SAARC ENERGY CENTRE
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Online Capacity Building of SAARC Professionals on Commercial Scale Biogas Plants
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Current Status and Future Potential of Commercial-scale Biogas in SAARC Members States

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- Biogas potential: global scenario
- Biogas for GHG emission reduction
- Potential waste resources for biogas
- Biogas status in SAARC member states
- Biogas in India
- Case studies: India and Nepal

Learning objective

- To learn about the potential waste resources for biogas, status of biogas in SAARC and some related case studies

BIOGAS MARKET

- Small scale digesters for biogas production
- Medium scale digesters for electricity generation or tri-generation (electricity, heat and cooling energy)
- Large scale digesters producing bio-methane to be used as vehicle fuel or for cooking through injecting in gas grid

Global Scenario

Source	Population (heads)	Manure production	Biogas yield m^3/t	Annual Growth rate %
Livestock population (2020)	1.49 billion	16 t/head/year	40-60	0.6
Pig (2020)	677.6 million	1.6 t/head/year	25-35	0.5
Poultry (2019)	25.9 billion	0.112 t/head/year	60-80	1.5
Sewage	7.6 million liters		18-26 lit/head/day	
Food waste	1.6 billion tonnes/year			

Total global potential

- Livestock, piggery and poultry has the potential of generating 250 to 370 billion cum of bio-methane or 2600 to 3800 TWh
- It can meet the electricity demand of 330-490 million people and has the potential to meet 100% energy needs of world agriculture replacing coal, electricity, fuel oil, LPG, gasoline and power irrigation energy.
- Sewage has the potential of generating 22 to 32 billion cum of bio-methane or 210 to 300 TWh energy

GENERATION


Anaerobic Digestion
is a Natural Process
Bio-gas
Feed
Digestate

Emissions reduction potential

- Livestock generates 7.1 Gt of CO2 eq. (14.5% of all GHG emissions)
- It is due to enteric emissions, emissions from manure management, production of animal fodder, energy used on farms, manure spread on soils and emissions from fertilizers used for the production of feed.
- The most volatile carbon is captured as biogas elimination methane emissions.
- By collecting and anaerobically digesting manure from livestock, there is a potential to offset 930 to 1260 Mt of CO2 eq. per year of GHG or 13 to 18% of the current livestock related emissions.

Food Waste as a potential source

- Food waste has the potential to generate 880 to 1100 TWh of energy if all available food waste / loss is collected and recycled.
- It can mitigate 510 to 560 Mt of CO2 eq
- 85 to 100 billion cum of biogas can be generated
- It can replace 2 to 5 % of current inorganic fertilizer consumption.

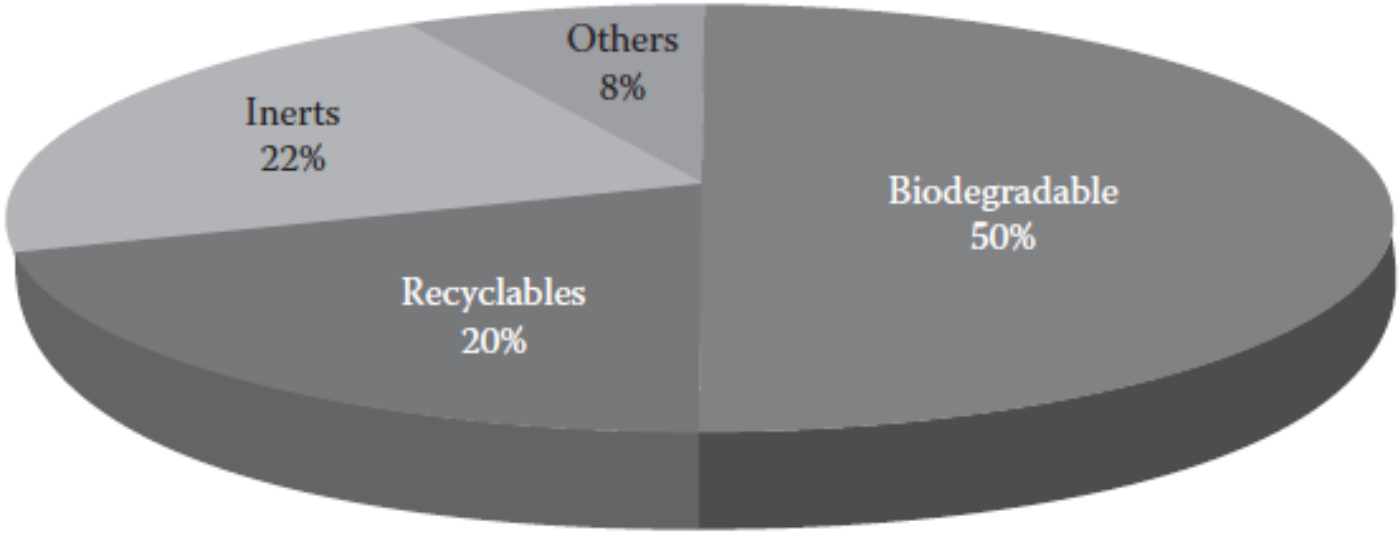
MUNICIPAL SOLID WASTE

Important MSW parameters for technical viability of Energy recovery		
Treatment method	Basic principal	Important Parameters
Thermo chemical conversion Incineration Pyrolysis Gasification RFD	Decomposition of organic matter by action of heat	Organic content Volatile matter Fixed carbon Calorific value
Biochemical conversion Anaerobic digestion/ Bio-methanation	Decomposition of organic matter by microbial action	Moisture content Organic content Volatile matter C/N ratio

Municipal solid waste

Organics	Recyclable	Inert	Soiled waste
Kitchen waste	Plastic	Sand	Blood stained cotton
Agro-waste	Paper	Pebbles	Sanitary napkins
Vegetable waste	Syringes	Gravels	Disposable syringes
Garden waste	Tablets		
	Tin can		
	Metals		
	Glass		

Composition of MSW in India



“Solid waste are the only raw materials we’re too stupid to use”

- Arthur C Clarke

“There is nothing more frightful than ignorance in nature”

- Geothe

You don’t have waste if you don’t make it

“The more that is thrown away (waste), the more minerals that must be mined, the more trees that must be cut, the more oil wells that must be drilled, producing enormous waste again”

Waste collection efficiency ranges from 50% to 90%. ULBs spend between Rs. 500/- to Rs. 1500/- per ton on solid waste management of which 60% to 70% is spent on collection alone, 20% to 30% on transportation and less than 5% on treatment and disposal which is very essential to prevent environmental pollution.

Composition of organic waste

Moisture (70-80%),

Total solids (TS) (20-30%)

Volatile solids(VS) (80-93%)

Protein (3-20%)

Lipids (6-24%)

Carbohydrates (45-70%)

Moisture

Total solids

Volatile solids

Cellulose (25-65%)

Hemicellulose (14-30%)

Lignin (15-40%)

(Anwar et. al. 2014, Kiran et. al., 2014)

Theoretical biogas production potential

468 kg of wet FW → 101.46 kg of Total Solids → 93.15 kg of Volatile Solids → 51.75 kg of total organic carbon → if 100 % degraded or, if 50 % degraded → 51.75 kg of carbon, or 25.88 kg of carbon

51.75 kg of carbon, or 25.88 kg of carbon → 41.4 kg of methane, or 20.7 kg of methane → 2587.5 moles of methane, or 1293 moles of methane → 57,960 litre of methane, or 28963 litre of methane → 57 m^3 of methane, or 28.5 m^3 of methane

45 m^3 of biogas → 1 m^3 of biogas = 0.45 kg of LPG → 20.25 kg of LPG → 7392 kg of LPG in a year → 358 LPG commercial cylinder

Note: 1 m^3 of biogas from AD is equivalent to 21 MJ of energy, and it could generate 2.04 kW h of electricity considering the 35% of generation efficiency

(Ananthakrishnan et. al 2013)

Crop residue as a potential source

- Utilizing standard energy conversion factors for residues by conservative moisture content and energy content of the fuels, the theoretical energy potential from residues can be in the range of 17.8 EJ to 82.3 EJ.
- Crop residue has a potential to generate 3080 to 3920 TWh or 300-380 billion cum of bio-methane per year.
- The electricity generated can meet the needs of 393 to 500 million people or 5.2 to 6.5 % of world's population.
- It is capable to mitigate gas emissions equal to 865 to 1100 Mt of CO2 eq. per year.

CROP RESIDUE STATISTICS - GLOBAL

- One of the most promising sectors for growth in bioenergy production is from agriculture sector.
- Currently, the sector contributes less than 3% to the total bioenergy production.
- Considering the fact that 50% of the residues have to be left on the field for soil quality purposes, the theoretical potential for utilizing agricultural residues is enormous. Data shows that utilizing the residues from all major crops for energy can generate approx. 4.3 billion tonnes (low estimate) to 9.4 billion tonnes (high estimate) annually around the world.
- Utilizing standard energy conversion factors, the theoretical energy potential from residues can be in the range of 17.8 EJ to 82.3 EJ.
- The major contribution would be from cereals – mainly maize, rice and wheat.
- Energy generation from agricultural residues could meet about 3 – 14% of the total energy supply globally.

- The amount of crop residue produced in the world is estimated at 2802x10(6) Mg/year for cereal crops, 3107x10(6) Mg/year for 17 cereals and legumes, and 3758x10(6) Mg/year for 27 food crops. The fuel value of the total annual residue produced is estimated at 1.5x10(15) kcal, about 1 billion barrels (bbl) of diesel equivalent.

Disposal methods of crop residue in SAARC member countries

Methods / uses	**Percentage**
Burnt in fields	80-85%
Animal fodder	5-10%
Composted	3-7%
Sold	2-4%
Cooking fuel	2-4%
Incorporated in soil	1-2%
Thrown away	1-2%

Table 23 Theoretical potential of agricultural residues globally
(FAOSTAT, 2019) (WBA 2019)

	Residues (Million tonnes)		Residues (EJ)	
Crops	Low	High	Low	High
Maize	1 532	4 540	5.67	35.7
Rice	770	2 041	3.29	15.2
Wheat	618	1 235	2.98	8.92
Barley	118	192	0.57	1.09
Millet	31.3	56.9	0.16	0.3
Oats	23.4	36.3	0.12	0.19
Rye	12.4	22	0.07	0.12
Sorghum	51.8	426	0.27	2.24
Olives	4.7	4.7	0.03	0.03
Rapeseed	107	152	0.78	1.11
Soybeans	353	1 389	1.86	7.31
Sunflower	105	153	0.71	1.03
Oil palm	110	140	0.15	0.67
Cassava	46.7	292	0.35	2.17
Sugar beet	60.2	120	0.12	0.25
Sugarcane	368	1 216	0.65	6.01
Total	3 942	10 801	17.1	76.3

Table 1: Gross and Surplus Residue Production Potential using all the Crops in SAARC Member States

Member State	Total crop production (Million Tons)	Gross Residue Production (Million Tons)	Surplus Residue Production (Million Tons)
Afghanistan	5.6	9.7	2.2
Bangladesh	81.5	99.6	24.3
Bhutan	0.4	0.4	0.1
India	744.3	912	300
Nepal	17.2	22.8	6.3
Pakistan	128.7	122.8	37.3
Sri Lanka	3.2	4.7	1.3
Total	981	1,172	372

Table 2: Power Generation Potential of SAARC Member States Using Rice and Wheat Farm Residues

Member State	Residue used	Total wheat and rice production (Million Tons)	Gross Residue Production (Million Tons)	Surplus Residue Production (Million Tons)	Total Power Generation Potential (MW)
Afghanistan	Wheat straws	4.2	6.4	1.4	58
Bangladesh	Rice and Wheat straws	38.1	57.2	15.6	1,100
India	Rice and Wheat straws	212.6	319	80.3	5,395
Nepal	Rice and Wheat straws	7.7	11.6	3	140
Pakistan	Rice and Wheat straws	36.3	54.4	13	834
Sri Lanka	Rice straws	2.4	3.5	1	71
Total		301	452	114	7,598

Crop residue burning is a source of Green House Gases (GHGs) and aerosols such as methane, carbon monoxide, nitrogen oxides and other hydrocarbons. This practice also emits huge amounts of particulates composed of a wide variety of inorganic and organic species. Each Tons of residue burnt releases 1.5 Tons of CO_2, 2.7 kg of CH_4 and smaller quantities of other GHGs into the atmosphere.

Majority of crop residue (80-85%) is burnt 'in-situ primarily to clean the field for timely sowing the next crop. The problem of in-situ burning of crop residues has intensified in recent years due to shortage of human labor, high hourly rentals of machines to remove the crop residue from the field and increased mechanized harvesting of crops that leave behind the crop stubbles.

BIOGAS STATUS IN SARRC COUNTRIES

- SAARC countries have 23% of the world's population
- India and Pakistan have a potential of fulfilling 56% of energy demand of the region through biogas
- The SARRC countries together have a potential to generate 4 Billion US $ per year annual carbon credit
- It has a potential to mitigate approx. 600 million Mt CO2 eq. per year net GHG emissions, through chemical fertilizer substitution, animal manure management, firewood and kerosene substitution, etc.

Livestock & Human Population (million)

	Chickens	Ducks	Buffaloes	Cattle	Pigs	Sheep	Human
Southern Asia (less India)	1078	29	37	77	1	96	579
India	613	35	107	172	14	66	1150
South Eastern Asia	2314	225	15	47	71	11	576

Available Resource and Biogas Potential

	Animal waste (Million metric tons/year)	Biogas (million cubic meter /year)	Annual carbon credit potential (Billion US $ / year)	Net GHG emission mitigation potential Million Mt CO2 eq/year
Southern Asia (less India)	98	26522	1	153
India	191	48178	2	249
South Eastern Asia	95	26338	1	198

Bio-energy in India

- India – conducive environment for acceleration and internalization of bioenergy technologies
- 25% primary energy
- 70% rural population depends
- Vast experience of demonstrating bioenergy potential
- Rate of spread and use – low?
- Major technologies:-
  - Biomass based generations: co-generation, gasification and combustion
  - Improved cookstove
  - Biogas
  - Bio-diesel

Availability and sources of biomass (India)

Categories	Biomass	Availability in Million Tonnes	Coal equivalent in Million tonnes
	Agriculture residues		
A	Rice straw	9	58.4
	Rice husk	19.9	15.7
	Jute Sticks	2.5	2.3
	Wheat straw	50.5	37.5
	Cattle dung	1335.00	128
	Agro-industrial by products		
B	Bagasse	28.1	22.4
	Molasses	2.1	0.8
	Oil-seed cakes	6.7	0.9
	Saw dust	2	3.4
C	Forest products		
	Mahua flowers	1	0.4
	Leaves , top etc.	3.3	3

Continued…

Biomass availability estimates			
Year	**Biomass estimates (in Million tonnes)**		
	Ravindranath	**Biomass Atlas IISC**	
		Production	**Surplus****
1996-97	626.5		
1998-99	653.4*	546.4	139.4
2004-05	741.0*	619.0*	157.9*
2010-11	840.6	701.2*	178.8*
2024-25	1127.3*	938.0*	239.2*

Notes: * Projections based on 2.12% annual growth (same as Ravindranath's two year values) ** Surplus biomass fraction assumed constant as given in biomass atlas of IISc.

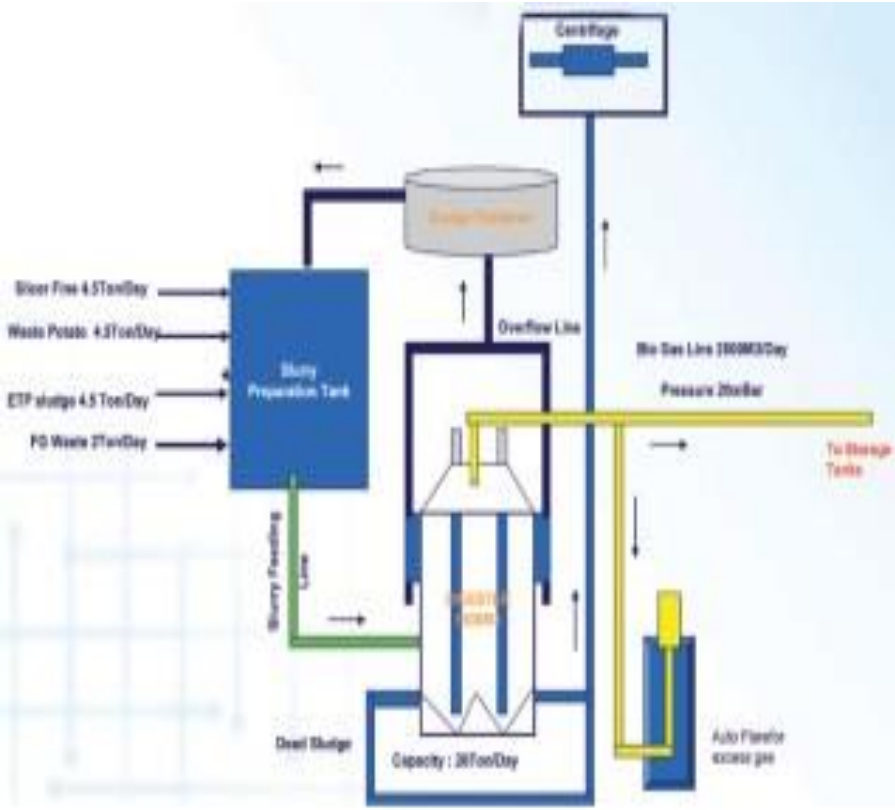
Where the overall potential lies ....

- Higher adoption rate for dairy and cattle farms
- AD on large farms is more economically viable
- Farms that are connected to the electricity grid
- Farms in countries where electricity supply is erratic and unreliable
- Farms that grow feed for animals and can expand to crop residues and energy crops
- Farms in countries with a specific tariff for energy generated from AD
- Farms in countries where specific schemes exists for promoting AD

- BIOENERGY CONTRIBUTES UP TO 12.9 % OF THE TOTAL ENERGY IN THE REGION WITH 43% PRODUCTION TO SAVE 500 Gt OF CO2 EMISSIONS BY THE YEAR 2030

Case study (Pepsico, Pune)

- The Pepsico plant in Pune on an average generates about 18MT of waste per day. The waste consists of potato rejects, peels, slices, process waste and wastewater sludge.
- In the initial stage, a pilot plant was installed to understand the process, its controls and variations and also to identify the potential of biogas production.
- The Bio Methane plant currently generates 2000 m^3 of biogas per day.
- Generated Biogas is used in Kurkure fryer by having a purification process and modifying the burners; therefore saving of 140MT of LPG and approximately cost of $140 million per annum.


Centrifuge
Slurry Preparation Tank
Overflow Line
Pressure 20bBar
Capacity : 20Ton/Day

- An automatic on line feeding system has been developed. This is first-of-its-kind initiative in PepsiCo where slicer fines are conveyed through screw conveyor crushed and then transferred through pump to the biogas digester. This not only saves manpower but has also improved hygiene conditions inside plant.
- The Pune plant is the first one across Frito-Lay's global operations to use biogas, according to The Economic Times.
- It also reduces carbon emissions by 600 tons annually.

Case Study from Nepal

- Envipower Energy and Fertilisers Pvt Ltd, Nepal's first-ever biogas plant commercially producing bottled compressed natural gas (CNG)
- The plant is located at Sukrauli, Nawalparasi.
- The company has invested Rs 220 million to establish the plant. It has been using German technology to produce 2 tonnes of cooking gas daily.
- The plant uses feedstock like cow dung, agricultural waste, waste food and pressmud and converts it to biogas to produce CNG.
- The company requires 30-40 tonnes of raw materials. It also produces 25 tonnes of organic fertiliser daily.

Suggested Readings

- Possible Uses of Crop Residue for Energy Generation Instead of Open Burning, report published by SAARC Energy Centre, December 2019
- Global Bioenergy Statistics 2019, World Bioenergy Association
- Biomass Management for Energy Purposes – Issues and Management, Edited by Pathak B S and Srivastava N S L. Published by SPRERI, Vallabh Vidyanagar, INDIA
- Biogas Production, Upgradation and Slurry Management, Edited by V K Vijay. Narosa Publishing House Pvt. Ltd., New Delhi, INDIA
- www.irena.org/statistics

Thank you