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THE IMPACT OF ENERGY ALTERNATIVES ON SOME MACROECONOMIC VARIABLES IN IRAQ: NATURAL GAS AND SOLAR ENERGY AS A MODEL

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Abstract:
The Iraqi economy faces complex challenges in the energy sector, as a result of its almost total dependence on crude oil and natural gas to generate electricity. This dependence has led to fragility in energy security, and high financial costs as a result of importing gas, as the annual import bill is estimated at about $4 billion, which is an increasing burden on the public budget and the balance of payments. In contrast, Iraq has a large and untapped potential in the field of solar energy, which is represented by high annual solar radiation rates, and provides large areas suitable for investment.
This research aims to analyze the overall economic impact of the shift towards solar energy as an alternative strategic option, by reducing domestic gas consumption and directing it towards export, thus enhancing public revenues, reducing dependence on imports, and contributing to economic stability.
The research also discusses the institutional and technical challenges that hinder the energy transition, and proposes practical policies to overcome them, in a way that supports diversification of sources of income and sustainable growth.
The study finds that solar energy is not only an environmental solution, but also an effective macroeconomic tool that contributes to improving macroeconomic indicators, especially reducing the fiscal deficit, improving the trade balance, and increasing employment opportunities.
The research calls for the adoption of a comprehensive national energy security strategy, combining economic efficiency, environmental justice and sovereign decision-making autonomy.

Keywords: For macroeconomics, solar energy, natural gas, public budget, energy security

Chapter I: The general framework of the study

Introduction :

The energy file is one of the most complex and sensitive files in the Iraqi economy. Fossil fuels are the main pillar of the Iraqi economy and one of the most influential factors in macroeconomic variables in Iraq , due to its rentier nature and its almost complete dependence on crude oil revenues. Although Iraq has huge reserves of hydrocarbon resources, the electricity sector faces an ongoing crisis, as a result of the heavy dependence on natural gas to operate generation plants, which is fragile, given the dependence of a large part of this gas on imports from abroad.
This reality poses multiple challenges at the level of the public budget, and puts energy security in the face of increasing geopolitical and economic pressures.
As domestic demand for electricity escalates and supply crises recur, it is imperative to move towards more sustainable strategic alternatives. In this context, solar energy is emerging as a promising option in which Iraq has significant comparative advantages, including high annual solar radiation rates, and provides large untapped areas. Despite this potential, the contribution of solar energy to the energy mix is still very small, indicating a significant gap between available capacity and the level of actual utilization.
The importance of this research stems from the need to restructure the energy system in order to achieve two main goals: the first is to reduce dependence on imported natural gas, and the second is to convert locally produced gas into an exportable economic resource, and turn it into an effective economic arm that reduces the burden of the public budget and enhances the balance of payments, which reflects positively on macroeconomic indicators in Iraq.,instead of consuming it locally only in the production of electricity. The exploitation of solar energy in electricity generation can

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provide a stable and sustainable alternative, enhance energy security, reduce pressure on the public budget, and open the way for Iraq to diversify its sources of income away from crude oil.
Based on the above, this research seeks to analyze the economic impact of the shift towards solar energy in Iraq, by studying the available potential, the feasibility of reducing natural gas consumption, reducing dependence on imports, and evaluating future opportunities for exporting surplus gas. It also aims to highlight the institutional, financial and technical challenges that may hinder this transformation, and to propose policies to overcome them

1-The importance of the study

The importance of this research stems from the need for a new strategic approach to managing Iraq's energy profile, in light of the existing environmental, economic and political challenges. The importance of the research can be summarized in the following points:

- **Economically:** Reduce government expenditures on gas imports, and achieve financial savings that can be directed to other development sectors.
- **Strategically:** Liberalize domestic gas for export purposes, promoting diversification of sources of income and reducing dependence on crude oil exports.
- **Environmentally:** Supporting the transition towards clean and sustainable energy sources that contribute to reducing carbon emissions and environmental pollution.
- **Developmental:** Stimulating investment in the renewable energy sector and creating new jobs.
- **Geopolitically:** Strengthen national decision-making independence by reducing reliance on energy imports from neighboring countries.
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2-The Objectives of the study

This research aims to analyze the **economic impact of transitioning towards solar energy utilization in Iraq** by:

- Reducing natural gas consumption in the electricity sector.
- Decreasing reliance on imported natural gas from abroad.
- Assessing the feasibility of exporting surplus gas as a new economic leverage.
- Highlighting the role of solar energy in supporting economic stability and national energy security.

3-The Problem of the study

Iraq experiences a persistent crisis in its electricity sector, primarily characterized by an excessive reliance on natural gas to operate power plants. A significant portion of this gas is imported from neighboring countries, particularly Iran, rendering Iraq vulnerable to political fluctuations and payment burdens, thereby imposing a considerable financial strain on the general budget. Simultaneously, Iraq's vast potential in solar energy remains largely unexploited, leading to continued resource waste and exacerbating imbalances within the energy system.

4- the Hypothesis of the study

- Reducing dependence on natural gas will contribute to reducing the burden on the Iraqi public budget
- Expanding the use of solar energy will have a positive impact on the balance of payments
- The combination of local gas and solar energy will bring Iraq a more efficient and cost-effective energy mix in the long term
- Increasing the use of solar energy and reducing dependence on natural gas will increase the possibility of exporting natural gas instead of consuming it locally, providing an additional resource that supports the stability of the Iraqi macroeconomy
- Investing in solar power will boost growth and create additional jobs for the unemployed

5- Previous studies

- The renewable energy file, especially solar energy, has witnessed increasing interest in the Iraqi and international scientific literature in recent years. Most of the previous studies focused on the technical and economic dimensions of the use of solar energy, but they rarely addressed the direct relationship between solar energy and reducing natural gas consumption, or future export potential.
- Al-Ansari et al. (2021) indicated that Iraq has significant renewable energy capabilities, but institutional challenges hinder their adoption. Hassan and Abdulhameed (2020) addressed the high radiation potential of Iraq, confirming

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its technical readiness to adopt solar energy. Jiyad and Al-Dulaimi (2023) focused on the economic impact and estimated significant financial savings from the partial shift towards solar energy.

- The *UNDP Iraq* (2022) report also included a strategic vision for energy security and proposed the integration of solar energy to reduce dependence on imported gas. Suhail and Al-Khafaji (2019) highlighted the financing and management challenges in the Iraqi renewable energy environment. The International Energy Agency (IEA, 2023) discussed opportunities to integrate solar energy into national energy policies to promote energy independence.

6. Research Gap

Despite the importance of previous studies, they often dealt with solar energy from a technical or environmental perspective, without linking it in an integrated manner to the direct economic dimensions, especially with regard to reducing gas consumption, liberalizing it for export purposes, and the impact on the trade balance and energy security. Hence, the importance of this research in bridging this gap, by providing a comprehensive economic analysis linking the transition to solar energy, reducing dependence on gas, and enhancing energy and financial security for Iraq

Conceptual frame of reference

In this chapter, the basic concepts related to energy security, natural gas and solar energy will be reviewed with the aim of understanding the dimensions of the research problem and analyzing it from an economic point of view. It also highlights the reality of energy in Iraq to pave the way for its evaluation in the subsequent chapters.

The first topic: The concept of energy security and sustainable energy

First, the development of the concept of energy security

Early recognition of the importance of oil was reflected in Winston Churchill's decision in 1912 to convert the British Navy's fleet from coal to oil, which highlighted the early relationship between energy and national security (it was said that he rode victory in World War I on a wave of oil (Yergin, 1991, p12), from which oil gained clear importance that began to grow rapidly and the process of securing it became a process related to the national security of any country.

The concept of energy security emerged clearly during the Second World War, as oil became a crucial element in the war, as its supply of military vehicles determined the results of battles such as Al-Alamein 1942(Yergin, 1991,p45).

What increased its importance was its inadequacy in the major industrialized countries, especially after it increased its contribution to providing the necessary energy for transport and production , which prompted them to import from developing countries. This problem was not to close the industrialized West in the 1950s and 1960s , because the entire oil industry was in the hands of Western oil companies, starting from the initial survey to drilling, production, transport and refining. However, in the 1970s, the matter differed. After the nationalization processes and OPEC's control of prices and the use of oil as a weapon in the 1973 war, this incident caused the first oil shock. A few years later, in the same decade, the supply of Iranian oil stopped during the peaceful revolution in Iran, causing the second oil shock. These two incidents prompted the major industrialized countries to think seriously about finding mechanisms to ensure the availability of energy and increase the flexibility and diversity of supplies, after there were real concerns about the smooth supply of energy to the major industrialized countries. The concept of energy security focused for long periods on securing oil supplies from developing oil countries, especially in the Middle East, to the major industrialized countries in Europe, America and Japan. This concept also developed more broadly when Global demand has increased rapidly from emerging economic countries such as China and India , and after the negative environmental effects that accompanied the oil industry and the consumption of oil to secure the energy necessary for production, which paved the way for the search for alternative energy sources that are environmentally friendly and sustainable, and due to the importance of the subject, several international conferences were held to reach agreements that reduce environmental pollution in the world .

. The International Energy Agency has defined the concept of energy security as "ensuring the availability of affordable and stable energy supplies, while reducing reliance on unreliable or unstable sources, and promoting energy efficiency and diversification in its sources".

IEA

What the World Bank has defined more comprehensively includes the environmental dimension explicitly (energy security means meeting current and future energy demand efficiently, while ensuring the sustainability of the environment and the resilience of systems to shocks such as price fluctuations or supply disruptions.)UN, 2015) as defined by the Organization for Economic Cooperation and Development through the identification of three dimensions (OCED, 2014) :

1. Physical availability of fuel andelectricity
2. Affordability for consumers and industries
3. Environmental sustainability to avoid climate crises

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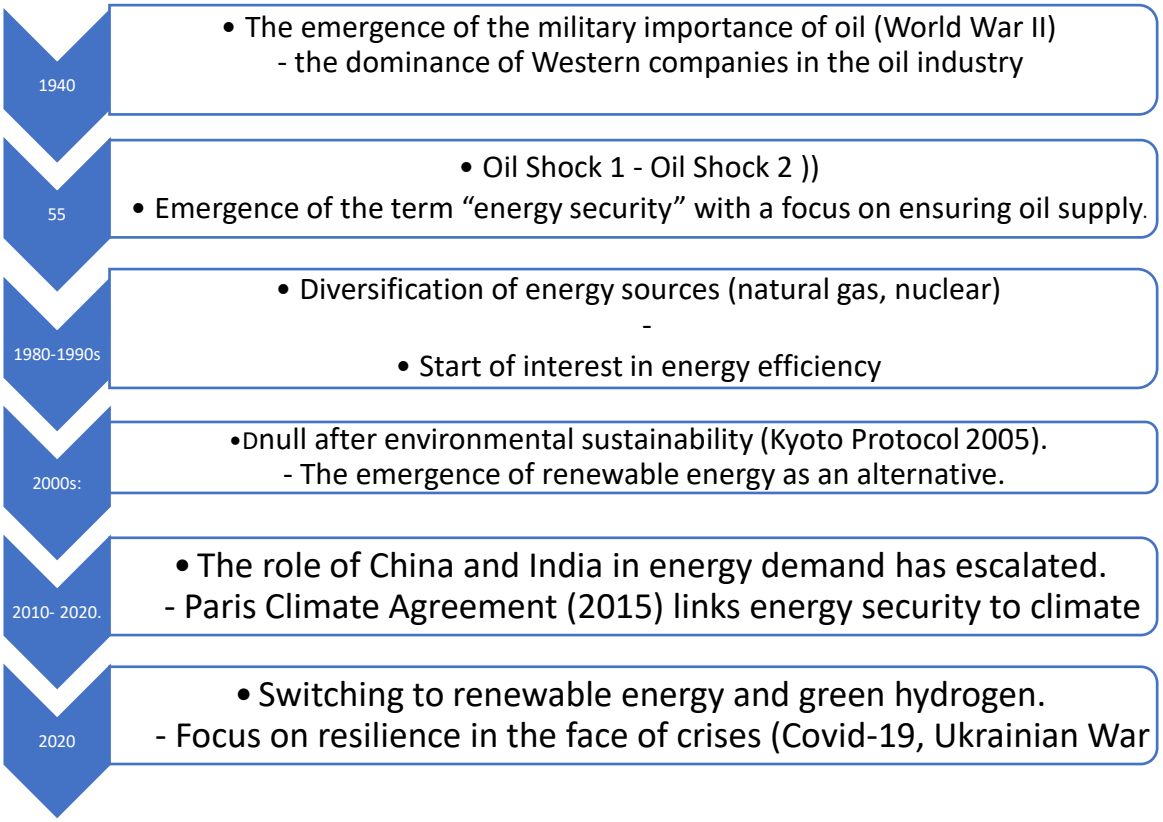
After 2021, with geopolitical and environmental developments, the concept became more emphatic on the environmental dimension, sustainability and emphasis on renewable energy sources. The concept became (energy security is the ability to ensure sustainable, flexible and affordable energy supplies, with a focus on the transition to clean energy and reducing dependence on fossil fuels, especially in light of geopolitical crises and price fluctuations) (IEA, 2023).
and defined by UNEP (energy security is the cornerstone of sustainable development, and must take into account equitable access to energy in developing countries, while accelerating the transition to wind and solar energy to avoid climate crises (UNPE, 2020,8))

Figure (1) Evolution of the concept of energy security



Source : From the work of the researcher

Second : The concept of sustainable energy

With the transformation of sustainable energy into a cornerstone of the concept of energy security as we have noted from the previous concepts, the need to clarify the concept of sustainability has emerged .
Sustainable energy is one that meets the needs of the present without compromising the capacity of future generations, while ensuring reasonable prices and minimizing environmental impacts (UNEP, 2021). In this context, we note the interdependence between the aforementioned concepts. Based on these data, the role of renewable energy emerges to meet the demands of these concepts. Renewable energy, because of its advantages of low pollution rates, by avoiding dependence on oil, gas and coal, and at the same time contributes to enhancing energy security. Here, several topics overlap, such as the equitable distribution of resources between the present and the future, the preservation of the environment and the quality of life for humans , all of which are approved development standards. Therefore, it is clear from this analysis that the interdependence between the previous concepts is not only theoretical, but also finds its practical embodiment in renewable energy projects, as shown in some successful projects such as the Moroccan project (Noor-Ouarzazate), which reduced fossil fuel imports by 20% (MASEN, 2022)
Countries that suffer from a shortage of energy supplies, including Iraq, can benefit from this experience, especially since the Iraqi government is working towards increasing reliance on solar energy, especially since it enjoys high solar brightness levels. This is what the Iraqi Ministry of Electricity has worked on, which aspires to produce (5 gigawatts)

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by investing in solar energy in southern Iraq, specifically in Al-Zubair district in Basra governorate, which enjoys a desert environment, and in Karbala governorate to install 500,000 solar panels (Iraqi Ministry of Electricity, 2023). This will be discussed in detail in the subsequent sections

Thus, the transition to renewable energy is not just an environmental choice, but a strategic tool for achieving economic, social and environmental sustainability at the same time.

The second topic: Natural gas in the energy economy

First :Components of Natural Gas

Raw natural gas consists of a mixture of hydrocarbon and non-hydrocarbon gases, of which methane (CH) is the main component at 40% to 50%, and is responsible for most of the calorific value of natural gas. This is followed by 5% to 10% ethane (C2H) and 1% to 5% propane(C2H), which are vehicles that are often used as household or industrial fuels after separation. Non-hydrocarbon components include carbon dioxide (CO_2) of up to 20% or more, which is an impurity that is removed during processing to raise combustion efficiency, in addition to hydrogen sulfide (H_2S) of 0% to 1%, which is a toxic and corrosive compound that is also removed at early stages of processing. The proportions of these components vary depending on the source of production and geological formation conditions. (Speight, 2007,p5)

Natural gas is one of the purest and most efficient fossil fuels. It contains less carbon than coal and oil. Studies show that the combustion of one ton of natural gas produces about 0.63 tons of carbon dioxide, compared to 0.82 tons of oil, and1.05 tons of coal (Hussein,1999, 2)

. Natural gas has several characteristics that make it one of the cleanest and most efficient fossil fuels, including (Al-Marsoumi, Abdulali,2015, 10)

1- Reduced emissions: When natural gas is burned, emissions of greenhouse gases, such as carbon dioxide (CO2), are lower compared to conventional fossil fuels such as coal or oil.
2- High efficiency: Natural gas is one of the most efficient fuels for power generation due to the ability to produce more energy using less fuel.
3- Ease of transportation and storage: Natural gas can be stored and transported through pipelines or through liquefied natural gas (LNG), which facilitates its widespread distribution.

Second: Natural Gas in the Energy Economy

Natural gas is divided into two main types:

1. Associated gas: It is the gas that is produced as a by-product when oil is extracted from wells. Associated gas is often burned at oil sites if there is not enough infrastructure to process and use it.
2. Non-associated gas: Gas that is produced independently of oil extraction. It is extracted from natural gas fields and represents a major source of energy, as it is processed for use in multiple fields such as electricity generation and industry.

Third: Uses of Natural Gas:

Uses of natural gas in the industrial and economic sectors

Natural gas is a vital nerve in modern industries, as its applications enter a value chain spanning multiple sectors. The importance of this resource goes beyond the fact that it is just a source of energy, to form an essential raw material in many manufacturing industries.

1- Petrochemical industries: The petrochemical industry, which today represents the heart of modern industry,

accounts for the largest share of natural gas uses, where ethane, propane and butane are extracted to manufacture bioplastics such as polyethylene. Studies indicate that about 60% of global plastic products rely on these gas-derived feedstocks (Speight, 2019). It is also involved in the manufacture of pipes used in water and gas networks, making it a key pillar of modern infrastructure.

2- Agricultural Fertilizers:

In the agricultural sector, natural gas plays a pivotal role across the nitrogen fertilizer production chain. The process begins with the production of ammonia from methane via steam reforming technology, which is one of the most energy-consuming industrial processes (Towler & Sinnott, 2013). The industry is a guarantor of global food security, contributing to crop productivity increases of up to 50% in some regions, according to FAO reports.

3- Power generation: A qualitative transformation in the electricity sector The last decade has witnessed a radical shift in power plants towards greater reliance on natural gas. For example, in China, due to the worsening energy crisis and pollution, the Chinese government announced its national contribution (2015) to reduce carbon emissions by (60-65%) by reducing the use of coal from 66% to 47% and increasing the use of natural gas by(11%) in 2035 (Yin & athers, 2017, 1)

- Up to 60% energy conversion efficiency in modern turbines (IEA, 2022).)
- 40-50% lower emissions compared to coal plants (IEA, 2021, p. 21)

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- High operational flexibility commensurate with renewable energy sources (Bhattacharyya, 2011)
- **Transport:** Compressed natural gas (CNG) and liquefied natural gas (LNG) technologies have transformed the transport sector, where:

- Reduces operating costs by 30-40% compared to conventional fuel
- Reduces import dependence in non-oil producing countries
- Contribute to improving the trade balance

Emerging markets such as Egypt and India are seeing annual growth of up to 15% in the use of CNG vehicles, supported by government incentives and stringent environmental legislation (World Bank, 2021).

4- Specialized industrial applications The use of natural gas goes beyond traditional applications to include:

- Glass industry: It provides clean energy for a high-purity product
- Drying of agricultural products: a safe alternative to traditional means
- Industrial Cooling: Via Extremely Operated Absorption Systems

The third topic: Solar energy – concept and economic applications

Solar energy is one of the most important sources of renewable energy, which is the energy resulting from the photovoltaic radiation emitted by the sun(Kalogirou, 2009, p121), and it is the most abundant on the surface of the earth , as the amount of solar energy reaching the surface of the earth is equivalent to the world's consumption for a whole year (IEA, 2022) , and it is also described as renewable due to its permanent abundance for the present and for thousands of years in the future. It is inexhaustible and not associated with any processes of extracting or burning fossil fuels. Therefore, the electrical or thermal energy resulting from it is described as sustainable energy that is environmentally friendly

Solar Energy:

Solar energy has several characteristics that have made it one of the preferred options for many countries that seek to reduce dependence on fossil fuels and form an energy mix that supports energy security. These characteristics include:

1- Sustainability : An inexhaustible source of energy that is permanent as long as life continues on Earth
2- Wide geographical spread: Sunlight reaches almost all parts of the earth in varying proportions, which enables many countries to benefit from it, especially in countries with high levels of sunshine, such as the countries of the Middle East, including Iraq
3- Environmentally friendly : The operation of solar energy does not result in any pollutants or carbon emissions, and many countries have used it to address the environmental impact resulting from increased production processes and economic growth, such as emerging countries such as China, India and Brazil .
4- Flexibility in use : Solar energy can be used on several levels, from large state projects to generate electricity to private production projects to private housing units and street lighting. It can also be integrated into local electricity networks or used independently.
(/commercialisation.esa.int)
5- Low costs at the long-term level: Although their initial costs are relatively high, at the long-term level they are significantly reduced, as the International Renewable Energy Agency indicates that the period from 2010 to 2021 is a radical shift in the competitiveness of renewable energy sources. The global weighted average levelized cost of electricity for newly commissioned utility-scale solar PV projects decreased by 88% (/wwwIRENA.orgy)

Second : Uses of Solar Energy

Solar energy can be used and employed in a series of multiple uses and in more than one sector and level, it is one of the most diverse sources of renewable energy in use, which meets the needs of individuals, industrial complexes, the agricultural sector and the state , in general, and its most common uses are:

1- **Electricity production:**
Through the use of solar cells, bright sunlight is converted into electrical energy, which can be integrated into the national grid, or in the feeding of housing units, farms and street lighting independently(Boyle, G., 2012, p. 109). Solar energy contributes to the production of 4.5-5% in the world and in some countries such as Germany and Spain up to 15%. The volume of electricity produced through solar energy worldwide in 2023 (1.2terawatts) (Irena.org). China alone produces 430GW.

2- Solar Water Heating and Heating:
Solar energy has been used to generate heat for heating water and heating since ancient times from domestic and industrial uses, as it was used in the United States in 1890 to heat water instead of coal and wood (Al-Marsoumi, and Hilal, 2023, p.239)

3- Agriculture sector

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Includes solar water pumping systems for irrigation purposes, and drying crops using solar dryers, which are especially effective solutions in rural areas.

Chapter Two: The Reality of the Energy Sector in Iraq – Natural Gas and Solar Energy Model

The energy sector in Iraq is one of the main pillars of economic development, and this is reflected in two main trends: the first is the heavy dependence on oil export revenues to finance annual budgets, which constitute between 90% and 95% (Al-Shammari,Al-Salem,2024,p. 150)of total public revenues, and the second is the excessive dependence on fossil fuels, especially natural gas, in the operation of electric power plants.

Although Iraq has large reserves of gas, the weakness of processing capacities and production infrastructure prompted it to import natural gas from abroad to cover the domestic deficit, which made gas a burden on the budget rather thana source of support for it.

On the other hand, Iraq has an important and untapped potential in the field of solar energy, which can form a sustainable solution to reduce dependence on natural gas, and achieve a safe mix that contributes to supporting energy security at a lower economic and environmental cost. From this standpoint, this chapter reviews the reality of energy in Iraq, with a comparative reading between gas and solar energy, in light of the challenges and opportunities available

This chapter aims to assess the realism and feasibility of switching to solar energy in Iraq, as a strategic option to enhance energy security and reduce the financial burden on the state.

The first topic: The reality of the gas sector in Iraq

Iraq is one of the countries rich in natural gas. It ranks fifth in the Middle East and twelfth in the world. According to statistics, it has proven reserves estimated at (130) trillion standard cubic feet (.oil.gov.iq/). Natural gas in Iraq is divided into two types.

- The first is associated gas, which is based in southern Iraq, specifically in Basra Governorate.
- The second, free gas, is mainly found in the Akkaz field in Anbar Governorate and some exploratory patches such as the Mansouriyah field in Diyala and the Saybah field in Basra .

The production and investment of oil in Iraq has gone through several stages .

1- The pre-neglect stage (1970)

Despite the abundance of this resource in Iraq , it remained out of focus for many years, as the history of gas extraction began with the beginnings of oil production from the Baba Karkar field in Kirkuk Governorate, and it was mostly burned or released into the air, because the foreign companies with the concession were not interested in gas or the environment in Iraq (Al-Kubaisi,Falah, 1992, p. 17), and most of their interest was based on profits from oil production, as the burned gas was estimated at (1) billion standard cubic feet, of course, this is due to the fact that oil production was originally low, as it was estimated at (1)million barrels per day(.opec.org/). There was very limited consumption of natural gas in the 1950s, as it was used as fuel to operate oil pumping turbines in the Kirkuk Tripoli-Kirkuk Baniyas line and as a raw material for Abu Al-Khasib fertilizer plant in southern Iraq (Al-Kubaisi,p. 26)

1-Early attention stage (1970-1980)

After the political change in Iraq in 1958, which made the control of oil one of its priorities, interest in natural gas began and paved the way for subsequent governments to benefit from natural gas. However, the actual start of natural gas investment was effectively launched with the beginning of the 1970s , which constituted a turning point in the course of gas investment in Iraq. The government developed a strategic plan to isolate and treat natural gas, as it concluded a contract with the Russian company Sogaz. In 1972, Iraq nationalized the assets and rights of the Iraq Oil Company (IPC) and established the state-owned Iraqi National Oil Company (ouriraq.org), which supported the government's efforts to invest gas more effectively. This rapid growth is due to the increase in oil production after the decision of Tamim and the rise in oil prices after 1973 and Iraq's need to finance its development plans.

These trends represented the main pillar for the establishment of several major industrial projects such as (petrochemical plant, iron and steel plant, chemical fertilizer plant, and Al-Wur plant.

From Figure (2), we note the increase in gas production from(6000)in 1970 (20,000million standard cubic meters)in 1979with a growth rate estimated at (12.6) , and the investment achieved growth estimated at (18%), and this indicates the acceleration of growth in the production and exploitation of natural gas in Iraq .

2-Degradation phase (1980-1990)

The year 1980 marked a turning point in Iraq's economic path following the outbreak of war with Iran, which exposed the oil industry to real risks after being bombed and low production rates,which directly affected gas production as it decreased from 2000

Gas production fell from (20,000) in 1979 to (4,769million standard cubic meters) in 1982. This decline coincided with the decline in oil production, as it was (3.4million /b/day) in 1979 to fall to (1million b/day). Then, the production of gas began to increase with the increase in Iraqi oil production, but very slowly, as it reached

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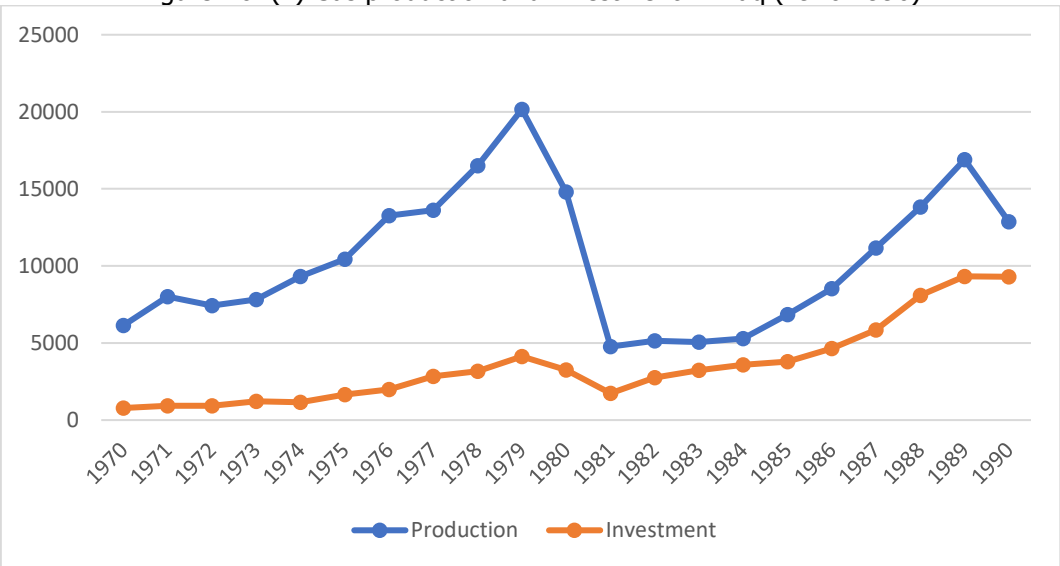
(5,200million standard cubic feet) in 1984, and after the end of the war in 1988, production recovered significantly until it reached (17,000million standard cubic meters) in 1989, achieving negative growth(1) for the period (1980-1990). From the drawing, we also note that investment was consistent with production .
Although the "oil-for-food" program was introduced in the late 1990s, its resources were mainly directed to securing food and medicine, not to developing the energy sector

Figure No. (1) Gas production and investment in Iraq (1970-1990)



Source: 1-digitallibrary.un.org/record/1308282?ln=ar&v=pdf

3-Economic blockade (1990-2003)
After 1991, the UN Security Council imposed on Iraq a comprehensive international economic embargo due to its occupation of Kuwait in 1990, which led to a near total paralysis in the development of energy projects, including natural gas projects.
Under this siege:

- Expansion and maintenance projects in existing gas fields have stopped.
- Technical equipment needed to build gas treatment plants or construct pipelines could not be imported.
- The quantities of random combustion of the associated gas have increased as a result of the absence of any technical capacity to process or store it.

Although the "oil-for-food" program was introduced in the late 1990s, its resources were mainly directed to securing food and medicine, not to developing the energy sector.

4-Licensing rounds (2009-2024)

Table No. (2) shows that Iraq has achieved a significant increase in crude oil production after the start of licensing rounds starting in 2009, as it rose from 2.3 million barrels/day to its peak of 4.5 million barrels/day in 2019. This was followed by a parallel rise in associated natural gas production from 1.5 to 3 billion standard cubic feet per day.

However, the data indicate that the first three licensing rounds did not include clear commitments on investing in associated gas or reducing flaring, which resulted in flaring rates remaining at high levels (approximately 1 billion cubic feet/day). Although the fourth round included objectives related to gas investment, poor implementation or lack of infrastructure prevented the achievement of tangible results.

Table (2) Oil production, production and consumption of natural gas in Iraq (2009-2024)

Year	Production (million barrels/day)	Production Bcf/day	Gazc Bcf/day	gas flaring Bcf/day
2009	2.3	1.5	0.6	0.9
2010	2.3	1.6	0.7	0.9
2011	2.6	1.7	0.8	0.9

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2012	2.9	1.8	0.9	0.9
2013	2.9	1.9	1	0.9
2014	3.2	2	1	1
2015	3.7	1.9	1	0.9
2016	4.1	2	1.1	0.9
2017	4.2	2.1	1.1	1
2018	4.2	2.1	1.0	1.1
2019	4.5	2.3	1.1	1.2
2020	3.9	2	1.1	1.1
2021	4.1	2.5	1.3	1.2
2022	4	2.7	1.5	1.2
2023	4.2	2.9	1.7	1.2
2024	4.1	3	1.7	1.3

Source:
1- https://www.oil.gov.iq/ Statistical Reports
2- OPEC - Annual Reports of Oil and Gas Production in Iraq.

This omission has resulted in direct economic losses, and exacerbated environmental impacts, especially in southern areas such as Basra. In response to these challenges, the Iraqi government established the Basra Gas Company in 2013 with an international partnership (the Iraqi government 51%, the Dutch Shell 44%, and the Japanese company Mitsubishi 5%), to process gas from major fields, which gradually helped to reduce burn rates, which are estimated to have decreased from 60% in 2009 to about 43% in 2024.

It should be noted that official interest in gas investment accelerated after 2018, as a result of the economic sanctions imposed on Iran, which exposed the fragility of Iraq's dependence on imported gas in operating gas power plants

The second topic: Iraq's need for gas to produce electricity

The electricity production sector in Iraq depends on natural gas at a rate of 70%, with a consumption rate ranging from 1.7 to 2.0 billion standard cubic feet per day. Of this amount, about 1.5 billion cubic feet is produced domestically, while the remaining quantity — which on some days of the year may reach 700 million cubic feet — is imported from abroad, especially from the Islamic Republic of Iran (Iraqi Ministry of Electricity, 2023).

This reality presents Iraq with a range of geopolitical, economic and technical challenges. At the geopolitical level, the US sanctions imposed on Iran have directly affected the supply of imported gas, which led to a decline in electricity production by up to 30% during peak periods, which represents an external constraint that limits the ability of the Iraqi decision-maker to control a vital and strategic file. On the other hand, the increase in outages, especially in the summer, exposes the government to great embarrassment. It is one of the most important drivers of public anger and the outbreak of major violence, as happened in the southern governorates, the most important of which is the province of Basra in August 2022, which is one of the largest oil-producing cities in Iraq and the world.

Economically, importing natural gas costs the Iraqi budget about $4 billion annually, which burdens the state and crowds out spending on other more sustainable development sectors. This is in addition to the technical challenge, as the efficiency of gas generation plants in Iraq is relatively low, as it does not exceed 50% on average, which leads to significant waste of fuel and additional consumption without a parallel energy return, while the efficiency of combined cycle plants in some countries reaches 60–65%, reflecting a technical gap that leads to additional fuel depletion without actual energy production . As well as the negative impact on environmental security in Iraq (Al-Marsoumi,Hilal 2025, 200)

Considering the estimates of the Ministry of Electricity, which expects the demand for natural gas to generate electricity to rise to 3 billion standard cubic feet per day by 2030, Iraq is about to double these challenges, unless realistic and sustainable solutions are developed.

From Table(3), we note that production increased from 9,000MW in 2014 until it reached 20,000MW in 2024 , but the deficit remained almost constant, due to the growth of demand from 23,000MW to 32,000MW, which is a natural growth as a result of population growth (3%), increase in income and increase in the number of housing units and large investment cities.

Table No. (3) shows the production and consumption of electricity in Iraq (2014-2024)

Year	Production (max) MW	Maximum consumption (MW)	Demand Gap	The most important sources of disability coverage (MW)

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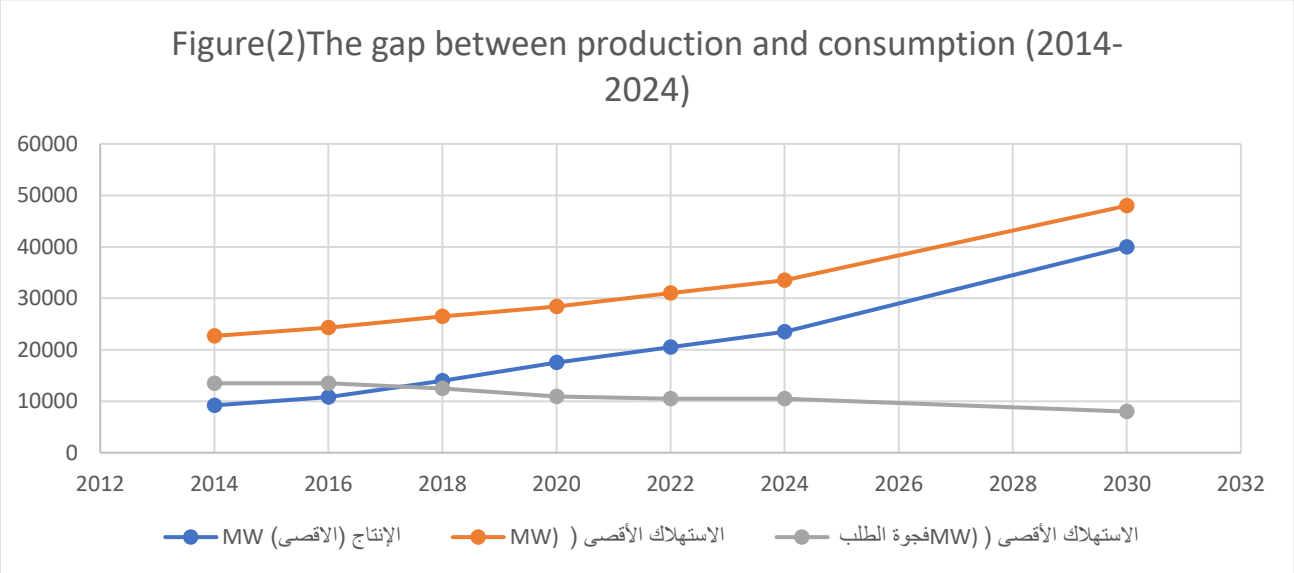
2014	9200	22700	13500	Iran 1200 - Turkey 150- Civil Generators 9500
2016	10,800	24300	13500	Iran 1400- Civil Generators 9500
2018	14000	26500	12500	Iran 1700- Civil Generators 10000
2020	17,500	28400	10900	Iran 1200- Private Generators 9000 Solar Power 50
2022	20500	31000.00	10500	Iran 1500- Civil Generators 9000
2024	23500	33500	10500	Iran 1200- Civil Generators -7000- Renewable Energy 500
2030	SAR 40,000	48000	8000 SAR	

Source:
1- Iraqi Ministry of Electricity Annual Reports (https://moelc.gov.iq/?page=2879)
2. Reports of the International Energy Agency (IEA) on Iraq (https://www.iea.org/)
3 (https://www.moelc.gov.iq/)
This means that the government has not been able to keep pace with the rising demand.
We also note that the demand coverage came mainly from civil generators and by about 70% and this has a negative impact in terms of the environment as it is one of the largest pollutants in urban cities,not to mention the increase in demand for diesel fuel obtained by the owners of civil generators in a subsidized manner. The second main source is the Islamic Republic, which is also subject to geopolitical and technical complications that hinder its supply more than once.



Source: From the researcher's work based on table (3)
From the above, we can say that Iraq's strategy has not achieved a model that preserves sustainable energy security for the country and its three pillars, which we mentioned in the first chapter, which are the provision of fuel and electricity at an acceptable financial and economic cost and environmental sustainability. It has put Iraq under serious political complications and high economic costs of up to $4 billion, and in light of an environment that suffers from air pollution and audio-visual pollution in urban cities. At the same time, citizens have not been provided with electricity throughout the day, but in some governorates, the hours of processing did not exceed more than 8 hours a day.
In this sense, the researcher believes that switching to solar energy is not only an environmental option, but a strategic necessity to address the energy gap and reduce dependence on imports, by building a balanced energy mix that combines natural gas and renewable energy. This shift would enhance energy security, ease the burden on the public budget, provide wider margins for sovereign energy decision making, reduce outages which reduce public congestion and increase citizens' confidence in government.

The third topic: Solar energy as a strategic option to enhance energy security in Iraq

1- The Potential of Solar Energy in Benin

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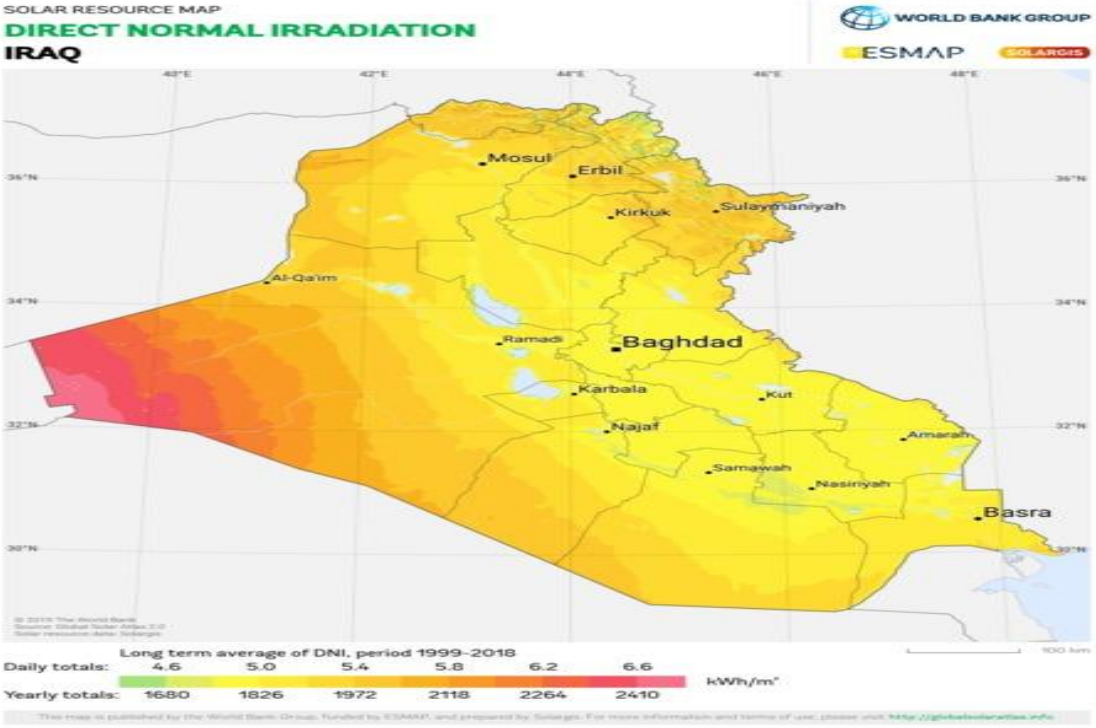
Iraq has a distinct geographical location, which allows it to invest in solar energy ideally, as it extends between two latitudes (29.5-37.22 degrees) north and two longitudes (39-48degrees)east , providing Iraq with a warm moderate climate in the south and a Mediterranean climate in the north (Al-Barwari, Al-Fahl,2022, p. 256). This location provides Iraq with high potential of solar energy, as it has an average radiation of 5.6 kilowatts/hour/per square meter per day and over 3000hours per year , and over an area of more than 65% of Iraq's area.
438,314) ^2km(Istepanian ,Harry, 2018, p7) , and this is shown in Map (1), which includes the map of Iraq and brightness levels, and every 100 ^2km in the Western and Southern Sahara has the ability to produce energy equivalent to (30million tons equivalent of fossil fuels) using solar photovoltaic panels, there is no doubt that these figures show prominently that Iraq has great potential of uninvested solar energy , which can effectively contribute to solving the supply gap in Iraq and meet future demand.

Map of (1) annual horizontal beam of solar energy in Iraq for the years



Source:World Bank Group(https://solargis.com/resources/free-maps-and-gis-data?locality=iraq)

2- The importance of soler energy

- Stopping the import of gas : It can contribute effectively to reducing the import of gas and stopping it permanently, freeing Iraq from a political and social constraint
- Achieving financial savings: Iraq loses billions of dollars annually, some of which are the costs of importing gas and the other part represents the amounts of government subsidies for fuel used in civil generators, which if this gap is filled, Iraq can export diesel at international prices.
- Environmental impact: It is known that solar energy is clean and environmentally friendly and therefore can contribute to reducing carbon dioxide emissions rates, especially in urban cities
- Attracting investment and job opportunities: The clean energy sector represents opportunities to attract foreign capital, develop national skills and increase employment opportunities
- Decentralization: One of the most important features of solar energy is the decentralization and the possibility of not connecting it to the national grid, which allows it to be established near modern investment cities, or on the roofs of houses and companies .

3- Barriers to investing in solar energy

- Weak infrastructure : Iraqi electricity networks lack the necessary technologies to link renewable energy sources with the national grid and need technical updates to enable them to absorb their production .
- Lack of necessary legislation and policies: The legal aspect is still unclear in terms of supporting renewable energy sources, as well as the lack of clear policies that can integrate renewable energy sources into Iraq's energy security mix.

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- Unstable security and political environment: Iraq needs a number of foreign investments in terms of the establishment of solar power plants, as well as the establishment of factories for the manufacture of solar panels and the necessary equipment , and there is no doubt that the political and security environment is an essential and important pillar of attracting or expelling investments

4- The reality of solar energy in Iraq compared to some countries in the Middle East

Despite the great potential of Iraq in the field of solar energy and the economic, political and environmental importance mentioned above , the actual reality confirms that Iraq has not exploited this potential in a way that raises the level of energy security, as the share of solar energy in the Iraqi energy map did not exceed (1%) until 2024, most of which are for small and limited projects, and if we compare this reality with the reality of some Arab countries and as shown in Table (4) and Figures (3)and(4), we find that Iraq ranks sixth after Jordan , Noting that Jordan has less potential than Iraq in terms of average solar radiation and the number of sun hours per year, but Jordan produces 1490(MW), which is twice what Iraq produces, noting that Jordan has a strategy entitled (Comprehensive Strategy for the Energy Sector 2020-2030), which aims to raise the contribution of renewable energy to 50% of the volume of energy produced. It is also noted that the potential of Egypt and the Sultanate of Oman is the same as the potential of Iraq, but they produce 3120 and 1690(MW) respectively. The development of the UAE in this field is also noted, as production reached 6300(MW) , and it has a fourth and eighth The largest solar power plant is Mohammed bin Rashid Al Maktoum and Noor Abu Dhabi , followed by the Kingdom of Saudi Arabia with a production capacity of 3300(MW)

Table (4) Comparison of the potential and production capacity of solar energy for some Arab countries until 2024

Country	Solar Radiation	Sun Hours yearly	Solar energy (Astrophysics)	Solar power MW
UEA	57	3500 (SAR)	8-9	6,350
Saudi Arabia	6-6.8	3200 - 3400	2-3	3300
Egypt	5.8-6.2	3000	3-4	3120
Amman	5.5.6	3200	1-2	1690
Jordan	5.4-5.6	2900	15-17	1490
Iraq	5.6 - 6 Inch	3000	0.8: 1	710

Source: Economy Middle East(economymiddleeast.com/news/uae-tops-arab-countries-in-electricity-production-using-solar-energy)

Figure 3: Comparison of Solar Capacity and Solar Contribution in Selected Arab Countries

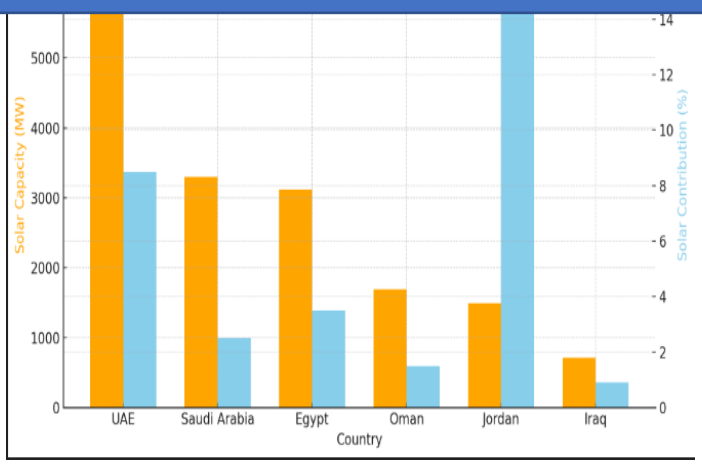
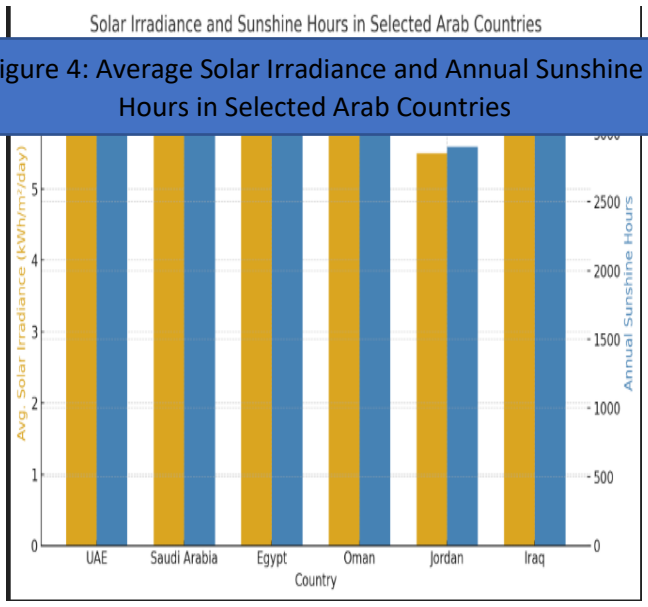


Figure 4: Average Solar Irradiance and Annual Sunshine Hours in Selected Arab Countries



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Iraq lacks a clear and comprehensive vision for the future of energy security, as the Iraqi government has not issued an energy security strategy linking production and consumption , the economy and the environmental, security and geopolitical dimensions, in the sense of ensuring the provision of energy in a sustainable, stable, affordable, and safe manner without interruption and for the longest possible period, taking into account the environmental and political economic aspects, and that what already exists is the endeavor of the Ministry of Electricity to increase production and reduce electricity losses, and the Ministry of Oil seeks to reduce gas burning rates, through increased investments , there are plans to offer investment opportunities to increase solar capacity to 12,000(MW) , knowing that there are a group of projects under construction , the most important of which is the project of the French company Total (Shams Al-Basrah) to produce (1000) (MW).

However, it is still far from achieving an acceptable level of energy security, at an acceptable economic cost, and it must include the economic cost, the financial burden on the budget ,and the cost of the opportunity to export gas, and that gas turns into an economic arm that supports the public budget and the cost of diesel support for civil generators, and that it can turn into export , as well as the cost of the economic environmental impact, that is, what is spent on public health to address the diseases caused by increasing carbon concentrations in the atmosphere , and the environmental cost in general .

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1- Excessive dependence on natural gas in Iraq has increased the burden of the public budget, increased the imbalance in the balance of payments, and weakened economic independence.
2- Although Iraq has large reserves of natural gas, poor infrastructure and low efficiency of power plants have caused a continuing deficit in electricity production and high levels of gas flaring.
3- Iraq has enormous potential in solar energy, but its contribution to the energy mix remains negligible, suggesting a gap between potential and actual exploitation.
4- The shift towards solar energy is a strategic option that supports economic stability by reducing operational expenses, reducing dependence on imports, and freeing up domestic gas for export purposes.
5- Regional experiences (e.g. Jordan, UAE, Egypt) have demonstrated that building an increased contribution of renewable energy to the energy mix has a direct impact on energy security and macroeconomic indicators, which can be replicated in Iraq, by building a clear energy strategy.
6- The absence of a clear institutional and legislative framework for renewable energy, in addition to the unstable political environment, remains a fundamental obstacle to attracting investments in this vital area.

Recommendations

1- Working on the formulation of an integrated national strategy for energy security in Iraq, integrating renewable energy sources, and setting quantitative targets to reduce dependence on imported gas.
2- Investing in solar energy in the southern and western regions of Iraq, as it has the highest levels of solar brightness, with priority given to projects that feed modern industrial and residential cities.
3- Improving the efficiency of existing electrical stations and gradually converting them to the combined cycle, and reducing technical losses, which contributes to reducing local consumption of gas, by increasing the efficiency of electrical stations, and reducing the percentage of waste in them
4- Establish an independent authority to regulate renewable energy and coordinate policies between ministries of oil, electricity, environment and planning to ensure integrated implementation of strategic projects.
5- Supporting education and scientific research in the field of energy economics, through the establishment of specialized graduate programs, and encouraging universities to develop economic models for the energy transition.
6- Issuing legislation obliging new projects (investment cities)and(industrial cities) to allocate (20%) of their area to solar panels.
7- The establishment of a national renewable energy fund funded by the export of gas ,because increasing the contribution of solar energy at the expense of natural gas in electricity generation will increase the opportunities to export natural gas at international prices.

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