Resource Value Mapping (REVAMP): A tool for evaluating the resource recovery potential of urban waste streams

There is increasing interest in the concept of the circular economy and "closing the loop" in our use of various vital resources – including water, energy and mineral resources. This is driven not only by an interest in reducing the social and environmental damage linked to resource extraction and waste disposal, but also in optimizing the use of resources in preparation for the end of the era of cheap oil and raw materials.

While the focus has been largely on industry, the case for "closing the loop" in relation to wastewater, sanitation and food and other organic waste is becoming ever stronger. Humans worldwide produce an estimated 9.5 million m^3 of excreta (Andersson et al. 2016), 900 million m^3 of municipal wastewater (Mateo-Sagasta et al. 2015) and 1.6 million tonnes of organic solid waste (Hoornweg and Bhada-Tata 2012) every day. Given the rapid growth of many of today's cities, these waste streams contain vast amounts of water, plant nutrients, organic matter and energy potential, all of which could be recovered and reused with cost-efficient investments – in the process alleviating burgeoning crises such as water scarcity, food security, climate change, energy security, disease epidemics and environmental degradation.

But to plan and obtain financing for these investments, urban planners and businesses need to know what resources are actually available in a city's waste streams, how they could be reused in a safe manner and, crucially, how much revenue could be obtained from reuse products. Stockholm Environment Institute is developing a new tool within the SEI Initiative on Sanitation (SISS) that will help to do this.

REVAMP

REVAMP is a tool being developed for quickly estimating, visualizing and valuing the resources that could be recovered from a city's organic waste streams: sewage sludge, faecal sludge, and food and other organic solid waste.

Users input available data on waste stream volumes and characteristics at city scale, along with values of different reuse products (currently biogas, solid combustion fuel, insect larvae for livestock feed, and compost fertilizer/soil conditioner). The tool can then:

- estimate the resources that could be recovered in various forms (such as plant nutrients, insect fat and protein, biogas);
- estimate the total quantities of reuse products that could be produced;
- estimate the potential revenues from different reuse products; and
- compare the reuse options on the basis of energy content, nutrient content and potential revenues, to support decision-making on city sanitation and waste management plans.

REVAMP outputs both numerical data and graphic visualizations.

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A man making briquettes from faecal sludge in Kampala, Uganda.

The current in-development version of REVAMP consists in a simple set of spreadsheets. However, as we develop the tool we hope to extend and refine its capabilities and explore the most user-friendly interfaces and outputs.

Target users

REVAMP is primarily intended for *policy-makers and planners* in cities as well as *managers* of water, sanitation and waste (along with the consultants, engineers and architects who support them), and for *entrepreneurs and investors* in urban sanitation and resource reuse. Given the vast sanitation access gaps and the rapid growth of cities in many low- and middle-income countries, REVAMP will also be useful for *development practitioners, students and researchers* . Finally, the breakdown of resources available should also be of interest to *researchers exploring innovative reuse products*.

Features

While REVAMP is not the first tool of its kind, previous tools have only been able to look at a single waste stream or resource recovery option, and have generally been designed for a particular project. In contrast REVAMP can capture all waste streams at city level, and compare a range of the most common reuse options. REVAMP is also tailored to the realities of the Global South; for example in taking into account faecal sludge from on-site sanitation systems, which are still prevalent in many cities, whereas most previous tools have been designed only for large-scale sewage collection.

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Cabbages grown in a commercial farm using urine and composted excreta as fertilizer in Adjumani, Uganda.

REVAMP uses the available data on the size and composition of the various organic waste streams, as well as local potential market values of different reuse products (or the products they could substitute for). However, it includes default values based on peer-reviewed literature where characterization and value data are unavailable, so it can still be used even where there are gaps in local data. Similarly, the calculation of available resources and potential for reuse products is based on scientific literature.

REVAMP considers a wide range of products, from energy (biogas and solid combustion fuels), agricultural fertilizer and soil conditioner, to animal feed ingredients (through breeding protein-rich black soldier fly larvae on treated waste), reflecting the dynamics of the resource recovery and reuse field.[1] This allows identification of the most viable reuse strategies for the specific municipality.

Testing REVAMP in Kampala

An early version of the tool was trialed in the Ugandan capital, Kampala, in 2016. Kampala is a city of 1.5 million people where around 90% of households use on-site sanitation systems (mainly pit latrines and septic tanks) while the rest, especially in the Central Business District, are connected to the sewer system.

In and around Kampala reuse products that could be generated from waste could meet some urgent needs. For example, biogas or solid combustion fuels could greatly alleviate the rapid forest loss that results from 78% of the city's population relying on woody biomass for cooking. At the same time, agricultural production in the city's wider hinterland is limited by the inadequate use of fertilizers, largely linked to the high cost of imported chemical fertilizers like urea (one of the most commonly used in Uganda). Financial revenues available from the reuse products were calculated using the current prices of propane, fuel briquettes and sludge-based soil conditioner. There are obviously additional economic and other benefits such as additional food production, job creation and environmental protection, besides the improvements in public health as a result of cleaner neighborhoods without indiscriminate disposal of excreta and organic solid waste.

1 For an example of an initiative using black soldier flies, see: http://www.agriprotein.com.

The trial used municipal data on the amounts of faecal sludge, sewage sludge and organic municipal solid waste collected daily in Kampala, along with data from characterization studies previously performed in the city. Calculations were made based on actual current collection (around 40% of what is generated) and also a scenario of 100% collection. The waste generated in Kampala every day could produce:

- 752 tonnes of solid combustion fuel (powder or briquette) – enough to substitute 1,108,700 people's firewood consumption, for total daily revenue of US$225,500; or
- 361,200 Nm^3 of biogas – enough to substitute around 824,000 people's firewood consumption – daily, along with 367 tonnes of residue that can be used as fertilizer or soil conditioner; total daily revenue US$121,000; or
- 198 tonnes of black soldier fly larvae – enough to substitute about 134 tonnes of dried fish meal – along with 526 tonnes of residue that can be used as fertilizer or soil conditioner; total daily revenue US$42,200; or
- 909 tonnes of composted fertilizer – containing nutrients enough to substitute 5 tonnes of urea fertilizer, along with organic matter that would improve soil condition, which chemical fertilizers do not provide; total daily revenue US$4,500.

These results were shared with officials from the Public Health and Environment Directorate of the Kampala Capital City Authority.

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Trucks emptying faecal sludge at Bugolobi Wastewater Treatment Plant in Kampala, Uganda.

The future of REVAMP

REVAMP is being developed within the SEI Initiative on Sustainable Sanitation. In the near future, we plan to expand the capacity of the tool to incorporate more waste streams (e.g. raw wastewater and animal manure) and more resource recovery options like reclaimed water.

We also aim to develop the tool to take into account another set of crucial variables: the capital and running costs, and environmental impacts, of different waste treatment and resource recovery technologies.

Other aims are to migrate the tool from spreadsheets into a platform where it can be more intuitive and provide an improved user experience along with better visualization.

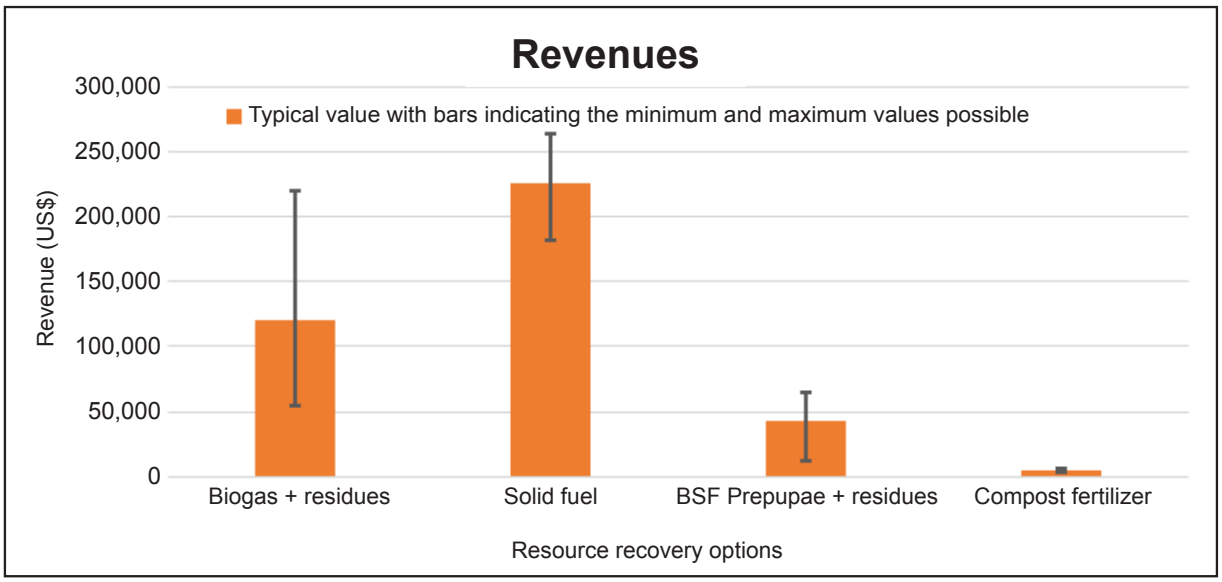

Figure 1: An output from REVAMP comparing the potential revenues from different resource recovery options, 100% collection of all organic waste streams in Kampala

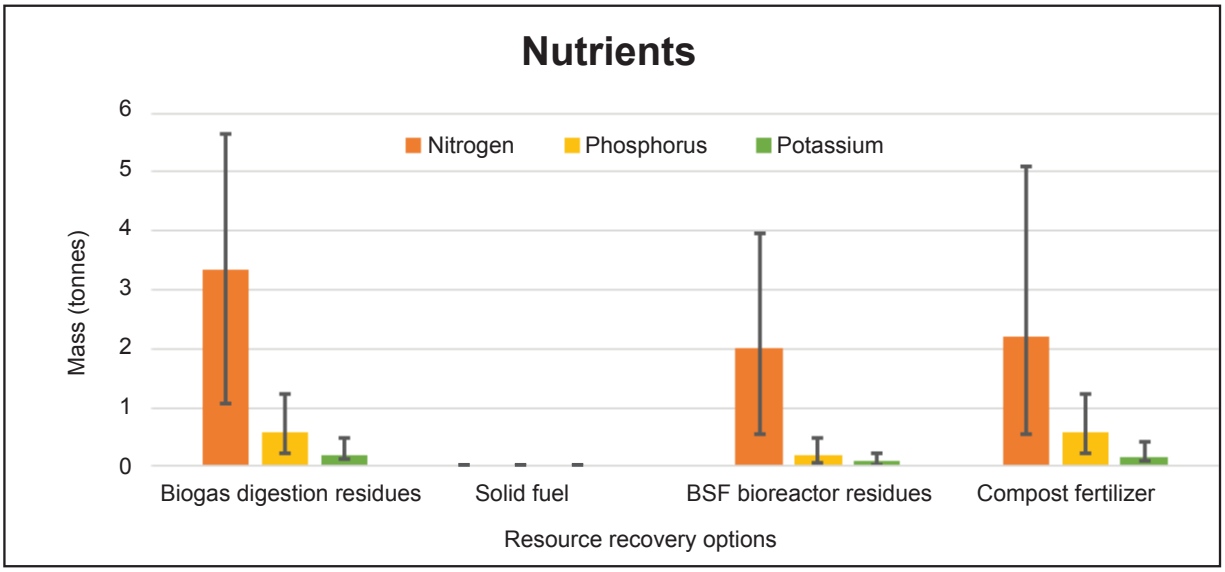

Figure 2: An output from REVAMP comparing the nutrient content that could be made available daily for agricultural reuse under different resource recovery options, 100% collection of all organic waste streams in Kampala

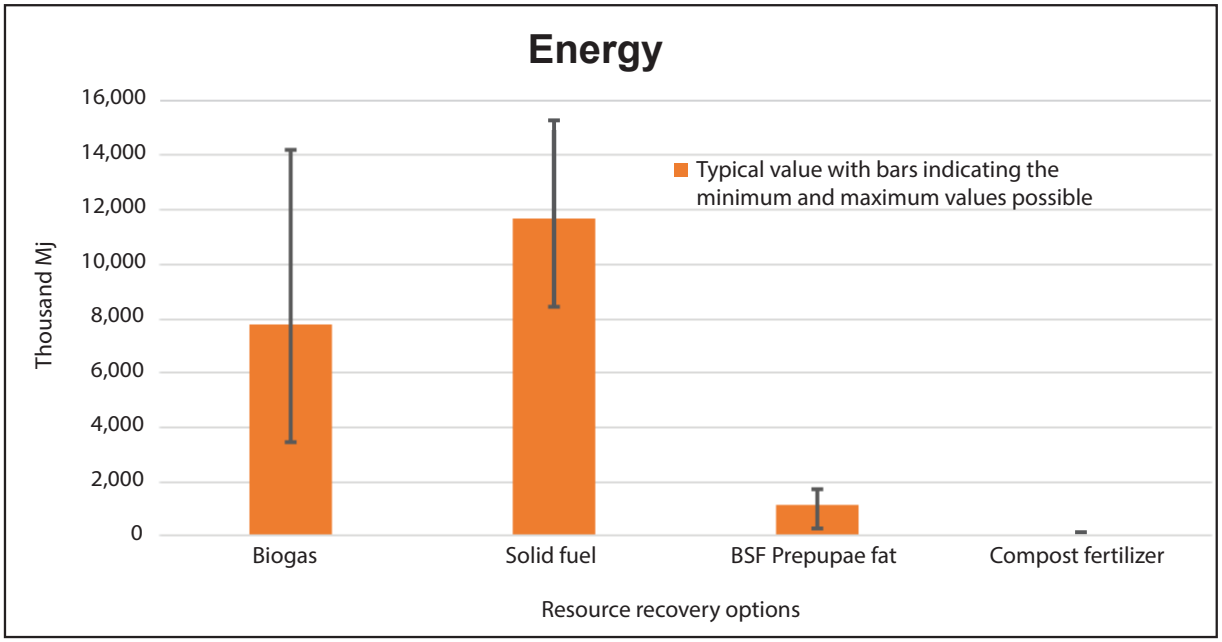

Figure 3: An output from REVAMP comparing the energy content that could be recovered daily under different resource recovery options, 100% collection of all organic waste streams in Kampala

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Sieving compost made from excreta and organic solid waste, in preparation for sale at a facility operated by SOIL Haiti

We will also explore linking the tool with other planning tools for energy, water resources, food security and waste management for a more integrated approach to natural resource planning and management.

SEI is keen to hear feedback about the REVAMP tool and to build partnerships with others who could help its further development. We are especially interested in institutions that can partner with us to calibrate and test the tool in more cities as well as funders who could support continued testing and development.

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Waste pickers weigh a bag of plastics for recycling at Kiteezi Landfill in Kampala, Uganda. While plastics, metal, paper and cardboard are removed and recycled, the organic part of the waste (up to 90%) is ignored.

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This discussion brief was written by Daniel Isaac Waya Ddiba, Kim Andersson and Arno Rosemarin. The first phase of the REVAMP tool was based on master's thesis work done by Daniel at KTH Royal Institute of Technology.

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Published by:
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2016

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