# Life Cycle Energy Use and Greenhouse Gas Emissions for a Coupled Algal-Membrane System versus a Direct Potable Reuse Technology

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## 1. Introduction

Climate change, rapid urbanization, population growth, and increasing energy costs are currently some of the causes of major challenges for public water supplies. Consequently, the development of new alternatives for the potable reuse of wastewater sources has been presented as a possible alternative to meet water demands, and effectively augment water supplies in the future. One of the alternatives is the use of algal based wastewater treatment along with a Forward Osmosis (FO) and Reverse Osmosis (RO) system to produce clean drinking water. This algal FO-RO makes use of algal photobioreactors for the cultivation of the bacteria *G. sulphuria*, which can successfully remove the dissolved organics and nutrients in the primary effluent and meet discharge standards through a period of 2-3 days. This treatment along with the hybrid FO-RO can achieve the respective discharge standards while also serving as a reliable source of potable water reuse.

This research is centered around the application of the Life Cycle Assessment (LCA) methodology to provide a comparative environmental analysis between the Algal FO-RO system and another direct potable reuse technology. The selected direct potable reuse technology for the comparison was based on the treatment train of the Advanced Water Purification Facility (AWPF) of El Paso Water, which consists of microfiltration (MF), reverse osmosis (RO), ultraviolet/advanced oxidation process (UV/AOP), and granular activated carbon for peroxide quenching (GAC).

## 2. LCA Methodology

An LCA is a cradle to grave approach that serves as a tool for the measurement of the environmental performance of products and processes. It is a structured, systematic phased approach that consists of four components: goal and scope definition, inventory analysis, impact assessment, and interpretation.

### 2.1 Goal and Scope

The general goal of this research is focused on the comparison of the environmental impact and energy consumption of a coupled algal-membrane system versus a direct potable reuse (DPR) treatment technology. The data and results collected throughout the LCA will be utilized for the improvement of different aspects of the algal-membrane system treatment train, to promote the reduction of resource requirements, and to minimize emissions that may harm the environment.

This study excludes the collection and transportation of wastewater across the pipelines that may be interconnected to the systems. The construction phase of the system is also excluded, because the impact of the operation phase is typically larger than that of the construction phase. The focus of this comparison is only directed to the system's operation. Some exclusions were also applied on the operation phase, such as sludge and waste disposal, due to lack procedure data and due to the lack of waste being generated on the Algal FO-RO. Preliminary and primary treatment of both systems were also excluded from the LCA analysis because it is a common factor for both systems. Therefore, the initial point of the LCA was the feed water origin. In the case of the Algal FO-RO system, it was the algal photobioreactor. For the AWPF, it was their secondary treatment process, which consists of an activated sludge system with extended aeration and a secondary clarifier. The flow rate considered for both treatment systems is around 100 GPM, and the functional unit is cubic meters of water treated. Some assumptions were also made due to lack of actual data, and treatment train modifications were done on both systems for a more accurate comparison.

## 2.2 Life Cycle Inventory

A life cycle inventory consists of quantifying the different inputs and outputs of the systems that are being evaluated, via the use of a spreadsheet. Typical inputs and outputs that are quantified can be energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, or any other releases throughout the entire life cycle of a product, process, or activity. Inputs of energy consumption and chemical consumption were quantified for both systems via pilot scale report data and typical literature data. The only output considered on both systems were the greenhouse gas (GHG) emissions, which consisted of $CO_2$ & $N_2O$.

## 2.3 Life Cycle Characterization

The Life Cycle Impact Assessment phase consists of the evaluation of the potential human health and environmental impacts of the different inputs and outputs identified during the Life Cycle Inventory Phase. A life cycle impact assessment attempts to establish a linkage between the product or process and its potential environmental impacts. The impact category of focus is the Global Warming Potential, as emissions from both systems (chemical manufacturing, electricity generation, and treatment emissions) can be further categorized into $CO_2$ equivalent emissions (Figure 1).

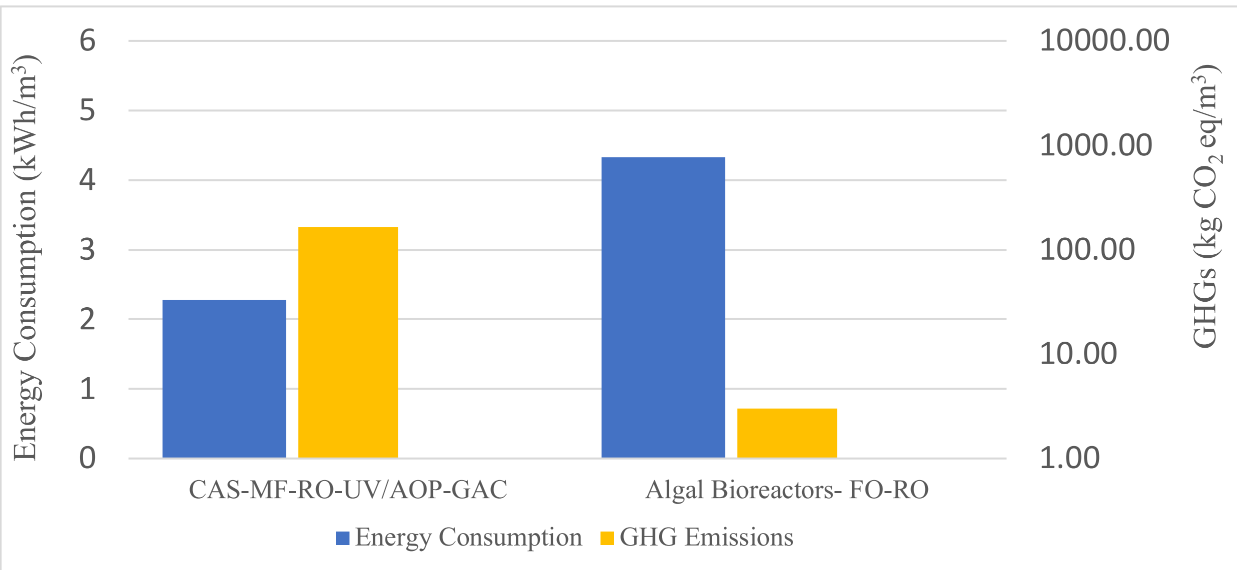


*Figure 1: Life Cycle Energy Use and GHG Emissions Benchmarking*

## 3 Interpretation of Results & Discussion

The life cycle assessment methodology was applied to this research to determine the different environmental impacts of both direct potable reuse systems that were evaluated. These impacts are quantified through the life cycle impact assessment, and their effects on the environment are interpreted and analyzed based on the data. Conclusions and recommendations can be made as to the environmental aspects of the product and the possible areas for improvement. Impact assessment results shows the need for improvement on the energy consumption of the Algal FO-RO system. The major factor for such a high energy consumption is centered around the energy requirement for the seawater RO operation, which consists of 64% of the energy being consumed. A possible improvement on this area, could be the increase of membrane elements on the system. Results show that the Algal FO-RO provides a lesser environmental impact that typical conventional treatment practices. While both systems assessment was based on pilot scale data, the results can be indicative of which system is has a lesser environmental footprint at full-scale.

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