Leveraging Knowledge on Renewable Energy in Southern and Eastern Mediterranean Region

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1 The South Mediterranean Framework Enabling the Implementation and Adoption of Renewable Energy

1.1 Why Renewable Energy Should Be Used in the Southwestern Mediterranean Region?

In recent years, the countries of the southwestern Mediterranean region have been affected by crises of political instability. However, this should not distract them from their economic and environmental efforts to be adapted to climate change and for a more sustainable development.

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In the next few years, the region must respond to several challenges in the field of energy (UNEP 2016; Moe 2020). The first challenge is to meet the demand for electricity. The latest report from the World Bank highlights the difficulty of the region's countries to meet their future electricity demand. Despite holding the world's largest oil and gas reserves, the region risks not being able to meet the future needs of its growing population and its industrial and commercial activities. Between 2005 and 2019, electricity production in the region increased from 198 to 367 TWh, representing an increase of 85% (IEA). With urbanization and economic growth, countries in the region are expected to double their energy demand by 2040. The second issue is the reduction of oil dependence in net-exporting countries that depend on oil for at least 40% of their exports and 80% of their economic revenues. Indeed, with the Covid19 crisis, oil and gas revenues in Algeria and Libya have dropped by nearly 75–90%, putting a strain on their economies. The third challenge is for net-importing countries to reduce their dependence on oil price fluctuations that can reduce the competitiveness and the growth of their economy in the long term. Although the future trend of oil prices is uncertain, it is very probable that in the long-term the demand will lead to an increase in the price of oil and natural gas. The availability of primary sources of renewable energy in the region is an advantage that will help meet these challenges while addressing the dual economic and environmental issues (IEA). Furthermore, several studies (Tagliapietra 2016; Duygu 2019; Agency IRE 2018) at the regional level have shown a positive relationship between renewable energy use and GDP.

The following section presents first the primary sources of renewable energy production in the region as well as the most sustainable sources in order to understand the development strategies of renewable electricity production adopted by the region. The second part consists of an overview of the institutional and regulatory framework in the region for the promotion of renewable energy. The last part presents the evolution of installed renewable energy in the region, its strengths as well as the constraints and limitations of its development.

1.2 Renewable Energy Potential in the Southwestern Mediterranean Region

The southwestern Mediterranean region is endowed with natural sources that provide opportunities for the production of clean energy, particularly solar and wind energy. The geographical position of the region provides the best solar radiation in the world with a solar radiation of more than 2000 kWh/m^2/year (Tagliapietra 2016). Surrounded by the Atlantic Ocean, the Mediterranean and the Red Sea, the potential for the development of wind energy is also very significant (average wind speed is 7 m/s). In addition to the solar and wind potential, the region also has geothermal, biomass and hydraulic resources that can be sources of clean energy production. For

example, Algeria and Morocco have a potentially exploitable field of geothermal energy with temperatures of 200 °C at 5000 m.

However, the evaluation of the real potential of a renewable energy source must not be limited to the saving of CO_2 emissions and the saving of primary resources. A prioritization of an energy source depends on its environmental, economic, social and technical aspects. Thus, the definition of a renewable energy strategy in a country is based on an evaluation of the performance and multidimensional reliability of each source. On the technical level, the most used criteria are the energy efficiency expressing the quantity of energy that can be obtained from the primary source, the reliability of the technology and its commercial maturity measuring the diffusion degree of the technology at the national and international markets.

On the economic front, the evaluation criteria are related to the cost, such as investment cost, cost of energy produced and payback time. The environmental criterion considers the impact on the soil, water and the surrounding environment through the production of noise and solid waste. The social criterion is based on the social benefits in terms of job creation, social welfare and revenue. This criterion is very important in the less developed countries because it allows to measure the social progress induced by the energy project. All of these criteria present indicators of the sustainability of an energy source, since they consider the needs of future generations.

In this sense, several studies have been carried out to analyze and rank the renewable electricity sources in the southwestern Mediterranean region (Et and Pratiques n.d.; Académie Hassan and des Sciences et Techniques 2019), considering environmental, economic and social criteria.

Their results place solar and wind energy in the first two positions. Solar electricity alone represents more than 68% of the renewable energy potential economically and technically exploitable in the region (Et and Pratiques n.d.) (Table 1). These results explain the strategies for renewable energy development in the region (Schaffrin and Fohr 2017), which are focused on the implementation of large solar and wind capacities by 2030. These programs are more detailed in the next section.

Table 1 Renewable energy potential that is technically and economically feasible

Country	Wind (%)	Wave and tide (%)	Geothermal (%)	Hydraulic (%)	Solar (%)
ALGERIA	1.3	0	0	0.2	98.5
EGYPT	20	0.2	0	1.3	78.5
LIBYA	31	1	0	0	68
MOROCCO	28	0.6	0	2.7	68.7
TUNISIA	27	0.6	0	0.2	72.2

1.3 Analysis of Energy Policies and the Institutional and Regulatory Framework by Country

The different energy strategies in the region include targets for the share of electricity generation from renewable energy in the energy mix.

Indeed, the development of renewable energy in the region is governed by national policy strategies (Table 2), such as the "National Renewable Energy and Energy Efficiency Plan" launched in Morocco in 2008, the "Renewable Energy and Energy Efficiency Program" launched in Algeria in 2009, and the "Solar Plan" in Tunisia launched in 2009. By 2030, these programs envisage achieving fixed targets in the electricity generation mix by setting capacities to be installed from several renewable energy technologies such as PV, CSP, and wind (SCOPUS 2016).

To ensure the promotion and achievement of these energy objectives, an institutional and regulatory framework has been established in each country of the region, as detailed in Table 3. The different laws adopted by each country provide the regulatory framework for the production of electricity from renewable energy sources. In Particular, they define the rules governing the development and implementation of projects (licensing procedures), and the commercialization of energy. As for the institutional framework, the region suffered in the past due to the lack of institutional actors committed to the promotion and development of renewable energy. Today, the institutional framework is progressing and becoming more consolidated through the reform of the main ministerial departments that have monopolized this sector in the past. This reform is based on a clear allocation of the roles and responsibilities of the different actors. The main missions of these institutes are the establishment of a fund for the development of RE, the participation in the design and realization of RE projects, and the establishment of research platforms involved in training the workforce required for these renewable projects. Financial incentives have also been introduced to encourage private investors to participate in RE development, such as capital subsidies, land ownership, tax exemption and preferential loans.

Table 2 Overall renewable energy targets in the selected country (Duygu 2019)

Country	Target	Year
Algeria	27% of electricity generation	2030
Morocco	52% of electricity generation	2030
Tunisia	30% of electricity generation	2030
Egypt	42% of installed capacity mix	2035
Libya	2219 MW of capacity installed	2025

Table 3 Regulatory and institutional framework and financial incentive mechanisms in the SWM region

Country	Legislation and regulations	Financing and subsidy	Redemption rates	Institutional actors
Algeria	• Law no. 04-09 August 2004 • Decree no. 13-218 June 2013 • Decree no. 15-69 February 2015 $\Longrightarrow$ Licensing procedures and incentives for diversification of power generation costs	National renewable energy and cogeneration fund (FNERC) $\Longrightarrow$ Funding allocated depending on the technology • Reduction of customs duties and VAT on the imported RE components	Feed-in tariffs based on installed capacity (MT, HT)	• SKTM: implementation of the national renewable energy plan • CREG: permits for RE producers • APPRUE et CDER
Morocco	• Law no. 13-09: promotion of renewable energies • Law no. 58-15 2015 $\Longrightarrow$ possibility of selling surplus energy • Law no. 16-08$\Longrightarrow$ authorization of self-generation by industrials by raising the installed capacity to 50 MW instead of 10 to MW	• Capital subsidy (10–15%) of credit • Tax exemption • Preferential loans ($300 K–-$5 M) • No public subsidies • SIG energy investment company: fund for the development of RE	Tariffs defined for high and medium voltage (possibility to sell the surplus but not exceeding 10% on the total annual production)	• CDER • MASEN: development of solar, wind and hydraulic energy • RESEN: R&D in renewable energy • AMEE: domestic use of RE
Tunisia	• Law no. 2009-7 autonomous production of electricity from RE • Decree no. 2009-2773 conditions for the sale of surplus to STEG • Law no. 2015-12 May 2015: national plan for renewable energy • Decree no. 2016-1123 August 24, 2016 conditions of the modalities and implementation	• 30–40% of investment (< 20,000 DT) depending on the project (RoofTop PV, solar water heater, solar pumping) • Tax exemption • Preferential loans • No public subsidies	Well-defined tariffs for LT, MT, and HT that depend on the time shift at STEG (possibility to sell the surplus of the electricity produced but not exceeding 30% of the total annual production	• STEG: design, implementation and operation of renewable energy facilities • ANME

(continued)

Table 3 (continued)

Country	Legislation and regulations	Financing and subsidy	Redemption rates	Institutional actors
Egypt	• Law no. 203 December 2014 $\Longrightarrow$ Authorizing private investors to provide renewable electricity to their customers • Decree no. 1947 2014 $\Longrightarrow$ feed-in tariffs • Law no. 87 2015: > establishing a competitive electricity market	• Incentive investment measures • Tax exemption • Tax reduction for renewable equipment	Feed-in tariffs defined for electricity received from wind and PV	• EEHC (6 generation companies, one transmission company, and 9 distribution companies) • NREA: implementation of the national renewable energy plan • EgyptERA: regulation of electricity services
Libya	• No specific law is currently in operation	No subsidies or incentives for private investment	No tariffs have been defined to date	REAOL: promotion of renewable energies

Abbreviation SKTM (Sharikat Kahraba wa Taket Moutajadida); CREG (Commission algérienne de régulation de l'électricité et du gaz); CDER (Centre de développement des énergies renouvelables); APPRUE (Agence pour la promotion et la rationalisation de l'utilisation de l'énergie); MASEN (Agence marocaine pour le développement durable); IRESEN (Institut de recherche en énergie solaire et énergies nouvelles); AMEE (Agence marocaine pour l'efficacité énergétique); STEG (Société tunisienne d'électricité et du gaz); ANME (Agence nationale pour la conservation de l'énergie); EEHC (Egyptian Electricity holding Company); EgyptERA (Egyptian electric utility and consumer protection regulatory agency)

1.4 Evolution of the Electricity Generation by Source for the Southwestern Mediterranean Countries (2005–2019)

To analyse the development strategy of renewable electricity production in the southwestern Mediterranean countries, we have chosen as an indicator the amount of renewable electricity produced by the International Energy Agency (IEA) and then comparing it with the trend of the different energy sources that are used in each country of the region (Fig. 1).

Although, the renewable energy potential in the region is one of the largest in the world, the increase in primary fossil fuel power generation has been greater than the growth in renewable power generation. As illustrated in Fig. 1, the energy mix of the different countries is predominantly based on gas. Except for Morocco, which has a very diversified energy mix. Morocco has indeed reduced its fuel consumption by 63% annually during the last decade to ensure its energy security with regard to

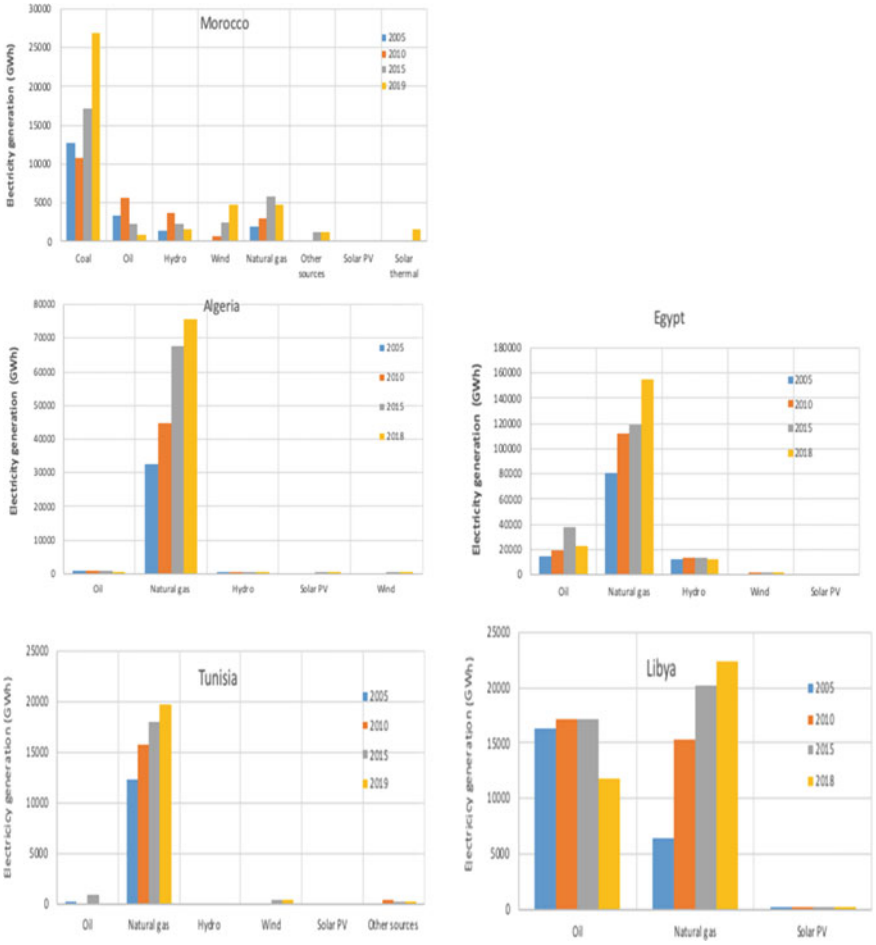
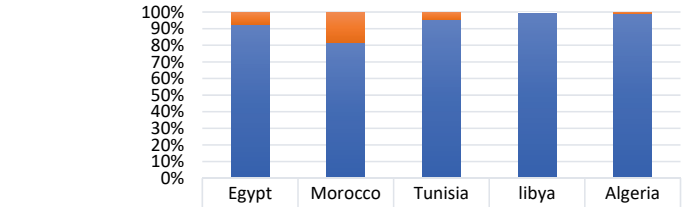


Fig. 1 Evolution of the renewable electricity generation in the region between 2005 and 2019

abroad while also increasing the share of renewable energy in the energy mix. In addition, an annual growth of 57% of coal has been noticed in the national energy transition. This is accompanied by the integration of new technologies at the power plant allowing the reduction of pollutant emissions (clean coal) while benefiting from the very low cost of this fossil energy source. Compared to other energy sources, the natural gas continues to predominate in the other countries of the region with an average annual increase of 17%. The two most widely used renewable energy sources in the southwestern Mediterranean region are solar photovoltaics and wind power, since their cost is continuously decreasing (Agency IRE 2018; Ciriminna et al. 2019). The average contribution of cleaner sources in the production of electricity in this region is thus 7%, with the maximum value of 22% reached in Morocco (Fig. 2). It should be noted, however, that the increase of renewable electricity in



	Egypt	Morocco	Tunisia	libya	Algeria
Renewable electricity genertaion	15.802	9.236	1.023	0.008	0.783
Electrecity genertaion (TWh)	194.069	41.65	20.737	34.171	76.663

Fig. 2 Share of renewable energy in the energy mix

the total production has not been observed in all countries. Morocco has indeed shown a very significant increase between 2010 and 2019 from 18 to 22%, while this evolution remains very low in Algeria and Tunisia from 0.4 to 1.02% and from 4 to 5% respectively, and even negative in Egypt (from 10% in 2010 to 8% in 2019).

Until 2010, hydropower dominated renewable electricity generation throughout the region. However, the hydropower potential is relatively limited compared to solar and wind potential because the available hydropower resources are already exploited to their maximum capacity.

Solar photovoltaics is currently the clean energy source with the highest annual growth rate in the region of 167%. This is explained by its world record low cost reaching one cent for one kWh. In 2019, solar photovoltaic is the second source of energy in Algeria after natural gas. In contrary to Libya, which registered the lowest ratio of clean energy in its energy mix (< 0.02%). This is explained by the war and political instability in the country since 2011.

This rapid increase of the renewable energy share in the region reflects the commitment of most countries to reach their targets in terms of installed renewable capacity by 2020–2030, as shown in Fig. 3 (Et and Pratiques n.d.).

National targets in North Africa are for 84 GW of non-hydropower renewable electricity capacity. Morocco, Tunisia and Egypt are currently the only countries that are on the right track to achieve the renewable energy targets by 2030, considering the development trends achieved between 2015 and 2019. In the next decade, Morocco, Tunisia and Egypt are led, indeed, to continue their deployment of renewable energy capacity with an annual growth rate of 52%, 108% and 211% respectively. For Algeria, it must however double the effort in its energy strategy by ensuring an annual growth rate of 420% in the years ahead compared to its current value of 207%.

Despite this remarkable presence of renewable energy in the southwestern Mediterranean region, ensuring an energy production of more than 26.8 TWh in

Targets	20 GW wind 22.9 GW PV 4.1 GW CSP	5 GW SOLAR 5 GW WIND	1.8 GW WIND 460 MW CSP 1.5 GW PV	1 GW WIND 844 MW PV 375 MW CSP	5 GW WIND 13 GW PV 2 GW CSP 1 GW BIOMASS
Horizon	**2030**	**2030**	**2030**	**2025**	**2030**

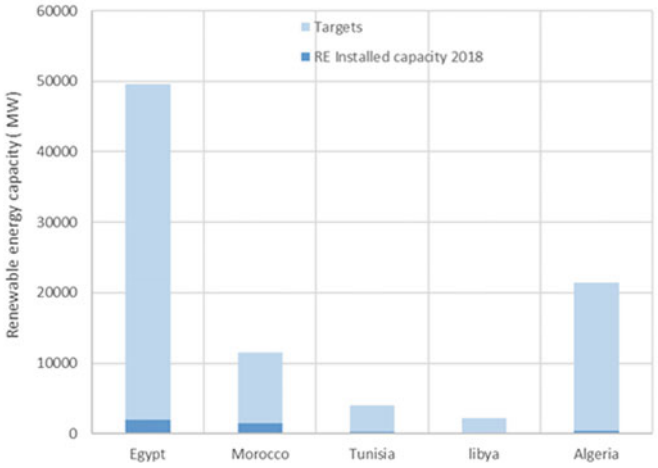


Fig. 3 Energy forecast of each country for 2020–2030 in terms of RE installed capacity (Et and Pratiques n.d.)

2019, this contribution represents only 17% of the overall renewable energy production of the southern Mediterranean region. The constraints and limitations that have hindered this development will be further detailed in the following section.

1.5 Modest Evolution of RE in the Region: Constraints and Limitations

The southwestern Mediterranean region is an excellent potential candidate to have one of the world's largest renewable energy capacities in the future due to the availability of resources and the numerous projects under development. These flagship projects have provided precious feedback at the regional level, in terms of both technical and financial aspects. Nevertheless, the pace of program implementation has been slow in the majority of the region's countries. Several reasons can be advanced to explain this situation (Tagliapietra 2016).

Table 4 Levelized cost of electricity produced by fossil energy 2020 in the Southwestern Mediterranean region

Country	Algeria	Morocco	Tunisia	Egypt	Libya
Lcoe ($/kWh)	0.03	0.09	0.031	0.045	0.0044

- Lower oil and natural gas prices due to government subsidies result in a cheaper and more competitive fossil fuel electricity production than that received by renewable energies (Tables 4 and 5).
- The majority of the region's energy plans have been restricted to public funding, as the use of private funding will require proof of economic viability for these RE projects to be funded.
- Many projects are still in the research and development stage, especially those to be installed in the desert area of the region. Although this zone has the best solar radiation in the whole region, the reliability and cost-effectiveness of solar technologies may be limited by the deposition of dust on the panels resulting from a high concentration of desert aerosols.
- Despite efforts to increase the electricity produced by renewable energies, its share in the final energy consumption will remain low. This is explained by the strong rising trend of other energy intensive sectors such as industry where 70% of energy needs are in heat.
- Geopolitical instability combined with slowing economic growth and low fossil fuel costs have led some countries to revise their targets downwards, such as Egypt and Libya.
- Unavailability of infrastructure and smart grid to receive the excess energy produced by renewable technologies has limited its value by regulation (between 10 and 30% on annual energy production). This has a negative impact on the profitability of the project.
- The cost of renewable electricity in the region is a key barrier to renewable energy deployment, as its average value in North Africa is higher than that obtained globally. This makes it more difficult for investors to engage in the development of these projects. The development of a local industry for renewable equipment is a condition for success, but a balance must be struck to avoid creating higher costs by clearly recognizing where a country can have the best competitive advantage and how to support it through R&D activities.

Table 5 Levelized cost of electricity produced by renewable energy 2020 (Ben and Ramadan 2017)

	Wind	PV	Hydro	Geothermic	Biomass
Lcoe in the Southwestern Mediterranean region ($/kWh)	0.067	0.068	0.055	0.073	0.066
Average Lcoh ($/kWh)	0.039	0.057	0.044	0.071	0.076

Given these obstacles, a few recommendations could be outlined to promote and accelerate the deployment of renewable energy:

- Establish clear and equitable rules to ensure market access for independent power producers while providing a long-term guarantee to private operators on the sale price.
- Phase out subsidies to fossil fuels, considering local socio-economic constraints.
- Accompany the increase of the renewable energy share by investments in the reinforcement and flexibility of the network by adopting, for example, smart grids, energy storage systems and new transmission methods
- Encourage research and development in industrial process electrification to enable the integration of renewable energy in industry.
- Finally, facilitate access to financing with concessional loans for industrials, SMEs and individuals by involving national commercial banks.

2 Research and Innovation Capacities Supporting the Renewable Energy Transition in South Mediterranean Countries

Southern Mediterranean countries have made important strides in structuring and strengthening their national research and innovation systems since the 2000's. The share of the budget allocated to scientific research has increased significantly between 2001 and 2016, passing from 0.19 to 0.72 for Egypt and from 0.55 to 0.75 for Morocco as an example (SCOPUS 2016; Académie Hassan and des Sciences et Techniques 2019).

Impact of research and innovation on the economic development of countries has no longer to be demonstrates. In the renewable energy sector, there is no successful global and local energy transition without innovation. Indeed, (Schaffrin and Fohr 2017) have demonstrated that local energy transition needs to consider the innovation, social, and political perspectives. This chapter section analyses the evolution of science and innovation capacities in the Southern Mediterranean countries which could be a driver toward the renewable energy adoption.

The considered countries in this study are Morocco, Algeria, Tunisia, Libya and Egypt. For some sections data related to Libya are not available or there is are no records in the extracted corpus. The scientific production of the five countries is analysed through a bibliometric approach for the 2000–2020 period relaying on SCOPUS database. We have explored as well the patenting activities through a search of filled patents from native inventors of the five countries during the same period. The data was retrieved from the Espacenet database.

In addition, we have analysed the role of EU-MED cooperation in science and technology through the participation of South Mediterranean countries to the European research programs (FP's and H2020) and join EU-MED programs such: ERANETMED and PRIMA (Zebakh and Finance 2017).

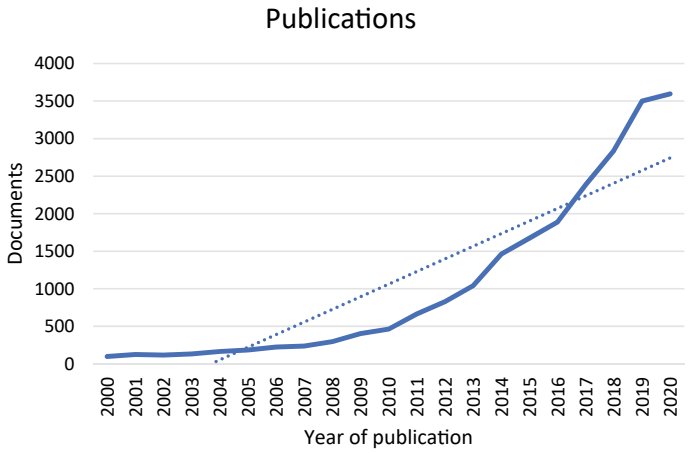


Fig. 4 Evolution of the number of renewable energy publications in South Mediterranean countries based on SCOPUS database (2000–2020)

2.1 Scientific Production in South Mediterranean Countries

- ***Impressive portfolio of publications***

In order to assess the scientific production of the Mediterranean countries, we conducted a bibliometric study based[1] on Scopus database relying on the wide coverage of SCOPUS for the region (SCOPUS 2016). Our research was based on keywords representing the main interest and potential of the south Mediterranean countries as renewable energy, solar energy, wind energy, biomass energy, clean energy, photovoltaic, etc. Our query in Scopus was limited to 2000–2020 period and focused on organizations with affiliations from Morocco, Algeria, Tunisia, Libya and Egypt. The extracted corpus was refined through combined filters. A total record of ***22,326*** contributions is registered for the last 20 years. The documents represent 70% of articles and 30% of conference papers.

The evolution of south Mediterranean countries is presented in Fig. 4. We observe a progressive growth in the number of articles with a significant rise from 2016 for the five countries. Egypt leads the ranking with a total of 8 336 publications, then Algeria with 6417. Tunisia and Morocco generate approximately the same share of outputs close to 3800 documents. Libya is ranked at the 18th position.

- ***Important international collaboration networks***

International collaborations are diversified and established through the co-authorship of publications with the authors from countries such as France, Saudi Arabia, Spain and Japan as presented in Fig. 5. Surprisingly, collaborations are noticed with non-

[1] The search was carried out on the 25.10.21.

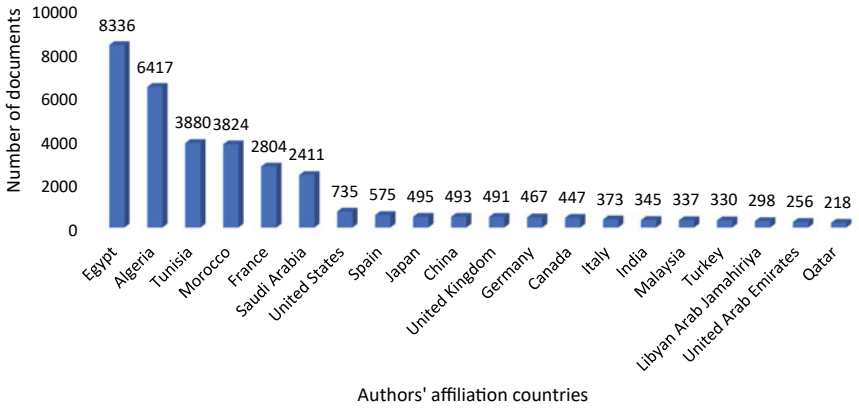


Fig. 5 Renewable energy co-authorship countries' affiliation

traditional partners of the Southern Mediterranean countries such India and Malaysia. Collaboration with EU countries except partners from France, Spain and Italy needs more support considering the availability of EU funding programs involving northern and eastern UE countries.

- ***Reliable research structures***

The main productive institutions are the Algerian Center of Renewable Energy Development, with publications accounting for approximately 5% of total documents, the Egyptians Cairo and Ain Sham universities (8.4%) and Mohammed V University in Morocco that hosts the Mohammedia School of Engineering (7.6%).

Table 6 shows that the top 15 performing institutions are mostly from Egypt. It is worth mentioning the establishment by Southern countries of specific research agencies and research infrastructures in the field of renewable energies. For instance, created in 2011, the Moroccan Research Institute for Solar Energy and New Energies (IRESEN), has stimulated the academia- industry links by offering technological support for the industrialization and marketing of entrepreneurs' innovations. IRESEN is also participating to European programs such LEAP-RE1 (COFUND) program carried by 83 European and African countries.

- ***Need to support papers quality through Journals choice***

A preliminary impression of the quality of the documents can be made through the impact factor of the newspapers. We note here that 46.7% of publications are published in 123 journals. Table 7 presents the list of journals with highest number of publications involving authors from Morocco, Tunisia, Algeria, Egypt and Libya. The 15 first journals in terms of total publications indicate that journals impact factor SJR for 2020 is variable. The Journal "Renewable and sustainable energy reviews,

Table 6 List of the top 15 main productive institutions

Affiliation	Country	Number of papers	% of total
Centre de Développement des Energies Renouvelables	Algeria	1108	5.0
Ain Shams University	Egypt	1015	4.5
Cairo University	Egypt	877	3.9
Mohammed V University in Rabat (435 Ecole Mohammedia des Ingénieurs, 510 Faculté des Sciences)	Morocco	1703	7.6
National Research Centre	Egypt	700	3.1
Université des Sciences et de la Technologie Houari Boumediene	Algeria	681	3.1
Université de Tunis El Manar (543 Ecole Nationale d'ingénieurs de Tunis)	Tunisia	1170	5.2
Tanta university	Egypt	606	2.7
Minia University	Egypt	511	2.3
Alexandria University	Egypt	494	2.2
Mansoura University	Egypt	493	2.2
University of Sfax	Tunisia	489	2.2
Ecole Nationale d'ingénieurs de Sfax	Tunisia	488	2.2
Assiut University	Egypt	484	2.2
Hassan II University of Casablanca	Morocco	484	2.2

with the highest SJR" corresponding to 3.52 records only 1.2 of total publications. 2.5 of the papers are published in Energy Procedia with a lower impact (0.47). More effort is required to motivate and support Southern Mediterranean researchers in the selection of high impact journals in view of enhancing the visibility of their research. A specific study could be useful to evaluate their publication citation in the future.

- ***Confirmed scientists with high expertise***

Table 8 highlights the high expertise of some researchers from Egypt, Algeria, Tunisia and Morocco, with high number of publications in indexed journals. Pr. Kabeel from Tanta University has reached 192 papers and Pr. TRARI from the Algerian university of Houari Boumediane counts 184. The four countries are equitably represented in the top 10 most productive authors. Incentives need to be implemented to award these scientists and encourage young and less productive researchers.

Table 7 Journals classified by number of papers, % of total publication and journal impact

Source title	Number of publications	% of publications	SJR (2020)
Energy Procedia	547	2.5	0.47
Solar Energy	445	2.0	1.34
Renewable Energy	426	1.9	1.83
Energy Conversion and Management	384	1.7	2.74
Renewable and Sustainable Energy Reviews	261	1.2	3.52
International Journal of Hydrogen Energy	260	1.2	1.21
Energy	241	1.1	1.96
International Journal of Renewable Energy Research	228	1.0	0.31
Journal of Materials Science Materials in Electronics	208	0.9	0.49
Desalination	197	0.9	1.79
Optik	197	0.9	0.48
Journal of Alloys and Compounds	191	0.9	1.11
Energies	176	0.8	0.6
AIP Conference Proceedings	162	0.7	0.18
Desalination and Water Treatment	161	0.7	0.25

Table 8 List of the top 10 main prolific authors by institution and country of origin

Author name	Number of papers	Institution	Country
Kabeel A. E.	192	Tanta University	Egypt
Trari M.	184	University of Science and Technology Houari Boumediene	Algeria
Ezzaouia H.	134	Center of Researchs and Technologies Energy	Tunisia
Mellit A.	128	Jijel University	Algeria
Maaroufi M.	112	Mohamed V University	Morocco
Ouassaid M.	107	Mohamed V University	Morocco
Allam N. K.	104	American University in Cairo	Egypt
Yahia I. S.	99	Ain Shams University	Egypt
Amlouk M.	93	University of Tunis El Manar	Tunisia
Kanzari M.	89	Université de Tunis El Manar	Tunisia

- ***Diversified funding organisations***

From 2000 to 2020, 4959 papers representing 60% of total recorded publications, have declared the research sponsorship origin. About 9.4% of the publications cited the King Saud University (Saudi Arabia) as a donor for their research work followed the European programs such the 7th Framework program and Horizon 2020. We note as well the contribution of local Funds and agencies supporting national researchers such the Egyptian Science and Technology Development Fund and the Algerian Ministry of Higher Education and Scientific Research. This support reflects a strong policy commitment to renewable energies research.

The most important financial backers are Saudi Arabia and Qatar as far as the Arab countries are concerned. Other donors such as the Chinese Research Fund also contribute to 3.4% of the projects and the Spanish Ministry of competitiveness to 1.5%. The total list of funding agencies shows the variance of donors: the Chinese cooperation support 308 research ranking China after the EU. The Japanese, Malaysian and Canadian cooperation are listed as well (Table 9).

Table 9 List of the top 15 main funding organizations

Funding agencies	Number of papers	%
King Saud University (Saudi Arabia)	470	9.4
European Commission (66 for the FP7, 64 H2020)	329	6.6
Ministry of Higher Education and Scientific Research (Algeria)	189	3.8
Science and Technology Development Fund (Egypt)	189	3.8
National Natural Science Foundation of China (China)	171	3.4
Centre National Pour la Recherche Scientifique et Technique (Morocco)	145	2.9
Ministry of Higher Education (Egypt)	169	3.4
European Regional Development Fund	108	2.2
King Abdulaziz University (Saudi Arabia)	103	2.1
Qatar National Research Fund (Qatar)	90	1.8
Deanship of Scientific Research King Faisal University (Saudi Arabia)	88	1.8
Direction Générale de la Recherche Scientifique et du Développement Technologique (Algeria)	88	1.8
Ministry of Higher Education and Scientific Research (Algeria)	82	1.6
(Morocco)	82	1.6
Ministerio de Economía y Competitividad (Spain)	75	1.5

2.2 Innovation in the South Mediterranean Countries

The Global Innovation index (GII) classification is considered as a valuable indicator to assess the ability of countries to innovate. The promotion of innovation in the southern Mediterranean countries has known important advances during last decade, through policy implementation, attraction of direct foreign investment, creation of technology parks, etc. However, the Maghreb countries (Tunisia, Algeria and Morocco), the innovation system is still suffering from a lack of connections between the academic world and the production world (Ben and Ramadan 2017).

The ranking of the four national innovation system capacities (Table 10) rank Tunisia in first position, then Morocco, Egypt, and Algeria, considering the Global innovation index for 2020. The data about Libya are not available. The progression of countries between 2012 and 2020 is variable. Morocco notes a constant positioning increase moving from position 88 in 2012 to 75 in 2020. The Tunisian situation is more fluctuating, with a significant loss of positions between 2012 and 2013 and a rebound between 2017 and 2018. The "Knowledge and technology outputs" indicator (Table 10) provides data on the generation of knowledge, which includes scientific articles and patents, as well as knowledge impacts and dissemination. The four countries record a positive trend from 2012 to 2020 as regards to knowledge and technology creation and diffusion. Morocco generates more innovation outputs in comparison to its level of innovation investments in 2020 data (University C Insead WIPO 2020a) and the QS university ranking (48) reveals a strength Human capital and research in Egypt (University C, INSEAD WIPO 2020b).

Looking more closely at the number of patent publications, we conducted an analysis of patents filed by Morocco, Tunisia, Algeria, and Egypt for the period 2000–2020. The Espacenet database has been interrogated with the same keywords used for the bibliometric search (presented in Sect. 2.1). The total results show a of 595 filed patents for the 2000–2020 period, considering the origin of inventors from

Table 10 GII indicators for Tunisia, Algeria, Egypt and Morocco

Global innovation index					Knowledge and technology outputs			
Year	Morocco	Algeria	Tunisia	Egypt	Morocco	Algeria	Tunisia	Egypt
2012	88	124	59	103	80	108	69	92
2013	92	138	70	108	119	115	103	113
2014	84	133	78	99	78	114	106	80
2015	78	126	76	100	73	115	87	79
2016	72	113	77	107	72	100	89	94
2017	72	108	74	105	77	107	69	93
2018	76	110	66	95	78	111	63	66
2019	74	113	73	92	69	113	60	66
2020	75	121	65	96	60	125	52	69

Source GII reports retrieved from https://www.wipo.int

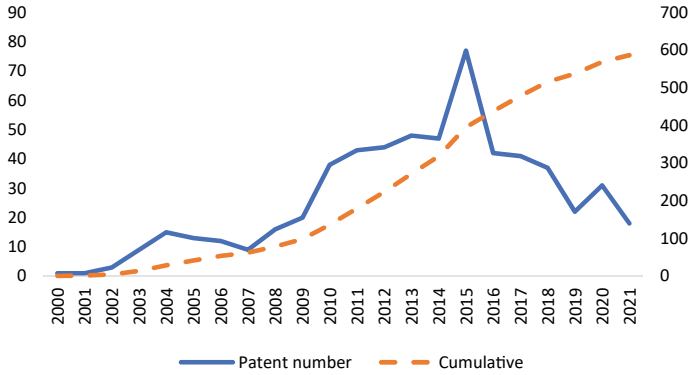


Fig. 6 Patents publication by Morocco, Tunisia, Algeria and Egypt. *Source* Extraction from ESPACENET on the 20.10.21

Morocco, Tunisia, Egypt and Algeria (Fig. 6). No records appear for Libya. Egypt is ranked first with 302 publications and Morocco 121. Tunisia and Algeria rank 89 and 83 respectively. There is an important co-patenting number of these countries with USA (115), France (91), Canada (42) and South Korea (32).

Despite the low number of Tunisian patents compared to other southern Mediterranean countries, other indicators place Tunisia at the top of the Global Innovation Index ranking since the global innovation index relies on 81 metrics that measure the multiple facets of innovation. Patents represents only one indicator for assessing the performance of the innovation system. Tunisia is ranked 7th among the 34 lower middle-income groups and performs well in 5 key areas: human capital and research; infrastructure, knowledge and technology outputs and creative outputs (University C, INSEAD WIPO 2020c).

Furthermore, the level of performance of the 4 countries is depicted in Fig. 7. The level of development of the countries is closely correlated with their levels of innovation. The countries in blue represent the most advanced in innovation. We note that Morocco and Tunisia are regarded as having a higher level of performance than their development level, unlike Egypt and Algeria. The size of the circles is related to the population size of the country.

The 2018 GII report has emphasized on the energy transition in some countries such China, Chile, Singapore, Viet Nam. The various experiences underline the role of innovation as a driving force to reach higher levels of technological and non-technological innovations (University C, INSEAD WIPO 2018). The innovation systems in the south med countries need more support to overcome development challenges.

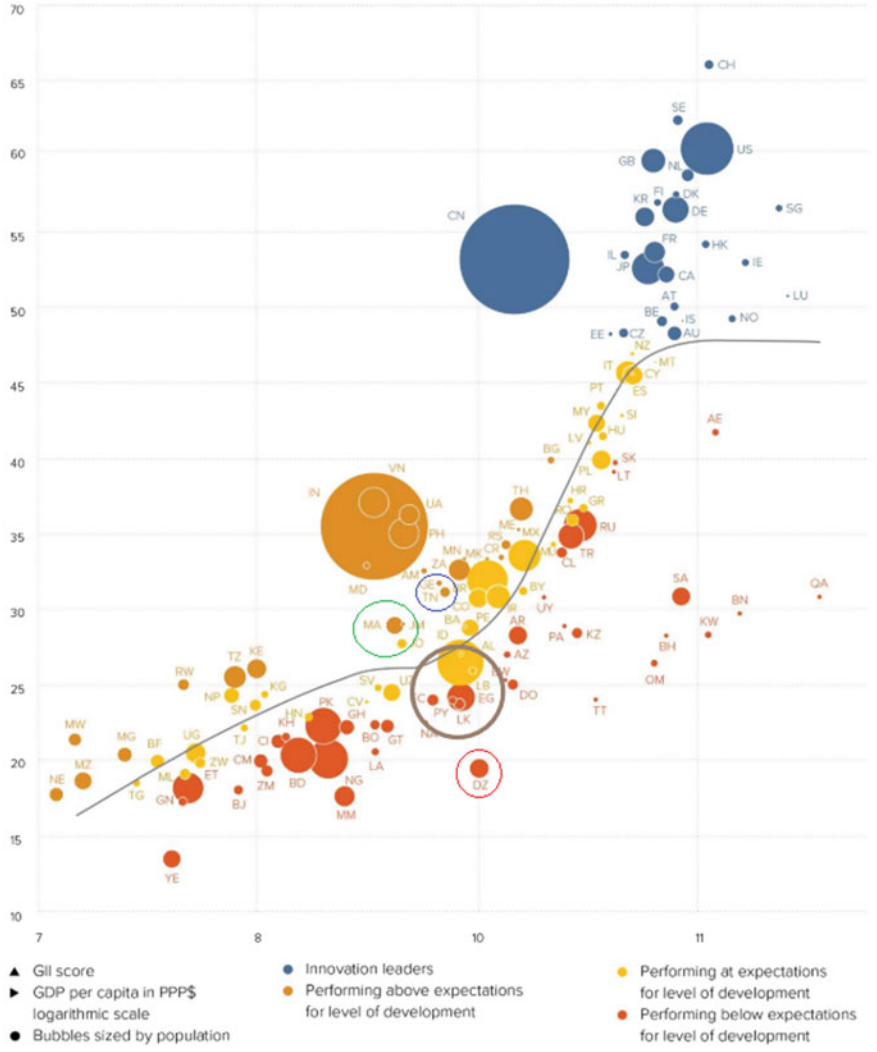


Fig. 7 Economies performance in innovation based on the global innovation index (University C, INSEAD WIPO 2020c)

2.3 Empowering Trans-Mediterranean Renewable Energy Research Cooperation: The EU-Med Research Programs

The Euro-Mediterranean partnership has known significant advances considering policy dialogue and implementation of programs to achieve the Barcelona process objectives. Research and innovation are considered as a pillar to people connection, encouraging exchange and development of human capital (European Commission

1995). The south Mediterranean countries have also taken part in the European Neighbourhood Policy, launched in 2004, which has supported national R&D in several countries such as Algeria, Tunisia and Egypt, between 2007 and 2011 (Zebakh and Finance 2017). Later on, the Union for the Mediterranean (UfM) initiative (2009) stressed on the importance to rationalize the use of natural resources to meet the global climate change. UfM has initiated the implementation of a regional platform on renewable energy and energy efficiency focusing the regulatory framework and the identification of integrated projects to develop energy markets and networks. Recently, on October, 6th 2021, a workshop was organized by the UfM inviting different stakeholders to exchange on the future of Euro-Mediterranean cooperation in Research and Innovation including renewable energy sector.

Furthermore, the last meeting of Ministers in charge of research and innovation from the Union for the Mediterranean (UfM) and the European Union (EU) was held in Malta on 4 May 2017. The resulting declaration on "Strengthening Euro-Mediterranean Cooperation through Research and Innovation, renewed the countries and the European commitment" has encouraged the development of further priorities for future research and innovation cooperation and the support of new join activities in fields such the renewable energy (Maltese Presidency of the Council of the EU 2017).

In the light of these many political engagements to strengthen the Euro-Mediterranean Partnership in Science and Technology, we were curious to examine the levels of collaboration between researchers on both sides of the Mediterranean. The analysis of the number of projects selected as well as the collaboration networks built through these projects are presented in this section. The specific projects related to renewable energy are extracted from the online databases of the European programs FP7, H2020, and the joint programs ERANETMED and PRIMA on the other.

- **Renewable energy projects in FP7**

The participation of the south Mediterranean countries has increased through the successive European Framework programs (Zebakh and Finance 2017). Since the launch of FP7, the European Commission has opened all calls to international cooperation partners. Participation of the southern Mediterranean countries is investigated for Morocco, Tunisia, Algeria, Libya and Egypt, the focus countries of our study. A reading of each of the 320 project's summary has been necessary to determine those related to renewable energies, which are not listed under the FP7 ENERGY program.

A total of 22 projects are funded under the FP7 program (2007–2014) involving 36 institutions from the four countries collaborating with 159 other partners from different EU and non-EU countries.

Morocco has participated in highest number of projects (9) involving 17 national institutions (Table 11). We expect that the Tunisian status, as an associated country to the European framework program since 2013, would distinguish it from other countries with respect to the number of selected projects. FP7 offers different funding schemes depending on the call objectives. South Mediterranean countries mostly participate to both Collaborative projects (CP) and Coordination and Support Actions

Table 11 Number of funded renewable energy projects and partners within FP7, H2020 and ERANETMED programs

	FP7		ERANETMED		H2020	
SMC	No. of energy projects	Number of participants	No. of energy projects	Number of participants	No. of energy projects	Number of participants
DZ	3	3	8	8	3	5
EG	6	11	8	9	5	6
LY	1	1	0	0	0	0
MA	9	17	9	10	9	13
TN	3	4	13	18	3	5
Other Partners	13	159	20	87	14	263
Total	35	195	58	132	34	292

(CSA). Collaborative projects are large-scale integrating projects with a budget up to 10 million Euros or small/medium-scale focused research projects. The CSA have a less limited budget around 1 million euros and aims at accompanying structuring measures such as standardization, dissemination, awareness-raising and communication, networking, coordination or support services, policy dialogues and mutual learning exercises. Examples of funded projects under the two funding schemes are presented hereafter.

- Coordination and support actions

Funded under FP7, the ETRERA 2020 project aims at Empowering Trans-Mediterranean Renewable Energy Research Alliance for Europe 2020 challenges. The project involved 11 countries including the Centre of Research for Energy Technologies (Tunisia) and the Moroccan Cadi Ayyad University. The project improved S&T and entrepreneurial relationships between European Member States and the neighbouring Mediterranean countries, with a focus on wind, photovoltaic, solar, hydrogen and fuel cells and grid connection technologies. The main project results, as presented in the EU cordis database, are:

– the catalogue of competence of the 8 Research centres: research capacity, equipment's, testing facilities, etc.
– a common R&DI strategy/roadmap with policy recommendations and a financial plan
– some tutorial/publication on market and risk assessment, finance opportunities, etc.
– the setting up of a Meta-cluster
– a Public–Private Partnership in RES technologies
– the exchange of best practices and mobility activities from Research to Enterprise
– technological/R&DI and business services

– the organisation of international brokerage events R2B
– the organisation of an international scientific conference.

- Collaborative actions

EUROSUNMED: funded with a budget of 5.2 million euros, the project has developed advanced research of new technologies in three energy field areas, namely photovoltaics (PV), concentrated solar power (CSP) and grid integration (GI), in strong collaboration with research 7 institutes, universities and SMEs from Europe and 6 partners from Morocco and 3from Egypt. The projects have published more than 9 scientific publications and conducted demonstration and testing activities. Indeed, different photovoltaic prototypes fabricated by the partners were tested under real functioning conditions. Several silicon based mini-modules were installed on the roof of three Moroccan universities, namely Rabat, Marrakech and Ifrane, which presents different conditions of altitude, temperature and solar radiation. Training and dissemination actions are also part of the projects.

- **Renewable energy projects within H2020**

The analysis of the South Mediterranean countries' participation in the FP7 (2007–2014) and H2020 (2014–2020) programs indicates a clear interest of researchers from Morocco, Algeria, Tunisia and Egypt in renewable energy projects.

The number of renewable energy projects involving southern Mediterranean countries in Horizon 2020 is about 14. In comparison to FP7, the 14 projects imply a higher number of partners from both Southern Mediterranean, European and non-European countries. Figure 8 illustrates the intensity of the connections between the countries

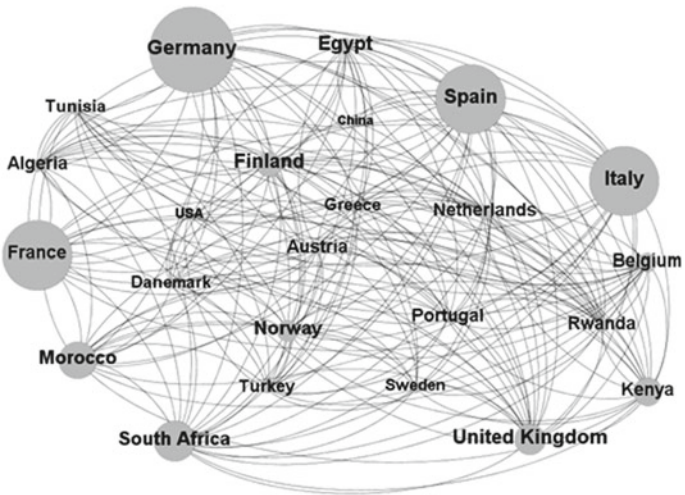


Fig. 8 Collaboration network for renewable energy H2020 projects involving Ma, TN, DZ and EG

that have worked together on the renewable energy research projects, using Gephi tool. The size of bubbles indicates the number of participants in the 14 projects.

- **ERANETMED program**

Funded under FP7, ERANETMED project aims at reducing fragmentation of programming in the Mediterranean region targeting high coordination between national research programs of European Member States, Associated Countries and Mediterranean Partner Countries. The program was launched in 2012 and enabled the funding of 67 projects in the fields of water, food and energy through 3 calls for proposals. South Mediterranean countries committed to ERANETMED co-funding with 6 million of euros. Our analysis resulted to 20 funded projects (30.5% of total projects) involving 132 institutions of which 45 belongs to Morocco, Tunisia, Egypt and Algeria (Table 11). Figure 9 illustrates the collaboration between partners from several countries in the framework of the renewable energy projects supported by the ERANETMED program. The high number of collaborations between the four southern Mediterranean countries demonstrates the development of significant subregional networks. As an example, the selected Projects have focused on design of desalination systems based on optimal usage of multiple renewable energy sources (DESIRES), Development and demonstration of a hybrid CSP-biomass gasification boiler system (BIOSOL). Other projects targeted the Water, Food and Energy nexus such the project HybridBioEnergies related to the development of an innovative hybrid renewable energy plant based on a combination of biomass and solar energy and the project EdGeWIsE dealing with Energy and Water Systems Integration and Management.

- **PRIMA**

Fig. 9 Collaboration network for renewable energy ERANETMED projects involving Ma, TN, DZ and EG

Prima represents a milestone of the Euro-Med policy dialogue in S&T. Prima program is based the article 185 of the European community treaty. PRIMA program has been launched in 2017 and a specific foundation was created in Barcelona to manage the program. This initiative enables the southern Mediterranean countries to play an active role in the design, launch, evaluation and monitoring of research projects addressing the region challenges related to water management, farming system and agri-food value chain. PRIMA calls for projects address the renewable energy topic through the Nexus Calls. However, Farming and water projects are targeting the use of renewable energy. As example, AWESOME will establish collaborations with local industry and SMEs in Egypt to establish models such as solar energy-based aquaponics and hydroponics as well as solar energy-based desalination for food production purposes.

3 Conclusion

The outcomes of this study demonstrate that several factors are in favour of the development of a rapid energy transition in the Southern Mediterranean countries: potential of renewable energy resources, policies and regulation in favour to the energy transition, developing infrastructure, programs and projects, etc.

Although, there is no transition without innovation (IRENA 2021). The implementation of changes needs in-depth research activities to reach innovative solution in products and processes. The analysis of research and innovation potentials of the South MED countries highlighted some key strengths/assets which may be listed as follow: confirmed researchers' expertise, strong sub regional and transnational networks, important portfolio of publications, co-publishing of quality papers, available research infrastructure, and diversity of research sources funding to support collaborative and coordinated actions. However, the innovation part is still weak considering the number of filled patents and the lack of initiatives to valorise the projects' results, confirming the statement of "Arab world has more problems in knowledge use than in knowledge creation" (Hanafi and Arvanitis 2016).

The renewable energy transition in the south Mediterranean countries needs to combine the policy dimensions (first section) with the scientific and innovative dimensions (second section) along with the social dimension.

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