SUSTAINABILITY AND SOCIAL ENTREPRENEAURSHIP FELLOWSHIP, TEAM MICROALGAE

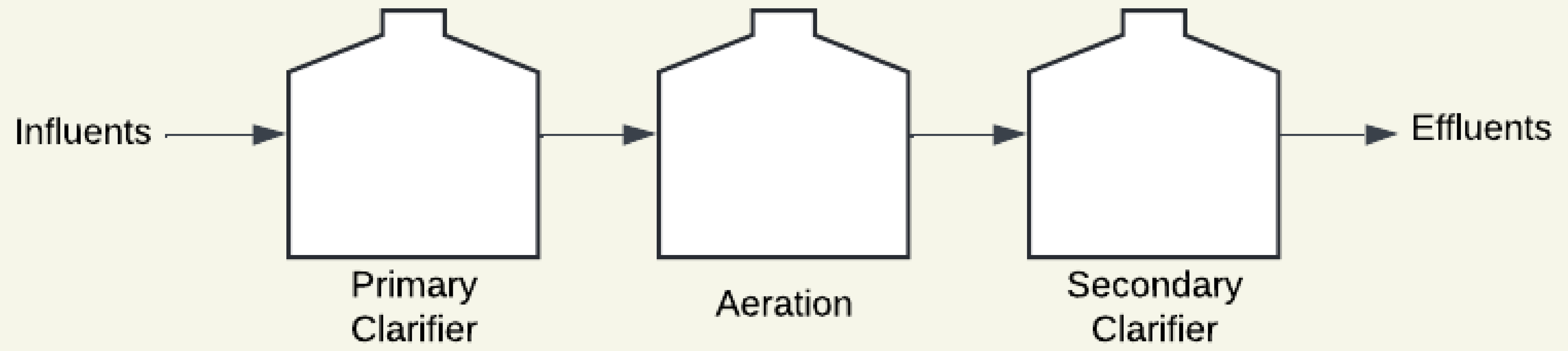
MICROALGAE CULTIVATION AT MID-HALTON WASTEWATER FACILITY

MEGHAN ALMEIDA, CRISTINA TZUNUN PALOMO, JUAN MANUEL

Pearl Sullivan Engineering IDEAs Clinic

BACKGROUND

Halton Region is projected to experience a twofold increase in population by 2051. Currently, the region owns and operates seven wastewater treatment facilities that process 232,000 cubic meters of wastewater daily [1]. Given the anticipated exponential population growth, it is imperative to consider strategies to manage the increase in wastewater volume. A brief overview of the wastewater plant:



PROBLEM STATEMENT

The Mid Halton Region Wastewater Treatment Facility currently lacks circularity, such as wasting biomatter in their facility due to issues with temperature variability, lack of sunlight availability, and economic constraints within the existing underutilized infrastructure.

OBJECTIVE

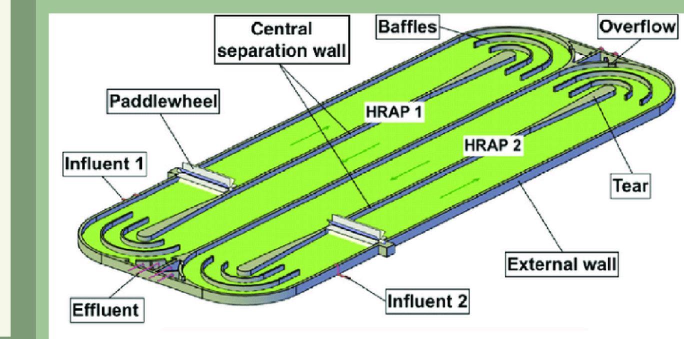
This project aims to utilise naturally growing microalgae and additionally cultivate an optimal yield of 0.90 g/L [2] of microalgae at the Mid Halton Region Wastewater Treatment Facility to treat organic matter in the wastewater economically.

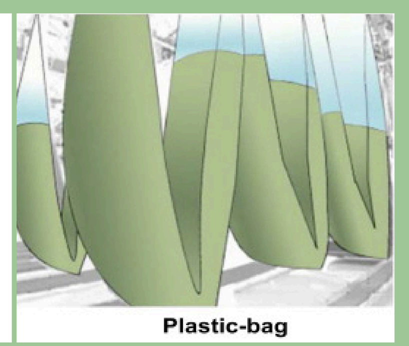
RECOMMENDED CULTIVATION

Microalgae Cultivation:

1.) High Rate Algal Systems (HRAP) [3]

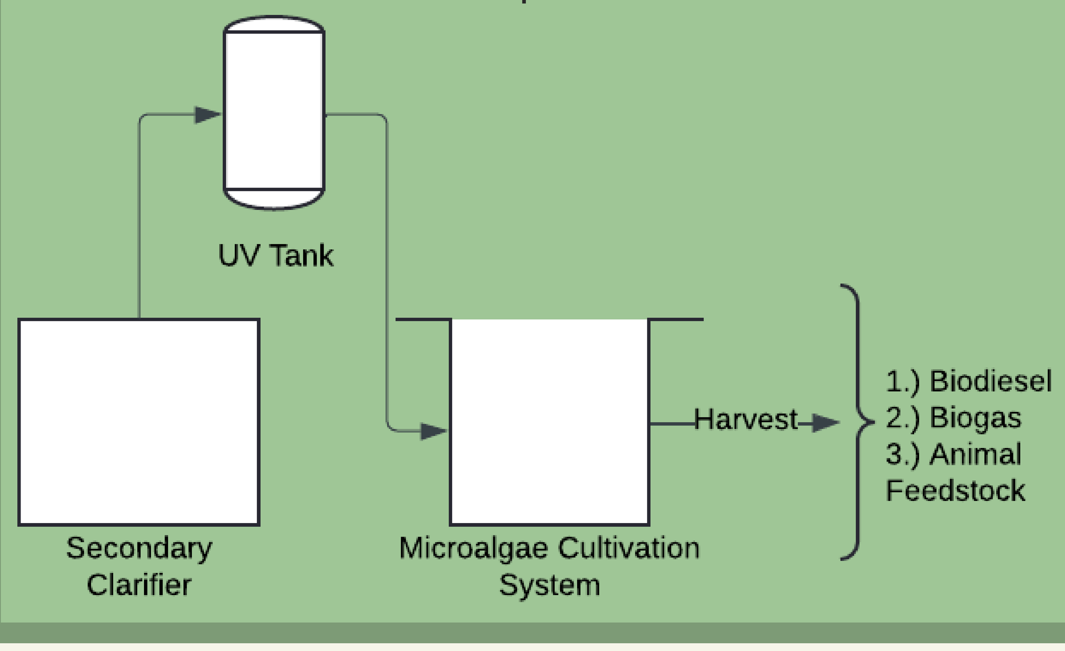
- shallow and open raceway ponds.
- high pollutant removal efficiency.
- high rate of nutrient intake.
- lost cost of implementation.
- low maintenance.
- high biomass production.





2.) Plastic Bag Photobioreactors [4]

- vertical and outdoor systems.
- cultures are re-circulated using a pump or aeration system.
- controlled environments.
- reduced contaminations.
- higher productivity due to higher cell concentrations.
- minimize water evaporation.



WATER PARAMETERS [2][5]

Parameters	Current Conditions	Ideal Conditions
pH	6.7	7.0
Temperature	18°C	25°C
C/N ratio	~	12:1
Light Intensity	About 18:6 hours	About 16:8 hours
Aeration	Diffusers	2.05 g/L in an aeration intensity of 3 cm3/s.

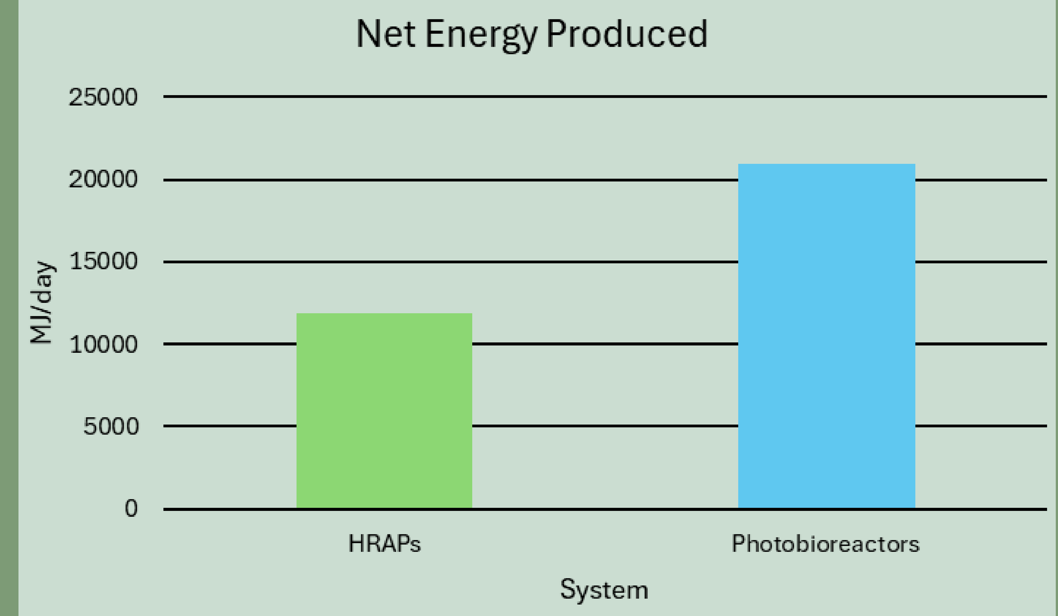
ENERGY BALANCE

Energy Balance was performed on both microalgae cultivation systems [6].

Net energy = energy out - energy in

Energy out: energy produced by microalgae.

Energy In: energy required to produce/cultivate the microalgae.



ECONOMIC ANALYSIS [7] [11]

The selling price for 10% profit margains for diesel produced from HRAPs is $9.84 and $20.53/gal for disel produced from PBRs, higher than cost for disel per gallon.

Process	Productivity	Total Capital Cost	Production Cost
HRAPs	0.9 $kg/m^3 \cdot day$ (Microalgae)	2.125 CAD/m^2	0.00792 CAD/g
PBRs	1.25 $kg/m^3 \cdot day$ (Microalgae)	14.83 CAD/m^2	0.01716 CAD/g
Biofuel HRAPS	0.00495 $liters/m^2/day$	131 $M	0.289 CAD/L
Biofuel Production PBRs	0.00495 $liters/m^2/day$	74 $M	6.31 CAD/L
Biogas Production	2,972,222 kwh/day	16.3 $M	$0.0821 CAD/kWh

METHANE RECIRCULATION

To optimize biomass production from microalgae, a drying process is necessary post-harvest. Presently, methane generated at the facility is flared and remains unutilized. This methane can be redirected to power the microalgae drying process [12], thereby eliminating the need for additional infrastructure expenditures.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

7 AFFORDABLE AND CLEAN ENERGY

6 CLEAN WATER AND SANITATION

SAFE AND SUSTAINABLE CITIES

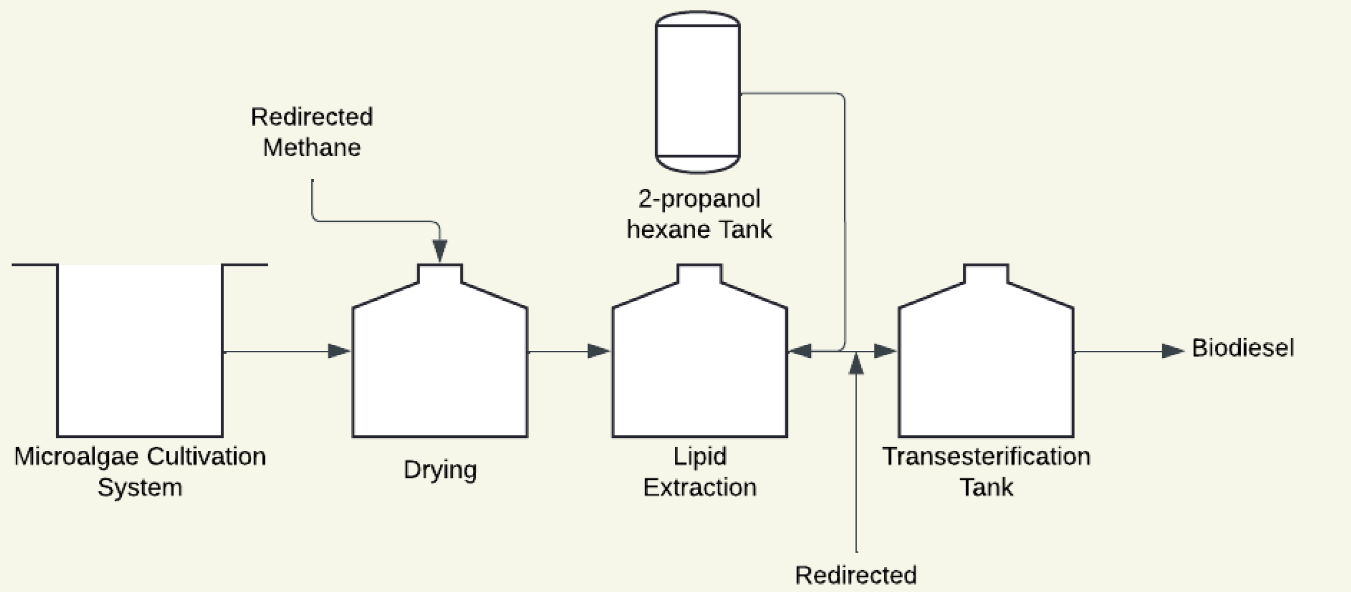
SUSTAINABLE INDUSTRIALIZATION

SAFE WATER IN OUR COMMUNITIES

BIOMASS UTILIZATION SUGGESTIONS

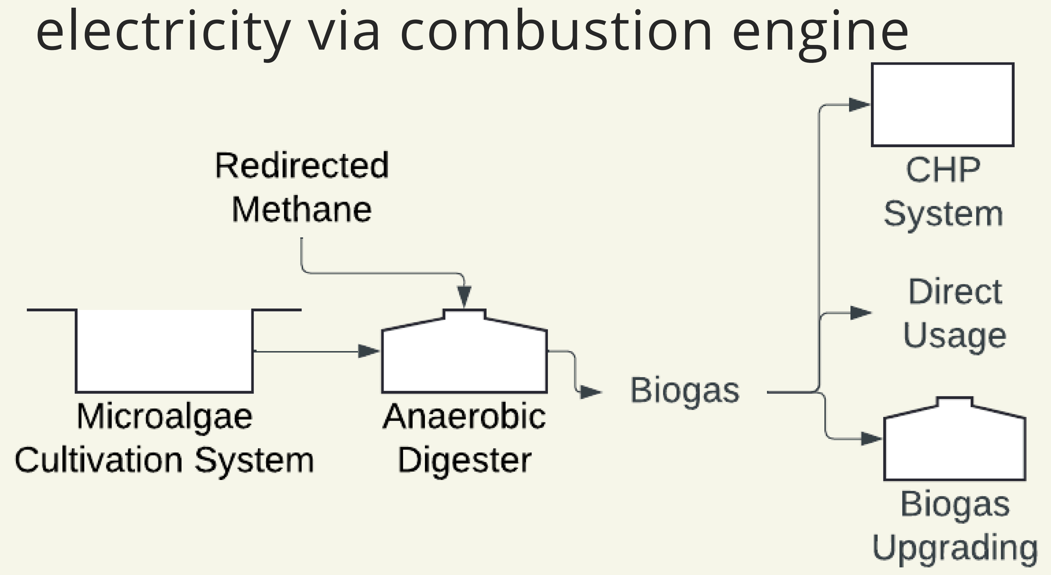
1.) Biofuel Production [8][9]

- Harvesting/Drying - Dry microalgae to produce biomass.
- Lipid Extraction - Use 2-propanol hexane due to low toxicity and easy disposal.
- Transesterification - Convert lipids to biodiesel.



2.) Biogas Production [10][11]

- Mixture of mostly methane (CH_4) and carbon dioxide (CO_2)
- Produced under controlled conditions in anaerobic digesters
- CHP operations, converting it into electricity via combustion engine



3.) Animal Feed Production [12]

- Process the dried biomass into a fine powder or pellets
- Blend with other feed ingredients to ensure an even distribution of nutrients.
- Presence of amino acids, PUFAs, carotenoids and vitamins enhances the nutritional quality of animal products [13].

REFERENCES

[1] "Wastewater collection and treatment," Halton Region, https://www.halton.ca/For-Residents/Water-and-Environment/Wastewater/Wastewater-Treatment-Plants-Tours (accessed Jul. 22, 2024).

[2] Y. Cai et al., "Effects of C/N ratio on the growth and protein accumulation of heterotrophic Chlorella in broken Rice Hydrolysate," Biotechnology for Biofuels and Bioproducts, vol. 15, no. 1, Oct. 2022. doi:10.1186/s13068-022-02204-z

[3] S. Ranjan, P. K. Gupta, and S. K. Gupta, "Comprehensive evaluation of high-rate algal ponds: Wastewater treatment and biomass production," Application of Microalgae in Wastewater Treatment, pp. 531–548, 2019. doi:10.1007/978-3-030-13909-4_22

[4] R. Sirohi, A. Kumar Pandey, P. Ranganathan, S. Singh, A. Udayan f, M. Kumar Awasthi, A. Tuan Hoang, C. Reddy Chilakamarry, S. Hyoun Kim, Sang Jun Sim, "Design and Applications of Photobioreactors- a Review." Bioresource Technology, Elsevier, 17 Feb. 2022, www.sciencedirect.com/science/article/pii/S0960852422001870.

[5] İ. DENİZ, "Determination of growth conditions for Chlorella vulgaris," Marine Science and Technology Bulletin, vol. 9, no. 2, pp. 114–117, Dec. 2020. doi:10.33714/masteb.717126

[6] K. D. Hall et al., "Energy balance and its components: Implications for body weight regulation," The American Journal of Clinical Nutrition, vol. 95, no. 4, pp. 989–994, Apr. 2012. doi:10.3945/ajcn.112.036350

[7] R. Davis, A. Aden, P. T. Pienkos, "Techno-economic analysis of autotrophic microalgae for fuel production, "Applied Energy, 2011.

[8] L. F. Eggers and D. Schwudke, "Liquid extraction: Folch," Encyclopedia of Lipidomics, pp. 1–6, 2016. doi:10.1007/978-94-007-7864-1_89-1

[9] N. A. Azeez et al., "Biodiesel potentials of microalgal strains isolated from fresh water environment," Environmental Challenges, vol. 5, p. 100367, Dec. 2021. doi:10.1016/j.envc.2021.100367

[10] N. Wu et al., 'Techno-Economic Analysis of Biogas Production from Microalgae through Anaerobic Digestion', Anaerobic Digestion. IntechOpen, Sep. 04, 2019. doi: 10.5772/intechopen.86090.

[11] H. M. Zabed, S. Akter, J. Yun, G. Zhang, Y. Zhang, X.Qi, "Biogas from microalgae: Technologies, challenges and opportunities," Renewable and Sustainable Energy Reviews, Volume 117, 2020, 109503, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2019.109503.

[12] A. López-Sánchez et al., "Valorization of livestock waste through combined anaerobic digestion and microalgae-based treatment in México: A techno-economic analysis for distributed biogas generation, animal feed production, and carbon credits trading," Environmental Technology & Innovation, vol. 32, p. 103321, Nov. 2023. doi:10.1016/j.eti.2023.103321

[13] Saadaoui et al., "Microalgal-based feed: Promising alternative feedstocks for livestock and poultry production," Journal of Animal Science and Biotechnology, vol. 12, no. 1, Jun. 2021. doi:10.1186/s40104-021-00593-z