Unlocking Value of Sludge: Landscape Assessment and Pathways towards circularity

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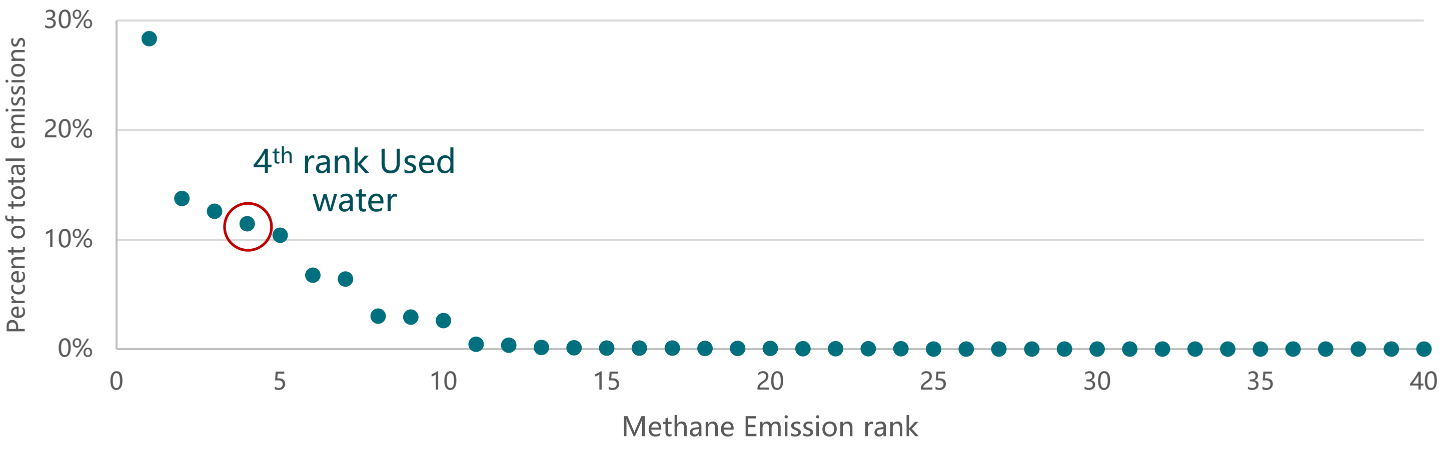
Photo Source: Author's Work

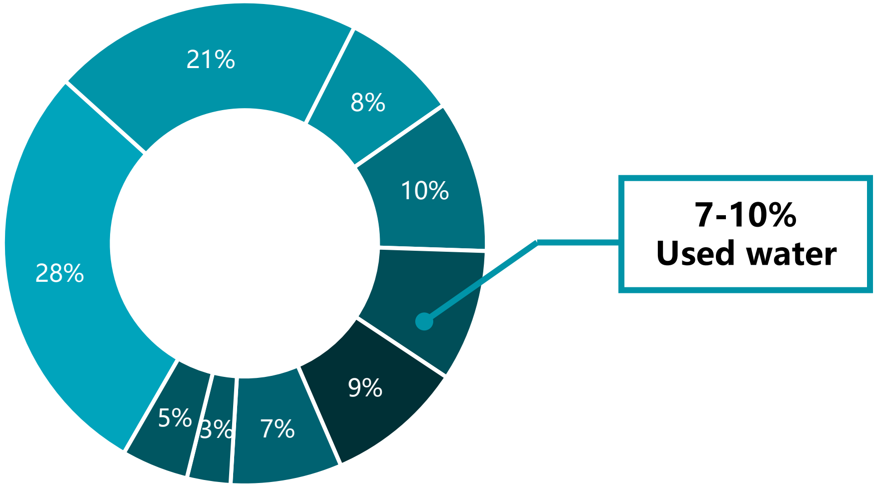
CWAS CENTER FOR WATER AND SANITATION | CRDF CEPT RESEARCH AND DEVELOPMENT FOUNDATION | CEPT UNIVERSITY

Methane Emissions from Domestic Used water in India: Trends & Significance

Percent of total emissions



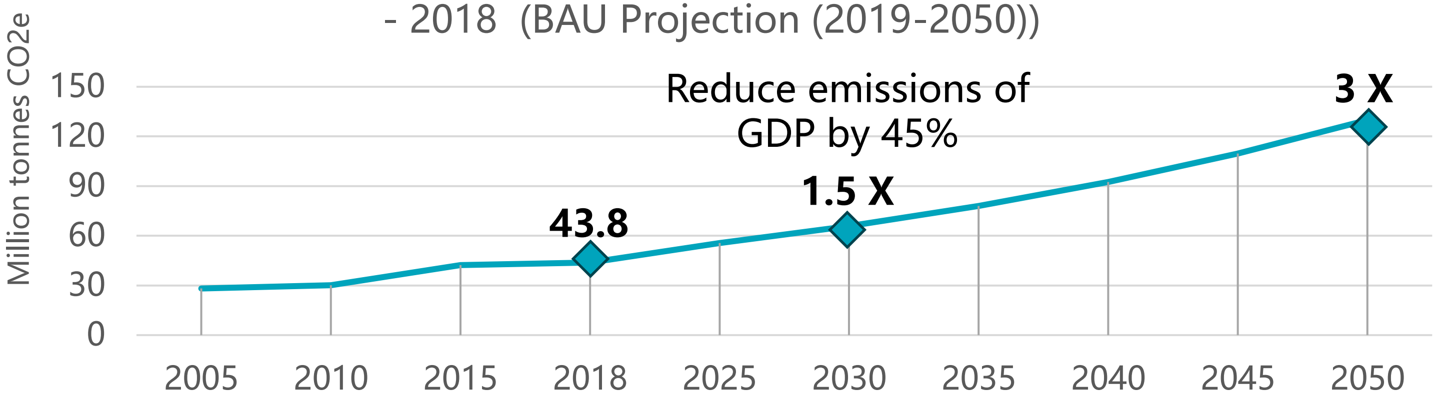
Global Anthropogenic CH4 Emissions



Source: Adapted from Cleveland, C. (2025, January 13). *Global anthropogenic methane emissions, 1970-2022*. Visualizing Energy

Methane Emission from Used water

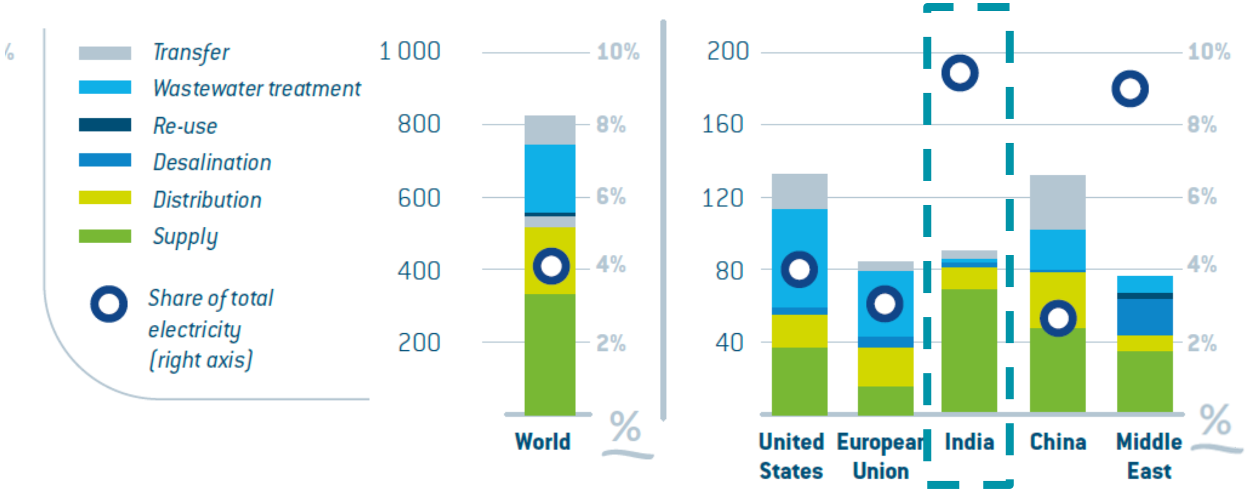
National Trend of CH4 emissions from domestic Used water, 2005 - 2018 (BAU Projection (2019-2050))



Source: GHG Platform India, 2022. Waste Sector GHG Emissions

Used water sector accounted for 4% of global electricity consumption in 2014

Electricity consumption in the water sector by process and region, 2014



Source: Adapted from BEE situational survey and CEA report and author analysis, 2016 & Mainstreaming energy efficiency in urban water and Used water management in the wake of climate change

≈

Power Consumption

5,500 GWh

annually

Source: Author's Analysis

Annual Power Supply

1.1 M

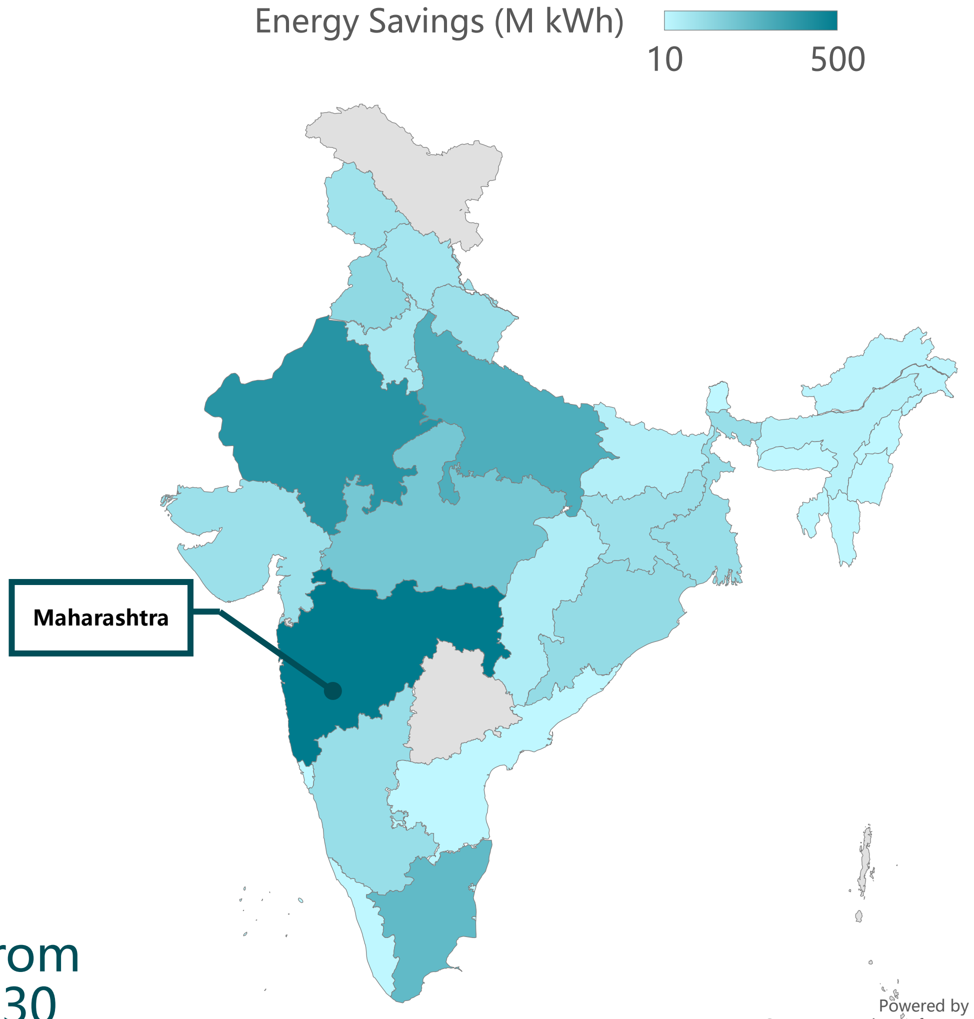
Households

50%

power capacity from non-fossil by 2030

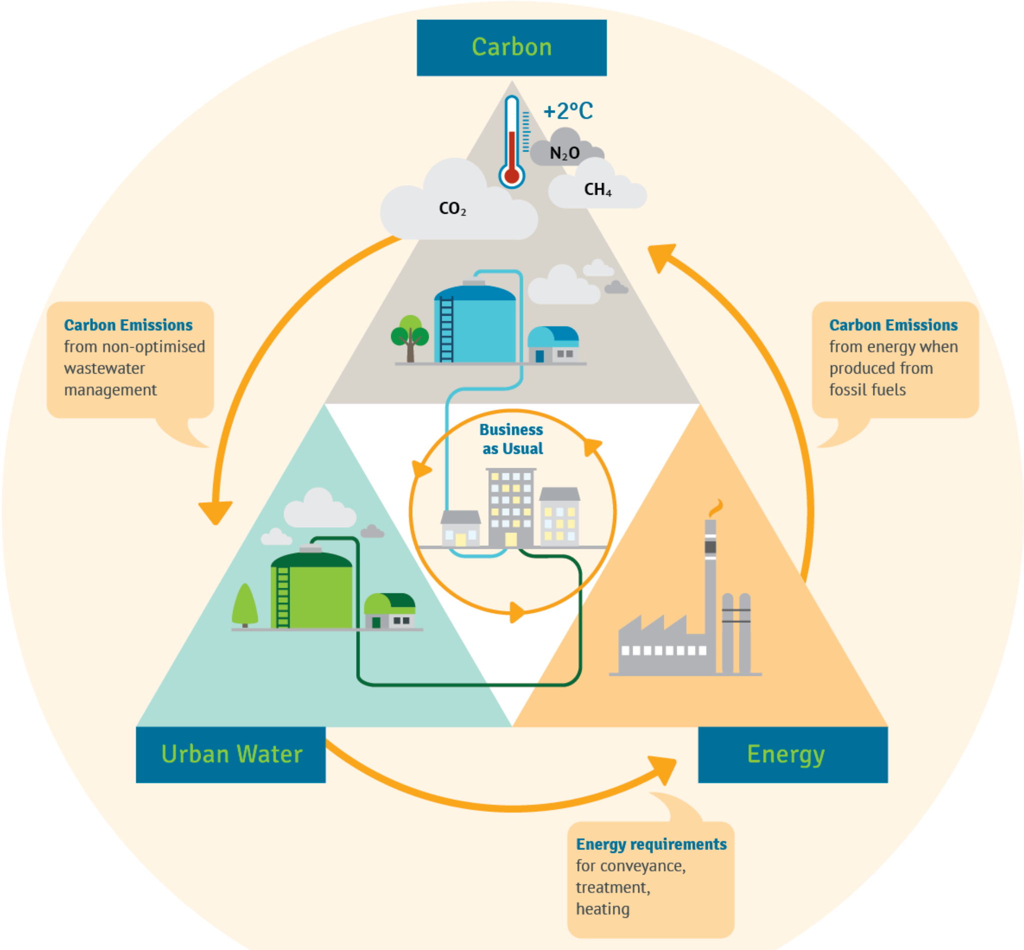
Source: United Nations Framework Convention on Climate Change, 2022

Potential energy savings across states in water utility

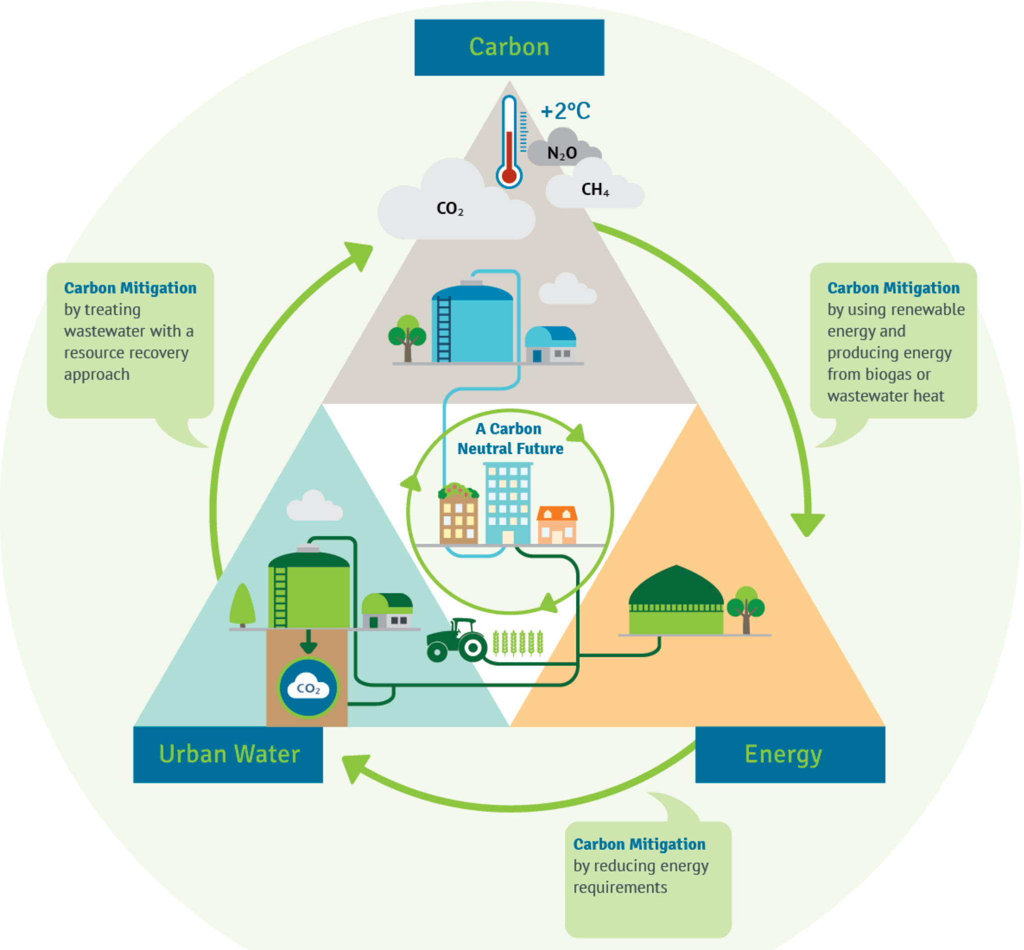


Source: Adapted from BEE situational survey and CEA report and author analysis, 2016 & Mainstreaming energy efficiency in urban water and Used water management in the wake of climate change

Link between urban Used water and emissions & Resource recovery



Business as usual aggravating the impacts of climate change



Low-carbon utilities for a carbon-neutral future

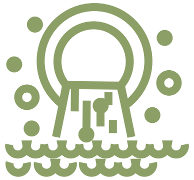
Source: Yan, X., Liu, X., He, L., & Bai, X. (2024). Greenhouse gas emissions from sanitation and Used water management: A global perspective. Journal of Water and Climate Change, 15(4), 1797–1814.

Liquid waste is always prioritized under circular economy

"The circular economy is a model of production and consumption that aims to minimize waste and extend the lifecycle of materials".

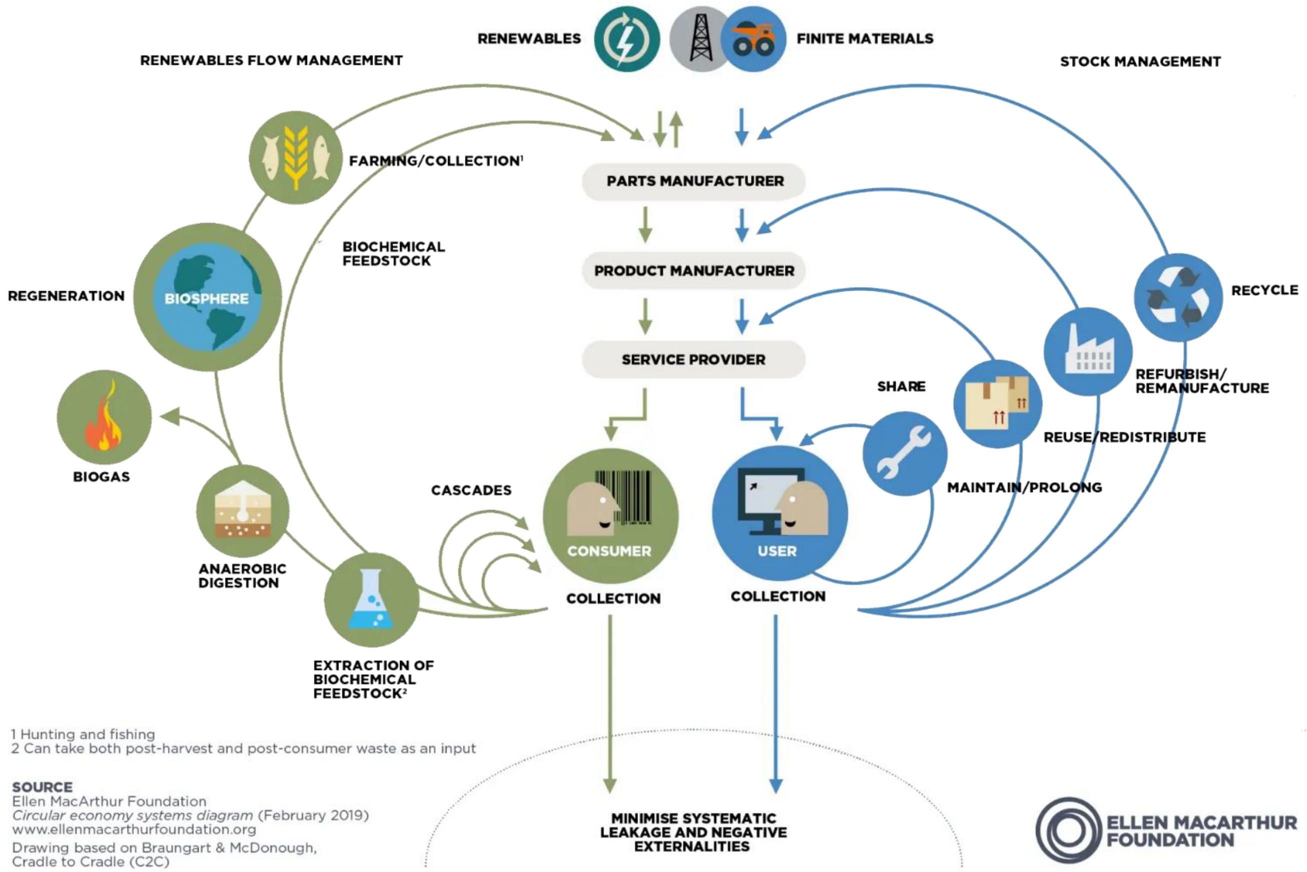
Sludge

- Resource Recovery
- Regeneration



Used water

- Reuse
- Recycle



Eight million tonnes of sludge generated annually in India

Current Situation

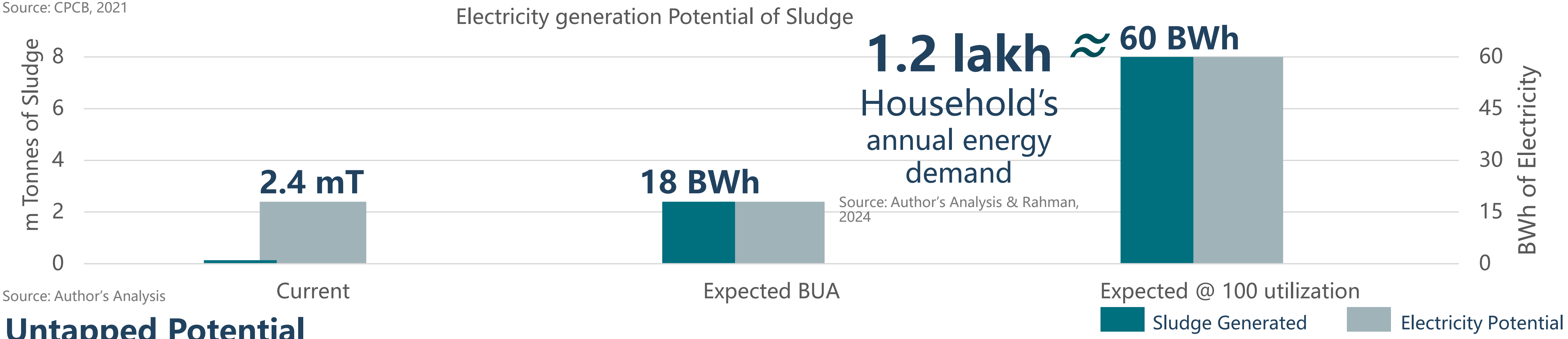
1093
Operational STP

72,368
MLD Sewage generated

8 m tonnes
of Sludge generated annually ≈

28%
Treatment

Source: CPCB, 2021



Source: Author's Analysis

Untapped Potential

₹6,700 Cr
Annual Return
≈
CH_4
82.5 lakh cubic meters / day
≈
50 % reduced dependency on natural gas
+
3,600 metric tonnes / day
≈
4,531 T
Per day of urea
≈
992 Cr
Annually

Source: *Ministry of Housing and Urban Affairs, 2022*

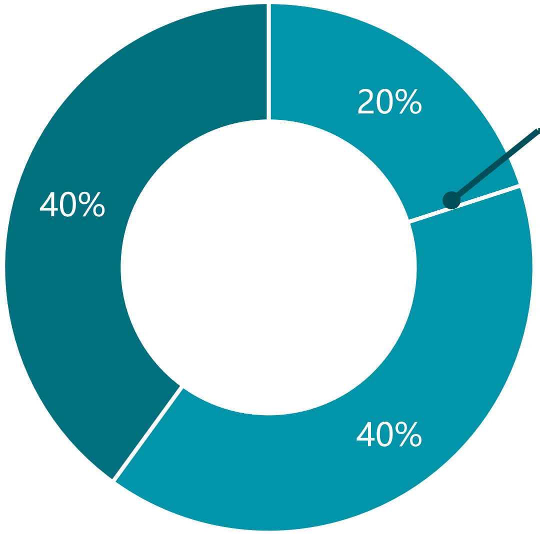
Source: Author's Analysis

Source: *Ministry of Housing and Urban Affairs, 2022*

Source: Ramakrishna, G. (2024, June 6). Sludge for food, food for thought. India Water Portal.

Key Challenges in Sludge Disposal for ULBs

Percentage Share of O&M cost based on technology



20-60% Sludge Management

Leading to 40% of emissions from Used water

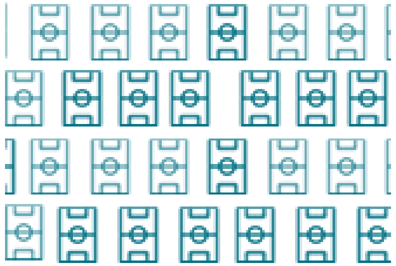
Source:Netsol Water. (n.d.). What are the disposal costs of sludge in India?

18% Treatment

Source: CPCB, 2021

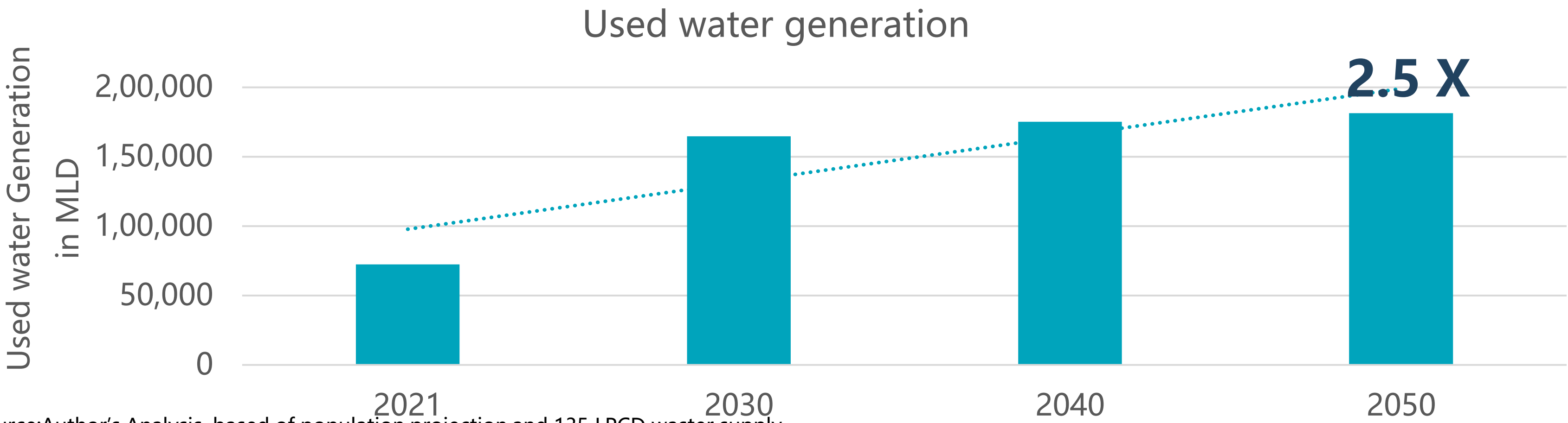
≈ **6.5 m tonnes** of Sludge disposed of annually

Source: Author's Analysis



≈ **340** (450 acres) Football Fields

Source: *Ministry of Housing and Urban Affairs, 2022*



≈ **1675** (2,217 acres) Football Fields (if not managed)

Source: Author's Analysis

Source:Author's Analysis, based of population projection and 135 LPCD waster supply

Current Sewage treatment regulations lack standards for sludge management in India

Sewage Treatment Regulations in India — Central and State Guidelines

National Green Tribunal

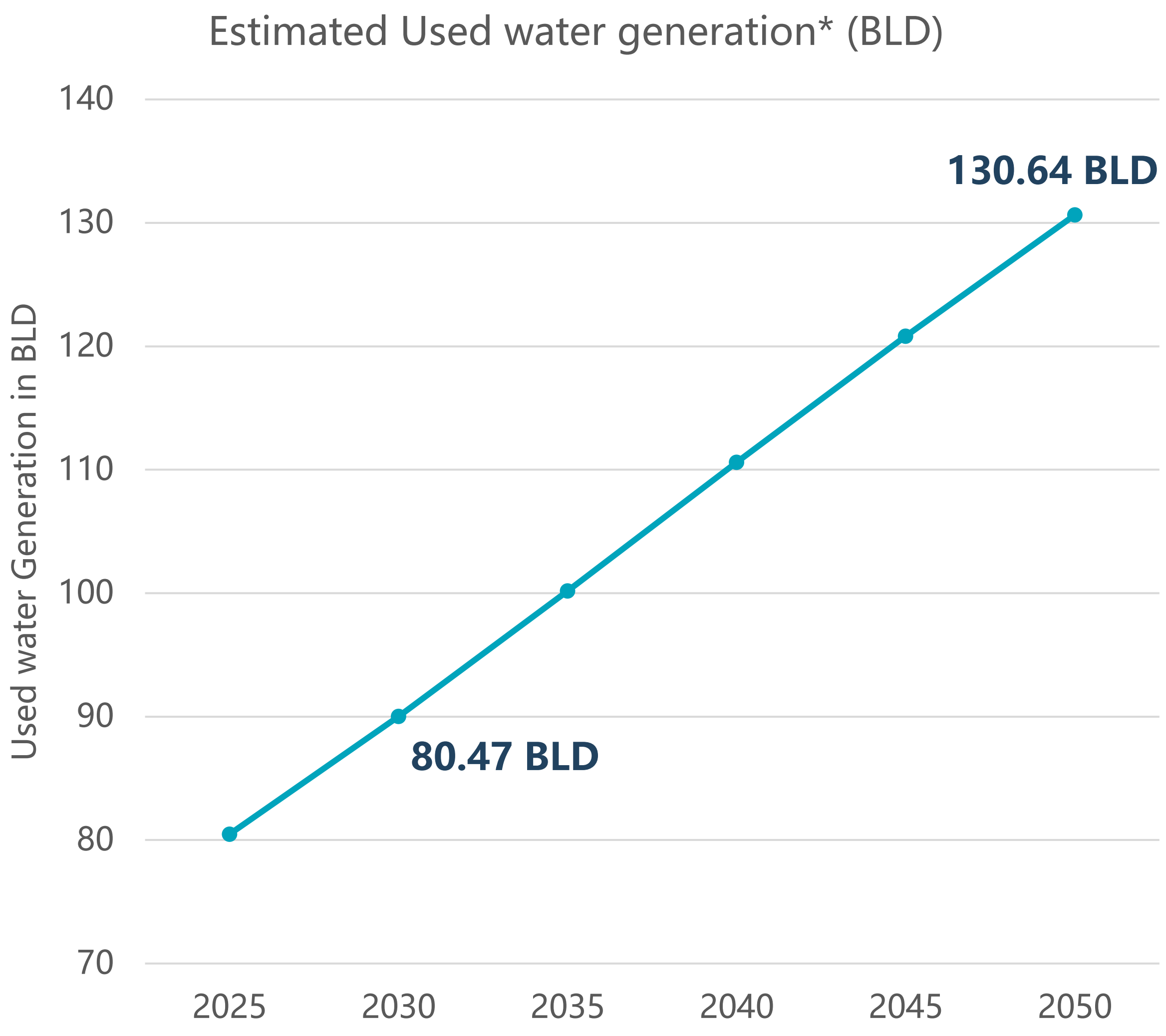
CPCB

Ministry of Environment, Forest & Climate Change

S. No	Parameter	NGT	CPCB	MoEF&CC
		Class I Cities	Class I Cities	Class I Cities
1	Outfall pH Range	5.5-9.0	6.5–8.5	6.5-9.0
2	Biochemical Oxygen Demand (BOD)	30 mg/L	<10 mg/L	Not Specified
3	Chemical Oxygen Demand (COD)	100 mg/L	<50 mg/L	Not Specified
4	Total Suspended Solids (TSS)	30 mg/L	<10 mg/L	Not Specified
5	Total Nitrogen (TN)	15 mg/L	<5 mg/L	Not Specified
6	Total Phosphorus (TP)	1 mg/L	Not Specified	Not Specified
7	Faecal Coliform (FC)	Permissible:1,0 MPN/100 mL	<100 MPN/100 mL	Not Specified

Source: NGT 2019 Order, CPCB guidelines, MoEF&CC: A Complete Guide to Revised STP Effluent Discharge Standards 2017

STPs upcoming in the ULBs under national Flagship Programs



Source:

7,000 MLD

Namami Gange Programme

+

5,791.94 MLD

Additional capacity under AMRUT 2.0

+

4,900 MLD

Additional capacity under SBM 2.0

15 lac Tonnes

of sludge generation annually

Source: Press Information Bureau (PIB), Government of India. (2024). Under Namami Gange Programme, initiatives have been taken for conservation and rejuvenation of river Ganga.

Source: Author's Analysis

Aim : To assess the **landscape and market feasibility** of resource recovery of sludge to sustain resilient sanitation services.

Objective :

- **Review existing resource recovery practices** and other potential products across the sanitation sector with the enabling policy environment.
- **Treatment Technology-wise assessment of methane emissions** and their resource recovery potential of sludge.
- Carrying **out market feasibility to understand possible business models** to boost resource recovery usage potential.
- Recommendations in policy and regulatory frameworks, **to boost the adaptation of sludge potential.**

Scope:

- This study focuses on cities with populations ranging from **1- 5 lakh**
- The study exclusively focuses on **sewage sludge** as the primary component of domestic liquid waste.

Hypothesis :

A sludge-based resource recovery business model can make sewage treatment plants financially self-sufficient (based on the technology of STP).

Methodology

Review existing resource recovery practices and other potential products across the sanitation sector with the enabling policy environment.

Document the current recovery of energy (biogas), and nutrients

Identify Potential Value-Added Products

Review national/state policies, guidelines, and schemes that support or hinder resource recovery and reuse

Treatment Technology-wise assessment of methane emissions and their resource recovery potential of sludge.

Collect data on sludge, composition, and plant operations

Estimate the methane yield by technology, including recovery and energy potential

Compare technologies by emissions, energy, and nutrient recovery

Carrying **out market feasibility to understand possible business models** to boost the resource recovery usage potential.

Interview end users (e.g., farmers, industrial units) for willingness to pay and quality expectations

Study existing business models that already monetize resource recovery

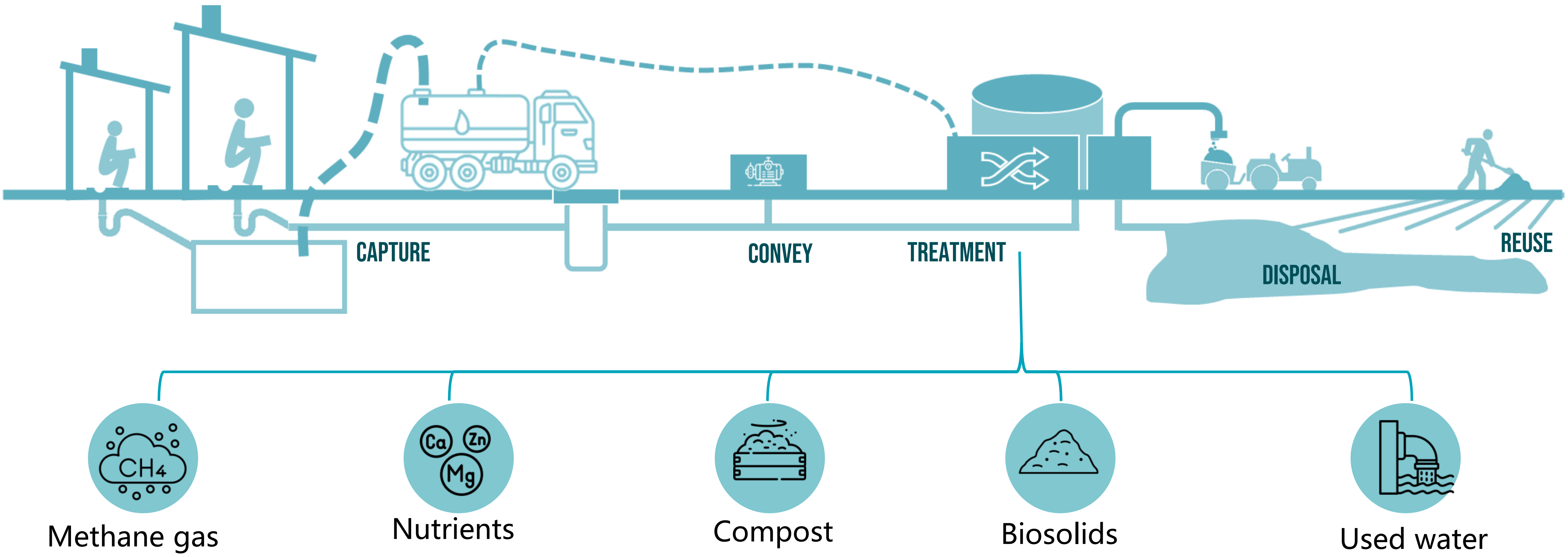
Estimate CAPEX, OPEX, and potential revenue streams

Identify market, technical, environmental, and social risks

Recommendations in policy and regulatory frameworks **to boost the adaptation of the sludge's potential.**

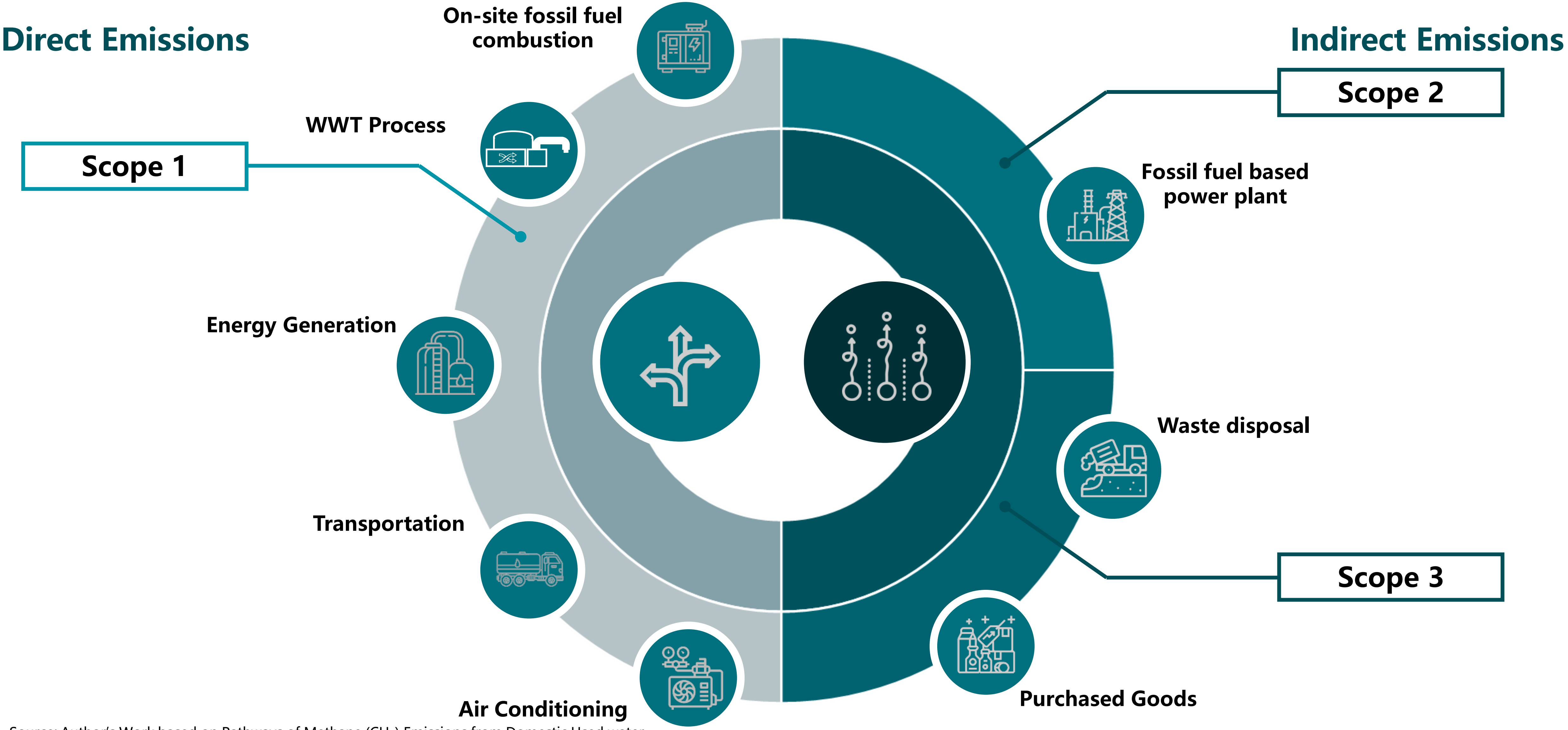
Understanding the resource recovery Potential in Liquid Waste Management

Resource Recovery Potential in Liquid Waste



Source: Author's Work

Pathways of Methane (CH_4) Emissions from Domestic Used water



Source: Author's Work based on Pathways of Methane (CH_4) Emissions from Domestic Used water

Biogas market in India is increasing rapidly

Union Budget 2023-24

$ 4.04 Billion

for move towards **Energy Transition**

5%

CBG mandates to be introduces

Excise Duty

On CBG to be **exempted**

Union Budget 2025-26

$ 2.27 Billion

injection of CBG into city gas distribution networks

20%

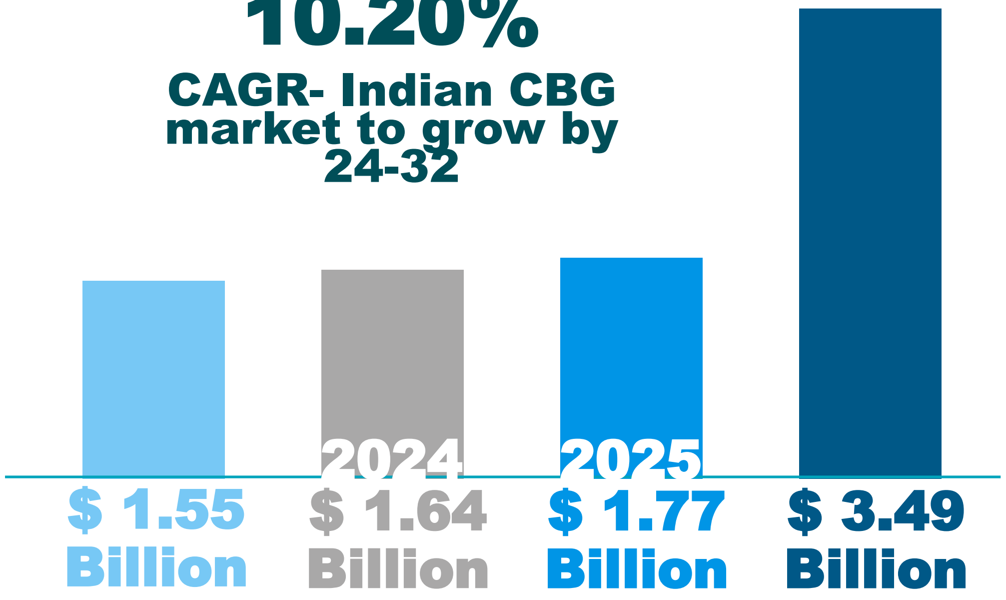
Relegation of fossil fuels

Tax Holidays

Corporate tax holidays specifically for **CBG production**

10.20%

CAGR- Indian CBG market to grow by 24-32



DRIVERS

Abundant Feedstock Availability & Utilization of Waste for Energy Production

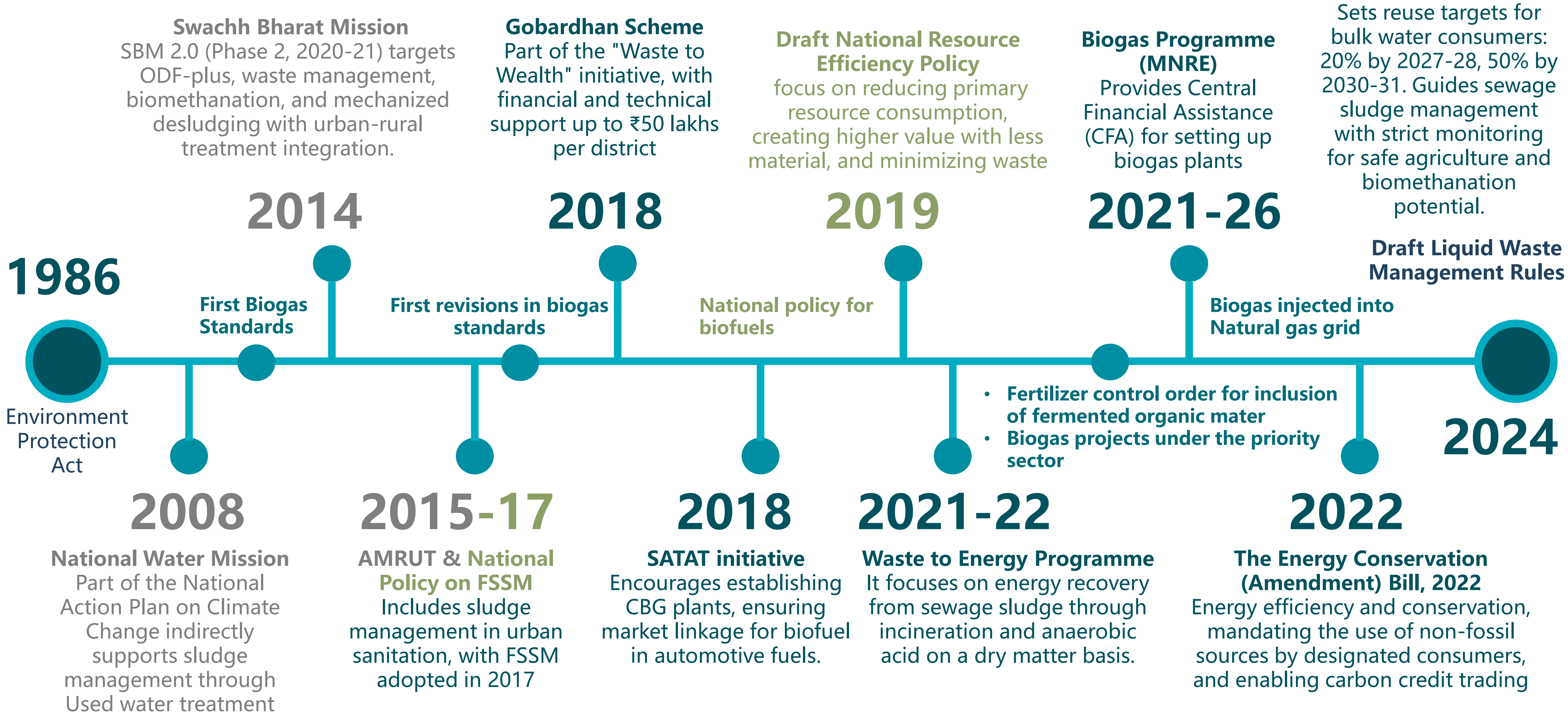
Increasing Energy Demand & Fossil-Fuel Consumption

TRENDS

Government Emphasis On Waste Management Schemes.

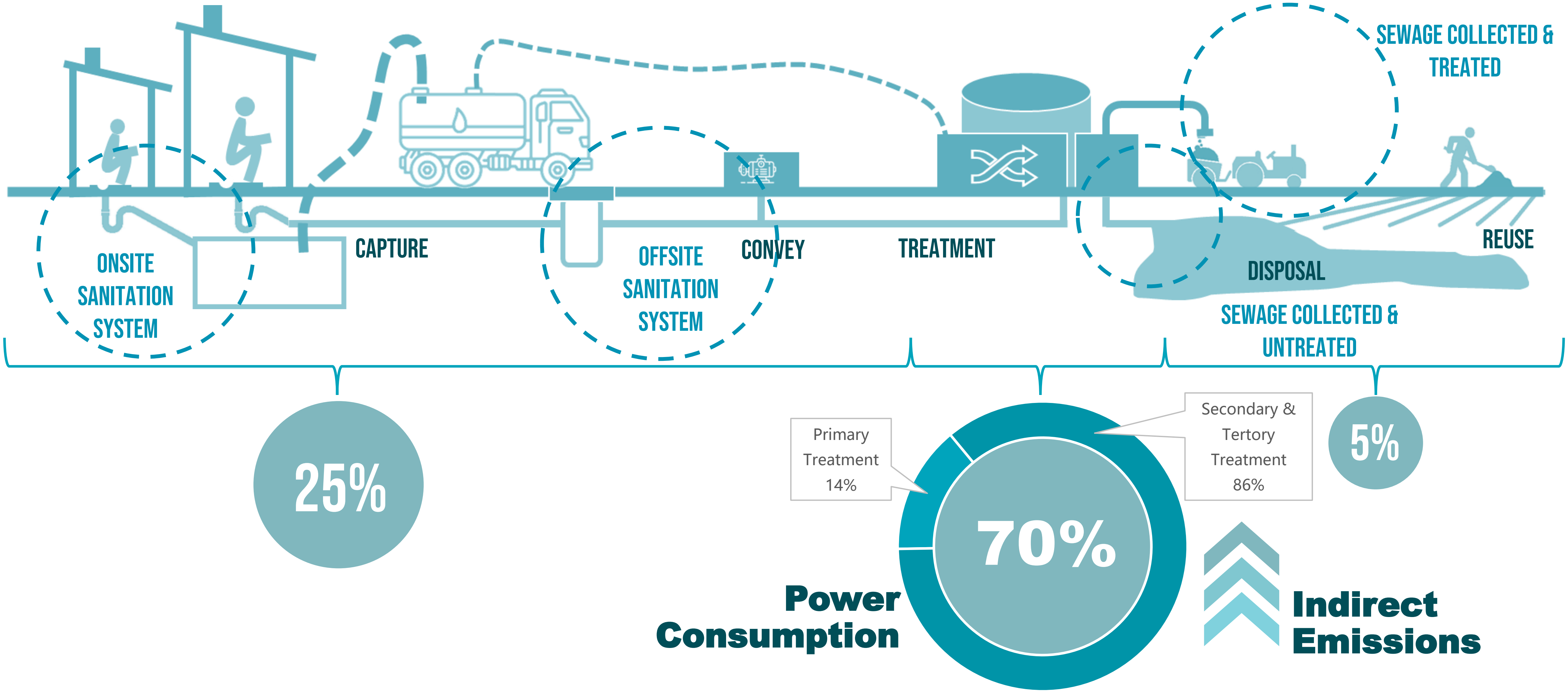
Source: National Budget

India has also recognized sludge as a potential



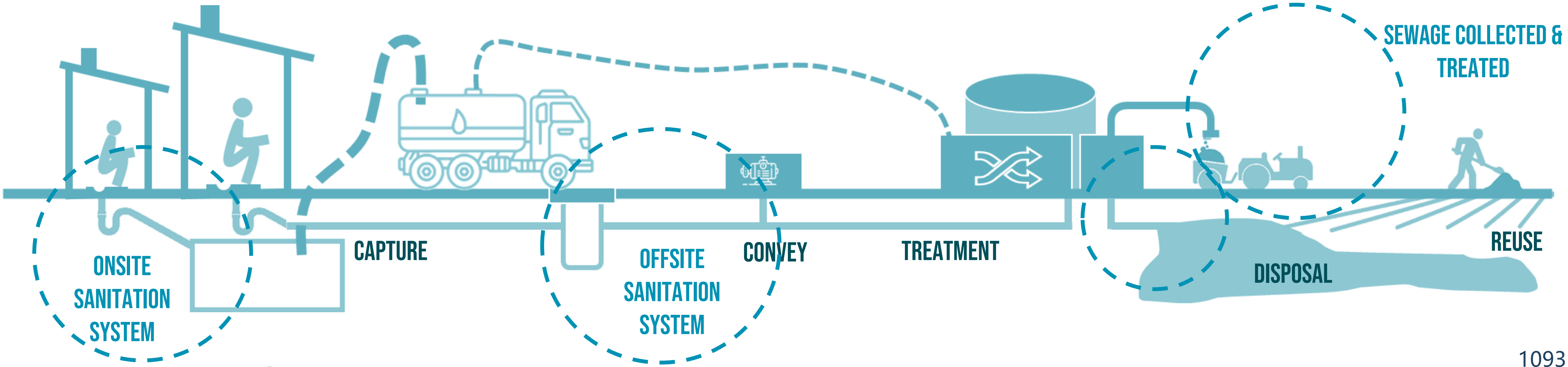
Source: Authors Analysis

The treatment process has the highest power use, causing more indirect emissions



Source: : Feacal Sludge and Used water management in Emergencies- Treatment products, UNICEF website. Sharawat, I., et al. (2020). Analysis of a Used water treatment plant for energy use and emissions. Int. J. Environ. Sci. Technol.

STPs in India and prominent Technologies



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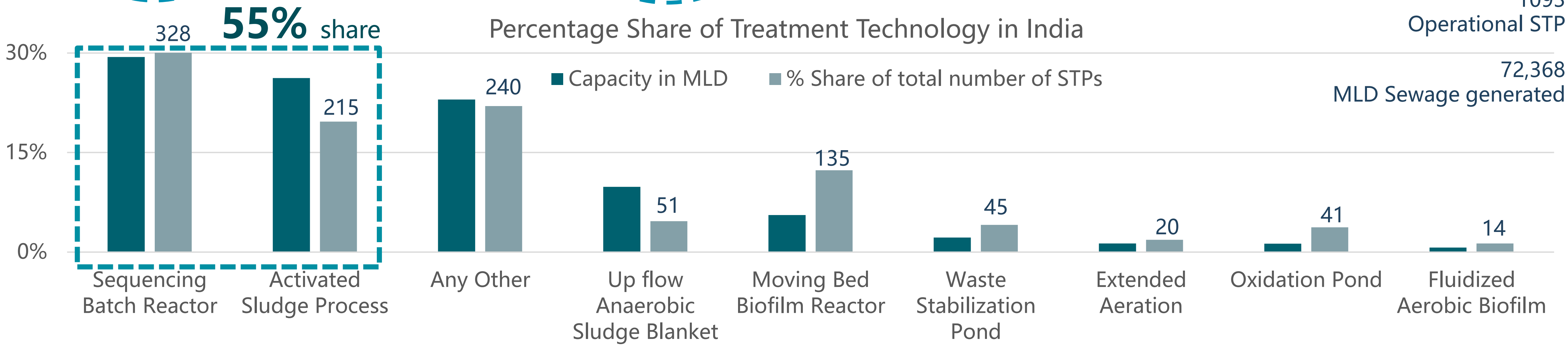
72,368
MLD Sewage generated



Source: *Authors Analysis, National Sample Survey Office. (2019). NSS Report No. 584: Drinking water, sanitation, hygiene, and housing condition in India, Central Pollution Control Board. (2021). Status of sewage treatment in India, 2006 IPCC guidelines for national greenhouse gas inventories: Volume 5 – Waste.*

Energy Requirement and Emissions from different STP Technologies

S. No.	Technology	Processes	Power Consumption (kWh/day/ MLD)	Avg. Power Use	Indirect Emissions (in kgCO2e) annually	Avg. Emissions
1	Activated Sludge Process	Aerobic processes	185.70	Moderate	17.7	Moderate
2	Extended Aeration		-		-	
3	Sequencing Batch Reactor		153.70		14.7	
4	Moving Bed Biofilm Reactor	Hybrid biofilm-based processes	223.70	High	21.25	High
5	Fluidized Aerobic Biofilm		-			
6	Up flow Anaerobic Sludge Blanket	Anaerobic processes	125.70	Low	11.94	Low
7	Waste Stabilization Pond		5.70		0.54	
8	Oxidation Pond		ND		ND	

* These values may differ based on sludge quality

Source: Central Pollution Control Board. (2021). National inventory of sewage treatment plants. Parivesh Bhawan (2012). Sewage sludge-to-energy approaches based on anaerobic digestion and pyrolysis, Renewable and Sustainable Energy Reviews

Resource recovery Potential of different STP technologies

S. No.	Technology	Processes	Volume of Sludge (kg/MLD)	Methane Production	Electricity Potential (kWh/Ton)	Biogas Generation potential (cubic m/ day/ tonne of sludge)
1	Activated Sludge Process		200.4 ± 45	59-64%	~550	~70
2	Extended Aeration	Aerobic processes	-	-	-	-
3	Sequencing Batch Reactor		192.5 ± 42	54-66%	~500	~65
4	Moving Bed Biofilm Reactor	Hybrid biofilm-based processes	181 ± 5.4	57-62%	~500	~63
5	Fluidized Aerobic Biofilm		-	-	-	-
6	Up flow Anaerobic Sludge Blanket		128.5 ± 15	50-60%	-	~40
7	Waste Stabilization Pond	Anaerobic processes	80.5 ± 8.1	35-52%	~300	~30
8	Oxidation Pond		ND	ND	ND	ND

* These values may differ based on sludge quality

Source: Singh, V., Phuleria, H. C., & Chandel, M. K. (2020). Estimation of energy recovery potential of sewage sludge in India: Waste to watt approach. *Journal of Cleaner Production, 271*, 122587., Malpani, S. K. (2024, November 5). Biogas production from sewage sludge. Save the Water.

Nutrient Content of Sewage Sludge vs. Chemical Fertilizers

Nutrient	Raw Sludge (%)	Digested Sewage Sludge (%)	Chemical Fertilizer (%)	References for digested sludge and chemical fertilizer
Nitrogen (N)	4.0-6.0	1.5 - 4.0	10-30	Kumar et al. (2017), EPA (2021)
Phosphorus (P)	2.0-6.0	0.5 - 2.0	5-15	Kumar et al. (2017), Cárdenas-Talero et al. (2022)
Potassium (K)	0.2-1.0	0.5 - 2.5	5-10	Kumar et al. (2017), Zhang et al. (2016), Orner et al. (2022)
Calcium (Ca)	3.0-5.0	1.0 - 5.0	1-5	Ghosh et al. (2024)
Magnesium (Mg)	0.4-1.0	0.3 - 1.0	1-3	Johnson (2016)
Sulphur (S)	0.3-3.0	0.2 - 0.8	10 - 20 (as sulphate)	EPA (2021)
Iron (Fe)	-	0.1 - 0.5	0.05 - 0.5	Kumar et al. (2017), Ghosh et al. (2024)
Zinc (Zn)	-	0.02 - 0.1	0.01 - 0.1	Cárdenas-Talero et al. (2022)
Copper (Cu)	-	0.01 - 0.05	0.01 - 0.1	Zhang et al. (2016)
Manganese (Mn)	-	0.01 - 0.1	0.01 - 0.05	Orner et al. (2022)
Boron (B)	-	0.005 - 0.02	0.01 - 0.02	Johnson (2016)

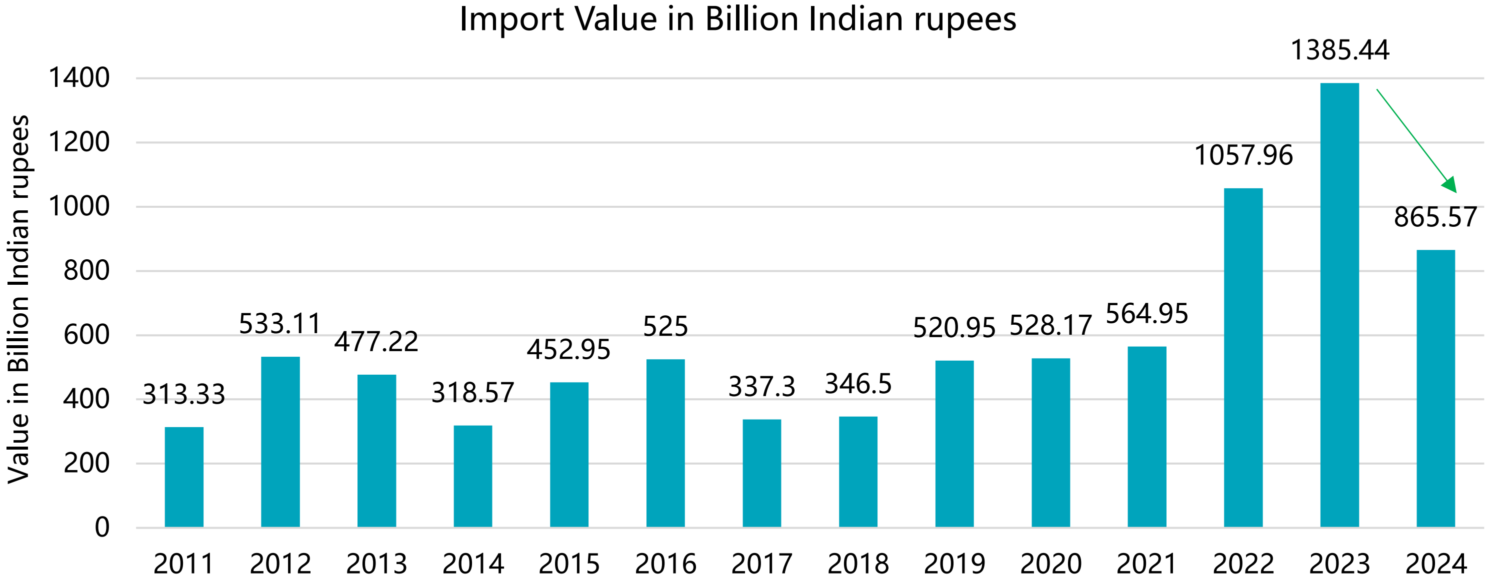
Source: Dewil, Raf & Baeyens, Jan & Roels, Joris & Steene, Boudewijn. (2008). The Distribution of Sulphur Compounds in Sewage Sludge Treatment. ENVIRONMENTAL ENGINEERING SCIENCE. 25. 879-886. 10.1089/ees.2007.0143.

Nitrogen-based fertilizer production by sludge is 50% of the import

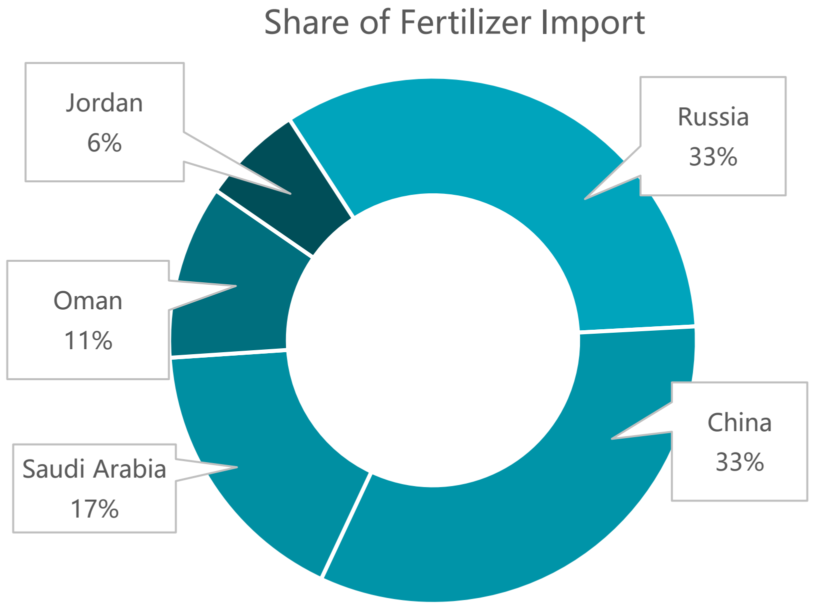
Quantity of N&P contained in Used water generated at present and projected in 2025 (in Lakh Tonnes)				
Year	Component	Weak	Medium	Strong
2021	Nitrogen (total as N)	5.28	10.56	22.45
	Phosphorus (total as P)	1.06	2.11	3.96
2030 (Projected)	Nitrogen (total as N)	6.57	13.14	27.92
	Phosphorus (total as P)	1.31	2.63	4.93

Consumption, Production and Import of N & P (in Lakh Tonnes)								
Year	2018-19		2019-20		2020-21		Average	
Category	N	P	N	P	N	P	N	P
Consumption	179	69	191	77	204	90	191	78
Production	133	46	137	48	137	47	136	47
Import	47	32	52	24	56	25	52	27

Source: World Bank. (2023). India mineral or chemical fertilizers with nitrogen, imports by country, 2023. World Integrated Trade Solution (WITS).



Source: Author's Analysis

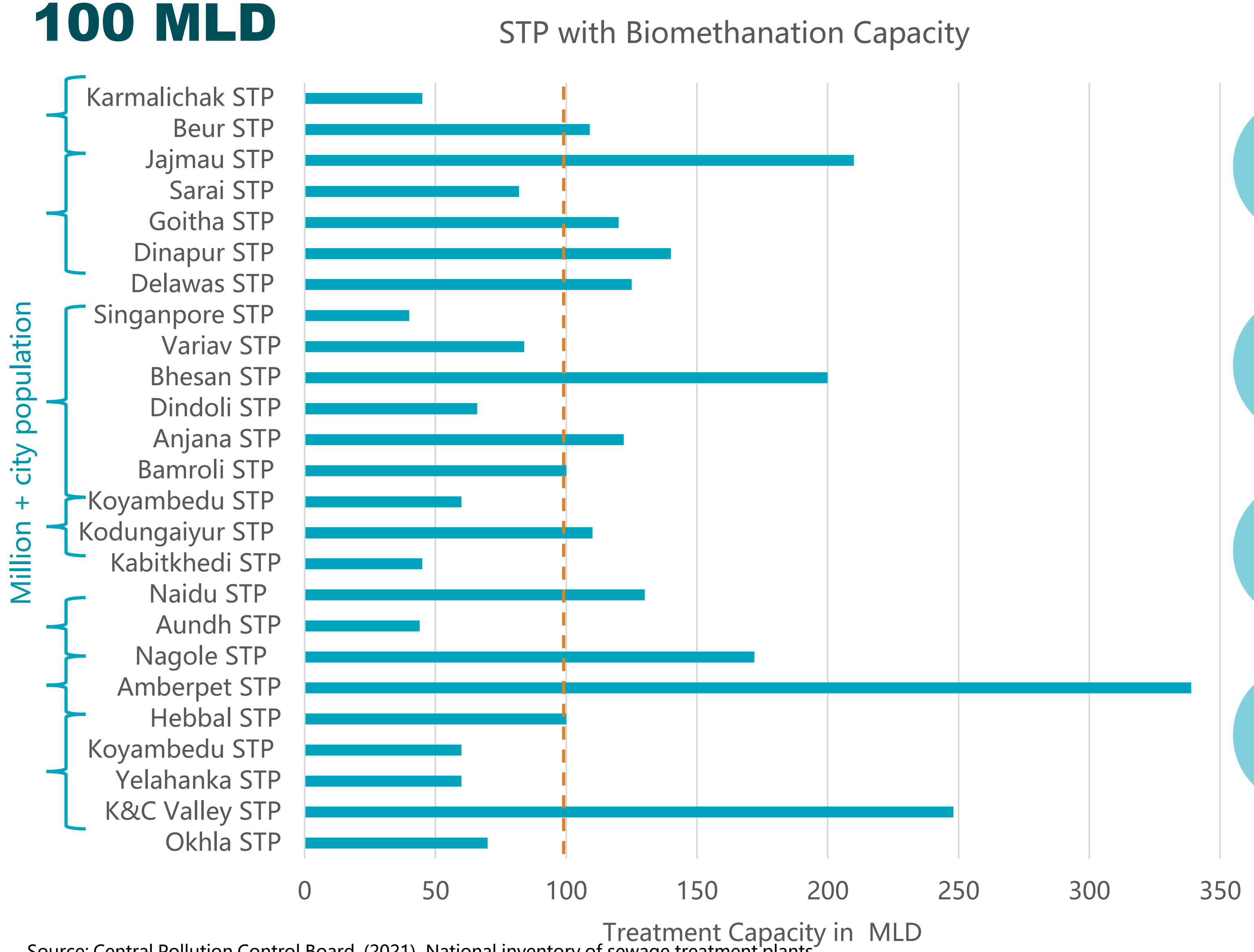


Source: Statista. (2024). Value of fertilizers imported into India from the financial year 2011 to 2024.

Existing Practices

Photo Source: Primary Survey

Over 50% of STPs with methane capture units have a capacity above 100 MLD



Source: Central Pollution Control Board. (2021). National inventory of sewage treatment plants

1093 – STP Operational

23 – Biomethanation plant

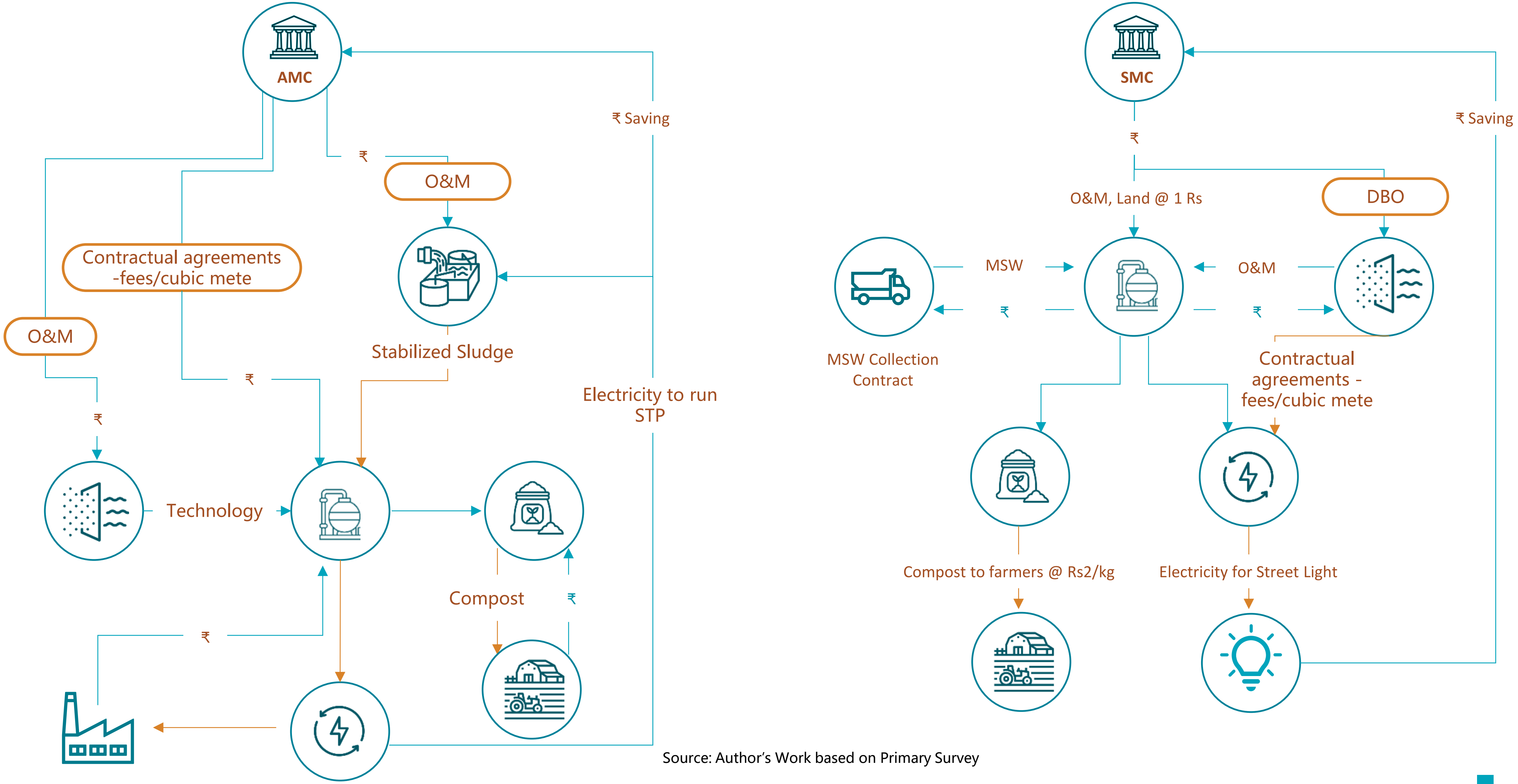
18 – Operational & Generating Power

0 – Power back to the grid

Comparing National Approach- all the projects in large towns

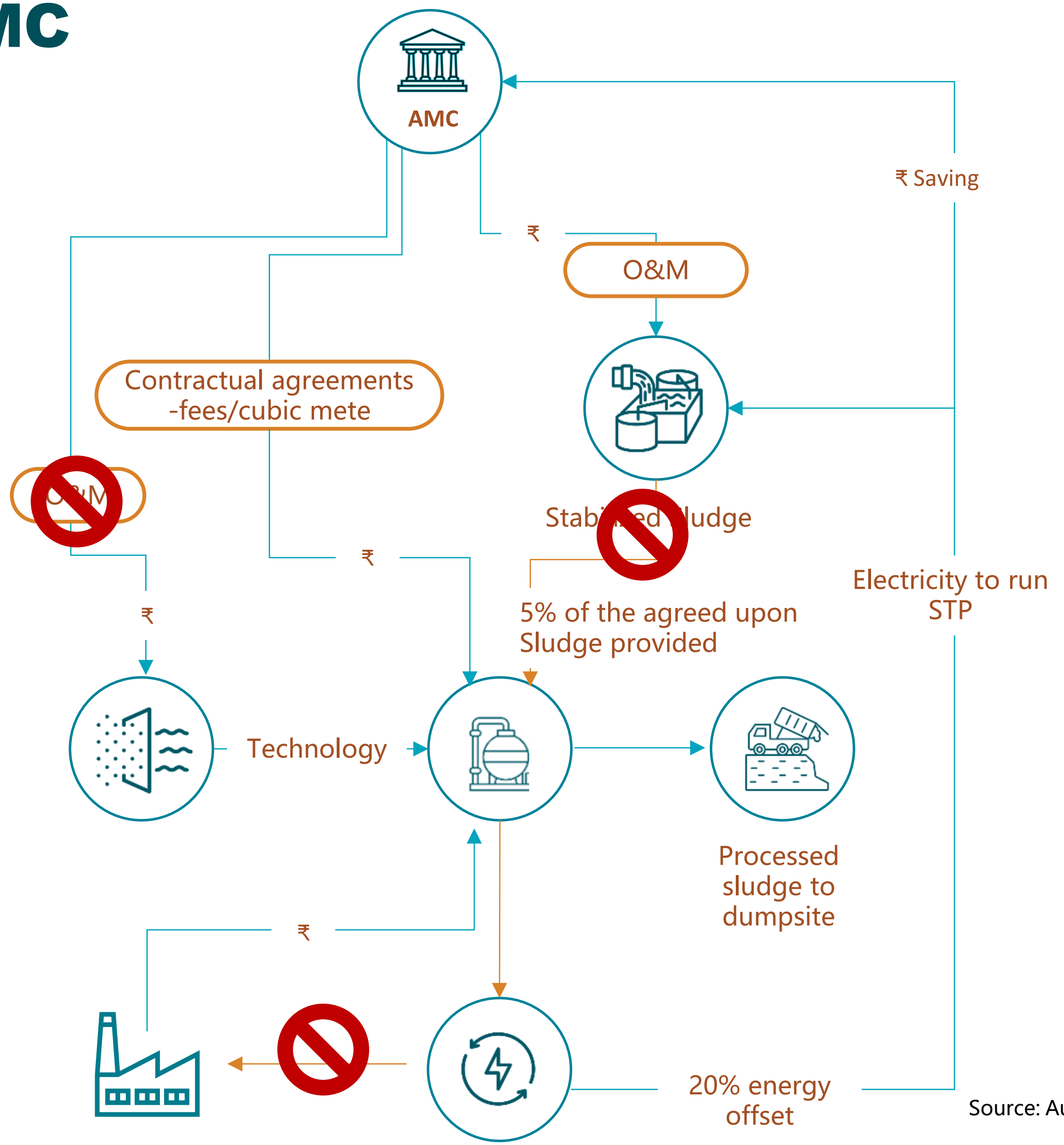
STP Name	Location	Capacity (MLD)	Technology	Biogas Use	Quantum of Gas Produced	Funding Source	Source
Okhla STP	Delhi	70	UASB Reactor	Electricity generation, Biogas supplied to nearby area	-	Delhi Jal Board + NMCG	link
Koramangala STP, Hebbal STP	Bengaluru, Karnataka	248 , 100	UASB + Activated Sludge	Powers STP, surplus to grid, meets 50% of plant's power needs	1 MW Electricity	BWSSB + Smart Cities Mission	Link, Link2, Link3
Amberpet STP, Nagol STP	Hyderabad, Telangana	339 (Amberpet), 172 , 320 (Nagol)	UASB + Biogas Recovery	Pvt O&M agency sells biogas to authorized companies (HPCL, IOCL, BPCL, etc.)	~5000 cum/day, 2000 cum/day	HMWS&SB (O&M by private)	Link
Dinapur STP	Varanasi, UP	140	Activated Sludge Process (ASP)	Electricity at STP, reduces O&M costs	~4,000 cum/day	Namami Gange Programme	Link1, Link2
Kodungaiyur, Perungudi, Koyambedu, Nesapakkam STPs	Chennai, Tamil Nadu	110 , 114 , 180 , 94	Activated Sludge Process (ASP)	Electricity for STP operation	1 MW Electricity	Pvt Operators + Chennai Metro Water	Link
Anjana, Variav, Dindoli, Barmoli, Bhesan STPs	Surat, Gujarat	122 , 84 , 66 , 100 , 200	UASB + Biogas Plant	Power generation for STP operation	-	Surat Municipal Corp + Enviro Cont Pvt Ltd	Link
Pirana STP	Ahmedabad, Gujarat	155	Activated Sludge Process (ASP)	Power generation for STP operation	-	AMC	Link
Akurdi STP	PCMC, Maharashtra	30	Combitrat SBR	Power generation for STP operation	-	-	Link1, Link2
Delwasa STP	Jaipur, Rajasthan	62.50	Activated Sludge Process (ASP)	Power generation for STP operation	-	Rajasthan Urban Infrastructure Development Project	Link1, Link2

AMC & SMC Business Model for Biomethanation



Source: Author's Work based on Primary Survey

Impact of Low-Quality Sludge on Biomethanation Plant Performance in AMC



Inadequate & Low-Quality Sludge

Reduced Biogas Generation

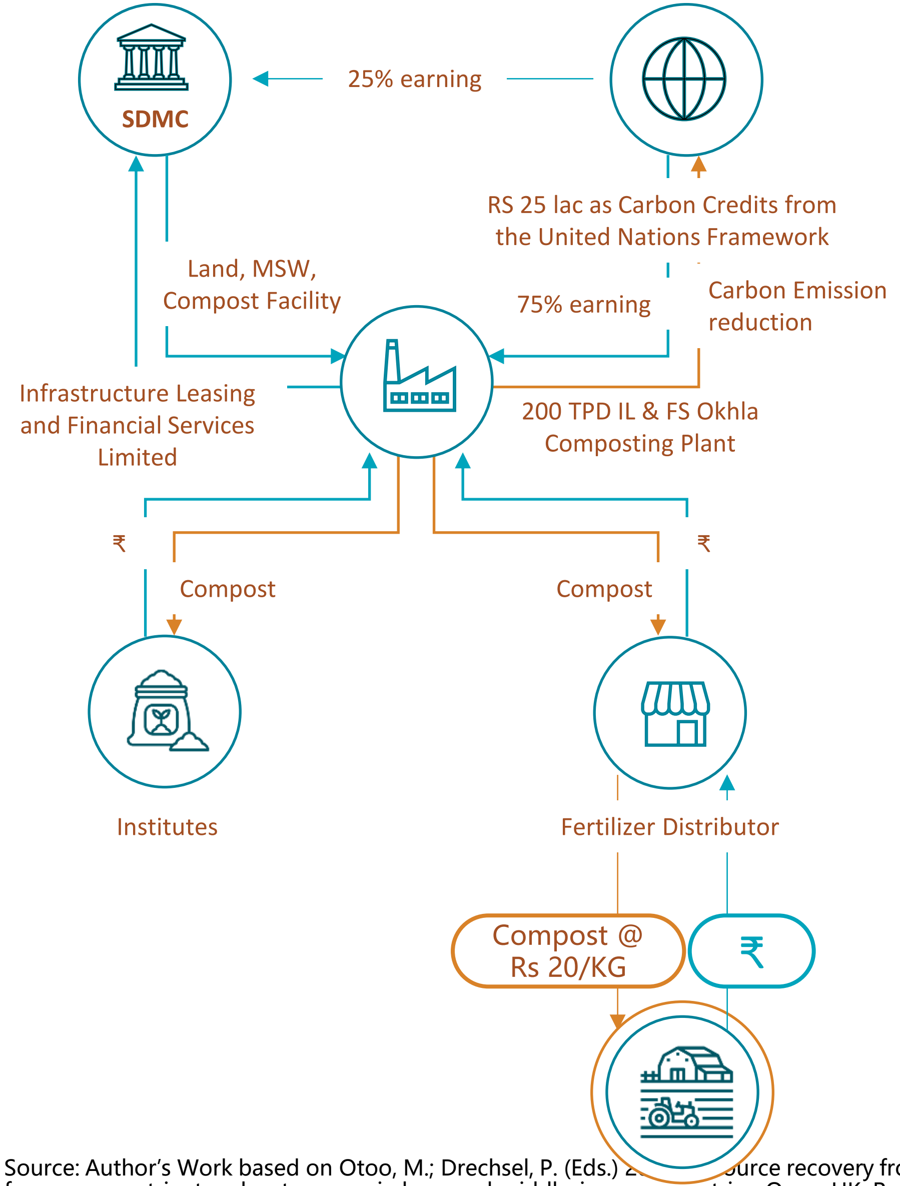
Lower Electricity Production

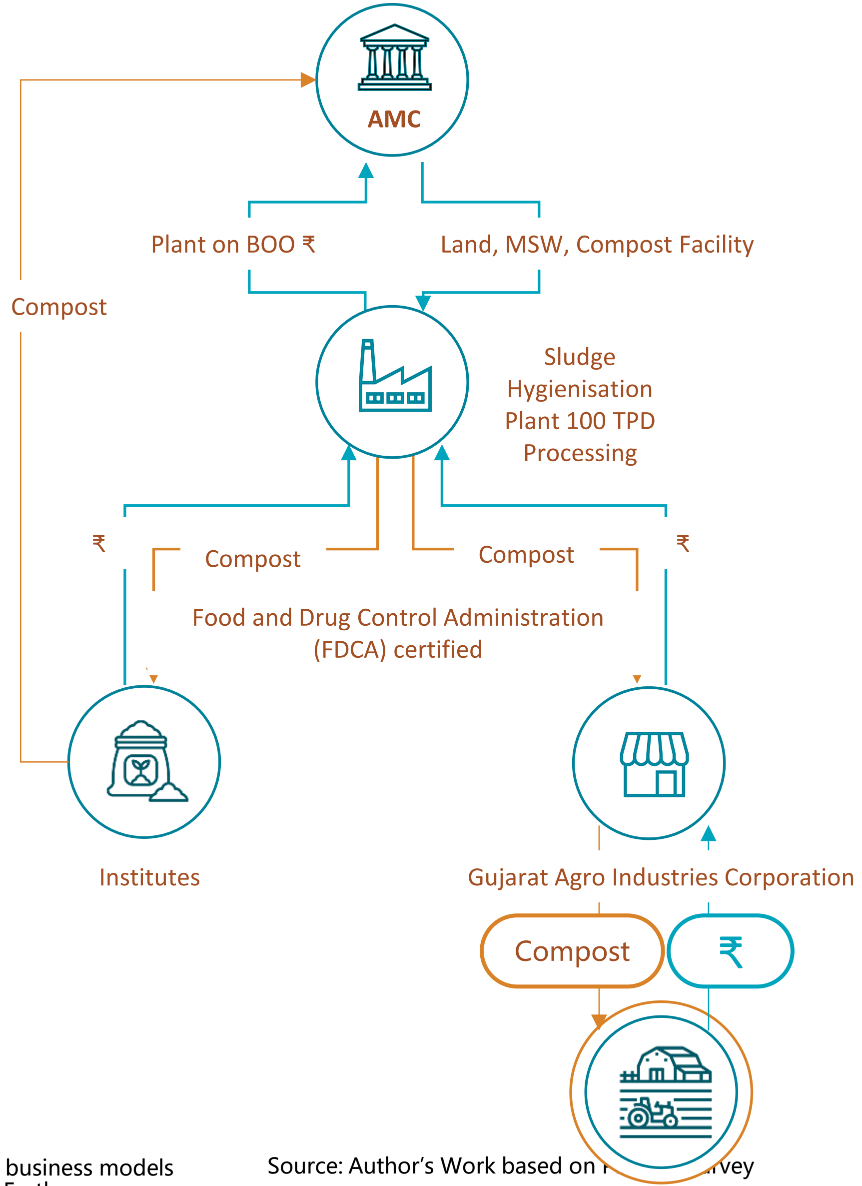
Unmet Supply Commitments to Industries

Financial Losses + Withheld O&M Payments by AMC

Source: Author's Work based on Primary Survey

SDMC & AMC Business Model for Organic fertilizer





Source: Author's Work based on Otoo, M.; Drechsel, P. (Eds.) 2[...]urce recovery from waste: business models for energy, nutrient and water reuse in low- and middle-income countries. Oxon, UK: Routledge – Earthscan.

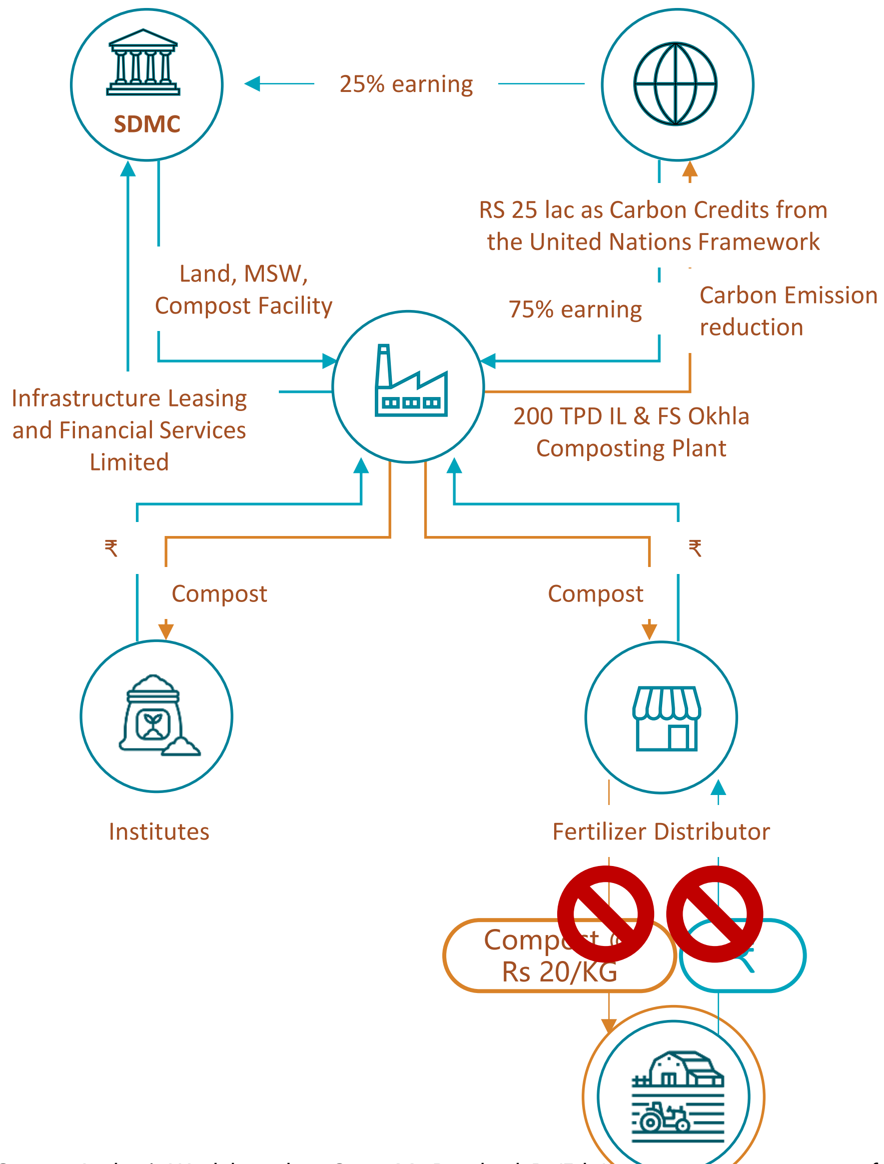
Source: Author's Work based on [...]rvey

Strong certification

Competitive Price

Private Distribution Network

No takers for tonnes of compost in South Delhi Municipal Corporation



Low quality Compost

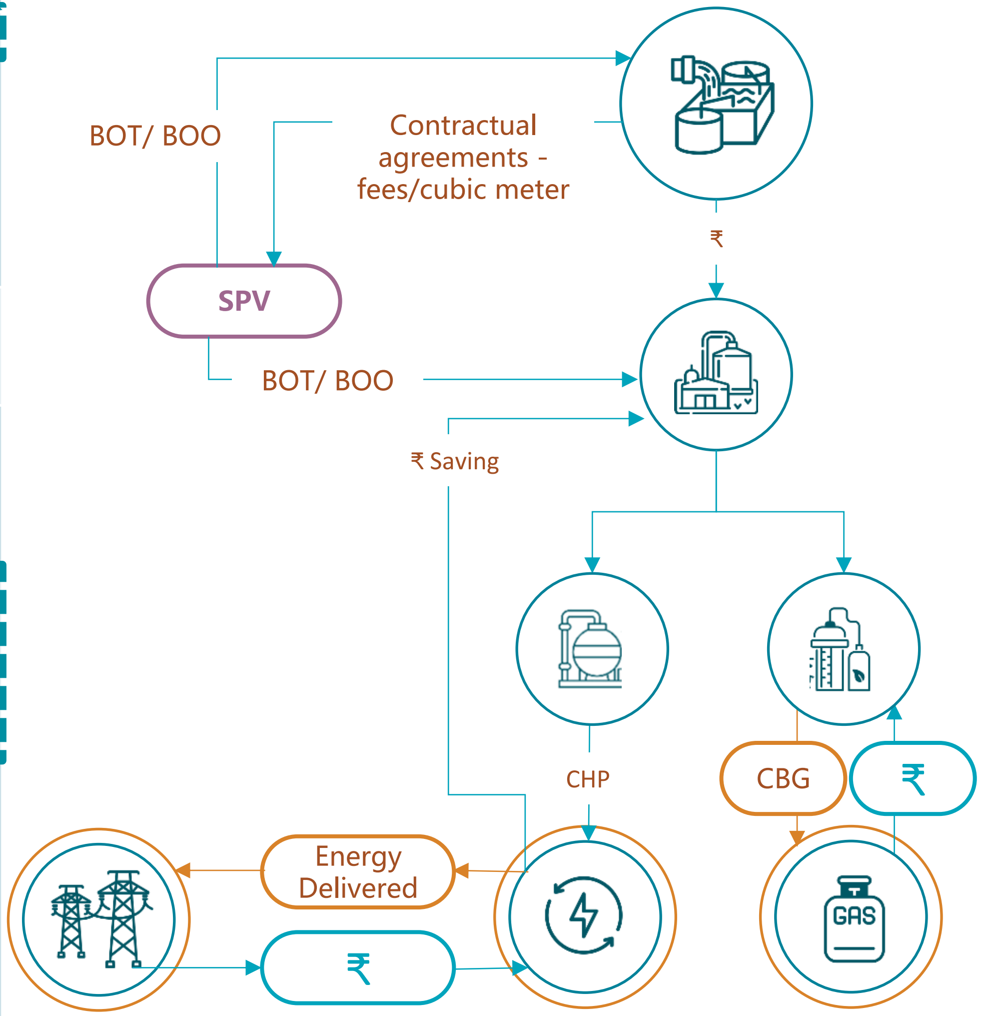
Lack of trust on compost

lack of demand for compost

Source: Author's Work based on Otoo, M.; Drechsel, P. (Eds.) 2[illegible]ource recovery from waste: business models for energy, nutrient and water reuse in low- and middle-income countries. Oxon, UK: Routledge – Earthscan.

Case Studies: Resource Recovery from Used water Treatment

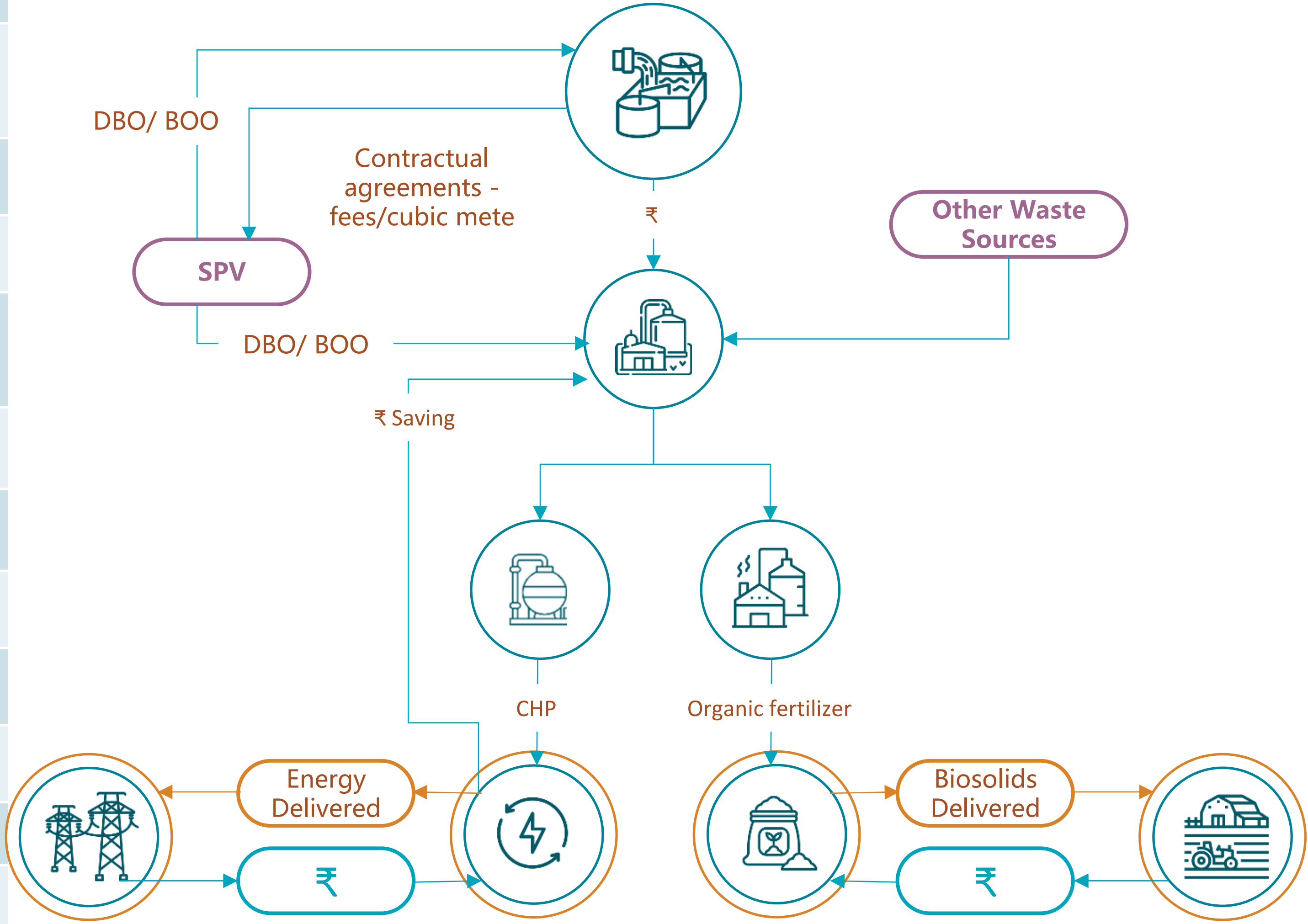
Category	Xiangyang, China	Toyohashi, Japan	Santiago, Chile	Veolia (China, Germany, and US)
Year	2012	2017	2005—	
Model	BOO (23 yrs)	BTO (20 yrs)	BOT + MoU	PPP
Capacity	300 TPD includes: (i) sludge (180–220 TPD) (ii) kitchen waste (80–120 TPD).	422 TPD including: (i) 315 TPD Sewage Sludge (ii) 59 TPD organic waste	800 TPD	
Inputs	Sludge (180–220 t/day), Kitchen waste (80–120 t/day)	Sewage sludge, Septic sludge, Food waste	760M L/day Used water, 800 t/day sludge	Sewage sludge, Organic waste
Outputs & Products	Biogas (CNG for 300 taxis), Sludge cake (soil amendment)	Electricity (sold via FIT), Carbonized fuel, Solar energy	Biogas (town gas for 30k homes), Dry biosolids (120 t/day)	Biogas, Green electricity, High-quality digestate
Revenue Streams	CNG ($1.41M/yr), Sludge cake ($0.12–0.13M/yr), Saplings ($6.3M/yr planned)	Biogas power sales, Fermented sludge sales, Solar energy	Biogas sales ($3M), Agriculture (free biosolids), Carbon credits (138,516 tCO_2e)	Energy sales, Grid injection, Digestate land use
Key Stats & Impact	$20.7M investment, 50% biogas for electricity, breakeven with $37/t subsidy, mitigation potential equivalent to 216k trees/year plantation	Public-private partnership, ownership transfers post-construction, the plant will be operated by Toyohashi Bio Will KK	$6M investment, $1M profit (2017), 13.5 km gas pipeline, Carbon credits, major GHG savings	Urumqi (930k m³ biogas/month), Braunschweig (100% energy self-sufficient), Gresham (94% energy self-suff.)



Source: aron, A., Singh, S., Drechsel, P., Ravishankar, C., & Ulrich, A. (2023). Sewage sludge: A review of business models for resource recovery and reuse. International Water Management Institute (IWMI).

Case Study: Advanced Sludge and Used water Treatment

Category	Billund Biorefinery, Denmark
Location	Billund, Denmark
Year of Upgrade/Operation	Initiated in 2015, operational since 2017
Capacity	127 TPD of food and industry waste
Partnership Model	**Public-Private Partnership** (Billund Vand A/S + Krüger A/S/Veolia)
Population Equivalent Served	70,000
Sources of Sludge/Waste	Used water, household organic waste, agricultural and industrial waste
Treatment Technologies	Integrated technologies for water purification, energy & fertilizer
Biogas Production	Increased energy production by 160% (to 22 million kWh/year)
Biosolids Output	Organic fertilizer for agricultural use
Reuse/Application	Energy used in-plant; surplus sold to grid
Cost/Investment	EUR 9 million (EUR 2 million in grants)
Cost Savings	Sludge treatment cost reduced by 30–40%
Key Impact	Model for converting urban waste streams into profitable resources



Source: aron, A., Singh, S., Drechsel, P., Ravishankar, C., & Ulrich, A. (2023). Sewage sludge: A review of business models for resource recovery and reuse. International Water Management Institute (IWMI).

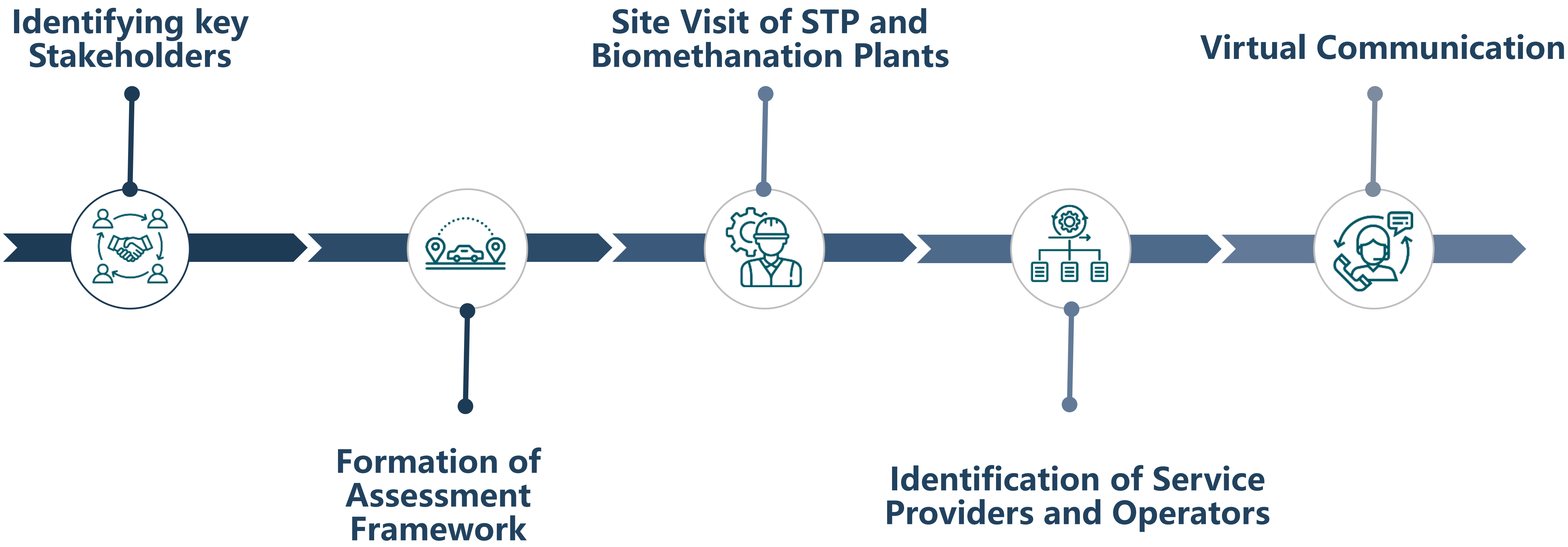
Lessons from International Practices

Region	Legal Framework	Primary Use	Key Initiatives	Energy Produced as of 2021 using Sludge as a resource	Sludge Reuse	Applications to India
EU	Directive Law 86/278/EEC, ongoing reviews	Land application in agriculture	Review for new pollutants, cost-efficiency	**13583.84** GWh	42% sludge recycled	**National Circular Economy Framework**
US	40 CFR Part 503, Clean Water Act	Land application, incineration	Biennial pollutant reviews, risk assessments	**3198.25** GWh	53% biosolids applied	**CPCB-led sludge regulations**
Japan	Decentralized, national guidelines	Incineration, energy recovery	Shift to energy utilization technologies	**2326** GWh	73.9% sludge incinerated	**Incineration for high-density cities**
Australia	National biosolids guidelines (2004)	Beneficial use in agriculture	Safe handling procedures, sustainability	**581.5** GWh	80% sludge in agriculture	**Rural-focused biogas expansion**
New Zealand	Targets to reduce landfill, guidelines	Mix of landfill, agriculture	Public engagement, Three Waters reforms	**116.3** GWh	95% treatment target	**Sludge reuse targets (50% by 2030)**
China	GB 24600-2009 and CJ 248-2007 guiding land application	land application and sludge greening	legal framework for sludge reuse aims to promote safe and sustainable utilization	-	-	**National Circular Economy Framework**

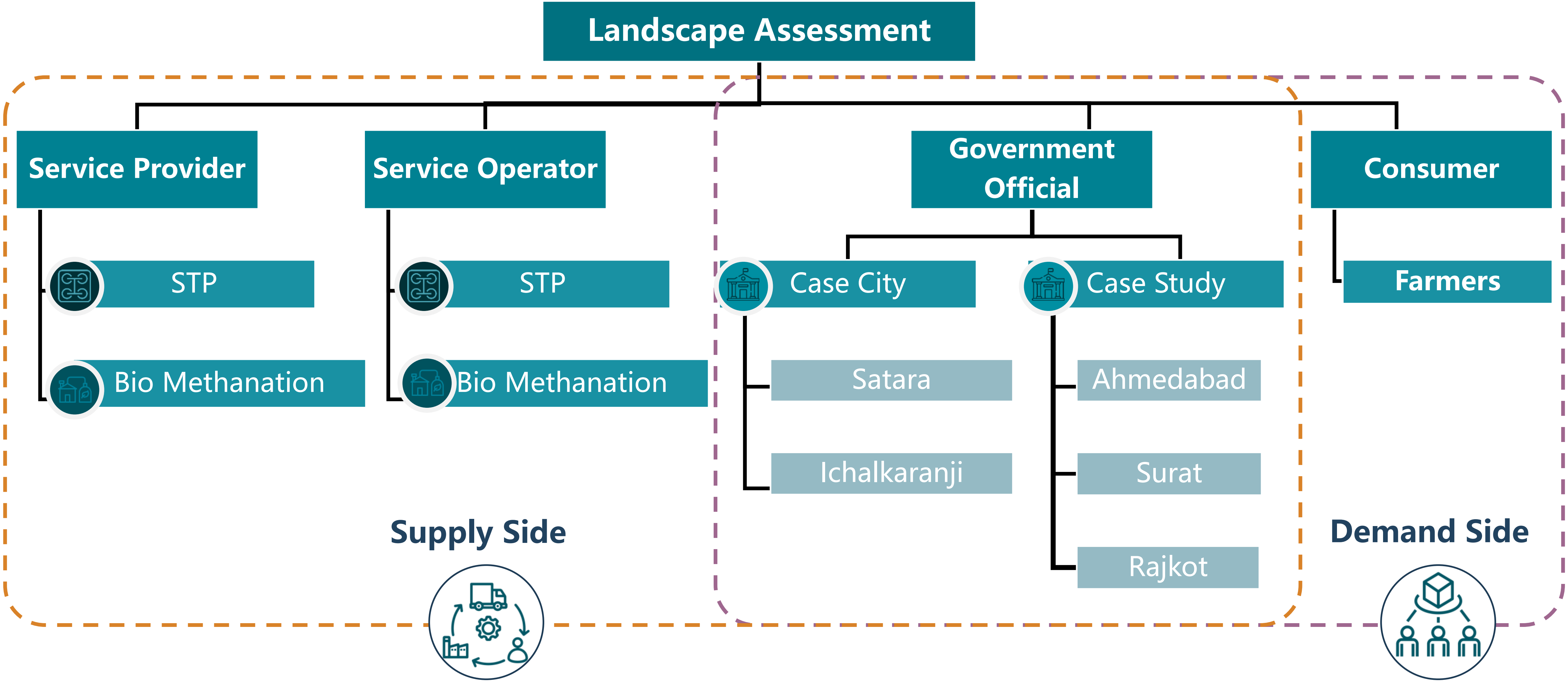
Source: EU: European Commission. (n.d.). Sewage sludge. US: Schaider, L. (2022, May 16). Used water: The best-hidden energy source you've never heard of. World Resources Institute. Japan: Wang, K., & Nakakubo, T. (2021). Strategy for introducing sewage sludge energy utilization systems at sewage treatment plants in large cities in Japan: A comparative assessment. Journal of Cleaner Production, 316, 128282. Australia: Australian Renewable Energy Agency (ARENA). (n.d.). Sewage treatment plants turn sludge into liquid fuel.. New Zealad:

Landscape Assessment: to understand market feasibility and feasible business models

Methodology for Landscape Assessment



Approach for Landscape Assessment



Assessment Mode

1. **Site Visit**
2. **Telephonic Interview**
3. **In-person Interview**
4. **Email & Video Calls**






Biomethanation- Operators & Providers

01 Client & Business Model

02 Feedstock & Processing Capability

03 Plant Design & Technical Parameters

04 Process Efficiency & Biogas Production

05 Digestate Management & End-Use

06 Financial Viability & Incentives

Source: Primary Survey

6

SWM Biomethanation Plant

2

Used water Biomethanation plant

10+

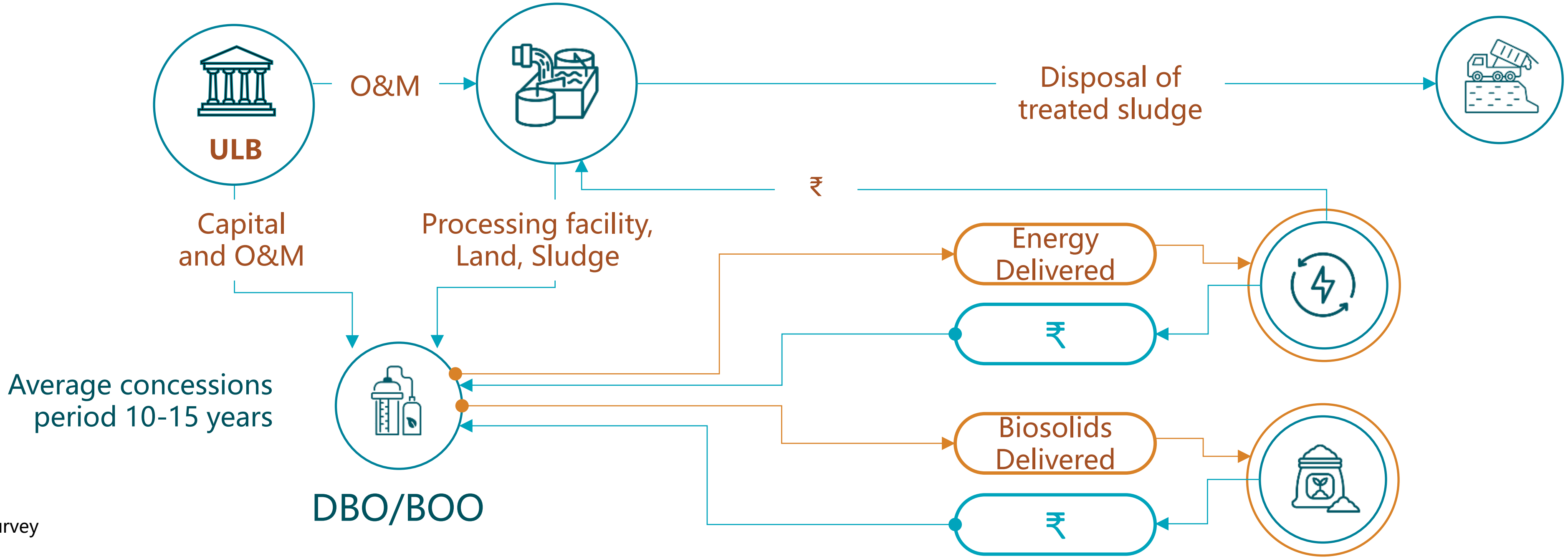
Service Operators

25

Service Providers

Biomethanation Plant Assessment

S. No.	Plant Capacity (in cubic meters)	Min Area (in acres)	Electricity (in KW per day)	Raw material (in Ton)	Human Resource	Capital Investment (in Cr)	CBG (in KG)	Fertilizer (in Ton)	ROI (in years)
1	12000	4-6	200	100-240	40	18-20	4500-5500	40	2-3
2	6000	3-5	100	50-120	20	8-10	2500	21	2-4
3	2400	2.5-4	50	20-40	12	3-5	1000	8	3-5
4	2100	1-3 acres	<40	15-20	12	2-4	-	-	5-7



Source: Primary Survey

Integrated Treatment of Sewage & Organic Solid Waste Useful for Decentralized Applications

Co-digesting

- Sewage generation- **2-4 MLD**
- Min Processing- **100kg/day**
- Waste Generation- **5-10 TPD**
- Min Processing- **250 kg/day**
- Outputs -**biogas, bio manure, and reusable water.**

Biogas & Fertilizer

- Sewage generation- **20- 50 MLD**
- Min Processing- **10 Tonne/day**
- Output- **biogas, bio manure**

Source: Primary Survey

STP- Operators & Providers

01 **Client & Business Model**

02 **Technology Overview: Process & System Design**

03 **Compliance with Standards: Critical Quality Parameters**

04 **O&M and Workforce Requirements**

05 **Resource Recovery Potential**

06 **Financial & Land Footprint Analysis**

6

STP Visits

12

Service Providers

5

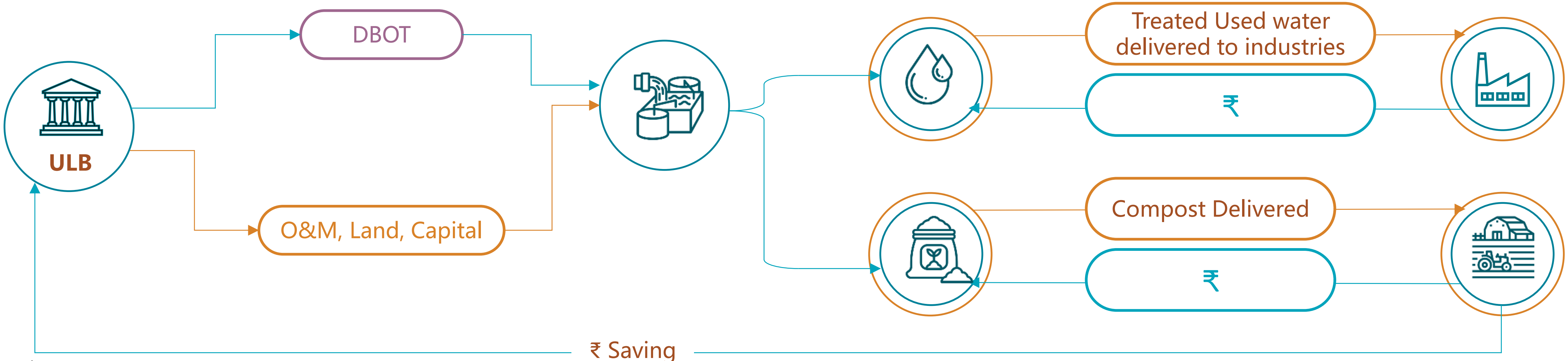
Operators

Comparison of Treatment Costs of Various Technologies for Class I Towns

Assessment Parameters/ Technology (per MLD)	ASP	MBBR	SBR	UASB+ EA	MBR	WSP
Capital Cost (Secondary Treatment) **(lacs)**	68	68	75	68	300	23
Capital Cost (Tertiary Treatment) **(lacs)**	40	40	40	40		40
Area Required **(sq m)** Secondary Treatment + Secondary Sludge Handling	900	450	450	1000	450	6000
Area Required **(sq m)** Tertiary Treatment + Secondary Sludge Handling	100	100	100	100	0	100

Source: Primary Survey & National Mission for Clean Ganga (NMCG). (n.d.). Environmental and Social Management Framework (ESMF) for Namami Gange Programme.

Case City- Indore



Primary Survey

Supply Side Key Highlights

	Biomethanation Plant		STP Plant	
Parameters	**Challenges**	**Implications**	**Challenges**	**Implications**
Economic and Financial	High investment, operational costs, market limitations.	Economic unviability, limited scalability	High out-of-pocket opex charges for management of sludge.	The operators struggle to find buyers or practical applications for the output.
Policy and Regulatory	Inconsistent policies, compliance burdens, lack of incentives	Delays in approvals, increased costs	Waste management and energy production regulations limited and no clear guidelines or incentives	Regulatory hurdles delay projects and increase costs
Infrastructure	Inadequate storage, purification, distribution facilities	Operational inefficiencies, higher logistics costs	STPs in India are outdated and not designed for biomethanation. Retrofitting them with anaerobic digesters, gas storage, and purification systems demands significant capital and technical expertise	Limited funding and uncertain returns
Social / Human Resource	Resistance due to odors, noise, and environmental concerns	Project delays, community opposition	Shortage of trained personnel	Leading to operational inefficiencies, frequent downtime, and higher maintenance costs, undermining plant reliability.
Feedstock and Technical	Variability, inhibitors, low methane yield, digester stability	Reduced efficiency, higher pretreatment costs	Mixed industrial and domestic waste, resulting in inconsistent organic content	This variability can lower biogas yields

Potential Consumers

01 **Assessment of farmer's preference for fecal sludge and municipal solid waste-based compost and fertilizer**

02 **Quantity of chemical fertilizer used/acre**

03 **Availability of organic compost**

04 **Awareness of using organic compost and fertilizers**

54

Farmers

12

Fertilizer Distributors

1

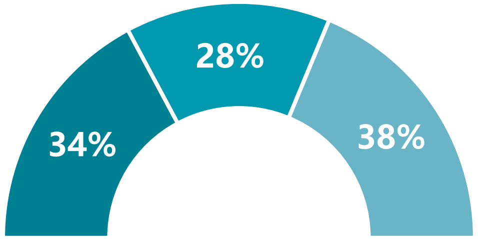
Primary Agricultural Credit Societies

Assessment of farmer's preference for fecal sludge and municipal solid waste-based compost and fertilizer

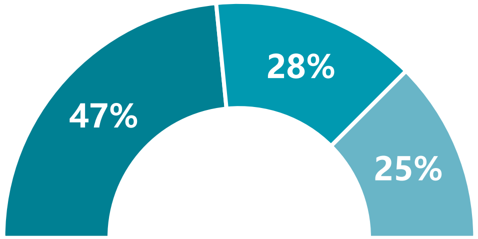
N=54

Willingness and Trust

Willingness to use fecal sludge fertilizer

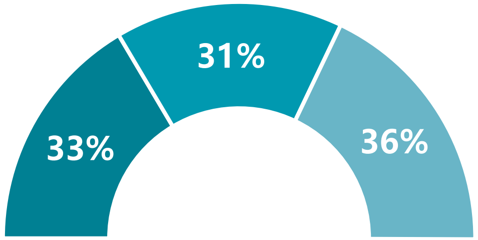


Fecal sludge compost should be government certified.



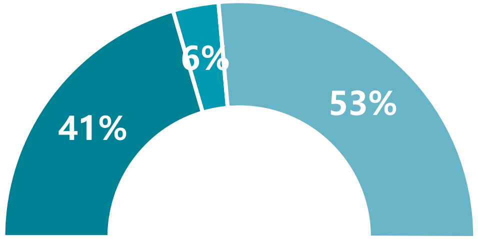
Safety

Pellets made from facal sludge are not safe to use

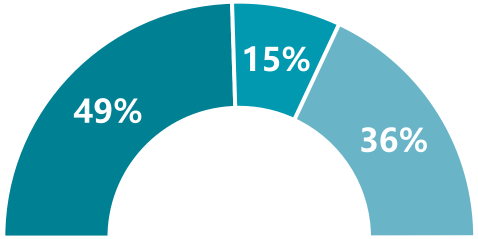


Impact of Price

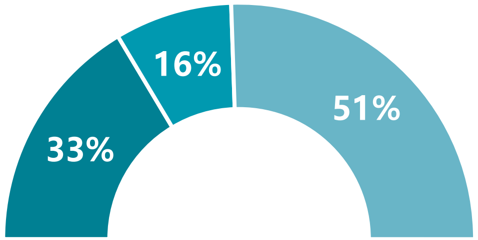
A Fecal Sludge compost should be priced the same as chemical fertilizer



A Fecal Sludge compost product should be cheaper than chemical fertilizer



Would buy fecal sludge compost no matter the price



Agree | Neutral | Disagree

Source: Primary Survey

Barriers and Perceptions Toward Fecal Sludge Compost Adoption

Nutrient	Chemical fertilizer		Organic Fertilizer		
	Ratio (Per Acres)	Price (Rs per Kg)	Ratio (Per Acres)	Price (Rs per Kg)	
				Solid	Liquid
Nitrogen (N)	1	6-7	Yet to connect with farmers practicing organic farming	10-30	>30 due to high processing costs)
Phosphorus (P)	1	28-30			
Potassium (K)	1	10-12			
Sulphur (S)	3	10-12			

Certification

47% support certification

Safety & Usage

36% agree that FSM pellets are safe, but 31% are neutral.

Competitive Pricing

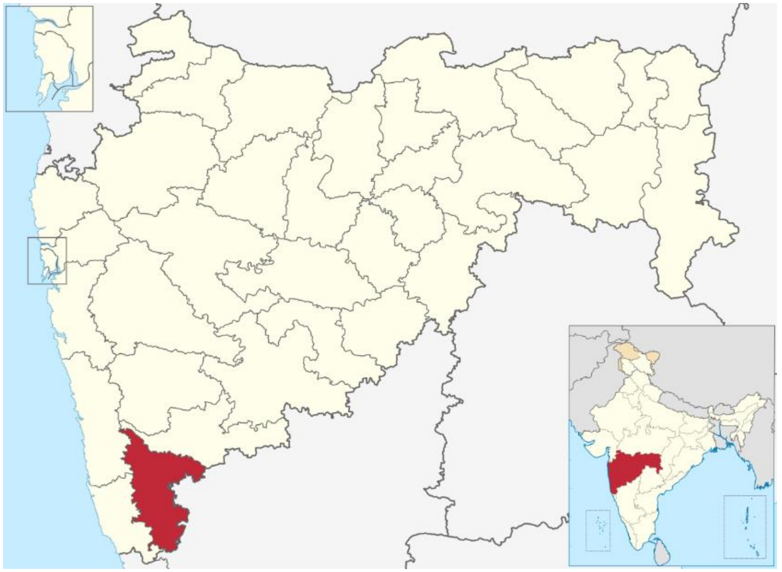
53% of people believe fecal sludge compost should cost the same or less than chemical fertilizers.

Source: Primary Survey

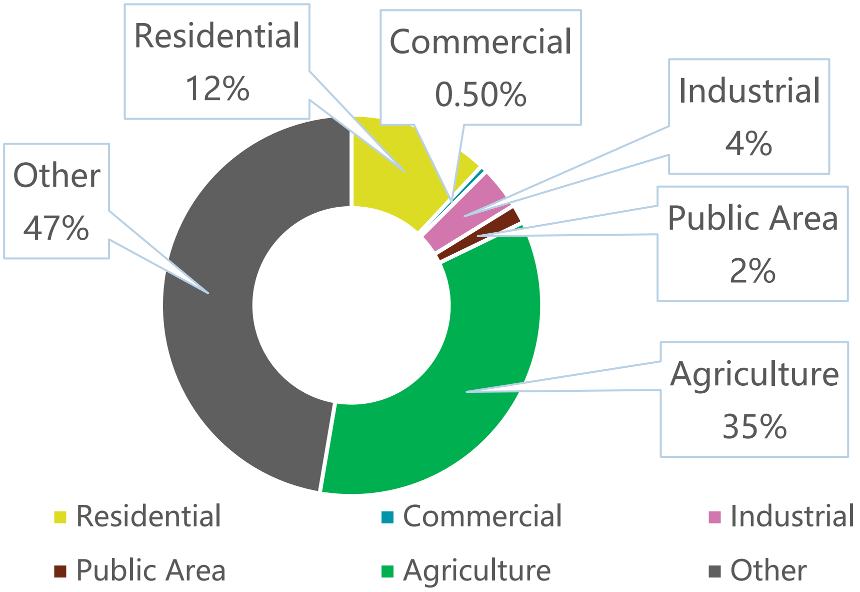
City Profile & Local Government Perspective

City Profile of Ichalkaranji

Location



Land use distribution



0.37 M

0.027% CAGR

29.84 sq Km

67,813 Households (2021)

Source: Primary Survey.

Source: Census2011.co.in. (n.d.). Ichalkaranji City Population 2025 | Literacy and Hindu Muslim Population.

Source: Primary Survey, IMC

20 MLD Operational + **12** MLD CETP + **18** MLD Under Construction & **1** Biomethanation plant

Source: CWAS. IMC Primary data Collection, SLB-PAS 2022

132 pph

Population Density

77%

Dependency on IHHTs

40%

Sewerage System Covers

16.2

MLD Sewage Collected

IMC to expand both the sewage network and STP

20 MLD – Extended Aeration Technology

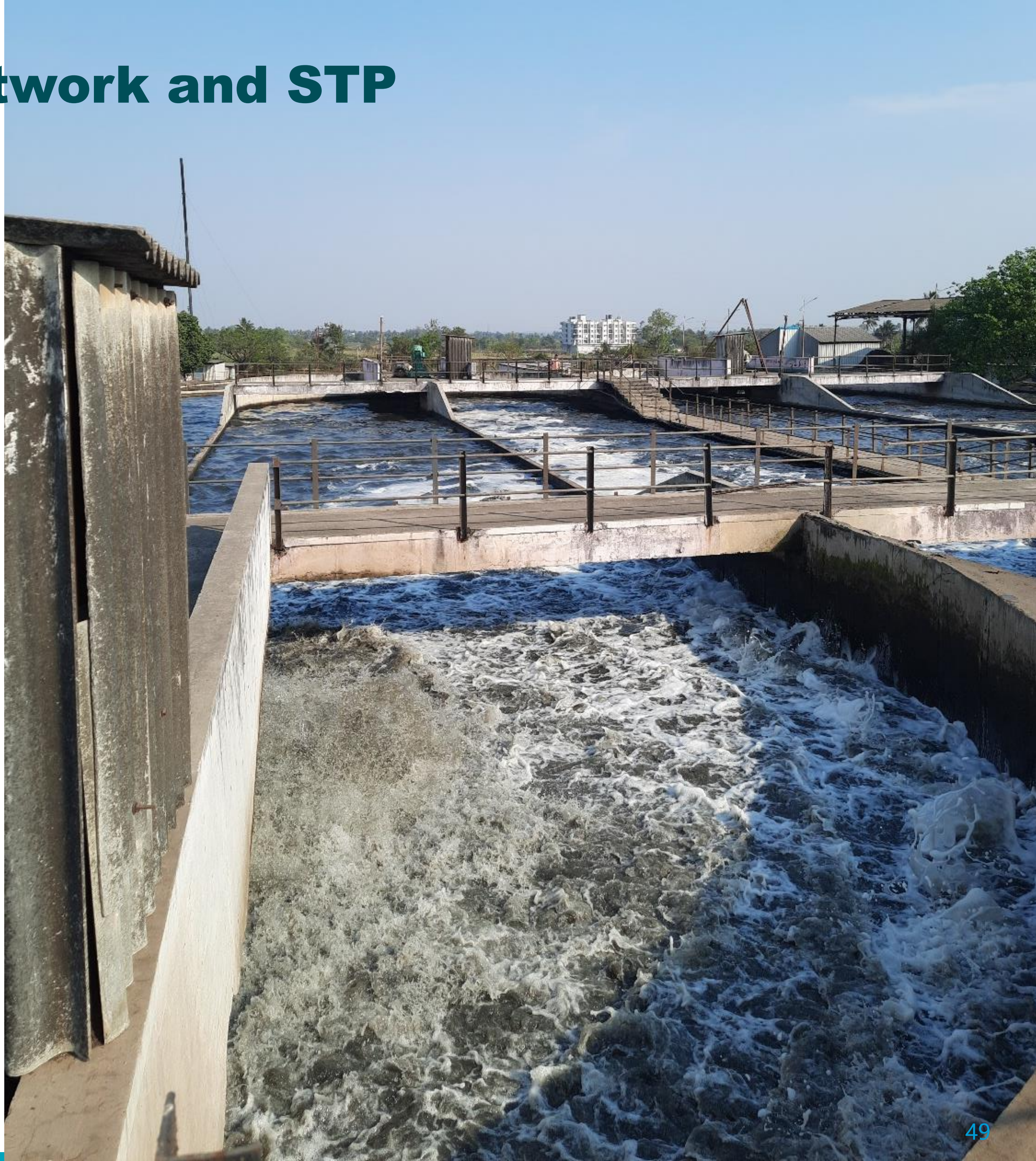
- 1994- till date
- ₹ 1,44,932/ month O&M on- Human resources, electricity, sample testing, and chlorination (FY2024)

₹ 3.36 Cr – Upgradation of technology

- Till 2010- ₹1000/ acre Used water and ₹2 kg compost to the farmers.
- 2011-till date free of cost

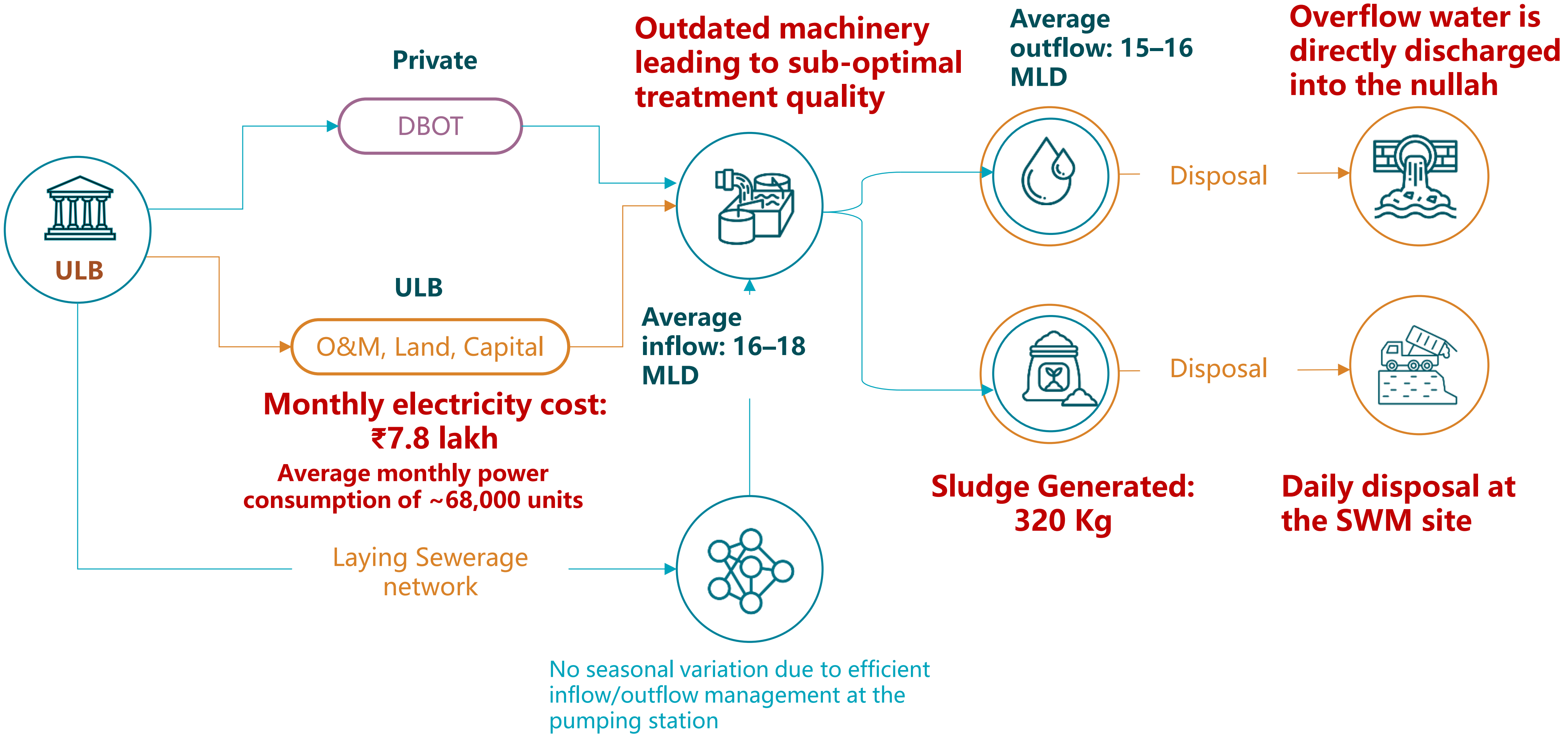
18 MLD- SBR technology

- Functioning to start by December
- Target to expand sewage network by 2027
- 19.5 and 13 MLD to be added in future
- Site near Scheduled Desludging pit.



Source: Primary Survey

Sewage Treatment Plant (STP) Overview



Sludge quality tests are not carried out
No reuse of treated Used water

Primary Survey

5TPD Biomethanation potential left unutilized due to lack of feedstock

Commissioning & Capacity

- Installed in 2022
- Occupies an area of 500 sq. m

Funding Capital Expenditure

- (CAPEX) funded by the Swachh Bharat Mission (SBM)

Operational Requirements

- Requires a minimum of 2 Tons of organic feedstock per day
- Currently receiving 800 kg/day

Key Challenge

- Insufficient feedstock availability hampering optimum operations

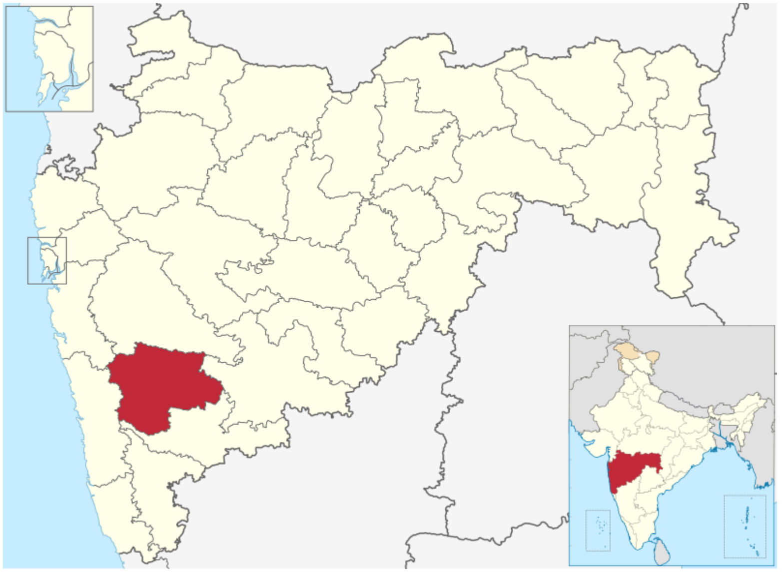
Opportunity

- Sludge can be used as feedstock to produce biogas

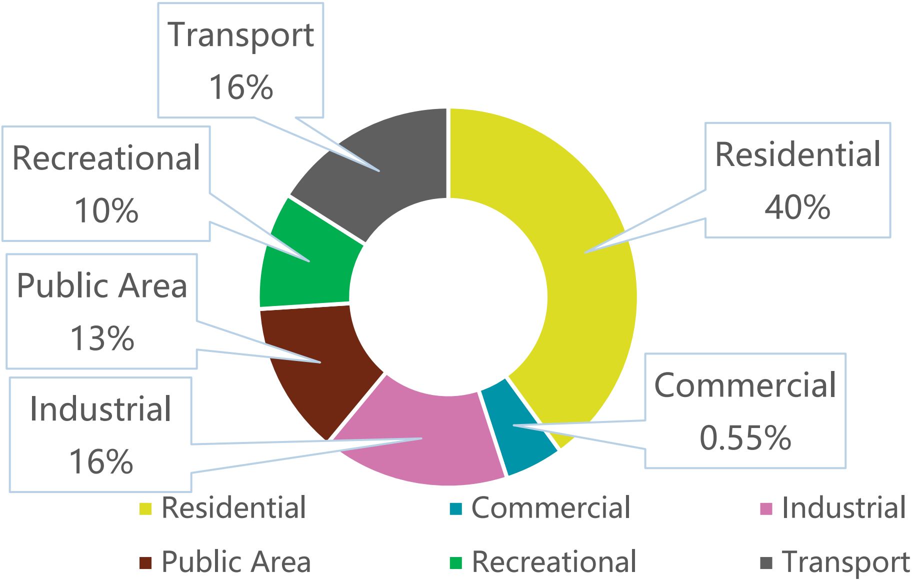
Source: Primary Survey

City Profile of Satara

Location



Land use distribution



0.13 M

0.026% CAGR

8.15 sq Km

33,800 Households (2021)

Source: Primary Survey.

Source: Census2011.co.in. (n.d.). Satara City Population 2025 | Literacy and Hindu Muslim Population.

Source: Primary Survey, IMC

20 KLD FSTP + **5** MLD Under Construction & **17.5** MLD Under Proposal

0 Biomethanation plant

147 pph
Population Density

79%
Dependency on IHHTs

30%
Sewerage System Covers

0
MLD Sewage Collected

Sludge Potential of Satara

20 KLD FSSM

- 5 TPD of Sludge
- Currently used as compost for Miyawaki forest on site

5 MLD -SBR technology

- 100 kg/day Sludge potential

17.5 MLD- SBR technology (Proposed)

- 350 kg/day Sludge Potential

Source: Primary Survey

Government officials

01 **Sewage Treatment & Infrastructure**

02 **Financial Support & Viability**

03 **Biomethanation & Market Potential**

04 **Challenges & Future Scope**

10+

Key Informant Interviews

2

City Coordinators

3

City Engineers

Key Insights




Economic and Financial

- Limited municipal budget of small municipal corporations, no direct schemes to set up a bio-methanation plant with STP
- Grants from state or central governments are not always

Shortage of skilled personnel

- Shortage of trained personnel, Complex approval processes
- No skilled project manager to develop the project and pitch

Infrastructure

- Inadequate coverage of the sewage network, retrofitting of Biomethanation in the existing plant is not feasible
- Less sewage collection, Old technology required high capital cost and land

Social and Community

- Hesitance to pay for compost
- Economic unviability, limited scalability

Policy and Regulatory Support

- Lack of uniform guidelines across
- Confusion and delays in project approvals, Increased financial burden, deterring adoption

Source: Primary Survey

Summarizing Gaps & Challenges

Lack of Cohesive National Policy

1. Central-level ministries like MoPNG, MoHUA, and MoEF, etc., consider biomass from cow dung, crops, and MSW, but lack a focus on sludge.

2. Despite existing schemes like SBM, FSM Policy (2017), Gobardhan, and Waste to Energy Programme, India lacks a national policy or circular economy framework specifically for sludge reuse.

3. The FSSM Policy primarily focuses on the safe disposal of faecal sludge, with limited emphasis on its potential for resource recovery and reuse. Moreover, no established guidelines or standards regulate the use of treated sludge as a fuel.

4. The FCO (1985, amended 2009) sets contaminant limits for compost but does not prescribe any dedicated standards for sludge-derived manure, despite its distinct contaminant profile.

Lack of enabling environment & policies = Lack of project momentum

Limited Financial Support & Awareness

1. Overall, a total subsidy of only Rs 18.9 crore has been released in the last 17 years under both parts of CISS to set up manufacturing units and marketing.

2. Despite multiple schemes promoting organic farming, chemical fertilizers continue to receive significantly higher subsidies than biofertilizers

3. The Central government's programmes to promote biofertilizers and organic fertilizers are limited in scale and funds and have had limited success. This discourages organic fertilizer from entering the market with competitive pricing, thus, there are no guaranteed takers.

Low financial support → Weak Market Engagement

High Potential, Low Utilization

1. According to the data released in the report "Inventorization of Sewage Treatment Plants, 2015," only 64% of Sewage Treatment Plants out of 1093 are operational, with only 18% of sludge treated, leaving a significant portion of dewatered sludge untreated
2. Despite high power consumption and biogas recovery potential, only 23 out of 1,093 STPs have operational biogas recovery units, resulting in substantial missed opportunities.
3. Lack of research and implementation on co-processing sludge with solid waste is leading to the utilization of existing infrastructure that lacks feedstock.

Untapped low-cost local renewable energy sources = Higher investments in fossil fuels, leading to a larger carbon footprint

Absence of Standardization

1. Many states do not have their own laboratories, leading to inferior quality and inauthentic biofertilizer and organic fertilizer products, thus building distrust in the usage of organic fertilizers.
2. CPHEEO provides recommendations for managing various types of sludge for land applications but does not provide any standards.

Lack of labs and standard guidelines = Poor-quality organic fertilizers and low user trust

Small ULBs, Big Challenges

1. The current national programs and funding agencies are focusing on infrastructure development, and little to no focus is given on the circular approach of sludge reuse, discouraging small ULBs with limited budgets from taking such projects.

2. Lack of capacity to plan and implement projects: The shortage of manpower in municipalities affects the planning, technical expertise, implementation, and monitoring. The small ULBs do not have a full sewerage network, thus, ULB had to invest the majority in facilitating the basic infrastructure.

3. National grants and subsidies exclude sludge treatment costs for reuse in benchmarking, resulting in project undervaluation and increased out-of-pocket expenses for ULBs, deterring them from setting up a biomanthation plant.

Low resources = Limited execution

Unbalanced Risk, Limited Innovation

1. Existing DBO/BOT PPP business models are not viable due to contractual challenges, payment mechanisms, and revenue streams, leaving private investors unwilling to bear the perceived risks of sludge-to-resource ventures.

2. Current practice involves that most of the risk is shared by the private entity, leaving them vulnerable to losses, thus discouraging the private parties from entering this sector.

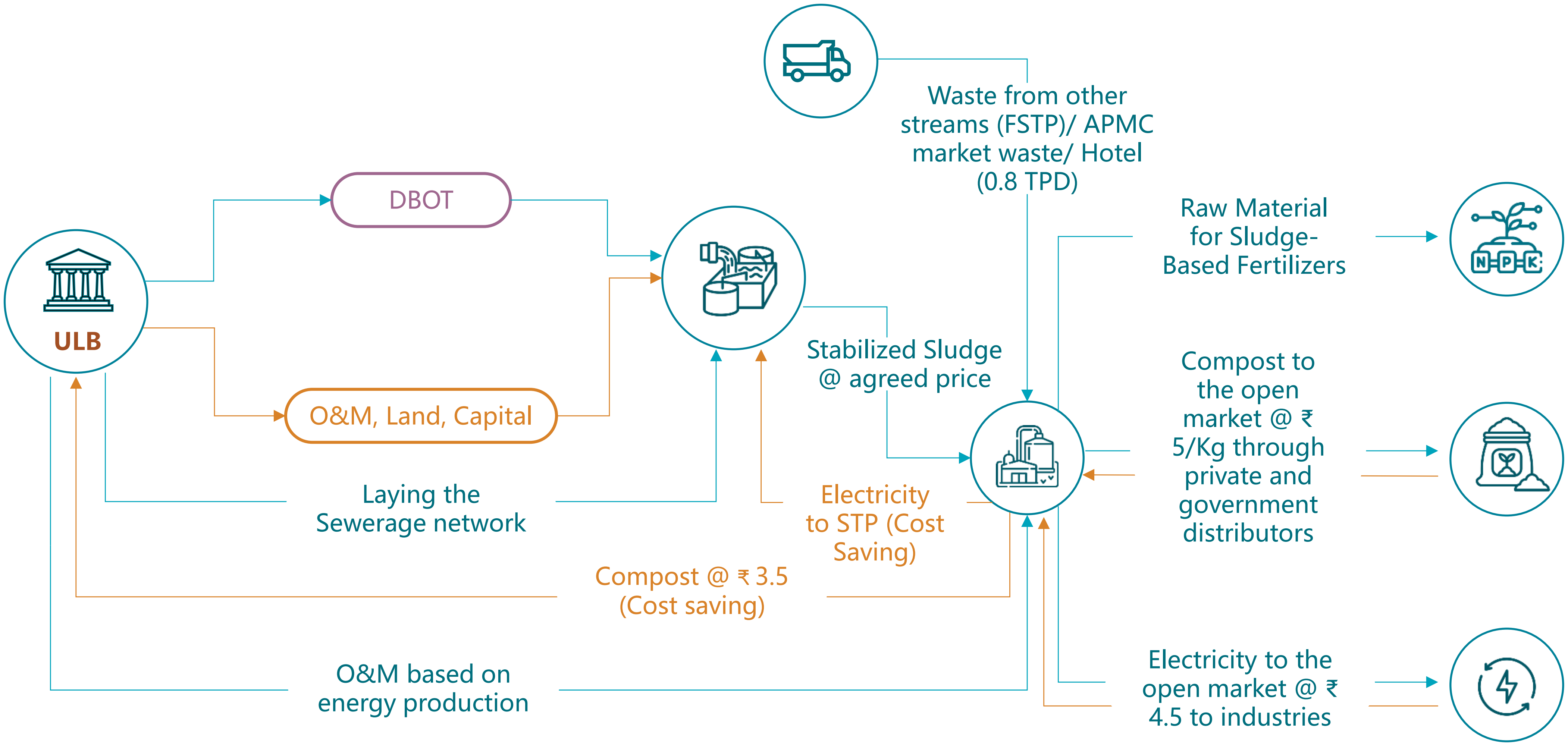
3. Shorter concession periods are discouraging the private players from having confidence to invest.

4. International case studies highlight SPVs under PPP frameworks as key to driving innovation and investment in advanced sludge treatment, ensuring long-term efficiency, financial viability, and balanced risk-sharing. In contrast, MoHUA's model RFP for "Waste to Compressed Biogas Project" restricts sludge use, limiting these opportunities.

Balanced partnerships = Sustainable innovation

Advancing Sludge Reuse and Circularity

Potential Business Model – Ichalkaranji



Source: Author's Work

Economic Feasibility Summary

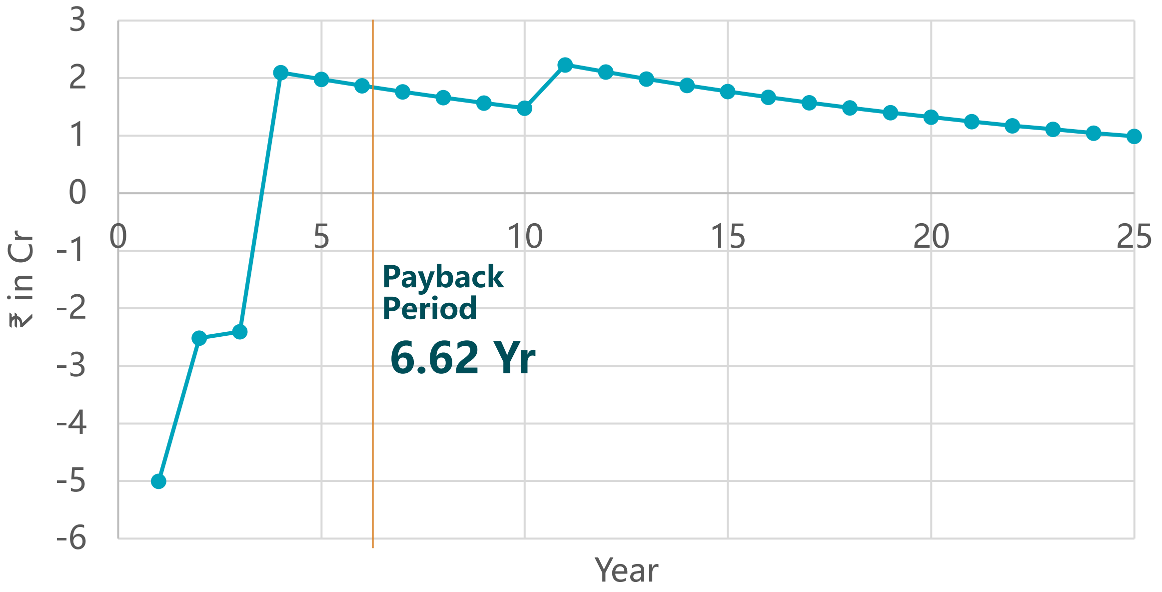
Capital Cost
8 Cr

O&M Cost
0.96 Cr

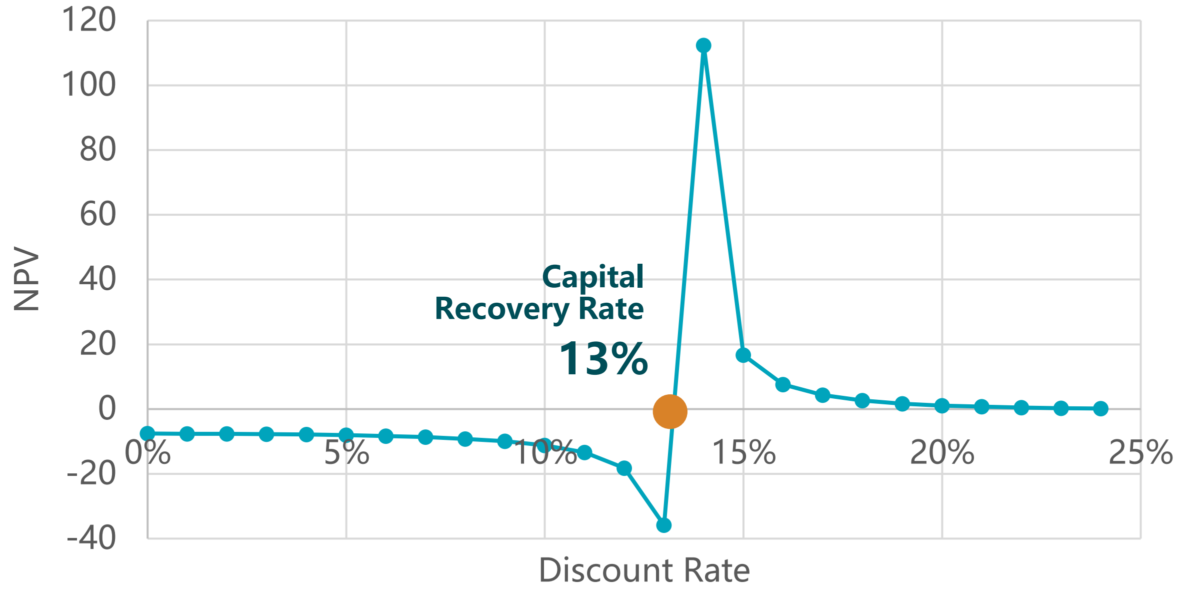
Annual Revenue (Private)
5.03 Cr

Cost Saving by ULB
0.9 Cr

Discounted Value



NPV VS Discount Rate



Annual Revenue (Electricity)
1.20 Cr

Annual Revenue (Compost)
0.35 Cr

Annual Revenue (Carbon Credits)
4.97 Cr

LCA
1.96 Cr

Roles and Responsibilities- Planning

ULB

- Develop a detailed project report to assess sludge volume, technology, capacity, and cost.
- Align with Maharashtra's comprehensive approach to sanitation excellence policy, which encourages cities to co-treat sludge at STPs via a formal MoU with the STP operator for sludge supply and co-digestion.
- The ULB should be responsible for implementing waste-to-biogas projects and preparing internal resolutions to allocate land and resources.
- Mandate the government and private nurseries to purchase organic compost from the plant to maintain parks, gardens and urban forests.

Private Operator (STP)

- Provide STP inflow/outflow data and sludge characteristics (TS%, contaminants), and evaluate existing sludge generation (volume and solids content).
- Ensure STP modifications and upgrades are installed and still meet Maharashtra Pollution Control Board norms for effluent quality.

Private Operator (Biogas)

- Procure consents (EPA, MPCB).
- Conduct detailed surveys of sludge availability (from Ichalkaranji STP and possibly nearby towns). It evaluates suitable anaerobic digestion technology and capacity.
- Secure funding (equity/debt). May utilize schemes: e.g., central/ govt subsidies for bioenergy, carbon credit.
- Negotiate SLAs (service levels) and payment terms.
- Run trail tests.

Roles and Responsibilities- Operations

ULB

- Monitor compost and energy production.
- Enable compost testing and certification from government-certified labs.
- Licensing of private desludging operators operating within municipal limits.
- The ULB should have an agreement with FS's private contractors to dispose of the sludge as feedstock.

Private Operator (STP)

- If the biogas plant is onsite, pump dewatered sludge directly
- Maintain effluent quality; coordinate with the plant operator; report sludge data.
- Carry out sludge quality testing from certified labs at every 15 days.

Private Operator (Biogas)

- If offsite, arrange transport. Under contract terms, the contractor should handle logistics.
- Supply monthly reports to ULB on quantities of sludge processed, biogas/energy produced, and digestate distributed.

Contract Clauses

ULB

- The ULB negotiates a long-term sludge supply agreement with the STP operator (public or contractor) to ensure continuous feedstock.
- The ULB will purchase a portion of both compost and electricity.
- The ULB also coordinates with power/gas utilities if the project produces electricity.
- The ULB (or developer) must apply for Environmental Clearance from the MoEFCC/MPCB.
- Third party quality testing audit for biogas.

Private Operator (STP)

- Adjust that the sludge is available on the schedule agreed with the biogas plant
- Monitor the STP's performance. The effluent quality should remain within norms and provide records of sludge volumes/qualities to ULB and the biomethanation plant operator.
- Conduct regular sludge tests to maintain sludge standards and implement necessary steps to maintain the right quality of sludge.
- STP operator will maintain annual emission inventory based on IPCC2019 GHG emissions estimation methodology.

Private Operator (Biogas)

- Finalize contracts with ULB (concession agreement or lease) and with STP operator.
- In case of offsite plant Privat Operator will setup infrastructure for sludge transportation.
- Operator will pay security deposit to ULB.

National Policy and Regulatory Framework

1. **Develop a comprehensive national policy** on sludge reuse, aligned with circular economy principles and focused on public health, environmental protection, and economic value.
2. **Establish clear and enforceable standards** for treated sludge reuse, with specific distinctions for land application and other end uses.
3. **Formulate easy-to-understand biosolids utilization standards** to enable safe agricultural use.
4. **Incorporate sludge reuse indicators** into existing government toolkits like the Swachh Bharat (SB) and Sustainable Sanitation (SS) frameworks.
5. **Include sludge reuse as compost and biochar** in state state-level climate mission under carbon sequestration strategies.
6. **Mandate sludge testing** for biogas potential and volume as a prerequisite for treatment planning.
7. **Ban the disposal of sludge at SBM landfill sites** to enforce reuse or recycling.
8. **Implement a penalty clause** for non-compliance with sludge reuse and recycling requirements.

Economic Incentives and Institutional Support

1. **Adopt a statewide sludge monetization mandate**, similar to *Arth Ganga*, requiring sludge-based compost use within a 500-meter buffer of river/nalla rejuvenation zones.
2. **Include sludge-based fertilizers** under the **Harit brand certification** to promote market acceptance.
3. **Offer GST exemptions or tax holidays** for sludge recycling and reuse projects.
4. **Allocate dedicated budgets** for long-term sludge management planning and implementation of standards.
5. The Government of Maharashtra adopted a single-window approach to expedite the establishment of the Biomethanation plant by centralizing and coordinating all approvals through a unified system.

Technology Promotion and Infrastructure

1. **Fast-track environmental clearances (ECs)** for sludge and waste processing plant development.
2. **Promote proven sludge treatment technologies**, such as composting, Hygienisation, and incineration with energy recovery.
3. **Encourage the use of sewage sludge for Compressed Biogas (CBG) production**, integrating it into existing biomass initiatives under the Ministry of Petroleum and Natural Gas.
4. **Support the establishment of CBG plants** across India for integrated solid waste and sludge management.

Monitoring and Quality Assurance

1. **Regularly monitor sludge quality**, especially to detect industrial waste contamination in domestic sewage networks.
2. **Ensure testing infrastructure at the state level** to improve biofertilizer quality and build trust among farmers and consumers.

Way Forward

ULB can circulate green bonds to fund these projects.

ULB can further integrate domestic solid waste, APMC market waste, and Hotel waste to co-treat for biomethanation.

ULB enables fertilizer production from treated sludge.

ULB can explore the potential reuse of biosolids as construction material.

THANK YOU

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