SAARC Energy Centre

THE REPORT

May 7, 2019

SAARC Energy Centre
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www.saarcenergy.org

Introduction

SAARC Energy Centre, (SEC) under its approved programme activity for FY 2019, successfully conducted a Webinar on “Waste-to-Energy Municipality-level Demonstration Project in Selected Areas of Member States” on 7th May 2019. The Webinar Agenda is attached at ***Annexure I***.

2. SEC, during thirteenth governing board meeting have proposed for the conduction of the webinar on the subject. The same was recommended by SEC governing board and approved by programming committee as an activity to be conducted in 2019. Over the month’s efforts were put upon looking for the relevant and potential resource person. With the already existing close working relation with the experts by our Research Fellow (RE) it was easier to approach them and bring them on board. Though six experts for South Asian region agreed to participate but only four could make it on the final day.

Participation

3. There were 102 professionals participated in the Webinar that included delegates from Member States, Representatives of Regional and International organizations, Academia and Private Sector. The resource persons for the Webinar from India, Nepal and Pakistan delivered detailed presentations on the subject of their expertise. Participants list

is available at ***Annexure II*** while list of resource person and SEC team members is available at ***Annexure III***.

Opening Remarks

4. Mr. Bhaskar Pradhan, Program Leader (Energy Trade) welcomed all the delegates and participants from around the globe for attending the webinar and extending keen interest in the subject program. He also acknowledged the commitment and contribution of resource persons in materializing the conduct of webinar.

5. He gave the brief introduction of the SEC and it plans ahead. He informed the participants that SEC conducts programme activities supervised by the Governing Board (GB); the GB comprises representation from all Member States of SAARC region. The programme activities of SEC includes policy-based research studies, knowledge sharing events i.e., workshops, seminars, webinars, trainings, and pilot projects in all fields of Energy.

6. He welcomes the elite panel of speakers for the webinar and thank them for their enthusiasm and eager willingness to participate in our webinar. He remarked that this webinar as one of the activities this year and SEC shall in future continue conducting such knowledge sharing events. At the end, he again thanked all the participants and resource persons for taking out time to attend this webinar.

Technical Proceedings

7. All the presentations delivered during the webinar are available at SEC's website www.saarcenergy.org. The presentations from the Experts are available at ***Annexure IV***.

Brief information on the content of the delivered presentations is as follows:

Presentation 1 - Decentralized WTE recovery for municipal waste management by Mr. Rahul Teku Vaswani

8. Mr. Rahul Teku Vaswani is a Sustainability Consultant based in Seoul, South Korea. Mr. Rahul started his presentation highlighting the Global solid waste generation from municipal sources for the year 2016, 2030 and 2050 given as below:

- 2016: 2.01 billion tonnes per year estimated
- 2030: 2.59 billion tonnes per year projected
- 2050: 3.40 billion tonnes per year projected

9. He stated that the solid waste collection rates in South Asia are only 44% compared to 90% in Europe and Central Asia. There are number of challenges of urban solid waste management namely:

- No segregation of waste at source
- Inefficient collection and unsanitary disposal of waste
- Low local capacity & resources
- Inefficient policies & regulations
- Lack of demonstrated SWM solutions
- Low local awareness of 3R practices

10. He also highlighted the role of IRRC: (Integrated Resource Recovery Centre). It is a recycling facility where a significant portion (80-90%) of waste can be processed in proximity to the source of generation, and in a decentralized manner. The IRRC concept is based on the reduce, reuse and recycle (3R) principles. The Integrated Resource Recovery Center model was developed by Waste Concern, and NGO based in Dhaka. The model is cost-effective, affordable, low-tech and community-based and allows transforming waste into various types resources. Numbers of economic benefits from IRRCs are discussed. They are namely, reduced landfilling costs, Reduced subsidy for chemical fertilizer, Extended landfill life, Improved crop yields, Social benefits of IRRCs, Better job opportunities, Reduced disease, Improved living conditions, Improve ecological awareness, Environmental benefits from IRRCs, Reduced pollution, Improved soil quality, Reduced greenhouse gas emissions and Low-carbon fuel.

Presentation 2 – Waste to Energy Power Potential & Opportunities in Punjab by Mr. Amir Shahzad Butt

11. Mr. Butt is a Manager Renewables/Biofuels, Punjab Power Development Board, Pakistan. He presented with main focus on Solid Waste Sector in Punjab, Integrated Solid Waste Management (ISWM) Approach – Framework Applicability and Waste to Energy Prospects. He talked about the 40 MW WtE Power project at Lahore & WtE potential in Punjab. He ended his presentation highlighting the WtE challenges and way forward.

The key takeaways from his presentation are:

- In Pakistan, 40 MW WtE project in Lakhodair landfill site would be the 1st of its kind which is under development stage,
- 60 MW WtE project at Sundar near Lahore would be launched shortly by PPDP,
- Private sector has shown keen interest in WtE project in other part of Punjab.

Presentation 3 – MSW Management in India by Dr. A. Gangagni Rao

12. Dr. Rao is the Chief Scientist, Bioengineering and Environmental Sciences Group, Center for Environmental Engineering and Fossil Fuels, CSIR-Indian Institute of Chemical

Technology (IICT), Hyderabad. He highlighted the MSW generation scenario in India, Calorific Value and mode of disposal. He talked about some of the key solid waste management rules (SWM), 2016 as per MOEF, GOI. He also presented on the types of conventional digesters, advantages and disadvantages of conventional digesters, technologies available in the region and its working principles. He also talked about the composition of solid waste. Further he covered number of topics on Technological intervention of CSIR-IICT for waste management, Waste to energy from kitchen, Remunerative Decentralized Solid Waste Management (Food Waste), Bio home etc.

Presentation 4 – Prospects of Waste to Bioenergy in Nepal by Dr. Sunil Prasad Lohani

13. Dr. Sunil is the Associate Professor at School of Engineering, Kathmandu University, Nepal. His presentation covered on the overall energy scenario in Nepal, Waste Problems, Conversion of Waste to Biogas, quick estimation of large biogas plant cost/benefit, Methane/Energy production potential, and Biogas plants in Nepal. He stated that Biogas plant was first installed in Nepal in the year 1955 at Godavari, Lalitpur with 200 liters oil drum digester with separate drum gas holder. At present there are almost 400,000 biodigesters installed in Nepal. He presented about household bio-digesters, biogas from poultry droppings etc. He also highlighted on large biogas plant in Syangja, Kotre Bazar, Pokhara and Nawalparisi and its operations.

Knowledge Sharing Session

14. The question and answer session were kept at the end of the presentations. Queries by the participants were asked to the expert through SEC moderator. There were number of questions to all the experts which were adequately been responded. Due to the lack of time many questions had to be forwarded to the experts through mail.

Conclusions and Recommendations

15. Number of participants of the webinar provided their feedback on the quality and content of the event. In general, they commented that it is a very useful topic for the region and more importance is to be given in coming years. There was suggestion that such programs should be conducted in future as well. Also, the way it was conducted giving opportunities to the participants to clarify the doubt were appreciated.

16. However, many questions were on the delay in materializing WtE projects in South Asia on large scale basis. Though private participants are eager to be part of these projects but there is concern about the support from the side of the government.

17. Mr. Bhaskar Pradhan, Program Leader (Energy Trade) read out some of the recommendations which were gathered during the course of the webinar. They are as follows:

a) The waste problem cannot be solved ‘at the last minute’ or by ‘business-as-usual’ approach; it requires integrated planning, with a multi-stakeholder approach, capacity building activities, and clear short- and long-term goals.
b) People are the consumers of resources, designers of products and the producers of waste. Their awareness building and participation is essential to SWM.
c) Waste management technologies should be local appropriate and generate local employment and revenue; the local government should have the capacity to assess and efficiently use technologies to recover ecological and economic value.
d) Segregation of MSW at source is key for its sustainable solution
e) Awareness of users for waste segregation may be done through electronic/print and social media.
f) Evolution of waste content and potential is very essential before realizing the project.
g) Federal government, provincial and local government should collaborate academia or industries to advance achieving tangible result.

Vote of Thanks and Closing of Webinar

Mr. Bhaskar Pradhan, Program *Leader* (Energy Trade), SAARC Energy Centre

18. Mr. Bhaskar Pradhan, Program Leader (Energy Trade) expressed his thanks to all participants and resource persons for joining the webinar. He acknowledged the cooperation and support extended by all of them in this regard. This depicts their resolve and commitment to the cause of energy and making it available to those who do not have it. He informed all the participants that the presentations will be available on SAARC Energy Centre’s website (www.saarcenergy.org). He requested the participants to submit suggestions and comments to SEC for any further improvement. Moreover, they may suggest and submit any topics of their interest to SEC for arranging future webinars. The webinar was closed with a thank you note to everyone attending the Webinar.

Annexure-I

Agenda

Webinar on "Waste-to-Energy Municipality-level Demonstration Project in Selected Areas of Member States"

Tuesday, May 7, 2019; 1100-1400hrs Pakistan Standard Time (PKT).

1100-1105	Introduction by Bhaskar Pradhan
1105-1130	1. "Decentralized WTE recovery for municipal waste management (By Mr. Rahul Teku Vaswani)
1130-1155	2. "Waste to Energy Power Potential & Opportunities in Punjab" (By: Amir Shahzad Butt, Manager, Punjab Power Development Board)
1155-1220	3. Bioenergy from Organic fraction of MSW and Leachate (By: Mr. Gangagni Rao)
1220-1245	4. "Prospects of Waste to Bioenergy in Nepal" (By: Mr. Sunil Prasad Lohani)
1245-1310	Question & Answer Session
1310-1315	Conclusions and Recommendations
1315-1320	Closing of Webinar

Information for the participants:

1. All times mentioned in agenda are according to Pakistan Standard Time (PKT). The participants from other Member States may attend Webinar by following their own national time. The time conversion for all Member States is given below for reference:

Country	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Sri Lanka	Australia
Conversion Time	(PKT-00:30)	(PKT+01:00)	(PKT+01:00)	(PKT+00:30)	PKT	(PKT+00:45)	(PKT+00:30)	(PKT+06:00)

2. The participants can ask questions to presenters by typing questions or clicking to the Raised Hand option into the Attendees Pane of the main window of GotoWebinar software. You may send in your questions at any time during the presentations; we will collect these and address them during the Q&A session at the end of each presentation.

3. All participants can also submit comments/views and/or observations to SAARC Energy Centre through email to Mr. Bhaskar Pradhan, Program Leader (Energy Trade) (plet@saarcenergy.org) before 14th May, 2019.

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List of Experts

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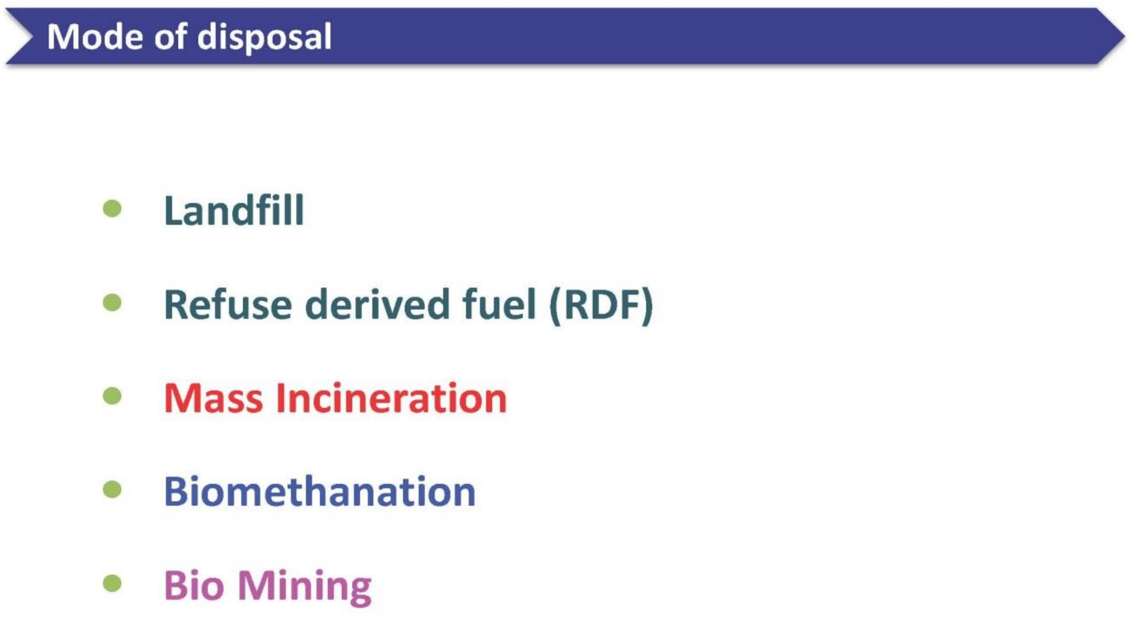
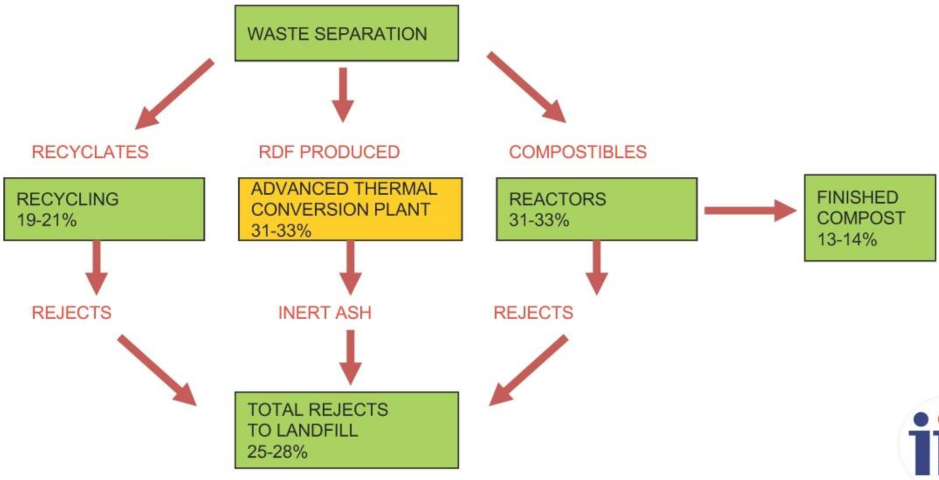
3.	Dr. Gangagni Rao	Chief Scientist Bioengineering and Environmental Science Group, Center for Environmental Engineering an Fossil Fuels	CSIR-Indian Institute of Chemical Technology (IICT), Hyderabad	gangagnirao@gmail.com
4.	Dr. Sunil Prasad Lohani	Associate Professor	School of Engineering, Kathmandu University	splohani@ku.edu.np

Presentations Delivered During the Webinar

Presentation on "Municipal Solid Waste Management in India" by Dr. A. Gangagni Rao

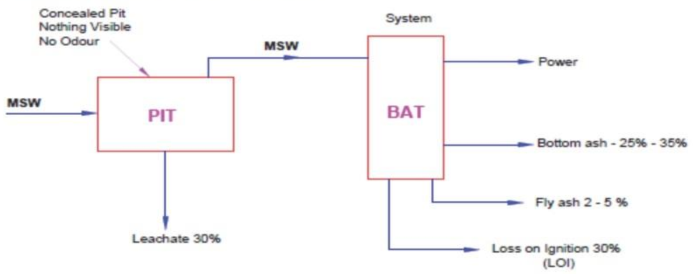


Landfill Application – Resource Recovery



Mass Balance of MSW Incineration

Objective of minimizing the Landfills



Input	Output		Remarks	Conclusion
MSW 100%	1. Leachate	30%	Can be Reused as a fuel, after separation of Water	Out of 100% MSW after salvage only 5% or even <5% will go to SLF. i.e, Fly ash only. This possible in mass incineration with today's available technology.
	2. Bottom ash	25 - 35%	Can be used as construction material	
	3. Fly ash	2 - 5%	Treatment and Land fill	
	4. LOI	30%	Irrecoverable	
	5. Power	-	Export to grid	
100%	Total	**100%**		

MSW : Muncipal Solid Waste

BAT : Best Available Technology In the world, even applicable to Indian conditions also.
i.e, Okhla (running for past 4 years) and Essle Jabalapur MSW Pvt. Ltd. (running past 6 months)

SLF : Scientific Land Fill

Solid Waste Management Rules (SWM), 2016: MOEF, GOI

- The segregation of waste at source has been mandated to channelize the waste to wealth by recovery, reuse and recycle
- The bio-degradable waste should be processed, treated and disposed of through composting or biomethanation within the premises as far as possible
- All hotels and restaurants should segregate biodegradable waste and such food waste should be utilized for composting / biomethanation

Need of the hour

Remunerative

Decentralized Solid Waste Management (OFMSW)

A way forward for SWACHHA BHARATH

Segregation of solid waste in India: 2 bin policy

- Kitchen and food waste
- Recyclable waste
- Plastic, paper, metal, Glass
- Placed near toilets and kitchen
- Minimize this by using stainless steel cutlery
- Avoid disposable cutlery

Collection Point
- Use labeled color coded 15 liter cans
- No plastic liners

Garbage pick up point

- Supervisor should monitor the process and provide training every 15 days.
- Assign a person to collect waste and transfer to collection point. He should be reporting to supervisor in case of any irregularities.
- Supervisor should manage a record of daily quantum of waste.

Initiative by GHMC

- 44 Lakh green and red bins to each household for home segregation
- Green bin for biodegradable waste
- Red bin for non recyclable waste

Source
http://www.deccanchronicle.com/151022/nation-current-affairs/article/clean-telangana-red-and-green-bins-change-city%E2%80%99s-face

Biological Processes

AEROBIC Vs ANAEROBIC

Aerobic respiration

ENERGY CONSUMPTION

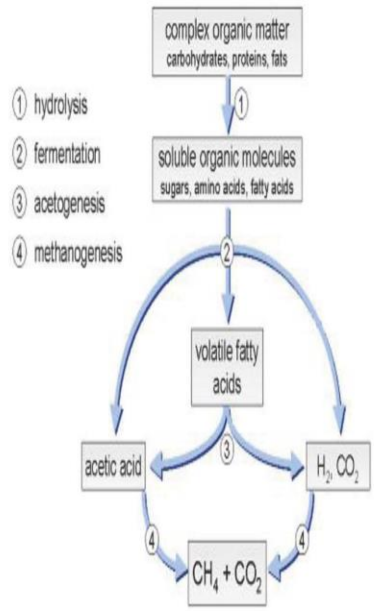
$$\text{Organic compound} + O_2 \longrightarrow CO_2 + H_2O$$

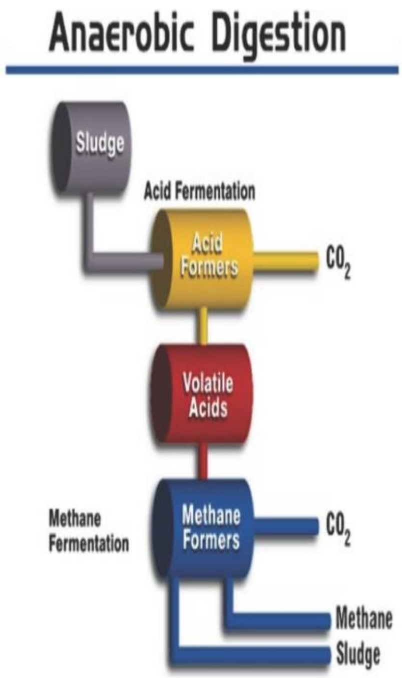
Anaerobic respiration

$$\text{Organic compound} \longrightarrow CH_4 + CO_2 + H_2O$$

BIO-ENERGY GENERATION

Mechanism





Suitability of substrates for biomethanation

❖ It is a biological process carried out by a set of bacteria in the absence of molecular oxygen

❖During the process complex organic solids are converted to Bio-gas and Bio-manure

Any Organic feedstock including

- Vegetables and other agricultural waste,
- Parts of animals,
- Poultry
- Fish that we cannot eat,
- Excreta of human and animal
- Weeds such as water hyacinth,

Suitable for Small Capacity installation near generation of feed stock where transportation is expensive

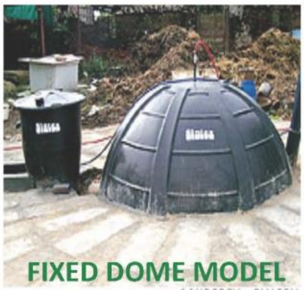
Vegetables Waste

Fish Waste

Poultry Waste

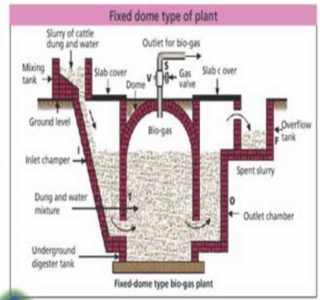
water hyacinth Waste

Types of conventional digesters



FIXED DOME MODEL (China)

COURTESY: SINTEX



FLOATING DOME (India)

- Designed for cattle manure
- Simple design and even mason can construct
- Low cost
- MNRE subsidy (50% cost)
- 12 million digesters in India
- As per survey, 50 to 60% digesters are abandoned

Advantages and disadvantages of conventional digesters

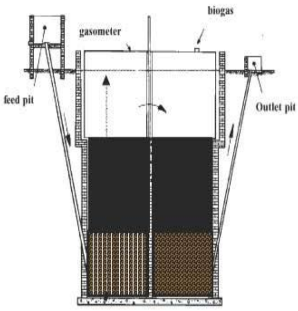


Figure 1 - Indian-type digester.

- Easy to construct, any mason can construct
- Suitable for small quantity of waste treatment
- Easy to clean re-assemble the unit below the capacity of 10 m^3
- MNRE, GOI, spent good amount of money for repair

Reasons for failure of conventional digesters

- Single stage digestion
- No mixing: Choking (scum formation at the top & Inorganic solids accumulates at the bottom) of the reactor
- Poor biogas quality (less methane content)
- Higher the capacity, the cost of repair is more than cost of installation

Conventional Digesters are not suitable for treating organic solid waste or cattle manure with quantities higher than 100 kg/day

High rate biomethanation technology

PRESENT REQUIREMENTS → HIGH RATE BIOMETHANATION TECHNOLOGY - SOLID WASTE

- HIGH RATE BIOMETHANATION TECHNOLOGY IS AN EFFICIENT MEANS FOR BIOGAS PRODUCTION USING ORGANIC SOLIDS
- MOST POPULAR TECHNOLOGY IN THE WORLD FOR SOLID WASTE TREATMENT
- M/s KOMPOGAS, VALORGA, DRANCO, PEARTH, AGRONIEN AND BIMA ARE THE LEADING VERSIONS OF THIS TECHNOLOGY
- THERE ARE INSTALLATIONS IN INDIA BASED ON BIMA TECHNOLOGY (By M/s Entec Austria)

Conventional V/s High rate

CONVENTIONAL	HIGH RATE
Requires 50 to 60 days to complete the digestion	Digestion completed within 15 to 25 days
Treatment efficiency is less than 50%	Efficiency in terms of solids digestion is 80-90%
Loading rate less than 1 kg/m³ volume of digester	Loading rate up to 10 kg/m³ volume of digester
Suitable ONLY for small installations	Suitable for any size
High water consumption and generate secondary effluents	Very little water consumption and no secondary effluents
Choking, Scum formation & many operational problems	No operational problems
Entire operation is manual	Fully mechanized

Anaerobic Digestion Process: Optimum parameters

- pH: 7-8
- Temperature:
- Mesophilic (Best : 33–42^{0}C); Thermophilic (Best : 55–60^{0}C)
- Total Solids/Slurry concentration:10-15% TS
- Volatile solids Loading Rate: 3 – 5 kg VS/m^3
- Hydraulic Retention Time (HRT):
  - 24-60 days for Solid waste
  - 1-6 days Liquid Waste
- C/N Ratio: 25-30 :1
- Volatile Solids: 70-80% of TS

Technological intervention of CSIR-IICT for waste management

Remunerative

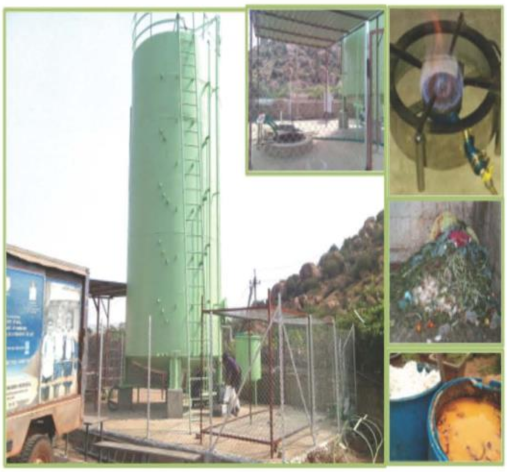
Decentralized Solid Waste Management (OFMSW)

Through

Anaerobic Gas lift Reactor (AGR) Technology Developed by CSIR-IICT

Highlights of Technology

- Advanced digester design
  - Smaller digester volume
  - Easier to scale-up and multiplication
  - Semi-automatic plant operation
- Higher biogas yield
- Generation of organic fertilizer
- Locally available enriched microbial consortia
- Remunerative for decentralized application
- Distributive biogas plants at waste generation source
- Use of by-products will make the plant sustainable
- Employment generation



Remunerative Decentralized Solid Waste Management (Food Waste)

Success Stories of full scale plants based on AGR Technology for food waste

Replacement of LPG with Biogas

- Food waste: 250 to 500 kg/day
- Biogas 35 to 80 m^3/day
- LPG 15 to 30 kg/day
- IICT, Hyderabad
- Capgemini, Hyderabad
- Kurnol vegetable market yard, AP

- Food waste: 1 TPD
- Biogas-150 m^3/day
- LPG 60 kg/day
- The Akshaya patra foundation (TAPF)
- Bellary and Hubli (Karnataka)
- Ahmadabad, Bhavnagar and Surat (Gujarat)
- Vrindavan (UP),
- Rourkela (Odisha)

- Feed chamber with mixer for convenience
- Recycling & enrichment of bacterial population
- Biogas stored at 50 psig pressure
- Better flame velocity

- Variety of feed stock can be used
- Choking & scum formation eliminated
- Portable, Occupies limited space and Aesthetic looks

AGR technology for different capacities of waste treatment

Quantity of organic waste per day	Footprint required for biogas plant installation	Power consumption (kWh)	Average biogas and biomanure generation per day		Equivalent LPG replacement (kg)	Commercial LPG cylinders 14.2 kg's replacement (No./day)
			Biogas (m^3/day)	Biomanure (kg/day)		
300 kg/day	6m x 3m = 18m^2	Below 10	35 – 40	45	15	1
500 kg/day	8.5m x 3m = 25.5m^2	10	60 – 70	75	30	2
750 kg/day	10m x 3m = 30m^2	Below 15	90 – 100	112	40	3
1 Ton/day	Vertical digester model 10m x 5m = 50m^2 Horizontal digester model 11m x 5m = 55m^2	15	120 – 140	150	60	4
3 - 5 Ton/day	600 m^2	50 - 60	360 – 600	450 – 750	165 – 275	12 – 20
10 Ton/day	1200 m^2	130 - 150	1220 - 1400	1500	550	40

BIOHOME

Quantity (kg/day)	5	10	25	50	75	100
Biogas generation (L/day)	400	800	2000	4000	6000	8000
Biogas generation (m3/day)	0.4	0.8	2	4	6	8
LPG equivalence (g/day)	160	320	800	1600	2400	3200
LPG equivalence (kg/day)	0.16	0.32	0.8	1.6	2.4	3.2
Size of the digester (L)	300	600	1500	3000	4500	6000
Size of the digester (m3)	0.3	0.6	1.5	3	4.5	6
Size of the biogas holder (L)	400	800	2000	4000	6000	8000
Size of the biogas holder (m3)	0.4	0.8	2	4	6	8
Foot print area required (m2)	2	3	4	6	8	10

BIOHOME at different capacities of waste treatment

Quantity (kg/day)	5	10	25	50	75	100
Biogas generation (L/day)	400	800	2000	4000	6000	8000
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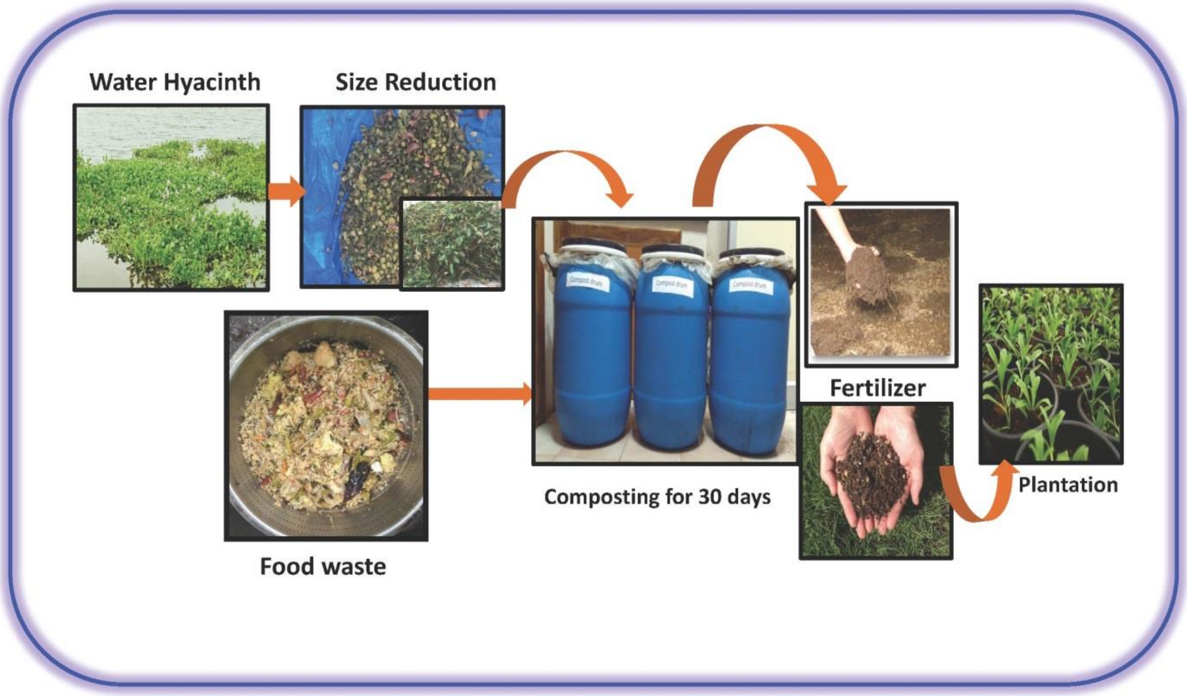
Foot print area required (m2)	2	3	4	6	8	10

Composting of solid waste

Accelerated Anaerobic Composting of food waste and water hyacinth



Composting of organic waste & Entrepreneurship development

Characteristics of fertilizer after composting

Accelerated Anaerobic Composting (AAC): Techno-Economics

- Food Waste: 50 Kg/day
- Compost: 10 Kg/day
- Capital cost for installing compost bins: Rs. 40,000/- (Forty thousand only)
- Cost of compost: Rs.25 to 50 per kg (varies from place to place based on composition)
- Compost generated per Month : 300 kg
- Revenue from compost : Rs. 7,500 to 15,000 per month
  - Unemployed youth could become entrepreneurs with AAC Technology
- CSIR-IICT is ready to train personnel who are interested in this activity

PARAMETER	WATER HYACINTH	FOOD WASTE	According to FCO, Schedule-iv, specification of organic matter Standard values		
			Organic manure	City Compost	Bio-Enriched Organic manure
Total Nitrogen (as N), percent by weight, Minimum	10.09	5.4	0.5	0.8	0,8
Total Phosphates (as P2O5), percent by weight, Minimum	0.40	1.63	0.5	0.4	0.5
Total Potash (as K2O), percent by weight, Minimum	0.48	2.78	0.5	0.4	0.8

Composting of organic waste & Entrepreneurship development

Accelerated Anaerobic Composting (AAC) Technology is developed by CSIR-IICT for the biological decomposition of the organic constituents of wastes under controlled conditions for the production of organic fertilizer

The technology has been licensed to M/s KHAR Energy Optimizers (KEO)
M/s KEO, CSIR-IICT and Greater Hyderabad Municipal Corporation (GHMC) jointly initiated a societal project for the removal of water hyacinth from Kapra Lake, Hyderabad

Accelerated Anaerobic Composting benefits

✓Composting makes a valuable resource out of organic waste
✓A wonderful soil amendment, improves soil nutrients
✓A slow release fertilizer without pollution
✓Feasible at ambient temperature
✓No oxygen requirement
✓Low cost
✓Minimization of the loss of carbon and nitrogen

Success Stories

Pilot plant based on AAC Technology at Kapra Lake, Hyderabad
Input: 12,000 Tons of Water hyacinth
Output: Production of 1,200 Tons of soil conditioner

Societal Impact

- Generation enriched compost with good NPK (more than three times better than vermi compost)
- Reduces the problems associated with landfills and incinerators
- Benefits municipalities and villages as well as environment
- Remunerative options for the decentralized treatment of organic wastes
- Useful for villages, apartments, gated communities, restaurants and so on
- Self help groups and unemployed youth could be trained in this area

Parameter	Water hyacinth	Standard (fertilizer control authority)
Nitrogen (N)	10.0	0.8
Phosphorous (P)	0.40	0.5
Potash (K_2O)	0.48	0.8

Waste to wealth: A sustainable approach for nutrients recovery

Research Team

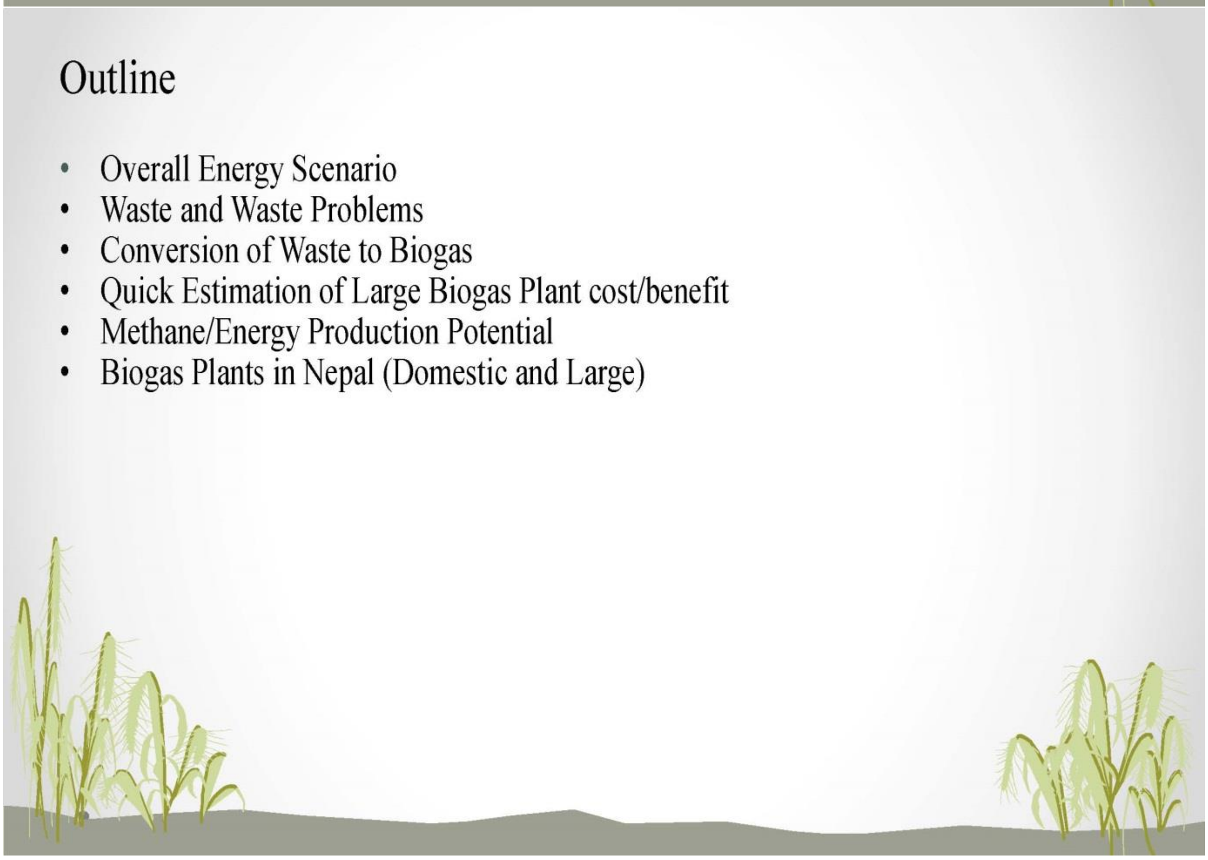
- Sameena Begum
- Kranthi
- Bharath
- Sudharshan
- Vijayalakshmi
- Anil
- Sarath
- Prasoona
- Gayathri
- Jayanth
- Sujan
- Aparna

Funding agencies

- DBT
- DST
- CSIR
- IICT

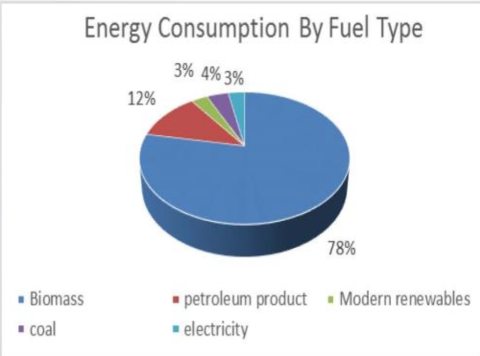
THANK YOU

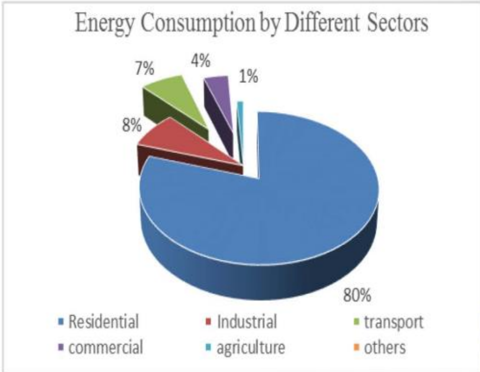
Presentation on "Prospects of Waste to Biogas in Nepal" by Dr. Sunil Prasad Lohani



Overall Energy Scenario

- Energy crisis, biomass energy covers around 78%
- 80% of energy consumes in residential sector, mainly cooking
- Burning of biomass causes INDOOR air pollution and inefficient due outdated technology

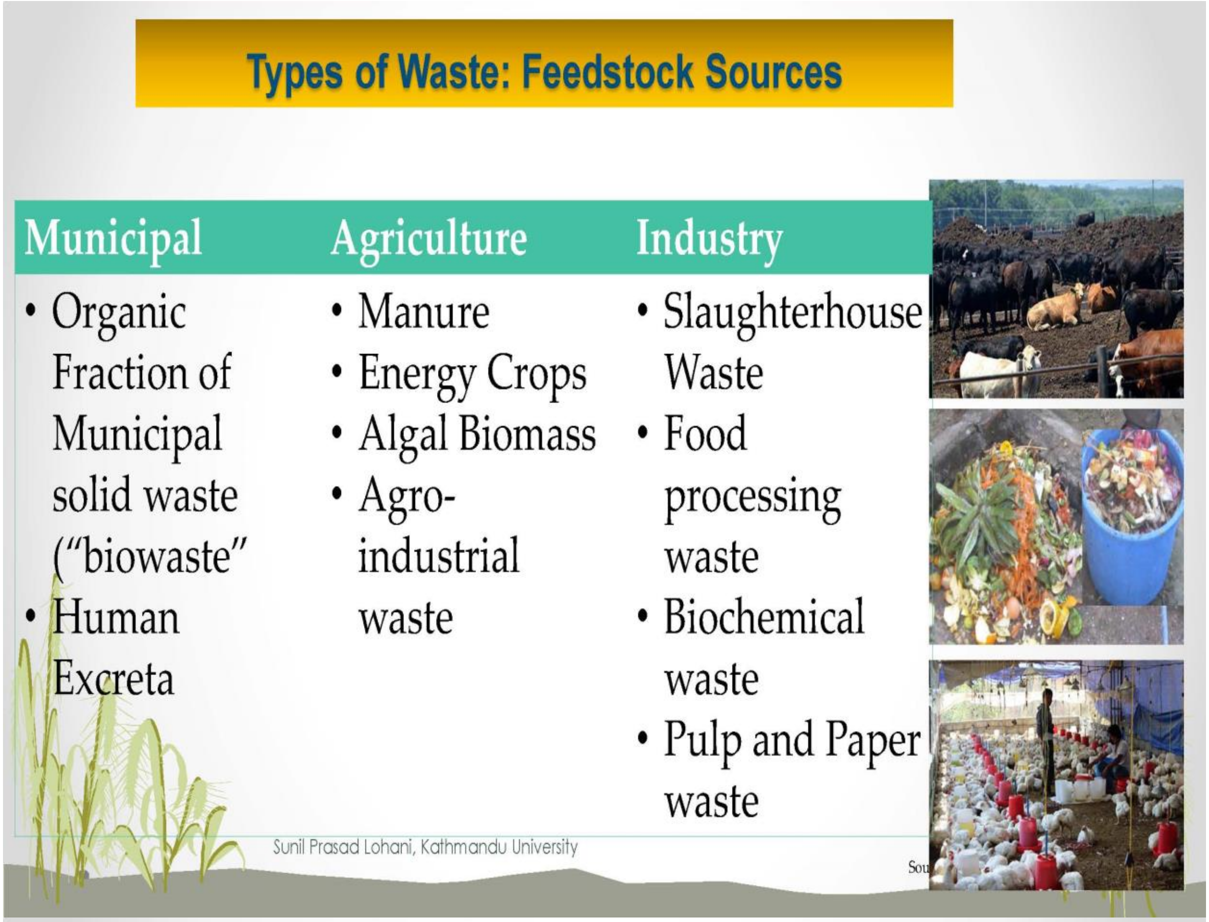




Source: Economic Survey

What are Wastes?

- Waste (also known as rubbish, trash, refuse, garbage, junk and litter) is any unwanted or useless materials.
- "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of the law" (Basel Convention Definition of Wastes).
- But any refuse or waste can be economic resource to others.


Types of Waste: Feedstock Sources
Municipal
• Organic Fraction of Municipal solid waste ("biowaste"
• Human Excreta
Agriculture
• Manure
• Energy Crops
• Algal Biomass
• Agro-industrial waste
Industry
• Slaughterhouse Waste
• Food processing waste
• Biochemical waste
• Pulp and Paper waste
Sunil Prasad Lohani, Kathmandu University


Solid Waste Problem in Nepal
Average Municipal Solid Waste Generation 0.32kg per capita
Total Solid Waste Generation in Urban Areas 631,000 tons per year
About 60% Organic Fraction
No Proper Management
Source: Internet Image

Manure Management Problem in Nepal

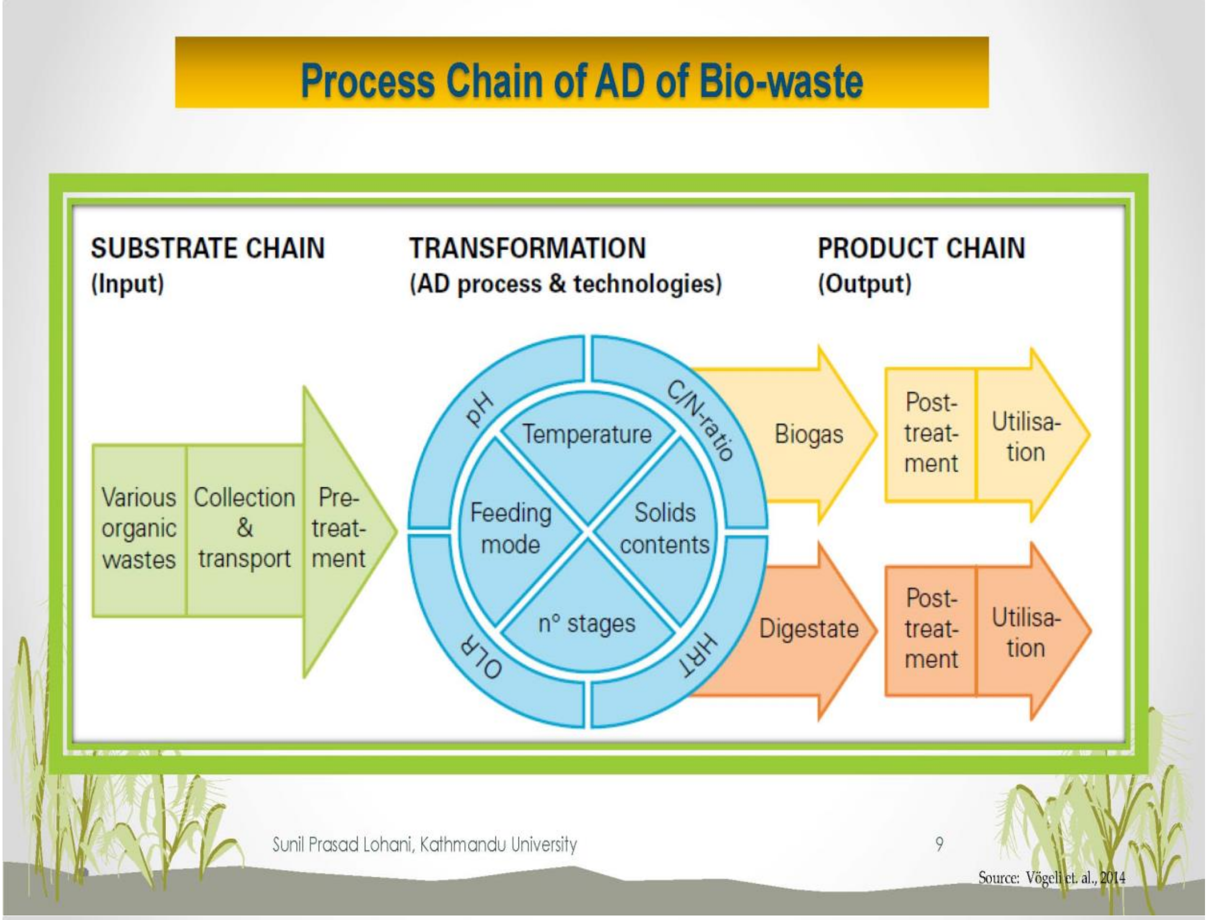
Cattle Farm is about 3400, Waste Generation 160,000 tons per year

Number of Chickens is about 47 million, Poultry Droppings Generation 508,000 tons per year

Source: Kantipur Daily

Source: Internet Image

Degradable organic waste to Biogas?


Process Chain of AD of Bio-waste
SUBSTRATE CHAIN
(Input)
TRANSFORMATION
(AD process & technologies)
PRODUCT CHAIN
(Output)
Various organic wastes
Collection & transport
Pre-treat-ment
pH
C/N-ratio
Temperature
Feeding mode
Solids contents
n° stages
OLR
HRT
Biogas
Post-treat-ment
Utilisa-tion
Digestate
Post-treat-ment
Utilisa-tion
Sunil Prasad Lohani, Kathmandu University
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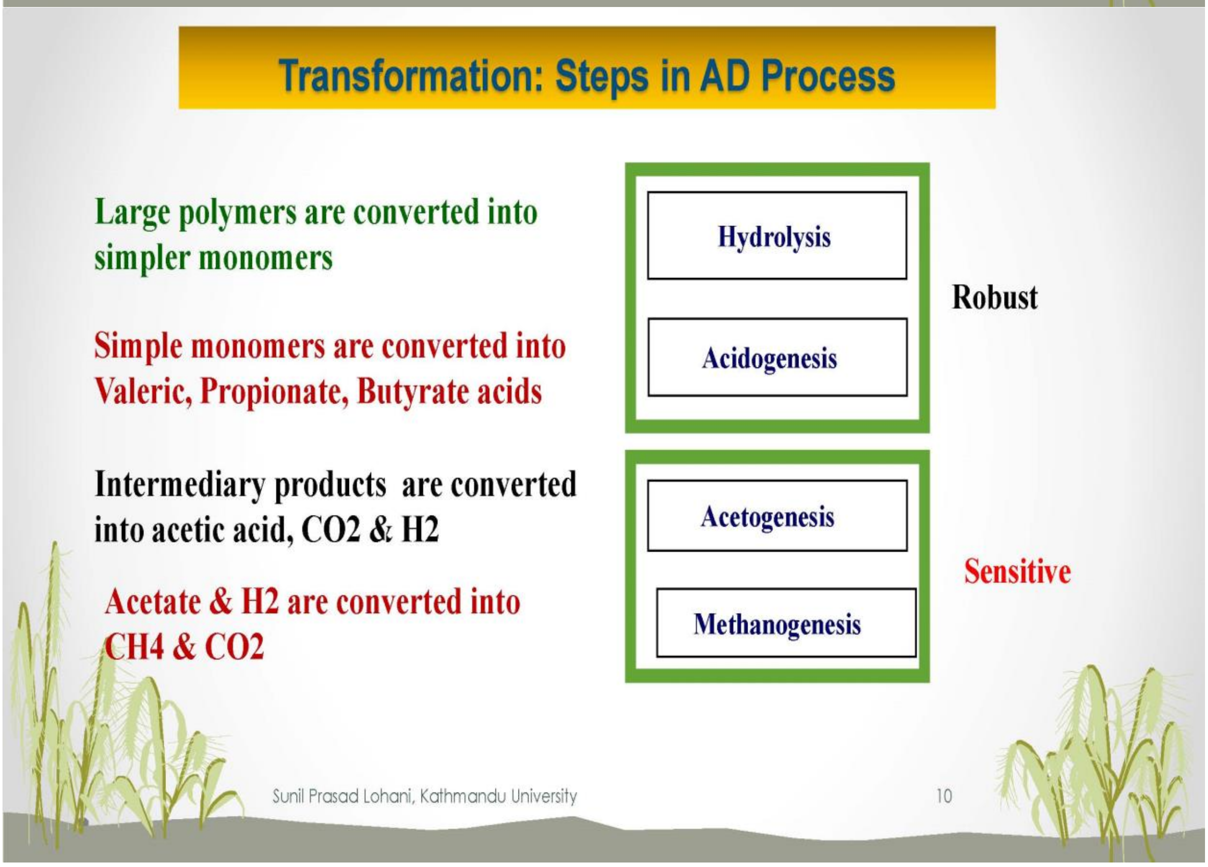
Source: Vögeli et. al., 2014


Transformation: Steps in AD Process
Large polymers are converted into simpler monomers
Simple monomers are converted into Valeric, Propionate, Butyrate acids
Intermediary products are converted into acetic acid, CO2 & H2
Acetate & H2 are converted into CH4 & CO2
Hydrolysis
Acidogenesis
Robust
Acetogenesis
Methanogenesis
Sensitive
Sunil Prasad Lohani, Kathmandu University
10

Biogas Composition

Biogas: Mixture of different gases obtained from AD of Organic Substance

Typical composition of biogas from bio-waste (adapted from Cecchi et al., 2003).

Components	Symbol	Concentration (Vol-%)
Methane	CH_4	55–70
Carbon dioxide	CO_2	35–40
Water	H_2O	2 (20°C) – 7 (40°C)
Hydrogen sulphide	H_2S	20–20000 ppm (2 %)
Nitrogen	N_2	<2
Oxygen	O_2	<2
Hydrogen	H_2	<1
Ammonia	NH_3	<0.05

Sunil Prasad Lohani, Kathmandu University

Energy Comparison

Biogas compared with other fuels

Fuel	Unit U	Calorific value kWh/U	Application	Efficiency %	U/m^3 biogas
Cow dung	Kg	2.5	cooking	12	11.11
Wood	Kg	5.0	cooking	12	5.56
Charcoal	Kg	8.0	cooking	25	1.64
Hard coal	Kg	9.0	cooking	25	1.45
Butane	Kg	13.6	cooking	60	0.40
Propane	Kg	12.0	cooking	60	0.39
Diesel	Kg	12.0	engine	30	0.55
Electricity	KWh	1.0	motor	80	1.79
Biogas	m^3	6.0	cooking	55	1

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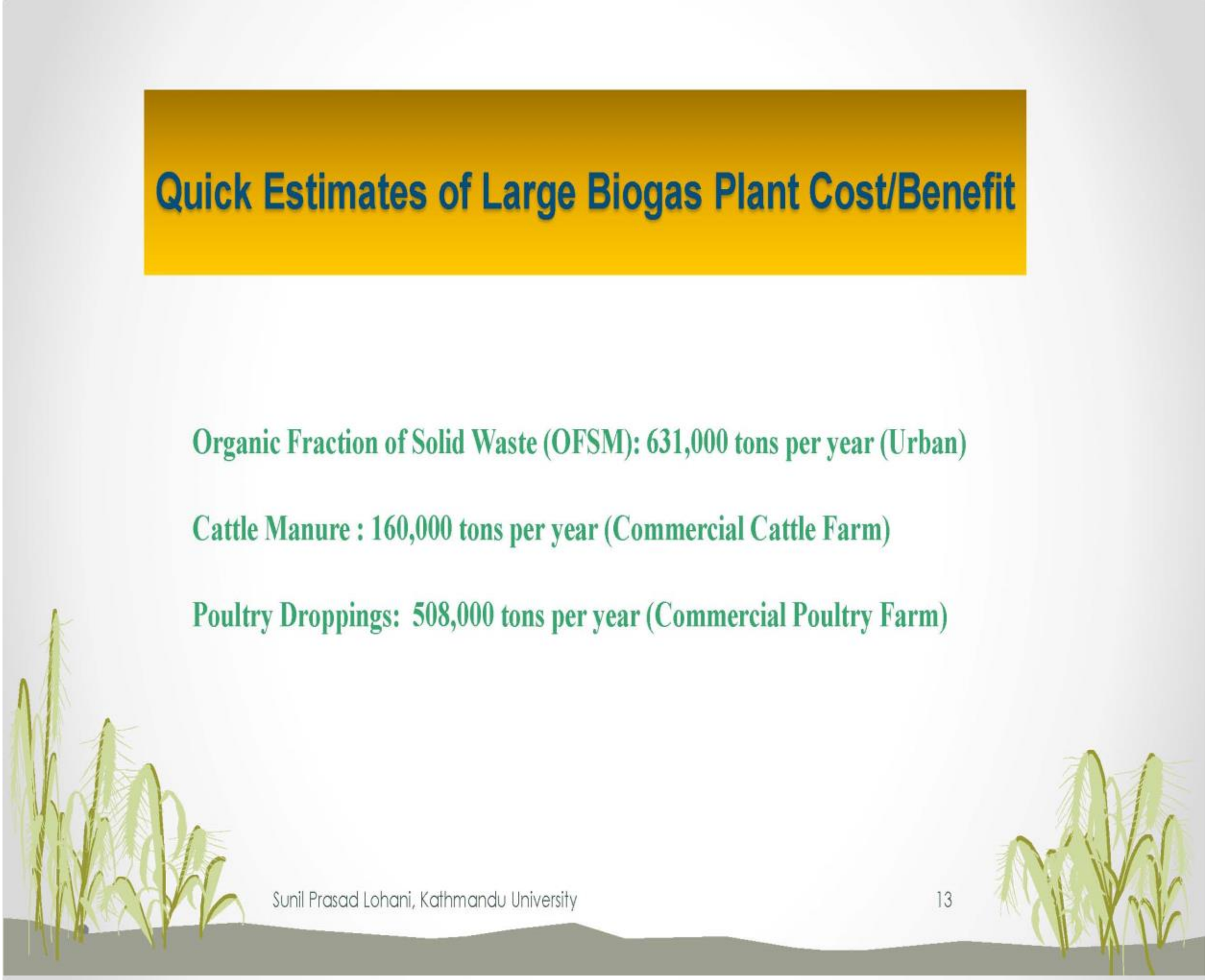
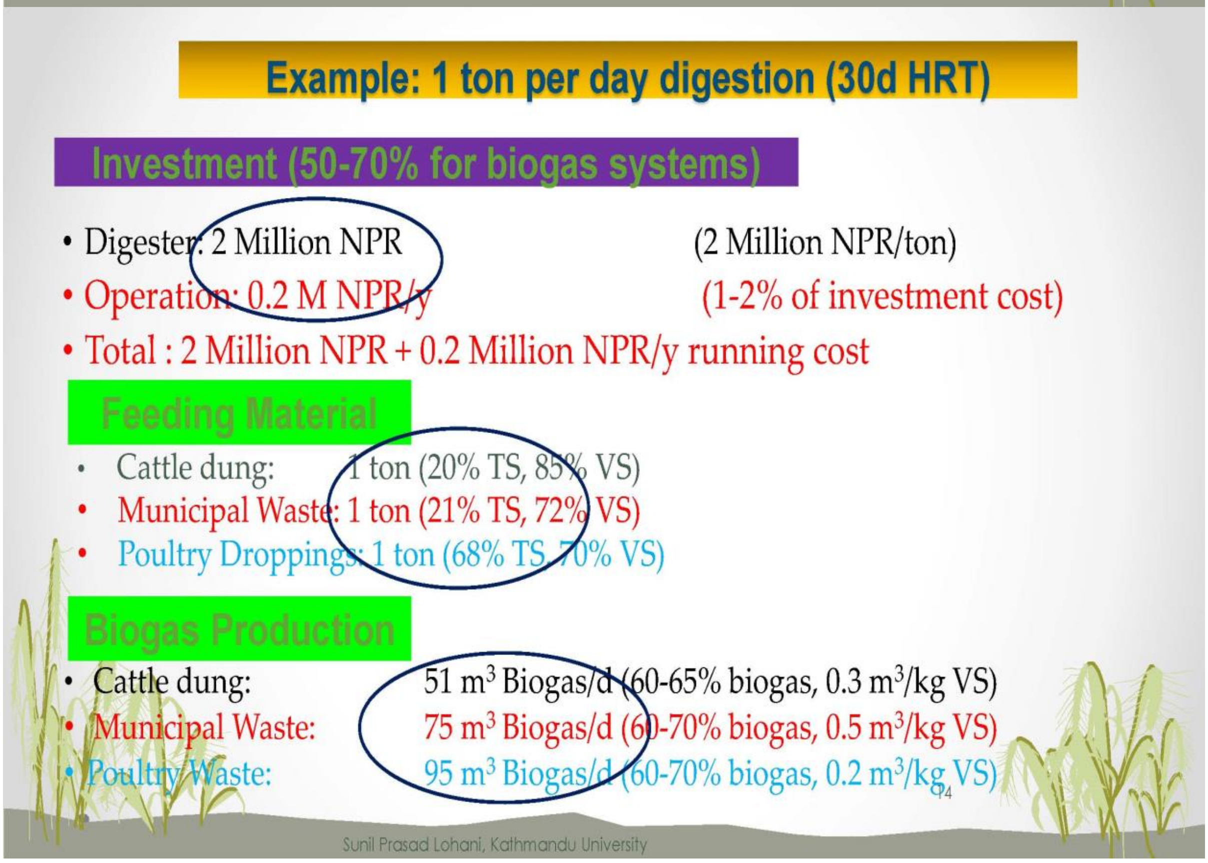

Quick Estimates of Large Biogas Plant Cost/Benefit
Organic Fraction of Solid Waste (OFSM): 631,000 tons per year (Urban)
Cattle Manure : 160,000 tons per year (Commercial Cattle Farm)
Poultry Droppings: 508,000 tons per year (Commercial Poultry Farm)
Sunil Prasad Lohani, Kathmandu University
13


Example: 1 ton per day digestion (30d HRT)
Investment (50-70% for biogas systems)
• Digester: 2 Million NPR (2 Million NPR/ton)
• Operation: 0.2 M NPR/y (1-2% of investment cost)
• Total : 2 Million NPR + 0.2 Million NPR/y running cost
Feeding Material
• Cattle dung: 1 ton (20% TS, 85% VS)
• Municipal Waste: 1 ton (21% TS, 72% VS)
• Poultry Droppings: 1 ton (68% TS, 70% VS)
Biogas Production
• Cattle dung: 51 m3 Biogas/d (60-65% biogas, 0.3 m3/kg VS)
• Municipal Waste: 75 m3 Biogas/d (60-70% biogas, 0.5 m3/kg VS)
• Poultry Waste: 95 m3 Biogas/d (60-70% biogas, 0.2 m3/kg VS)
14
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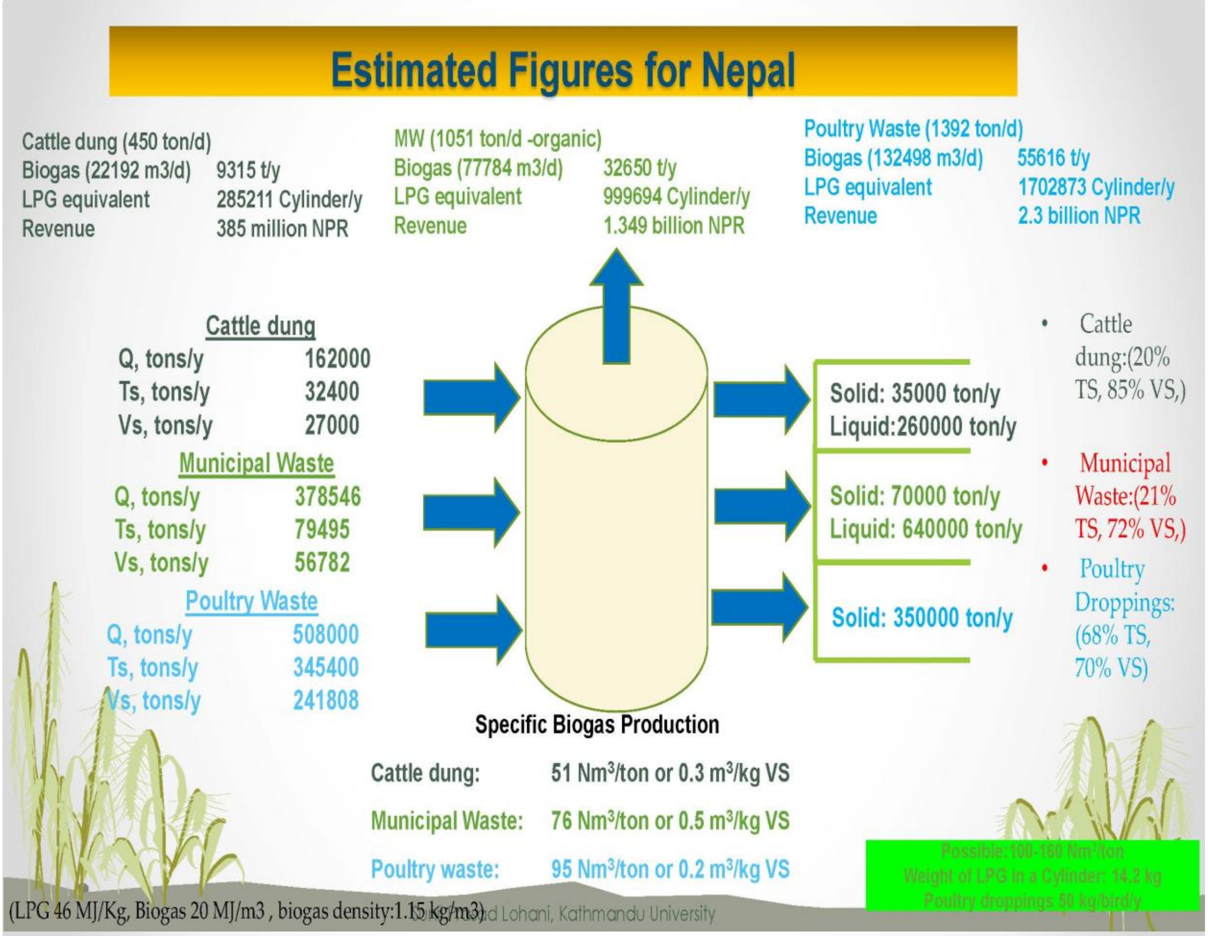


Methane Production Potential

Type	Methane Production Potential/year
Degradable MSW	999 thousand LPG Cylinder Equivalent
Cattle Farm Manure	285 Thousands LPG Cylinder Equivalent
Chicken Farm	1.7 million LPG Cylinder Equivalent

Could replace 4 billion NRS Equivalent LPG Cylinders

5 billion NRS Equivalent Organic Fertilizer (11 NRS/kg)

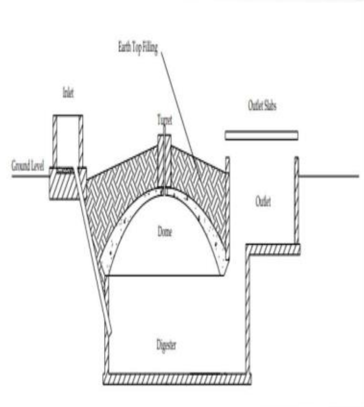
Around 30 to 60 billion NRS construction cost of biogas plants (15000 tons waste, 2 to 4 million/ton plant cost)


Biogas plant in Nepal


Biogas plant in Nepal
• First installed in year 1955 AD at Godavari, Lalitpur ; 200 liters oil drum digester with separate drum gas holder
• Almost 400,000 biodigesters installed
• Domestic biodigester of sizes 4, 8 or 10 m3 mostly popular
Source: Biogas support program and Alternative Energy Promotion Center

Household Bio-digesters in Nepal

- **Fixed dome Digester: GGC concrete model Biogas plant**
- Developed by Gobar gas and agricultural equipment development company (GGC)
- Modification of Chinese fixed dome
- Uses air tight underground digester
- GGC 2047 model popular in Nepal
- Sizes rage 4-20 m^3
- Reliable, well-functioning, durable ,less maintenance ,simple



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Household Bio-digesters in Nepal

- **Sahari Gharelu Biogas Plant (ARTI Model)**
- Developed in India in 2003
- Introduced in Nepal by AEPC, Nepal in 2012/13 for piloting in Kathmandu valley
- Based on principles of floating drum
- Plant size 1 cubic meter ,plastic made similar to water storage
- Accustomed to temperate climate of India
- Didn't function well in Kathmandu

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Biogas from Poultry Droppings

Small household digester has been constructed of volume $50m^3$

Feeds poultry manure of the farm

The end product is used as cooking fuel inside the farm and has been also distributed to some local houses around the farm

Distribution of the biogas through pipeline

Large Biogas plant in Nepal

Large Biogas Plant in Syangja, Nepal

Mostly uses poultry manure and cow dung as feed

The upgraded biogas used to generate electricity which is used to make the biofertilizer

The volume of the bio-digester is $3500m^3$

The daily feed input the digester is 40 tons of poultry litter and cow dung

Biogas Upgradation | Double fuel generator

Large Biogas Plant in Kotre Bazar, Pokhara, Nepal

Recently completed and feed with cow dung has been started

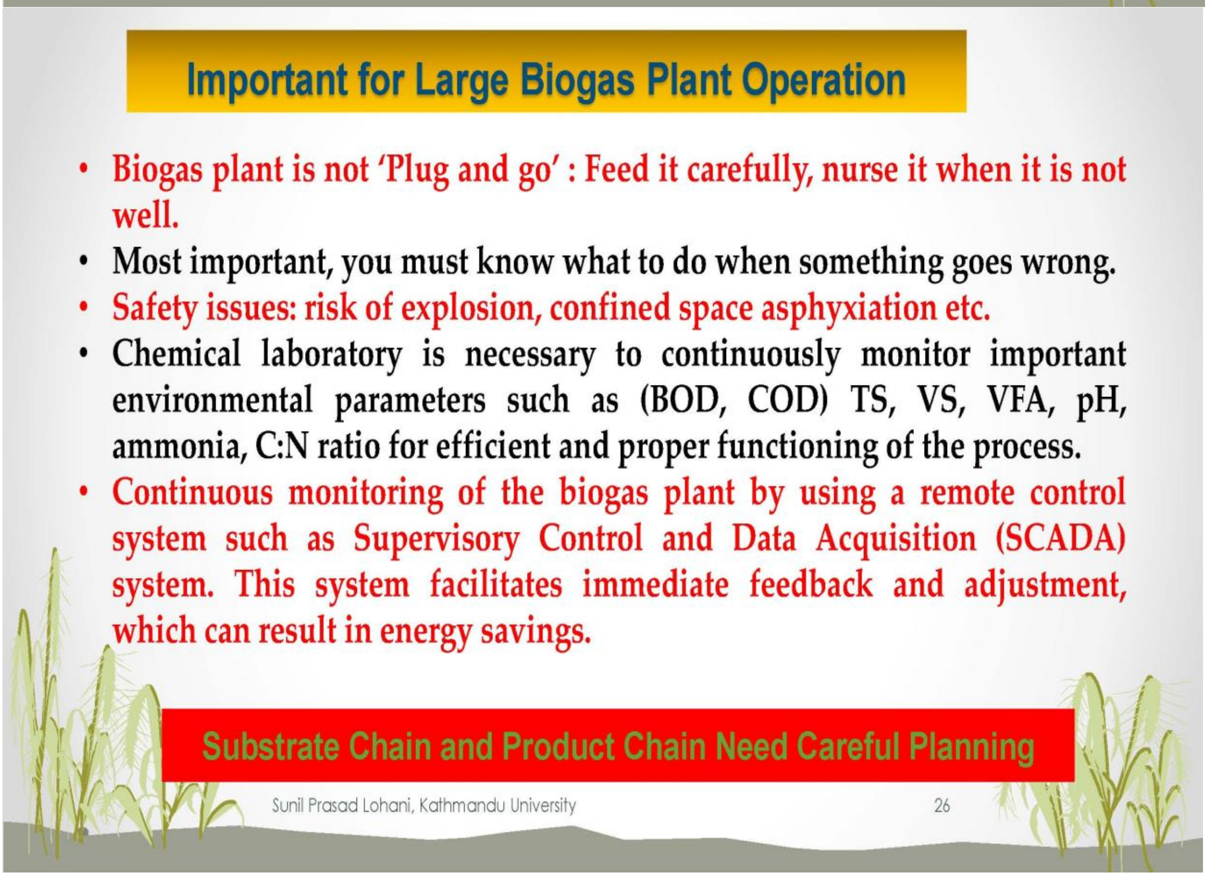
The upgraded biogas shall be used for bottling to be taken to the local hotels, restaurant and market

Digester volume is 4200 m^3 and gas production upto $3600m^3$

The daily feed shall be 45 ton into the digester, poultry litter, cow dung and food waste is planned

Second Digester UC | Bottle Storage | Scada Monitoring


Large Biogas Plant in Nawalparasi, Nepal
Feeding materials are press mud, poultry manure and cow dung
The volume of the biogas digester is 3750m3.
Feeding strategy for a week is forecasted and 25 tons of feeding material is fed into the digester daily
End product used for bottling and use for industry, hotels, restaurants, schools, etc.
Solid fertilizers are made packages (5/10 kgs/25 kgs) and sold to the local consumers
Membrane Based Technology
Biogas Upgradation
Bottling Facility


Important for Large Biogas Plant Operation
• Biogas plant is not 'Plug and go' : Feed it carefully, nurse it when it is not well.
• Most important, you must know what to do when something goes wrong.
• Safety issues: risk of explosion, confined space asphyxiation etc.
• Chemical laboratory is necessary to continuously monitor important environmental parameters such as (BOD, COD) TS, VS, VFA, pH, ammonia, C:N ratio for efficient and proper functioning of the process.
• Continuous monitoring of the biogas plant by using a remote control system such as Supervisory Control and Data Acquisition (SCADA) system. This system facilitates immediate feedback and adjustment, which can result in energy savings.
Substrate Chain and Product Chain Need Careful Planning
Sunil Prasad Lohani, Kathmandu University
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Thank You!
Green the World
for better Future!
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Phone: +9779849278175
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Presentation on "Waste to Energy Power Potential & Opportunities in Punjab" by Mr. Amir Shahzad Butt

Energy Department
Government of the Punjab

'Waste to Energy Power Potential & Opportunities in Punjab'

Presented by

Amir Shahzad Butt
Manager Renewables/Biofuels
Punjab Power Development Board

1

Sequence

- Pakistan Power sector – Key Players
- Promoting Private Power Projects – Punjab Initiative
- Solid Waste Sector in Punjab
- Integrated Solid Waste Management (ISWM) Approach – Framework Applicability
- Waste to Energy Prospects
- 40 MW WtE Power Project at Lahore & WtE Potential in Punjab
- WtE Challenges – Limiting Factors
- Way forward – WtE is a success in Regional Countries

2

Pakistan Power Sector – Key Players

3

Key players in the power sector

- National Electric Power Regulatory Authority (NEPRA)
- National Transmission & Despatch Co. Ltd. (NTDC)
- Central Power Purchase Agency (CPPA-G)
- Private Power Infrastructure Board (PPIB) / Alternative Energy Development Board (AEDB)
- Provincial Facilitators – Punjab Power Development Board (PPDB), Energy Department in Punjab

4

Promoting Private Power Projects – Punjab Initiative

5

Role of Provinces in Power Sector

- The Constitution of Pakistan allows provinces to construct or cause construction of power projects of any size based on any technology – clarification provided by CCI on April 28, 2011
- Punjab provides facilitation to power projects under Punjab Power Generation Policy 2006 revised 2009 – this policy is in full conformance with federal power policies
- Federal Power Policy, 2015 & Renewable Power Policy, 2006 fully recognize this facilitation role of provinces

6

Functions of PPDB

- Facilitate development of hydro, coal, solar, wind, biomass / solid waste potential in Punjab
- Award of private power projects in raw or solicited mode
- Facilitate private investors for setting up power projects in line with the provincial and national power policies
- Extend fiscal & financial concessions to projects under the policy
- Supervise Feasibility Studies through independent panel of experts
- Support to projects during project agreements and financial close
- Facilitation, in coordination with Federal counterparts, during project construction and operation

Recent Success Stories

In exercise of its constitutional & policy role and to mitigate the then prevailing severe power shortfall situation, Punjab initiated development of;

- Large imported coal projects of 3960 MW – 1320 MW Sahiwal Coal project has started commercial operation (CPEC)
- Quaid-e-Azam Solar Park 1000 MW – 400 MW has started commercial operation (CPEC)
- RLNG based power projects 3600 + 1200 MW – 3600 has started operation

PPDB Project Portfolio

Technology	Capacity (MW)
Thermal Projects	3960
Renewable Projects	2719
Hydro Projects	274
TOTAL	**6953**

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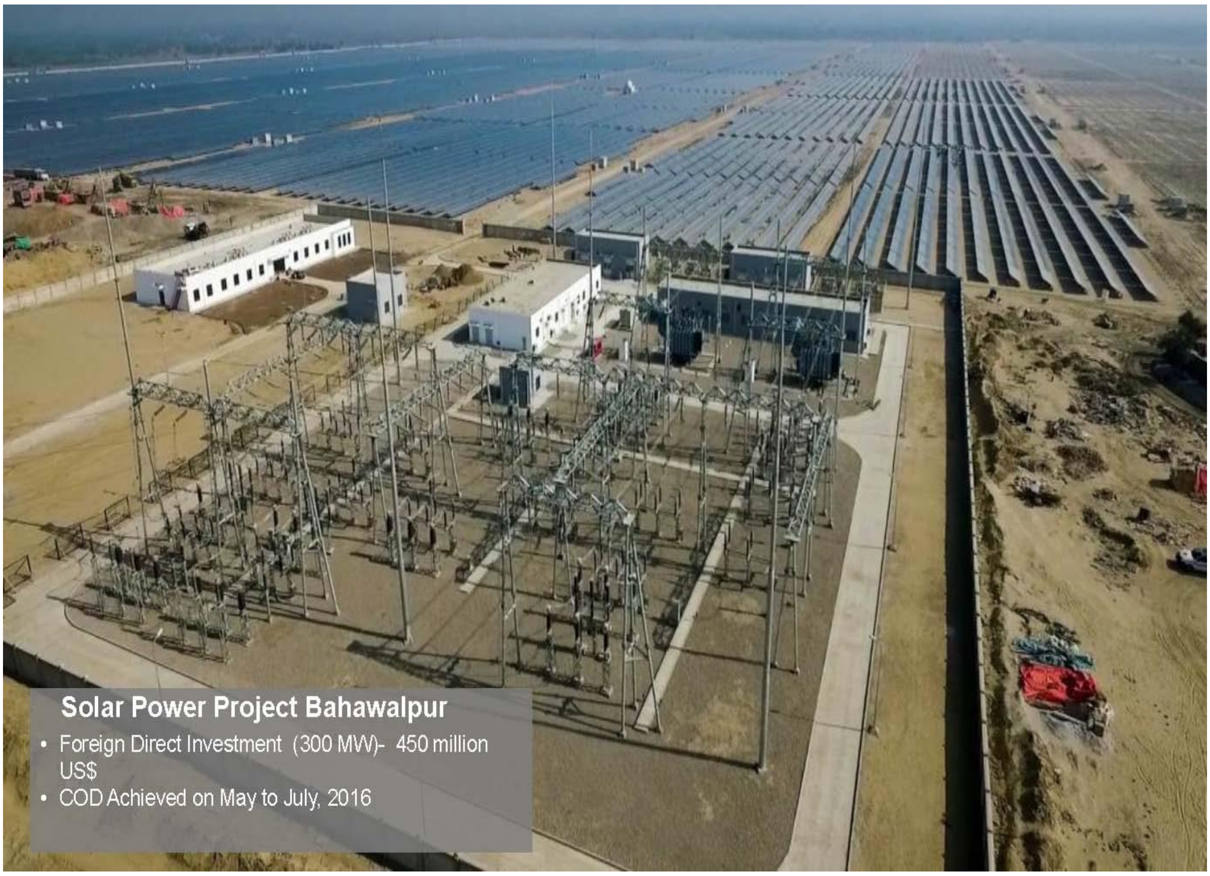
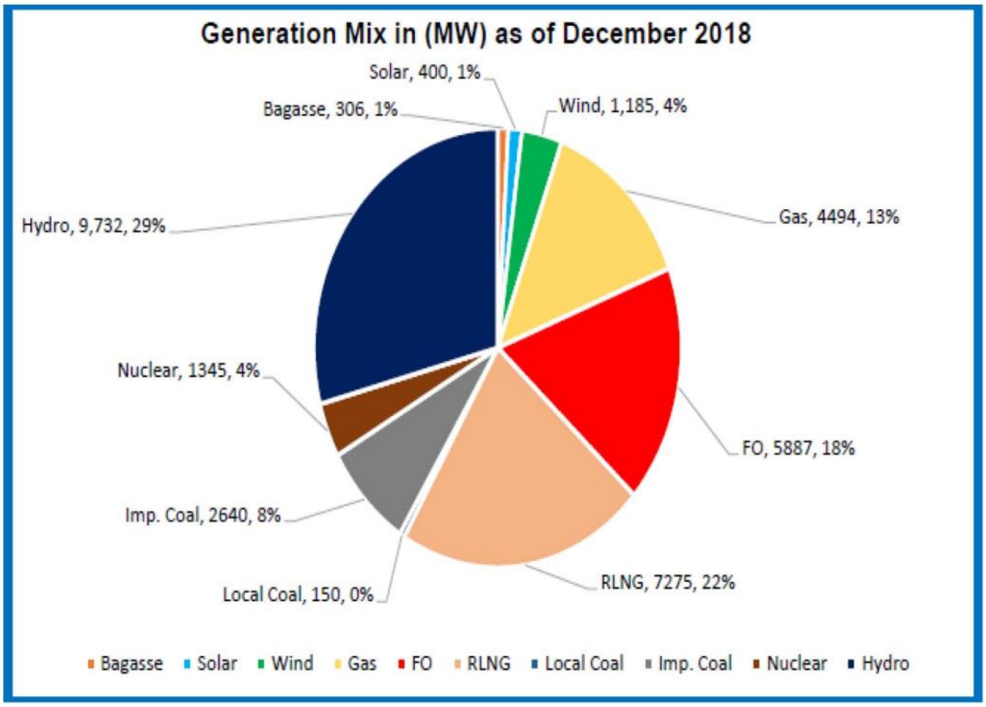


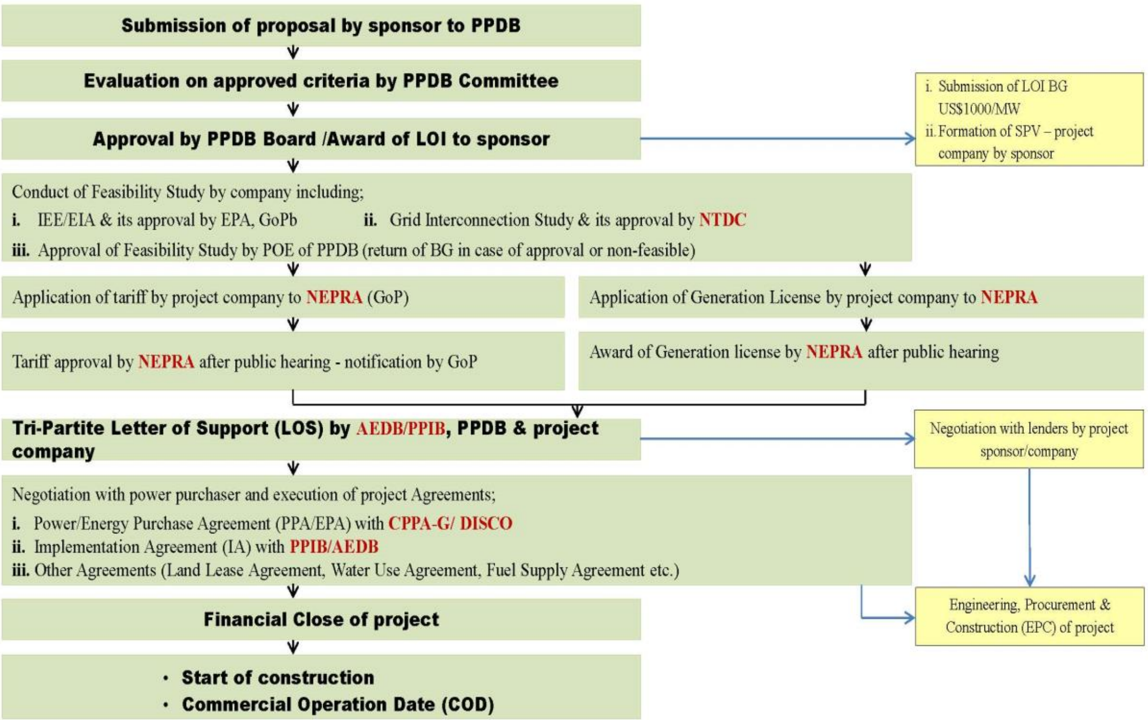
Country's Installed Fuel Mix – 33,414 MW (31st Dec 2018)



Source: NTDC

11

Project Development Cycle - IPPs



Solid Waste Sector in Punjab

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Municipal Solid Waste Management

- As per World Bank Report 2016, Pakistan's solid waste generation per capita per day 0.43 kg
- Total MSW generation of country is about 31 Million tons/year – Census 2018
- Punjab, the largest province having population more than 110 million generates more MSW amongst other provinces
- Waste Management Companies are established at larger populated cities like Lahore, Faisalabad, Gujranwala etc.
- Prime objective is for centralized collection of waste, collection & transportation to respective dumping/landfill sites

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Solid Waste Profile at Lahore

- Solid Waste generation 7000 TPD
- Solid Waste collection 6500 TPD
- Commitment by LWMC;
  - RDF Plant to Cement Factory 1000 TPD
  - Compost Plant 500 TPD
- MSW available for Waste to Energy (WtE)
  - At Lakhodair landfill site 2000 TPD
  - MRF at Sundar 3000 TPD

Source: Lahore Waste Management Company (LWMC)

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ISWM Approach - Framework Applicability

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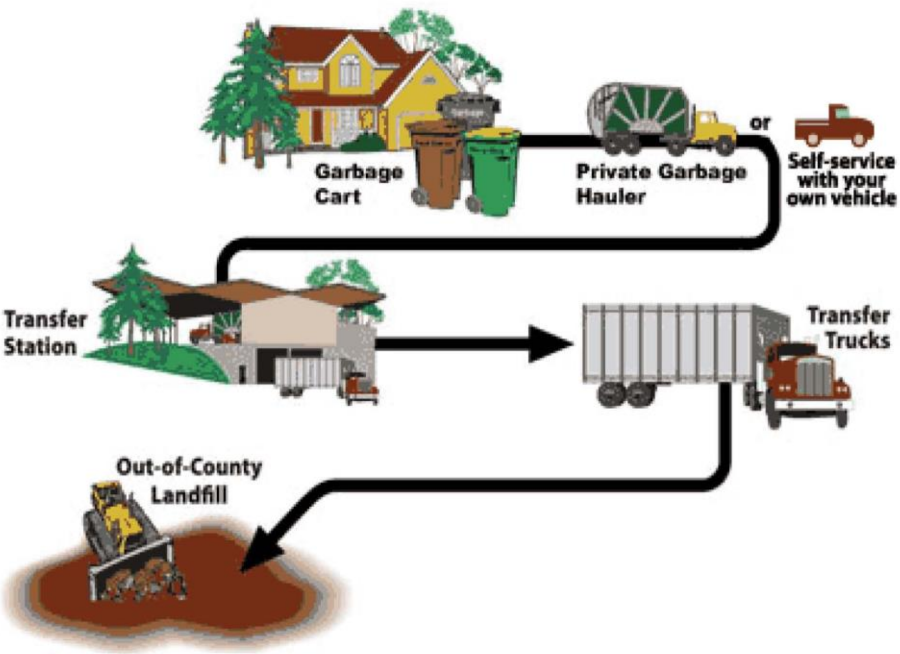
How Waste is Managed?



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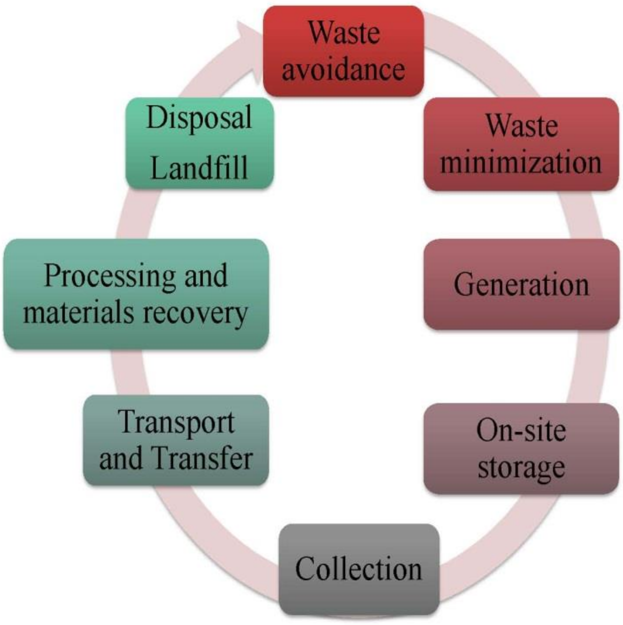
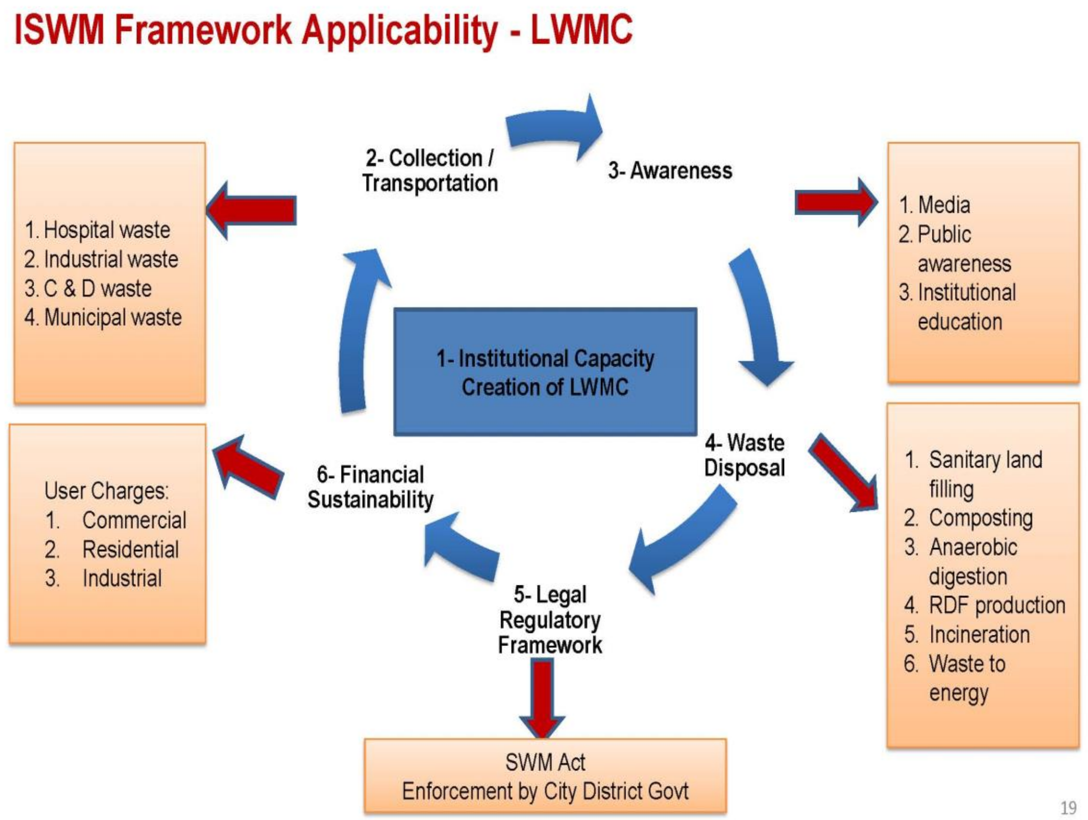
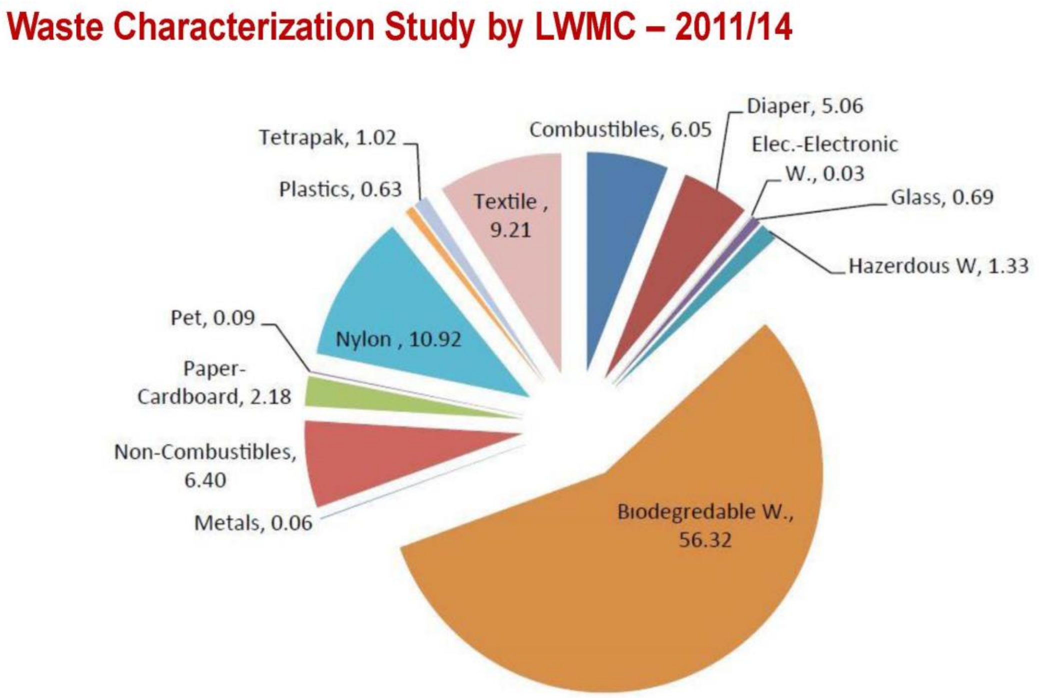
ISWM Approach




ISWM Framework Applicability - LWMC
2- Collection / Transportation
3- Awareness
1. Hospital waste
2. Industrial waste
3. C & D waste
4. Municipal waste
1. Media
2. Public awareness
3. Institutional education
1- Institutional Capacity Creation of LWMC
4- Waste Disposal
User Charges:
1. Commercial
2. Residential
3. Industrial
6- Financial Sustainability
1. Sanitary land filling
2. Composting
3. Anaerobic digestion
4. RDF production
5. Incineration
6. Waste to energy
5- Legal Regulatory Framework
SWM Act
Enforcement by City District Govt
19


Waste Characterization Study by LWMC – 2011/14
Diaper, 5.06
Combustibles, 6.05
Tetrapak, 1.02
Elec.-Electronic W., 0.03
Plastics, 0.63
Textile , 9.21
Glass, 0.69
Hazerdous W, 1.33
Pet, 0.09
Nylon , 10.92
Paper-Cardboard, 2.18
Non-Combustibles, 6.40
Metals, 0.06
Biodegredable W., 56.32
20

Waste Characterization Study by LWMC – 2011/14

Season	Calorific Value (kCal/kg)	Moisture Contents (%)
April 2011	1428	53.07
July 2012	1657	47.01
November 2012	1481	62.69
Sep 2014	1711	43.62

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Waste to Energy Prospects

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Backdrop of WtE - MSW Risks

- Serious threat to ambient air & underground water
- Hazardous Methane gas emissions from dumping sites
- Rain and Seepage cause under ground water contamination - potential threat for drinking water
- Risk of air and water bourn diseases - Hepatitis, Malaria, Gastrointestinal
- Perpetual need for new landfill sites if waste is untreated

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Dumping/Landfill Site at Lahore

Mahmood Booti – Closed Dumped site

- 77 acre full of heaps of garbage
- 13 million ton waste is dumped
- More than 80 feet waste heap
- Site closed since September 2016

Lakhodair landfill site

- 130 acre reserved area
- Dumping started in October, 2016
- 6 million ton waste already dumped on 60 acre
- Area reserved for WtE project

Waste to Energy Prospects

- WtE power projects are considered as environment projects through scientific disposal/reduction of MSW – power generation additional benefit
- WtE help in saving precious public land that could otherwise be used for dumping waste at dumping site
- Other key benefits include;
  - Air quality improvement
  - Reduced health risks
  - Safeguard against contamination of underground water table
  - Long life of environmentally hazardous dumping / landfill sites

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40 MW Waste to Energy Power Project at Lahore

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40 MW Waste to Energy Power Project at Lahore

- Based on effective waste management supply chain at Lahore by LWMC, private sector was encouraged for WtE project
- Subsequently, LWMC provided waste assurance of 2000 TPD of MSW
- Private sector shown keen interest for development of approximately 40 MW WtE power project in IPP mode under Punjab Power Generation Policy
- After competitive process & fulfillment of procedural requirements, LOI was awarded by PPDB to international private company for conduct of detailed bankable Feasibility Study (FS)
- FS completed/approved including grid & environment studies
- Company has been awarded Upfront Tariff & Generation License by NEPRA
- Next steps are projects agreements under LOS before financial close

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Waste to Energy Power Potential in Punjab

Waste Management Companies	Total Waste Generation (tons/day)	Waste Collection (tons/day)	Estimated Potential (MW)	Dumping sites status
Lahore Waste Management Company	7000	6500	100 MW	• Mehmood Booti dumping site – 100% filled • Lakhodair landfill site • Sundar Material Recovery Facility
Faisalabad Waste Management Company	1650	1150	25 MW	• Jaranwala Road Faisalabad
Gujranwala Waste Management Company	1000	700	15 MW	• Gondlawa (operational -700 tons/day) • Sherakot (in pipeline)
Multan Waste Management Company	850	510-550	10-12 MW	• Habiba Sial (operational)
Rawalpindi Waste Management Company	850	-	10-12 MW	• Muza Losar (95% filled)

Waste to Energy Challenges – Limiting Factors

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Waste to Energy Challenges – Limiting Factors

- Mixed MSW contain all type of waste including biodegradable, C&D waste etc.
- Scavenging of high calorific value waste & recycling in absence of waste regulations
- Waste assurance limitation in general
- No mechanism in place for tipping /gate fee – generally provided to project developers on account of waste disposal
- Province wise ceiling of 50 MW to each province to avail Upfront Tariff
- Upfront Tariff regime in Pakistan has almost exhausted
- Introduction of competitive bidding for RE projects - New RE Policy is expected in few months
- No grid-connected WtE completed project in place so far

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Way forward – WtE a success in Regional Countries

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Way forward – WtE is a success in Regional Countries

- Countries like China is way ahead in incineration based WtE power projects - As per China National Renewable Energy Centre June 2017, China has completed 296 projects in 28 provinces with aggregate capacity of 6250 MW
- India has also installed 138 MW capacity of WtE projects and number of projects are under development – Ministry of New Renewable Energy (March 31, 2018)
- Similarly Thailand, Turkey & Japan have also established WtE projects
- In Pakistan, 40 MW WtE project at Lakhodair landfill site would be the 1st of its kind which is under development stage
- 60 MW WtE power project at Sundar near Lahore would be launched shortly by PPDB
- Private sector shown keen interest for WtE projects in other cities of Punjab

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Thank you

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Presentation on "Decentralized and Integrated Municipal Solid Waste Management" by Mr. Rahul Teku Vaswani

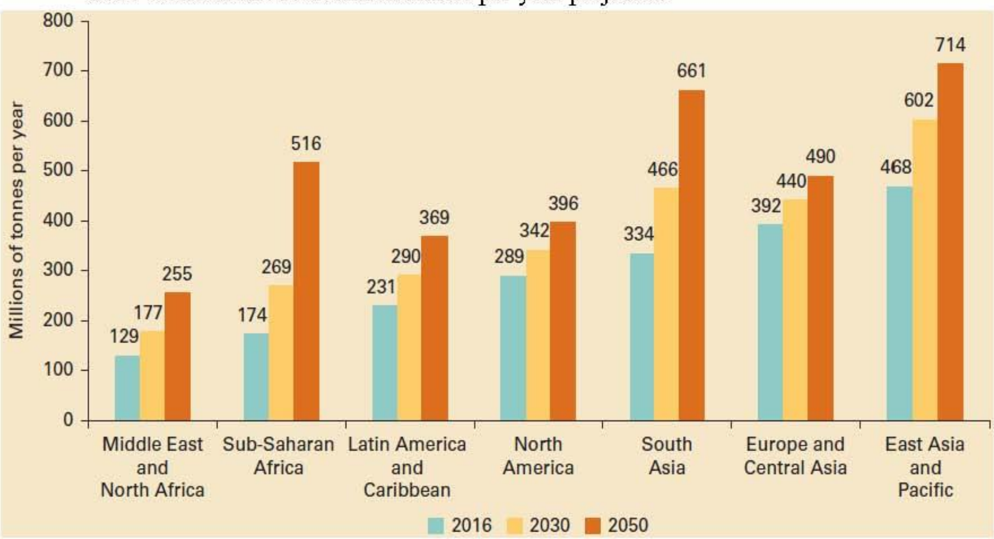
Decentralized and Integrated Municipal Solid Waste Management

Mr. Rahul Teku Vaswani
Sustainability Consultant

SAARC Energy Centre
Webinar on Waste-to-Energy Municipality-level Demonstration Project in Selected Areas of Member States
07 May2019

Global solid waste generation: 2016 to 2050 1

- 2016 world total : 2.01 billion tonnes per year estimated
- 2030 world total : 2.59 billion tonnes per year projected
- 2050 world total : 3.40 billion tonnes per year projected

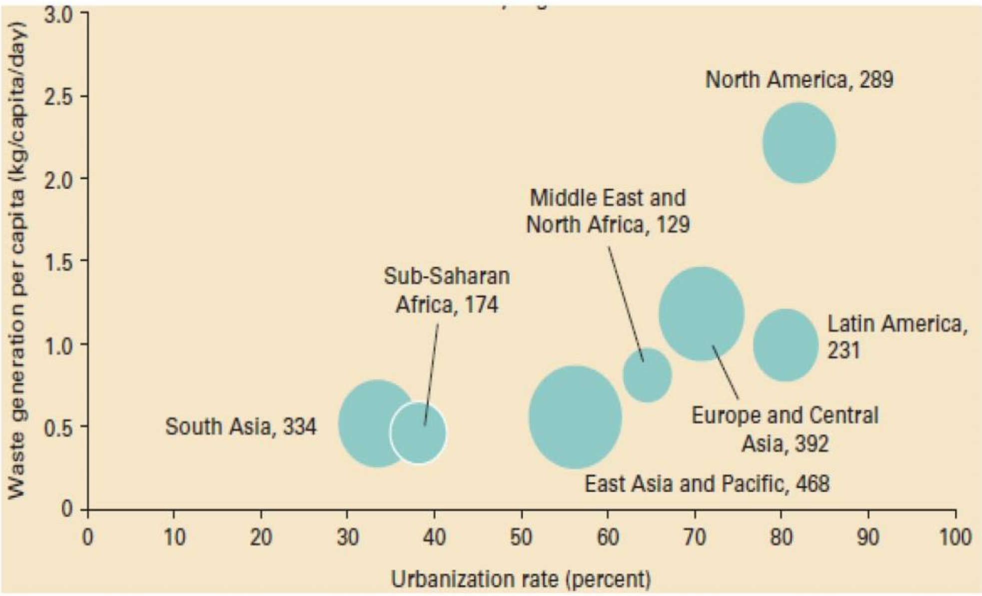


The waste figures are only for municipal sources (residences, public institutions and commercial establishments); the figures do not include construction and demolition waste, hazardous waste, industrial waste, and medical waste.

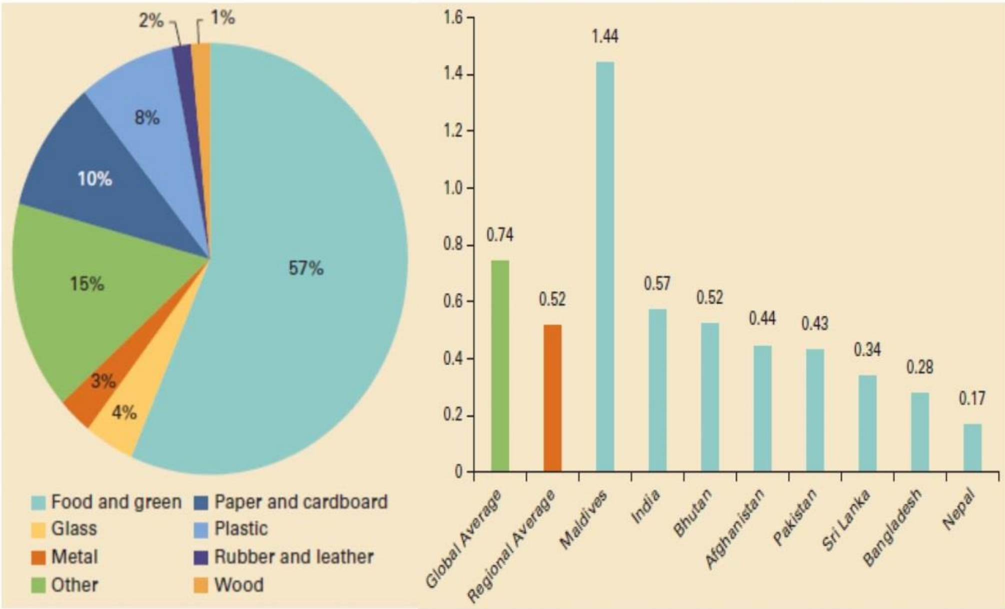
Aspects of solid waste generation

- As ***we*** become ***more affluent***, we not only consume more resources, but also produce ***more waste***.
- As our ***societies urbanize***, we produce ***more waste***.
- As our ***world*** becomes ***more industrialized*** and urbanized, more and ***more of our waste is non-biodegradable***.
- We produce about ***300 million tonnes of plastic every year***, equivalent to the weight of the humans on the planet. [2]
- Municipal solid waste alone produces ***5 percent of global emissions or 1.6 billion tons of CO_2-equivalent.*** This will be ***2.6 billion tonnes of CO_2-equivalent by 2050***. [1]
- Open dumping, landfilling, and incineration, are the main methods of waste management globally. ***In several low-income countries, less than half of municipal solid waste is collected***.
- Our global oceans are now becoming the largest unmanaged waste dump. It is estimated that ***by 2050, there will be more plastic in oceans than fish (by weight).***[3]

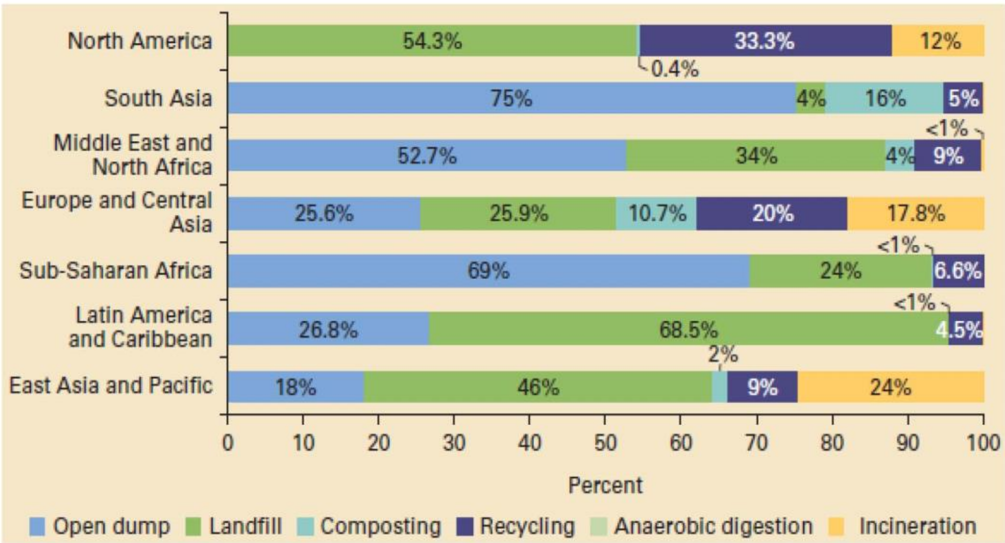
Waste and urbanization regional distribution (2016) [1]



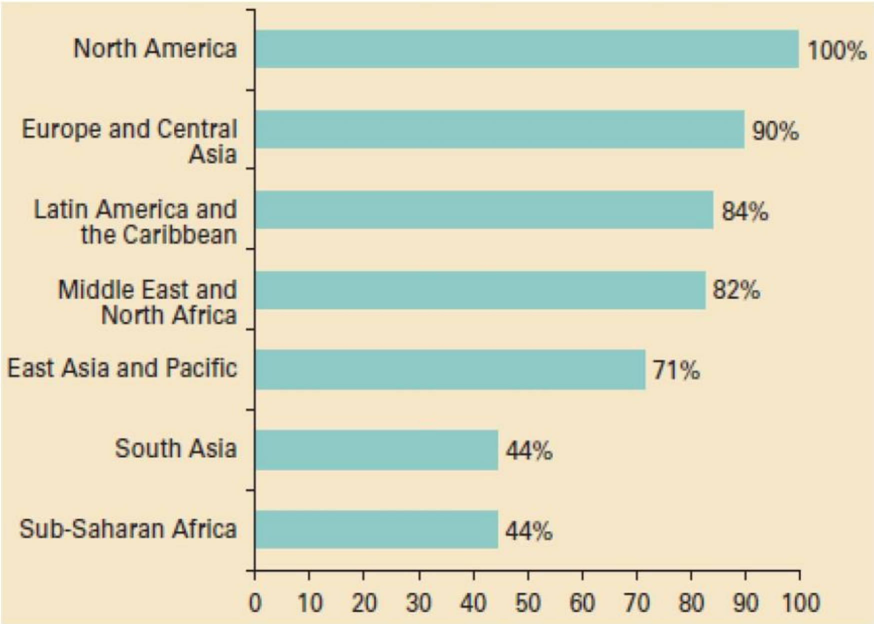
South Asia: solid waste generation (kilogram/person/day) and waste composition (2016) [1]



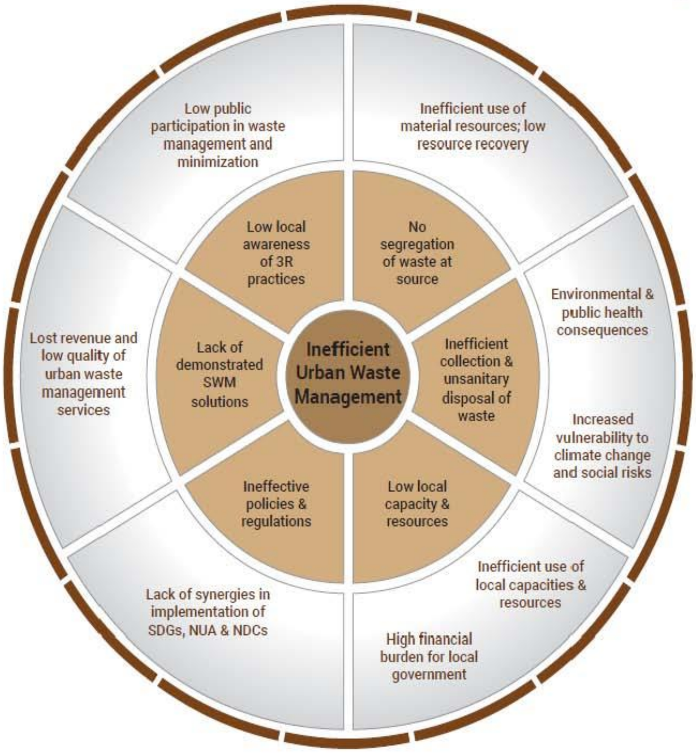
Solid waste disposal/management methods by region (2016) [1]



Solid waste collection rates by region (2016) [1]



Urban solid waste management challenges [4]



Political issues related to waste management

- SWM is seen as difficult/untenable, with unclear entry points
- Lack of skilled personnel in governments with knowledge of developing useful policies and regulations, and multi-stakeholder partnerships
- No clear analysis of potential economic gains from improving waste recovery and mitigation, and of long term societal costs from not sustainably managing waste
- No clear information of locally appropriate solutions for waste management (low cost, low technology, decentralized)
- Lack of financial resources and technical or managerial capacity (in low income and lower middle income countries)
- Lack of private interest in investing in waste recovery due to no enabling policy and regulatory environment

The waste problem cannot be solved 'at the last minute' or by 'business-as-usual' approach; it requires integrated planning, with a multi-stakeholder approach, capacity building activities, and clear short and long term goals.

Social-economic issues related to waste management

- Grave ongoing health impacts from air, water, and soil pollution due to unsustainably managed waste
- Poor people are most affected – they live close to or work on open dumpsites
- Significant ecological and economic resources being lost in unrecovered waste (especially in the organic fraction of waste)
- High present and future costs to society – waste collection and disposal, health treatment, environmental remediation, strengthening of social-ecological resilience, climate change mitigation and adaptation
- Lack of public awareness of and participation in 3R (Reduce, reuse, recover/recycle; in addition refuse & redesign products)
- Private sector investment is low due to unfavorable policy environment
- Unsustainable waste management inhibits local and national efforts to develop sustainably (SDGs, NDCs, NUA)

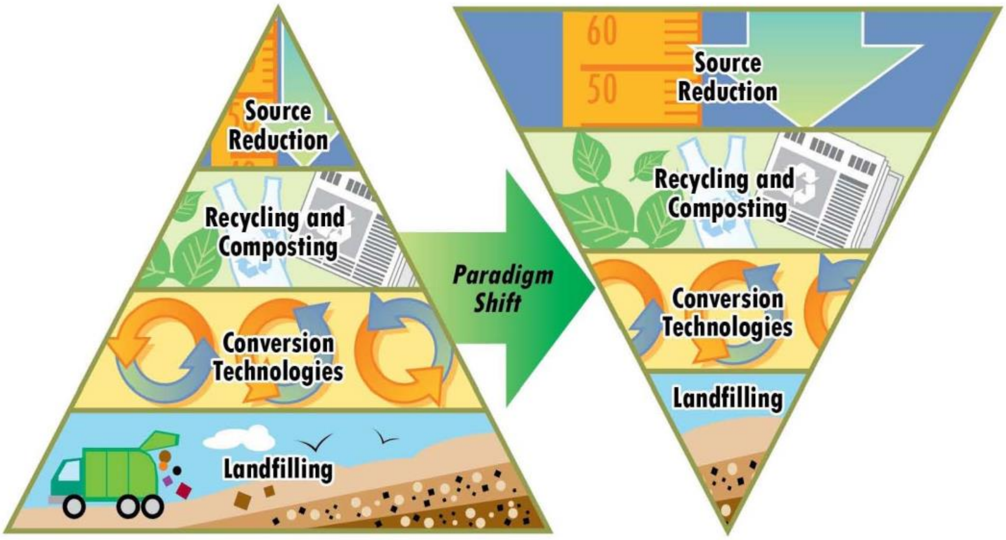
People are the consumers of resources, designers of products, and the producers of waste. Their awareness building and participation is essential to SWM.

Technological issues related to waste management

- Applied technologies are often not locally appropriate and result in large trade-offs
- Focus is on large end-of-pipe solutions – collect and dump or burn – not on decentralized solutions that recover value and reduce waste at source
- No focus on building awareness among waste generators to reduce waste at source or participate in 3R practices
- Technology transfer (North-South-South) can be costly and entail outdated or unsustainable solutions
- No local capacity building of waste managers to efficiently manage/operate the technology, which increases dependency on solutions providers and increases costs/failure rates
- Planning for technological applications does not focus on enhancing local circular economy and social-ecological resilience

Waste management technologies should be locally appropriate and generate local employment and revenue; the local government should have the capacity to assess and efficiently use technologies to recover ecological and economic value.

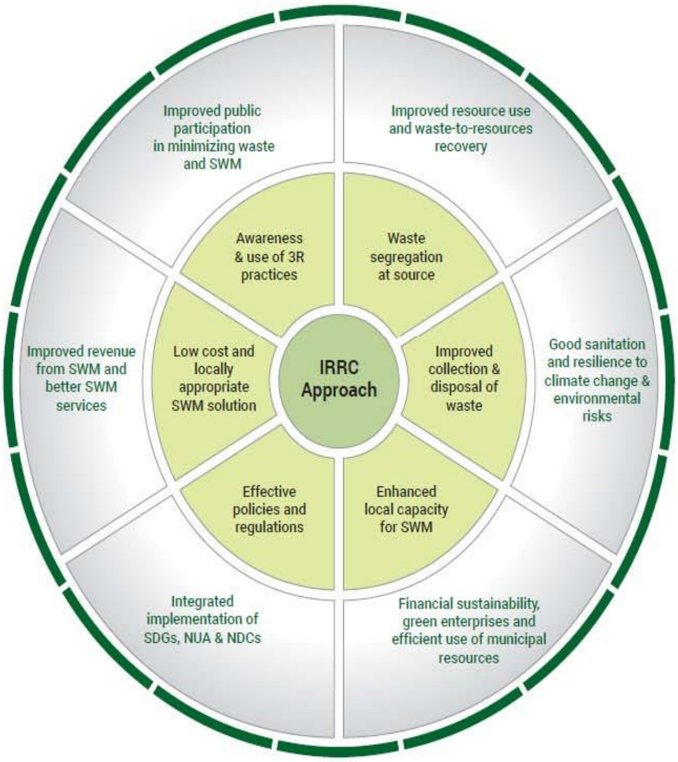
Paradigm shift in solid waste management [5]



Hierarchy of Preferred Solid Waste Management Strategies

Paradigm Shift for the 21st Century

Solid Waste Management - an integrated and multi-stakeholder approach [4]



IRRC and SDGs [4]

Different partners – Different resources

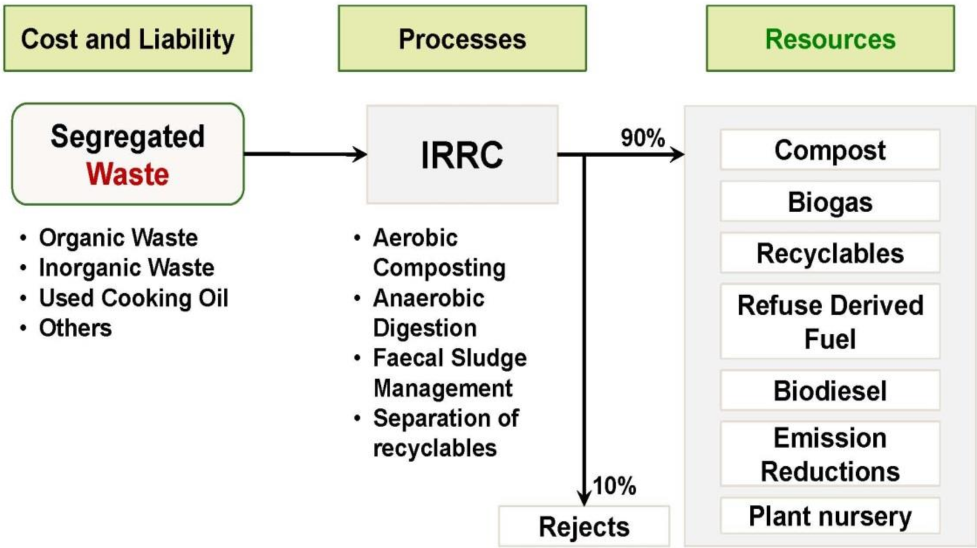
Community	*Municipal/Provincial*	*National/International*
Households • Separated waste	**Municipal government** • Regulatory power • Public funds, resources • Waste collection	**National government** • Regulatory power • Market intervention • Public funds, resources
Civil society organization • Community access		
Ward governments • Community trust	**Waste company** • Facility operations	**Multilateral and bilateral development agencies** • Networking • Technical knowledge • Climate financing
Waste pickers • Access to waste • Market knowledge	**Provincial government** • Regulatory power	

IRRC: A pioneering solution

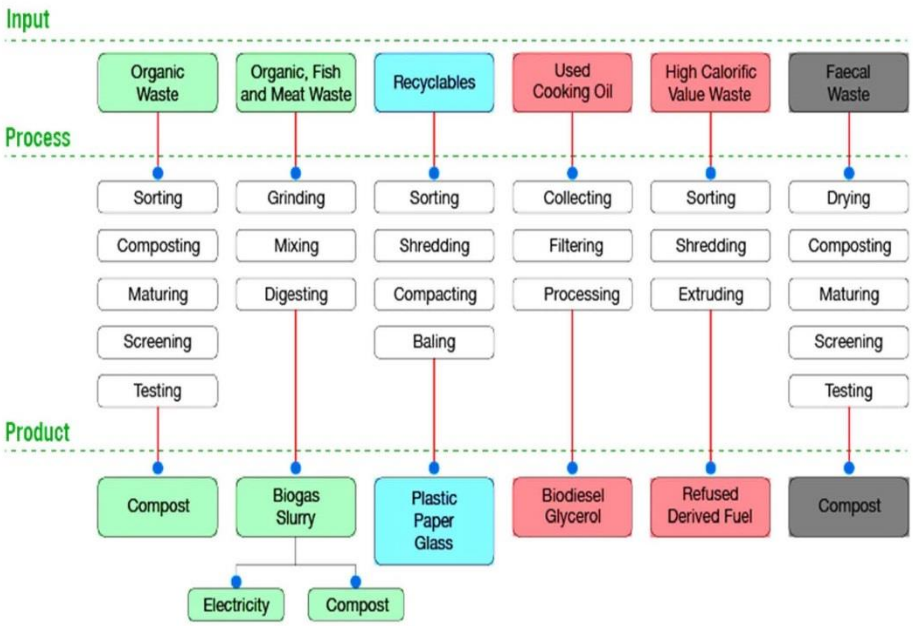
- An **Integrated Resource Recovery Center (IRRC)** is a recycling facility where a significant portion (80-90%) of waste can be processed in proximity to the **source** of generation, and in a **decentralized** manner. The IRRC concept is based on the reduce, reuse and recycle (3R) principles
- The **Integrated Resource Recovery Center** model was developed by Waste Concern, an NGO based in Dhaka
- The model is **cost-effective, affordable, low-tech and community-based**, and allows transforming waste into various types of resources



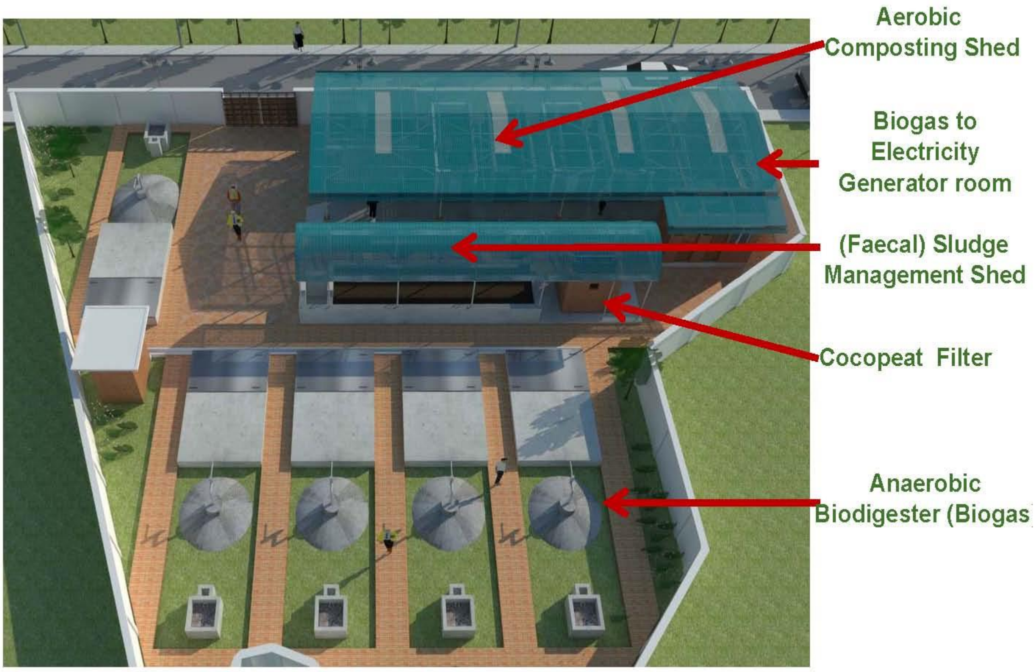
IRRC: Turning Waste into Resources [6]



IRRC material flows [6]



IRRC: Aerial view 6



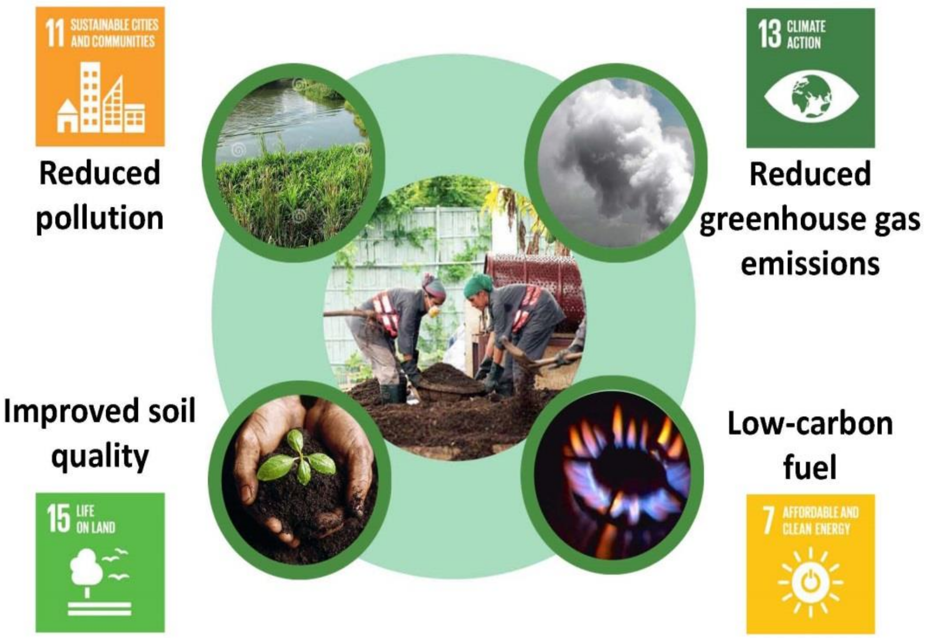
IRRC: Aerial view 6

IRRC: Aerial view [6]

Economic benefits from IRRCs

Social benefits from IRRCs

Environmental benefits from IRRCs



Capital and Operational Estimates for IRRCs [7]

Activity	IRRC with composting and recyclables	IRRC with Anaerobic Digestion (biogas)
Land requirement	150-200 m^2 per ton of waste	400-500 m^2 per ton of waste
Waste required	High quality organic waste required; cost of segregation	High quality organic waste required; cost of segregation
Technical training & capacity building for establishing policies and programs	USD 5,000 to USD 10,000 per 1 to 2 tons of waste	USD 5,000 to USD 10,000 per 1 to2 tons of waste
Community awareness building, & waste separation advocacy programs	USD 5,000 to USD 10,000 per 1 to 2 tons of waste	USD 5,000 to USD 10,000 per 1 to2 tons of waste
Permits, surveys, assessments	USD 10,000 to USD 15,000	USD 10,000 to USD 15,000
Establishment of IRRC (CAPEX)	USD 20,000 to USD 30,000 per ton of waste	USD 30,000 to USD 40,000 per ton of waste
Operation of IRRC (electricity, waste, staff, maintenance) (OPEX)	USD 2,000 to USD 3,000 /ton/year (about 10% of CAPEX)	USD 3,000 to USD 4,000 /ton/year (about 10% of CAPEX)

Economic Benefits of IRRCs (composting only)

Benefit	Type	Value (US$)		
		Banglades h	Sri Lanka	Viet Nam
Job creation: additional income for waste-pickers employed	Social/Economic – Public & Private	3.76	3.00	N/A
Cost savings for the municipality for avoided landfilling of waste	Economic – Public	11.68	28.75	34.85
Savings in chemical fertilizer use (25% reduction)	Economic/Environ-mental – Private & Public	4.85	1.13	10.54
Savings in subsidy to chemical fertilizers	Economic – Public	2.07	2.74	N/A
Increase in crop yields	Economic – Private & Public	24.55	21.52	46.71
	TOTAL	46.91	57.14	92.10

All values are in USD, for composting of 1 ton of organic waste; *Source: ESCAP and Waste Concern*

Sources of information

[1.] Kaza, Silpa, Lisa Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 2018. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. Urban Development Series. Washington, DC: World Bank. doi:10.1596/978-1-4648-1329-0. License: Creative Commons Attribution CC BY 3.0 IGO

[2.] United Nations Environment Progamme. 2018. Access here: https://www.unenvironment.org/interactive/beat-plastic-pollution/

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