TECHNOLOGY FOR PRODUCING GREEN ENERGY FROM POLLUTED LAKES ON THE APSHERON PENINSULA AND ITS ECO-ECONOMIC JUSTIFICATION

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Abstract

This technological development is aimed at using renewable energy sources to provide electricity to oil wells on the Apsheron Peninsula, which contributes to improving the environmental situation and justifying the economic efficiency of this approach. The technology for producing green energy from polluted lakes on the Apsheron Peninsula has enormous potential for solving two main problems: environmental pollution and energy shortage. This project represents an innovative approach to utilizing polluted water resources, combining it with electricity production to support the energy needs of oil wells and the population.

Keywords: hydrogen production, electricity, renewable energy sources, water electrolysis, thermal power station, sustainable energy solution

I. Introduction

The Apsheron Peninsula, located on the shores of the Caspian Sea, is one of the key regions of Azerbaijan. It is rich in natural resources, including lakes and water bodies, which play an important role in the region's ecosystem. However, in recent decades, due to various anthropogenic and natural factors, many of these water bodies have become polluted, posing a serious threat to both the environment and the health of local residents [1-3].

One of the key challenges facing the region is not only the cleaning of polluted water bodies but also the use of their potential for green energy production. In this context, the technology for producing green energy from polluted lakes on the Apsheron Peninsula represents an important and promising direction for development.

The aim of this work is to study and analyze the possibility of using technology for producing green energy based on the purification of polluted lakes on the Apsheron Peninsula to achieve ecological and economic benefits. Within the framework of this work, the main aspects of the technology, its potential in the context of the region, as well as the ecological and economic benefits that can be obtained through its implementation will be considered [4-6].

This study is not only important in terms of improving the region's ecology but also has the potential to stimulate economic development through the creation of new jobs, increasing investments in infrastructure, and reducing dependence on traditional energy sources [7; 8].

II. Methods

Key aspects of this technology:

- Installation of wind turbines on the surface of polluted lakes: wind turbines will be placed on the surface of polluted lakes to harness wind energy for electricity production. This is an efficient way of utilizing available natural resources for generating clean energy.

- Hydrogen production: using electrolysis powered by the electricity generated from wind turbines, hydrogen will be produced. This process involves splitting water into hydrogen and oxygen, with hydrogen being utilized as a green fuel.

- Provision for oil wells: hydrogen can be used as a clean energy source to power oil wells, reducing dependence on traditional energy sources such as oil or natural gas, and decreasing emissions of greenhouse gases and other harmful substances.

- Providing energy to the population: the generated electricity and hydrogen can be used to meet the energy needs of the population in nearby areas, contributing to improving the quality of life and reducing environmental pollution from oil operations.

Thus, this technology represents an integrated approach to addressing multiple issues simultaneously, including energy security, reducing environmental pollution, and supporting the oil industry.

Overall, the technology for producing green energy from polluted lakes on the Apsheron Peninsula presents an effective and sustainable solution for reducing environmental pollution and providing a sustainable energy source for the region.

1. Investigation of Polluted Lakes on the Apsheron Peninsula

An analysis is conducted to identify contamination with oil products. Water samples are collected, then gas chromatography-mass spectrometry (GC-MS) is used to determine the types and concentrations of hydrocarbons in the water. Additionally, analysis of heavy metals is performed using atomic absorption spectrometry (AAS) [9].

For the chemical analysis of the polluted water bodies of "Boyuk Shor" on the Apsheron Peninsula, various apparatuses and methods were used depending on the specific analysis objectives and types of pollutants. The table below includes the main stages of analysis, equipment, and methods employed: 12 water sample bottles were collected from 12 different local sites and depths of Lake "Boyuk Shor."The results of the chemical analysis of the polluted waters of "Boyuk Shor" indicate significant contamination of water bodies on the Apsheron Peninsula with heavy metals, especially lead (Table 1).

Problems with the presence of oil products and coliform bacteria are also identified, posing a risk to public health. Urgent measures are needed to reduce emissions of pollutants and restore water quality in the region.

Despite the identified contamination of water bodies on the Apsheron Peninsula with heavy metals, oil products, and the presence of coliform bacteria, hydrogen in this context can be identified as a potential resource that can be used for clean and sustainable energy [10].

The specific gravity of lead (Pb) is 11.34 g/cm^3, mercury (Hg) is 13.55 g/cm^3, and cadmium (Cd) is 8.65 g/cm^3. The specific gravity of these metals is significantly higher than that of water, and they are concentrated at the bottom, with the rest located in the upper layer. Based on our measurements, the average depth of the lake in different locations is about 5 meters, so considering the presence of heavy metals in the bottom layer of the lake and other lighter impurities in the upper layer, the analysis should be taken at a depth of 2.5 meters using filters for electrolysis.

Table 1: *Results of the analysis of water pollution in "Boyuk Shor" of the Apsheron Peninsula*

Materials	Unit of Measurement	Standard	Actual	Analytical Instruments
Heavy Metal Content:				
Lead	Mg\L	0,05	0,15	Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
Mercury	Mg\L	0,05	0,02	-«-
Cadmium		0,03	0,01	-«-
Organic compounds				
Sum of pesticides	Mg\L	0,1	0,02	Liquid chromatographymass spectrometry (LC-MS)
Content of petroleum products	Mg\L	0,1	0,5	: Gas chromatographymass spectrometry (GC-MS) - conducted according to the USEPA standard.
Water quality parameters	pH	6,5-8,5	7,2	ASTM D 1293
Oxygen solvents	Mg\L	5-10	8,5	Oxygen Meter (DO sensor)
Water temperature	^0C	20	-	Thermometer
Microbiological analysis				
Number of coliform bacteria	CFU/ml	10	100	Filtration methods
Escherichia	E.coli		within the norm	The method of membrane filtration

2. Renewable Energy Sources

The Apsheron Peninsula in Azerbaijan has the potential to utilize several renewable energy sources. Some of these include: wind energy, solar energy, hydro energy, geothermal energy, biomass.

Each of these sources has its advantages and limitations, and a combination of various renewable sources can ensure sustainable and efficient energy production on the Apsheron Peninsula.

In the case of wind turbines on the Apsheron Peninsula, the height of installation plays a critical role in determining their effectiveness. It is important to place wind turbines at a sufficient height to ensure maximum capture of wind flow with minimal turbulent effects (Fig.1) [11-13].

The power of the power station depends on several factors, including the quantity and characteristics of the installed wind turbines, the efficiency of the electrolysis system for hydrogen production, and the overall electricity demand for oil wells. Let's assume several parameters to specify the answer.

Wind turbine power: according to our calculation, it is necessary to install a wind power station with wind turbines of 2 megawatts (MW) each. With the installation of 5 wind generators, the total required power will be 10 MW.

Electrolysis power: assuming an electrolyzer with an efficiency of 80%, meaning 80% of the wind turbine's electricity is used for hydrogen production. In this case, the electrolysis power will be 0.8 * 10 MW = 8 MW.

Hydrogen power station capacity: if hydrogen is used in hydrogen fuel cells with an efficiency of 60%, the hydrogen power station capacity will be 0.6 * 8 MW = 4.8 MW. Thus, in this scenario, the total power of the power station, including the wind farm, electrolysis system, and hydrogen power station, will be approximately 4.8 MW. Let's conduct a comprehensive analysis of the economic and environmental efficiency for the proposed project, which includes the use of electrolysis for hydrogen production and the purification of polluted water bodies on the

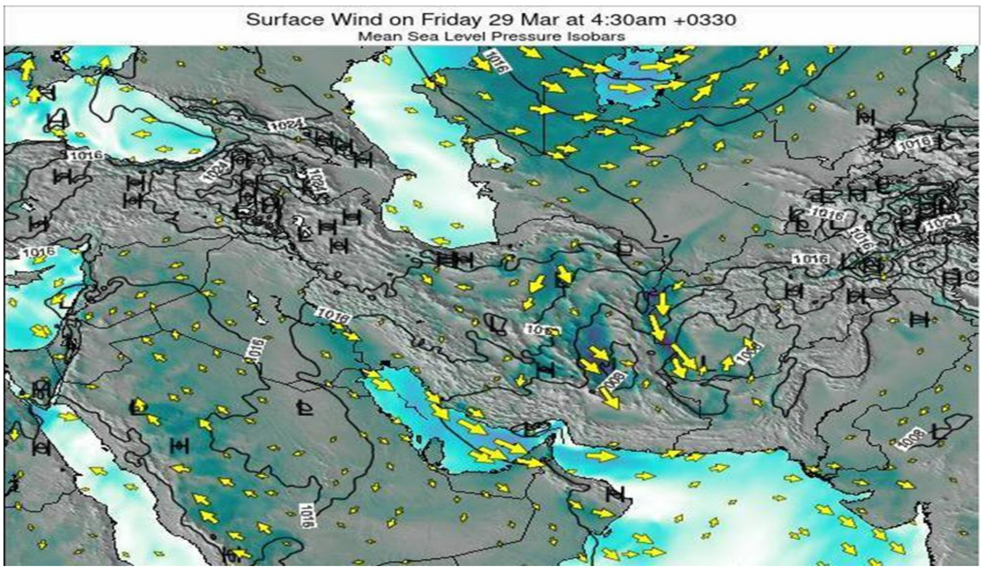

Figure 1: *Wind Map of Azerbaijan*

3. Energy Efficiency and Energy Consumption of Water Electrolysis Apsheron Peninsula.

Water electrolysis is a process in which water is decomposed into oxygen and hydrogen using an electric current passing through an electrolyte. There are several different types of water electrolysis, including alkaline (potassium-sodium) electrolysis, acidic electrolysis, variable electrolysis, and photoelectrolysis [14;15].

The energy efficiency and energy consumption of water electrolysis depend on several factors, including the technology used, operating conditions, and the efficiency of the electricity source. Here are the key aspects: There are several methods of water electrolysis, such as alkaline electrolysis (Fig. 2), PEM (polymer electrolyte membrane) electrolysis (Fig. 3), and high-temperature electrolysis (Fig. 4). Each has its energy consumption characteristics. For example, PEM electrolysis is typically more energy-efficient compared to alkaline electrolysis [16].

4. Electrolysis Technology

The hydrogen production processes discussed in this article are processes where water is the only input material, and hydrogen and oxygen are the only output materials. Moreover, the required energy expenditure should mainly consist of heat rather than useful work, such as electricity. As mentioned above, these processes can be represented as a series of chemical reactions summing up the decomposition of water [17].

Hydrogen production through water electrolysis is one of the most promising methods for obtaining "green" hydrogen that does not produce greenhouse gases when used. However, as noted, the high energy consumption of this process is a serious concern.

Advantages of Different Methods: The advantages of various methods depends on production conditions, raw material availability, energy costs, and environmental considerations. The development and diversity of hydrogen production methods play a crucial role in providing a sustainable and environmentally friendly energy source for the future [18]. In Azerbaijan, the development of these hydrogen production methods will depend on specific production conditions: raw material availability, energy costs, and environmental characteristics. Let's consider several methods of hydrogen production and their potential benefits for Azerbaijan: steam methane reforming (SMR), water electrolysis, thermochemical water splitting, and photocatalytic water splitting.

Water Electrolysis: If Azerbaijan has available renewable energy sources such as solar or wind, water electrolysis can be an effective and environmentally friendly method of hydrogen production. This may be particularly relevant in areas where there is potential for deploying renewable energy sources.

The use of platinum coating on a steel electrode can increase the efficiency of water electrolysis. Platinum is a well-known catalyst for water electrolysis, as it possesses high catalytic activity and corrosion resistance in aggressive electrolysis conditions.

Steel can be an inexpensive and sturdy material for electrodes. However, without a catalyst like platinum, water electrolysis may require higher voltage for an efficient process. Coating the steel electrode with a thin layer of platinum can significantly reduce this potential and provide more efficient water electrolysis.

However, it is worth noting that the use of platinum can make the process more expensive due to the high cost of this precious metal. In this regard, researchers are working on finding more affordable and efficient catalysts for water electrolysis.

Therefore, the use of nanostructured catalysts, such as metal nanoparticles or their compounds, can increase activity and enhance catalyst efficiency.

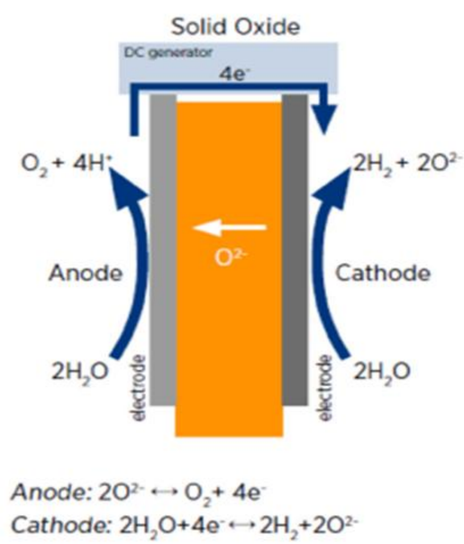

Figure 2: *SOEC reaction mechanism [16].*

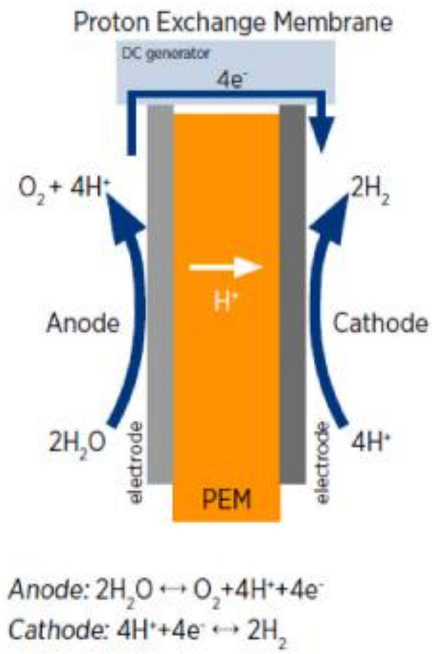

Figure 3: *PEM water electrolyzer schematic diagram and reaction mechanism [16].*

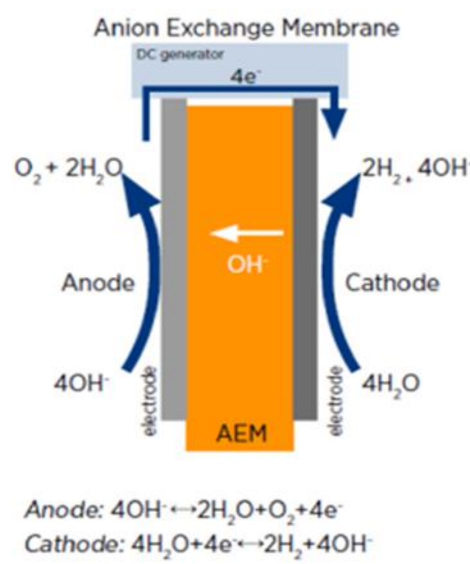

Figure 4: *Alkaline water electrolysis technology [16].*

Scientific research in the field of water electrocatalysis using metal nanoparticles is actively being pursued, and numerous metals have been tested for their catalytic properties. Some of the materials include [19]:

- Platinum nanoparticles (Pt): Although platinum is an expensive metal, platinum nanoparticles exhibit high electrocatalytic activity in water electrolysis.

– Iridium nanoparticles (Ir): Iridium can be used as a catalyst for efficient water electrolysis, especially in combination with other materials.

– Rhodium nanoparticles (Rh): Rhodium has also been investigated as a catalyst for water electrolysis.

- Nickel nanoparticles (Ni): Some research focuses on the use of nickel nanoparticles and their alloys, which may be more affordable compared to precious metals.

– Iron nanoparticles (Fe): Iron and its alloys are also considered as catalysts, especially in combination with other materials.

Nanoparticles provide a larger surface area for interaction with reactants, which can enhance process efficiency. However, besides the material itself, the architecture and structure of nanoparticles also play an important role in determining their catalytic properties [17].

In an experiment conducted by us under laboratory conditions, the coating applied to the metal surface using iron (Fe) method exhibited high operational characteristics, low cost, and a very short and simple production process duration compared to other coatings.

Each method has its unique advantages and limitations, and their application in Azerbaijan will depend on available resources, technical capabilities, and the country's energy and environmental strategy goals. Developing a balanced and sustainable hydrogen production strategy can help Azerbaijan utilize its potential for producing and using this clean energy source.

Let's assume that wind energy is used for water electrolysis to produce hydrogen. In this case, wind turbines generate electric current, which is then used in the electrolyzer to split water into hydrogen and oxygen. The process of producing hydrogen from water (H_2O) using electrolysis looks as follows:

$$2H_2O(l) + \text{electric current} \rightarrow 2H_2(g) + O_2(g)$$

At the anode, water oxidation occurs, forming oxygen (O_2), and at the cathode, hydrogen (H_2) is formed [18].

The advantages of such an approach include:

1. Use of renewable energy: Wind energy is a renewable energy source, allowing hydrogen production with minimal environmental impact and without greenhouse gas emissions.

2. Reduction of dependence on fossil fuels: Producing hydrogen using wind energy helps reduce dependence on fossil fuels and ensures a more sustainable energy system.

However, it should be noted that implementing such a system requires appropriate infrastructure for wind energy generation, hydrogen storage, and utilization. The efficiency and economic viability of this approach should also be considered based on specific conditions and regional characteristics.

The technology for obtaining hydrogen from water is called water electrolysis. This process involves splitting water into hydrogen and oxygen under the action of an electric current. This requires the use of an electrolyzer - a device containing electrodes and electrolyte through which the electric current passes (Fig. 5).

Brief outline of water electrolysis technology:

Step 1: Preparation of the electrolyzer.

The electrolyzer consists of an anode and a cathode separated by an electrolyte, which allows for the passage of ion current between the electrodes. The electrolyzer is filled with water or a solution of alkali or acid to create a conducting medium. These solutions provide the presence of ions in the water, allowing the passage of electric current through the water, causing the decomposition of water into hydrogen and oxygen [19].

The electricity consumption for producing one cubic meter (m^3) of hydrogen can vary significantly depending on the technology used, type of electrolyzer, system efficiency, energy source, and environmental conditions. Additionally, it is important to consider the temperature and pressure at which hydrogen production occurs, as these factors can also affect process efficiency (Fig.6).

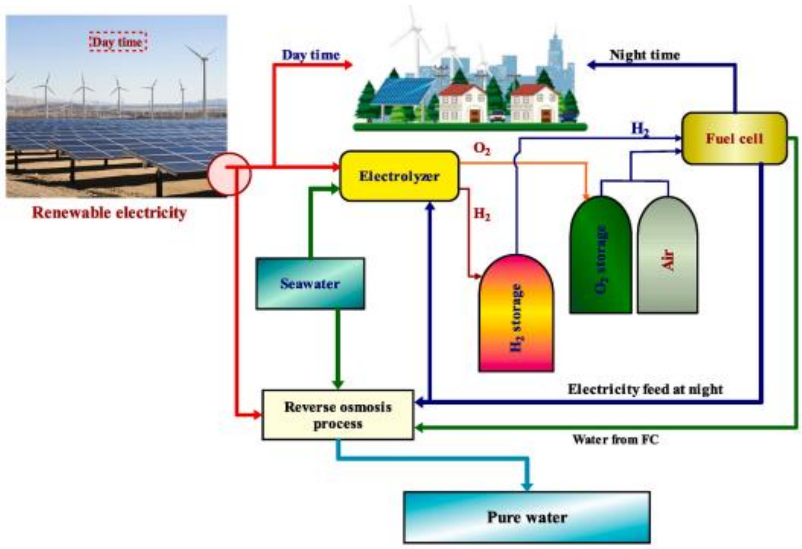

Figure 5: *Proposed integrated system for meeting energy and clean water needs using seawater [17].*

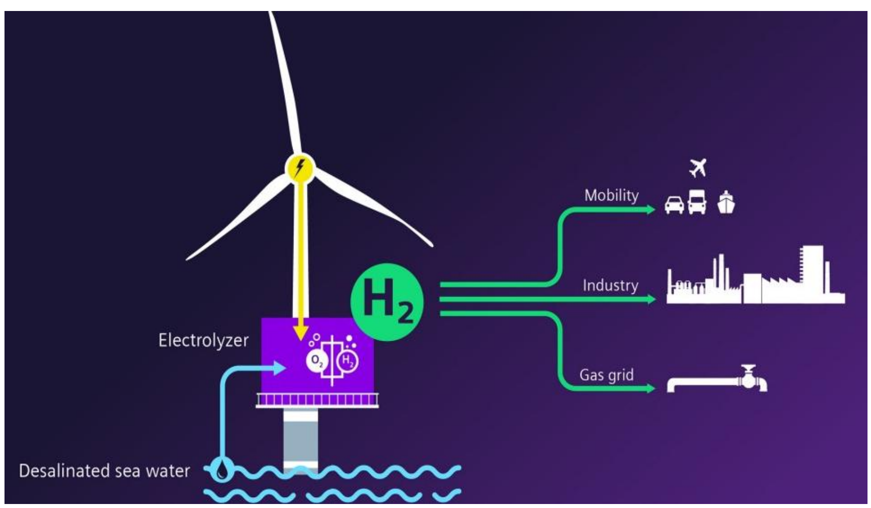

Figure 6: *Schematic structure of the electrolysis-polluted lake - H2Mare [20].*

An approximate estimate of the electricity consumption for producing one cubic meter of hydrogen by water electrolysis is about 4-6 kilowatt-hours (kWh). This value may vary in different systems and conditions, and precise values require more detailed data.

The cost of the electricity source, as well as the efficiency of the production process, will impact the overall energy expenditure of hydrogen production. Producing hydrogen using renewable energy sources such as solar or wind power can reduce environmental impact and make the process more sustainable in terms of climate aspects.

The water consumption for obtaining one cubic meter (m^3) of hydrogen via electrolysis depends on the chemical reactions that occur in the process of water decomposition into hydrogen and oxygen [21].

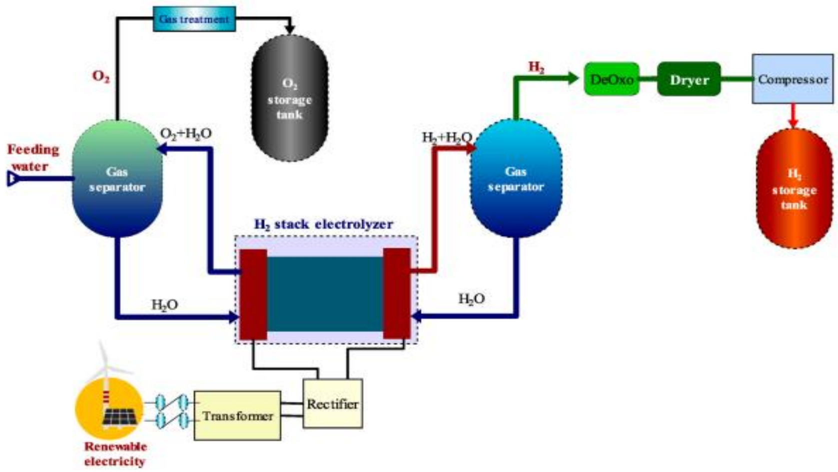

Figure 7: *Basic scheme of H2 and O2 production, including an electrolyzer [17].*

5. Heat Release of Hydrogen

1. Hydrogen has high heat release upon combustion, making it an efficient energy source. The primary reaction during hydrogen combustion is the combination of hydrogen with oxygen, forming water and releasing a significant amount of heat [22]:

Heat release of hydrocarbons (e.g., gasoline or diesel fuel):

$$2H_2+O_2 \rightarrow 2H_2O+\text{heat}$$

2. Hydrocarbons also have high heat release upon combustion. The primary components of hydrocarbon fuels are carbon and hydrogen, and the combustion reaction is similar to that of hydrogen:

$$C_nH_m + (n + m/4)O_2 \rightarrow nCO_2 + m/2H_2O + \text{heat}$$

3. Heat Release of Biomass: Biomass, such as wood or agricultural residues, is also an energy source. Its heat release is associated with the combustion process of organic materials, such as cellulose and lipids:

$$C6H10O5+6O2 \rightarrow 6CO2+5H2O+\text{heat}$$

6. Environmental Consequences of Renewable Energy Production from Polluted Lakes

While producing green energy from polluted lakes on the Apsheron Peninsula may have significant environmental benefits, such as improving water quality and restoring ecosystems, it may also have certain environmental consequences that need to be considered and minimized. Below are some potential environmental consequences of renewable energy production from polluted lakes:

- Ecosystem Alteration: Infrastructure construction for green energy production may lead to changes in lake ecosystems and surrounding areas. This can affect local plant and animal species, as well as the region's biodiversity [23].

- Loss of Natural Areas: Building hydroelectric power stations or other infrastructure for green energy production may require the allocation of natural land areas, potentially resulting in the loss of ecologically important territories or biological corridors for animal migration.
- Hydrological Regime Alteration: Operating hydroelectric systems may alter the hydrological regime of lakes and water bodies, which can impact their ecological condition as well as plants and animals dependent on this regime.
- Potential Increase in Water Consumption: Large amounts of water may be required to cool hydroelectric power station equipment, leading to decreased water levels in lakes and water bodies. This could negatively affect local flora and fauna, as well as water availability for the local population.
- Risk of Harmful Substance Emissions: While producing green energy from water is considered environmentally cleaner compared to traditional energy sources, there is a risk of emitting harmful substances into the environment due to accidents or improper equipment operation [24].

To minimize these environmental consequences, a comprehensive analysis of potential impacts is necessary. Furthermore, appropriate environmental protection measures should be developed and implemented, along with effective project management for green energy production projects considering environmental aspects.

7. Economic Justifications

The economic efficiency and payback period of capital investments in green energy production technology from polluted lakes on the Apsheron Peninsula may depend on various factors such as construction and maintenance costs, electricity prices, government support, and others.

To do this, it is necessary to take into account not only capital investments but also operating expenses, taxes, inflation, discount rate, and other factors. However, for simplification of calculations, let's focus only on capital investments and assume that all project revenues go towards repaying capital investments [25].

First, let's determine the annual income from hydrogen and oxygen production using windmill electricity:

Annual income = (electricity = 4800 kWh * $0.0388 * 8760 h) + (hydrogen 84.096 x 0.49 x 8760 h) = $1.632 + $360.974 = $1.993 thousand.

Payback period = Capital investments / Annual income

Payback period = $12,000 / $1,993 = 6 years

Conducting comprehensive economic analysis and developing a business plan for the project will help accurately determine its economic efficiency and payback period. Considering the potential environmental benefits and incentives for using renewable energy, as well as the growing demand for green energy worldwide, projects of this kind can have significant potential for successful implementation and economic success.

III. Results

Despite the identified pollution of water bodies in the Apsheron Peninsula with heavy metals, oil products, and the presence of coliform bacteria, hydrogen in this context can be identified as a potential resource that can be used for clean and sustainable energy.

The heat release of hydrogen is an important parameter when considering it as an energy carrier. Hydrogen has high potential as a clean energy source, and its use becomes increasingly relevant with the growing interest in alternative energy sources.

The developed technology for hydrogen production from polluted lakes on the Apsheron Peninsula represents an innovative and sustainable solution capable of contributing to the efficient generation of electricity to operate oil wells. The main stages of the process include electrolysis of water using renewable energy sources, purification of polluted lake water, and obtaining high-quality hydrogen. After that, hydrogen can be integrated into the energy system, providing stable and clean energy supply to oil wells.

This technology has significant advantages, such as sustainable use of local resources, including polluted lakes, for energy production, reduction of greenhouse gas emissions, and improvement of the environmental situation in the region. At the same time, it contributes to strengthening energy independence and increasing the efficiency of the oil industry.

It is important to note that successful implementation of this technology requires joint efforts from scientific and engineering teams, government agencies, investors, and the business community. However, the potential benefits in the form of sustainable energy, reduced environmental pollution, and improved economic efficiency make this approach highly attractive and promising for further research and practical implementation.

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