SIWI WORLD WATER WEEK

Seminar: Water in the circular economy: opportunities and challenges

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ABSTRACT VOLUME

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Water and waste: reduce and reuse

Seminar: Water in the circular economy: opportunities and challenges

Contents

A circular economy approach to wastewater treatment - A Danish example

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Highlights

A biorefinery has been built at the existing Grindsted WWTP in Denmark that demonstrates circular economy. The plant utilizes new technologies that process raw materials consisting of wastewater, separated organic household waste and organic waste from industries. Outputs are purified water, energy, fertilizer and feedstock for polymer production

Introduction and objectives

The Billund BioRefinery was developed and built in a PPP-project supported by a grant from the Danish EPA to demonstrate how Denmark and the utility sector together with technology suppliers can take a circular economy approach in wastewater and waste handling. Drivers for the project included:

- EU initiatives on Circular Economy
- Finding renewable and storable energy sources
- Danish water sector law requiring savings on utility operations but limiting the types of acceptable activities
- Local Municipal strategy to lower energy consumption and CO_2 emissions
- Local Municipal strategy to lower nutrient loading on local receiving waters

Methodology approach

The heart of the refinery is the thermal hydrolysis system. The purpose is to recover energy and produce more refined products from wastewater and organic waste, i.e. biofertilizer, Struvite, biogas, biopolymer and water for reuse. The nutrients in the wastewater are mainly captured in the WWTP in simultaneous biological processes and made accessible in excess hygienized biofertilizer. The influent is a mix of domestic and industrial wastewater and some rainfall from combined sewers generating biological sludge. Household waste is sorted and collected in paper bags. The industrial waste is delivered by trucks and categorized by energy density

Analysis and results

The BioRefinery demonstrates new waste and wastewater technologies in a new, fully-integrated configuration. All processes are interconnected through on-line control “smart” systems that adapt to alternating load. The amount of remaining biofertilizer is minimized and the yield of CO_2-neutral biogas is maximized with thermal hydrolysis and double digestion. The BioRefinery is an "open concept" that can collect all types of organics and convert them into valuable resources, closing the loop of carbon and nutrients from farm to table and back. To avoid pollutant components in the wastewater (and thus eventually the biofertilizer), all industries have outlet control of flow, heavy metals content and content of xenobiotic components. The approval is published by the local authority - Billund Municipality. The biowaste is sorted and collected at local households and industries. Sludge and organic waste is carefully mixed and codigested to give energy excess of +200%, turning biogas into electricity and excess heat. Actual Effluent Values 2016 for the WWTP (10 months operation) are as low as 25% of regulatory. The biofertilizer contains 6 kg P/ton and 11 kg N/ton and has a slow rate release in the local agricultural soil. Annual energy production is around 12 Gwh.

Conclusions and recommendation

The biorefinery is a showcase example of the circular economy demonstrating how wastewater utilities can contribute to the local and national economy and improve the environment. The Danish example business model has ROI of 8-10 years. The biorefinery is scalable and replicable, and can be built anywhere these raw materials are available for reasons of hygiene and the environment need to be treated safely; and the output products can be applied locally, regardless of geography. With the proven technologies, setup and business case it is recommended for other Wastewater utilities to be proactive as Billund and close the local/regional loops.

GreenSpeed - Integrated wastewater treatment and biobased production

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Highlights

GreenSpeed may transform wastewater treatment plants into net energy producers
GreenSpeed may provide climate change mitigation services and added value bioproducts

Introduction and objectives

Several Danish wastewater treatment plants (WWTPs) have implemented energy as well as nitrogen, phosphorous and carbon management strategies, resulting in several of the Danish WWTPs to become carbon neutral energy producing plants. Besides reducing GHG emissions and energy consumption, technologies for combined water treatment and green production is emerging in Denmark and globally. GreenSpeed wastewater treatment represents a low carbon technology, designed to reduce the energy consumption and N_2O emission, while assimilating CO_2, NH_4+, PO_4- and K by microalgae subsequently used as a carbon rich resource for biogas production or for the production of high-value products.

Methodology approach

A comparative Life Cycle Assessment (LCA) of introducing the GreenSpeed technology at existing WWTP in Denmark were analyzed. The WWTP designs differ regarding: (1) treatment capacity, (2) N and P management strategies (e.g. chemical precipitation vs. biological treatment), (3) C management strategy (e.g. biogas and sludge-derived fertilizer production). The increased resource-efficiency obtained from implementation GreenSpeed were assessed with focus on the potential to reduction in GHG (CH_4 and N_2O) emissions, and substitution of COD consumption with CO_2 release, by microalgal production. The LCA were accompanied by a cost-benefit structure analysis and performed in accordance with international standards ISO 14040-44.

Analysis and results

Implementation of GreenSpeed at decentralized WWTPs (≤ 20.000 PE) vs. centralized WWTPs ≥ 100.000 PE showed differences in the environmental and economic cost-benefit structure. Several environmental and economic benefits were observed for the decentralized plants, while a reduction in biogas production at the centralized WWTPs receiving sludge from decentralized WWTPs represents a reduction in the return on Investment. Pilot plant testing at a two-step WWTP of the size 25.000 PE showed that a GreenSpeed process volume of 3,240 m^3, are able to capture 53-67% of the nitrogen and 15-19% of the phosphorous in the influent wastewater. Such microalgae assimilation capacity results in reduction in the energy consumption for aeration during conventional biological treatment. Furthermore, a reduction in the N_2O emission corresponding to the percent N assimilated in the microalgae biomass is resulting. Pilot testing shows a continuous growth rate corresponding to 10.8 ton fresh weight microalgae harvest per day with a dry matter (DM) content of 20%. Data showing a CH_4 conversion factor of 300 l CH_4/ kg VS points towards a biogas production per year in the range of 2-3 TJ, which corresponds to an increase in the biogas production at the test study plant of 36%.

Conclusions and recommendation

Initial studies reveal a budget economic opportunity for decentralized plants in valorizing their resources in wastewater. The results of the LCA and cost-benefit analysis have identified barriers and opportunities for WWTPs to become net energy producers contributing to climate change mitigation. Emerging opportunities for increased revenues from integrated wastewater treatment and biobased production systems have been identified in terms of protein and antioxidant extraction prior to biogas and fertilizer production. GreenSpeed is a low carbon resource-efficient wastewater treatment technology providing the opportunity for WTPs to become climate neutral while returning resources in wastewater back into the economic system.

Local circular economy loops in between sectors

Presenting Author: Dr. Martine Vullierme, France, Veolia

Co-Authors:

Highlights

Municipalities and industry need to optimize their water management within the watershed in which they are located. Taking a Circular Economy - CE- approach with water assets maintenance and development can be the enabling factor for a healthy local economy and in line with the central role of water.

Introduction and objectives

Population growth, economic development, improved quality of life, and limited resources provide the catalyst for a circular economy approach not only for water, but also its nexus with energy and materials. Water and the water-material nexus can benefit and be leveraged through the restorative and reuse nature of CE. Based on their experiences with connecting best practices and applying them in an impactful way for the benefits of their municipal and industrial customers around the world, the authors have identified and will share a number of CE pathways, success factors and barriers towards implementation.

Methodology approach

The circular economy is based on the concept that waste is designed out of or extracted from flows at the onset, and that net material flows are balanced, such that extraction rates do not exceed return or output rates. As appropriate based on geography and local conditions, evidence shows progress is aligned with the three CE Design Principles:

- All durables are reused,
- Consumables are used in multiple cascading cycles before safe return into the natural environment, and
- All natural capital (including energy) is used only to the extent they can be regenerated

Analysis and results

Examples from water scarce regions illustrate the benefits and challenges of the CE approach. The authors experience reveals that CE best develops in three basic ways:

- by removing the technical, administrative, and governance silos between water and wastewater. Since 2003, this allowed the Windhoek potable water direct reuse scheme to support 300,000 inhabitants;
- by removing the social and sectoral silos between industries, cities and the civil society. The Durban (SA) Recycling Plant makes it possible for industry to switch manufacturing processes to recycled water, using 98% of the city's reclaimed wastewater. In Honolulu, Hawaii, the 38,000 m3/d municipal treatment plant produces water for its industrial park and for irrigation.
- By moving beyond infrastructure and operation silos to a holistic, integrated life-cycle view. This approach is increasingly applied by public utilities in arid zones with a strong push towards Non-Revenue Water Management such as in Oman, Riyadh or Tangiers). The concept is also applied in the industry, such as Shell in Qatar where the water generated during the gas-to-liquid process is fully reused on site, leading to zero liquid discharge management.

Conclusions and recommendation

Current linear economic and business models need to move to a circular model to alleviate escalating demand for scarce water resources. Technical solutions are already available and more effective ones will continue to become available. However, implementation of technical solutions can be a challenge if the enabling environment is not ready. Changes in regulatory and institutional frameworks are necessary to encourage circular solutions. Effective implementation of CE concepts will require acknowledging and adapting practices to local conditions, obtaining stakeholder consensus, having accurate metrics, and allowing adequate time for implementation.

One Water' strategies for corporate engagement

Presenting Author: Dr. Alex Money, United Kingdom, Smith School of Enterprise and the Environment

Co-Authors:

Highlights

The circular water economy can improve the alignment between corporate water strategy and stakeholder expectations.
This could catalyse social, economic and political momentum necessary to facilitate broader transitions to non-linear water use.
It would unlock value that is embedded in water as a corporate asset, rather than a risk liability.

Introduction and objectives

Questions of quality, quantity and social licence are well rehearsed in the literature on corporate water strategy. I begin by challenging the orthodoxy of current best-in-class approaches by companies to manage stakeholder expectations - focusing on efficiency and replenishment. From there I present a paradigmatic model using the circular water economy as a unique and powerful tool to align corporate strategy; accountability and disclosure; and stakeholder engagement.
Presented as a work in progress, I propose avenues for incorporating circular economy approaches as a tool to catalyse innovation, enhance stewardship, and benchmark progress towards the sustainable management of water resources.

Methodology approach

Question: Can the sharing economy paradigm align corporate water strategy with stakeholder expectations, and unlock the embedded value of water as an asset?
Approach: I will describe gaps between strategy and expectations based on extant best-in-class approaches, and illustrate how and why a 'one water' methodological approach could close those gaps.
Method: Using real-world exemplars of efficiency and replenishment targets, I will discuss their limitations as proxy solutions, and contrast this to a 'one water' approach. I will suggest that incorporating the shared economy into corporate water strategies will expedite the development of new models that facilitate broader environmental transitions.

Analysis and results

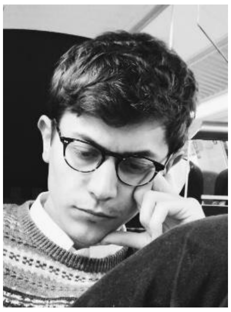
Many companies have public targets to reduce their water use per unit of output. But let us imagine all incremental efficiency measures have been taken. Now, suppose an exogenous shock results in reduced water availability. The efficient company has no 'fat in the system' - which means that the shock cannot be mitigated. As a result there is either a direct effect on operations (making performance more volatile) or the company has to take a greater share of available water (threatening its social licence). Perversely, a less efficient water user may not face this Hobson's choice.
This presents philosophical and practical questions as to whether targeting absolute efficiency is the optimal approach for companies and stakeholders. But rather than the strategy above - that identifies water as a liability whose use should should be minimised - what are the prospects for a 'one water' strategy that identifies water as an asset whose value should be maximised?

In this context, what becomes salient is 'water asset turnover' - a much richer conception of efficiency than per unit approaches. It allows for the value of water to be recaptured and realised both within and beyond the operational fence line.

Conclusions and recommendation

Examples of 'one water' frameworks are emerging, e.g. Nestle's Lagos de Moreno dairy factory in Jalisco. But the approach is still largely dependant on companies' local production imperatives rather than their global strategic aspirations. The circular water economy can improve alignment between corporate water strategy and stakeholder expectations. This in turn could catalyse the social, economic and political momentum necessary to facilitate broader transitions to non-linear water use. It will expedite the technological innovation necessary to capture a growing share of the value that is embedded in water as a corporate asset; rather than its risk as a corporate liability.

Quantifying the circular water economy: The case of Singapore



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Highlights

- Singapore is the world's model country on the circular water economy
- We provide the very first quantitative assessment of this circular water economy showcasing the economic value created compared to a linear economy
- Our assessment provides a fact base and a quantification approach for policymakers and water managers contemplating the transition to a circular water economy

Introduction and objectives

Singapore is internationally recognized as the model country on the circular water economy. Although the various measures undertaken in Singapore to reduce, reuse and retain water have been described by a variety of scholars, e. g. Luan (2010), Chen et al. (2011), Tortajada et al. (2013), Tortajada & Joshi (2013), or Lee & Tan (2016), no holistic quantitative assessment has been undertaken so far on Singapore's closed water loop. Our paper intends to address this gap. We quantify the economic value of Singapore's circular water economy compared to a linear water economy.

Methodology approach

The economic model developed for this paper refines the modeling approach chosen by Hieminga et al. (2017) who calculated the economic value of a circular water economy for selected countries, while our break-even point calculations emulates the approach chosen by Louwen et al. (2016). Our model is iterated with decision-makers and experts of Singapore's circular water economy, e. g. policy-makers interviewed at Singapore's Public Utilities Board (PUB) and/or Singapore's Ministry of the Environment and Water Resources (MEWR).

Analysis and results

Our quantifications indicate that Singapore's circular water economy creates less economic value in the short-term than a linear water economy since particularly recycling water is a costly endeavor. However, we also evidence that the economic value of the country's circular water economy is far greater than the value created by a linear water economy in the medium- and long-term since it helps to reduce exacerbating water scarcity in the country. In particular, our findings on the break-even point are largely in line with previous quantitative assessments of the circular economy. Various measures are discussed which may further reduce the amortization period for a circular water economy, while we also outline the particularities of our case study to highlight the limits on external validity of our findings.

Conclusions and recommendation

Our quantitative assessment indicates that Singapore's circular water economy creates vast economic value compared to a linear water economy in the medium- and long-term and is thus instrumental in ensuring sustainable water access for the country's private and industrial water users. The quantification approach outlined in our paper may be replicated by those interested in calculating the economic value implications of a circular water economy, while our overall assessment provides a fact base for those contemplating the transition to a circular water economy.

Replication of circular sanitation economies enables opportunity

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Co-Authors: Ms. Brenda Achiro Muthemba, Uganda, N/A
Mr. Steve Sugden, United Kingdom
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Highlights

Creating a circular economy around human waste - or brown gold - is the ultimate contribution to improving health, protecting the environment, and generating business opportunities. Making a step-change aligned with Sustainable Development Goal 6.2 requires new technologies, proven business models, capacity building, market forces, and government partnerships.

Introduction and objectives

The world is in a state of crisis – one third of the global population still does not have access to a toilet. Developing disruptive and game-changing approaches are required to overcome this global scourge and solve this crisis. Water For People has a scalable model in East Africa that is tested and replicable for decentralized sanitation systems. By coupling sanitation with resource-recovery technologies with business models and capacity building, we aim to catalyze a sanitation renaissance and through scale and progress faster towards safely managed sanitation for all.

Methodology approach

The rural and peri-urban areas in East Africa will not be sewered by 2030 (if ever). Water For People plays a facilitating role to catalyze business opportunities within the market system along the value chain of on-site sanitation while also providing quality, affordable, and accessible services to the poor. We apply proven technologies (e.g., desirable toilets, pit life extender, DEFAST, etc.) to cover the entire value chain of sanitation (toilets, pits/tanks emptying, collection, sludge treatment, and sludge reuse). Our approach builds upon Water For People's impact model – Everyone Forever (EF) and our ideal is zero waste.

Analysis and results

EF provides sustained sanitation services for every community member through infrastructure and institution building. We work with government partners and private sector to help create business opportunities using market forces that are all part of the circular economy of brown gold.
Business opportunities that Water For People is currently incubating and accelerating are:

- Building toilets
- Improving toilets
- Supporting start-up of pit emptying businesses and continuous development of better pit emptying technologies
- Reuse of wastewater (where available) for flush toilets
- Building and operating decentralized fecal sludge treatment plants (DEDFAST)
- Working with governments to support smart subsidies to spark sanitation
- Developing sludge products for sale such as fuel briquettes, fertilizers and compost
- Creating and supporting sources of credit for loans for toilets
- Starting call centers and enabling infrastructure for pit emptiers in peri-urban areas
- Partnering with others for large-scale urban treatment works of fecal sludge

Water For People has 38 sanitation market initiatives in various stages throughout East Africa. The outcome of developing this circular economy sanitation paradigm is stronger communities that are cleaner, healthier, and more economically productive.

Conclusions and recommendation

One of the most exciting aspects of decentralized sanitation is the ability to create business opportunities while also solving a societal problem and working towards SDG6. This change occurs through infrastructure development as well as through creation and transformation of sanitation services. We are focused on driving this change with market forces and innovative technologies with a holistic approach and a vision on creating circular economies. All of this we will do in partnership with government to ensure long-term success. Our track record is good to date and we are focused on scale and replication.

Technology innovation in implementing a circular economy strategy

Presenting Author: Mr. Cody Friesen, United States, Zero Mass Water

Co-Authors: Mr. William Sarni, United States, Zero Mass Water

Highlights

Alternative sources of water are an integral part of a circular economy strategy for water. In particular, air moisture capture technology for residential use is a viable technology to move towards an off-grid solution to providing access to water.

Introduction and objectives

The objective of this presentation is to highlight the importance of water technology innovation in addressing SDG 6.1. Specifically, how air moisture capture technology "powered" by solar technology can provide an alternative to centralized drinking water or access to unsafe water. A roadmap of technology identification, funding and scaling the technology solution will be presented along with recommendations to facilitate water technology innovation and adoption.

Methodology approach

Universal access to safe drinking water remains a global challenge and traditional approaches have had limited success. Traditional solutions of deploying centralized water systems or residential systems remain challenging in emerging markets. "Democratizing" access to safe drinking water through deploying air moisture capture systems powered by solar systems frees individual families to secure access to safe drinking water - providing high quality and high security. This innovative off grid approach bypasses many of the hurdles in deploying large scale and more traditional small scale water systems.

Analysis and results

A case study will presented highlighting the success of bringing together academic research in material science with proven entrepreneurship and socially mined funding sources from outside the water sector. The challenges of implementing an innovative water technology will be presented along with a long term strategy to identify and build a business ecosystem of stakeholders to scale the off grid solution to accessing safe drinking water. Technical, funding and adoption challenges will be presented along with examples of successful implementation in the Middle East, Central America, Mexico and the US.

Conclusions and recommendation

Stakeholders need 21st Century technology solutions to achieve SDG 6.1 Accelerating technology innovation coupled with catalyzing an ecosystem of stakeholders to fund and deploy these technologies shows promise in ensuring universal access to safe drinking water. Technology innovation and entrepreneurs outside the traditional water sector can bring new ideas and strategies to address the poor access to safe drinking water. These entrepreneurs working with the public sector, socially responsible funders and multinationals have been successful in implementing new solutions to a circular economy strategy.

Urban water services transitioning to a circular economy

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Highlights

Four case studies from Mexico, Peru, Thailand and Jordan demonstrate the opportunities for urban utilities to transition to a circular economy by adopting energy recovering, water reuse, and nutrient recycling measures. Challenges include access to financing to implement new technologies as well as incentives for a low carbon water sector.

Introduction and objectives

A resource-hungry future urgently requires the water sector to embrace a paradigm shift from removing pollutants in wastewater to resource recovery opportunities. By transitioning to a circular economy approach and towards recycling nutrients, reusing treated wastewater, and recovering clean energy, utilities can significantly reduce their carbon footprint. Four case studies from across the world (Mexico, Peru, Thailand and Jordan) demonstrate how utilities are pioneering the way to a low carbon water industry for others to follow and contribute to carbon targets agreed to under the nationally determined contributions.

Methodology approach

The project 'Water and wastewater utilities for climate change mitigation (WaCCliM)' supports climate change mitigation efforts in the water sector using a cross-sectoral approach that links water, energy and food security to developing concepts for a climate resilient and low emission water industry.

The project uses a systems approach and considers all components of the urban water cycle from water supply, wastewater to reuse of water. Pilot measures on energy efficiency, water loss reduction as well as energy generation from biogas are implemented with lead executing agencies to reduce overall greenhouse gas emissions.

Analysis and results

Optimising energy use as well as wastewater treatment processes provide opportunities for significant GHG reductions across the entire urban water cycle. Through energy generation from biogas, energy efficient pumps, significant amounts of CO_2e can be reduced. In the city of Cusco, Peru, for example ~ 4000 t CO_2e/a were avoided through improved sludge management resulting in increased biogas production. Furthermore, 1230 tons CO_2e/a can be reduced through refurbishing old pumps with new energy efficient pumps. In the city of Chiang Mai in Thailand, 130 tCO_2e/a can be reduced through more energy efficient pumping stations and the reduction of infiltration in the sewer network. In Guanajuato, Mexico; the wastewater utility reduced its carbon footprint by 20% (120tCO_2e/a) through energy optimisation measures. Expanding wastewater service levels led to additional reductions of 2200tCO_2e/a.

At the national level, the program provides technical support to water experts and utility staff managers to improve the political, regulatory and institutional framework and integrate emission reduction measures to reduce the waters sector carbon footprint. Technical assistance is provided to support the multiplication of pilot measures, development of incentives for national mitigation strategies and the introduction of appropriate financing instruments.

Conclusions and recommendation

While utilities are engaging in technologies and practices that support a circular economy, some challenges remain: remodeling of the water sector towards a sustainable low-carbon future requires country ownership and the provision of sufficient financing that facilitates the deployment of new technologies. In addition, robust water sector GHG accounting and monitoring, and sharing best practices within the industry to ensure wide adoption of an economically viable and sustainable transition to decarbonisation is needed. Investment in decarbonizing the water sector significantly contributes to meet the Nationally Determined Contributions agreed in the COP21 Paris Agreement and the Sustainable Development Goals.

Poster: Managing waste streams in a house - lessons in decentralization

Presenting Author:	Mr. Vishwanath Srikantaiah, India, Biome Environmental Trust
Co-Authors:	

Highlights
Water management, urban, technology, storage, sanitation

Introduction and objectives
Running an ecological design practice provides an opportunity to include management of water and waste-water in individual buildings and institutions we design.
In the context of Bengaluru,where at a city level water has become a scarce resource,it is possible to easily integrate rainwater harvesting , greywater recycling, kitchen waste composting, and terrace gardening into individual homes and institutional buildings such as schools to reduce dependency on external water and sanitation systems. Not only is harvested rainwater a major supplement but the nutrients from ecosan and greywater can be used productively for food production at household level.

Methodology approach
Designing of building often avoids services such as water and wastewater infrastructure assuming a link to the city lines. More often than not buildings in the periphery of a growing city have to create independent services such as a borewell for water supply and septic tanks for sanitation systems.Analysing rainfall pattern both storage and recharge systems were designed to hold and reuse rainwater. Greywater tanks were located to catch clothes wash and bath water and filtered using biological systems for reuse in toilet flushing and for vegetable cultivation. Ecosan toilets provided urine and dessicated faeces as fertiliser for crops.

Analysis and results
In the design of a large school building it was possible to capture almost all the rainwater falling in a large sump tank. This water is filtered before being used for drinking. For toilets it is used directly. Greywater treatment system recycle water for flushing requirement. The school with 200 students is independent of the city system for water and wastewater management.
In most houses depending on the rooftop area between 100,000 to 200,000 litres of rainwater is harvested annually.Where a perched aquifer exists an open well provides all the water requirement of the house and is recharged using rooftop rainwater. Greywater systems recycle almost all shower and washing machine water. By replacing detergents with ecofriendly soaps it is possible to simplify treatment requirements. Twin leach pit toilets and ecosan toilets provide safe containment and reuse of faeces.This in turn is reused for growing rooftop vegetable gardens. Kitchen waste is composted and reused on site. A rooftop provides an ideal space for reusing greywater and nutrients from human waste as also to harvest rain. About 40 sq. mt. of roof area can provide water, food and energy security and also take care of waste from a house in Bengaluru.

Conclusions and recommendation

By designing for rainwater harvesting,water efficient fixtures,recycling systems,ecosan toilets it is possible to supplement water requirements to a great extent and complete the food cycle using nutrients from human and kitchen waste.Ecological design is the way forward in closing the water and nutrient loop.

Architects and engineers can play a crucial role in addressing the water and wastewater management of cities Simple design tools and filters for rainwater and greywater recycling is needed to help take the design implementation forward. Building byelaws and tax incentives can be thought of aprropriately for each city to to encourage such designs .