Sustainable Farming through Decentralized Energy Systems: opportunities and barriers

The Promise of the WEF nexus approach in Algeria's Energy Transformation

Redha Agadi[1,2], *Khadidja* Sakhraoui[1,2], *Christian* von Hirschhausen[1,2,3], and *Noara* Kebir[2]

[1] Workgroup for Infrastructure Policy (WIP), Technical University of Berlin, 10623 Berlin, Germany
[2] Microenergy Systems (MES), Technical University of Berlin, 10623 Berlin, Germany

[3] German Institute for Economic Research (DIW Berlin), 10117 Berlin, Germany

Abstract: Algeria heavily relies on fossil fuels, particularly oil and gas, leading to inadequate energy supply in rural areas. However, the country possesses vast agricultural land and abundant renewable energy resources like solar and wind. Due to the insufficient national electricity grid, rural farmers must resort to expensive and environmentally unfriendly diesel generators to meet their energy needs. To address this issue, decentralised energy systems are proposed as a solution to enhance energy resilience on Algerian farms. These systems can power irrigation pumps, lighting, and other electrical appliances on the farm. Furthermore, surplus energy generated by the PV systems can be sold back to the grid or used to offer paid energy services, creating a new revenue stream for farmers. This study evaluates the potential opportunities for implementing Decentralized and Distributed Renewable Energy Systems (DRES) on farms in Algeria. It will review current policies and regulations for microgrids in the country and present various scenarios for bottom-up energy transformation. This paper will identify the challenges and barriers Algerian farms face in energy, water, and agriculture practices. The findings will demonstrate how DRES can improve energy efficiency, reduce costs, increase the share of renewable energy, and enhance electricity supply reliability in Algeria. The study will provide practical guidance to policymakers and identify opportunities for integrating DRES on farms while suggesting future research directions in sustainable energy.

Keywords: Renewable energy; Decentralized energy systems; agriculture; energy transformation; Algeria; energy system.

1 Introduction

Access to reliable and sustainable electricity remains crucial for human development and economic growth worldwide. Despite numerous efforts to address this challenge, the International Renewable Energy Agency (IRENA) reports that 789 million people still lack access to electricity, and 2.8 billion people do not have access to clean cooking facilities (Müller et al. 2021). The problem is more prevalent in rural regions, where most of the population resides. The electricity demand is expected to increase with population growth, and it is projected that 2.3 billion people will still lack access to electricity in 2030 (Bouznit, Pablo-Romero, and Sánchez-Braza 2020). Urgent and proactive measures are necessary to achieve the planned targets under the current policy.

Algeria is among the world's leading producers of fossil fuels, with a heavy reliance on oil and gas for electricity generation, which accounted for 98.75% of the country's energy supply in 2016 (Bouznit, Pablo-Romero, and Sánchez-Braza 2020). Nonetheless, Algeria possesses enormous potential in renewable energy, and in 2011, the country launched a development program to expand the use of renewable energy, with a projected implementation of 1200 MW. The program has since been updated, with the Algerian government setting a new target to deliver 22,000 MW of renewable energy and achieve a 27% share of renewable energy in total electricity production by 2030.(Bouznit, Pablo-Romero, et Sánchez-Braza, 2020). For a country heavily reliant on fossil fuels and previously 100% electrified, adopting a sustainable electricity supply through decentralized renewable energy systems (DRES) is crucial for energy security. In response to this challenge, the local government has worked on policies and national plans and set targets to increase the share of renewable energy in the country's energy mix by 2030. Numerous researchers have also conducted studies on renewable energy planning, measures to promote renewable energy for electricity generation, energy strategy, and sustainable energy transformation in Algeria.

Despite the efforts by the Algerian government to increase the share of renewable energy in the country, the lack of access to sustainable electricity still poses a significant challenge, especially in rural and remote areas. The centralized national electricity grid is facing difficulties due to high demand, and the agriculture and industry sectors are highly affected. As a result, farmers living far from the national grid are forced to rely on diesel motors to meet their energy needs, leading to high greenhouse gas emissions and negative environmental impacts. Thus, addressing the challenge of access to sustainable electricity remains an urgent issue that requires proactive and sustainable solutions.

2 Algeria's energy landscape:

2.1 Fossil fuels in Algeria

Algeria is a country that has long relied heavily on fossil fuels as its primary source of energy. The country boasts the world's third-largest natural gas reserve and the seventh-largest oil reserves, with these resources primarily located in seven key areas. These areas include the Reggane and Tindouf basins in the southwest, the Ghedames and Illizi basins in the east, and the Timimoun, Ahmet, and Mouydir basins in the central region. Given the abundance of these resources, it is unsurprising that Algerian gas and oil contribute a significant portion of the country's electricity generation. In fact, according to recent research (Zahraoui et al. 2021), natural gas and oil account for 64.84% and 34.63% of Algeria's electricity generation, respectively.

Fig. 1. the location of gas and oil basins in algeria (zahraoui et al. 2021)

While these resources have undoubtedly been crucial to the development of Algeria's energy sector, they also present several challenges. As with many countries that rely heavily on fossil fuels, Algeria is vulnerable to fluctuations in global oil and gas prices, which can have a significant impact on the country's economy. In addition, the extraction and use of fossil fuels contribute to environmental degradation, including air and water pollution, as well as greenhouse gas emissions that contribute to climate change.(Auping et al. 2016).

Renewable energy in Algeria

Algeria, a country in the northern region of Africa, has a vast potential for renewable energy due to its favorable geographic location. This potential includes various sources of renewable energy, such as hydropower, wind, geothermal, biomass, and solar(Amine Boudghene Stambouli 2011).

Algeria's potential for solar energy is immense, with a direct irradiation rate of 169,440 kW/m2/year and a power generation capacity of 3000 kWh/year, according to the Energy ministry of algeria (Ministère de l'Énergie | Algérie). This potential is because 80% of Algeria's land contains a high average of irradiation, with an insolation duration of around 2000 to 3900 hours annually, as reported by ((Himri et al. 2009)).

Table 1 provides an overview of the average sunrise and energy received in Algeria per area, highlighting the country's vast solar energy potential. With this level of solar irradiation, Algeria is well-positioned to develop a robust solar energy industry and reduce its reliance on non-renewable sources. Moreover, Algeria's favorable geographical location and abundant sunlight create ideal conditions for developing large-scale solar energy projects. The government has recognized this potential and has launched initiatives to promote renewable energy sources, including solar energy, to meet the country's energy needs.

Table 1:Solar potential in Algeria (A Boudghene Stambouli and Koinuma 2012)

	Location		
	Coastal area	Inner area	Desert area
Surface (%)	4	10	86
Average of the sunrise (hour/year)	2650	3000	3500
Average energy received (Kwh/m2/year)	1700	1900	2650

The Algerian government has identified wind energy as a key renewable source, second only to solar energy. This decision is based on a comprehensive assessment of the potential wind resources in 21 different zones across the country, which are divided into various regions. The southwestern region of Algeria is particularly promising, as wind speeds at several sites there are estimated to exceed those of the northern region. According to (Laidi et al. 2012) the site of Bechar in southwestern Algeria has wind

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speeds exceeding 4m/s, while the site of Tindouf has speeds of around 5m/s. The site of Adrar in this region has particularly high wind speeds, exceeding 6m/s. Such promising wind resources in the southwestern region make Algeria an ideal location for developing wind energy projects.

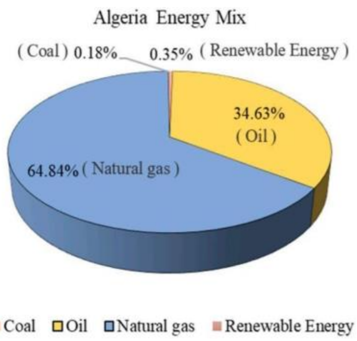

Figure 2:Algeria fossil fuel generation mix in 2019 (Zahraoui et al. 2021)

2.2 Algeria's Agriculture Landscape

2.2.1 Agricultural Production Capacity

In Algeria, the government has identified the agricultural sector as a critical priority for economic diversification, contributing to 14.23% of the country's GDP in 2020 (O'Neill 2021). The Ministry of Agriculture has implemented programs that provide land grants to private investors to promote agricultural development and production. These partnerships may involve public and private Algerian investors, solely Algerian private investors, or foreign investors with Algerian partners.

Cereal products hold a strategic position in Algeria's food system and national economy. From 2000 to 2017, cereals occupied an average of 40% of the Useful Agricultural Area (UAA), according to the Ministry of Agriculture's website a . During this period, the average cereal production was 41.2 million quintals, a 26% increase from the preceding decade's 32.6 million quintals. Durum wheat and barley were the primary cereal products, accounting

for 51% and 29% of production, respectively.

Industrial crops, namely tomatoes and tobacco, were cultivated on an average of 19,830 hectares per year during the two periods. The average tobacco area was 4,850 hectares. Industrial tomato production increased substantially by 136% from 2000-2009 to 2010-2017, primarily due to improved yields. Market gardening production also saw significant growth, recording an average increase of 121% from 2010-2017 compared to 2000-2009. Potatoes and onions, which make up over 36% and over 12% of market gardening production, respectively, experienced increases of +143% and +102%.

The production of arboricultural sectors has increased from 2010-2017 compared to the previous decade (2000-2009), representing Stone and pome fruits with 102%, Olives 99%, Citrus fruits 91%, Dates 82%. The production of the vine has also experienced a clear improvement with evolution of + 75% between the periods 2010-2017 and 2000-2009 .(MADR 2018).

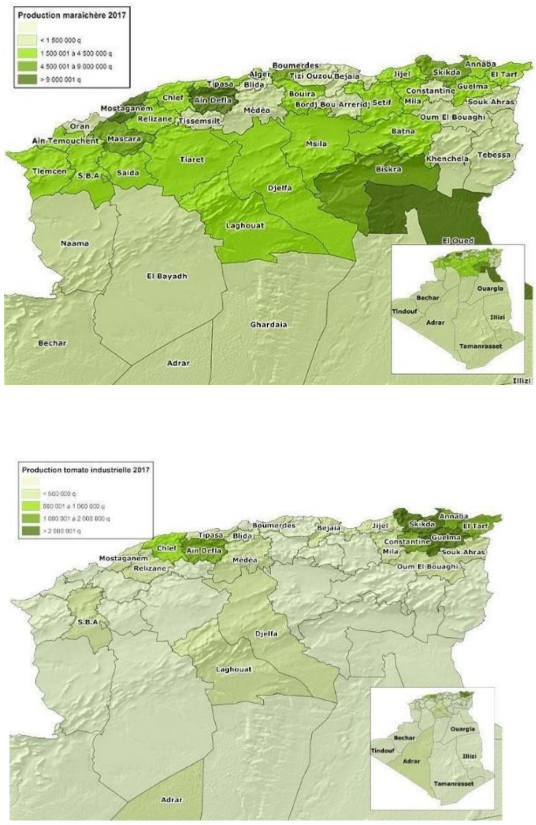

Figure 3:the average market gardening production {algeria's agriculture ministry}

2.3 Agricultural policy:

2.3.1 National Agricultural Development Program (PNDA 2000-2010):

The Algerian government has committed a substantial sum of €600 million to the National Program for Agricultural Development (PNDA) as part of its 2001-

a http://madrp.gov.dz/agriculture/statistiques-agricoles/, accessed in September 2021.

2004 economic recovery support plan focusing on revitalizing the agricultural sector. The program's primary goal was to ensure the country's food security and promote income and employment opportunities in rural areas while managing fragile natural resources. To achieve these objectives, the program aimed to improve agricultural production by expanding production capabilities, increasing the availability of agricultural inputs and reproductive materials, preserving and protecting the environment, and promoting economic and functional reforestation in mountainous regions. The ultimate target of the program was to achieve an annual growth rate of 10%, a significant improvement from the previous decade's rate of 4% (Bessaoud et al. 2019).

2.3.2 The Agricultural and Rural Renewal Policy (PRAR 2010-2014)

The agricultural and rural renewal policy's strategic objectives center on reinforcing the nation's food security. This necessitates exploring, in the medium term, substantial transformations that could have structural implications for the nation's food security framework. The program consists of three pillars: Agricultural Renewal, Rural Renewal, and Strengthening of Human Capacities and Technical Support to producers (PRCHAT) (MADR 2012).The first pillar, Agricultural Renewal, aims to improve agricultural productivity and promote sustainable farming practices. The second pillar, Rural Renewal, focuses on enhancing the living standards of rural communities by providing basic infrastructure, such as roads, water supply, and sanitation facilities. The third pillar, PRCHAT, aims to support and enhance the technical skills of farmers, providing them with the necessary training and capacity building to manage their production systems more efficiently.

2.3.3 FILAHA Plan (2014-2020)

The Minister of Agriculture, Rural Development, and Fisheries, by Sid Ahmed Ferroukhi, presented the Agricultural Action Plan to reduce agricultural imports by $2 billion by 2019. The plan is based on the successful outcomes of the 2015-2016 agricultural season, with the wilaya of El-Oued exporting around 4,800 tons of potatoes to eight countries. This season's abundant harvest has generated significant interest in Algerian potatoes from four Arab countries, namely the United Arab Emirates, Saudi Arabia, Qatar, and Tunisia, as well as four European countries, including Russia, Italy, France, and Spain.

The FILAHA plan is divided into four main sectors: agriculture and livestock, forests and watersheds, fisheries, and aquaculture. The Ministry of Agriculture's new guidelines aim to achieve an average agricultural growth rate of 5% by 2019, with an irrigated agricultural area of 2 million hectares and a production value of DA 4,300 billion, including DA 110 billion for fishing. With an expected afforestation rate of 13%, the plan aims to reduce imports by more than $2 billion by promoting domestic production, exporting products worth $1.1 billion, and creating approximately 1.5 million permanent jobs, including 80,000 in the field of fishing and aquaculture (Hamza 2016).

2.2.4 A five-year roadmap (2020-2024) for the development of the agriculture sector

The Ministry of Agriculture and Rural Development has developed a sectoral program that outlines a roadmap for implementing various actions to improve the current and future situation of agriculture and rural development. The program incorporates relevant data to assess current affairs and identify opportunities for qualitative and/or quantitative progress that can be achieved in the short term or even immediately for specific actions.The main objective of this strategy is to enhance agricultural production through the extension of irrigated areas, promote agriculture production and rural development in mountainous regions, and integrate knowledge and digitization into agriculture development programs (Ferrah 2021).

This comprehensive approach will help to modernize the agriculture sector, increase productivity and efficiency, and foster sustainable development in rural areas. By leveraging digital technologies, the sector can overcome critical challenges such as climate change, water scarcity, and land degradation. The program represents a significant step towards achieving the goals of national food security, economic growth, and job creation in Algeria.

2.4 Centralized Renewable Energy Systems (DES):

Centralized energy systems are typically characterized as energy generation facilities on a large scale, which distribute energy through an extensive network, often over considerable distances from the end-users (Vezzoli et al. 2018)

2.5 Decentralized and distributed Renewable Energy Systems (DES)

Decentralized energy systems refer to the generation and distribution of energy at or near the point of consumption. These systems are typically smaller in scale and often employ renewable energy sources such as solar, wind, hydro, and biomass. Decentralized energy systems can operate independently of the centralized energy grid or be connected through a "smart grid" that allows for two-way energy flow and more efficient energy use (Vezzoli et al. 2018).

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Decentralized energy systems offer several benefits, including improved energy security, increased access to energy in remote areas, reduced transmission losses, and lower greenhouse gas emissions. They also have the potential to support local economic development by creating jobs and reducing dependence on imported energy.Examples of decentralized energy systems include rooftop solar panels, small wind turbines, micro-hydro systems, and biogas digesters. These systems can be deployed in various settings, from individual homes to entire communities, and can be used for electricity, heating, and cooling.

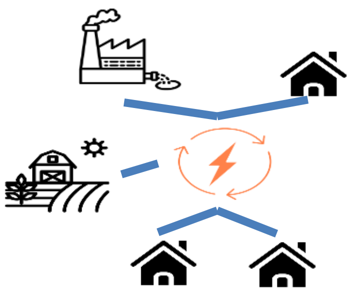

Figure 4:Centralised energy system. Source designed by the Authors.

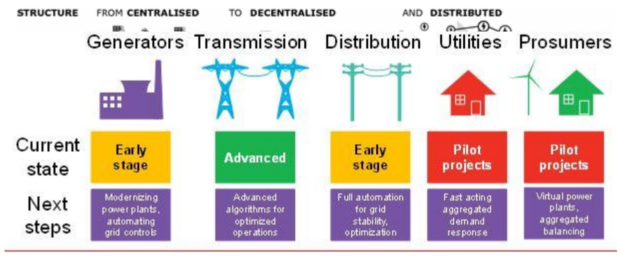

Figure 5: From centralised resources to decentralized and distributed (Vezzoli et al. 2018)

2.6 The Interconnectedness of Decentralized Energy systems and Water-Energy-Food Security

The close relationships and interdependencies between the water, energy, and food sectors are widely acknowledged. Energy is essential for various agricultural activities such as irrigation, mechanized agriculture, and post-harvest processing and transportation.(Guta et al. 2017). Food production at all levels is also found to have significant water and energy footprints (Ringler, Bhaduri, and Lawford 2013).

Decentralized energy systems (DES) can help address clean water availability problems in developing countries. However, challenges like limited local capacity, lack of spare parts, and high upfront costs hinder the use of modern DES.(Guta et al. 2017).

2.7 The Interconnectedness of Decentralized Energy systems and Digitalization

Digitalization are essential to the transition towards a more sustainable energy system. Digitalization refers to converting information into a digital format, allowing for easier storage, processing, and analysis of data. In renewable energy sources (RES),(Kangas et al. 2021) digitalization refers to using innovative technologies and solutions to manage and control electricity production. For example, smart grids can help integrate and optimize the output of different renewable energy sources. In contrast, energy storage technologies can help balance the intermittency of sources like wind and solar.(El Bassam 2021)

However, According to Bloomberg NEF[b] RES companies face several challenges in the digitalization process. One challenge is predicting the development of information and communication technologies (ICT) and identifying opportunities for innovation and collaboration with ICT companies. The pace of technological change can be rapid, and it can be difficult to keep up with the latest developments and determine which solutions will be most effective in the long term. Another challenge is ensuring that digitalization efforts are aligned with broader sustainability goals. While digitalization can help improve the efficiency and reliability of renewable energy systems, it can also lead to increased energy consumption and greenhouse gas emissions if not managed carefully. Therefore, RES companies need to consider the environmental impact of their digitalization efforts and strive to minimize any negative effects[c]

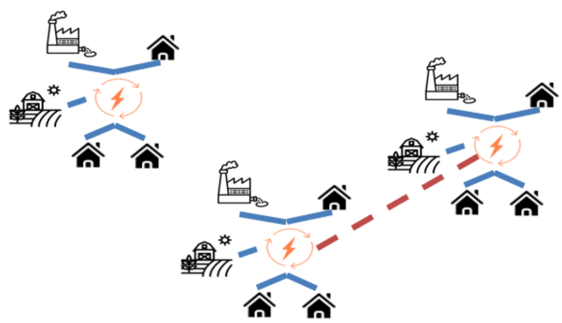

Figure 6: Digitalization of energy systems (« digitalization of energy systems » 2017)

2.8 Application and Potentials of DRES In agriculture

Innovative technology and the Internet of Things are leading the agricultural revolution in recent years. The technology that dwells on computer intelligence enables the use of Wireless Sensor Network to create a series of connections between different devices for communication and real-time data-based monitoring(Khoa et al. 2019) . In modern agriculture, innovative technology is applicable in fire detection, water quality and quantity control, asset management, farmer education, and farm insurance, among others(Blasch et al. 2020).

b https://about.bnef.com/blog/digitalization-energy-systems/, acessed in September 2021.

c IEA (2017), Digitalisation and Energy, IEA, Paris https://www.iea.org/reports/digitalisation-and-energy, License: CC BY 4.0.

The most common form of intelligent technology application in Agriculture is the monitoring of plant conditions and water quality on farms(Vecchio et al. 2020). The successful application rests on collecting and keeping accurate data, which the Wireless Sensor Network then uses to perform its task. Recent literature suggests that upon establishing and maintaining a high- quality database on a farm, moisture and nutrient content can be monitored, and best practices to improve crop not only yield but also the quality of the final product can be simulated (Vecchio et al. 2020). Again, using drones, the scope of the technology can further be applied to monitor sensors for irrigation, insect and pest detection, crop status, fertilization, and soil preparations, among others. Thus, the extent to which intelligent digital technology and the Internet of Things can be applied in agriculture is inexhaustible.

In the MENA region, the literature suggests that the most common challenges associated with agricultural production include a limited prevalence of modern technologies for irrigation and drying, low quality of data management for predictive plans, over-dependence on less climate- friendly energy sources, limited scale of production due to low technological intensity, limited collaboration between diverse stakeholders in the agricultural value chain, limited access to extension and support services and consequently limited capacities in defining and implementing best agricultural practices among a large proportion of farmers (Ben Abdelmalek and Nouiri 2020; Colin et al. 2021). This implies that even though diverse, innovative technologies can be applied to agriculture, technologies for the MENA region must seek to provide sustainable solutions to the challenges.

Recent sensitivity to climate change led to the emergence of climate-smart agriculture- a paradigm that thrives mainly on applying innovative technology (including digitalization). the Internet of Things (Chavula 2014; Khoa et al. 2019). This is well reflected in the agricultural, energy, and ICT infrastructure policies of the various countries in the MENA region (see the section on review of these policies). However, studies that seek to explore the application of these novel technologies suggest that the willingness to adopt and implement apt responses to advance such targets is primarily defined by both behavioral and systemic factors(Castle, Lubben, and Luck 2016 .). Therefore, the preceding suggests that even though these technologies are irrefutably paramount to enhancing production and productivity, their application cannot be successful without enhancing the capacities of the end-users of the technologies.The project’s adoption of digitalized smart grid in the region's agricultural sector will target the use of digitalized renewable energy (specifically solar PV technology) to refine agricultural practices among beneficiary farms in the region. The technology will therefore basically be applied in the irrigation of crops, monitoring rates of pest and diseases infestations, providing options for drying and storage of farm produce, predicting weather patterns and their likely effects on crops so that proactive measures can be taken to reduce the anticipated losses, and enhancing access to information among farmers. Aside from the hardcore infrastructure, the reliance on digital technology will further enhance the education of farmers by providing them with time-sensitive information on their activities through an interactive manner and increasing the management of data concerning farms for further planning and development activities.

2.9 Conceptual Framework for the Study

The application of decentralized energy systems to transform the agricultural sector of Algeria requires a comprehensive understanding of the country's agricultural landscape. Preliminary evidence from the literature suggests that Algeria's production base is diversified, ranging from short-production span crops like vegetables to longer-maturation span crops like dates and grapes. Despite variations in crop types, the value chain is composed of similar actors, from production to trade and consumption. The production stage is crucial, with indications that production levels are influenced by input stage variables such as technology availability and pest and disease management awareness. The availability of relevant utilities, especially water, is essential to boosting production capacity and quality. However, water scarcity in the region makes water conservation a priority for the government. Additionally, increasing environmental awareness and the need to reach COP21 Paris agreement targets imply a shift towards cleaner and renewable energy systems in agriculture. The optimization of technology use will have significant effects on achieving energy, water, and agricultural needs. The existing political structure and systems play a significant role in defining agricultural practices. Policies specify targets, investment directions, and provisions for essential inputs such as water and energy. Thus, the extent to which renewable energy technology, such as microgrids, can be utilized in Algerian agriculture will largely depend on availability and appropriateness. The literature reviewed suggests that the country has made significant strides in policy and its revision towards achieving sustainability objectives. Available policies significantly shape local attitudes and practices and define cross-sectoral collaborations that can drive sector-specific objectives. Several theories, including the Theory of Diffusion of Innovations(Dearing and Cox 2018), suggest the relevance of people's behavior in defining the extent to which they will adopt emerging technology in their activities. The surrounding environment's climate significantly informs such behavior. Attaining these targets will eventually lead to achieving sustainability targets in the country.

3 Methodology

Previously, we thoroughly reviewed the relevant literature to identify essential variables pertinent to the current research. This review focused on theoretical perspectives behind the Water Energy and Food Nexus approach, Algeria's Energy and agriculture Landscape, Algeria's agriculture strategies and policies, decentral renewable energy systems energy transformation, and their applications to the field. The literature review provided valuable insights into the potential contribution of Decentralized Renewable Energy Systems to the agriculture sector in Algeria. The necessary data has been identified, and it will be collected and examined to answer the research question effectively.

Next, we will describe and discuss the study setting. The setting will provide a contextual background for the study, including the location, climate, and other relevant factors that could impact the research findings. We utilized a qualitative data collection and analysis approach, drawing on its strengths to explore diverse visions and perspectives despite differing philosophical worldviews. The methodology employs a rigorous process of data collection, integration, analysis, and discussion while combining the strength of each technique to understand connections and contradictions, minimize weaknesses, and overcome challenges. The strategy includes reviewing documents related to the energy, agriculture, sectors in Algeria and policies and regulatory frameworks in these areas. Additionally, Algeria's 2030 agenda and conducting interviews with farmers, company representatives, energy experts, policymakers, regulators, and representatives from local companies (Research study population, (Otzen and Manterola 2017)).

To obtain information about the Algerian government's strategy to increase the use of RE, mitigate greenhouse gas emissions and adapt to climate change impacts in different sectors, we reviewed key documents such as the Intended Nationally Determined Contribution (INDC) - Algeria in 2015, which outlines the planning and institutional framework for implementation under the climate change committee between 2016 and 2020. The National Program to Develop Renewable Energies and Energy Efficiency in 2011 and the Algerian Roadmap 2024 will also be reviewed to understand Algeria's plan to expand the usage of renewable energies and diversify the energy sector. Excel and various tools will be used in a qualitative method to analyze collected data documents, interviews, questionnaires, and video recording. Both primary and secondary data sources were used in the study, as stated in (Rabianski 2003). Most of the data were collected through interviews with all the sources mentioned earlier.

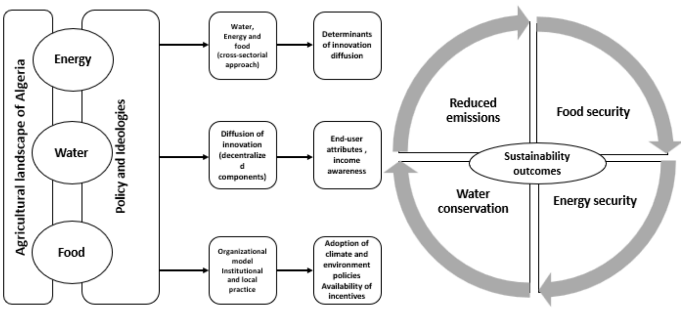

Figure 7: Conceptual model of the Algerian sustainability targets (authors design

3.1 Study Settings

3.1.1 Case study 1: Biskra

The wilaya of Biskra, situated at 4°15' and 6°45' E and 35°15' and 33°30' N and at an altitude ranging from 29 to 1600 meters, is in the central-eastern region of Algeria, serving as a gateway to the Algerian Sahara. Spanning across an area of approximately 21671 km², it is positioned about 450 km southeast of the capital city. Biskra acts as a vital buffer zone between the North and South of the country and shares its borders with the wilayas of Batna and M'sila to the North, Ouargla and El-Oued to the South, Khenchela to the East, and Djelfa to the West. The Biskra region has four diverse geomorphological elements: mountains, plains, plateaus, and depressions. Various wadis and temporary main-flow rivers crisscross the area and flow into the Chott Melghir depression. The most important is the Oued El Arab, in the east, whichtakes its source southwest of Khenchela, and the Djedai wadi receives run off of the South Wing of the Saharan Atlas traverses the South of the region from West to East (Diab 2015).

3.1.2 Case study 2: Eloued

The wilaya of El Oued Souf is in the southeast of Constantine. It is bordered to the north by the wilayas of Biskra, Khenchela, and Tébessa, to the east by the Tunisian border, to the west by the Wilaya of Djelfa, and to the south by the wilaya of Ouargla. The wilaya covers an area of 54,573 km² with a total population of 504,401 inhabitants, resulting in a population density of 9.7 inhabitants per km².(Kholladi 2005).

The relief of the region consists of three main areas. The first is a sandy region that covers the entire Souf region and the eastern and southern parts of Oued-Righ. This region is part of the significant eastern erg and has little agricultural potential. The second area is a rocky plateau that runs along national road 3 to the west of the wilaya and extends southwards. The third area is a depression known as the chotts area, located north of the wilaya, and extending to the east. Due to its high salinity, this region is unsuitable for agriculture.

The climate of the wilaya is of the Saharan and desert type, with hot summers and mild winters. Summer temperatures can reach up to 54°C in the Souf, while winter temperatures can drop to as low as 1°C in El Meghaïr. Precipitation is very low, with an average of only 80 mm/year.(Kholladi 2005; Castany 1982).

The main natural constraints in the region are related to its climatic conditions. The most critical factors are low rainfall, frequent violent winds, and high summer temperatures. The primary sources of water in the region are shallow phreatic water, which extends almost everywhere in the territory of El Oued Souf and is supplied mainly by rainwater infiltration. The second water source is the continental or terminal complex, composed of a sheet of sand covering practically all of north of the Algerian Sahara. The third and most important source is the continental intercalative, which consists of permeable sandstone predominance(Kholladi 2005; Castany 1982).

In conclusion, the wilaya of El Oued Souf is a region with unique relief and climatic conditions, which present various natural constraints. Nevertheless, the wilaya has essential sources of water that provide the necessary resources for the region's socio-economic development.

3.1.3 Case Study 3: Tipaza

The wilaya of Tipaza is geographically bounded by the Mediterranean Sea, stretching along a coastline of nearly 123 kilometers. It shares its borders with the Wilaya of Algiers to the east, the Wilaya of Blida to the southeast, the Wilaya of Aïn Defla to the south, and the Wilaya of Chlef to the west. Covering a land area of 1,707 square kilometers, the wilaya of Tipaza encompasses diverse terrains, including mountains (336 km2), hills and foothills (577 km2), plains (611 km2), and other areas (183 km2)[d].

On the northeastern side, the region known as Mitidja primarily extends over the wilaya of Blida, with the Sahel mountains (with an average elevation of 230 meters) acting as the boundary with the wilaya of Tipaza. Notably, the wilaya boasts a significant hydraulic network comprising the Mazafran, El Hachem, Djer, and Damous wadis, contributing to the region's water resources. Agricultural practices in the wilaya of Tipaza are diverse and depend on the soil characteristics. The predominant crops cultivated in the region include cereals, occupying an area of 19,866 hectares (30.7%). Market gardening covers 14,623 hectares (22.6%), while dried legumes account for 398 hectares (0.7%). Tree cultivation encompasses 8,823 hectares (13.7%), followed by vineyards with 4,133 hectares (6.4%). Fodder production spans 6,103 hectares (9.5%), and industrial crops cover 455 hectares (0.7%).

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3.1.5 Case Study 5: Tlemcen

The wilaya of Tlemcen, in the western region of Algeria, on the northwest coast of the country bordering Morocco. Agriculture represents an important sector in the economy of the wilaya, with a total area of agricultural land of 538 581ha, including a UAA of 351 579ha with 22 450ha of irrigated land. These lands are enhanced by various agricultural products such as cereals (durum and soft wheat, barley, oats), fruit growing, market gardening, dry vegetables, artificial fodder, and olive trees. In particular, in the arboriculture sector, olive trees remain the predominant trees, which extend over more than 43 000 ha, or almost 91% of the total area reserved for fruit farming with an average production of over 100 000 tons in a normal year.

The wilaya of Tlemcen covers a forest area of around 225 000 ha, which corresponds to an afforestation rate of 24%, made up of forest, maquis, and brushwood, adding to this an alfa layer with an area of 154 000ha.

4 Results:

4.1 Status of agriculture in Algeria (case of study Biskra and Eloued)

4.1.1 Overview of farmer characteristics (Socio-Demographic)

To provide adequate responses regarding the farming process under study, the socio-demographic characteristics of farmers, such as gender, age, occupation, and education level, are crucial for data field analysis. In the study, all 30 farmers interviewed were male and considered the farms and agriculture business owners. However, women's participation in the study area could have been more engaging, and more focus could have been placed on engaging them in farming activities. The respondents confirmed this information in the field.

Biskra and El Oued, like other wilayas in Algeria, have an excellent potential for engaging the youth population in agriculture and farming. Therefore, most of the respondents were between 25-45, and this youthful potential is a crucial driver to achieving the Algerian roadmap in raising agriculture incomes and helping young people create agriculture businesses. The interview results revealed that about 80% (N=24) of the respondents had a primary education level. Thus, a low level of education can impact efficient energy use. Farming is the primary activity that can significantly increase the employment rate, create jobs, and improve the area's standard of living, well-being, and health.

4.1.2 Institutional policies, regulations, and strategies

Lower levels of government directly or indirectly influence agriculture in Algeria. The country is divided into wilayas, dairas, and municipalities, with each region having its authority, starting from the wali in wilayas, the chief or responsible for dairas, and the mayor in the municipalities.

Farms can be registered with the Chamber of Agriculture in their respective Wilaya. Although registration is not mandatory, most farmers register to receive a card that grants them access to subsidies and chemical fertilizers, except for those who think they can afford the expenses and do not need government support.

[d] Ministry of Interior and Local Government. (2023). Wilaya of Tipaza. Retrieved from http://wilaya-tipaza.dz/.

[e] Ministry of Interior and Local Government. (2023). Wilaya of Tipaza. Retrieved from http://wilaya-tipaza.dz/.

As part of its effort to limit imports, increase self-sufficiency, and ensure food security, the Algerian government seeks to develop the agricultural economic sector by improving production practices and productivity. The government has deployed a financial support program to help farmers by providing subsidies, such as a 25% discount on fertilizers, 20-30% on machinery, and 20-30% discounts on irrigation systems. In addition, the government has created a financial program for growing and storing potatoes called "Le Système de régulation des produits agricoles de large consommation (SYRPALAC)," or the Regulatory System for Agricultural Products of Large Consumption. This program aims to ensure a sufficient supply of potatoes during periods of scarcity and shortage as part of the overall objective of the food security plan.

To benefit from the funding program, farmers must declare the quantity and location of stored potatoes to the National Interprofessional Office of Vegetables and Meat (ONILEV) and are only allowed to sell them with authorization from the organization. Furthermore, the government financially supports seed production to encourage farmers and help them with an organized program from the National Center for Seed Control and Certification (CNCC) to ensure planting and seed quality. Therefore, farmers must declare their farming activity to the Ministry of Agriculture before starting, and the CNCC checks the sanitary and plotting location.

4.1.3 Water and energy use in farms

In El Oued, where the desert climate and sandy soil drain exceptionally well, potato fields are irrigated daily for 6-8 hours in the 1st season (Jan to April) and 16-18 hours in the 2nd season. Farmers start the irrigation system in the early evening to avoid high temperatures, from 6 pm to 11 am. They use a centre pivot irrigation system, consisting of circular plots ranging from 0.5 to 1.3 ha, with a diesel motor with long metal arms and nozzles. This system circulates water in high pressure and mists it out. On the other hand, tomato greenhouses are irrigated using drip irrigation, which is considered the most efficient water and nutrient delivery system for growing tomatoes. This system delivers water and nutrients to the plant's root zone directly in the right amount and at the right time, allowing for optimal growth while saving water, fertilizers, energy, and crop protection products. It takes three to four hours to irrigate one greenhouse using this method, and farmers deliver water and nutrients to the field through pipes called "drip system lines," containing smaller units called "drip systems." Each drip system emits drops containing water and fertilizer, ensuring uniform application throughout the field.

Several farmers have experience with drip irrigation, but it has proven unprofitable due to the increased labour required. On the other hand, Pivot irrigation is easy to establish and use, but it requires maintenance to prevent leaks. Electricity expenses are high between 5 and 9 PM, so farmers tend to water their crops constantly before and after that period. The crop requires a large quantity of water and will quickly wilt if there are delays or less watering time. That is why farmers prefer to irrigate their crops at night and at the more excellent times of the day.

Wells and water tanks are the primary sources of water for farmers. However, the cost of establishing a well depends on the area, with variations in Biskra and Eloued. Aquifers or groundwater also have different levels, starting from a depth of 10-50 meters in Eloued, 50-70 meters in Biskra, and ranging from 180-250 meters, 300-400 meters, and up to 1000 meters in depth. Only the government can reach the most profound levels due to the high costs involved (12000 dz per meter

Figure 8: farming in open circular or pivot systems and greenhouses

WEF	Challenges and barriers
Energy	The use of diesel motors in different farming process; planting, fertilization devices, irrigation systems and harvesting, Pumping water from welts. Leak in Diesel motors and require a significant amount of maintenance. Instability of centralized agriculture electricity grid in farms, insufficient supply. High consumption of diesel during the 1st days of growing crops Leakages of irrigation systems which cost more energy consumption. High cost of energy supply to meet the agriculture needs Dependency on diesel for all farming process. Lack of energy supply for other unnecessary activities (lighting, ventilations). Lack of cooling chambers or storage chambers. Transportation of fuel (diesel) costs and road challenges (Saharan roads).
Water	Leaking in irrigation systems causing high water wastes and shortage. Low use of water tanks Labour dependency in irrigation time Carelessness from farmers about the leakages and high water consumption because the water is for free. Diesel water pumps. High humidity resulted by high water consumption. High costs of welt digging High costs of renting or borrowing irrigation systems
Food	Over production Products and crop wastes : Lack of storage chambers Lack of cooling chambers Lack of ventilations Low commercialisations programs and markets.

5 Discussions:

5.1 Potential of DRES in addressing agriculture challenges within the WEF nexus approch

5.1.1 Energy

Access to clean, sustainable, and modern energy is critical to the agricultural sector's growth and development. It enables farmers and agricultural businesses to increase production and productivity, leading to higher income and improved living standards. It also helps reduce energy costs for those living far from the national electric grid and in rural areas. The use of diesel generators is expensive and harmful to the environment, and the switch to renewable energy systems can bring about a more sustainable solution(Abraham and Pingali 2020).

DRES (Decentrlized Renewable Energy System) has introduced renewable energy systems based on solar energy to the agricultural sector. The integration of renewable energy systems has proven successful in removing all the challenges related to energy supply in many case studies in North Africa(Ben Jebli and Ben Youssef 2017). These systems provide a reliable and sustainable energy source to power the agriculture sector's needs without the drawbacks of traditional fossil fuels.

However, the integration and deployment of renewable energy systems are challenging. The lack of policy and finance programs has prevented many countries from adopting RE systems. Governments must support implementing these systems by creating favourable policies, providing financial incentives, and promoting awareness campaigns(Sen and Ganguly 2017).

In Algeria, most farmers have shown great interest and willingness to deploy renewable energy systems to reduce costs and improve productivity. However, a significant need for more awareness about the profitability of integrating RE is a major obstacle. Education and awareness campaigns are essential to overcome this challenge and encourage more farmers to adopt renewable energy systems.

The Algerian government has increased its share of renewable energy and reduced its dependency on fossil fuels. By 2030, the government aims to achieve a 27% RE share in total electricity production, which is a significant step towards a more sustainable future.(Bouznit, Pablo-Romero, and Sánchez-Braza 2020) Implementing renewable energy systems in the agricultural sector will play a critical role in achieving this goal and promoting sustainable economic growth.

5.1.2 Water

Water scarcity is a significant issue in MENA countries, which have limited access to freshwater resources due to climatic, geographical, and demographic factors(Tzanakakis, Paranychianakis, and Angelakis 2020). Hot and arid climates, low and irregular rainfall, and high evaporation rates characterise the region. This has resulted in a severe water shortage compounded by rapid population growth and increasing urbanization, industrialization, and agricultural production(Golla 2021).

To address this pressing problem, algeria has prioritised conserving clean water and groundwater resources and ensuring that all citizens have access to drinkable water(Läderach et al. 2022). However, given the challenges posed by climate change, innovative solutions are needed to tackle this issue effectively.

In particular, farmers in the region are seeking solutions to reduce their labour dependency in irrigation periods and address the inherent leakages in traditional irrigation systems. This is where DRES comes in, with their new concepts for irrigation systems that can manage watering systems and reduce water waste while providing high performance to the irrigation process . By delivering the exact amount of water required for crop growth, this solution can ensure that water is not wasted and is used as efficiently as possible(Miran et al. 2022).

In addition, DRES' solution can quickly respond to any leakage, which can have a significant impact on reducing energy costs and energy bills. This is particularly important in North African countries where energy resources are scarce and expensive, making it critical to find ways to use resources as efficiently as possible.

In conclusion, addressing the water scarcity issue in North African countries requires innovative and sustainable solutions to optimize water usage and reduce waste. DRES' new concepts for irrigation systems offer a promising solution that can help farmers reduce their labour dependency and conserve water resources while ensuring that crops receive the exact amount of water they need to grow.

5.1.3 Food

In many rural areas and farms, access to reliable and affordable energy can be a challenge, negatively impacting food security. An adequate energy supply can make storing and transporting food more accessible, resulting in food loss and waste. Furthermore, it can be challenging to operate irrigation systems, farm equipment, and other essential infrastructure without reliable access to energy(Puri 2016).

Decentralized energy systems can help address these challenges by providing a local source of energy that is more reliable and affordable than grid electricity. For example, solar panels can be installed in rural areas to provide electricity for refrigeration, storage, and transportation systems for food(Sadi and Arabkoohsar 2020). This can help reduce food loss and waste, improve food quality, and increase access to food for otherwise isolated or underserved communities.

In addition, decentralized energy systems can also support the development of local food systems by enabling farmers and food producers to process and store their products more effectively. For example, farmers can use renewable energy to power cooling and processing equipment to extend the shelf life of their produce(Rahman et al. 2022), making it easier to transport to local markets or sell to consumers.

By contributing to food security, decentralized energy systems can positively impact rural communities' economic and social well-being. In addition to improving access to food, these systems can create new economic opportunities and help build more sustainable and resilient food systems that are better equipped to withstand disruptions or emergencies(Guta et al. 2017).

6 Conclusion

The objective of this research was to identify the potential contribution of decentralized renewable energy systems in the agriculture sector in Algeria, as well as to understand the best agriculture activities and government strategies. The key findings indicate that farms accept renewable energies and IoT facilities as well. There are considerable opportunities to deploy DRES, which can help solve all farm challenges, including energy use, water use, and ICTs. However, the lack of renewable finances, research, and innovation, RE strategies, and fossil fuel subsidies remain enormous concerns for farmers willing to develop the agriculture sector and expand their business by replacing diesel generators with solar panels.

The study findings and analysis confirm the starting hypothesis of integrating DRES in agriculture. It unveils the potential contribution of DRES to removing many challenges that block the road towards energy transformation in Algeria. It shows how the farming process can be more energy-efficient, affordable, less energy waste, less water waste, and innovative using the latest technologies.

The relevant lessons learned from case studies in smart agriculture determine the contribution of decentralized systems in a new approach, the Water-Energy-Food Nexus, to support food security and sustainable agriculture. In conclusion, this research highlights the importance of DRES integration in the agriculture sector and the need for more investment in renewable energy, research, and innovation, and RE strategies to support farmers in their quest for sustainable agriculture and energy efficiency.

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