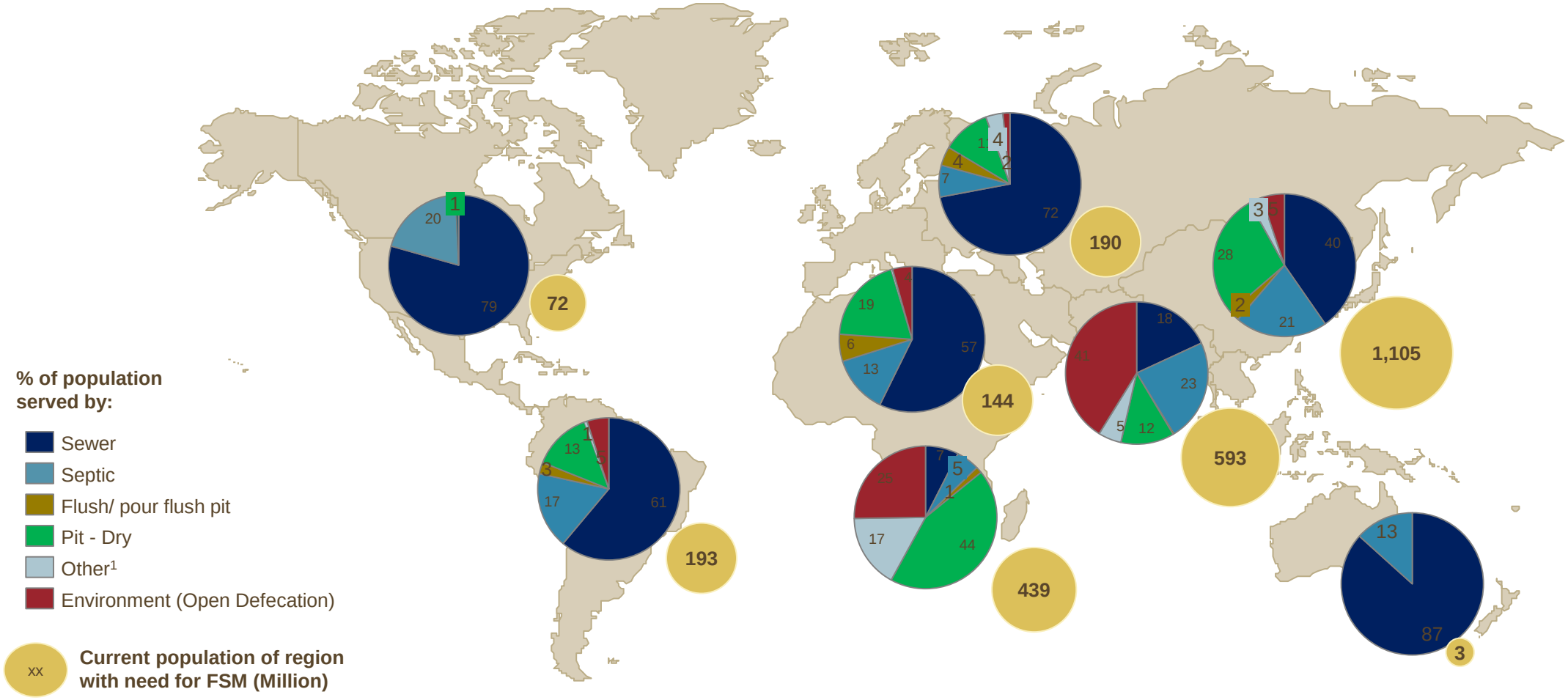
THE NEED FOR DISRUPTIVE GAME CHANGING APPROACHES IN WATER SANITATION AND HYGIENE

Carl E. Hensman, Ph.D.
Senior Program Officer,
Bill & Melinda Gates Foundation

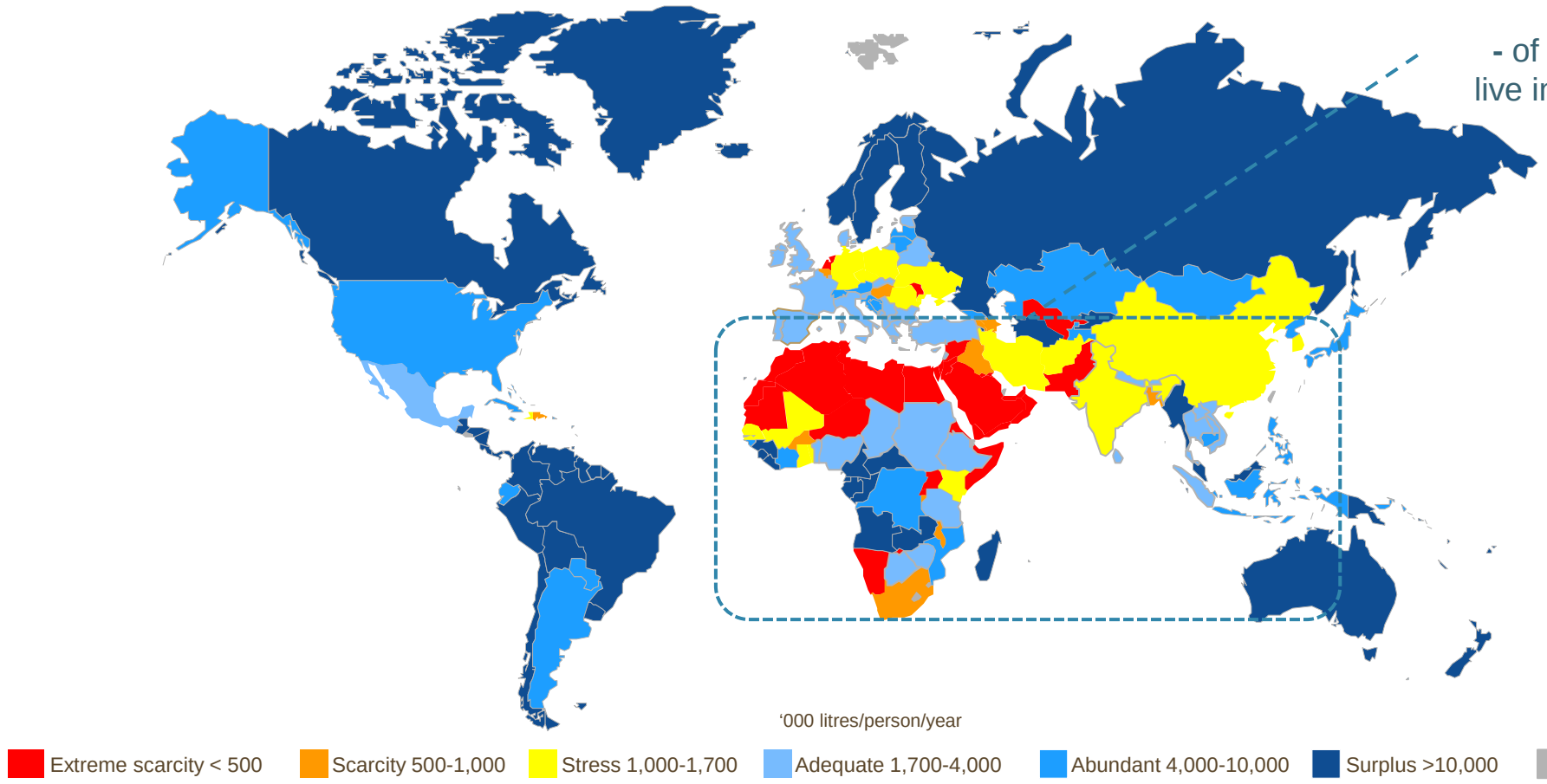
~2.5 BILLION PEOPLE WORLDWIDE TODAY NEED FECAL SLUDGE MANAGEMENT (FSM)



1. Open pits, pits without slabs and composting toilets included in "Other" as these do not need FSM (open pits/ pits without slabs covered up when full)
Source: UN JMP sanitation data, BCG analysis

WATER SCARCITY WILL MAKE FECAL SLUDGE MANAGEMENT (FSM) INCREASINGLY IMPORTANT

Projections 2030



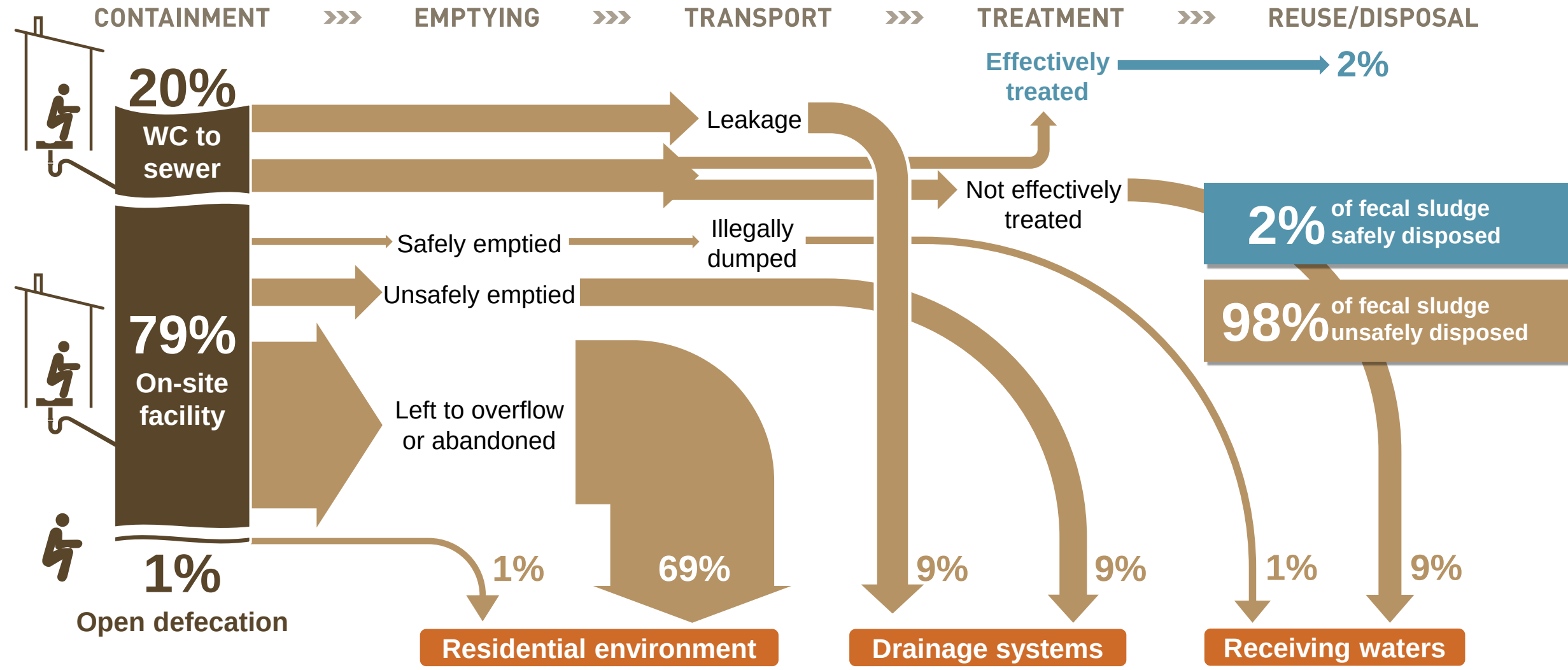
74%

- of world's population will live in Sub-Saharan Africa & Asia.

1. United Nations environment programme
Source: 'Global Water Initiative' (June 2005), GEF International Waters Conference, The Coca-Cola Company, Grail Research, BCG Analysis

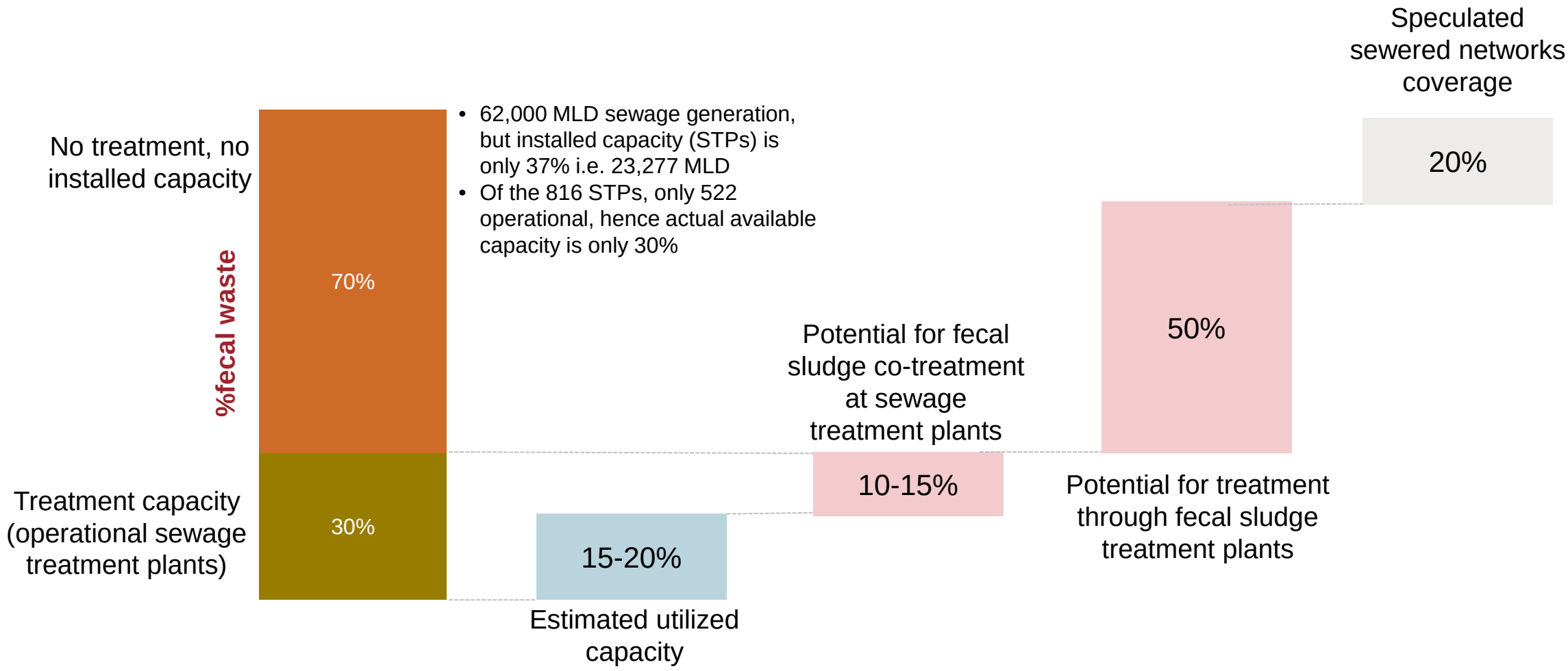
POOR FSM IS AKIN TO INSTITUTIONAL OPEN DEFECATION

Sludge direct to the environment when no service chain



Source: WSP analysis, using BMGF funded research

INDIA SANITATION STATUS



Based on estimates: Center Pollution Control Board, IndiaSpend, Center for Science and Environment

CURRENT SOLUTIONS ALL HAVE SIGNIFICANT LIMITATIONS

Current solutions, both centralized and decentralized, have significant limitations that jeopardize health and safety and, in many cases, perpetuate open defecation practices.

HANGING TOILETS

Foul odors
Poor user experience
Safety hazards
Environmental contamination

PIT LATRINES

SEPTIC TANKS

Expensive to install, maintain
Require infrastructure
Require considerable water
Treatment not assured

SEWERAGE

TRANSFORMATIVE TECHNOLOGIES: 3 SUB-PORTFOLIOS

REINVENTED TOILET

Single-unit (SURT)

Multi-unit (MURT)

OMNI INGESTOR

OMNI PROCESSOR

Household scale *Multi-unit scale* *Pumping and processing*

THE REINVENTED TOILET PROGRAM IS DESIGNED TO ADDRESS TODAY'S LIMITATIONS

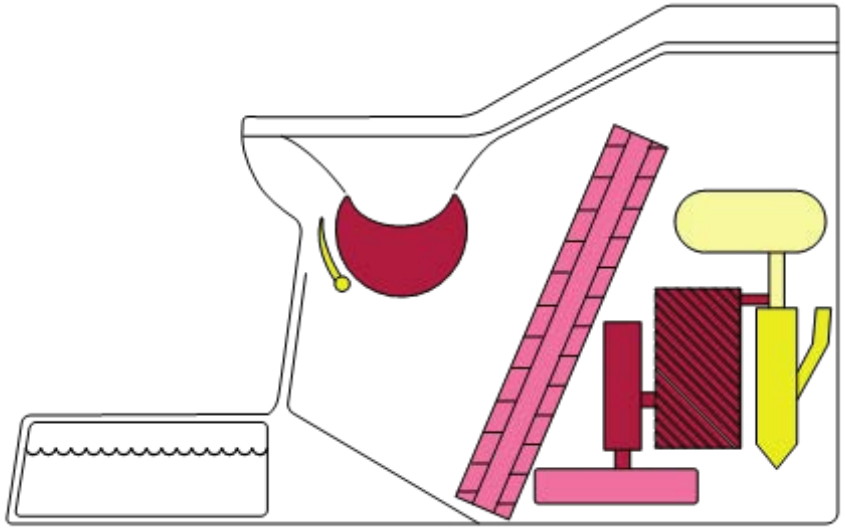
The Reinvented Toilet is a modular, transformative technology that offers a non-sewered sanitation solution, eliminating the need for a piped collection system. The aim of the Reinvented Toilet is to: destroy all pathogens onsite and recover valuable resources, operate without sewer, water or electricity connections and cost less than $0.05/user/day in a sustainable business model.

ELIMINATE PATHOGENS

- Eliminate safety concerns via handling
- Reduce disease burden
- Improve environmental safety

OPERATE OFF GRID

- Eliminate need for external inputs such as water and energy
- Make portable and easy to install



CONVEY LOW LIFE-CYCLE COSTS

- Reduce need for pit emptying
- Ensure a sustainable business model, including maintenance via service providers

PRESENT MODULAR, ATTRACTIVE INTERFACE

- Reduce / eliminate construction costs
- Provide clean and dignified product
- Eliminate odors and waste

OUR CORE PROCESSING TECHNOLOGIES

ELECTROCHEMICAL

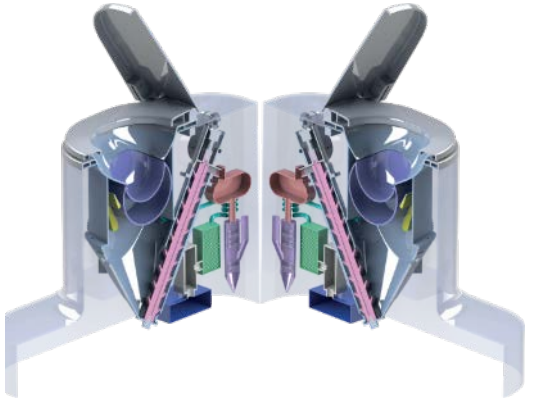
Caltech

WET OXIDATION

Loughborough University

eawag aquatic research

DRY COMBUSTION



University of Toronto

Cranfield University

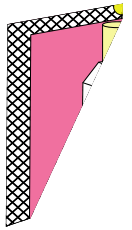
Duke University

RTI International

Three Bird Swan Consulting Group

JANICKI BIOENERGY

BIOLOGICAL



USF University of South Florida

UWE Bristol

INDIAN SINGLE-FAMILY HOUSEHOLD CONNECTED PROCESSING SYSTEMS - SEGMENT DESCRIPTORS – VALUE FOR BY-PRODUCTS

Use Case	Dwelling (Sq.M)	Electric Cost US$/Month
1	46-74	3.5-7.5
2	46-74	<3.5
3	>74	>7.5
4	<46	<3.5
5	<46	3.5-7.5
6	>74	>7.5
7	46-74	3.5-7.5
8	>74	>7.5
9	46-74	3.5-7.5

Age of construction (a)		New construction (<1 year)		Existing construction (>1 year)			
Toilet ownership				No toilet		Toilet	
Drain availability		No drain	Drain			No drain	Drain
Age of construction (b)				Old (>10 yrs.)	Recent (<10 yrs.)		
Occupation of Chief Wage Earner	*Highest education achieved in family*						
Skilled labor and small business owners		1	3	4	5	6	8
Salaried	**Some college education**						
	No college education	2				7	9
Unskilled labor							

Utility for by-products

By-product type

Electricity | Biogas | Water | Ash | Fertilizer

Utility color coding

Negative | Neutral | Medium | High

Value for By-products was evaluated on a relative basis, and as 'stated value'. This does not imply absolute lack of value and households may use by-products evaluated as 'neutral' with behavior change and education.

Source: FSG primary research; FSG analysis

INDIAN MULTI-FAMILY HOUSEHOLD / COMMERCIAL SECTOR PROCESSING SYSTEMS - SEGMENT DESCRIPTORS – VALUE FOR BY-PRODUCTS

Use Case	Generator /Solar	Key Decision Maker
1	Both	BAC
2	Gen	BA
3		BA
4		BA/BC
5	Gen	BA/BC
6	Gen	H
7		H
8		BO

B – Builder
A – Architect
C – Contractor
O – Owner
H – Homeowner

Age of construction		New construction		Existing construction	
Usage type		Residential	Commercial/ Institutional	Residential	Commercial/ Institutional
Primary price/ ULB land categori-zation	*Average hours of electricity supply*				
Premium & Luxury		1	5		8
Mid-segment	**Low electricity (≤80% hours)**	2		6	
	High electricity (>80% hours)	3			
Affordable		4		7	

Note: For biogas, commercial / institutional segments do not have any consumption usage and find the odor of the waste gas undesirable.

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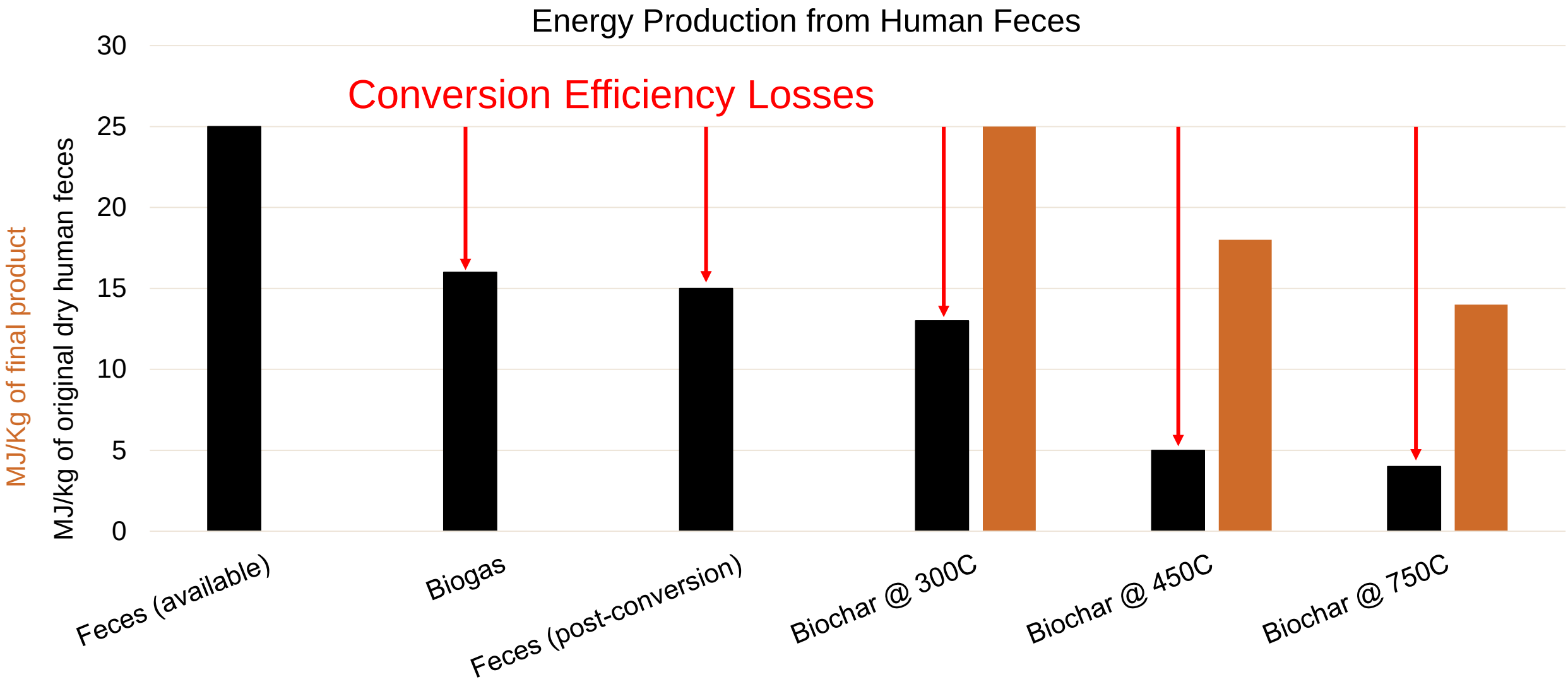
By-product type: Electricity, Biogas, Water, Ash, Fertilizer

Utility for by-products / *Utility color coding*: Negative, Neutral, Medium, High

Value for By-products was evaluated on a relative basis., and as 'stated value'. This does not imply absolute lack of value and HHs may use by-products evaluated as 'neutral' with behavior change and education.

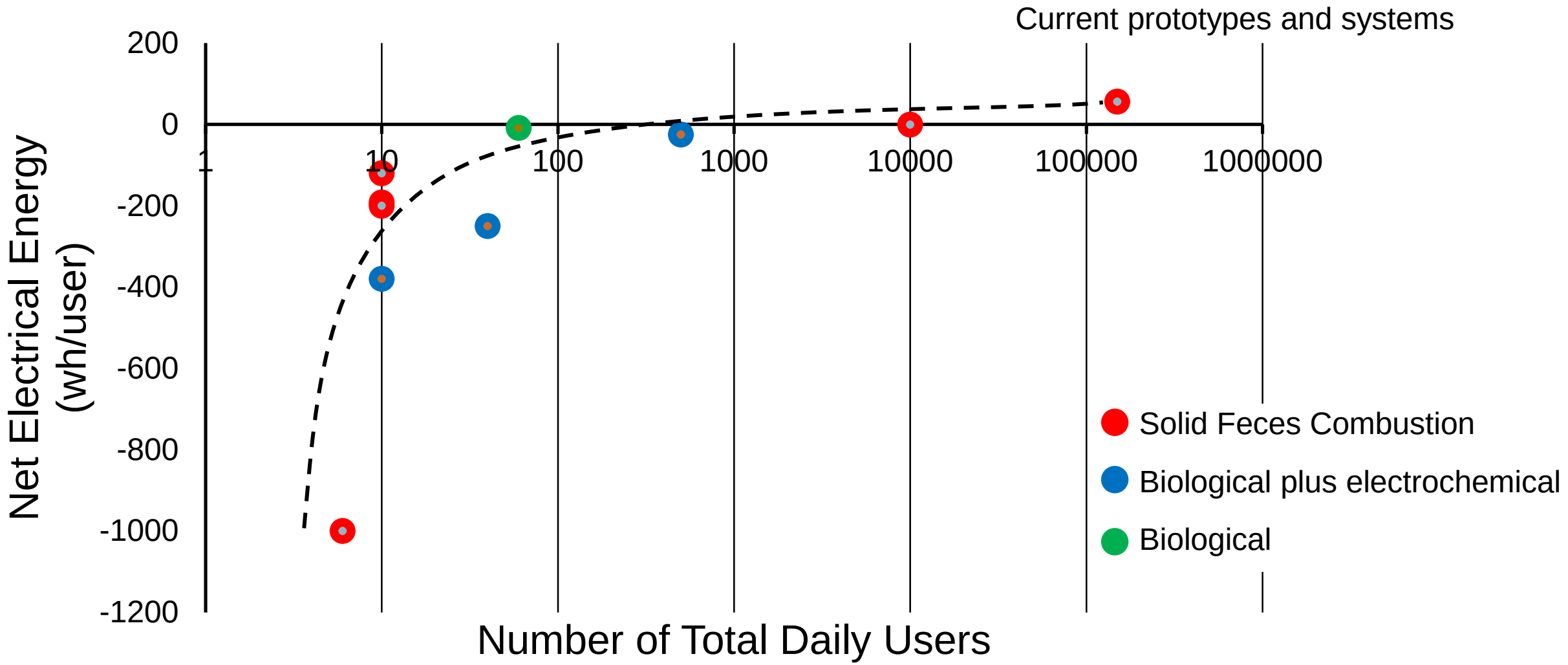
Source: FSG primary research; FSG analysis

ENERGY FOR OFF-GRID SANITATION



Onabanjo, 2016; Ward, 2014; UNU-INWEH, 2015

BMGF-WSH TRANSFORMATIVE TECHNOLOGIES PORTFOLIO – PEOPLE SERVED V'S NET ENERGY



“TRADITIONAL” RENEWABLE RESOURCES BEYOND WATER AND ENERGY

Resource	Urine (g/Person/Year)	Feces (g/Person/Year)
Nitrogen	1577	548
Phosphorous	131	183
Potassium	474	406
Sulphur	131	---

UNU-INWEH, 2015

Nitrification and stabilization reactor at Durban, South Africa utility, eThekwini Water Services Division. Fed from the buildings urine diverted toilets.

Simple struvite field production in Durban, South Africa. Testing being performed by the eThekwini Water Services Division. Fed from a village urine diverting toilets.

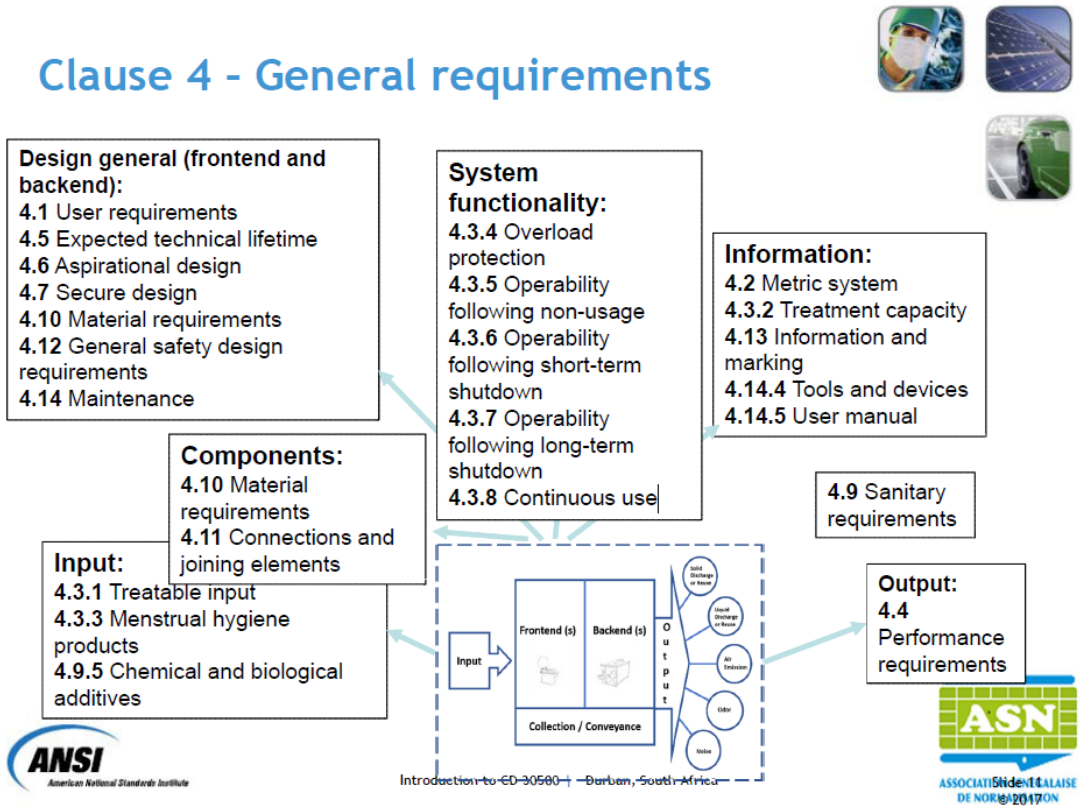
http://www.eawag.ch/en/department/eng/projects/vuna/

MARKET DRIVEN OPPORTUNITIES: EXCRETA BY- PRODUCTS

- **Urine fed Microbial Fuel Cells** (University of West of England)
  - Charging cell phones, lighting, Electrochemically Active Solution (ECAS), direct resource capture
- **Feces consuming Black Soldier Fly Larvae** (BSFL)
  - 40-50% protein (Fishmeal in Africa = US$1500 / ton)
  - 20 ton / day facility in Durban South Africa (eWS/AgriProtein)
- **Distilled water from excreta drying process**
  - Potentially lucrative engine coolant fluid market in Africa
- **Feces derived biochar** worth US$6 / ton in India
  - Use steam from the pyrolysis process to produce activated carbon worth US$60 / ton
- **Feces derived pyrolysis liquid** (Bio-oil)
  - Higher energy content compared to woody biomass derived bio-oil due to lipids converting to aromatic and aliphatic hydrocarbons
- **Feces derived volatile fatty acids including acetic acid**
  - Industrial reagent stock

STANDARDS (PC 305) TO DRIVE RESOURCE RECOVERY THROUGH POLICY CHANGE

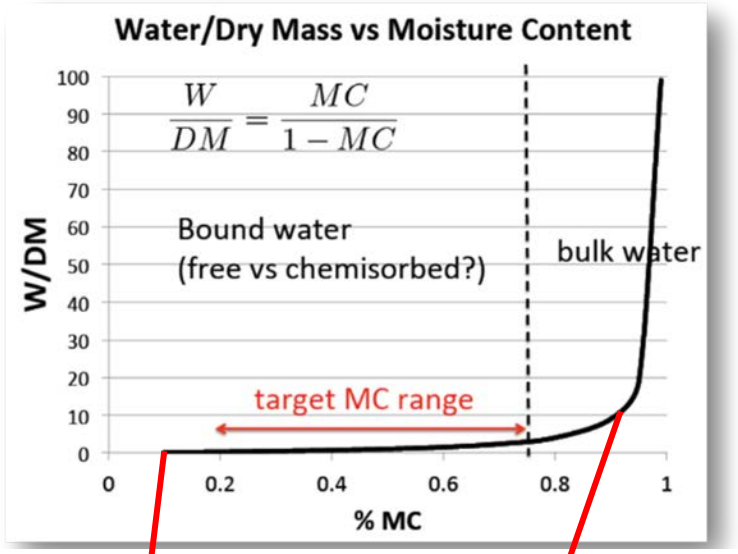
EXAMPLE OF REQUIREMENTS



EXAMPLE OF KEY INDICATORS

Parameters	Justification	Threshold
Human Enteric Pathogens	Bacteria (E. coli as surrogate) Virus (MS2 Coliphage) Protozoa (Clostridium perfringens spores)	≤100 per liter ≤10 per liter ≤1 per liter
Helminth eggs	Helminth eggs are considered a major health burden in many developing countries (Ascaris suum ova - surrogate)	≤ 1 eggs per litre
COD	Standard environmental performance parameter	≤ 50 (Category A) ≤ 150 (Category B)
TSS	Standard environmental performance parameter	≤ 10 (Category A) ≤ 30 (Category B)
Total nitrogen	Nitrogen is a pollutant for surface water and can cause eutrophication.	> 70% reduction
Total phosphorous	Phosphorous is a pollutant for surface water and can cause eutrophication	> 80% reduction
pH	Too high or too low pH is harmful to biological life.	6-9
Odor	Indicator of pleasantness and comfort - Maximum percentage of observations reported as “unacceptable”	< 2%
PM2,5 (µg/m³)	Air pollution indicator - Emission thresholds (1 h average)	< 10
Noise	Noise pollution indicator over the course of 24h	≤ 70 dBA ($L_{EX,24h}$)

FINALLY - BEYOND JUST SANITATION RESOURCE RECOVERY



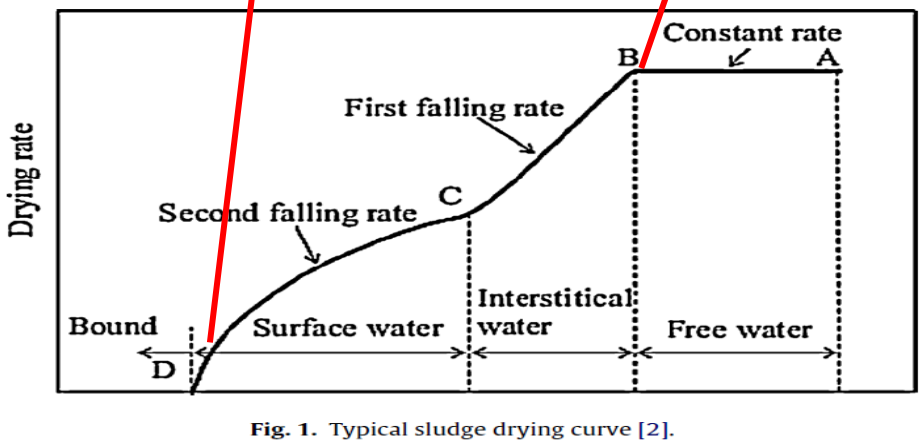


Fig. 1. Typical sludge drying curve [2].

Deng WY, Yan JH, Li XD, Wang F, Lu SY, Chi Y, et al.

	LHV (dry) (MJ/Kg)	Moisture (%)
Medical Waste (Non Anatomical)	30	1.5
Feces	25	75
Wood Fuel	19	50
Medical Waste (Anatomical)	17	70
Medical Waste (Maternity)	16	59
Lignite Coal	15	60

Potential Outputs from FS Microbiome studies (Kartik Chandran)

- Fundamental understanding of the microbes present.
  - How far can we push them and what else can they do?
  - Can we move past the ‘black-box’ understanding through mathematical modeling
- They are inherently linked to the human source.
  - Inference of human health?