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Using Renewable Energy Sources for Improving Fuel Stations Efficiency

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ABSTRACT

This study explores the feasibility of using renewable energy sources—specifically solar and wind power—to operate fuel stations, either partially or fully, as an alternative to conventional fossil fuels. The research is driven by growing environmental concerns, escalating energy costs, and the global pursuit of sustainability and lower carbon emissions." The research, within its theoretical framework, addresses the definition of renewable energy sources, their types, and their generation mechanisms, highlighting the techniques for linking these sources to fuel station operating systems. A number of applied models of stations in various countries that have relied partially or fully on renewable energy were also analyzed, evaluating the economic, technical, and environmental feasibility of this transition. The research concluded that relying on renewable energy in this field is not only a possible option, but a future necessity, due to its benefits, including reduced long-term operating costs, reduced environmental footprint of stations, and enhanced energy independence. It also demonstrated that technical challenges can be overcome through the use of smart storage and load management technologies, along with governmental and legislative support. The research concludes with practical recommendations for adopting these solutions, proposing a general framework for implementing renewable energy projects in the fuel station sector in environments with high solar radiation, such as Iraq.

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1. Introduction

In recent decades, the world has witnessed a significant increase in energy dependence, particularly in the service and industrial sectors, most notably the fuel station sector. With the escalation of environmental warnings about climate change and carbon emissions resulting from the use of fossil fuels, the trend toward renewable energy has begun as a strategic and sustainable alternative. Fuel stations represent continuous electricity consumption centers for operating pumps and technical systems, placing pressure on traditional electrical grids. Therefore, integrating renewable energy into the operation of these stations has become an environmental, economic, and technical necessity. This research reviews the possibility of using solar, wind, and other clean energy sources to operate fuel stations, examining the technical and economic feasibility of this use, and presenting the most prominent challenges and opportunities. Many fueling stations, especially in remote areas or with high loads, suffer from complete dependence on traditional electricity sources, leading to:

- High operating costs.
- Increased carbon footprint and harmful emissions.
- Operational continuity is affected by power outages.

The research problem lies in the limited use of renewable energy sources at these stations, despite the availability of technologies and environmental and economic incentives. This calls for investigating the causes and evaluating possible solutions to expand this use.
The importance of this research emerges from several aspects:
1. Environmental: The use of renewable energy contributes to reducing carbon emissions and pollution resulting from fossil electricity.
2. Economic: Reducing long-term operating costs and increasing energy efficiency.
3. Developmental: Promoting the concept of sustainability within energy and transportation infrastructure projects.
4. Technical: Stimulating innovation in integrating solar and wind energy technologies into the fuel sector.
5. National: Supporting the state's drive towards diversifying energy sources and achieving energy security.
1. Analyze the reality of electrical energy consumption at fuel stations.
2. Study the technical potential of using renewable energy (solar, wind, etc.) to operate these stations.
3. Evaluate the economic and environmental feasibility of integrating renewable energy into stations.
4. Propose practical or design models for operating fuel stations with renewable energy.
5. Identify the challenges and obstacles that may hinder the implementation of this type of project and develop recommendations to resolve them.

2. Methodology

This research relies on the descriptive-analytical approach and uses the following methods:
• A theoretical study through a review of the literature and previous studies related to renewable energy and fuel stations.
• An economic and technical analysis of energy consumption data and the potential for renewable energy compensation.
• A comparative study of international and local models for stations that use renewable energy.
The first energy source exploited by humans was their own local energy. Then, a succession of energy sources were used, reaching their current state and what may be discovered in the future. Energy originates from multiple sources, including:
1- Radiant energy, whose source is the sun. This energy has led to several types of energy, including various types of fossil fuels (which are considered exhaustible and non-renewable energy sources), wind, biomass, and hydraulic energy .
2- Gravitational energy, resulting from the interaction of the Earth with the moon and the sun (tidal energy).
3- Geothermal energy, generated from the Earth's interior.
4- Nuclear energy, which is abundant but non-renewable .
Energy is defined as the ability to perform work. A body that can perform more is said to have more energy, and vice versa.
Renewable energy is a resource derived from nature that is permanent, inexhaustible, and replenishable. It is clean energy, meaning it does not pollute the environment. The United Nations defines it as energy generated from natural resources that are replenished at a rate exceeding their consumption. Renewable energy sources are abundant and all around us.
It is also defined as any form of solar, geophysical, or biological energy source that is replenished by natural processes at a rate equal to or greater than its consumption rate. This means that renewable energy sources have played an important role in providing sustainable energy services. They are available everywhere on Earth and can be easily converted into energy. They are also a means of achieving justice between the rich and poor countries of the world, ensuring the lives of those living today and future generations. The advantages of renewable energy are that they are readily available throughout the world, and they are clean and environmentally friendly. The increased use of renewable energy has led to a reduction in polluting emissions, with carbon dioxide levels declining after 2019. They are also permanently available, renewable, and easy to use using simple technologies and mechanisms. They are an important factor in developing the social environment.

1: Solar Energy: This is a renewable energy source that continues to exist with the sun. Solar energy is an effective and readily available alternative to fossil fuels, especially in electricity generation after they are depleted. Its most important uses are heating water and swimming pools, heating and cooling, and generating electricity. To produce electricity from solar energy, the method of mirrors and lenses is used, called concentrated solar power, or the method of photovoltaic cell complexes that convert solar energy into electrical energy, called photovoltaic conversion . Algeria is one of the Arab countries with significant solar energy potential. It possesses the largest percentage of solar energy in the Mediterranean basin, estimated at (4) times the total global solar energy

consumption, and (60) times the electrical energy area of European countries. According to specialized studies, Algeria receives (2000-3900) hours of sun, and an average of (5) kilowatts per hour of energy over an area of 1 square meter over the entire land of Algeria, meaning that the power reaches (1700) kilowatts/meter per year in the north and (2263) kilowatts/meter per year in the south, but Algeria only uses (5%) of this energy only .

2: Hydroelectric power: It is one of the energy sources that were used in the past, and German energy works to generate hydroelectric power, as it is considered a renewable and clean energy source, and depends on rivers, dams and wave movement, and it constitutes (20%) of the global production of electrical energy according to the latest statistics, after it used to produce about (16.4) of electrical energy production in the year (2014), and China comes in first place as it produces about (26.7) of the global production (12), and its importance decreased when coal was discovered, then its importance returned after scientific and technological development and the discovery of electrical generators . Among the most important Arab countries that produce hydroelectric power are the countries that have rivers and water, and Egypt comes at the forefront of the Arab countries that produce hydroelectric power, with a production capacity of (2700 megawatt hours), followed by Iraq with a capacity of (2513) megawatt hours.

3: Wind Energy: Wind energy is an indirect component of solar energy. Approximately 1% of the solar radiation reaching the Earth is converted into wind energy. Wind is formed as a result of the difference in temperature between the land and the surrounding atmosphere due to the sun. The sun heats different parts of the Earth at varying rates, causing air to move from cold to warmer regions. This wind movement is a significant source of renewable energy, but it varies from one location to another depending on wind speed and direction. Geographical location plays a significant role in determining wind speed. Wind has the potential to significantly deploy wind energy in most regions of the world, as global wind energy technical capabilities can exceed global electricity production. The general rate at which electricity can be produced from wind energy is a wind speed of no less than 3-5 m/s and no more than 25 m/s. This is because the ability to convert wind into electrical energy is proportional to the cube of the wind speed. Each time the wind speed doubles, the capacity increases eightfold. Any change in wind speed leads to a change in capacity. India is one of the countries with significant potential wind energy reserves. Scientific and statistical estimates indicate that India's wind energy reserves have reached more than 20,000 megawatts of generating capacity. Thus, India ranks high among developing countries with a high wind energy reserve. This means that the future of wind energy in India should be an economical alternative to traditional electrical power sources. Over the past three decades, the use of wind and its conversion into a source of electrical energy has begun to expand. California has installed more than 15,000 wind turbines, and Denmark has installed 2,800. It should be noted in this context that wind speed is not constant, but varies according to time, day, and month.

4: Geothermal Energy: This is a renewable energy source. It is a naturally occurring, high-temperature energy stored in magma deep within the Earth. It is estimated that more than 1,699% of the Earth's mass is composed of rocks with temperatures exceeding 1,000°C. The temperature increases with our depth in the Earth's interior at a rate of approximately (2.7 m) for every (100 m) of depth, i.e., it reaches (27) per (acre) or (55) at a depth of (2 km), and so on. The formation of this energy depends largely on the geological nature of the area. Areas containing permeable pores are water-retaining layers, meaning that the layers contain water or water vapor. In this case, this energy can be produced. Italy was the first to use this energy in 1911. Furthermore, (5%) of the current electrical energy in California, USA, comes from geothermal energy.

5: Biomass Energy: Biomass has been used as a fuel since humans learned to use fire and burn wood. Biomass is the newly formed material resulting from photosynthesis, and includes wood and any other plant or animal material that can be directly combusted and converted into fuel. Materials derived from biological materials are also biomass, such as methanol gases, wood alcohol, and ethanol produced from sugarcane, among others.

Converting biomass into energy is done through processes that convert waste, plants, and animal manure into natural gas, such as the gas produced by landfills where pits are filled with waste, covered, and dug through to provide a conduit for the gas produced by the decomposition of organic matter. The United Nations indicates that bioenergy accounts for 6% of global energy use. However, a detailed survey reveals that this percentage reaches 15% of global energy consumption. Developing countries consume more bioenergy than developed countries, with energy use reaching 38% of total energy use. In some developing countries, bioenergy use reaches 90% of the total energy used. In industrialized countries, bioenergy is used at similar rates, such as the United States, which uses 4%, Austria, 10%, and Sweden, 9% of the total energy used.

Third: Advantages of Renewable Energy

It is a type of energy generated from natural sources. This means that it does not burn out with high consumption and is constantly renewable. It differs from non-renewable energy sources, which are unlimited, environmentally friendly, and do not affect the environment at all. Alternatively, its impact is minimal, incomparable to that of fossil fuels, for example. Renewable energy sources have become an integral part of corporate responsibility seeking to

achieve sustainable development, and consumption of this energy is increasing day by day. In 2017, renewable energy covered approximately 8% of the world's electricity. After this amount, the United States, India, and Japan acquired the term "sustainable energy" because its sources are permanent and support the perpetuation of life on planet Earth. These sources do not require extraction, mining, or mechanization, as they are 100% natural. It is also sometimes called alternative energy. It should be noted that this term is more general, as it includes sources used instead of fossil energy sources or produce fuels similar to those produced by fossil fuels. However, not all alternative energy sources are considered renewable. For example, nuclear energy is considered an alternative to fossil fuels, but it is considered exhaustible. It is also called green energy because it does not produce waste or gases that increase global warming, such as carbon dioxide or nitrogen oxides. Although this term appears environmentally friendly, it also includes agricultural waste, which can be included as a renewable energy source because it is also exhaustible. The idea of using renewable energy is to achieve sustainable and cleaner development.

Energy Advantages:

Renewable energy has several advantages that benefit humans and the environment. The following is an explanation of the most important of these advantages:

1- It is renewable and cannot be depleted. It will remain as long as humans remain on Earth. Water flows constantly, the sun shines every day, and light winds never stop. However, strong winds are constant in some places, providing the world with a significant source of energy.

2- It is environmentally friendly: Unlike fossil fuels, which produce carbon, The installation cost of some types is relatively low, and they do not require much maintenance. Their maintenance costs are reasonable, as generating energy from wind and solar using photovoltaic panels is less expensive than generating gas.

3- They are safe for humans: They are non-flammable, and their use helps the world eliminate these dangerous materials that constantly require maintenance.

4- They are money-saving. With progress, increased efficiency, and widespread use, their costs will become simple, and they will also reduce monthly electricity bills.

5- They do not produce greenhouse gases such as carbon dioxide: This means reducing the phenomenon of global warming and halting its progression. Unnatural materials have caused the so-called climate crisis, particularly after the Industrial Revolution, forest fires, and rapid melting of ice.

6- They boost the country's economy by reducing the need to import or purchase energy from producing countries, meaning the country is self-sufficient in its own energy.

7- They protect human health because they do not release harmful gases into the atmosphere, which means reducing the incidence of widespread diseases.

Fourth: Challenges facing the development of the renewable energy sector. These challenges include the following:

A- The security challenge: The issue of national security and stability is one of the most important strategies that are taken into consideration, as well as the threats that are in friction with neighboring countries, such as the financial crisis and the great fear of repeating the scenario of terrorist events, as the security and safety of the state’s sovereign economic facility is maintained, as in the energy facility, in addition to that, after the security challenge, it is one of the basic principles of the economy, and countries must provide security, and without the presence of security, there is no economy, as the economist Smith Adam stated in the past in 1776 AD ( ). B- The political challenge is evident in the lack of clear policies for governments to implement to achieve sustainable development. This is compounded by the lack of clarity and organization of steps that support the growth, expansion, and support of the sector and its investments, as well as the lack of cooperation between executive and governmental bodies. The political challenge at the domestic level is more closely related to the political administration, which does not take risks and seeks to exploit energy alternatives and develop development projects to develop sectors that are balanced with the energy sector. Furthermore, corruption within some structures causes the failure of controlling programs in the energy sector and advancement through enhancing competencies and expertise, while maintaining the current situation, which demonstrates the administrative inadequacy.

C- The environmental challenge includes the practice of using energy resources, especially traditional ones that pollute the environment, from an environmental security perspective, through international restrictions and complex agreements in the field of environmental conservation, the most important of which are:

First: The United Nations Convention on Sustainable Development, 2012.

Second: The United Nations Convention on Climate Change, 1992.

D- The Technological Challenge: This includes the lack of specialized expertise and competencies in the field of energy technology, the lack of technology associated with the use of energy resources, the lack of a suitable climate, the lack of interest and focus on energy research and development, and the impediment and lack of training programs for competencies and skills, as well as the lack of access to foreign expertise . (Nashana 2016, pp. 62-63)

E- **The Challenge of Energy Resources Depletion**: This challenge for any country in the world includes the depletion of traditional energy resources such as gas and oil, as indicated by energy reserve statistics, whose indicators reflect the disappearance and depletion of these resources if they are used unregulated and alternatives are not sought in the future to reduce the pressure on them, enabling future generations to enjoy the country's wealth.
It is worth noting that there are other challenges that hinder the development of the sustainable energy sector, especially in some developing countries.

We summarize the most important of these:

First - Weak local legislation. What distinguishes developing countries is their clear lack of energy management legislation. This makes the process of improving the quality and efficiency of energy use and encouraging the use of renewable energy a voluntary process subject to market forces. Since most energy markets in these countries are still not fully competitive and are controlled by governments, it is therefore difficult to encourage and persuade consumers to improve their energy efficiency (Ghazlani, 2016, 158).

Second: Energy Pricing Policy: The policy of subsidizing energy prices has made it easier for the majority of the population to access services, due to their prices being significantly lower than the actual cost. This encourages increased consumption and waste due to the use of low-efficiency equipment. Thus, consumers are unable to appreciate the true value of their consumption due to subsidized prices.

Fifth: The Role of Inexhaustible Energy in Achieving Sustainable Development

Sustainable development is defined by the use it seeks to promote or preserve. The first to use the definition of sustainable development was Edward Baber, who defined it as: "The economic activity that leads to increased social welfare, with the greatest degree of care for available natural resources, and with the least amount of environmental damage and abuse." That is, the current generation should preserve the balance of the future generation, and that achieving sustainable development lies in the use of renewable energy to achieve global climate goals. However, international public financial flows to developing countries supporting the use of clean energy decreased by (24%), as they became (10.9) billion dollars in (2019), after they were (175) billion dollars between (2014) and (2018), despite the increase in the percentage of renewable energy use in the world from (1.6%) of the energy used to (17.7%) of clean and renewable fuel sources (27). This is because this use of energy sources can determine the quality of life, as the per capita share of electricity consumption can be obtained from the total electricity used in the country, divided by the total population, and thus establishes a common basis for comparison between electricity consumption in countries with large populations and countries with small populations, as the increase in the per capita share of electricity consumption indicates an improvement in the quality of life for the individual (). The relationship between renewable energy sources and sustainable development:

The relationship between renewable energy and sustainable development is very close, as renewable energy sources are a major driver of sustainable development. This is achieved through the application of three development aspects:

First: The environmental aspect:

The role of renewable energy in preserving the environment is very important, as the issue of environmental pollution has become one of the most serious and important issues. Protecting the environment from pollution has emerged as a significant issue on the international level. Therefore, the use of fossil fuels has begun to be limited due to the significant environmental pollution they cause. The world has begun searching for energy sources that are environmentally friendly, renewable, clean, and derived from nature, which is a primary source for producing this energy. What distinguishes them from traditional energy is that they are non-polluting and inexhaustible.

Second: The economic aspect

The future of renewable energy is very significant in industry, given its richness. It has begun to spread widely, especially wind, solar, and hydroelectric power. With scientific and physical progress, it has many uses in the future, making this energy economical, easy to use, and compatible with the needs of all members of society. It also helps create new job opportunities and uses simple technologies that can be manufactured locally in developing countries.

The economic relationship between renewable energy and sustainable development, including human development, is strong, as it links average per capita consumption of energy resources with human development indicators, especially in developing countries. This relationship changes patterns of energy production and consumption due to population growth, which leads to increased energy use. Hence, the importance of moving towards the use of renewable energy becomes clear.

Third: The social aspect: The connection between renewable energy and sustainable development is established through understanding the per capita consumption of energy resources and raising development indicators through per capita consumption rates of commercial energy resources, and their role in improving education and health services, and thus overall living standards.

Section Two: The Reality of Renewable Energy in Iraq and Prospects for its Application

First: The Current Reality of Renewable Energy in Iraq

1: Solar Energy

Solar energy relies on solar radiation, which is an important climate element. It emits large amounts of energy in the form of waves ranging in length from very short, such as gamma and x-rays, to long, radio waves, radiating in all directions. Solar energy can be defined as the light and heat derived from the sun, which humans harness using modern technologies through the photovoltaic phenomenon. This is achieved by using mirrors arranged in large groups called solar farms in open areas to harness solar radiation to generate electrical energy. This differs from solar cells placed on the roofs of buildings for use in heating water, as the mirrors reflect light onto tanks filled with water to heat it and generate steam, which drives turbines to generate electrical energy.T he data in Table 1 show the variation in solar radiation values over the studied climate stations (Mosul, Rutba, Baghdad, Al-Hay, Basra) for the period from 1989 to 2019. The highest value was recorded in the months of June and July (8088 and 801) milliwatts/cm³, respectively. The table above and Figure 1 show the variation in the total solar radiation amounts in Iraq between the climate stations from the general average of (570.3) milliwatts/cm³. The highest average was in the Rutba station, at (18007) milliwatts/cm³. The solar energy index in Iraq is increasing in strength from north to south and west, and photovoltaic solar cells are suitable for electricity production throughout Iraq. The deserts of Iraq could become a global provider of solar energy in the future, as the desert west of Iraq has the highest solar radiation for electricity generation compared to the global average surface radiation of 170 watts (W) m. The Iraqi deserts produce an average energy density of 270-290 watts (W) m and a peak energy density of 2310 kilowatts (kWh) m/year. Solar energy in Iraq ranges from 1800 to 2390 kWh/m/year.

Table (1) shows the monthly average total solar radiation (mW/cm) at selected climate stations in Iraq for the period from 1989 to 2019.

Months	Mosul	Al-Rutba	Baghdad	Al-Hayy	Basra	Rate
September	621	747	588	613	350	642
October	453	569	447	449	497	493
November	328	462	341	362	377	374
December	253	283	282	302	333	309
January	273	417	304	302	340	339
February	368	519	395	414	430	425

Source: Ahmed Essam Abdel Nabi Hanoun Al-Nafie, Balsam Shaker Shenishil, Atmospheric aerosols and their impact on the variation of solar radiation values in Iraq for the period (1989-2019), Journal of Sustainable Studies, Fourth Year, Fourth Volume, First Issue, Supplement 2 for the year 2022, p. 1039.

2- Wind Energy:

Wind energy can be harnessed to generate electricity when wind speeds are no less than 3-5 m/s and no more than 25 m/s. Wind farms can be built on land or offshore near the coast. The location selection depends on several factors, including wind directions and speed variations, and the geographical and topographical characteristics of the area. Electricity production from this source is affected by changes in wind speed, both rising and falling, and requires the availability of backup capacity from other sources. When establishing large wind farms, climate change must be studied and wind speed prediction programs used. Wind farms connected to the electrical grid can contribute approximately 21% of the energy, without significantly impacting the stability of the grid. Therefore, consideration must be given to distributing wind farms over wide geographical areas, ensuring the availability of other energy sources to supply the grid with its electrical energy needs, and providing backup capacity in the event of a decrease in wind speed.

3- Hydropower:

Hydropower is a clean and universally accepted energy source that relies primarily on the water cycle in nature. Hydropower is divided into three types: tidal energy, ocean energy, and hydroelectric power, which is produced by constructing dams on rivers and installing turbines that convert them into electrical energy . The estimated amount of potential energy in the Tigris and Euphrates rivers and their tributaries is (68.5) billion kilowatt-hours/year, as the construction of hydroelectric power stations is jointly linked with other projects that benefit from the construction of dams and reservoirs, such as using their water to irrigate agricultural lands and preserve fish wealth. Map (1) shows Iraq's ability to use hydropower dams for pumped storage and electricity generation by taking advantage of the geographical distribution of dam and reservoir projects on the Tigris and Euphrates rivers, where their total water revenue amounted to (49.59) billion m3 in 2020 (8). The data in Table (2) indicate the hydroelectric power dams used to generate electricity for the period (2015-2020), as the Mosul Dam station came in first place, despite its production declining from (750) megawatts in 2015 to (609) megawatts in 2020, and the Dokan and Darbandikhan Dam stations came in second place. In second place with a capacity of 221 megawatts each for the year 2020, the

Haditha Dam Station came in third place with a capacity of 188 megawatts for the year 2020 after it had occupied second place in 2015 with a generation capacity of 660 megawatts, and the Hamrin Dam Station occupied fourth place for the period from 2015 to 2020. Hydroelectric power constitutes the main source of renewable energy mix in Iraq, at a rate of 90%, and the development of hydroelectric power stations in Iraq helps to increase the rate of electricity generation from renewable energy sources, which constituted 2% of the generation mix.

Table 2: Hydroelectric dam capacity in Iraq to generate electricity (megawatts) for the years 2015-2020

Serial	Years\ dam	2015	2016	2017	2018	2019	2020
1	Mosul Dam	750	505	236	205	609	609
2	Dokan Dam	400	217	87	151	221	221
3	Darbandikhan Dam	240	243	119	164	221	221
4	Hamrin Dam	50	46	29	38	44	44
5	Haditha Dam	660	142	170	82	188	188

Source: Republic of Iraq, Iraqi Ministry of Planning, Central Statistical Organization, Water Resources Reports for the years 2015-2020, Directorate of Agricultural Statistics, p. 9.

4- Bioenergy:

This is the potential energy contained in plants, crops, forest waste, and human and animal waste. This energy can be harnessed either by harnessing it to produce thermal energy, or by producing liquid or gaseous fuels called biofuels for use in power plants. Biofuels must be extracted from organic waste, not from food crops, to avoid creating a food crisis, especially in light of the limited renewable water resources and arable land. Iraq is currently seeking to develop plans for projects to convert waste into thermal energy to generate electricity, and is seeking to establish factories that burn waste to become one of the renewable energy sources in Iraq. This is due to the presence of large quantities of conventional solid waste containing organic waste, which is released into the environment in various urban and rural settlements and population centers, and the resulting significant risk to human health, in addition to the uncivilized appearance it reflects on the environment. This depends on the extent of the country's progress in waste management and investing in the potential energy therein, as well as utilizing agricultural crop residues and converting them into energy. It appears from the data in Table 3 and Figure 3 that the amount of waste removed amounted to (314,319,000) tons, representing 64.3% of the total amount of waste released into the Iraqi environment for the year 2021, and the percentage of use of this waste to generate bioenergy from it is (0%), while the percentage of landfill operations in sites that do not have environmental approval constitutes (87.5%) of the Iraqi governorates, and dumping in empty yards constitutes 50%, and the percentage of recycling and reuse constitutes 12.5% in the outskirts of Baghdad and Dhi Qar governorates. Human waste and garbage contain a mix of organic and inorganic materials that can be used as a source of energy and methane production. The waste recycling and waste-derived fuel production project in the Tanjaro area of Sulaymaniyah Governorate is the first in Iraq to produce environmentally friendly biofuel for use as an alternative to fossil fuels in a cement factory. **Biodegradable waste includes:**

1 - Household waste, including garbage, food and fruit scraps, etc.
2 - Industrial waste, including food industry waste
3 - Plant waste, including energy crop residues, damaged branches and fruits, and weed waste
4 - Animal waste, including livestock manure and poultry and domestic bird manure waste.

Second: The developmental impacts of renewable energy in Iraq

The relationship between renewable energy and sustainable development is highlighted by the continuous and permanent provision of energy at an affordable cost, in quantities commensurate with local and global demand. Development is based on the concept of environmental protection and ensuring the optimal use and equitable distribution of resources. The role of renewable energy in development is evident in ensuring the supply of the current development system with a reliable and sustainable source that can be relied upon to prolong investment.

Iraq has sought to establish a national renewable energy policy by coordinating the work of relevant state ministries and working to create a knowledge base for renewable energy that would facilitate the integration of renewable energy into future projects. The Iraqi Ministry of Electricity established the Renewable Energy and Environment Unit in 2010. Related legislation includes the Ministry of Electricity Law of 2017, the first chapter of which stipulates support and encouragement for the use of renewable energy in various fields and the localization of its industries. Chapter Four of the law encourages the private sector to invest in the construction of renewable energy power plants, providing the necessary incentives. Iraq's energy system relies heavily on fossil fuel-based energy sources, with the energy mix being mostly fossil fuels in 2018. Oil ranked first, accounting for 78% of Iraq's energy mix, compared to 21% for natural gas. The share of renewable energy was very low, not exceeding 0.3%. Despite the diversity of renewable energy sources that Iraq possesses, it is still behind in this field, as 1,875 gigawatt-hours of electricity were generated by renewable energy sources, including 1,818 gigawatt-hours from hydroelectric power and 57 gigawatts from solar energy. Reliance on fossil fuels was 80% of electricity generation, 50% of which was

from natural gas and 48% from oil. The total final energy consumption amounted to 22,552 kilotons of oil equivalent in Iraq in 2018. This consumption varied between economic sectors, with the transportation sector ranking first, accounting for 50%, followed by the domestic uses sector, accounting for 10%. 24%, industry 19%, and other sectors 7%. Iraq sought to develop its own plan to reduce per capita carbon emissions by 6% by 2030 compared to 2010 levels . The data in Table 4 shows the amount of generation from hydroelectric plants in Iraq, whose contribution increased from 3.1% to 4%, with an actual production rate that increased from 291 megawatts in 2015 to 567 megawatts in 2019.

Table 4: Electrical energy produced (megawatts) by hydroelectric plants in Iraq, years for the period 2015-2019

Years	Oil Production Rate	Participation Rate%
2015	291	3,1
2016	385	2
2017	248	2
2018	208	2
2019	567	4

Source: Iraqi Ministry of Electricity, Annual Statistical Reports 2015-2019, Information and Systems Department, Central Statistics Division.

Third Section :Renewable Energy and Fuel Stations

First: Introduction

This chapter aims to study the possibility of using renewable energy sources as an alternative or complement to conventional energy in operating fuel stations, in light of the environmental and economic challenges facing the energy sector. This chapter also addresses the practical applications of solar and wind energy in fuel stations, presenting application models from some countries, and analyzing the technical, economic, and environmental feasibility of using this energy.

Second: Types of Renewable Energy Used in Fuel Stations

1. Solar Energy

• Relies on converting sunlight into electricity using photovoltaic panels.

• It is considered one of the most common renewable energy sources for operating fuel stations, especially in sunny areas.

2. Wind Energy

• It can be exploited in open areas with sufficient wind speed.

• It is used to generate electrical power via wind turbines to power station equipment.

3. Bioenergy

• It is used in some rural or industrial stations and is extracted from organic residues such as waste oils and plant materials.

Third: Benefits of Using Renewable Energy in Fueling Stations

Benefit	**Interpretation**
Reducing operating costs	Lower electricity bills and long-term maintenance.
Reducing carbon emissions	Reducing the station's dependence on fossil fuels, thus reducing harmful emissions.
Energy independence	Reducing dependence on the national electricity grid, especially in remote areas.
Enhancing environmental image	The station is perceived as environmentally friendly, which attracts a wider segment of customers

Fourth: Challenges facing the use of renewable energy in fuel stations

Challenge	**Explanation**
High initial cost	The cost of installing solar panels or wind turbines is high.
Limited space	Some stations do not have sufficient space to install the systems.
Climate change	This may negatively impact energy production (clouds, rain, low wind).
Need for a hybrid system	Renewable energy cannot be fully relied upon; it must be supplemented by conventional energy.

Fifth: Application Model - Solar-Powered Gas Station

Case Study: Gas Station in Jordan

Data	Element
Location	Mafraq Governorate
Number of solar panels	80 panels with a total capacity of 20 kilowatts
System type	Off-grid system + storage batteries
Monthly savings	US$1,000 in electricity bill
Payback period	4-5 years

Results: The station achieved a 40% reduction in operating costs and a reduction in carbon emissions equivalent to 25 tons annually.

Sixth: The economic feasibility of using renewable energy in fuel stations

Item	Estimated data (for medium-sized station)
Solar System Cost	$20,000
Annual Savings	$10,000 (electricity + less maintenance)
System Lifespan	20-25 years
Cost Payback Period	2-3 years
Return on Investment	300% over 10 years

Seventh: The Environmental Impact of Using Renewable Energy
- Reducing carbon dioxide emissions by up to 60%.
- Reducing noise pollution from diesel generators.
- Improving air quality around the station.
- Promoting the move toward a green economy.

Eighth: Technical Recommendations

Details	Recommendation
Using hybrid systems	Combining solar power with generators to ensure continuity.
Investing in storage	Installing high-quality batteries to ensure continuous operation at night or during cloudy weather.
Periodic system maintenance	Ensuring the operational efficiency of panels and turbines.
Staff training	On how to operate and maintain renewable systems.

Ninth: General Results of the Chapter
- Renewable energy can effectively contribute to reducing the operating costs of fuel stations.
- Economic and environmental savings are particularly noticeable when using solar energy.
- Challenges exist that require technical and administrative solutions to ensure the effective transition to renewable energy.

4. Conclusions

First: Conclusions

1. **Reliability of Renewable Energy**: The research demonstrated that renewable energy, particularly solar energy, represents a practical and sustainable option for operating fuel stations, especially in areas with high solar radiation.
2. **Long-Term Economic Feasibility**: The research concluded that the initial investment cost in renewable energy systems can be recovered within a relatively short period of time through reduced operation and maintenance costs.
3. **Positive Environmental Impact**: The results showed that the use of renewable energy sources reduces carbon emissions and environmental pollutants, contributing to improved air quality and a reduced environmental footprint of fuel stations.
4. **Achieving Energy Independence**: The use of renewable energy enhances the independence of stations from traditional electrical grids, especially in rural or remote areas.
5. **Technical and operational challenges**: Despite the numerous advantages, there are obstacles related to storage capacity (batteries), maintenance requirements, and technical training.

Second: Recommendations

1. **Adopt supportive national policies**: It is necessary to issue legislation and encourage government policies that support the transition to the use of renewable energy in fuel stations through tax incentives and soft loans.
2. **Initiate pilot projects:** Implement model projects in selected areas to evaluate practical performance and develop a local model suitable for comprehensive implementation.

3. **Collaborate with the private sector**: Strengthen partnerships with companies operating in the field of renewable energy to provide technologies, technical support, and training of specialized personnel.
4. **Adopt hybrid systems**: Integrate renewable energy sources with the national grid or conventional generators during the transitional phase to avoid intermittent power supply problems.
5. **Raise environmental awareness**: Organize awareness campaigns targeting station owners and the community to inform them of the benefits of using renewable energy.

Third: Proposals

1. Conduct comparative studies between the performance of conventional fuel stations and those that rely on renewable energy in various climatic environments.
2. Expand the scope of research to include the use of other renewable energy sources, such as wind energy and biomass, depending on the nature of the region.
3. Design a unified national system for evaluating the energy efficiency of fuel stations and adopting it as a criterion for providing incentives or support.
4. Include curricula in universities and technical institutes on the design and operation of renewable energy stations and their applications in critical infrastructure.
5. Develop a national database to document local and international experiences in this field to guide future planning and energy decisions.
6. Conduct a practical experiment in one of the government stations, which consists of installing a system to utilize solar energy to feed the lighting networks and cameras as a first stage to reduce the pressure on the national electricity source or the diesel generators operating therein, and then generalize the experiment to feed the processing equipment (fuel equipment and submersibles) in which the energy consumption is somewhat low compared to the pumps (processing or emptying) that contain electric motors. It is preferable to choose stations that contain large vacant spaces to deploy solar panels in them, or it is possible to exploit the large spaces of the processing sheds or the roofs of the service buildings in those stations.

References

[1] Safaa Hashim Abdul Rahman, Mu'ad Mohsen Mahwal, A Guide to Renewable Energy Sources and Their Impact, Baghdad College of Economics University, 2022.
[2] Salehi Policy Summary: Renewable Energy Sources and the Impacts of Climate Change, Intergovernmental Panel on Climate Change, 2011.
[3] REN21(2020) Renwables2020, Global Status Report. Paris, pp. 28.
[4] Safaa Hashim Abdul Rahman, Mu'ad Mohsen Mahwal, A Guide to Renewable Energy Sources and Their Impact, Baghdad College of Economics University, 2022.
[5] Abdul Ali Al-Khafaf, and Tha'ban Kazim Khudair, Energy and Building Pollution, Dar Al-Seera for Printing and Publishing, Amman, 2007.
[6] Forouhat, Renewable Energy as an Approach to Sustainable Development in Algeria, Al-Baheth Al-Kabir Magazine, Issue (11), 2012.
[7] Riad Shadid, Renewable Energy Potential in Lebanon, Ab'ad Magazine, 1998, p. 90. Wahid Mustafa Ahmed, Peaceful Uses of Engineering, Energy, and Nuclear Power, Dar Al-Kotob Al-Ilmiyah for Publishing and Distribution, Cairo, 2013.
[8] EA Key Renewable Trends: Excerpt from: Renewable Information, International Energy Agency, 2016: p. 3.
[9] Hisham Hariz, The Role of Renewable Energy Production in Restructuring the Energy Market, Al-Wafa Legal Library, Alexandria, 2014.
[10] Mervat Mohamed Abdel Wahab, Renewable Energy and the Possibility of Meeting the Challenges of Conventional Energy and Enhancing Egypt's Role as a Side Market for Carbon Trade, Scientific Journal of the Faculties of Commerce Sector, Issue 17, Cairo 2017.
[11] Dr. S. Shauhan Sharif Estafa, Non-Conventional Energy Sources, translated by Atef Youssef Mahmoud, General Authority for Amiri Printing Affairs, Cairo, 2012.
[12] Wissam Nazih Abdel Qader, Evaluation of the Strong and Weak OH-Link Splitting Process in the Presence of a Catalyst by Laser Excitation to Secure Hydrogen Energy, Master's Thesis, Higher Institute of Laser Research and Applications, Damascus University, Syria, 2014.
[13] Al John Rafanshi, Technical Energy and Future Directions, translated by Dr. Abdul Basit Ali Saleh Karman, Arab Organization for Translation, Beirut, 2011.
[14] Shauhan Sharif Estafa, Non-Conventional Energy Sources, translated by Atef Youssef Mahmoud, General Authority for Amiri Printing Affairs, Cairo, 2012.
[15] Abdullah Hassoun Mohamed and others, Sustainable Development: Concept, Elements, and Dimensions. Diyala University Journal, Issue (67), Iraq.
[16] Halima Khawalef, The Importance of Renewable Energy in Environmental Protection and Its Positive Impacts on the Economy, Algerian Journal of Comparative Law.

[17] Lahib Ahmed Mohammed, Khansa Nasser Oqla, The Importance of Renewable Energy in Environmental Protection for Sustainable Development, University of Baghdad, 2022.
[18] Salima Boulgrinat, Masoud Shabib, The Contribution of Renewable Energy in the World to Achieving Sustainable Development, Economic Researcher Journal, Volume (10), Issue Two, Algeria, 2022.
[19] Sil Raquel Arsoy Julia Terrabon, Sustainable Transformation in the Iraqi Energy System, Al-Bayan Center for Studies and Planning, Iraq, 2020.
[20] Harry Estepanian, Solar Energy in Iraq: From Dawn to Dusk, translated by Muhammad Khalouk Ibrahim, Al-Bayan Center for Studies and Planning, Iraq, 2020, pp. 9-13.
[21] United Nations Economic and Social Commission for Western Asia, Bioenergy and Sustainable Development in the Arab Countryside, Beirut, 2019.
[22] Hadi Faisal Saadoun, Environmental Pollution in Iraq and Its Impact on Health and Health Security, Journal of the College of Basic Education, Volume 24, 2006.
[23] Bushra Ramadan Yassin, Renewable Energy Sources and Their Development Applications in Iraq, Madad Al-Adab Journal, College of Education for Humanities, University of Basra, 2023.
[24] Safaa Hashim Abdul Rahman Maad Mohsen Majoul, A Guide to Renewable Energy Sources and Their Impact on the Surrounding Environment and Environmental Pollution, Baghdad College of Economics, University of Baghdad, 2022.
[25] Abdul Ali Al-Khafaf and Taban Kazim Khadir, Energy and Environmental Pollution, 1st ed., Al-Maysarah Printing and Publishing House, Amman, 2007.

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