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Redha AGADI

Deployment of Decentralized and Digitized Renewable Energy Systems to promote the energy transformation in the Maghreb Countries Case Study of Algeria.

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PAN-AFRICAN UNIVERSITY

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DEPLOYMENT OF DECENTRALIZED AND DIGITIZED RENEWABLE ENERGY SYSTEMS TO PROMOTE THE ENERGY TRANSFORMATION IN THE MAGHREB COUNTRIES CASE STUDY OF ALGERIA

A thesis submitted to the Pan African University Institute of Water and Energy Sciences

(Including Climate Change) in partial fulfilment of the requirements for the degree of

Master of Science in Energy (Policy option).

By

Redha AGADI (Electrical engineering)

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Tlemcen, Algeria

December 21, 2021

DEDICATION

This work is completely dedicated to my beautiful family and to my institution mentors.

STATEMENT OF THE AUTHOR

I, Redha AGADI hereby declare that this thesis represents my original work and has not been submitted to another institution for the award of a degree, diploma, or certificate. I also declare that all words and ideas from other works presented in this thesis have been duly cited and referenced in accordance with the academic rules and regulations.

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BIOGRAPHICAL SKETCH

Redha Agadi obtained an Electrical engineering from the Superior School of Applied Sciences in Tlemcen, Algeria. He conducted an experimental study and design of a smart energy meter in Algeria with appropriate simulation tools. Redha developed a strong interest in issues surrounding energy policies and climate change. He is due to graduate from the Pan African University Institute of Water and Energy Sciences (PAUWES) in Tlemcen, Algeria, with a Master of Sciences in Energy Science (Renewable Energy Policy option). His Master of Sciences' research is focusing on deploying digitised decentralised renewable energy systems to promote energy transition in Algeria.

Regarding his professional experience, he worked as a Research assistant at Micro energy international firm in Berlin, to carry out design, research, and planning projects on Renewable energy and Microgrids in farms. His primary duties were to support the company with data collection and literature review on energy, water, agriculture, and ICTs strategies in the Maghreb countries (Algeria, Morocco, and Tunisia).

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Acronyms and abbreviations

DDRES	Digitize decentralized Renewable energy systems
SKTM	Sharikat Kahrabaa Wa Taqua'at Motajadida
SONALGAZ	National Society for Electricity and Gas
SONATRACH	National Society for Research, Production, Transport, Transform, and Commercialisation of Hydrocarbon
SYRPALAC	The Regulatory System for Agricultural Products of Large Consumption
ONILEV	National Interprofessional Office of Vegetables and Meat
CNCC	National Center for Seed Control and CNCC Certification
RE	Renewable energy
RES	Renewable Energy Sources
EE	Energy efficiency
ICT	Information and communications technology
IT	information technology
IOT	internet of things
MADR	Ministry of Agriculture, Rural Development (Algeria
MENA	Middle East and north Africa
GDP	Gross domestic products
ALGEX	Agence Nationale de Promotion du Commerce Extérieur
WEF	Water Energy food
CDER	Renewable Energy Development Centre
CREG	Electricity and Gas Regulation Commission

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Abstract

Algeria is a leader in producing fossil fuels, and its energy supply still relies on oil and gas, while the country has great potential for solar energy. The demand for energy supply increases, and the national electricity grid is having difficulties supplying farms and communities far from it. Farmers are using diesel generators as an alternatives solution to supply their energy needs. This study will examine the potential contribution of DDRES development of a sustainable, intelligent energy system in farms (i.e., reduce energy costs, optimize energy consumption, increase the reliability of the Electricity supply, grow the share of RE in the energy mix, contribute to the creation of attractive jobs in the agricultural sector, the study aims to look at the best agriculture activities and investigate on the responsiveness of DDRES to needs of farms, the study will review the existing policies and regulatory framework for microgrids in Algeria, propose different scenarios to accelerate the bottom-up energy transformation, and propose a policy and regulatory framework to support Algeria in meeting its targets by 2030. To find answers to this study, A literature and data review on the relevant aspects of the energy situation in Algeria and its Agenda by 2030, focusing on RE policy, agriculture, and ICT sectors, the regulatory framework for access to the low voltage grid, and the current political discussions around this topic. Results and discussion will give orientation on how DDRE will revolutionize the future of the grids, leverage energy efficiency, reduce the energy costs and increase the share of RE and the reliability of the electricity supply in Algeria, and how DDREs can be mainstreamed into the planning process with impact on many other sectors such as the modernization of agriculture sector and the creation of local jobs and SMEs.

Keywords: Decentralized renewable energy systems, energy transformation, digitalization, rural and urban electrification, smart farming, sustainable development, Algeria

Résumé

L'Algérie est un leader dans la production de combustibles fossiles. Son approvisionnement énergétique repose toujours sur le pétrole et le gaz, alors que le pays dispose d'un grand potentiel d'énergie solaire. La demande d'approvisionnement en énergie augmente et le réseau électrique national a des difficultés à alimenter les fermes et les communautés éloignées du réseau. Les agriculteurs utilisent des générateurs diesel comme solution alternative pour répondre à leurs besoins énergétiques. Cette étude examinera la contribution potentielle du développement par la DDRES d'un système énergétique intelligent et durable dans les fermes (c'est à dire réduire les coûts énergétiques, optimiser la consommation d'énergie, augmenter la fiabilité de l'approvisionnement en électricité, augmenter la part des énergies renouvelables dans le mix énergétique, contribuer à la création d'emplois attractifs dans le secteur agricole, l'étude vise à examiner les meilleures activités agricoles et à enquêter sur la réactivité de la DDRES aux besoins des fermes, l'étude examinera les politiques existantes et le cadre réglementaire pour les micro-réseaux en Algérie, proposer différents scénarios pour accélérer la transformation énergétique ascendante, et proposer une politique et un cadre réglementaire pour aider l'Algérie à atteindre ses objectifs d'ici 2030. Pour trouver des réponses à cette étude, une revue de la littérature et des données sur les aspects pertinents de la situation énergétique en Algérie et son Agenda 2030, en se concentrant sur la politique des énergies renouvelables, les secteurs de l'agriculture et des TIC, le cadre réglementaire pour l'accès au réseau basse tension et les discussions politiques actuelles autour de ce sujet. Les résultats et la discussion donneront une orientation sur la façon dont la DDRE révolutionnera l'avenir des réseaux, l'efficacité énergétique, la réduction des coûts de l'énergie et l'augmentation de la part des ER et de la fiabilité de l'approvisionnement en électricité en Algérie, et comment la DDRE peut être intégrée dans le processus de planification avec un impact sur de nombreux autres secteurs tels que la modernisation du secteur agricole et la création d'emplois locaux et de PME.

Mots-clés : Systèmes d'énergie renouvelable décentralisés, transformation énergétique, numérisation, électrification rurale et urbaine, agriculture intelligente, développement durable, Algérie.

Chapter 1

1.1 Introduction

This chapter covers a general introduction to the research. Specifically, it discusses the research problem, the research questions and objectives of the research, the significance of the study, the scope of the study, and an outline of the tentative chapters that the study entails.

1.2 PROBLEM STATEMENT

According to IRENA, the world is still addressing the lack of access to electricity and clean energy for cooking, with 789 million population without electricity and 2.8 billion people without access to clean cooking (Müller et al. 2021). Rural areas are the most affected, and many challenges have influenced sustainable electricity supply with off-grid systems. Sustainable electricity is considered a critical component in providing the community's needs for lighting, cooking, agricultural and industrial use. The demand is increasing with the growing population, and as a result, 2.3 billion people are still without access to electricity in 2030 (Panos, Densing, et Volkart 2016). With the current policy, actions are highly and urgently recommended to achieve the planned targets. Algeria is a leader in producing fossil fuels. Its energy supply still relies on oil and gas, with a 98.75 % share in electricity generation in 2016 (Bouznit, Pablo-Romero, et Sánchez-Braza 2020). On the other side, Algeria has immense potential in renewable energy, of which in 2011 has launched a development program to enlarge the utilization of renewable energies. The project was programmed to implement 1200 MW. However, the Algerian government has updated the program and set a new target to deliver 22000 MW of REs and achieve a 27 % RE share in total electricity production by 2030(Bouznit, Pablo-Romero, et Sánchez-Braza 2020). Adapting sustainable electricity supply with DDRES systems is essential for energy security, especially for a country that still relies on fossil fuels and used to be 100% electrified., For that benefit, the local government has worked on policies, national plans and set a target to increase the share of RE by 2030, Many projects have been done by researchers to study the planning of renewable energies, measures to promote RE for electricity generation, energy strategy in Algeria, energy mix and sustainable energy transformation. At the same time, the world is growing, and energy access is still a challenge in some rural and village areas in the south of Algeria. The national electricity grid is centralized and is registering difficulties due to the high demand. The agriculture and industry sector are highly affected farmers living far from the national grid are using diesel motors to supply their energy needs, in addition to the leak in energy management services (leak in irrigation systems, ventilation, etc.), the lack of network technologies (Communication, smart metering, remote control, automation systems) and the use of ancient Tools in farms that can waste much energy and affect our environment. Climate change is becoming a critical problem with actual actions needed. Therefore, how the Algerian government can address these challenges and progress on securing the basic human needs of the society while at the same time taking strong measures versus irreversible effects on its environment, DDRES, Digitalization, and clean energy are the essential keys to solve this dilemma. The digital solutions for our energy system will eliminate the waste of our resources, reduce energy costs, Optimize energy consumption, and increase the reliability of the electricity supply. In total, our connected systems will be more efficient, the absence of this new parameter that must be taken into considerations and limited studies created policies and literature on this subjects, on the role of DDRES and digitized off-grid systems to sustainable Adaptation of Renewable Energy Systems and Technology to farms for rural and urban electrification in Algeria and the accelerate path to energy transformation is what attracts the research to address this topic.

1.3 RESEARCH QUESTIONS:

1.3.1Main research question

What is the potential contribution of Digitized Decentralized Renewable Energy Systems to the agriculture sector in Algeria?

1.3.2 Specific research question

- What are agriculture practices in Algeria?
- What are the energy and ICT needs of Algerian farmers?
- How can existing technologies respond to the farm’s needs?
- What are Algeria's measures, plans, and current energy, agriculture, ICT, and energy transformation policies?
- How can DDRES contribute to more sustainable farms and energy transformation in Algeria?
- What changes and policy recommendations are required to promote renewable energy systems to farms and integrate decentralized energy systems in Algeria?

1.4 RESEARCH OBJECTIVES

Main research objectives:
To determine the potential contribution of digitized Decentralized Renewable Energy Systems to the agriculture sector in Algeria.

Specific research objectives:

- To identify the agriculture practices in Algeria.
- To determine the energy and ICT needs of Algerian farmers.
- To review Algeria's current policies and strategies toward the energy situation, Agriculture, ICT, and energy transformation.
- To investigate the responsiveness of DDRES to the energy needs of farmers.
- To study the adaptation of DDRES to farms in Algeria
- To propose a policy framework required to promote renewable energy systems to farms and integrate decentralized energy systems in Algeria

1.5 Significance of the study

Results expected from this study provide a coherent approach, outlook, and perspective to the future of Algeria's grid. This research document will be very functional and practical for policymakers in planning the grid of the future. In addition to that, a significant contribution to the process of implementing a digitalized decentralized renewable energy system that ensures sustainable Adaptation of Renewable Energy Systems and Technology to farms for rural and urban Electrification (reduce energy costs, optimize energy consumption, increase the reliability of the Electricity supply) in Algeria.

This research will bring intensive knowledge on the grid of the future, decentralized systems, and digital solutions to improve the electricity supply, supervise energy consumption, and monitor the grid to Algerian communities' farms.

The study will propose a developed strategy based on effective policies and regulations to increase RE's share in Algeria and accelerate the energy transformation in Algeria.

Through the research method (collecting data, questionnaires, discussions, and interviews) from several representatives, companies' professionals, and experts that are working on digital and ICT solutions, DDRES enterprises, and different national institutions, this study with the effective collaborations of the various actors will clarify the road to revolutionize Algeria's grid, Renewable energy systems and access to sustainable and secure Energy that's lead to reduce GHG emissions, mitigate the impacts of climate change, and finally to facilitate energy transformation and the achievement of the Algerian government targets by 2030

This study will be an essential reference to assist students and researchers who may work and tackle related topics in the future.

1.6 Scope of the Study

The study focuses on assessing the contribution of digitized Decentralized Renewable Energy Systems to the agriculture sector in Algeria and how these contributions can facilitate the energy transition process. This assessment identifies the agriculture practices, the energy and ICT needs, and the responsiveness of DDRES to the energy needs of farmers, The content of the study is organized into four main chapters.

The first chapter presents an introduction to the research, and the second chapter presents a relevant literature review, and the third chapter explains the methodology used to conduct the research. The fourth chapter discusses the results, summarizes the findings, and presents recommendations and conclusions. The case study of the research is Eloued and Biskra, Algeria. The two regions are well-known and ranked places in agriculture activities and provide high opportunities to implement DDRES. The entire study was conducted within a period of six months, from April to September 2021.

CHAPTER TWO

REVIEW OF RELEVANT LITERATURE

2.1 Introduction

This chapter presents a review of scholarly works that are consistent with the study's overall aim. The relevant literature reviewed was grouped into four main sections: a review of essential concepts, relevant theories, a review of the empirical literature, and a conceptual framework based on the study's critical conceptual and theoretical underpinnings. Key topics covered include the existing policies and regulatory framework in the energy, agriculture, and ICT sector in Algeria and Algeria's agenda by 2030.

Literature utilized in this study relates to those accessed only through well-established scientific databases such as Scopus, Web of Science, and ScienceDirect. Other relevant literature was obtained from the publications and reports of relevant institutions such as the Ministry of Energy and Mining, Ministry of Water Resources and Environment, Ministry of Agriculture, Rural Development, and the Ministry of Communication. Other relevant reports accessed by institutions relevant to the study were utilized, and sources duly indicated.

2.2 Overview of relevant concepts

2.1.1 Digitized Renewable Energy Systems

Elbassam defined that Digitalisation is about converting collected information into a digital format where this information is organized into bits(El Bassam 2021), while the digitalization of RES is the process of using innovative technologies and solutions that can manage and control electricity production, which can be different for each source of energy. (Kangas et al. 2021) however, RES companies face challenges in predicting ICT development and opportunities for innovation and collaboration with ICT companies.

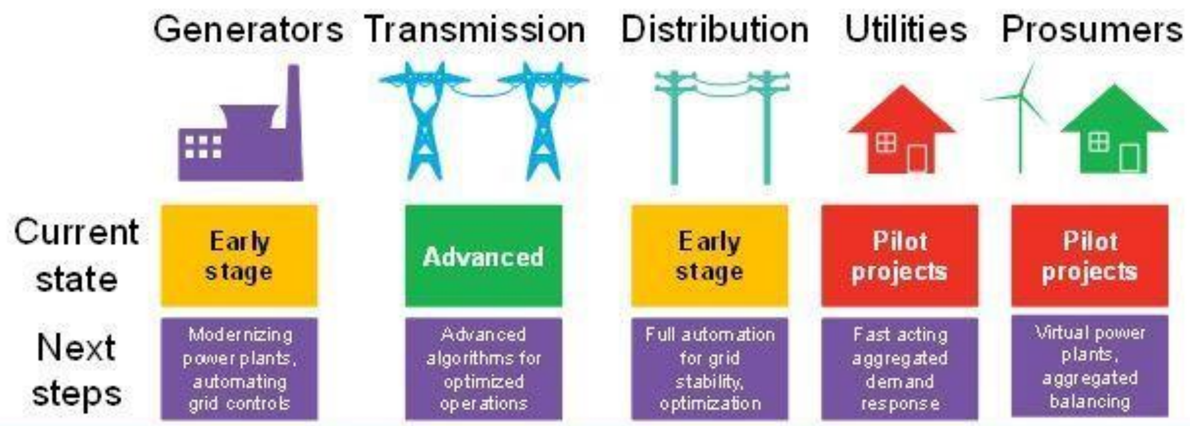


FIGURE 1. DIGITALIZATION OF ENERGY SYSTEMS (« DIGITALIZATION OF ENERGY SYSTEMS » 2017)

According to Bloomberg NeF, the digitalization of energy systems can ensure and maintain grid stability and reliability, where the frequency can be regulated in real-time, and accurate response to the system demand will be provided. It can also provide the opportunity to monitor the grid and identify the weakness point using digital technologies, optimization, and energy production forecasting tools that can help us integrate RE easily with efficient equipment. Consumers will have more control over their system, easy access to the data (energy consumption, power generation)…(« Digitalization of Energy Systems » 2017).

2.1.2 Decentralized and distributed Renewable Energy Systems

(Vezzoli et al. 2018a)has defined a decentralized energy system by the small-scale unit that can generate energy for the local clients. Therefore, DES can be stand-alone or connected and shared to the network. Figure 2.2 presents an explanation of how the DES can be in the Local grid. Additionally, according to (Labrousse 2006a), Decentralized production, especially electricity (cogeneration or dedicated production), is an essential element, but it is not the only characteristic of a distributed energy system. When the lines between "supply" and "demand" blur, the energy operator does much more than sell final energy, it mainly provides services and optimizes the use of available energy resources.

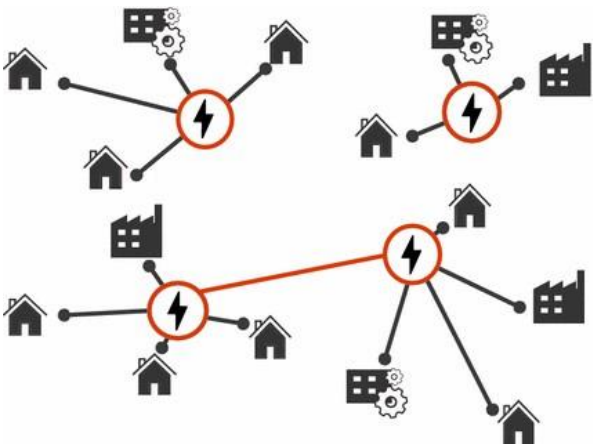


FIGURE 2. DIGITALIZATION OF ENERGY SYSTEMS **(VEZZOLI ET AL. 2018A)**

(Vezzoli et al. 2018a) also, defer between the decentralized and distributed energy system. He explained that the distributed energy system is a small-scale generation unit where the users (individuals, small businesses, or local communities) can be producers simultaneously. Moreover, Distributed energy systems can be stand-alone or connected and shared to the network.

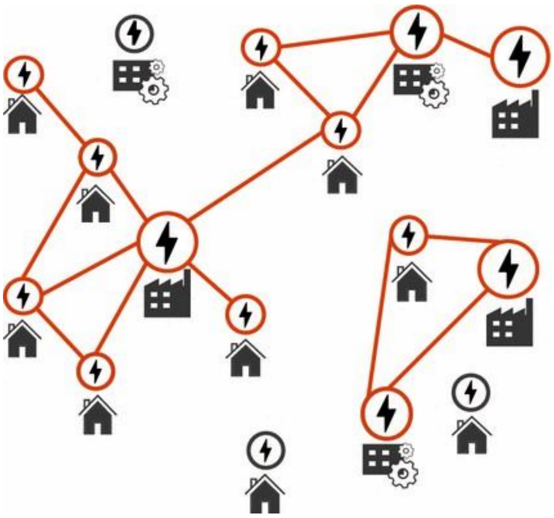


FIGURE 3 DISTRIBUTED ENERGY SYSTEM(**VEZZOLI ET AL. 2018A)**

Decentralized and off-grid systems can be efficient solutions to increase energy access to populations. This solution, including Digitalization with good policy, can accelerate the pace to targets by 2030. Digitalization refers to the expanding application of ICT systems across the economy, collection and analysis of data, innovation, and connectivity between humans and devices, sensors, and data centers are used to analyze the energy consumptions of systems. This also allows automatic controlling and monitoring in real-time, which increases the reliability of the energy management system and increases energy efficiency. Through the gathered data from smart meters, the system will analyze it and act instantly.

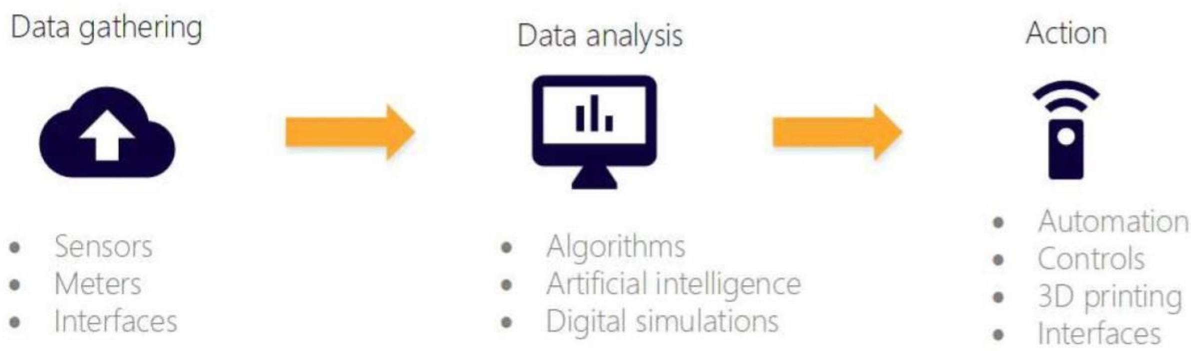


FIGURE 4 HOW DIGITALIZATION CAN IMPROVE EFFICIENCY THROUGH A COMBINATION OF TECHNOLOGIES.**(« DIGITALIZATION OF ENERGY SYSTEMS » 2017)**

2.1.3 Water Energy and Food Nexus

The interactions between water, food, and energy are diverse, and each of such interactions is very significant, particularly within the specific scope in which the interaction is being analyzed. A significant amount of water is utilized in the production of energy, from direct energy extraction as in hydroelectric power generation to indirect contributions such as in the production of either feedstock or relevant crops for synthesizing biofuels (Mehmood et al. 2019). In the fossil world, water provides a site for deposition of residuals, which is most typical in the cases of offshore oil drilling (Mehmood et al., 2019). Again, water is relevant in determining the generation potential of geothermal energy across many regions of the world. Modern-day renewable energy such as wind energy harnessing capacities has been enhanced significantly by affixing wind turbines on water bodies.

Whether with the aid of water or not, the energy produced is significant in food production and the further development of water resources. Managing water on farms to minimize wastage has been described as more effective with electricity (Jackson, Khan, et Hafeez 2010). Consequently, traditional irrigation methods of using hand-based technology such as watering cans are being replaced, particularly on large farms with electricity-powered drip irrigation systems. Therefore, the direct results of utilizing energy in attaining a dual output of boosting food production with proper water management are incontestable. Literature is further consistent on the complexity of such relationships, suggesting that it is challenging, if not nearly impossible, to identify and isolate all the relationships between water, energy, and food (Chen, G., Maraseni, T.N., Banhazi, T. & Bundschuh, J. 2015).

The recent interest surge in analyzing such relationships led to the nexus approach in analyzing such interactions. This management approach targets a green economy with sustainability objectives (Bellfield, H. 2015). The nexus approach has been viewed more in literature as a management framework that coordinates the interactions between diverse variables across different scales and sectors. Hence its application to the study of water, energy, and food is often geared towards resource use efficiency and policy coherence (Lahcen El Youssefi et al. 2020). The preceding suggests that applying digitized microgrid technology in crop production to ensure effective use of water resources and boost food production using clean energy is consistent with the tenets of the Water Food Energy Nexus ideological propositions.

The application of a nexus perspective in the study of water, energy, and food resources is further described by El Youssfi et al. (2020) as one that is not only justified by the position of these three variables as pillars of most economies of the world but also by the need to maintain an equilibrium in the drive to achieving securities across these three key sectors (Mehmood et al. 2019). This way, while the internal dynamics of such interactions are being studied, the influence of external force on these variables will also be examined from a holistic perspective. With the advent of climate variability and contestations surrounding climate change, such nexus perspectives further suggest that policy interventions that would emanate from such studies have a higher likelihood of sensitivity to climate mitigation and adaptation.

2.3 Theoretical Underpinnings of the Study

2.3.1 Roger's theory of diffusion of innovations

The evolution of research on technology use and agricultural research has been consistent in the contributions of diffusion theories to the uptake of technologies among farmers. The most dominant of such theories often cited is Rogers' Theory of Diffusion of Innovations. Propounded in 1962, Rogers provided a comprehensive overview of how emergent ideas and technologies (innovation) is gradually taken up by people within a given social system (Sahin, 2006). Essentially, Rogers identified four significant vital elements in the diffusion of innovations process. The process begins with an idea (also known as innovation) and is communicated through a series of channels. A certain period is required for the diffusion, after which potential adopters then take up the innovation within the social system (Rogers et al., 2019).

It is essential to note that the theory posits that for an idea to be considered an innovation, it must be perceived by the people within the given social system (Rogers et al., 2019). Relating this to the given agricultural system being studied in this research, preliminary evidence on the limited knowledge of the farmers on the use and operation of digitized decentralized micro-grid systems on their farms implies that such systems can be considered as innovation among them. This further indicates that if applied elsewhere in a more developed context, such systems may not be viewed entirely as innovations, limiting the applicability of the tenets of Rogers' theory.

Following this, it is essential to highlight the role of the various stakeholders in enhancing the uptake of such technology. Rogers suggested that communication is the pathway through which the ideas behind the innovation are driven. Therefore, it is arguable that for such DDRES to be diffused in the study region, adequate profiling of the various needs of the people along the value chains of the farm will aid in streamlining the ideas to their needs. Such a need-based communication process, therefore, increases the likelihood of adoption. It buttresses further the claim of Rogers that innovation can be diffused at a higher rate if the potential adopters perceive the idea to be of use to them since communication is the primary strategy used in influencing people to see the relevance of a new idea.

Sailing from the above, the study argues tentatively that for such DDRES to be diffused on farms in Algeria, there are likely to be two main groups of adopters: the early adopters and the late adopters, both of which are separated by a time factor (see Figure 5). The early adopters in this context are those who are quick to understand the technology as very important to their farming activities. This in the scope of this study includes the pilot forms where such technology implementation is studied. Over time, the channels of communication and the message being communicated then influence the latter group to perceive the usefulness of the technology to them, and then eventually, a more comprehensive number of farmers within the region can take up such DDRES to improve their production and productivity.

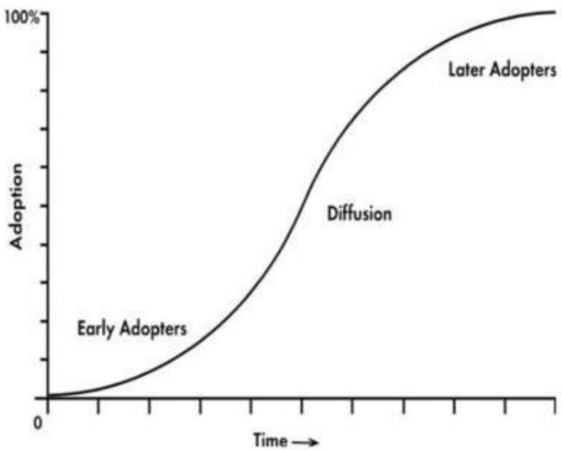


FIGURE 5 THE EARLY ADOPTERS AND THE LATE ADOPTERS**(MEJLGAARD ET AL. 2019)**

In essence, the theory sought to explain why some innovations succeed in getting adopted while others fail. The unique idea is that the perception of the potential adopters in the given social system on the relevance of the innovation influences their likelihood of taking up such new tenets. While the original tenets of the theory have been severally reviewed by subsequent researchers, a key observation is the contestations regarding the seemingly linear process initially communicated by the theory. Thus, more recent studies have considered the complexities of the social system and severally refuted the linear process, throwing more light on complexity in the diffusion process. Therefore, the tenets of this theory are applied with sensitivity to the complexities of the modern social system, as opposed to the original linearity of the process.

2.4 Understanding the Adoption of DDRES

2.4.1 Evolution of DDRES

Earlier literature suggests that traditional practices have primarily characterized agriculture in the developing context. Consequently, production and productivity levels on the continent have been low (Saghir 2014). However, the advent of technology and the Internet of Things led to a revolution of the agricultural sectors across many economies in such contexts (Chavula 2014). While adoption rates of smart agriculture (elsewhere referred to as "precision agricultural practices") are most significant in the developed context, Africa and other developing countries are more recent in the introduction of intelligent technologies on their farming activities (Barrios, Ouattara, et Strobl 2008; Chavula 2014).

Prior to modernization, agricultural activities on the continent had been characterized by their relatively lower levels of mechanization (Hamamouche et al., 2018). Land preparations were done with light equipment together with the aid of animals. Seeds were planted manually, with crop and pest management supervised by human-trained exerts (agriculture extension officers). Irrigation and drying were dependent on natural weather processes; hence production and productivity were defined by the favourability of the weather in the production season (Barrios, Ouattara, et Strobl 2008; Chavula 2014; Saghir 2014). Best farm management practices were discussed among farmers through Farmer Based Organisations (FBOs) in their farming rooms, with limited records keeping and consequently limited abilities to predict patterns and plan mitigation alternatives ahead of time (Saghir 2014).

However, as society evolved, the emergence of innovative farm technologies has altered practices in the developed contexts and the global south, including the MENA region. Scholarly works by Klerkx et al. categorized agricultural innovation technologies into four main groups (Klerkx, Van Mierlo, et Leeuwis 2012). They suggested that around the 1950s-1980s, technology integration in Agriculture was limited to Technology Transfer (TT). This era's modernization of agricultural practices was usually implemented through centralized approaches that focused on increasing productivity levels. The extent of decentralization and active interconnection between diverse socio-political and institutional components of the farming society in this era were primarily limited.

Following this period, scientific research on agricultural production technologies highlighted more systems-oriented approaches (Klerkx, Van Mierlo, et Leeuwis 2012). Dominant among these approaches include the Farming Systems approach, Agricultural Knowledge and Information System, and Agricultural Innovation System. The need for a more integrated perspective in applying technology to agricultural practice thus gained prominence after the 1980s. The Farming Systems approach, for instance, was dominant between the 1980s and 1990. This way of thinking and agricultural practice paved the way for sensitivity to the diverse socio-economic, cultural, and ecological contextual issues. Thus, a more integrated perspective was adopted during the period, characterized by an increased transition from simple technologies to more advanced ones. The Agricultural Knowledge and Information System approach, which followed in the 1990s, transformed the agricultural practice into one characterized by a more profound exchange of knowledge and information between all relevant stakeholders (ibid). Agricultural practice thus extended beyond top-down approaches to bottom-up practices, which paid adequate attention to the diverse institutional issues which directly or indirectly affect practice.

Other complex practices, such as embodied in the ideologies of the Agricultural Innovation System, emerged in more recent years, with a deepened synergy between innovation and practice (Klerkx, Van Mierlo, et Leeuwis 2012). Such innovations do not necessarily have to emerge from the agricultural sector only but encompass all forms of innovation that are amenable to agriculture. This new thinking created a deeper application of intelligent technology and the Internet of Things (IoT) to modern-day agricultural practice. Thus, activities can even be simulated, and consequences predicted before actual implementation decisions are made, with high degrees of effectiveness and efficiency.

While significant policy evidence has been substantiated on the drive to increase agricultural production and productivity in the MENA region, intensifying technological innovation is essential towards advancing food security objectives in the entire region (Ben Abdelmalek et Nouri 2020; Colin et al. 2021). The rates of success in the advancement of technology, particularly the use of digital within Europe and other developed contexts, have been significant (Busse et al. 2014; Paustian et Theuvsen 2017; Vecchio et al. 2020). Regardless, the willingness of farmers to adopt these technologies, as well as a well-coordinated interaction between all relevant stakeholders, is essential towards the successful implementation of such innovations. Therefore, it is with this rationale that this project seeks to adopt a collaborative approach, grounded on evidence-based research, to introduce digitalized agriculture within the

MENA region, enhance the advancement of food security objectives, and stimulate overall economic development in the region.

2 .4.2 **Application and Potentials of DDRES 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).

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 (Busse et al. 2014; Chavula 2014; Paustian et Theuvsen 2017; 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 et 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) and 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, et 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.

2.5 Overview of Algeria's Agricultural Landscape

2.5.1 Agricultural Production Capacity

In Algeria, The government considers the Agricultural sector the main priority to diversify its economy, accounting for 14.23% of Algeria's GDP (2020 estimates), and 34.25 % came from the industry and 47.78 % from the services sector (O'Neill 2021). The Ministry of Agriculture is engaged in programs involving land grants to private investors to boost agricultural development and production. Partnerships can be between Algerian public and private investors, Algerian private investors only, or a foreign investor with an Algerian partner.

According to the website of the ministry of agriculture, Cereal products occupy a strategic place in the food system and the national economy during the two periods 2000-2009 and 2010-2017, the area of cereals occupies an annual average of 40% of the Useful Agricultural Area (UAA).

The production of cereals during the period 2010-2017 is estimated at 41.2 million quintals on average, an increase of 26% compared to the decade 2000-2009 when production is estimated on average at 32.6 million quintals. The production consists mainly of durum wheat and barley, representing 51% and 29% of all cereal production on average 2010-2017. For the Industrial crops (tomatoes and tobacco), the area devoted annually during the two periods amounts to 19 830 ha. Regarding tobacco, the area is 4 850 ha on average during the same period. In terms of production, the industrial tomato has experienced a substantial increase of 136%, resulting from the improvement of yields that have gone from almost 200 q /ha during the period 2000-2009 to more than 500 q /ha in 2010-2017. The average market gardening production recorded a significant increase from 2010-2017, reaching + 121% compared to the period 2000-2009. the potato and onion, respectively over 36% and over 12% of market gardening production, recorded an increase of + 143% and + 102%, respectively.

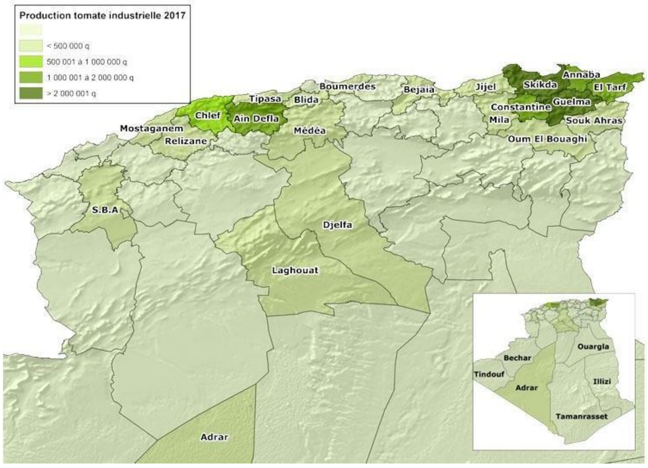


FIGURE 6.THE AVERAGE MARKET GARDENING PRODUCTION **(ZAHRAOUI ET AL. 2021)**ALGERIA'S AGRICULTURE MINISTRY}

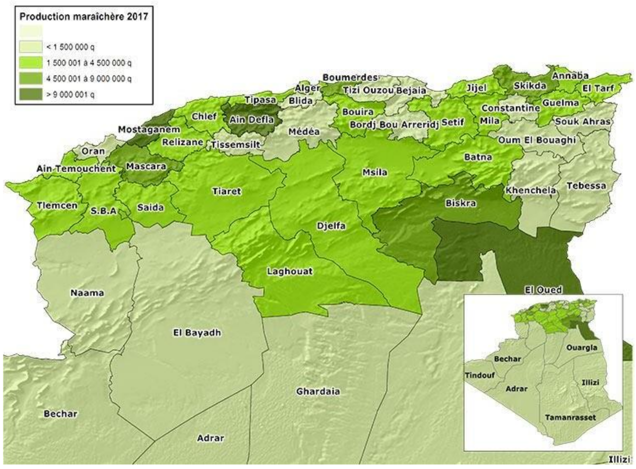


FIGURE 7 THE AVERAGE MARKET GARDENING PRODUCTION {ALGERIA'S AGRICULTURE MINISTRY}

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).

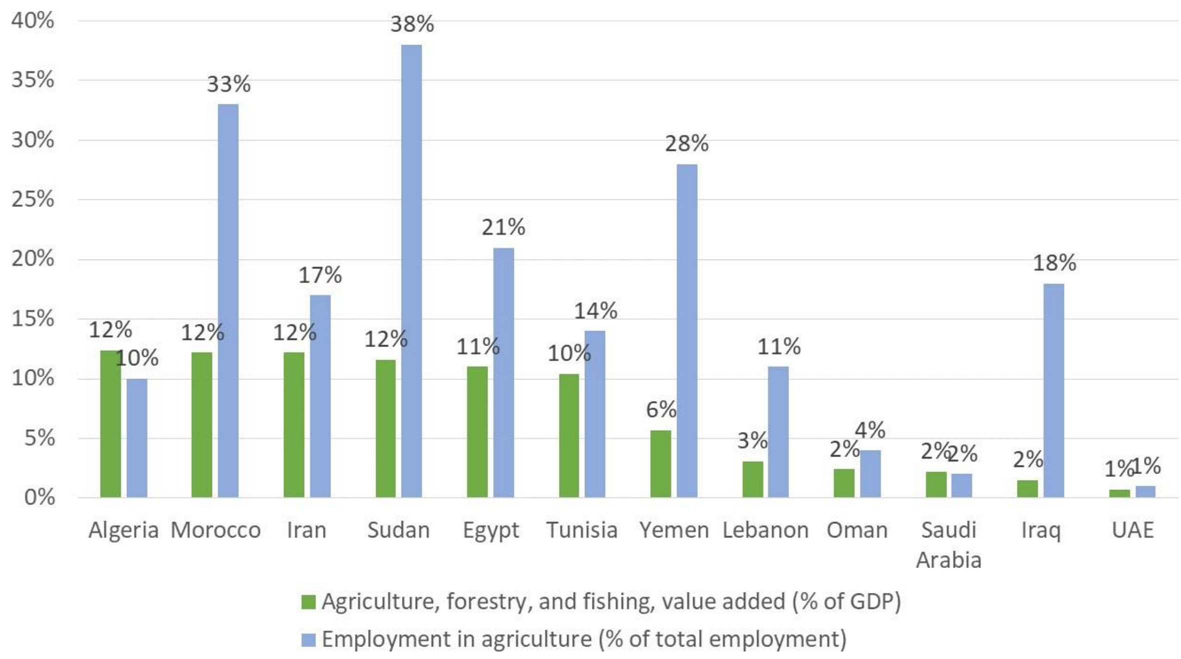


FIGURE 8 AGRICULTURE IN MENA ECONOMIES (2019)

2.5.2 Policy Landscape of the Agricultural Sector

2.5.3 Agricultural trade policy

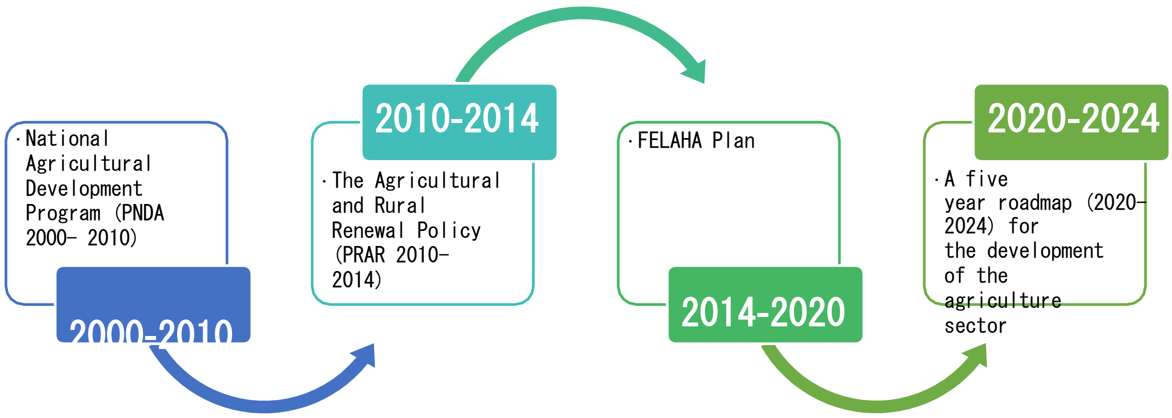
Due to the drop in hydrocarbon revenues and a continuous increase in imports of food products which are very expensive in foreign currency, the Algerian government has implemented trade policy aims to ensure the country's food security while protecting its agricultural sector from external competition, in order to increase production and thus reduce dependence on the country to imports of commodities especially grains and milk, Diversify its foreign currency exports by increasing exports of agricultural products and improving the quality and traceability of exported products to meet the development of sanitary, phytosanitary and technical standards by promoting these products through processing and the development of labels, thus meeting consumers expectations in terms of healthy food respect for the environment and animal welfare and by diversifying both the range of exported products and the partners

Commercial.

Under the supervision of the Ministry of Commerce, the National Agency for the Promotion of Foreign Trade (ALGEX) was created in 2004 by decree to provide support for non-hydrocarbon exports. It relies on the Special Fund for the Promotion of Exports established in

1996 and intended to provide financial support for promoting and placing products on foreign markets, in particular by taking charge of part of the costs. Costs related to the transport of goods and the participation of companies in fairs and exhibitions abroad. For agricultural products, the international transport subsidy is 80% for dates and 50% for other products (Bessaoud et al. 2019).

Agriculture policy and strategy in Algeria:



Source: author design

2.5.4 National Agricultural Development Program (PNDA 2000-2010)

The Algerian government has allocated more than €600 to the PNDA Within the framework of the 2001-2004 economic recovery support program and to the revival of the agricultural sector. The objective of the program was to ensure the country's food security, to promote income and employment income and employment in rural areas and to manage fragile natural resources the fragile natural resources in a sustainable manner, to Improve agricultural production by developing production capacities, multiplication of agricultural inputs, and reproductive material, Preservation and protection of the environment and enhancement of mountains through economic and functional reforestation. It aimed to achieve an annual growth rate of 10%, compared to 4% in the last years of the previous decade (Bessaoud et al., 2019).

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

The strategic axes of implementation of the agricultural and rural renewal policy aim at strengthening national food security. This inevitably involves the research, in the medium term, for significant changes and impacts on the structural bases on the structural bases which found the state of food security of the nation. The program has three pillars:

- The Agricultural Renewal

- The Rural Renewal
- Strengthening of Human Capacities and Technical Support to producers (PRCHAT) (MADR 2012)

2.5.6 FILAHA Plan (2014-2020)

the Agricultural Action Plan that was presented by the Minister of Agriculture, Rural Development and Fisheries, Sid Ahmed Ferroukhi, aims, among other things, to reduce agricultural imports by 2 billion dollars by 2019. This plan is based primarily on the 2015-2016 agricultural season results. Namely, nearly 4,800 tons of potatoes produced in the wilaya of El-Oued were exported to eight countries. With the "abundant" harvest achieved this season at the level of farms in this wilaya, the Algerian potato has opened the appetite of four Arab countries (the United Arab Emirates, Saudi Arabia, Qatar, and Tunisia), and four other European (Russia, Italy, France and Spain). The FILAHA plan is divided into agriculture and livestock, forests and watersheds, fisheries, and aquaculture. The new guidelines of the Ministry of Agriculture aim, by 2019, to achieve an average agricultural growth of 5%, to reach an irrigated agricultural area of 2 million hectares, and a production value of DA 4,300 billion, including 110 billion for fishing. As it is expected a rate of afforestation of 13%, the reduction of imports of more than 2 billion dollars by the substitution of domestic production, export of products for a value of 1.1 billion dollars, and the creation of nearly 1.5 million permanent jobs including 80,000 in the field of fishing and aquaculture (Hamza 2016).

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

the Ministry of Agriculture and Rural Development, through its Rural Development, through its sectoral program, translates their implementation into a roadmap, with data to assess the current and future situation, and mainly the qualitative and/or quantitative improvements that can be quantitative progress achievable in the short term, or even immediately for certain actions.

This strategy aims to develop agricultural production through the extension of the irrigated areas, increase agriculture production and rural development in mountain areas, and integrate knowledge and digitization in agriculture development programs (Ferrah 2021).

2.6 Examining Algeria's Energy Landscape

2.6.1 Status of Fossil Energy Resources in Algeria

Algeria relies heavily on fossil fuels. The country has the third most significant reserve of Gas and 7th oil reserves in the world located in seven areas: the Reggane and Tindouf basins in the southwest,the Ghedames and Illizi basins in the east, the Timimoun, Ahmet and Mouydir basins in the central region figure (2) , Algerian gas and oil contribute 64.84% and 34.63%, respectively for electricity generation(Zahraoui et al. 2021).

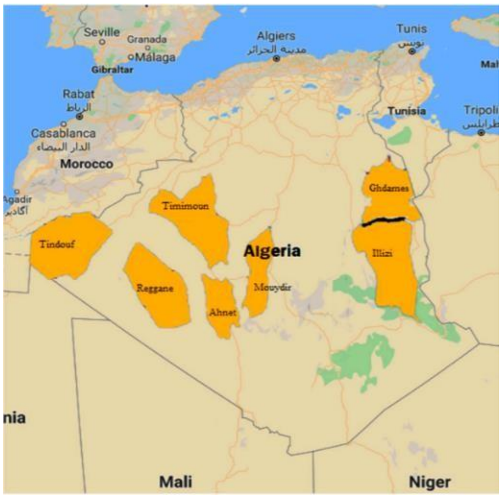


FIGURE 9 THE LOCATION OF GAS AND OIL BASINS IN ALGERIA **(ZAHRAOUI ET AL. 2021)**

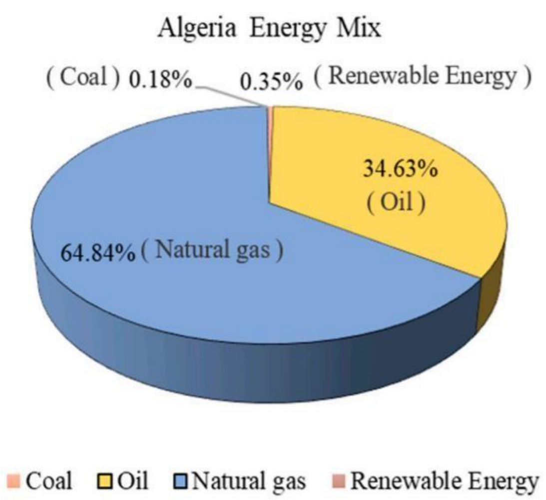


FIGURE 10 ALGERIA FOSSIL FUEL GENERATION MIX IN 2019 (ZAHRAOUI ET AL. 2021)

2.6.2 Renewable energy status in Algeria

Due to its geographical location, Algeria has a high promising potential for renewable energy, such as hydropower, wind, geothermal, biomass, and solar.(Amine Boudghene Stambouli 2011b)

Potential of Solar energy

Algeria has great potential in solar energy, the direct irradiation has been estimated at 169,440 kW/m2/year with 3000 kWh/year of power generation (« Ministère de l’Énergie | Algérie » s. d.).80% from the Algeria’s land which contains high average of irradiation, the insolation duration is around 2000 to 3900h annually(Himri, Malik, et al. 2009). Table 1 presents the average of sunrise and energy received in Algeria per area.

Table 1. Solar potential in Algeria (A Boudghene Stambouli et 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/m^2/year)	1700	1900	2650

Potential of Wind energy:

The Algerian government is considering wind resources as the seco[nd] primary source of renewable energy due to the high potential that has been identified in 21 zones and it is divided into different regions. The southwestern region has great potential compared to the northern part with speeds exceeding 4m/s for the site of Bechar, 5m/s for the site of Tindouf and even above 6m/s for the site of Adrar (Laidi et al. 2012)

Sonelgaz website

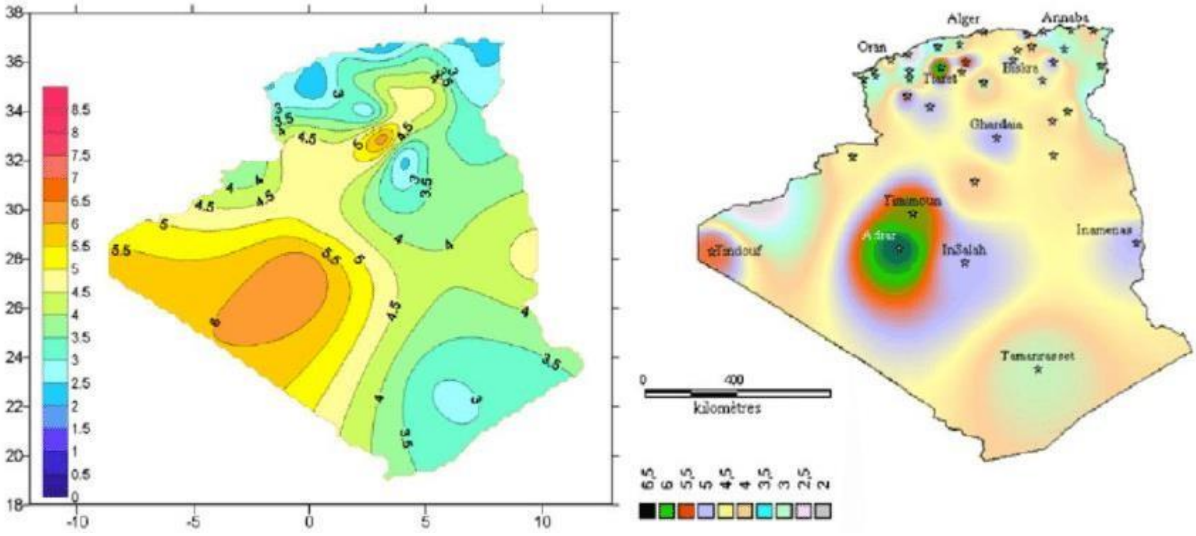


FIGURE 11 MAPS OF WIND SPEED IN ALGERIA(**LAIDI ET AL. 2012**)

2.7 Conceptual Framework for the Study

An inquiry into the application of digitized decentralized mini-grid to transform the agricultural sector of Algeria requires a thorough understanding of the agricultural landscape of the study country. Preliminary evidence from the literature suggests Algeria has a diversified production base, ranging from produce with a short production span such as vegetables to those with a longer maturation span such as dates and grapes. Despite the numerous variations in crop type, the value chain is made up of similar actors, from production to trade and consumption. The production stage is arguably the most relevant stage of the value chain, with indications that production levels are influenced by the input stage variables such as availability of technology and the level of awareness on pest and disease management among others. Essential to bosting production capacity and quality is the availability of relevant utility, particularly water. Regardless, the scarcity in the region makes water conservation a prime objective of the country's government. Similarly, increasing environmental awareness and the need to pus towards the attainment of COP21 Paris agreement targets imply that energy systems used in the farm be transformed to more cleaner and renewable options. Optimising technology use will have significant effects therefore on achieving the energy, water and agricultural needs.

Interestingly, the role of the existing political structure and systems in defining agricultural practices are significant. While policy specifies targets and directions of investment., they also specify the provisions for essential input such as water and energy, hence the extent to which renewable energy technology can digitised microgrids can be utilised in agriculture in Algeria will largely depend on availability and appropriateness. Interestingly, the literature reviewed suggest that the country has made significant strides in policy and its revision towards the attainment of sustainability objectives. In essence, the nature of available policies significantly shapes local attitudes and practice. Again, such policies define the nature of cross-sectoral collaborations that can exist to drive attainment of sector specific objectives.

Notably, several theories, with the most relevant adopted for this study being the Theory of Diffusion of Innovations suggest the incontestable relevance of people behaviour in defining the extent to which they will adopt emerging technology in their activities. Such attributes of the people are further significantly informed by the climate of the environment that surrounds the people. Such targets when attained will eventually lead to the provision of the sustainability targets in the country (see Figure 12).

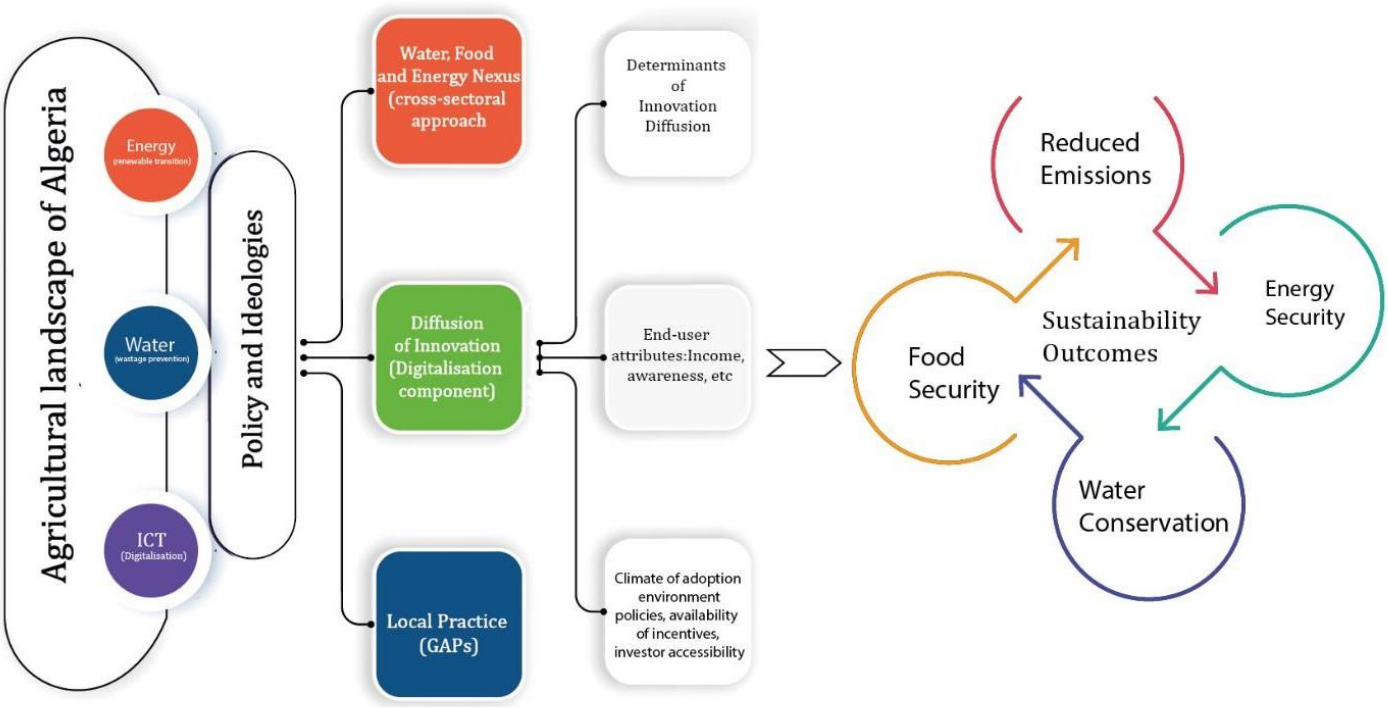


FIGURE 12 CONCEPTUAL MODEL OF THE ALGERIAN SUSTAINABILITY TARGETS (AUTHOR DESIGN)

Research methodology

3.1 Introduction

Earlier in the previous chapter, we outlined and examined relevant literature highlighting essential variables pertinent to the current research. The literature summarized the theoretical perspectives behind the Water Energy and Food Nexus approach, Algeria's Energy and agriculture Landscape, the energy and agriculture strategies and policies of Algeria, decentral and digitized Renewable energy systems energy transformation, and its applications to the field.

As a result of the review, all needed data has been identified to be collected and exanimated to answer the research question on the potential contribution of digitized Decentralized Renewable Energy Systems to the agriculture sector in Algeria.

In the next chapter, we describe and discuss the study setting and then look at the methodology used by the researcher

3.2 Study Setting 1 (Biskra)

The wilaya of Biskra (4 ° 15 'and 6 ° 45' E and 35 ° 15 'and 33 ° 30' N, raised to 29 and 1600 meters) is located in central-eastern Algeria, at the gateway to the Algerian Sahara. It is a real buffer space between North and South, about 450 km southeast of the capital. It is spreading over an area of approximately 21671 km2 It is limited to the North by the wilayas of Batna and M'sila, to the South by the wilayas of Ouargla and El-Oued, to the east by the wilaya of Khenchela and to the West by the wilaya of Djelfa.(Diab 2015)

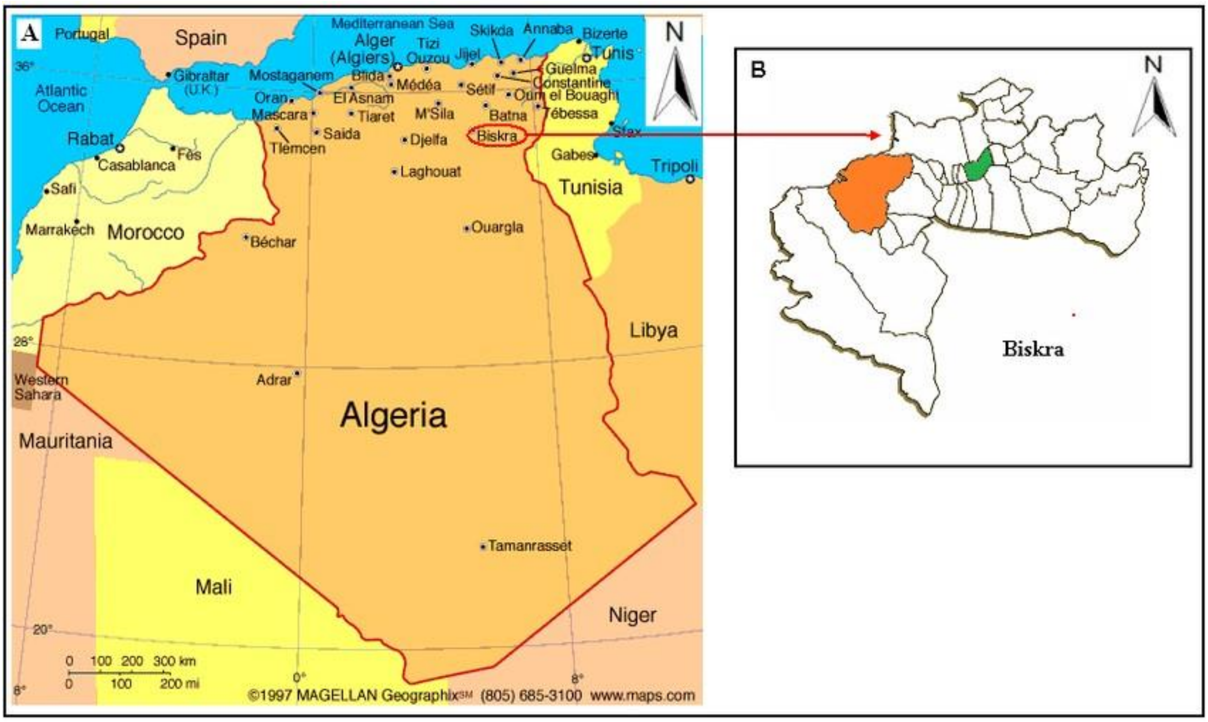


Figure 13 Map of Biskra province (Algeria).(BENZETTA et al., s. d.)

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, which takes 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).

3.3 Study Setting 2 (ElOued)

The wilaya of El Oued Souf is located in southeast Constantinos. It is limited to the North by the wilaya Biskra, Khenchela, and Tébessa, in the east by the Tunisian border, to the West by the wilaya of Djelfa, and in the South by the wilaya of Ouargla. It occupies an area of 54573 km² for a total population of 504,401 inhabitants, a density of 9.7 inhabit / km².

The relief is composed of three sets; a sandy region covers the entire Souf region and the eastern and southern parts of Oued-Righ. This region is part of the significant eastern erg. It only presents very little interest in agriculture. It is a tray shape rocky: it runs along national road 3 west of the wilaya and extends to the South. A region of depression: this is the chotts area. It is located at North of the wilaya and extends to the east. Saw the high salinity of this region, it presents no utility for agriculture. The climate of the wilaya is Saharan and desert type, with hot summers and sweet winters. Temperatures are very high in summer (54 ° C in the Souf) and can drop to 1 ° C in winter (El Meghaïr). As it concerns precipitation, they are a very low little difference of 80 mm/year. The main natural constraints encountered are of climatic types. From most critical climatic conditions in this region, we can cite

• Low rainfall, around 80 mm / year(Kholladi 2005).

• The regular frequency for most of the year and their violence. Sirocco causes significant damage (drying out, dehydration). Sandy winds slow down significantly any socio-economic activity.

• The high summer temperatures accelerate the evaporation process, more than 200

to 600 mm / year(Kholladi 2005).

In the region of El Oued Souf, the three primary sources of water are:

1. The surface water table shallow phreatic water extends almost everywhere the territory of El Oued Souf and is made up of Quaternary formations whose thickness varies between 10 to 40 meters. It is supplied mainly by rainwater infiltration (wadis, streams) and benefits from deep water tables. According to the map of isopièzes, the feed direction is generally from the South to the North. This tablecloth occupies a place important in terms of water supply, and it is easy to operate (the number of wells drilled reaches 10,000) (Castany 1982).
2. The continental or terminal complex is composed of the sheet of sands covering Practically all the North of the Algerian Sahara, particularly the sizeable eastern erg (350000km²). Its water is of poor quality, and the salinity rate varies between 3 to 5 gr / l with traces of fluorine.(Castany 1982)
3. The continental Intercalative: this is the more important. It has a sandstone predominance permeable. The boreholes that crossed the continental interlayer showed a more significant proportion of clay large, the sandstones of the intercalated continental very variable faces. The many boreholes that have passed through all secondary education allow us to know the thickness of the continental interlayer.(Kholladi 2005)

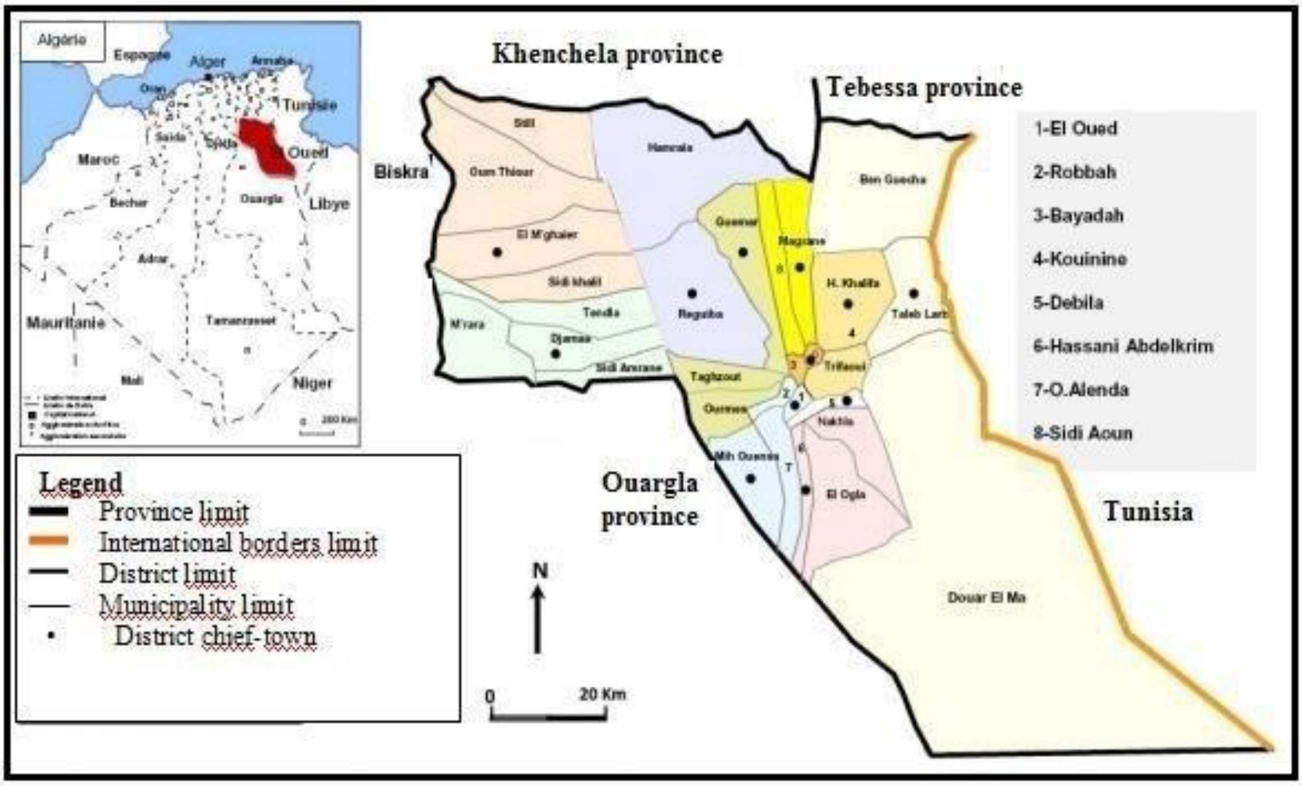


Figure 14 Map of Biskra province (Algeria) (BENZETTA et al., s. d.)

3.4 **Methods:**

This study begins with an overview of current issues regarding Algeria's energy, agriculture, and ICTs sector. It is presented with specific references to some challenges that constrain the transformation process. A conceptual framework that attempts to link the different variables is then proposed to explain how DDRES in the agriculture sector can facilitate this process.

Methods and techniques employed for collecting, analyzing, and presenting results are described in this section.

3.5 **Research Approach:**

The methodology of this research is based on qualitative approach where data will be collected and analysed. This method draws on the strengths of qualitative methods to allow readers and researchers to explore diverse visions and perspectives despite their philosophical worldviews (Creswell et Creswell 2017). It uses an accurate method in data collection, integration, analysis, discussion, and combining the strength of each technique, allowing researchers to understand connections and contradictions and have better help to minimize the weakness, and remove the challenges studied. The strategy is based on reviewing documents on the energy, agriculture and ICTs situations in Algeria, different installed off-grid systems in Algeria, the existing policies, and regulatory framework in the energy, Agriculture and ICTs sector in Algeria. Moreover the Algeria's agenda by 2030 and discussion, questionnaire and interviews from farmers in study locations. Company's representatives, an expert in energy transformations, policymaker and regulator, SKTM (Shariket Kahraba wa Taket Moutadjadida) and MicroEnergy International GmbH (MEI) representatives.

Reviewing document such the Intended Nationally Determined Contribution INDC-Algeria in 2015 will help the researcher to obtain information about the willing and the ambition of Algerian government to mitigate Green gas emissions through the adaptation measures to adopt the impact of climate change in different sector strategies (agriculture, public health, transport). This document will show the planning and institutional framework for implementation between 2016 and 2020 under the climate change committee.

The National Program to Develop Renewable Energies and Energy Efficiency in 2011 and the Algerian roadmap 2024 are other key documents that shows Algeria's plan to expand the usage of renewable energies and diversification of the energy sector.the research will contribute to analyse the techno-economic performance of the system based on the data collected from real implemented projects.

ATLAS.ti software will be used in a qualitative method to analyse collected data documents, interviews, questionnaires and video recording.

3.6 Study fieldwork strategies

Area (wilayas)

Researchers study populations when they examine all the entities they wish to investigate (Otzen et Manterola 2017). A research objective stipulates which objects, places, or people will be included in the study based on their relevance to the study's objectives.

In this research, the population that has been addressed is all the agriculture actors, farmers, institutions, and agencies in the study region (Biskra and Eloued). The study is focused on assessing the contribution of renewable energies systems in the agriculture sector to promote energy transformation in Algeria. Agriculture chambers, local agriculture agencies and institutions, farmers, private sector and local communities, and investors are the critical stakeholders that will help to obtain the needed data and undertake the research questions.

3.7 Investigative units (institutions)

The primary units of analysis and investigation in this research are the farmers, the chamber of agriculture, and governmental agencies in Biskra and Eloued that assist the agriculture sector in this region. Data collected from investors who are from different wilayas and have been found in Biskra where they are involved in agriculture business, furthermore the local government representatives and head of the chamber of agriculture in two wilayas, Biskra and Eloued.

3.8 Participants

In this study, purposive of sampling was used to select participants. This non-probability sampling technique is appropriate for this research since information is gathered from only those who are involved in farming and agriculture concerns. In addition, the farmers provide sustainable energy issues and ICTs and thus have the in-depth knowledge needed to answer the research questions. During an initial data collection and snowballing phase, a preliminary literature search was conducted to select participants.

firstly, a literature review was conducted to identify the actors involved in energy sources agriculture activities in Biskra and Eloued. A review of the wilayas and local governments that are currently involved in sustainable agriculture was also conducted, emphasizing institutional policy documents and strategies in energy, Agriculture, and ICTs. Next, a field visit was conducted to the chamber of agriculture in biskra and Eloued, where they provided us with the list of the agriculture productions and regions that have high annual productions. Additionally to the literature review, this list helped the researcher to understand regions that are most in need of energy and gave him an overview of the other parameters, which include (energy consumption and water use). However, all this information was helpful in the process of analysis.

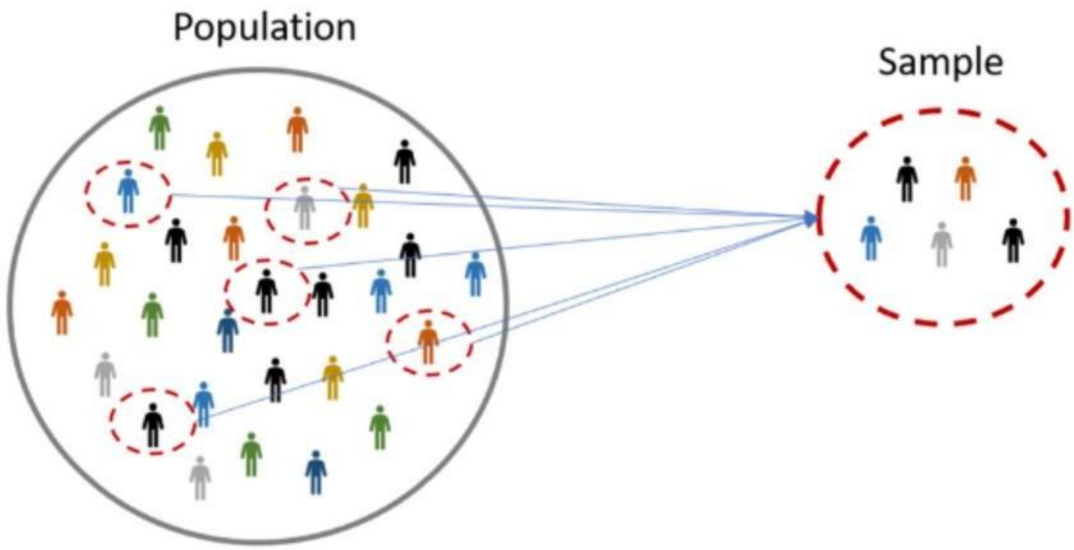


FIGURE 15 FIGURE. PURPOSIVE SAMPLING.(SAYEM 2020).

Types of data

Both primary and secondary sources of data (Rabianski 2003) were used in the study. Most of the data were collected through interviews from all sources mentioned before. Primary were obtained from interviewing the leading actor (farmers). Interviews cover all agriculture practices, including financing, laws and regulations, and land ownership. To obtain the secondary data, the researcher used published documents and unpublished papers, including government reports (Algeria's roadmaps, Algerian energy program, and targets 2030) and other studies and works. The researcher analyzed the current state of two regions to identify possible gaps that have resulted in Renewable energy systems, agriculture activities, and ICTs.

3.9 Methods of data collection:

The choice of method depends on the data collection strategy, the type of variable, the desired precision and the point of collection, and the skills of the researcher. The relationships that exist between a variable, its origin, and the actual methods used for its collection can help in choosing the appropriate method. The main collection methods in the research are interviews and field observations, and through this method, the research seeks to obtain information on the attitudes, behaviours, and representations of one or more individuals in the field.(Gill et al. 2008)

The research of the current system went through many adjustments due to lack of access to the research areas, time, and resources. Ultimately, the research was done through interviews followed by a short literature review of a proposed method to organize the research.

The research used directive and no directive interviews. These mixed-methods allowed the researcher to announce the topic of the interview without asking direct questions. It gives the actors the freedom to organize their speech as they wish. The role of the investigator, in this case, is not to encourage informal speaking. On the contrary, it adopts a neutral position and facilitates the process of obtaining the correct answers. However, the researcher establishes a series of specific questions before going into the field. In order to scientifically compare the data, the researcher will ask the same questions to all the actors. The researchers used vocals and pictures to assimilate the huge and iterative information form the actors.

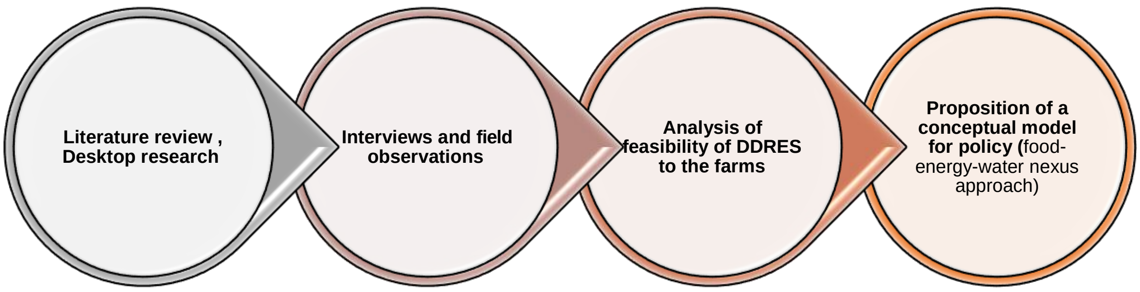


FIGURE 16 FIGURE: SIMPLIFIED SCHEMATIC OVERVIEW OF THE METHODOLOGICAL APPROACH (AUTHOR DESIGN)

TABLE 1 METHODS OF DATA COLLECTION

Type of Data	Method applied	Tools	characteristics	Results
Primary data	Interviews	Interviews questions and guidelines	Field and in presence interviews and questions to the actors and institutions selected for the research	• Data about the energy situation in biskra an Eloued • Agriculture practices • Water source and use • ICTs use
	Observations	Field observations	The research is involved in the research group, and he can observe the field and all helpful phenomena without asking the farmers	• Data on energy sources and systems used for energy access. • Irrigation systems • Agriculture technologies and methods

Secondary data	Desktop research and Documents reviewing	Desktop research, Document and papers	Desktop Evaluating and analysis	Data on the biskra and eloued, the potential of grounded water, existing renewable no-renewable projects in the area

3.10 Qualitative Analysis of Observations:

Observing the energy sources and the energy applications, which methods are using for the irrigation systems, water sources and management. Farming process in open field or green houses, type of green houses.

3.11 Qualitative Analysis of Interviews

The interviews were analysed for each region to describe the farming process and its framework, with special focus on profitability for the farmer and sustainability, as well as on opportunities to remove several barriers using the proposed system.

The questionnaire of the interview covers the following information:

- Institutional policies, regulations and strategies
- Farm description (Land owners, access to resources and site descriptions)
- Farming process (General information about planting (distance, depth), machinery, Seed and crop cycles)
- Energy use (Energy management, Energy sources)
- Water use (water management, water sources)
- Irrigation systems, methods, quantity and timing.
- Harvesting (method, time)
- Funds and subsidies
- Costs
- Markets and commercialization
- Experiences of farmers (general experiences, challenges and barriers).

FIGURE 17 DATA COLLECTION (AGRICULTURE CHAMBER IN BISKRA)

3.12 Qualitative analysis of document:

Atlast.ti and Excel, two softwares have been used to analyse the collected data from the field and present them in tables and graphics however, a content analysis technique was used to describe the study's descriptive aspects.

3.13 The nexus approach:

Nexus permits the analysis of interconnections between Energy, water and food sectors, enabling positive synergies and managing trade-offs effectively, In this research, the nexus approach will be used to analyse the challenges in the agriculture sector and look at the interlink between energy, water and food to help the research to addresses these challenges and recommend the best practises that can develop the farming process, save energy, save water waste and therefore promote the energy transformation and meet the Algerians targets

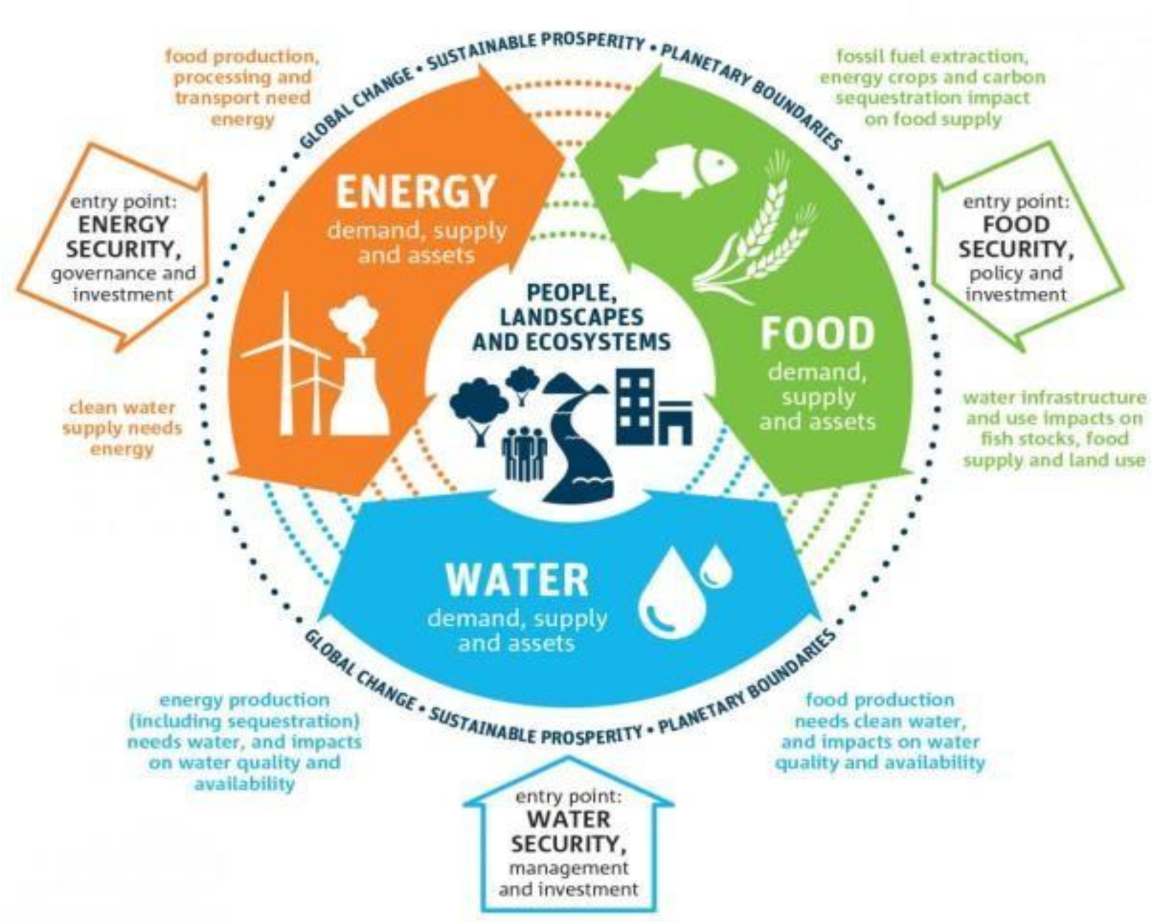


FIGURE 18 THE FOOD-ENERGY-WATER NEXUS, WITH SOME OF THE LINKS BETWEEN EACH FEATURE IDENTIFIED AND EXPLAINED. SOURCE: IWA, 2018. SUSTAINABLE DEVELOPMENT: THE WATER-ENERGY-FOOD NEXUS

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3.14 Ethical considerations

Local communities (farmers) in the 2 regions, local institutions and all actors are aware and informed that all collected data is for research purposes and academic work As well, respondents' confidentiality and privacy were respected and maintained.

Chapter 4

Results and discussions

4.1 Introduction

The research results and the analyzed collected data from the field will be present in this chapter, following the research objectives. Accordingly, this chapter starts by giving an overview of the status of agriculture in Biskra and Eloued, identifying the agriculture practices in the area. Determine the energy and ICT needs of Algerian farmers and study the adaptation of DDRES to farms in Algeria. This chapter will discuss lessons learned from countries to help the researcher to compare and adapt the operational framework of DDRES in Algeria.

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

Overview of farmer characteristics (Socio-Demographic)

In order to provide adequate responses concerning the farming process under study, socio-demographic characteristics of farmers such a gender, ages, occupation, and education statutes and levels, farmers are crucial in data field analysis.

With the study of the respondent, 100% of farmers interviewed are male (30). These farmers are considered the owners of farms and the agriculture business. However, the participation of women is meager in the area of study, which can be more focused on farming activities. This information was confirmed in the field by respondents.

Biskra and elOued, like the other wilayas in Algeria, have an excellent potential of youth population engaging in the agriculture business and farming; therefore, most of the respondents were between 25-45. This youthful potential is a crucial driver to meet the Algerian roadmap in raising agriculture incomes and helping youth create agriculture businesses.

Interviews results unveiled that about (80%. N=24) of the respondents have a primary level of education. Therefore, a low level of education can affect the use of efficient energy.

The major activities is farming. This can highly increase the employment rate, create jobs, and improve the standard of living, well-being, and health in the area.

4.3 Institutional policies, regulations and strategies:

Agriculture in algeria is directly or indirectly influenced by the lower levels of government. The country is divided into wilayas, dairas and municipalities, each region has its own responsible starting from the wali in wilayas, chief or responsible for dairas and the mayor in the municipalities.

Farms can be registered with the Chamber of Agriculture of their respective Wilaya. Registration is not mandatory but Most of the farmers do register and receive a card to have the access to subsidies and chemical fertilizer except those who think they can afford the expenses and they don't the need the support of the government in this area.

As part of its effort to limit imports and increase self-sufficiency and ensure food security, the Algerian government seeks to develop the agricultural economic sector by developing production practises and productivity.

The government has deployed a financial support program to help and give subsidies starting by making discount on products, 25% on fertilizers, 20-30 on machinery and 20-30% discounts on irrigation systems. In addition, the government has constructed a financial program in the area of growing and storing potatoes" Le Système de régulation des produits agricoles de large consommation (SYRPALAC)" The Regulatory System for Agricultural Products of Large Consumption (SYRPALAC) the aim of this program is to ensure the supply of potatoes in scarcity and shortage periods as part of the overall objective; food security plan.

The main measures adopted relate to subsidies granted to a number of basic products (bread, milk, sugar and edible oils), the organization of a system of regulation of basic products (SYRPALAC), support for basic sectors (wheat and milk) via production or processing aid, and finally direct food aid.

The farmers can benefit from the funding program only if they declare the quantity and the location of stored potatoes to the National Interprofessional Office of Vegetables and Meat (ONILEV) which they are not allowed later on to sell it without an authorization for the organisation. Furthermore, the government also support financially seeds production in order to encourage farmers and help them with an organized program from the National Center for Seed Control and Certification (CNCC) to control planting and seeds quality. Therefore farmers are obligated to declare the ministry of agriculture before starting the farming activity. Then CNCC check the sanitary and plotting location.

4.4 Governmental loans:

Bank of Agriculture and Rural Development (BADR) is the only institution providing loans to creditworthy farmers and farms in large scale. So this loans is giving to help them to expand their business. Two types of loans are available from BADR which were initiated by the Ministry of Agriculture. An operating loan is used to purchase inputs, while an investment loan is used to secure investments. Both are only offered to creditworthy farmers.

4.5 Crop production process and harvesting:

Tomatoes production is different from the potatoes, farmers in Biskra use greenhouses to produce tomatoes which allow them to stay longer about 6 to 9 months in the production process. However, late spring and early summer are the best periods for farmers to plant their seeds. In ElOued, the production of potatoes has two preferable periods, 1st season starts from January, ends in April and the 2nd season starts from September, ends in November.Tomatoes and potatoes can be produced in open fields and green houses, however, farmers prefers green houses for tomatoes and open pivot field for tomatoes.

FIGURE 19 PRODUCING TOMATOES IN GREEN HOUSES (BISKRA)

FIGURE 20 PRODUCING POTATOES IN OPEN CIRCULAR OR PIVOT SYSTEMS

TABLE 2 THE PRODUCTION SCALE (PIVOT =0.9)

Region	Small scale	Mid scalle	Large scalle
Eloued	1-2 pivots	10-20 pivots	20-70 pivots

In the planting process, the farmers use different machines (tractors, planting machines, irrigation systems) while harvesting by hand is very common.

4.6 Farm description (Landowners, access to resources, and site descriptions)

In Algeria, the government owns the lands, opening them to people to rent them for a long or short period. For example, El Oued is part of the Saharan side of Algeria. The government encourages farmers to use it for agriculture activities by giving it for free considering all costs and efforts given by the farmers to make the Saharan land functional farm because of the climate challenges; dune, wind ….etc the minimum period to own the land is after five years of utilization. Only a few posts require investment, such as the leveling of soil, installing wind protection, and irrigation systems. Farming on a large scale requires specialized machinery. At the same time, small-scale producers use classic methods (by hand). Still, they use tractors for soil preparation whether they own them, rent them, or borrow them. However, throughout the growing season, a tractor is not essential since the soil is very loose.

4.7 Farming process (General information about planting (distance, depth), machinery, Seed and crop cycles, labor)

The farmers prepare the land before starting the farming process by borrowing an excavator to remove sand and dune and trace the area for the pivots. Apart from that, they use different equipment for other farming phases; the tractor, pesticides devices pivot installation, pumps. etc. However, labor is needed because farmers still rely on working by hand for a few activities; for planting and harvesting, farmers hire 20 workers to work on one pivot (0.9ha), which takes 4 hours to plan. One worker costs farmers 1300 DA per day.

The cycle of potatoes production is 2-3 years at the same field, each year use the field in two seasons, for the tomatoes, Can take longer inside the greenhouses as long as they keep irrigating. Farmers in Eloued and Biskra apply organic fertilizers and pesticides transported from the North of Algeria, costing around 12,000,000DA per ton.

FIGURE 21 HARVESTING IN ELOUED

4.8 Water and energy use on farmers:

Irrigation management:

The potatoes fields are irrigated every day because El Oued has a desert climate and sandy soil, which drains exceptionally well. The 1st season (Jan to April) goes for 6 to 8 hours per day and the 2nd season goes for 16 -18 hours.

The farmer starts the irrigation system in the early evening from 6 pm to 11 am to avoid high temperatures.

Farmers use a center pivot irrigation system in potatoes irrigation, circular plots ranging in size from 0.5 to 1.3 ha. The system is a diesel motor having long metal arms and nozzles on top of the arms. The water circulates in high pressure and goes out in a mist. Figure 22

The tomatoes greenhouses are irrigated using drip irrigation, where it takes three up to 4 hours to irrigate one greenhouse. Water and nutrients are delivered to the field in pipes called "drip system lines" containing smaller units called "drip systems." Each drip system emits drops containing water and fertilizer, which allows a uniform application of water and nutrients directly to the root zone of each plant over an entire field. Farmers consider Drip irrigation the most efficient water and nutrient delivery system for growing tomatoes. It delivers water and nutrients directly to the plant's root zone, in the right amount, at the right time, so that each plant gets the exact amount of quantity amount that it needs, at the right time, to thrive optimally. Farmers can achieve better yields with drip irrigation while saving water, fertilizers, energy, and even crop protection products.

FIGURE 22 CENTRE PIVOT IRRIGATION SYSTEM

FIGURE 23 DRIP IRRIGATION SYSTEM

Several farmers have experience with drip irrigation, but it has so far shown to be unprofitable due to the increased labor required. Pivot irrigation is an easy and simple device to establish and use but it does require maintenance to keep it from leaking.

Electricity expenses are high between 5 and 21 PM, thus farmers tend to water theirs crops constantly before and after that period. The crop needs huge quantity of water and will easily wilt if there are any delays or less watering time that's why famers prefer to irrigate in nights and in less heat times of the day.

Welts and water tanks are the source of water for farmers, however, the cost of having a welt depends on area (Biskra and Eloued). Aquifers or grounded water has different level starting from the lowest 10-50 depth m in eloued, 50 to 70 m depth in biskra, the medium 180-250 m depth, 300 to 400 m depth, and highest level is up to 1000 m depth where only the government arrives at that level because of the high costs (12000 dz per meter).

4.9 Challenges of agriculture production with the WEF nexus approach:

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.

4.10 Potential of DDRES in addressing agriculture challenges within the WEF nexus

Energy:

Access to clean, sustainable and modern energy allows farmers and agriculture business to increase production and productivity, it helps famers who are living far from the national electric grid and in villages to reduce cost causing from the use of diesel generators.

DDRES introduce renewable energy systems based on solar energy to the agriculture sector where Integration of renewable energy systems succeeded to remove all the challenges related to energy supply in many case of study in North African (Ben Jebli et Ben Youssef 2017).however, lack of policy and finance programs prevented many countries to integrated and deploy RE systems.

In Algeria, most of the farmers show big interests and willingness to deploy renewable energy systems and reduce costs causing from diesel generators, however, a remarkable lack of awareness about the profitability of integration of RE.

The Algerian government has deployed an agenda to increase the share of renewable energy and reduce dependency on the fossil fuels by 2030 (27 % RE share in total electricity production).

Water

Water scarcity, saving clean water and ground, drinkable water is main priority of North African countries, however, innovative solutions that must address this challenges are required to solve this problem that can be worse with the climate change dilemma.

Most of farmers are looking for solutions to their labour dependency in the irrigation periods and the leakages that are facing with the classic irrigations systems.

DDRES is bringing new concepts of irrigation systems that is able to manage the watering systems and reduce water wastes by provide high performance to the irrigation process and provide the exact amount of water needed in growing crops, the solution may also have also quick and real response to any types of leakages, this will lead to reduce the energy costs and the energy bills. (Dhehibi et al. 2020).

ICT

The adoption of ICT became a necessity to agriculture production, it brings innovation methods to develop the farming process and farmers can have relevant information and real time accurate services.

Fear of high costs from the farmers and a remarkable lack of awareness about the facilities that help the farmers to increase their productivities and raise their incomes.

The deployment of DDRES help the farmers to manage high range of risks in the farming process, it establish a bridge between them and the market which will make more transparent and its increase the value chain of agriculture production.

The Algerian government has encouraged the new agribusiness to start introduce the concept of digitalization and provide digital data in order to help the revolutionize the agriculture sector.

4.11 Summary of potential contribution and responsiveness of DDRES in addressing agriculture challenges with lesson learned from case of studies in North Africa (Tunisia).

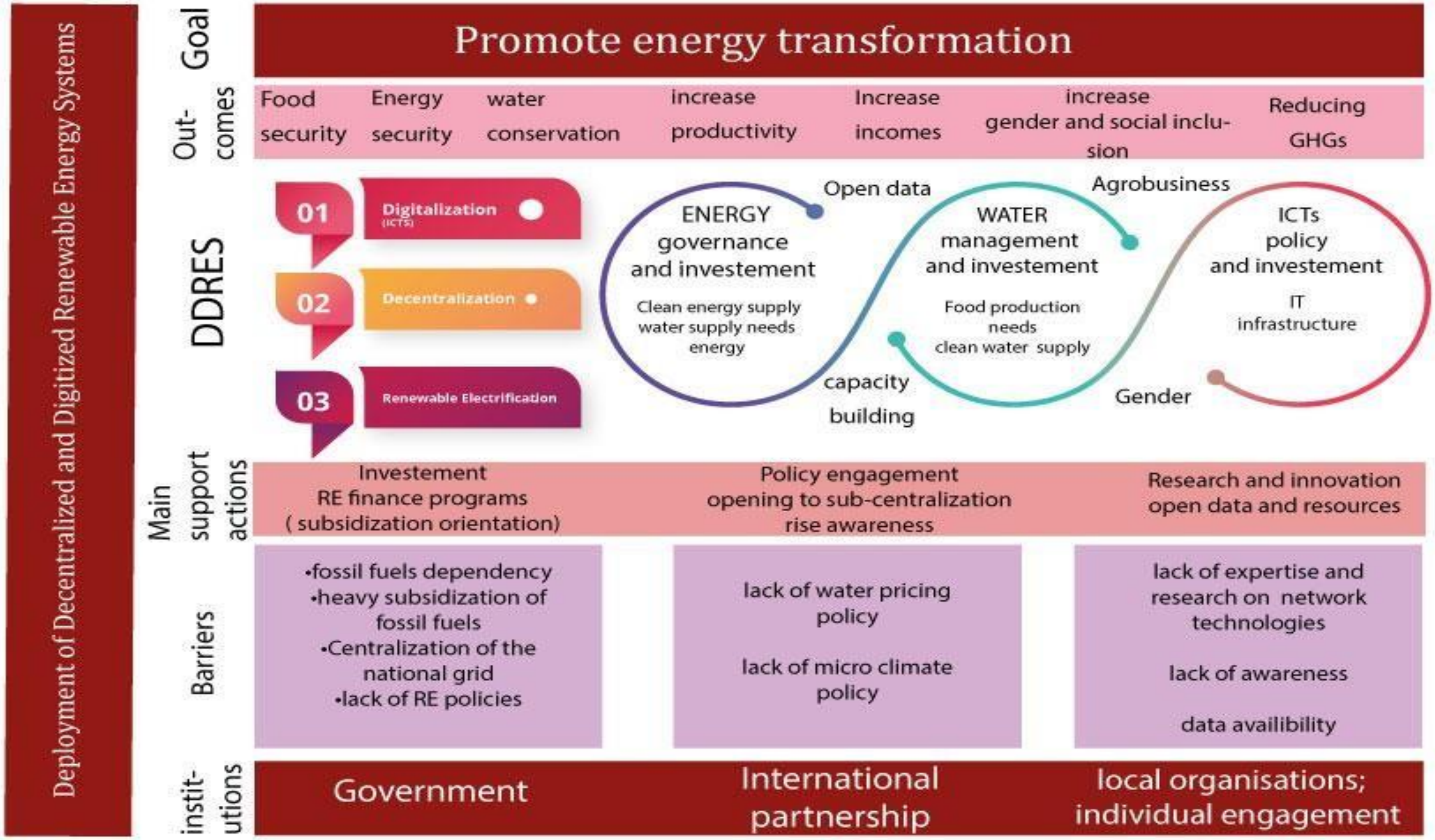
WEF	Challenges and barriers	The potential Contribution of DDRES
Energy	• The use of diesel motors in different farming process; planting, fertilization devices, irrigation systems and harvesting, Pumping water from welts. • Leak in Diesel motors and require a significant amount of maintenance	• Deployment of REs; - low running costs - long life; - clean energy - Reduce Greenhouse gas emissions. • Decentralized solar energy systems to increase access to energy and supply farms far from the national grids. • Energy efficiency audits and low

	• 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). • Transportation of fuel (diesel) costs and road challenges (Saharan roads).	maintenances services • Solar pumping • Reduce dependency on fossil fuels • Reduce the energy cost and energy bills • Solar lightings with batteries. • Decentralized (no need of transportation of fuels or electricity. • Increase energy supply will lead to increase productivity and incomes. • Introduction to developed smart devices (IOT systems, sensors, smart meters). • In line with the Algerian government to promote energy transformation and raise incomes from The agriculture sector.

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	• Smart agriculture devices and sensors that can conserve water waste by providing real time data and services. • Autonomous and reduce useless dependency on labour. • Water management, reduce energy and costs. • Solar pumping and water tanks.
FOOD	• Over production • Products and crop wastes : • Lack of storage chambers • Lack of cooling chambers	• Production management and predictable productivity.

	• Lack of ventilations • Low commercialisations programs and markets.	• Increase food security
ICT		• Real time prevention from risks (early warning systems) • Efficient and reliable data. • Transparent markets • Sustainable environment • Monitoring access • Climate smart solutions

4.12 Operational framework of DDRES in Algeria



4.13 CONCLUSION AND RECOMMENDATION

Conclusion

The objective of this research were to identify potential contribution of digitized decentralized renewable energy systems as well as to understand best agriculture activities and energy and agriculture and ICT strategies in Algeria, all key findings indicate renewable energies and IOT facilities are well accepted in farms and there huge opportunities to deploy DDRES which can help to solve all challenges in farms including energy use, water use and ICTs. However, fossil fuel subsidies lack of Renewable finances, research and innovation and lack of RE strategies remain huge concerns to farmers who are willing develop the agriculture sector and expand their agriculture business and to farmers who are willing to replace their diesel generators by solar panels . The study findings and all the analysis confirm the starting hypothesis of Integration of DDRES in the agriculture.this study unveils the potential contribution of DDRES to remove many challenges that block the road towards energy transformation in Algeria, It shows how farming process can be more energy efficient, affordable, less energy waste, less water waste and innovative using the recent technologies. Relevant lesson learned from case of studies in smart Agriculture determine the contribution of digitized and decentralized in new approach, Water-Energy-Food Nexus to support Food Security and Sustainable Agriculture.

Recommendation for further researchers

In light with this research, further recommendations to ensure the responsiveness of DDRES in the agriculture sector is to study the implementation of the operational framework of this study and looking at the feedbacks from the farmers in term of the responsiveness to the farmer’s needs (energy supply, clean water, income growth, increase productivity. to study youth and women engagement in agriculture business and opportunities to agriculture start-ups, to simulate the installation of DDRES, in off grid and on grid parameters. Finally, DDRES in agriculture practises for mitigation climate change.

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APPENDIX

Data collection,

The questionnaire of the interview covers the following information:

- Institutional policies, regulations and strategies
- Farm description (Land owners, access to resources and site descriptions)
- Farming process (General information about planting (distance, depth), machinery, Seed and crop cycles)
- Energy use (Energy management, Energy sources)

- Water use (water management, water sources)
- Irrigation systems, methods, quantity and timing.
- Harvesting (method, time)
- Funds and subsidies
- Costs
- Markets and commercialization
- Experiences of farmers (general experiences, challenges and barriers).

Plagiarism results is 7% using grammarly