Lifecycle energy & carbon footprint of sewered and non-sewered sanitation

Evidence from India and Zambia

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Motivations

Population growth & urbanization

Images: UN-Habitat (Julius Mwelu), 2014; NYT (Joao Silva), 2016; Laramee, 2015
Alternative sanitation approaches

**Non-sewered**
- ('FSM')

**Decentralized sewered**
- ('DEWATS')

**SDGs – ‘safely managed sanitation services’**
- New approaches and increasing investment
- Limited knowledge on the long-term environmental impacts
Research questions

1) What are the energy and carbon costs and benefits of decentralized sewered and non-sewered sanitation approaches?

2) To what extent does energy recovery affect costs and benefits?
Methods: Life Cycle Assessment (LCA)

• Methodology “to assess the environmental impacts associated with all the stages of a product or system’s life” (ISO, 2006)

• Functional unit: “Lifecycle management of excreta, urine and wastewater along the entire sanitation value chain: per-capita per-year”
Methods: System boundary

• Construction and use phase (20-year lifespan assumed)
Methods: Case studies

Non-sewered, Zambia
(12,000 people)
Dry pit latrine, manual conveyance, AD+SDB, biogas recovery

Non-sewered, India
(7,000 people)
Flush pit latrine, motorized conveyance, AD+SDB, biogas recovery

Decentralized Sewered, Zambia
(400 people)
Small-bore sewerage, DEWATS, biogas recovery

Decentralized Sewered, India
(600 people)
Small-bore sewerage, DEWATS, biogas recovery
PRELIMINARY FINDINGS

1. Overview - energy and carbon impacts at varying percentages of energy recovery
2. Construction Phase
3. Use Phase
Findings: Energy and carbon per % energy recovery

Energy resources - annual
(Construction & Use Phase)

NON-SEWERED: Lower per-capita energy required at no energy recovery

(100MJ ~ 3L Diesel)
Findings: Energy and carbon per % energy recovery

SEWERED: Greater potential to reduce energy resources at 100% energy recovery
Findings: Energy and carbon *per %* energy recovery

Energy resources - annual (Construction & Use Phase)

Sewered, Zambia: greatest potential to reduce energy (charcoal replaced)
Findings: Energy and carbon per % energy recovery

Energy resources - annual
(Construction & Use Phase)

NON-SEWERED: Minimal potential to reduce per-capita energy resources (most biogas lost during containment)
Findings: Energy and carbon per % energy recovery

Energy resources – annual (Construction and Use Phase)

CO₂(eq) emissions – annual (Construction and Use Phase)

100kgCO₂e ~ Driving 250km
Findings: Energy and carbon per % energy recovery

Energy resources – annual (Construction and Use Phase)

CO$_2$(eq) emissions – annual (Construction and Use Phase)
Construction: energy and carbon impacts

Energy resources
Construction (C)

MJ/capita/year

- Non-sewered, IND
- Non-sewered, ZM
- Sewered, IND
- Sewered, ZM

Containment (C) → Conveyance (C) → Treatment (C) → Disposal / Reuse (C)
Construction: energy and carbon impacts

Lower energy use for non-sewered versus sewered construction
Construction: energy and carbon impacts

Energy resources
Construction (C)

Minimal energy for disposal/reuse infrastructure

Sewered: treatment infrastructure ~70% energy use

Non-sewered: containment infrastructure (household pit latrines) ~ 60-80% energy use

Non-sewered, IND
Non-sewered, ZM
Sewered, IND
Sewered, ZM

Containment (C) → Conveyance (C) → Treatment (C) → Disposal / Reuse (C)
Construction: energy and carbon impacts

Energy resources

Construction (C)

Higher energy use for \textit{sewered} system in Zambia \textit{versus} India

Similar energy use for \textit{non-sewered} systems in Zambia and India
Construction: energy and carbon impacts

Energy resources
Construction (C)

CO₂(eq) emissions
Construction (C)

- Containment (C)
- Conveyance (C)
- Treatment (C)
- Disposal / Reuse (C)
Use phase: energy and carbon impacts

Assumptions (‘realistic’ scenario):
- 80% biogas production recovered
- Conventional fuel offset per energy content and fuel efficiency
Use phase: energy and carbon impacts

Lower energy requirements for non-sewered *versus* sewered systems

Sewered - higher potential energy recovery:
- Most biogas lost during containment phase (non-sewered)
- Higher energy recovery for Zambia system due to charcoal use
Use phase: energy and carbon impacts

Non-sewered systems:
- Minimal energy use for conveyance
Use phase: energy and carbon impacts

**Sewered systems:**
- Conveyance (water supply): 60-90% energy use
- Higher for India system due to water supply *via* deep borehole and tanker truck
- Minimal energy use for treatment
Use phase: energy and carbon impacts

Energy resources
Use Phase (U)

CO₂(eq) emissions
Use Phase (U)

Non-sewered: High emissions in containment stage
Use phase: energy and carbon impacts

Energy resources
Use Phase (U)

CO$_2$(eq) emissions
Use Phase (U)

Sewered: High emissions in treatment stage
Use phase: energy and carbon impacts

Energy resources
Use Phase (U)

Energy resources
Use Phase (U)

CO₂(eq) emissions
Use Phase (U)

Sewered: Higher potential for emissions reduction
Combined construction and use phase

Energy resources:
Construction (C) & Use (U)

CO$_2$(eq) emissions
Construction (C) & Use (U)

Substantial energy resources for construction

Most emissions produced in use phase

Construction phase:

Use phase:
Key takeaways – what matters?

• Non-sewered:
  1) Substantial carbon emissions during containment
  2) Minimal impact from motorized conveyance
  3) Minimal potential to reduce energy and carbon impacts via biogas recovery

• Sewered:
  1) Water supply may have a substantial impact on energy use
  2) Anaerobic treatment may produce substantial CO$_2$(eq) emissions
  3) Biogas recovery can substantially reduce energy use and CO$_2$(eq) emissions, particularly when replacing inefficient fuels
Thank you

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The research underlying this presentation has been supported by grants from the UPS Foundation and the Bremen Overseas Research and Development Association (BORDA). All opinions and conclusions expressed in this paper reflect the views of the author/s, and not necessarily the views of these sponsors.
Net energy and carbon impacts

Energy resources
Construction (C) & Use (U) Phase

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<th></th>
<th>MJ/capita/year</th>
<th>kgCO2e/capita/year</th>
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<tbody>
<tr>
<td>Non-sewered, IND</td>
<td>75</td>
<td>-150</td>
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<tr>
<td>Non-sewered, ZM</td>
<td>24</td>
<td>-100</td>
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<tr>
<td>Sewered, IND</td>
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<td>Sewered, ZM</td>
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Carbon emissions:
Construction (C) & Use (U)

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<th>kgCO2e/capita/year</th>
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<td>Non-sewered, IND</td>
<td>87</td>
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<tr>
<td>Non-sewered, ZM</td>
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<tr>
<td>Sewered, IND</td>
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<tr>
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