

A Scientific Research for an Artificial BioSystem Reactor Unit Including a Thermodynamic Energy Conversion System to be used for Space Science

***Emin Taner ELMAS¹**

^{*1} Assistant Professor Dr., Vocational School of Higher Education for Technical Sciences, Division of Motor Vehicles and Transportation Technologies, Department of Automotive Technology, Iğdır University, Turkey & Graduate School of Natural and Applied Sciences - Major Science Department of Bioengineering and Bio-Sciences, Iğdır University, Turkey

Iğdır University, 76000

Iğdır – TURKEY

^{*1}ORCID ID: <https://orcid.org/0000-0002-7290-2308>

Abstract

Human exploration of celestial bodies such as the Moon and Mars necessitates the management and recycling of life support-derived wastes, alongside the vital conservation of resources like fuel, water, and oxygen. Anticipated waste streams include three primary categories: (1) black water (originating from sanitation systems), (2) food waste (from meal preparation and consumption), and (3) grey water (or hygiene-related wastewater). To sustain human life during prolonged off-Earth missions, efficient recovery of carbon, oxygen, hydrogen, and other essential microchemicals from food, water, and air is essential. This minimizes the frequency of costly resupply missions for these critical resources. Any recovery technology implemented must adhere to strict criteria: it should be compact, lightweight, energy-efficient, and require

minimal oxygen use while ensuring simplicity in operation and low maintenance demands. Additionally, these systems must maximize the recovery rates of life support resource chemicals for reuse. The ideal design would also incorporate flexibility to accommodate unexpected challenges, maintaining functionality through built-in failsafe mechanisms. The proposed Biochemical Conversion System offers a comprehensive solution, effectively processing waste generated from human activities—including black water, grey water, and food waste—while delivering valuable by-products. These outputs include recyclable potable water, oxygen, fuel, protein-rich cake, and machinery lubricants, facilitating sustainable long-term human presence in extraterrestrial environments.

The main development objectives for the BioSystem Reactor project are as follows: (a) achieve energy and oxygen neutrality; (b) maintain a compact process footprint with minimal payload weight; (c) ensure the system's ability to treat both water and air to reusable standards; and (d) generate byproducts that contribute to life support functionality. The core design concept incorporates a series of treatment processes aimed at converting wastewater components and cabin CO₂ into valuable life support outputs. This system integrates anaerobic and aerobic bioreactor units, lipid extraction, a microalgae reactor, and an adsorption polishing step. Through these processes, contaminants in water are reduced to near-zero levels. The design facilitates the production of multiple outputs, including: (1) hydrogen fuel for use in fuel cells; (2) methane, which can either serve as fuel for fuel cells or be utilized in the aerobic bioreactor for additional protein or lipid production; (3) recycled oxygen that can be reintroduced into the cabin environment; (4) lipids for creating "green" lubricants or nutraceutical applications; (5) protein cake (with or without lipids) as a potential food source; (6) fertilizer for soil enrichment; and (7) purified water recycled as potable water. A notable challenge involves oxygenating the aerobic unit, as it creates an oxygen demand that may prove too energy-intensive. To address this, an alternative design will be considered, replacing the aerobic stage with a passive solids separator to minimize energy and oxygen consumption. The research plan includes assessing the performance of each individual unit through small-scale reactors tested under a wide range of feed rates and compositions, simulating both standard and stress scenarios. Once optimized individually, these units will be integrated into a bench-scale system and evaluated under stress conditions. Mass and energy balance analyses will be performed across the system and within each unit to enhance the overall efficiency of the bench system. Insights from this stage will inform the development of a pilot-scale system, whose performance will undergo thorough testing. The comprehensive evaluation will also include payload analysis and operational

protocols as part of the final design considerations. Ultimately, the BioSystem Reactor aims to operate at a nearly neutral energy footprint, with an energy output-to-input ratio of 1.0, while targeting a more ambitious ratio exceeding 1.2. (energy ratio E_{out}/E_{in}] equal to 1.0 with 1.2+ being a target). [1-105]

Keywords: BioSystem Reactor Unit”, Recovery, Recycling, Thermodynamics, Energy, Energy Transfer, Energy Conversion, Energy Ratio, Mathematics, Waste Water, Moon, Mars,

Introduction

Humanity's ambitious journey to Mars aims to send astronauts to the Red Planet in the 2030s, with long-term plans to establish a sustainable colony capable of supporting human life for extended periods. Central to this endeavor are vital components such as waste management and energy provision, which are indispensable for sustaining life and human activities on Mars. This project proposes the development of an advanced waste management system, the BioSystem Reactor Unit (BIOSYS). The system is designed to transform water-based waste streams and associated pollutants into valuable byproducts, including reclaimed water, energy (in the form of hydrogen and/or methane), lipids for food production, lubricating oils, microbial protein for consumption, and soil amendments for cultivating crops on Mars. Additionally, the BIOSYS will remove carbon dioxide from cabin air, recycling it for life support purposes. Comprising a combination of microbial-based (bacteria, yeast, and algae) and physical unit processes, the BIOSYS is engineered to achieve several goals: (a) maintain energy and oxygen neutrality; (b) operate within a compact footprint; (c) treat water and air to reusable quality standards, ensuring resource recycling; and (d) produce surplus co-products to enhance long-term survival on Mars. The sustainability of human life in a Mars colony requires a suite of advanced life support technologies, encompassing waste management systems and on-site food production capabilities. In tandem with Martian colonization, humanity is also gearing up for lunar habitation as a precursor to Mars missions and as a launchpad for deeper space exploration. Consequently, life support systems tailored for colonization of both the Moon and Mars are paramount research and development priorities. These systems—particularly the BioSystem Reactor Unit—must meet stringent criteria: low energy consumption, high efficiency in resource recycling, and adaptability to human needs in extraterrestrial environments. Human activity within these future residences will inevitably generate waste while consuming vital resources such as water and oxygen. Key waste streams identified by space mission experts

include: (1) Black Water (toilet waste such as feces, urine, toilet paper, and water); (2) Food Waste (from kitchen and cafeteria operations, contributing some water content); (3) Grey Water (primarily hygiene-related wastewater, e.g., sink or shower runoff containing soap); and (4) Plastic/Paper Trash. To sustain a crew member during a space mission, approximately 5.8 kg of food, water, and oxygen are required per day. On missions like those aboard the International Space Station, fresh water constitutes a significant portion of the life support consumable resupply weight. Current scientific understanding of lunar and Martian geochemical and atmospheric systems suggests that in-situ production of water and oxygen from native resources poses significant challenges. Therefore, efficient conservation and recycling of available resources are critical. To enable sustainable human presence on the Moon, Mars, and beyond, it is essential to recover and reuse the chemical components that comprise astronauts' food, water, and air. Reducing dependence on frequent resupply missions will dramatically lower cost and logistical constraints. The proposed technology must meet a range of criteria: compact design with low weight; minimal energy consumption and oxygen usage; ease of operation with low maintenance requirements; and high efficiency in recovering life support resources for reuse. These advancements will be crucial in ensuring the feasibility and success of humanity's interplanetary ambitions. [1-105]

Material, Method, and Discussion

This project aims to develop an innovative waste management system that operates with energy and oxygen neutrality, balancing or exceeding its consumption of these resources. The system is designed not only to achieve effective treatment goals but also to generate additional life-support resources as valuable byproducts. The primary concept for the BioSystem Reactor Unit is outlined below and illustrated in Figure 1. Central to this design is the inclusion of an aerobic biotreatment phase, among other integrated processes, which supports the production of lipid-enriched biomass. This phase will necessitate some form of oxygen input or may alternatively utilize nitrate as an anoxic electron acceptor. The system is engineered to treat the chemical oxygen demand (COD) in water influents to near-zero levels. Essentially, almost all COD will be converted into value-added chemicals, with minimal residuals addressed in a downstream polishing stage. [1-105]

The outputs of this system include a diverse range of useful products:

1. ****Hydrogen**** – to serve as fuel for fuel-cell applications.

2. **Methane** – usable as fuel for fuel cells or alternatively fed back into the aerobic bioreactor to enhance protein and/or lipid production via methanotrophic processes.
3. **Recovered Air** – containing reduced CO₂ levels, to be recycled into the cabin environment for reuse.
4. **Lipids** – suitable for the production of "green" lubricants or as nutraceuticals.
5. **Protein Cake** (with or without lipids) – a potential food source for animals and even humans.
6. **Soil Amendments** – usable as soil fertilizers and conditioners.
7. **Recovered Water** – treated and purified for reuse as potable water. Two distinct waste influent scenarios are considered within the system design:
 - **Scenario A:** All three waste streams (grey water, black water, and food waste) are processed through the anaerobic digestion stage.
 - **Scenario B:** Black water and food waste are directed into the anaerobic stage for treatment to maximize COD input into the reactor. Higher COD loads lead to increased hydrogen and methane outputs. In this scenario, grey water bypasses the anaerobic process and is treated directly in the aerobic bioreactor, potentially sacrificing some mass hydrogen production but offering increased lipid yield. Additionally, secondary processing pathways are evaluated, such as routing digester biogas through an algal bed. This step serves to remove carbon dioxide while fostering the generation of additional algal biomass, further enhancing the system's sustainability and productivity. [1-105]

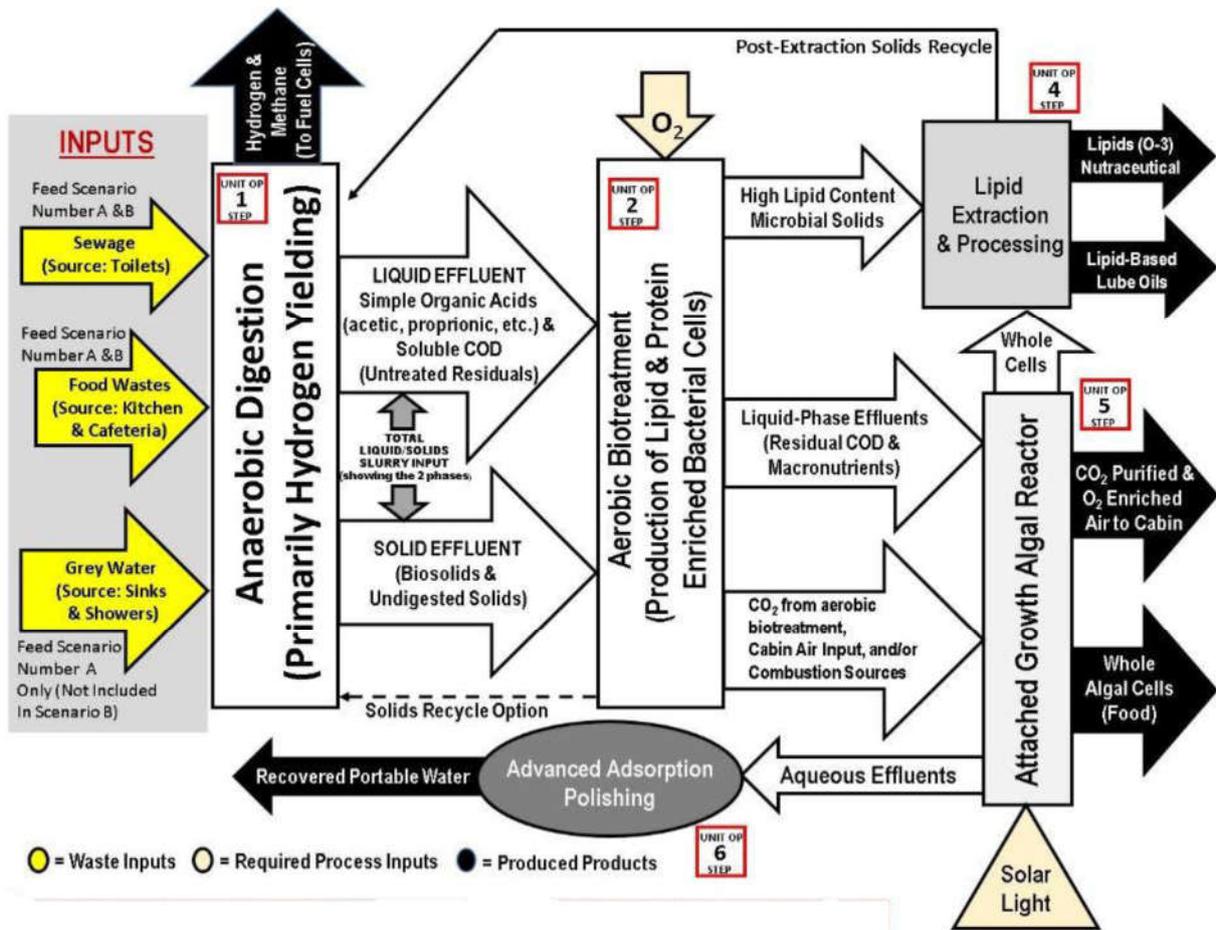


Figure 1: BioSystem Reactor Design Process Flow Diagram. [1-105]

The system as a whole consists of a sequence of unit operations, or process steps, designed to either add or remove mass or energy. Consequently, a comprehensive Mass and Energy Balance for inputs, internal processes, and outputs across the entire system will be conducted regularly to assess R&D progress. This methodology has previously been applied to the development of less integrated and holistic life support systems for space exploration. [1-105]

Conclusion

In conclusion, the BioSystem Reactor is designed to effectively process all human-derived water-based waste streams, including black water, grey water, and food residues, by combining biological and physicochemical approaches. The primary technical objective is for the system to generate valuable by-products such as reclaimed potable water, purified breathable air (with carbon dioxide reduced to standard atmospheric levels), edible protein cake (with or without lipids), soil enhancements, and machinery-grade lubrication oils. Additionally, the reactor will capture and bind carbon dioxide within microalgal cells and associated by-products—such as oxygen—effectively producing recovered cabin air. The project aims to achieve the following goals: (a) restore breathable air within colonies to normal oxygen and carbon dioxide levels (21% and 0.04% v/v, respectively); (b) ensure the removal of more than 99% of organic pollutants and nutrients; (c) provide reclaimed water of potable quality; (d) achieve total conversion of solid waste into microbial biomass (either algal or bacterial), protein cake, hydrogen, and/or methane; (e) develop a compact and lightweight system constrained to a target volume of 10 cubic feet and weight of 100 pounds per individual; (f) fully optimize the system for comprehensive recycling, leaving no residual waste; and (g) design the system to operate with an energy balance that is either neutral or positive (targeting an energy output-to-input ratio of 1.0, with a goal of exceeding 1.2). (energy ratio E_{out}/E_{in}] equal to 1.0 with 1.2+ being a target). [1-105]

BIOGRAPHY OF AUTHOR:**Asst. Prof. Dr. Dipl.-Ing. Emin Taner ELMAS**

Asst.Prof. Dr. Emin Taner ELMAS is a Mechanical Engineer having degrees of B.Sc., M.Sc., Ph.D., and was born in Sivas in 1974. He completed his doctorate at Ege University, Graduate School of Natural and Applied Sciences, Mechanical Engineering Department, Thermodynamics Science Branch, and his master's degree at Dokuz Eylül University, Mechanical Engineering Department, Energy Science Branch. He also completed his undergraduate education at Hacettepe University, ZEF, Mechanical Engineering Department and graduated from the faculty with honors in 1995 and became a mechanical engineer. He was awarded a non-refundable scholarship by the Turkish Chamber of Mechanical Engineers in his 4th year because he was the most successful student during his first 3 classes study at the faculty. He graduated from İzmir Atatürk High School in 1991.

Asst. Prof. Dr. ELMAS has completed his military service as a NATO Officer in Bosnia and Herzegovina. He was a “Reserved Officer” as a “2nd Lieutenant” as an “English-Turkish Interpreter”. He was also a “Guard Commander” and served in Sarajevo, Camp Butmir within the SFOR task force of NATO. He has been awarded with 2 (two) NATO Medals and Turkish Armed Forces Service Certificate of Pride (Bosnia & Herzegovina).

In addition to his academic duties at universities, he has worked as an engineer and manager in various industrial institutions, organizations and companies; He has served as Construction Site Manager, Project Manager, Management Representative, Quality Manager, Production Manager, Energy Manager, CSO-CTO, CBDO, Factory Manager, Deputy General Manager and General Manager.

Asst. Prof. Dr. Elmas is Department Head and is an Assistant Professor of Automotive Technology at the Department of Motor Vehicles and Transportation Technologies at Vocational School of Higher Education for Technical Sciences at IGDİR UNIVERSITY, Turkey. He is also an Assistant Professor of Bioengineering & BioSciences at the same university. He has nearly 30 years of total experience in academia and in industry.

He has served as a scientific referee and panelist for ASME, TUBITAK and many scientific institutions, organizations and universities, including NASA.

“Mechanical Engineering, Energy Transfer, Thermodynamics, Fluid Mechanics, Heat Transfer, Higher Mathematics, Evaporation, Heat Pipes, Space Sciences, Automotive, Bioengineering, Medical Engineering Applications, Neuroengineering, Medical Technique” are his academic and scientific fields of study; “Heating-Ventilation Air Conditioning Applications, Pressure Vessels, Heat Exchangers, Energy Efficiency, Steam Boilers, Power Plants, Cogeneration, Water Purification, Water Treatment, Industrial Equipment and Machinery, Welding Manufacturing, Sheet Metal Forming, Machining” are his industrial experience fields.

Asst. Prof. Dr. Emin Taner ELMAS is also a musician, saz (baglama) virtuoso player and ney (Nay, Turkish Reed Flute) performer. He plays also cümbüş instrument and performs darbuka rhythm instrument. He has a YouTube Music Channel (Emin Taner ELMAS) which includes some of his sound recordings of him playing the saz-baglame and blowing the ney. He composed the poem written by the great poet Âşık Veysel ŞATIROĞLU under the name of “Raşit Bey” in memory of his father Judge (Hâkim) Raşit ELMAS as “Raşit Bey Türküsü”, wrote it down, notated and published it as an academic article and broadcasted this song on his own music channel. He wrote the poems entitled “Canım Babam” and “Geldim Babam” which he wrote also in memory of his father and published in an academic literature journal, and composed instrumental musics for these poems. He also composed an instrumental song called “Annem Annem Türküsü” and gave it to his mother, Lawyer Tuna ELMAS, as a gift on Mother’s Day, 11.05.2025. He also has a poem titled "Ney and Neyzen." He also wrote and presented a poem titled "Esra Kardeşim" to his sister, Esra ELMAS, an archaeologist and English teacher. He has published books including "Saz-Bağlama Tuning System Method" (“Saz- Bağlama Akort Sistemi Metodu”) and "Ney and Neyzen; Ney's Pitches, Frets, Sound Stages, Octaves, Structure, Performance, Ney Maintenance and Basic Music Theory" (Ney ve Neyzen; Ney’de Perdeler, Ses Devreleri, Oktavlar, Yapısı, İcrası, Ney Bakımı ile Temel Musiki Nazariyatı). He continues his artistic studies by writing various articles, books, poetry, lyrics and also realizing musical composition and repertoire works.

References

- [1] Fulcher, J., 2013, "Water-Recycling in Space Evolves", April 2013 WEF Highlights, Water Environment Federation, Washington DC, URL: <http://news.wef.org/water-recyclingtechnology-in-space-evolves/>
- [2] Ganzer, B. and Messerschmid, E., 2009, "Integration of an Algae Photobioreactor into an Environmental Control and Life Support System of a Space Station", *Acta Astronautica*, 65, pp. 248-261.
- [3] Jones, H. and Kliss, M., 2010, "Exploration of Life Support Technology Challenges for the Crew Exploration Vehicle and Future Human Missions", *Advances in Space Research*, 45, pp. 917-928.
- [4] Nelson, M., et al., 2008, "Integration of Lessons from Recent Research from "Earth to Mars" Life Support Systems", *Advances in Space Research*, 41, pp. 675-683.
- [5] Larson, W. and Wertz, J., 1999, *Space Mission Analysis and Design*, Space Technology Library, ISBN: 1-881883-10-8.
- [6] Cath, T., et al., 2005, "Membrane Contactor Processes for Wastewater Reclamation in Space II: Combined Direct Osmosis, Osmotic Distillation, and Membrane Distillation for Treatment of Metabolic Wastewater", *Journal of Membrane Science*, pp. 111-119.
- [7] Peterson, L., et al., 2006, "Recommendations for Water Systems in Future Space Applications", Society of Automotive Engineers International (SAE) paper 2006-01-2095.
- [8] Sridhar, K., et al., 2000, "In-Situ Resource Utilization Technologies for Mars Life Support Systems", *Advanced in Space Research*, 25, pp. 249-255.
- [9] Moore, C., 2010, "Technology Development for Human Exploration of Mars", *Acta Astronautica*, 67, pp. 1170-1175.
- [10] Drake, B., 2009, *Human Exploration of Mars Design Reference Architecture 5.0*, Report No. NASA/SP-2009-566.
- [11] Rapp, D., 2006, "Mars Life Support Systems", *Mars*, 2, 72-82.

- [12] Morton, S., et al., Feasibility of Ground Testing A Moon and Mars Surface Power Reactor in EBR-II, INL/CON-05-00768, DOE Idaho National Laboratory.
- [13] NASA, 2002, Waste Collection System, URL:
<http://spaceflight.nasa.gov/shuttle/reference/shutref/orbiter/eclss/wcs.html>.
- [14] Zhao, et al., 2013, “Water Regeneration from Human Urine by Vacuum Membrane Distillation and Analysis of Membrane Fouling Characteristics”, *Separation and Purification Technology*, 118, pp. 369-376.
- [15] Guo, B., et al., 2005, “Two-Phase Oxidizing Flow in a Volatile Removal Assembly Reactor under Microgravity Conditions”, *American Institute of Aeronautics and Astronautics Journal*, 43(12), pp. 2586-2592.
- [16] Thomas, E., et al., 2010, “Design Considerations for Sustainable Spacecraft Water Management Systems”, *Advances in Space Research*, 46, pp. 761-767.
- [17] Drysdale, A., et al., 2003, “Life Support Approaches for Mars Missions”, *Advances in Space Research*, 31, pp. 51-61.
- [18] Bamsey, M., et al., 2009, “Canadian Advanced Life Support Capacities and Future Directions”, *Advances in Space Research*, 44, pp. 151-161.
- [19] Calvo-Lopez, A., et al., 2013, “Biparametric Potentiometric Analytical Microsystem for Nitrate and Potassium Monitoring in Water Recycling Processes for Manned Space Missions”, *Analytica Chimica Acta*, 804, pp. 190-196.
- [20] Tong, L., et al., 2012, “The Fluxes of Carbon, Nitrogen, and Water in the Multi-Biological Life Support System”, *Ecological Engineering*, 43, pp. 91-94.
- [21] Do, S., et al., 2016, “An Independent Assessment of the Technical Feasibility of the Mars One Mission Plan – Updated Analysis”, *Acta Astronautica*, 120, pp. 192-228.
- [22] Aydogan-Cremaschi, S., et al., 2009, “A Novel Approach for Life-Support-System Design for Manned Space Missions”, *Acta Astronautica*, 65, pp. 330-346.
- [23] Rice, E., et al. (Eds.), 2012, *Standard Methods for Examination of Water and Wastewater*, 22nd Ed., APHA, ISBN: 9780875530130.

- [24] Fortela, D.L., et al., 2016, "Microbial Lipid Accumulation Capability of Activated Sludge Feeding on Short Chain Fatty Acids as Carbon Sources through Fed-Batch Cultivation", *Journal of Bioprocessing and Biotechniques*, 6(275), DOI: 10.4172/2155-9821.1000275.
- [25] Raeshwari, K., et al., 2000, "State-of-the-Art of Anaerobic Digestion Technology for Industrial Wastewater Treatment", *Renewable and Sustainable Energy Reviews*, 4, pp. 135-156.
- [26] Han, S. and Shin, H., 2004, "Biohydrogen Production by Anaerobic Fermentation of Food Waste", *International Journal of Hydrogen Energy*, 29, pp. 569-577.
- [27] Kim, S., et al., 2004, "Feasibility of Biohydrogen Production by Anaerobic Co-Digestion of Food Waste and Sewage Sludge", *International Journal of Hydrogen Energy*, 29, pp. 1607-1616.
- [28] Dhoble, A., 2014, "Design and Operation of an Anaerobic Digester for Waste Management and Fuel Generation during Long-Term Lunar Missions", *Advances in Space Research*, 54, pp. 1502-1512.
- [29] Cakir, F. and Stenstrom, M., 2005, "Greenhouse Gas Production: A Comparison between Aerobic and Anaerobic Wastewater Treatment Technology", *Water Research*, 39, pp. 4197-4203.
- [30] Fraser, S., 2009, *Mars: Prospective Energy and Materials Resources*, Springer-Berlin-Heidelberg, ISBN: 978-3-642-03628-6.
- [31] Belz, S., et al., 2013, "Hybrid Life Support Systems with Integrated Fuel Cells and Photobioreactors for a Lunar Base", *Aerospace Science and Technology*, 24, pp. 169-176.
- [32] Choo, K., and Lee, C., 1996, "Membrane Fouling Mechanisms in the Membrane-Coupled Anaerobic Bioreactor", *Water Research*, 30, pp. 1771-1780.
- [33] Pinske, C., et al., 2014, "Physiology and Bioenergetics of [NiFe]-hydrogenase 2-catalyzed H₂-consuming and H₂-producing Reactions in *Escherichia coli*", *Journal of Bacteriology*, 197(2), pp. 296-306.
- [34] McDowall, J., et al., 2014, "Bacterial Formate Hydrogenlyase Complex", *PNAS*, 111(38), pp. E3948-E3956.

- [35] Venkata Mohan, S., et al., 2007, “Anaerobic Biohydrogen Production from Dairy Wastewater Treatment in Sequencing Batch Reactor (anSBR): Effect of Organic Loading Rate”, *Enzyme and Microbial Technology*, 41, pp. 506-515.
- [36] Bharathiraja, B., 2016, “Biohydrogen and Biogas – An Overview on Feedstocks and Enhancement Process”, *Fuel*, 185, pp. 810-828.
- [37] Sinha, P., 2016, “Genomic and Proteomic Approaches for Dark Fermentative Biohydrogen Production”, *Renewable & Sustainable Energy Reviews*, 56, pp. 1308-1321.
- [38] Taconi, K., et al., 2008, “Methanogenesis Under Acidic pH Conditions in a Semi-Continuous Reactor System”, *Bioresource Technology*, 99, pp. 8075-8081.
- [39] Jiang, J., et al., 2013, “Volatile Fatty Acid Production from Food Waste: Effects of pH, Temperature, and Organic Loading Rate”, *Bioresource Technology*, 143, pp. 525-530.
- [40] Zhang, R., et al., 2007, “Characterization of Food Waste as Feedstock for Anaerobic Digestion”, *Bioresource Technology*, 98, pp. 929-935.
- [41] Izumi, K., et al., 2010, “Effects of Particle Size on Anaerobic Digestion of Food Waste”, *International Journal of Biodeterioration and Biodegradation*, 64, pp. 601-608.
- [42] Taconi, K., et al., 2007, “Feasibility of Methanogenic Digestion Applied to a Low pH Acetic Acid Solution”, *Bioresource Technology*, 98, pp. 1576-1585.
- [43] Fortela, D.L., et al., 2016, “Biodiesel Profile Stabilization and Microbial Community Selection of Activated Sludge Feeding on Acetic Acid as a Carbon Source”, *ACS Sustainable Chemistry & Engineering*, 4, pp. 6427-6434.
- [44] Berkovich, Y., et al., 2009, “Vegetable Production Facility as a Part of the Closed Life Support System in a Russian Martian Space Flight Scenario”, *Advances in Space Research*, 44, pp. 170-176.
- [45] Rosenberger, S., et al., 2002, “Performance of a Bioreactor with Submerged Membranes for Aerobic Treatment of Municipal Wastewater”, *Water Research*, 36, pp. 413-420.
- [46] Munoz, R., et al., 2009, “Biofilm Photobioreactors for the Treatment of Industrial Wastewaters”, *Journal of Hazardous Wastes*, 161, pp. 29-34.

- [47] Petruccioli, M., et al., 2000, "High-Rate Aerobic Treatment of Winery Wastewater Using Bioreactors with Free and Immobilized Activated Sludge", *Journal of Bioscience and Bioengineering*, 90, pp. 381-386.
- [48] Garcia-Ochoa, F., et al., 2000, "Oxygen Transfer and Uptake Rates during Xanthan Gum Production", *Enzyme, and Microbial Technology*, 27, pp. 680-690.
- [49] Zappi, M., et al., 1994, Development of a Zero HeadSpace Aerobic, Suspended Growth Bioreactor, Report No. MP-EL-94-8, USAE Waterways Experiment Station, Vicksburg, MS.
- [50] Pai, S., et al., 1999, "Potential Applications of Aerobic Denitrifying Bacteria as Bioagents in Wastewater Treatment", *Bioresource Technology*, 68, pp. 179-185.
- [51] Lee, W., et al., 2014, "A Review of the Production and Applications of Waste-Derived Volatile Fatty Acids", *Chemical Engineering Journal*, 235, pp. 83-99.
- [52] Quinchia, L., et al., 2010, "Viscosity Modification of Different Vegetable Oils with EVA Co- Polymer for Lubrication Applications", *Industrial Crops and Products*, 32, pp. 607-612.
- [53] Ting, C., 2011, "Viscosity and Working Efficiency Analysis of Soybean Oil Based Bio-Lubricants", *Measurement*, 44, pp. 1337-1341.
- [54] Nagendramma, P., 2012, "Development of Eco-Friendly/Biodegradable Lubricants: An Overview", *Renewable and Sustainable Energy Reviews*, 16, pp. 764-774.
- [55] Sparks, D., et al., 2006, "Extraction of Rice Bran Oil Using Supercritical Carbon Dioxide and Propane", *Journal of the American Oil Chemists' Society*, 83, pp. 885-891.
- [56] Dufreche, S., et al., 2007, "Extraction of Lipids from Municipal Wastewater Plant Microorganisms for Production of Biodiesel", *Journal of the American Oil Chemists' Society*, 84, pp. 181-187.
- [57] Sierra, E., et al., 2008, "Characterization of a Flat Plate Photobioreactor for the Production of Microalgae", *Chemical Engineering Journal*, 138, pp. 136-147.
- [58] Moreno-Garrido, I., 2008, "Microalgae Immobilization: Current Techniques and Uses", 99, pp. 3949-3964.
- [59] Jacob-Lopez, E., et al., 2008, "Rates of CO₂ Removal by *Aphanothece microscopica Nageli* in Tubular Photobioreactors", *Chemical Engineering and Processing*, 47, pp. 1365-1373.

- [60] Abdel-Raouf, A., et al., "Microalgae and Wastewater Treatment", Saudi Journal of Biological Sciences, 19, pp. 257-275.
- [61] Cai, T., 2013, "Nutrient Recovery from Wastewater Streams by Microalgae: Status and Prospects", Renewable and Sustainable Energy Reviews, 19, pp. 360-369.
- [62] Ugwu, C., et al., 2008, "Photoreactors for Mass Cultivation of Algae", Bioresource Technology, 99, pp. 4021-4028.
- [63] Delgadillo-Mirquez, L., et al., 2013, "Nitrogen and Phosphate Removal from Wastewater with a Mixed Microalgae and Bacteria Culture", Biotechnology Reports, 11, pp. 18-26.
- [64] Vergara, C., et al., 2016, "Influence of light Intensity on Bacterial Nitrifying Activity in Algal-Bacterial Photobioreactors and its Implication for Microalgal-Based Wastewater Treatment", International Biodeterioration and Biodegradation, 114, pp. 116-121.
- [65] Dalibauman, L. and Finn, J., 1999, "Adsorption Processes in Spacecraft Environmental Control and Life Support Systems", Studies in Surface Sciences and Catalysis, 120, pp. 455-471.
- [66] Chang, E.E., et al., 2007, "Establishment and Implementation of Source Water Implementation Plan for Water Treatment Plants in Taiwan", Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management, 11(1), pp. 20-27.
- [67] Kim, J. M., et al., 1998, "Synthesis of MCM-48 Single Crystals", Chemical Communications, 2, pp. 259-260.
- [68] Zhao, D., et al., 1998, "Triblock Copolymer Syntheses of Mesoporous Silica with Periodic 50 to 300 Angstrom Pores", Science, 279, pp. 548-552.
- [69] Van Vliet, B.M., 1991, "The Reactivation of Activated Carbon", Journal of the Southern African Institute of Mining and Metallurgy, 91(5), pp. 159-167.
- [70] Kanazawa, S., et al., 2008, "Space Agriculture for Habitation on Mars with Hyper-Thermophilic Aerobic Composting Bacteria", Advances in Space Research, 41, pp. 696-700.
- [71] Gebrezgabher, S., et al., 2010, "Economic Analysis of Anaerobic Digestion – A Case for Green Power Biogas Plant in the Netherlands", Wageningen Journal of Life Sciences, 57, pp. 109-115.

[72] Alcantara, C., et al., 2013, "Evaluation of Mass and Energy Balances in the Integrated Microalgae Grown-Anaerobic Digestion Process", *Chemical Engineering Journal*, 221, pp. 238-246.

[73] Emin Taner E. (2023). Thermodynamical And Experimental Analysis of Design Parameters of a Heat Pipe Air Recuperator. *Global Journal of Research in Engineering & Computer Sciences*, 3(6), 6–33. <https://doi.org/10.5281/zenodo.10116309>

[74] Elmas, Emin Taner (2019) Thermodynamical Balance Associated with Energy Transfer Analysis of the Universe Space as a Pressure Vessel Analogy. *Journal of Applied Sciences*, Redelve International Publications 2019(1): RDAPS- 10002.

[75] Elmas, Emin Taner (2017) Productivity and Organizational Management (The Book) (Chapter 7): Prospective Characteristics of Contemporary Engineer (By the Approach of Mechanical Engineering) Contribution and Role of the Mechanical Engineer to the Organization Management and Productivity. Machado Carolina, Davim J Paulo (Eds.), DEGRUYTER, Walter de Gruyter GmbH, Berlin / Boston, Spain (ISBN:978-3-11-035545-1)

[76] Elmas, Emin Taner (2017) Prospective Characteristics of Contemporary Engineer (By the Approach of Mechanical Engineering) Contribution and Role of the Mechanical Engineer to the Organization Management and Productivity). DeGruyter, Germany (DOI 10.1515 / 9783110355796-007)

[77] Elmas, Emin Taner, Evaporation Plant for Recycling of Caustic Soda, *INTERNATIONAL JOURNAL of ENGINEERING TECHNOLOGIES-IJET* Emin Taner Elmas., Vol.3, No.3, 2017

[78] Elmas, Emin Taner, (2014), Çağımızın Mühendisinden Beklenenler, Gece Kitaplığı, ISBN:9786053244158

[79] Emin T. E. (2023). Design, Production, Installation, Commissioning, Energy Management and Project Management of an Energy Park Plant Consisting of Renewable Energy Systems Established at Iğdir University. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 3, Number 6, pp. 67–82). <https://doi.org/10.5281/zenodo.10406670>

[80] Essentials of Energy Technology; Sources, Transport, Storage, Conservation, Jochen Fricke and Walter L. Borst; 2013 Wiley-VCH Verlag & Co. KGaA, Germany, ISBN: 978-3-527-33416-2

[81] Energy Storage in Power Systems, Francisco Diaz-Gonzalez, Andreas Sumper, Oriol Gomis-Bellmunt, WILEY, John Wiley & Sons Inc., 2016, United Kingdom, ISBN: 9781118971321

[82] ÇELİK ÜRETİMİNDE ELEKTRİK ARK OCAKLARINDA ENERJİ MALİYETLERİNİN VE ENERJİ VERİMLİLİK FAKTÖRLERİNİN ARAŞTIRILMASI INVESTIGATION ON ENERGY COSTS AND ENERGY EFFICIENCY FACTORS OF ELECTRIC ARC FURNACE FOR STEEL PRODUCTION, Fenerbahçe Üniversitesi Tasarım, Mimarlık ve Mühendislik Dergisi - Journal of Design, Architecture & Engineering Hasan TAMSÖZ *, Emin Taner ELMAS ** FBU-DAE 2021 1 (3): 163-180

[83] SİNER TESİSLERİNDE ENERJİ KULLANIM NOKTALARI VE ENERJİYİ VERİMLİ KULLANACAK YÖNTEMLERİN BELİRLENMESİ DETERMINATION OF ENERGY UTILIZATION POINTS AND THE METHODS USING THE EFFICIENT ENERGY FOR SINTERING PLANTS, Fenerbahçe Üniversitesi Tasarım, Mimarlık ve Mühendislik Dergisi - Journal of Design, Architecture & Engineering Adem KAYA *, Emin Taner ELMAS** FBU-DAE 2022 2 (2): 170-181

[84] Emin Taner ELMAS. (2024). The Electrical Energy Production Possibility Research Study by using the Geothermal Hot Water Resources, which is a kind of Renewable Energy Resource, located at the Region of Mollakara Village which is a part of Diyadin Town and City of Ağrı, Turkey. In Global Journal of Research in Engineering & Computer Sciences (Vol. 4, Number 1, pp. 90–101). <https://doi.org/10.5281/zenodo.10729333>

[85] ELMAS, Emin Taner. (2024). Energy Analysis, Energy Survey, Energy Efficiency and Energy Management Research carried out at Iğdır University. In Global Journal of Research in Engineering & Computer Sciences (Vol. 4, Number 2, pp. 12–30). <https://doi.org/10.5281/zenodo.10828077>

[86] ELMAS, Emin Taner. (2024). A Research Study of Salt Dome (Salt Cave) Usage Possibility for CAES – Compressed Air Energy Storage Systems. In Global Journal of Research

in Engineering & Computer Sciences (Vol. 4, Number 2, pp. 128–131).
<https://doi.org/10.5281/zenodo.10980421>

[87] ELMAS ET (2025), Tam Akışlı Isı Borulu Hava Kanalları İçin Geliştirilmiş Bir Reküperatör Sistem Tasarımı, Studies in Science of Science | ISSN:1003-2053, <https://sciencejournal.re/> | Volume 43, Issue 10, 2025

[88] ELMAS ET (2025), Thermal & Mechanical Design and Production of a Cooling Machine Heat Exchanger with Thermoplates for Granular Solids Using the Solid-Liquid-Gas Energy Transfer Mechanism, Studies in Science of Science | ISSN:1003-2053, <https://doi.org/10.5281/zenodo.17346071>, <https://sciencejournal.re/> | Volume 43, Issue 10, 2025

[89] ELMAS ET (2025), Rankine Çevrimine Göre Çalışan; Buhar Türbini Çıkışından 10 Mwatt Güç Elde Edilecek Şekilde, Yakıt Doğal Gaz Olmak Üzere, Bir Enerji Santrali Dizaynı Ve Projelendirilmesi, Studies in Science of Science | ISSN:1003-2053, <https://doi.org/10.5281/zenodo.17346226>, <https://sciencejournal.re/> | Volume 43, Issue 10, 2025 |

[90] ELMAS ET (2025), DOĞAL GAZ YAKITLI KOJENERASYON TERMODİNAMİK ÇEVİRİMLİ ENERJİ SANTRALİ SİSTEM, Studies in Science of Science | ISSN:1003-2053, <https://doi.org/10.5281/zenodo.17346584> <https://sciencejournal.re/> | Volume 43, Issue 10, 2025|

[91] Elmas, Emin Taner, "ELMAS's Theory of Thermodynamics": A Scientific Approach for 5th Law of Thermodynamics -A Theoretical Application Example for Medical Thermodynamics. Op Acc J Bio Sci & Res 2(1)-2020. DOI: 10.46718/JBGSR.2020.01.000030

[92] ELMAS, Emin Taner. (2024). Three – Pass Fire Tube Boilers for production of Steam, Hot Water and Superheated Water. In Global Journal of Research in Engineering & Computer Sciences (Vol. 4, Number 4, pp. 29–38). <https://doi.org/10.5281/zenodo.12741030>

[93] ELMAS, Emin Taner. (2024). An innovative solar dish type collector – concentrator system having an original – unique geometrical mathematical model called as DODECAGON which has 12 equal segments. In Global Journal of Research in Engineering & Computer Sciences (Vol. 4, Number 3, pp. 31–38). <https://doi.org/10.5281/zenodo.11397848>

- [94] Emin Taner ELMAS*. Waste Heat Recovery Boilers (WHRBs) and Heat Recovery Steam Generators (HRSGs) used for Co-generation and Combined Cycle Power Plants. *Op Acc J Bio Sci & Res* 12(1)-2024. DOI: 10.46718/JBGSR.2024.12.000284
- [95] ELMAS, Emin Taner. (2024). Energy Analysis, Energy Survey, Energy Efficiency and Energy Management Research carried out at Iğdır University. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 4, Number 2, pp. 12–30). <https://doi.org/10.5281/zenodo.10828077>
- [96] Emin T. E. (2023). Design, Production, Installation, Commissioning, Energy Management and Project Management of an Energy Park Plant Consisting of Renewable Energy Systems Established at Iğdir University. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 3, Number 6, pp. 67–82). <https://doi.org/10.5281/zenodo.10406670>
- [97] ELMAS, Emin Taner. (2024). Dimensional Unit Analysis Applications for Heat Pipe Design. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 4, Number 5, pp. 12– 26). <https://doi.org/10.5281/zenodo.13741540>
- [98] ELMAS, Emin Taner. (2024). Calculation of the Filling Amount of Working Fluid to be Placed in a Heat Pipe. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 4, Number 5, pp. 100–108). <https://doi.org/10.5281/zenodo.13844847>
- [99] ELMAS, Emin Taner. (2024). Providing Fully Developed Flow for Waste Exhaust Gas at the Inlet Region of a Heat Pipe Air Recuperator. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 4, Number 5, pp. 118–124). <https://doi.org/10.5281/zenodo.13931542>
- [100] Emin Taner ELMAS, Doktora (Ph.D.) Tezi, “Yüksek Sıcaklıklı, Isı Borulu, Isı Geri Kazanım Ünitelerinin Tasarım Parametrelerinin Termodinamiksel ve Deneysel Analizi”, Tez Danışmanı:Prof. Dr. Ali Güngör, Ege Üniversitesi Fen Bilimleri Enstitüsü Makina Mühendisliği Anabilim Dalı, Termodinamik Bilim Dalı, İzmir, 2011
- [101] Elmas, Emin Taner, (1999), Yüksek Lisans (M.Sc.) Tezi, “Evaporation Plant For Recycling of Caustic Soda”, Thesis Advisor: Prof. Dr. Fehmi Akdoğan, Dokuz Eylül Üniversitesi Fen Bilimleri Enstitüsü Makina Mühendisliği Anabilim Dalı, Enerji Bilim Dalı, İzmir.
- [102] ELMAS, Emin Taner, & ALMA, M. H. (2025). Iğdır University ISO 50001 Energy Management System Certification Studies. In *Global Journal of Research in Engineering & Computer Sciences* (Vol. 5, Number 2, pp. 6–24). <https://doi.org/10.5281/zenodo.15011984>

[103] Emin Taner Elmas. A Review for Combined Cycle Power Plants. Biomed J Sci & Tech Res 58(1)-2024. BJSTR. MS.ID.009087. DOI: 10.26717/BJSTR.2024.58.009087

[104] Emin Taner Elmas, Thermodynamic Cycle and Energy Transfer Fundamentals by a P&ID principle diagram for "Salt Caves" (Salt Domes) in Iğdır, Tuzluca province to be used as an "Energy Storage System", Journal of Systems Engineering and Electronics (ISSN NO: 1671-1793) Volume 36 ISSUE 1, 2026

[105] Emin Taner Elmas, Organik Rankine Çevriminin (ORC- Organic Rankine Cycle) Termodinamiksel ve Enerji Transfer İmkân ve Kabiliyetleri ile Uygulama Alanlarının Araştırılması, Journal of Systems Engineering and Electronics (ISSN NO: 1671-1793), Volume 36 ISSUE 1 2026