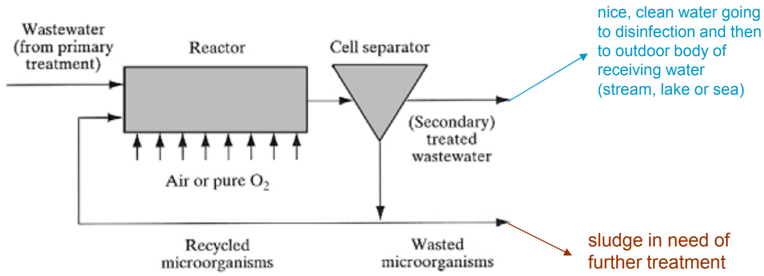
Anaerobic Digestion of Wastewater Sludge
(Nazaroff & Alvarez-Cohen, Section 6.E.3)



The goal is to reduce the amount of sludge that needs to be disposed.

The most widely employed method for sludge treatment is anaerobic digestion.

In this process, a large fraction of the organic matter (cells) is broken down into carbon dioxide (CO_2) and methane (CH_4), and this is accomplished in the absence of oxygen. About half of the amount is then converted into gases, while the remainder is dried and becomes a residual soil-like material.

What the equipment looks like

The tank is capped
- to prevent oxygen from coming in,
- to prevent odors from escaping, and
- to capture the methane produced.

This methane, a fuel, can be used to meet some of the energy requirements of the wastewater treatment facility (co-generation).

What the sludge looks like after anaerobic digestion and subsequent drying.

It is rich in nitrates and performs well as a fertilizer.

(Photos from http://www.madep-sa.com/english/wwtp.html)

How the system works

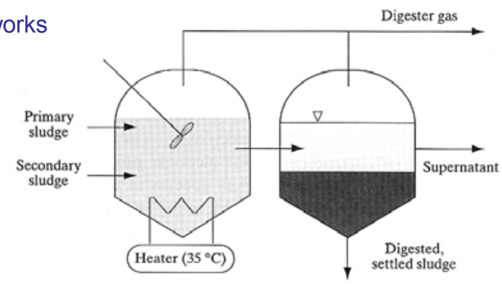


Figure 6.E.7 Schematic of a two-stage, high-rate anaerobic sludge digester (Metcalf & Eddy, 1991).

(Nazaroff & Alvarez-Cohen, Figure 6.E.7)
(Originally from Metcalf & Eddy, 1991)

The treatment of wastewater sludge, from both primary and secondary treatment steps, consists of two main phases.

- In the 1st step, all incoming flows of sludge are combined, and the mixture is heated to a mild temperature (about body temperature) to accelerate biological conversion. The residence time here ranges from 10 to 20 days.
- In the 2nd tank, the mixture is allowed to undergo further digestion. There is no longer active mixing in order to promote separation, and there is no need of heating as the process generates its own heat.
- In further processes (not shown on the diagram) the settled sludge is dewatered and thickened. The goal is to separate as much water as possible to decrease the volume of material. Finally, a phase known as *sludge stabilization* reduces the level of pathogens in the residual solids, eliminates offensive odors, and reduces the potential for putrefaction.

The outcome

Anaerobic digestion of municipal wastewater sludge has been widely practiced since the early 1900s and is the most widely used sludge treatment method.

Overall, the process converts about 40% to 60% of the organic solids to methane (CH_4) and carbon dioxide (CO_2). The chemical composition of the gas is 60-65% methane, 30-35% carbon dioxide, plus small quantities of H_2, N_2, H_2S and H_2O. Of these, methane is the most valuable because it is a hydrocarbon fuel (giving 36.5 MJ/m^3 in combustion).

The residual organic matter is chemically stable, nearly odorless, and contains significantly reduced levels of pathogens.

(Poppendieck, 2008)

End step: Dewatering

The purpose of thickening the sludge is to reduce its volume, which can be several fold.

Typical sludge comes at 1% solid fraction. Thickening it to 2% halves the volume, to 10% reduces the volume by a factor 10. [1% solid fraction ≈ 10,000 mg/L]

The various existing methods are:

- Gravity thickening (can achieve up to 10% solid fraction)
- Gravity belt thickening (can achieve up to 6% solid fraction)
  (uses a polymer to coagulate the solids, from which follows a rejection of water)
- Dissolved air flotation (can achieve up to 6% solid fraction)
- Thickening centrifuge (can achieve up to 8% solid fraction).

An example of gravity belt thickener and its product

www.cityofbatavia.net/

www.rendertech.co.nz/wastewater_treatment.htm

Controlling Municipal Energy Costs

(based on articles by Lyn Corum and Lori Lovely, *Distributed Energy*, Nov-Dec 2006, pages 16-26)

Fact:

Treating and pumping water and wastewater ranks near top of energy needs for municipalities across the United States.

Example:

According to the California Energy Commission, 56% of energy usage by municipalities is spent on water and wastewater treatment facilities.

Consequence:

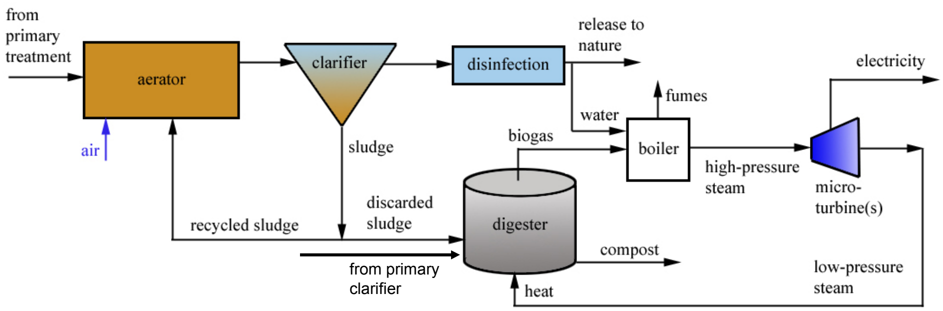
Energy efficiency in water and wastewater facilities translates into substantial savings benefiting agencies and taxpayers.

Energy source:

Anaerobic digestion of secondary-treatment sludge generates plentiful biogas.

In California, out of 242 sewage treatment plants,
already 10 generate 38 MW from biogas, and
another 12 burn biogas to produce hot water to heat digesters.

What about the 220 others?



Biogas emanating from digester = methane (CH_4), hydrogen sulfite (H_2S)
and some siloxane (feedstock for personal care products)

Electricity is used to power pumps and the compressor to inject air in the aerator.

Variations:

1. Combust gas directly in microturbines
   + no need for boiler
   – corrosion of turbine blades by sulfur (from H_2S)
   – deposition of SiO_2 (from siloxane)

   → need to scrub the biogas before passing it through the turbines.

2. Pass biogas in fuel cells (molten carbonate type)
   → more electricity, less heat, but more costly to install.

3. Simply burn the biogas and use the heat (no electricity co-generation)

4. Complement energy source with solar.

Albert Lea facility in Minnesota:

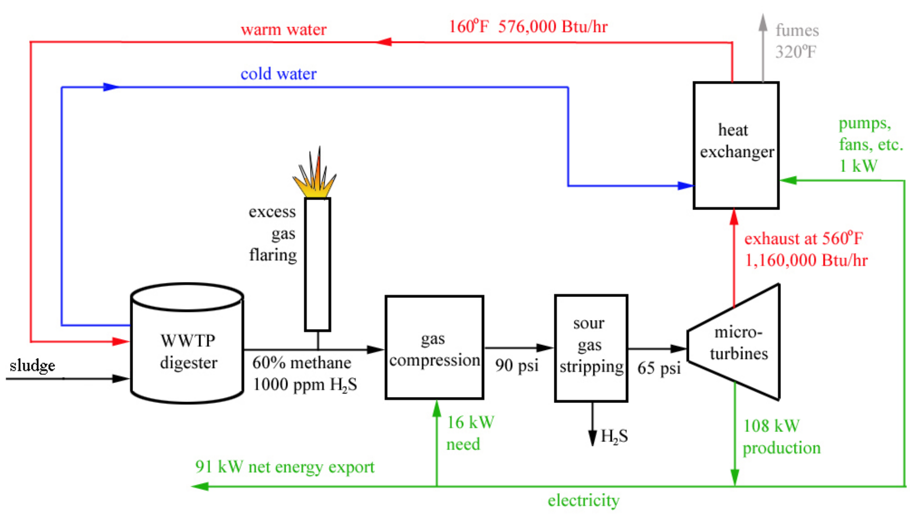
12 million gallons/day of sewage

4.5 million gallons/day sludge

75,000 ft^3/day of biogas

Biogas is 60% CH_4 and 10^3 ppm H_2S
plus traces of siloxane.

4 Capstone microturbines, 30 kW each
producing 2,500 kWh per day at peak production
plus 28,000 Btu/day of heat.



Process flow diagram
Albert Lea Wastewater Treatment Plant, MN

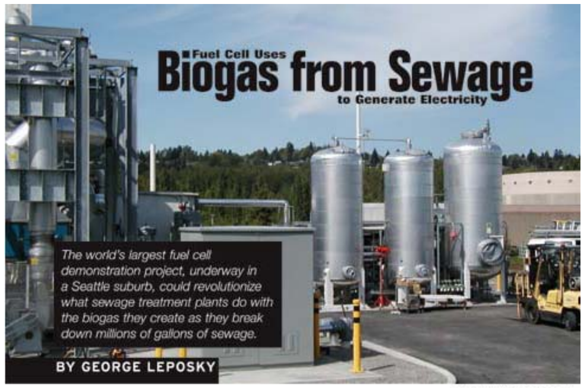
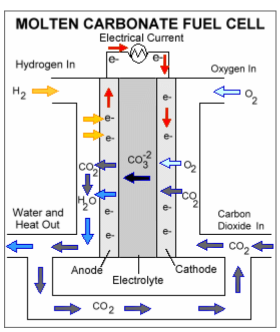


PHOTO: KING COUNTY

The fuel cell, located at the South Treatment Plant in Renton, WA, can consume about 154,000 ft^3 of biogas a day to produce up to 1 MW of electricity. That's enough to power 1,000 households, but it is being used instead to help operate the plant.

The fuel cell's electric output will save the Wastewater Treatment Division (WTD) of King County's Department of Natural Resources and Parks about $400,000 a year—money that otherwise would be spent to buy electricity from the local utility.

(George Leposky – *Distributed Energy*, 31 October 2005)
(http://www.distributedenergy.com/DE/Articles/1856.aspx)



(http://en.wikipedia.org/wiki/Molten-carbonate_fuel_cell)

Molten-carbonate fuel cells (**MCFCs**) are high-temperature fuel cells, that operate at temperatures of 600ºC and above. They have the highest efficiencies of any type of fuel cell, including solid-oxide fuel cells, proton-exchange membrane fuel cells, and phosphoric-acid fuel cells. They are not subject to the high-temperature material issues that affect solid-oxide technology.
(Excerpted from Wikipedia)

Performance of fuel cell at King County wastewater treatment plant:

- Continuous operation since 2004

- Generating 1 MW (90% of the time) and can easily be upgraded to generate 1.5 MW

- Efficiency in generating electricity: 43% to 47%

- With heat recovery, efficiency increases to 65%.

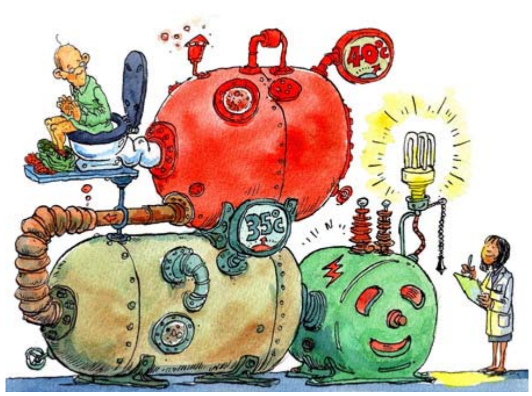
Initial cost: $23.9 million

For update, see:
http://your.kingcounty.gov/dnrp/library/wastewater/energy/FuelCell/0904FuelCellReport.pdf

Other places where fuel cells are used in wastewater treatment facilities:

Los Angeles (downtown & Palmdale), Santa Barbara (El Estero), New York (Yonkers)

The bottom line…



Cartoon by David Simonds
(http://www.greenm3.com/gdcblog/2010/1/4/sewage-treatment-plants-using-methane-for-fuel-cell-power-ge.html)