

BUILDING FUTURE SANITATION MODELS

A REPORT PREPARED FOR THE
TOILET BOARD COALITION
SPONSORED BY UNILEVER

AUTHOR:
JONATHON HAGUE

DRAFT REPORT NOT FOR
FURTHER CIRCULATION



1. BACKGROUND AND APPROACH

A piece of work was commissioned to understand how new technologies and future sanitation models could be harnessed to accelerate the goal to accelerate the provision of access to affordable, hygienic, economic and environmentally sustainable sanitation for the 2.5 billion people on the planet lacking such access.

The review aims to recommend how the Toilet Board Coalition could 'add unique value' to help accelerate sanitation technologies currently in the research and development phase to commercialization. It will demonstrate how to leverage the assets that have been developed or are being developed, to contribute in a way that is unique, collaborative, scalable and incremental to key existing initiatives, and so the overall sector.

The work has recognized the need to take a broader systems perspective towards the sanitation challenge, since in many cases today sanitation approaches experience market failure or shift the problem of creating affordable, hygienic, economic and environmentally sustainable sanitation solutions towards the treatment end of the value system.

The key criteria to assess and determine viable future approaches are as follows:

ECONOMIC
works in the context of the end to end value chain.



ENVIRONMENTAL
via an appropriate environmental standard, which should be absolute in nature.



SOCIAL
the protection of human health and provides local employment and improves communities.



CONSUMER
provides dignity, convenience and value.



TECHNOLOGICAL
likely to perform technically and be implementable at scale





The approach used the following basic sanitation value system as the framework to map where each technology solution functioned in the value system.

Unless each element in the value system is properly considered we will continue to see the proliferation of sub-optimal approaches that fail to deliver significant interventions on one or more of the criteria noted above. Recommendations made in this report for future intervention will not compromise on any of these criteria. Recognizing that many players in the sanitation sector aim to improve or address parts of the existing value chain, the Futures report is specifically looking to identify disruptive technologies and models. These have the potential to create new value chains and in doing so leapfrog some of the key barriers currently faced (emptying, transport, treatment). They will have the potential to adapt / succeed in future scenarios (E.g. water or land scarcity etc), and potentially make better investment opportunities due to the fact that they extend the sanitation value chain into the creation of valuable or useful products from waste.

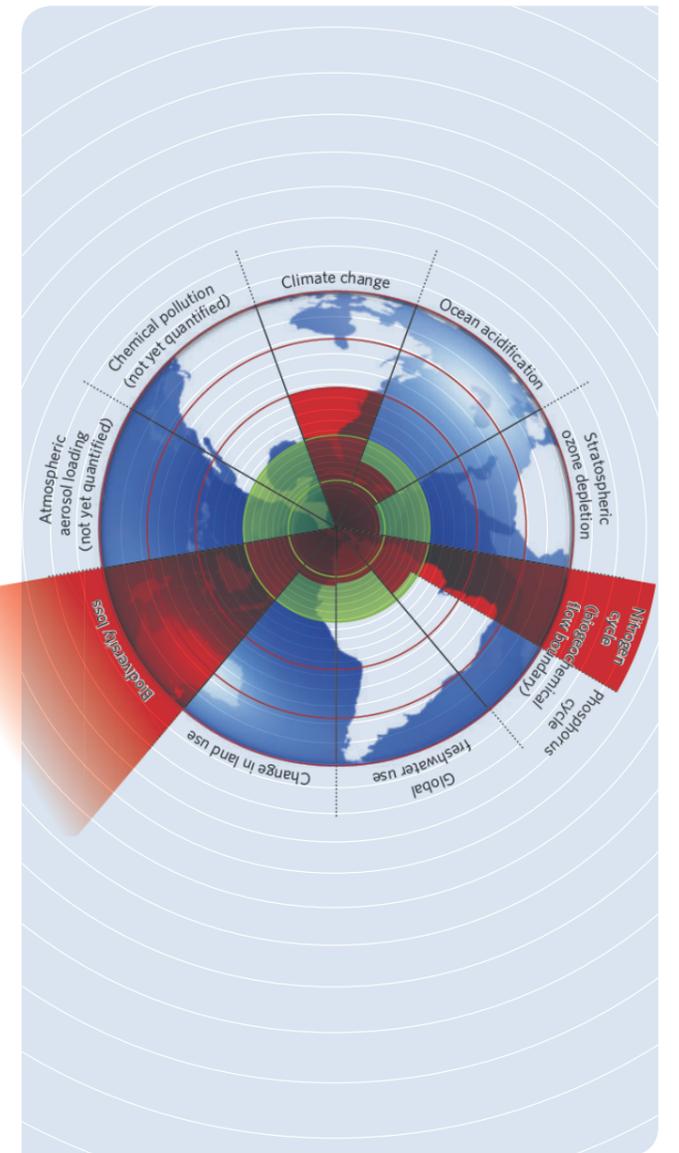
2. INPUTS

2.1 AN ASSESSMENT OF FUTURE PLANETARY BOUNDARY SCENARIOS

This future thinking about the planetary boundaries (Rockstrom et al, Nature, 2009 (1)) that potentially limits sanitation solutions in the assessment of future models has been mapped for the first time alongside the spectrum of existing solutions.

The summary of our assessment of the impact of planetary boundaries in the next decade is as follows:

- Proper management of human waste is on such a systems-scale that there is scope to consider directional reversal of the phosphorus (P) and nitrogen (N) planetary boundary overload
 - Amount of nitrogen removed from the atmosphere for human use is around 120Mt/year on a proposed boundary of 35 Mt/year¹
 - Quantity of phosphorus flowing into the oceans is around 9Mt/year against a proposed boundary of 11Mt/year¹
 - These boundaries have been largely driven by the need for fertilizer in agriculture. The sustainable business model focuses on the need for fertilizer to grow the food for a growing population in those markets where the ~2.6bn people do not have access to sanitation. Human waste could be the source of nutrients for this fertiliser requirement.
- In water scarce countries, zero or low water solutions will be required, or water will need to be recovered and reused. Our analysis shows many places with poor sanitation are also water scarce / access to water is limited
- Energy neutral / energy positive solutions should be viable, leading to a reduction in overall carbon footprint from the sanitation sector.
 - 'Every day over 2 million tones of human waste are disposed of in water courses'²
 - Contributions of methane (CH₄) and nitrous oxides (N₂O) from human waste is relatively small in the total global context, however is expected to grow significantly from 2010 to 2020 with the increase in urbanization and the open disposal of human waste. Emissions related to human waste are estimated to increase from 610Mt CO₂eq/year to 770Mt CO₂eq/year in this 10 year period – albeit the estimates have high uncertainty.³ This is equivalent to the impact of the size of a nation like Germany, about 5th biggest in the world, and so not an insignificant contribution. Capturing the methane from the waste of the 2.6 Bn people without access to proper sanitation today would reduce impact by over 300 Mt CO₂eq/year.



Nature 461, 472-475 (24 September 2009)

All developing countries are expected to have the majority of their citizens living in cities by 2030. Although the percentage of people living in slums is declining, the absolute numbers will continue to grow, with over 889 million people predicted to live in slums by 2020.⁴ Therefore, it is vital that we make urban sanitation a priority area to tackle. Given the lack of planning of the urban environment in many megacities, any solution has to provide a low land impact. A low capital, low land impact, stand alone solution that is commercially viable, for the district scale treatment in mega cities would be a very valuable step forward in human sanitation. Furthermore we cannot ignore the fact that there will be more rural consumers also as the overall population continues to grow to 2050. There is little hope that we can centrally manage waste in this environment so individual home and village scale solutions are needed.

¹ Rockstrom et al. A safe operating space for humanity. Nature 461, 472-475 (24 September 2009) | doi:10.1038/461472a; Published online 23 September 2009. <http://www.nature.com/nature/journal/v461/n7263/full/461472a.html>
² United Nations, Water and Cities Facts and Figures, http://www.un.org/waterforlifedecade/swm_cities_zaragoza_2010/pdf/facts_and_figures_long_final_eng.pdf accessed via <http://www.wsup.com/programme/issues/sanitation/>
³ Bogner, J., M. Abdelrafie Ahmed, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, T. Zhang, Waste Management, In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Chapter 10, section 10.3.3
⁴ UN Habitat, (2010). State of the World's Cities 2010/1011 – Cities for All: Bridging the Urban Divide.

2.2. MAPPING OF THE TECHNOLOGICAL DEVELOPMENTS THAT ARE UNDERWAY ACROSS THE VALUE CHAIN FOR SANITATION

A mapping exercise was undertaken on the technological developments in the sanitation sector. This is not exhaustive and will clearly evolve with time, but is illustrative of what is happening in the human sanitation R&D. We chose to map the technologies assessing technology readiness and position in the value chain, and offer a view on which technologies has the scope for delivery of a new values chain and / or the elimination of the existing value systems.

Our findings

- The current technical innovation approach has skewed R&D in waste capture towards disruptive, and very ambitious technical solutions. This is a deliberate and welcome initiative to stimulate research in the sector. These are split into three broad groups; toilets that will eliminate waste at source, equipment to remove some of the water from sludge while removing and transporting it from storage tanks and neighbourhood scale waste treatment units. NASA's technology readiness level system proved useful when exploring the development of these technologies, although the two pivotal points were felt to be when the scientific proof of principle was reached and when the cost was engineered down to an acceptable level where the risk involves execution rather than scientific advance. Some of these technologies have advanced to field trials of working prototypes, and so have passed the first of these points.
- There is little R&D in waste collection and transport. This is perhaps not a surprise, as it possibly is the lowest level of

technical sensitivity in the value system but this cannot be overlooked especially in the urban environment where land scarcity and high population density mean the safe, hygienic removal of waste from homes or public facilities is a critical social element of the value system.

- There are many technologies for waste treatment, mostly variants on well recognised technologies that exist today such as digestion techniques. As we will see later there are significant barriers to the widespread adoption of these technologies. More radical approaches are being examined (such as 'vermi composting' soldier fly larve and pyrolysis) but in the end there are three fundamental challenges to wider adoption of waste treatment technologies. Firstly, the absence of a planned and highly invested city infrastructure, secondly, the ability to generate valuable waste streams from the treatment of human waste and thirdly, the lack of necessary regulations and sanctions to prevent waste being disposed of irresponsibly.

Neighbourhood scale

<ul style="list-style-type: none"> Yellow = where technologies could make elements of value chains redundant or create new value chains Green = supports existing value chains 	Toilet technology (facility & installation, usage, cleaning, storage)	Transport technology (collection of waste)	Processing technology (treatment, disposal & recovery)
Technologies that are uncertain to succeed because success depends on scientific advance or even a breakthrough (>5 years)	2 3 4 5 7 9 10 11 12 13 15 16		
Technologies that involve risk to develop and commercialize but where the risk involves execution rather than scientific advance. (3-5 years)	8	1	6 17 31 32 41 53 54 64 65 67 71
Technologies ready to scale or at scale. (1-3 years)	21 22 25 26 28 29 30 33 34 14 18 19 20 23 24 27 35 39	75 76 78	36 37 38 66 68 70 73 80 81 82 83 84 86 88 40 42 43 44 45 46 47 48 49 50 51 52 55 56 57 58 59 60 61 62 63 69 72 74 77 79 85 87

- | | | | |
|---|---|--|---|
| 1 Omni-Ingestor (Synapse) | 23 Overhung latrine | 45 Anaerobic filter | 67 Terra Preta Sanitation |
| 2 Plasma Gasifier (Delft) | 24 Flush urinals | 46 Septic tanks | 68 Drying beds |
| 3 Biochar (Climate Foundation) | 25 Waterless urinals | 47 Upflow anaerobic sludge reactor | 69 Thinkening ponds |
| 4 Biological filter toilet (eawag) | 26 Urine diversion components | 48 Anaerobic digestion (large scale) | 70 Mechanical dewatering |
| 5 Sand smoldering (Toronto Univ.) | 27 Pit latrine | 49 Rotating biological contactors | 71 Advanced nutrient recovery |
| 6 Pyrolysis of mixed waste (Unilever) | 28 Ventilated improved pit (VIP) | 50 Trickling filters | 72 Incineration (small scale) |
| 7 Solar dry/biochar/fuel cell (Univ. Singapore) | 29 Urine-diversion dehydration toilets (UDDT) | 51 Aerated ponds | 73 Incineration (large scale) |
| 8 Solar portaloos (Santec) | 30 Composting toilet | 52 Advanced integrated ponds | 74 Landfill |
| 9 Sol-char toilet (Univ. Colorado Boulder) | 31 Fossa Alterna | 53 Aquaculture (plants) | 75 Simplified & condominal sewers |
| 10 Nanomembrane Toilet (Cranfield Univ.) | 32 Terra Preta | 54 Aquaculture (animals) | 76 Transfer and discharge stations |
| 11 Supercritical Oxidation (Duke) | 33 Peepoo | 55 Free-surface constructed wetland | 77 Human powered emptying & transport |
| 12 Microbial fuel cell (and others) (Asian Inst. Technology) | 34 Twin-pits | 56 Horizontal flow constructed wetland | 78 Motorised emptying & transport |
| 13 Hydrothermal Carbonisation HTC (Loughborough University) | 35 Cesspit | 57 Hybrid constructed wetland | 79 Urine fertilisation (small scale) |
| 14 eToilet (ERAM) | 36 Urine storage | 58 Non-planted filters (sand/gravel) | 80 Urine fertilisation (large scale) |
| 15 Waterless Toilet (RTI) | 37 Drying and storage of faeces | 59 Activated sludge treatment | 81 Fertiliser from urine (struvite) |
| 16 PV Powered Domestic Toilet and Wastewater Treatment (Caltec) | 38 Composting (small scale) | 60 Fixed film activated sludge | 82 Fertiliser from sludge |
| 17 Omni-Processor, dryer/incinerator (Janicki) | 39 Septic tanks | 61 Membrane bioreactor | 83 Use of dehydrated faeces |
| 18 Pour-flush toilets | 40 Compost filter | 62 Membrane filtration | 84 Use of compost |
| 19 Flush toilets | 41 Anaerobic digestion (small scale) | 63 Anammox | 85 Arboloo |
| 20 Urine diversion flush toilet | 42 Imhoff tank | 64 Struvite | 86 Heat recovery from sludge |
| 21 Low-flush toilet | 43 Biogas settlers | 65 Composting (large scale) | 87 Direct use of biogas |
| 22 Vacuum toilet | 44 Anaerobic baffled reactor | 66 Anaerobic digestion (general) | 88 Biogas electricity (small scale/large scale) |

CASE STUDY 1: Sanitation NoW! Toilet by University of Toronto

Technology

This is a 10 user toilet that collects, rapidly disinfects and recovers nutrients from human waste using a smouldering process. The disinfected liquid can be used as a fertilizer on a family garden, while the ash from the smouldering process can be used as a soil conditioner.

Impact on sanitation value system

The Sanitation NoW! toilet has the potential to 'leapfrog' the existing sanitation value system as the waste is treated entirely in the home and so there is no need for collection and aggregated treatment processes. A new sanitation value chain, possibly with a service and maintenance element, as well as supply, would need to be built around the technology.



CASE STUDY 2: Omni Ingestor for pit emptying by Synapse Product Development

Technology

Synapse Product Development have received funding to create an Omni-Ingestor pit emptying technology. The Omni-Ingestor program is a suite of technologies that include specialized pumping mechanisms, de-trash, de-grit, de-watering instruments, and treatment systems. These technologies enable vault emptying services to access pits and tanks that cannot currently be reached with mechanical pumping systems, empty the contents of both wet and dry vaults, reduce sludge transportation costs, increase profits, and operate sustainably.

Impact on sanitation value system

Because of its compact size, the Synapse Omni Ingestor has the potential to replace manual pit emptying in places where the practice is used because pits are not accessible by large vacuum trucks. The opportunity to also complete basic pre-treatment of the waste, such as removal of grit and dewatering may alter the dynamics of the existing value chain where automated emptying is commonplace. Through dewatering, a smaller volume is taken into the tank, and so fewer trips to empty the truck are required. Receiving more concentrated waste will also benefit the treatment technologies, as the first step is always to dewater which can be energetically demanding.



CASE STUDY 3: Pyrolysis, Oya by Unilever

Technology

Oya is a neighbourhood-scale treatment system that processes human waste in combination with household, industrial, or clinical wastes. The central technology is pyrolysis, which decomposes organic matter with heat in the absence of oxygen to produce energy and inert ash. The system uses the energy generated from the first batch of waste to power the treatment of the second, so once the system is in 'self sustaining' mode there should be no need for additional energy inputs. The system is currently undergoing trial in the United Kingdom.

Impact on sanitation value system

Pyrolysis has the potential to extend the sanitation value system through the creation of valuable products from waste, energy, fertiliser and water. The 'stand-alone' nature of the process once it is running may indicate that the technology can 'leapfrog' existing barriers such as electricity and water connections.



In addition we examined adjacent industries to assess the level of development and implementation of waste recovery technologies. This included interviews with GENeco (Wessex Water) to understand how the developed world is evolving the treatment of human waste, and examination of practices in UK and US agriculture, where significant incentives are in place to invest in technologies at the farm scale for anaerobic digestion, and in the foods / other organic waste recycling industry. UK Government incentives are shown in Table 1, and represent a very significant stimulus to the investment in biogas systems.

Table 1. UK Government Incentives for Biogas Generation

Plant Size	Clean Energy "Cashback"	Export To Grid Price
< 250 kW	£ 0.17 / kWhr	£ 0.045 / kWhr
250 - 500 kW	£ 0.14 / kWhr	£ 0.045 / kWhr
500 kW – 5,000 kW	£0.099 / kWhr	£ 0.045 / kWhr

Reproduced from Biogas UK (<http://www.biogas-info.co.uk/>)

Our findings from this analysis

• Most European and US local authorities / municipalities have retrofitted large scale anaerobic digestion capabilities to generate biogas. There are four valuable outputs from this process; power which can be used on existing built infrastructure to lower energy costs, surplus electricity which can be sold back to the grid, biogas which can be sold to the gas grid and fertiliser produced from waste converted to a suitable grade of fertilizer that has regulatory approval to sell back to farms. The latter industry has developed due to the banning of use of landfill and sea dumping for the residue of waste treatment, for environmental reasons. This created a viable business case for the major treatment sites based on human waste alone, but many authorities are also collecting food waste from homes, because the higher calorific value

and higher density of solids makes the creation of energy in particular a much more efficient process for essentially the same investment.

• Other newer technologies that offset costs are being deployed to capture and eliminate struvite precipitation in waste water treatment plants, which requires expensive chemical treatment to avoid build up and blockages. Thames Water in the UK recently announced installation of technology from Ostara Nutrient Recovery that will avoid the need for chemical treatment in the plant and yield 150 Tonnes of high value fertilizer. If deployed in a more systematic way this will make a significant difference to the planetary boundary for phosphorous.⁵

• This is inspirational work, and offers great hope for the future, but does not solve the challenge that most emerging market cities face – that they are far away from large scale integrated sewer and waste treatment plants. In general the approach to retrofitting large scale facilities works because there is a viable case for investment on top of large already installed capital base. With modernization the infrastructure can become net carbon negative, and money can be made from energy production and sale of waste products. Appropriate environmental regulation and green energy incentives are key enablers which allow the development of this value system.

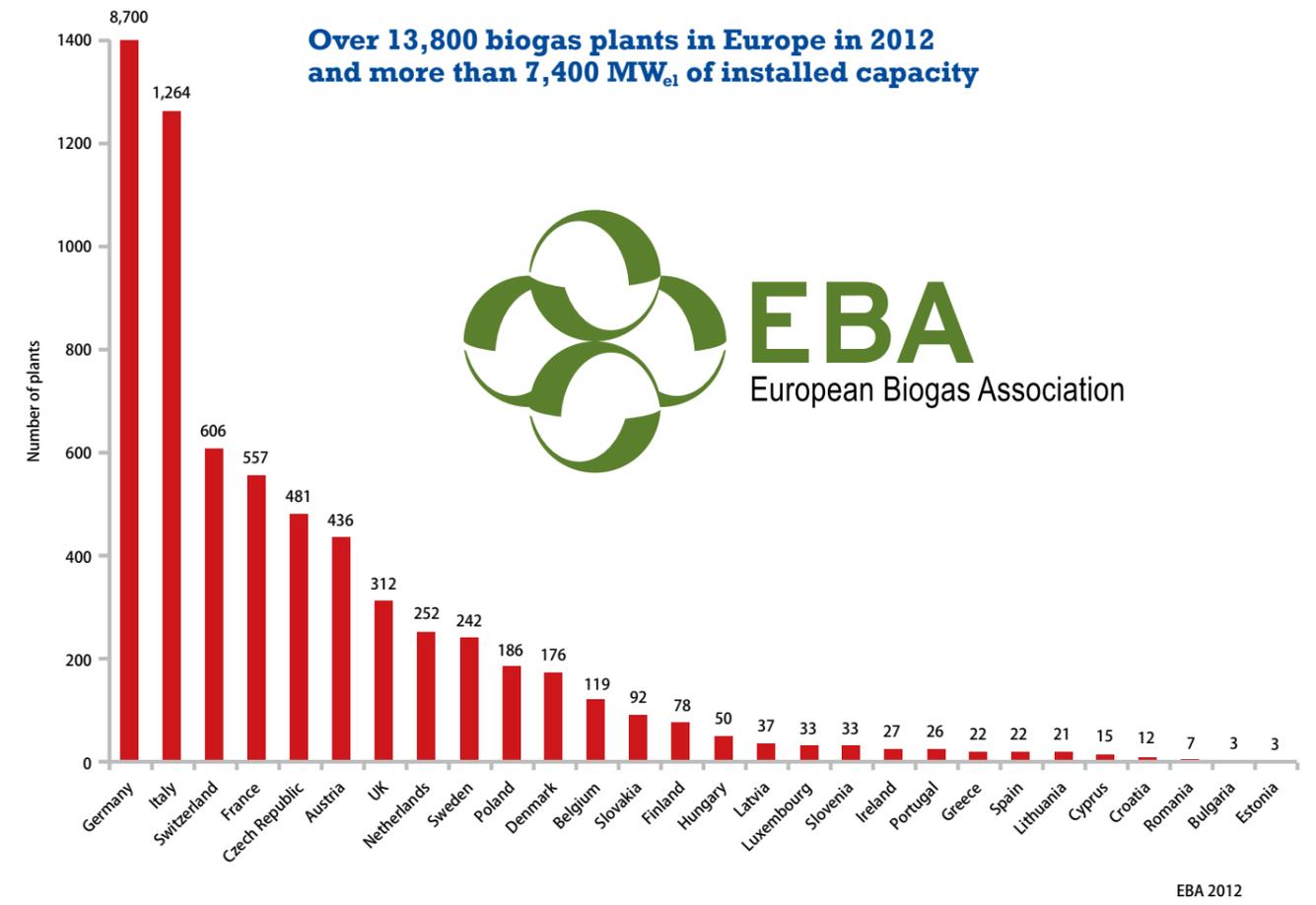
• Many farms in the UK and USA have installed anaerobic digestion technology, generally handling manure from dairy farms but other biomass is in scope. There are over 13,000 biogas plants already installed in Europe. The type of facilities that are used for this digestion are interesting for peri-urban solutions and are the subject of a study underway with WSUP and Cranfield University to assess and select the appropriate AD technology for the 2,500 home / 10,000 people scale.



Ostara Nutrient Recovery Plant, Slough, Berkshire UK

⁵ <http://www.ostara.com/sloughUK>

⁶ <http://www.waste-management-world.com/articles/print/volume-11/issue-3/Features/danes-lead-the-way-in-biowaste-to-energy.html>



Reasheath 50 kW Anaerobic Digester, Cheshire UK

• A number of companies are offering modular container sized anaerobic digesters to enable smaller generators of organic waste to take advantage of the ability to create energy, revenue and fertilizer from their waste. (E.g. SEAB Energy, Southampton UK, <http://seabenergy.com/products/anaerobic-digesters/>) The focus once again is on the digestion of higher calorific value from food waste, which yields a better methane return than human waste. The size and scale of such modules is attractive for the low land footprint 10,000 people urban scale but without clean energy subsidies the capital and running costs are unlikely to be viable in emerging markets.



SEAB's Muckbuster Containerised Modular Anaerobic Digester

• Blending organic waste streams from different sources to drive a richer feedstock is established in Europe particularly Denmark. In Denmark, the concept of mixing high energy potential substrates such as food waste with low energy potential animal slurries has been successfully applied to improve nutrient management mainly by using commercial or industrial sources of biodegradable wastes from food processing and even animal slaughter. The predominant mix of feedstock is typically between 60% and 80% slurry with between 40% and 20% imported material, with a typical three-fold increase in biogas production, compared to processing slurry alone, and corresponding fertiliser value. This is a concept of some value since it has the potential to tip a marginal business case for energy production into a viable one.⁶

2.3 UNDERSTANDING OF THE EXISTING MARKET FOR WASTE TREATMENT PRODUCTS FROM HUMAN WASTE

This is most pertinent to the urban environment, where the removal of human waste from the city environment is a particular challenge.

At present 80% of the wastewater in emerging market cities is not treated. 50% of African cities have no wastewater treatment and those that do treat only a small fraction of the waste in the city region (e.g. only 5% in Harare).

The main barriers to establishing large scale sewage infrastructures are well understood;

- vast capital cost
- major water burden
- low skills in place to operate advanced facilities
- no regulation to enforce compliance
- poor or non-existent urban planning

Water and Sanitation for the Urban Poor (WSUP) has proved that people in emerging cities are willing to pay to upgrade their sanitation experience as demonstrated by Clean Team, a scale-able model for dignified in homes waste collection and disposal in Kumasi, Ghana. Clean Team presently dispose of the human waste through the municipal disposal routes, which include transport to the city outskirts by vacuum truck and release into lagoons. This is clearly a sub-optimal system, but this is better than the treatment solutions found in most developing cities, which are often non-existent and involve direct discharge into the sea or other water bodies.

If we reference Clean Team, collection revenues for disposal of waste in Ghana reach \$150 / household per year, with gate fees for disposal about \$6 / per household per annum. In contrast, using anaerobic digestion to convert this waste to electricity (from biogas) and fertiliser (from pelletized solids) will generate only \$13 / household per year.⁷ The capital expenditure for such a digester is prohibitive (estimated \$200,000 - \$400,000) and NPV is negative over any sensible timeframe. Without the equivalent of the UK's

Feed in Tarrifs as a clean energy incentive there is little scope for a viable business case unless extremely low cost modules are developed.

An alternative approach would be to blend human waste with other higher calorific value feedstocks to reach a point where the energy content would be sufficient to deliver a positive NPV based on electricity generation and sale. Modelling of this approach using SEAB's "Muckbuster" containerised Anaerobic digester suggests scaling to 3700 homes, and co-mingling the digestate with 800 Kg of Sorghum waste per day would generate positive 10 year NPV, assuming that the Capex is \$400,000.⁸ At present such units are closer to £500,000 and ancillary equipment would be needed. However, this approach is worthy of further investigation. A fully developed field trial using an appropriate digester configuration would be needed to test the viability of co-mingling and its ability to create better economics from human waste treatment.

If appropriate scale and capital cost can be indentified then a viable model should emerge but hurdles still remain;

- Regulated and enforced waste collection, which in turn will drive supply and allow operators to charge higher gate fees
- Appetite for public (donor) money to reduce the Capex burden
- For mixed-waste facilities, efficient and large-scale collection of other types of waste (e.g. animal slurry, food and organic waste)



⁷ Stopford Engineering Calculations, 2012.

⁸ <http://seabenergy.com/products/anaerobic-digesters/>

Table 2: The ideal specification for a neighbourhood scale waste treatment solution

Scale	1,000 – 10,000 people. Average dry mass faeces per person per day 0.1 kg and 1.5 L urine. Chemical toilet waste = 4.5% dry solids. Pit latrine waste = 3.5% dry solids. UK waste water = 0.1% dry solids.
Aesthetics	
Smell	Technology should remove odour and control release of odour so as not to impact on the local community.
Noise	The technology will be deployed in residential areas and noise levels should be appropriate to this setting.
Appearance	The unit should not be an eye sore and it will not be obvious from the outside that it is a sewage treatment facility.
Infrastructure/Inputs	
Footprint	Footprint of less than roughly 15 m ² per 1,000 people serviced and ideally could be transported on a shipping container.
Consumables	Any consumables required must be readily available in developing and emerging cities.
Maintenance	Maintenance materials should be readily available in developing and emerging cities.
Energy	Unit should not require a consistent electricity supply due to the frequent power outages in urban developing environments. Unit should be as close to energy neutral as possible and should ideally export energy. Energy for start up is acceptable, but sources of power must not rely on national level infrastructure. Renewable energy sources should be utilised to reduce the energy demand.
Water	No additional water should be required for the system.
Technology	
Technologies considered	Any including pyrolysis/gasification, combustion, anaerobic digestion and other appropriate technologies.
Outputs	
Emissions	Emissions should be below the thresholds set by the European Waste Incineration Directive. http://europa.eu/legislation_summaries/environment/waste_management/l28072_en.htm
Water	Water quality should meet that set out in the European Urban Waste Water Directive if released into local water courses. http://ec.europa.eu/environment/water/water-urbanwaste/ or the European Drinking Water Directive if this will be marketed for human reuse. http://ec.europa.eu/environment/water/water-drink/legislation_en.html
Fertiliser	Soil conditioner products should comply with the standards set out in the UK safe sludge matrix. At a minimum these should meet the same levels as conventionally treated sludge (99% pathogen destruction) and preferably meet the levels of enhanced sludge treatment (99.9% pathogen destruction).
Heat	Any heat generated should be recovered as far as possible.
Costs	
CAPEX	<£ 100,000
Operating costs	£900 per month
ROI	10 years
Staff	
Operation	Operation will be suitable for unskilled labourers with on the job training.
Maintenance	Maintenance regime should be as simple as possible and should be easily taught through on the job training. An engineering degree might be necessary background but no other specific skills or expertise will be required.
Waste	
Sewage	At least 50% of the waste input should be human waste streams.
Supplementary waste	Other waste streams may be used if these are required for successful treatment of the waste or for optimisation of valuable by-products.

Our findings from this analysis

- Overall the ability to economically extract valuable waste products and generate viable markets for them is a barrier to investment in the more innovative downstream waste treatment technologies required to them to scale.
- A key element of the "unlock" would be a 40' container size low land impact solution for the 2,500 home / 10,000 people scale solution that provides useful end products
- Co-mingling higher calorific value organic feedstocks may provide a further economic unlock.
- Of further value would be a drive to stimulate an end market for waste products. For example if a major agricultural raw materials user with a large emerging markets footprint committing to a circular economy initiative where the agricultural ingredients it procures is grown using fertilizer procured from food and human waste recovery and treatment. There are a number of taboos around the use of human waste as fertilizer in emerging markets, but the practice from sewage sludge is now regulated for widespread use in this manner in Europe and the USA.

2.4. SETTING FUTURE STANDARDS FOR SANITATION

Setting aside social factors, the ability of any sanitation model that takes cost, however little, from consumers or operators through the value chain for sanitation treatment, to compete with zero cost alternatives, such as untreated dumping into lakes or rivers, is a tough ask.

The futures team has not conducted an exhaustive scan of the regulatory environment in markets where access to sanitation is limited but clearly for a sanitation intervention to deliver successfully against the factors considered by the Futures team, market intervention through meaningful regulation is needed. To establish an enabling legislative and regulatory framework the following factors, amongst others, need to be considered.⁹

- Outdated regulation or regulation that is new and useful but not yet incorporated into the daily work of the regulatory authorities
- From the point of view of use of treated waste products, there is a need to analyse existing regulatory frameworks from the “what is not prohibited” rather than “what is allowed” perspective. Many Individual projects will have tested the frameworks in many places.
- Often, sanitation policies of emerging countries have been developed with donor assistance and reflect the view of the donor, not of the indigenous situation. This leads to the dichotomy between advanced regulatory environment in many places, but in reality low or zero enforcement needs to be factored into any attempt to build a different legal framework to promote viable future approaches.
- There is little or no consideration of the planetary boundary impacts (Nitrogen, Phosphorous, water and the reduction in carbon footprint from harnessing human waste to biogas / bioenergy) in sanitation
- Unlike in developed markets there are no clean energy incentives to drive adoption of the use of biogas to create energy

Having a clear point of view of what is a starting set of standards for future sanitation models across the key factors considered (Economic, Environmental, Social, Technological and Consumer) is essential aspect of advocacy for any entity that is looking to make a long term impact in the adoption of responsible sanitation solutions. Awareness is increasing of the major global risks that are either magnified or mitigated by responsible future sanitation systems. Our assessment is that large scale responsible future sanitation has the ability to impact six of the 31 key global risks considered by the World Economic Forum WEF Global Risk Report 2014. These are:

- The water crisis
- Major biodiversity loss (land and ocean)
- Failure of climate change mitigation
- The food crisis
- The unmanaged burden of disease
- Mismanaged urbanization

Much more needs to be done to make the link between responsible future sanitation interventions and the ability to contribute to mitigation of the key risks to the planet, but awareness is increasing and the clearer the links the greater will be the political and economic will to invest in responsible sanitation.



⁹ A Review of Sanitation Regulatory Frameworks, Mats Johansson and Elizabeth Kvarnström, EcosanRes Report 2005-1



SETTING A GOLD STANDARD FOR FUTURE SANITATION

A good start to the setting of a gold standard is the work conducted on behalf of the Toilet Board that has culminated in a report on Critical Success Criteria for Evaluation Sanitation Models. Here many of the key factors that drove our analysis have been factored into a simple to use tool to assess sanitation approaches. These are People (social and consumer) Economic, Environmental and Technical, viewed through the value chain. This approach can be iterated and improved under the guidance of the Toilet Board as standards and regulations develop.



Critical Success Criteria – Economic

	Score = 0 major deficiencies	Score = 1 common practice, some deficiencies	Score = 2 good practice	Score = 3 the ultimate
Value chain set-up	No holistic view of value chain, who is providing which services, necessary hands-off etc. Patchy co-operation between players. Unskilled field force/ community workers.	Some parts of the value chain are integrated and hands-off (e.g. between sales force & masons) take place. Other parts of the value chain are not operational or do not meet the needs of the setting. Predominantly male workforce. Review streams ill-defined.	Value chain is appropriately designed for the setting and is operating reasonably well although some weaknesses exist (e.g. in demand, disposal). Services levels to customers are monitored. Revenue streams tied up and transparent. Gender-balanced workforce is in place. Compliance with relevant regulations throughout the value chain.	The value chain is inclusive & well integrated with established businesses working together to deliver a complete service of a high standard. Customer service levels are monitored and complaints dealt with swiftly & efficiently (care-lines!).
Rewards	Individuals & groups involved in the value chain do not make sufficient money to meet their needs. Model is propped up by donor funding.	Individual players in the value chain (e.g. sales people, masons) make salaries around minimum wage levels. At project level, donor funding is required to ensure continuity of the model.	At the level of the project (e.g. people who supervise the sales force, marketers, latrine manufacturer...) sufficient profit is made to ensure that employees are well paid and the model continues. High-level head-office/ organisation overheads relating to the model are not covered.	At the level of the initiative (e.g. head-office staff, co-ordination, communications resources), revenues from the model cover costs, whilst all those involved make returns that incentivise their continued involvement.
Scalability*	Local/single town-based model using local materials and services. Less than 10,000 users use the facilities daily. Cannot cope with increasing demand for neighbourhood and farther habitats.	Regional model that can potentially serve populations up to 100,000+ across a few habitats within a region. Service levels and user satisfaction drops beyond a scale of 200,000 users & /or locations (towns / villages) expanding beyond 10.	Model equipped to serve a population of over a million with standard suite of materials and services catalogued and ready to deploy. Modern business enablers (Internet/ phones/ banking/ credit card) actively deployed across the business model to ensure efficiency in services and satisfy increasing demand (up to 10 million).	Global partnership-based model where all partners across the technical value chain, demand creation specialists finance and state/ country leads are committed to the sanitation priority through a strategic vision and 3-4 country relevant implementation plans are developed to reach a scale of 50 million population.
Attractive returns on investments	Capital/ one time investment (mainly from donor funding) for setting up improved sanitation facilities. Little consideration for running expenses and ROI.	Capex & Opex both considered. Besides the field operators and managers making money investors believe they will get healthy returns but may be disappointed at times (e.g. when large numbers of users move over to another model).	Besides consistent financial returns, monitoring of social ROI (e.g. reduced school dropouts, improved health confidence & dignity) is considered.	Ideal model. Financers and social entrepreneurs keen to invest in the partnership and are assured of financial returns and enhanced reputation/ goodwill.

*Scalability could be considered across both existing as well as future models (for future models relevant predictive tools to estimate the scalability/ replication potential may need to be developed/ deployed)

Critical Success Criteria – People (users)

	Score = 0 major deficiencies	Score = 1 common practice, some deficiencies	Score = 2 good practice	Score = 3 the ultimate
Value Equation - people want a toilet	People are not aware of the option of having/ using the model's toilet.	People are aware of the option of having/ using better sanitation facilities (including the model's toilet) and are interested in it, but are not clear on what benefits they would derive or the costs (financial & non-financial) of having one v/s not having one.	High awareness among individuals & communities to improve existing sanitation. Mixed appreciation of its value. In field trials, innovators & early adopters have picked up the model resulting in penetration >15% but struggling to reach tipping point.	Best in class demand creation. Consumers are motivated to advocate/ promote (with friends and relatives) improving existing sanitation conditions. In field trials >50% penetration is achieved as the model delivers on its promised benefits. Innovative products, services & communication ensure the model does not lose customers to lower cost/ lower quality copycat competitors.
Usage - ease of getting and using the toilet	Purchase: Logistical barriers (lack of space, transport, installation skills) prevent installation. Pay-per-use: Logistical barriers (distance to facility, opening hours...) prevent use.	Purchase: Specialist equipment & expertise required for installation at additional cost. Pay-per-use: Logistical barriers (distance, opening hours...) mean facility is used c.50% of time. Facility design does not meet one or more of the basic functional needs of a toilet (safety, security, cleanliness, queuing time/ conditions...).	Purchase: To keep costs down, toilet can be installed by householder or with help from neighbours. Pay-per-use: There are no logistical barriers to use so compliance is high, >75% of time. Facility design meets the basic functional needs (safety, security, cleanliness, queuing time/ conditions...) of the whole community incl. women, children, elderly, disabled.	Purchase: Toilet is easy to install and expert services are accessible and affordable. Pay-per-use: Value-adding associated services drive compliance close to 100%. Facility design also delivers emotional needs for dignity, privacy. It's considered a pleasant place to go.

Critical Success Criteria – Environmental & Technical

	Score = 0 major deficiencies	Score = 1 common practice, some deficiencies	Score = 2 good practice	Score = 3 the ultimate
Waste	Waste (including menstrual waste) is not securely contained under most conditions (e.g. heavy rain). Mismatch between installed & actual waste capacity. Waste transportation, disposal & / or treatment is not managed.	Waste (including menstrual waste) is securely contained but services around removal (e.g. pit emptying) not fully harmonised. Waste capacity adequate but gaps may exist in transport, disposal and treatment services.	Waste (including menstrual waste) is contained, ongoing management services in place and treatment (inactivation of infectious material) and disposal complies with global health and environmental standards.	Value is derived from waste (via household use or sale) in the form of fuel / fertiliser.
Water	Water is required but is not readily and constantly available.	Water is required and is available for most applications. Water scarcity might be experienced from time to time.	Minimal water required (for hand-washing & cleaning) & is available, or significant water is required but is readily available.	Water use is minimised in water-scarce countries. Solid waste is dewatered to lower transport & treatment costs & enhance value (of waste).
Robust design & manufacturing	By design, the installation has a limited (<3 yr) lifespan. Wide variable in materials & construction methods result in variable quality of finished product.	The installation is designed for long-term use (3+ years). Basic systems in place to guarantee materials & manufacturing quality.	The installation is proven to withstand long-term (3+ years) use, either in field or via product-testing. Materials sourcing & manufacturing enables high quality installations.	World-class design has created a product that consumers love (vs. like). Manufacturing is optimised not only for quality/ cost, but also to offer flexibility & choice, providing a desirable product line of sanitation options.
Maintenance & cleaning	Facility is not designed with ease of maintenance in mind. No maintenance services are operational. There are no arrangements for cleaning, with resulting problems of dirt, odour, pests & disease.	Some aspects of the design lend themselves to ease of maintenance. Maintenance services (spare parts, technicians) can be found but are not readily available. Communities/ consumers/ operators have the products & knowhow to keep the toilet sufficiently clean to use. Occasionally malodour and pests/ insects encountered in the facility.	Design optimised for minimal, easy maintenance. Maintenance services are readily available. Products & knowhow are available to keep the toilet free from malodour & premises are pleasant to use/ visit.	Design optimised for minimal, easy maintenance. Maintenance is proactively managed, pre-empting blockages & service disruption. Products & knowhow are available to keep the toilets hygienically clean on a routine basis.
Hygiene	No facilities for hand-washing with soap. Little consideration to prevent exposure of field operators to human waste. No ventilation for dry pit latrines resulting in breeding ground for flies.	Facilities for hand-washing with soap exist but at some distance from toilet. Provision to address exposure of field operators to human waste. Provision of ventilation for dry pit latrines.	Facilities for hand-washing with soap are next to toilet and are well maintained. Technical provisions and good training of field operators, minimises exposure to human waste.	Integrated hygiene/ hand-washing promotion results in high levels of compliance and protection across consumers and field operators.

3. SUMMARY AND RECOMMENDATIONS FOR FURTHER ACTION

Major technological developments in the sanitation sector focus primarily on promising pathogen free toilets in future years, but the technology readiness for mass deployment is estimated at 3-5 years for the lead options and local supply chains are not yet in place.

Large scale developed market sewage infrastructure in the western world is rapidly being upgraded to generate energy to offset the running costs of plants, and legislation to prevent landfill and sea dumping is driving operators to create viable end products (fertilizer) from human waste sludge. In adjacent sectors (food waste, agriculture) energy tariff and other incentives are making viable the investment in robust technologically advanced smaller size anaerobic digesters to deliver the same outputs at single business and farm scale. All of these interventions, if deployed more widely, have the potential to drive significant impacts in carbon footprint, offset extraction of nitrogen via a very energy intensive process, and mitigate the planetary boundary for phosphorous. Properly operated systems will also eliminate the pathogen burden of human waste.

The developments in adjacent sectors gives great hope that engineering companies can engage on the challenge of a low cost but highly robust "40 foot container" solution to waste treatment in the urban environment. Such modules (likely based on anaerobic digestion), if deployed at scale, could revolutionize waste treatment in the same way that modular anaerobic digesters are doing in developed markets. The number of units required would dwarf the existing 13,000 anaerobic digesters already operating in Europe.

Incentives for mixed waste treatment to add higher calorific value materials to the system would most probably enable viable peri-urban waste treatment businesses if appropriate mixed feedstocks were available.

A coalition of major raw agricultural product buyers prepared to pioneer the use of properly treated waste from sanitation in growing agricultural products in emerging markets could create a market pull of a significant size and lead the creation of a circular economy.

A robust global standard for responsible future sanitation interventions needs to be evolved from the work the Toilet Board has already commissioned on critical success criteria for evaluating sanitation models. This needs to be used in advocacy and lobbying by entities such as the Toilet Board Coalition, otherwise, despite technological advances, these models will be unable to compete with zero cost alternatives where no treatment occurs.

We Recommend

1

A "grand challenge" style competition with appropriate prize money awarded to create ideal 40' containerized solutions to enable the economically viable treatment of human waste in the urban environment. This sits outside the current approaches where large amounts of funding are available where very radical technologies are sought, rather focuses on creating the engineering and cost specifications and manufacturing conditions for the translation of the latest anaerobic digestion technology which is being deployed at scale to the emerging market city environment. The target network would be the range of engineering companies that are transforming the biogas landscape in Europe and North America. Our working assumption is that co-mingling has to be established to enrich the waste streams sufficiently to generate strong income streams from energy. A suitable budget for such a challenge would be approximately \$2 - 5 million. Once established this unit would be a franchizable business model, and would enable the ability to deploy collection models in urban environments where no existing treatment options lie, and yield a viable business for the operators.

2

Formally commission a piece of work to map out the "gold standard" for future sanitation, across the whole value chain, to be used by the Toilet Board Coalition in advocacy, lobbying and in engagement with National Governments as new initiatives are being driven. This should include a deeper analysis of how responsible sanitation can mitigate planetary boundaries and alleviate a number of the major planetary risks identified by the WEF. Without this the new initiatives will be hampered by competition with irresponsible low or zero cost options. This analysis would be executed by an external consultant with an estimated budget of £250,000.

3

Convene an alliance of the major corporations who are using large volumes of agricultural raw materials sourced from emerging markets, and explore the appetite for a circular economy where the buyers work together to generate a model to actively promote the procurement of fertilizer that is sourced from treated human waste. This would be a size-able impact in the sector in its own right and would set an example to the wider industry. EU and EPA standards are available for guidance on levels of treatment for safe use of treated human sludge, and the practice is widespread already. This requires only in kind commitment from the companies to meet under the neutral ground of the Toilet Board Coalition, and to be prepared to make a commitment to drive the adoption of such practices in a responsible way.

Contributors:

Lisa Hawkes (Unilever)
Carolyn Jones (Unilever)
Mike Parkington (Unilever)
Edward Price (Unilever)
Nimish Shah (Unilever)
Helena Wayth (Sanitation Consultant)
Val Curtis (London School of Hygiene),
Yu-Ling Cheng (University of Toronto)
Tyler Goodwin (WSUP),
Guy Hutton (World Bank Group)
Jessica Graf (Hystra)
Olivier Kayser (Hystra)
Irene Jeffery (Marketing Mums)
Bob Crawford (C-TEC Innovation)



Unilever