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UTILIZATION OF RENEWABLE ENERGY SOURCES IN TUNISIA

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1. INTRODUCTION

This section outlines the focus of the respective study and mentions its significance and what it aims to achieve.

1.1 Overview of Tunisia's Energy Landscape

In the recent period, the worldwide movement towards sources of renewable energy has witnessed a notable acceleration as nations strive to diminish their ecological footprints and pivot to practices that are more enduring. Tunisia, positioned in North Africa and blessed with copious solar and wind potentials, is advancing along this path too. The presence of renewable power options within Tunisia offers an exceptional chance to reduce reliance on fossil fuels while reinforcing energy independency (Brand–Missaoui, 2014).

The energy scenario in Tunisia offers a substantial chance to exploit renewable energy sources to meet increasing energy needs and foster sustainable growth. Despite hurdles such as development in the private sector and deficiencies in workforce skills, Tunisia is well-placed to use its rich solar and wind potentials for socio-economic betterment. As underscored by the 2022 analysis of Europe's economy, challenges like foreign competition and market vulnerabilities affect Tunisia's production industries, calling for strategic measures to boost profits and decrease risks. Through benchmarking against Portuguese firms regarding market dangers and financial health, critical perspectives can be extracted that could shape Tunisia's energy governance policies and investment tactics. Focusing on improving management practices, achieving sustainable expansion, and enhancing returns on investments will guide Tunisia toward intensified use of renewable energies while strengthening economic robustness amid worldwide challenges.

1.2 Importance of Renewable Energy for Tunisia's Future

For Tunisia, the shift towards renewable energy sources like solar and wind power is paramount for its sustenance and future growth. The nation's overreliance on fossil fuels imported from abroad makes it imperative to move towards renewables to ensure energy security and lessen the reliance on the unpredictable oil markets (Jbir & Zouari-Ghorbel, 2009). Furthermore, by channelling investments into renewable energy technologies, Tunisia positions itself to counteract climate change effects through diminished greenhouse gas emissions and fostering a sustainable mix of energy sources. This transition not only promises environmental benefits but also opens up economic avenues by generating employment

opportunities in the burgeoning sector of green energy and drawing capital towards projects based on renewables. By exploiting its significant potential in solar and wind resources, Tunisia stands at the threshold of cultivating an eco-friendly and enduringly viable pathway for its energy needs, thereby enhancing both its economic brunt and ecological fortitude (Akermi–Triki, 2017).

1.3 Objectives of the research

This thesis evaluates Tunisia's existing usage of renewable energy, identifies possible advantages and limitations, and proposes policymakers' options for improving renewable energy integration into the country's energy framework.

The study will provide a detailed analysis of the potential and challenges connected with adopting renewable energy sources in Tunisia, including government initiatives, technology advancement and investments, and environmental and economic implications. This project will contribute to the current knowledge of renewable energy deployment in Tunisia by conducting a detailed assessment of relevant literature and data analysis, as well as providing insightful direction for future research and policy development in the region.

2. LITERATURE REVIEW

2.1 Historical Context of Energy Use in Tunisia

2.1.1 Traditional Energy Sources and Usage Patterns

In Tunisia, the prevalent use of conventional energy types and consumption habits significantly outlines the nation's energy framework and plays a crucial role in steering towards greener energy alternatives. Traditionally, fossil fuels have been at the core of meeting Tunisia's power needs, with the rise in tourism greatly influencing how energy is consumed. The deployment of these age-old energy varieties has gone together with initiatives aimed at economic growth and social progress within Tunisian borders. Nonetheless, recent research (Jeffrey & Bleasdale, 2017) underscores an urgent call for diversifying power sources and adjusting to novel demands amidst hindrances like political upheavals and environmental shifts. This dependency on old-fashioned power methods is further complicated by scarce reliable weather data critical for informed decision-making (Acheampong et al., 2021), highlighting the shift towards renewable energies as vital for bolstering climate adaptability and enhancing output efficiency. By leaning into renewables, Tunisia stands not only to alter entrenched patterns of power consumption but also promote enduring ecological practices while reducing vulnerability to climatic disturbances for a steadier future in terms of its energetic prospects.

2.1.2 Shifts In Energy Policy And Infrastructure

The Tunisian Ministry of Energy, Mines, and the Energy Transition (MEMTE) oversees managing Tunisia's electricity sector since March 2020. MEMTE oversees electricity infrastructure, national policy implementation, energy efficiency and renewable energy planning.

However, Tunisia lacks an independent regulator, and MEMTE monitors supply and demand with specific directorates responsible for different energy sector activities:

- The Directorate General for Electricity and Renewable Energy implements state policies in the renewable energy sector and reviews requests for private renewable energy production and self-consumption.
- The Directorate General for Energy from Hydrocarbon sources handles state policies related to the hydrocarbon sector. The Directorate General for overseeing Strategy and

Co-ordination develops programs, strategies, and policies for the energy sector, focusing on resource management.

- The Directorate General for Manufacturing Industries implements government policies, including creating an enabling environment for the promotion of the renewables industry.

Moreover, STEG Tunisian Company of Electricity and Gas (Société Tunisienne d'Electricité et du Gaz), a state-owned company, held a monopoly on electricity generation, transmission, and distribution in Tunisia from 1962 to 1996. It now manages the production, transmission, and distribution of electricity and gas, including renewable energy projects. Tunisian National Agency for Energy Conservation (ANME), a public institution under the Ministry of Energy, focuses on promoting energy efficiency measures and renewable energy deployment. ANME is responsible for proposing regulations, managing the Energy Transition Fund, specific renewable energy programs, and awareness and training campaigns.

Amidst the intensifying global focus on sustainability and efforts to combat climate change, Tunisia has witnessed marked transformations in its energy strategies and physical systems to bolster the adoption of green energy sources. The nation is striving towards lofty aspirations for diminishing its ecological footprint while improving the reliability of its energy supplies through a broader spectrum of energy types. Official actions have involved establishing feed-in tariffs, fiscal benefits, and strategic frameworks aimed at fostering investments in green energy ventures (Saadaoui–Chtourou, 2022). Additionally, there's been an upsurge in creating infrastructure for renewable energies like solar installations and wind turbines, leveraging Tunisia's vast reserves of natural wealth. These alterations in both policy and physical infrastructure are pivotal moves towards securing a greener, more eco-friendly realm within Tunisia's energy sphere. As actions to prioritize green power persist, anticipations rise for augmenting national grid stability alongside contributing valiantly to worldwide initiatives against climate upheaval (Akermi–Triki, 2017).

2.1.3 Early Initiatives in Renewable Energy

Tunisia's advancement in renewable energy sources showcases a complex strategy shaped by political, geographical, and fiscal elements. In its history, STEG has been the primary actor in Tunisia's energy framework, originally showing reluctance towards adopting renewable technologies due to its established dominance and historic validity. Nonetheless, facing increasing pressures on national energy autonomy in the early 21st century prompted Tunisian

authorities to advocate for renewable solutions more vigorously than before, although not as rapidly as hoped. The Tunisian revolution brought about major shifts in authority structures, facilitating new partnerships and critiques against STEG which led to the launch of varied projects focused on green energy. These efforts are aimed at not only addressing rising energy needs sustainably but also have the potential to redefine economic ties with Europe through engaging with abundant local solar and wind capacities notably within regional cooperation frameworks (Attig-Bahar et al., 2021).

2.2 Tunisia's Energy Demand and Supply

2.2.1 Current Energy Consumption Statistics

Statistics on the usage of energy presently occupy a central position in grasping the nuances of how energy is expended and transitioning towards renewable means, with a spotlight on places like Tunisia. The deep dive into analysing energy consumption's critical assessment in both progressing and advanced nations, as underscored within (Zhuang et al., 2022), reveals insights significant to the worldwide scene of energy. Considerations such as alterations in demand for energy, patterns across various sectors regarding energy loads, and moving towards sources of renewable power including solar and wind energies are paramount. Furthermore, ties between usage levels of energy and indicators economic, elaborated upon in (Zhuang et al., 2022), highlight the intricate association amidst transitions in energy forms, output economically grossed total-wise (GDP), along enduring networks for food supply sustainably managed. Grasping these stats not merely illuminates upon structuring present-day of energetic type but as well manoeuvres policymakers plus stakeholders within Tunisia strategically to exploit resources powered by renewal effectively aiming at futures sustained betterment-wise. By diving further into data on existing consumptive activities energetically speaking, Tunisia has the ability to establish quadrants ahead efficiently channelling fresh energies source-wise, fostering ecosystems energy, and environmentally friendly imitations.

2.2.2 Projections of Future Energy Needs

Estimations for Tunisia's future requirements in terms of energy point towards a marked escalation because of increasing inhabitants, city expansion, and the growth of industries. The nation's dependency on imported non-renewable energy sources underlines an urgent requirement to broaden its energy palette and shift to renewable alternatives. The national authorities have set lofty aspirations for incorporating renewable energies, with objectives to

hit 30% electricity production from such sources by the year 2030. Pivotal investments in technologies like solar power, wind turbines, and biomass are vital for attaining these targets while also maintaining the country's energy self-sufficiency. By exploiting Tunisia's significant potential for solar power alongside capitalizing on its advantageous position for generating wind power, it is possible to lessen reliance on the uncertain market of fossil fuels while aiding worldwide endeavours against climate alterations. Strategic foresight and cooperation among public entities, commercial stakeholders, and global allies will play a critical role in making these estimations a reality thereby paving the path toward an enduring energetically autonomous future within Tunisia (Alimi–Azar, 2021).

2.2.3 The Balance Between Domestic Production and Imports

In the realm of harnessing renewable energy sources within Tunisia, it is imperative to strike an intricate equilibrium between internal production and external imports for ensuring a sustainable energy framework (Dridi, 2021). The in-house generation of renewable power could bolster national autonomy in energy matters and diminish dependence on fossil fuel imports. However, deliberate acquisitions of sophisticated technologies and specialized know-how are deemed essential to expedite the shift towards greener energies. Positioned advantageously geographically, Tunisia is ripe with possibilities for generating solar and wind energies; nonetheless, pouring investments into infrastructure and technological advancements is vital to exploit these natural assets effectively. Engaging in partnerships at the global level might serve as a conduit for the exchange of technology and insights, thereby enhancing indigenous capacities in producing renewable energies. Through maintaining a harmonious balance between local output and calculated import strategies, Tunisia stands to refine its segment of renewable energies while charting a course towards an eco-friendlier and enduring future.

2.3 Government Policies on Renewable Energy

2.3.1 National Strategies and Action Plans

When crafting plans and strategies at the national level for deploying renewable energy resources in Tunisia, it's critical to acknowledge the dynamic between objectives related to climate and those aiming for sustainable growth. Insights gleaned from investigations into

how select Sustainable Development Goals (SDGs) interact with one another in Nepal (Prashamsa Thapa et al., 2023) reveal that grasping the connections among adopting renewable energies, sustainable usage patterns, and actions toward climate is fundamental for crafting sound policies. Moreover, considering evaluations of Research and Development (R&D) activities focusing on renewable energy within Malaysia highlights how crucial directed R&D efforts are in pushing forward technologies related to renewable energy (Fairuz et al., 2020). Utilizing such knowledge, Tunisia has launched an energy transition process to address energy security challenges and volatile international energy prices. The process includes extensive consultations with key energy stakeholders from various institutions, public and private organizations, civil society, experts, financial organizations, and academia. The objective is to enhance energy security, preserve economic competitiveness, and safeguard the environment by re-evaluating production methods, processing techniques, and energy consumption. The shift to clean energy relies on a strategy centred on enhancing energy efficiency and advancing renewable energy sources (Banacloche et al., 2020).

Adopting this comprehensive stance aids in weaving renewable energy solutions into Tunisia’s broader energetic blueprint, setting a course towards an infrastructure that is both more robust against challenges and conducive to environmental sustainability.

2.3.2 Incentives and Subsidies for Renewable Energy Projects

Within the frame of employing sources of renewable energy in Tunisia, grasping the importance of encouragements and financial support for projects focusing on renewable energy is critical. By analysing comparisons amongst countries such as Nigeria, China, Russia and the USA, as underscored in (Idoko et al., 2024) and (Ganieva et al., 2023), it becomes clear that mechanisms provided by the government play a vital role in propelling growth within sectors dedicated to renewable energy. These include regulations set by authorities, financial aids, loans with special preferences, and tax benefits designed to foster low-emission initiatives across different economic domains.

In Tunisia's case, creating incentives and subsidies that are customized for its unique scenario could significantly contribute to enhancing the general acceptance of technologies based on renewable energy. Through examining practices of excellence internationally and moulding them to fit Tunisia's distinct demands and hurdles, decision-makers can amplify their backing for ventures focused on renewable energy. This effort will decisively push forward Tunisia's

shift towards an ecosystem powered by sustainable forms of energy (Saadaoui–Chtourou, 2022).

2.3.3 Regulatory Frameworks and Legislation

Legislative frameworks and regulatory measures are essential for enhancing the use of renewable energy resources in Tunisia. The government of Tunisia has taken remarkable steps to establish laws and regulations that encourage the implementation of technologies based on renewable energy. Tunisia is the most advanced country in North Africa in terms of institutional and regulatory instruments for the promotion of renewable energy (RE). In fact, since the early 1980s, Tunisia has put in place an evolving regulatory and institutional framework for energy efficiency and RE promotion (for example **Law n° 85-48** related to the promotion of RE and **Law n° 85-8** related to energy saving) (Omri, 2014):

- **Law No. 2004-72** Energy Control: paves the way for Tunisia to move to a higher level in terms of the use of renewable energies and, first of all, solar and wind energy, thus enabling further legal actions to advance the production of eco-friendly energy.
- **Law No. 2009-7**: authorises self-production of electricity from renewable energy sources through Grid-connected solar PV systems. Grid connected solar PV has mainly been implemented through the "PROSOL électrique programme" initiated in May 2010 by ANME and STEG.
- **Law No. 2009-2773** laying down the conditions for the transport of electricity produced from renewable energies and the sale of its surpluses to the Tunisian Electricity and Gas Company: the establishment or grouping of establishments operating in the industrial, agricultural or tertiary sectors and producing electricity from renewable energies for its own consumption, has the right to transport the electricity thus produced by the national power grid to its points of consumption and the right of selling the surpluses of electricity exclusively to STEG within the limits of 30% of the annual electricity produced. These limits may be exceeded for projects producing electricity from biomass provided that installed power does not exceed 15 megawatts per project.
- The transport of electricity and the sale of surpluses are carried out under a model contract approved by the energy supervisory authority on the basis of transport and sales rates established by decision of the Minister responsible for energy.

- **Law No. 2015-12** sets the framework for renewable energy proliferation, which includes electricity production from renewable energy to generate electricity, transport the generated electricity to other consumption points through the national grid, and sell the excess produced energy to STEG at fixed prices within the limits of the maximum rate. With that said the law introduced three new regulatory regimes: (i) self-generation/ consumption; (ii) independent power production for local consumption (concession and authorisation); and (iii) independent power production for export. The fixed prices are set by the Minister in charge of energy - in this case MEMTE - on opinion of the technical commission, with a contract subject to approval by MEMTE.
- Law No. 2015-12, however, was amended by **Law 2019-47** with adjustments to allow for corporate PPAs. This provides the right for companies adopting renewables for self-production to sell electricity to other consumers or companies with subscribed power greater than the threshold set by MEMTE electricity 30% and use the national grid network to transport electricity.

Moreover, the National Renewable Energy Action Plan (NREAP) seeks to boost renewable energies' contribution to Tunisia's total energy composition to 30% by 2030, showing its dedication towards environmental sustenance and ecological resilience. By shaping an encouraging legislative backdrop, Tunisia aspires to exploit its abundant renewable resources optimally and fulfil its objectives concerning sustainable power management efficiently.

2.4 Solar Energy Potential in Tunisia

Solar energy is the radiation from the Sun capable of producing heat, causing chemical reactions, or generating electricity (Ashok, 2024). Solar energy is commonly used for solar water heaters and house heating. The heat from solar ponds enables the production of chemicals, food, textiles, warm greenhouses, swimming pools, and livestock buildings. Cooking and providing a power source for electronic devices can also be achieved by using solar energy (Ashok, 2024). Solar radiation may also be converted directly into electricity by solar cells, or photovoltaic cells, or harnessed to cook food in specially designed solar ovens, which typically concentrate sunlight from over a wide area to a central point (Ashok, 2024).

2.4.1 Geographic and Climatic Advantages

Tunisia is graced with various geographical and meteorological strengths, positioning it as a prime spot for the engagement with sources of renewable energy. Its advantageous placement in North Africa offers abundant sunshine all year round, rendering solar energy a practical and enduring solution for power production. Moreover, Tunisia's lengthy shoreline presents opportunities for capturing wind power by constructing wind turbines along its coastal areas. These geographical attributes, alongside an overall dry climate, foster preferable conditions for implementing technologies based on renewable energies. In addition to this, Tunisia's dedication toward diminishing its dependence on fossil fuels and alleviating impacts related to climate alteration plays a critical role in emphasizing the need to capitalize on these geographical and climatic benefits for broad scale embrace of renewable energies. Therefore, exploiting solar and wind energies within Tunisia carries immense promise in altering its energetic framework towards sustainability over extended periods (Rekik–El Alimi, 2023).

2.4.2 Current Solar Energy Projects and Capacity

The adoption of green energy sources, especially solar power, is on the rise in Tunisia due to ongoing projects related to solar power and efforts to increase its capacity. Organizations like the World Bank and programs such as Mission Innovation are playing a key role in advancing solar energy development in less developed nations, including those situated in North Africa. With the cost-effectiveness of solar photovoltaic (PV) technology improving, Tunisia shows great promise for extensive solar initiatives. Moreover, given the region's optimal weather conditions for producing solar energy, tapping into this resource could play a critical role in achieving Tunisia’s objectives for renewable energy. Concentrating on effectively executing and overseeing these solar ventures can propel Tunisia toward greater self-sufficiency regarding energy needs reduces reliance on imported fuels ensures continuous improvement along sustainability lines which includes supporting economic advancement while safeguarding the environmental landscape (Rocher–Verdeil, 2019).

2.4.3 Future Prospects for Solar Energy Development

Prospects for the advancement of solar power present vast opportunities for Tunisia's initiatives in renewable energies. Studies that assess worldwide trends demonstrate how adopting technologies focused on photovoltaic solar systems and concentrating solar power

could greatly enhance capacity and production of energy (Alsharif et al., 2023). By the year 2060, it is projected that there will be a significant rise in the generation of solar energy, with an expected large share belonging to green solar output within the total renewable energy spectrum. Moreover, broadening the scope of generated solar energy may act as a crucial answer to navigating through challenges related to energy while improving both environmental sustainability and security regarding energy resources. At present, Tunisia utilizes a variety of sources for its energy needs, including forms of renewables; yet delving into advancements within the domain of solar technologies, as explored by research concerning potential developments within locales such as Cameroon and countries partaking in European Union activities, might create an avenue towards accomplishing an enhanced state of durability and protection concerning future supplies. Capitalizing on local potentials pertaining to sunlight exposure and committing wisely in infrastructures dedicated to harnessing sun-based power would enable Tunisia to amplify its efficacy relating usage patterns around renewably sourced energies.

2.5 Wind Energy Utilization

Wind energy is regarded as one of nature’s cleanest, safest, and most durable sources of energy among renewable energy sources (Tasnim et al. 2024).

Wind energy has become one of the fastest-growing renewable energy resources, accounting for 22% of the renewable energy generation worldwide (Almuni et al., 2020).

2.5.1 Assessment of Wind Resources in Tunisia

Evaluating wind potentials in Tunisia stands as a pivotal element for fruitfully capitalizing on sources of renewable energy within the nation. The geographical stance of Tunisia holds considerable prospects for generating wind power, particularly across its coastal areas and mountainous terrains. Numerous investigations have been carried out to appraise the nation's wind potentials, taking into account aspects like the speed of wind, its direction, and variability across different times. These evaluations are crucial in providing insights that aid in planning wind energy activities efficiently by identifying prime sites for establishing wind turbines and enhancing the production of energy. By exploiting its copious resources of wind, Tunisia aims at curtailing dependence on conventional fossil fuels, diminishing emissions contributing to carbon footprint, and advancing towards self-sufficiency in energy supply

(Alemzero et al., 2021). Persistent study and supervision over these resources are imperative to ensure seamless incorporation of wind energy into Tunisia's portfolio mix aimed at sustaining ecological balance while transitioning towards advances favouring an eco-friendly approach ahead.

2.5.2 Existing Wind Farms and Their Output

In Tunisia, the operational wind farms are pivotal in shifting the nation towards greener energy alternatives. The focus on both economic efficacy and functionality reveals that combining financial indicators with Data Envelopment Analysis (DEA) serves to evaluate the productivity and efficiency of companies managing these wind farms. By fine-tuning both inputs and outputs alongside employing benchmarking methods, it's feasible for these enterprises to uplift their performance while addressing a wider audience of stakeholders. Moreover, blending wind energy into the national grid can see improvements via spatial smoothing methods and by harnessing electrical storage solutions like plug-in hybrid electric vehicles (PHEVs). Through comprehensive generation management tactics, optimally integrating wind power at elevated electrical demand levels becomes achievable, boasting utilisation rates surpassing 65%. As Tunisia advances its commitment to renewable energies, capitalizing on current wind turbines and bolstering their efficiency through cutting-edge practices stand central to fostering sustainable energetic growth within the locale.

2.5.3 Challenges and Opportunities in Wind Energy Expansion

The pursuit of expanding wind energy in Tunisia unveils a multifaceted scenario for eco-friendly progress. The nation's geographical stance is inherently rich with prospects for exploiting wind as a sustainable source of power. Initiatives by authorities to boost investments in this domain, through measures like feed-in tariffs and fiscal deductions, are noteworthy. Yet, considerable hurdles loom large, such as the imperative for infrastructural enhancements, assimilation into the existing grid system, and educating a proficient workforce. Furthermore, the process is often bogged down by intricate regulatory structures and bureaucratic red tape that stifle the swift evolution of wind-powered enterprises. Notwithstanding these barriers, the advantages tied to bolstering wind energy within Tunisian borders are significant — spanning enhanced energy reliance, employment creation, and conservation of nature. Confronting these challenges with coherent strategies and cooperative

ventures positions Tunisia on a promising path towards leveraging wind energy growth to foster an environment-friendly and resilient energetic future (Attig-Bahar et al., 2021).

2.6 Biomass and Bioenergy Resources

Biomass energy is derived from organic materials such as plants, crop residues, and wood waste, which can be replenished through natural processes (Nguea & Fotio, 2024). The Global Status Report 2019 (REN21, 2019) indicated that biomass is a source of renewable energy that contributes to more than 6% of the world's energy supply and 55% of renewable energy (excluding traditional use of biomass) (IEA, 2021).

2.6.1 Types of Biomasses Available in Tunisia

In the nation of Tunisia, a plethora of biomass types are consistently accessible for generating energy. These sources of biomass encompass residues from agriculture, leftovers from the forestry sector, waste produced by animals, and refuse from municipal locales. Due to its vibrant agriculture industry, the country is awash with agricultural leftovers such as remnants from date palms, olive mash, and various crop detritus. Additionally, residual materials stemming from the processing of wood in industries and trimming activities related to trees add to Tunisia's array of biomass offerings. Waste emanating from domestic animals due to operations in livestock cultivation alongside collective urban waste adds more options for making use of biomass. Such varied biomatter acts as a sustainable and perpetually renewable source towards an energy solution within Tunisia that resonates with its pledge towards embracing renewable energy means for satisfying demand (Anvari et al., 2024). Tunisia has the potential to reduce carbon footprints by utilising domestic biotic resources and shifting away from reliance on fossil fuels. By prioritising environmental sustainability, the country can enhance security and energy capabilities and maintain a forward-thinking path.

2.6.2 Bioenergy Projects and Their Impact

Initiatives focused on bioenergy could significantly influence Tunisia's shift towards utilizing renewable energy forms. These efforts are pivotal in diminishing the nation's dependence on fossil fuels imported from abroad, thereby fostering a more enduring and diversified energy framework. The deployment of such bioenergy initiatives within Tunisia has yielded

encouraging outcomes, notably an upsurge in power production derived from biomass. Furthermore, these undertakings have propelled economic upliftment through job creation and invigoration of community economies. Nonetheless, it's imperative to meticulously assess the ecological ramifications tied to the propagation of bioenergy, especially concerning land allocation and the preservation of biological diversity. For the sustained viability of Tunisia's bioenergy ventures, enacting stringent regulations coupled with efficient oversight is essential. Balancing economic progression with ecological stewardship enables these projects to address critical energy requirements while contributing to climate change mitigation efforts effectively (Ben Abdessalam et al., 2023).

2.6.3 Sustainability of Biomass as A Renewable Resource

The endurance of biomass as a regenerative resource within Tunisia offers both advantages and obstacles for the nation's shift towards the adoption of renewable energy sources. Biomass, encompassing farm leftovers and organic refuse, holds the capability to furnish a dependable and adaptable power supply while aiding in waste management and the development of rural areas. Nevertheless, the prolonged durability of employing biomass hinges on effective management of resources, progress in technology, and ecological considerations. Recent inquiries have put an emphasis on the necessity for sustainable actions like proficient production of biomass, allocation of resources, and strategies for usage to maintain biomass as an enduring regenerative resource. With adequate backing from policies, investments into research plus development, along with involvement from communities, plays a pivotal role within Tunisia’s assortment of renewable energies contributing towards energy assurance as well viability environmentally (Banacloche, 2020).

2.7 Geothermal Energy Prospects

Among other renewable sources, geothermal energy is essential in providing a stable energy supply, allowing continuous electricity generation regardless of the weather conditions (Kubota et al., 2013). It has a less ecological effect as a source requiring less land (Li et al., 2015). Geothermal has a higher capacity factor of up to 96 % than other renewable systems (Lund, 2003) and lower emissions than coal and natural gas, making it a critical tool for nations’ zero carbon targets (Korucan et al., 2024).

2.7.1 Geothermal Resources in Tunisia

Employing geothermal assets in Tunisia reveals an encouraging prospect for the nation's renewable power sector. Despite Tunisia having concentrated on harnessing solar and wind powers, the existence of unexplored geothermal potentials proposes a versatile path to enrich the energy diversity (Chekir–Hassen, 2022). As observed in adjacent Eastern African nations such as Kenya and Ethiopia, geothermal potency has been validated as a dependable and perpetual powerhouse. The exploitation of both low and medium enthalpy geothermal resources could be uniquely beneficial for Tunisia, considering its geographic traits. By exploiting geothermally warmed waters at milder temperatures via economical drilling methods, not only could Tunisia diminish its dependability on traditional fossil fuels but also reinforce its power stability while enhancing the sustainability quotient of its energy framework. Integrating geothermal power into Tunisia’s array of renewable energies might serve a pivotal function toward forging a more durable and zero-emission energy scenario within the realm.

2.7.2 Exploration and Exploitation of Geothermal Energy

The pursuit of geothermal energy sources to enrich Tunisia's array of renewable energies holds considerable promise. The reliance on conventional fossil fuels brings about ecological predicaments, whereas geothermal potentials stand as a resilient alternative. Research conducted in Nigeria unveils the untapped capabilities within various districts for identifying thermal discrepancies ideal for drilling sites and regions apt for capturing heat essential for producing energy (Akpan et al., 2023). Furthermore, the development of supercritical geothermal resources, highlighted by Iceland's IDDP-2 initiative, illustrates the progress in technology and financial feasibility of exploiting high-grade geothermal power with minimized carbon dioxide outputs (Yu Wang et al., 2022). When melded into Tunisia’s agenda for renewable energies, delving into and utilizing these geothermal prospects is seen as a forward step towards a reliable supply of eco-friendly power. This aligns seamlessly with national ambitions to embrace an assortment of renewable energies to achieve its demand for energy in ways that are effective and kinder to our planet.

2.8 Hydropower and Marine Energy

Hydroelectricity is a renewable energy source that converts water into electricity through the use of turbines, generators, and convertors (Görtz et al., 2022). Hydroelectric plants convert potential energy into kinetic energy, turning turbines powered by water flowing into estuaries and falling into dams (Donbosco, 2022). Hydroelectricity refers to the process of generating electricity from water as the initial energy source (Spasenic et al., 2022).

Hydropower is a flexible, mature technology for power generation, and hydropower reservoirs (dams) can provide energy storage (Almuni et al., 2020).

2.8.1 Small-Scale Hydropower Plants

In Tunisia, the development of minor hydropower installations emerges as a promising path for augmenting the adoption of renewable energy resources. Learning from the experiences in nations such as Ukraine and Japan, where diminutive hydropower facilities have significantly contributed to enhancing energy security and sustainability, Tunisia might consider adopting analogous strategies to enrich its energy diversity. Although embarking on major hydroelectric projects could encounter obstacles related to environmental concerns and restrictions on location, petite hydropower plants offer suitable alternatives that exploit local aquatic resources without necessitating extensive infrastructure investments. Utilizing small streams and pre-existing water distribution mechanisms permits Tunisia to seize advantages of localized power generation, thus facilitating an upsurge in renewable energy integration at a grassroots level (Alnaqbi et al., 2022). By underscoring sustainable practices in energy usage along with community engagement, weaving small-scale hydroelectric stations into its framework resonates with Tunisia's ambition to broaden its spectrum of clean energies while diminishing dependence on conventional fossil fuels.

2.8.2 Potential for Marine Energy (Wave and Tidal)

Harnessing the power of the sea, specifically through wave and tidal energy, could be a key renewable resource for Tunisia. With its long shoreline on the Mediterranean Sea, Tunisia is in a prime position to exploit ocean waves and currents. Studies show that devices capturing marine current energy, like tidal stream turbines, are promising for producing sustainable power. Despite hurdles such as fluctuating energy flux density and varying speeds of currents, new technologies like diffuser augmented tidal stream turbines offer novel solutions to boost

power output. Additionally, due to their concentrated form, water-based energy sources can be cost-effective for human consumption. In light of a worldwide pivot towards renewable energies, Tunisia has an opportunity to diversify its energy portfolio and lessen its reliance on traditional fossil fuels by utilizing its plentiful marine resources. By embracing these vast marine energies at hand, Tunisia stands to push forward with its renewable objectives and play part in achieving an eco-friendlier future (Saadaoui–Chtourou, 2022).

2.8.3 Environmental and Economic Considerations

In Tunisia, the shift towards renewable energy sources is heavily influenced by both environmental and economic factors. The nation is on a path to adopting more sustainable energy options but must navigate the complexities of ensuring this transition is economically feasible while also environmentally friendly. The anticipated expansion in renewable energies such as solar power, wind energy, bioenergy, and waterpower offer a hopeful outlook for diminishing greenhouse gas emissions and bolstering energy independence. Additionally, venturing into nascent sectors like oceanic renewable energies could further amplify the diversity within Tunisia's energy portfolio. Nevertheless, considerations regarding grid integration capacities, cost-effectiveness, ecological consequences, and legal structures are critical to thoroughly evaluate in order to unlock these resources' full potential. Engaging in initiatives focused on research, development, and demonstration concerning technologies for converting hydrokinetic power into usable forms stands out as vital for surpassing present obstacles and propelling a lasting shift towards greener energy practices. To successfully integrate renewable energy into Tunisia's national fuel grid, the country must navigate an environment in which budgetary possibilities and green goals coexist (Boufateh, 2021).

3. MATERIAL AND METHODS

The following chapter explains the methodology and procedures of the respective study.

3.1 Study Area

The study areas for the interviews are located in north Africa, Tunisia (Figure1) and illustrated in Figure 2 and Figure 3. Sidi Bouzid (average solar exposure time of at least 3,200 hours per year, with peaks of 3,400 hours per year) and Tunis (average solar exposure time of at between 2,500 and 3,000 hours per year) are two Counties of Tunisia, situated respectively in the central west of Tunisia and the northern east of Tunisia.

Figure 1: Map of Tunisia

(Source: World Atlas)

Figure 2: The Study Area 1 in the Sidi Bouzid County of Tunisia

(Source : https://www.researchgate.net/)

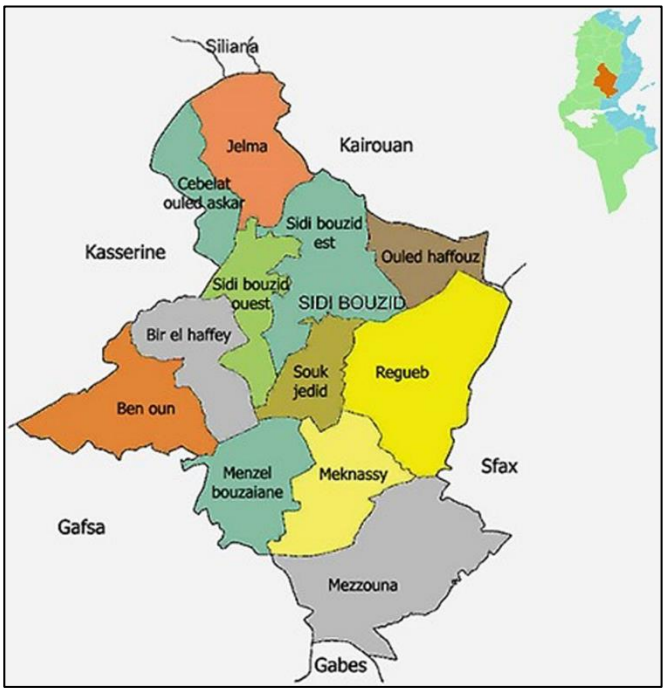
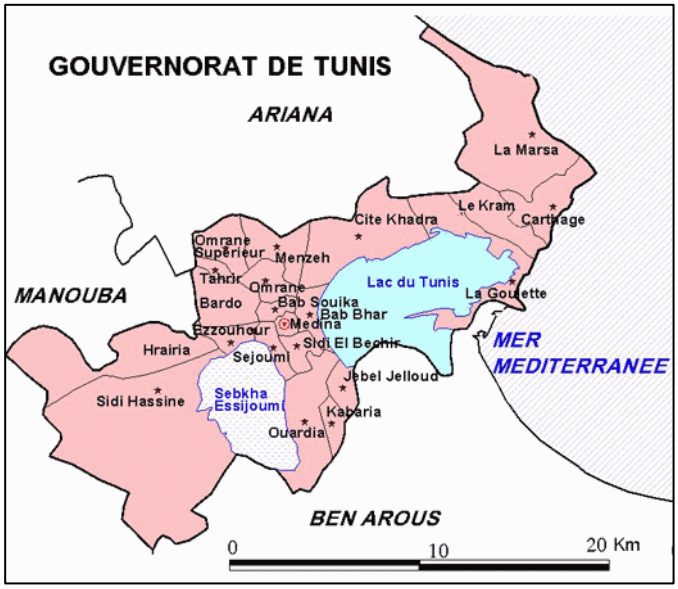


Figure 3: The Study Area 2 in the Tunis County of Tunisia

(Source : https://cgdr.nat.tn/)



3.2 Research Methodology

This study used secondary data literature review and primary data in the form of interviews to have the necessary data to achieve the research objectives set in section 1.3.

3.3 Interviews

Two structured interviews (Elhami & Khoshnevisan, 2022) were conducted with a young farmer and a retired man in the study area. The interviews were executed using a set of questions for discussion (see appendices) and the secondary data results to explore the themes of the study. The interviews centred around feedback of the status of renewable energy adoption in Tunisia specifically solar energy and analyse the potential benefits and challenges associated with implementation of renewable energy sources. The interviewees agreed to the interview with the independent consultant of the respective study. Interviewees' identity remains anonymous in this report and careful consideration is taken that their identity and some other data are not implied in the information provided.

3.3.1 Interviews Questions

The list of interview questions is attached in the appendices of this report. The interviews were conducted in Arabic and French, and translated to English for the author. The interviews took about one hours each. There are three themes contained in the interviews. Firstly, the general situation of the farm / house and the electricity consumption, secondly, the transition to renewable energy (solar energy) and, finally, the opinion of each interviewee about the government's policies and financial aid provided to facilitate this environmental friendly energy generation. However, the questions in the interview are considered prompts for in-depth discussion on the themes.

3.4 Data Analysis

The structured, in-depth interviews collect qualitative data and the descriptive feedback from the farmers are critically discussed while referring to the literature findings and secondary data analysis. Answers to the list of questions were recorded on notepaper by the interviewer and further comments or discussions were noted as well. The information was summarised and added to conclusions from literature sources in chapter 4.

4. RESULTS AND THEIR EVALUATION

This section precedes with the results of the secondary data analysis. Following the interview results are presented and discussed.

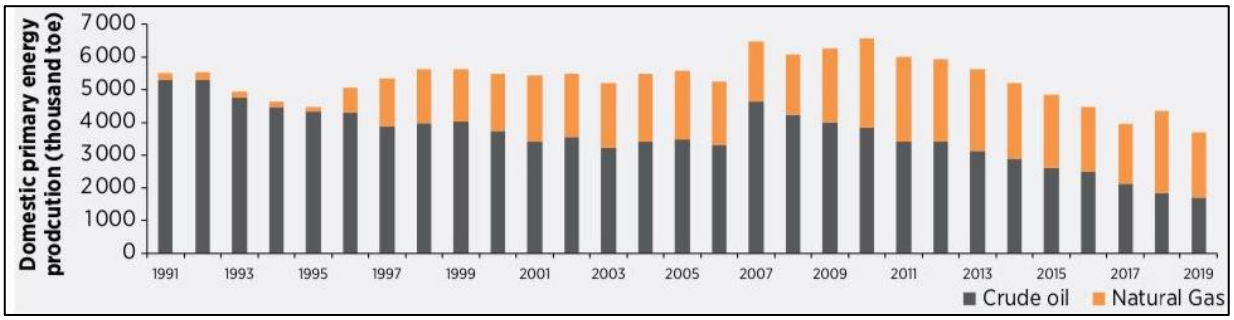
4.1 The Results of The Secondary Research

4.1.1 Electricity Supply and Demand

The country is close to being fully electrified at 99.8%. The electricity generation mix is dominated by natural gas at 97.5%. The strong dependence on natural gas has serious implications for Tunisia's energy security, as domestic production of natural gas has stagnated and even declined during recent years. Domestic production of oil and natural gas has dropped significantly since 2010 (54% and 47%, respectively). Between 1990 and 2019, primary energy production fell from 5400 ktoe to 3703 ktoe as presented in Graph 1.

Graph 1: Domestic Energy Production Of Crude Oil And Natural Gas, Tunisia, 1991-2019

(Source: IRENA 2021)

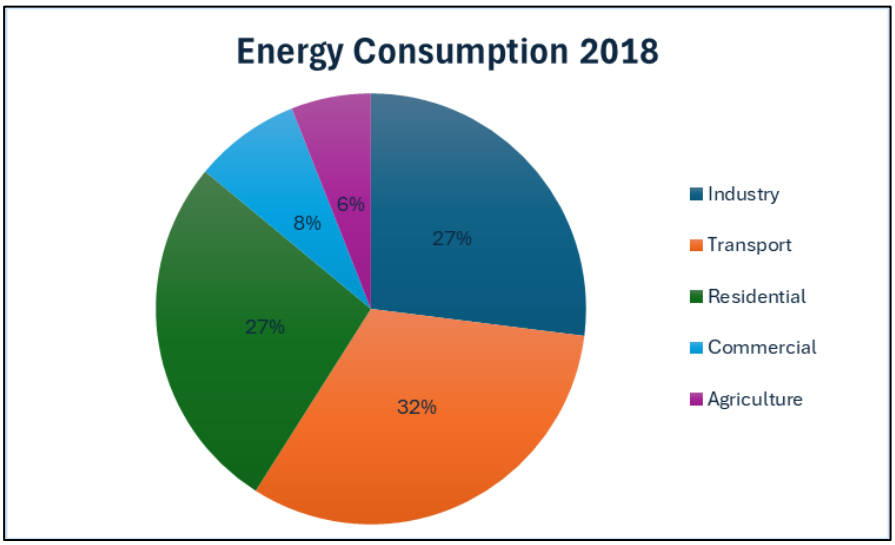


Tunisia heavily relies on fossil fuels to meet its energy demands, with primary energy demand reaching 9,606 ktoe in 2019 and an average annual growth rate of 1.7%. The country's energy deficit has been increasing since 2017, leading to an import dependency rate of 60% in 2018, up from 7% in 2010. The energy deficit is expected to worsen as energy demand rises and oil and gas production declines. In 2014, the energy import bill peaked at over TND 7 billion (USD 3.5 billion at the time or USD 2.5 billion at mid-2019 exchange rates), further highlighting Tunisia's economic and social vulnerability to volatile international energy prices and the devaluation of the Tunisian dinar.

In 2019, Tunisia's total final energy consumption (TFEC) (Graph 2) was approximately 8,710 ktoe, with oil products accounting for 53% of TFEC, followed by natural gas and electricity in equal shares. Energy is used in various end-use sectors in the economy, including transport (32%), industry (27%), and the residential sector (27%). The commercial and agricultural sectors followed with 8% and 6%, respectively. Excluding biomass, TFEC amounted to 7,620 ktoe. Tunisia's heavy reliance on fossil fuels poses a challenge to transitioning to a low-carbon future, and its energy deficit is expected to worsen as energy demand rises and oil and gas production declines, further highlighting the country's economic and social vulnerability.

Graph 2: Total Final Energy Consumption By Sector, Tunisia, 2018

(Source: Created by author in Excel with information from IRENA 2021 report)



4.1.2 Energy Transition Strategy

Tunisia has launched an energy transition process to address energy security challenges and volatile international energy prices. The process includes extensive consultations with key energy stakeholders from various institutions, public and private organizations, civil society, experts, financial organizations, and academia. The goal is to revise the modes of production, processing, and energy consumption to strengthen energy security, safeguard economic competitiveness, and protect the environment. The energy transition is based on an energy management strategy focused on increasing energy efficiency and developing renewable energy sources.

The main objectives of this strategy, developed in 2014 and updated in 2019, are as follows:

- Energy efficiency: Strengthen policies and measures for the rational use of energy to reduce overall primary energy consumption by 30% in 2030, compared to the baseline scenario.
- Renewable energy: Increase the share of renewable energy in the electricity production mix to reach 30% in 2030.

In 2017, ANME started working on a low carbon strategy that includes carbon pricing instruments. The United Nations Development Programme (UNDP), World Bank, and Partnership for Market Readiness support Tunisia in implementing its Nationally Determined Contributions (NDCs) and low carbon strategy. Tunisia's NDCs aim to reduce carbon intensity by 41%, with 75% of reductions from renewable energy measures. The Tunisia Solar Plan (TSP) reflects this commitment and includes measures to address planning gaps. The low carbon strategy will be finalized in 2020, based on carbon pricing instruments, the 30-30 target, Energy Transition Fund (FTE – Fonds de transition énergétique), and development of its Nationally Appropriate Mitigation Actions. International support through financial and technical assistance will be necessary.

The energy transition strategy in Tunisia is driven by the need for energy security due to a growing energy balance deficit. Renewable energy sources are being prioritized due to a decline in conventional resources and an increase in demand. The benefits of renewable energy include availability, accessibility, affordability, and a long-term outlook.

Renewable energy technology costs have significantly reduced over the past decade. Solar PV prices dropped from USD 241/MWh to USD 66/MWh, and onshore wind prices dropped from USD 79/MWh to USD 46/MWh. In 2018, solar PV prices fell to USD 62/MWh, and onshore wind prices slightly increased to USD 55/MWh. The Middle East/North Africa region has witnessed very low prices for renewable energy projects, with Tunisia recording the lowest bid in Africa for a 500 MW solar PV tender at USD 0.0244/kWh.

Tunisia aims to reduce its carbon intensity by 41% through renewable energy solutions, with 75% of reductions coming from mitigation measures. The strategy aims to secure a reliable energy supply, and in 2018, renewable energy generation avoided nearly 1.5 million tons of carbon emissions.

Moreover, around 20 energy efficiency actions have been included in the calculation of avoidable emissions, covering the industrial, building, transport, and agriculture sectors. This commitment is well reflected in the TSP, and the country has taken measures to build institutional capacity and further address the planning gaps from the first round to the second round of NDC reviews in 2020. In 2017, ANME initiated work on a low carbon strategy for 2050 that would include carbon pricing instruments. The Partnership for Market Readiness, United Nations Development Programme and World Bank are supporting Tunisia in the implementation of its NDC and low carbon strategy.

The Tunisian Solar Plan is a Public-Private Partnership initiated in 2015 to promote renewable energy production through a set of 40 projects and partnerships focused on wind and solar technologies and energy efficiency. The plan aims to reduce national energy consumption by 22% in 2016 and GHG total emissions by 1.3 million tons CO2 every year. It includes two major long-running projects, PROSOL ELEC for electricity production from solar PV and PROSOL for solar thermal water heating and is financed by the National Fund for Energy Efficiency, STEG, private funding, and international cooperation funds.

Tunisian Solar Plan project main features:

- Objective: 30% renewable energy in electricity production in 2030
- NDC pledges: Reduce carbon intensity by 41%, with 75% of the reduction resulting from the energy sector
- Target for installed renewable capacity:3 815 megawatts (2030)
- Market access mechanism: Net metering – Self-production – Independent power production for domestic consumption – Private concession by tender – Direct public investment by Tunisian Company of Electricity and Gas (STEG)
- Investment cost (2015): USD 9 436 million
- Renewable projects (2015): USD 7 465 million
- Project for strengthening the electrical system: USD 1 971 million
- Funding: Public sector: USD 3 106 million; Private sector: USD 6 331 million

• Impacts:

1. Cumulative energy savings over the period 2015–2030: 16 million tons of oil equivalent.
2. Cumulative carbon dioxide emissions reduction over the period 2015–2030: 38 million tons of carbon dioxide equivalent.
3. Gain on the energy bill: USD 16 billion.
4. Jobs created: Approximately 10 000.

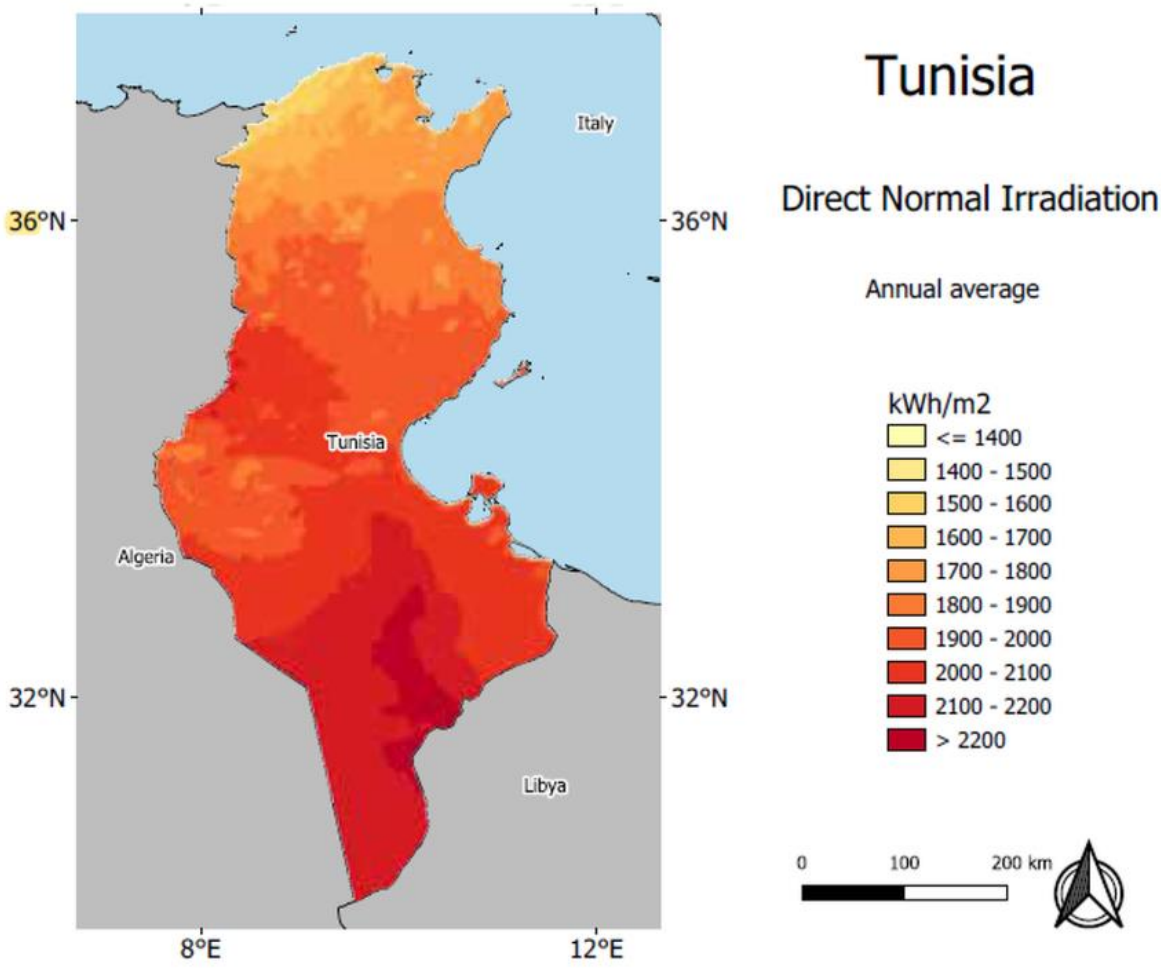
Tunisia is endowed with abundant renewable energy resources, particularly solar and wind energy; however, renewable energy currently plays a minor role in the country's energy supply. Tunisia's total installed renewable power generating capacity had reached approximately 352 MW by the end of 2019, with wind energy at 245 MW, hydropower at 66 MW) and PV at 62 MW. The use of solar thermal energy for heating water can be regarded as a success story, with a total installed area of 980 000 square meters (m^2) at the end of 2017.

4.1.4 Solar Energy

Tunisia has over 3000 hours/year of solar resources, with southern provinces having more than 3200 hours/year and northern provinces having between 2500-3000 full-sun hours equivalent. Solar irradiation ranges from 1800 kWh/m^2/year in the north to 2600 kWh/m^2/year in the south. As Figure 4 illustrate, the direct average global solar irradiance is between 4.2 kWh/m^2/day in the northwest and 5.8 kWh/m^2/day in the far south. Annual electricity production by PV solar systems varies between 1450 kWh per kilowatt-peak (kWp) in the northwest and 1830 kWh/kWp in the extreme southeast. Direct solar irradiation in the south and most of the central region exceeds the typical Direct Normal Irradiance (DNI) value of 2000 kWh/m^2/year, with some regions reaching up to 2300 kWh/m^2/year.

Figure 4: Direct Normal Solar Irradiance

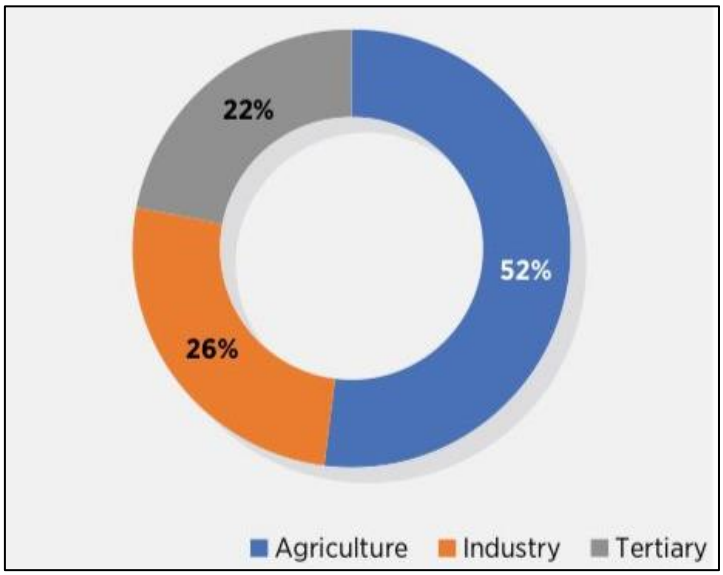
(Source: IRENA: Global Atlas, Map data: World Bank, ESMAP, 2021, 2021 OpenStreetMap contributors, 2021 United Nation administrative boundaries)



Tunisia has about 13,200 rural households electrified by PV systems, with an installed capacity of around 1,450 kWp. By the end of 2019, 3,644 solar PV systems were connected to the Low Voltage grid, with a total installed capacity of around 11,298 kWp. 90% of this capacity was installed in the residential sector. Ministry of Industry, Energy and Mines (MIEM) has granted authorization for 150 solar PV installations, with a total capacity of approximately 26 MWp, intended for production to the Medium Voltage (MV) grid. The agriculture sector has the largest share of PV energy projects, followed by the industry and tertiary sectors, with 64% of the installations below 100-kilowatt capacity (Graph 3).

Graph 3: Sector Distribution of Photovoltaic Projects Relating to The Medium-Voltage Grid, Tunisia

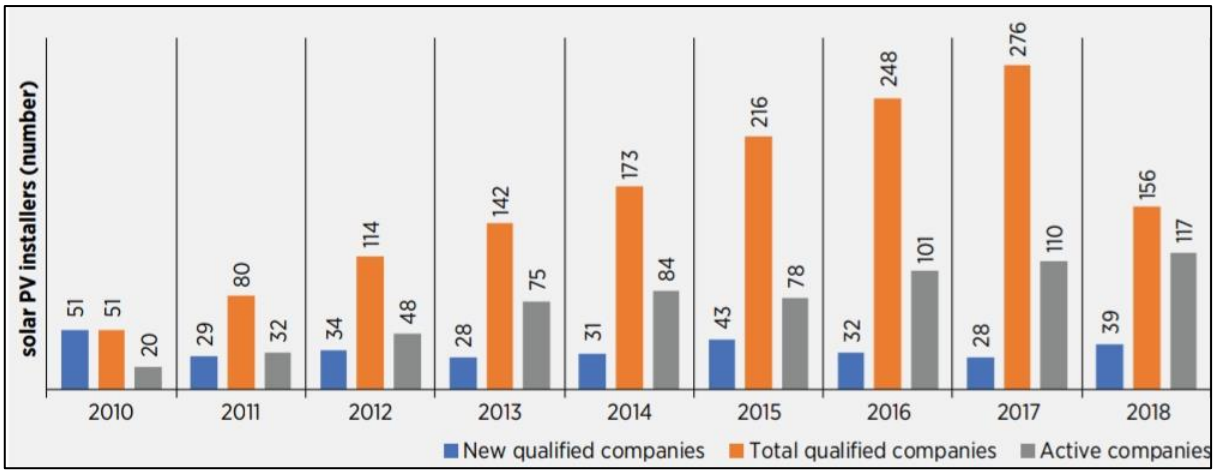
(Source: ANME 2019)



The increasing demand for solar PV in Tunisia (Graph 4) has fuelled the growth of a network of specialized companies focused on PV installation. As of 2019, ANME had registered a total of 350 companies, with 150 of them being active.

Graph 4: Evolution of Registered Solar PV Installers

(Source: Nur Energie (n.d.))



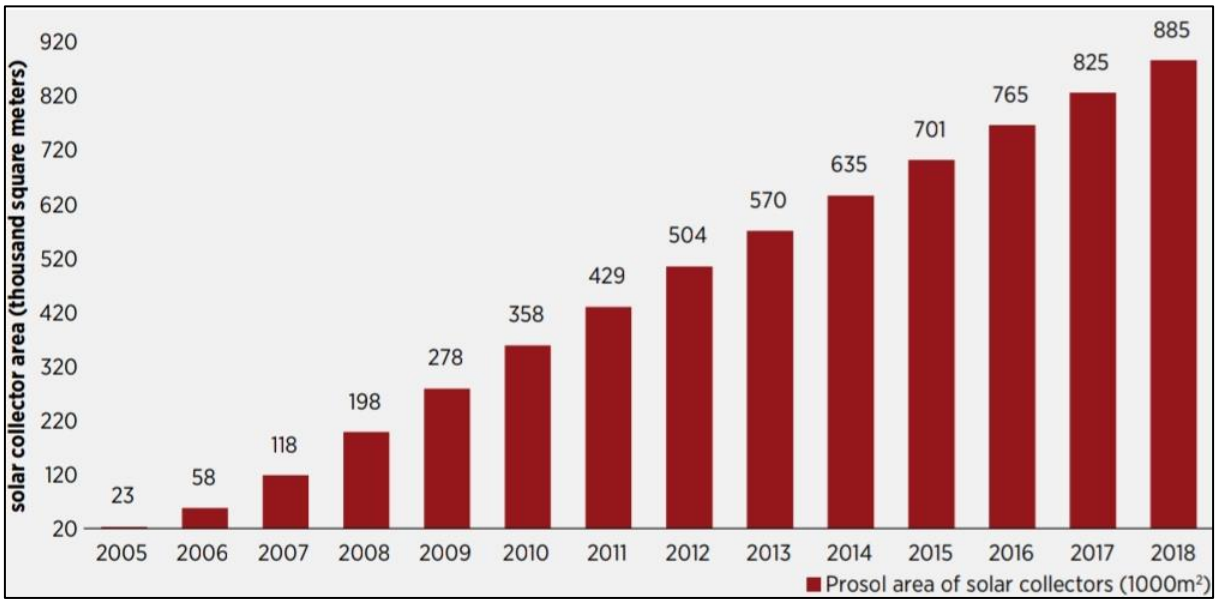
In the 1980s, Tunisia began its Solar Water Heating (SWH) sector. However, skills limitations led to a decline in installations. A Global Environmental Facility project provided grants and requirements for solar water heaters, reviving the market until its end in 2001. By 2004,

installations dropped to less than 8000 m². In 2005, Tunisia introduced the Prosol program to stimulate the SWH market. It offers capital grants, tax exemptions, reduced custom duties, and low-interest loans repaid through electricity bills.

The Prosol program led to a significant increase in the installation of solar water heaters in Tunisia's residential sector (Graph 5). The cumulative collector area installed under Prosol is around 885,000 m².

Graph 5: Solar Collector Area Installed Under Prosol Programme, Tunisia, 2005–2018

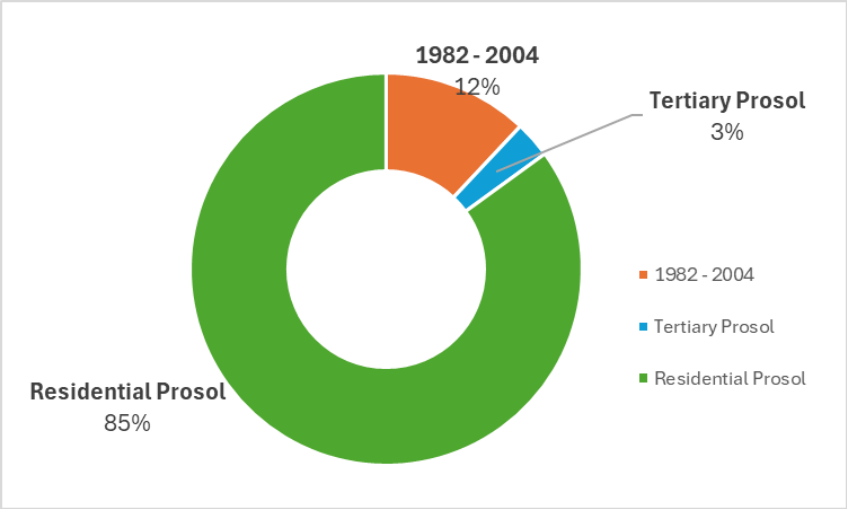
(Sources: ANME 2019)



However, the solar collectors' area for commercial and industrial sector-specific program, which is called Tertiary Prosol, has not had the same success due to competition from heavily subsidized natural gas (Graph 6). As of 2018, the total area of solar collectors installed in Tunisia is estimated to be 1,040,000 m², with 53 suppliers, 1,200 installers, and 250 approved SWH system models present in the market.

Graph 6: Area of Solar Collectors, Tunisia, 2018

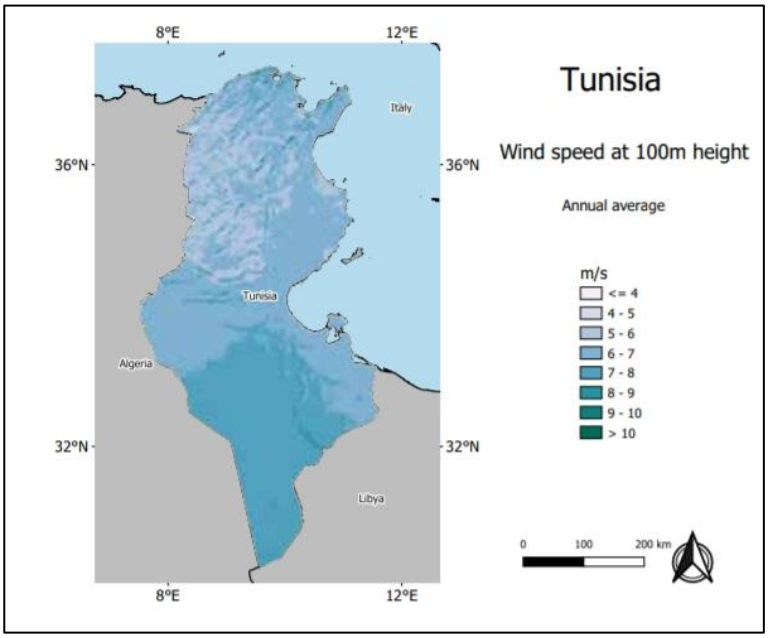
(Source: IRENA 2021)



4.1.5 Wind Energy

Tunisia has several suitable sites for wind farms (speed exceeding 7 meters per second (m/s) at 80 meters height), with the most interesting sites located in Bizerte, Nabeul (in the northern region), Kasserine (in the central region), Tataouine, Western Cape, Gabes, and Kebili (in the southern regions) shown in Figure 5.

Figure 5: Wind Map of Tunisia

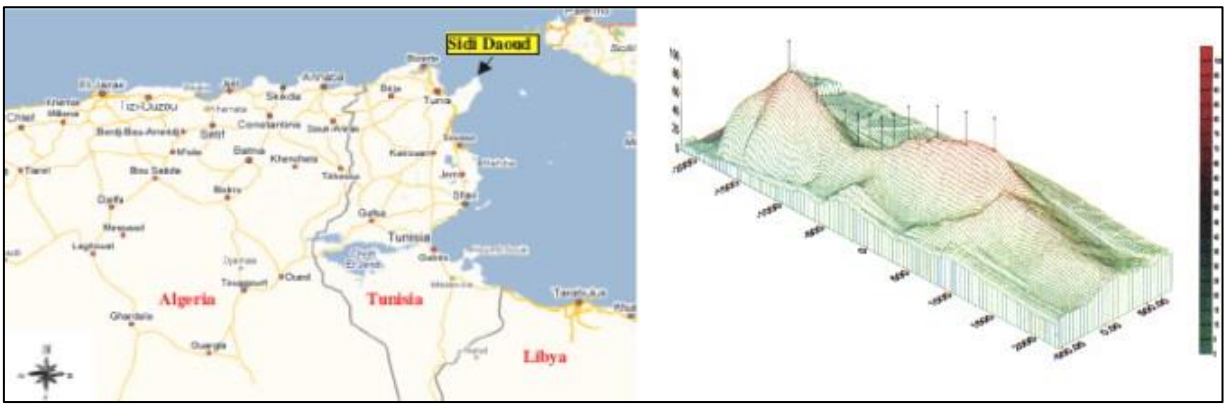


(Sources: IRENA: Global Atlas; Map data: Technical University of Denmark (DTU), 2021, 2021 OpenStreetMap contributors, 2021 United Nation administrative boundaries)

The total area available for wind power development is about 32,200 km², with a gross wind energy potential estimated at over 8,000 MW. Tunisia's wind generation development began in 2001, when STEG brought a wind farm at the Sidi Daoud site in the north-east (Cape Bon), with an initial capacity of 10 MW and later expanding to 55 MW in 2008 (Figure 6). The wind farm of Sidi Daoud is comprised of three diverse wind turbine profiles: two small turbine models of 300 kilowatts and 800 kilowatts, and larger turbines of 1.32 MW.

Figure 6: Sidi Daoud Wind Farm Geographical Position and Site Relief

(Sources: STEG, F. Ben Amar, & al.)



STEG launched two other wind farms in 2012 at the sites of Metline and Kchabta (Bizerte region), with a total of 143 wind turbines and a capacity of 190 MW. In 2017, the total electricity production of the three wind farms was 449 GWh, with peak production recorded in 2014 at 507 GWh.

4.1.6 Hydropower

Tunisia initially tapped into hydropower resources in 1956 with the establishment of two stations, Arroussia and Nebeur, with a combined capacity of 18 MW. As of 2018, Tunisia's installed hydro capacity had increased to 66 MW across seven stations. However, Tunisia's hydropower potential is limited due to the absence of large dams (Table 1).

Table 1: Hydropower Stations Capacities 2018

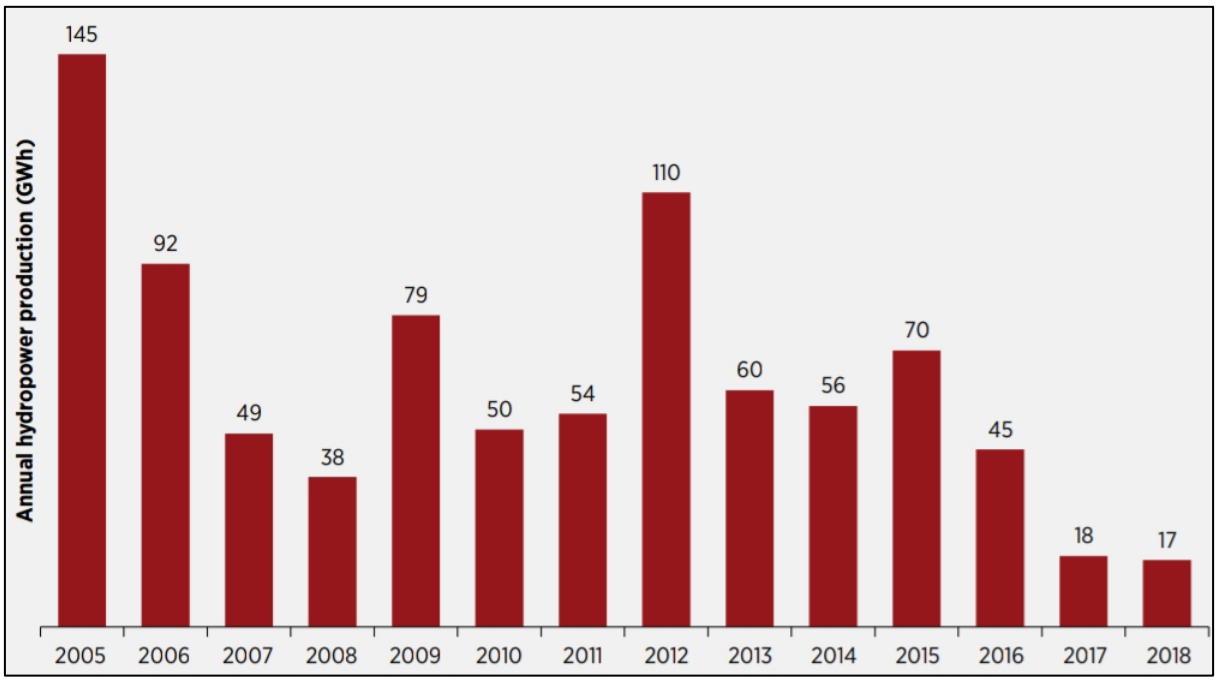
(Source: STEG)

Hydropower stations	Capacity (MW)
Sidi Salem	36.00
Fernana	9.70
Nebeur	13.20
Aroussia	4.80
Kasseb	0.66
Bouhertma	1.82
Sejnene	0.60
Total	**66.78**

Hydropower production is variable as shown in Graph 7, and its contribution to the country's total electricity production is minimal. In 2018, hydropower accounted for approximately 18 GWh of electricity, representing only 0.12% of STEG's total electricity production.

Graph 7: Annual Hydropower Production, 2005-2018

(Source: MISME 2019a)



4.1.7 Geothermal Energy

Figure 7 present the southern regions of Kebili, Gabes, and Tozeur in Tunisia which are known for their significant geothermal potential. This is evidenced by the presence of hot springs, which serve as an indicator of geothermal activity in the area. The geothermal resources in these regions are derived from the vast Continental Intercalary aquifer, which stretches over an area of 1 million km^2 and extends into neighbouring countries such as Libya and Algeria.

The Continental Intercalary aquifer is characterized by its considerable depth, reaching approximately 2.8 km beneath the surface. The aquifer's temperatures range from 30°C to 80°C, making it a valuable source of geothermal heat.

Figure 7: Map of Geothermal Energy Distribution of Tunisia

(Source: ThermoGIS World Aquifer Viewer)

However, despite the abundance of geothermal resources, their utilization in the power sector remains underdeveloped in Tunisia. This is primarily due to the relatively low enthalpy or heat content of the geothermal resources, which makes them less suitable for electricity generation compared to higher-enthalpy geothermal sources found in other regions of the world.

Nevertheless, Tunisia has found alternative applications for geothermal energy. The most prominent use is the direct utilization of geothermal heat in agriculture. Geothermal energy is employed to provide warmth for greenhouses, enabling year-round cultivation of crops and improving agricultural productivity. Additionally, geothermal heat is harnessed to power irrigation pumps, facilitating efficient water distribution for crop irrigation.

Furthermore, the recreational and wellness sector benefits from geothermal resources in Tunisia. Thermal baths and spas take advantage of the naturally heated water from the geothermal springs, offering visitors a relaxing and therapeutic experience.

4.1.8 Biofuels and Waste-To-Energy

The use of traditional biomass fuels is minimal in Tunisia due to widespread access to electricity and non-solid fuels for cooking. Charcoal production has remained stable at around 150 ktoe/year, and wood is commonly used in traditional ovens.

Tunisia produces approximately 6 million tonnes of organic waste annually, including household waste, agricultural waste, olive oil processing waste, poultry droppings, and wastewater treatment by-products. The National Waste Management Agency estimates the potential for generating 1000 GWh/year of electricity from this waste. However, several challenges hinder the exploitation of this potential, such as initial investment costs, limited technical knowledge, unclear biomass resource availability, uncertainty in long-term power plant supply from low-cost waste, and overlapping roles between ANGED and municipalities responsible for waste collection.

In 2010, a pilot biogas plant capable of generating 2.4 GWh/year of electricity was developed using waste from the Bir El Kassaâ wholesale market (Figure 8). However, the plant remains offline due to technical issues.

Figure 8: Bir El Kassaâ Waste Management Unit

(Source : La Presse de Tunisie, 10June 2010)

4.2 The Results of the Interviews

The two interviewed individuals are respectively a young farmer using arable land primarily in Sidi Bouzid has an operation of 10 hectares, and a retired employee residing in Tunis (capital city). To distinguish between them, the terms ‘Interviewee 1’ and ‘Interviewee 2’ will be used.

This section outlines responses by the interviewees and mentions connections with the literature discussed in Chapter Two.

As the two interviewees have different usage nature of electricity, and as mentioned before in section 3.3.1, the data from each interview will be presented case by case while respecting the themes and the questions order.

4.2.1 General Situation and Electricity Consumption

First interview:

Interviewee 1 is a young man in his late 20s who, after graduating from university in June 2018, preferred to start a small agricultural project using his father land. In November 2018, He started by drilling a deep water well of 155 m using the 15 Horsepower Comarco pump.

According to Interviewee 1 statement, he uses the pump to irrigate potato (Spunta), olive trees (Sehli and Chemlali), almond trees (Mazzetto) and alfalfa (Gabsi), twice a day, early in the

morning and late at night to avoid the rush hours of electricity demand that STEG defined from 11:00 to 16:00 and also to keep the consumption cost at its lowest since the price of electricity become expensive during electricity's rush hours.

Interviewee 1 consumes around 200 KW per day which coast him around 1000 TDN (≈ 315 $) per month.

By referring to the literature review chapter 2, Interviewee 1 confirmed that the electricity grid is available in most of the rural areas of his county and its surrounding. Adding that there are some shortcuts in electricity availability, especially in summer due to the high demand, that's why he has built an irrigation water storage pool connected to a fuel pump that cost him around 200 TND (≈ 65 $) to 400 TND (≈ 130 $) per month.

Second interview:

Interviewee 2 is a retired employee in his early 60s. He owns a 100 m^2 three story house in the suburbs of the capital city of Tunisia since 1996. The house is equipped with two fridges, a medium size freezer, an oven, a microwave, an extractor hood, an automatic washing machine, two TVs, two air conditioners, a Wi-Fi router, a hair dryer, twelve lamb bulbs.

The retired employee claimed that he wasn't really attentive about the energy saving practices promoted by the Tunisian government but after retiring in 2018, he started to pay attention since he wants to cutoff some expenses using the "Special Practical Guide"(ANME, ESCWA, 2021). So, he started by using energy saving LED bulbs and applying the energy saving recommendations such as setting air conditioners for heating at a temperature not exceeding 20 degrees Celsius and to turn them off when going to sleep and for cooling at a temperature not lower than 26 degrees Celsius specially between 11:00 and 16:00, seasonal maintenance for air conditioners at least twice a year, disconnecting the electricity supply from electrical appliances that are not in use (such as computers, televisions, etc.), using ECO mode for the washing machine, etc.

According to the electricity bill he provided (Figure 9 in section 9.2), his electricity consumption is 91 TDN (≈ 29 $) per month.

By referring to the literature review chapter 2, Interviewee 2 also confirmed that the electricity grid is available in most of the country and mentioned the shortcuts in electricity availability, especially in summer due to the high demand.

4.2.2 Transition to Renewable Energy (Solar Energy)

Talking about the motivation for the transition, both interviewees affirmed that they wanted to reduce the cost and guarantee the electricity availability, especially in summer.

First interview:

Starting early 2020, Interviewee 1 got interested in solar energy and started gathering information about the solar panels' types, brands, the companies specialized in installing and the legislations that are set by the government about this matter.

While searching, he discovered that the most suitable panels where the Chinese "Ja Solar" as they function very well under the Tunisian sun.

Despite Covid-19 slowed down his research pace, the young man finally was able to set down his preferences about the installing company (the company refused mentioning its name) which is located in his county to facilitate the intervention in case of a technical problem.

In May 2023, Interviewee 1 successfully started the process by submitting a request to the installing company so they can start their process with STEG. It took about two months to finally operate his water pump in July 2023 using renewable energy. He has 42 panel producing 450 KW each (recommended by the company) (Figure 10 in section 9.2).

Interviewee 1 said that the transition costed in total 46000 TDN (≈ 14375 $). The company provides a 25-year warranty covering technical problem only. However, if damage was caused by a natural fact, Interviewee 1 should cover the cost of the maintenance.

Since the new system was active in summer, Interviewee 1 was really satisfied since he didn't face any electricity shortcuts unlike his neighbor-farmers. Also, he mentioned that he could sell the extras of his electricity production thanks to the double way meter and the legislation permitting this action.

As for the challenges he encountered, he only mentioned the long process and the high number of papers that he needed to submit the request for governmental financial aid.

From what he experienced, Interviewee 1 advises small farmers like himself to invest in photovoltaic energy since it's the future and a way to help secure energy to keep the production line to solidify the important farmer role in the society.

Second interview:

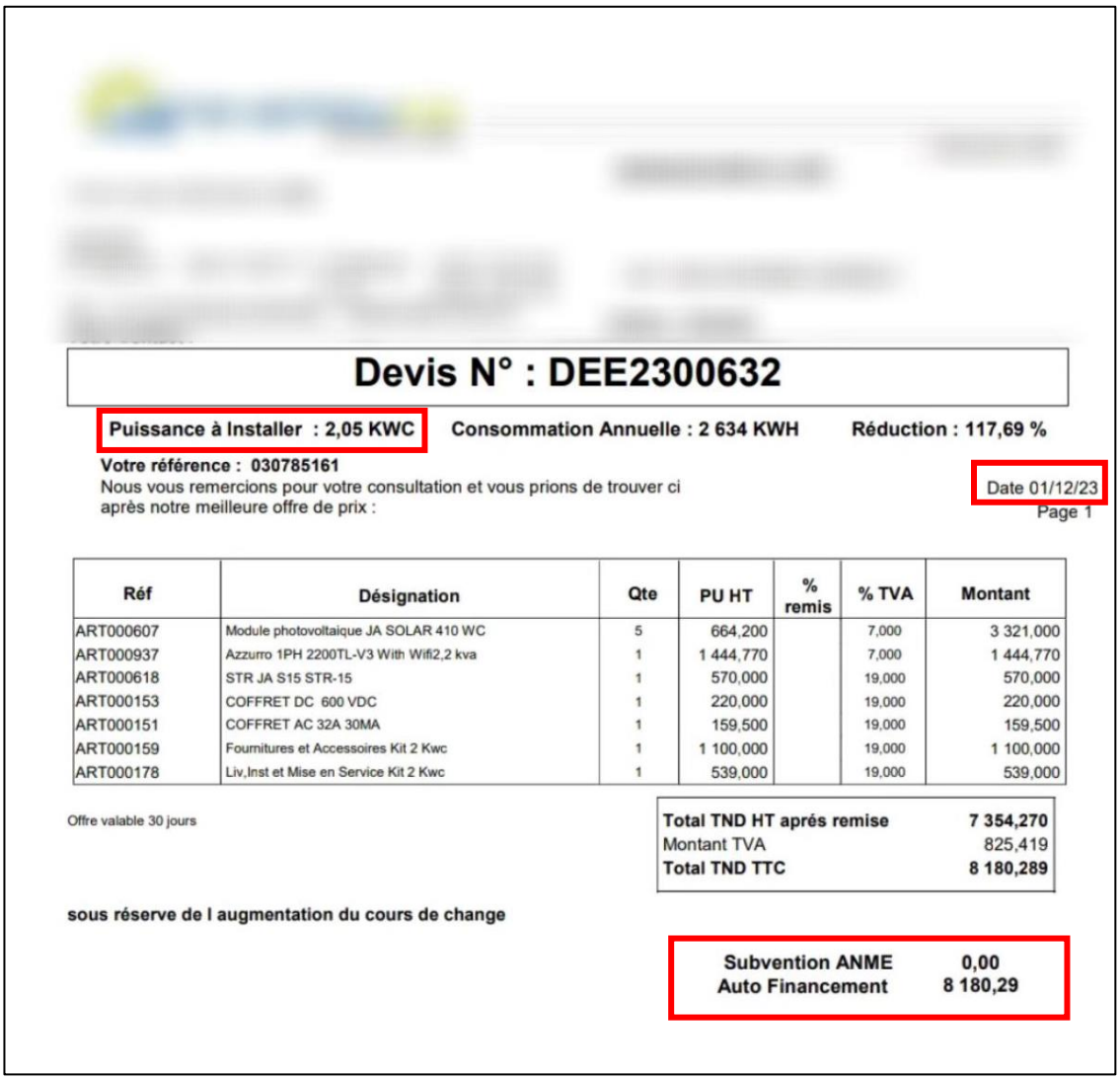
As he wanted to reduce his costs, the retired employee started a small research with the help of his daughter and her friend, a renewable energy technician, who recommended the company he works for and it was a good choice since they offered a good deal.

First step was knowing the house needs through an official request to STEG by the company which took two weeks to get the reply and was studied by the installing company.

The following documents (Figure 10 and Figure 11) present all the details of the consumption needs, the number of panels, the cost and the way of payment.

Figure 11: Quotation for The Cost

(Source: Interviewee 2)



Devis N° : DEE2300632

Puissance à Installer : 2,05 KWC **Consommation Annuelle : 2 634 KWH** **Réduction : 117,69 %**

Votre référence : 030785161

Nous vous remercions pour votre consultation et vous prions de trouver ci après notre meilleure offre de prix :

Date 01/12/23

Page 1

Réf	Désignation	Qte	PU HT	% remis	% TVA	Montant
ART000607	Module photovoltaique JA SOLAR 410 WC	5	664,200		7,000	3 321,000
ART000937	Azzurro 1PH 2200TL-V3 With Wifi2,2 kva	1	1 444,770		7,000	1 444,770
ART000618	STR JA S15 STR-15	1	570,000		19,000	570,000
ART000153	COFFRET DC 600 VDC	1	220,000		19,000	220,000
ART000151	COFFRET AC 32A 30MA	1	159,500		19,000	159,500
ART000159	Fournitures et Accessoires Kit 2 Kwc	1	1 100,000		19,000	1 100,000
ART000178	Liv,Inst et Mise en Service Kit 2 Kwc	1	539,000		19,000	539,000

Offre valable 30 jours

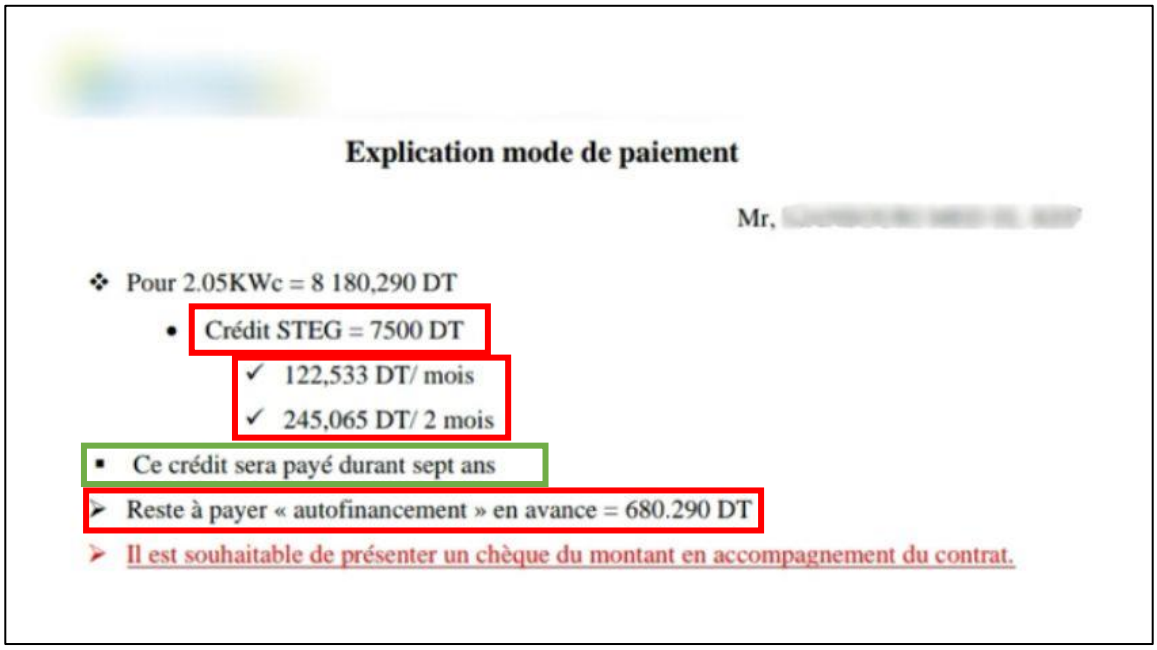
Total TND HT aprés remise	**7 354,270**
Montant TVA	825,419
Total TND TTC	**8 180,289**

sous réserve de l augmentation du cours de change

Subvention ANME	**0,00**
Auto Financement	**8 180,29**

Figure 12: Payment Mode

(Source: Interviewee 2)



Explication mode de paiement

Mr,

- Pour 2.05KWc = 8 180,290 DT
  - Crédit STEG = 7500 DT
    - ✓ 122,533 DT/ mois
    - ✓ 245,065 DT/ 2 mois
  - Ce crédit sera payé durant sept ans
- Reste à payer « autofinancement » en avance = 680.290 DT
- Il est souhaitable de présenter un chèque du montant en accompagnement du contrat.

For households the case is a bit different, mentioned Interviewee 2 since they only must contact the installation company and it will take care of all the processes with STEG.

He signed the contract with the company in late January 2024 and they started installing the panels in mid-March 2024.

He stated, after the system started functioning, that he is satisfied since he has electricity but there is no data from the electricity bill (since it come every 2 months and the next one will arrive in May) to show the difference between both bills.

But he stated that he is happy about taking this step since he now feels that he is part of the change that will affect the environment. Plus “people in the neighborhood showed interest and want to have solar panels as well” said Interviewee 2.

4.2.3 Government Policies and Financial Aid

In May 2023, Interviewee 1 successfully started the process by submitting a request to the agricultural rectorate of Sidi Bouzid to benefit from the financial aid reserved to farmer shifting to photovoltaic energy. The Tunisian state paid half of the total cost as a financial aid and this was the reason that encouraged him to shift to renewable energy.

And for Interviewee 2, the government has no direct financial aid. Instead, STEG, as a government representative, will pay the installation company 91% of the total price as showed in Figure 11 and the citizen then will pay STEG in monthly payment for 84 months (7 years) plus the 8% of total cost as a self-financing payment when signing the contract with the company.

Both interviewees are quite optimistic about the government's current policies and initiatives aimed at promoting renewable energy adoption, especially solar energy for agriculture use and households. "It is great to see a proactive attitude to sustainability and renewable energy transition" claimed Interviewee 2. "The emphasis on solar energy not only provides a dependable and clean energy source, but also creates considerable opportunity for farmers like me and homes to minimize their carbon footprint and energy expenditures" said Interviewee 1.

Interviewee 2 added that:" By rewarding and supporting the use of solar energy, the government not only promotes responsible environmental behavior but also fosters local economic resiliency and energy independence".

They also agree that the government could establish several additional policies and support measures to stimulate the use of renewable energy in agriculture and the residential sector. Expanding financial incentives for renewable energy installations, such as tax credits or subsidies, might help house owners and farmers handle the upfront expenses. Moreover, offering accessible financing alternatives customized to the needs of agricultural and residential consumers may encourage investment in renewable energy projects.

Also, providing farmers and individuals that are interested in switching to renewable energy with technical support and training programmes on renewable energy system design, installation, and maintenance may help increase their ability and confidence. With all factors taken into account, a comprehensive strategy that includes accessible funding, financial incentives, and technical assistance might greatly quicken the adoption of renewable energy in Tunisia and help create a more sustainable future.

Concerning the government support, Interviewee 1 said:" Looking forward, I believe that the government ought to keep playing an active role in accelerating the transition to renewable energy by enacting innovative policies, providing financial incentives, and encouraging stakeholder engagement. Furthermore, it should prioritize investments in renewable energy infrastructure and research to accelerate technical developments and assure the transition's long-term viability". And interviewee 2 shared the same thoughts as well.

They both think if the government remains committed to renewable energy and aggressively tackling issues, this can pave the path for a cleaner, more resilient energy future for farmers, homes, and the community.

5. CONCLUSION AND RECOMMENDATION

This exploratory study cannot demand firm conclusions from the results obtained. Therefore, important factors noticed during the study area highlighted and could possibly guide themes to consider for future research endeavours.

5.1 5. Conclusion

For many decades, Tunisia has been suffering from an increment in energy consumption combined with a decline in national production of fossil fuels. This situation and the volatility of the energy prices have generated many socio-economic problems. For this reason, diversifying the Tunisian energy mix toward greener sources is a vitally important strategy for achieving a satisfaction in the energy demand and mitigating environmental issues (Saadaoui, 2024).

Tunisia aims to prepare for the transition towards climate resilience with its actions primarily focusing on the sectoral level. Over the last few years, Tunisia's government has focused on the implementation of its NDC targets, largely based on clean energy transition. The country has made visible efforts to support the deployment of renewable energy and energy efficiency projects, pursuing a secure and low-emission energy future. Relevant legislations are also in place, combined with specific policy instruments on major emitting sectors (Fragkos & Zisarou, 2022). The individuals' experiences mentioned in section 4.2 prove the seriousness of the government towards this matter.

Despite the lack of exploiting solar and wind power, the electricity sector transformation with large-scale increase in solar and wind power is a major pillar for Tunisia's transition, as the country has large renewable energy potential that can be efficiently exploited (Morsy et al., 2018).

In addition to the utilization of renewable energy sources, Tunisia has also focused on special developments in the areas of energy saving and energy storage. Tunisia has implemented various energy-saving initiatives and programs to promote energy efficiency across different sectors (section 4.2.1). This includes improving the energy efficiency of buildings, appliances, and industrial processes. Efforts have been made to raise awareness about energy conservation practices and promote the adoption of energy-efficient technologies. These

measures aim to reduce energy consumption, lower greenhouse gas emissions, and enhance overall energy sustainability.

Since the beginning of the PROSOL project, the evolution of SWH market and industry has been very satisfying (Omri, 2014). In fact, we have witnessed a great growth in the market and local industry of SWH. According to Baccouche (Baccouche, 2014), due to the PROSOL project, the local industry is composed now of 45 eligible suppliers containing eight local manufacturers, 1100 authorized installer sand 206 models of SWH systems and/or collectors, whereas before the beginning of PROSOL the local industry of SWHs contains just one manufacturer and 200 installers. The growth of SWH market is accompanied mainly by a development of a local industry. In fact, there are eight factories which produce 70% of all installed SWHs (Baccouche, 2014). So, just 30% of all installed SWHs are imported (mainly from Germany, Greece, Turkey and China) (Omri, 2014).

The transition towards renewable energy affects policy makers, stakeholders, industry and citizens as well; in order to be successful, it is crucial to involve the participation of citizens. Tunisian society seems to have limited information and knowledge about the positive socio-economic effects of renewable energy uptake (Fragkos & Zisarou, 2022).

Tunisia has many opportunities to reduce its energy import dependence and import bill through a shift to clean energy technologies. Switching to renewable energy can improve the energy import bill and the balance of payments by strengthening energy security and limiting vulnerability to the fluctuations of oil and gas import prices. The development and uptake of renewable energy may contribute to economic growth, attract foreign investment and create new, high-quality jobs (Fragkos & Zisarou, 2022).

5.2 Recommendation

Tunisia can attract international green finance and become a major climate policy partner in the Mediterranean region and in Africa. The development of a committed low-emission energy strategy for the medium and long term will be based on renewable energy expansion, electrification and energy efficiency. The required investment for a decarbonized, renewable-based power generation may be high, as solar and wind technologies are more capital intensive than fossil-based options. However, this leads to large reduction in energy imports

as well as in the fuel purchasing costs, while ensuring the diversification of Tunisia’s energy mix (Fragkos, P. 2022).

Improving the capacity and resilience of the power grid is critical for successfully incorporating renewable energy sources into the energy mix. This entails improving and extending the grid infrastructure to meet the fluctuation of renewable energy output while ensuring consistent electricity delivery. Investments in smart grid technology, energy storage systems, and grid modernization programmes can aid in the integration of renewable energy sources while improving grid reliability and flexibility. Furthermore, developing transmission and distribution networks to connect renewable energy resources to demand centers will help realize the full potential of renewable energy deployment across the country.

Moreover, the current analysis demonstrated that a negative change in government stability negatively affects the consumption of clean sources in Tunisia, while a positive change has no real effect. This outcome demonstrates that the actual circumstance in Tunisia, which is characterized by the lack of government stability, is a real handicap to the transition to clean energies. This upshot could be explained by the fact that the recurrent change in governments has delayed the applications of many laws and institutional changes concerning the diffusion of green energies in Tunisia. It is therefore very advisable to establish a global vision and broad outline of the Tunisian renewable energy strategy. This strategy must not be affected by the government that will be elected (Saadaoui, H., 2024).

According to Souissi wind energy is suitable for most cities. It is even more profitable and competitive than photovoltaic (PV) in northern and central Tunisia. In contrast, the PV system has great potential for development in the southern regions of the country. The economic benefit of the renewable energy project for each site is between 11 and 16 years during the 25-years project lifetime, proving its economic attractiveness. Furthermore, this study's sensitivity analysis proves that the PV system becomes competitive if its capital cost is reduced to less than 57% of its current capital cost (Souissi, 2021).

Incorporating geothermal power into Tunisia's national grid offers a notable path for the advancement of sustainable energy. Given the country's location, which is rich in geothermal resources, this incorporation could greatly enhance Tunisia's objectives regarding renewable

energy. Utilizing the natural warmth from beneath the Earth's surface allows for a diversified energy portfolio while decreasing dependence on non-renewable fossil fuels. Hence, crafting a strategic agenda that leverages Tunisia’s specific geothermal assets alongside enacting encouraging policies and strengthening infrastructure stands as crucial for effectively melding geothermal power with Tunisia’s electrical grid—thereby propelling forward its commitments to renewably sourced electricity.

6. SUMMARY

To sum up everything that has been stated so far, Tunisia faces significant challenges in its energy supply and demand dynamics. The country heavily relies on fossil fuels, particularly natural gas, which poses risks to its energy security due to declining domestic production. Tunisia's energy deficit has been increasing, leading to a high import dependency rate. The country's heavy dependence on fossil fuels also hinders its transition to a low-carbon future and makes it economically and socially vulnerable to volatile international energy prices.

The governance of Tunisia's electricity sector is managed by the Ministry of Energy, Mines, and the Energy Transition, which oversees infrastructure, policy implementation, and renewable energy planning. However, the country lacks an independent regulator. The state-owned company, STEG, holds a monopoly on electricity generation, transmission, and distribution. ANME, a public institution, focuses on promoting energy efficiency and renewable energy deployment.

Tunisia has made efforts to address its energy challenges through an energy transition strategy. Tunisia's energy transition strategy includes several key initiatives. One of the main goals is to increase the share of renewable energy in the country's energy mix. This involves promoting the development of solar, wind, and biomass energy projects. Tunisia has significant potential for solar and wind energy generation, and it has already made progress in implementing renewable energy projects, such as the installation of solar power plants and wind farms.

In addition to renewable energy, Tunisia is also focusing on improving energy efficiency to reduce energy consumption and reliance on imports. This includes implementing energy-saving measures in buildings, promoting energy-efficient appliances, and encouraging industries to adopt more efficient technologies. The National Agency for Energy Conservation (ANME) plays a crucial role in promoting energy efficiency and providing support for energy-efficient practices.

Tunisia has also been working on diversifying its energy sources by exploring other options such as nuclear energy. The country has expressed interest in developing nuclear power as a means to meet its growing energy demands. However, the nuclear energy plans are still in the early stages, and there are several challenges and considerations to address, including safety, environmental impact, and public acceptance.

It is worth noting that the success of Tunisia's energy transition strategy depends on various factors, including policy implementation, attracting investment in renewable energy projects,

technological advancements, and public awareness and participation. The government's commitment to sustainable energy development and the collaboration between different stakeholders, including the public and private sectors, will be crucial in achieving the desired outcomes.

Overall, Tunisia recognizes the need to transform its energy sector to reduce its dependence on fossil fuels, improve energy security, and mitigate the impacts of climate change. The country's energy transition strategy, with its focus on renewable energy, energy efficiency, and diversification, provides a roadmap for achieving these goals. However, it will require sustained efforts, investments, and a supportive policy framework to successfully transition to a more sustainable and resilient energy system.

The growing consumption of energy has caused serious damages to the planet. It is, therefore, necessary to use renewable energy in order to protect our environment and follow the path of sustainable development. Tunisia is a net importer of energy with a huge potential of renewable energy. That’s why Tunisia has accorded a great importance to its promotion.

But we must note that efforts are insufficient, and that the renewable energy market faces several obstacles. In fact, the Tunisian experience is far from the successful experiences of other countries such as Germany, Spain, and Denmark. Tunisia has all the necessary conditions, a great potential of renewable energy, a very qualified labour but the government support and the institutional and regulatory instruments still insufficient.

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9. APPENDICES

9.1 Interview Questions

Study: Consideration of renewable energy sources use in Tunisia

Student details: Nesrine Mansouri, Bachelor of Agricultural Engineering, MATE

The aim of this interview is to explore the implementation of solar energy as the most common renewable energy for public use.

The questions consist of three parts: the first on the general situation of the farm / house and the electricity consumption and the second on the transition to renewable energy (solar energy). The third part on the opinion of each interviewee about the government's policies and financial aid provided to facilitate this environmentally friendly energy generation.

1. General Situation and Electricity Consumption:
   1.1. Can you describe the overall setup of your farm/house in terms of its size, layout, and any specific energy-consuming activities or equipment?
   1.2. What is your typical monthly electricity consumption like, and what are the main factors influencing it?
   1.3. Have you implemented any energy-saving measures or technologies in your farm/house to reduce electricity consumption? If so, what are they and how effective have they been?
   1.4. How do fluctuations in electricity prices or availability impact your farm/household operations?
2. Transition to Renewable Energy (Solar Energy):
   2.1. What motivated you to transition to renewable energy, specifically solar energy, for your farm/house?
   2.2. Can you describe the process of installing solar panels systems on your property?
   2.3. How has the transition to solar energy impacted your electricity consumption, costs, and overall energy sustainability?
   2.4. Have you encountered any challenges or obstacles during the transition to solar energy, and if so, how did you overcome them?
   2.5. What advice would you give to others who are considering transitioning to solar energy for their farms/houses?
3. Government Policies and Financial Aid:
   3.1. What is your opinion on the government's current policies and initiatives aimed at promoting renewable energy adoption, particularly solar energy, for farms/houses?
   3.2. Have you benefited from any government financial aid or incentives for installing solar panels or adopting renewable energy practices? If so, how has it influenced your decision-making process?
   3.3. Are there any additional policies or support measures you believe the government could implement to further encourage the adoption of renewable energy in the agricultural or residential sectors?

9.2 Figures

Figure 9: Electricity Bill

(Source: Interviewee 2)

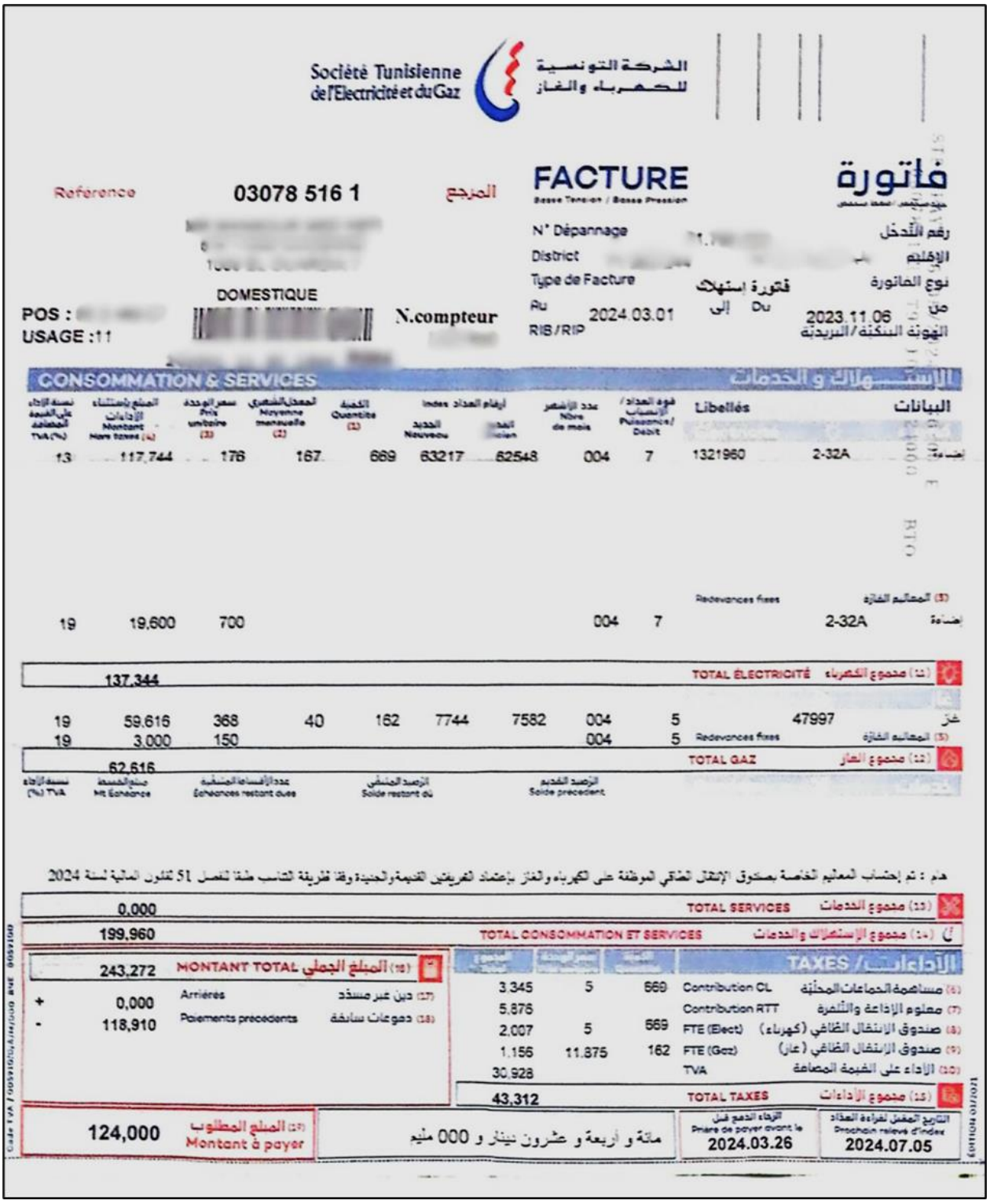

Figure 10: Solar Panel

(Source: Interviewee 1)

10. DECLARATIONS

DECLARATION

on authenticity and public assess of final essay/thesis/mater's thesis/portfolio[1]

Student's name:	Nesrine Mansouri
Student's Neptun ID:	YN5H9J
Title of the document:	UTILIZATION OF RENEWABLE ENERGY SOURCES IN TUNISIA
Year of publication:	2024
Department:	Institute of Rural Development and Sustainable Economy

I declare that the submitted final essay/thesis/master's thesis/portfolio[2] is my own, original individual creation. Any parts taken from an another author's work are clearly marked, and listed in the table of contents.

If the statements above are not true, I acknowledge that the Final examination board excludes me from participation in the final exam, and I am only allowed to take final exam if I submit another final essay/thesis/master's thesis/portfolio.

Viewing and printing my submitted work in a PDF format is permitted. However, the modification of my submitted work shall not be permitted.

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Place and date: Budapest, 2024 year 04 month 24 day

Student's signature

[1]Please select the one that applies, and delete the other types.
[2]Please select the one that applies, and delete the other types.

STATEMENT ON CONSULTATION PRACTICES

As a supervisor of **Nesrine Mansouri** (NEPTUN ID: **YN5H9J**), I here declare that the thesis[1] has been reviewed by me, the student was informed about the requirements of literary sources management and its legal and ethical rules.

I recommend/don't recommend[2] the thesis to be defended in a final exam.

The document contains state secrets or professional secrets: yes **no***[3]

Place and date: Gyöngyös, 16 April 2024.

Internal supervisor
Dr. Gábor Koncz

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[3] Please underline applicable.