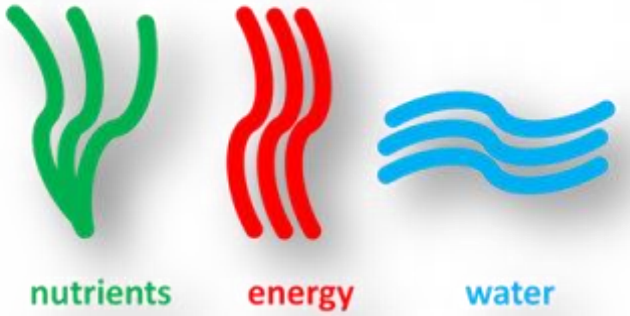
NEWGENERATOR™

Technology for the global sanitation challenge



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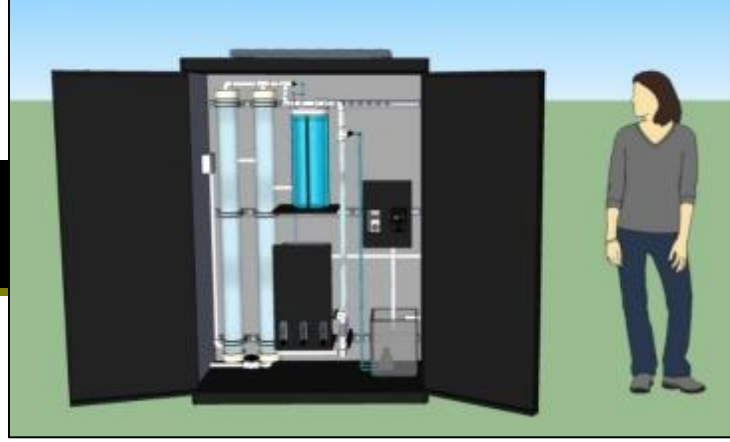
Background



- The ***NEWgenerator***^{TM} is a resource recovery machine that harvests **energy (biogas or electricity), nutrient fertilizers and clean water** from human wastes.
- The machine achieves a high level of waste treatment through the use of **anaerobic membrane bioreactor technology (AnMBR).**
- A high level of pathogen destruction is achieved to ensure safe sanitation.
- This robust, low-energy and off-the-grid technology enables a number of treatment and resource reuse applications.

- Decentralized wastewater treatment option. used for water recycling or dewatering of wet sludge pits.
- The technology is **highly scale-able**. It can be sized for single family to neighborhoods. Several versions can be made available.
- ***NEWgenerator***^{TM} can be sized to treat waste and wastewater of a wide range of quantity. **The processing capacity is adaptable.**

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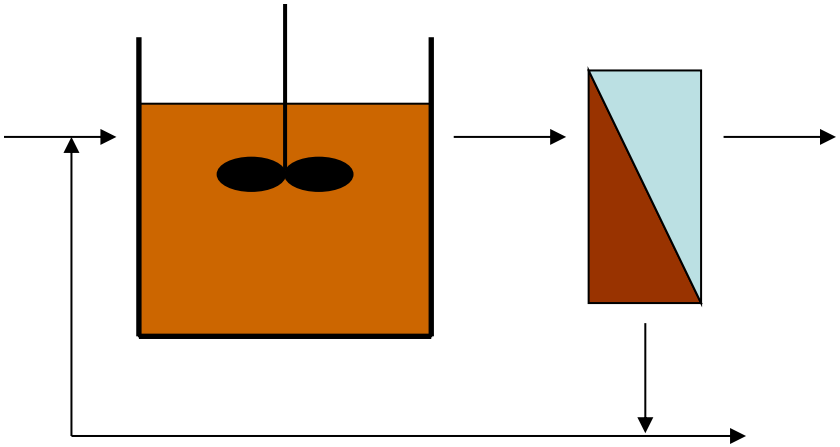
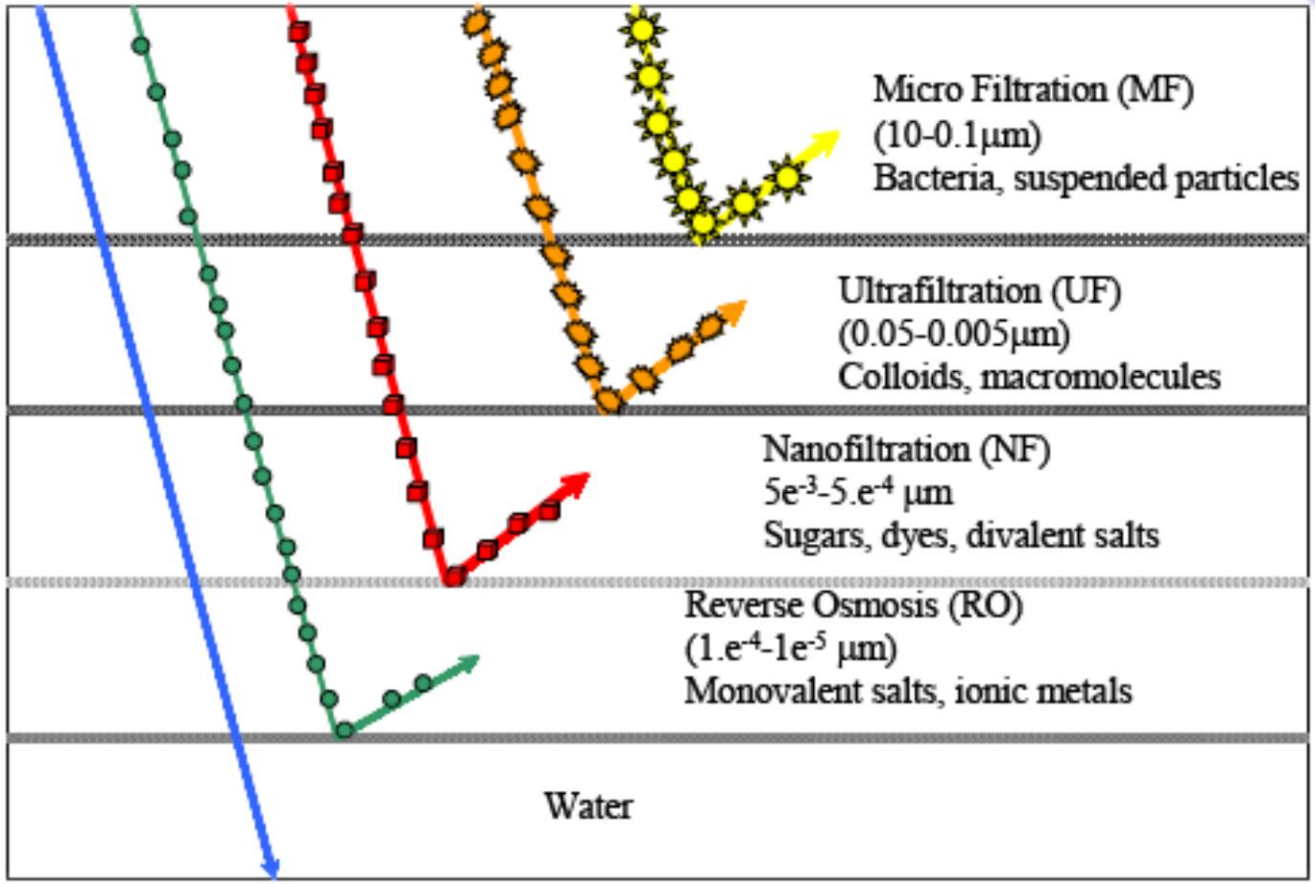
Membrane Bioreactor (MBR)



- MBR is the coupling of a membrane and a biological processes, where membrane separation and biological conversion of substrate occur **synergistically** to achieve results not possible by each process alone. It is the state-of-the-art in WWT.
- All solids are removed from effluent, including micron sized colloids which can harbor pathogens, but cannot be removed via gravity settling.

Filtration Spectrum



Membranes provide an absolute physical barrier for pathogen removal for safe dewatering

Pathogen	Log removal
Helminths	8 (99.999999%)
Bacteria	6 (99.9999%)
Viruses	4 (99.99%)

- NEWgen membrane pore size: 0.03 µm Font and Garcia
  - Helminths (Ascaris) eggs size: 35µm
  - Vibrio cholorae: 1-3µm

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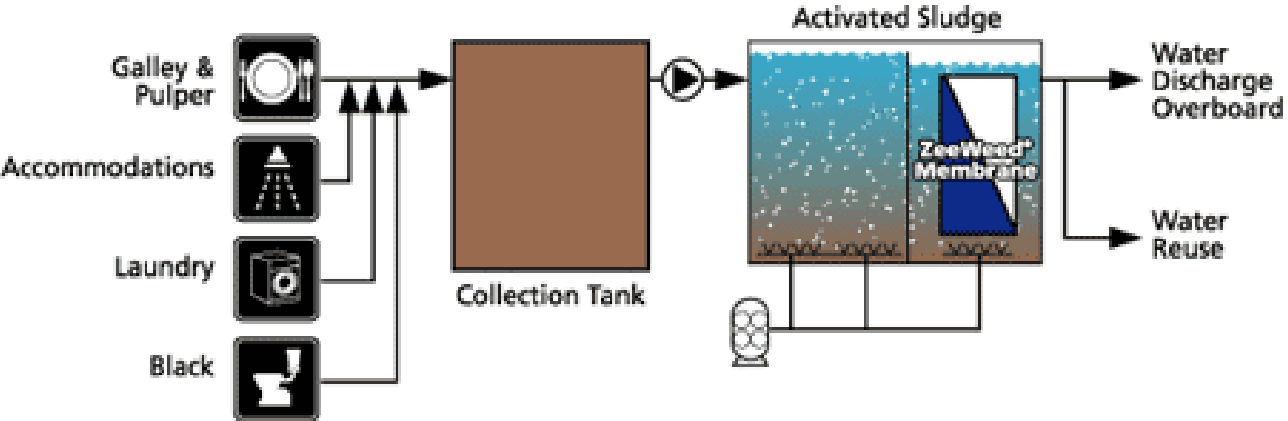
Membrane Bioreactor (MBR)

- State-of-the-art WWTP (STP). MBRs used in cruise ships, green buildings, and potentially in space colonies.
- The ***NEWgenerator™*** improves upon existing MBR systems:
  - **Low energy demand**
  - **Low maintenance**
  - **Membrane fouling controlled**
  - **Recovers energy as biogas**
  - **Recovers nutrients for reuse**

Helena Apt. Bldg, NYC (50,000 GPD blackwater to cooling water and irrigation)



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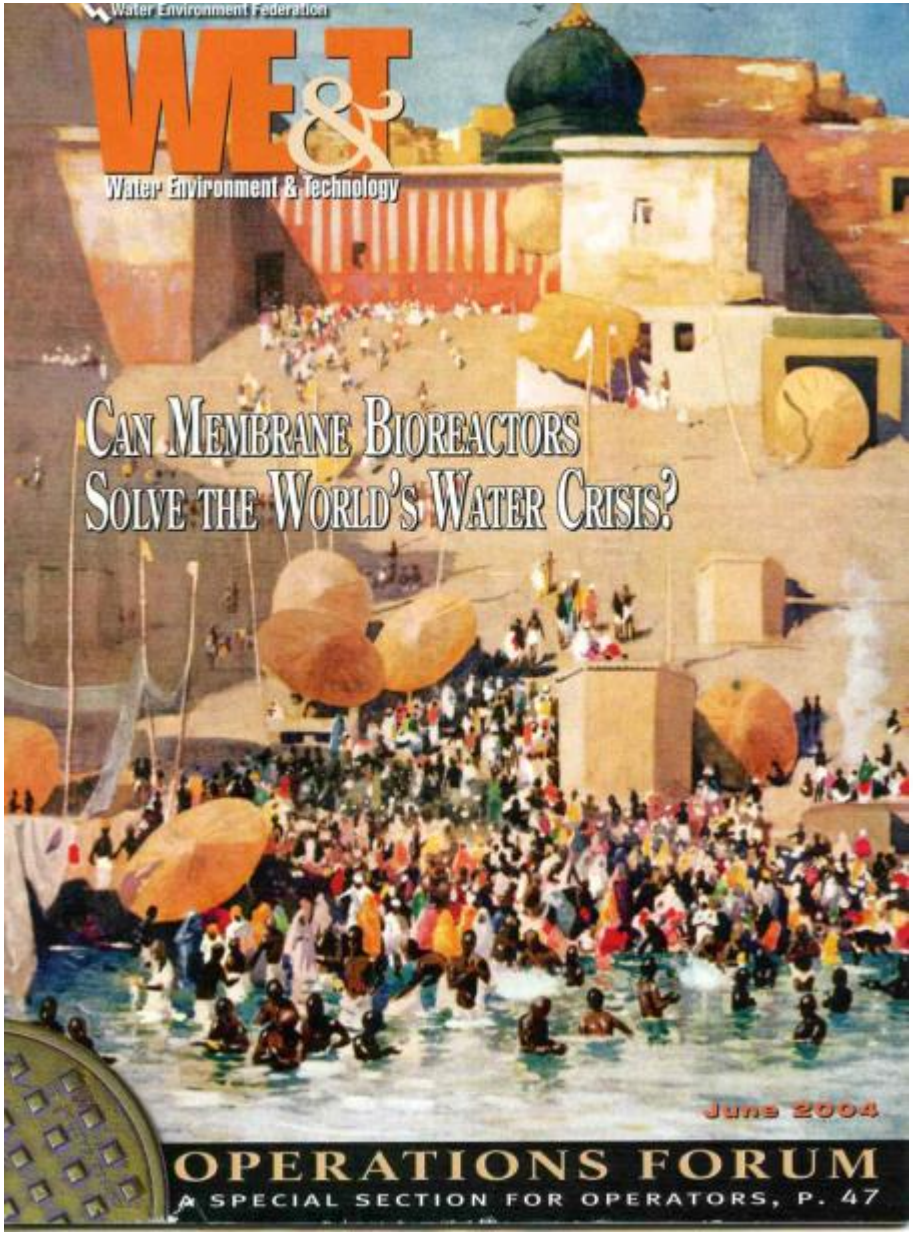


SAFE WATER FOR EVERYONE

Experts suggest that membrane bioreactors may be a key to global water sustainability

Francis A. DiGiano, Gianni Andreottola, Samer Adham, Chris Buckley, Peter Cornel, Glen T. Daigger, A G (Tony) Fane, Noah Galil, Joseph G. Jacangelo, Alfieri Pollice, Bruce E. Rittmann, Alberto Rozzi, Tom Stephenson, and Zaini Ujang

Reuse and decentralization will be essential for meeting human needs for water and sanitation in both developing and developed countries. Membrane bioreactors (MBRs) will be an essential part of advancing such water sustainability, because they encourage water reuse and open up opportunities for decentralized treatment.

These were the conclusions of a Rockefeller Foundation-sponsored Team Residency held at the Bellagio (Italy) Study and Conference Center on April 23–26, 2003. The foundation invited 14 experts on membrane technology, water treatment technologies, and water sustainability from the United States, United Kingdom, Germany, Italy, Australia, Israel, South Africa, and Malaysia to explore the role of MBRs and other membrane processes in achieving sustainable water and sanitation. (The foundation periodically brings together up to 14 participants from developed and developing countries to discuss topics of global importance. The format permits structured and unstructured time to explore common ground and forge shared solutions to tough challenges.)

Membrane Bioreactors Come of Age

MBRs combine activated sludge with membrane filtration (see Figure 1, p. 32). So, in addition to removing biodegradable organics, suspended solids, and inorganic nutrients (such as nitrogen and phosphorus), MBRs retain particulate and slow-growing organisms (thereby treating more slowly biodegraded organics) and remove a very high percentage of pathogens (thereby reducing chemical disinfection requirements). They also require less space than traditional activated sludge systems because less hydraulic residence time (HRT) is needed to achieve a given solids retention time (SRT). In addition, MBRs are more automated, making them ideal for decentralized treatment because they are simpler to operate.

We base the readiness of MBR technology on the following reasons:

- **The engineering principles underlying MBRs are familiar enough to ensure reliability.** Because MBRs combine two familiar technologies — activated sludge and membrane filtration — significant engineering expertise can be applied to MBR design and operation. Several stud-

MBR is extremely promising, but improvements are needed before its full potential for global sanitation can be realized

Sustainability Criteria for MBR Technology

(Balkema *et al.*, 2002 and indicates the Team's ratings for MBRs)

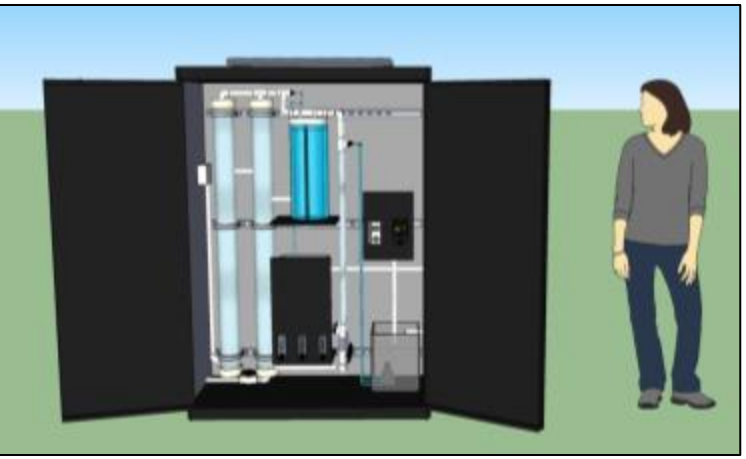
Criteria	Indicators	Improvement needed	Good now
Economic	Cost and affordability	X	
Environmental	Effluent water quality		
	Microbes		X
	Suspended solids		X
	Biodegradable organics		X
	Nutrient removal		X
	Chemicals usage	X	
	Energy	X	
	Land usage		X
Technical	Reliability		X
	Ease of use	X	
	Flexible and adaptable		X
	Small-scale systems		X
Socio-Cultural	Institutional requirements	X	
	Acceptance	X	
	Expertise	X	
OVERALL SUSTAINABILTY GOOD			

From the **Bellagio Framework 2004**, where, at the invitation of the Rockefeller Foundation, 14 w/ww experts from around the world met in Italy to evaluate MBR technology.

Areas of strength for MBR are highlighted in blue. In an effort to introduce MBRs to developing communities for sanitation, our research mission since 2004 has been focused on improving the MBR attributes highlighted in red.

Resource Recovery

nutrients energy water



The use of **anaerobic digestion** allows for the efficient recovery of energy, nutrients and water from wastewater.

- Embodied energy is recovered in the form of **Biogas (methane)**
- **Nutrients such as nitrogen and phosphorous** are released by digestion and allowed to be reused for plant growth
- **Clean, pathogen-free water** leaves the system after treatment. Perfect for irrigation or other reuse applications

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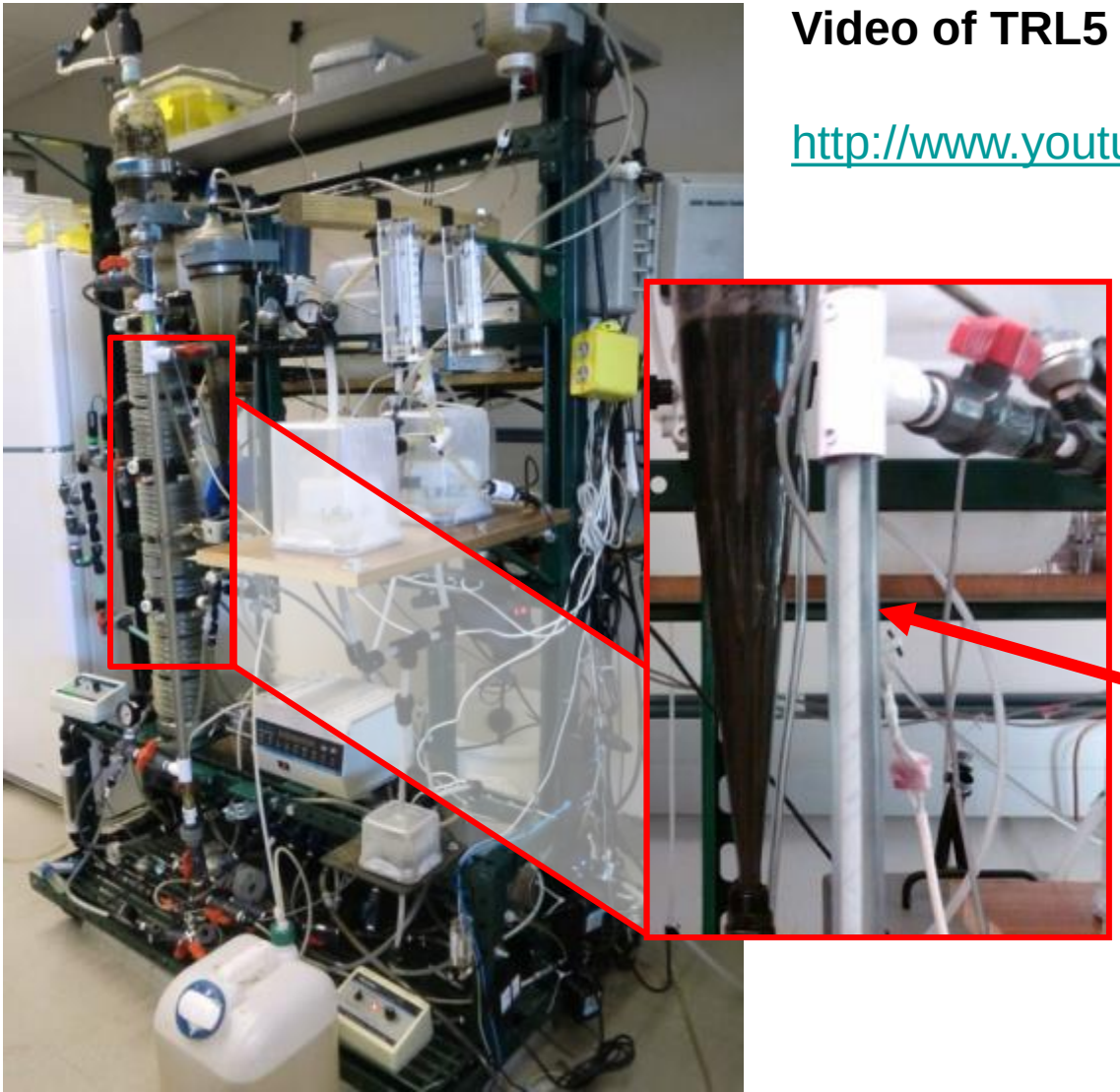
nutrients energy water

Technology Development: TRL 5



Video of TRL5 system

http://www.youtube.com/watch?v=-s9HAyTJ38s

First, a lab-scale system was developed. This TRL 5 system treated synthetic wastewater within the controlled conditions of the lab.

Membrane module consisted of a tubular ultrafiltration membranes. Wastewater enters the center of the tube and is filtered out into the membrane module.

TRL 5 : Summary

Turbidity
447±8.4 NTU

Turbidity
6.9±2.3 NTU

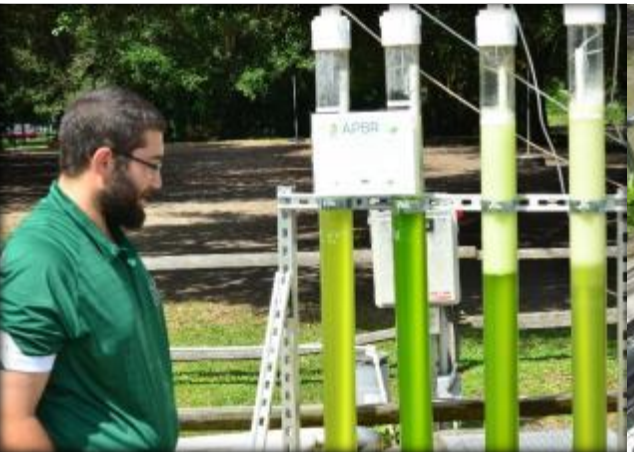
- Filtration sustained at a flux of 10-15 LMH.
- Removal efficiencies of organic matter (i.e., up to 98% and 95% in COD and TOC removal respectively)
- Biogas production (4.5 L/d)
- Recovery of soluble fertilizers from sewage (95% N and 93% P)
- Results were published in the following peer-reviewed journal:
- AL Prieto, H Futselaar, PNL Lens, R Bair, DH Yeh. 2013**. Development and start up of a gas-lift anaerobic membrane bioreactor (GI-AnMBR) for conversion of sewage to energy, water and nutrients**. - *Journal of Membrane Science*, 441: 158-167

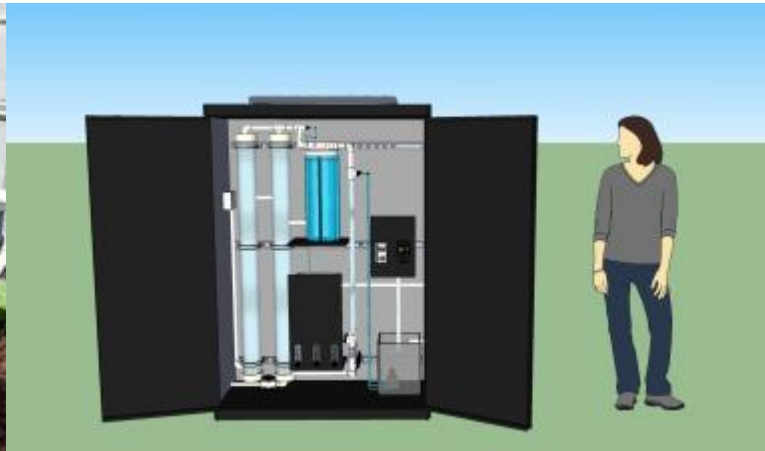
Relevant Environment: Actual wastewater

TRL6 *NEWgenerator™*

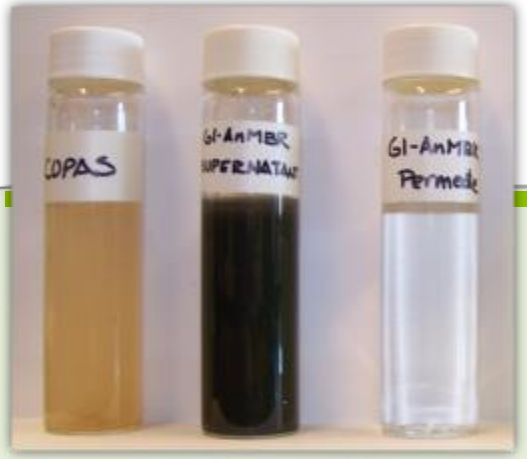
- Resource recovery machine in a box
- Field pilot operated almost 1 years using real wastewater (septic tank influent) from a Florida school; went through different seasons and weather conditions
- Demonstrated nutrient recovery via
    1) fertigation for crops via hydroponics;
    2) struvite recovery;
    3) microalgae cultivation via photobioreactors

BRATS Biorecycling & Bioenergy Research and Training Station





Sanitation

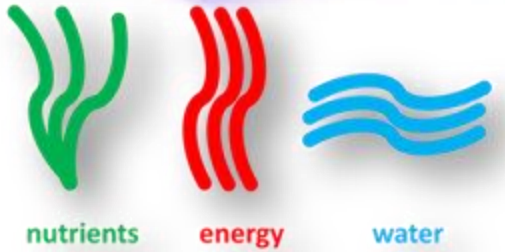


Use for irrigation (fertigation)

Sewage → Anaerobic sludge → Recovered nutrients & water

UF membrane filter

NEWgenerator ™



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Potential to contribute on:

Sanitation	Water
Energy	Food
Health	Gender
Economics	Empowerment

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Creating Value Added Products

Domestic wastewater
feces, urine, flush water and wash water

Biogas
methane for energy (e.g., cook stoves)

NEWgenerator

membrane

Filtered liquid
fertilizer for irrigation (fertigation)

Fertilizer
Disinfected and stabilized solid fertilizer for soil conditioner

Funding and Path Forward

- BMGF GCE Round 7 (2011)
  - Developed and piloted tested **TRL6** system

BILL & MELINDA GATES foundation | Grand Challenges | EXPLORATIONS

- BMGF / India DBT-BIRAC (2014)
  - Reinvent the Toilet Challenge – India
  - With Eram Scientific Solutions (Kerala, India)
  - Next step: pilot testing **TRL7** in Kerala with eToilet

- Cade Museum Prize for Invention and Creativity (2014)
  - **Final Four** Round (Winner on May 8, 2014)
  - http://www.cademuseum.org/prize/

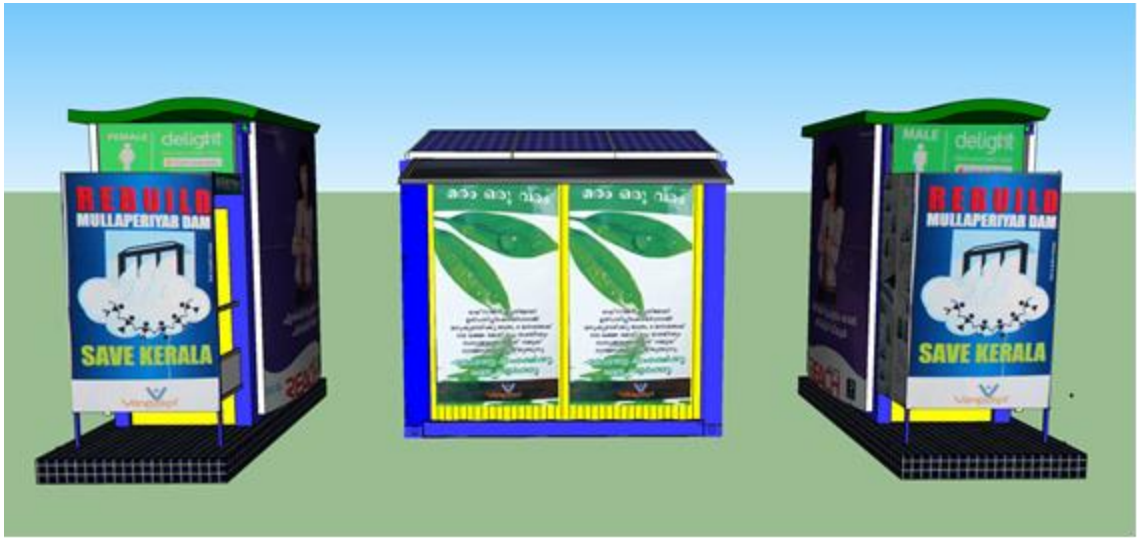
cade museum
creativity + invention

- Patents, licensing, commercialization
  - Two patents pending (on reactor configurations and use), two more applications in progress
  - Startup planned

nutrients energy water

Technology Development: TRL 7

- Next stage: Field testing in India with **Eram Scientific Solutions** (Trivandrum City, Kerala)
- The NEWgenerator will be coupled with an **e-toilet** to achieve an integrated total sanitation and closed-loop resource recovery system.
- The integrated system (sized for 100 users/d) will be an off-grid sanitation solution which produces more than enough energy to power both the eToilet and NEWgen.
- Water is cleaned, sanitized and recycled.



Eram Scientific

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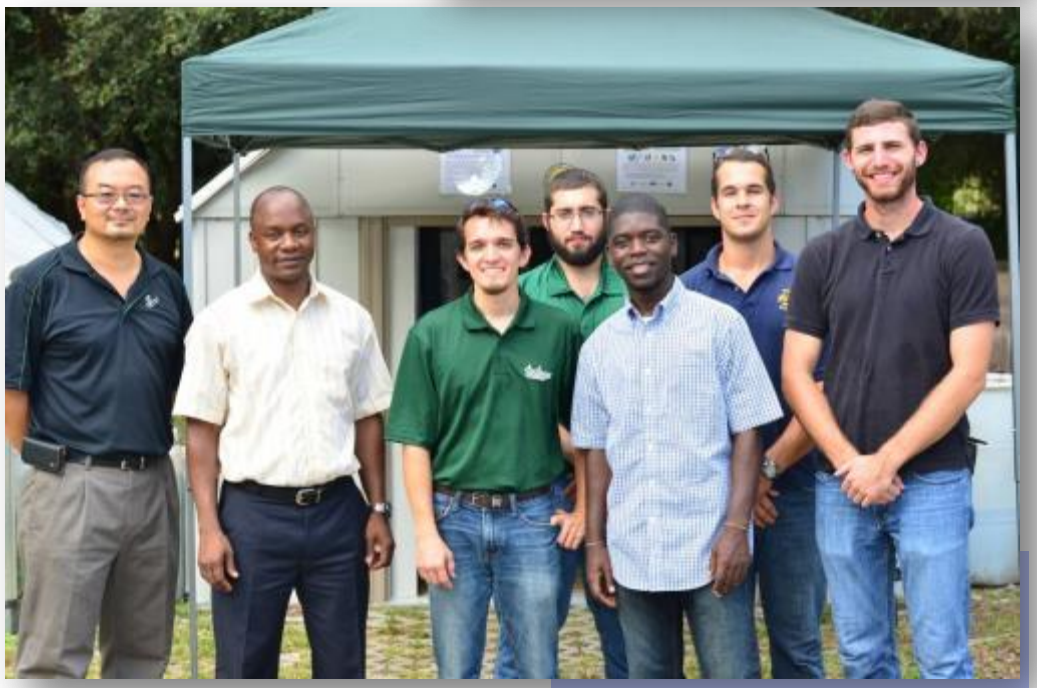
Q & A

Graphics: Ana Lucia Prieto



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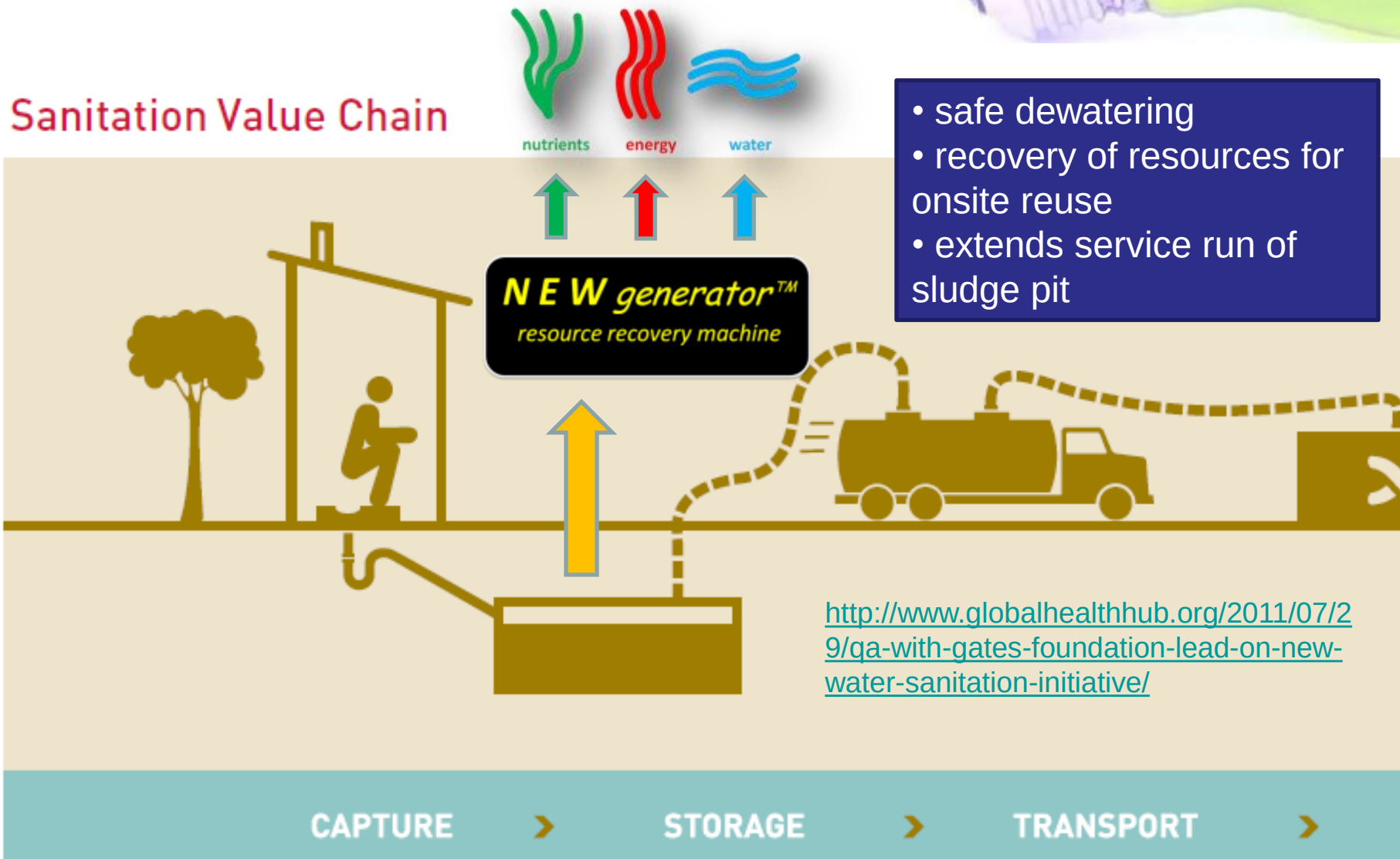
http://NEWgenerator.tumblr.com

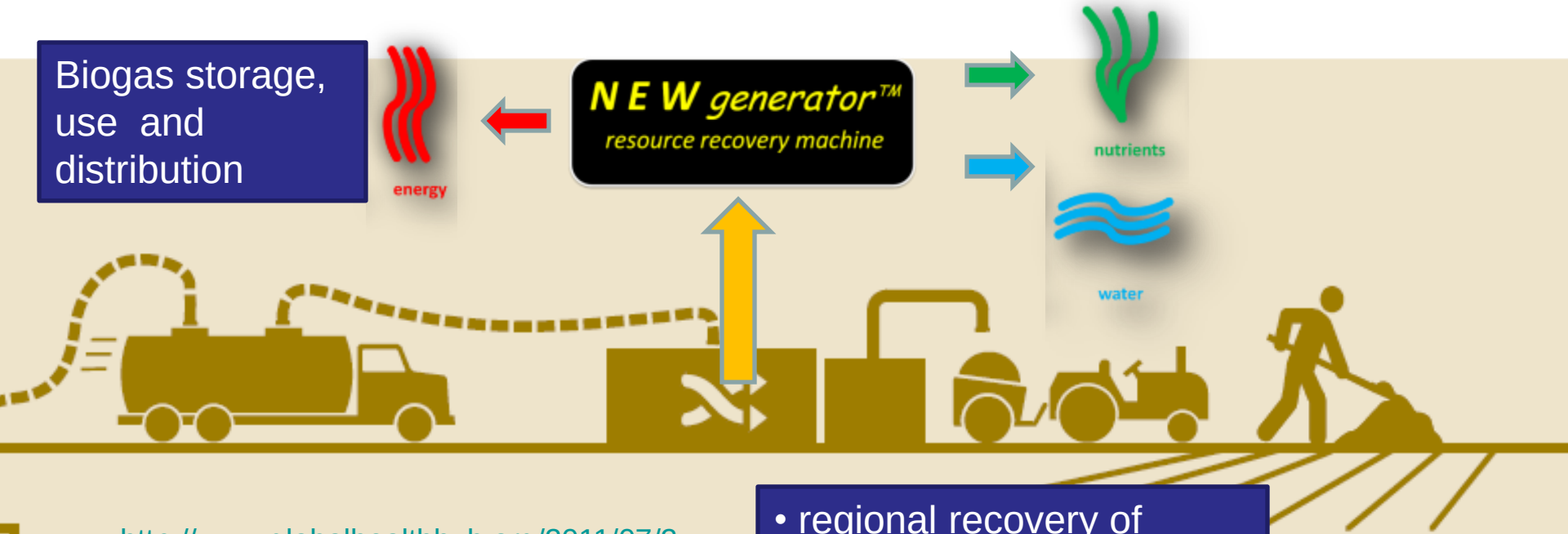
USF Membrane Biotechnology Lab
http://mbr.eng.usf.edu/

Additional Slides

Small-scale *NEWgenerator™*
for **onsite** resource recovery and reuse



Larger-scale *NEWgenerator™*
for **regional** resource recovery and reuse



http://www.globalhealthhub.org/2011/07/29/qa-with-gates-foundation-lead-on-new-water-sanitation-initiative/

- regional recovery of resources for reuse
- steady operation
- economy of scale

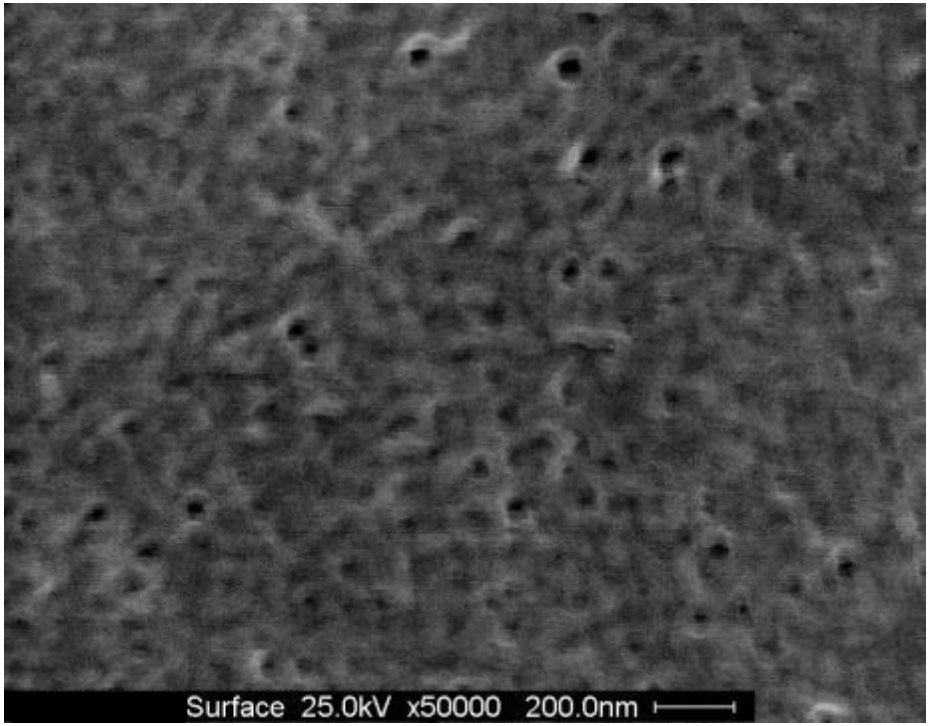
RAGE › TRANSPORT › TREATMENT › REUSE

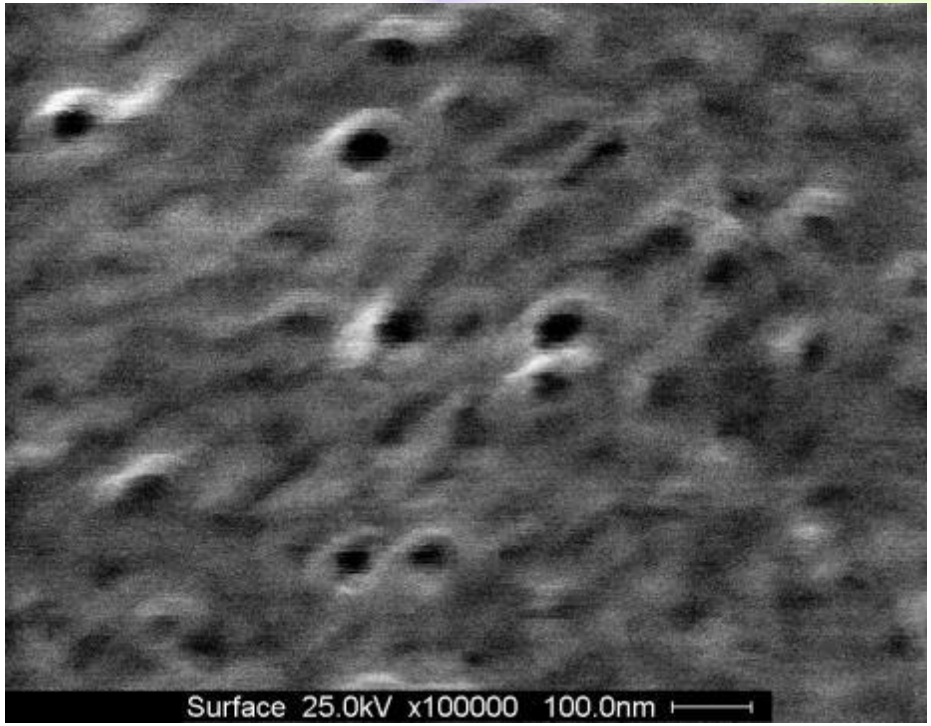
Process Focus: Membranes

- A membrane is **barrier**, generally a thin polymeric film, whereby only select substances can pass (e.g., clean water) but impurities (salt, contaminants, bacteria, dirt) are rejected.
- Uses:
  - Desalination
  - Water purification
  - Medical (e.g., artificial kidney)

UF Membrane Surface

nutrients energy water





- Average membrane pore size: 0.03 µm
  - Helminths (Ascaris) eggs size: 35µm
  - Vibrio cholorae: 1-3µm

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nutrients energy water

TRL 6: Site preparation

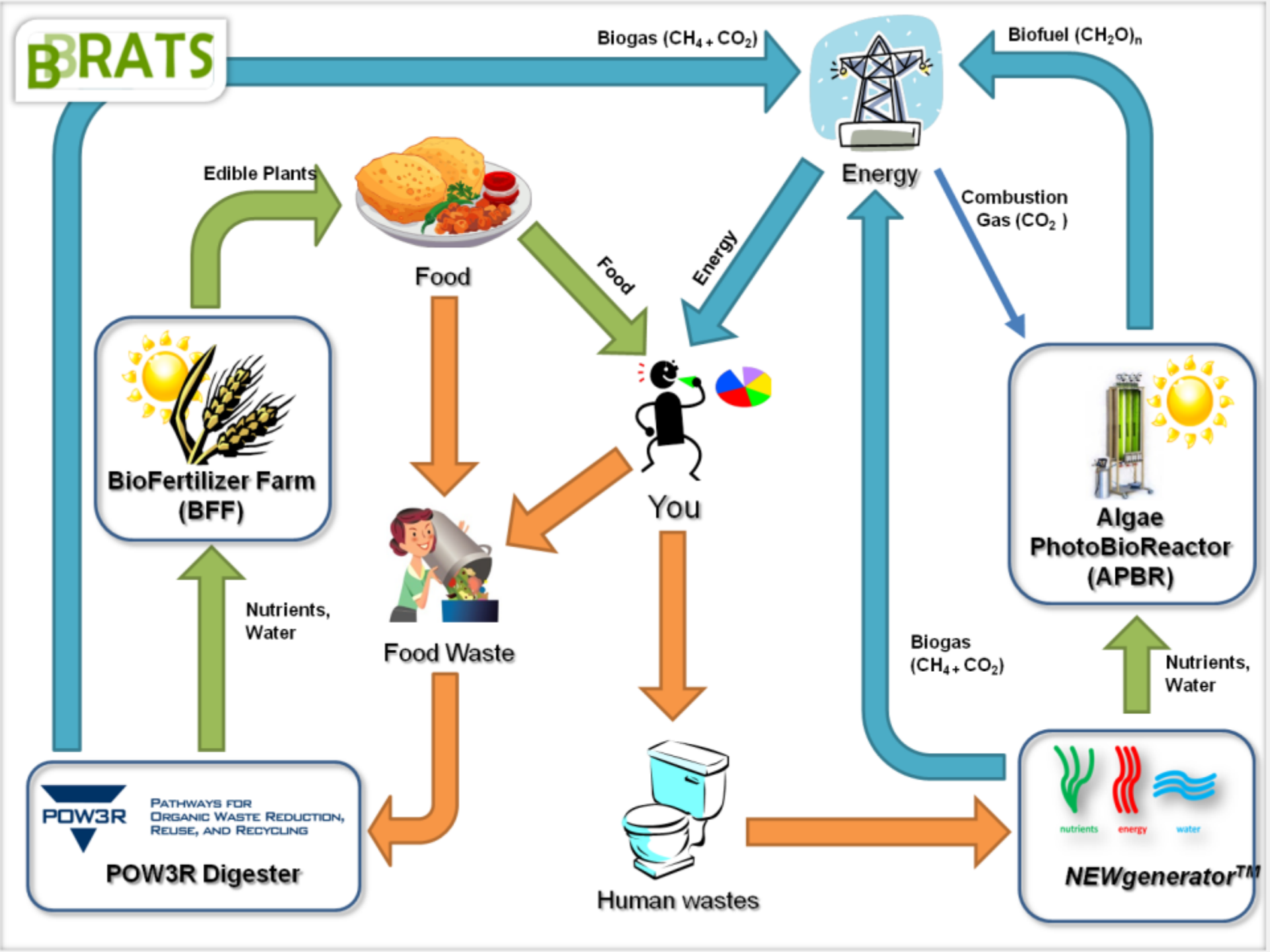
Using **co-funding** from the **National Science Foundation** and **University of South Florida**, we established a sanitation technology testing platform at a Florida green school (Learning Gate). The **BioRecyclnig/BioEnergy Research and Training Station (BBRATS)** enables research on global sanitation, algae biofuel and food waste digestion.

BBRATS

Biorecycling & Bioenergy Research and Training Station

The **Biorecycling & Bioenergy Research and Training Station (BBRATS)** at Learning Gate is a unique educational platform to help the younger generation develop an understanding and appreciation of **sustainability**, closed-loop elemental **biorecycling**, waste-to-**bioenergy** conversion, **biomimicry engineering**, and real world applications of innovative **environmental technologies**. Integrating research, education and practice, BBRATS is a confluence of research projects on the topics of:

- **Global sanitation challenges** (Bill & Melinda Gates Foundation)
- **Microalgae biofuel production** (National Science Foundation), and
- **Sustainable food waste management** (University of South Florida Graduate School).


BRATS
Biogas ($CH_4 + CO_2$)
Biofuel $(CH_2O)_n$
Energy
Edible Plants
Food
Food
Energy
Combustion Gas (CO_2)
BioFertilizer Farm (BFF)
You
Algae PhotoBioReactor (APBR)
Nutrients, Water
Food Waste
Biogas ($CH_4 + CO_2$)
Nutrients, Water
POW3R
Pathways for Organic Waste Reduction, Reuse, and Recycling
POW3R Digester
Human wastes
nutrients
energy
water
NEWgenerator™

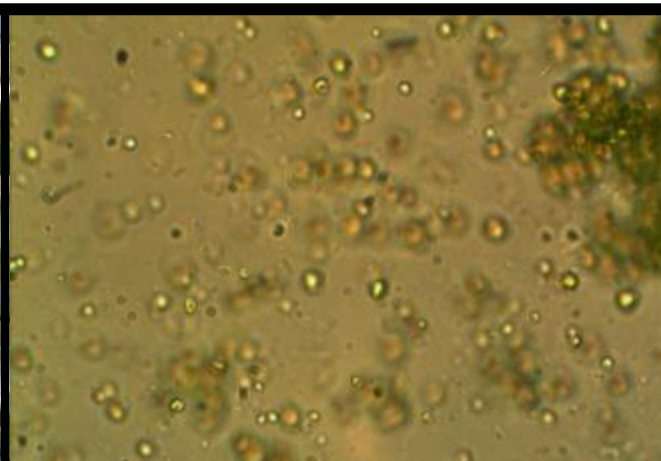
nutrients energy water

Resource Recovery: Microalgae

- **Growing Microalgae** on the nutrients available in the permeate can help boost biogas production if they are fed back to the reactor. The algae can also be harvested to make biodiesel from their lipids, as well as nutraceuticals.

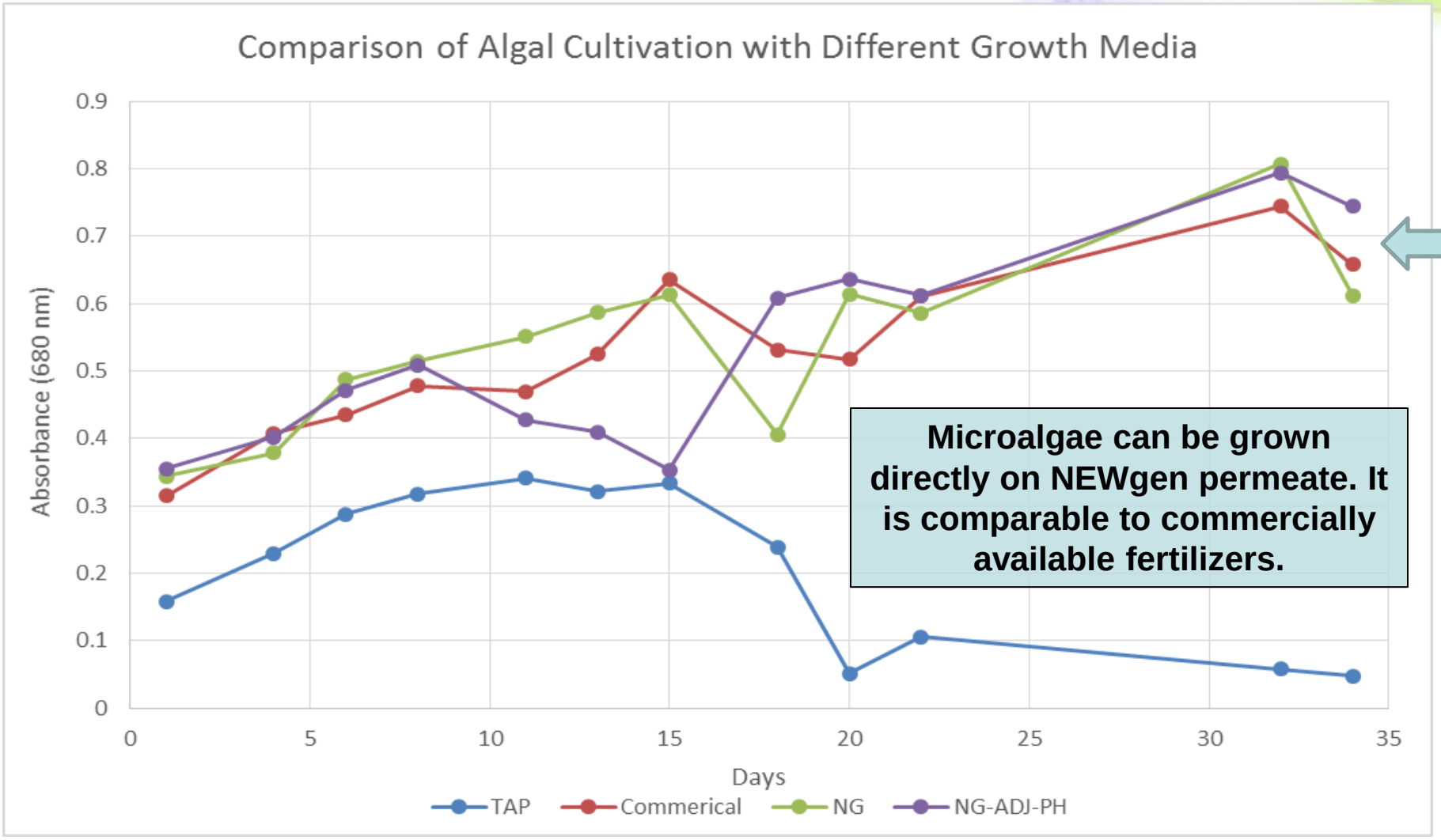
- **Outdoor Photobioreactors** were used to test the real-life growth potential of microalgae.

- **Lab batch tests** were also conducted to determine the nutrient uptake and growth kinetics of microalgae grown on NEWgen Permeate.



Actual wastewater

Resource Recovery: Microalgae



nutrients energy water

Resource Recovery: Crops

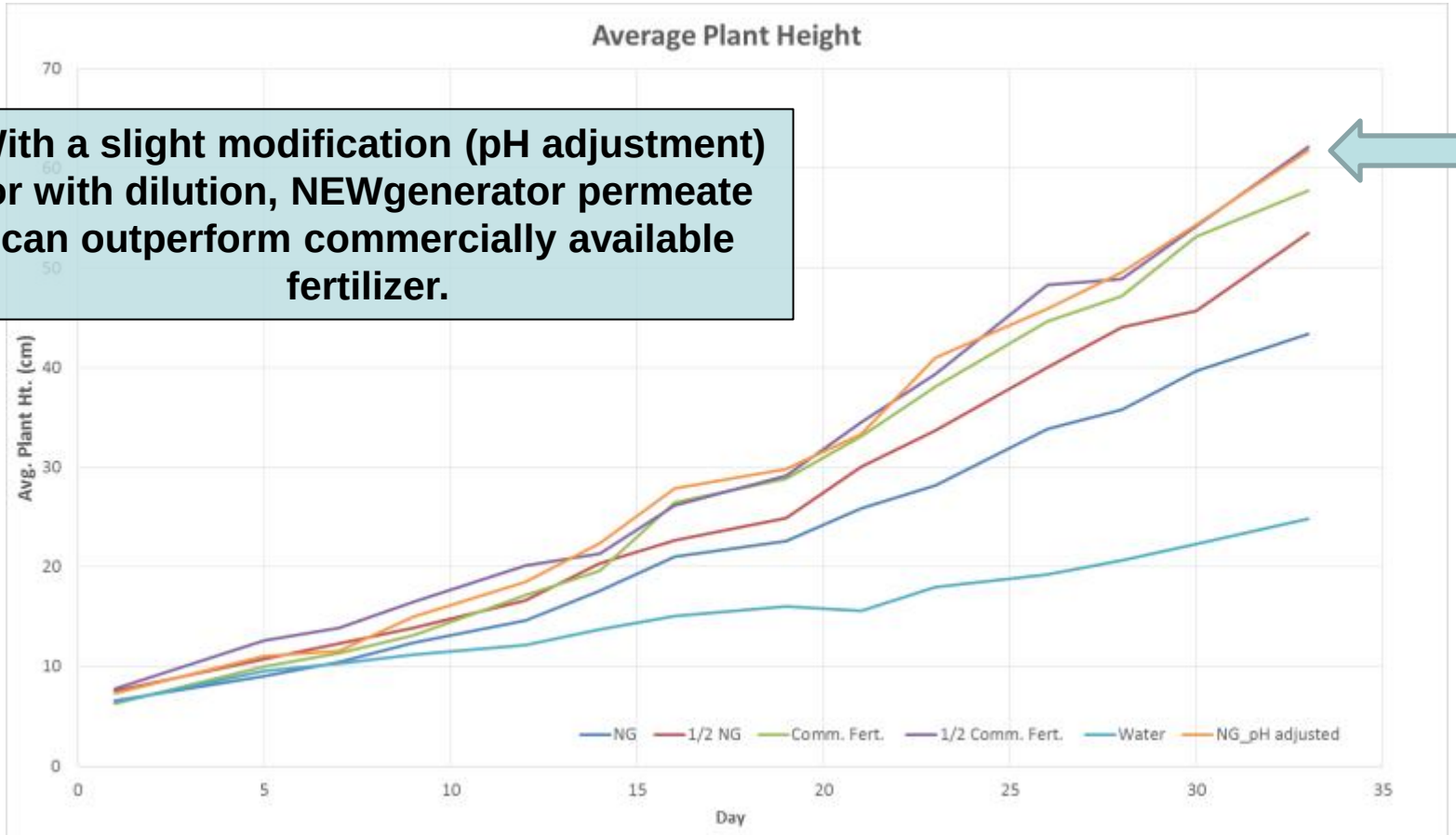
- **Direct plant fertigation** was tested for growing food and material crops.
- **Green House testing** was conducted to observe real-life growing conditions of plants
- **Lab testing** was conducted to monitor nutrient uptake rates as well as plant growth rates.

nutrients energy water

Resource Recovery: Crops

- **NEWgenerator Permeate** can be used directly to irrigate and fertilize plants (tomato and cucumbers) in a hydroponic garden. The permeate can be used as a substitute for commercial fertilizer.

With a slight modification (pH adjustment) or with dilution, NEWgenerator permeate can outperform commercially available fertilizer.



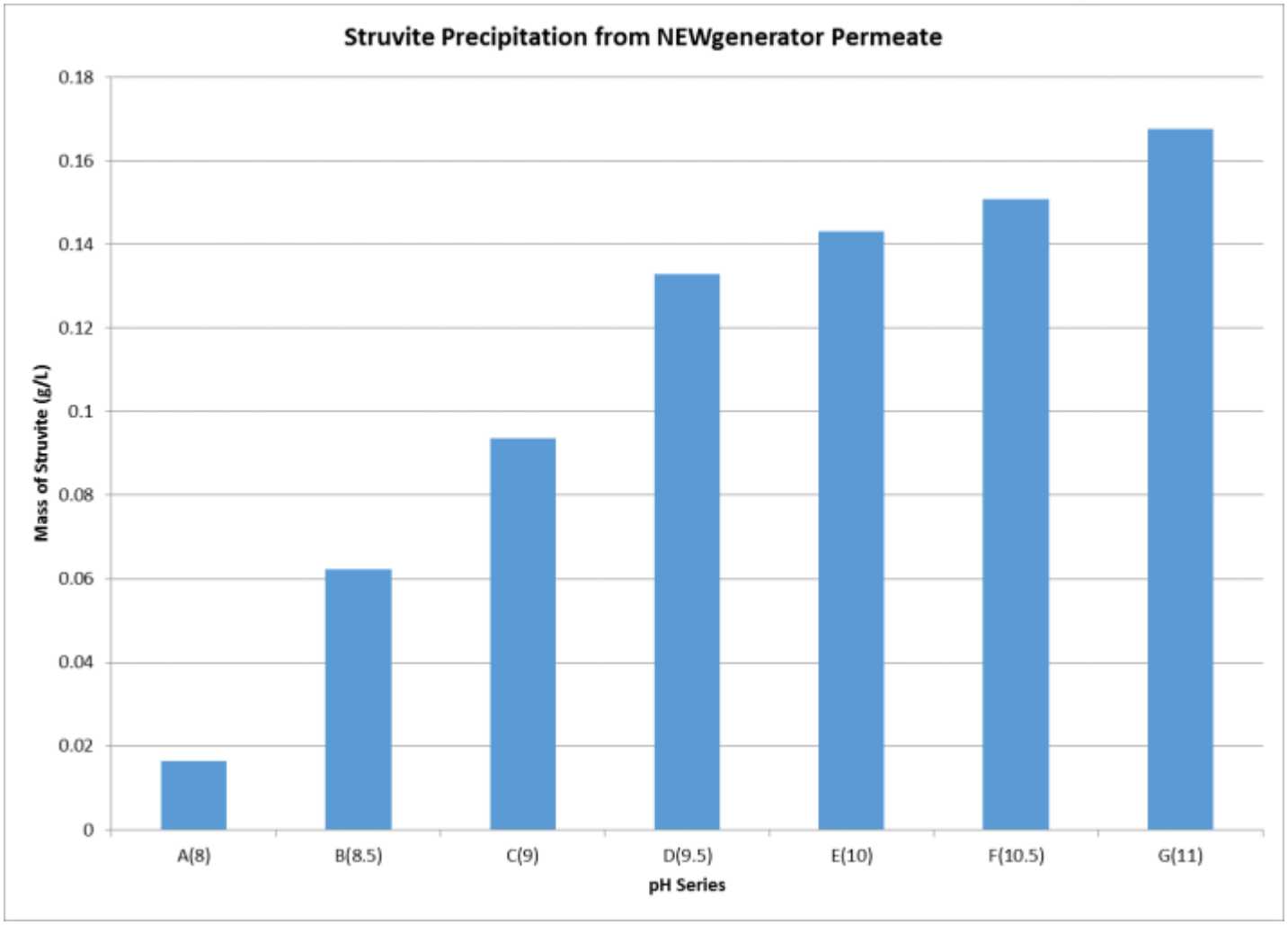
nutrients energy water

Resource Recovery: Struvite

- **Another way of harvesting nutrients in the permeate is to remove them by precipitating them out as a solid fertilizer called struvite ($MgNH_4PO_4 \cdot 6H_2O$).**
  - **Struvite can easily be removed and transported to agricultural areas that desire the nutrients.**
  - **Lab tests were conducted to determine the struvite forming potential of the NEWgenerator permeate.**

Actual wastewater

Resource Recovery: Struvite



Media Coverage

- **Fox 13 News story of our lab's work on wastewater as a renewable resource**

  http://www.myfoxtampabay.com/story/18612577/could-a-new-energy-source-start-right-here

- **Media coverage of NEWgenerator project**

  http://NEWgenerator.tumblr.com