5th International Conference on
Sustainable Solid Waste Management

Estimation of biogas potential in Indian communities using a Geographic Information System combined with Material Flow Analysis

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Department of
Science and Technology

Introduction and background

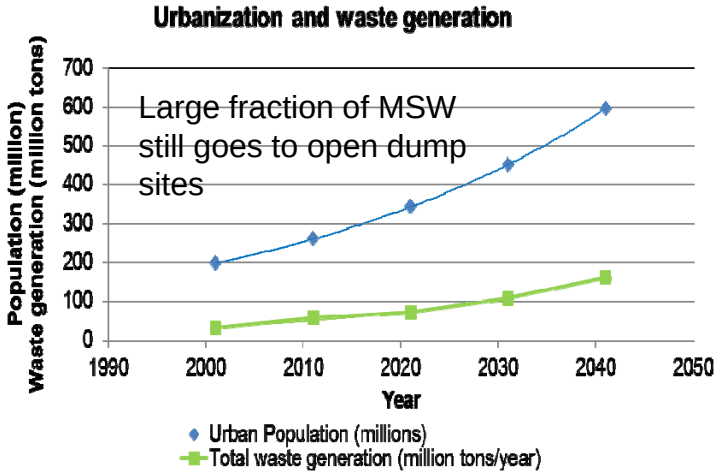
Introduction and background

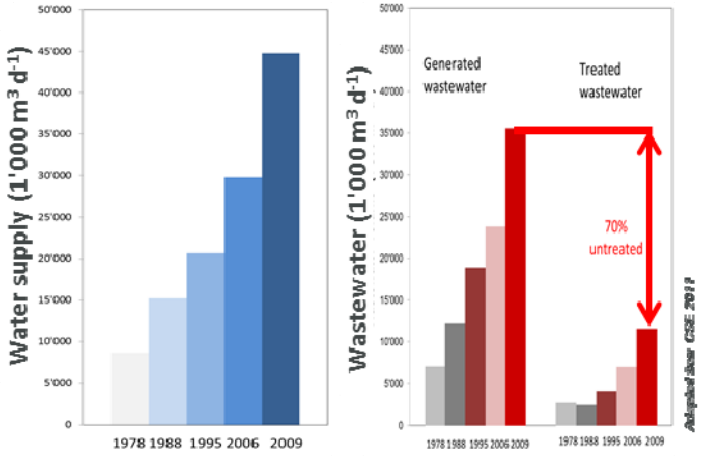
Major drivers on municipal waste generation in India

Population growth

Industrialization

Urbanization



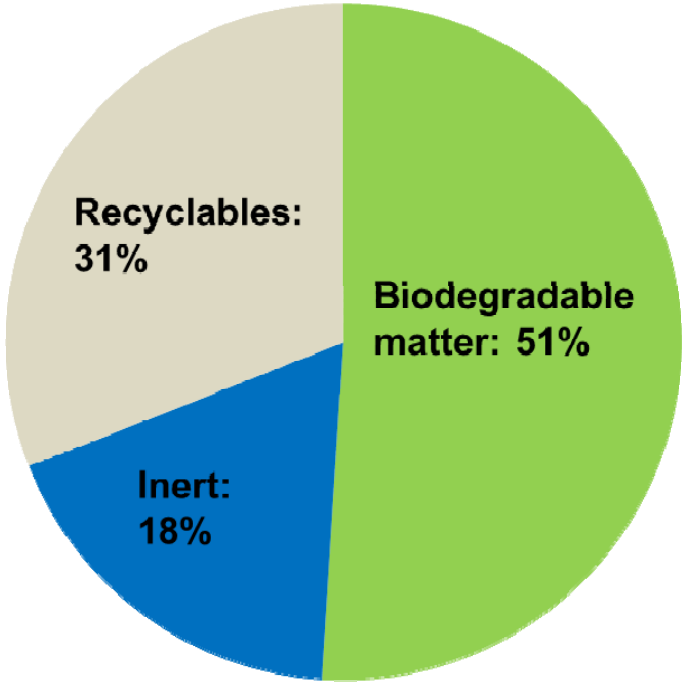


Pollution of natural resources

Public health hazards

Source of data: Annepu KA (2012) for solid waste and SCE (2011) for wastewater

Introduction and background
Biodegradables in MSW > 50%



Percentage of total wet weight MSW in urban India

Source: Annepu (2012)

Waste processing technologies

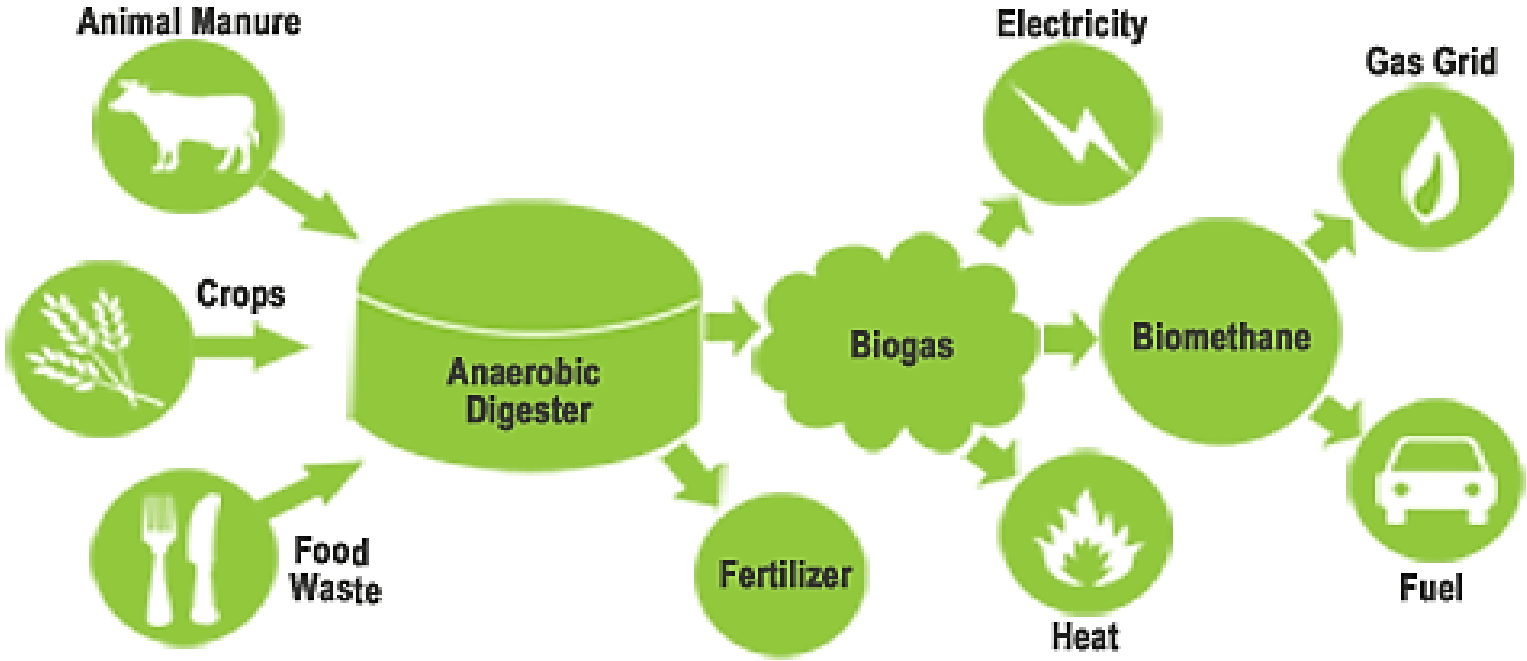
Thermal conversion processes:
- Incineration
- Pyrolysis
- Gasification
- Refuse-derived fuel

Bio-chemical conversion processes:
- Composting
- Vermi-composting
- Anaerobic digestion/ biomethanation

Chemical conversion processes
- Transesterification

→ **High organic fraction makes bio-chemical conversion processes particularly interesting**

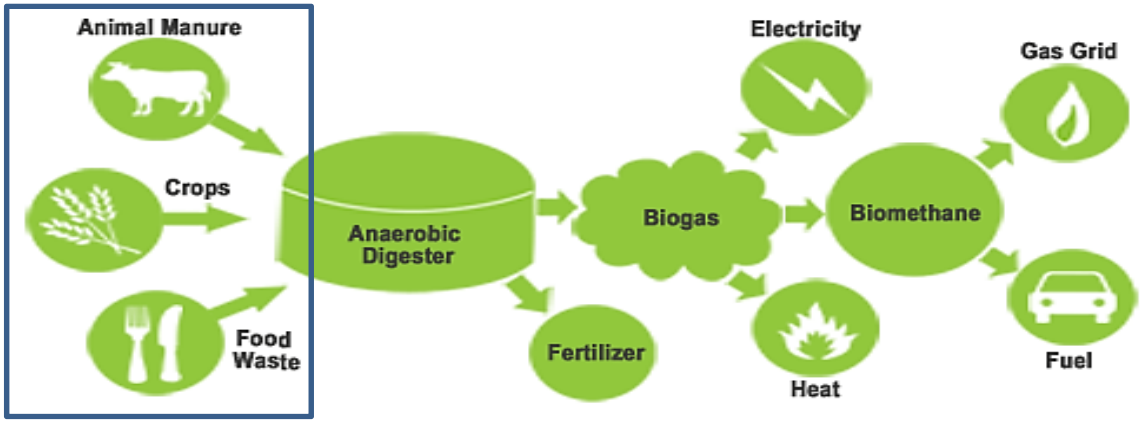
Introduction and background
Anaerobic digestion for organic MSW



… at the crossroad between MSW treatment, energy and agriculture

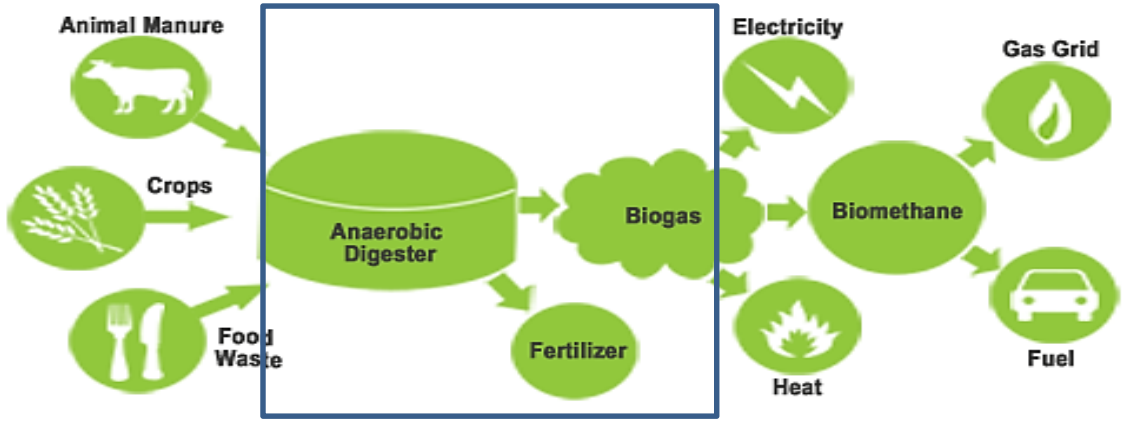
Sources: Minde GP, Magdum SS, Kalyanraman V (2013); Kalyani KA, Pandey KK (2014)

Introduction and background
Estimation of outputs, benefits and trade-offs



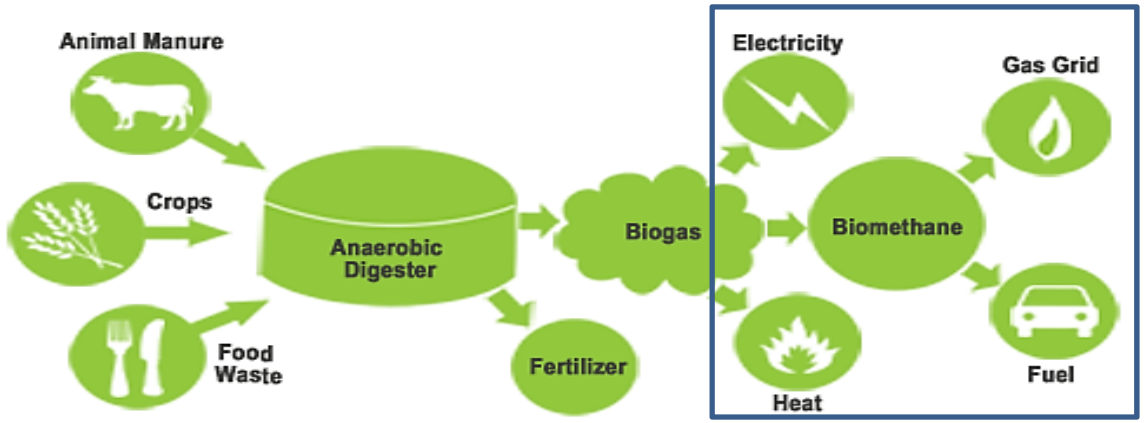
- Information on **quantity and quality** of biowaste

Introduction and background
Estimation of outputs, benefits and trade-offs



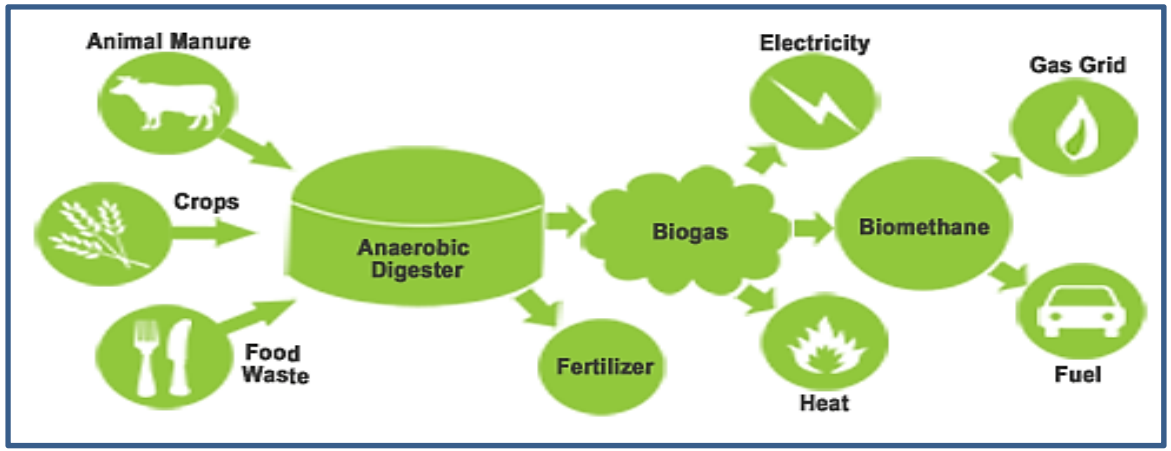
- Information on **quantity and quality** of biowaste
- Biogas/methane and fertilizer **output per unit waste**

Introduction and background
Estimation of outputs, benefits and trade-offs



- Information on **quantity and quality** of biowaste
- Biogas/methane and fertilizer **output per unit waste**
- **Demand** for outputs

Introduction and background
Estimation of outputs, benefits and trade-offs



- Information on **quantity and quality** of biowaste
- Biogas/methane and fertilizer **output per unit waste**
- **Demand** for outputs
- Interactions with other **sectors and interests** (e.g. agriculture, water and energy sectors etc.)

Research questions

Potential *vs.* demand estimation:

What is the energy potential from biowaste in Indian villages, towns and cities? Which fraction of the energy demand can be covered?

Interactions with other sectors (trade-offs/synergies):

Does biowaste have other functions which might be taken away? By how much could waste deposition be reduced?

Approach for (Indian) communities:

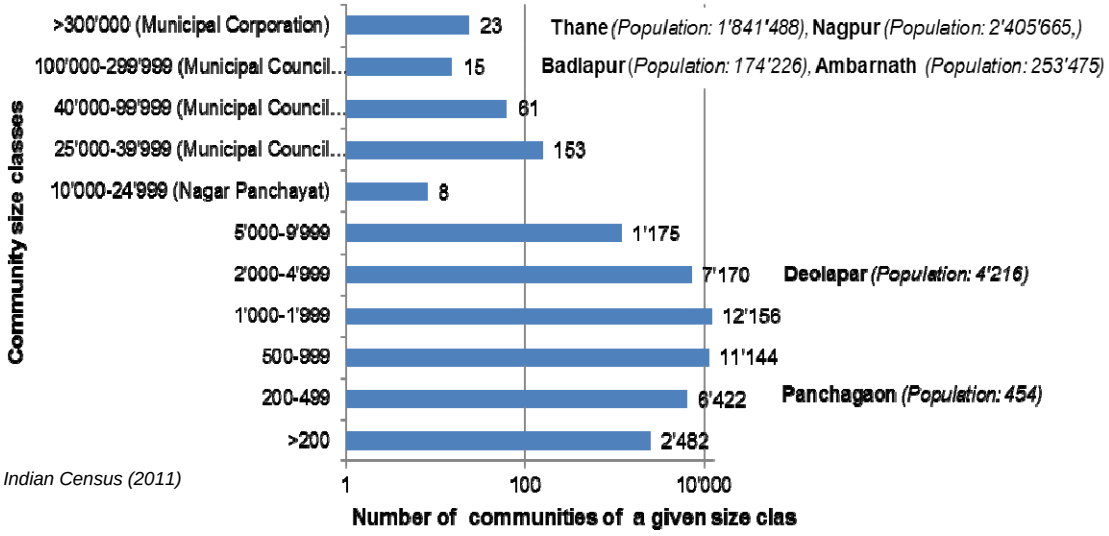
Are data available at relevant scales? How can these be utilized at a community scale for planning?

This is part of the project **'Optimization of organic waste to energy systems in India'** funded by the Swiss National Science Foundation and the Indian Department of Science and Technology under the Indo Swiss Joint Research Programme (ISJRP) 2013-2016.

Methods and materials

Methods

Six case study communities in Maharashtra



Indian Census (2011)

Nagpur, urban area

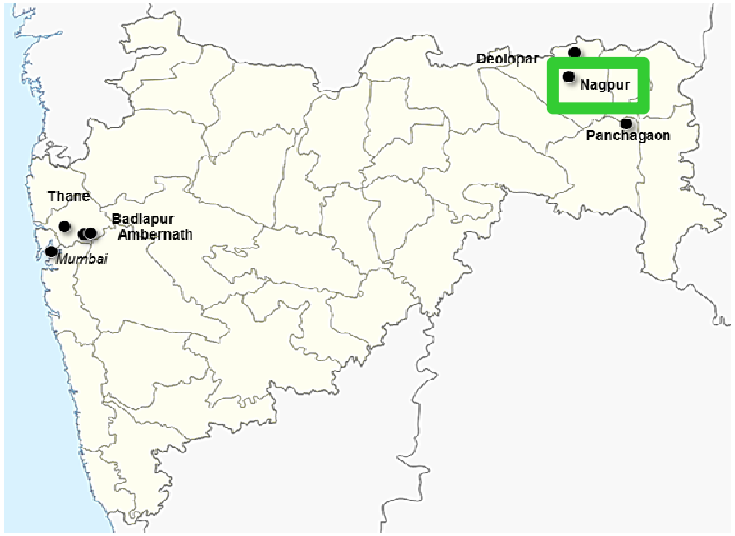
Ambarnath, urban and agricultural area

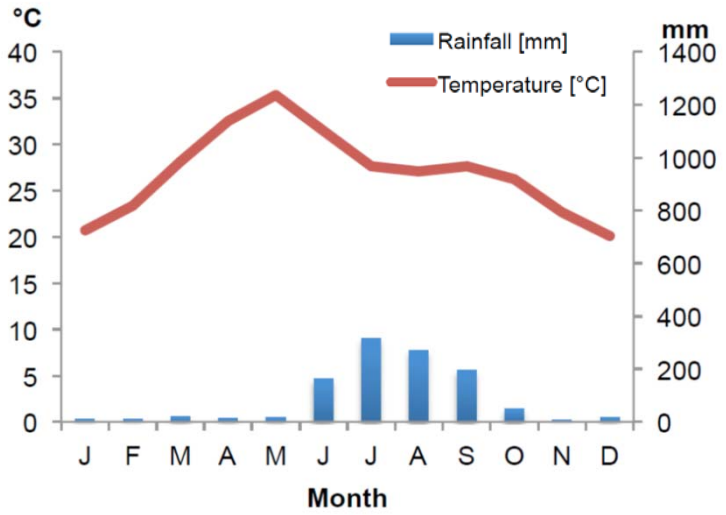
Panchagaon, agricultural area

Photographs: © Birgit Baumgartner

Methods

Worked example in this presentation: Nagpur City





- Ca. 2.4 Mio. inhabitants (2011)
- At the geographical centre of India with a tropical savannah climate
- Mainly urban area, with some agricultural land use at the boundary

Methods
Potential and demand

Land cover/'ecosystem' (LC/ES) properties

- Urban: Population density
- Agricultural, pastures: Livestock density
- Agricultural, cropland: Crops grown

LC/ES functions

- Biowaste/capita/time
- Manure/animal (livestock)/time
- Crop residues

Societal activities

- Energy consumption in households, industries, transportation etc.
- Agriculture, parks etc.




Methods

Potential and demand

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LC/ES functions

- Biowaste/capita/time
- Manure/animal (livestock)/time
- Crop residues/area$_{\text{crop type}}$/time

Societal activities

- Energy consumption in households, industries, transportation etc.
- Agriculture, parks etc.

LC/ES service

→ Biogas/methane potential (MJ/cap/yr)

→ Slurry production

LC/ES synergies and trade-offs

→ Reduces deposition needs

→ Water requirements for AD

Societal demand

→ Energy demand (MJ/cap/yr)

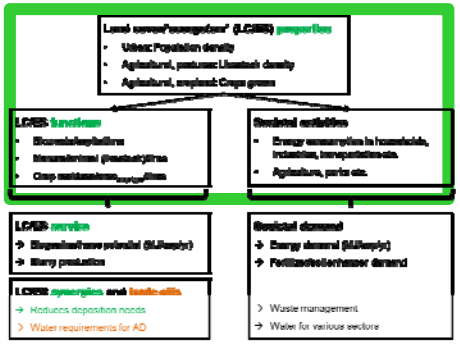
→ Fertilizer/soil enhancer demand

→ Waste management

→ Water for various sectors

Methods

Free open source tools applied



Geographic Information System

GIS platform: QGIS
(www.qgis.org)

Methods

Free open source tools applied

Geographic Information System

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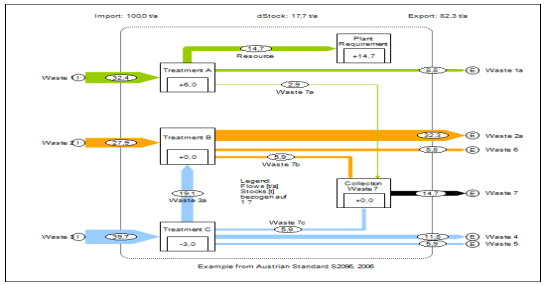
Material Flow Analysis



MFA tool: STAN
(http://stan2web.net)

- Transferable to various stakeholders (governmental, NGOs, engineering etc.)
- Learning events held in India and Nepal (for PhD/Postdocs)

Methods
Biochemical Methane Potential (BMP)

Waste sampling in six case study communities (biodegradable fraction, total solids, volatile solids, C/N etc.)

Biochemical Methane Potential (BMP) assays of local biowaste to estimate bioenergy potential

Semi-continuous experiments in 25 L mini-reactors

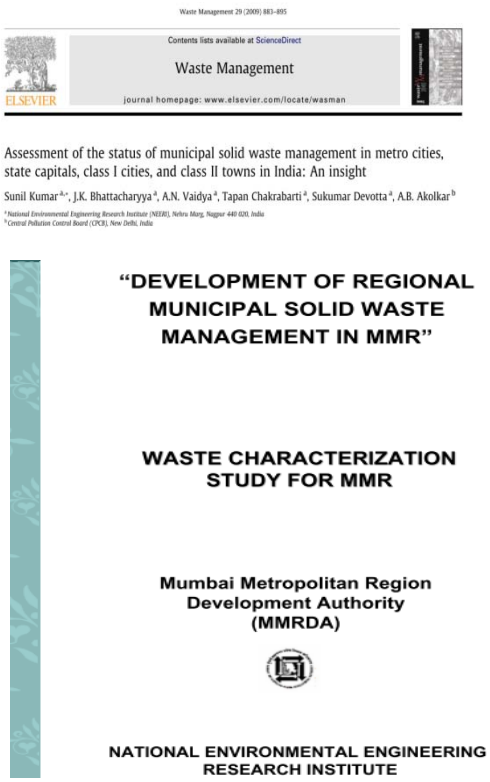
→ Breitenmoser et al., in prep.

Methods
Data inputs (examples)

GIS input

- Official ward map
- Indian national Census of 2011

MFA input


Waste Management 29 (2009) 883–895

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight

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"DEVELOPMENT OF REGIONAL MUNICIPAL SOLID WASTE MANAGEMENT IN MMR"

WASTE CHARACTERIZATION STUDY FOR MMR

Mumbai Metropolitan Region Development Authority (MMRDA)

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE

- Scientific papers
- Reports
- Interviews

Verification & refinement

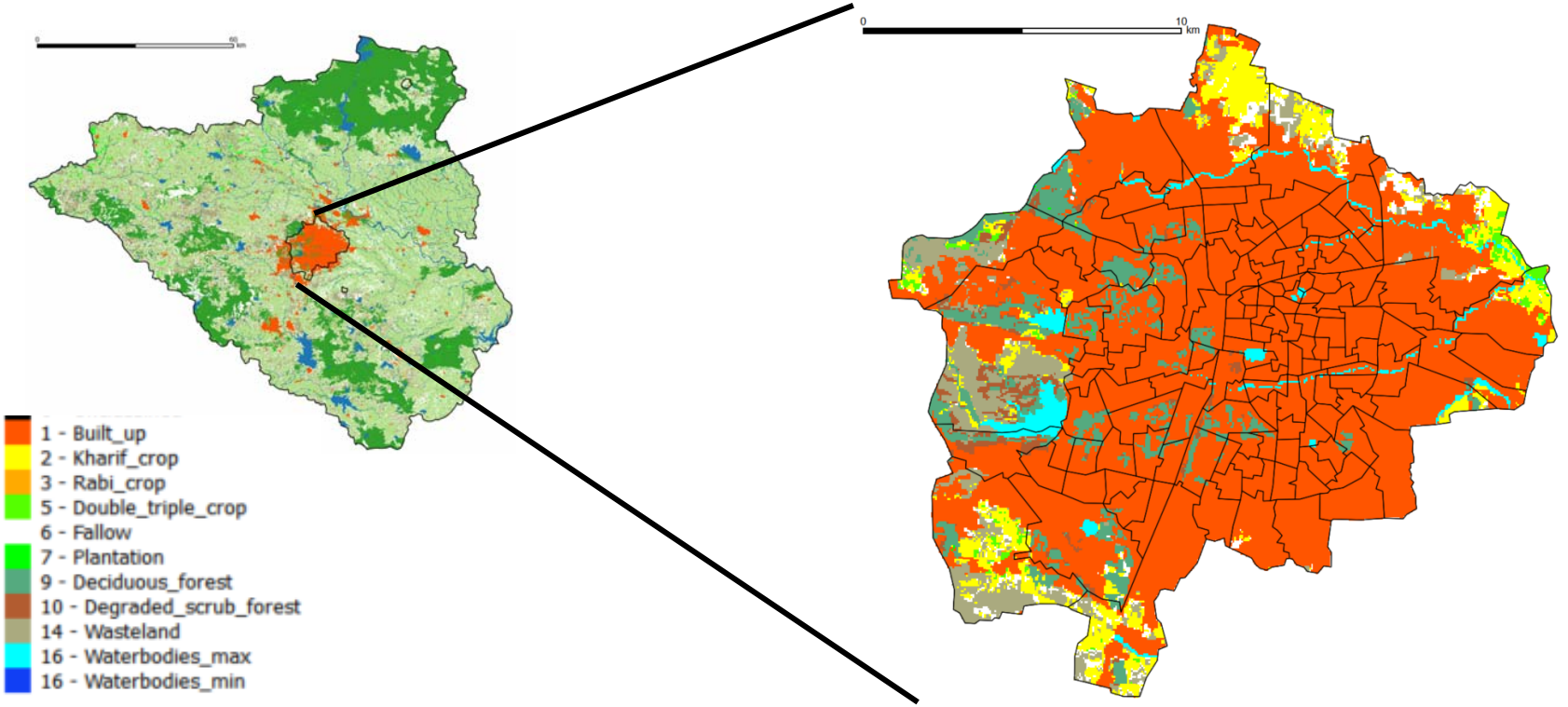
Results and discussion

Results
LC/ES properties: Land cover

Worked example:

Nagpur District (left)

Nagpur City (right)



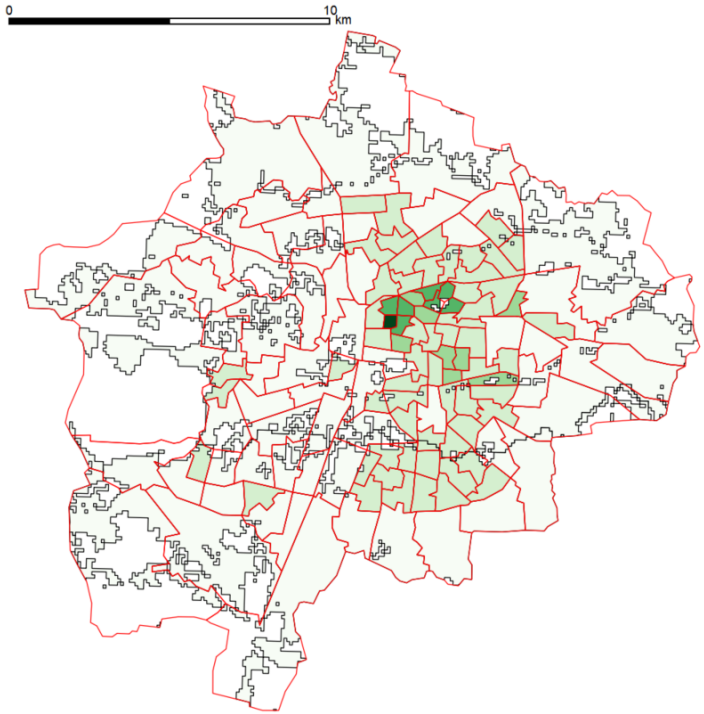
Results
LC/ES functions: Organic waste (examples)

Household biowaste:

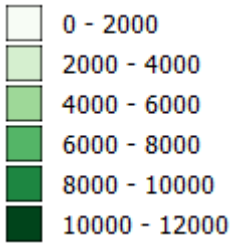
Population density

X

Biowaste per capita and year



Organic waste density ($tons_{wet}/km^2/yr$)



Manure:

Livestock density

X

Manure per animal and year

Results
LC/ES services: BMP results

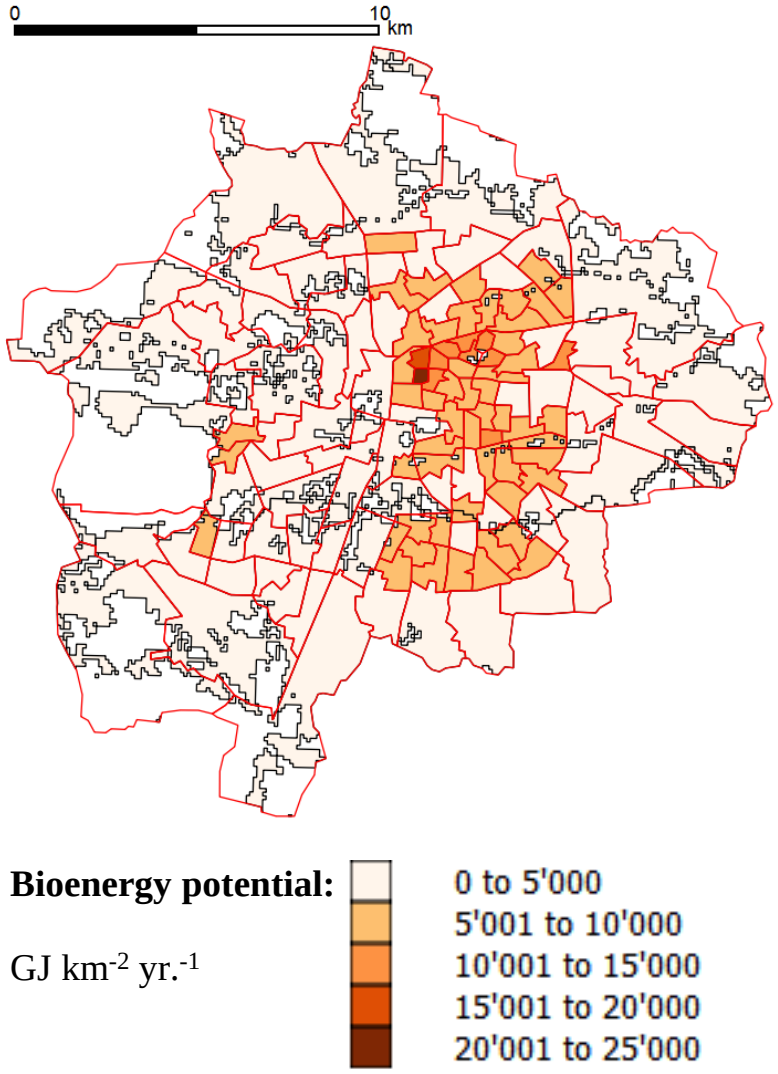
- Translation of LC/ES **functions to services**
- For energy derived from biogas: Waste characterization and biochemical methane potential (BMP) experiments:

Organic waste	TS ($\%_{ww}$)	VS ($\%_{TS}$)	Methane yield (m^3/t_{vs})
Biowaste (urban)	20-35	75-89	190-370
Cattle slurry	15-25	70-90	120-300
Market waste (various)	5-30	75-85	200-380

→ Preliminary results (Breitenmoser et al., in prep.)

Results

‘Ecosystem’ service: Renewable energy potential



$$\underline{\text{Biowaste}} \times BMP_{biowaste}$$

$$+$$

$$\underline{\text{Manure}} \times BMP_{manure}$$

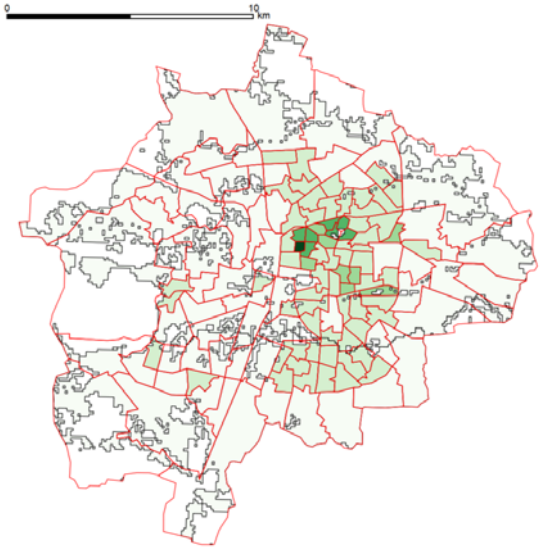
$$+$$

$$(\underline{\text{Crops residues}} \times BMP_{crop\ res})$$

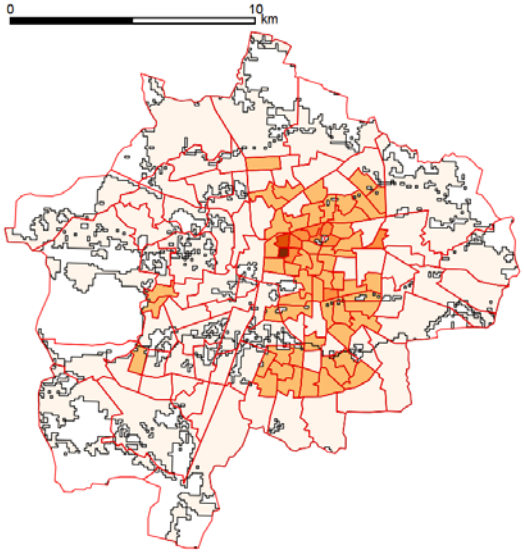
→ Spatial distribution of waste vs. energy **useful for AD planning** (where, how large, which substrate)

Results
Integration into existing MSWM system

Biowaste



Energy potential

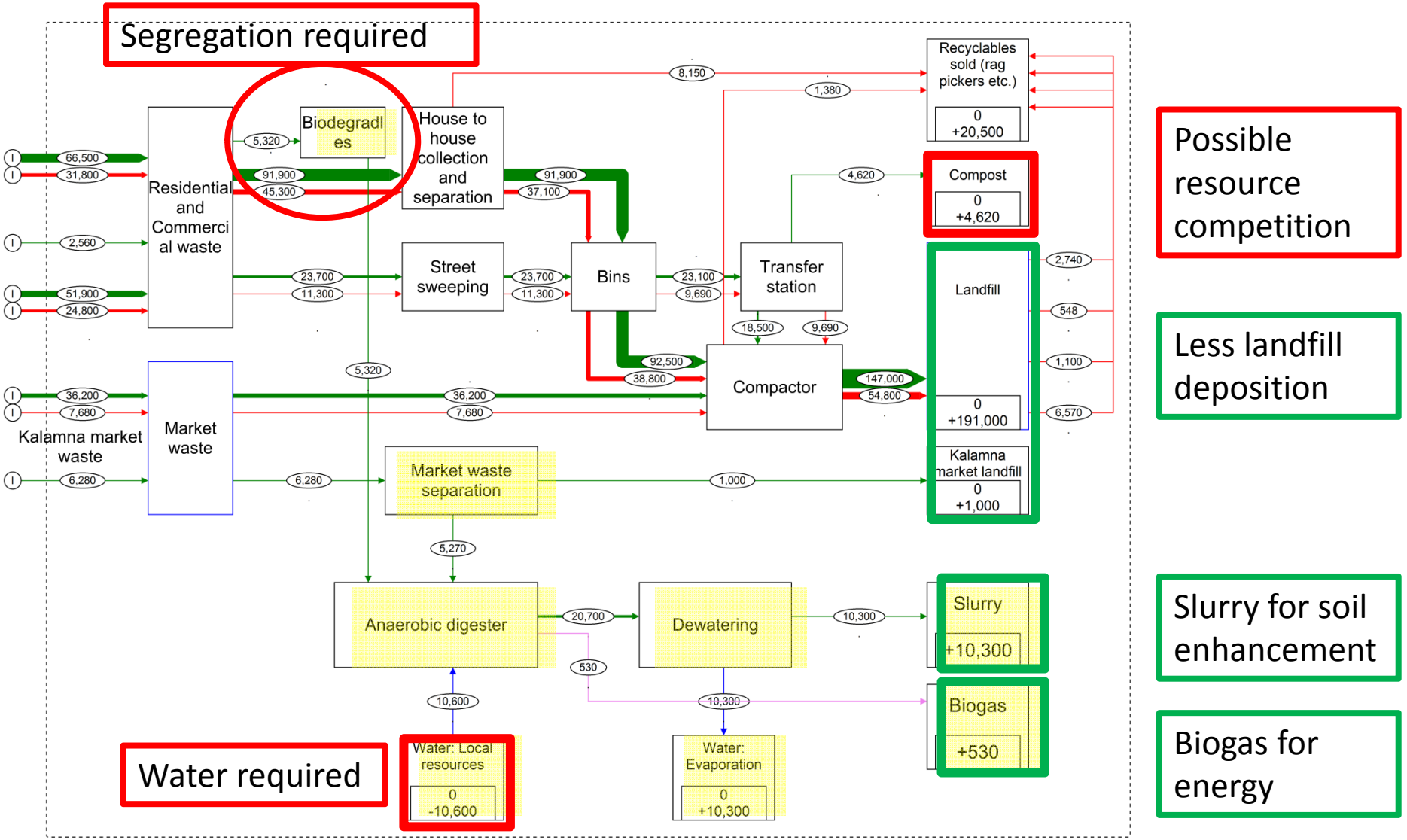


From waste **to output utilization** is not always straight forward, e.g.:

- Current utilization of some waste fractions (e.g. composting or feeding to animals)
- Which fractions are source segregated?
- Where is the waste currently deposited…
- Stakeholder involved

Results

MFA to visualize synergies and trade-offs



Possible resource competition

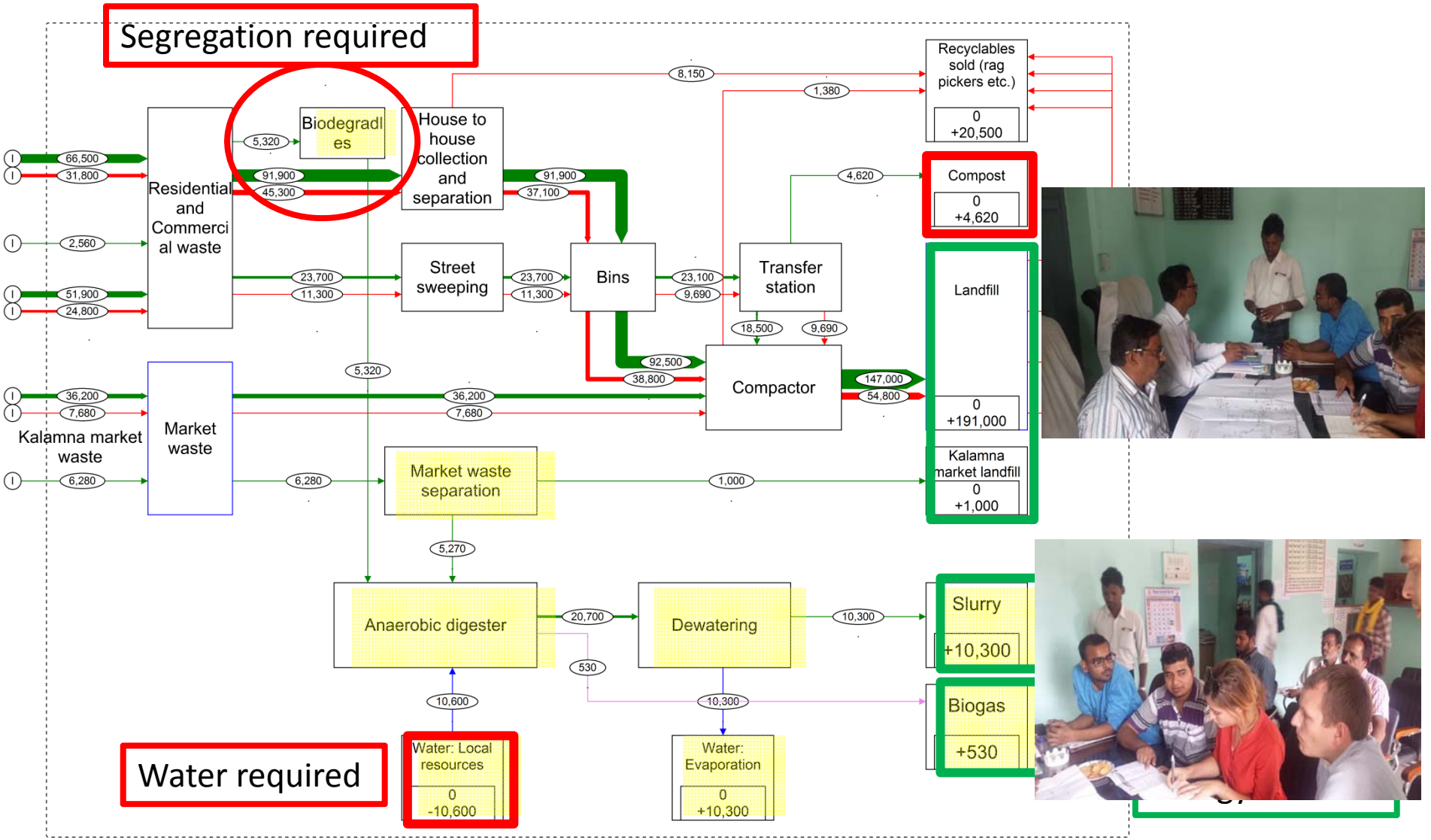
Less landfill deposition

Slurry for soil enhancement

Biogas for energy

Results

MFA to visualize synergies and trade-offs



Results
Data availability/practicability (excerpt)

Item	Data source	Spatiotemporal resolution	Data readiness
Population number	National census of India	Wards; 1991, 2001, 2011	++
Land cover/Land use	National Remote Sensing Institute of India	2001, 2011	++
Biowaste per capita and day	Available for some cities from official municipality reports	Various	+
Number of livestock per 1'000 households	Department of Animal Husbandry, Dairying & Fisheries	Districts;	+
Local waste management situation	At community level, interviews etc. required	Community	-
Methane potential of organic waste	Various; this study	Various	+/++

++ Very good
+ Ok, but more assumptions required
- Only locally available, on-site research required

Results
Potential *vs.* demand

Preliminary results for city context (Nagpur):

Theoretical biogas potential (if 100% of **available** biowaste were used and collected):

0.5 - 0.7 GJ/cap/yr

→ Ca. **2-3% of total energy** demand

→ Ca. **15-25% of LPG demand for cooking** (77% of households in Nagpur cook with LPG)

→ *Assumptions: 0.5 Nm^3 methane per person and day, 60% methane content in biogas, 38 MJ Nm^{-3} methane*

On-going research:

- Logistics of biogas to end-user
- Slurry utilization in an urban context

Conclusions

Conclusions (I)

Biogas potential in Indian communities

- In the urban example, up to ca. 5% of total energy demand and up to **25% of LPG cooking needs**
- More expected in rural context (work in progress)

Trade-offs and synergies

- In the **urban** example, **little trade-offs** are expected
- In rural communities, concurrence with animal feeding has to be avoided
- Reduced need for organic waste deposition; **inputs for agriculture and urban green spaces**

Conclusions (II)

Approach:

- Allows to **integrate information** from different sectors and results from lab analyses
- Helps **communicating** with stakeholders from different sectors
- **Transferable** to other sites, no financial barriers due to freeware tools

- Maximum quality of MFA is that of its input data
- Broad approach to facilitate between sectors (MSWM, energy, agriculture), does not replace detailed project planning

Thank you for your attention
Dhandyavaad!

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