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Techno-Economic Feasibility Study of Wind Energy for Electricity Generation in Algeria

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This thesis is as much yours as it is mine.

Dedication:

I dedicate this thesis with all affection sentiments in the world to:

My Father and my Mother… Shakespeare needs to put up some efforts to create a word that describes my love to them

My Brother Brahim

My Sisters, Romaissa and Fatima

To all the people I love (they know themselves)

And finally, to myself.

Lamine

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List of Abbreviations:

Abbreviation	Signification
AGL	Above Ground Level
ALCS	Annual Life Cycle Savings
BCR	Benefit-Cost Ratio
CDER	Centre de Développement des Energies Renouvelables
CF	Cash Flow
COE	Cost of Electricity
DCF	Discounte Cash Flow
FiTs	Feed-in Tariffs
GHG	Greenhouse Gases
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
LCOE	Levelized Cost of Electricity
MLM	Maximum Likelihood Method
NPV	Net Present Value
PBP	Simple Payback Period
PDF	Power Density Function
PV	Photovoltaic
PVC	Present Value Costs
S-ER	Sonelgaz – Energies Renouvelables
TPCF	Time to Positive Cash-Flow
UN	United Nations
WACC	Weighted Average Capital Cost
WTG	Wind Turbine Generator

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Abstract:

This study aims to evaluate the techno-economic feasibility of wind energy as a sustainable solution for electricity generation in Algeria, with a focus on the regions of Batna, Djelfa, Saida, Oran, and Setif. Data from these regions were considered for the year 2006 in the case of Oran, and for the period from 2020 to 2024 for the remaining provinces. A sample of wind turbines was analyzed using key technical and economic indicators such as Annual Energy Production (AEP), Levelized Cost of Electricity (LCOE), Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (PBP). This study adopts a quantitative and analytical approach. The aforementioned financial and technical indicators were applied to assess the techno-economic feasibility of wind energy. The analytical dimension lies in the interpretation of economic results and the sensitivity analysis of key variables influencing project viability. The results indicate that the **H25.0-60kW** turbine model represents a cost-effective option under current conditions, with LCOE values falling within acceptable limits. Regarding the project's profitability, positive NPV values were recorded in Djelfa, Saida, and Setif, with **Djelfa** emerging as the overall best site. In contrast, Batna and Oran are recommended to be excluded from any wind energy investment due to the negative results observed under the current assumptions.

Key words: Feasibility Study, Wind Energy, Capital Structure, LCOE, NPV.

الملخص:

تهدف هذه الدراسة إلى تقييم الجدوى التقنية والاقتصادية لطاقة الرياح كحل مستدام لتوليد الكهرباء في الجزائر، مع التركيز على مناطق باتنة، الجلفة، سعيدة، وهران وسطيف. حيث تم أخذ بيانات هذه المناطق لسنة 2006 بالنسبة لوهران و الفترة الممتدة من 2020 إلى 2024 بالنسبة لباقي الولايات، حيث تم تحليل عينة من التوربينات الهوائية باستخدام مؤشرات تقنية واقتصادية رئيسية مثل إنتاج الطاقة السنوي التكلفة المستوية للكهرباء، القيمة الحالية الصافية، معدل العائد الداخلي، ومؤشر الربحية، وفترة الاسترداد . تعتمد هذه الدراسة منهجًا كميًا وتحليليًا. حيث تم تطبيق مؤشرات مالية و تقنية المذكورة أعلاه لتقييم الجدوى التقنو-اقتصادية لتحليل جدوى طاقة الرياح. وتكمن البُعد التحليلي في تفسير النتائج الاقتصادية وتحليل حساسية المتغيرات الأساسية التي تؤثر على جدوى المشروع .تشير النتائج إلى أن نموذج التوربين **H25.0-60kW** يمثل خيارًا فعالًا من حيث التكلفة في ظل الظروف الحالية، حيث أظهرت قيم تكلفة المستوية للكهرباء واقعة ضمن الحدود المقبولة. أما من حيث ربحية المشروع، فقد تم تسجيل قيم القيمة الحالية الصافية إيجابية في الجلفة، سعيدة، وسطيف، وكانت **الجلفة** أفضل موقع بشكل عام، في حين يُوصى باستبعاد باتنة و وهران من أي استثمار في مشاريع طاقة الرياح نظرا للنتائج السلبية المسجلة تحت الافتراضات الحالية

الكلمات المفتاحية: دراسة الجدوى، طاقة الرياح، التكلفة المستوية للطاقة، القيمة الحالية الصافية ، هيكل رأس المال

General Introduction

Introduction:

With the rapid evolution of energy needs, the global energy sector faces unprecedented challenges. Fossil fuels are now widely recognized as unsustainable due to their finite nature and the environmental damage they cause. This growing awareness has prompted a shift towards renewable energy sources, which are not only sustainable but also environmentally friendly.

Renewable energy sources, represent viable alternatives to fossil fuels. Algeria is prioritizing solar photovoltaic energy due to its abundant solar resources, Where Algeria possesses one of the highest technical and economic potential for solar power in MENA region, estimated at approximately 170 terawatt-hours (TWh) annually.[1] Algeria has launched significant projects, including a 1Gw solar initiative and the use of solar energy by Sonatrach for its remote operations.[2] Nevertheless, Wind energy is also a strategic choice for Algeria to consider. While solar PV remains the priority, wind energy offers a complementary solution due to Algeria's significant wind resources. The country has already developed a 10 MW wind farm in Adrar and aims to install at least 1,000 MW of wind capacity by 2030.[3]

Several studies have assessed the feasibility of wind energy in Algeria. Himri et al. (2008)[4] analyzed wind power potential at key locations, while Boudia et al. (2016)[5] investigated the technical and financial feasibility of wind farms in various climatic zones. Recent work by Aroua et al. (2024)[6] emphasized the role of wind farms in stabilizing Algeria's power grid. However, Gaps remain most importantly the focus on technical aspects without sufficient financial depth, mostly relying on Weibull distribution and the lack of a sensitivity analysis reflecting the real-world financial uncertainty. Evaluating the techno-economic feasibility of wind energy projects is essential for identifying viable solutions and guiding investment

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[1] Zhao, L. et al., (2018), "*Economic analysis of solar energy development in North Africa*". Global Energy Interconnection, vol. 1, no. 1, p58
[2] Sonatrach, (2023), *Annual report 2022*, p85.
[3] Algerian Agency for Investment Promotion web-site: aapi.dz/ar/secteur-des-energies-nouvelles-et-energies-renouvelables-ar/, visited in 28/01/2025 at 14:06
[4] Himri Y. et al. (2020), "*Potential and economic feasibility of wind energy in south West region of Algeria*", Sustainable Energy Technologies and Assessments, vol.38, p1-8.
[5] Boudia, S. M et al., (2016), *"On the use of wind energy at Tlemcen, North-western region of Algeria"*, Energy Procedia, vol. 93, p141-145.
[6] Aroua F.Z et al. (2024), "*Wind energy cost evaluation based on a techno-economic assessment in the Algerian highlands*", Energy for Sustainable Development, vol. 81, p1-11.

decisions. Tools such as LCOE, NPV, and PVC (provide critical insights into the profitability and feasibility of such projects. For example, Aroua, F.Z. et al. (2024) [1] used PVC for wind energy cost evaluation, *Himri, Y. et al.* (2020)[2] studied the economic feasibility of wind energy using the NPV. As for Myhr, A.et al (2014) LCOE was used for wind energy cost assessment of offshore floating wind turbines.

In this study, we will assess wind potential across various regions in Algeria to identify the most suitable for wind energy generation. We will then conduct a financial analysis to determine the viability of installing wind farms in these regions. This study contributes to the broader goal of transitioning to a low-carbon economy and reducing reliance on fossil fuels

Research Problem:

To what extent is wind energy techno-economically viable for electricity generation in Algeria?

This research problem is accompanied by several sub-questions:

- How does the choice of wind turbine influence the technical and financial viability in Algeria?
- How does the techno-economic feasibility vary between Algerian regions?
- How sensitive are key financial indicators to changes in key variables?

Hypotheses:

- **H1:** Wind energy viability vary significantly between regions.
- **H2:** The choice of wind turbine influence significantly the technical and financial viability.
- **H3:** The economic feasibility metrics of wind energy projects are highly sensitive to variations in key variables.

[1] Aroua F.Z et al. (2024), "*Wind energy cost evaluation based on a techno-economic assessment in the Algerian highlands*", Energy for Sustainable Development, vol. 81, p1-11.
[2] Himri, Y. et al., (2020), "*Potential and economic feasibility of wind energy in south West region of Algeria*", Sustainable Energy Technologies and Assessments, vol. 38, p1-8.

Research Methodology:

This study adopts a quantitative and analytical approach. It employs economic evaluation models such as Levelized Cost of Energy, Net Present Value, Internal Rate of Return, and sensitivity analysis to assess the techno-economic feasibility of wind energy projects across different turbine models and scenarios in Algeria..

Research Plan:

the study will be conducted in three main chapters:

The first chapter introduces the concept of renewable energy as a fundamental part of the global energy transition and environmental sustainability. It explores key technologies related to renewable energies and wind energy in particular, highlighting their benefits, challenges and socio-economic impacts.

The second chapter concerns the economic feasibility framework of wind energy projects, it highlights key economic metrics used in such studies, The financial risk of wind projects, And finally a literature review for existing studies for such projects.

The last chapter Empirical Study will analyze data of Algeria's wind energy potential, applying economic evaluation methodologies such as LCOE, NPV, and other key indicators to assess the viability of wind energy projects. A sensitivity analysis will be conducted to evaluate the impact of variations in key technical and financial variables on project viability.

Chapter 1:

Renewable Energy and Its Relevance to Algeria

Chapter 1: Renewable Energy and Its Relevance to Algeria

Introduction:

In today's world, with the increasing energy demands and the pressing need to mitigate climate change, renewable energy has become a central focus for governments and organizations worldwide. As nations shift away from fossil fuels, the adoption of renewable energy sources is not only seen as a solution to environmental challenges but also as a means of achieving energy security and economic growth. Algeria, like many other countries, is seeking to harness its renewable energy potential to diversify its energy portfolio and reduce its dependence on fossil fuels.

The importance of renewable energy lies in its ability to provide sustainable, clean, and abundant energy while reducing greenhouse gas emissions and environmental degradation. It is essential to understand the different types of renewable energy, their advantages, and how they compare to traditional fossil fuels. Additionally, the socioeconomic impacts of renewable energy, such as job creation, energy independence, and public health improvements, highlight its transformative potential. Among the various renewable energy sources, wind energy stands out as a viable option for Algeria due to its favorable geographic conditions and significant wind resources. However, the successful adoption of wind energy also comes with challenges that need to be addressed.

The main objective of this chapter is to present what one needs to know about renewable energies in general and wind energy in particular, and what are Algeria's renewable energy strategies and policies.

This chapter is divided into three sections:

- Section 1: Introduction to Renewable Energy:
- Section 2: Renewable Energy Sector in Algeria
- Section 3: Wind Energy

Section 1: Introduction to Renewable Energy:

This section introduces the concept of renewable energy, emphasizing its importance in tackling global energy challenges. It begins with a general overview, defining renewable energy and highlighting its role in sustainable development. A comparative analysis between renewable energy and fossil fuels is then presented, focusing on their environmental, economic, and sustainability dimensions. Finally, the various types of renewable energy which will be briefly explained, providing insights into their principles and applications.

1. General View on Renewable Energy:

Renewable energy has gained increasing attention as a sustainable alternative to conventional fossil fuels. To better understand its significance, it is essential to define what renewable energy is and explore its key characteristics.

1.1.Definition of Renewable Energy:

Energy obtained from natural and persistent flows of energy occurring in the immediate environment. Fossil fuels - coal, oil and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form.[1]

1.2. The Role of RE in Sustainable Development and Combatting Climate Change:

Renewable energy plays a crucial role in both sustainable development and combating climate change. By harnessing clean energy sources like wind power, we can significantly reduce our reliance on fossil fuels, which are major contributors to greenhouse gas emissions and global warming. Renewable energy promotes sustainable development by providing access to clean and reliable energy sources, particularly in remote and isolated communities. This can improve living standards, enhance economic growth, and create jobs in the renewable energy sector. By shifting towards renewable energy, we can drastically reduce greenhouse gas emissions, the primary driver of climate change. This helps to mitigate the impacts of global warming, such as rising sea levels, extreme weather events, and biodiversity loss.[2]

[1] Twidell, J. and Weir, T. (2006), *Renewable Energy Resources*, 2nd edition, Taylor and Francis, p7.
[2] Krishna, K.J. et al., (2022), *"Renewable and sustainable clean energy development and impact on social, economic, and environmental health",* Energy Nexus, vol. 7, p1-10.

1.3.Global Trends in Renewable Energy Adoption:

Renewable energy adoption has seen unprecedented growth over the last two decades, driven by technological advancements, falling costs, and increasing awareness of climate change. As of 2023, global renewable energy capacity reached approximately 3864 gigawatts**,** this represents a 227.55% increase compared to the previous decade in 2014, demonstrating consistent growth in renewable energy investments.[1] Notably:

- Solar power accounts for the largest share of this growth, with a total installed capacity of over 1418 GW. Solar photovoltaic (PV) technologies have become increasingly cost-competitive, with solar PV costs dropping by 85% since 2010, Figure 1 illustrates the declining price of solar panels since 1975, dropping from over 120 $/W to nearly 0.31 $/W. This reduction is driven by technological advancements, making solar PV more competitive.

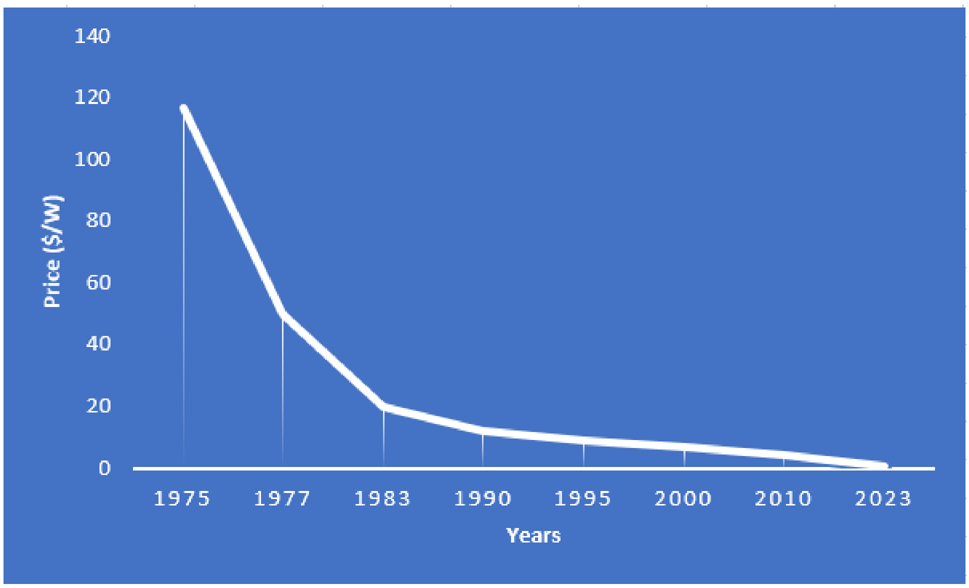

Figure 1: **Solar Panels Price Overtime**

Source**:** OWID website: ourworldindata.org/grapher/solar-pv-prices, visited 14/03/2025 at 15:30

- Wind power follows closely, with a total capacity of 1017 GW.[2]

[1] IRENA, (2024), *Renewable energy statistics 2024 report*, International Renewable Energy Agency, Abu Dhabi, p2
[2] Ibid, p26.

2. Comparison Between Renewable Energy and Fossil Fuels:

Table 1 highlights key differences between the two sources of energy:

Table 1: **Comparison Between Renewable Energy and Fossil Fuels**

Element	Conventional Energy	Renewable Energy
Availability	- Finite resources that are unevenly distributed across the globe. - Concentrated in specific regions (oil in the Middle East, coal in the U.S. and China).	- unlimited and replenished. - Sources like solar, wind, and hydropower are widely available,. - Renewable energy availability can vary seasonally and daily
Environmental Impact	- Burning fossil fuels releases significant amounts of (GHGs), such as carbon dioxide (CO_2) and methane (CH_4). - Causes air pollution, acid rain, and water contamination from spills and toxic by-products. - Mining and drilling degrade ecosystems and biodiversity (deforestation, habitat destruction).	- Produces little to no GHG emissions during operation (solar panels and wind turbines generate energy without combustion). - Environmental impacts are mainly associated with manufacturing and installation (e.g., mining raw materials for solar panels).
Sustainability	- unsustainable, Reserves are being depleted faster than they are replenished, making them.	- Sustainable: Harnesses natural processes that are replenished

GHGs	Account for 75% of global GHGs and 90% of CO_2 emissions. With coal-fired power plants emit around 820 gCO_2/kWh, while natural gas emits 490 gCO_2/kWh.[1]	- Solar, wind, and hydropower emit less than 20 gCO_2/kWh over their life cycle, making them far cleaner. - Transitioning to renewables could reduce 75% of global CO_2 emissions by 2050.[2]
Cost Trends	- Historically cheaper due to established infrastructure and government subsidies. - Costs are rising due to resource scarcity, environmental regulations, and carbon pricing.	- Costs have been falling rapidly due to technological advancements and economies of scale. - Between 2010 and 2022, the cost of solar PV fell by 89%, and onshore wind fell by 70%. - Renewables are now cheaper than fossil fuels in many regions, even without subsidies.

Source: Student's work based on data from the UN and IRENA

[1] UN web-site: un.org/en/climatechange/science/causes-effects-climate-change, visited in 24/12/2024 at 15:12
[2] IRENA, 2019, *Global energy transformation: A roadmap to 2050 report*, International Renewable Energy Agency, Abu Dhabi, p23

3. Types of Renewable Energies:

Renewable energies, like fossil fuels have many types, or rather say sources, Hydropower as shown in Figure 2 is the leader in renewable energy market, where it accounts for more than 50% of energy production in 2024, followed by wind energy.

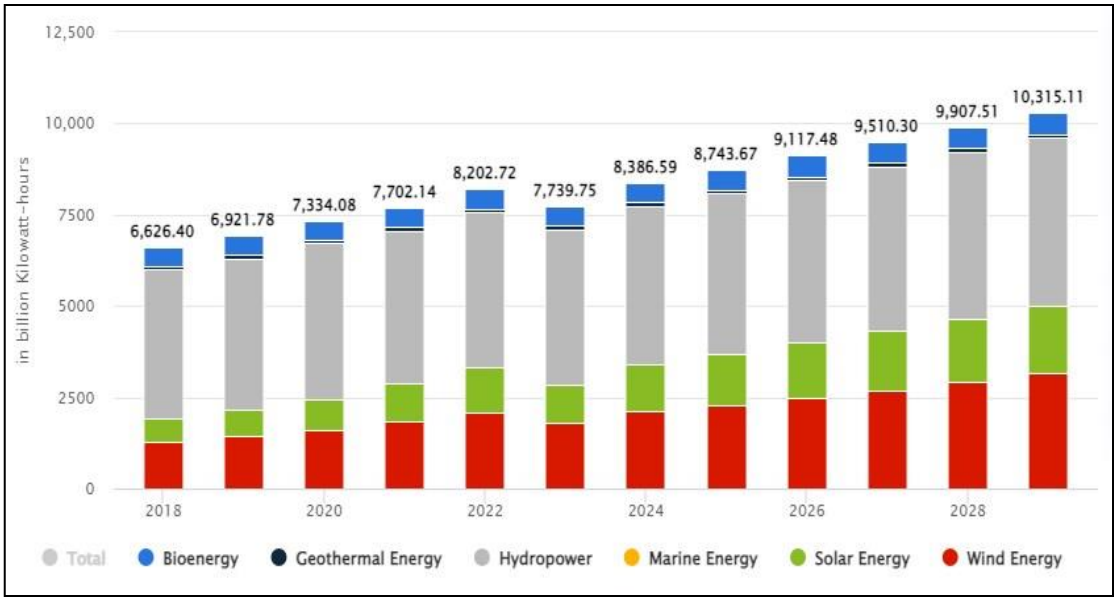

***Figure 2: Global* Renewable Energy Production by Type (2018-2028)**

***Source*:** Statista website : statista.com/outlook/io/energy/renewable-energy/worldwide, visited in 25/12/2024 at 13:12

3.1. Wind Energy:

Wind energy is the process by which wind is used to generate mechanical power or electrical power. The power of the wind has been used for at least 3,000 years. Until the 20th century, wind power was used to provide mechanical power to pump water or to grind grain. At the beginning of modern industrialization, the use of the fluctuating wind energy resource was substituted by fossil-fuel-fired engines or the electrical grid, which provided a more consistent power source. So, the use of wind energy is divided into two parts: mechanical power generation; and electrical power generation.[1]

[1] Mohd Hassan Ali, (2012), "*Wind Energy Systems*", 1st ed, CRC Press, p2.

3.2. Solar Energy:

Solar energy is produced directly by the sun and collected elsewhere, usually the Earth. The sun creates its energy through a thermonuclear process that converts about 650 mega tons of hydrogen to helium every second. The process creates heat and electromagnetic radiation. The latter (including visible, infrared, and ultraviolet) streams into space in all directions.[1] The main technologies of solar energy are: Photovoltaic (PV) systems, which directly convert sunlight into electricity using solar panels made of semiconductor materials.[2] And Concentrated Solar Power (CSP) systems, which use mirrors or lenses to focus sunlight onto a small, concentrated area, creating intense heat. This heat is used to produce steam, which drives turbines to generate electricity. A CSP station is shown in Figure 3, A 100 MW CSP located in Abu Dhabi.

Figure 3: Shams Solar Power Station for CSP (United Arab Emirates)

***Source*:** Shams Solar Power Station website: shamspower.ae visited in 24/12/2024 at 13:12

3.3. Hydropower:

Hydropower technologies are used for both storage and production of energy. Hydroelectric plants use the potential energy of water, due to the different heights of the waterflow and the turbines of the plant. Potential energy is then turned into mechanical energy by the turbines themselves and, consequently, into electric energy through a generator.[3]

[1] Silva, O.K.T.N et al. (2024), "*Solar energy technologies: A complete review of the solar system technologies*", Journal of Research Technology and Engineering, vol. 5, no. 1, p85.
[2] Kaygusuz, K., *"Renewable Energy: Power for a sustainable future, Energy Exploration and Exploitation"*, vol. 19, no. 6, 2001, p615.
[3] Matarazzo, A. and Sgandurra, M. (2018), "*Hydropower as an important renewable energy source*", International Journal of Natural Resource Ecology and Management, vol. 3, no. 4, p67.

3.4. Biomass Energy:

Biomass energy is a generic term applied to energy production achieved from organic material broken down into two broad categories: Woody biomass. Forestry timber, residues and co-products, other woody material including thinning and cleaning from woodlands (known as forestry arisings), untreated wood products, energy crops such as willow, short rotation coppice (SRC), and miscanthus (elephant grass). And Non-woody biomass. Animal wastes, industrial and biodegradable municipal products from food processing and high-energy crops such as rape, sugarcane, and corn.[1]

3.5. Geothermal Energy:

Geothermal energy harnesses heat from within the Earth to generate electricity or provide heating. This renewable energy source utilizes the thermal energy stored in the Earth's crust.[2] Geothermal energy is reliable, sustainable, and provides a consistent energy supply independent of weather conditions. Direct use involves tapping into geothermal reservoirs near the surface for applications such as space heating, greenhouse heating, aquaculture, and industrial processes. Geothermal power plants[3] use heat from the Earth to generate electricity. Geothermal Heat Pumps (GHPs) Use the Earth’s stable near-surface temperatures to heat and cool buildings by circulating fluid through underground pipes, exchanging heat efficiently year-round.[4]

3.6.Wave Energy:

Wave energy is a promising renewable source with a global potential estimated at 29,500 TWh/year, significantly exceeding the world's electricity consumption. The most productive wave energy regions include the North Atlantic, North Pacific, and the Southern Ocean. Leading countries in wave energy development, such as the UK, Portugal, and Australia, have deployed various technologies, including oscillating water columns, point absorbers, and overtopping devices. Despite challenges like high capital costs (ranging from €3-7 million per MW for pilot

[1] Kalogirou, S. (2009), “*Solar energy engineering: Processes and systems*”, Academic Press, P38.
[2] IRENA web-site : *irena.org/Energy-Transition/Technology/Geothermal-energy* visited in 26/12/2024 at 16:58
[3] US Energy Information Administration web-site *eia.gov/energyexplained/geothermal/geothermal-power-plants* visited in 26/12/2024 at 17:20
[4] US Department of Energy web-site :*energy.gov/energysaver/geothermal-heat-pumps* visited in 27/12/2024 at 14:58

projects) and harsh marine environments, advancements in materials and maintenance strategies are improving feasibility. With estimated LCOE values between €150-450/MWh, further technological innovations and policy support are needed to enhance commercial viability and integration into grids.[1]

3.7.Tidal Energy:

Tidal energy is an energy harnessed from ocean tides, with technologies such as tidal barrages, tidal stream generators, and tidal lagoons. The global tidal energy potential is estimated at 1 terawatt (TW), with leading projects like France's 240 MW La Rance Tidal Power Station and South Korea's 254 MW Sihwa Lake Tidal Power Plant. Despite its advantages, including long-term sustainability and low emissions, tidal energy faces challenges such as high initial costs, which can exceed $300 million per project, and environmental concerns, including impacts on marine ecosystems. However, advancements in tidal stream technology, like Scotland's 398 MW MeyGen Project, demonstrate its growing feasibility as a clean energy solution.[2]

4. Socioeconomic Impacts of Renewable Energy:

The transition to renewable energy systems, including wind energy, has proven to be a significant driver of socioeconomic development globally. Investments in renewable energy not only help mitigate environmental challenges but also contribute to job creation and economic growth across various sectors of the economy. This section explains how renewable energy sectors, particularly wind energy, generate employment opportunities and provide examples of countries and regions where renewable energy has supported economic development.

4.1. Job Creation and Economic Growth:

4.1.1. Employment Opportunities in Renewable Energy Sectors:

Renewable energy projects, including wind farms, involve a wide range of activities that generate employment opportunities at different stages of their lifecycle. These stages include manufacturing, installation, operation, and maintenance, as well as research and development (R&D).

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[1] IRENA, (2014), "*Wave energy: Technology brief*" [technical report], International RE Agency, p5-12.
[2] IRENA, (2014), "*Tidal energy: Technology brief*" [technical report], International RE Agency, p3-15.

The renewable energy sector employed approximately 16.2 million people globally in 2023, with the wind energy sector alone accounting for 1.4 million jobs.[1]

Different types of employment created by industries like renewable energy are : Direct Jobs**,** which include roles in manufacturing wind turbine components, constructing wind farms, and maintaining wind energy systems. Jobs in this category require specialized skills in engineering, technology, and construction. Or Indirect Jobs**,** which are created in supply chains that support renewable energy projects, such as the production of raw materials, transportation, and logistics. Moreover, renewable energy jobs tend to be more labor-intensive during the installation phase compared. For example, the construction of onshore wind farms requires a significant workforce for site preparation, turbine installation, and grid connection. Additionally, offshore wind energy projects generate opportunities in maritime transport, port infrastructure, and engineering services.[2]

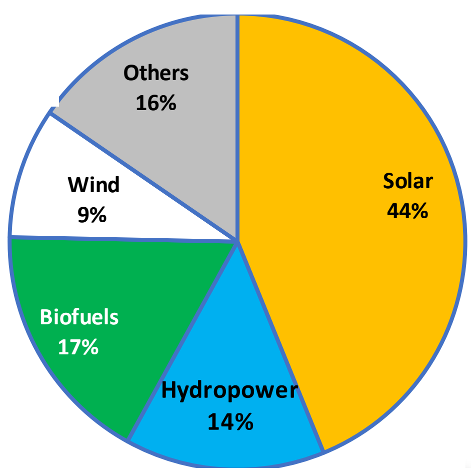

Figure 4: **Renewable Energy Workforce by Sector**

Source: IRENA and ILO (2024), Renewable energy and jobs: Annual review, p10.

Figure 4 shows the renewable energy workforce by sector, as of 2024, the solar sector is the leader in jobs making, where it accounts for 44% of the global renewable energy workforce, followed by Biofuels (Biomass), Hydropower and Wind respectively, The other renewable energy sources account for just 16% of the workforce.

[1] IRENA and International Labor Organization, (2024), "*Renewable energy and jobs: Annual review 2024*", p10.
[2] Aldieri, L. et al., (2019), *"Wind Power and Job Creation"*, Sustainability, vol.12, no. 45, p5-10.

4.1.2. Economic Development Through Renewable Energy:

The fight against climate change has the potential to generate $26 trillion by 2030. This leads to wealth creation and encourages states and businesses to engage effectively.[1] Renewables will increase the global GDP by 2.4% in 2050. In the case of Algeria, RE offers significant socio-economic benefits, including cost savings. By reducing dependency on fossil fuels, Algeria can free up over 550 million cubic meters of gas annually for export, generating at least $100 million. The sector is expected to create 200,000 jobs, 100,000 for national energy production and 100,000 for exports. Large-scale solar projects could employ 56,000 workers during construction and 2,000 during operation. Environmentally, renewable energy could help Algeria cut CO_2 emissions by 1.3 million tons annually, valued at $70 million. Additionally, It aims to strengthen its international market presence by developing 34,411 km of transmission lines, facilitating renewable electricity exports. Despite the high investment cost of $120 billion, declining technology costs will enhance affordability. Local manufacturing and financing requirements will drive domestic industrial growth, while RE education initiatives will build expertise for future sector development.[2] Below is an overview of leading countries in RE in their regions:

- China is the world's largest investor in renewable energy, accounting for over 30% of global renewable energy investments in 2022.China is the largest producer of solar panels, wind turbines, and batteries. The renewable energy sector generated 7.4 million jobs until 2022 (46% of world's total RE jobs).[3] RE investments reached $546 billion in 2022.
- Egypt aims to generate 42% of electricity from renewables by 2035, with major investments in solar (e.g., the 1.5 GW Benban Solar Park) and wind projects (e.g., Gulf of Suez farms). The private sector plays a key role, supported by grid upgrades and international partnerships. RE capacity reached 6,378 MW by 2021, reducing CO_2 emissions and advancing sustainability goals.[4]
- Kenya is a leader in renewable energy in Africa, with geothermal energy being a key driver of economic development. Kenya generates over 50% of its electricity from geothermal sources.

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[1] Ahmedbelbachir, M, (2023), "*Renewable energies, transition and prospects: The case of Algeria*", The Eurasia Proceedings of Educational and Social Sciences, vol. 32, p64.
[2] Slimane, S et al., (2022), *Financial or Socio-Economic Feasibility? Potential Assessment of Renewable Energy Investment in Algeria*, Journal of Asian Energy Studies, vol. 6, p48-58.
[3] IRENA and ILO (2024), *Renewable energy and jobs: Annual review 2024*, p10.
[4] International Trade Administration web-site: trade.gov/country-commercial-guides/egypt-electricity-and-renewable-energy visited in 03/01/2024 at 10:33

The renewable energy sector has created 300,000 direct and indirect jobs. Electrification rat increased from 28% in 2010 to 75% in 2023**.** Contribution of geothermal energy to GDP is estimated at 1.3% annually**.** Renewable energy investments was $1.4 billion in 2022.[1]

- As for the US, rural communities hosting wind farms benefit from $1.6 billion in annual lease payments to landowners. Share of renewables in electricity generation jumped to 23% in 2023, up from 8% in 2008. RE jobs counted for slightly more than a million in 2023.[2]

4.2. Contribution to Energy Security:

Energy security refers to the reliable and uninterrupted availability of energy sources, minimizing reliance on imports. It involves supply diversification, system resilience, and protection against disruptions from geopolitical or market instabilities. Renewable energy significantly strengthens energy security by reducing dependence on fossil fuel imports and stabilizing energy costs. Technologies like wind and solar, being modular and distributed, are less prone to large-scale failures. Unlike finite fossil fuels, renewables are abundant and locally sourced, enhancing national resilience and autonomy. Countries such as Kenya and Costa Rica have achieved near energy self-sufficiency through geothermal and hydropower. In rural and off-grid areas, renewables improve access and reduce energy poverty. The U.S. has similarly boosted its energy security, with the Inflation Reduction Act of 2022 expected to channel $369 billion into renewable investments by 2030, reducing dependence on imported oil and gas.[3]

Algeria faces increasing challenges to long-term energy security due to resource depletion, price volatility, and geopolitical risks. Integrating RE particularly solar and wind into its energy mix can strengthen national energy independence. With vast desert areas and high solar irradiation, Algeria holds one of the greatest solar energy potentials in the Mediterranean. Investments in large-scale solar PV, CSP, and wind power would reduce reliance on finite hydrocarbons and shield the economy from fossil fuel market instability. Moreover, decentralized renewable systems can enhance electricity access in remote regions, promoting rural

[1] Kenyan Ministry of Energy and Petroluim, (2023), *Kenya Energy Transition and Investment Plan 2023-50 [government report]*, p15-20.
[2] US Energy Department web-site energy.gov/eere/energy-independence-and-security, visited in 01/01/2025 at 12:00
[3] UN Trade and Development (UNTAD) web-site : investmentpolicy.unctad.org/investment-policy-monitor/measures/4004/-369-billion-in-investment-incentives-to-address-energy-security-and-climate-change-, visited in 21/12/2024 at 13:54.

development and national resilience. This transition also aligns with Algeria's international climate commitments and supports its broader strategy for economic diversification.[1]

4.3. Environmental Impacts:

Renewable energy plays a pivotal role in mitigating environmental challenges by reducing greenhouse gas emissions, decreasing air and water pollution, and conserving natural resources. Unlike fossil fuels, renewable energy sources emit little to no carbon dioxide during operation, making them critical tools in combating climate change. For instance, the U.S. Energy Information Administration reported that wind and solar energy combined to offset over 600 million tons of CO_2 emissions in 2022. RE also help preserve biodiversity by reducing the need for mining and drilling.

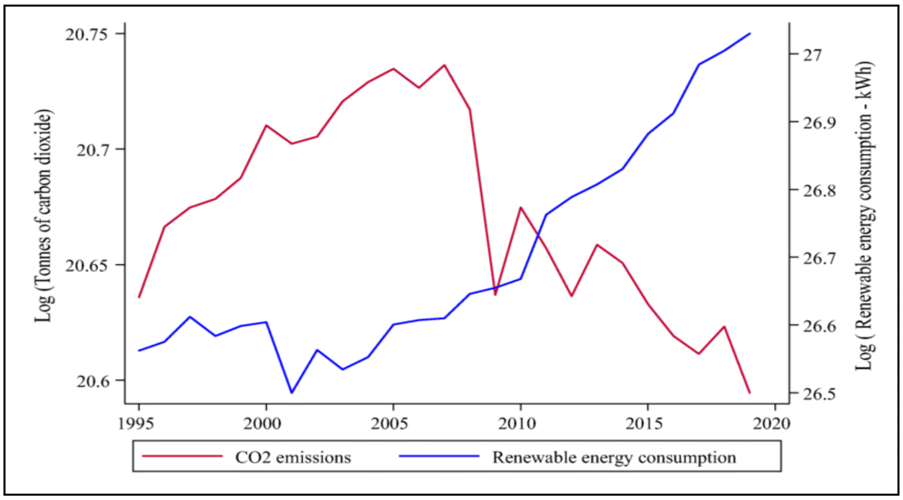

***Figure 5*: Relation Between CO_2 Emissions and Renewable Energy Consumption**

<u>Source</u>: Ponce, P. Khan, S. A. R., (2021), "*A Causal Link Between RE, Energy Efficiency, Property Rights, And CO_2 Emissions In Developed Countries: A Road Map For Environmental Sustainability*", Environmental Science and Pollution Research International, vol. 28, p 206.

Figure 5 illustrates the relation between CO2 emissions an renewable energy consumption, It is clearly observable that there is an inverse relationship between the two, This trend highlights the role of renewable energy in reducing carbon emissions, supporting global decarbonization efforts.

[1] Mokrani, M.D and Moudjari, R., (2022), Energy Security in Algeria: Opportunities and Challenges", Finance and Business Economics Review vol. 6, no. 4, p266-277.

Nevertheless, like every other technology, RE while essential, faces several challenges. Its intermittency affects reliability, as seen in Germany's energy transition after the Russo-Ukranian war and the cut off of Nord Stream 2, where insufficient wind or sunlight risks supply stability. High upfront costs are another barrier, with Australia's full renewable transition projected to exceed $642 billion. Additionally, renewables require up to 10 times more land than fossil fuel plants, raising environmental concerns. Supply chain issues also persist, as mining for rare-earth elements generates 2,000 tons of toxic waste per ton extracted. The economic impact is evident in rural Australia, where rushed renewable projects threaten local economies. Finally, grid integration is a major hurdle, with Victoria, Australia, facing blackout risks due to renewable supply gaps.[1]

4.5. Public Health:

Renewable energy reduces air pollution caused by burning coal, oil, and gas, which is linked to respiratory and cardiovascular diseases. A study found that transitioning to 100% clean energy could save over 90,000 lives annually in the U.S. by improving air quality.[2] Air pollution from fossil fuels contributes to over 8 million premature deaths globally each year.[3]

Traditional energy sources release harmful pollutants, including: Sulfur dioxide which worsens asthma and respiratory illnesses and Nitrogen oxides which leads to smog formation, increasing asthma and bronchitis. So transitioning to RE will reduce the rate of such illnesses

Burning fossil fuels releases carbon dioxide and methane accelerating global warming, which leads to: Heatwaves, heat-related deaths, especially among the elderly. Extreme weather events, lead to injuries and displacement. And Vector-borne diseases Rising temperatures expand mosquito- and tick-borne diseases like malaria and Lyme disease. Scientific advances help quantify climate change related health impacts, such as attributing 37% of heat-related deaths to human-induced climate change. WHO projects climate change will cause 250K additional deaths annually by the 2030s. The crisis threatens decades of progress in global health and poverty reduction, exacerbating inequality

[1] Australian Labor Party web-site: liberal.org.au/2024/11/15/the-real-cost-of-labors-energy-plan-revealed visited in 3/8/2025 at 13:01.
[2] American Lung Association web-site: lung.org/media/press-releases/2023-driving-to-clean-air-report Visited in 30/12/2024 at 20:14
[3] Vohra, K. et al., (2021), *"Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem"*, Environmental Research, vol. 195, p. 110757.

and limiting access to healthcare. Over 930 million people already face high healthcare costs, with climate-related health shocks pushing 100 million into poverty annually. The transition to to renewable energy sources will combat climate change thus reducing its impacts.[1]

[1] World Health Organization web-site: who.int/news-room/fact-sheets/detail/climate-change-and-health Visited in 30/12/2024 at 20:45

Section 2: Renewable Energy Sector in Algeria

In this section, we will display the reality of the renewable energy sector in Algeria, highlighting strategies and policies adopted by the Algerian government, Algeria's potential in different renewable energy sectors and existing projects.

1. Overview of Algeria's Renewable Energy Policies and Strategies:

Algeria, A country rich with vast solar and wind resources, is strategically positioned to transition from being predominantly a hydrocarbon-based economy to one that integrates renewable energy sources. This shift is propelled by a combination of environmental concerns, economic diversification needs, and the global push towards sustainable energy.

Algeria recognizes the critical importance of integrating renewable energy into its national energy strategy. The country aims to produce 27% of its electricity from renewable resources by 2030, with a significant focus on solar power.[1]

However, Algeria is still far behind, not only world widely but even from Arab countries shown in Figure 6, we observe that the leaders in the Arab world are Egypt (including 1856MW solar and 1890MW wind), UAE (including 5952MW solar and 104MW wind) and Morocco (including 934MW solar and 1858MW wind) respectively. Countries with similar population and even smaller GDP like Morocco, has 10 times installed capacity compared to Algeria. Even Tunisia, a country with 4 times less GDP and population has a higher installed capacity then Algeria, which raises questions regarding the current situation of Algeria's renewable energy sector even though it has the potentials to be one of the leaders in renewables.[2]

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[1] Algerian Agency for Investment Promotion web-site: aapi.dz/ar/secteur-des-energies-nouvelles-et-energies-renouvelables-ar/, visited in 28/01/2025 at 14:06

[2] IRENA, (2024), *RE Capacity Statistics,* International RE News Agency, *p14-23*.

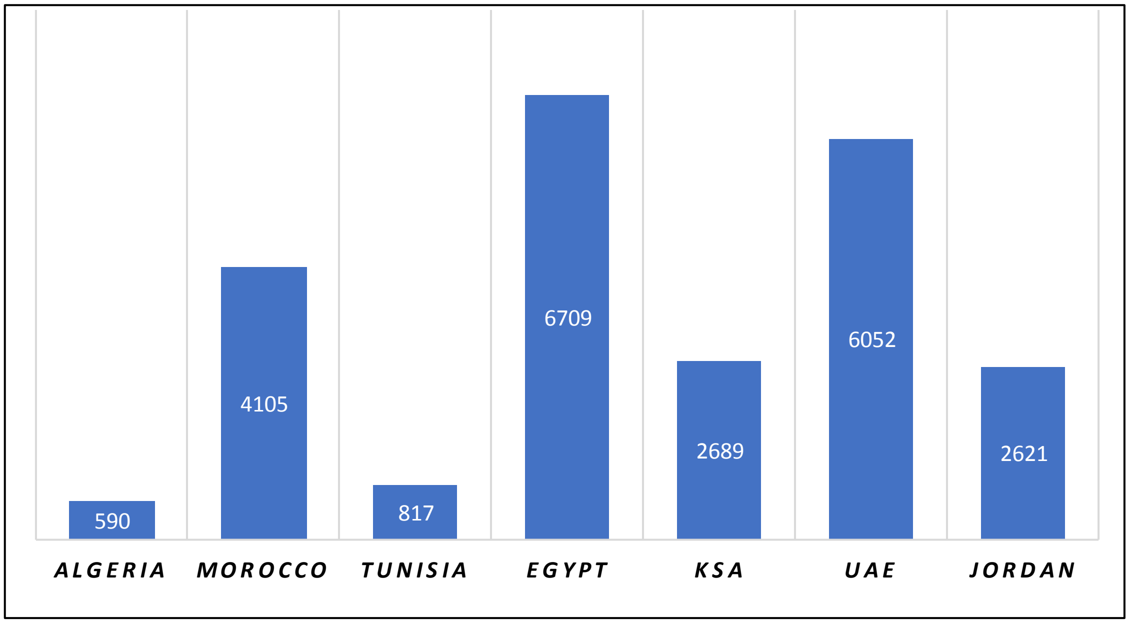

Figure 6: Renewable Energy Installed Capacity in Arab Countries (2023)

Source: Student's work based on stats from IRENA (2024*), RE Capacity Statistics, p2-4.*

1.1. Renewable Energies Potentials in Algeria:

Algeria has one of the highest solar fields in the world. The sun shines for nearly 2,000 hours annually across the entire national territory, and this can reach up to 3,900 hours (in the high plateaus and the desert). The energy obtained annually on a horizontal surface of 1m² is about 3 kW/m² in the north and exceeds 5.6 kW/m² in the vast south.[1]

Existing Renewable Installations:

One of the most important renewable installations in Algeria is the hybrid solar-gas power plant located in Hassi R'mel,. Commissioned in 2011, it has a total installed capacity of 150 MW, of which 25 MW is produced by a CSP thermal system, while the rest is generated from a natural gas component. This project integrates renewable and conventional energy.[2]

Wind energy has seen modest deployment so far, with the main project being the Kabertene wind farm in Adrar, operational since 2014. It comprises 12 GAMESA G52 turbines with a total installed capacity of 10.2 MW. The farm produced approximately 12.57 GWh in 2024. It connects to the 220kV Kabertene substation and contributes to the In Salah–Adrar–Timimoun power network.[3]

[1] Algerian Agency for Investment Promotion web-site: aapi.dz/ar/secteur-des-energies-nouvelles-et-energies-renouvelables-ar/, visited in 28/01/2025 at 14:06
[2] Ibid
[3] Sonelgaz, 2025, Kabertane Cost Structure [Unpublished internal document].

In the PV sector, Algeria has implemented numerous grid-connected projects, with the total installed PV capacity reaching 344.1 MW by mid-2018. A key example is the experimental PV station in Adrar city, with a 20 MW capacity, as well as the Bir Rebaa 10 MW plant developed in 2018 in partnership between Sonatrach and ENI. These projects contribute to both national electricity supply and to research and performance monitoring under desert climatic conditions.[1]

Planned Renewable Installations:

For Sonelgaz group, the projects under development for its subsidiary S-ER are:

Table 2: **S-ER Projects Under Development**

	Projects Under Development (All Solar)
	Project ABADLA (Béchar) 80 MW peak
	Project Batmete (M'sila) 220 MW peak; Tamacine (Touggourt) 250 MW peak.
	Project Gueltlet sid saad(LAGHOUAT) 200 MW peak
	Project Douar EL Maa (El oued) 200 MW peak
	Project Ouled Djellal(Ouled Djellal) 80 MW peak
	Project LEGHROUS (Wilaya BISKRA) 200 MW peak
	Project de KHENGUET SIDI NADJI (Wilaya de BISKRA) de 150,03 MW peak
	Project TENDLA 200 MW peak (MGHAIER); Tindouf 11 MW peak
	Project d' EL EUCH (Bordj Bou Arreridj) 80.1 MW peak
	Project de TALEB LARBI (wilaya de EL OUED) 80,1 MW peak
	Project GUERRARA (GHARDAIA) 82 MW peak
	Project de OULED FADEL (Wilaya BATNA) de 80 MW peak
	Project Kenadsa (Béchar) 123 MW peak; Gara Djebilet 200 MW peak
	Project de BENI OUNIF (Wilaya de BECHAR) de 50 MW peak
	Project de d'AIN EL BEIDA (Wilaya de OUERGLA) 100.56 MW peak
	Project Foulia (EL OUED) 300 MW peak; BEH 1MW peak
	Project Hassi Delaa (Laghouat) 316,80 MW peak

Source: Given by S-ER's Management Control Department.

[1] Bouraiou, A. et al., (2020), *"Status of renewable energy potential and utilization in Algeria"*, Journal of Cleaner Production, vol. 246, p1-16.

Capacity of the Renewable Energy Development Program:

The required capacity for the renewable energy program to meet national market needs from 2015 to 2030 is estimated at 22,000 MW, distributed according to the following sectors:

- Photovoltaic energy: 13,575 MW.
- Concentrated solar power project: 5,010 MW.
- Combined generation: 2,000 MW.
- Wind energy: 400 MW.
- Biomass: 1,000 MW.
- Geothermal energy: 15 MW.

2. Government Policies and Initiatives:

2.1.Creating New Ministries and Companies:

To oversee the renewable energy rollout, the government established the Ministry of Energy Transition and Renewable Energies (MTEER) by the Executive Decree No.322-20 dated 6th of Rabii' al-Thani 1442, corresponding to November 22, 2020.[1]

This ministry aims to deepen its communication activities regarding the challenges of the energy transition towards all components of society, especially the youth generation.

This will be done through educational media starting from intermediate educational years, as well as through its work related to vocational training programs directed at various technicians who will undertake, among other tasks, the practical implementation of renewable energy facilities, including both large centralized systems and decentralized systems for self-consumption, throughout the country. Additionally, in 2021, the government created a new renewable energy company, SHAEMS, to further support these initiatives and contribute to electricity generation by solar energy.[2]

[1] Algerian Agency for Investment Promotion web-site: aapi.dz/ar/secteur-des-energies-nouvelles-et-energies-renouvelables-ar/, visited in 28/01/2025 at 14:06

[2] Ibid

2.2.Financial Incentives, Subsidies, and Partnerships:

Algeria has been proactive in forming strategic partnerships to attract investments in the renewable energy sector. In 2021, the government sought to develop partnerships with countries including China, Germany, and the United States to advance renewable energy projects.[1]

3. Feed-In Tariffs:

3.1.Definition:

A feed-in tariff (FiTs) is an energy-supply policy focused on supporting the development of new renewable power generation. The FiT contract provides a guarantee of payments in DZD per kilowatt hour (DZD/kWh) for the full output of the system for a guaranteed period of time (typically 15-20 years). A separate meter is required to track the actual total system output. There are two main methodologies for setting the overall return that renewable energy developers receive through FiT policies. The first is to base the FiT payments on the levelized cost of renewable energy generation; the second is to base the FiT payments on the value of that generation to the utility and/or society. This payment guarantee is often coupled with the assurance of access to the grid and the actual payment amount is usually differentiated based on technology type, project size, quality of the resource and/or other project-specific variables.[2]

3.2.Executive Decree 13-218:

The Decree 13-218 of June,18th,2013 establishes the framework for providing financial incentives to electricity producers who utilize RE sources, It aims to compensate for the additional costs associated with these technologies to encourage the diversification of Algeria's electricity production. These incentives take the form of a guaranteed purchase tariff (FiT), which ensures that electricity producers receive a fixed rate for selling electricity to distributors. This compensates for the higher costs of RE production compared to conventional fossil fuel-based generation. The decree applies to electricity production from:

[1] International Trade Administration Web-site: trade.gov/country-commercial-guides/algeria-renewable-energy visited in 28/01/2025 at 15:50
[2] K. Cory et al. (2009), "*Feed-in tariff policy: Design, implementation, and RPS policy interactions*", National Renewable Energy Laboratory, Colorado, p2.

- **Renewable Energy Sources:**

Solar energy both PV and solar thermal systems, Wind power. Geothermal energy, Waste-to-energy electricity generation from waste recovery, Small-scale hydropower and Biomass energy.

- **Hybrid Power Plants:**

Existing hybrid plants that combine fossil fuels and renewable sources are eligible if at least 5% of their annual electricity production comes from renewable energy.

- **Cogeneration (Combined Heat and Power - CHP):**

Installed power capacity must not exceed 50 MW. The system must achieve at least 5% primary energy savings compared to conventional separate heat and power production. The minimum ratio of useful heat to electricity produced must be 0.5.

- **The Guaranteed Purchase Tariff System:**

Electricity generated from renewables is purchased by the national grid operator (usually Sonelgaz Distribution), provided the project is authorized and connected to the grid. power producers must first obtain a production license from the Commission de Régulation de l'Électricité et du Gaz (CREG) that validates the project's eligibility for the guaranteed tariff scheme. Once approved, a Power Purchase Agreement (PPA) is signed between the power producer and the designated electricity distributor. This agreement obliges the distributor to purchase all surplus electricity (excluding internal self-consumption) at a fixed, technology-specific tariff proposed by CREG and formalized by ministerial decree. This tariff reflects the capital cost, operational cost, and expected production based on the site's potential.

The injection of electricity into the grid is monitored by metering systems installed at the point of connection. These meters provide verified data on the amount of energy delivered, which forms the basis of monthly or quarterly payments to the producer. Payments are typically handled by the distribution utility and are subject to audit and verification by the CREG.

If, after five years, the actual energy output deviates by more than 15% from the estimated reference used in the tariff calculation, the Ministry of Energy following CREG's proposal may revise the tariff for the remaining contract period. This adjustment ensures fair compensation while maintaining the system's integrity.[1]

[1] Executive Decree No. 13-218 of 9 Sha'ban 1434 corresponding to June 18, 2013 setting the conditions for granting premiums related to the costs of diversification of electricity production.

Section 3: Wind Energy

This section will display what one needs to know in general about wind energy, It will cover key definitions and characteristics of wind energy and its types, The wind turbines and their pivotal role in harnessing wind and transforming it into an environment friendly energy source, and finally the pros and cons of implementing such type of renewable energy.

1. Essentials of Wind Energy:

1.1. Definition:

As defined earlier, Wind energy is the process by which the wind is used to generate mechanical power or electrical power[1].The relationship between wind power and speed is:

$$P = 0.5 \times \rho \times A \times V^3 \qquad (1)$$

Where:

P = Power in watts (W) ; **ρ** = Air density (kg/m³)

A = Swept area of the turbine blades (m²) ; **V** = Wind speed (m/s).

1.2. Types of Wind Energy: wind energy has two main types:

1.2.1. Offshore Farms Generated Wind Energy:

Offshore wind energy involves generating electricity from wind turbines located in water bodies. It offers advantages like access to stronger, more consistent winds, larger installation areas, and proximity to high-demand urban centers. However, it also faces challenges like higher costs, specialized equipment needs, and limited accessibility for servicing.[2]

1.2.2. Onshore Farms Generated Wind Energy:

Onshore wind farms consist of wind turbines installed on land, ranging from small setups to large-scale arrays. They offer benefits like land use compatibility allowing coexistence with agriculture and scalability to suit different energy needs. However, challenges include wind intermittency requiring storage or backup, visual impact leading to public resistance, and significant land requirements that may cause environmental or land-use conflicts.[3]

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[1] Manwell,J. F.et al. (2009), "*Wind Energy Explained: Theory, Design and Application*", 2nd ed, John Wiley and Sons, UK, p53.

[2] Ibid, p461

[3] Haces-Fernandez, F. et al., 2022, "*Onshore Wind Farm Development: Technologies and Layouts*", Energies, vol. 15, p14.

2. Wind Turbines:

Wind turbines are complex machines designed to convert wind energy into electrical power. To understand the process by which the turbines generate energy from wind we have to first look at the main components of these turbines are:

Blades: Designed to capture wind, their shape and angle are crucial for efficient energy conversion. Modern blades have shapes similar to WWII aircraft wings.

The Hub: The hub connects the blades to the rotor shaft. Some hubs include pitch mechanisms allowing blades to adjust their angle to the wind for optimal performance.

Nacelle: Houses the gearbox, generator, controller, and other components.

Generator: Converts mechanical energy into electrical energy. There are various types, including synchronous generators, induction generators, and more modern direct-drive generators which eliminate the need for a gearbox.

Tower: Elevates the turbine to catch stronger, less turbulent winds higher above the ground.

Control Systems: Manage yaw (turning the nacelle to face the wind), pitch (adjusting the blade angle for optimal efficiency or to protect from high winds), and other operational parameters.[1]

Figure 7 illustrates the components of a wind turbine.

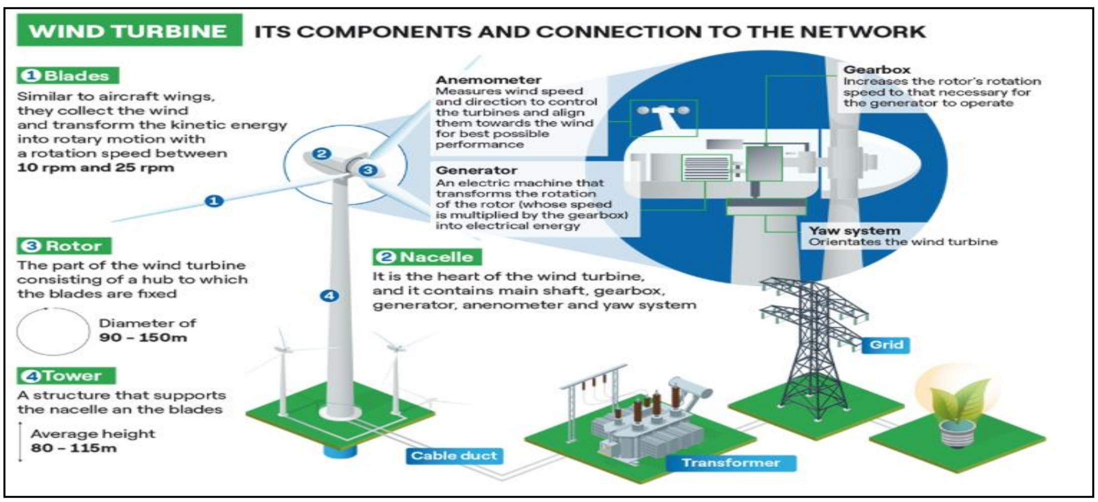

Figure 7: **Wind Turbine Components**

Source: Enel Green Power company's website :enelgreenpower.com/learning-hub/renewable-energies/wind energy/wind-turbine, visited in 29/12/2024 at 14:37

[1] Ibid, p4-6.

2.1.Types of Wind Turbines:

Wind turbines come in two main types:

2.1.1. Horizontal Axis Wind Turbines (HAWT):

Most common type, with blades rotating around a horizontal axis. They can be further classified into Upwind where blades face into the wind. Or Downwind where wind blades face away from the wind.[1] An illustration of a HAWT is presented in Figure è

2.1.2. Vertical Axis Wind Turbines (VAWT):

Blades rotate around a vertical axis as shown in Figure 8, offering advantages like not needing to be pointed into the wind, but generally less efficient than HAWTs at large scales.[2]

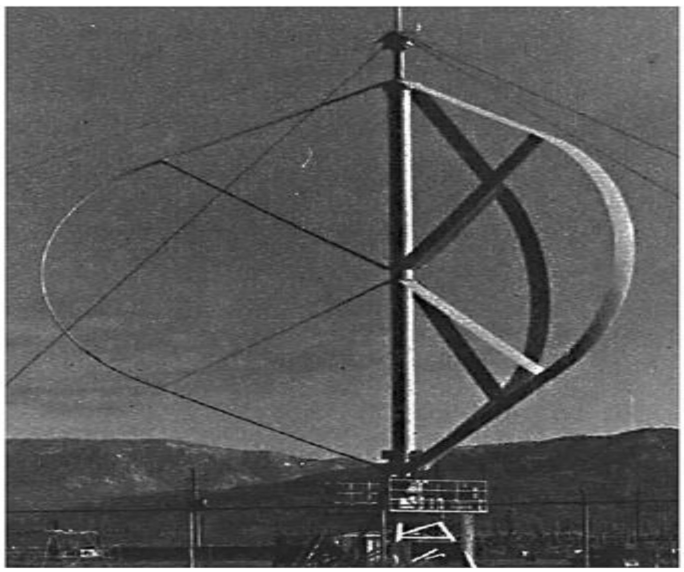

Figure 8: **A Vertical Axis Wind Turbines**

Source: Tjui W. et al., (2015), *"Darrieus Vertical Axis Wind Turbine for Power Generation I: Assessment Of Darrieus VAWT Configurations"*, Renewable Energy, vol. 75, p54.

[1] Sadrehaghighi, I., (2022), *"Horizontal Axis Wind Turbines (HAWT) with Case Studies"*, CFD Open Series/Patch [Technical Report], p10.

[2] Ibid, p11.

3. Advantages and Challenges of Adopting Wind Energy

Like any other technology, wind energy has its own advantages and challenges.

3.1.Advantages of Wind Power:

Wind power creates good-paying jobs. According to the U.S. Bureau of Labor Statistics, wind turbine service technicians are the fastest growing U.S. job of the decade. Offering career opportunities ranging from blade fabricator to asset manager. Wind power is a domestic resource that enables economic growth. Wind power is a clean source. Not only is wind an abundant and inexhaustible resource, but it also provides electricity without burning any fuel or polluting the air. Wind energy in the United States helps avoid 336 million metric tons of carbon dioxide emissions annually equivalent to the emissions from 73 million cars. Wind power benefits local communities. Communities that develop wind energy can use the extra revenue to put towards school budgets, reduce the tax burden on homeowners. Wind power is cost-effective. Land-based, utility-scale wind turbines provide one of the lowest-priced energy sources available, Finally, Wind energy generation fits well in agricultural and multi-use working landscapes.[1]

3.2.Challenges of Wind Power:

Ideal wind sites are often in remote locations, Where challenges must be overcome to bring electricity from wind farms to urban areas, where it is needed to meet demand. Upgrading the nation's transmission network to connect areas with abundant wind resources to population centers could significantly reduce the costs of expanding land-based wind energy. Turbines produce noise and alter visual aesthetics. Wind plants can impact local wildlife. Research is still needed to minimize wind-wildlife interactions. Advancements in technologies, properly siting wind plants, and ongoing environmental research are working to reduce the impact of wind turbines on wildlife.[2]

[1] US Energy Department web-site: https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy, visited in visited in 03/01/2025 at 10:37

[2] Ibid

Conclusion:

Renewable energy has emerged as a crucial pillar of sustainable development and energy security worldwide. This chapter has provided an overview of various renewable energy sources, highlighting their environmental and economic advantages over fossil fuels. In particular, wind energy stands out as a viable and promising solution due to its abundance, cost-effectiveness, and low environmental impact.

The Algerian government has undertaken initiatives to promote renewable energy development through strategic policies, investment programs, and infrastructure projects. However, despite the progress made, the deployment of wind energy remains limited due to financial, technical, and regulatory challenges. To fully harness its renewable energy potential, Algeria must overcome these barriers by fostering technological innovation, attracting foreign investment, and implementing effective policies.

This chapter has laid the foundation for understanding the relevance of renewable energy in Algeria’s energy transition. The next chapter will provide a comprehensive literature review on economic feasibility studies, exploring key methodologies and previous research on assessing the viability of wind energy projects.

Chapter 2:

Wind Energy Feasibility Framework

Introduction:

Assessing the economic feasibility of renewable energy projects requires a structured methodological framework and a thorough review of previous research. Economic viability is one of the most critical factors influencing the adoption of renewable energy, particularly wind energy, which involves substantial upfront capital investment. This chapter aims to provide an in-depth analysis of the methodologies and financial metrics used in feasibility studies, such as Levelized Cost of Electricity (LCOE), Net Present Value (NPV), Internal Rate of Return (IRR), and sensitivity analysis. These methods help in evaluating the profitability and long-term sustainability of wind energy projects under different economic and policy scenarios.

Additionally, this chapter will explore relevant studies that have assessed the economic and technical feasibility of wind energy in different regions, including Algeria. Reviewing these studies will offer valuable insights into best practices, challenges, and key variables affecting the feasibility of wind farms. By examining the existing literature, this chapter aims to establish a strong theoretical foundation for the economic analysis that will be conducted in the following chapter.

The main objective of this chapter is to provide a comprehensive framework for evaluating the feasibility of wind energy projects by exploring the methodologies, sensitivity analysis techniques, and real-world feasibility studies.

The chapter thus will be conducted in three main sections:

- Section 1 will explain the methodologies and economical metrics used for feasibility studies.
- Section 2 will explain the sensitivity analysis as a crucial part in feasibility studies.
- Section 3 will have an overview of feasibility studies of wind energy projects.

Section 1: Methodologies and Metrics Used for Feasibility Studies

This section will outline the essential methodologies and key metrics used to assess the feasibility of wind energy projects. It will cover the three main dimensions of feasibility analysis: market feasibility, technical feasibility, and economic feasibility.

1. Market Feasibility:

Market feasibility the first process that evaluates whether a business idea, product, or project can succeed in a specific market by systematically analyzing factors such as consumer demand, competition, regulatory constraints, pricing strategies, and potential risks. This assessment begins with understanding the target audience's needs and preferences through primary research methods like surveys, focus groups, and interviews, which provide firsthand insights into customer behavior and willingness to purchase. Secondary research complements this by leveraging existing data from industry reports, government publications, and academic studies to identify broader trends and validate findings. Tools like Porter's Five Forces framework are instrumental in examining the competitive landscape, helping businesses understand industry attractiveness, barriers to entry, and the power dynamics among competitors. Additionally, estimating the total addressable market (TAM) and serviceable available market (SAM) provides clarity on growth potential and scalability, while pricing models ensure alignment with perceived value and market norms. Regulatory considerations, including licensing requirements and compliance standards, are also evaluated to avoid legal pitfalls. Risk assessment frameworks, such as SWOT analysis, further enable organizations to identify internal strengths and weaknesses alongside external opportunities and threats, ensuring robust contingency planning.[1]

2. Technical Feasibility:

Technical feasibility is the second critical process that evaluates whether the technology required for a project is achievable within the desired timeline, budget, and operational constraints by technical experts, engineers, and specialists in the project's field to assess the viability of the proposed solutions. Based on the results it decides whether the technical team is able to convert the idea into reality.[2]

[1] Agrawal, R. and Mehra, Y. S, (2021), "*Project Appraisal and Management*", 1st ed, Taxmann Publications, p47-57.
[2] Momin, M. and Sahadev, R., (2017), "*Feasibility Studies and Important Aspect of Project Managemen*t", International Journal of Advanced Engineering and Management, vol. 2, no. 4, p98.

For wind energy projects, this involves evaluating the suitability and efficiency of wind turbine technologies, energy generation capacity and a comprehensive evaluation of the country's wind resources, the availability of suitable sites for wind farms, and the potential for integration with the national grid. The assessment also considers the existing technologies available for harnessing wind energy and their efficiency, focusing on factors such as turbine design, energy output, and system integration.

3. Financial/Economic Feasibility:

The next step in a feasibility study is the financial or economic feasibility which assesses whether or not a project is financially viable by evaluating its costs, potential revenue, profitability, and return on investment. It involves financial analysis methods and metrics most essentially:

3.1. Net Present Value (NPV):

NPV is the present value of a project's cash inflows minus the present value of its costs, tells us how much the project contributes to shareholder wealth. The NPV is calculated by summing up the discounted cash flows that are related with the investment. The present cash flows for each year include all inflows and all outflows discounted with the discount rate for the investment. The inflows are calculated as positive values and the outflows are calculated as negative values. If the NPV is positive the investment is profitable and the greater positive value of the NPV it is the more profitable is the investment, to implement this approach, we find the present value of each cash flow, including the initial cash flow, discounted at the project's cost of capital (or discount rate 'r'), Then Sum these discounted cash flows; this sum is defined as the project's NPV.[1]

The equation of the Net Present Value is as follows:

$$\boldsymbol{NPV = \sum_{t=0}^{N} \frac{CF_t}{(1+r)^t} = \text{Present Value Benefits} - \text{Present Value Costs}} \qquad (2)$$

With:

- CF_t = Cash flows of year t (after tax)
- r = discount rate for the project

[1] Ehrhardht, M.C. and Brigham, E.F., (2016), "*Financial Management: Theory and Practice", 13th ed*, Cengage Learning, p383-384.

3.2. Levelized Cost of Electricity (LCOE):

The levelized cost of electricity (LCOE) is a metric used to measure and compare alternative methods of electricity production over the lifetime of the energy project. The LCOE of an electricity-generating asset can be thought of as the average total cost of building and operating the asset per unit of total electricity generated over an assumed lifetime. LCOE is essentially the net present value of the unit-cost of electricity over the lifetime of a generating asset. It is calculated by summing the total lifetime costs of building and operating the plant, and then dividing by the total amount of electricity generated over that period:[1]

$$\textbf{LCOE}\ (\boldsymbol{DZD/KWh}) = \frac{\boldsymbol{PV\ of\ Total\ Cots\ Over\ Lifetime}}{\boldsymbol{PV\ of\ Total\ Electric\ Energy\ Produced\ Over\ Lifetime}} \qquad (\mathbf{3})$$

Where:

- NPV of Total Cots Over Lifetime $= \sum_{t=0}^{n} \frac{(I_t + M_t + F_t)}{(1+r)^t}$
- NPV of Total Electrical Energy Produced Over Lifetime $= \sum_{t=0}^{n} \frac{E_t}{(1+r)^t}$

With:

- I_t = investment expenditures in the year t
- M_t = the operations and maintenance expenditures in the year t
- F_t = the fuel expenditures in the year t (if found)
- E_t= the electricity generation in the year t
- r = is the discount rate
- n = the lifetime of the asset.

The method of levelized cost of electricity (LCOE) makes it possible to compare power plants of different generation and cost structures with each other. The basic thought is that one forms the sum of all accumulated costs for building and operating a plant and comparing this Figure to the sum of the annual power generation. This then yields the so-called LCOE in Euro per kWh. It is important to note that this method is an abstraction from reality with the goal of making different sorts of generation plants comparable. The method is not suitable for determining the cost efficiency of a specific power plant. For that, a financing calculation

[1] US Department of Energy, (2015), "*Levelized Cost of Energy (LCOE)*" [Government Report], *P3-5*.

must be completed considering all revenues and expenditures on the basis of a cash-flow model.[1]

Statistics show that wind energy (especially onshore) has the lowest LCOE out of all other energy sources as shown in Figure 9, that's due to multiple factors, most importantly lower operational costs, because firstly wind farms do not require fuel to generate electricity, which eliminates the variable fuel cost that is significant for fossil fuels like coal or natural gas. This aspect significantly reduces the overall LCOE since fuel costs can be a major component for thermal plants. And secondly the maintenance costs are low because wind turbines are designed for longevity with relatively low maintenance requirements compared to traditional power generation methods. Typically, operations and maintenance for wind turbines are estimated around 2-3% of the initial capital cost annually.[2]

Table 3: **Installed Costs, Capacity Factor and LCOE Trends by Technology (2010-2023)**

RE Technology	**Total Installed Costs 2023 $/KW**			**Capacity Factor (%)**			**LCOE 2023 ($/KWh)**		
	2010	**2023**	**%**	**2010**	**2023**	**% change**	**2010**	**2023**	**%**
Bioenergy	3010	2730	-9%	72	72	0%	0.084	0.072	-14%
Geothermal	3011	4589	52%	87	82	-6%	0.054	0.071	31%
Hydropower	1459	2806	92%	44	53	20%	0.043	0.057	33%
Solar PV	5310	758	-86%	14	16	14%	0.46	0.044	-90%
CSP	10453	6589	-37%	30	5	83%	0.39	0.117	-70%
Onshore wind	2272	1160	-49%	27	36	33%	0.11	0.033	-70%
Offshore wind	5409	2800	-48%	38	41	8%	0.2	0.075	-63%

Source: IRENA, (2023), "*Renewable Energy Generation Costs" report*, p15

[1] Christoph Kost et al. (2013), *LCOE renewable Energy Technologies Study*, Fraunhofer Institute for Solar Energy Systems ISE, p36
[2] Wind Measurement International web-site: windmeasurementinternational.com/wind-turbines/om-turbines visited in 29/01/2025 at 14:36

Solar PV and onshore wind demonstrate remarkable progress, with total installed costs plummeting by 86% and 49%, respectively, and LCOE decreasing by 90% and 70%. In contrast, geothermal and hydropower show increased installed costs (52% and 92%) and higher LCOE, indicating challenges in scaling these technologies. These contrasting trends underscore the rapid advancements in some renewables while highlighting ongoing economic barriers in others.

3.3. Present Value Cost (PVC):

The Present Value Cost (PVC) is a key financial metric used to evaluate the total cost of a project (in our case wind energy project) over its lifetime. It helps in determining the cost-effectiveness of the project by accounting for both initial and future costs in present value terms. The PVC equation is presented as follows:[1]

$$\mathbf{PVC} = \mathbf{I} + C_{OMR}\left(\frac{1+i}{r-i}\right)\left[1-\left(\frac{1+i}{1+r}\right)^{n}\right] - S\left(\frac{1+i}{1+r}\right)^{n} \qquad (4)$$

Where:

- I is the investment cost
- C_{OMR} is the operation, maintenance and repair cost
- i is the inflation rate
- r is the interest rate
- n is the expected lifetime of the wind turbine
- S is the salvage value (estimated value of an asset at the end of its useful life).

3.4.Internal Rate of Return (IRR):

The IRR is defined as the discount rate that forces the NPV to equal zero, thus the rate in which the discounted inflows equal the discounted outflows, IRR is the rate at which an investment breaks even in terms of present value. [2] The IRR equation is presented as:

$$NPV = \sum_{t=0}^{N} \frac{CF_t}{(1+IRR)^t} = 0 \qquad (5)$$

It represents the average annual return generated by the project and serves as a decision-making tool: if the IRR exceeds the required rate of return, the investment is considered financially attractive. However, IRR has notable limitations. In projects with irregular cash flow

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[1] Boudia S.M et al. (2016), *On the Use of Wind Energy at Tlemcen, North-western region of Algeria*, Energy Procedia, vol. 93, p143.

[2] Ehrhardht, M.C. and Brigham, E.F., (2016), "*Financial Management: Theory and Practice", 13th ed*, Cengage Learning, p387.

patterns, multiple IRRs may arise, making interpretation difficult. Moreover, for mutually exclusive projects, the IRR may conflict with the NPV criterion, potentially favoring smaller projects with higher percentage returns but lower absolute value creation. IRR also assumes reinvestment of interim cash flows at the same rate, which is often unrealistic. Therefore, while IRR is a useful indicator, it should be applied cautiously and preferably in combination with NPV for robust investment decisions.[1]

3.5. Simple Payback Period (PBP):

Simple Payback Period (SPP), Also referred to as Simple Payback Time (SPT), Is simply the number of years needed for cumulative cash-flows to cover the initial investment costs, It equals the ratio of the initial investment's size to the value of the estimated cash flow, Thus It is calculated as follows:[2]

$$\boldsymbol{SPP = \frac{I_0}{CF}} \qquad (6)$$

Where:

- I_0 is the invested capital
- CF is the estimated cumulated annual cashflow.[3]

Or more specifically $SPP = \frac{C-IG}{(C_{ener}+C_{capa}+C_{RE}+C_{GHG})-(C_{O\text{and}M}+C_f)}$

Where:

- C: Total initial cost of the project.
- IG: Incentives and grants.
- C_{ener}: Annual energy savings.
- C_{capa}: Annual capacity savings.
- C_{RE}: Annual renewable energy (RE) production credit income.
- C_{GHG}: Greenhouse gases reduction income.
- $C_{O\text{and}M}$:Annual operation and maintenance cost.
- C_f: Annual cost of fuel or electricity.

[1] Azouani, N., (2023), PDF du Module Finance d'Entreprise (Chapitre 4): La politique d'investissement,p17-19.
[2] Himri Y et al. (2020), *Potential and economic feasibility of wind energy in south West region of Algeria*, Sustainable Energy Technologies and Assessments, vol. 38, p7
[3] Gorshkov A.S et al. (2018), *Payback period of investments in energy saving*, Magazine of Civil Engineering, vol. 23, no. 2, p67.

3.6.Year to Positive Cash Flow (YPCF):

The YPCF is the first year in which the accumulated cash flows for the project are positive. It represents the period that it needs for the investor to recover its initial investment out of the project cash flows generated. It is determined as:[1]

$$\sum_{n=0}^{Npcf} CF_n = 0 \tag{7}$$

Where CF_n: After-tax cash flow over a period of n years.

3.7.Benefit Cost Ratio (BCR):

Benefit-Cost Ratio (or Profitability Index) is based on the principle of compensation, expressed as a ratio close to 1. When a company faces capital rationing that is, limited access to investment funds it should prioritize investments that offer the highest return per unit of capital invested. In such cases, the Profitability Index becomes a key decision-making criterion. It is defined as the ratio between the present value of cash flows generated by the project and the initial investment amount. The BCR reflects the discounted return per unit of currency invested. BCR equals:[2]

$$BCR = \frac{NPV + I_0}{I_0} \tag{8}$$

- I_0 = initial investment cost

Where we find the following cases:

- BCR > 1: The project is considered economically beneficial, thus a positive NPV
- BCR = 1: The project breaks even; benefits equal costs, thus a null NPV
- BCR < 1: The project is not economically viable, costs exceed benefits, thus a negative NPV

3.8.Annual Life Cycle Saving (ALCS):

The ALCS is the minimal yearly reserve having the equivalent life and NPV as the project. It can be interpreted as the average discounted cash flows.[3]

$$ALCS = \frac{NPV}{[1 - (1 + r)^{-n}]} \tag{9}$$

[1] Gorshkov A.S et al. (2018), *Payback period of investments in energy saving*, Magazine of Civil Engineering, vol. 23, no. 2, p67.

[2] Taverdet-Popiolek, N. (2006). *Guide du choix d'investissement: Préparer le choix, sélectionner l'investissement, financer le projet* (Préface de M. Poix). Éditions d'Organisation, Groupe Eyrolles. P177.

[3] Singh. S et al. (2022), "*Performance evaluation and financial viability analysis of grid associated 10 MWP solar photovoltaic power plant at UP India*", Scientific Reports, vol. 12, no. 22380, p14.

Section 2: Sensitivity Analysis in Wind Energy Projects

Sensitivity analysis plays a crucial role in assessing the financial resilience of wind energy projects by evaluating how uncertainties in key parameters affect economic outcomes. This section explores the input variables commonly tested such as investment costs, operation and maintenance expenses, interest and inflation rates, land rental costs, and turbine lifetimes, and their impact on key financial metrics. Different analytical approaches are discussed, including one-way sensitivity testing, scenario-based analysis, and Monte Carlo simulations.

1. Introduction to Sensitivity Analysis:

1.1. Definition of Sensitivity Analysis:

Sensitivity analysis can be defined as the evaluation of a project under a number of different assumptions on the values of one or more uncertain variables. This process involves systematically varying key input parameters such as discount rates, inflation rates, or various costs to assess how changes in these variables impact the project's economic outcomes.[1]

1.2. Purpose of Sensitivity Analysis:

Sensitivity analysis serves as a critical tool in projects evaluation studies, by systematically assessing how uncertainties or variations in input parameters influence a model's outputs, thereby highlighting areas of risk and vulnerability. This process not only quantifies the range of potential outcomes but also enhances decision-making by revealing the fragility of a project's feasibility under varying conditions. Its primary purpose is to identify which variables most significantly affect key metrics or project viability, allowing researchers to prioritize data accuracy and focus mitigation efforts on high-impact factors.

1.3. Relevance to Wind Energy Projects:

Wind energy projects are influenced by multiple uncertainties, making sensitivity analysis a crucial tool in assessing their techno-economic feasibility. These uncertainties arise from technical and economic factors, which can impact investment decisions and long-term financial viability.

One of the most critical factors in wind energy feasibility is wind speed variability, where it directly affect energy output, capacity factor, thus these variations can alter revenue projections and cost-effectiveness, influencing key financial indicators like the LCOE and NPV. Additionally,

[1] Short, W. et al, (1995), "*A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies*", National Renewable Energy Laboratory, p95.

uncertainties in turbine performance and maintenance requirements further complicate financial planning.

2. Methods of Sensitivity Analysis:

There are several methods to conduct a comprehensive sensitivity analysis. In the case of a wind energy feasibility study, the most suitable methods are:

2.1. Monte Carlo Simulations:

Monte Carlo simulation (MCS) is a type of simulation that relies on repeated random sampling and statistical analysis to compute the results. This method of simulation is very closely related to random experiments for which the specific result is not known in advance. In MCS, we identify a statistical distribution which we can use as the source for each of the input parameters. Then, we draw random samples from each distribution, which then represent the values of the input variables. For each set of input parameters, we get a set of output parameters. The value of each output parameter is one particular outcome scenario in the simulation run. We collect such output values from a number of simulation runs. Finally, we perform statistical analysis on the values of the output parameters, to make decisions about the course of action. We can use the sampling statistics of the output parameters to characterize the output variation, where the accuracy of results improves with a larger number of simulations.[1]

In the context of wind energy analysis, MCS allows us to model uncertainties in key variables such as electricity prices, wind speed, and costs, by running multiple simulations.

2.2. Scenario Analysis:

Scenario analysis emphasize the impact of combinations of uncertainty on the total outcome.[2] This method involves defining a set of alternative scenarios based on changes in key input variables. Each scenario represents a specific combination of assumptions about different factors, such as wind speed inconsistency, policy changes, or cost variations. In scenario analysis, we typically define a base case scenario, which represents the most likely outcome, along with optimistic and pessimistic scenarios (best case/worst case) to account for uncertainty. Each scenario is then analyzed separately to assess how variations in input parameters affect the final results. By comparing the outcomes across different scenarios, we can evaluate the range of possible results and understand the risks

[1] Raychaudhuri, S., (2008), "*Introduction to Monte Carlo Simulation*" [conference paper], Proceedings of the 2008 Winter Simulation Conference, p91-92.
[2] Eschenbach, T. G., (2003), "*Engineering Economy: Applying Theory to Practice", 3rd ed*, Oxford University Press, p475-476.

associated with a project. This method is particularly useful when dealing with economic and financial uncertainty, as it allows decision-makers to prepare for different future conditions.

2.3. One-at-a-time (OAT) Analysis:

One-at-a-time or One-way sensitivity analysis is a method used to evaluate how changes in a single input variable impact the output of a model while keeping all other inputs constant. This technique helps identify which variables have the most significant influence on the results. In this type of analysis, we systematically adjust the value of one input parameter within a defined range while observing the corresponding changes in the output. This allows decision-makers to assess the robustness of their conclusions and determine the key risk factors in a study. One-way sensitivity analysis is widely used in financial modelling, economic feasibility studies, and risk assessment to understand how uncertain variables affect key performance indicators such as (NPV) or (LCOE).[1]

Table 4 explains the key differences between the three methods:

Table 4: **Comparison Between OAT, MCS, and Scenario Sensitivity Analyses**

Element	OAT	MCS	Scenario Analysis
Approach	Varies one parameter at a time to assess its individual effect.	Runs numerous simulations (thousands/millions) by sampling from distributions.	Defines a set of possible future states based on expert judgment or trends.
Use	Identifying the most sensitive variables in models.	Risk analysis in finance, engineering, and energy modeling and other fields.	Strategic planning, policy analysis, and economic forecasting.
Example	What if interest rates go up 2%?	What's our chance of profit next year?	How would a supply shortage affect us

Source: Student's work based on the definitions of the mentioned elements.

[1] Satelli, A. et al, (2008), "*Global Sensitivity Analysis: The Primer*", John Wiley & Sons, Ltd., p66-70.

Section 3: Overview of Feasibility Studies of Wind Energy Projects

This section presents an overview of literature related to wind energy feasibility studies at both the global and Algerian levels. It examines various research efforts that have assessed wind energy potential and economic viability associated with wind farm development. By reviewing key studies, this section provides insights into methodologies used, challenges faced, and lessons learned in different contexts. The findings from these studies will help in shaping the empirical analysis of wind energy feasibility in Algeria.

1. In the global Context:

Shata (2018) conducted a study on wind resource assessment and the economic feasibility of electricity generation in the Sinai Peninsula, Egypt. The research analyzed wind speed data from multiple coastal locations Ras Seder, Abu Redis, El Tor, and Nabq over a 6 to 15-year period. The study employed the Weibull distribution for wind speed modeling and estimated wind power density at multiple heights (10m–50m). Economic evaluation was conducted through electricity generation cost analysis, revealing that installing a 580 MW inshore wind farm at these locations could generate 2335 GWh annually, with a generation cost ranging from 0.0184 to 0.0422 $/kWh cheaper than Egypt's grid electricity price. The findings found Ras Seder and Nabq as the most viable wind energy sites due to their high wind energy potential and cost-effectiveness.[1]

Jung and Schindler (2019) conducted a comprehensive review of wind speed distribution models for wind resource assessment. The study evaluated 46 research papers (2010–2018) that compared the goodness-of-fit of various probability distribution functions (PDFs) used for wind speed modeling. The analysis covered 115 different distributions. The study found that the two-parameter Weibull distribution was the most commonly used, but newer models such as the Wakeby and Kappa distributions performed better in capturing wind speed variations, especially in regions with complex wind patterns. The study highlighted that Maximum Likelihood Estimation (MLE), Least-Squares Estimation (LSE), and L-Moment Method (LMOM) were the most frequently applied

[1] Ahmed, A.S. (2018), "*Wind Resource Assessment and Economics of Electric Generation At 4 Locations In Sinai Peninsula Egypt*.", Journal of Cleaner Production, vol. 183, p1170-1183.

parameter estimation techniques. The findings suggested the need for standardized methodologies in wind resource assessment to improve comparability and accuracy across studies.[1]

Shata (2021) investigated the technical and economic feasibility of the first wind farm on the Mediterranean coast in Sidi Barrani, Egypt. The study involved wind resource assessment at a meteorological station and extrapolated data to 100m height. Wind power density was found to be 441 kW/m² annually, indicating an excellent wind energy potential. The study evaluated three 2000 kW wind turbine models to determine the best-suited turbine for the location. The economic analysis of a proposed 200 MW coastal wind farm was conducted using the PVC method. The project was estimated to generate 988 GWh/year with an LCOE of c$1.7/kWh, making it cost-competitive.[2]

Lins et al. (2023) conducted a comparative analysis of wind speed distribution models for onshore and offshore wind sites in Northeast Brazil. The study evaluated the Weibull, Nakagami, Extended Generalized Lindley, Generalized Gamma, and Generalized Extreme Value distributions. Three different parameter estimation methods were used: Maximum Likelihood Estimation (MLE), Modified Maximum Likelihood Estimation, and Multi-Objective Moments. To determine the best-fitting model, the study applied Kolmogorov-Smirnov, Deviation of Skewness and Kurtosis (DSK), and Akaike Information Criterion tests. Results showed that no single model consistently outperformed across all locations. The Weibull and Generalized Gamma distributions were superior for onshore wind speeds, while the Extended Generalized Lindley distribution provided the best fit for offshore wind speeds. The study concluded that regional-specific wind distributions should be selected rather than relying solely on the Weibull model.[3]

Deep et al. (2020) evaluated the wind energy potential of coastal locations in India using the Weibull model. The study highlighted that conventional methods overestimate wind energy potential by nearly 25%, as they fail to consider the cut-in and cut-out wind speed limits of wind turbines. To improve accuracy, the study proposed a novel three-parameter Weibull model, where the location parameter is set equal to the cut-in wind speed. This adjustment resulted in more realistic wind energy estimates, better aligned with actual turbine performance. The study also compared various Weibull parameter estimation methods, including Maximum Likelihood Method , Modified Maximum Likelihood Method, Energy Pattern Factor Method, and Least Squares Method. Results confirmed

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[1] C. Jung and D. Schindler (2019), "*Wind speed distribution selection – A review of recent development and progress", Renewable and Sustainable Energy Reviews*, vol. 114, p1-13.

[2] A. S. Ahmed (2021), "Technical and economic feasibility of the first wind farm on the coast of the Mediterranean Sea", Ain Shams Engineering Journal, vol. 12, p. 2145–2151.

[3] D. R. Lins et al. (2023), "*Comparison of the performance of different wind speed distribution models applied to onshore and offshore wind speed data in the Northeast Brazil*", Energy, vol. 278, p1-13

that the three-parameter Weibull model provided a more accurate representation of the wind resource and should be preferably used for wind farm feasibility studies.[1]

2. In the Algerian Context:

Kasbadji (2000) in order to establish a wind energy map of Algeria and to assess the feasibility of using wind energy for agricultural applications, such as water pumping, collected wind speed data were from 48 meteorological stations in Algeria and an additional data from 16 stations in neighboring countries were used to refine the wind map. The dataset included wind speed measurements recorded for at least 10 years without interruptions. The Weibull distribution was used to model wind speed variations across different locations. The study estimated wind power density for different locations to classify their wind energy potential. The results were used to identify promising regions for wind energy development. Wind speeds across Algeria ranged between 1 and 6 m/s at 10 meters height. The windiest regions were found Sahara region like Adrar (6 m/s), Tindouf, In Salah and In Amenas. Wind speed increases during the day, peaking around 3 PM in the Tellian Atlas and High Plains. In southern regions, wind speeds peak at 9 AM except in In Amenas and El Golea, where maximum speeds occur around noon. Coastal regions experience higher wind speeds in summer. High Plains and Sahara regions have maximum wind speeds in spring. The shape factor (k) ranged between 1.26 and 2.28. The scale factor (c) varied from 3.3 m/s to 6.7 m/s. Wind speeds in southern Algeria exceed 3 m/s. The study suggested small-scale wind energy applications in rural areas. Wind farms could be feasible in specific regions but would require taller turbines (≥25m height).[2]

Himri et al. (2008) presented a wind data analysis and wind energy potential at 3 sites Adrar, Timimoun and Tindouf using a hypothetical wind farm of 30 MW which costs around $ 42,664,310, The maximum wind speed was found to occur at 09:00 h at all the locations while the minimum at 21:00h, higher electricity could be produced during 09:00–18:00 h, They estimated the energy yield using data related to wind turbine DEWIND 62, wind power curve, the annual average wind speed, the mean temperature and pressure, etc. And found the best site to install a wind farm is Adrar with a yield of 1091 kWh/m²with the highest capacity factor of 38%,

[1] S. Deep et al. (2020), "Estimation of the wind energy potential for coastal locations in India using the Weibull model", Renewable Energy, p1-37.
[2] Kasbadji Merzouk, N. (2000), "*Wind energy potential of Algeria*". Renewable Energy, vol. 21, no. 1,p553–562.

Followed by Timimoun and Tindouf, The same for the economic metrics shown in the 1st section.[1]

Boudia et al. (2012) collected wind speed data using the daily average of wind speed over a period of 5 years at 10m AGL, For the wind analysis they used the Weibull distribution where wind energy potential were assessed and compared using six hypothetic commercialized 600 kW WECS installed at 50 m AGL. The annual analysis of Weibull parameters of the studied region (Mecheria) showed that the shape parameter and the scale parameter are equal to 2.00 and 5.19 m/s, respectively. The annual mean wind speed at 10 meters was found to be 5.19 m/s. The best seasons for wind energy production were: Spring (mean wind speed 5.78m/s) and Winter (mean wind speed 5.5m/s) where April had the highest wind energy potential (8.42 m/s) and August had the lowest wind speeds (6.51 m/s). Among the six tested wind turbines, the Fuhrländer FL600 produced the highest energy output 3203.46 MWh/year. whereas the Vestas V44 turbine had the lowest energy production 2280.88 MWh/year.[2]

Boudia and Guerri (2015) investigated wind power potential at Oran, ten years of wind data have been used to evaluate the potential of wind power on the Oranie region, The wind analysis model was done using the Weibull distribution, They used the present value of the money method to determine the costs. They found out that the annual mean wind speed in the region of Oran is equal to 4.2 m/s corresponding to an annual mean power density equal to 129 W/m2, The annual energy production ranges from about 2.822 GW h in Site 3 with the Nordex N50 model to 12.425 GW h in Site 2 using Vestats V90 wind turbine. The minimum cost of unit energy is 0.0181$/kWh is obtained with the Power Wind 90 in Site 2.[3]

Belabes et al. (2015) conducted an evaluation of wind energy potential and estimation of cost using wind energy turbines for electricity generation in north of Algeria, Samples of 10 years (1981–1990) monthly wind data were obtained of six sites, the annual mean wind speeds using the Weibull distribution was found varying from 2.64 to 5.07 m/s in Tlemcen and Tiaret, respectively. The annual average power densities, were the highest in Tiaret then Oran. The highest value of annual energy

[1] Y. Himri et al. (2007), "*Wind power potential assessment for three locations in Algeria*", Renewable and Sustainable Energy Reviews, vol. 12, p2495–2504.
[2] Boudia, S. M et al. (2012). "*Monthly and seasonal assessment of wind energy potential in Mechria region, Occidental Highlands of Algeria*". International Journal of Green Energy, vol. *9*, no. 3, p243-255.
[3] Boudia S. M. and Guerri O., "*Investigation of wind power potential at Oran, northwest of Algeria*", Energy Conversion and Management, vol. 105, p81-92.

output among the three turbines was obtained in Tiaret was 5.81 GWh with Vestas V80/2 MW wind turbine model with a capacity factor of 33.16%, The lowest value of electricity cost is obtained in Tiaret as US $0.0342/kW h with the minimum specific cost of wind turbine using Vestas V80/2 MW model.[1]

Koussa et al. (2016) conducted a study on wind turbine generator production across different Algerian climatic zones. Thirteen sites were analyzed using wind speed data recorded over ten years to estimate capacity factors and the economic feasibility of wind energy. The study used the Weibull distribution to model wind speed characteristics and employed an economic assessment method considering three lifetime periods and three interest rate values. Results indicated that the capacity factors varied from 17% in Bejaïa to 66% in Adrar. The cost of electricity generation was found to be as low as $0.03/kWh in Adrar. Among the four evaluated WTG models, the AVENTA AV7 was found to be the most cost-effective in terms of energy production.[2]

Himri et al. (2020) investigated the potential and economic feasibility of wind energy in the southwest region of Algeria. They analyzed wind power potential and evaluated the economic viability of a wind farm project in Adrar. The study utilized six years of wind data (2003–2008) to determine wind characteristics, including mean wind speed, energy flux, dominant wind direction, and Weibull distribution parameters. The results indicated that the Adrar region had a mean wind speed of 5.9 m/s at 10 m height and an annual energy production of 3,146 MWh/year for a 30 MW wind farm. The capacity factor was found to be 36%. Economic analysis showed that the project had a simple payback period of 3.9 years, a net present value of $70.9 million, and a cost of electricity of 0.0325 $/kWh, which was lower than the feed-in tariff price. The study concluded that wind energy in Adrar is economically viable and has the potential to contribute to Algeria's renewable energy transition.[3]

[1] Belabes B. et al. (2015), "*Evaluation of wind energy potential and estimation of cost using wind energy turbines for electricity generation in north of Algeria*", Renewable and Sustainable Energy Reviews, vol. 51, p1246–1254.
[2] Koussa D. S et al. (2016) "*Assessment of various WTG production in different Algerian climatic zones*", Energy, vol. 96, p449-460.
[3] Himri Y. et al. (2020), "*Potential and economic feasibility of wind energy in south West region of Algeria ",*
Sustainable Energy Technologies and Assessments, vol.38, p1-8.

Meziane et al. (2021) conducted a wind flow simulation study for energy planning in Hassi R'mel, Algeria. The study analyzed 14 years (2003–2017) of wind speed data at 10m AGL and used the results to predict wind characteristics in four additional sites without direct measurements. The researchers assessed the feasibility of wind and hydrogen production using Bonus B54 (1MW) and Nordex N100 (2.5MW) wind turbines. The study found that Hassi R'mel had an annual mean wind speed of 6.73 m/s with a power density of 365 W/m². The Nordex N100 at 100m height produced 12.41 GWh/year of electricity and 177.37 tons of hydrogen yearly, with an LCOE of $0.055/kWh. The study concluded that Hassi R'mel and Bellil were promising sites for large-scale wind energy projects.[1]

Aroua et al. (2024) conducted a techno-economic assessment of wind energy production in the Algerian highlands. The study analyzed wind speed data from three selected sites El Bayadh, Setif, and Djelfa using ten years of wind speed measurements at 10 meters AGL. The researchers assessed the economic feasibility of four wind turbine models: Vestas V-80, Suzlon S-82, Enercon E-58, and Gamesa G-114. The results showed that the Gamesa G-114 turbine was the most suitable for all sites, particularly for El Bayadh, where it achieved the highest annual energy production and capacity factor while ensuring the lowest unit energy cost (UEC).[2]

Taoussi et al. (2024) conducted a techno-economic feasibility study on wind turbine development in Algeria. The study employed the bimodal mixture Weibull distribution to model wind speed and evaluated four different parameter estimation methods for optimal data fitting. Economic analysis focused on the levelized cost of electricity (LCOE), present value cost (PVC), and net present value (NPV) to assess economic viability. The results indicated that In-Salah was the most suitable location for wind energy projects due to its high capacity factor (75.52%), short payback period, and competitive electricity costs (0.0193 $/kWh). Sidi-Bel-Abbes, while less favorable, still demonstrated feasibility with a capacity factor of 38% and an annual energy production of 202 GWh at 0.0381 c$/kWh. [3]

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[1] Meziane F. et al. (2021), "*Wind flow simulation and characteristics prediction using WAsP software for energy planning over the region of Hassi R'mel*", International Journal of Green Energy, vol. 18, no. 6, p634-644.
[2] Aroua F.Z et al. (2024), "*Wind energy cost evaluation based on a techno-economic assessment in the Algerian highlands*", Energy for Sustainable Development, vol. 81, p1-11.
[3] Taoussi, B. et al., (2024), "*Techno-economic feasibility study of developing wind turbines in Algeria*", 2024 3rd International Conference on Advanced Electrical Engineering (ICAEE), IEEE, p1-6.

Conclusion:

This chapter has established a comprehensive framework for assessing the economic feasibility of wind energy projects. It has explored key financial metrics such as Net Present Value (NPV), Levelized Cost of Electricity (LCOE), and Present Value of Costs (PVC), among others, which are essential for evaluating the profitability and sustainability of wind energy investments.

The chapter also examined the sensitivity analysis associated with such projects and its importance in assessing the impact of economic variables on feasibility outcomes.

Furthermore, it reviewed existing feasibility studies in both global and Algerian contexts, providing insights into best practices conducted in wind energy assessments. These findings serve as a foundation for the next chapter, which will apply these methodologies to analyze the techno-economic feasibility of wind energy projects in Algeria.

Chapter 3:

Wind Energy Feasibility Study

Introduction:

The empirical study of wind energy projects requires a robust analytical framework that integrates both technical and economic assessments to evaluate their feasibility. This chapter focuses on the empirical analysis of wind energy potential in Algeria. The primary objective of this chapter is to conduct an empirical investigation of wind energy potential across selected sites in Algeria. This involves analyzing wind resource characteristics, estimating electricity generation capacity, and evaluating the financial viability of deploying various turbine models. The findings will help inform decision-making processes for optimal site selection and turbine deployment. The process of the applied part is shown in Figure 10 below:

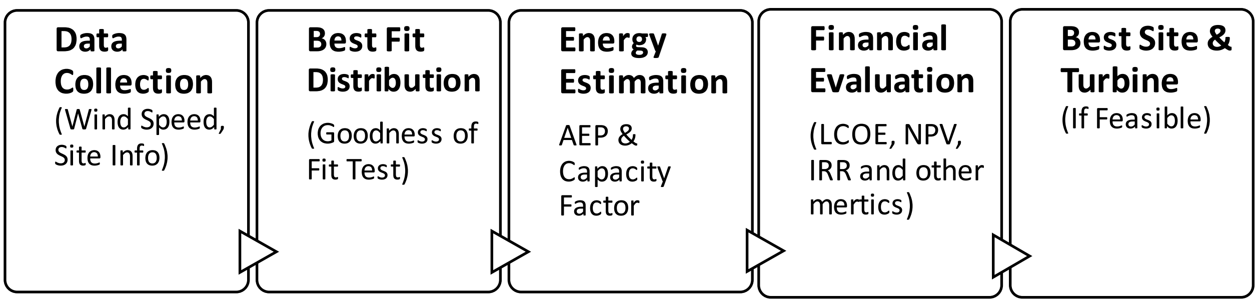

Figure 10: Empirical Study Flowchart

Source: Student's work.

This chapter is organized into three main sections:

- Section 1: Descriptive Statistics and Wind Modeling
- Section 2: Wind Power Assessment
- Section 3: Comprehensive Financial Viability Assessment

Section 1: Descriptive Statistics and Wind Modeling

This section provides an initial analysis of the wind speed data collected from selected Algerian sites. It begins with a general presentation of host company (S-ER), then descriptive statistics to understand the basic characteristics and variability of the wind resource. Following this, the wind speed data is modeled using several probability distributions, These distributions are fitted to the data using statistical estimation methods, and their accuracy is evaluated using goodness-of-fit tests.

1. Presentation of Host Company (Sonelgaz – Energies Renouvelables):

Sonelgaz is a public Algerian company whose field of activity includes the production, transmission, and distribution of energy. It is a joint-stock company subject to the applicable legislation, in accordance with the legal provisions outlined in Legislative Decree No. 02-195 dated June 1, 2002. The company's capital amounts to 150 billion DZD. Sonelgaz is a holding company that manages a multi-company, multi-activity industrial group. One of these companies is Sonelgaz – Energies Renouvlables (S-ER). In 2013, a new company named Electricity and Renewable Energy Company was established, commonly known as SKTM. It is responsible for electricity generation using conventional means in the southern regions, and RE at the national level. The company was tasked with producing electricity as well as studying the potential for electricity generation through renewable energy sources. Its goal is to improve existing electricity production methods and support the development of new power generation sectors. SKTM also focuses on developing the electrical infrastructure of isolated grid production parks in the south (diesel and gas turbines), operating, maintaining, and managing power plants within its field of expertise, and marketing the electricity it produces. In 2022, as part of the group's new organizational structure, the company was renamed Sonelgaz – Renewable Energies.[1]

S-ER is dedicated to developing and implementing RE projects in Algeria, particularly PV solar energy. This initiative aligns with a national strategy, and its primary mission is to produce electricity using RE sources across all of Algeria. The aim is to reduce reliance on traditional resources and promote energy sustainability. It is a joint-stock company with a capital of 38.7 billion Algerian DZD, wholly owned by Sonelgaz.[2]

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[1] SER, (2024), *Internal report* [Unpublished document], Management Control Department.
[2] S-ER, (2024), *Unpublished Balance Sheet*, Management Control Department.

2. Data Description:

In this study, five sites were selected for analysis: Batna, Djelfa, Saida, Oran, and Setif. Wind speed data were obtained from two primary sources. For the Oran site, observational data were provided by the Algerian National Office of Meteorology (ONM). For the other four locations, Batna, Djelfa, Saida, and Setif, the data were sourced from the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2). MERRA-2 is a global atmospheric reanalysis dataset developed by NASA’s Global Modeling and Assimilation Office (GMAO). It integrates satellite and ground-based observations with numerical weather prediction models to generate consistent and long-term climate records. The geographic coordinates of each site, the temporal resolution of the data, and the measurement periods are detailed in Table 5.

Table 5: Coordinates, Temporal Resolution, and Measurement Periods of Studied Sites.

Site	Latitude, Longitude	Altitude (m)	Time Resolution (min)	Measurement Period
Batna	35.56° N, 6.16° E	1048	60	From 01/01/2020 to 31/12/2022
Djelfa	34.67° N, 3.19° E	1100	60	From 01/01/2020 to 31/12/2022
Saida	34.85°N, 0.12°E	980	60	From 01/01/2020 to 31/12/2024
Oran	35.64°N, -0.62°E	77	30	From 01/01/2006 to 31/12/2006
Setif	36.21°N, 5.39°E	1096	60	From 01/01/2020 to 31/12/2024

Wind speed data for each site were plotted as time series graphs as illustrated in Figure 10. These visualizations allow for the identification of temporal patterns, seasonal fluctuations, and variability in wind speed across the selected locations, where we can observe:

- For Batna, over a two-year period (2020–2022), wind speeds fluctuate frequently, with values generally ranging between 0 and 12 m/s, indicating highly variable wind conditions. Peaks occur periodically.

- For Djelfa, over a two-year period (2020–2022). Wind speeds are highly variable, with frequent fluctuations and occasional spikes up to 16 m/s.
- For Saida, Wind speed shows significant variability over 2020-2024, with peaks reaching ~17.5 m/s and frequent fluctuations.
- For Oran, the plot shows wind speed variations one-year period (2006). Wind speeds are highly variable, with frequent fluctuations and occasional spikes up to 17.5 m/s.
- For Setif, the time series data shows wind speed measurements from 2020 to 2024. The values fluctuate between up to 13.5 m/s, indicating significant variability.

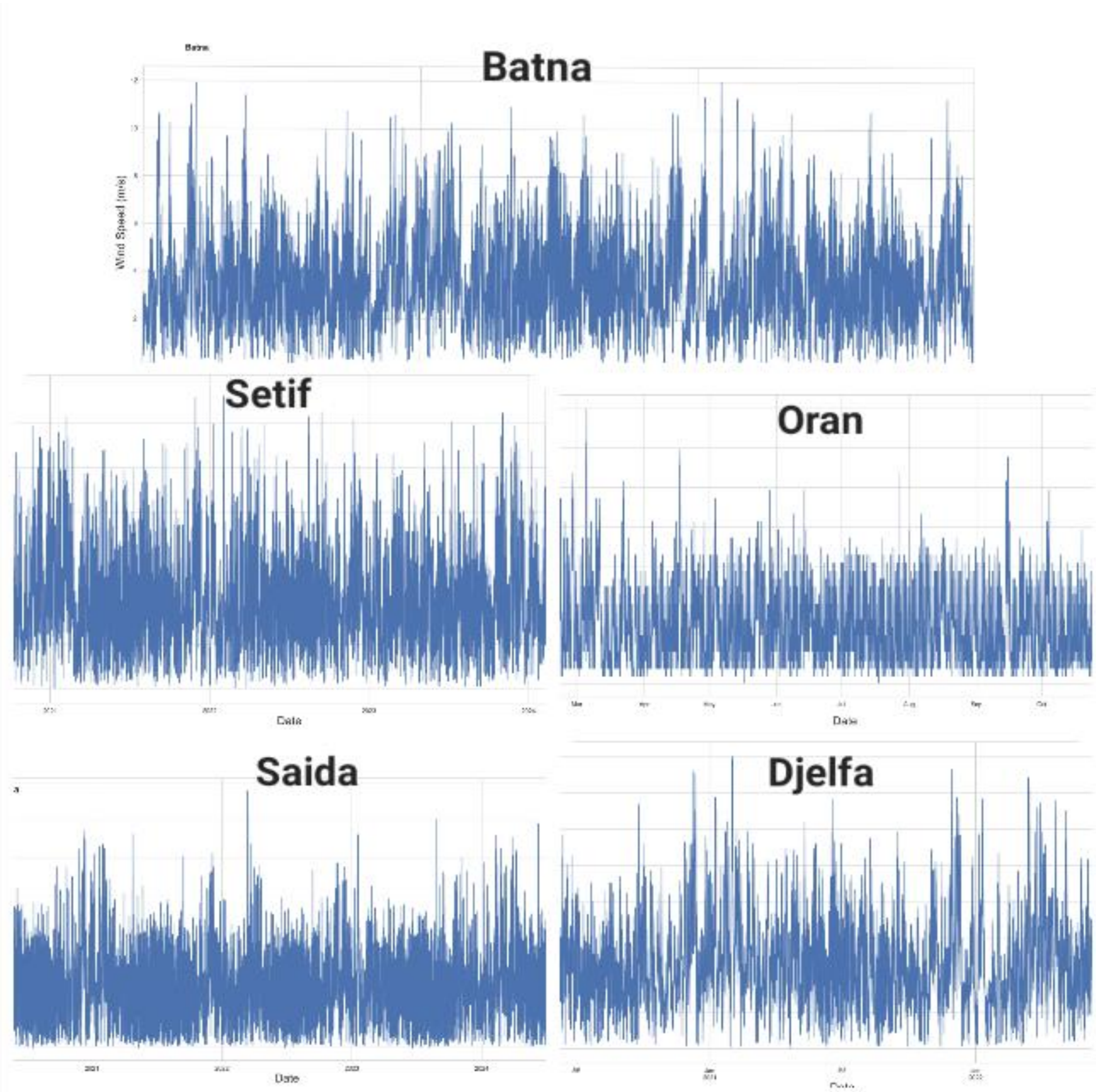

Figure 10: **Wind Speed Time Series of the Studied Regions**

Source: Results obtained by the student using Python

3. Descriptive Statistics:

- The mean wind speeds across the five regions range from 3.52 m/s (Batna) to 4.55 m/s (Djelfa), indicating that Djelfa generally experiences the strongest wind conditions, followed by Saida (4.06 m/s). Batna and Oran show the lowest mean values, implying relatively calmer wind regimes.
- The variability of wind speeds, as indicated by the standard deviation (σ), is highest in Djelfa /(2.42 m/s) and lowest in Batna (1.9 m/s), suggesting that wind in Djelfa is more fluctuating, while Batna's wind conditions are more stable.
- All sites show positive skewness (between 0.89 and 0.99), meaning the wind speed distributions are slightly right-skewed with more frequent lower wind speeds and occasional higher extremes.
- Kurtosis values for all regions lie between 0.7 and 0.94, indicating light tails and less frequent extreme wind events compared to a normal distribution. Overall, while Djelfa stands out with the highest wind potential and variability, Batna shows the most consistent wind profile. The other regions fall in between, with moderate wind speeds and distributions.

Table 6: Descriptive Statistics of Wind Speeds

Site	Mean (m/s)	Median (m/s)	σ (m/s)	Skewness	Kurtosis
Batna	3.52	3.05	1.9	0.96	0.7
Djelfa	4.55	4.03	2.42	0.95	0.94
Saida	4.06	3.59	2.32	0.89	0.79
Oran	3.58	3.1	2.36	0.99	0.86
Setif	3.9	3.42	2.12	0.98	0.81

Source: Results obtained by the student using Python

4. Wind Speed Modeling:

In this study, wind speed data were modeled using four probability distributions: Rayleigh, Log-normal, Gamma, and Weibull. These distributions have been widely employed in wind energy assessments in previous literature. For instance, the Weibull distribution is commonly applied due to its flexibility in capturing wind behavior, while Rayleigh distribution, a special case of the Weibull, is frequently used for its simplicity, especially in regions with less variable wind speeds.[1] The Log-normal distribution has been considered in studies where wind speeds are positively skewed,[2] while the Gamma distribution has been adopted for its capability to model wind speed variations with skewness and kurtosis different from those captured by Weibull or Log-normal.

To evaluate the suitability of each distribution at different sites, five Goodness-of-Fit (GoF) metrics were applied (where x_i is the actual value $\widehat{xi}$ is the predicted value, $\bar{x}$ is the mean value and n is the number of obesrvations):

- $$\textbf{Root Mean Square Error (RMSE)} = \sum_{i=1}^{n} \frac{1}{n} (x_i - \widehat{xi})^2 \qquad (10)$$

It measures the square root of the average of the squared differences between the predicted and actual data. It penalizes larger errors more severely than smaller ones, The model with the lowest RMSE is the fittest according to this metric.[3]

- $$\textbf{Mean Absolute Error (MAE)} = \frac{1}{n} \sum_{i=1}^{n} | x_i - \widehat{xi} |^2 \qquad (11)$$

It calculates the average magnitude of the absolute errors between predicted and observed data. Unlike RMSE, all errors are weighted equally. The model with the lowest MAE is the fittest according to this metric.[4]

- $$\textbf{Coefficient of Determination } (R^2) = 1 - \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{\sum_{i=1}^{n} (x_i - \widehat{xi})^2} \qquad (12)$$

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[1] Celik, A.N, (2004), A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey, vol. 29, no. 4, p593-604.

[2] Kenfack, C.S. et al., (2021), Potential of wind energy in Cameroon based on Weibull, normal, and lognormal distribution, International Journal of Energy and Environmental Engineering, p1-9.

[3] T. Chai, and R. R. Draxler, *"Root mean square error (RMSE) or mean absolute error (MAE)?"*, Geoscientific Model Development, vol. 7, no. 3, p1247-1250

[4] ibid

It measures the proportion of variance in the observed data that is explained by the model. It indicates how well the model captures the variability. The model with the highest R^2 is the fittest according to this metric.[1]

$$\textbf{Kolmogorov–Smirnov statistic (KS)} = max \mid F_1(x) - F_0(x) \mid \qquad (13)$$

Where $F_0(x)$ is the empirical cumulative distribution function (ECDF) and $F_1(x)$ is the theoretical cumulative distribution functionIt evaluates the maximum distance between the cumulative distribution functions of the observed and predicted data. The model with the lowest KS is the fittest according to this metric.[2]

Table 7 represents goodness-of-fit evaluation of wind speed distributions across selected sites. To identify the most suitable distribution, the model exhibiting the lowest values of RMSE, MAE, and KS statistics, along with the highest of R^2, is considered the best fit.

- At Batna, the Gamma distribution achieved the lowest RMSE (0.014 m/s) and MAE (0.009 m/s), along with a high R^2 of 0.971, indicating strong predictive accuracy. Although the Weibull distribution had the lowest KS value (0.055), Gamma's superior performance in error metrics and goodness-of-fit justifies its selection as the best fit.
- For Djelfa, Gamma again emerged as the best-fitting distribution, with the lowest RMSE (0.008 m/s) and MAE (0.005 m/s), and the highest R^2 value (0.984). With Weibull having the lowest KS, but its overall performance across key metrics outweighs this.
- In Saida, Gamma distribution provided the most accurate fit with the lowest RMSE (0.007 m/s), MAE (0.004 m/s), and the highest R^2 (0.990) despite Weibull having the lowest KS value (0.029).
- At Oran, the Log-normal distribution was chosen as the best fit due to its lowest RMSE (0.020 m/s) and MAE (0.013 m/s), and the highest R^2 (0.926). Despite the Weibull distribution yielding the lowest KS value (0.102), its overall fit was weaker, particularly in R^2 and error metrics, validating the preference for Log-normal.
- In Setif, Gamma was identified as the best fit, achieving the lowest RMSE (0.010 m/s) and MAE (0.006 m/s), and the highest R^2 (0.984). Although Weibull had the lowest KS value (0.048), Gamma demonstrated superior overall modeling performance, justifying its selection.

[1] James, G. el al., (2013), "*An Introduction to Statistical Learning: with Applications in R*", Springer, *p70*.
[2] Dimitrina, S. et al.,(2020), *"Computing the Kolmogorov-Smirnov Distribution When the Underlying CDF is Purely Discrete, Mixed, or Continuous"*, Journal of Statistical Software, vol. 95, no. 10, p2-3.

Table 7: Goodness-of-Fit Evaluation

Location	Distribution	RMSE (m/s)	MAE (m/s)	R^2 (%)	KS	Best Fit Distribution
Batna	**Rayleigh**	0.023	0.014	92.30	0.397	**Gamma**
	Log-normal	0.015	0.01	97.00	0.384	
	Gamma	**0.014**	**0.009**	**97.10**	0.868	
	Weibull	0.023	0.014	92.50	**0.055**	
Djelfa	**Rayleigh**	0.015	0.01	94.90	0.393	**Gamma**
	Log-normal	0.012	0.008	96.60	0.38	
	Gamma	**0.008**	**0.005**	**98.40**	0.87	
	Weibull	0.015	0.01	94.90	**0.044**	
Saida	**Rayleigh**	0.012	0.007	96.60	0.338	**Gamma**
	Log-normal	0.016	0.011	93.80	0.334	
	Gamma	**0.007**	**0.004**	**99.00**	0.74	
	Weibull	0.009	0.005	98.20	**0.029**	
Oran	**Rayleigh**	0.032	0.016	80.80	0.333	**Log-normal**
	Log-normal	**0.02**	**0.013**	**92.60**	0.348	
	Gamma	0.022	**0.013**	90.50	0.573	
	Weibull	0.026	**0.013**	87.00	**0.102**	
Setif	**Rayleigh**	0.019	0.012	93.80	0.394	**Gamma**
	Log-normal	0.011	0.007	97.90	0.383	
	Gamma	**0.01**	**0.006**	**98.40**	0.862	
	Weibull	0.019	0.011	94.00	**0.048**	

Source: Results obtained by the student using Python

The histograms for the probability density function (PDF) of the four distributions across the studied regions are shown in the Figure 11 below:

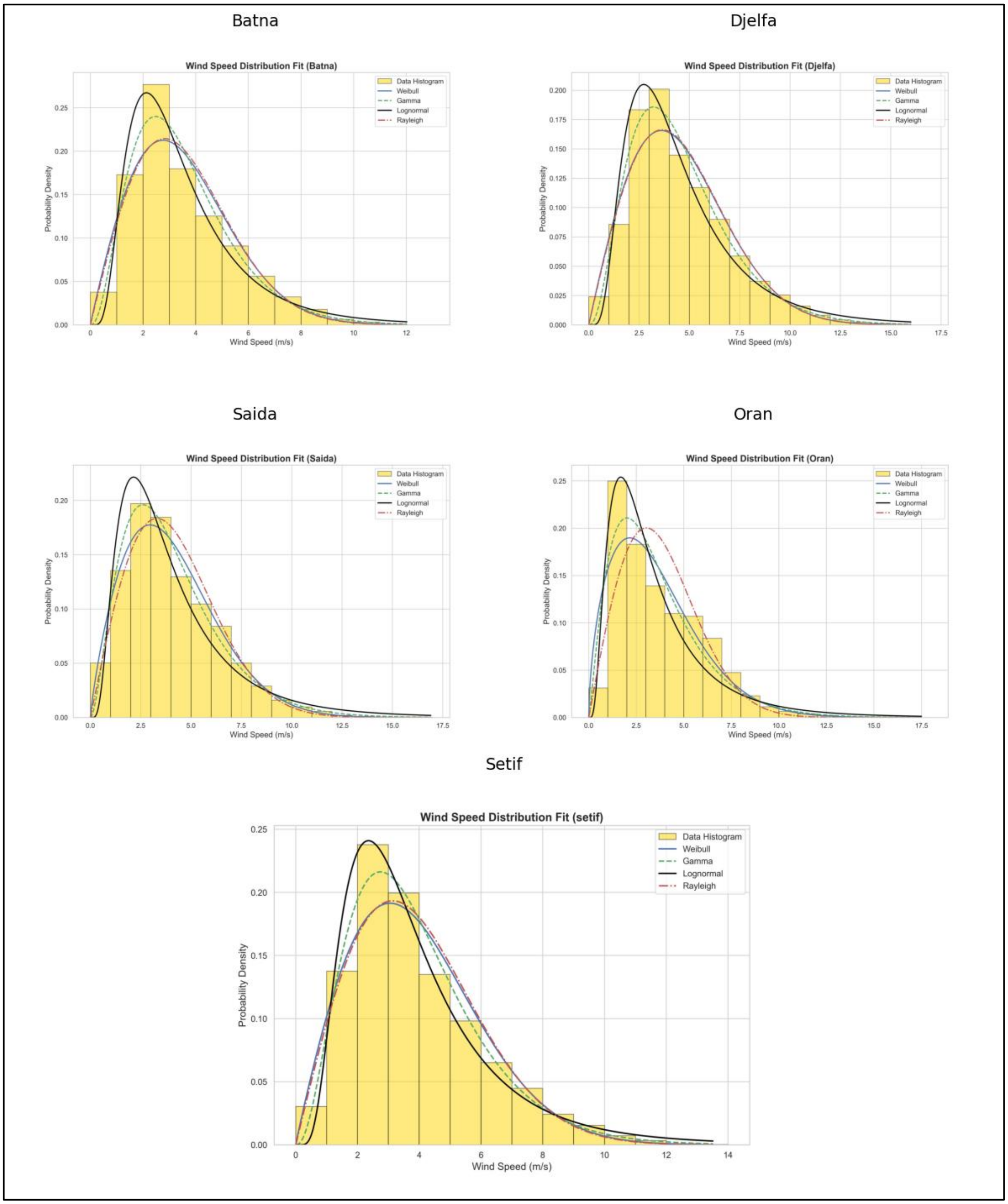

Figure 11: Probability Density Functions Histograms

Source: Results obtained by the student using Python

Section 2: Wind Power Assessment:

This section assesses the wind energy potential and electricity generation capacity of studied sites. It begins by analyzing critical power indicators mean wind speed, variability, most probable and energy-carrying wind speeds, and wind power density (WPD) to evaluate site suitability. The Pacific Northwest Laboratory (PNL) classification ranks wind resources. Next, the section examines electricity generation by extrapolating wind data to turbine hub heights and calculating capacity factors (CF) and annual energy output (AEP) for various turbine models.

1. Wind Power Indicators:

Table 8 presents the probabilistic mean wind speed, standard deviation (δV), most observed thus probable wind speed, wind speed carrying maximum energy V_{maxE} , mean wind power density (WPD) and Pacific Northwest Laboratory classifications. [1] Upon initial observation, Oran stands out with notably higher values in terms of standard deviation and WPD (supposing that ρ = 1.225 kg/m³), suggesting a greater variability and stronger wind energy potential. This highlights Oran, in particular, as a more favorable candidate for wind energy development among the listed locations.

Table 8: Wind power metrics at 10 m AGL.

Sites	Mean (m/s)	δ_V (m/s)	Mode (m/s)	V_{maxE} (m/s)	WPD (W/m²)	PNL Classification
Batna	3.52	1.91	2.48	3.12	54.98	1
Djelfa	4.55	2.47	3.21	4.02	118.76	2
Saida	4.06	2.42	2.61	4.34	95.13	1
Oran	3.66	3.02	1.68	7.97	142.32	2
Setif	3.9	2.12	2.74	3.47	75.05	1

Source: Results obtained by the student using Python

[1] K. Mohammadi and A. Mostafaeipour, “Economic feasibility of developing wind turbines in Aligoodarz , Iran,” Energy Convers. Manag., vol. 76, p 645-653.

2. Electricity Generation:

All the wind speeds (V_1) for each site were recorded 10m (Z_1) AGL, so in order to estimate the AEP for each site, we have to first extrapolate the wind speed (V_2) at the hub height of the wind turbines (Z_2) from 10m, to do that, we use the logarithmic law where (Z_0) is the terrain roughness length is expressed as:[1]

$$\boldsymbol{V_2 = V_1 \frac{ln(Z_2/Z_0)}{ln(Z_1/Z_0)}} \quad (14)$$

The terrain roughness length for each site is:

Table 9: Terrain Roughness Length

Site	Batna	Djelfa	Saida	Oran	Setif
Z_0	0.01	0.08	0.01	0.01	0.01

Source: Nedjari, H.D. et al., (2018), Optimal windy sites in Algeria: Potential and perspectives, Energy, vol. 147, p1243.

This study considers the following wind turbines:[2]

Table 10: Wind Turbines Characteristics.

Turbine Model	P_r (kW)	V_{ci} (m/s)	V_r (m/s)	V_{co} (m/s)	Hub Height (m)
AVENTA AV7	6.5	2.5	7	14	22
Polaris P10-20	20	2.5	10.5	25	30
E-3120	50	3.5	9.5	25	30.5
Nordex-150	150	3	10	25	30
H21.0-60kW	60	2.5	9	25	40
H25.0-60kW	60	2.5	7.5	20	40
Gamesa G52	850	4	15	28	55
E53/800	800	2	13	25	60

Where:

- P_r **:** The maximum power output the turbine can produce under ideal wind conditions.
- V_r **:** The wind speed at which the turbine produces its rated power (Pr).
- V_{ci} **:** The minimum wind speed at which the turbine starts generating electricity.

[1] Taoussi, B. et al., (2024), "*Techno-economic feasibility study of developing wind turbines in Algeria*", 2024 3rd International Conference on Advanced Electrical Engineering (ICAEE), IEEE, p1-6.
[2] Ibid.

- V_{co} **:** The maximum speed at which the turbine operates, above this it shuts down for safety.

The results of energy yield estimation using the wind turbines in Table 10 for Batna, Djelfa, Saida, Oran and Setif are shown from Table 11 to Table 15, where:[1]

- $\mathbf{AEP} = P_r \times 8760 \times Capacity\ Factor$**:** The total amount of electricity a wind turbine actually produces in a year.
- $\mathbf{Capacity\ Factor} = \frac{AEP}{P_r \times 8760}$ **:** represents the ratio of actual energy produced in a year to the maximum possible energy it could have produced if it operated at full capacity.
- $Net\ \mathbf{Hours} = \frac{AEP}{P_r}$ **:** The number of hours the turbine would need to run at full capacity to generate the same amount of energy it actually produced.

2.1.Batna:

The H25.0-60kW and AVENTA AV7 turbines exhibit the highest capacity factors (26.75% and 26.20%, respectively), indicating strong efficiency in energy generation relative to their rated capacity. However, despite a very low capacity factor (7.90%), the E53/800 achieves the highest AEP, which compensates for its lower efficiency.

Table 11: Performance Comparison of Wind Turbine Models in Batna

Turbine Model	Capacity Factor	AEP (KW)	Net Hours	Availability Factor
AVENTA AV7	26.20%	14,918.55	2295	71.83%
Polaris P10-20	11.17%	19,574.97	979	73.97%
E-3120	13.81%	60,466.51	1209	53.54%
Nordex-150	12.48%	163,981.17	1093	63.67%
H21.0-60kW	18.01%	94,635.49	1577	75.72%
H25.0-60kW	**26.75%**	140,603.28	**2343**	75.71%
Gamesa G52	4.76%	354,273.69	417	49.31%
E53/800	7.90%	**553,359.92**	692	**86.41%**

Source: Results obtained by the student using Python

[1] Manwell,J. F.et al. (2009), "*Wind Energy Explained: Theory, Design and Application*", 2nd ed, John Wiley and Sons, UK, p63.

2.2.Djelfa:

The H25.0-60kW model stands out with the highest CF (46.65%) and a strong AEP, indicating excellent efficiency and output. Meanwhile, the E53/800 and Gamesa G52 turbines, despite lower capacity factors (19.16% and 15.63%), achieve the highest AEPs due to their large rated capacities and high availability especially the E53/800 with a remarkable AVA of 94.15%.

Table 12: Performance Comparison of Wind Turbine Models in Djelfa

Turbine Model	Capacity Factor	AEP (KW)	Net Hours	Availability Factor
AVENTA AV7	43.56%	24,804.08	3816	83.98%
Polaris P10-20	28.81%	50,473.64	2524	74.47%
E-3120	32.66%	143,046.59	2861	62.94%
Nordex-150	30.73%	403,737.29	2692	68.60%
H21.0-60kW	35.39%	185,994.89	3100	88.14%
H25.0-60kW	**46.65%**	245,208.86	4087	88.02%
Gamesa G52	15.63%	1,164,076.49	1370	64.38%
E53/800	19.16%	**1,342,527.49**	1678	**94.15%**

Source: Results obtained by the student using Python

2.3.Saida:

The H25.0-60kW turbine leads in both capacity factor (35.04%) and net operational hours, indicating strong efficiency and utilization. However, the E53/800 achieves the highest AEP (880,404.57 KW) and availability (87.45%).

Table 13: Performance Comparison of Wind Turbine Models in Saida

Turbine Model	CapacityFactor	AEP (KW)	Net Hours	Availability Factor
AVENTA AV7	34.04%	19,380.79	2982	75.05%
Polaris P10-20	17.08%	29,930.97	1497	77.32%
E-3120	20.72%	90,761.95	1815	60.55%
Nordex-150	18.88%	248,028.73	1654	68.95%
H21.0-60kW	25.48%	133,935.22	2232	78.73%
H25.0-60kW	**35.04%**	184,157.75	**3069**	78.68%
Gamesa G52	7.32%	545,172.55	641	54.66%
E53/800	12.56%	**880,404.57**	1101	**87.45%**

Source: Results obtained by the student using Python

2.4.Oran:

The H25.0-60kW turbine again shows strong performance with the highest capacity factor (26.21%) and net hours, indicating reliable and efficient energy production. In contrast, the E53/800 dominates in total AEP (758,321.00 KW) and availability (78.50%), proving that high energy output can be achieved even with moderate efficiency when uptime and turbine capacity are substantial.

Table 14: Performance Comparison of Wind Turbine Models in Oran

Turbine Model	Capacity Factor	AEP (KW)	Net Hours	Availability Factor
AVENTA AV7	24.60%	14,006.74	2155	60.67%
Polaris P10-20	14.06%	24,638.12	1232	64.40%
E-3120	16.37%	71,720.67	1434	46.10%
Nordex-150	15.22%	200,025.60	1334	54.63%
H21.0-60kW	19.84%	104,304.56	1738	66.17%
H25.0-60kW	**26.21%**	137,775.78	**2296**	65.76%
Gamesa G52	7.59%	564,888.14	665	42.81%
E53/800	10.82%	**758,321.00**	948	**78.50%**

Source: Results obtained by the student using Python

2.5.Setif:

The H25.0-60kW turbine leads in capacity factor (32.69%) and net hours, reflecting high efficiency and consistent operation. Meanwhile, the E53/800 achieves the highest AEP (1,308,681.40 KW), highlighting its substantial energy production capacity.

Table 15: Performance Comparison of Wind Turbine Models in Setif

Turbine Model	Capacity Factor	AEP (KW)	Net Hours	Availability Factor
AVENTA AV7	31.99%	18,215.81	2802	76.79%
Polaris P10-20	14.67%	25,696.56	1285	78.80%
E-3120	18.07%	79,163.73	1583	60.42%
Nordex-150	16.34%	214,757.56	1432	69.72%
H21.0-60kW	22.84%	120,038.09	2001	**80.31%**
H25.0-60kW	**32.69%**	171,806.58	**2863**	80.30%
Gamesa G52	13.93%	1,037,537.07	1221	52.60%
E53/800	18.67%	**1,308,681.40**	1636	76.11%

Source: Results obtained by the student using Python

Section 3: Comprehensive Financial Viability Assessment:

This section evaluates the financial feasibility of wind energy projects at the studied sites by analyzing key economic indicators and investment metrics for each turbine. It begins with the estimation of discount rate then capital, operational, and maintenance costs associated with wind power generation systems to calculate the LCOE. We will then determine the NPV, IRR, and PBP and compare the values to determine the most suitable site and turbine (if found). The section concludes with sensitivity analyses to evaluate the impact of variations in key parameters.

1. Discount Rate Calculation:

The discount rate is generally taken as 8-12% in wind energy feasibility papers discussed in the literature review section of the second chapter, for our assessment, we will determine it using WACC method:

$$\boldsymbol{WACC = R_e \frac{E}{E+D} + R_d \frac{D}{E+D}(1 - Tax\ Rate)} \qquad (15)$$

where:

- **E and D:** Equity and Debt respectively, we assume that the project will be financed 75% by debt and 25% by equity, this was based on Wind Europe organization industry report, wind energy projects are usually financed 70-80% by debt.[1]
- $\boldsymbol{R_e}$**:** Cost of Equity. Based on Capital Asset Pricing Model (CAPM) we have:[2]

$$\boldsymbol{R_e = R_f + \beta * (R_m - R_f) + Country\ Risk\ Premuim\ (CRP) + Liquidity\ Risk} \qquad (16)$$

- $\boldsymbol{R_m}$ - $\boldsymbol{R_f}$**:** Equity risk premium (ERP), for Algeria it equals **8.35%.** [3]
- $\boldsymbol{CRP = 4.02\%}$ and **liquidity risk=2%.**[4]
- $\boldsymbol{R_f}$**:** Risk-free rate (government bond yield), in our case, we selected a 15 years Algerian government bond as the proxy for the risk-free rate, which was **5.01%** at the time of the

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[1] O'Connor, R., 2023, *"Financing and Investment Trends 2022"[industry report],* Wind Europe org, p10.
[2] Damodaran, A., 2014, *"Applied Corporate Finance",* 4th ed, Stern School of Business, NYU, p40.
[3] Damodaran website ,https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html, visited in 20/05/2025 at 12:28.
[4] Ibid.

study. Although the project's lifetime is 20 years, the 15-year OAT was chosen due to the unavailability of a 20-year bond rate.[1]

- ***β:*** Sensitivity to market risk, and since we don't have in Algeria active financial markets, we will rely on US stats. Based on Damodaran website, β unlevered of renewable energy sector in the US equals 0.49**,** we re-lever the beta using Hamada equation (1972) and the project's estimated capital structure we find $\boldsymbol{\beta_L}$**=**$\boldsymbol{\beta_u}$***(1+(1-Tax Rate)*D/E)** where the D/E ratio is found based on S-ER capital structure (see appendix 2), the debt corresponding to the project's debt (75%*wind turbine cost = 10,093,561.34 DZD) and the equity is the overall equity (S-ER's and the project's = 43,003,577,744.00+3,364,520.45)[2]
  We now find $\boldsymbol{R_e = 15.12\%}$
- $\boldsymbol{R_d}$ **:** Cost of Debt, in Algeria for a 5 year loan it equals = **5.75%.**[3]

by applying the WACC formula, we finally get:

$$\boldsymbol{r = WACC = R_e \frac{E}{V} + R_d \frac{D}{V}(1 - Tax\ Rate)} = 7.27\%$$

2. Levelized Cost of Electricity (LCOE):

In the literature and real-world wind energy project assessments, yearly operation and maintenance costs typically range from 2% to 5% of the initial cost of wind turbines, factoring in land lease costs, a total of **5%** is considered a reasonable and widely accepted approximation.

The turbine price was estimated based on a sliding scale per rated capacity, reflecting economies of scale. For turbines below 20 kW, a cost of $2550/kW was used; for medium-scale turbines (20–200 kW), $1900/kW; and for turbines above 200 kW, $1300/kW. [4]

The total initial cost of a wind energy project typically includes not just the price of the wind turbine itself, but also several other costs, such as:

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[1] Algeria's Bank website, bank-of-algeria.dz/statistiques-associes-au-marche-des-valeurs-du-tresor/, visited in 20/05/2025 at 11:11.
[2] Damodaran website, https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html, visited in 20/05/2025 at 13:38.
[3] Algeria's National Bank, (2025), Debt Service.
[4] Aroua F.Z et al. (2024), "*Wind energy cost evaluation based on a techno-economic assessment in the Algerian highlands*", Energy for Sustainable Development, vol. 81, p5.

- Transportation and installation
- Civil and electrical infrastructure (e.g., foundation, cabling, grid connection)
- Permitting, engineering, Project management and other costs

In our study, we assume based on literature that Total Initial Cost = **1.3** × Turbine Price

From Table 16 we observe that the cost evaluation of various wind turbine models reveals differences in both upfront investment and lifetime costs. Among the smallest turbines, the AVANTA AV7 has the lowest turbine price at $16,575, with a corresponding total initial cost of $21,547.50 and a relatively low present value of lifetime costs at $32,722.40.

- In contrast, large-scale models like the Gamesa G52 and E53/800 show dramatically higher financial requirements, with turbine prices exceeding $1 million and PV of lifetime costs at $2,181,493.65and $2,053,170.50 respectively.
- Mid-sized models such as the Nordex-150 and E-3120 show intermediate values, with PV of lifetime costs of $384,969.47 and $128,323.16 respectively. Notably, the H21.0-60kW and H25.0-60kW share identical pricing and cost profiles, both having a PV of lifetime costs of $153,987.79, indicating a standardized cost structure
- And since we assumed that the AEP is stable during the project's lifetime, then the yearly costs and revenues are effectively stable.

Table 16: Turbine Price and Initial Cost.

Turbine Model	Turbine Price	Initial Cost	Yearly Costs	PV of life time Costs
AVANTA AV7	$ 16,575.00	$ 21,547.50	1,077.38	32,722.40
Polaris P10-20	$ 26,000.00	$ 33,800.00	1,690.00	51,329.26
E-3120	$ 65,000.00	$ 84,500.00	4,225.00	128,323.16
Nordex-150	$ 195,000.00	$ 253,500.00	12,675.00	384,969.47
H21.0-60kW	$ 78,000.00	$ 101,400.00	5,070.00	153,987.79
H25.0-60kW	$ 78,000.00	$ 101,400.00	5,070.00	153,987.79
Gamesa G52	$ 1,105,000.00	$ 1,436,500.00	71,825.00	2,181,493.65
E53/800	$ 1,040,000.00	$ 1,352,000.00	67,600.00	2,053,170.50

Source: Obtained by the student using Excel

- The exchange rate was obtained in 20/05/2020 where 1 dollar equaled 132.72 DA.[1]
- The results are obtained in Table 16 where we can clearly observe that LCOE values presented reflect significant variation across turbine models and locations.
- The LCOE ranges from a low of **8** DZD/kWh for the H25.0-60kW turbine in Djelfa to a high 78.79 DZD/kWh for the Gamesa G52 model in Batna, indicating that turbine selection and site-specific wind resources play critical roles in determining project viability.
- Djelfa and Saida generally exhibit lower LCOEs, suggesting more favorable conditions for cost-effective wind power generation. While Batna and Oran tend to yield higher LCOEs.
- Notably, the H25.0-60kW turbine consistently outperforms others in terms of cost-efficiency, particularly in Djelfa, making it a promising candidate.
- Conversely, larger turbines like the Gamesa G52 and E53/800 show high LCOEs, which may be attributed to higher capital expenditures and low capacity factors.

Table 17: LCOEs Results

Turbine Model	Batna	Djelfa	Saida	Oran	Setif
AVANTA AV7	28.066	16.881	21.604	29.893	22.986
Polaris P10-20	33.553	13.013	21.944	26.658	25.560
E-3120	27.156	11.479	18.091	22.894	20.742
Nordex-150	30.040	12.201	19.861	24.627	22.938
H21.0-60kW	20.821	10.594	14.712	18.891	16.415
H25.0-60kW	**14.014**	**8.036**	**10.700**	**14.302**	**11.469**
Gamesa G52	78.792	23.980	51.202	49.415	26.904
E53/800	47.477	19.569	29.841	34.645	20.075

Source: Obtained by the student using Excel

[1] Algeria's Bank website: https://www.bank-of-algeria.dz/taux-de-change-journalier/, visited in 20/05/2025 at 16:00

3. Present Value Costs:

Since we assumed that the O&M and rental costs are constant and equal 5% of the initial investment cost, and since the turbine used for financial assessment is the **H25.0-60kW** because of it having the lowest LCOE

- The inflation rate for Algeria was taken from the world bank website.[1]
- C_{OMR}($) = $5070
- I ($) = 101,400
- $r = 7.27\%$
- n = 20 years
- The project has a salvage value to wind turbines having an average lifetime of 25 years based on literature so the residual value equals 5/25= 20% of the initial investment
- The PVC was found to be $**164,897.29** or **21,885,613.69 DZD**
- The PVC is almost equal to the PV of life time Costs $153,987.79 found in Table 17 which suggests consistency between the two costing approaches. The small difference is attributed to the incorporation of inflation in the PVC formula, which slightly increases the present value of recurring OMR costs.

4. Net Present Value:

- The NPV results using the discounted cash flows are presented in Table 18 (and are explained in depth in appendices 3 to 7)
- The reference selling price was taken 13DZD based on unpublished S-ER document setting the price per Kwh for the electricity generated from the Adrar wind farm.
- Since the AEP is assumed constant every year, the revenue which equals AEP*13DZD is considered constant, this assumption is commonly used in early stage feasibility studies to simplify financial assessment.
- The turbine taken for the financial assessment was the **H25.0-60kW** turbine due to it having the lowest LCOE in each site and due it LCOE being inferior than the 13DZD (for most sites).
- Batna demonstrates unfavorable financial viability, with a negative NPV of **(1,556,067.04)** DZD. The discounted cash flows (DCF) across the 20-years remain modest. the project's returns are insufficient to cover the capital and O&M costs, due to wind conditions being poor compared to

[1] World Bank webiste : https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG, visited in 25/05/2025 at 19:10.

other sites. Batna should be excluded from investment consideration unless external factors such as subsidies or improved technology significantly shift its performance.

- Djelfa stands out as the most financially attractive site, yielding a strong positive NPV of **10,920,710.20** DZD. The DCF values are consistently higher than all other locations, reflecting the observed favorable wind resources. With high returns starting from year 1 and maintaining a steady trend, the project offers a substantial margin over the initial investment. This makes Djelfa a top-priority location for wind energy development from the other sites.
- Saida presents a positive investment opportunity with an NPV of **3,638,870.17** DZD. While not as lucrative as Djelfa, its DCF values are relatively stable, and the project does manage to recover its investment and generate additional value, making it suitable as a secondary option.
- Oran delivers a negative NPV of **(1,893,315.66)** DZD, making it the least financially viable option among the five locations. DCF values are low throughout the time horizon.
- Sétif shows a positive NPV of 2,165,690.67 DZD**,** indicating modest profitability**.** While not as profitable as Djelfa or Saïda, the project remains economically viable.

Table 17: NPV Results

Years	DCF (Batna)	DCF (Djelfa)	DCF (Saida)	DCF (Oran)	DCF (Setif)
0	(101,400.00)	(101,400.00)	(101,400.00)	(101,400.00)	(101,400.00)
1	8,111.86	17,663.10	12,088.70	7,853.69	10,960.94
2	7,561.83	16,465.45	11,269.02	7,321.17	10,217.74
3	7,049.10	15,349.01	10,504.93	6,824.76	9,524.92
4	6,571.14	14,308.27	9,792.64	6,362.00	8,879.09
5	6,125.58	13,338.10	9,128.65	5,930.63	8,277.04
6	5,130.99	10,577.00	7,398.54	4,983.79	6,755.51
7	4,783.09	9,859.83	6,896.88	4,645.86	6,297.45
8	4,458.77	9,191.28	6,429.24	4,330.85	5,870.45
9	4,156.44	8,568.07	5,993.30	4,037.19	5,472.41
10	3,874.61	7,987.11	5,586.93	3,763.45	5,101.35
11	3,611.90	7,445.54	5,208.11	3,508.27	4,755.45
12	3,366.99	6,940.70	4,854.97	3,270.39	4,433.01
13	3,138.69	6,470.09	4,525.78	3,048.64	4,132.43
14	2,925.87	6,031.38	4,218.91	2,841.93	3,852.23
15	2,727.48	5,622.42	3,932.85	2,649.23	3,591.03
16	2,542.55	5,241.19	3,666.18	2,469.60	3,347.54
17	2,370.15	4,885.82	3,417.59	2,302.15	3,120.56
18	2,209.44	4,554.53	3,185.86	2,146.05	2,908.97
19	2,059.63	4,245.71	2,969.85	2,000.54	2,711.73
20	6,899.68	8,937.53	7,748.18	6,844.59	7,507.56
NPV ($)	**(11,724.20)**	**82,282.16**	**27,417.09**	**(14,265.20)**	**16,317.41**
NPV (DZD)	**(1,556,067.04)**	**10,920,710.20**	**3,638,870.17**	**(1,893,315.66)**	**2,165,690.67**

Source: Obtained by the student using Excel

5. Benefit Cost Ratio:

- BCR or Profitability index reflects the NPV results obtained
- In Batna, the BCR came out to just **88.44%** which is well below 100%. This aligns with the negative NPV of **(1,556,067.04),** confirming that the project fails to generate enough returns to cover its costs over the 20-year period.
- On the other hand, Djelfa stands out as the most economically attractive site, with a strong BCR of **181.15%**. Combined with its high positive NPV, this makes Djelfa not only viable but highly profitable an ideal candidate for wind energy development.
- Saïda shows a BCR of **127.04%** indicating a modest surplus in benefits over costs. While not as strong as Djelfa, it still represents a secondary viable investment.
- In contrast, Oran has a low BCR of **85.93%** reinforcing its poor economic viability. The deeply negative NPV of (1,893,315.66 DZD**)** confirms that the project is far from recovering its initial investment, making it unsuitable for development.
- Lastly, Sétif breaks-even point with a BCR of **116.09%** above the threshold of 1. This suggests the project slightly recovers its costs in present value terms.

6. Internal Rate of Return (IRR):

The IRR results are shown in Figure 12

- The IRR for Batna is well below the discount rate, confirming that the project's return does not cover its cost of capital. So, Batna should not be taken for investment under current conditions.
- Djelfa stands out with an IRR significantly higher than the discount rate, indicating strong economic performance.
- Saida’s and Sétif’s IRRs are above the discount rate, confirming the estimated results.
- Oran's IRR is well below the discount rate, confirming that the project would generate returns insufficient to cover capital costs. Oran is not a viable investment under the current assumptions

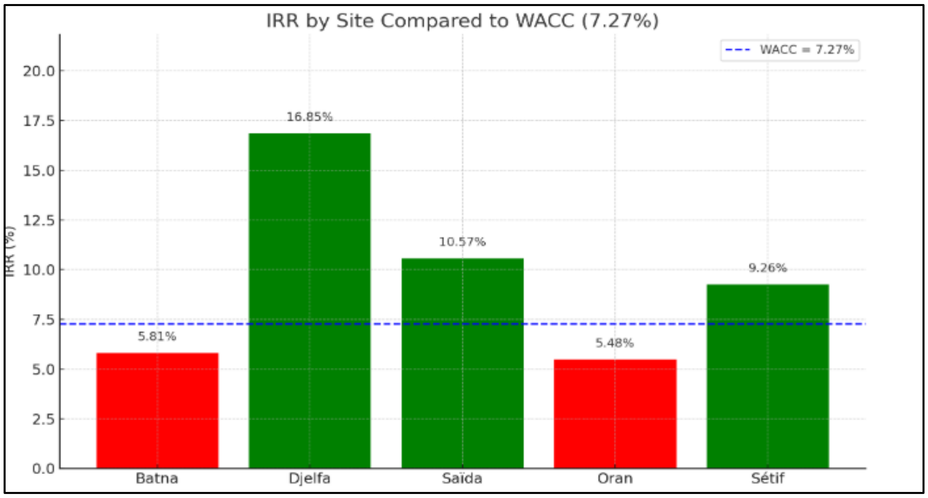

Figure 12: IRR Results

Source: Results obtained by the student using Python

7. Payback Period:

The discounted cash flow payback periods are shown in Figure 13 where the results were obtained from the accumulated cash flow (and accumulated discounted cash flow) tables (see appendices 9 and 10)

- Djelfa achieves payback the fastest within **7 years 5 months**, crossing the break-even point in less than a decade. It stands out as the most attractive site in terms of liquidity.
- Saïda and Setif break even within **13 years 4 months** and almost **15 years** respectively**.**
- Batna and Oran's Cumulative DCF remain negative. The projects fail to recover their investment in present-value terms and are not financially viable as the BCR an NPV results indicate

The cash flow payback periods are shown in Figure 14

- Djelfa achieves payback the fastest within **5.5 years**.
- Saïda breaks even within **8 years and 3 months**.
- Sétif within **9 years and 2 months.**
- For Batna **12 year 5 months** and Oran within **12 years and 10 months.**

From a liquidity standpoint, Djelfa clearly outperforms all other sites, recovering its costs rapidly in both nominal and discounted terms. Saïda and Sétif offer borderline liquidity, while Batna and Oran fail to meet even minimum viability thresholds.

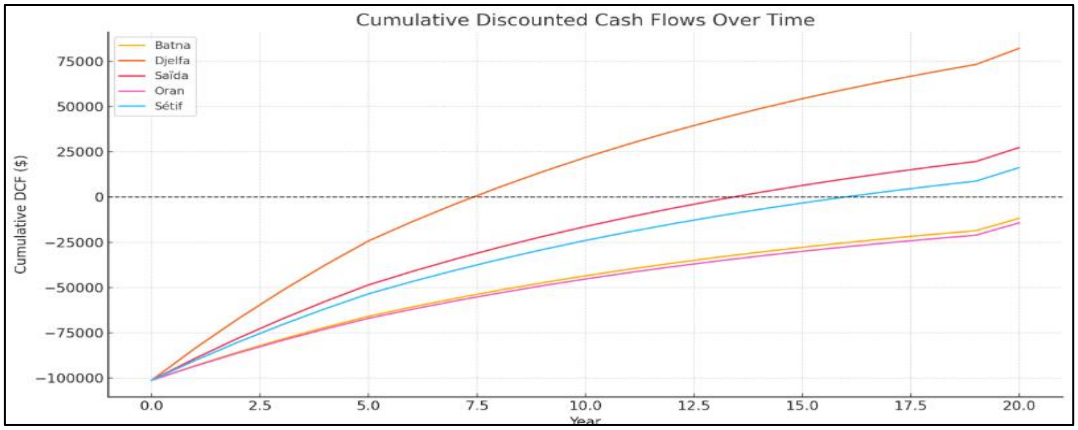

Figure 13: PBP Results (DCF)

Source: Results obtained by the student using Python

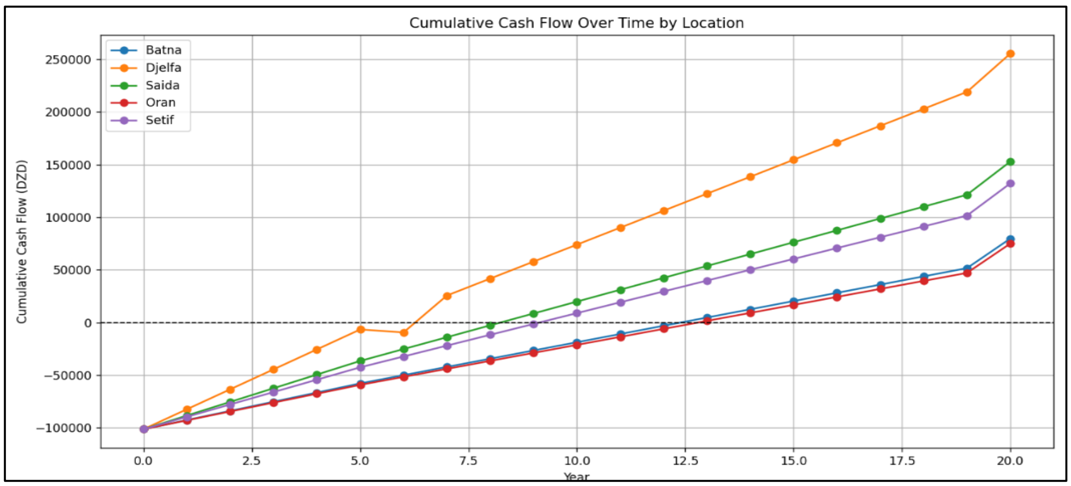

Figure 14: PBP Results (CF)

Source: Results obtained by the student using Python

8. Year to Positive Cash Flow (YPCF):

In addition to the cumulative payback analysis, the Year to Positive Cash Flow (YPCF) was used to assess annual liquidity performance. From the results of the PBP we conclude the YPCF and Year to Positive Discounted Cash Flow (YPDCF) in Table 19.

Table 19: YPCF Results

Site	Batna	Djelfa	Saida	Oran	Setif
YPCF	12	**5**	8	12	9
YPDCF	-	**7**	13	-	15

Source: Results obtained by the student using Python

9. Annual Life Cycle Savings (ALCS):

- Djelfa demonstrates the highest ALCS at 1,052,868.05 DZD, indicating excellent annual profitability and reinforcing its superior performance seen in earlier metrics.
- Saïda and Sétif also achieve positive ALCS values (350,824.27 DZD and 208,794.71 DZD, respectively), signifying that they generate net savings each year and are economically viable.
- Batna and Oran, however, show negative ALCS (–150,020.76 DZD and –182,534.97 DZD, respectively), which means they deliver net annual losses over the project lifetime.

Table 20: ALCS Results

Site	Batna	Djelfa	Saida	Oran	Setif
ALCS (DZD)	- 150,020.76	***1,052,868.05***	350,824.27	- 182,534.97	208,794.71

Source: Results obtained by the student using Python

10. Sensitivity Analysis:

In the sensitivity analysis, we will take in consideration the potential changes in key variables, each variable at a time, so we will rely on One-at -a-Time analysis (OAT).

10.1. Regarding the Subsidized Rate:

If we take the debt rate where state supports 3% of the debt cost, the cost of debt will become $\boldsymbol{R_d}$ **= 2.75%**, this will have an enormous impact on the projects viability as a whole, because the change in the cost of debt means the change in the discount rate value, which affects the present values of both costs and benefits as shown in Table 21:

- The discount rate drops from 7.27% to 5.45% since the project uses a mix of debt and equity**,** and debt becomes cheaper
- Under these circumstances, all the projects will become viable (financially speaking), where the NPV doubles in Djelfa, Saida and Setif, and marginally reach the threshold in Batna and Oran

Table 21: Cost of Debt Sensitivity Results

		NPV ($)				
Debt Rate	**Discount Rate**	**Batna**	**Djelfa**	**Saida**	**Oran**	**Setif**
$\boldsymbol{R_d}$ **= 2.75%**,	5.45%	3,211	111,117	48,140	295	35,399

Source: Results obtained by the student using Excel

10.2. Regarding the Project's Capital Structure:

Due to the absence of existing wind farms in Algeria except for the Adrar project it is challenging to determine a representative capital structure based on domestic benchmarks. Consequently, we decided to adopt a scenario-based approach, examining three possible financing structures: one in which debt exceeds equity (the original assumption), another where equity exceeds debt, and a third scenario where both components are equally balanced. This sensitivity analysis allows for a better understanding of how varying capital structures may affect the project's financial viability, the results are presented in Table 22:

The analysis reveals a clear sensitivity of project viability to changes in capital structure, as reflected in both the NPVs and associated discount rates.

- When debt constitutes 75% of the capital (D = 75%, E = 25%), the lowest discount rate (7.27%) is applied, resulting in generally higher NPVs that we discussed earlier
- In the balanced scenario (D = 50%, E = 50%), the discount rate rises to 9.89%, leading to decreased NPVs across all sites. While Djelfa remains viable $50,694, profitability declines significantly for all others even Setif which exhibits a negative NPV.
- Under the most equity-heavy scenario (D = 40%, E = 60%), the discount rate increases further to 10.94%, making the projects even less attractive. Djelfa $40,511 remains the only site with a clearly positive NPV, confirming its robustness across financing conditions. All other locations experience either marginal or negative NPV.
- We conclude that debt financing has a positive impact on the project's financial viability.

Table 21: Capital Structure Sensitivity Results

		NPV ($)				
Capital Structure	**Discount Rate**	**Batna**	**Djelfa**	**Saida**	**Oran**	**Setif**
D = 75% E = 25%	7.27%	(11,724.20)	82,282.16	27,417.09	(14,265.20)	16,317.41
D = 50% E = 50%	9.89%	(27,896)	50,694	4,826	(30,021)	(4,453)
D = 40% E = 60%	10.94%	(33,061)	40,511	(2,428)	(35,050)	(11,115)

Source: Results obtained by the student using Excel

Conclusion:

Wind energy development hinges not only on environmental and technical feasibility but also on a rigorous financial assessment to determine the economic viability of proposed projects. This chapter has provided a detailed evaluation of the financial aspects associated with deploying wind turbines in selected Algerian regions. Through a comprehensive analysis of capital investment, operational expenditures, and electricity production costs, we calculated key economic indicators such as the Levelized Cost of Electricity, Net Present Value, and Internal Rate of Return, supplemented by sensitivity analyses to account for uncertainty.

The findings reveal that turbine selection and site-specific wind conditions are critical determinants of financial performance. Djelfa emerged as the most economically favourable site, demonstrating a high NPV and the lowest LCOE with the H25.0-60kW turbine model followed by Saida and Setif. In contrast, Batna and Oran presented negative NPVs, signalling weak financial viability under current assumptions. The weighted average cost of capital (WACC) was calculated using the CAPM and industry-standard financing ratios, anchoring the financial models in both academic theory and industry practice.

These insights underscore the importance of conducting detailed site-by-site financial evaluations before committing to large-scale wind energy investments. They also highlight the need for policy support and incentive structures to enhance project bankability, particularly in regions where natural wind resources alone do not yield strong financial returns.

This chapter has established a quantitative basis for comparing wind energy projects across regions and turbine types, offering practical guidance for future investment decisions. The following chapter will delve into the strategic and regulatory context, assessing risk factors and externalities that may influence the deployment of wind energy projects in Algeria.

General Conclusion

General Conclusion:

The objective of this study was to evaluate the techno-economic feasibility of wind energy for electricity generation in Algeria, with a focus on how turbine-specific and site-specific variables influence this feasibility. In doing so, the research sought to determine whether wind energy could serve as a viable option to diversify Algeria's energy mix and contribute to the country's energy transition and sustainable development goals.

Chapter 1 introduced the broader context of renewable energy and its importance for Algeria. It highlighted Algeria's significant potential in renewable resources, especially solar and wind. The chapter also outlined the socio-economic benefits of renewable energy deployment, including job creation, enhanced energy security, and environmental protection. Wind energy emerged as a strategic yet underutilized resource with notable potential across various regions in Algeria.

Chapter 2 developed a comprehensive framework for assessing the feasibility of wind energy projects. It detailed the economic metrics (LCOE, NPV, IRR, PVC, etc.) and methodologies used in feasibility studies. The chapter also emphasized the importance of sensitivity analysis in understanding the risk and uncertainty associated with investment decisions in the renewable sector. The literature review confirmed that while previous Algerian studies mainly focused on the technical aspects, financial depth and uncertainty analysis were often lacking indicating a gap this study aimed to address.

In the final Chapter, we found significant variation in the techno-economic viability of wind energy projects across the selected Algerian regions. The NPV, LCOE, and other financial indicators varied widely between sites such as Djelfa and Oran. For example, Djelfa consistently produced the highest NPVs under different financing scenarios, while Oran often showed negative results. This variation is primarily due to regional differences in wind speeds. These findings confirm Hypothesis 1 (H1): Wind energy viability varies significantly between regions.

Additionally, the choice of wind turbine model had a substantial impact on the technical and financial performance of the projects. Turbines with higher rated capacity (e.g., E-3120, Gamesa G52) yielded high AEP but less favorable economic outcomes. While mid rated capacity like the H25 turbine delivered more favorable economic outcomes. The results showed that the same site could yield either viable or unviable results depending on the selected turbine. This confirms Hypothesis 2 (H2): The choice of wind turbine significantly influences the technical and financial viability of wind projects.

Finally, the sensitivity analysis using the One-at-a-Time (OAT) method demonstrated that economic feasibility metrics are highly responsive to changes in key variables such as the cost of debt, and capital structure. Even minor adjustments in these parameters led to significant shifts in NPV values, particularly for borderline sites. This underlines the importance of financial assumptions in project appraisal. These outcomes validate Hypothesis 3 (H3): The economic feasibility of wind energy projects is highly sensitive to variations in key variables.

Regarding the added value of this thesis, it offers three main contributions, Theoretical where Chapters 1 and 2 contribute to the academic literature by offering a structured review of global best practices and economic evaluation frameworks. Methodological, this study employed a robust financial analysis suited to the renewable energy sector, incorporating discounted cash flow techniques, real-world assumptions, and sensitivity analysis. Managerial where the empirical results offer decision-makers insights into optimal site selection, turbine choice, and financial structuring.

This study however faced several limitations. Firstly, the wind speed data were limited to specific time frames, sites and altitudes (10m AGL), which may not fully capture long-term or higher-altitude wind patterns. Secondly, financial assumptions (turbine/project costs) were based on generalized estimates that may not be exactly accurate. And lastly, Assumption of constant annual energy production, which may not fully reflect turbine degradation or environmental variability and affect the cash flows and thus the entire financial assessment.

Future research should consider incorporating longer-term wind datasets, a broader selection of wind turbine models, using statistical estimation techniques other than Maximum Likelihood Method (MLM) and other probability distributions with more than two parameters, with scaling the analysis to the wind farm level rather than a single turbine and addition to studying other potential sites for wind projects installation.

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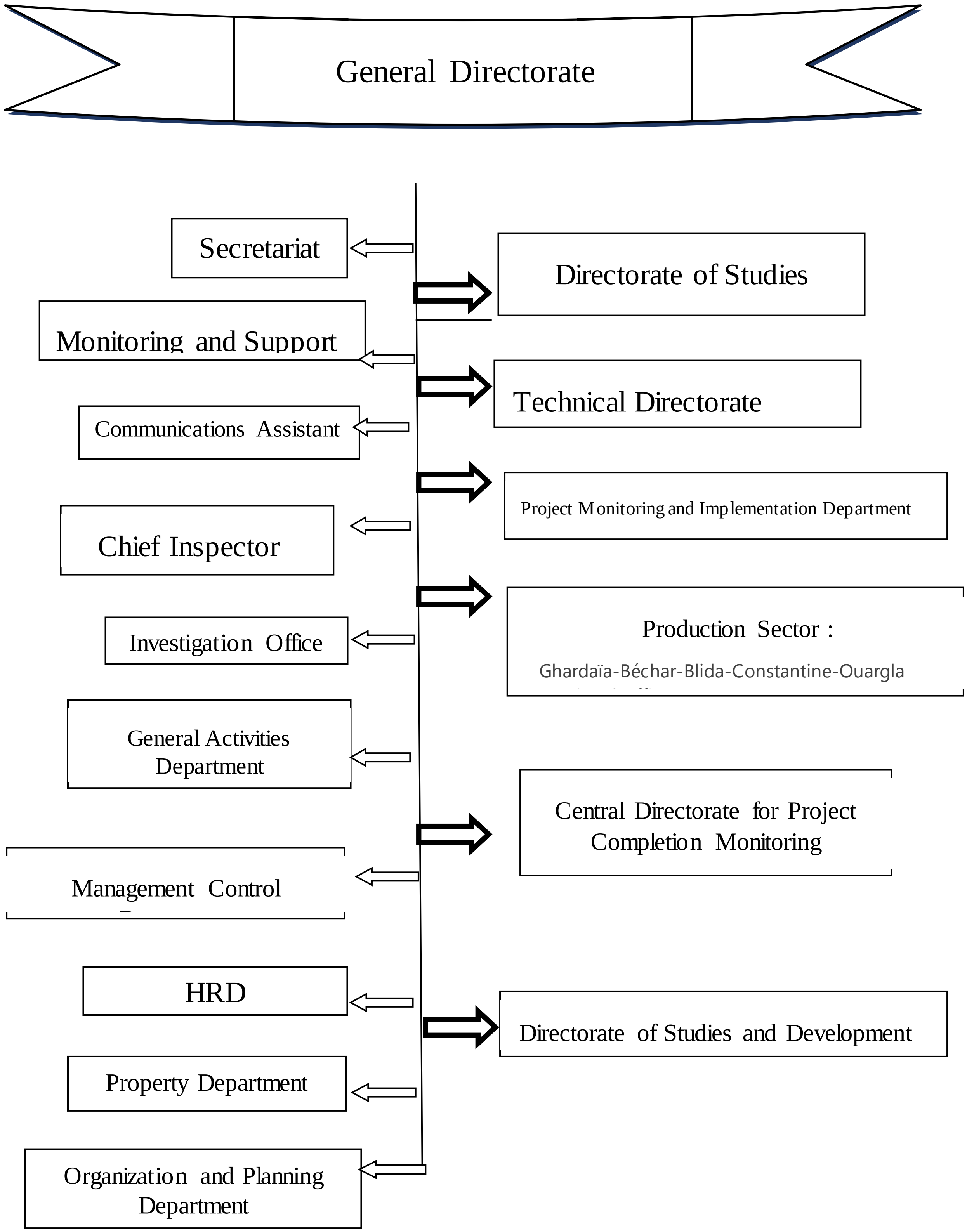
Legal Texts:

- Law 04-09
- Executive Decree 13-218
- Executive Decree 17-98
- Investment Law 22-18

Appendices



Appendix 1: S-ER's Organizational Chart.

Source: Management Control Department

		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
101	Capital émis	38,700,277,657.55	38,700,277,657.55	38,700,000,000.00	38,700,000,000.00	38,700,000,000.00	38,700,000,000.00	38,700,000,000.00	38,700,000,000.00	38,700,000,000.00	38,700,000,000.00
109	Capital non appelé	-	-	-	922,714,012.00	922,714,012.00	922,714,012.00	922,714,012.00	922,714,012.00	922,714,012.00	-
104 +	Primes et réserves	-	-	922,714,012.00	-	-	2,336,300,034.39	3,339,432,392.61	3,740,408,262.88	3,740,408,262.88	3,740,408,262.88
105	Ecarts de réévaluation	-	-	-	-	-	-	-	-	-	922,714,012.00
107	Ecart d'équivalence	-	-	-	-	-	-	-	-	-	-
12	Résultats net – part du groupe	39,800,382.82	67,103,365.55	477,351,154.47	537,108,933.26	631,035,634.53	1,003,132,358.22	400,975,870.27	- 217,056,466.31	- 553,688,269.48	- 814,687,235.11
11	Report à nouveau	- 374,909,586.49	- 335,109,203.67	- 1,196,709,850.12	- 719,358,695.65	1,705,264,399.86	228,200,595.82	228,200,595.82	228,200,595.82	- 1,671,907,190.73	455,142,704.23
PSC	Part de la societe consolidante	-	-	-	-	-	-	-	-	-	-
PM	Part des minoritaires	-	-	-	-	-	-	-	-	-	-
T1	**TOTAL**	38,365,168,453.88	38,432,271,819.43	38,903,355,316.35	39,440,464,249.61	41,959,014,046.39	43,190,347,000.43	43,591,322,870.70	43,374,266,404.39	41,137,526,814.67	43,003,577,744.00
1+	**PASSIFS NON COURANTS**	-	-	-	-	-	-	-	-	-	-
16+	Emprunts et dettes financières	-	-	-	-	-	-	-	-	-	-
134	Impôts (différés et provisionnés)	-	-	-	-	455,702,585.10	455,702,585.10	455,702,585.10	455,702,585.10	455,702,585.10	455,702,585.10
229	Autres dettes NC (Droits du concédant)	-	-	75,000.00	825,000.00	825,000.00	-	-	-	-	150,000,000.00
15+	Provisions et produits comptabilisés d'avance	2,147,927,473.83	2,136,790,373.48	2,103,916,897.12	3,784,366,254.00	3,694,409,618.56	9,538,098,600.14	9,971,232,778.19	9,736,025,586.95	9,441,700,964.54	9,697,421,719.89
T2	**TOTAL PASSIFS NON COURANTS**	2,147,927,473.83	2,136,790,373.48	2,103,991,897.12	3,785,191,254.00	4,150,937,203.66	9,993,801,185.24	10,426,935,363.29	10,191,728,172.05	9,897,403,549.64	10,303,124,304.99
4+	**PASSIF COURANTS**	-	-	-	-	-	-	-	-	-	-
40	Fournisseurs et comptes rattachés	8,261,372,452.26	10,528,308,906.85	11,420,865,042.69	9,086,530,097.00	6,181,293,783.79	9,510,946,919.23	10,557,828,058.05	13,750,214,998.86	10,463,451,412.94	5,691,879,778.32
444	Impôts	61,658,855.90	6,212.35	6,108.10	99,739.79	82,316,765.23	141,108.10	6,108.10	889,914.76	320,000.00	1,620,000.00
459	Dettes sur sociétés du groupe zt associés		97,054,924,293.20								
42+	Autres dettes	33,348,804,588.10	495,130,807.54	121,066,203,424.90	141,655,407,238.43	147,385,997,419.72	148,407,219,846.71	157,349,521,120.72	171,768,945,222.77	161,919,304,782.36	30,964,925,472.79
52+	Trésorerie Passif	987,498,302.10	565,259,927.24	156,008,915.77	-	-	9,967.65	-	174,569,012.52	-	-
T3	**Total Passif Courant**	42,659,334,198.36	108,643,630,147.18	132,643,083,491.46	150,742,037,075.22	153,649,607,968.74	157,918,317,841.69	167,907,355,286.87	185,694,619,148.91	172,383,076,195.30	36,658,425,251.11
TGP	**TOTAL GENERAL PASSIF**	83,172,430,126.07	149,212,692,340.09	173,650,430,704.93	193,967,692,578.83	199,759,559,218.79	211,102,466,027.36	221,925,613,520.86	239,260,613,725.35	223,418,006,559.61	89,965,127,300.10

Appendix 2: S-ER's Organizational Chart.

Source: CNRC

Years	Investment Cost	Revenue	Charges	EBITDA	Depreciation	EBIT	Profit Tax	Net Income	Depreciation Reintegration	CAF	Residual Value	Cash Flows	Discount Factor	DCF
0	$ (101,400)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		$ -	$ (101,400)	1.00	$ (101,400)
1	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ -	$ 4,646	$ 4,056	$ 8,702	$ -	$ 8,702	1.07	$ 8,112
2	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ -	$ 4,646	$ 4,056	$ 8,702	$ -	$ 8,702	1.15	$ 7,562
3	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ -	$ 4,646	$ 4,056	$ 8,702	$ -	$ 8,702	1.23	$ 7,049
4	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ -	$ 4,646	$ 4,056	$ 8,702	$ -	$ 8,702	1.32	$ 6,571
5	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ -	$ 4,646	$ 4,056	$ 8,702	$ -	$ 8,702	1.42	$ 6,126
6	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	1.52	$ 5,131
7	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	1.63	$ 4,783
8	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	1.75	$ 4,459
9	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	1.88	$ 4,156
10	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	2.02	$ 3,875
11	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	2.16	$ 3,612
12	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	2.32	$ 3,367
13	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	2.49	$ 3,139
14	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	2.67	$ 2,926
15	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	2.87	$ 2,727
16	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	3.08	$ 2,543
17	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	3.30	$ 2,370
18	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	3.54	$ 2,209
19	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ -	$ 7,819	3.80	$ 2,060
20	$ -	$ 13,772	$ 5,070	$ 8,702	$ (4,056)	$ 4,646	$ 882.72	$ 3,763	$ 4,056	$ 7,819	$ 20,280	$ 28,099	4.07	$ 6,900

Appendix 3: Batna's' DCF.

Source: Student's work using Excel

Years	Investment Cost	Revenue	Charges	EBITDA	Depreciation	EBIT	Profit Tax	Net Income	Depreciation Reintegration	CAF	Residual Value	Cash Flows	Discount Factor	DCF
0	$ (101,400)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		$ -	$ (101,400)	1.00	$ (101,400)
1	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ -	$ 14,892	$ 4,056	$ 18,948	$ -	$ 18,948	1.07	$ 17,663
2	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ -	$ 14,892	$ 4,056	$ 18,948	$ -	$ 18,948	1.15	$ 16,465
3	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ -	$ 14,892	$ 4,056	$ 18,948	$ -	$ 18,948	1.23	$ 15,349
4	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ -	$ 14,892	$ 4,056	$ 18,948	$ -	$ 18,948	1.32	$ 14,308
5	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ -	$ 14,892	$ 4,056	$ 18,948	$ -	$ 18,948	1.42	$ 13,338
6	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	1.52	$ 10,577
7	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	1.63	$ 9,860
8	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	1.75	$ 9,191
9	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	1.88	$ 8,568
10	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	2.02	$ 7,987
11	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	2.16	$ 7,446
12	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	2.32	$ 6,941
13	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	2.49	$ 6,470
14	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	2.67	$ 6,031
15	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	2.87	$ 5,622
16	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	3.08	$ 5,241
17	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	3.30	$ 4,886
18	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	3.54	$ 4,555
19	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ -	$ 16,118	3.80	$ 4,246
20	$ -	$ 24,018	$ 5,070	$ 18,948	$ (4,056)	$ 14,892	$ 2,829.45	$ 12,062	$ 4,056	$ 16,118	$ 20,280	$ 36,398	4.07	$ 8,938

Appendix 4: Djelfa's DCF.

Source: Student's work using Excel

Years	Investment Cost	Revenue	Charges	EBITDA	Depreciation	EBIT	Profit Tax	Net Income	Depreciation Reintegration	CAF	Residual Value	Cash Flows	Discount Factor	DCF
0	$ (101,400)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		$ -	$ (101,400)	1.00	$ (101,400)
1	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$ -	$ 8,912	$ 4,056	$ 12,968	$ -	$ 12,968	1.07	$ 12,089
2	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$ -	$ 8,912	$ 4,056	$ 12,968	$ -	$ 12,968	1.15	$ 11,269
3	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$ -	$ 8,912	$ 4,056	$ 12,968	$ -	$ 12,968	1.23	$ 10,505
4	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$ -	$ 8,912	$ 4,056	$ 12,968	$ -	$ 12,968	1.32	$ 9,793
5	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$ -	$ 8,912	$ 4,056	$ 12,968	$ -	$ 12,968	1.42	$ 9,129
6	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	1.52	$ 7,399
7	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	1.63	$ 6,897
8	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	1.75	$ 6,429
9	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	1.88	$ 5,993
10	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	2.02	$ 5,587
11	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	2.16	$ 5,208
12	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	2.32	$ 4,855
13	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	2.49	$ 4,526
14	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	2.67	$ 4,219
15	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	2.87	$ 3,933
16	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	3.08	$ 3,666
17	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	3.30	$ 3,418
18	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	3.54	$ 3,186
19	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ -	$ 11,275	3.80	$ 2,970
20	$ -	$ 18,038	$ 5,070	$ 12,968	$ (4,056)	$ 8,912	$1,693.28	$ 7,219	$ 4,056	$ 11,275	$ 20,280	$ 31,555	4.07	$ 7,748

Appendix 5: Saida's DCF.

Source: Student's work using Excel

Years	Investment Cost	Revenue	Charges	EBITDA	Depreciation	EBIT	Profit Tax	Net Income	Depreciation Reintegratio	CAF	Residual Value	Cash Flows	Discount Factor	DCF
0	$ (101,400)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		$ -	$ (101,400)	1.00	$ (101,400)
1	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ -	$ 4,369	$ 4,056	$ 8,425	$ -	$ 8,425	1.07	$ 7,854
2	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ -	$ 4,369	$ 4,056	$ 8,425	$ -	$ 8,425	1.15	$ 7,321
3	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ -	$ 4,369	$ 4,056	$ 8,425	$ -	$ 8,425	1.23	$ 6,825
4	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ -	$ 4,369	$ 4,056	$ 8,425	$ -	$ 8,425	1.32	$ 6,362
5	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ -	$ 4,369	$ 4,056	$ 8,425	$ -	$ 8,425	1.42	$ 5,931
6	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	1.52	$ 4,984
7	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	1.63	$ 4,646
8	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	1.75	$ 4,331
9	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	1.88	$ 4,037
10	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	2.02	$ 3,763
11	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	2.16	$ 3,508
12	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	2.32	$ 3,270
13	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	2.49	$ 3,049
14	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	2.67	$ 2,842
15	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	2.87	$ 2,649
16	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	3.08	$ 2,470
17	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	3.30	$ 2,302
18	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	3.54	$ 2,146
19	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ -	$ 7,595	3.80	$ 2,001
20	$ -	$ 13,495	$ 5,070	$ 8,425	$ (4,056)	$ 4,369	$ 830.10	$ 3,539	$ 4,056	$ 7,595	$ 20,280	$ 27,875	4.07	$ 6,845

Appendix 6: Oran's DCF.

Source: Student's work using Excel

Years	Investment Cost	Revenue	Charges	EBITDA	Depreciation	EBIT	Profit Tax	Net Income	Depreciation Reintegration	CAF	Residual Value	Cash Flows	Discount Factor	DCF
0	$ (101,400)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -		$ -	$ (101,400)	1.00	$ (101,400)
1	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ -	$ 7,702	$ 4,056	$ 11,758	$ -	$ 11,758	1.07	$ 10,961
2	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ -	$ 7,702	$ 4,056	$ 11,758	$ -	$ 11,758	1.15	$ 10,218
3	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ -	$ 7,702	$ 4,056	$ 11,758	$ -	$ 11,758	1.23	$ 9,525
4	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ -	$ 7,702	$ 4,056	$ 11,758	$ -	$ 11,758	1.32	$ 8,879
5	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ -	$ 7,702	$ 4,056	$ 11,758	$ -	$ 11,758	1.42	$ 8,277
6	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	1.52	$ 6,756
7	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	1.63	$ 6,297
8	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	1.75	$ 5,870
9	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	1.88	$ 5,472
10	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	2.02	$ 5,101
11	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	2.16	$ 4,755
12	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	2.32	$ 4,433
13	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	2.49	$ 4,132
14	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	2.67	$ 3,852
15	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	2.87	$ 3,591
16	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	3.08	$ 3,348
17	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	3.30	$ 3,121
18	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	3.54	$ 2,909
19	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ -	$ 10,295	3.80	$ 2,712
20	$ -	$ 16,828	$ 5,070	$ 11,758	$ (4,056)	$ 7,702	$ 1,463.42	$ 6,239	$ 4,056	$ 10,295	$ 20,280	$ 30,575	4.07	$ 7,508

Appendix 7: DCF.

Source: Student's work using Excel

Les critères de qualification des grands projets d'investissement, sont fixés par voie réglementaire.

Art. 20. — Les guichets uniques décentralisés sont les interlocuteurs uniques des investisseurs au niveau local. Ils assurent les missions d'assistance et d'accompagnement des investisseurs dans l'accomplissement des formalités relatives à l'investissement.

Art. 21. — Le guichet unique des grands projets et des investissements étrangers et les guichets uniques décentralisés, regroupent les représentants des organismes et des administrations directement chargés de l'exécution des procédures liées :

— à la concrétisation des projets d'investissement ;

— à la délivrance des décisions, autorisations et tout document lié à l'exercice de l'activité en relation avec le projet d'investissement ;

— à l'obtention du foncier destiné à l'investissement ;

— au suivi des engagements souscrits par l'investisseur.

Art. 22. — Nonobstant toutes dispositions contraires, les représentants des organismes et des administrations au sein des guichets uniques, sont habilités à délivrer, dans les délais fixés par la législation et la réglementation en vigueur, l'ensemble des décisions, documents et autorisations en lien avec la concrétisation et l'exploitation du projet d'investissement enregistré au niveau des guichets uniques.

Art. 23. — Il est créé une "plate-forme numérique de l'investisseur", dont la gestion est confiée à l'Agence, permettant d'offrir toutes les informations nécessaires, notamment sur les opportunités d'investissement en Algérie, l'offre foncière, les incitations et avantages liés à l'investissement, ainsi que les procédures y afférentes.

Cette plate-forme numérique, interconnectée aux systèmes d'informations des organismes et administrations chargés de l'acte d'investir, permet la dématérialisation de l'ensemble des procédures et l'accomplissement en ligne de toutes les formalités liées à l'investissement.

Elle constitue, également, un instrument d'orientation, d'accompagnement et de suivi des investissements depuis leur enregistrement et pendant la période de leur exploitation.

Les modalités de gestion de cette plate-forme, sont définies par voie réglementaire.

CHAPITRE 4

DES REGIMES D'INCITATION ET DES CONDITIONS D'ELIGIBILITE AUX AVANTAGES

Art. 24. — Les investissements, au sens de l'article 4 de la présente loi, peuvent bénéficier, sur demande de l'investisseur, de l'un des régimes d'incitation, cités ci-après :

— le régime d'incitation des secteurs prioritaires, ci-après désigné « régime des secteurs » ;

— le régime d'incitation des zones auxquelles l'Etat accorde un intérêt particulier, ci-après désigné « régime des zones » ;

— le régime d'incitation des investissements revêtant un caractère structurant, ci-après désigné « régime des investissements structurants ».

Art. 25. — Pour le bénéfice des avantages prévus par les dispositions de la présente loi, les investissements doivent faire, préalablement à leur réalisation, l'objet d'un enregistrement auprès du guichet unique compétent, visé à l'article 18 de la présente loi.

L'enregistrement de l'investissement est matérialisé par la délivrance, séance tenante, d'une attestation accompagnée de la liste des biens et services éligibles aux avantages autorisant l'investisseur à faire valoir auprès des administrations et organismes concernés.

Les modalités d'application du présent article ainsi que la liste des biens et services non éligibles aux avantages, prévus par les dispositions de la présente loi, sont fixées par voie réglementaire.

Art. 26. — Sont éligibles au « régime des secteurs » les investissements réalisés dans les domaines d'activités suivants :

— mines et carrières ;

— agriculture, aquaculture et pêche ;

— industrie, industrie agroalimentaire, industrie pharmaceutique et pétrochimie ;

— services et tourisme ;

— énergies nouvelles et renouvelables ;

— économie de la connaissance et technologies de l'information et de la communication.

La liste des activités non éligibles aux avantages prévus au titre du régime des secteurs, est fixée par voie réglementaire.

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Art. 27. — Les investissements éligibles au "régime des secteurs" bénéficient, outre les incitations fiscales, parafiscales et douanières prévues dans le cadre du droit commun, des avantages suivants :

— Au titre de la phase de réalisation :

1) exonération des droits de douane pour les biens importés entrant directement dans la réalisation de l'investissement ;

2) franchise de la TVA pour les biens et services importés ou acquis localement, entrant directement dans la réalisation de l'investissement ;

3) exonération du droit de mutation, à titre onéreux, et de la taxe de publicité foncière, pour toutes les acquisitions immobilières effectuées dans le cadre de l'investissement concerné ;

4) exonération des droits d'enregistrement exigibles pour les actes constitutifs de sociétés et les augmentations de capital ;

5) exonération des droits d'enregistrement, de la taxe de publicité foncière ainsi que de la rémunération domaniale portant sur les concessions des biens immobiliers bâtis et non bâtis, destinés à la réalisation de projets d'investissement ;

6) exonération de la taxe foncière sur les propriétés immobilières, entrant dans le cadre de l'investissement, pour une période de dix (10) ans, à compter de la date d'acquisition.

— Au titre de la phase d'exploitation : pour une durée allant de trois (3) à cinq (5) ans, à compter de la date d'entrée en exploitation, de :

1) l'exonération de l'impôt sur le bénéfice des sociétés (IBS) ;

2) l'exonération de la taxe sur l'activité professionnelle (TAP).

Art. 28. — Sont éligibles au « régime des zones », les investissements réalisés dans :

— des localités relevant des Hauts-Plateaux, du Sud et du Grand Sud ;

— des localités dont le développement nécessite un accompagnement particulier de l'Etat ;

— des localités disposant de potentialités en ressources naturelles à valoriser.

La liste des localités relevant des zones auxquelles l'Etat accorde un intérêt particulier est fixée par voie réglementaire.

Art. 29. — Les investissements éligibles au régime des zones, dont les activités ne sont pas exclues des avantages prévus par le présent article, peuvent bénéficier, outre les incitations fiscales, parafiscales et douanières prévues dans le cadre du droit commun, des avantages suivants :

— Au titre de la phase de réalisation : des avantages prévus à l'article 27 de la présente loi.

— Au titre de la phase d'exploitation : pour une durée allant de cinq (5) à dix (10) ans, à compter de la date d'entrée en exploitation, de :

1) l'exonération de l'impôt sur les bénéfices des sociétés (IBS) ;

2) l'exonération de la taxe sur l'activité professionnelle (TAP).

La liste des activités non éligibles aux avantages prévus par le "régime des zones", est fixée par voie réglementaire.

Art. 30. — Sont éligibles au régime « des investissements structurants », les investissements à haut potentiel de création de richesse et d'emplois, susceptibles d'augmenter l'attractivité du territoire et de créer un effet d'entraînement sur l'activité économique pour un développement durable.

Les critères de qualification des investissements éligibles au régime « des investissements structurants », sont fixés par voie réglementaire.

Art. 31. — Les investissements éligibles au régime des investissements structurants, peuvent bénéficier, outre les incitations fiscales, parafiscales et douanières prévues dans le cadre du droit commun :

— Au titre de la phase de réalisation : des avantages prévus à l'article 27 de la présente loi.

Les avantages de la phase de réalisation prévus au présent article, peuvent être transférés aux co-contractants de l'investisseur bénéficiaire chargés de la réalisation de l'investissement, pour le compte de ce dernier.

— Au titre de la phase d'exploitation : pour une durée allant de cinq (5) à dix (10) ans, à compter de la date d'entrée en exploitation, de :

1) l'exonération de l'impôt sur les bénéfices des sociétés (IBS) ;

2) l'exonération de la taxe sur l'activité professionnelle (TAP).

Les investissements structurants peuvent bénéficier de l'accompagnement de l'Etat par la prise en charge, partielle ou totale, des travaux d'aménagement et d'infrastructures nécessaires à leur concrétisation, sur la base d'une convention établie entre l'investisseur et l'Agence agissant au nom de l'Etat. La convention est conclue après son approbation par le Gouvernement.

Les modalités d'application des dispositions du présent article, sont fixées par voie réglementaire.

Appendix 8: Investment Law 22-18

Years	Batna	Djelfa	Saida	Oran	Setif
	Σ DCF	Σ DCF	Σ DCF	Σ DCF	Σ DCF
0	-101,400	-101,400	-101,400	-101,400	-101,400
1	-93,288	-83,737	-89,311	-93,546	-90,439
2	-85,726	-67,271	-78,042	-86,225	-80,221
3	-78,677	-51,922	-67,537	-79,400	-70,696
4	-72,106	-37,614	-57,745	-73,038	-61,817
5	-65,980	-24,276	-48,616	-67,108	-53,540
6	-60,849	-13,699	-41,218	-62,124	-46,785
7	-56,066	-3,839	-34,321	-57,478	-40,487
8	-51,608	**5,352**	-27,891	-53,147	-34,617
9	-47,451	**13,920**	-21,898	-49,110	-29,144
10	-43,577	21,907	-16,311	-45,347	-24,043
11	-39,965	29,353	-11,103	-41,838	-19,288
12	-36,598	36,293	-6,248	-38,568	-14,855
13	-33,459	42,764	**-1,722**	-35,519	-10,722
14	-30,533	48,795	**2,497**	-32,677	-6,870
15	-27,806	54,417	6,429	-30,028	**-3,279**
16	-25,263	59,659	10,096	-27,559	**69**
17	-22,893	64,544	13,513	-25,256	3,189
18	-20,684	69,099	16,699	-23,110	6,098
19	-18,624	73,345	19,669	-21,110	8,810
20	-11,724	82,282	27,417	-14,265	16,317

Appendix 9: PBP Determination (DCF Method)

Source: Student's work using Excel

Years	Batna	Djelfa	Saida	Oran	Setif
	Σ DCF	**Σ DCF**	**Σ DCF**	**Σ DCF**	**Σ DCF**
0	(101,400)	(101,400)	(101,400)	(101,400)	(101,400)
1	(92,698)	(82,452)	(88,432)	(92,975)	(89,642)
2	(83,996)	(63,504)	(75,464)	(84,550)	(77,884)
3	(75,294)	(44,556)	(62,496)	(76,125)	(66,125)
4	(66,592)	(25,609)	(49,528)	(67,700)	(54,367)
5	(57,891)	**(6,661)**	(36,560)	(59,275)	(42,609)
6	(50,071)	**9,458**	(25,285)	(51,680)	(32,314)
7	(42,252)	25,576	(14,011)	(44,086)	(22,019)
8	(34,433)	41,695	**(2,736)**	(36,491)	(11,725)
9	(26,614)	57,813	**8,539**	(28,896)	**(1,430)**
10	(18,795)	73,931	19,814	(21,301)	**8,865**
11	(10,976)	90,050	31,088	(13,706)	19,160
12	**(3,156)**	106,168	42,363	**(6,111)**	29,455
13	**4,663**	122,287	53,638	**1,483**	39,749
14	12,482	138,405	64,912	9,078	50,044
15	20,301	154,523	76,187	16,673	60,339
16	28,120	170,642	87,462	24,268	70,634
17	35,940	186,760	98,736	31,863	80,929
18	43,759	202,879	110,011	39,458	91,223
19	51,578	218,997	121,286	47,053	101,518
20	79,677	255,395	152,841	74,927	132,093

Appendix 10: PBP Determination (CF Method)

Source: Student's work using Excel