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ENERGY COOPERATION BETWEEN EUROPE ANDNORTH AFRICA

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Abstract-

To reduce its dependence on fossil fuels and promote renewable energies, Europe needs to strengthen its energy cooperation with North Africa. At present, Europe is heavily dependent on imports of fossil fuels, which poses challenges in terms of energy security. North Africa, on the other hand, has immense potential for renewable energies, particularly solar and wind power, which is still largely under-exploited. Greater collaboration would enable Europe to diversify its energy sources while helping North Africa to develop its renewable energy capacities. This approach would contribute to global climate objectives and promote regional economic development. This research explores energy policies, energy needs, cooperation opportunities and proposes recommendations for sustainable and mutually beneficial energy cooperation. By integrating new perspectives and additional analysis, it offers pragmatic solutions for successful collaboration.

Keywords

-Energy cooperation, renewable energies, North Africa, energy security, energy transition, Europe-Africa partnerships, sustainable development.

I. INTRODUCTION

A: Background: Challenges in energy cooperation between Europe and North Africa.

Energy cooperation between Europe and North Africa has been an important article from the point of view of global power. Europe has relied heavily on fossil fuels during the pandemic, including accounting for about 57% of its energy consumption in 2020, and Russia is a major supplier of natural gas (45% of EU imports in 2021) [1]. This power relies on the emergence of energy security issues, mainly because it is a recent analysis of political tensions [2].

At the same time, North African countries (Morocco, Algeria, Tunisia, Libya, Egypt) have great potential for renewable energy, especially solar and wind. Irena (International Renewable Energy Agency) has measured this potential, which is 20 times the current demand in the power district, although it is still very low [3]. Only a few countries, such as Morocco, are firmly committed to the power of conversion [4].

The partnership between Europe and North Africa in the energy sector therefore offers a unique opportunity to reduce the delivery of fossil fuels in Europe and facilitate the transition to renewable natural gas. This partnership will not only meet the energy needs of the two regions, but also contribute to the achievement of global climate goals and promote the country's sustainable economy and sustainable development in North Africa [5].

B. Research Objectives and Presentation Plans.

The main interest of this study is to look at how much deeper energy cooperation can be added between Europe and North Africa:

Reducing European fuels to fossil fuels by 2030,
facilitating the transition of renewable energy to both regions to meet climate goals,
Promote sustainable economic development in North Africa.

To achieve these goals, we will explore Europe's current energy panorama in detail. We will assess domestic production and imports of fossil fuels, which are still the continent's main source of supply. At the same time, we will look at emerging trends in renewable energies, such as wind, solar and biomass, which are gradually gaining in importance. This section will also look at the impact of the various national policies implemented by the Member States on Europe's overall energy dynamics.

Our analysis continues with an in-depth look at EU energy policies and initiatives to accelerate the transition to a more sustainable future. We will dissect the ambitious targets and strategies set by the European institutions for renewable energies,

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energy efficiency and emissions reductions. The various policy instruments, whether financial incentives, binding regulations or international cooperation projects, will be explored in detail.

We will then look at the foreseeable evolution of energy needs in Europe over the coming decades. The analysis will focus on the consumption of fossil fuels by key economic sectors, such as transport, industry and construction. At the same time, we will study the expected growth in renewable energies.

II . Examination of Energy Availability in Europe

A . Dependence on fossil fuel production and imports: a critical assessment.

Europe is one of the region's most dependent on fossil fuel imports for its energy needs. In 2022, about 58% of the total energy consumption in the European Union (EU) came from imported fossil fuels [6]. This dependence is particularly evident in the gas sector, where Russia is the main supplier, accounting for about 40% of the EU's total gas imports in 2021 [7]. However, due to recent geopolitical tensions, especially the Ukraine crisis, Europe was forced to diversify energy sources and reduce its dependence on Russian supplies [7].

Massive imports of fossil fuels have exposed Europe to price volatility in global markets and geopolitical instability. As a result, the EU has intensified its efforts to diversify energy sources, increasing LNG imports from the US, Qatar and other producing countries [6]. At the same time, there has been an increase in investment in LNG reception and regasification infrastructure to enhance EU energy security [8].

B . Renewable energy trends: the transition to a sustainable future?

In recent decades, Europe has made significant progress in the development of renewable energy. In 2021, renewables accounted for 23.1% of the EU's final energy consumption [8]. This proportion continues to rise, driven by supportive policies and technological advances. The main sources of renewable energy in Europe include hydropower, wind, solar and biomass [8].

Wind and solar, in particular, have seen rapid growth. In 2021, wind power contributed 14% to electricity production in the EU, while solar PV accounted for about 5% [9]. This growth was driven by incentives such as subsidies and feed-in tariffs, along with ongoing reductions in the cost of wind and solar technologies [10].

Germany, for example, has invested heavily in renewable energy through its "Energy Transition" program, which accounts for 46.7% of its total energy consumption in 2021 [10]. This success stems from intensive investment in wind and solar infrastructure, supported by favorable regulations encouraging the adoption of these technologies [10].

Other European countries have also made significant progress. Despite France's focus on nuclear power, France has increased its share of renewable energy, especially through hydropower [11]. Spain and Denmark are recognized as world leaders in wind energy, and most of their electricity production comes from this source [11].

C . Impact of national policy: does it affect energy dynamics?

National energy policies play a key role in driving Europe's energy transition. Each EU member state adopts specific strategies based on its natural resources, economic priorities and climate goals.

In Germany, uranium converting to uranium energy reflects a strong commitment to transition to a sustainable energy system. This policy has led to a significant increase in the share of renewables (especially wind and solar) in Germany's energy mix [10]. Tax subsidies and incentives have stimulated private investment in these technologies and boosted innovation and competitiveness in Germany's renewable energy sector [10].

France's energy strategy remains largely focused on nuclear power, which accounts for about 70% of the country's electricity production [11]. Despite this, France is also investing in hydropower and developing wind and solar projects to diversify the energy mix and reduce carbon emissions [11]. France's energy transition aims to achieve a 33% share of renewables in final energy consumption by 2030 [8].

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Spain positions itself as a leader in wind energy in Europe, with wind power accounting for about 23% of electricity generation in 2021 [9]. Driven by supportive government policies and abundant sunlight, the country has also made significant progress in solar energy development [9].

Denmark is known for its ambition to achieve 100% renewable electricity by 2030. In 2021, about 50% of Denmark's electricity came from wind energy [9]. Denmark's success depends on innovation policies, significant public and private investment in wind energy technology, and a culture of innovation in the energy sector [9].

To explain the above data, the table below shows the energy distribution between offshore oil and renewables until 2021.

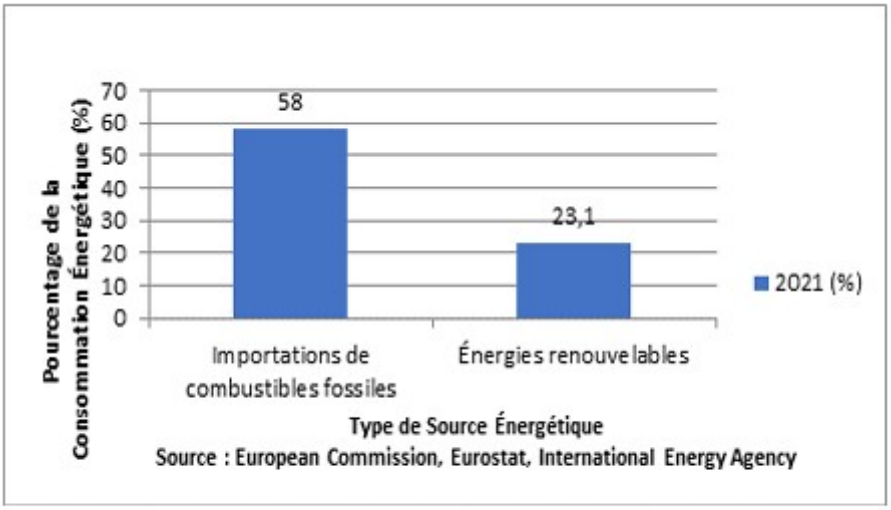

Fig. 1 Breakdown of EU energy consumption in 2021

D . Conclusion.

Europe's dependence on fossil fuel imports poses significant challenges, exposing the region to significant geopolitical and economic risks. However, advances in renewable energy and national energy transition policies offer promising opportunities to reduce this dependence. Germany, France, Spain and Denmark have shown different approaches and success stories in the transition to a more sustainable and resilient energy mix.

III. European Energy Policy and Transition Initiative

A. EU Objectives and Strategy: Transition to Renewable Energy.

The European Union has set ambitious targets to boost the energy transition and reduce dependence on fossil fuels. The European Green Deal, launched in December 2019, aims to make Europe the first carbon-neutral continent by 2050 [20]. This target includes temporary commitments, such as reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels [21].

1) *European Green Deal:The European Green Agreement is the main framework for EU climate policy.*

It is a set of policies and strategies aimed at transforming the EU into a modern, resource-efficient and competitive economy, while ensuring climate neutrality by 2050 [22]. The plan covers different sectors such as energy, transport, industry and agriculture, and sets specific targets for each sector to reduce emissions and promote sustainable practices.

2) *Medium-term goals*: The interim targets of the Green Deal include reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. To achieve these goals, the European Union has adopted regulatory and financial measures to encourage the use of renewable energy, improve energy efficiency, and support technological innovation [23].

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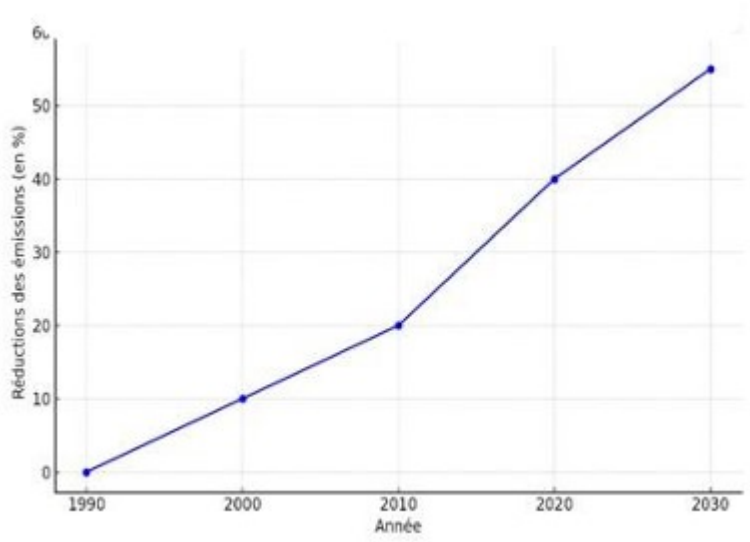

Fig. 2 Objectifs de réduction des émissions de gaz à effet de serre de l'UE

Source: European Commission, "Greenhouse Gas Reduction Targets", 2021.

3) Post-COVID Recovery Plan: The Next Generation of the EU The post-COVID recovery plan, dubbed the "Next Generation of the European Union", is a €750 billion financial plan designed to support the economies of member states affected by the pandemic. A significant portion (30%) of the fund is allocated to climate and energy projects, thus strengthening the EU's efforts to accelerate the transition to a green economy [24].

B. Incentives and regulations: promoting the adoption of clean energy.

The European Union has put in place several incentives and regulations to encourage the adoption of renewable energy. These initiatives aim to create an enabling environment for investment in green technologies and ensure that Member States achieve their energy transition goals.

1) *Funding Mechanism:* Financing schemes such as InvestEU and Horizon Europe play a vital role in supporting innovative projects in the renewable energy and clean technology sectors. InvestEU ensures the mobilization of private investment in sustainable projects, while Horizon Europe funds research and innovation to develop new energy technologies [25].

2) *Renewable Energy Directive (RED II):* The Renewable Energy Directive (RED II) requires Member States to meet binding national targets for the share of renewable energy in their energy mix. The Directive sets an overall EU target for renewables to account for at least 32% of total final energy consumption by 2030, with each Member State making a specific contribution [26].

3) *EU Emissions Trading System (EU ETS):* The European Union Emissions Trading System (EU ETS) is a key mechanism for reducing carbon emissions. It operates on an emissions trade-off basis, capping the total amount of some greenhouse gases that may be emitted from facilities covered by the scheme. Companies receive or buy emission allowances, which can be traded as needed. This mechanism incentivizes companies to reduce emissions by allowing them to sell unused allowances [27].

C. International cooperation projects: key to joint transition.

The EU is also involved in international cooperation projects to support the energy transition. These projects aim to develop renewable resources outside Europe and enhance energy security.

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1) *Desertec Project:* The Desertec project aims to harness the potential of solar energy in the Sahara Desert and produce electricity via submarine cables for export to Europe. Despite the financial and political obstacles the project faces, it illustrates the potential for Euro-Mediterranean cooperation in the field of energy. The central idea is to use the abundant solar resources of the Sahara Desert to provide clean energy to Europe, thus contributing to the reduction of CO2 emissions and energy diversification [28].

2) *Medgrid Project*: The "MedGrid" project aims to develop an integrated electricity network between Europe and North Africa, thus facilitating the exchange of green electricity between the two regions. The project aims to build an infrastructure capable of transporting large amounts of renewable energy produced in North Africa to Europe. This is part of a long-term vision to integrate regional energy markets and promote the use of renewable energy across continents [29].

3) *Public-Private Partnership Initiatives:* Public-private partnerships also play a key role in the implementation of international cooperation projects. These partnerships have made it possible to mobilize significant financial and technical resources and share risks between the public and private sectors. The EU actively encourages these partnerships to develop resilient and sustainable energy infrastructure, while facilitating access to clean technologies in developing countries [30].

D. Challenges and future prospects.

1) Implementation challenges: There are many challenges to the implementation of energy transition policies and projects in the context of European and international cooperation. These challenges include regulatory barriers, the high cost of clean technologies, and the need for coordinated multi-stakeholder efforts. In addition, existing infrastructure often needs to be upgraded to accommodate new renewables [31].

2) Outlook: Despite these challenges, the outlook for Europe's energy transition remains positive. The EU continues to adopt ambitious policies and support mechanisms to foster innovation and investment in green technologies. Technological advances and economies of scale should also help reduce the cost of renewable energy, making it more accessible and attractive to Member States and their international partners [32].

E. conclusion.

EU energy policy is at the heart of the transition to a green economy. Ambitious targets, incentives and international cooperation projects demonstrate the EU's commitment to reducing carbon emissions and promoting renewable energy. Despite the challenges, the future prospects remain promising thanks to technological advances and the continued engagement of the EU and its partners. This energy transition is not only an environmental imperative, but also an economic and social opportunity to build a sustainable future.

IV. CHANGES IN ENERGY DEMAND IN EUROPE

A. Fossil energy consumption: industry analysis and projections.

In Europe, the distribution of fossil energy consumption varies from sector to sector, with transport and industry being the largest users. In 2020, transport accounted for about 30% of total energy consumption, followed by industry with 25% [33]. Heavy dependence on fossil fuels in these key sectors is a major obstacle to Europe's energy transition.

1). *Industry Analysis:*Due to the dominance of internal combustion engine vehicles, the transport sector is dominated by the use of fossil fuels such as diesel and gasoline. This dependence not only increases greenhouse gas emissions, but also exposes Europe to changes in oil prices on the international market [34].

As for industry, it relies on a combination of coal, natural gas and petroleum products to fuel its production process. Heavy industries such as steel, chemicals, and cement are particularly dependent on these energy sources due to the high temperatures and specific chemical processes required [35].

2). *Transition perspectives*: Recent projections point to a gradual decline in fossil fuel consumption, mainly due to the growing popularity of renewable energy and improvements in energy efficiency. Ambitious EU policies and technological innovations facilitated this shift, making alternatives more accessible and competitive [36].

However, this transformation will require significant investments in infrastructure, research and development, and strong policies to overcome technical and economic challenges. The transport and industry sectors need to adopt innovative solutions, such as electricity, green hydrogen and improved energy efficiency, to reduce dependence on fossil fuels [37].

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B . Renewable energy growth: towards a new energy era.

Over the past few decades, renewable energy development in Europe has been impressive. Between 2010 and 2020, wind and solar increased by 250% and 500%, respectively [38]. This rapid expansion is the result of favorable policies, government subsidies, and technological advances that have reduced the cost of producing renewable energy.

1) *Expand production capacity:* Europe has developed regulatory frameworks and economic incentives to encourage investment in renewable energy. Subsidies and feed-in tariffs have encouraged the installation of new wind and solar energy, while technological advances have reduced the cost of producing these clean energy sources [39].

Renewables are projected to account for 50% of EU energy consumption by 2030, provided current trends continue and additional efforts are made to support their deployment [40]. The continued growth of renewables is key to reducing Europe's dependence on fossil fuels and achieving its long-term climate goals.

2) *Technological progress and innovation*: Technological advancements play a crucial role in the development of renewable energy. Improving the efficiency of solar panels, developing new energy storage technologies, and improving distribution networks enable renewable energy to be more effectively integrated into the energy mix [41].

In addition, innovations in energy storage technologies, such as large-scale batteries and pumped storage systems, are helping to overcome the challenges of intermittent renewables such as solar and wind. These solutions are essential to ensure a stable and reliable energy supply while increasing the share of renewable energy in total consumption [42].

C. Implications for energy security: economic and environmental issues

The transition to renewable energy has a significant impact on Europe's energy security. By reducing its dependence on fossil fuel imports, Europe can improve its resilience to geopolitical shocks and energy price fluctuations [43].

1) *Energy Security:* The adoption of renewable energy sources has enabled the diversification of energy sources. By reducing its dependence on fossil fuel imports, Europe can better cope with geopolitical crises and supply disruptions [44]. In addition, renewable resources such as wind and solar are abundant locally, enhancing energy independence.

2) *Economic Opportunities:* The development of renewable energy has also created enormous economic opportunities. Investments in green infrastructure and clean technologies are stimulating employment opportunities in innovative and sustainable sectors. In addition, the growth of the renewable energy industry can attract new investments and enhance Europe's economic competitiveness in the global market [45].

3) *Environmental impact:* Reducing greenhouse gas emissions through the adoption of renewable energy sources can help combat climate change. Reducing air pollution and protecting ecosystems are additional benefits of this energy transition [46]. In addition, Europe can serve as a model for the rest of the world by demonstrating the benefits of transitioning to a low-carbon economy.

D. Challenges and future prospects.

1) *Implementation challenges:* The implementation of energy transition policies faces many challenges. The high costs of clean technology, regulatory barriers, and the need to modernize existing infrastructure are major obstacles. Governments, businesses and communities must coordinate efforts to overcome these challenges [47].

2) *Future prospects:* Despite these challenges, the outlook for Europe's energy transition is promising. Ambitious EU policies, technological advances and stakeholder participation are key factors supporting the growth of renewable energy. Economies of scale and continuous innovation should also help reduce costs and make renewables more competitive [48].

E . conclusion.

energy demand in Europe is heading towards a major shift from fossil fuels to renewables. Ambitious targets, incentives and international cooperation projects demonstrate the EU's commitment to reducing carbon emissions and promoting renewable energy. Despite the challenges, the future prospects remain promising thanks to technological advances and the continued engagement of the EU and its partners. This energy transition is not only an environmental imperative, but also an economic and social opportunity to build a sustainable future

V. ENERGY COOPERATION ISSUES AND OPPORTUNITIES

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A. Renewable energy potential in north Africa: a source of energy for Europe.

North African countries have great potential in renewable energy, mainly solar and wind. For example, the Sahara Desert receives an average of 2,500-3,000 kWh/m²/year of solar radiation per year, making it one of the sunniest regions in the world. Algeria, Tunisia, and Egypt also have large arid areas that lend themselves to large-scale solar parks [50].

1) *Solar potential*: Algeria, for example, has an ideal climate for solar energy development. In Algeria, the potential production capacity of solar energy is estimated at around 169,440 TWh/il, far better than the country's current energy needs. These projects will not only meet domestic demand, but will also allow Europe to export electricity, thus creating new economic dynamics [51].

2) *Wind situation:* The wind energy potential in the region is also promising, especially on the Atlantic and Mediterranean coasts. For example, Morocco has built several wind farms and plans to produce 52% of its electricity from renewable sources by 2030 [52]. Both Libya and Egypt have potential wind zones along the coast. These winds can generate electricity at sustainable and affordable prices [53].

3) *Economic and strategic impact:* The development of renewable energy in North Africa is also likely to have significant economic and strategic implications. By reducing their dependence on imported fuels, countries in the region can improve energy security and stabilize their economies. In addition, revenues generated from the export of renewable energy to Europe can be reinvested in sustainable development projects and infrastructure modernization [54].

To illustrate this dynamic, the graph below shows the distribution of solar and wind energy potential in the major countries of North Africa.

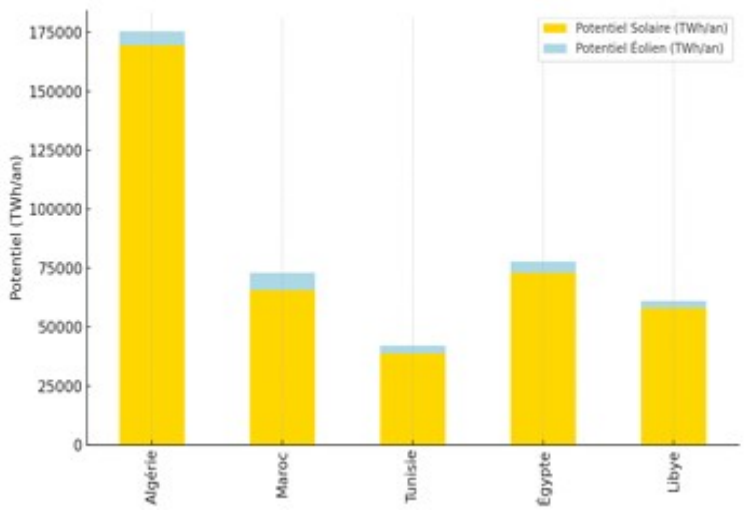

Fig.3 Potentiel d'énergie renouvelable en Afrique du nord.

Source: International Energy Agency, Ou North Africa's Renewable Energy Potential Reference, 2022.

B. Technology Transfer and Infrastructure Development: Towards Energy Smart.

Technology transfer and infrastructure development are key to harnessing the full potential of renewable energy in North Africa. Collaborative projects could include the construction of solar and wind power plants, as well as the creation of a trans-Mediterranean electricity network to transmit the generated electricity to Europe.

1) *Infrastructure projects:* Initiatives such as the MedGrid project aim to promote the establishment of an integrated electricity network between Europe and North Africa and the exchange of green electricity between the two regions [56]. The Desertec project remains an iconic example of this integrated image, although it faces some challenges. The goal of the project is to harness the sun's potential in the Sahara Desert to provide clean energy to Europe [57].

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2) *Storage technology:* The development of energy storage technologies, such as large-scale batteries and pumped hydro storage systems, is essential for a stable and reliable power supply [58]. These technologies allow us to compensate for renewables intermediates and stabilize the grid. Investments in R&D are needed to improve the efficiency and cost of these technologies.

3) *Technical cooperation :* The technical cooperation framework between Europe and North Africa may also include training and knowledge transfer programs . By sharing advanced technologies and optimization practices, European countries can help North African partners maximize the efficiency and sustainability of energy projects [59]. Such collaboration can strengthen local opportunities and drive endogenous technology development.

C. Creating jobs and combating climate change: the benefits of sustainable cooperation.

Energy cooperation between Europe and North Africa has many economic, social and environmental benefits. The development of renewable energy sources can create thousands of local jobs in the construction, operation, and maintenance of energy facilities [60]. These jobs can help reduce unemployment and boost the local economy.

1) *Create jobs:* The renewable energy sector is a driver of job creation. Building solar and wind farms requires skilled labor for the installation and maintenance phases. In addition, the manufacturing of components for renewable energy facilities can boost the development of local industries. Projections suggest that the huge growth of renewable energy in North Africa could create hundreds of thousands of direct and indirect jobs [61].

2) *Environmental impact:* Depending on the environment, the transition to renewable energy can help combat climate change by reducing greenhouse gas emissions. Energy partnership projects may also include renewable energy and local ecosystem conservation programs to address the environmental impacts of energy infrastructure. Reducing pollution and conserving natural resources are the added benefits of the transition.

3) *Sustainable development opportunities:* Energy cooperation projects can also contribute to sustainable development by promoting environmentally friendly agricultural practices and supporting water management initiatives. By integrating clean energy solutions into the agriculture and water sectors, North African countries can improve their resilience to climate and environmental challenges [63].

D. Challenges of energy cooperation.

1) Financial and institutional challenges: The implementation of energy cooperation projects between Europe and North Africa faces a number of financial and institutional challenges. The high upfront cost of infrastructure and advanced technology can be a significant deterrent. In addition, the complexity of the regulatory framework and the need for policy coordination across all jurisdictions could slow progress. [64]

2) *Regional security and stability:* Political stability and regional security are also key factors in the successful implementation of energy cooperation projects. Conflict and geopolitical tensions can hinder project implementation and hurt investment. Therefore, ensuring peace and stability in the region is essential to ensure an enabling environment for sustainable investment [65].

3) *Infrastructure and logistics*: The development of transport and logistics infrastructure is essential to support energy projects. Electric transmitter networks, roads, and port facilities need to be modernized and retrofitted to transport the equipment and materials needed for the construction and operation of energy parks.

E . Conclusion.

the challenges and opportunities for European-North African energy cooperation are broad and diverse. Combined with the potential of renewable energy, the region's technology and financial cooperation, it could transform the energy landscape on both continents. By addressing institutional challenges and investing in sustainable infrastructure, such partnerships can create significant economic, social and environmental benefits. The transition to a green and sustainable economy is not only a necessity to combat climate change, but also an opportunity for growth in Europe and North Africa.

VI. SCENARIOS FOR REDUCING EUROPE'S ENERGY DEPENDENCE

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A. Energy Cooperation scenarios: different ways to reduce dependency.

The objective of this chapter is to explore different scenarios for energy cooperation between Europe and North Africa to reduce European dependence on fossil fuels and promote the transition to renewable energies. Each scenario will be analyzed based on several key indicators, such as annual investment, energy production capacity, reduction of energy dependence, CO2 emissions, job creation, economic benefits, and impact on GDP.

1) Scenario 1: Medium investment: In Scenario 1, we assume an annual investment of $25 billion. This averaging method was chosen to assess the gradual transition to minimize financial and political risks. The assumptions used for each indicator are as follows:

-Production power: We believe that renewable energy capacity can be increased relative to annual investment. The investment amount is US$15 billion (60%) and that of North Africa is US$10 billion (40%). This assumption is based on an initial capacity of 900 megawatts, with an annual growth rate of 1.2% in Europe and 1.8% in North Africa. This growth rate is consistent with historical trends and projections observed by the International Energy Agency (IEA) [67].

-Energy dependence: It is assumed that dependence on fossil fuels is declining relative to the growth of renewable energy production. However, in Europe, the annual decline rate was 0.8 per cent and in North Africa it was 1.2 per cent. The assumptions are based on the EU's 2030 targets and the energy strategies of the North African countries. This indicates a common desire to reduce energy dependence [68].

-CO2 emissions: There is an assumption here that CO2 emissions are decreasing relative to the adoption of renewable energy. he annual rate of decline in Europe was 1.2 percent, while in North Africa it was 1.8 percent. These projections are based on models of the Intergovernmental Panel on Climate Change (IPCC) and the Resolute National Commitments (NDCs) under the Paris Agreement [69].

-Create jobs: It is assumed that the jobs created are consistent with the investment in renewable energy. We estimate that within 10 years there will be 120,000 jobs in Europe and 80,000 in North Africa. This calculation is based on the International Renewable Energy Agency (IRENA) report and market analysis. These reports reflect previously observed employment ratios [70]. The projection methodology used is based on an analysis of the historical rate of job creation per billion people invested, adjusted for regional specifications and the technologies used. Historical data provides a reliable basis for calculating the impact of new investment on employment.

-Economic benefits: We believe the return on investment (ROI) is in line with renewable energy investments. In Europe, the annual return on investment was 3.5% and in North Africa it was 4.5%. The assumptions justify the profitability study of renewable energy projects reported by Bloomberg New Energy Finance (BNEF) [71].

-impact on UDM: Presumably, investment and energy production contribute to economic growth. In Europe, the impact of UDM is estimated at $33 billion/year and in North Africa at $17 billion. According to reports from the European Commission and the World Bank, these calculations use an economic multiplier of 1.8 in Europe and 1.3 in North Africa [72].

*2) Scenario 2:*More aggressive investment policy . In Scenario 2, we assume an annual investment of $45 billion. This situation is a trade-off between austerity and efficiency. It is designed to achieve meaningful results while maintaining an acceptable level of risk.

-Production power: Renewable energy capacity is growing relative to annual investments. $30 billion (66.7%) is invested annually and $15 billion (33.3%) is invested in North Africa. We have an initial capacity of 900 MW with an annual growth rate of 2.5% in Europe and 3.5% in North Africa. These assumptions are based on historical trends and projections from the International Energy Agency [73].

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-Energy dependence: We hypothesize that there is less reliance on fossil fuels relative to the growth of renewable energy production. The annual decline rate in Europe was 1.5 percent, while in North Africa it was 2.5 percent. These prices are adjusted in line with the 2030 energy target [74].

-CO2 emissions: We assume that CO2 emissions have been reduced relative to the consumption of renewable energy. The annual rate of decline in Europe was 2.0 per cent, while in North Africa it was 3.0 per cent. This assumption is correct in line with the IPCC projections and NDC commitments [75].

- Create jobs: We believe that job creation is consistent with investment in renewable energy. In 10 years, there will be 270,000 jobs in Europe and 130,000 in North Africa. These calculations are based on IRENA reports and previous market analysis [76]. The in-depth reporting methodology uses historical rates of job creation per billion, taking into account sectoral and regional differences. These reports and historical data provide a solid basis for calculating the impact of new investment on employment, while adjusting for technological innovation and productivity gains.

- Economic benefits: The return on investment is considered to be in line with the investment. In Europe, the annual return on investment was 5.0% and in North Africa it was 6.0%. These figures are derived from the profitability study of BNEF [77].

-impact on UDM : We assume that investment and energy production contribute commensurate to economic growth. The dollar in Europe is estimated at $67.5 billion and in North Africa at $26 billion. This effect uses an economic multiplier, which is 1.8 in Europe and 1.3 in North Africa [78].

3) Scenario 3: Major strategic reorientation. In Scenario 3, we assume an annual investment of $80 billion. This scenario is the most ambitious and aims to maximize economic and environmental benefits, albeit with higher risks. The assumptions used for each indicator are as follows:

- Production power: We believe that renewable energy capacity can be increased relative to annual investment. The annual investment in Europe is $55 billion (68.75%) and in North Africa is $25 billion (31.25%). The IEA estimates that the initial power is 900 MW in Europe and 300 MW in North Africa, with an annual growth rate of 5.0% [79].

- Energy dependence: We are starting to reduce our dependence on fossil fuels by increasing renewable energy. The annual decline was 3.0% in Europe and 4.0% in North Africa, which is in line with long-term energy targets [80].

- CO2 emissions: It is assumed that CO2 emissions are decreasing relative to the adoption of renewable energy. According to ipCC projections and NDC commitments, the annual decline rate is 3.5% in Europe and 4.5% in North Africa [81].

- Create jobs: We believe that job creation is consistent with investment in renewable energy. In 10 years, there will be 600,000 jobs in Europe and 350,000 in North Africa. These estimates are based on the IRENA report [82]. The in-depth reporting methodology takes into account historical job creation ratios while adapting to sector-specific and regional conditions. These programmes include adjustments to technological innovation and expected productivity gains. A realistic estimate of the impact of large-scale investment on employment in both regions is provided.

- Economic benefits: The return on investment is considered to be in line with the investment. In Europe, the annual return on investment was 7.0% and in North Africa it was 8.0%. These calculations are derived from the profitability study of BNEF [83].

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- impact on UDM : We assume that investment and energy production contribute commensurate to economic growth. The dollar in Europe is estimated at $129 billion and in North Africa at $50 billion. This effect uses an economic multiplier, which is 1.8 in Europe and 1.3 in North Africa [84].

Table of simulation results.

index	**Scenario 1:** *Medium Investments*	**Scenario 2:** *More aggressive investment policy*	**Scenario 3: Major strategic reorientation**
Investment	$25 billion per year	$45 billion per year	$80 billion per year
Europe's share	$15 billion/IL (60%)	$30 billion/IL (66.7%)	US$55 billion/IL (68.75%)
North Africa's share	$10 billion/IL (40%)	US$15billion/IL (33.3%)	$25billion/IL(31.25%)
Manufacturing Powerhouse (Europe)	900 MW, +1.2%/il	900 MW, +2.5%/litre	900 MW, +4.0%/il
Retail Power (North Africa)	300 MW, +1.8%/L	300 MW, +3.5%/il	300 MW, +5.0%/litre
Energy Dependence (Europe)	-0.8%/il	-1.5%/il	-3.0%/il
Energy Addiction (North Africa)	-1.2%/IL	-2.5%/ml	-4.0%/ml
CO2 Emissions (Europe)	-1.2%/IL	-2.0%/il	-3.5%/liter
CO2 Emissions (North Africa)	-1.8%/IL	-3.0%/il	-4.5%/ml
Job Creativity (Europe)	120,000 jobs (10 years)	270,000 jobs (10 years)	600,000 jobs (10 years)
Work Ideas (North Africa)	80,000 jobs (10 years)	130,000 jobs (10 years)	350,000 jobs (10 years)
Economic benefits (Europe)	3.5%/il ROI	5.0%/il ROI	7.0%/il ROI
Economic benefits (North Africa)	4.5%/il ROI	6.0%/il ROI	8.0%/il ROI
Impact on UDM (Europe)	$33 billion per year	$67.5 billion per year	$129 billion per year
Impact on UDM (North Africa).	$17 billion per year	$26 billion per year	$50 billion per year

B . Comparative Scenario Analysis: What to Choose.

When evaluating the three scenarios proposed to reduce Europe's energy dependence, it is crucial to review the targets set at the beginning and the results set for 2030. Each scenario has unique strengths and weaknesses that are identified by key metrics such as reduced energy dependence, reduced CO2 emissions, increased renewable energy production capacity, increased employability, return on investment (ROI), and impact on GDP.

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1). *Scenario 1*: Medium Investment: This scenario proposes a conservative approach based on an annual investment of $25 billion between Europe ($15 billion) and North Africa ($10 billion). This situation is ideal for reducing upfront expenditures, thereby promoting political and social acceptance. It also allows us to gradually transition to renewable energy and de-risk investors and government agencies. However, the results for 2030 show reduced energy dependence and limited CO2 emissions. In fact, energy dependence in Europe is reduced by 0.8% per year, and in North Africa by 1.2% per year, while CO2 emissions are reduced by 1.2% and 1.8%, respectively [85] - [86]. Beyond that, capacity growth remains modest. The annual growth rate is 1.2% in Europe and 1.8% in North Africa [87]. The economic impact is also limited. In 10 years, there will be 120,000 jobs in Europe and 80,000 in North Africa. The annual return on investment (ROI) is 3.5% in Europe and 4.5% in North Africa. This led to an average growth of $33 billion in Europe and $17 billion in North Africa [88] - [90].

2). *Scenario 2*: More aggressive investment policy : This scenario involves an annual investment of $45 billion. These investments are split between Europe ($30 billion) and North Africa ($15 billion). In this case, there is a trade-off between cost and efficiency. Larger investments can significantly reduce energy dependence and CO2 emissions while boosting economic growth. By 2030, energy dependence will be reduced by 1.5% per year in Europe and 2.5% per year in North Africa, while CO2 emissions in Europe will be reduced by 2.0% per year and by 3.0% per year in North Africa [91] - [92]. The growth in manufacturing capacity has also been more significant. The annual growth rate is 2.5% in Europe and 3.5% in North Africa [93]. But higher costs represent political and financial risks that require a strong commitment from governments and investors. Economic uncertainty and potential volatility in the market may also affect the vitality of the situation. Despite these challenges, this situation is expected to create more jobs. In 10 years, there were 270,000 jobs in Europe and 130,000 in North Africa, compared to 5.0% in Europe and 6.0% in North Africa. In Europe, UDM increased by $67.5 billion / year, and in North Africa by $26 billion [94]-[96].

2). *Scenario 3*: Major strategic reorientation: This Option provides an annual investment allocation of $80 billion, split between Europe ($55 billion) and North Africa ($25 billion). This scenario offers the greatest benefits in terms of reducing energy dependence, reducing CO2 emissions, creating jobs, and stimulating economic growth. By 2030, energy dependence will be reduced by 3.0% per year in Europe and 4.0% per year in North Africa, while CO2 emissions in Europe will be reduced by 3.5% per year and 4.5% per year in North Africa [97] - [98]. Growth in the manufacturing sector has peaked. The annual growth rate in Europe is 4.0%, and in North Africa is 5.0% [99]. However, very high upfront costs and associated risks can be difficult to manage. This situation requires close cooperation between the government and investors, as well as political and economic stability. Uncertainties about the future, such as non-technological advances or changes in global energy policy, can also pose challenges. However, this situation is expected to create the greatest number of jobs. In 10 years, there will be 600,000 in Europe and 350,000 in North Africa. The annual return on investment was 7.0% in Europe and 8.0% in North Africa. In Europe, UDM increased by $129 billion / year, and in North Africa by $50 billion [100]-[102].

C. Joint approach to help bring public authorities and investors closer together.

This could mean a common strategy to anticipate future uncertainties and encourage fair cooperation that respects the sovereignty of each region. These include the establishment of intergovernmental cooperation frameworks, the provision of financial and financial incentives, the development of risk-sharing mechanisms, the promotion of technology transfer and capacity, and the enhancement of the attractiveness of local legal entities. By adopting this approach, governments and investors can work together to create a sustainable energy future while respecting the interests and sovereignty of each region.

To better understand the differences between the three proposed scenarios, we developed a comparable annual investment plan and its expected impact on renewable energy generation capacity in Europe and North Africa. This diagram helps illustrate the benefits of each scenario.

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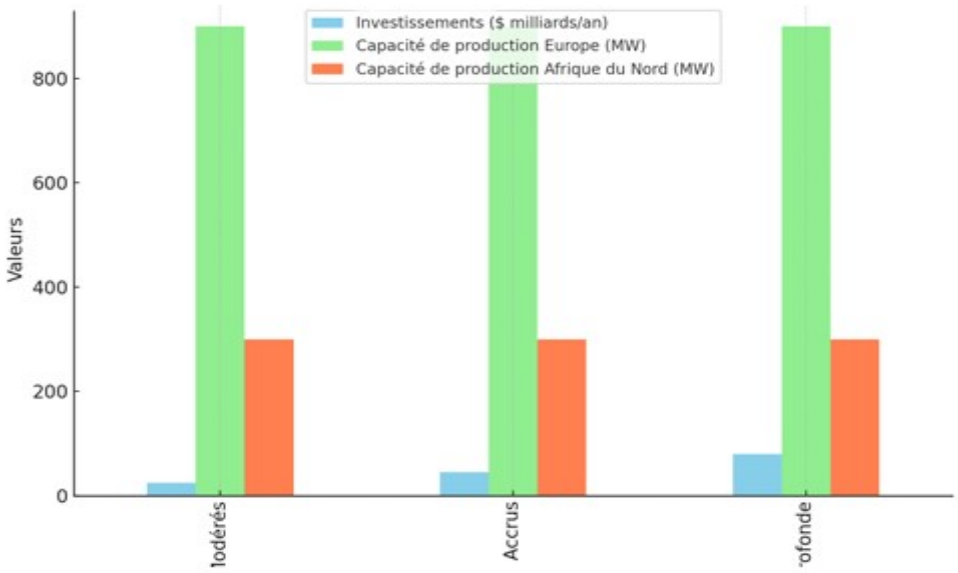

Fig.4 Annual investment and renewable energy capacity

Source: International Energy Agency report Energy Transition Scenari

VII. CHANGING THE COOPERATION PARADIGM

A.Energy cooperation models: rethinking international partnerships.

Energy cooperation between Europe and North Africa requires, for the first time, the traditional model of international cooperation being withdrawn from the first category. Historically, energy relations have often been based on asymmetrical bilateral agreements. European countries mainly benefit from the energy resources of African countries, without sharing the benefits [103] equitably. It is necessary to develop a model of cooperation based on [103] mutuality, transparency and respect for national sovereignty in order to ensure sustainable and mutually beneficial cooperation.

The new partnership model should include benefit-sharing mechanisms, technology transfer contracts and investment in local infrastructure to ensure that local people directly benefit from energy projects [104]. In addition, it is crucial that local actors are involved in the planning and implementation of the project to ensure its relevance and community acceptance of the issue [105].

1) *Profit sharing:*The distribution of benefits is the core element of the new energy cooperation model. This means that revenues generated by energy projects must be distributed equitably among partner countries. For example, rumors and taxes levied on energy production and exports can be used to fund local development projects such as infrastructure, schools, and hospitals. [106] This approach ensures that local communities directly benefit from energy projects. It can improve their support and commitment to these initiatives.

2) *Technology transfer* : Technology transfer is necessary to build local capacity and ensure the sustainability of energy projects. This includes the development of modern equipment, but also technical training and local skills. For example, partnerships could be established between universities and research centers in Europe and Africa to develop educational programs that specialize in renewable energy technologies. These initiatives will create a skilled workforce to ensure the management and maintenance of energy infrastructure.

*3) Investment in local infrastructure :*Investment in local infrastructure is critical to maximizing the impact of energy projects. This includes the construction of energy distribution networks, roads and ports to facilitate the transportation of equipment and materials needed to carry out the project. In addition, these investments help boost the local economy and create jobs. This is essential for sustainable growth.

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B. New cooperation model: building the energy future together.

Innovative partnership models are needed to build a shared energy future. For example, public-private partnerships (PPPs) can play a key role in the financing and management of renewable energy projects. These partnerships combine financial resources and technical expertise from the public and private sectors to maximize the impact of the project. [109]

1) *Public-Private Partnership (PPP):* Public-private partnerships provide a flexible and effective framework for the financing and management of energy projects. They have enabled us to mobilize substantial financial resources and to draw on the technical expertise and operational efficiency of the private sector. For example, a solar or wind farm project can be developed in partnership with a private company. These projects provide the necessary investment and management of the business's operations, while the government provides regulatory and policy support.

2) *Multinational consortia:* Another promising model is the multinational consortium. A number of countries and companies are joining forces to develop large-scale energy projects. The alliance can benefit from the sharing of risks and costs, while making it easier to transfer technology and knowledge among partners [111]. In addition, they can explain the removal of regulatory barriers and the adjustment of technical standards. This is essential for the integration of the energy network between Europe and North Africa.

3) Coordination of technical standards:The harmonization of technical standards is a key factor in the successful implementation of cross-border projects. This includes *standardizing* equipment, maintenance procedures, and security protocols. For example, establishing common standards for solar panels and wind turbines could make them easier to mass produce and reduce costs. In addition, the harmonization of standards can ensure better interconnection of energy systems, which is essential for the integration of cross-border power grids.

C. the importance of political commitment. The key to successful collaboration.

Political commitment is critical to the success of energy cooperation between Europe and North Africa. Governments in both regions must demonstrate a strong and sustained commitment to the energy transition and international cooperation. This means establishing an affordable legislative and regulatory framework, as well as deploying the necessary resources to support energy projects [113].

1) Legal and regulatory framework: There is a need to establish a legislative and regulatory framework to attract investment and ensure the implementation of energy projects. This includes clear laws and regulations on property rights, feed-in tariffs and tax incentives for renewable energy investments. For example, support mechanisms such as feed tariffs or green certificates can encourage private investment in renewable energy.

2) *Resource mobilization:* The mobilization of financial and human resources is also critical to the successful implementation of energy projects. Governments must commit to public financing and attract private investment to support the development of energy infrastructure [115]. In addition, the development and mobilization of skilled workers is essential for the implementation and implementation of the project.

3) *International cooperation platform:* International summits and forums, such as the United Nations Climate Summit (COP), can be an important platform for strengthening political solidarity and promoting energy cooperation [116]. These events provide an opportunity for political leaders to discuss challenges and opportunities, share best practices, and achieve common goals. For example, agreements reached at the Conference of the Parties can serve as a blueprint for national and international energy transition commitments.

D. Technology transfer and use of raw materials.

Technology transfer is a key factor in ensuring effective and sustainable energy cooperation between Europe and North Africa. Such transfers should not be limited to the supply of equipment, but should also apply to technical training and local capacity-building initiatives. [117]

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1) *Technical training:* Investments must be made in the technical training of local people in African countries. This includes the development of specialized education programmes in renewable energy technologies and the establishment of technical training centres. These initiatives will create a skilled workforce to ensure the management and maintenance of energy infrastructure.

2) *Investment in the production of technical products: In* addition, it is important to encourage investment in the production of technological products in African countries. In addition to increasing the value of the raw materials used in energy projects, it will also stimulate the local economy and create jobs. For example, local production of solar panels, wind turbines, and energy storage elements can help reduce production costs and improve access to technology.[119]

3) *Self-maintenance:* It is vital that equipment maintenance is not used as a means of political or economic pressure. Cooperation agreements should include a framework to guarantee ownership of energy infrastructure by African countries [120]. This can be achieved through collaboration, further transfer of training and technical skills.

E. Joint strategies to facilitate engagement between government agencies and investors.

This could mean a common strategy to anticipate future uncertainties and encourage fair cooperation that respects the sovereignty of each region. These include the establishment of intergovernmental cooperation frameworks, the provision of financial and financial incentives, the development of risk-sharing mechanisms, the promotion of technology transfer and capacity, and the enhancement of the attractiveness of local legal entities. By adopting this approach, governments and investors can work together to create a sustainable energy future while respecting the interests and sovereignty of each region.

1) *Intergovernmental Cooperation Framework:* It is essential to establish an intergovernmental cooperation framework to coordinate the efforts of various actors and ensure cooperation in energy policy. These frameworks may include bilateral and multilateral agreements, platforms for dialogue and discussion, and mechanisms for monitoring and evaluating projects. [121] For example, the establishment of the Joint Europe-North Africa Energy Cooperation Committee could facilitate the implementation of the project and monitor progress on a regular basis.

2) *Fiscal and tax incentives:* The implementation of fiscal and tax incentives is an important tool to attract private investment and support the development of energy infrastructure. This could include grants, deductions, concessional-rate loans, and innovative financing mechanisms such as green bonds. For example, a tax on renewable energy investments could encourage companies to participate in cross-border projects.

(3) *risk sharing mechanisms:* The establishment of a risk-sharing mechanism is essential to ensure the fairness and sustainability of energy projects. This includes the establishment of guarantee funds, insurance, and revenue-sharing partnerships to equitably distribute profits and risks among different participants [123]. For example, the Renewable Energy Investment Guarantee Fund can help reduce financial risks and attract more investors.

4) *Promote technology transfer and capacity building: Technology* transfer and capacity-building are key factors in ensuring the sustainability of energy projects. This includes technical training, the development of local skills, and the promotion of innovation and research. For example, training and capacity development programmes can be developed to ensure that local people have access to new energy technologies and to ensure their autonomy in infrastructure management.

5) Attract local legal entities: Local legal entities need to be involved in the acceptance and relevance of energy projects. This includes issues related to project planning and implementation, as well as consultations and local communities to address their needs and concerns. [125] For example, public consultations and engagement workshops can be organized to engage local communities in the decision-making process and ensure that they support the project.

F . Conclusion.

Energy cooperation between Europe and North Africa is a unique opportunity to stimulate the energy transition, reduce dependence on fossil fuels and boost economic growth in both regions. It is possible to create a sustainable and prosperous energy future for all stakeholders through the adoption of cooperation models based on mutuality, transparency and respect for national sovereignty, intergovernmental cooperation frameworks, fiscal and fiscal incentives, the establishment of risk-sharing mechanisms and the promotion of technology transfer and capacity enhancement.

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VIII .CONCLUSION

A. Main results and conclusions of the study.

The study highlights the crucial importance of energy cooperation between Europe and North Africa. Strategic investments, technology transfer and strengthened policy partnerships are essential to reduce Europe's dependence on fossil fuels and transition to renewable energy. Education has shown that with huge investments and increased cooperation, Europe can significantly reduce its energy dependence while stimulating economic and social development in North Africa. The environmental benefits, including the reduction of greenhouse gas emissions, are also considerable. This is a driving force in the fight against climate change. [126] [127]

B. Recommendations on sustainable and mutually beneficial energy cooperation.

A number of actions are recommended to ensure sustainable and mutually beneficial energy cooperation. It is imperative to increase funding for renewable energy projects and trans-Mediterranean infrastructure to support an effective energy transition. Harmonization of legislative and regulatory frameworks between Europe and North Africa is also necessary to facilitate the implementation of cooperation projects. In addition, the transfer of technology and knowledge between the two regions should be encouraged in order to maximize the efficiency of energy projects. At the end of the day, a strong and sustained political commitment on both sides is critical to supporting the energy cooperation initiative and ensuring its success. [128]-[131]

C. Future Prospects.

Energy cooperation between Europe and North Africa is promising. Through clear commitments and concrete actions, it is possible to build an energy partnership that meets the needs of both regions while promoting economic stability and prosperity. The establishment of pilot projects and innovation programs can serve as a basis for expanded and sustainable collaboration. This can pave the way for opportunities for growth and development.

Energy cooperation also plays an important role in tackling climate change. By reducing greenhouse gas emissions and increasing the use of renewable energy, Europe and North Africa can make a significant contribution to global climate goals. Such an energy partnership, based on reciprocity, transparency and respect for national sovereignty, could serve as a model for international cooperation in other parts of the world [132][133].

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