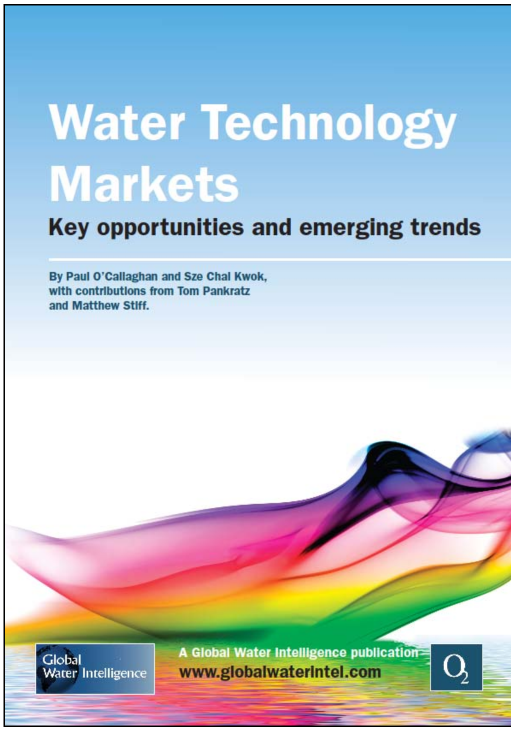


Water & Energy

Water Innovations Alliance

Paul O'Callaghan
O_2 Environmental
paul.ocallaghan@o2env.com
+ 1 604 676 3581

.com

Our Current Water System

1. Our current water system is inefficient and energy intensive
2. Due to mounting global pressures we can no longer afford an inefficient and energy intensive system
3. This is driving radical change and creating opportunities for technology development.

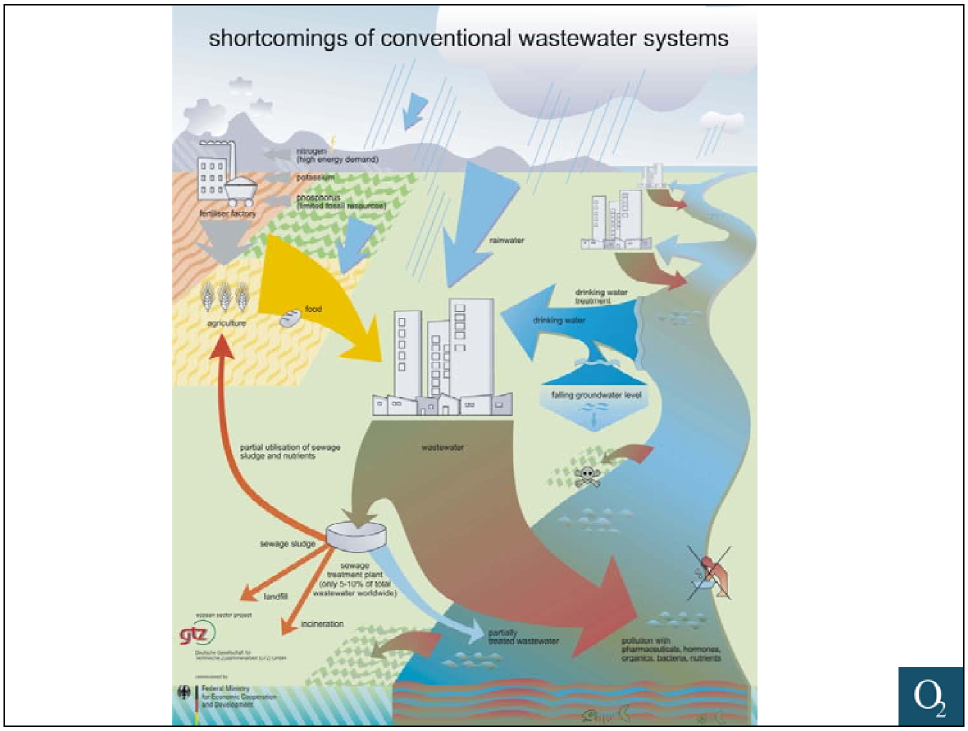
info@o2env.com

We began work on this publication '**Water Technology Markets –** ***Key Opportunities and Emerging Trends*'**, by asking a few key questions about our current water system and the picture which emerged could be summarized in three key points:

1. Our current water system is very inefficient and wasteful.

2. Due to mounting global pressures we can no longer afford an inefficient and wasteful system
3. This is driving real changes in how we manage water and creating opportunities for technology development.

Let's look at where we are, how we got here, and where we are going.



Current Model:
We produce one type of water, potable water, we use it have '**use once'** approach to water, currently, which would be the exact opposite of a cradle to cradle approach.
We take fresh water filter it, chlorinate it, distribute it, lose anywhere from 30%-60% in that process due to leaking pipes, **we use it once**, we add faeces, urine, food waste, pharmaceutical and personal care products, transport it all to a centralized treatment plant where we try and take everything out again, take out the nutrients, take out the organics, produce a treated water which we don't re-use but discharge into our rivers & oceans, and it turns out this is very energy intensive.

About half of the energy bill of any Municipality is associated with providing water services. Half of that is associated with moving water from one place to another, distribution, and the other half is taken up with water and wastewater treatment. In fact energy represents the single largest controllable cost of providing water services.

Energy footprint of Water

- In the Unites States Water services represents between **1% - 5% of total national energy use**
- 2-3% of total global energy consumption is utilised in the pumping and treatment of water for industrial and residential use.
- **30%-60% of a city's energy bill is associated with the provision of water services,**
- U.S. **water-related energy use** is equivalent to **13% of the nation's electricity** consumption.
- The **carbon footprint** currently associated with moving, treating and heating water in the U.S. **represents 5% of all U.S. carbon emissions**

info@o2env.com

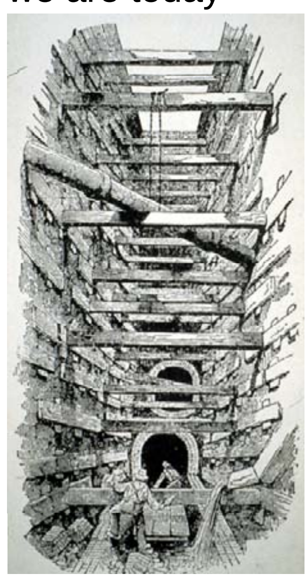
Source – The Carbon Footprint of Water, by Bevan Griffiths-Sattenspiel and Wendy Wilson, May 2009

How we arrived at where we are today

- 1850 – the Water Closet and the Sewer adopted.
- 1914 – the Activated Sludge Wastewater Treatment Process invented

At this time there were less than 2 Billion people in the world mostly rural

- Today: 6 Billion people, mostly urban
- Future: Population and urbanisation are set to increase.



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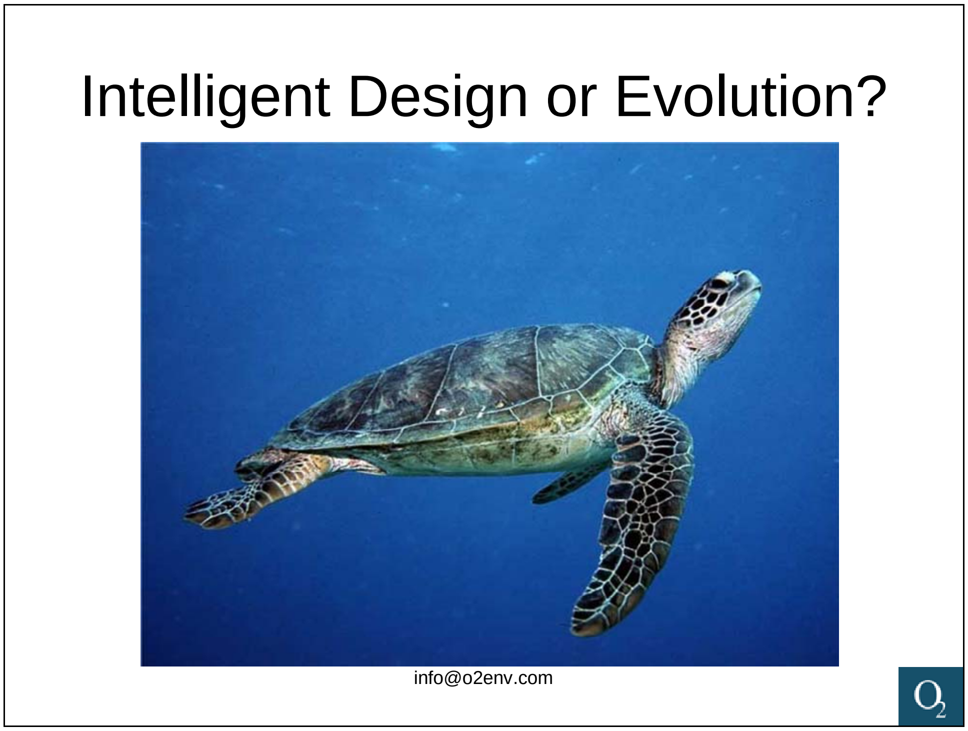
Now this system wasn't designed with efficiency in mind. In fact it wasn't really designed at all. It just happened over time. Sewers were constructed in the 1850's to take wastes 'seaward' that's where the word sewer comes from. This was driven by a requirement to improve Public Health.

Then, due to environmental concerns, we started to build large treatment plants at the end of these large pipes, and that's how we got to where we are today. With an inefficient system, that is very heavy on energy.



Intelligent Design or Evolution?

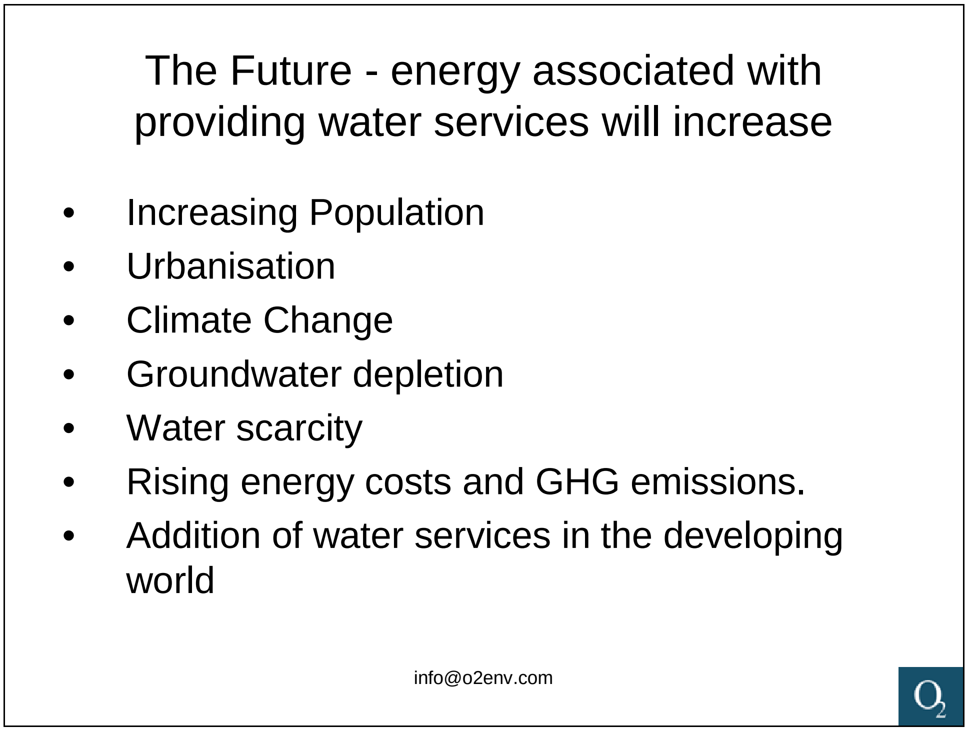
Our water system is an example of something which evolved. It was not designed with efficiency in mind, in fact it would be a stretch to say that it was designed at all. This is evolution, not intelligent design.

Let me give you an example from the world of evolution to help illustrate this point. Do you know that Green Turtles which feed off of the Coast of Brazil migrate 2,000km to an island in the middle of the Atlantic, called Ascension Island, to lay their eggs? The reason they do this is that when they started to do this tens of millions of years ago, the Atlantic was much smaller and Ascension island was much closer to the coast of Brazil. Gradually, at a rate of cm per year, the land masses moved further apart, and every year the turtles made a slightly longer journey and over millennia they had time to adapt to this journey.

Now our water system has evolved over a much shorter time period, 150 years, however we have seen more change in that 150 year period than in the past 10,000 years. And in the next 50 years, we are likely to see even more change.

The question is, like the Green Turtle, are we going to try and continue swimming in the same direction, or stand back, evaluate the system and re-design it if necessary.   I think the answer is, we have to re-design it.

A combination of different pressures are coming together which are bringing us closer to a tipping point and forcing us to re-think how we manage water.

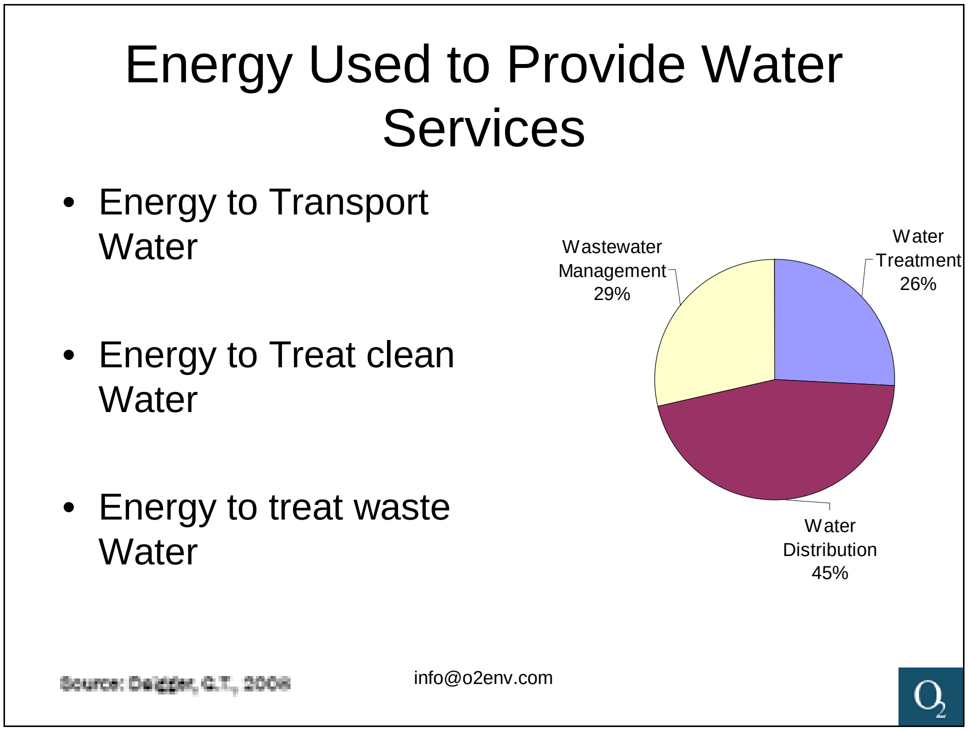


The reasons why a change is underway are:
Increasing Population, Climate Change, Depletion of groundwater resources,Water scarcity, Rising energy costs and a drive to reduce GHG emissions. Urbanisation – Over 50% of the planet now lives in Cities. Resource depletion – more and more people competing for less and less resources. Ageing infrastructure in the developed world and a requirement for new infrastructure in the developing world.

Urbanisation and water scarcity will make water service provision more energy intensive

For the first time in human history the population of the planet is now more urban than rural and this trend is set to continue. As cities expand and grow, it will be necessary to look at water sources in more distant catchments, which will increase water transportation costs.

In water-scarce regions, desalination is increasingly being used to meet water needs. The use of desalination to produce potable water is more energy intensive than conventional means of producing potable water from surface and groundwater. Reverse Osmosis desalination consumes in the region of 4-5 kWh per m^3 at a large modern desalination facility (Danfoss, 2006). With the use of energy recovery devices this can be brought down to 3.73kWh/m^3 (Geisler, P. 2001). Smaller scale desalination facilities typically have higher energy consumptions 9-12 kWh/m^3.

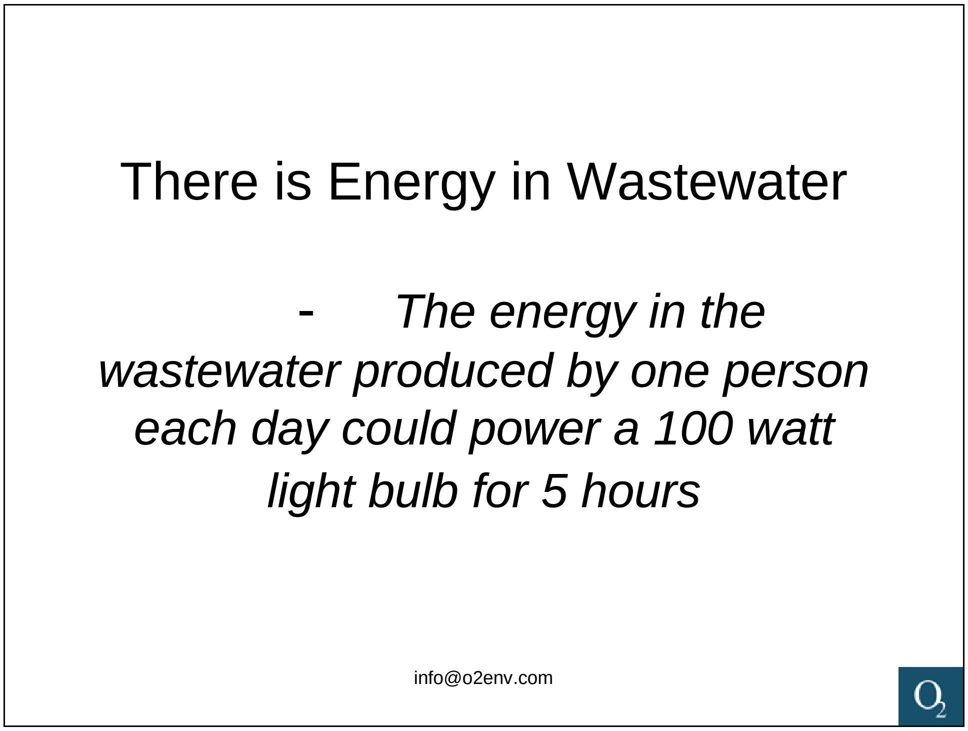


The energy we use to provide water services divides up into three areas:

1. Energy to transport water,
2. Energy to treat drinking water and
3. Energy to treat wastewater

There are opportunities in each of these areas to reduce the amount of energy embedded in providing these services.

Nowhere perhaps is this more apparent than in the area of wastewater treatment.
There is an opportunity here to make this area a net source of renewable energy.



ENERGY RECOVERY

I would like to talk now about an area where there is huge opportunity for change and this is energy generation from wastewater. ……

Now the current prevailing technology for secondary wastewater treatment is the activated sludge process. And its been with us just about 100 years.

There are two problems with the activated sludge process.

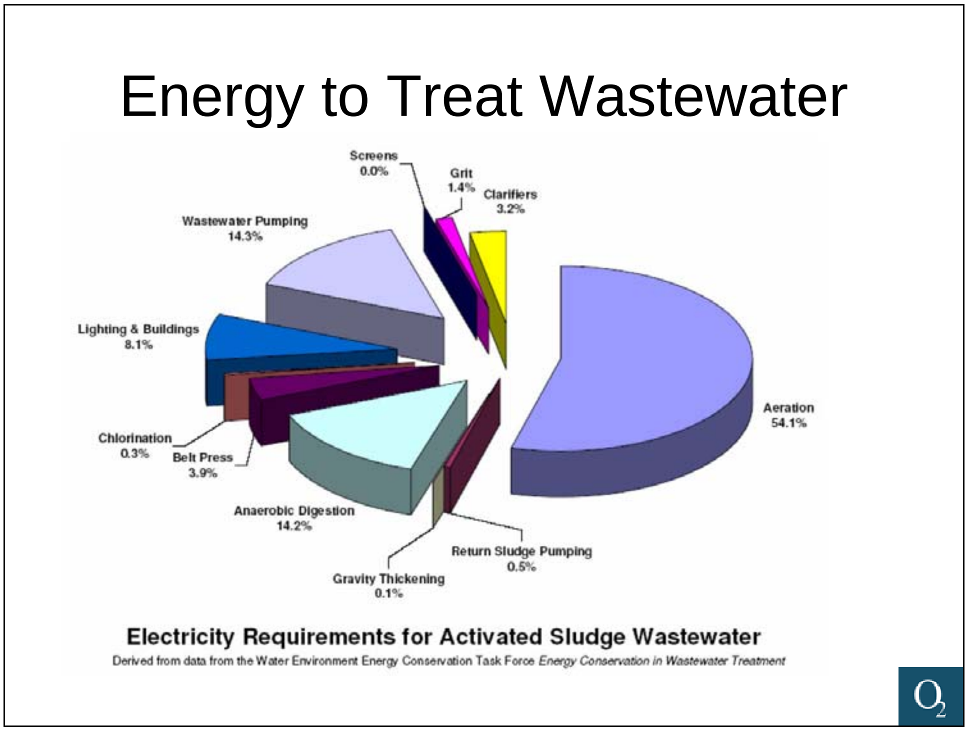
1. It consumes large quantities of energy and
2. It produces a waste sludge is problematic and costly to dispose of.

I would like to introduce a key point here.
Wastewater represents a significant untapped source of energy.
There is energy present in wastewater.

If you were take the wastewater produced by one person and convert the chemical energy into electricity, you could power a 100 watt light bulb for 5 hours. *They estimate the energy embedded in wastewater, if harnessed, could meet between 2% and 12% of the national electricity demand*
So if there is energy present in wastewater, why do we spend energy to treat it?
There is something fundamentally wrong with that picture.

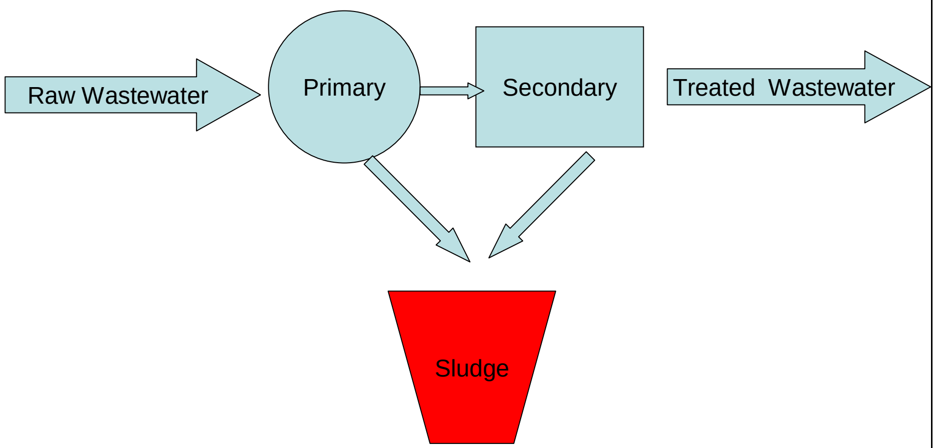
Our current WWT process is essentially an exercise in growing bacteria. We provide them with food & nutrition, in the form of wastewater, give them air and oxygen, which consumes energy, and then end up with a waste sludge which we have to dispose of. We are in essence giving bacteria a free lunch, paying them to eat it.

They say that if you stop and ask an Irishman for directions to a particular location, he will look at you and say, '*well if I were you, I wouldn't start from here*'. Well if you were setting out to design an efficient water system, you wouldn't start from here either. However most of the development in wastewater treatment has been focused on trying to improve this process and make it more efficient, as opposed to looking at alternatives to the process itself.



At individual water and wastewater treatment plants, energy represents a significant element of the overall annual operational costs of running these facilities. It is estimated that on average, water treatment facilities and wastewater treatment facilities spend 11% and 7% of their operating budgets on energy respectively (AwwaRF, 2003). This was based on a benchmarking study carried out by the AwwaRF (now the Water Research Foundation). Estimates vary however and some sources report that energy typically makes up approximately 25% of the costs associated with operating a wastewater treatment plant. RWE estimates that 15% of the operational costs for a medium sized Wastewater Treatment Plant come from energy (Gyurasits, M. 2008). Recent rises in energy prices, especially in Europe, 2005-2008 mean that the proportion can be significantly higher.

Opportunities for Energy Recovery in Wastewater



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Sludge to Energy Technologies

- Sludge to Syngas — Gasification – *e.g. KOPF*
- *Sludge to Biogas* — *Anaerobic digestion +/- pre-treatment*
- Biogas Utilisation — *Microturbines / Stirling Engines/ Fuel Cells*
- Sludge to Oil: — Pyrolysis *e.g. STORS*
- Sludge to Fuel: — Carbonisation & Torrefaction *E-coal and E-Fuel*
- Supercritical Water Oxidation: *Aquacritox*

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Biosolids Management Can Produce Energy Now

Working within the existing wastewater treatment system, one of the most immediate opportunities to generate energy from wastewater is through use of biosolids.

During the wastewater treatment process, we remove contaminants from the wastewater and we concentrate these in the solid phase. And this is where much of the chemical energy present in the wastewater ends up.

The energy density of dried sludge is somewhere in the region of 11,000 BTU's per pound of dried solids (this varies from plant to plant depending on the ratio of primary to secondary sludge and whether or not there is anaerobic digestion). The energy content of Bituminous coal is 14,000 BTU's per pound. So clearly there is a significant energy resource there. There are a variety of technologies now being developed to generate energy from biosolids. Gasification, pyrolysis, carbonisation,torrefaction and supercritical water oxidation are just a few.

Anaerobic digestion is one of the easiest and most widely practiced methods to release *a portion* of the energy present in biosolids and convert it to Methane gas (CH4). As of 2004, there were a total of 1,066 WWTP's in the USA with a flow rate greater than 5 MGD. Of these, 544 utilised anaerobic digestion of biosolids as part of the treatment process. However of these 544 WWTP, only 19%, or 106 WWTPs, actually had some way of using the methane gas produced to generate heat and power. The other 81% of the facilities flared the biogas. There is an opportunity there for increased use of Biogas, particularly at smaller facilities. Some technologies which can enable this are Stirling Engines, Microturbines and Fuel Cells.

While anaerobic digestion with pre-treatment, can release in the region of 50% of the energy present in biosolids, and destroy 50% of the sludge in the process, this still produces a waste sludge which has to be disposed of and which still contains energy.
This creates an opportunity for downstream technologies such as thermal treatment processes.

One of the challenges with releasing this energy in thermal sludge treatment processes, such as incineration, gasification, pyrolysis, carbonisation & torrefaction is that water has to be removed from the sludge so that these processes can work, and this requires energy, which affects the overall energy balance. Supercritical water oxidation represents a new and interesting approach to energy release in that the sludge does not first have to be dewatered. The sludge is heated to in excess o 37o deg C and 220 bar of pressure in the presence of oxygen, and complete oxidation of all of the organic material occurs.

Energy from Wastewater

- **Anaerobic Membrane Bioreactors**
  - Proposed demonstration plant at the Masdar Ecocity in Abu Dhabi.
- **Microbial Fuel Cells**
  - The Israeli company EMEFCY is marketing the MEGAWATTER process which does just this.
- **Advanced Primary Treatment**
  - Micromedia Filtration have a demonstration plant operating in Woodsville, New Hampshire

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There are three main technologies that I see emerging as viable alternatives to the Activated Sludge process.

1. **Anaerobic Membrane Bioreactors**

Produce very little sludge, require very little energy, produce re-use quality water and generate methane gas, so there is a potential for net energy production. Back & Veatch did trial work on this which won an award from the Royal Society they are now collaborating with a number of large industry players including Siemens, Memcor, Noritt and Zenon and there are proposals to construct a 5,000m3/day demonstration facility and I have seen some proposals that this will be used at the new Masdar EcoCity in AbusDhabi.

2. **Microbial Fuel Cells**

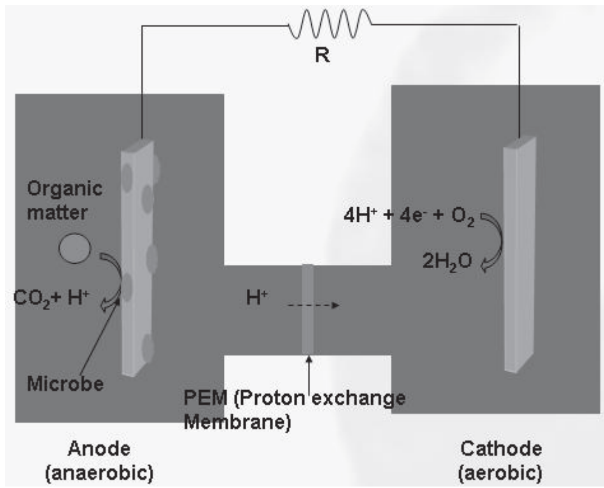
This is a very clever system where you use of special group of bacteria, known as exo-electrogens, which release electrons as they treat wastewater. The electrons are collected on Anodes used to generate electricity. The Israeli company EMEFCY is marketing the MEGAWATTER process which does just this. So this could turn a wastewater treatment plant into a power generating facility.

3. **Advanced Primary Treatment**

Micromedia Filtration is an example of a very small company trying to do something game changing. They have a demonstration plant operating in Woodsville, New Hampshire in the US. This facility treats 60,000 gpd.
Now these three technologies are not simply incremental improvements on an existing process. There are completely alternative, game changing strategies which could

eliminate the energy consumption and GHG emissions associated with WWT and potentially turn a WWTP into a net energy producer.

Microbial Fuel Cell



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Energy efficient methods of meeting water challenges

- Water quantity
  1. Increased Efficiency: e.g. Irrigation & Leakage
  2. Alternative models for providing water services: e.g. decentralised, rainwater use
  3. Water Re-use - 30% <energy than Desal
  4. Forward Osmosis for Desalination
- Water quality
  - Have different grades of water
  - Recover energy from wastewater
  - Alternative model: **source separation and re-use**

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I have focused on opportunities to reduce the energy associated with wastewater treatment. There are opportunities right across the board to reduce the energy associated with water services.

Over 80% of irrigation worldwide is achieved by flooding fields. But with often less than 40% of the water actually reaching crops. Sprinkler irrigation and drip irrigation can get efficiencies in excess of 75%. So use of sprinkler and drip irrigation systems would effectively double efficiencies, thereby enabling the same productivity with half the water. (Citi, 2009). The use of drought resistant crops is also an area of opportunity to achieve the same, or higher levels of production, with less water. Using less water means using less energy.

Water Re-use.

Currently it is estimated that approximately 5% of wastewater which is treated and collected is re-used (GWI Water Re-use Report). It is predicted that the rate of growth in water re-use market will outstrip the rate of growth in the desalination market in the next 10 years (GWI

Water re-use has the potential to use 30% less energy than desalination. What also has to be considered in Water Re-use, is the it is really the Marginal capital and operational costs of going from treated wastewater quality, to re-use quality water, which should be considered, when making the comparison with desalination.

There are three different levels at which we can approach energy recovery in wastewater.
I have outlined how within the existing system, we can implement sludge to energy solutions. By altering the treatment process, we can implement energy generation further upstream. There is a third alternative, which requires a re-engineering of how we manage water. If we implement source separation, different grades of water and water re-use, we can greatly enhance efficiencies and reduce the energy embodied in water use by reducing the need to transport water long distances and implementing more efficient processes.

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Energy Opportunities In Wastewater And Biosolids. – WERF Research Update_Reinhart_2009

Fueling the Flames, WEF, David L. Parry, 2008

Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities, U.S. Environmental Protection Agency Combined Heat and Power Partnership, 2007