RETHINKING WATER TREATMENT
by Ethan Jackson

WASTING WATER
Current wastewater treatment practices are inefficient. Modern designs require large amounts of energy to power mechanisms that natural processes already perform. Additionally, typical practices generally dump the treated water into the nearest waterway, offering no replenishment of resources [1]. As populations rise, water resources fall and climate change threatens the dependability of our water sources, it is tantamount to survival that urban infrastructure close its water cycle [2]. We must not let our wells run dry, and be forced to confront the true price of water.

Treatment must be self sustaining and produce as few unusable end-products as possible. Waste is a human invention; virtually every biological product serves a purpose for another life form. By harnessing these processes we can reduce energy requirements while purifying our wastewater to drinking standards.

A SOLUTION
The Vertical Farm has the potential to clarify municipal graywater (treated non-potable wastewater) to drinking standards by simply growing crops. It is also possible to use other mechanisms to power treatment processes by using the energy inherent in wastewater streams. For example, filter feeding organisms can benefit from consuming impurities in sewage effluent. Additionally, processes such as pyrolysis have the potential to extract viable fuel oil from sewage sludge to power the treatment.

A hypothetical design is proposed in which a portion of New York City's 1.4 *billion* gallons of daily municipal wastewater is treated to irrigate a Vertical Farm in Manhattan [3]. These processes require less total energy consumption when considering all energy needs for the total waste management process. The final product, distilled water, can be reinstated into the city's drinking water supply.

THE PROCESS
Separation of solids and liquids has long been viewed as an efficient approach to treatment. Processing begins with high speed centrifuges which are currently used as an integral step in NYC sludge dewatering [3,4]. Though centrifugation draws more energy than other dewatering processes, it greatly reduces human exposure to pathogens and odors, a significant concern in densely populated areas [5].

As shown in the flowchart below, collected sewage, or blackwater, is centrifuged into separate effluent and solids streams and treated independently. Effluent treatment begins with piping to Ward's Island for zebra mussel filtration.

Effluent Treatment
The zebra mussel (*Driessena Polymorpha*) is widely considered one of the most effective filter feeders on the planet. The one-quarter square inch shellfish has the ability to filter one quart of water per day, consuming particulates 0.7 microns to 0.75 millimeters in size [6]. This includes silts, clays, and large pathogens such as worm eggs and more notably Cryptosporidium and Giardia. These cysts are particularly dangerous organisms in human waste, and their removal defines a current EPA standard for disinfection [7]. Zebra mussels are so effective at filtering water that they have been credited with cleansing Lake Erie to the point of nearly exterminating the phytoplankton population [8].

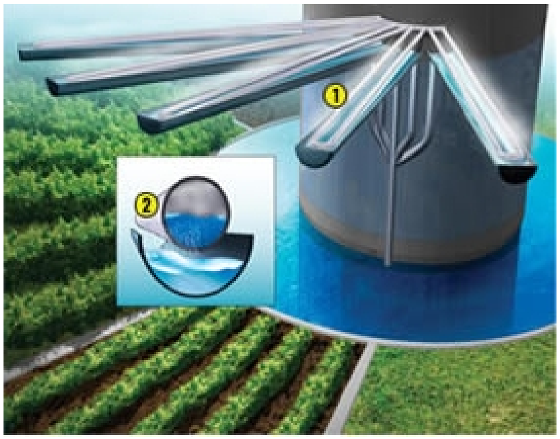

Source: University of Michigan

Source: EPA

First brought to the Great Lakes in the late 20th century, this fresh water creature has monopolized nearly every aquatic ecosystem it has reached [6]. Its invasive history demands careful containment measures. Ward's Island is an ideal location for zebra mussel filtration because it is already home to an NYC wastewater treatment facility, and is surrounded by marine water. This is useful because zebra mussels are intolerant of salt water environments brackish water defines the current population front in the Hudson River (which is notably clearer since their introduction) [9]. Feeder filtration on a marine island would add an additional degree of containment.

The current filtration design involves cascading waterfalls in which effluent flows down a series of walls coated with several thousand zebra mussels (see figure). Each wall empties to a tank, which drains to another wall. This not only ensures maximum effluent contact with the animal, it offers information towards the efficiency of this novel technology. A 10' x 6' wall with a single layer of mussels could filter over 8,000 gallons of effluent each day. This is a conservative estimate wehen considering the prolific nature of the animal. Ensuring a populated wall surface is more dependent on available nutrition than reproduction a single female lays approximately 100,000 eggs per year [10]. Therefore, the zebra mussel eggs must be neutralized.

Ultraviolet irradiation immediately following feeder filtration will remove not only the threat of zebra mussel infestation down stream, but also inactivate any pathogens too small for feeder filtration (bacteria and viruses). Ultraviolet light does not kill, but rather prevents the accurate reproduction of DNA [11]. Though UV irradiation is energy intensive, it replaces the larger energy demand of activated sludge treatment which is a common process typically drawing half of a treatment plant's energy [12]. This also displaces the need for effluent exposure to chlorine disinfection, eliminating the possibility of hazardous disinfection by-products.



Source: Verticalfarm.com

A two-phase sand and activated carbon filtration system will follow sterilization to remove any inactivated particulates not consumed, such as mussel eggs. This ensures a particle-free irrigation supply to the Vertical Farm pipes and in turn the crops, the final treatment step to drinking water.

As the graywater irrigates the farm, photosynthesis naturally produces water vapor by evapotranspiration. Pipes flowing with chilled brine will condense atmospheric water vapor on the outer surface and collect underneath in a drainage basin. Following water quality testing, the water is reintroduced into the municipal water supply.

Solids Treatment

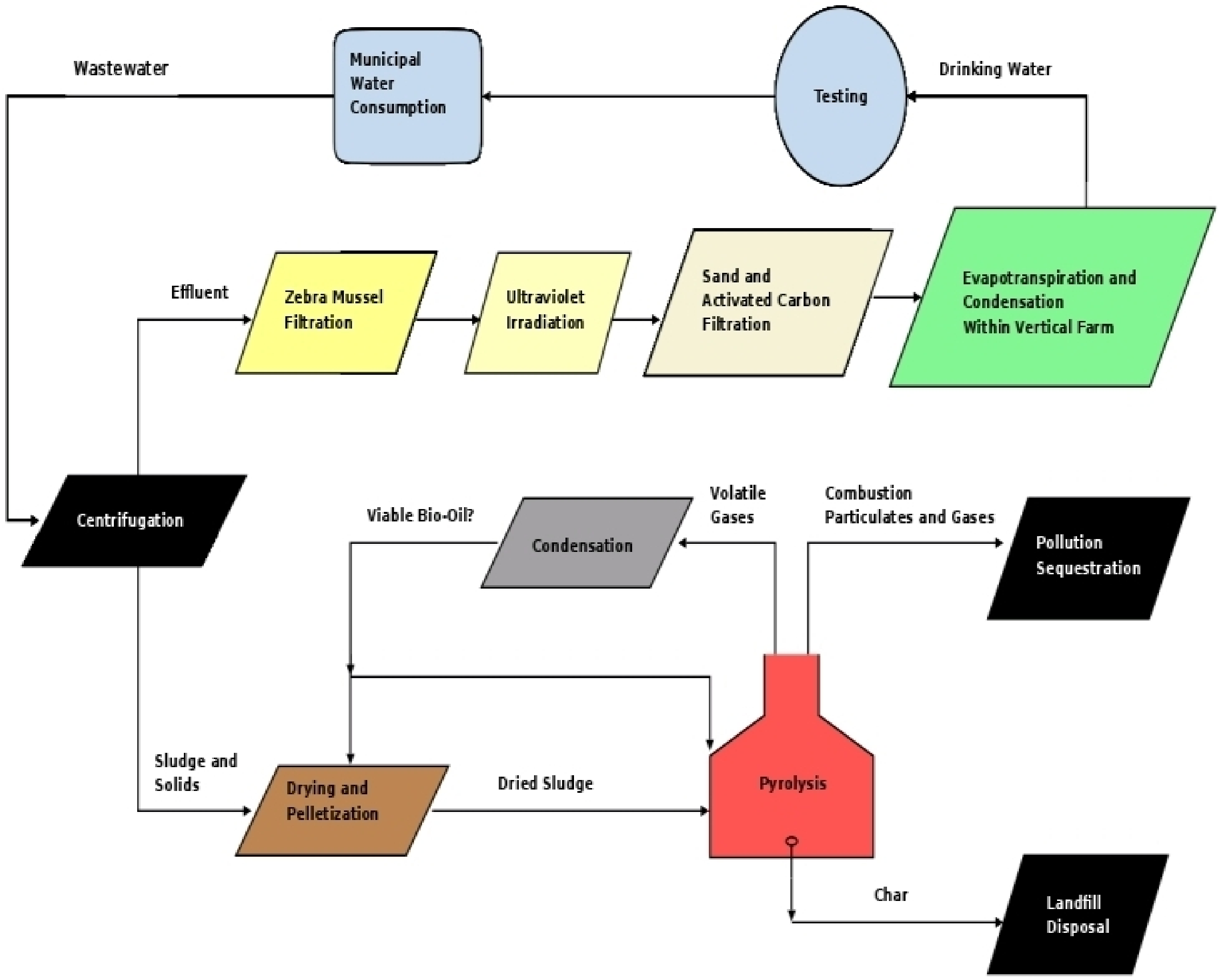
Though the sludge end-product is planned for landfilling, the energy demands for processing are significantly reduced. While a typical sludge treatment process dries sludge to a 'cake' for landfilling, New York City currently processes much of its sludge to EPA accepted fertilizer pellets, which are shipped across the country to Texas, Florida, and other agricultural states [3]. Though most of the waste is reused, processing and shipping the pellets requires copious amounts of fossil fuel, thus hastening the consequences of climate change. New York also utilizes methane digestion which is often energy sustaining, but requires large retention times, enormous processing tanks and produces noxious odors that require careful monitoring [3,4]. Pyrolysis, on the other hand, is a relatively fast process and has potential to power itself as well [13].

Source: Dynamotive.com

Following centrifugation, sludge is dried and pelletized to increase treatment efficiency. The pellets are then exposed to a pyrolysis chamber. Volatile gases from materials are released by exposing the pellets to high pressure and temperature (~800°F) in an anaerobic environment, allowing them to escape the solids without combusting. The end products, combustible gases and benign char, can be reused. The gases can be condensed into a diesel-like fuel, commonly referred to as bio-oil, which has potential to power the process [13]. There are also potential applications for the char such as building materials and soil amendment, but currently the most viable solution is landfilling. Though landfilling still requires transportation, daily waste disposal requires less energy than trucking across the country and far less than trucking a dewatered sludge cake to the same landfill.

Pyrolysis also offers potential for energy recovery from crop refuse and local restaurant food-waste. Any excess power generated could be put into the grid and waste heat could serve as climate control for the farm in winter months. If the sludge process can indeed power itself, a carbon neutral system will replace the fossil fuel demand. Any carbon sequestration measures taken could lead to a carbon *negative* power supply.

Proposed NYC Wastewater Recovery System



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REFERENCES

[1] Crites, R. W., Reeds, S. C., Middlebrooks, E.J. (2005). *Natural Wastewater Treatment Systems.* CRC Press, Boca Raton, FL.

[2] Green, P., Lammers, R. B., Salisbury, J., Vorosmarty, C. J. (2007). Global water resources: vulnerability from climate change and population growth. *Science,* 289, 5477, 284-288.

[3] New York City Department of Environmental Protection. *New York City's Wastewater Treatment System: Cleaning the Water We Use, Protecting the Environment We Live in.* New York City Department of Environmental Protection, New York.

[4] Davis, M. L., Masten, S. J. (2004). *Principles of Environmental Engineering and Science.* McGraw Hill, New York, New York.

[5] United States Environmental Protection Agency. Biosolids technology fact sheet: centrifuge thickening and dewatering. *Fact Sheet EPA 832-F-00-053,* United States Environmental Protection Agency, Office of Water, Washington, D. C.

[6] Beckett, D. C. Environmental effects of zebra mussel infestations Zebra Mussel Research Technical Note ZMR-1-14. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

[7] United States Environmental Protection Agency. Guidance for people with severely weakened immune systems. *EPA 816-F-99-005,* United States Environmental Protection Agency, Washington, D. C.

[8] Benson, A. J., and Raikow, D. (2007). *Dreissena polymorpha*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL.

[9] Findlay, S. E. G., Fischer, D., Pace, M.L. (1998). *Effects of an Invasive Bivalve on the Zooplankton Community of the Hudson Rive*r. Institute of Ecosystem Studies, Millbrook, New York.

[10] Tammi, K. A. (1999). Zebra mussel: an unwelcome visitor. *Fact Sheet P1326,* Rhode Island Sea Grant, Narragansett, Rhode Island.

[11] United States Environmental Protection Agency (1999). Wastewater technology fact sheet: ultraviolet disinfection. *Fact Sheet EPA 832-F-99-064,* United States Environmental Protection Agency, Washington, D. C.

[12] Ferguson, L., Keenan. P. (1998). On-line process monitoring and electric submetering at six municipal wastewater treatment plants. *Report 98-12*, New York State Energy Research and Development Authority, Albany, New York.

[13] Shen, L., Zhang, D. K., (2002). An experimental study of oil recovery from sewage sludge by low-temperature pyrolysis in a fluidised-bed, *Fuel,* 82, pp. 465-472.