

Toward a Sustainable Energy Model in Algeria: Biomass Energy, Waste Valorization, and the Energy Transition

Vers un modèle énergétique durable en Algérie : énergie de la biomasse, valorisation des déchets et transition énergétique

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Abstract:

This study aims to examine the relationship between energy and the environmental dimensions of sustainable development, particularly in light of the attention devoted by Agenda 21 to achieving a set of objectives related to protecting the atmosphere and reducing the negative impacts of the energy sector through the development of sustainable energy policies and programs. Algeria is among the countries that have increasingly focused on renewable energy as a means of reducing the vulnerability associated with fluctuations in oil prices. It is therefore more necessary than ever for Algeria to identify development alternatives beyond the hydrocarbon sector by promoting investment in renewable energy. In this context, Algeria has attached considerable importance to renewable energy, as reflected in the launch of ambitious programs aimed at developing this sector.

This orientation was further reinforced within the framework of the 2020–2024 Economic Recovery Program, which proposed an alternative development approach to Algeria's oil-rentier model based on three major principles: sustainable and equitable human development; energy and digital transition; and the protection of environmental resources. With regard to energy transition, particular emphasis was placed on renewable energy and its integration into Algeria's energy system in order to build a diversified energy-consumption model capable of mobilizing national capacities across different energy sources. One of the initiatives in this context is the waste-to-energy project, which entered into operation in 2023 as an alternative option for reducing reliance on fossil fuels.

Keywords: Sustainable Development; Renewable Energy; Energy Transition; Biomass Energy.

Résumé:

Cette étude vise à examiner la relation entre l'énergie et les dimensions environnementales du développement durable, notamment au regard de l'attention accordée par l'Agenda 21 à la réalisation d'un ensemble d'objectifs liés à la protection de l'atmosphère et à la réduction des effets négatifs du secteur énergétique, à travers l'élaboration de politiques et de programmes énergétiques durables. L'Algérie figure parmi les pays qui accordent une importance croissante

aux énergies renouvelables comme moyen de réduire la vulnérabilité liée aux fluctuations des prix du pétrole. Il apparaît ainsi plus nécessaire que jamais pour l'Algérie d'identifier des alternatives de développement au-delà du secteur des hydrocarbures, notamment en favorisant l'investissement dans les énergies renouvelables. Dans ce contexte, l'Algérie a accordé une importance considérable aux énergies renouvelables, comme en témoigne le lancement de programmes ambitieux visant à développer ce secteur.

Cette orientation a été davantage renforcée dans le cadre du Programme de relance économique 2020–2024, qui a proposé une approche alternative au modèle rentier pétrolier de l'Algérie, fondée sur trois principes majeurs : un développement humain durable et équitable ; la transition énergétique et numérique ; et la protection des ressources environnementales. En matière de transition énergétique, une attention particulière a été accordée aux énergies renouvelables et à leur intégration dans le système énergétique algérien, afin de construire un modèle de consommation énergétique diversifié, capable de mobiliser les capacités nationales à partir de différentes sources d'énergie. Parmi les initiatives inscrites dans ce cadre figure le projet de valorisation énergétique des déchets, mis en service en 2023 comme une option alternative visant à réduire la dépendance aux combustibles fossiles.

Mots-clés : Développement durable ; énergies renouvelables ; transition énergétique ; énergie de la biomasse.

Introduction:

Rapid technological and industrial development has made energy a central concern of contemporary economic and environmental policy. Growing human dependence on energy resources has generated several challenges, including environmental problems associated with pollution and economic problems resulting from price volatility. The growing human dependence on energy resources has generated several challenges, including environmental problems associated with pollution and economic problems resulting from price volatility. These challenges have stimulated efforts to identify mechanisms and alternatives capable of ensuring access to renewable energy sources characterized by a relatively greater degree of price stability.

In this context, renewable energy sources play an important role in reducing energy-price volatility and enhancing energy security, as they constitute clean sources of energy production. Some renewable energy sources can be utilized continuously throughout the day, such as ocean energy, whereas others are intermittent, such as solar and wind energy, because their availability is associated with climatic phenomena that vary over time.

Given the importance of renewable energy in the contemporary period, particularly in the context of declining oil prices and growing environmental concerns, the development of renewable energy has become a priority of economic policies in countries around the world and, in particular, in Algeria.

Effective implementation of renewable-energy policies could generate substantial economic, environmental, and social benefits for Algeria. The accelerated implementation of the national renewable-energy program, supported by appropriate incentives, financial resources, institutional

mechanisms, and qualified human capital, could contribute to a gradual transformation of the country's energy model. In the longer term, sustained investment in renewable energy could help reduce Algeria's dependence on hydrocarbon revenues while supporting environmental protection and economic diversification.

Within this context, biomass energy emerges as one of the renewable energy sources capable of combining the energy dimension with environmental and economic considerations. Biomass resources include organic materials such as agricultural and forestry residues, household and industrial waste, wastewater, and other forms of organic matter. These resources can be converted into different forms of energy, including biogas, heat, and electricity.

The importance of this resource for Algeria derives from the country's efforts to develop renewable energy and diversify its energy mix. The revised National Renewable Energy Development Program has incorporated biomass, particularly through waste valorization, among the areas targeted for development.

Although considerable research has examined Algeria's solar-energy potential and broader renewable-energy transition, comparatively less attention has been devoted to biomass as an integrated component of energy diversification, waste valorization, and circular-economy development. Existing discussions frequently address biomass either from a technical perspective or within broader waste-management policies, leaving a need for an integrated policy-oriented analysis of its energy, environmental, economic, and institutional dimensions in Algeria. Accordingly, the research problem is formulated around the following central question:

How can sustainable development be promoted in Algeria through reliance on renewable energy, particularly biomass energy, and through the valorization of waste?

Methodology:

This study adopts a descriptive-analytical and documentary approach to examine the role of biomass energy in Algeria's transition toward a more sustainable energy model. The analysis draws on Algerian legislation, national energy-transition programs, official government reports, institutional documents, and relevant academic literature. Particular attention is given to the relationship between biomass valorization, waste management, energy diversification, environmental protection, and sustainable development. The study does not rely on primary field data; rather, it critically examines existing policy frameworks, institutional arrangements, and documented biomass and waste-to-energy initiatives in Algeria.

The study is therefore primarily policy- and document-oriented and does not attempt to estimate Algeria's total technically recoverable biomass potential or the precise future contribution of biomass to national electricity generation.

To address this question, the study examines the following issues:

First: The Concept of Sustainable Development and Renewable Energy

Second: Renewable Energy Projects in Algeria

Third: Biomass Energy in Algerian Energy Policy

First: The Concept of Sustainable Development and Renewable Energy

Sustainable development has remained one of the major challenges facing developing countries, given that it represents an essential pathway toward achieving progress while safeguarding the rights of future generations. The strategies and policies adopted by these countries have varied, as they have experimented with different approaches and implemented various methods in an attempt to achieve sustainable development. The concept itself has been defined in several ways, including the following:

A. Definition of Sustainable Development

Sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It therefore seeks to preserve opportunities for future generations while recognizing the principle of intergenerational equity.¹

It has also been defined as genuine development characterized by continuity and sustainability in the use of natural resources. Such development can be achieved through a strategy that places ecological balance at its core. This balance can be attained within a social and environmental framework aimed at improving individuals' living standards through political, economic, social, and cultural systems that preserve the integrity of the environmental framework.²

B. Principles of Sustainable Development

Sustainable development is based on five major principles:³

- **Living within environmental limits:** respecting ecological diversity, preserving natural resources, and ensuring their availability for future generations.
- **Ensuring a strong, healthy, and equitable society:** meeting the diverse needs of all members of society, both now and in the future.
- **Achieving a sustainable economy:** providing prosperity and opportunities for all while ensuring the efficient use of resources.
- **Ensuring evidence-based policy-making:** ensuring that policies are developed and implemented in accordance with scientific knowledge and scientific culture.
- **Strengthening good governance:** ensuring an effective and participatory governance system.

C. Definition of Renewable Energy

Renewable energy refers to sustainable, non-conventional energy obtained from natural resources. It is characterized by continuous renewal and, from a scientific perspective, does not have a finite lifespan in the same sense as conventional energy resources. Renewable resources remain available as long as the natural processes sustaining them continue, in contrast to conventional energy sources such as oil, gas, and coal, which are finite and depleted through

¹ - Abdallah Hassoun Mohamed et al., "Sustainable Development: Concept, Components, and Dimensions," *Diyala Journal*, no. 67 (2015), p. 341.

² - Sustainable Development in Algeria between the Imperative of Development and the Reality of Management," University of Chlef, <https://www.univ-chlef.dz>, accessed January 23, 2026, at 22:30.

³ - Principles of Sustainable Development," International Labour Organization, <https://www.ilo.org>, accessed January 24, 2026, at 23:10.

consumption. Modern renewable energy sources are also considered environmentally friendly because of their favorable environmental characteristics and are therefore commonly referred to as “green energy.”⁴

Renewable energy can also be defined as energy derived from natural sources that are replenished at a rate greater than the rate at which they are consumed, such as sunlight and wind. These resources are continuously renewed and are abundant and widely available. This contrasts with non-renewable resources, whose formation may take hundreds of years. The combustion of fossil fuels for energy production generates harmful emissions, particularly carbon dioxide.⁵

Article 3 of Law No. 04-09 concerning the promotion of renewable energy within the framework of sustainable development in Algeria defines renewable energy as follows:

“Forms of electrical, kinetic, thermal, or gaseous energy obtained through the conversion of solar radiation, wind power, geothermal heat, organic waste, hydropower, and biomass utilization technologies.”⁶

D. The Role of Renewable Energy in Achieving the Dimensions of Sustainable Development⁷

1. The Economic Dimension

Economic development depends on the availability of energy services necessary to increase and improve productivity and to contribute to the growth of domestic income. Without access to energy services, employment opportunities, productivity gains, and consequently available economic opportunities become severely constrained. The availability of such services contributes to the establishment of small enterprises and supports livelihood activities and private businesses.

2. The Social Dimension

The social issues associated with energy use include poverty alleviation and the expansion of opportunities. Limited access to energy services marginalizes vulnerable populations and significantly reduces their ability to improve their living conditions. Approximately one-third of the world's population lacks access to essential energy resources. Reliance on new and renewable energy sources, such as solar water heaters, photovoltaic cells, and the recycling of agricultural residues into organic fertilizer, can contribute to reducing unemployment and poverty while preventing the waste of financial and material resources.

3. The Environmental Dimension

In light of the evident climate changes affecting the world, serious consideration must be given to reducing greenhouse-gas emissions resulting from the use of fossil-energy sources, which

⁴ - Sara Jeddi and Tarek Jeddi, “The Reality and Prospects of Renewable Energy in Algeria,” p. 3.

⁵ - Definition of Renewable Energy,” United Nations, <https://www.un.org/ar/climatechange/what-is-renewable-energy>, accessed January 23, 2026, at 23:49.

⁶ - People’s Democratic Republic of Algeria, Law No. 04-09 of August 14, 2004, on the Promotion of Renewable Energies within the Framework of Sustainable Development, Official Gazette of the People’s Democratic Republic of Algeria, no. 52, issued August 18, 2004, p. 9.

⁷ - Noureddine Chenoufi and Sofiane Maamire, “The Role of Renewable Energy in Achieving Sustainable Development in Algeria: Solar Energy as a Future Alternative Energy Source,” Journal of Commercial Sciences, no. 20, pp. 10–11.

are closely associated with climate change. Moreover, given the potential depletion of oil and gas over the coming decades, as emphasized by numerous researchers, the transition toward clean alternative energy sources in their various forms has become increasingly necessary.

E. Renewable Energy Sources

Among the most important renewable energy sources are the following:⁸

- **Solar Energy:** The sun is the primary source of most other renewable energy resources. Solar energy is generated through nuclear reactions occurring within the sun, and its thermal energy reaches the Earth in the form of radiant energy consisting of ultraviolet, visible, and infrared radiation. A significant proportion of ultraviolet radiation is filtered by the atmosphere. The total amount of solar energy reaching the Earth is extremely large, and theoretically, solar energy collected over a very small proportion of the Earth's surface could cover global electricity demand.
- **Wind Energy:** Wind has been used as a renewable energy source since ancient times, particularly for drawing water from wells and grinding grain. Its use declined during the Industrial Revolution because it could not keep pace with technological developments. The Danish engineer Poul la Cour is considered a pioneer in the development of electricity generation through wind turbines. His work contributed to the development of wind power as a renewable, non-depletable, clean, and environmentally safe energy source.
- **Hydropower:** Hydropower is a renewable energy source that can utilize the movement of water to generate energy. It includes three principal forms: hydroelectric power, tidal energy, and marine wave energy.
- **Biomass Energy:** Biomass energy is derived from organic materials such as plants, bones, animal residues, waste, and agricultural residues. Biomass used for energy production may include fast-growing trees, vegetable oils, and agricultural residues. Various technologies can be employed to process these materials into different forms of biofuel.
- **Geothermal Energy:** Geothermal energy refers to the natural heat stored beneath the Earth's surface that can be recovered and used for productive purposes. Geothermal resources with temperatures ranging from approximately 20°C to 150°C can be used directly for residential heating and certain industrial processes. Higher-temperature geothermal resources can be used to generate electricity.

Second: Renewable Energy Projects in Algeria

In recent years, Algeria has increasingly focused on developing renewable energy projects as part of its efforts to diversify its energy mix and reduce its dependence on hydrocarbons.

A. Why Is Algeria Moving toward Renewable Energy?

As part of its efforts to promote renewable energy, achieve economic sustainability, and move toward a green economy, Algeria developed long-term renewable-energy plans within the

⁸ - Mourad Cherif, "Renewable Energy and Its Role in Achieving Sustainable Economic Development," *Journal of Administrative and Economic Research* 2, no. 4 (2018), pp. 194–195.

framework of the Renewable Energy Program for 2011–2030. This program included several pioneering projects, some of which have already been implemented, while others have been implemented at varying rates or scheduled for future development.

The implementation phases of the Renewable Energy Development Program can be summarized as follows:

First phase: 2011–2013, during which a total capacity of approximately 110 MW was planned.

Second phase: establishment of a total capacity of approximately 650 MW.

Third phase: extending to 2020, during which a total capacity of approximately 2,600 MW was planned for the domestic market, with the possibility of exporting approximately 2,000 MW.

Fourth phase: extending to 2030, during which approximately 12,000 MW was planned for the domestic market, with the possibility of exporting approximately 10,000 MW.

Table 1. Evolution of Algeria's Renewable Energy Targets and Implementation Frameworks

Period	Policy/Program	Target	Main Technologies	Status
2011–2014	Initial Renewable Energy Program	—	Solar/Wind	Historical
2015–2030	Revised Renewable Energy Program	22 GW	Mainly Solar	Historical target
2019–2035	Revised Renewable Energy Strategy	15 GW	Mainly Solar	Revised target
2024–2035	Current Implementation Framework	15 GW	PV/Renewables	Ongoing

Source: Compiled and elaborated by the author based on official documents of the Algerian Ministry of Energy and Renewable Energies and Sonelgaz.

Table 1 illustrates the gradual evolution of Algeria's renewable-energy policy from the initial programs launched in the early 2010s toward a more recent framework extending to 2035. The comparison also highlights a shift from broad long-term capacity targets toward a stronger emphasis on implementation. Although solar photovoltaic energy remains central to the current transition, the inclusion of biomass and waste valorization provides an additional pathway for diversifying the renewable-energy mix and linking energy policy with environmental management.

The program was revised three times in response to changing circumstances, particularly successive crises and fluctuations in oil prices, which constitute a major source of Algeria's economy. Algeria has sought to reach a total renewable-energy capacity of 15,000 MW by 2035, including 6,000 MW during the period 2023–2027.⁹

⁹ - People's Democratic Republic of Algeria, Ministry of Energy and Mines, "Statement by Mohamed Arkab, Minister of Energy and Mines," 12th Arab Energy Conference, Doha, December 2023, p. 3.

Algeria has established several mechanisms and institutional structures to facilitate the energy transition. The most important are discussed below.¹⁰

- **The National Energy Transition Program 2020:** Energy transition occupies an important position in the government's action plan, which focuses on a threefold economic renewal strategy centered on food security, energy transition, and the digital economy. In addition to diversifying energy sources, the energy-transition program emphasizes energy efficiency as a complementary and strategically important component.

Accordingly, Algeria seeks to overcome the constraints associated with conventional energy resources and initiate a dynamic process toward locally available green and sustainable energy. This approach is based on:

- preserving and valorizing fossil resources;
 - changing the energy model of production and consumption;
 - promoting sustainable development and environmental protection; and
 - controlling the costs of establishing renewable-energy facilities.
- **The 2030 Program:** Algeria established an ambitious program for the development of renewable energy and energy efficiency for the period 2011–2030. Its strategy focused on valorizing renewable natural resources and using them to diversify energy sources. The program aimed to develop renewable energy through the production of 22,000 MW by 2030, including 10,000 MW intended for export, provided that the necessary conditions were met.

The program was to be implemented through three phases: the first phase (2011–2013), focusing on pilot projects; the second phase (2014–2015), focusing on program deployment; and the third phase (2016–2030), focusing on large-scale implementation of solar power plants.

It should be noted that the program included 60 projects, comprising photovoltaic solar plants, solar thermal plants, wind farms, and hybrid power plants.

Source: Ministry of Energy and Mines, Renewable Energy and Energy Efficiency Program in Algeria, p. 139.

The table shows that the National Renewable Energy Development Program sought to achieve a cumulative capacity of 22,000 MW during the period 2015–2030, distributed among several renewable energy sources. Photovoltaic solar energy accounted for the largest share, followed by wind energy.

The table also demonstrates the integration of biomass energy into the transition toward a more diversified and sustainable energy model. The program allocated a total capacity of 1,000 MW for biomass energy production by 2030. This capacity represents approximately 4.5% of the total targeted renewable-energy capacity of 22,000 MW.

The inclusion of biomass is particularly important because of its connection with waste valorization and the transformation of waste from an environmental burden into an energy

¹⁰ - Samir Tahine and Fatima Zahra Rais, “The Energy Transition Strategy: Prospects for 2035 as a Mechanism for Achieving Energy Security in Algeria,” *Journal of Financial, Banking and Business Economics and Management* 14, no. 2 (2025), p. 326.

resource. This creates an opportunity to integrate the energy, environmental, and economic dimensions of sustainable development.

- **Government Plan toward 2035:** The government plan includes the Solar 1000 project, which aims to generate 1,000 MW of solar energy. The company responsible for the project, Shaams, has subsequently been placed under the umbrella of the Sonelgaz Group and has become one of its subsidiaries. This development is expected to contribute to increasing national renewable-energy generation capacity and to saving substantial quantities of natural gas that would otherwise have been used for electricity generation. Such gas resources could subsequently be redirected toward national transformation and industrial projects.
- **Establishment of Algerian Institutional Structures to Support the Energy Transition:** Algeria has adopted several institutional measures and arrangements to integrate renewable energy and energy efficiency into its energy policy, with the objective of diversifying energy resources and initiating the energy transition.

As part of the institutionalization of renewable-energy promotion, Algeria developed the basic mechanisms necessary to support renewable-energy activities and established several administrative structures to serve this sector. These included the establishment of the National Observatory for the Promotion of Renewable Energy and the approval of the establishment of the National Energy Management Fund to finance projects and provide loans and guarantees through banks and financial institutions. These mechanisms were intended to support and promote renewable energy, encourage both public- and private-sector investment, and strengthen the contribution of sustainable development to economic growth, social welfare, and living standards. Algeria also approved the establishment of the High Commission for Renewable Energies in 2019 and subsequently created a Ministry responsible for energy transition and renewable energy.¹¹ The transition toward renewable energy has increasingly become a necessity rather than merely an option, particularly in order to avoid crises associated with the depletion of finite resources. This orientation entails several potential benefits:¹²

- **Mitigating the Effects of Climate Change:** The first objective of engaging in sustainable development is to comply with the country's commitments under the United Nations climate-change framework, particularly those associated with COP21. Achieving this objective requires sound governance, which is also essential for the preparation and submission of relevant national reports.

Strengthening Energy Resilience and Security

Energy security can be considered from the perspective of the energy-consumption model. This involves ensuring that the state has sufficient energy supplies to meet its needs through 2050, including reasonable energy requirements across different economic sectors.

¹¹ - Safia Ould Rabah Iqlouli and Mohamed Iqlouli, "The Legal and Institutional Framework for Renewable Energy in Algeria," *Sawt Al-Qanun Journal* 8, no. 2 (2022), p. 1396.

¹² - Toufik Hosni et al., *Algeria 100% Renewable Energy: Recommendations for a National Renewable Energy Strategy*, Friedrich-Ebert-Stiftung, January 2021, pp. 8–9.

- **Supporting the Local Economy and Creating Employment Opportunities/** Engagement with sustainable development can contribute to strengthening its fundamental social dimension. In particular, the creation of employment opportunities in renewable-energy industries represents a tangible potential benefit.
- **Reducing Pollution and Improving Human Health:** Environmental protection requires appropriate measures, including waste separation at source, waste treatment, and large-scale recycling. Uncontrolled organic waste in northern Algeria, for example, could potentially be utilized to improve soil fertility in agricultural areas devoted to desert farming.

B. Requirements for the Energy Transition

The principal requirements for the energy transition include the following:

- A clear political commitment from the country's highest authorities to gradually reduce dependence on conventional energy sources in favor of renewable energy.
- Provision of the financial resources required for the transition by identifying appropriate financing mechanisms for renewable-energy projects, including private-sector participation and the promotion of foreign investment in this field.
- Conclusion of international agreements and partnerships to develop renewable-energy generation and manufacturing.
- Promotion of scientific and technological research in renewable energy.
- Establishment of dedicated renewable-energy markets characterized by flexibility, transparency, and clear transactional frameworks.¹³

C. Projects Implemented between 2011 and 2018

The discussion focuses primarily on solar energy, which received the largest share of renewable-energy investment. Several projects were completed and entered service, including the following:¹⁴

- **The Hassi R'Mel Integrated Solar Combined-Cycle Power Plant (SPP1):** commissioned in May 2011 with a total generation capacity of 150 MW, including 25 MW generated from solar energy.
- **The Algerian–Japanese Sahara Solar Breeder Project:** one of the major cooperation initiatives between the University of Algiers and Japanese universities. The project involved three Algerian partner institutions and eight Japanese universities and research institutes. It was approved in August 2010 through the signing of an agreement between the two sides. The project aimed to convert solar radiation into electricity and transmit the generated electricity to northern Algeria through cables designed to minimize energy losses. Implementation began

¹³ - Aïcha Amiche and Siham Tarachani, "Energy Transition as a Mechanism for Sustaining Energy Security in the Arab Maghreb Countries: Prospects and Challenges," *Journal of Studies and Economic Research on Renewable Energy* 8, no. 1 (2021), p. 208.

¹⁴ - Mohamed Kadaïssa and Aïcha Kadaïssa, "The Reality of Renewable Energy in Algeria and Its Future Prospects," *Journal of Development and Applied Economics* 3, no. 2 (2019), pp. 84–85.

during the same year but was postponed until early 2012 following the natural disasters that affected Japan.

- **Shariket Kahraba wa Takat Moutajadida (SKTM):** headquartered in Ghardaïa, the company specializes in alternative and renewable electricity generation and conducts feasibility studies for investment projects. It is a joint-stock company affiliated with Sonelgaz and was established in April 2013.
- **The Ghardaïa Pilot Photovoltaic Power Plant:** commissioned in July 2014 and based on photovoltaic solar technology. The plant is affiliated with SKTM and has a total capacity of approximately 1.1 MW.
- **Three hybrid solar-energy plants:** these projects were developed jointly by the Algerian Renewable Energy Company and a Spanish company, including the second solar power plant in El Meghaier, the third solar power plant in Naâma, and the fourth solar power plant at Hassi R'Mel.
- **Photovoltaic plant in Adrar:** a pilot photovoltaic plant with a capacity of 30 kW entered service during the first half of 2017 at the Renewable Energy Research Unit in the Saharan region of Adrar Province. The plant demonstrated its effectiveness in reducing the financial cost of electricity consumption at the unit.
- **Pilot solar power plant at Bir Rebaa North Field:** a pilot solar-energy plant with a generation capacity of 10 MW was established in northern Ouargla to meet part of the electricity requirements of the oil field.
- **Twenty-two photovoltaic solar plants:** in 2017, Sonelgaz's electricity, gas, and renewable-energy subsidiary completed 22 photovoltaic solar plants in the High Plateaus and southern regions, with a combined capacity of 343 MW.

D. Obstacles to the Exploitation of Renewable Energy in Algeria

The principal obstacles that have limited the optimal exploitation of Algeria's renewable-energy potential can be summarized as follows:¹⁵

- **High investment costs:** renewable-energy projects involve relatively high initial investment costs, together with shortcomings in existing financing mechanisms.
- **Limited technical and technological capacities:** the deployment of renewable-energy technologies requires specialized technical expertise and detailed assessments of local manufacturing capacities, including the requirements for producing renewable-energy components and equipment and the availability of qualified labor.
- **Limited awareness and understanding:** insufficient attention to renewable energy and misconceptions regarding its applications among relevant stakeholders and society at large constitute significant obstacles to increasing reliance on renewable energy. This highlights the role of media and public awareness in developing an appropriate understanding of clean and

¹⁵ - Aïssa Ben Lakhdar and Youssef Iftikhar, "The Reality of Renewable Energy in Algeria and Its Future Prospects: An Evaluative Study," *Journal of Contemporary Commercial and Economic Studies* 3, no. 2, p. 231.

environmentally friendly energy production and in clarifying the economic, environmental, and technical dimensions of renewable-energy technologies.

- **Continued dependence on oil:** Algeria continues to rely heavily on oil for energy production despite the finite nature of this resource. This dependence negatively affects the transition toward alternative energy sources that could contribute substantially to preserving hydrocarbon resources. %
- **Third: Biomass Energy in Algerian Energy Policy:** The green economy, as a clean economic model, promotes investment in renewable energy and the development of modern technologies for converting biomass into energy, a process commonly referred to as energy valorization. This can make an important contribution to energy supply alongside solar and wind energy.

A. Definition of Biomass Energy

Biomass encompasses living or recently living organic materials of plant origin, such as trees and agricultural products rich in starches and sugars, as well as animal-derived residues and industrial and human organic waste. The energy contained in these materials can be released through processes such as direct combustion and fermentation. Several methods can be employed to convert biomass into usable fuels in solid, liquid, or gaseous forms.¹⁶

B. Sources of Biomass

Biomass-energy sources consist of organic materials that can be converted into energy. The main sources include:

- **Forest and wood residues:** firewood, tree-pruning residues, and similar materials.
- **Animal residues:** cattle, sheep, and poultry manure, which can be used to produce biogas.
- **Household and food-related organic waste:** food scraps, vegetables, and fruit residues.
- **Organic industrial waste.**
- **Energy crops.**

Biomass can be converted through physicochemical and thermochemical processes into energy or an energy carrier. Mechanical preparation is among the most widely used methods, including transforming wood residues and straw into briquettes or pellets, as well as extracting vegetable oils. Conversion efficiencies may reach approximately 20% for electricity generation and 70% for heat generation. Biomass can also be converted using air into producer gas, with efficiencies potentially reaching 70–80%.

Biomass resources in Algeria are concentrated in two major geographical areas:

- **The arid Saharan region:** covering approximately 90% of the country's total area.
- **The forested region:** representing approximately 10% of Algeria's geographical area. Forests cover approximately 1.8 million hectares, while mountainous forest formations cover

¹⁶ - Abderraouf Triki, "The Status of Renewable Energy and Its Role in Achieving Sustainable Development," Master's Thesis, University of Algiers 3, 2014, p. 109.

approximately 1.9 million hectares. Maritime pine and eucalyptus are important species for energy conversion, although they account for only approximately 5% of Algeria's forest area.¹⁷

Table 2. Biomass Resources and Potential Energy Applications in Algeria

Biomass Source	Main Geographic Areas	Conversion Technology	Energy Product	Main Constraint
Agricultural residues	Agricultural regions	Anaerobic digestion/combustion	Biogas/heat/electricity	Collection and logistics
Animal manure	Rural/agricultural areas	Anaerobic digestion	Biogas	Infrastructure
Municipal organic waste	Urban areas	Anaerobic digestion/WtE	Biogas/electricity	Waste sorting
Forestry residues	Forest regions	Combustion/gasification	Heat/electricity	Sustainable harvesting
Wastewater sludge	Urban treatment plants	Anaerobic digestion	Biogas	Treatment infrastructure

Source: Author's elaboration based on the literature on biomass conversion technologies and official Algerian documents on renewable energy and waste management.

Table 2 indicates that Algeria's biomass resources are diverse and geographically distributed, encompassing agricultural residues, animal manure, municipal organic waste, forestry residues, and wastewater sludge. Their energy potential, however, cannot be assessed solely on the basis of resource availability. Collection systems, waste sorting, transportation, conversion infrastructure, and technological capacity constitute critical conditions for their effective valorization.

Biomass has acquired particular importance within Algeria's efforts to diversify renewable-energy sources. The National Renewable Energy Program incorporated biomass and waste valorization among the areas that can be developed as part of the transition toward renewable energy sources.

C. Biomass Conversion Technologies

Biomass is primarily converted into energy through combustion, whereby plant-based fuels are burned and the resulting heat is used directly. This heat can also be used to generate electricity. The efficiency of biomass conversion varies substantially according to feedstock characteristics, conversion technology, moisture content, scale, and end-use configuration. Other innovative technologies for converting biomass into energy include:¹⁸

¹⁷ - Mohamed Si Ahmed, "Towards the Imperative of Exploiting Renewable Energy in Algeria in Light of Changes in the Current Economic Situation," *Journal of Economics and Environment* 3, no. 2 (2020), p. 73.

¹⁸ - Antar Hassani, "Energy Transition in Algeria: The Role of Natural Gas and Renewable Energy in Algeria's Future Energy Mix," PhD Dissertation in Management Sciences, University of Algiers 3, 2025, p. 15.

1. Gasification

Gasification is a thermochemical process used to convert biomass into a combustible gas mixture that can be used to generate heat or electricity.

2. Anaerobic Digestion

This process involves the biological conversion of organic materials of plant or animal origin into biogas rich in methane.

3. Oleochemical Conversion

The use of biofuels has a long history. Historically, vegetable oils and alcohols were used in lamps and other applications. Biofuels have been examined as energy alternatives with potential environmental, economic, and strategic benefits. However, their environmental and socioeconomic effects depend substantially on the type of feedstock, production pathway, land-use implications, and end-use application.

Two major categories dominate biofuel production:

- **Ethyl alcohol (ethanol):** used in gasoline engines.
- **Vegetable-oil methyl ester (biodiesel):** used in diesel engines.

The technological characteristics of biomass should also be considered in relation to Algeria's dominant solar-energy pathway. Table 3 summarizes the principal complementary characteristics of the two energy sources.

Table 3. Comparative Characteristics of Solar and Biomass Energy in the Algerian Context

Criterion	Solar Energy	Biomass Energy
Resource availability	Very high	Regionally variable
Intermittency	High	Lower when feedstock is available
Waste-management benefit	Limited	High
Dispatchability	Limited without storage	Potentially higher
Infrastructure requirements	Grid and/or storage	Collection, logistics, and conversion infrastructure
Environmental benefit	High	Depends on feedstock and technology
Main challenge	Intermittency and storage	Feedstock collection and logistics

Source: Author's elaboration based on the literature on solar and biomass energy systems and Algeria's renewable-energy policy documents.

Table 3 highlights the complementary characteristics of solar and biomass energy rather than suggesting that one resource should replace the other. Solar energy offers substantial resource availability in Algeria but remains dependent on solar conditions and therefore raises issues related to intermittency and storage. Biomass, by contrast, can provide more controllable energy when an adequate and reliable feedstock supply is available, while also contributing to waste valorization. Its principal constraints are therefore associated with feedstock collection, logistics, infrastructure, and conversion technologies.

D. Types of Fuel Derived from Biomass

- **Biogas:** Biogas can be readily produced from waste, particularly waste generated by paper and sugar industries, wastewater, and animal manure. It is increasingly produced through the conversion of wastewater-treatment facilities into biogas plants, where methane is recovered while the remaining solid residues can be used as organic fertilizer with limited adverse effects on soil and the environment.
- **Liquid Biofuels:** Liquid biofuels include alcohol-based biofuels such as ethanol and bio-oils such as biodiesel, which can be used in diesel engines with limited or no modification, depending on the fuel and engine specifications. They can be produced from vegetable materials and their derivatives as well as animal fats.

Diesel engines were historically designed to operate using vegetable oils rather than fossil-derived oils. One of the advantages of biofuels is their relatively low emissions, particularly carbon monoxide and other hydrocarbons. However, increasing criticism has been directed toward biofuels produced from food crops because of concerns related to food security and environmental impacts.

- **Solid Biomass:** Solid biomass mainly consists of heating fuels derived from wood, charcoal, animal waste, and food-crop residues. Cattle manure retains a substantial proportion of the energy originally consumed by the animal. In practical terms, however, these solid materials are difficult to use as vehicle fuels.

The combustion of wood for cooking and heating is among the most common examples of solid biomass use. Wood and wood products can also be converted into biofuels such as wood gas. Solid biomass can likewise be converted into producer gas and, through appropriate processes, into biogas.¹⁹

Within this framework, Algeria is moving toward electricity generation from waste through a partnership program involving the National Waste Agency and the High Commission for Renewable Energies and Energy Efficiency.

This program forms part of broader plans aimed at reducing dependence on fossil fuels within the energy mix through the transition toward renewable energy and the utilization of bioenergy. In this context, the agreement was signed on 11 January 2023.

E. Objectives of the Waste-to-Electricity Project

The project aims to develop studies on electricity generation from waste and launch pilot projects for electricity generation from biogas at technical landfill facilities. Biogas has characteristics similar to natural gas and can be used to generate heat and electricity or as a biofuel. It is regarded as one of the important gases within renewable-energy development frameworks and as a potential alternative to natural gas.

Biogas can play an important role in achieving energy-transition objectives by supporting green growth and reducing greenhouse-gas emissions.

¹⁹ - Kamilia Boukra and Abdelwahab Chemmam, "Biomass Energy between the Problem of Energy Security and the Challenge of Rising Food Prices," *Economic Visions Journal* 6, no. 2 (2016), pp. 222–223.

The program will also create opportunities for waste valorization and the implementation of pilot projects for electricity generation from waste through methane utilization. This requires addressing existing legal and regulatory gaps concerning electricity generation from waste in order to stimulate investment and create direct and indirect employment opportunities.

Algeria is preparing to launch a major project valued at EUR 4.4 billion to convert waste into electricity. The project is based on strategic public-private partnerships and cooperation with major economic institutions, including the Cosider Group through one of its subsidiaries, the Madar Group, the National Investment Fund, and a leading European partner.

The objective is to establish a national system encompassing the collection, sorting, valorization, and conversion of waste into clean energy. This would require waste collection and sorting centers distributed across different regions of the country, including five major sorting and recycling centers equipped with modern technologies and operating in direct coordination with five industrial units for waste-to-energy conversion.

The proposed system would rely on Swedish and German technologies, digitally connected waste-collection vehicles, electronic systems for selective sorting and waste collection, and a decentralized administrative organization. Estimates indicate that the project could create approximately **68,000 direct jobs**.²⁰

F. Waste Incineration and Landfilling Technologies²¹

Within the framework of the aforementioned project, waste can be utilized through incineration technology. The concept of burning waste is not new, as humans have historically used combustion to generate heat for cooking and heating. Today, this approach is implemented through modern waste-incineration technologies.

Waste can first be sorted and recyclable materials separated, while the remaining waste is incinerated in specialized facilities. Properly designed and regulated waste-incineration facilities can control air emissions while simultaneously recovering energy from waste.

Sanitary landfilling is another important technology for waste management and valorization. Algeria has established numerous landfill facilities, including approximately 124 technical landfill centers and 54 technical landfill centers for inert waste. Nevertheless, insufficient attention has been devoted to waste-to-energy technologies despite the availability of significant resources and successful experimental applications conducted by institutions such as the National Institute of Agronomic Engineering in El Harrach and the New and Renewable Energy Development Center, including studies on biogas production from cattle manure.

G. The Importance of Alternative Energy Production from Waste

Under a linear economy, raw materials pass through manufacturing processes to become products, whose life cycle ends after use when they are discarded as waste. By contrast, a circular

²⁰ - The €4.4 Million Waste Valorization Project,” El Khabar, <https://www.elkhabar.com/economie/>.

²¹ - Faïza Khaddar and Naïma Amara, “Waste as a Source of Renewable Energy within the Green Economy: A Study of Algerian Legislation,” *Journal of the Professor Researcher for Legal and Political Studies* 6, no. 2 (December 2021), pp. 1991–1992.

economy introduces an additional stage into this cycle, whereby waste is transformed into raw materials once again, thereby initiating a new life cycle.

Alternative energy production from waste constitutes one of the important branches of the circular economy. It seeks to balance environmental and natural-resource protection with the requirements of a new economic system. This can be achieved through the following dimensions:²²

1. Economic Dimension

The economic dimension can be achieved through:

- reducing the amount of land used as waste dumps;
- reducing or eliminating waste-removal costs;
- generating financial revenues through the sale of energy and organic fertilizer produced from waste; and
- reducing domestic consumption of oil and gas so that greater quantities can potentially be directed toward export.

2. Environmental Dimension

The environmental dimension can be achieved through:

- reducing methane emissions from landfills, methane being one of the significant greenhouse gases; and
- protecting agricultural land and fisheries from the risks associated with waste leakage and contamination.

3. Social Dimension

The social dimension can be achieved through:

- reducing diseases associated with pollutants originating from uncontrolled dumpsites;
- creating new employment opportunities through waste-treatment and waste-valorization projects; and
- improving residential conditions by reducing unpleasant odors and the visual degradation associated with the proliferation of uncontrolled dumpsites.

Conclusion:

Algeria is among the countries seeking to consolidate environmental protection and sustainable development as part of its efforts to strengthen its future economy through energy policies based on identifying viable alternatives capable of achieving these objectives. Such policies aim to preserve Algeria's finite petroleum resources and ensure their efficient exploitation and management in support of sustainable development. Accordingly, Algeria has attached increasing importance to renewable energy as a means of promoting economic and social development.

The study concludes that the transition toward a more sustainable energy model in Algeria is no longer limited to diversifying energy sources. Rather, it increasingly requires reconsideration

²² - Ali Said and Lilia Ben Mansour, "An Econometric Study of the Impact of Alternative Electricity Production from Waste on Total Electricity Production Worldwide during the Period 1990–2018," *Journal of Financial, Accounting and Administrative Studies* 8, no. 3 (2021), p. 372.

of the nature of available resources and the ways in which they can be effectively utilized. In this context, biomass energy emerges as one of the renewable resources capable of supporting this transition.

The available potential suggests that the valorization of biomass resources should not be viewed solely as a means of producing energy, but rather as an integrated mechanism for waste management, environmental-impact reduction, economic opportunity creation, and employment generation. Nevertheless, realizing this potential remains subject to several challenges, most notably limited investment and the high costs associated with certain technologies. Consequently, the integration of biomass into Algeria's energy system requires an integrated policy vision supported by genuine political commitment.

Future Research Directions:

This study opens up several avenues for future research, the most important of which include:

1. Conducting quantitative and field-based studies to assess Algeria's actual biomass potential, particularly agricultural, municipal, animal, and forestry residues, and to determine the quantities that can be effectively converted into energy.
2. Assessing the economic and technical feasibility of biomass energy projects by examining the costs associated with the collection, transportation, and processing of organic materials and comparing them with the expected energy and economic returns.
3. Investigating the environmental impacts of waste-to-energy projects, including their potential contribution to reducing greenhouse gas emissions and decreasing reliance on conventional waste landfilling.
4. Analyzing the legal and institutional frameworks governing biomass energy and waste valorization in Algeria, with particular attention to developing investment incentives and strengthening public-private partnerships.
5. Undertaking comparative studies of successful international experiences in biomass-based energy and waste-to-energy development, with a view to identifying practices that could be adapted to Algeria's economic, environmental, and social context.
6. Developing prospective models to assess the potential contribution of biomass to Algeria's energy mix over the medium and long term, while linking this contribution to the objectives of energy transition, sustainable development, and the circular economy.

References:

1. Abdallah Hassoun Mohamed et al. "Sustainable Development: Concept, Components, and Dimensions." *Diyala Journal*, no. 67 (2015).
2. Aïcha Amiche and Siham Tarachani. "Energy Transition as a Mechanism for Sustaining Energy Security in the Arab Maghreb Countries: Prospects and Challenges." *Journal of Studies and Economic Research on Renewable Energy* 8, no. 1 (2021).
3. Aïssa Ben Lakhdar and Youssef Iftikhar. "The Reality of Renewable Energy in Algeria and Its Future Prospects: An Evaluative Study." *Journal of Contemporary Commercial and Economic Studies* 3, no. 2 (2019).

4. Ali Said and Lilia Ben Mansour. "An Econometric Study of the Impact of Alternative Electricity Production from Waste on Total Electricity Production Worldwide during the Period 1990–2018." *Journal of Financial, Accounting and Administrative Studies* 8, no. 3 (2021).
5. Antar Hassani. "Energy Transition in Algeria: The Role of Natural Gas and Renewable Energy in Algeria's Future Energy Mix." PhD diss., University of Algiers 3, 2025.
6. Abdelwahab Chemmam and Kamilia Boukra. "Biomass Energy between the Problem of Energy Security and the Challenge of Rising Food Prices." *Economic Visions Journal* 6, no. 2 (2016).
7. Faïza Khaddar and Naïma Amara. "Waste as a Source of Renewable Energy within the Green Economy: A Study of Algerian Legislation." *Journal of the Professor Researcher for Legal and Political Studies* 6, no. 2 (2021).
8. Mohamed Kadaïssa and Aïcha Kadaïssa. "The Reality of Renewable Energy in Algeria and Its Future Prospects." *Journal of Development and Applied Economics* 3, no. 2 (2019).
9. Mohamed Si Ahmed. "Towards the Imperative of Exploiting Renewable Energy in Algeria in Light of Changes in the Current Economic Situation." *Journal of Economics and Environment* 3, no. 2 (2020).
10. Mourad Cherif. "Renewable Energy and Its Role in Achieving Sustainable Economic Development." *Journal of Administrative and Economic Research* 2, no. 4 (2018).
11. Nouredine Chenoufi and Sofiane Maamire. "The Role of Renewable Energy in Achieving Sustainable Development in Algeria: Solar Energy as a Future Alternative Energy Source." *Journal of Commercial Sciences*, no. 20.
12. Safia Ould Rabah Iqlouli and Mohamed Iqlouli. "The Legal and Institutional Framework for Renewable Energy in Algeria." *Sawt Al-Qanun Journal* 8, no. 2 (2022).
13. Samir Tahine and Fatima Zahra Rais. "The Energy Transition Strategy: Prospects for 2035 as a Mechanism for Achieving Energy Security in Algeria." *Journal of Financial, Banking and Business Economics and Management* 14, no. 2 (2025).
14. Sara Jeddi and Tarek Jeddi. "The Reality and Prospects of Renewable Energy in Algeria."
15. Toufik Hosni et al. *Algeria 100% Renewable Energy: Recommendations for a National Renewable Energy Strategy*. Friedrich-Ebert-Stiftung, January 2021.
16. Abderraouf Triki. "The Status of Renewable Energy and Its Role in Achieving Sustainable Development." Master's thesis, University of Algiers 3, 2014.
17. People's Democratic Republic of Algeria. Ministry of Energy and Mines. "Statement by Mohamed Arkab, Minister of Energy and Mines." 12th Arab Energy Conference, Doha, December 2023.
18. People's Democratic Republic of Algeria. Law No. 04-09 of August 14, 2004, on the Promotion of Renewable Energies within the Framework of Sustainable Development. *Official Gazette of the People's Democratic Republic of Algeria*, no. 52, August 18, 2004.

19. "Definition of Renewable Energy." United Nations. Accessed January 23, 2026. <https://www.un.org/ar/climatechange/what-is-renewable-energy>.
20. "Principles of Sustainable Development." International Labour Organization. Accessed January 24, 2026. <https://www.ilo.org>.
21. "Sustainable Development in Algeria between the Imperative of Development and the Reality of Management." University of Chlef. Accessed January 23, 2026. <https://www.univ-chlef.dz>.
22. "The €4.4 Million Waste Valorization Project." El Khabar. <https://www.elkhabar.com/economie/>.