Wastewater Energy Optimization

Pearl Sullivan Engineering
IDEAs Clinic

Sustainability and Social Entrepreneurship Fellowship (Spring 2024)
Halton Energy Savers

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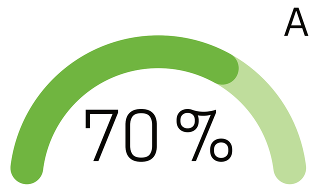
CHALLENGE

As Halton Region's population is expected to double by 2051 (to almost 1.4M people) how can they support the transition to a circular economy and ensure services such as water, wastewater and solid waste management remain environmentally and financially sustainable?

Ontario commits to reducing our emissions to 30 per cent below 2005 levels by 2030.



A target that aligns with the Federal Government's Paris commitments.

PROBLEM STATEMENT

The Halton region is currently burning a substantial volume of digester gas each day, resulting in lost energy potential. Additionally, inefficiencies in the aeration process of wastewater treatment plants due to outdated diffuser technology contribute to higher energy usage. There is a need to capture and repurpose this digester gas and upgrade the aeration systems for improved efficiency.

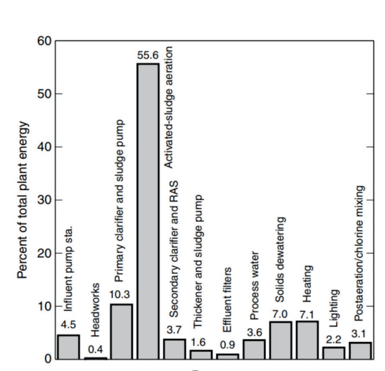
RESEARCH /METHODOLGY

- **5,871** tons of Co2 released from wastewater treatment in 2023 [6]
- **35%** of the total municipal electricity consumption came from wastewater treatment in 2023 [7]
- This project aims to propose cogeneration for methane capture and use, alongside MABR technology as an alternative to traditional aeration.

MABR

Over **50%** of wastewater plant energy is used for traditional aeration.

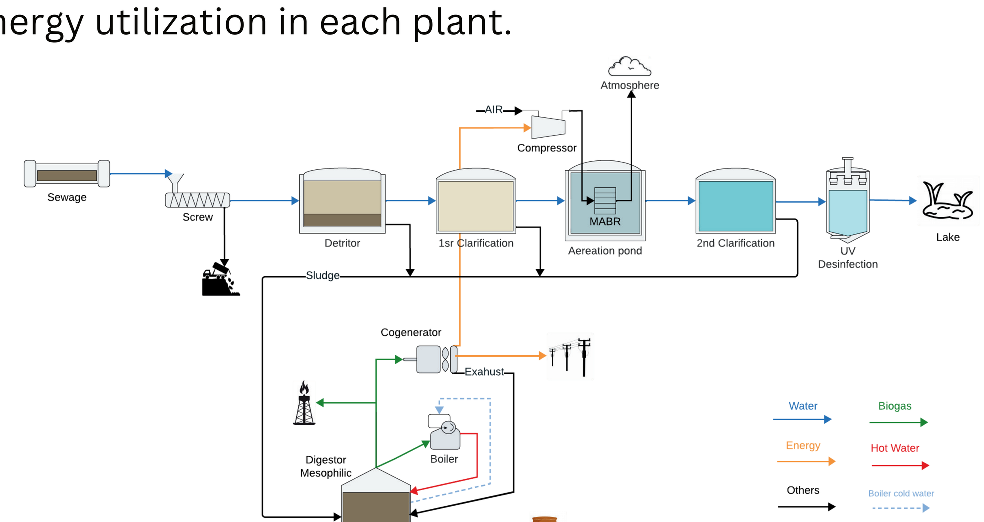
- Review existing knowledge, theories, and research gaps on MABR.
- Develop a research plan with objectives, questions, experiments, simulations, and timeline.
- Collect and analyze empirical data from MABR installations to address research questions and validate findings.



[1] Metcalf & Eddy Inc

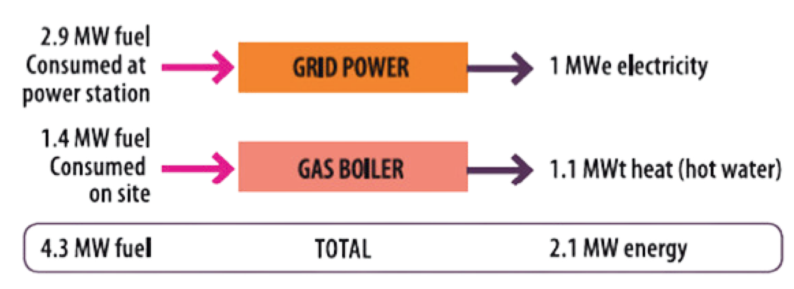
COGENERATION

- Data Collection: Gather data on the volume of digester gas flared in each wastewater plant.
- Energy Calculation: Estimate energy production from cogeneration systems using literature and municipal values.
- System Sizing & Recommendations: Size cogenerators based on potential heat and electrical energy, and provide recommendations for energy utilization in each plant.



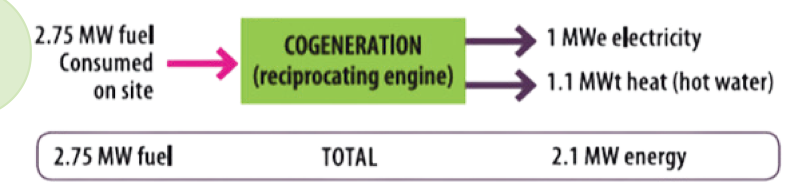
Process diagram of the Mid-Halton plant illustrating the proposed modifications and their applications.

COGENERATION



The Halton region flares **7,132,225 m³** of digester gas annually across all wastewater plants.
The gas Boiler consumes **2,877,064 m³** of digester gas annually across all wastewater plants

Electricity from Mid Halton's digester gas could power **585** homes.



Cogeneration (CHP): Simultaneous production of electricity and useful heat from the same energy source.

- **Efficiency**: Higher overall energy efficiency compared to separate heat and power generation.
- **Cost Savings**: Reduced energy costs due to efficient use of fuel.
- **Environmental Impact**: Lower greenhouse gas emissions by utilizing waste heat and reducing reliance on fossil fuels.

Plant	Power consumption (kwh/day)	Electrical energy (kwh/day)	Heat energy (kwh/day)	CHP Capacity (kwh)	Capital cost of CHP (CAD$) [5]	Electricity consumption (kwh/hour)	GHG savings Tons (CO2/year) [3]
Acton	2609.68	1140	2090.54	40	90569.6	31.06	34.78
Georgetown	11175.07	6337	11618.13	150	339636	133.03	148.96
Mid-Halton	59645.20	21953	40248.04	800	2173616	712.06	797.29
Southeast	12610.83	4955	9084.29	150	339636	150.12	168.09
Southwest	18179.57	5521	10122.49	240	543417.6	216.42	242.32
Skyway	75109.51	32491	59566.99	900	2445318	894.16	1001.19

- The data in the table above is derived from the **2023** digester gas data across six wastewater treatment facilities in the Halton region.
- The CHP capacity and electricity consumption calculations are based on a target of offsetting **20%** of energy use through CHP installations.

MABR

The Membrane Aerated Biofilm Reactor (MABR) is an advanced wastewater treatment technology that uses **gas-permeable membranes** to introduce oxygen directly into the biofilm on the membrane surface. Oxygen diffuses from the air inside the membrane to the biofilm due to a **concentration gradient**, where it is utilized by microorganisms to break down organic contaminants in the wastewater. [2]

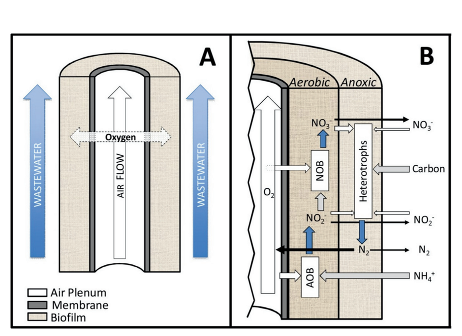
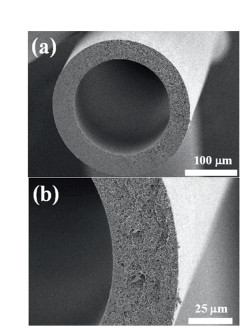
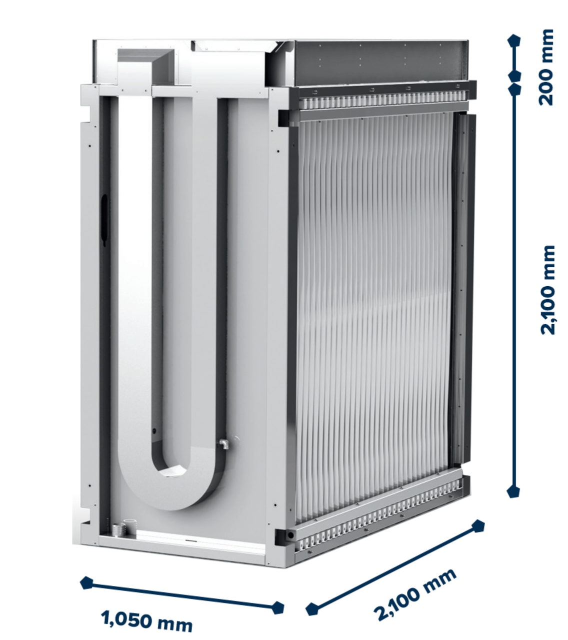


Diagram illustrating mass transfer through a concentration gradient in a MABR. The diagram highlights how oxygen diffuses through the membrane to the biofilm, enhancing biodegradation. Additionally, the membrane facilitates the exchange of nitrogen and phosphorus, offering extra benefits in nutrient removal.



Scanning electron microscope image of a membrane fiber, resembling a 'straw', showcasing the material's porosity. This detailed view highlights the fine pores that facilitate efficient gas transfer and interaction with the biofilm in a MABR.



Oxymem is recognized for its innovative membrane technologies, providing advanced solutions for efficient wastewater treatment

The energy consumption of MABR is significantly lower compared to conventional aeration systems because it **eliminates the need to compress air** at high pressures. By transferring oxygen directly to the microorganisms through the membrane, MABR reduces air flow resistance and associated energy losses, resulting in **more efficient oxygen transfer and lower energy usage**. [2]

By simply considering the addition of an MABR operating in parallel with the current diffusion systems in each of the seven plants, we can save 393 tons of CO2 eq, which is equivalent to **7% of the annual emissions** that Halton corporate has associated with wastewater treatment. [4]

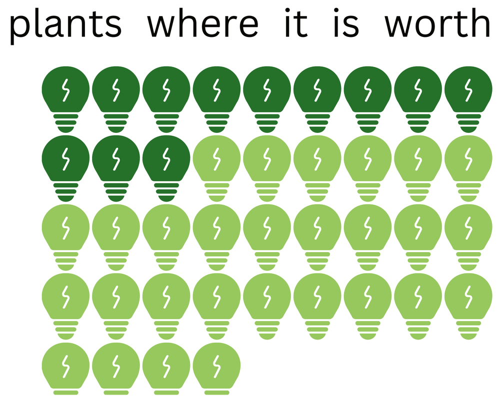
CO2

5,871 CO2 e tonnes

Emissions considering the energy savings from MABR, equivalent to ≈ 2,000 residential complexes in Ontario.

We can **save** around 45% of the energy used in the aeration process, which represents **24% of the total energy consumption** in the plants where it is worth implementing MABR. [4]

45%



ASSUMPTIONS

Parameter	Assumption
Weather	Average annual temperature
Average flow	Constant daily flow rate.
Opearation time	Constant 24 hour plant operation
CHP Efficiencies	Heat energy- 55, Electrical energy- 45
BOD demands	Constant Biochemical oxygen demand
Load factor	0.7
Energy content of digester gas	35.846 MJ/m3

RECOMMENDATIONS

Conduct a comprehensive large-scale study to assess the capital costs, energy savings, and greenhouse gas reductions associated with CHP installations at each plant.

It is essential to verify that the biological conditions of all plants match those of Mid-Halton, as our proposal is based on the specific conditions observed there. This is crucial because the capability of MABRs to simultaneously degrade carbonaceous and nitrogenous pollutants through SND in a single-stage vessel needs further research, particularly for space-based water reuse applications.

CONCLUSION

The combination of cogenerators for methane utilization and MABR technology offers significant energy and environmental benefits. This approach could potentially save around 2,787 tonnes of CO2 equivalent per year, which represents 15% of Halton Corporate's emissions in 2019. [4]

Cogenerators generate energy from methane, while MABR optimizes oxygen transfer and reduces energy consumption. However, it is crucial to conduct a thorough economic analysis to assess feasibility and determine the optimal timing for implementing these technologies, ensuring their effectiveness and long-term sustainability.

REFERENCES

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