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Advancing Sustainability through Energy Innovation and Climate Action: Insights from ETUT

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Abstract. This study explores the potential of sustainable energy solutions to address global energy challenges and mitigate climate change. Oguz Han Engineering and Technology University (ETUT) serves as a case study, displaying its innovative approaches to energy efficiency, waste management, and renewable energy production. The university's implementation of energy-saving devices, smart building automation systems, and LED lighting demonstrates a commitment to reducing carbon emissions and promoting sustainable practices. Additionally, the study investigates the conversion of plastic waste into liquid fuel and the production of bioethanol from cotton stalks as potential solutions for waste management and renewable energy generation. Further, the research explores the deposition of thin film bismuth vanadium tetraoxide for hydrogen production, highlighting its potential as a clean energy source. Overall, this study emphasizes the importance of sustainable energy solutions and the role of academic institutions in driving innovation and promoting a greener future.

Keyword:

Bioethanol, energy-efficient technologies, smart building systems, plastic waste, liquid fuel, bismuth vanadium tetraoxide thin films

1. Introduction

Energy is the bedrock of existence, sustaining life, driving human activities, and shaping the environment. Recognizing the critical role of energy is essential to advancing sustainable, environmentally responsible, and equitable solutions for all human beings [1].

The significant change in climate plays a very important role in achieving and maintaining the quality of life. One of the major factors and the key component for the society is to find out the ways for providing more amount of energy, with minimum emissions of greenhouse gases (GHGs). Today, our lives depend heavily on the energy resources available in our areas of existence. To ensure a prosperous life by addressing climate change, the world's rapidly growing population needs enormous energy to find ways to minimize toxic carbon dioxide emissions. Various fuel companies have long been recognized for accepting the challenges of climate change and maintaining the higher quality of life. With the increasing technological developments, significant cultural change and effective policies are ultimately required to drive the business of low-carbon emissions and to prefer the customer's choices. The meaningful "government-led carbon pricing mechanisms" best underpins the transitions of fuels for the low-carbon emissions. Therefore, government efforts are always welcomed to achieve a joint agreement on global climate change, support long-term climate objectives, and balance environmental pressure and development opportunities.

The "United Nations Paris agreement" on climate change was welcomed on November 4, 2016. This agreement seeks to limit the effects of global warming, below 2^0 C, by managing the environmental pressure and climate change, along with the encouragement of economic development. Until today, some major primary gas brands and major oil companies, having long traditions of innovations, are striving very hard to meet the international standards of fuels by maintaining the purity of environment. The long-term success of these types of projects mainly depends on the (1) types of fuels, (2) ability to properly anticipate the different forms of energies, and (3) to remain commercially competitive and environmentally benign. The natural gas business of various international brands provides the opportunity for the government to minimize the toxic emissions of GHGs from the production of electricity, by replacing the coal. Few major fuel companies have also heavily invested on the "lowest carbon biofuels," through joint venture with some other international companies, and continued to explore the new options for the "second generation biofuels" [7].

Local fuel companies in third-world countries have created new energy companies to explore investment opportunities, solve energy-related problems, including the combined businesses of solar, and wind power along with natural gas. All these opportunities help to connect the different consumers of energy. Numerous fuel brands are the permanent supporter of "government-led carbon pricing mechanisms." Numbers of vehicles are abundantly available for supporting the new investment trends in advanced technologies, including some major ventures. The actual focus of this venture of technology is to combine the traditional oil and gas processing techniques with the advanced, clean, and green technologies. In the past few decades, some major global ventures have supported the "Wind business" and "Solar business." However, reducing toxic emission levels, enhancing energy efficiency, and ending continuous flaring remain key goals.

The “global fuel scenario” envisages future where renewable energy processes can easily become the largest components of the “global energy system”. Despite the rapid growth of renewable energy processes, the “global fuel scenario” anticipates that the only possibility of providing the full range of energy products is (1) combining renewable energy resources with cleaner hydrocarbons like natural gas and (2) deploying the technologies to capture and store the significant amount of carbon dioxide. To achieve this goal for the global population of more than 8 billion people, enormous amount of global undertaking supports is ultimately required, along with (1) effective governmental policies, (2) sense of urgency, and (3) long-term vision. Under the “global fuel scenario,” the future energy system will be a patchwork. Few economic sectors and economic countries can easily be decarbonized in the future, while all other energy intensive industries will ultimately require more time for the development of technological solutions.

Some important methods and techniques that can leads to the future of “low-carbon emissions” include (1) improved energy efficiency, (2) use of renewable energy resources instead of the non-renewable energy resources, (3) increased electrification processes, and (4) switching from the coal toward the natural gas. The appropriate options include (1) increased use of “low-carbon fuels,” (2) reutilization of land areas, (3) following the proper agriculture policies, and (4) improving the plans for the low-carbon infrastructure for the transit systems and cities. The “global fuel scenario” suggests that the world will ultimately require the means for achieving the “negative emissions,” in major energy sectors, to offset the remaining toxic emissions. One of the most appropriate methods is to use the “combined sustainable biomass gasification system”, which is designed to capture and store the carbon dioxide through “carbon capture and storage” of the power generation sector [7].

In the ongoing global pursuit of sustainable development and climate action, integrating energy-efficient technologies, innovative solutions, and community-driven initiatives plays a pivotal role. Leveraging advancements like smart building systems and LED lighting to curtail energy consumption and combat climate change is central to achieving these sustainability goals. In addition, innovative initiatives such as transforming plastic waste into fuel, generating bioethanol from cotton stalks, and deposited thin films for producing green hydrogen, all play a role in decreasing dependence on non-renewable resources.

Overall, the study discusses the deployment of intelligent lightening systems using Wi-Fi connectivity, the conversion of plastic waste into oil fuel through pyrolysis, the production of bioethanol from cotton stalks via distinct hydrolysis and fermentation procedures, and the creation of thin film coatings using RF sputtering technique.

2. Embracing sustainable technologies

2.1 ETUT’s path to energy efficiency

Energy conservation and energy efficiency are related but separate concepts. Energy conservation is achieved when growth of energy consumption is reduced, measured in physical terms. Energy efficiency may be defined as a practice of judicious use of energy with an aim to reduce its economic cost and environmental impact. It has been in practice ever since after the first oil shock in 1973. Now it has assumed even more importance because of being the most cost-effective and reliable means of mitigating the global climate change. The four primary energy sources are coal, oil, gas, and nuclear energy, and the energy efficiency was considered as fifth fuel. At present the energy efficiency became the first one and the world governments exploit energy efficiency as their energy resource of first choice because it is the least expensive and most readily scalable option to support sustainable economic growth, enhance national security, and reduce further damage to the climate system [7].

The energy efficiency is a fundamental element in progress towards sustainable energy future. The concept of energy efficiency can be applied in energy extraction, transportation, conversion as well as in consumption. As global energy demand continues to grow to find the needs and aspirations of the population across the globe, actions to increase energy efficiency will be essential. Many developing countries have also implemented major efficiency drives. Energy efficiency is a means to conserve natural resources, reduces environmental degradation, and not least to save money. It is true that energy efficiency helps to reduce greenhouse gas (GHG) emissions that it is an essential part of an effective strategy to climate change. It is estimated that, by using the most advanced technologies, a CO_2 reduction of about 50 % is possible until the year 2050. Energy efficiency is a gold mine for CO_2 reduction and should not be overlooked in aiming for the Kyoto Protocol and beyond. Energy efficiency improvements have multiple advantages, such as the efficient utilization of natural resources, reduction in air pollution levels, and lower spending by the consumer on energy-related expenditure. Investments in energy efficiency result in long-term benefits, which are reduced energy consumption, local environmental enhancement, and overall economic development [7].

In this context, Oguz Han Engineering and Technology University (ETUT) has taken significant strides in sustainable development by incorporating energy-saving devices in its buildings and implementing smart building automation systems. From energy-efficient appliances to advanced lighting controls, the university has focused environmentally conscious practices, setting a remarkable example in the pursuit of energy efficiency.

2.2 Revolutionizing Campus Infrastructure

ETUT has prioritized energy efficiency by installing sustainable appliances like refrigerators, washing machines, and dryers in its residential buildings. These energy-efficient appliances help reduce electricity consumption and contribute to a greener campus environment. The university's commitment to minimizing energy consumption is evident through the deliberate choice of sustainable appliances.

In classrooms, laboratories, and offices, ETUT has implemented a comprehensive approach to sustainable technology integration. Energy-efficient computers, monitors, printers, and projectors have been deployed to minimize power usage and promote eco-friendly practices. This integration aligns with the university's dedication to sustainability and reflects its proactive stance toward energy-conscious technology adoption.

By embracing sustainable appliances and technology, ETUT not only reduces its carbon footprint but also sets an example for the community and the higher education sector.

This holistic approach to energy consciousness underscores the university's visionary commitment to sustainable practices, benefiting both the environment and its constituents.

2.3 Optimizing Energy Utilization with Smart Building Automation Systems

2.3.1 Background

The building sector is the largest contributor to global greenhouse gas (GHG) emissions. Buildings use about 40 % of global energy, 25 % of global water and they emit approximately 30 % of GHG emissions. The energy used by the building sector continues to increase, primarily because new buildings are constructed faster than old ones are retired.

Smart building solutions are attractive tools for energy management because they provide visibility into system-wide operational and energy efficiency and provide tools for analyzing, tracking, and communicating the impact of energy-efficiency improvements [8].

Employing cutting-edge smart building automation systems, ETUT has revolutionized energy management on its campus. Embracing sophisticated controls and sensors, the university has optimized energy consumption by leveraging motion sensors and timers to curtail wastage. This forward-thinking approach not only enhances operational efficiency but also significantly contributes to energy conservation and sustainability (*Figure 1*).

Figure 1. Prototype of “Smart home” in ETUT

The implementation of smart lighting controls, coupled with the predominant use of LED lighting in academic buildings for corridor illumination, exemplifies the university's unwavering commitment to energy-efficient methodologies [2].

2.3.2 Materials and Method

There are two ways of controlling the lighting system: using a mobile phone and voice commands. The first one is the electric lights with basic controls a wired method based on connecting via conductive wires. This is one of the most reliable methods, the disadvantage of which is that it is often necessary to drill the walls of the house to run wires and damage its decorative coverings. But, it requires additional costs. The second way is without wires it can be controlled by a remote. The rationale for employing this approach lies in its convenience for remote control through dedicated applications on smartphones, tablets, or computers. Utilizing a Wi-Fi connection will eliminate the need for physical wiring, which can be costly and aesthetically invasive, especially when it involves drilling into walls. Wi-Fi connection also offers economic advantages and enables seamless control of the lighting system without the constraints of physical connections. Additionally, the use of Wi-Fi technology aligns with the current trend toward digitalization and smart technologies, enhancing the overall efficiency and functionality of the lighting system.

For the development of a smart home lightening system, it is important to define components. In general, to turn an electric light on or off, current must flow or cut through the circuit as needed. In conventional lighting systems, it can be done with the help of a simple switch. Controlling the current in the circuit according to the transmitted electrical signal is done with the help of relays or semiconductor transistors.

Companies such as ZigBee and SONOFF have developed wireless lighting control technology. In the systems they offer, the current in the circuit is controlled by electromagnetic relays. Electromagnetic relays have disadvantages, such as long response time to the sent signal, generation of interference waves when connecting and storing the circuit (which is inconvenient for wireless communication), and sticking of matching contacts when connecting inductive and high voltage devices. Semiconductor thyristors do not have these drawbacks and are smaller compared to electromagnetic relays [2].

The Smart lighting system, developed at the research center “Nanoelectronics and Internet of Things” of the ETUT has small dimensions, consumes little energy for operation, and has a large electrical coefficient. A BTA 600V type thyristor was used, providing amplifying the current, and capable of passing a large electric current through it. "Optron MOC3063" transistor was used to avoid branching of the current controlled by the thyristor.

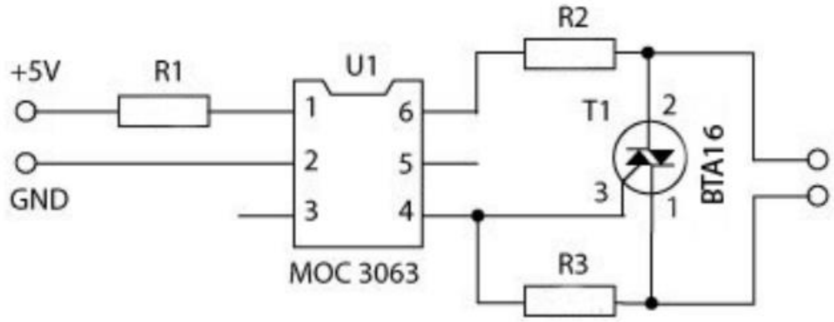


Figure 2. Connection of MOC3063 triac with BTA 600V thyristor

To assemble a smart lighting system, it is necessary to design a printed circuit board, i.e. draw a board drawing on a computer using the Sprint-Layout_6.0 program. It should then be transferred to the surface of a rectangular sheet of epoxy resin measuring 5.5 x 6.3 cm.

To position the system components on the plane, it is necessary to drill holes at suitable locations in the circuit and insert the components through soldering [2].

2.3.3 Result

The study successfully developed an innovative "Smart" lighting system based on smart technologies, utilizing Wi-Fi connectivity for enhanced control and efficiency. Through rigorous testing in various conditions, the system demonstrated robust performance and reliability. Subsequently, the Smart lighting system was seamlessly integrated into the ETUT buildings, displaying its practical application in real-world settings. This solution signifies a significant technological advancement and contributes to reducing dependence on imported products for digitalization in the industry. The implementation of this system marks a pivotal step towards sustainable and energy-efficient building solutions, aligning with the growing trend towards smart technologies and digital innovations in the modern era.

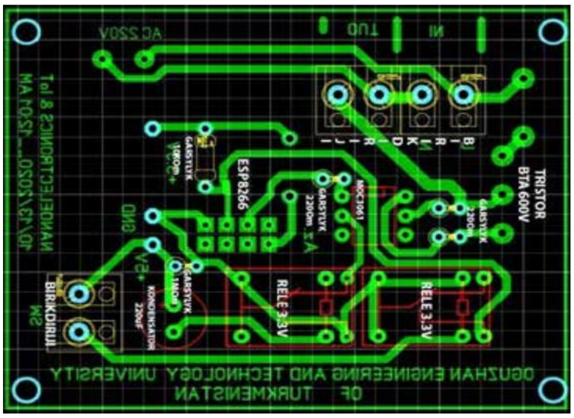


Figure 3. Smart lighting system board

2.4 Impact on Environmental Conservation and Climate Mitigation

The amalgamation of energy-saving devices and smart building automation systems has profound implications for environmental conservation and climate mitigation.

Figure 4. LED lighting in academic buildings

Through its proactive measures, ETUT has significantly reduced its carbon footprint, fostering a culture of responsible energy consumption and environmental stewardship. By minimizing energy wastage and embracing LED lighting, the university is actively contributing to the global imperative of sustainable development and climate action (*Figure 4*).

2.5 Pioneering a Sustainable Future

ETUT's steadfast embrace of energy-efficient appliances, smart building automation systems, and LED lighting serves as a beacon for sustainable development in academic institutions. As a trailblazer in the realm of energy efficiency, the university not only enhances its operational sustainability but also inspires students, faculty, and staff to champion environmentally conscious practices. By integrating technology and sustainability, ETUT lays the groundwork for a greener and more resilient future, where innovation and environmental responsibility harmoniously converge.

3. Transforming Waste into Liquid Fuel

3.1 Background

Plastic pollution has emerged as a pressing environmental concern, with vast quantities of plastic waste accumulating in landfills, oceans, and natural habitats. The detrimental impact of plastic pollution on ecosystems, wildlife, and human health underscores the urgent need to mitigate this global challenge. It is possible to take a proactive step towards combating plastic pollution while simultaneously addressing energy needs sustainably.

Turkmenistan implemented a comprehensive code on waste management in 2015 to promote sustainable development and protect the environment. The code covers various aspects of waste management, including waste generation, collection, transportation, treatment, and disposal. It also includes provisions for the establishment of waste management facilities, the promotion of recycling and composting, and the enforcement of environmental regulations. The code aims to reduce waste generation, promote waste reduction and recycling, and ensure the safe and responsible disposal of waste.

Enhancing the efficiency of waste disposal through innovative methods to reduce plastic waste and derive environmentally and economically valuable products is considered an aim of the study [5].

Today, only 20% of plastic waste is processed in the world, and the rest is burned, polluting the atmosphere with carcinogens and greenhouse gases. In addition, although the number of natural energy resources decreases day by day, the production of plastic products is growing. In this context, the treatment of plastic waste and the creation of new products are significant to sustain environmental well-being [6, 10].

3.2 Materials and method

Currently, a portion of the plastic waste undergoes secondary processing, resulting in the extraction of various products and raw materials. The study has examined the methods and technologies employed globally for recycling plastic waste. Plastic waste was processed at the “Ecological Biotechnology” research center of the Oguz Han Engineering and Technology University of Turkmenistan. The pyrolysis approach was used to obtain liquid fuel from plastic waste through the study. This approach is the process of decomposition of chemical reactions in the inert atmosphere at high temperatures [5].

Pyrolysis has advantages in converting plastic waste into liquid fuel. First, it provides an effective means of waste management, reduces the amount of waste going to landfills, and helps to minimize environmental pollution and greenhouse gas emissions. Second, this process produces a combustible gas called syngas, which can be used to generate heat and electricity.

Plastic waste (PETF, PVC, PP, PS related to thermoplastics) was used in mixed form for the experiment. A gas cylinder is used to collect gases. Before commencing the experiment, the plastic waste underwent washing and fragmented by mechanical device. After fragmentation, plastic waste was placed in the reactor and heated to 450 °C. In the experiment, high-temperature steam flows through the copper pipe and condenses, causing the vaporous hydrocarbons to transition into a liquid state. The spiral shape of the copper tube, and its passage through water, provide smooth and quick condensation of vapors. The liquid fuel accumulated in the second part of the device. The non-condensed vapors are collected through a gas pipe into the wheel chamber of the car (*Figure 5*). Besides non-condensed vapors, the resin-like residue is left. The remained residue is used for obtaining sand-polymer products.

Figure 5. A process for converting plastic waste into a liquid fuel

3.3 Result and discussion

As a result, 1 liter of liquid fuel was obtained from 2 kg of plastic waste. The resulting fuel was passed through a filter paper. The chemical composition of liquid fuel was analyzed by gas chromatography (*Table 1*) [5].

Table 1. Compound identified via GC-MS analysis

№	Time	Name	Formula	Total %
1	3.552	Toluene	C_7H_8	1.96
2	3.615	Cyclohexene, 1-methyl-	C_7H_{12}	0.32
3	3.974	Fumaryl chloride	$C_4H_2Q_2O_2$	2.21
4	4.016	2-Octene, (Z)-	C_8H_{16}	2.56
5	4.217	Octane	C_8H_{18}	2.99
6	5.443	2,4-Dimethyl-1 -heptene	C_9H_{18}	0.44
7	6.203	Ethylbenzene	C_8H_{10}	0.84
8	7.556	Bicyclo[4.2.0]octa-1,3,5-triene	C_8H_8	3.01
9	7.661	1-Nonene	C_9H_{18}	3.21
10	8.126	Nonane	C_9H_{20}	1.95
11	11.560	Benzaldehyde	C_7H_6O	0.65
12	12.500	Benzonitrile	C_7H_5N	1.69
13	12.806	1-Decene	$C_{10}H_{20}$	8.12
14	13.049	Decane	$C_{10}H_{22}$	2.83
15	13.197	2-Decene, (Z)-	$C_{10}H_{20}$	0.41
16	13.651	p-Cymene	$C_{10}H_{14}$	0.32
17	13.757	D-Limonene	$C_{10}H_{16}$	1.09
18	14.697	Acetophenone	C_8H_8O	1.74
19	15.162	1,11-Dodecadiene	$C_{12}H_{22}$	0.89

№	Time	Name	Formula	Total %
20	15.405	Cyclopropane, octyl-	$C_{11}H_{22}$	6.47
21	15.648	Undecane	$C_{11}H_{24}$	3.44
22	15.786	2-Undecene, (Z)-	$C_{11}H_{22}$	0.46
23	16.726	1,2-Propanedione, 1-phenyl-	$C_9H_8O_2$	1.84
24	18.004	Benzoic acid, ethyl ester	$C_9H_{10}O_2$	0.45
25	18.490	1,11-Dodecadiene	$C_{12}H_{22}$	0.72
26	18.881	5-Dodecene, (Z)-	$C_{12}H_{24}$	5.02
27	19.251	Undecane	$C_{11}H_{24}$	4.09
28	19.473	Benzoic acid	$C_7H_6O_2$	2.03
29	19.885	Benzoic acid	$C_7H_6O_2$	3.57
30	24.702	5-Tridecene, (E)-	$C_{13}H_{26}$	2.33
31	25.283	Tridecane	$C_{13}H_{28}$	1.61
32	29.752	Biphenyl	$C_{12}H_{10}$	1.04
33	30.925	5-Tetradecene, (E)-	$C_{14}H_{28}$	2.46
34	31.358	Tetradecane	$C_{14}H_{30}$	1.59
35	36.006	6-Tridecene, (Z)-	$C_{13}H_{26}$	1.62
36	36.376	Decane, 2,3,5-trimethyl-	$C_{13}H_{28}$	1.05
37	40.443	Cyclohexadecane	$C_{16}H_{32}$	1.33
38	40.760	Hexadecane	$C_{16}H_{34}$	0.87
39	45.356	9-Octadecene, (E)-	$C_{18}H_{36}$	0.91
40	45.800	Heptadecane	$C_{17}H_{36}$	0.66
41	52.128	9-Octadecene, (E)-	$C_{18}H_{36}$	0.99
42	52.466	Heptadecane, 8-methyl-	$C_{18}H_{38}$	0.74
43	55.297	9-Eicosene, (E)-	$C_{20}H_{40}$	0.93
44	55.445	Nonadecane	$C_{19}H_{40}$	0.74
45	56.745	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	0.82
46	57.167	3-Eicosene, (E)-	$C_{20}H_{40}$	0.88
47	57.262	Dodecane, 2-methyl-6-propyl-	$C_{16}H_{34}$	0.76
48	58.572	3-Eicosene, (E)-	$C_{20}H_{40}$	0.80
49	58.646	Heneicosane	$C_{21}H_{44}$	0.84
50	59.164	9-Octadecenoic acid, (E)-	$C_{18}H_{34}O_2$	0.57
51	59.745	3-Eicosene, (E)-	$C_{20}H_{40}$	0.77
52	59.798	Hexacosane	$C_{26}H_{54}$	0.81
53	60.759	1-Tricosene	$C_{23}H_{46}$	0.82
54	60.812	Hexadecane	$C_{16}H_{34}$	0.77
55	61.689	1-Docosene	$C_{22}H_{44}$	0.77
56	61.742	Tetracosane	$C_{24}H_{50}$	0.81
57	62.587	Hexacosane	$C_{26}H_{54}$	1.30
58	63.390	Hexadecane	$C_{16}H_{34}$	1.23
59	64.150	Hexadecane	$C_{16}H_{34}$	1.04
60	64.869	Hexacosane	$C_{26}H_{54}$	0.99
61	65.566	Heptadecane	$C_{17}H_{36}$	0.74
62	66.274	Octadecane	$C_{18}H_{38}$	0.68
63	67.066	Oxalic acid, allyl hexadecyl ester	$C_{21}H_{38}O_4$	0.45

According to the *Table 1,* the produced fuel includes hydrocarbons with carbon numbers of C_6-C_{26}. The fuel composition corresponds to the composition of gasoline fractions and the density of the obtained fuel corresponds to the density of gasoline AI-92 (715-760 kg/m^3). The chemical composition of the resulting gas consists of H_2, CO and CH_4 gases. These gases can be used as a secondary ignition source for the process itself.

During the study, an economically profitable product was obtained. The composition of the obtained liquid fuel is similar to the composition of gasoline used for railways and automobile vehicles, as well as agricultural machinery. Along with this, it can be used as a solvent for various dyes, paints. In addition, the ingredients of this fuel are widely used in perfumery [5].

In summary, converting plastic waste into liquid fuel through the pyrolysis process offers a sustainable and environmentally friendly solution to plastic waste management while providing economic value by producing a useful and versatile product.

4. Producing bioethanol from cotton stalks

4.1 Introduction

Organic waste, including materials like food scraps, agricultural residue, and plant matter, constitutes a significant portion of global waste, with its improper management leading to environmental challenges such as greenhouse gas emissions, landfills, and soil degradation. Addressing the impact of organic waste is crucial for promoting sustainability and reducing the strain on natural resources. Among them cotton stalks are often considered waste after harvesting cotton fibers, contain valuable lignocellulosic biomass that can be harnessed to produce bioethanol, a renewable and cleaner alternative to fossil fuels. The process of converting cotton stalks into bioethanol involves various stages including pretreatment, enzymatic hydrolysis, fermentation, and distillation [6]. By exploring the potential of cotton stalks for bioethanol production, we not only address the issue of agricultural waste management but also contribute to the transition towards a greener and more sustainable energy future. This innovative approach not only showcases the versatility of cotton stalks but also highlights their significant role in the renewable energy landscape.

The study successfully demonstrated bioethanol production from agricultural residues, such as cotton stalks, which offers a sustainable solution to the pressing challenges of energy demand and environmental degradation. By harnessing the valuable lignocellulosic biomass present in cotton stalks, the research aimed to contribute to a greener and more sustainable energy future while addressing agricultural waste management issues. [3].

4.2 Materials and method

Cotton stalks collected from the fields of the village of Magtymguly, Ak Bugday district in the Ahal region, were used as the main raw material in the study. The process of obtaining bioethanol from cotton stalks consists of three steps:
- Acid hydrolysis;
- Neutralization and detoxification;
- Fermentation.

Acid hydrolysis. This step consists of a two-step acid hydrolysis. At the beginning of the study, the cotton stalks were kept under the sun until they were completely dry, and the outer husk and small dirt were removed. Then, it was milled to a size of one mm. 1:2 ratio (by weight) of crushed cotton were undergone reaction with 75% H_2SO_4. In the second step, the solution was reacted with diluted sulfuric acid. The solution was then sterilized in an autoclave device. The autoclaved solution was heated in a water bath for 4 hours.

Neutralization and detoxification. The resulting hydrolat was neutralized in an alkaline environment by adding $Ca(OH)_2$. It was then stirred with a magnetic stirrer for 1 hour. After 1 hour, it was filtered and the pH was again neutralized with sulfuric acid (H_2SO_4). The experiment was continued by treating the hydrolat with carbon (C). The hydrolat was filtered after mixing it with carbon on a magnetic stirrer for 30 minutes.

Fermentation. Detoxified hydrate of cotton stalk was used as the main carbon source for fermentation. Saccharomyces cerevisiae (Brewer's yeast) is used for fermentation.

Figure 6. A process for converting plastic waste into a liquid fuel

These yeasts were mixed with a small amount of glucose ($C_6H_{12}O_6$) in 10 ml of water heated to 35°C for the activation. Then, activated carbon, NH_4Cl, NaH_2PO_4, as well as $MgSO_4*7H_2O$, $CaCl*2H_2O$, and $ZnSO_4$, were added to the hydrolat in a 250 ml chemical flask. Yeasts can survive only in a certain range of stable pH. Therefore, the pH of the solution was also adjusted to 5.5. Then, a vacuum was created inside the flask using an air pump and placed in an incubator at 30°C for 72 hours for fermentation. A tube connects the mouth of the flask, and the mouth is placed inside the flask filled with water, to exhaust the CO_2 gas that will be released during the process. The practical ethanol yield was calculated based on the amount of consumed sugar. The ethanol yield was found to correspond to the sugar consumption, with 0.51 grams of sugar being consumed per gram of ethanol produced [3] (*Figure 6*).

4.3 Result

As a result, environmentally friendly bioethanol from cotton stalks was obtained. The successful derivation of bioethanol from cotton stalks highlights the feasibility and efficiency of utilizing agricultural residues for renewable energy production. The choice of acid hydrolysis as the initial step was crucial in breaking down the complex biomass and releasing sugars for fermentation. The meticulous neutralization and detoxification processes further ensured the quality and purity of the bioethanol product. By employing Saccharomyces cerevisiae for fermentation, a well-known and efficient fermenting agent, the study achieved a practical yield of bioethanol, showcasing the effectiveness of the chosen method.

Implementation of the technology not only offers an economically viable means to utilize local raw materials but also contributes significantly to reducing atmospheric pollution by providing a renewable and cleaner alternative to fossil fuels. The method presented in this study opens up possibilities for scaling up bioethanol production from cotton stalks, potentially making a substantial impact on the transition towards a more sustainable energy landscape [3].

5. Thin film deposition of bismuth vanadium tetraoxide for hydrogen production

5.1 Background

The growing worldwide concern about carbon emissions and the depletion of fossil fuel reserves is driving the advancement of technology based on alternative energy sources. Solar photovoltaic cells typically produce electricity. However, the variability in daily solar irradiance has led to the exploration of converting sunlight into chemical energy as an inherently sustainable solution to address the global energy shortage [11].

In 1972, Akira Fujishima and Kenichi Honda made a groundbreaking discovery that would forever change the landscape of renewable energy research. Their experiment, now famously known as the Fujishima-Honda experiment, demonstrated the photoelectrochemical splitting of water into hydrogen and oxygen using a semiconductor electrode. This breakthrough marked the birth of a new field of research and ignited a global quest to harness solar energy for a sustainable future [14].

Fujishima and Honda utilized a titanium dioxide (TiO_2) electrode as the photoanode. When exposed to ultraviolet light, TiO_2 absorbs energy and generates electron-hole pairs. These charge carriers are then used to drive the oxidation of water at the anode (producing oxygen) and the reduction of protons at a platinum cathode (producing hydrogen) (*Figure 7*). The key to their success was the use of a semiconductor material that could efficiently convert light energy into chemical energy [14].

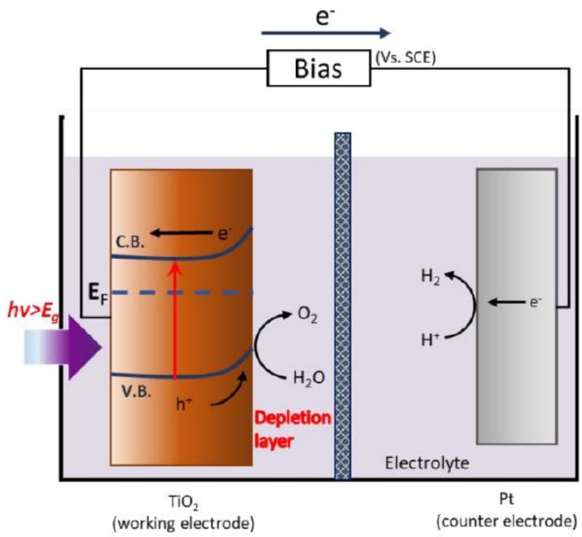
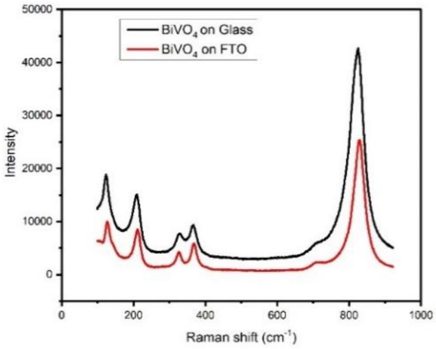


Figure 7. The schematic diagram of the photo-electrochemical cell in which TiO_2 is used as the photoanode and Pt as cathode [16].

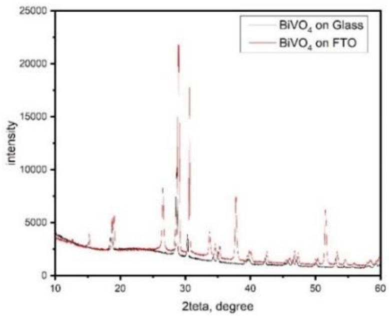
5.2 Materials and methods

Monoclinic scheelite bismuth vanadate is a promising photoanode for photoelectrochemical water splitting [12]. This research work aims to develop a visible-light-driven photocatalyst system based on $BiVO_4$ that can be easily scaled up and with good absorptive properties and efficient charge separation. During this research work, samples of Bismuth vanadium tetraoxide thin film are deposited on the Fluorine doped Tin dioxide (FTO) coated glass and pure glass by plasma reactive sputtering (RF) powered (75 W) single target, as well as characterization of the film is done with several spectrophotometers.

The optimal 200 nm film is deposited by bombarding the target with Argon gas at room temperature with an AR/Ox ratio of 75/25%. The annealing process is conducted at the temperature of 50^o C for 2 hours. The Raman spectroscopy (*Graph 1*) and XRD measurements (*Graph 2*) of the samples are shown in the below diagram.



Graph 1



Graph 2

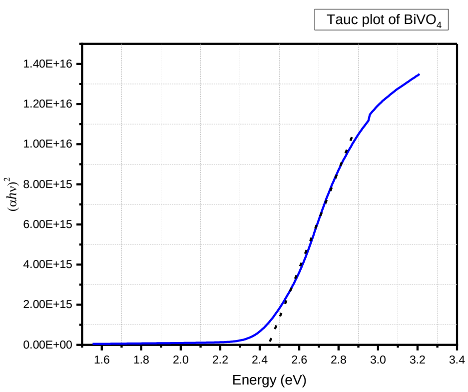
The optical absorbance spectrum was measured by Jasco V-670 UV-Vis-Nir spectrophotometer. The transmittance and reflectance of the samples were measured by optical spectrophotometer using 200 nm-800 nm wavelength and band gaps were calculated using the following relation

$\alpha = \frac{1}{d}\ln(\frac{(1-R)^2}{T})$ (1)

Where α is the absorption coefficient, d is the film thickness, R and T are reflection and transmission coefficients respectively. If we plot, $(\alpha h\nu)^n$ vs.$h\nu$, we can get a straight line, the intersection gives the band gap value.

n=2 for direct and n=1/2 for indirect transition [13].

According to the Tauc plot method for our case, the value of energy band gap is $E_g = 2.45\ eV$ (*Graph 3*)



Graph 3

5.3 Results and discussion

As a result, electrons passing through the conduction band are driven to undergo electrolysis, splitting water molecules into hydrogen (H_2) and oxygen (O_2). This process, also known as photoelectrochemical (PEC) water splitting, occurs due to the photoexcitation of the semiconductor material, in this case, bismuth vanadium tetraoxide ($BiVO_4$). When $BiVO_4$ absorbs photons from sunlight, electrons in the valence band are excited to the conduction band, leaving behind positively charged holes in the valence band [4].

The excited electrons, now in the conduction band, possess sufficient energy to participate in the reduction reaction at the cathode, where they combine with protons (H^+) to produce hydrogen gas:

$$2H^+ + 2e^- \longrightarrow H_2$$

Simultaneously, the holes remaining in the valence band are involved in the oxidation of water at the anode, leading to the generation of oxygen gas:

$$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$$

One of the critical advantages of $BiVO_4$ over traditional semiconductors like titanium dioxide (TiO_2) is its ability to absorb a wider range of the solar spectrum. While TiO_2 is primarily responsive to ultraviolet (UV) light due to its wide band gap (~3.2 eV), $BiVO_4$, with a narrower band gap (~2.4-2.5 eV), can efficiently harness the visible light spectrum, which constitutes nearly 43% of the total solar radiation reaching the Earth's surface.

This capability significantly enhances the practical efficiency of the water-splitting process because sunlight is predominantly composed of visible light. Using $BiVO_4$, the system can absorb more photons, generate more electron-hole pairs, and produce more hydrogen through the water-splitting reaction. The broad absorption range and suitable band structure of $BiVO_4$ enable it to serve as an effective photocatalyst in real-world applications, where reliance solely on UV light would limit the scalability and practicality of solar-to-hydrogen conversion systems.

Moreover, the efficiency of charge separation and transport in $BiVO_4$ contributes to its effectiveness in photoelectrochemical water splitting. The material exhibits a relatively long electron diffusion length, allowing the photo-generated charge carriers to reach the respective electrodes without significant recombination losses. This reduces the likelihood of electron-hole recombination, a common issue in other photocatalytic materials, which limits overall efficiency.

In summary, the incorporation of $BiVO_4$ in PEC systems presents a highly promising approach for achieving sustainable hydrogen production from water using solar energy. By leveraging the visible spectrum, $BiVO_4$-based photoanodes maximize photon absorption and electron excitation, offering a feasible pathway for large-scale hydrogen generation while addressing global energy demands and reducing dependency on fossil fuels. The successful integration of such materials into renewable energy technologies could play a pivotal role in the transition to a hydrogen-based energy economy [4].

6. Conclusion

ETUT stands as an exceptional institution of environmental sustainability, demonstrating an unwavering commitment to integrating energy-saving technologies and embracing smart building automation systems. By leveraging cutting-edge innovations, the university paves the way for responsible energy consumption and environmental preservation, setting the stage for a future defined by ecological resilience and energy consciousness. Moreover, the successful conversion of plastic waste into economically viable fuels and environmentally friendly bioethanol from cotton stalks not only mitigates atmospheric pollution but also fosters sustainable practices in fuel usage, underscoring the university's profound impact on environmental stewardship. In addition, the pioneering efforts in obtaining thin nanolayers from Bismuth Vanadium tetraoxide for the production of green hydrogen further solidify the university's role as a beacon of sustainability and ecological consciousness. Through its exemplary initiatives, ETUT set a compelling precedent for academic institutions in spearheading the preservation of the planet's natural heritage and fostering a more sustainable future for all.

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