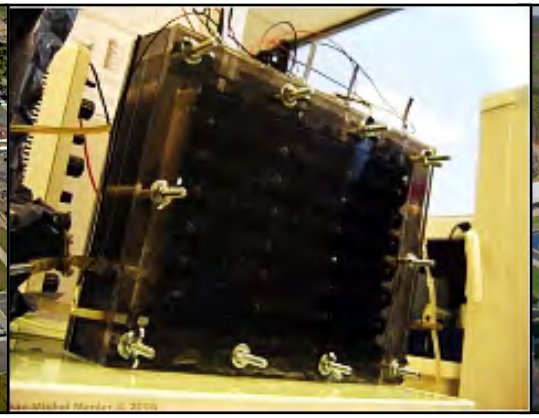
Exceptional service in the national interest

Sandia National Laboratories


Microbial Fuel Cell Possibilities on American Indian Tribal Lands

Kimberlynn Cameron

South Dakota School of Mines & Technology

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

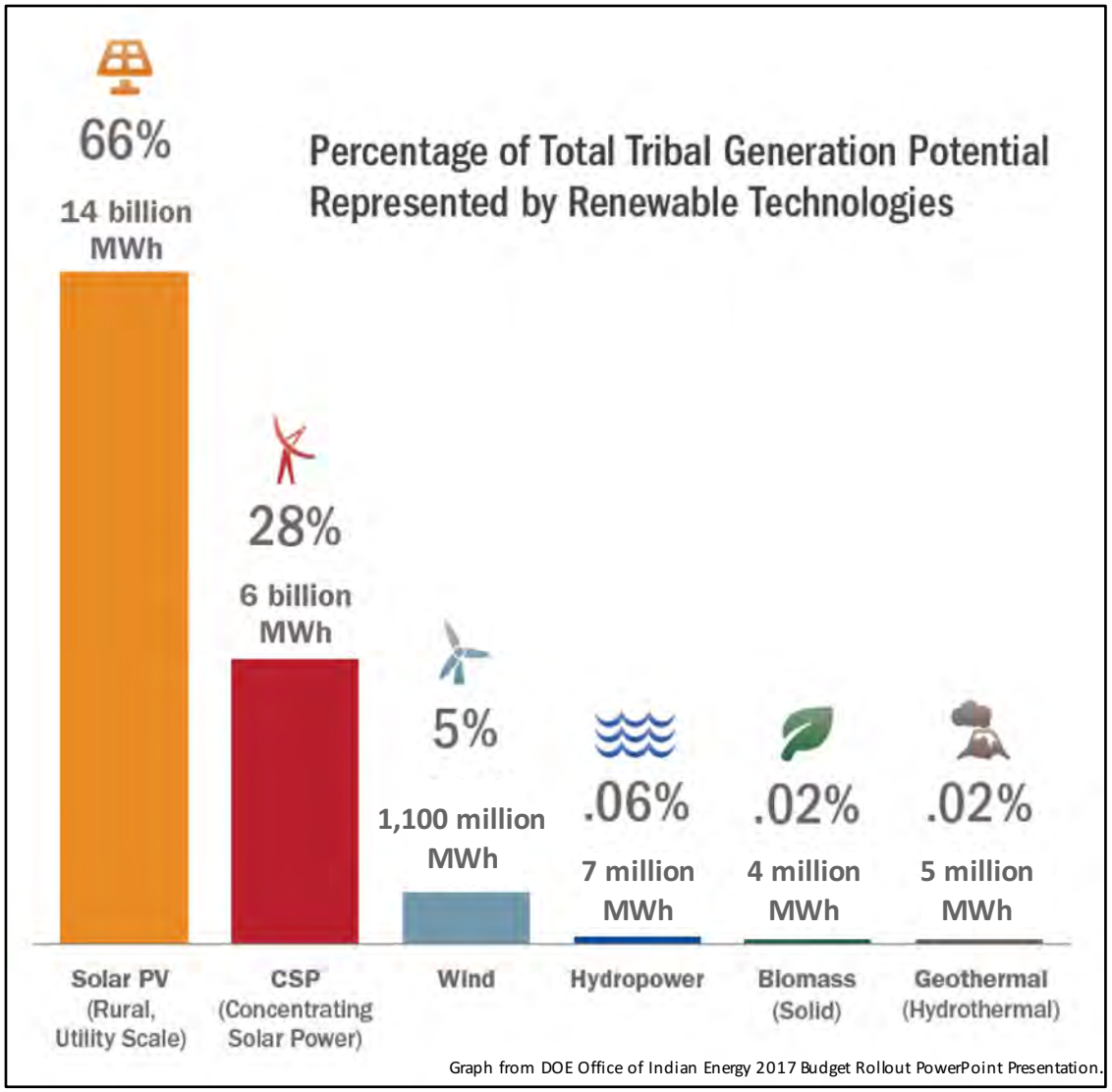
SAND2016-7820 PE

About me

Sandia National Laboratories

South Dakota School of Mines & Technology
Majors: MS Civil & Environmental Engineering
MS Engineering Management
May 2017
Degree: BS Geological Engineering, May 2014

Background



Graph from DOE Office of Indian Energy 2017 Budget Rollout PowerPoint Presentation.

- American Indian lands comprises ~2% of US and contains ~5% of all renewable energy resources.
- Total technical potential on tribal lands ~21 billion MWh.
- Waste as renewable vs. waste conservation?

Waste to Energy

- Generating energy in the form of electricity and/or heat from the incineration of waste.
- Processes: Thermal & Non-thermal
- Thermal:
  - Depolymerization
  - Gasification
  - Pyrolysis
  - Plasma arc gasification
- Non-thermal:
  - Anaerobic digestion

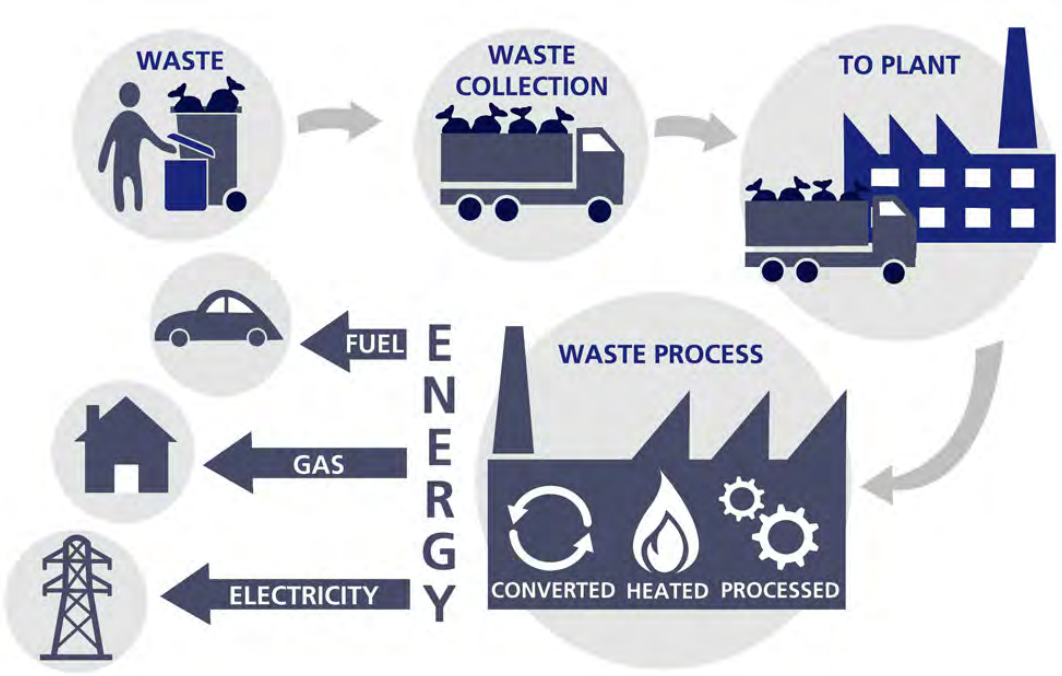


Figure from Global Re-Energy Website: www.globalre-energy.com/about-waste-to-energy-facilities/

Forest County Potawatomi Community

Sandia National Laboratories

- A 2 MW anaerobic digester and biogas generation facility.
  - converts food waste into electricity power 1,500 homes
- Long-term energy goal to reduce its carbon footprint to zero.
  - Assumed a leadership role in creating a sustainable and healthy world
  - 2014: Ranked among the Top 100 and Top 30 Local Government green power users

FOREST COUNTY POTAWATOMI
Keeper of the Fire

Microbial Fuel Cell (MFC) Technology

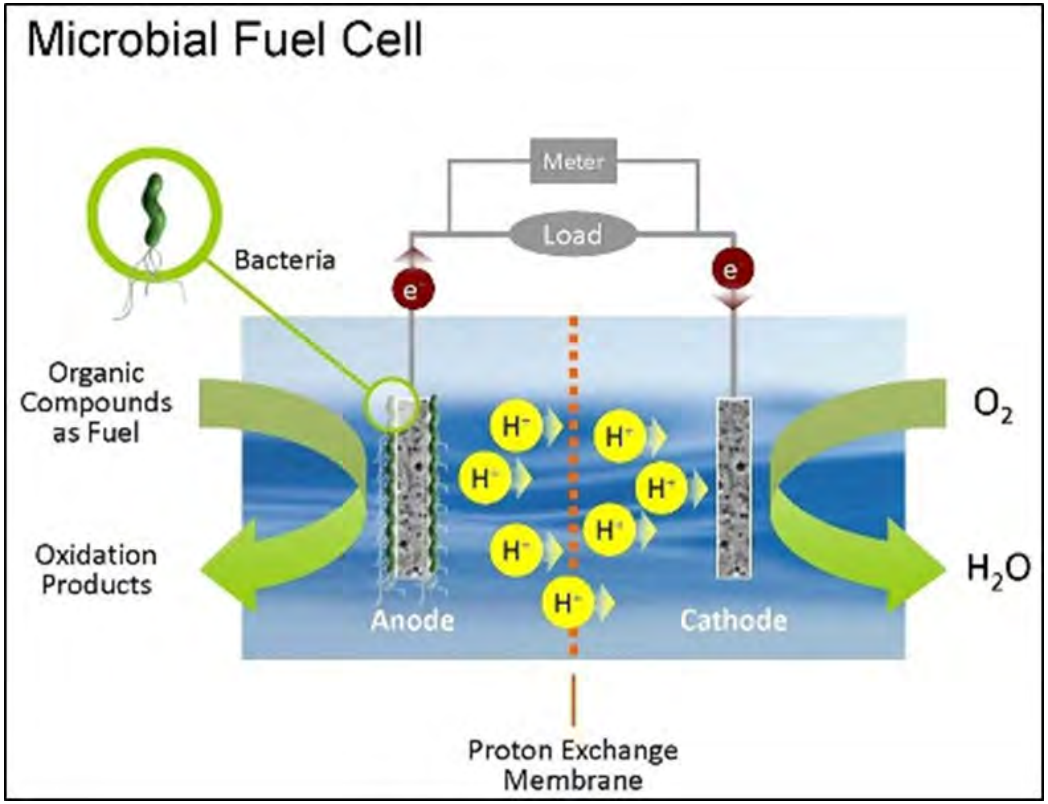


Diagram from Avanti Corporation website: http://www.avanticorporation.com/green-remediation/

- Four parts: anode, cathode, proton exchange membrane (PEM), external circuit

- MFCs require "fuel."
  - Organic waste, food waste, wastewater
- MFCs are fed with the wastewater containing both the fuel and the bacteria responsible for its degradation.
- MFC bacteria will oxidize the fuel and use the anode as an external electron acceptor.
- Electrical power is generated by the electrons flowing from the anode through an electrical circuit to the cathode, where the reduction of an electron acceptor (oxygen) occurs.
- At the cathode, the protons and electrons combine with oxygen to create water.

Wastewater Treatment

- Types of treatment:
  - Physical, Biological and Chemical

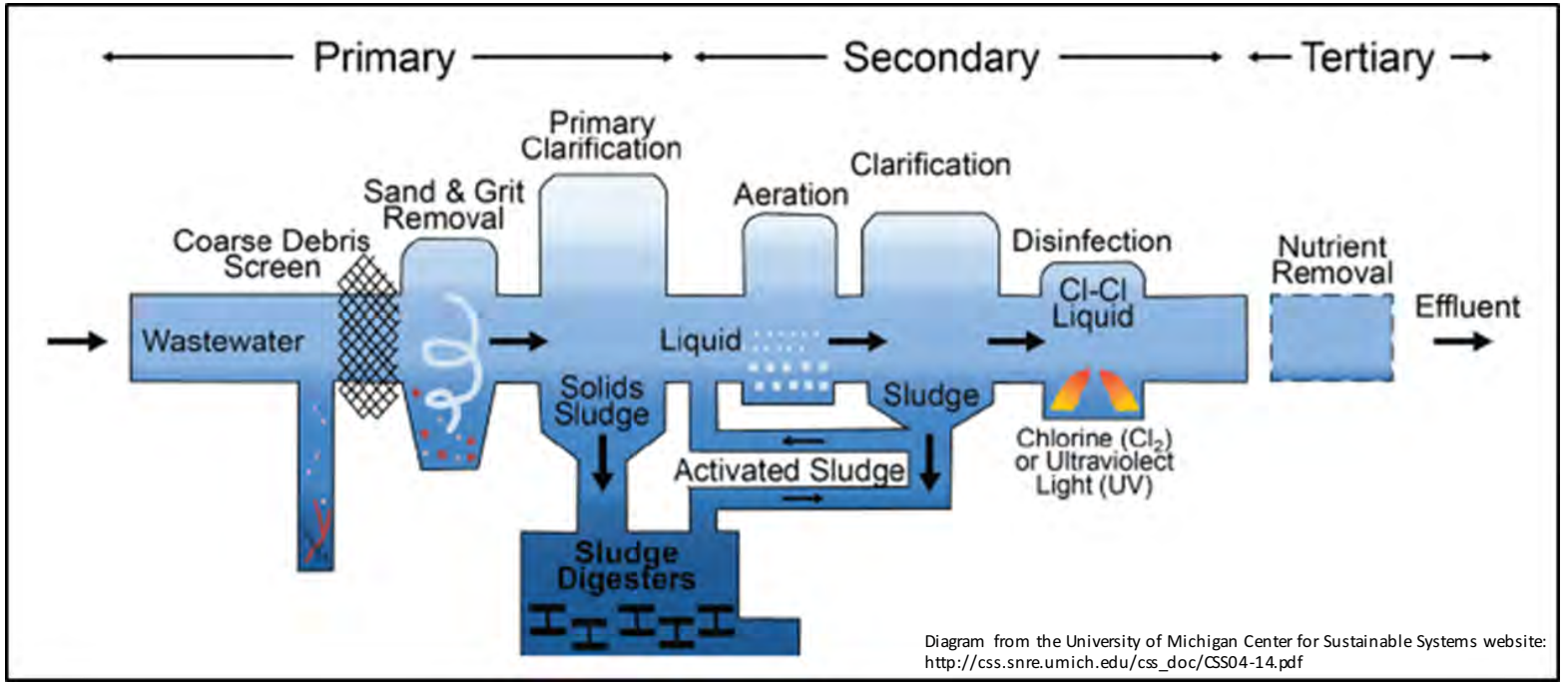
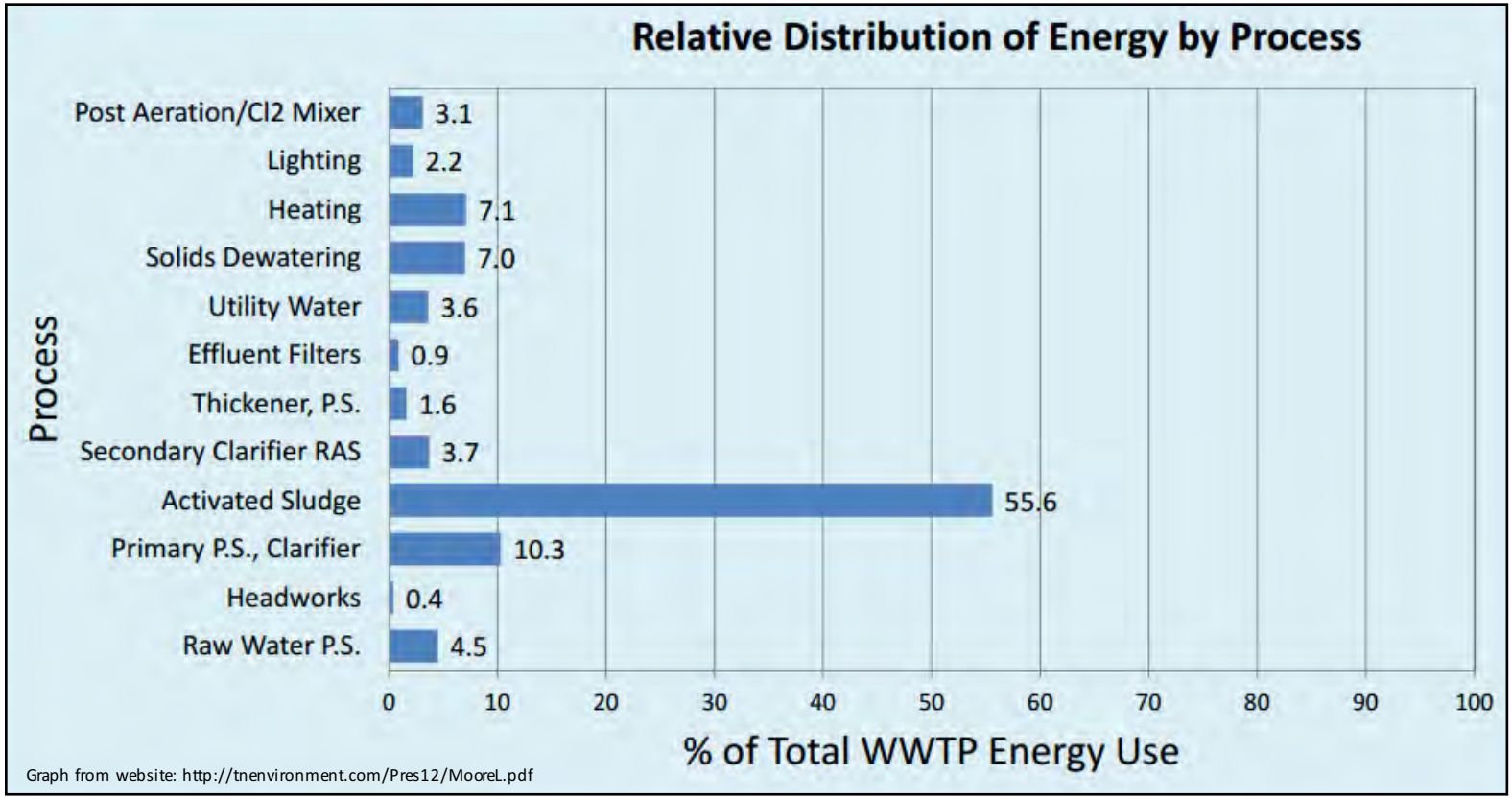


Diagram from the University of Michigan Center for Sustainable Systems website: http://css.snre.umich.edu/css_doc/CSS04-14.pdf

- Energy consumption:
  - ~3% of total U.S. electricity consumption
- Treating and pumping of water requires substantial amounts of power
  - ~80% of total energy used is from transportation of water

Relative Energy Distribution of Wastewater Treatment Processes

Sandia National Laboratories



- Based on secondary wastewater treatment plant (7 MGD)

Potential Benefits and Practical Challenges

Sandia National Laboratories

Benefits:

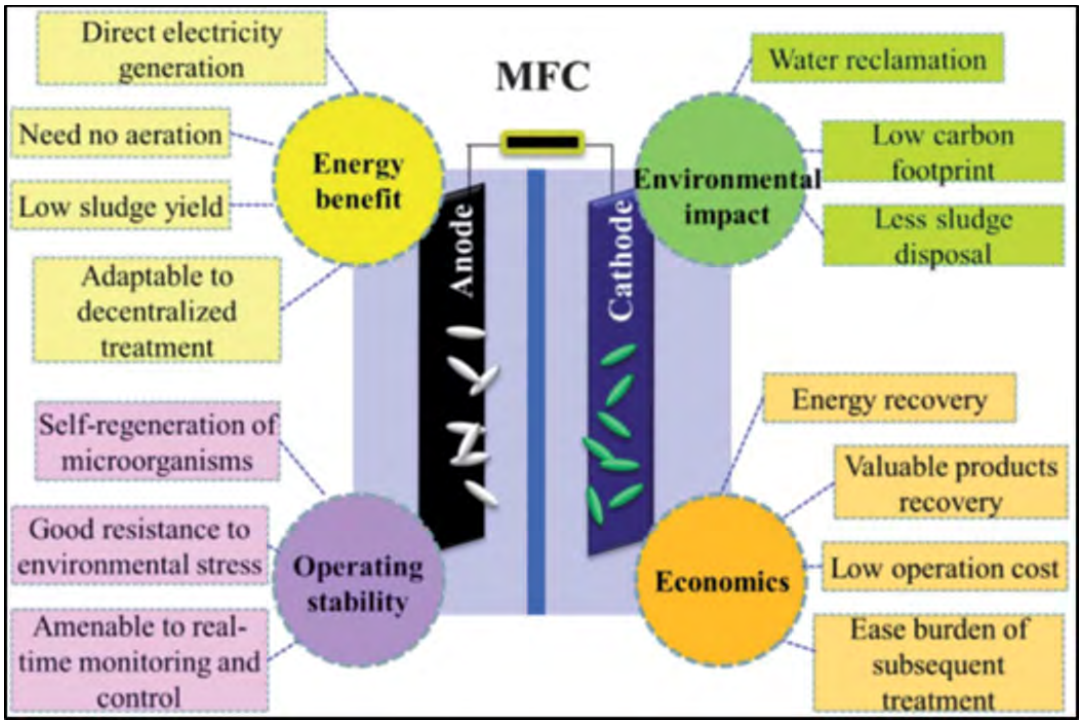
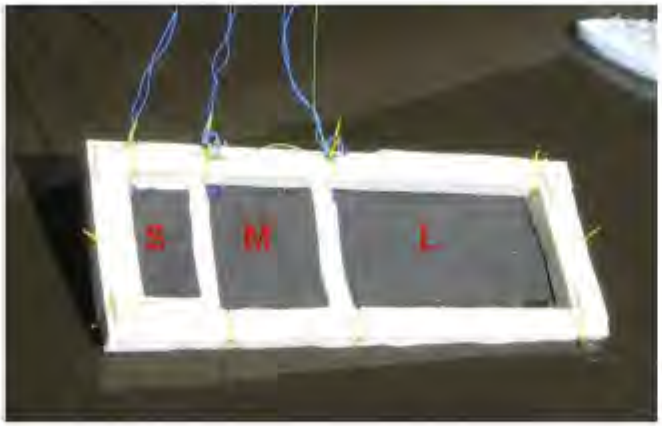


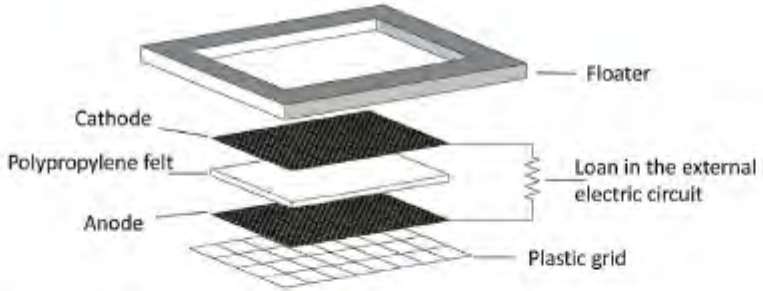
Figure from "Towards sustainable wastewater treatment by using microbial fuel cells-centered technologies" article by W.Li.

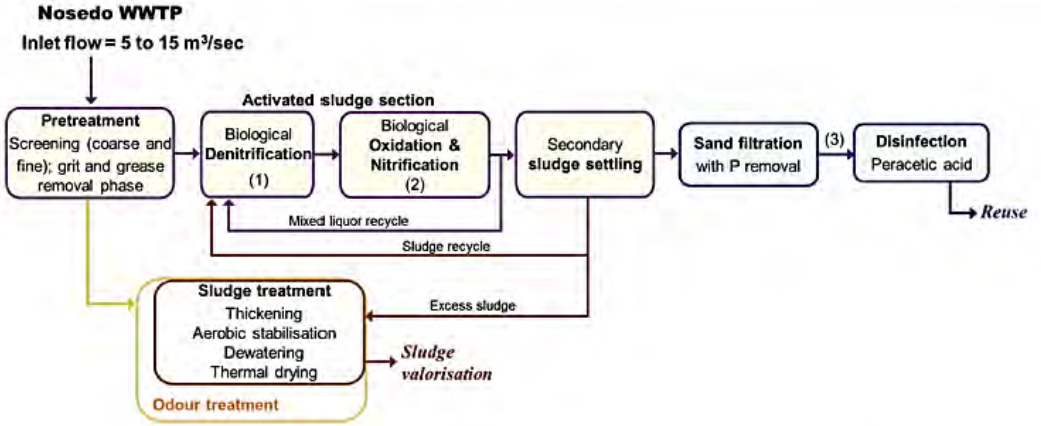
Challenges:

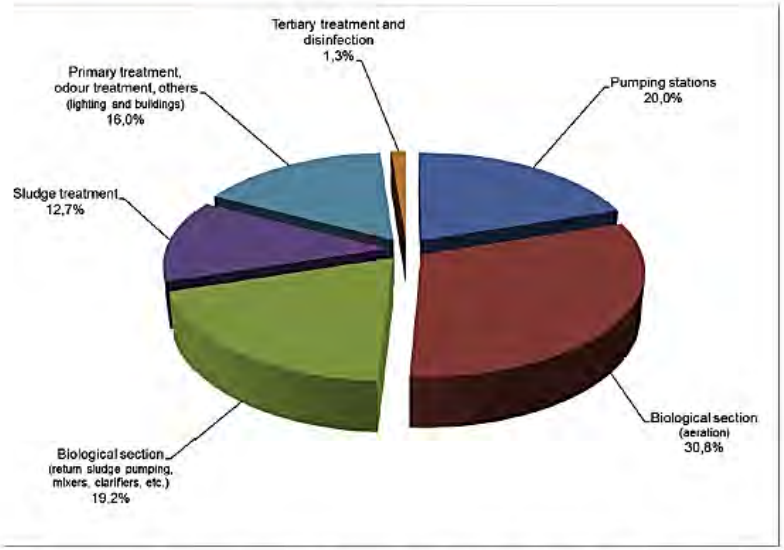
- Initial capital investment, operation and maintenance expenses associated with energy, chemicals and materials consumption, and deteriorated performance during long-term operation
- Scaling up an MFC system for real world application
- Weak current generation when singular

Example: Completed Case Study for Milan-Nosedo Wastewater Treatment Plant









- Variable output; smallest MFCs showed better performances
- Limit of scaling up MFCs suitable for stack system and to improve the produced power.

Figures from Energy balance and microbial fuel cells experimentation at wastewater treatment plant Milano-Nosedo article by E. Martinucci.

Example: Prototype Completed by Penn State Research Team

Sandia National Laboratories

- Proof of concept device that can generate 0.9 kWh of electricity per kg of organic waste.
  - Plants that consume, on average, 1.2kWh per kg of waste, can produce a positive amount of current while continuing to perform their conventional function.
- Device combines an MFC with a reverse electrodialysis system—which separates ions in a series of membranes.
- MFC's in the proof of concept also act as a final cleaning stage in the wastewater treatment process.
- Organic matter treated much faster.

Why Microbial Fuel Cells (MFCs)?

Sandia National Laboratories

- Waste to energy technology
- MFCs use bacteria to convert organic matter (fuel) directly into electricity.
  - Reduction/elimination of methane produced/transported
- Reduction of sludge and removal of aeration process.
  - Reduction of energy consumption and solid waste removal
- Organic matter treated quicker.
- Emerging technology with potential for positive impact and technological advancements.
- Application of MFCs to tribal application.
  - Managing wastewater to potentially use as a form of energy.

Future Work

- Collection of data on wastewater treatment infrastructure on tribal lands.
  - Collection of data for energy consumption on tribal lands.
- Determine MFC potential on tribal lands using wastewater as a renewable resource
  - Determine quantity of municipal wastewater
  - Quantifying the amount of Gibbs free energy available in the waste compound in order to estimate the electric power than can be generated.

Pilamaye Tanka!

- Department of Energy - Office of Indian Energy
- Sandia National Laboratories
- Sandra Begay
- Fellow Indian Energy Interns:
  - Len Necefer, Tommy Jones, Rachael Gutierrez
- SDSM&T Faculty:
  - Dr. Jennifer Benning, Dr. V. Gadhamshetty

References

- http://www.globalre-energy.com/about-waste-to-energy-facilities/
- http://www.genomenviron.org/Research/MFC.html
- http://water.usgs.gov/edu/wwvisit.html
- http://www.renewableenergyworld.com/articles/2014/01/an-independent-engineering-evaluation-of-waste-to-energy-technologies.html
- http://www.conserve-energy-future.com/waste-to-energy.php
- http://energy.gov/indianenergy/articles/forest-county-potawatomi-recognized-renewable-energy-achievements
- http://gizmodo.com/5891157/new-microbial-fuel-cells-could-turn-sewage-plants-into-power-plants
- http://tnenvironment.com/Pres12/MooreL.pdf
- http://www.lewwtp.org/
- http://www.avanticorporation.com/green-remediation/
- http://www.hoffmanandlamson.com/applications/wastewater.aspx
- http://www.bbc.co.uk/schools/gcsebitesize/science/triple_aqa/humans_and_environment/biofuels/revision/4/
- https://www.edf.org/energy/methaneleakage
- http://www.ecovillage.org.in/ecopedia/alternate-energy/advantages-and-disadvantages-of-biogas
- http://energy.gov/indianenergy/articles/forest-county-potawatomi-recognized-renewable-energy-achievements
- http://www.bia.gov/FAQs/