

ARPA-E Energy from Wastewater

Breakout Group #3 - Net Energy from Wastewater: Science and Technology Needed, with Associated Metrics

Group 1: Science and technological challenges to obtaining energy from wastewater with more than an order of magnitude better performance than current technologies

Chair: Mohamed Dahab, University of Nebraska



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Studies have shown that there is ~10x as much energy in wastewater as what is required to treat it. How far can we realistically expect science/technology to take us along that gap?

- It would be good to have a metric of net Joule/1000 gallons (J/kgCOD is only organic loading + thermal content (J/differential temperature)) to match \$ / 1000 gallon concept → we need a good BENCHMARK on what we are at today for energy recovery for existing WWTPs with today's technology
- How does the value of X scale across facility?
- Zero X is no net energy recovery; most facilities today have a NEGATIVE X (what is
- The "best X" is probably the facility in Switzerland from WERF talk – find out what the X value is for that facility
- A metric should be P in wastewater versus P "embedded" in per capita P consumption. Would removing even 100% of P from wastewater make a difference?
- PKN is important for fertilizers (phosphorous, potassium, nitrogen = PKN) and may be important metric to compare against conventional fertilizers
- Is wastewater available for "water-splitting" technologies to produce hydrogen



- Biosolids, solid fuels, water splitting to generate hydrogen all forms of energy you could extract,
- An ongoing approach is to mix agricultural waste with municipal ww biosolids to see how much energy can be extracted (Michigan state)
- Anaerobic biogas -> electricity (established process, efficiency varies – Lincoln Nebraska, 40MGD plant that can support 70% of it's power on site)
- Benchmark system: Swiss system at net energy neutral. ARPA-E should baseline off that and try to develop technologies beyond that
- If you start with new technologies only after the secondary treatment step, you won't reach the energy goals. Analysis and innovation needs to start at the pipe.
- Some plants can make use of natural resources to make up for some of its energy use (like around lakes where algae can be used)

Slide 3

What are the roadblocks that are preventing current systems from maximizing the energy extracted from the biomass produced from wastewater treatment?

- Nutrient recovery is important to meet demands of keeping nutrients out of receiving waters; nutrients also have an economic value
- Take a systems approach to capture energy at different points in a system and don't rely upon only one approach/technology – LCA approach is critical
- Use high capacity digester (MBR) to reduce volume of reactor which increases the ease of heating, etc. (reduced capital)




- Question to answer: How much COD do you have to convert to biogas to sustain your plant?

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Roadblocks

- Low concentration of COD in wastewater (300 mg/L COD)
- High flow rates/volume (throughput) & continuous flow
- Byproduct has to be clean water (e.g., salt) – which is a moving target
- Always exhibits variable organic (and unforeseen) loadings
- Today many systems are centralized
- Combined sewers (storm / sanitary) exists is considered a legacy (<20% of systems) but even modern systems have a lot of I&I (infiltration and inflow)
- Existing technologies are currently very energy intensive:
 - Aeration is prevalent
 - RO for state of the art reuse is energy intensive
- Energy has not been driving force – it has been what is the cheapest way to purify water to regulatory limits (this was probably aeration in the past)
- Disconnect between capital costs (and funding) versus O&M; O&M is often in the rate bills. Fed's and other funds paid for a large part to the up front capital.
- LCA has not been the approach taken for selection of unit processes, replacement parts or entire new facilities
- Institutional barriers exist for funding utilities a bundled or not (water, WW, trash, power, etc)
- Scalability – 70% are small. Roadblocks for a 1 MGD are not the same for a 10 or 100 MGD facility
- Size of Mark Shannon's "box" (around WWTP) may be too small – you may need to look at the integrated drinking water + WWTP
- "Pump once" concept
- Not a roadblock: more flexibility exists for innovation in WWTP than drinking water treatment, but how flexible are regulators really? (should regulators be involved in a ARPA-E project?)



- Challenge – seasonality, availability of certain organics
- Expertise is required by operators in wastewater treatment plants that are efficient, as the operator needs to know how to maneuver around the normal process to optimize it.
- If digesters go sour, they are out of operation for long stretches of time (months)
- Challenge is how to grab COD out of the water without using thermal energy
- Overall challenges: dilute wastewater, high flowrates/throughput and byproduct, variability of wastewater – needs to be resistant to loading changes. The concept of “clean water” is a moving target. Centralization of our current systems. Combined collection systems are a problem - stormwater is being mixed with regular municipal water. Salting. Old pipes leading to either leaking, or intrusion. Aeration required and is very energy intensive – infrastructure inadequacy.
- Policy wise, electricity and sewage have to be decoupled. Mayors cannot be allowed to hike up electricity to pay off sewer to keep the cost of that down, since price hikes in elec are more socially acceptable. Must make America realize the importance of WW as a resource
- Processes don't necessarily scale for different types of source WW
- A lot of energy gets wasted in the transport – so many pumps always running, and many different lift stations. Perhaps the WW should be dealt with at the point of flush, and should go to benefiting the house or origin for energy/cost efficiency

What technologies/combo of technologies have the greatest potential to overcome these roadblocks?

- Cogeneration using WW and other organics delivered to site; mixes of agriculture and biosolids waste – roadblock removed => it allows small systems to be more feasible because it increases total available load of organics, thus allowing energy recovery from small WWTP facilities (facilitating option)
- Separation of solids of different sizes because they have different properties that affect biodegradability. One example – fabric filters, sorbents, etc.
- Granular bioflocs are easier to separate
- Aerobic systems
- Current WW is only 70% anaerobically digestible
- More efficient bioprocess would be an advantage; use microbial ecology to understand population shifts, learn from these observations and engineer it
- The challenge is how to extract energy from a dilute COD water from ARPA-E
- N & P recovery from biomass is essential for algae farms, etc after beneficial extraction of fuel or other products → and approach will be the same as N & P recovery from residual WW biomass
- MFCs convert COD to electrons or H₂ – key barriers exist here including PEM, electrode materials, pretreatment requirements
- MFCs are viewed as a “competitor” of anaerobic membrane bioreactors – poses an interesting question which is more “net” energy efficient
- How can we leverage existing resources within a WWTP
- Is there a need for better sensing and control?
- Feed syn gas directly to digester...reducing environment?
- Push innovative projects/solutions as **alternative energy systems**



- Renewable biodegradable biowaste adsorbent – adsorbs organics and not water then it goes into digester
- An innovation that is out there is very efficient fabric filters, rather than membranes to efficiently separate out larger constituents and put into anaerobic digester. They have surface properties like membranes, but short lives. Does/can the fabric have embedded energy? Perhaps it can be developed such that its can be energy extracted after it can no longer be used to extract COD
- Membrane bioreactors with nanofiltration. Can we have granular type of biosystems, rather than (floc?) which are more prone to fouling
- Use natural microbial ecologies to identify population shifts to get stronger and most efficient populations. Allows for selection of more ideal strains.
- Systems approach required. Should try to capture energy from all components of WW: biogas, sludge, and remaining CODs.
- Microbial fuel cells about “10 years” out. The benefit of MBFC is the efficiency jump because of direct electrical conversion of COD. One major challenge is that a concentrated energy source is required.
- Synthetic biology going on, trying to get systems to do things biology doesn’t do
- Fuel cells research is declining since operation is difficult enough with hydrogen. Would be significantly more challenging with wastewater.
- Regarding variability – perhaps develop technologies to sense and control variability
- If you increase H₂ concentration or produce syngas... maybe feed it to the digester? Keep it in a completely reduced state. Use sludge to form syngas, feed the syngas right back to the digester. Biological water shift reaction

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What are some possible sustainable methods/technologies to remove nutrients from water with net energy?

- N & P recovery from biomass is essential for algae farms, etc after beneficial extraction of fuel or other products → and approach will be the same as N & P recovery from residual WW biomass
- Keeping nutrients out of surface waters limits algae blooms that produce toxins or T&O compounds in drinking water that cost \$ to treat and/or health problems & ecosystem costs – how do you include these prevented costs in **LCA / cost-benefit**



- If all P was extracted from wastewater, would have significant impact on P balance
- Nutrient recovery = N and P
- PKN value in the wastewater – the question is, what is the value of recovering these nutrients compared to the cost/energy to produce. Perhaps an area to go after if balance is favorable
- To breed algae P and N are needed, so really P and N must be recovered from waste for system to be realized. P and N requirement is the biggest economic roadblock
- It is a hard challenge to separate algae from affluent and it needs to be done. Algae has to be collected in order to be processed

