



بحوث المؤتمر الدولي الأول

التنمية المستدامة وخدمة المجتمع

نحو مستقبل شامل ومتوازن

جامعة سرت 29 أكتوبر 2025م

تنظيم وإشراف

مركز خدمة المجتمع وتنمية البيئة بجامعة سرت

الجزء الثاني

تحرير

أ. د. الطيب محمد القبي

أ. د. حسين مسعود أبو مدينة

د. صلاح محمد اجبارة





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منشورات مركز البحوث والاستشارات بجامعة سرت
الطبعة الأولى 2026م

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ب

مركز خدمة المجتمع وتنمية البيئة / جامعة سرت - ليبيا

كلمة رئيس الجامعة

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

والصلاة والسلام على أشرف الأنبياء والمرسلين،

أما بعد ،،،

يسرنا في هذا المقام العلمي المتميز أن نحتفي بإصدار كتاب أعمال المؤتمر العلمي حول التنمية المستدامة وخدمة المجتمع، والذي انعقد تحت شعار "نحو مستقبل شامل ومتوازن" في التاسع والعشرين من شهر أكتوبر 2025م. والذي نظمته مركز خدمة المجتمع وتنمية البيئة بالجامعة، ويأتي ذلك في إطار تنفيذ رسالة الجامعة الأكاديمية والوطنية الرامية إلى ترسيخ دورها في خدمة قضايا المجتمع والتنمية الشاملة.

إن هذا الإصدار العلمي يُجسد ثمرة جهد جماعي شارك فيه نخبة من الباحثين والأكاديميين والمتخصصين من داخل الجامعات والمراكز الليبية وخارجها، حيث تناولت بحوثه محاور متعددة عكست عمق الإشكاليات المرتبطة بالتنمية المستدامة، وأبرزت العلاقة التكاملية بين المعرفة العلمية ومتطلبات خدمة المجتمع، في أبعادها الاقتصادية والاجتماعية والبيئية والمؤسسية.

ويأتي هذا الكتاب ليؤكد إيمان جامعة سرت بدور البحث العلمي بوصفه ركيزة أساسية في دعم السياسات التنموية، وتقديم الحلول العلمية القابلة للتطبيق، والمساهمة في تحقيق أهداف التنمية المستدامة، بما يتماشى مع خصوصية المجتمع الليبي واحتياجاته الراهنة والمستقبلية.

ولا يفوتنا في هذه المناسبة أن نتقدم بجزيل الشكر والتقدير إلى إدارة مركز خدمة المجتمع وتنمية البيئة وإلى اللجنة العلمية للمؤتمر، واللجنة التنظيمية، وكافة الباحثين المشاركين، وكل من أسهم بفكره وجهده في إنجاح هذا المؤتمر وإخراج أعماله في هذا الكتاب العلمي القيم، الذي نأمل أن يكون مرجعاً علمياً يسهم في إثراء المكتبة الأكاديمية، ويدعم مسارات البحث والدراسة وصنع القرار.

وفي الختام، نؤكد أن جامعة سرت ستظل حاضنة للعلم والفكر، ومنبراً للحوار الأكاديمي الجاد، وشريكاً فاعلاً في خدمة المجتمع وتحقيق التنمية المستدامة.

والسلام عليكم ورحمة الله وبركاته.

أ. د. سليمان مفتاح الشاطر

رئيس جامعة سرت

كلمة وكيل الجامعة للشؤون العلمية ورئيس اللجنة العلمية للمؤتمر

بسم الله الرحمن الرحيم

والصلاة والسلام على أشرف المرسلين، سيدنا محمد، وعلى آله وصحبه أجمعين.
يسرني، ويشرفني، بصفتي رئيس اللجنة العلمية لمؤتمر التنمية المستدامة وخدمة المجتمع، أن أتقدم بهذه الكلمة بمناسبة صدور الكتاب العلمي المحكم الخاص بأعمال المؤتمر، الذي انعقد في رحاب جامعة سرت، في إطار أكاديمي اتم بالجدية العلمية والتكامل المعرفي، وبمشاركة نخبة من الباحثين والمتخصصين من مختلف الجامعات والمؤسسات العلمية.

إن هذا الإصدار العلمي يعد توثيقاً معرفياً لخبرات المؤتمر، ويحسّد الجهود البحثية التي تناولت قضايا التنمية المستدامة وخدمة المجتمع من زوايا متعددة، مستندة إلى أطر نظرية ومنهجيات علمية رصينة، وبما يعزز الربط بين البحث الأكاديمي واحتياجات المجتمع الفعلية، ويسهم في دعم صنّاع القرار والمهتمين بالشأن التنموي.

ويؤكد صدور هذا الكتاب الدور الحيوي الذي تضطلع به الجامعات في إنتاج المعرفة وتوجيهها نحو خدمة المجتمع، وترسيخ مبادئ التنمية المستدامة بأبعادها الاقتصادية والاجتماعية والبيئية، من خلال البحث العلمي الجاد والتعاون الأكاديمي البناء.

ولا يسعني في هذا المقام إلا أن أتقدم بجزيل الشكر وعظيم الامتنان إلى السادة الباحثين على إسهاماتهم العلمية المتميزة، وإلى أعضاء اللجنة العلمية ولجان التحكيم لما بذلوه من جهود علمية دقيقة أسهمت في ضمان جودة البحوث المنشورة، كما أتوجه بالشكر إلى اللجنة التحضيرية وإدارة جامعة سرت على دعمهم المتواصل وتوفيرهم للبيئة العلمية الملائمة لإنجاح المؤتمر وإخراج هذا الكتاب في صورته المشرفة.
ختاماً، نسأل الله أن يكون هذا الكتاب إضافة نوعية للمكتبة العلمية، ومرجعاً بحثياً يُنتفع به في الدراسات المستقبلية، وأن يسهم في تعزيز مسارات التنمية المستدامة وخدمة المجتمع، وترسيخ ثقافة البحث العلمي المسؤول والفاعل في مجتمعاتنا.

والسلام عليكم ورحمة الله وبركاته.

أ. د. الطيب محمد القبي

وكيل الجامعة للشؤون العلمية ورئيس اللجنة العلمية للمؤتمر

كلمة مدير مركز خدمة المجتمع وتنمية البيئة

الحمد لله القائل في محكم تنزيله: "وَقُلْ اَعْمَلُوا فَسِرَّيَ اللَّهِ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ"، والصلاة والسلام على المبعوث رحمة للعالمين، وبعد،،

إنه لمن دواعي سرورنا واعتزازنا في مركز خدمة المجتمع وتنمية البيئة بجامعة سرت، أن نضع بين أيدي الباحثين والمختصين هذا السجل العلمي الرصين، الذي يضم نتاج أعمال "المؤتمر الدولي الأول للتنمية المستدامة وخدمة المجتمع"، والذي انعقد تحت شعار "نحو مستقبل شامل ومتوازن" في التاسع والعشرين من أكتوبر 2025م.

لقد انطلقت فكرة هذا المؤتمر من إيماننا العميق بدور الجامعة في قيادة قاطرة التغيير نحو الاستدامة، ليس فقط كصرح تعليمي، بل كشريك فاعل في تنمية البيئة وخدمة المجتمع المحلي والدولي. وتجسد هذا الطموح في استقطاب كوكبة من العلماء والباحثين من مختلف الجامعات والمراكز البحثية من ليبيا، والمغرب، والجزائر، وموريتانيا، والعراق، ومصر.

يحتوي هذا الكتاب بين دفتيه على دراسات معمقة تناولت محاور جوهرية شملت:

- الحوكمة والقيادة المستدامة: ودورها في تحسين الأداء المؤسسي في الجامعات والشركات.
 - الاقتصاد الأخضر والمسؤولية الاجتماعية: كركيزة أساسية لتحقيق الاستدامة في القطاعات النفطية والزراعية.
 - التقنيات الحديثة والذكاء الاصطناعي: ودور التكنولوجيا والنانو في حماية البيئة والتخطيط الحضري المستدام.
 - التحديات البيئية والمجتمعية: بدءاً من إدارة النفايات والموارد المائية وصولاً إلى تمكين المرأة وحماية المكونات البيئية من منظور شرعي وقانوني.
- إننا نأمل أن تكون هذه الأعمال العلمية مرجعاً قيماً لصناع القرار والباحثين، ومساهمة حقيقية في وضع الحلول للتحديات التي تواجه مجتمعاتنا في طريقها نحو تحقيق أهداف التنمية المستدامة ورؤية الأمم المتحدة 2030م.
- ختاماً، أتوجه بوافر الشكر والتقدير لرئاسة جامعة سرت على دعمها المتواصل، ولجنة العلمية والتحضيرية التي سهرت على إنجاح هذا الحدث، ولكل الباحثين الذين أثروا هذا المحفل بعلمهم وفكرهم.
- والسلام عليكم ورحمة الله وبركاته

د. صلاح محمد إجابة

مدير مركز خدمة المجتمع وتنمية البيئة

Renewable Energy as a Strategic Driver for Sustainable Development

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Abstract

Renewable energy has become a central pillar in the pursuit of sustainable development worldwide, as nations seek alternatives to fossil fuels to address climate change, energy insecurity, and economic volatility. For Libya, despite its significant oil and gas reserves, renewable energy represents a vital opportunity to diversify the economy, enhance energy access, and ensure long-term sustainability. This research analyzes the role of renewable energy as a strategic force for sustainable development in Libya, focusing on economic, environmental, and social dimensions. It draws on secondary data from international organizations and academic literature, supported by comparative insights from regional and global experiences.

The findings indicate that renewable energy has the potential to support economic diversification, generate employment, and strengthen energy security. Environmentally, it can reduce greenhouse gas emissions and promote sustainability, while socially, it enhances equity and resilience in energy access. The study concludes that renewable energy is not only an alternative energy source but also a strategic driver for Libya's long-term sustainable growth.

Keywords: Renewable energy, Sustainable development, Energy security, Economic diversification, Libya, Environmental sustainability, social equity.

الملخص

أصبحت الطاقة المتجددة ركيزة أساسية في السعي لتحقيق التنمية المستدامة في جميع أنحاء العالم، حيث تبحث الدول عن بدائل للوقود الأحفوري لمعالجة تغير المناخ وانعدام الأمن في مجال الطاقة والتقلبات الاقتصادية. بالنسبة لليبيا، على الرغم من احتياطياتها الكبيرة من النفط والغاز، تمثل الطاقة المتجددة فرصة حيوية لتنويع الاقتصاد، وتعزيز الوصول إلى الطاقة، وضمان الاستدامة على المدى الطويل. يحلل هذا البحث دور الطاقة المتجددة كقوة استراتيجية للتنمية المستدامة في ليبيا، مع التركيز على الأبعاد الاقتصادية والبيئية والاجتماعية. وهو يعتمد على بيانات ثانوية من المنظمات الدولية والأدبيات الأكاديمية، مدعومة برؤى مقارنة من التجارب الإقليمية والعالمية.

وتشير النتائج إلى أن الطاقة المتجددة لديها القدرة على دعم التنويع الاقتصادي، وتوليد فرص العمل، وتعزيز أمن الطاقة. من الناحية البيئية، يمكن أن يقلل من انبعاثات غازات الاحتباس الحراري ويعزز الاستدامة، بينما يعزز اجتماعيا الإنصاف والمرونة في الحصول على الطاقة. وتخلص الدراسة إلى أن الطاقة المتجددة ليست مصدرا بديلا للطاقة فحسب، بل هي أيضا محرك استراتيجي للنمو المستدام على المدى الطويل في ليبيا.

الكلمات المفتاحية: الطاقة المتجددة، التنمية المستدامة، أمن الطاقة، التنويع الاقتصادي، ليبيا، الاستدامة البيئية، العدالة الاجتماعية.

1. Introduction to Renewable Energy in Libya

1.1 Definition of Renewable Energy

Renewable energy is derived from natural resources that replenish rapidly, including solar, wind, hydroelectric, geothermal, and biomass energy. Unlike fossil fuels, which contribute to environmental harm through carbon emissions, renewable energy presents a sustainable solution to combat climate change. The United Nations has highlighted this transition by designating 2014–2024 as the decade for sustainable energy for all.

Renewable energy not only reduces greenhouse gas emissions but also enhances energy security and supports economic stability. This shift aligns with international climate commitments like the Paris Agreement. In Libya, the potential for renewable resources is significant due to favorable geographic conditions, including high solar radiation and beneficial wind patterns. Integrating renewables into Libya's economy is crucial for achieving sustainable development. Additionally, this transition can create jobs and promote economic diversification, allowing Libya to build resilience against fluctuations in oil dependency while investing in sustainable technologies and infrastructure (Almaktar & Shaaban, 2021; Ibrahim, 2025; Maka et al., 2021).

1.2 Importance of Renewable Energy for Sustainable Development

Renewable energy plays a crucial role in advancing sustainable development in Libya. Transitioning from fossil fuels to renewable sources like solar and wind is essential for environmental health, economic growth, and social equity. This shift aligns with international climate agreements, potentially leading to a 57% reduction in CO₂ emissions, contributing significantly to global climate efforts.

Investing in renewable energy creates numerous economic opportunities, generating jobs and fostering new industries that decrease oil dependency. This strategic move builds a resilient economic framework capable of adapting to fluctuating oil prices while promoting innovation within local communities.

Additionally, access to reliable clean energy can improve living standards, especially for marginalized groups, through initiatives like solar microgrids. Engaging communities in outreach programs cultivates public support for renewables, ensuring projects reflect local needs. Embracing renewable energy is vital for Libya's sustainable development, balancing environmental preservation with socio-economic progress and community empowerment (UNDP, 2025; Al-Hashmi, Salem, & colleagues, 2017).



Figure 1 A 10-day training and study tour in Cairo, Egypt, organized by UNDP Libya to build national expertise on renewable energy (Source: UNDP, 2025).

1.3 Overview of Libya's Energy Landscape

Libya's energy landscape is primarily characterized by its heavy reliance on hydrocarbon resources, with oil and natural gas making up the majority of the country's energy supply and export revenues. Despite having abundant fossil fuel reserves, Libya is confronted with an energy demand that increasingly exceeds its supply capabilities, highlighting the urgent need to shift towards renewable energy sources. The nation benefits from exceptional solar irradiation and wind potential, which positions it advantageously for developing renewable energy projects. With an impressive average solar photovoltaic (PV) output potential estimated at 1.9 MWh/kW/year, along with considerable onshore wind capacity, the opportunities for renewable development are promising.

Recently, various initiatives have emerged to accelerate Libya's transition to sustainable energy. The government has recognized the importance of creating a diversified energy portfolio to mitigate economic vulnerabilities associated with fluctuating oil prices and environmental challenges. International partnerships, particularly those led by the United Nations Development Programme (UNDP), have significantly enhanced technical expertise and established the necessary infrastructure for the effective implementation of renewable technologies. This dynamic evolution highlights Libya's commitment to integrating sustainable practices into its energy policy while addressing pressing economic and environmental challenges (UNDP, 2025; Almaktar & Shaaban, 2021; IEMed, 2025).

2. Current State of Renewable Energy in Libya

2.1. Existing Renewable Energy Initiatives

Libya has initiated several renewable energy projects to diversify its energy mix. The Government of National Unity set a target of integrating **4 gigawatts (GW)** of renewable energy into the national grid by **2035**, starting with **1.7 GW of solar photovoltaic (PV) systems** by 2025 and reaching **3.3 GW by 2035**, alongside **600 megawatts (MW) from wind power**. One initiative includes the installation of solar panels on public and private buildings, contributing an additional **500 MW**.

Furthermore, a **200 MW solar PV project in Ghadames** has been licensed, creating opportunities for Independent Power Producers (IPPs). International investment is also growing, with **TotalEnergies** engaging in a solar project in **As-Saddadah**, reflecting increased confidence in Libya's renewable potential. These initiatives represent a strategic shift towards reducing fossil fuel dependence while fostering economic recovery through sustainability. The **Renewable Energy Authority of Libya (REAOL)** plays a central role in aligning these projects with the **Renewable Energy Strategic Plan (2013–2025)** (Azubike & Gatiesh, 2024; El-Assasy, 2023; Energy in Libya, 2024; Algadi, 2025)

Table 1
Total renewable energy capacity in Libya, 2014–2023 (MW).

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
MW	5	5	5	5	5	5	5	6	6	8

Source: *Energy in Libya* (2024).

2.2. Government Policies and Regulations

The Libyan government has recognized the importance of diversifying its energy portfolio through renewable energy policies and regulations. The creation of the **Renewable Energy Authority of Libya (REAOL)** represents a strategic institutional step, evolving from a solar research center to an agency dedicated to promoting solar and other renewable sources.

Nevertheless, challenges persist due to **fossil fuel subsidies**, which distort the market and reduce the competitiveness of renewables. Addressing these subsidies is essential to foster a level playing field. Additionally, Libya's lack of full engagement in international climate commitments, such as the **Paris Agreement**, has limited its global contribution to environmental sustainability.

The **National Strategy for Renewable Energies and Energy Efficiency (2023–2035)** aims to generate **4,000 MW** from renewables, showcasing the government's ambition for a green energy transition. However, achieving this goal depends on regulatory reform, subsidy restructuring, and political stability that can attract investment in renewable technologies (Azubike & Gatiesh, 2024).

2.3. Investment Landscape and Opportunities

Libya's renewable energy investment landscape is promising, thanks to its abundant solar and wind resources and the global momentum toward sustainability. The country's hybrid renewable projects have demonstrated both financial viability and environmental benefits compared to fossil fuels.

Government efforts, including the **Electricity Law**, are critical to providing regulatory clarity and investment incentives. Reforming tariff structures and reallocating fossil fuel subsidies are vital steps for creating a more attractive investment climate.

International partnerships can also play a transformative role by introducing **advanced technologies and infrastructure development**. Libya's geographic location offers potential for **clean energy exports to Europe**, where demand for low-carbon energy continues to grow.

Investments in renewable energy not only promise **economic diversification** and job creation but also strengthen Libya's resilience to climate change and reduce its dependency on hydrocarbons (Azubike & Gatiesh, 2024; Renewables in Libya, 2025; Algadi, 2025).

3. Economic Implications of Renewable Energy Adoption

3.1. Job Creation and Economic Diversification

Libya's transition toward renewable energy presents significant opportunities for **job creation** and **economic diversification**, reducing its dependence on fossil fuels. The government aims to integrate up to **4 GW of solar and wind energy** into the national grid by 2035, creating employment opportunities in manufacturing, installation, and maintenance. This transition fosters new industries beyond oil and gas, thereby insulating Libya from global oil price fluctuations and promoting sustainable growth.

Investments in renewable infrastructure not only support **local businesses** but also attract **foreign investment**, which is crucial for job creation. Successful regional examples, such as Morocco, demonstrate how renewable investments can enhance employment and economic resilience. Moreover, reduced greenhouse gas emissions yield **health benefits**, which in turn improve workforce productivity. Through supportive policies and regulatory frameworks, Libya can build a solid foundation for long-term **economic stability** aligned with global green initiatives (Ibrahim, 2025, pp. 16–20; Ibrahim, 2025, pp. 21–25).

3.2. Impact on Local Industries

The shift to renewable energy is poised to significantly influence **local industries** and promote sustainable economic practices in Libya. By integrating solar and wind power into the grid, businesses can benefit from **lower operational costs** and **reduced fossil fuel dependence**, enhancing their competitiveness. Current initiatives

illustrate that renewable projects not only diversify the energy sector but also revitalize manufacturing and services related to renewable technologies.

As the government implements policies to attract private sector investment, **local companies** are increasingly participating in renewable ventures, creating markets for solar panels, wind turbines, and related services. This fosters **technology transfer**, knowledge sharing, and innovation. Moreover, the renewable sector is expected to generate jobs across multiple skill levels, stimulating ancillary industries and supporting traditional sectors transitioning toward sustainable methods. Achieving these outcomes, however, requires local industries to embrace advanced technologies and enhance operational efficiencies consistent with **sustainable development goals** (Ibrahim, 2025, pp. 16–20; Ibrahim, 2025, pp. 21–25; Maka et al., 2021).

3.3. Cost-Benefit Analysis of Renewable Projects

The economic feasibility of renewable energy projects in Libya depends largely on the **Levelized Cost of Electricity (LCOE)**, which represents the total cost of generation over the project's lifespan divided by total energy output. Research indicates that renewable sources such as solar and wind can achieve LCOE values as low as **3.5 cents per kilowatt-hour**, significantly lower than Libya's current electricity costs.

In addition to direct cost savings, renewable projects generate **environmental benefits** by reducing greenhouse gas emissions, which in turn decreases **Environmental Damage Costs (EDC)** associated with fossil fuels. Furthermore, renewable infrastructure projects are expected to create jobs, contributing to **economic diversification** and reducing reliance on hydrocarbons. Establishing a **robust financial framework**, including policy incentives and risk-reduction mechanisms, will further enhance the attractiveness of investment and encourage technological collaboration in Libya's renewable energy sector (Almaktar et al., 2025; Almaktar & Shaaban, 2021; Ibrahim, 2025, pp. 16–20).

4. Environmental Benefits of Renewable Energy Development

4.1. Reduction of Greenhouse Gas Emissions

Libya's transition to renewable energy is essential for **reducing greenhouse gas (GHG) emissions** and addressing climate change. With its substantial oil reserves, the country has long relied on fossil fuels, resulting in high per capita CO₂ emissions, recorded at **8.73 tons in 2018**. By shifting to solar and wind power, Libya could reduce its carbon footprint significantly, with projections suggesting a **57% decrease in CO₂ emissions** compared to diesel generation.

This transition supports **national sustainability objectives** and aligns with **international commitments**, particularly the Paris Agreement. The Renewable Energy Authority of Libya (REAOL) plays a pivotal role in promoting renewable energy initiatives, though entrenched fossil fuel subsidies continue to pose challenges.



Robust government policies and effective investment frameworks are critical for enabling widespread adoption of clean technologies.

Beyond emissions reduction, renewable projects improve **community health** by lowering air pollution, while simultaneously advancing **economic diversification** and **environmental restoration**. Adopting sustainable practices thus offers Libya a pathway to enhanced environmental integrity, greater economic resilience, and improved quality of life (Azubike & Gatiesh, 2024; Almaktar & Shaaban, 2021; Renewables in Libya, 2025; Badi et al., 2023, pp. 1–5).

4.2. Preservation of Natural Resources and Biodiversity

The expansion of renewable energy also contributes to the **protection of natural resources** and **biodiversity** in Libya. By reducing dependence on fossil fuels, solar and wind energy minimize extraction activities that cause environmental degradation and habitat destruction. This transition reduces GHG emissions, positively influencing **ecosystem stability** and climate regulation.

Moreover, renewable initiatives can promote **environmental stewardship**, incorporating practices that support biodiversity. For example, **agrovoltaics**—the integration of solar farms with agricultural production—can improve land use efficiency while fostering biodiversity and food security.

In addition, the establishment of **stronger regulatory frameworks** can enhance conservation strategies, ensuring that renewable projects safeguard wildlife habitats and ecosystems. Renewable energy also supports **sustainable agriculture**, providing clean power for irrigation and food processing without harming natural environments. This synergy ensures that energy development and biodiversity conservation advance together (Almaktar & Shaaban, 2021; Belrzaeg & Ahmed, 2023; Badi et al., 2023, pp. 1–5).

4.3. Mitigation Against Climate Change Effects

Adopting renewable energy represents a vital tool for **mitigating climate change impacts** in Libya. Replacing fossil fuels with solar and wind technologies could reduce CO₂ emissions by nearly 57%, strengthening Libya's alignment with international climate obligations under the Paris Agreement.

Renewable initiatives also improve **air quality and public health**, reducing respiratory and cardiovascular illnesses linked to pollution from traditional energy sources. Furthermore, investment in renewable infrastructure enhances **energy security** while protecting biodiversity and ecological systems.

This transition not only supports sustainable environmental practices but also provides **economic resilience** in the face of climate challenges, leveraging Libya's abundant solar potential for long-term development. Ultimately, renewable energy serves as both a climate mitigation strategy and a foundation for a **sustainable, low-**

carbon economy (Abdunnabi et al., 2023; Almakhtar et al., 2025; Almakhtar & Shaaban, 2021).

5. Social Dimensions of Renewable Energy Implementation

5.1. Community Engagement and Public Awareness

Community engagement and public awareness are essential for the successful adoption of renewable energy projects in Libya. A smooth energy transition cannot rely solely on government initiatives; it requires the **active participation of local communities**, whose input is vital in shaping policies and ensuring acceptance. Educational campaigns, public discussions, and training workshops can effectively highlight the benefits of renewable energy, such as **lower energy costs, job creation, and environmental protection**.

Equity must also be a priority, ensuring that **marginalized groups** have access to renewable options and the knowledge to utilize them. Clear communication about technologies and incentives can empower individuals and communities to invest in renewable systems. Showcasing **local success stories**—such as villages benefiting from solar projects—can build trust and encourage wider participation. An inclusive dialogue around renewable energy not only empowers communities but also advances Libya's broader **sustainable development goals** (Crafting a Just Energy Transition in North Africa: IEMed, 2025; El-Assasy, 2023; Ibrahim, 2025, pp. 21–25).

5.2. Access to Clean Energy for Marginalized Populations

Access to **clean energy** is a matter of both **equity and sustainability**. In Libya, many underserved communities—particularly in rural and remote regions—suffer from limited or unreliable access to electricity. Expanding renewable solutions such as **solar microgrids** offers affordable, sustainable energy that can transform livelihoods, improve healthcare services, and enhance educational opportunities.

Programs targeting marginalized populations ensure **fair distribution** of renewable benefits, aligning with **social justice principles**. Training initiatives can empower local populations with skills in renewable installation and maintenance, fostering **entrepreneurship** and job creation. Moreover, government incentives and financial support mechanisms can enable low-income households and small businesses to adopt renewables, ensuring **inclusive participation** in the energy transition (Abdunnabi et al., 2023; United Nations, 2025).

5.3. Health Impacts Associated with Transitioning to Renewables

The adoption of renewable energy offers **significant health benefits** by reducing air pollution caused by fossil fuel combustion. High reliance on oil and gas has led to elevated greenhouse gas emissions in Libya, contributing to **respiratory and cardiovascular diseases**. Shifting to clean sources such as solar and wind energy can improve **air quality**, with vulnerable populations like children and the elderly benefiting the most.

Renewable energy also mitigates risks linked to traditional biomass use, which produces harmful indoor pollutants. Access to clean energy further enhances **healthcare services**, by ensuring reliable electricity for hospitals, medical equipment, and vaccine refrigeration. Collectively, these improvements advance **public health** and foster healthier communities as Libya transitions toward a sustainable energy future (Azubike & Gatiesh, 2024; Crafting a Just Energy Transition in North Africa: IEMed, 2025).

6. Comparative Insights from Regional and Global Experiences

6.1. Successful Case Studies in Other Countries

Several **North African countries** provide valuable lessons for Libya's renewable energy transition.

- **Morocco** has emerged as a leader, with a national target of generating **52% of its electricity from renewables by 2030**. Large-scale projects such as the Noor Solar Complex have positioned Morocco as a hub for **solar exports and green hydrogen** development.
- **Egypt** has addressed power shortages and now maintains an **electricity surplus**, thanks to projects like the **Benban Solar Park**, one of the world's largest, supporting its goal of **42% renewable integration by 2030**.
- **Tunisia** pioneered **energy efficiency initiatives** as early as 1985, establishing the **National Agency for Energy Conservation (ANME)**. Through financial incentives and the **Energy Transition Fund**, Tunisia successfully reduced energy costs and boosted renewable uptake.

These case studies show that with **clear policy frameworks, stable regulations, and targeted financial incentives**, renewable energy transitions can enhance both sustainability and economic diversification. For Libya, these examples highlight the importance of strong governance, investment promotion, and regional cooperation in shaping its renewable future (Crafting a Just Energy Transition in North Africa: IEMed, 2025; IEA, 2025).

7. Challenges to Implementing Renewable Energy in Libya

7.1. Infrastructural Barriers

Libya faces serious infrastructural barriers that constrain renewable energy expansion. The **outdated national grid** struggles to meet demand, resulting in frequent outages, particularly during peak summer months. High **transmission losses** and damage to facilities since 2011 have further weakened the system. Limited investment in **maintenance and spare parts** exacerbates inefficiencies, while **fossil fuel subsidies** divert resources away from renewable infrastructure. Regional inequalities also

persist, as rural areas experience greater energy access challenges. Addressing these barriers is crucial if Libya is to achieve its target of **4 GW renewable capacity by 2035** (Libya Energy Situation, 2025; Badi et al., 2023, pp. 1–5; Maka et al., 2021).

7.2. Financial Constraints

Financial constraints significantly hinder renewable energy adoption. Subsidies for fossil fuels distort market prices, making renewable projects **less competitive**. To date, Libya has only developed **5 MW of solar capacity** through small-scale projects. **Political instability** and **economic uncertainty** discourage both domestic and foreign investors, while underdeveloped regulatory frameworks limit private sector participation. Reliance on imported technologies further inflates costs, contrasting with Morocco and Egypt's stronger local supply chains. Overcoming these challenges requires **public-private partnerships (PPPs)**, subsidy reforms, and innovative financing strategies to create a transparent investment environment (Libya Energy Situation, 2025; ElShazly, 2025; Badi et al., 2023, pp. 1–5).

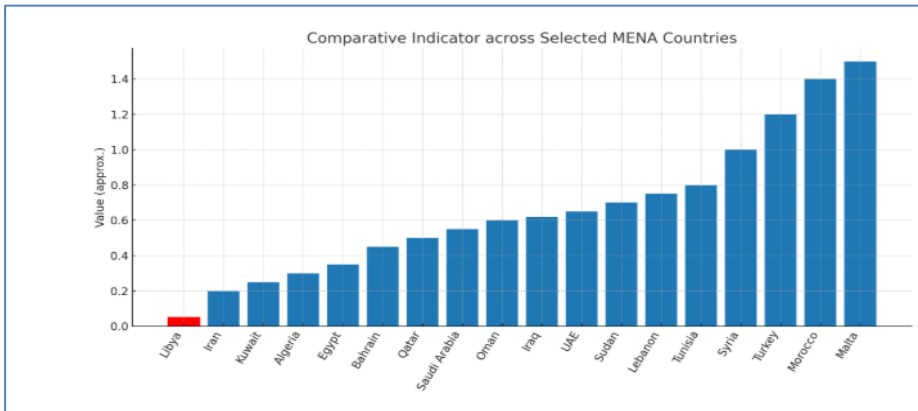


Figure 2. Gasoline prices in Libya (US\$/liter). Source: ElShazly (2025).

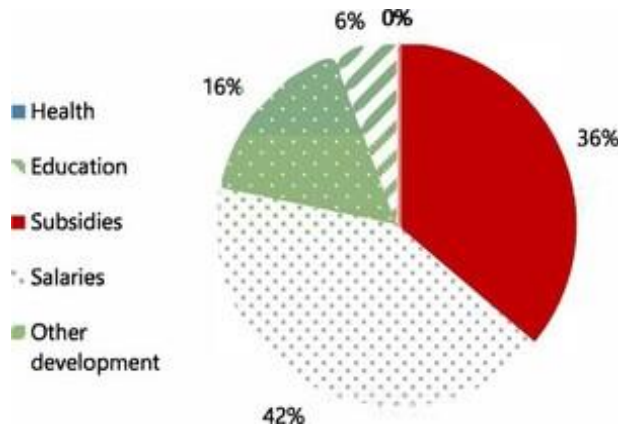


Figure 3. Health and education spending as share of total expenditures (2024). Source: ElShazly (2025).

7.3. Political Stability Issues

Political instability remains one of the **largest obstacles** to renewable energy development in Libya. Fragmented governance and ongoing unrest undermine consistent energy policy implementation. Subsidies for fossil fuels, coupled with unclear regulations, create **policy uncertainty** that deters investment. The conflict has also caused **severe infrastructure damage**, further complicating the deployment of renewables. Stable institutions and effective governance are prerequisites for attracting foreign capital and ensuring **community participation** in renewable projects. Without addressing political instability, Libya risks failing to capitalize on its substantial renewable potential (Azubike & Gatiesh, 2024).

8. Strategic Recommendations for Enhancing the Renewable Energy Sector

8.1. Policy Framework Improvements

Strengthening Libya's **policy framework** is essential for scaling up renewables. A **coherent Electricity Law**, effective tariff reforms, and the redirection of fossil fuel subsidies toward clean energy are key steps. Transparent regulations and **compliance mechanisms** can build investor trust, while institutional reforms and anti-corruption measures will improve governance. Workforce **capacity-building programs** can ensure Libyan workers are equipped for renewable industries. Public awareness campaigns and **international partnerships** will also facilitate knowledge transfer and enhance adoption (Ibrahim, 2025, pp. 6–50; Renewables in Libya, 2025).

8.2. Incentives for Private Sector Participation

Encouraging private sector participation requires **clear regulations, fiscal incentives, and partnerships**. Tax breaks, grants, and financing schemes can reduce barriers to entry, while **public-private partnerships** share risks and accelerate project timelines. Partnerships with international firms can promote **technology transfer**, while labeling systems and efficiency standards guide consumer choices. Stronger institutional oversight is also needed to ensure transparency and boost investor confidence (Azubike & Gatiesh, 2024; Almakhtar et al., 2025).

8.3. International Collaborations and Partnerships

International partnerships are pivotal for Libya's renewable transition. Collaborations with **neighboring countries** like Egypt and Morocco can provide tested models, while global partnerships offer access to advanced technologies such as **concentrated solar power (CSP)** and large-scale **energy storage**. Engagement with international organizations and development banks can unlock financing and technical support. Furthermore, collaboration with philanthropic groups can enhance **community-level awareness**. Together, these efforts can align Libya with global renewable energy momentum (Fuad, 2025; Borrowing Agency, 2025; Abdunnabi et al., 2023).

9. Future Prospects for Renewable Energy in Libya

9.1. Trends in Global Energy Markets

Global energy markets are rapidly shifting toward renewables, driven by declining costs, climate commitments, and technological advances. The **IEA forecasts strong growth** in wind and solar, with energy storage technologies reducing intermittency challenges. This global momentum underscores the importance of Libya integrating renewables to remain competitive while diversifying its economy. Public support for clean energy, enhanced by awareness of environmental and economic benefits, further strengthens this trajectory (Almaktar & Shaaban, 2021; IEMed, 2025; Belrzaeg & Ahmed, 2023; Azubike & Gatiesh, 2024; Goyal, 2020).

9.2. Technological Innovations on the Horizon

Emerging technologies present opportunities for Libya to **leapfrog traditional systems**. Advances in **solar PV efficiency**, **wind turbine design**, and **next-generation batteries** will enhance reliability and affordability. Hybrid systems combining renewables with storage can improve grid stability, while **digital smart grids** and IoT solutions optimize distribution. Additionally, renewable hydrogen production is becoming a viable future fuel. Embracing these innovations can position Libya as a **regional renewable leader** (Azubike & Gatiesh, 2024; Almaktar et al., 2025; Almaktar & Shaaban, 2021; Belrzaeg & Ahmed, 2023).

9.3. Long-term Vision for Sustainable Development through Renewables

Libya's long-term renewable vision is anchored in **economic diversification**, **energy security**, and **environmental sustainability**. Investments in renewable infrastructure, supported by stable policy frameworks and **regional cooperation**, will drive job creation and climate resilience. Strengthening institutions, upgrading the grid with **smart technologies**, and aligning with global **climate commitments** will be crucial. By pursuing this pathway, Libya can reduce fossil fuel dependence, attract international investment, and emerge as a proactive regional actor in the renewable energy sector (Azubike & Gatiesh, 2024; Almaktar & Shaaban, 2021; IEMed, 2025; Ibrahim, 2025, pp. 6–10).

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