# TRANSFORMING TECHNOLOGIES

## SCIENCE AND TECHNICAL COUNCIL OF THE AFRICAN WATER ASSOCIATION

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17 July 2017
Accra, Ghana

# THE REINVENTED TOILET (RT) PROGRAM IS DESIGNED TO ADDRESS EACH OF TODAY'S LIMITATIONS

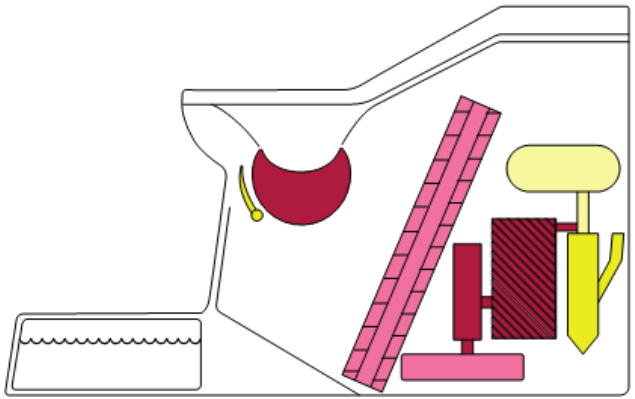
The Reinvented Toilet is a modular, transformative technology that offers a non-sewered sanitation solution, eliminating the need for a piped collection system. The aim of the Reinvented Toilet is to: destroy all pathogens onsite and recover valuable resources, operate without sewer, water or electricity connections and cost less than $0.05/user/day in a sustainable business model.

## ELIMINATE PATHOGENS

- Eliminate safety concerns via handling
- Reduce disease burden
- Improve environmental safety

## OPERATE OFF GRID

- Eliminate need for external inputs such as water and energy
- Make portable and easy to install



## CONVEY LOW LIFE-CYCLE COSTS

- Reduce need for pit emptying
- Ensure a sustainable business model, including maintenance via service providers

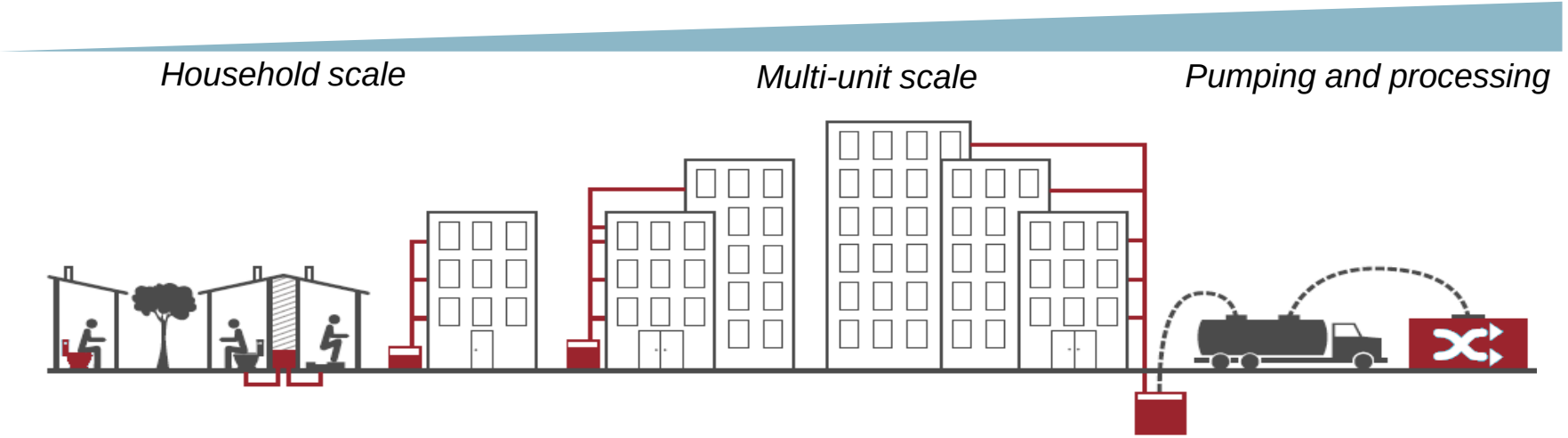
## PRESENT MODULAR, ATTRACTIVE INTERFACE

- Reduce / eliminate construction costs
- Provide clean and dignified product
- Eliminate odors and waste

# THE TRANSFORMATIVE TECHNOLOGIES (TT) PORTFOLIO SUPPORTS A RANGE OF SYSTEMS AND CAPACITIES

From household systems that can be used inside the home, to external units that process waste from multiple dwellings or apartment units, the RT portfolio includes technologies for a range of use cases, with varying sizes and capacities.

## RT SUPPORT A RANGE OF USE CASES, SIZES, CAPACITIES



# EXAMPLES OF LEADING RT PROTOTYPES

## LOUGHBOROUGH UNIV.

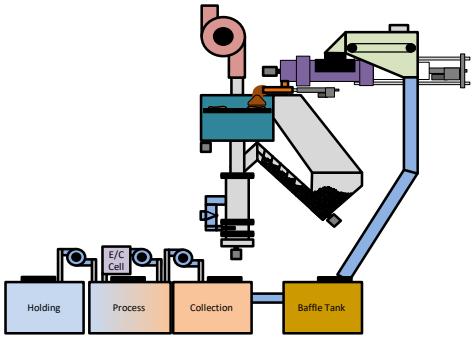
*Hydrothermal carbonization*

## CALTECH

*PV + electrochemical process*

## RTI INTERNATIONAL

*Combustion + electrochemical process*




**Already in field trials – more designs will enter trials this year**

# THROUGH OUR TECHNOLOGY PARTNERS, WE HAVE TACKLED SIGNIFICANT TECHNICAL CHALLENGES

- Solid/liquid separation
- Energy recovery
- Novel interfaces
- Water efficient flush
- Advanced reactor-based systems
- Scaling down of physical and mechanical processes
- Malodor reduction
- 100% pathogen removal
- Repurposing of existing components
- Wide range of thermal processes
- Electrochemical disinfection
- New materials and coatings
- Controls and monitoring systems

*… LEADING TO PROOF OF CONCEPT AND DE-RISKING PRODUCT DEVELOPMENT*

# BEYOND R&D, WE WILL CONTINUE TO HELP EXPAND THE INDUSTRY

## Enabling environment

**Collaborate with local governments to enhance demand for sanitation**

**Support implementation of international product standards**

## Marketplace readiness

**Foster a supportive regulatory environment**

**Leverage relationships with development banks to facilitate access to financing**

# TECHNOLOGY PORTFOLIO

# TRANSFORMATIVE TECHNOLOGIES: 3 SUB-PORTFOLIOS

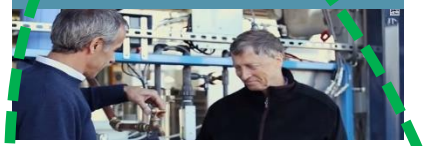
## REINVENTED TOILET

*Single-unit (SURT)*

*Multi-unit (MURT)*

## OMNI INGESTOR

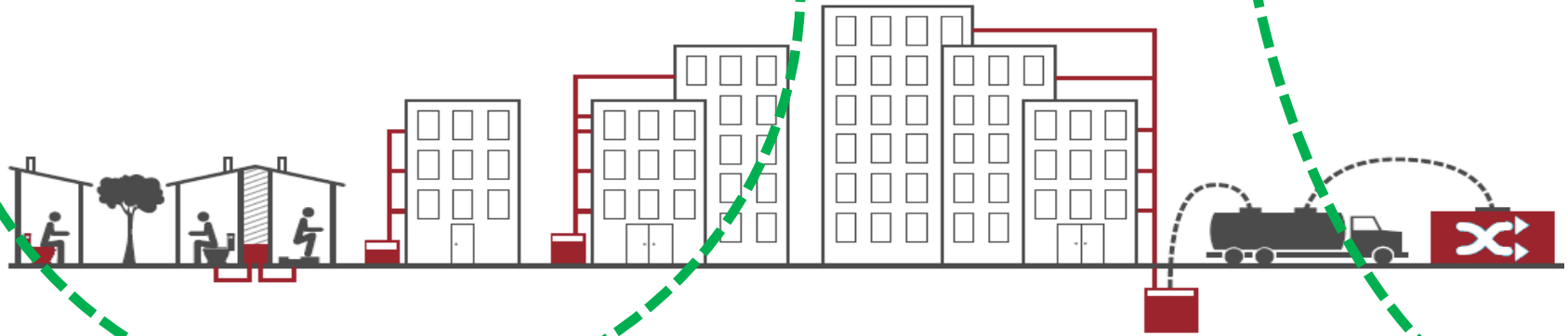

## OMNI PROCESSOR



*Household scale*

*Multi-unit scale*

*Pumping and processing*

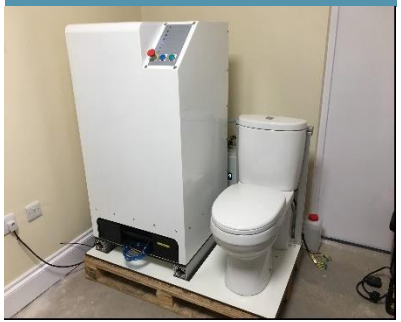


# OUR CORE PROCESSING TECHNOLOGIES

## ELECTROCHEMICAL

Caltech

## WET OXIDATION

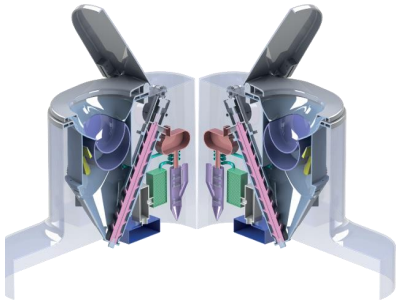


Loughborough University

eawag aquatic research

Duke University

## DRY COMBUSTION



University of Toronto

Cranfield University

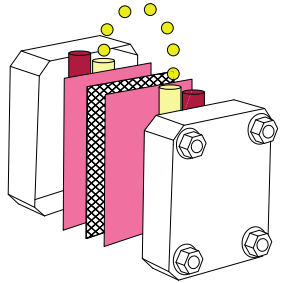
Duke University

RTI International

Three Bird Swan Consulting Group

JANICKI BIOENERGY

## BIOLOGICAL



USF University of South Florida

UWE Bristol

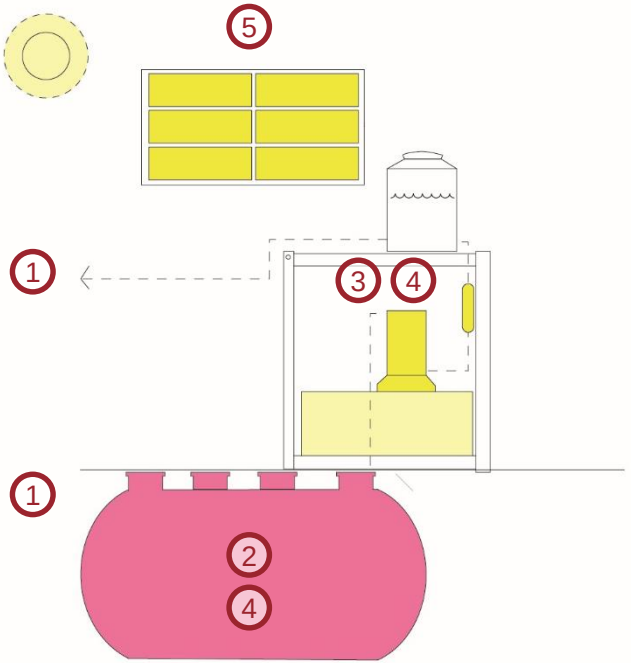
# RT TECHNOLOGY PORTFOLIO

# THE CALTECH TOILET TREATS AND RECYCLES WASTEWATER FOR REUSE AS FLUSHING WATER.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | Includes one (or more) toilets and urinals located near the backend processing components. Collaboration with partners Kohler Company, Eram Scientific, and Yixing Eco-Sanitary Manufacture Co., Ltd. on various frontend designs and technology. |
| 2. Urine/Feces Separation | Passive settling and anaerobic digestion occurs. Active pre-processing in anaerobic/aerobic is available. |
| 3. Liquid Processing | An electrochemical system oxidizes the waste water at a semiconductor anode and water is reduced at the metal cathode to form H2. Chloride from table salt is oxidized to reactive chlorine species, increasing disinfection. Final membrane microfiltration may be included for polishing. |
| 4. Solids Processing | Feces are macerated and the suspended fraction is treated with the liquids. Settled solids are evacuated once a year. |
| 5. Power System | Solar panels with energy storage in batteries and/or grid electricity. |



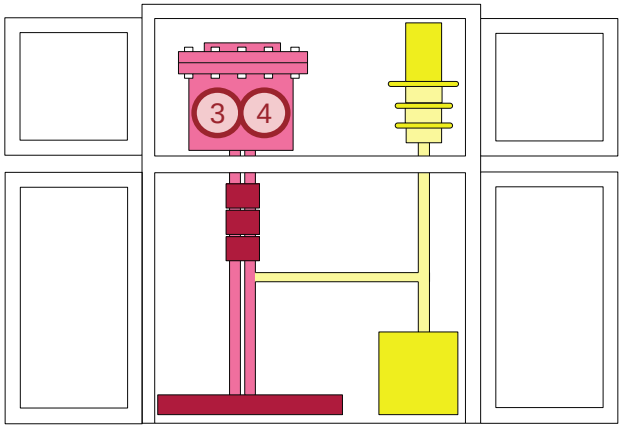
# CALTECH'S ELECTROCHEMICAL DISINFECTION PROCESS PRODUCES HYDROGEN THAT CAN BE USED AS A FUEL.

| | |
|---|---|
| Capacity | Up to 500 users per day |
| Key Features | • Unique **electrochemical process** treats urine and wastewater and produces hydrogen<br>• Residual chlorine guarantees the **safety of the recycled wastewater** for flush reuse.<br>• Compatible with **any type of flush toilets** (squat pan, western style, etc.) |
| Current Status | Partnered with The Kohler Company and Eco-San to develop optimized versions of the system for commercialization. |
| IP Status | Patent pending in the United States, India, and China. See WO 2014/058825 A1 for further information. |
| Links | http://hoffmann.caltech.edu/ |

# THE LOUGHBOROUGH TOILET IS A BACKEND PROCESSING UNIT SIMILAR TO A PRESSURE COOKER.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | Backend processing unit built into a cabinet with a small footprint. Intended to be paired with any toilet in a household setting. |
| 2.Urine/Feces Separation | No separation is required, urine, feces, and wash water are processed as a single stream. |
| 3. Liquid Processing | Solid and liquid waste is pumped into the system and held in an input tank, then sent to a high temperature and pressure reactor for hydrothermal carbonization. Pathogen-free liquid and biochar are then sent to a material collection for use outside the system. |
| 4. Solids Processing | Solids are processed to biochar which is then separated from the system by gravity settling and filtration for use as fertilizer. See “Liquids Processing” for details. |
| 5. Power System | Current prototype uses batteries charged by a solar collector with supplemental power from the grid or a generator. Energy balance indicates that the final system should be off-grid. |



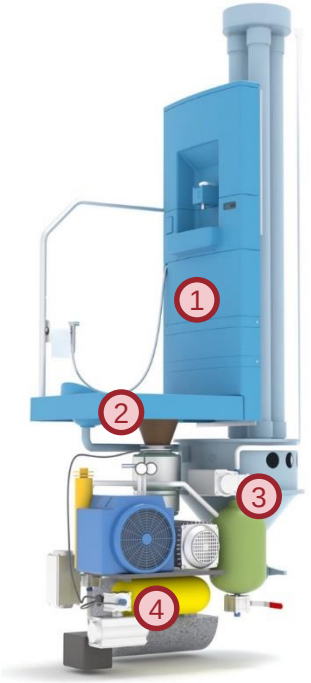
# THE LOUGHBOROUGH TOILET HAS A COMPACT DESIGN, AND BIOCHAR PRODUCED CAN BE USED AS FERTILIZER.

| | |
|---|---|
| Capacity | Estimated 6 to 40 users/day. Future larger versions could serve more than 100 users per day. |
| Key Features | • System is designed to be **compact**, for deployment in a home<br>• A unique **hydrothermal carbonization** process sanitizes urine and feces without the need for separation<br>• Produces approximately 10-15 g/user/day of biochar and liquor that can be used as **fertilizer**<br>• Char has a calorific value similar to lignite and can be used for carbon capture<br>• Estimated to be energy positive, generating ~1.2 kWh/user/day |
| Current Status | Functional, field tested prototype |
| IP Status | In process |
| Links | |

# THE AUTARKY SYSTEM IS DESIGNED FOR A HOUSEHOLD OR PUBLIC TOILET WITH A SQUAT PLATE + WASH STATION.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | Urine-diverting squat pan with water flush, hand wash station and anal cleansing hose. Designed by EOOS. |
| 2. Urine/Feces Separation | Diversion squat plate (designed by EOOS) enables urine and feces to be separated. |
| 3. Liquid Processing | Urine is stabilized and evaporated to extract nutrients for fertilizer. Water extracted from urine and feces is combined with wash water and treated by a unique gravity-driven membrane filtration system. |
| 4. Solids Processing | Intended design will treat fecal sludge through a hydrothermal oxidation at 400C and high pressure until completely oxidized to carbon dioxide and water. |
| 5. Power System | Options for powering the system are still under evaluation. |



# AUTARKY COMBINES A SPECIALLY DESIGNED FRONTEND WITH NOVEL BACKEND TREATMENT PROCESSES.

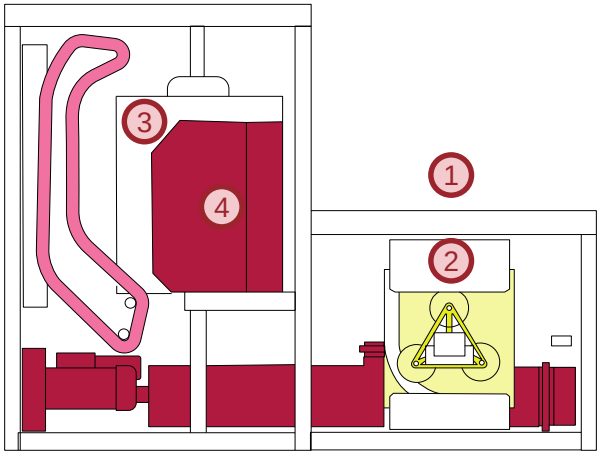
*Source: © Eawag/ EOOS*

| | |
|---|---|
| Capacity | Still in development. |
| Key Features | • Attractive frontend developed through extensive user testing with design firm partner, EOOS<br>• Unique backend processing systems for both liquids and solids<br>• Produces fertilizer: phosphate- and nitrogen-based |
| Current Status | Components have been proven at lab scale. Component optimization, scale-up, and system integration is ongoing. |
| IP Status | Patent protection on the frontend of the device is being pursued by EOOS. See WO 2014/022873 A2 for more information. |
| Links | http://www.bluediversiontoilet.com/ |

# THE TORONTO SYSTEM USES A SMOLDERING PROCESS FOR BATCH CONTINUOUS PROCESSING OF FECES.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | Currently used with an elevated squat plate that is above backend components. |
| 2.Urine/Feces Separation | Novel component at the bottom of the squat plate separates liquids from solids. |
| 3. Liquid Processing | Continuous thermal kill that uses heat and emissions from solids reactor to elevate temperature above 70C for an extended time, killing pathogens. |
| 4. Solids Processing | Fecal matter is transferred via piston and peristaltic pump into a reactor, and mixed with granular particles, and in situ dried. Mixed fecal matter and granular media are then combusted in the smoldering column in a cyclic continuous manner. |
| 5. Power System | Currently considering options for on-site generation, including solar panels or a thermoelectric generator. |



# UNIVERSITY OF TORONTO'S SMOLDERING PROCESS HAS BEEN SHOWN TO BE ROBUST AND EFFECTIVE.

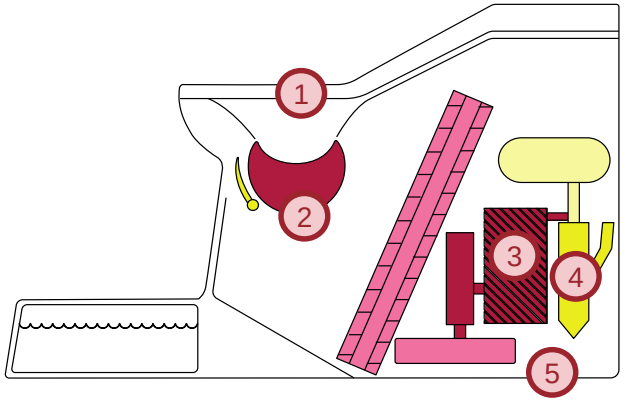
| | |
|---|---|
| Capacity | Household of approximately 10 users per day |
| Key Features | • Unique, mechanical **separation device** is built into the squat plate interface<br>• **Peristaltic pump** for conveyance of fecal matter<br>• Cyclic continuous **smoldering process** for processing of fecal matter and consistent heat production<br>• Post-smoldering **catalytic conversion** generates additional heat, and mitigates emissions. |
| Current Status | Prototype stage, working towards field testing |
| IP Status | Provisional patent filed. |
| Links | http://cgen.utoronto.ca |

# THE NANOMEMBRANE TOILET IS A 100% SELF-CONTAINED HOUSEHOLD TOILET – NO EXTERIOR WATER OR POWER NEEDED.

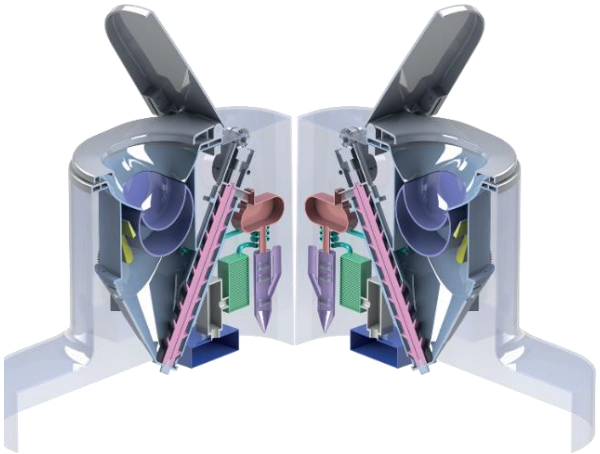
SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | User encounters a pedestal toilet with a unique waterless flush system. A rotating odor barrier and scraper mechanism manages odor and enables dry flushing. |
| 2. Urine/Feces Separation | Solids are separated by gravity sedimentation while liquids flow over a weir to liquids processing. |
| 3. Liquid Processing | A nanomembrane removes clean water and potentially volatile organics (such as ammonia) from the contaminated urine. Non-potable, clean water is then sent to a storage tank for later use. |
| 4. Solids Processing | Solids are dried, pelletized and gasified to achieve complete disinfection. Excess heat is used in liquids disinfection process and for power generation. |
| 5. Power System | In the final design, the team is considering options to convert waste heat to electric power to operate the system, but development is still in process. |



# THE NANOMEMBRANE TOILET FEATURES A UNIQUE WATERLESS FLUSH SYSTEM AND PRODUCES SURPLUS POWER.

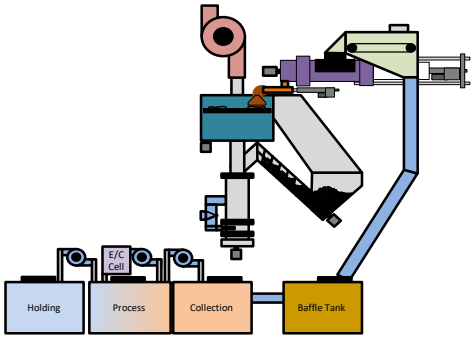


| | |
|---|---|
| Capacity | 10 users/day (potential for larger capacity) |
| Key Features | • **System design** is completely self-contained, no water or power connections are required<br>• **Unique waterless flush system** minimizes water requirements<br>• **Heat from the gasification process** is used to increase filtration efficiency<br>• System produces **surplus power and potable water** each day for household use<br>• Ash requires regular disposal |
| Current Status | Working on system component integration in preparation for field testing. |
| IP Status | Multiple filed but not yet published. |
| Links | http://www.nanomembranetoilet.org/ |

# THE DUKE/ RTI TOILET GENERATES ENERGY FROM SOLID COMBUSTION AND TREATS AND RECYCLES LIQUID FOR FLUSHING.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | Enclosed cabin ROCA 1.5l low-flush squat plate, body wash hose, hand-wash station, menstrual product disposal bin and menstrual pad dispenser. Additional 2 urinals located on exterior. |
| 2. Urine/Feces Separation | A unique conveyor with mesh belts is used for initial separation. Baffle tanks in liquid processing stream allow for additional settling of solids. |
| 3. Liquid Processing | Multi stage baffle tank coupled with pulsing electrochemical disinfection. A post baffle filter is used for Helminth egg removal and a final liquids polishing step is being considered. Disinfected liquid recycled for flush water. |
| 4. Solids Processing | After initial separation, solids flow through a macerator before being dewatered, pelletized, and combusted. Combustion generates heat for drying and energy for electrochemical processing. |
| 5. Power System | Harnesses energy from combustion and includes a thermoelectric. Optional solar panels for supplemental energy. |



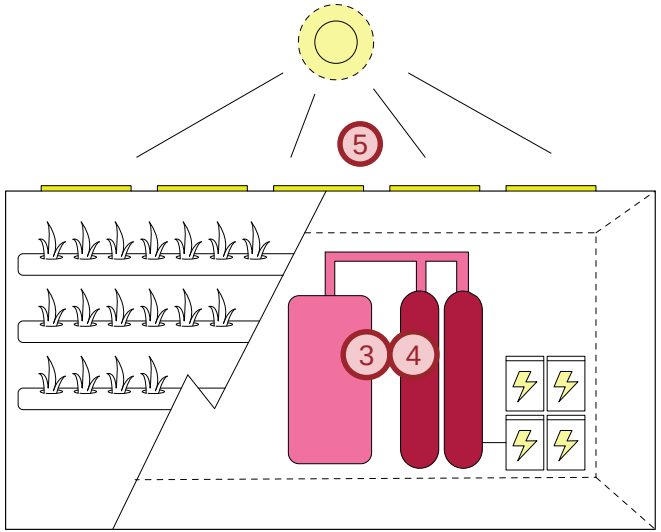
# THE SOLID AND LIQUID TREATMENT PROCESSES ARE MODULAR AND CAN PAIR WITH OTHER TECHNOLOGIES.

| | |
|---|---|
| Capacity | Approximately 10-50 users per day |
| Key Features | • **Frontend** is pleasant to use and safe<br>• Liquids are process via **pulsing electrochemical disinfection**<br>• Solids are **dried** and prepared as **pelletized fuel** for combustion<br>• Thermal energy from combustion process converted to electricity to drive liquid disinfection<br>• **Independent solid and liquid processing streams** that can be used as modules and paired with other technologies |
| Current Status | Field testing underway in Ahmedabad, beta prototype update in process for deployment |
| IP Status | Disclosures prepared; no patent protection has been filed. |
| Links | http://abettertoilet.org/ |

# NEWGENERATOR™ CAN BE PAIRED WITH ANY TOILET TO PROCESS A DILUTE OR CONCENTRATED WASTE STREAM.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | Agnostic to user interface; can be paired with a variety of designs. |
| 2.Urine/Feces Separation | No separation required; fecal solids are incorporated into a dilute liquids stream for processing. |
| 3. Liquid Processing | First, an anaerobic membrane bioreactor digests pathogens and organics. Then membrane filtration and a hydroponic system on the exterior are used to remove additional organics and minerals. Electrochlorination is used as a final polishing step. |
| 4. Solids Processing | Solids are processed in dilute concentrations along with liquids in a single stream (TSS range of 100-10,000 mg/L). The mixed waste processing stream is digested by and remediated by bioreactor and membrane filtration system. |
| 5. Power System | Currently using solar panels to charge deep-cycle flooded batteries that power the system and capturing biogas for other uses. |



# NEWGENERATOR™ IS CURRENTLY BEING FIELD TESTED AT A SCHOOL IN INDIA.

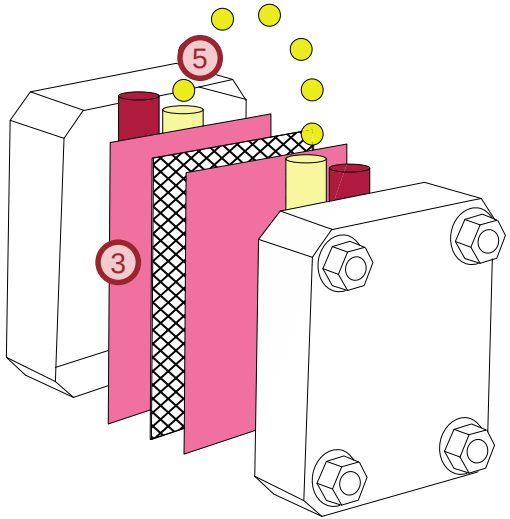

| | |
|---|---|
| Capacity | Average of 100 users per day, 250 users per day peak capacity. |
| Key Features | • **Anaerobic membrane bioreactor** processes solid and liquid in a single, dilute waste stream<br>• Minerals and nutrients are removed from the wastewater by a **hydroponic system**<br>• **Biogas** from waste product digestion is collected for use outside of the system (e.g. cooking, heating) |
| Current Status | Currently in field testing at a school in India, paired with the eToilet from Eram as the frontend. |
| IP Status | Provisional patent has been filed, see WO 2015/143160 A1 for more information. |
| Links | http://newgenerator.tumblr.com/ |

# THE MICROBIAL FUEL CELL (MFC) PROCESSES URINE TO GENERATE ELECTRICITY.

SYSTEM COMPONENTS

| | |
|---|---|
| 1. Frontend | The MFC is a processing component that can be integrated with a urinal or solids liquid interface. |
| 2.Urine/Feces Separation | No separation components, separation must occur upstream of the MFC. |
| 3. Liquid Processing | Organic compounds and pathogens in urine are digested by microbes in the MFC, generating electricity. Digestion enables movement of protons through a proton exchange membrane, and causes exchange of electrons between the electrodes. |
| 4. Solids Processing | Can process a small amount of solids at a low Total Suspended Solids concentration. |
| 5. Power System | System's primary function is generation of electricity from urine. Integrated systems solving multiple urinals may require power for pumps and valves. |



# MULTIPLE MFCS CAN BE INTEGRATED TO PROCESS LARGER VOLUMES AND PAIRED WITH ANY USER INTERFACE.

| | |
|---|---|
| Capacity | Scalable since cell size may vary and multiple cells can be integrated together. |
| Key Features | • System design is a small, cubicle cell.<br>• System produces electricity via breakdown of microbes and organic compounds in urine.<br>• System is scalable to treat large or small volumes of urine. |
| Current Status | Lab results have shown that 1mW can be generated from a 10mL-MFC. Field testing has shown that integrated groups of MFCs are robust and can process small volumes (1-2 users per week at a university) or large volumes (many users at a music festival) of urine effectively. |
| IP Status | Patent pending in the United States, Great Britain, China, and Japan, with additional EU designation pending. See US 2014/0057136 A1 for addtional detail. |
| Links | http://www.brl.ac.uk/researchthemes/bioenergyself-sustaining.aspx |

# OMNI-PROCESSOR TECHNOLOGY PORTFOLIO

# JANICKI OMNI-PROCESSOR TECHNOLOGY

## TURNING FECAL SLUDGE INTO ELECTRICITY

- Population served ~ 100k people *(evolving)*
- Kills all pathogens
- No harmful emissions
- Electricity produced: 300 kW (250 kW net)
- Potable water produced: 80,000 liter/day
- Also produced: steam, dry sterile ash

# DUKE OMNI-PROCESSOR TECHNOLOGY

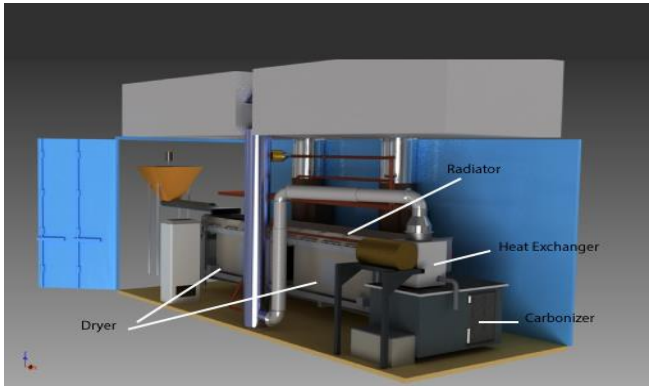
## SUPER CRITICAL WATER OXIDATION

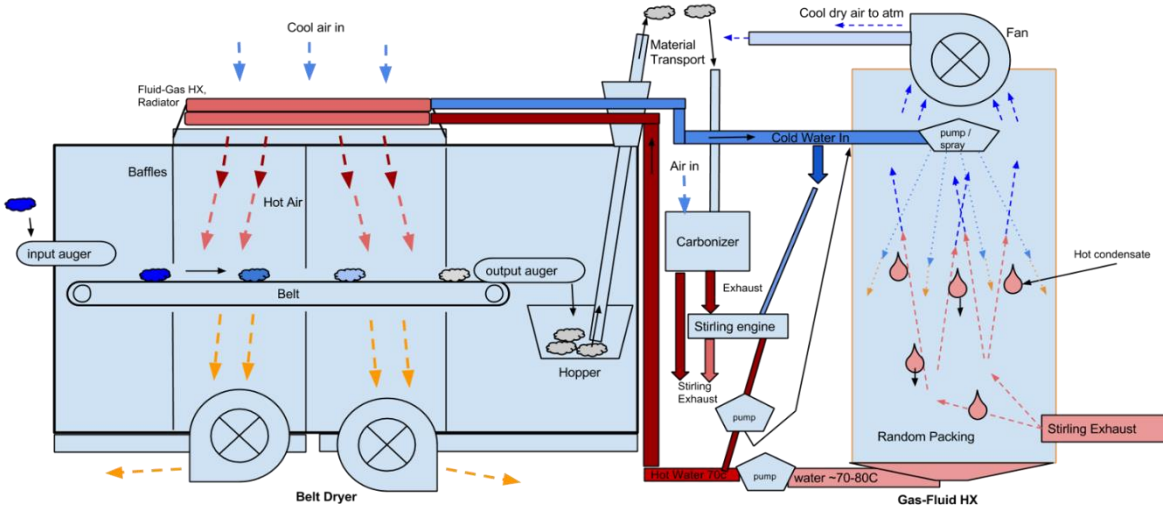
- Population served ~ 1k people *(evolving)*
- Kills all pathogens
- No harmful emissions
- Outputs clarified heated water and ash

# TIDE TECHNOCRATS OP TECHNOLOGY

## PYROLYSIS

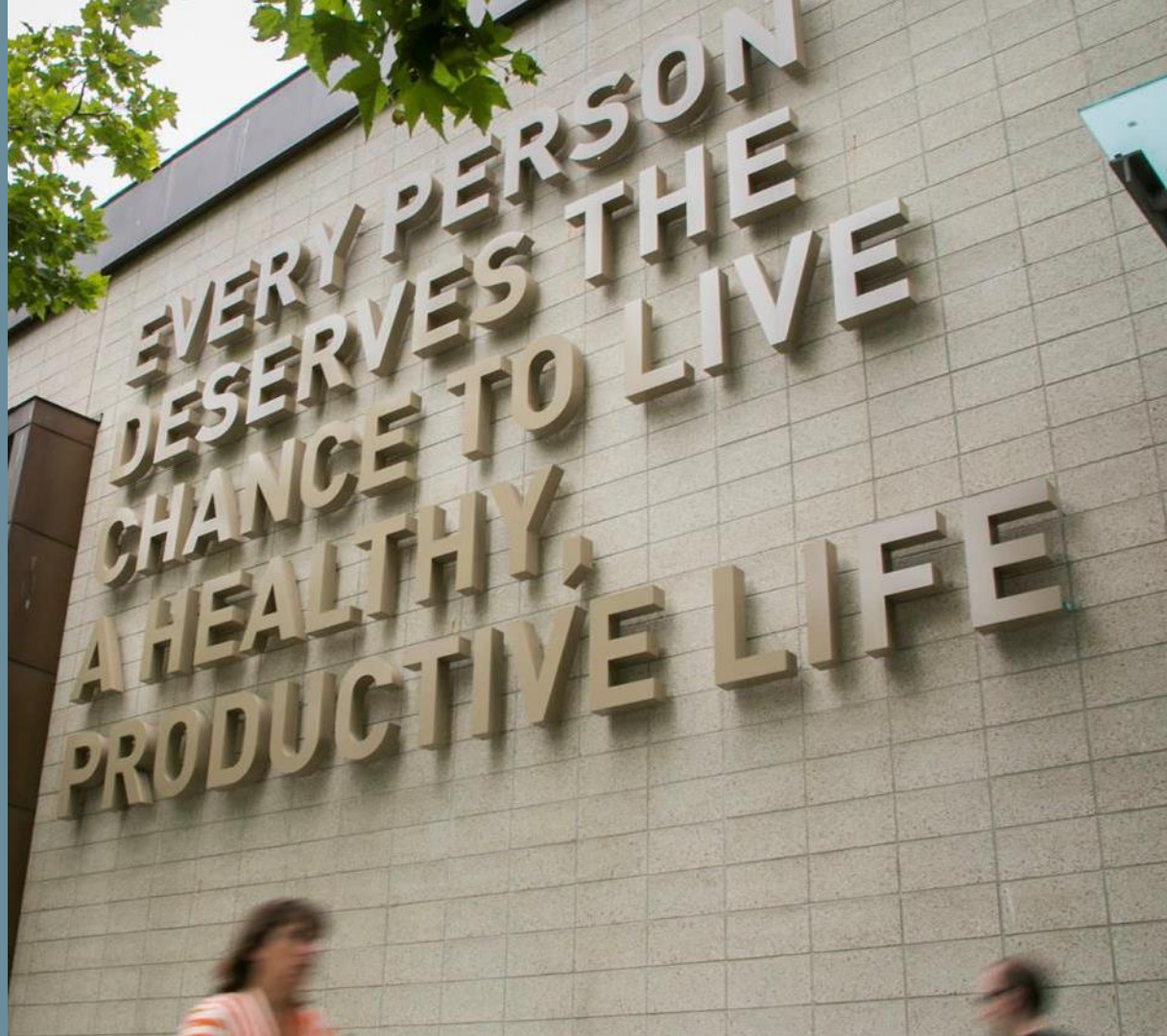
- Population served 15,000 – 30,000 people
- Kills all pathogens
- No harmful emissions
- Outputs Sterile Bio-Char



# THANK YOU!


EVERY PERSON
DESERVES THE
CHANCE TO LIVE
A HEALTHY,
PRODUCTIVE LIFE