

# **Existence Hypothesis: Resource Recovery Plant**

To Extract Maximum Energy From Municipal Wastewater

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## Abstract

In the U.S. there are 21,600 Publicly Owned Treatment Works (POTWs), treating 8.2 trillion gallons of wastewater (WW) from 226 million people; and therein, a potential to produce 43.5 billion kWh of electricity, annually. Instead, to treat that same volume of WW, those POTWs are consuming 18.6 billion kWh of electricity, an unintended consequence of incorporating the same basic designs, as those of the past 100 years. The Existence is based on the fact that current WW treatment and AD (anaerobic digester) technologies do not isolate, nor do they provide for the treatment of isolated Energy Latent Organics (ELOs). This shortcoming has resulted in a limited energy recovery of 729 kWh/MG (million gallons), out of a potential 5,260 kWh/MG. The Hypothesis is based on the assertion that the ELOs can be concentrated and quantitatively recovered, by centrifugation; prior to flowing into an AD containing four independent, sequential stages; with stage specific enzymes, controlled environments, and the ability to achieve complete conversion within one hour of retention time; thus, producing the maximum output of methane to energy. This Existence Hypothesis maintains that the Resource Recovery Plant will become the fundamental technology that will ultimately transform all energy consuming Wastewater Treatment Plants into net-energy producing Resource Recovery Plants.

## Overview

"Wastewater is a renewable source of energy and nutrients. In the twentieth century, we aimed to get rid of these. In the twenty-first century, we must recover the energy, nutrients and potable water. We are still using the same [wastewater treatment plant] designs of 100 years ago. This has had a negative impact on many treatment plants, as the unintended consequences of old designs have impacted on current designs, and will have an impact on future designs. The new basis of design and refit for all wastewater treatment plants must be the aim of not only making the plants more efficient, but also extracting and reusing the energy nutrients and potable water found in wastewater," says George Tchobanoglous. Professor Emeritus, Department of Civil and Environmental Engineering, University of California, Davis. Quote from Engineering News Online, available at: <http://www.engineeringnews.co.za/article/recovery-reuse-to-reshape-wastewater-treatment-plant-designs-2012-11-02>

## Existence

- 43.5 billion kWh<sup>1,2,3,4</sup> of electricity is available, each year, from the Energy Latent Organics in municipal wastewater, at 21,600 U.S. Publicly Owned Treatment Works<sup>1</sup> (POTWs). An energy potential that is more than 1.77 times the 2011 output of the mighty Grand Coulee Dam (24.6 billion kWh<sup>5</sup>).
- Each year, 18.6 billion kWh<sup>1,2,3,4</sup> of electricity is required to treat 8.2 trillion gallons<sup>1</sup> of municipal wastewater, at the POTWs that serve 226 million people<sup>1</sup>.
- Each year, 11.2 billion kWh<sup>1,2,3,4</sup> of electricity is required to produce an untenable wastewater byproduct of 7.24 million tons<sup>1,6</sup> of sewage sludge, at those same POTWs.
- 8.2 trillion gallons of municipal wastewater contain 7.0 million tons<sup>1</sup> of Energy Latent Organics.
- One million gallons (MG) of municipal wastewater contains an average 1,700 pounds<sup>7</sup> of Energy Latent Organics, measured as biological oxygen demand (BOD), with an energy potential equal to 5,260 kWh<sup>2</sup> of electricity.
- In an ongoing attempt to reduce costs and extract energy from municipal wastewater, recent advances in Anaerobic Digestion (AD) have increased energy recoveries by 38.3%; from 450 kWh/MG<sup>8</sup> in 2003 to 729 kWh/MG<sup>9</sup> in 2011. A slight 5.3% increase in available energy recovery: The result of 8 years of rigorous effort.

- Current wastewater treatment and AD technologies do not isolate, nor do they provide for the treatment of isolated Energy Latent Organics (ELOs); hence, the inherent, limited recovery of only 13.9% of the available 5,260 kWh/MG.

## Hypothesis

- Subsequent to preliminary treatment of the wastewater influent—screening, shredding, separating, and washing and dewatering of the solids/grit debris—if there are additional micro screens in the system that are designed to remove grit larger than 300 micron; then, that inert grit can be recovered, washed, dewatered, and added to the already present solids/grit stockpile, for immediate disposal. In addition, the wash water can be recovered, by recycling back to the influent stream.
- After micro screening, if the influent stream flows directly into a volume equalization tank; then, that tank can serve as a reservoir, to compensate for the irregular 24-hour influent flow.
- If the stream flowing from the equalization tank is subjected to centrifugation, with a unique configuration of filters (30-micron, to remove the 30 to 300 micron grit; and 0.2-micron, to remove the 0.2 to 30 micron ELOs); then, the centrifugal and Coriolis forces, generated therein, can efficiently remove the water; and simultaneously concentrate the grit and ELOs.
- If, during centrifugation, 97.5% of the processed influent volume, with an average BOD concentration of 200 mg/L<sup>7</sup>, flows through the 30-micron filters; then, the 30 to 300 micron grit can be concentrated and quantitatively recovered in the remaining 2.5% volume, with an average BOD of 5.0 mg/L. The grit can then be washed, dewatered, and added to the solids/grit stockpile, for disposal. In addition, the wash water, containing residual BOD, can be recycled back to the influent stream.
- If the filtered ELO water is subjected to further centrifugation, wherein, 95% of that volume flows through the 0.2-micron filters, with an average BOD of 10 mg/L (well within EPA's 30 mg/L<sup>10</sup> effluent limit), and out of the centrifuge; then, that water can flow directly into a trickling filter to efficiently remove ammonia, and any remaining organics. Then, prior to release into the environment, the effluent can be disinfected, efficiently, by U.V. radiation.
- If the recovered ELOs can be concentrated in the 5% retentate volume (with an average BOD of 3,800 mg/L); then, that ELO enriched fluid can flow directly into a unique Anaerobic Digester (AD), designed to efficiently extract maximum energy.
- If the design of the AD has four independent, sequential stages: Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis; then, each stand-alone stage can be self-contained, have stage specific enzymes, have a controlled environment (pH, temperature, and flow), and be capable of complete conversion; within one hour of retention time.
- If the Hydrolysis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the complex organic polymers (carbohydrates, fats, and proteins) into solubilized monomers.
- If the Acidogenesis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the solubilized monomers (sugars, fatty acids, and amino acids) into intermediate products.
- If the Acetogenesis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the intermediate products (carbonic acids, alcohols, hydrogen, carbon dioxide, and ammonia) into simple molecules.
- If the Methanogenesis Stage contains specific, immobilized enzymes; then those enzymes can efficiently convert the simple molecules (hydrogen, acetic acid, and carbon dioxide) into biogas:  $\geq 65\%$  methane and  $\leq 35\%$  carbon dioxide.
- If the methane is recovered, refined, and used as a fuel to run a gas engine; then, two useable products can be generated. The first will be electrical power. The second will be thermal; which can be used to heat the AD and the facilities. Thus, if the RRP has the ability to produce onsite electricity and heat, independent of the grid; then, the facility can meet EPA's requirement for a Combined Heat and Power (CHP) Partnership<sup>11</sup>.

- If 5,000 kWh of electricity is produced, from each million gallons of municipal wastewater processed (MGP), and 850 kWh (conservative estimate) are consumed internally; then, there will be an excess 4,150 kWh of electricity that can be sold to the local grid.
- If all the ELOs that flow into the AD are completely digested; then, in addition to biogas, there can be a useable digestate byproduct, which can be dewatered and sold as fertilizer; with the recovered water recycled back to the influent stream. Additionally, because the dewatered digestate will be essentially pathogen-free and environment friendly, the fertilizer can be designated Class A<sup>12</sup> by EPA standards.

## Resource Recovery Plant

- The innovative Resource Recovery Plant could very well become the fundamental technology that will transform those twentieth century, energy consuming, municipal wastewater treatment plants (WWTPs); into twenty-first century, net-energy producing, Resource Recovery Plants (RRPs).
- The RRP will have the ability to produce a net energy advantage of 6,400 kWh/MGP: The summation of avoiding the consumption of 2,250 kWh<sup>3,4</sup> of electricity (conservative average, per MGP); plus, selling 4,150 kWh of excess electricity, per MGP, to local grids. Thus, the net energy advantage, from all 21,600 POTWs, will provide an extra, eco-friendly benefit. Reduce the unrelenting strain on the ageing, electricity grid infrastructure by 52.5 billion kWh, annually.
- In addition to occupying a footprint less than 20% of that required for current WWTPs, and a similar reduction in capital and operation and maintenance costs, the RRP will be 24/7 volume adjustable, scalable (up or down), and indoor capable; avoid sedimentation tanks, aeration tanks, aeration/evaporation ponds, and lagoons; and, most importantly, avoid sewage sludge. By design, the RRP will mitigate those chronic environmental, waste disposal, and sustainability problems; currently associated with the annual production of 7.24 million tons of sewage sludge, at an ongoing cost of 11.2 billion kWh of electricity.
- In the U.S., in predominantly small cities and towns, there are more than 8,000 wastewater treatment ponds<sup>12</sup>, occupying a land mass equal to 48,000 acres<sup>13</sup> (75 square miles). Because each pond is exposed to the atmosphere, evaporation will occur 24/7. Also by design, the RRP will deliver an added bonus: The avoidance of ponds; thereby, realizing an annual gain of more than 114 billion gallons<sup>12</sup> of water that would have been lost, due to evaporation.

“In the popular myth, science is neat and tidy: We know what we know. But real science is replete with controversy, doubts, and debates about what we really know.” (Daniel J. Levitin)

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Beyond delving into the technologies of wastewater treatment, during the past nine years, Mel has more than 30 years of research, development, application, and administrative experience in three disparate disciplines: centrifugation, filters/filtration, and protein/enzyme immobilization. His two prior patents on filtration, separation, and quantitative recovery of antigen and antibody molecules; subsequently led to the developmental concept of the net-energy producing Resource Recovery Plant. For this unique process, he has one patent; one patent pending, with follow-on patents anticipated. In addition to having performed basic research in immunology, at the Oregon Regional Primate Research Center, Beaverton, Oregon; Mel holds a Pre-Med A.A. degree from Bismarck Junior College, Bismarck, North Dakota.