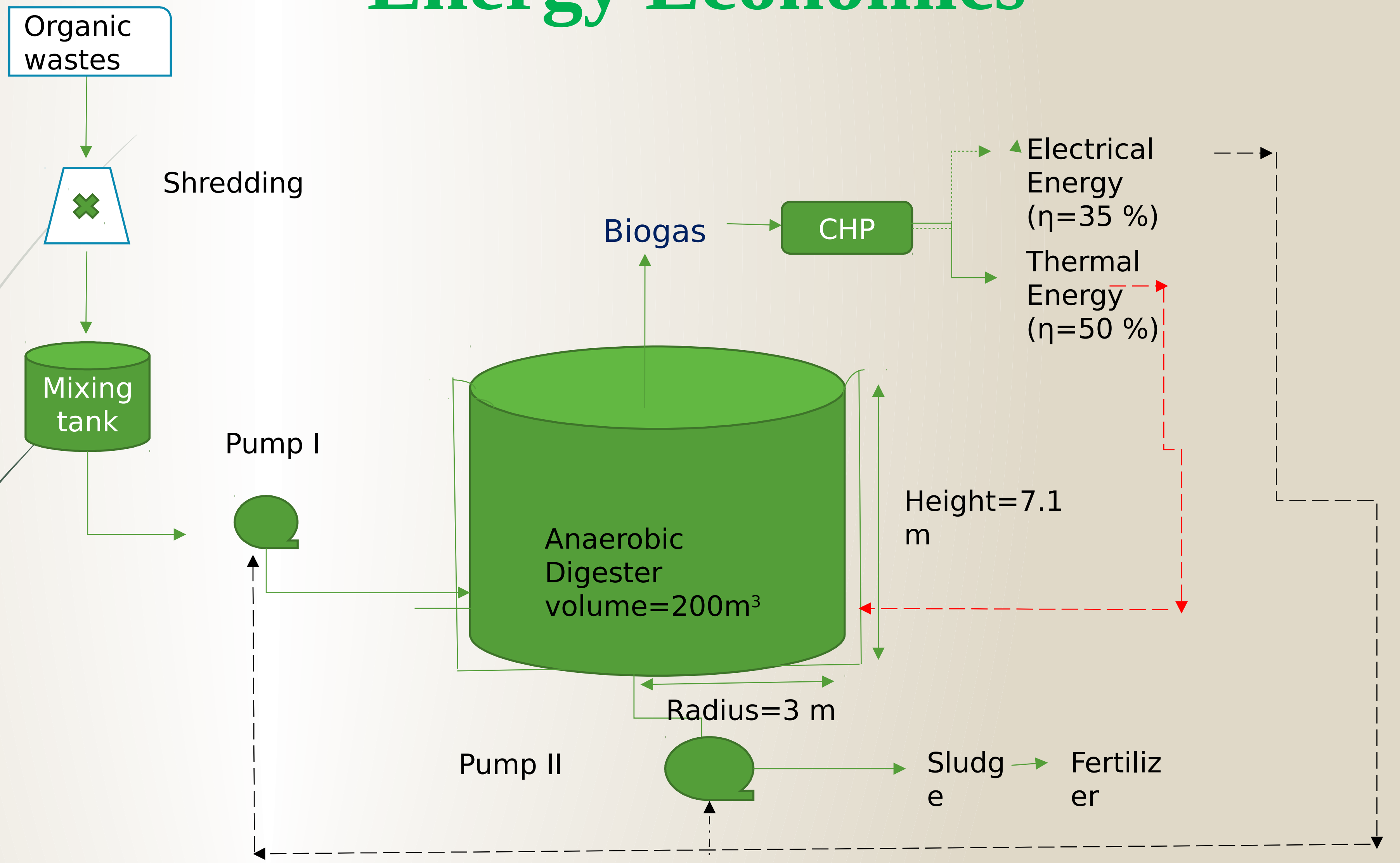
Energy Economics



Results & Discussion

Performance of the full-scale digester plant

	Rice straw	Dairy manure	Co-digestion
Specific methane production (mL CH_4/g VS added)	152	216	240
Electrical energy production(kWh/day)	224	319	354
Thermal energy production (kWh/day)	320	455	506
Electrical energy consumption (kWh/day)	25	11	18
Thermal energy consumption (kWh/day)	35	35	35
Net electrical energy production (kWh/day)	199	308	336
Net thermal energy production (kWh/day)	285	420	471

Energy Consumption

Substrate	Shredding (kWh/day)	Pumping and discharging of feed and digestate (kWh/day)	Conveyance (kWh/day)	Thermal energy to raise the temperature to 5^{O} C (kWh/day)	Thermal energy against heat losses (kWh/day)	Total electrical energy requirement (kWh/day)	Total Thermal energy requirement (kWh/day)
Rice straw	14	0.8	10	23	12	35	25
Dairy manure	0	0.8	10	23	12	35	11
Co-digestion	7	0.8	10	23	12	35	18

Net Energy production

Economy of the anaerobic digestion

	Rice straw	Dairy manure	Co-digestion
Scenario I (Direct use of energy)			
Total capital cost	20,00,000	20,00,000	20,00,000
Annual capital charge (11.7 %)	2.34,000	2.34,000	2.34,000
Annual O& M costs (4%)	80,000	80,000	80,000
Labour cost (0.5 worker)	1,20,000	1,20,000	1,20,000
Total annual cost	4, 34,000	4, 34,000	4, 34,000
Net electrical energy production (kWh/day)	199	308	336
Annual Net electrical energy production (kWh/year)	72,635	1,12, 420	1,22,640
Cost of energy (Rs/kWh)	5.3	3.7	3.3

Economy of the anaerobic

	Rice straw	Dairy manure	Co-digestion
Scenario II (Supplied to electric grid)			
Electrical Energy Revenues (Rs/year) EER	4,50,337	6,97,004	7,60,368
Net cash flow (EER-$C_{O\ \&\ M}$ – Labour cost)	2,50,337	4,97,004	5,60,368
Pay back period (Discount rate= 10 %)	16.8 years	5.3 years	4.5 years
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Conclusions

- The net electrical and thermal energy production of co-digestion of substrates was higher than that of mono-digestion
- The high energy production from the co-digestion results in low pay back periods (4.3 years) whereas for mono-digestion of dairy manure results in longer periods (5.3 years)
- The results are encouraging the co-digestion of rice straw and dairy manure as well as for full-scale implementation for maximum benefit.

Thank you

For your Attention

Floor Open for Discussion