# Action Plan for the Development of Renewable Energy in South and East Mediterranean Countries

Union for the Mediterranean

PLAN SOLAIRE MÉDITERRANÉEN

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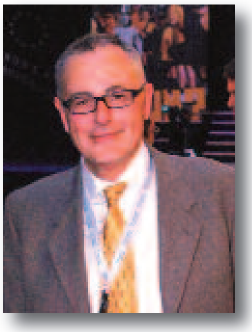
# CONTENT

# EDITORIAL

**By the Director of Directorate K - Energy**
**European Commission - DG for Research**



The Mediterranean region is emblematic of several socio-economic, environmental and energy challenges of the 21st century: demographic an migratory pressure, cross-road between continents and civilizations, sensitive point for the water and climate change issues and key region for the current and future European Energy Supply.

With almost three quarters of the EU imported oil that transit through the Mediterranean Sea, the Mare Nostrum is an important oil turn-table. The Mediterranean Sea also plays a strong role in, the EU natural gas supply through gas pipelines – mostly from Algerian fields to Italy and Spain – and, more and more, through liquefied natural gas (LNG) tankers crossing the Sea towards the EU regasification terminals. The ongoing Mediterranean electricity ring aims to provide the interconnection of electric power transmission grids from Spain to Morocco though the remaining Maghreb countries, on to Egypt and the Mashreq, and from there up to Turkey. From Turkey the electricity ring would then link back into the European grid.

With the renewed Barcelona process and the European energy and climate change package including the strategic energy technology plan (SET-plan), new promising perspectives appear for wind and solar technologies. Both solar and thermal technologies – at low and high temperatures – and photovoltaic's have an enormous potential that has still to be exploited for heating water and for producing electricity in the region. One important task of the upcoming Secretariat of the Union for the Mediterranean will be to explore the feasibility, the development and the creation of a Mediterranean Solar Plan.

The Euro-Mediterranean relations have entered a challenging energy and environment area. While the European Union is committed to reach the Kyoto targets and to ensure a better energy security of supply, the energy demand is increasing rapidly in the Southern and Eastern Mediterranean region with its consequent greenhouse gas emissions. Low-carbon technologies associated to improvements in energy efficiency and change of behaviours are part of the solution to this dilemma.

Beyond peace in the Middle East, the energy and environment questions are at the top of the agenda of the renewed Barcelona process. Research and development, science and technology, education and innovation are key win-win components to extend the Euro-Med partnership. Through several past and current initiatives, including the "Action Plan for the high priority renewable energy initiatives in Southern and Eastern Mediterranean Area" (REMAP), the European Union is demonstrating its willingness to work for a common sustainable development in the region.

After the rivalries between the Carthaginians and the Romans in Antiquity, after being the centre of knowledge in the Middle-Age, the Mediterranean regions should become today an example of smart use of scarce resources. The public authorities, the researchers, the industry and the citizens from both sides of the Mediterranean have to take their responsibility. It is in the interest of future generations.

Raffaele LIBERALI

# 1. Context

## 1.1. Energy in the Mediterranean region: situation and prospects

The Energy sector in the Mediterranean region is confronted with 3 major challenges: allow access to energy for all, ensure the supply in a rational and efficient way to face a fast growing energy demand and limit the impacts on the environment, especially by mastering the greenhouse gas emissions associated with generation and use of energy.

The Mediterranean region is strongly concerned with global warming. Recent IPCC (Intergovernmental Panel on Climate Change) studies have shown that the countries in the region are exposed to the most important warming effects (+ 4 to + 5.5°C in 2090-2099 and - 20% of precipitation at this horizon, as compared to 1980-1999 levels) (IPCC, 2007). Mediterranean countries are then vulnerable to climate change and this raises interrogations and concerns for the socio-economic and energy development in particular and sustainable development in general.

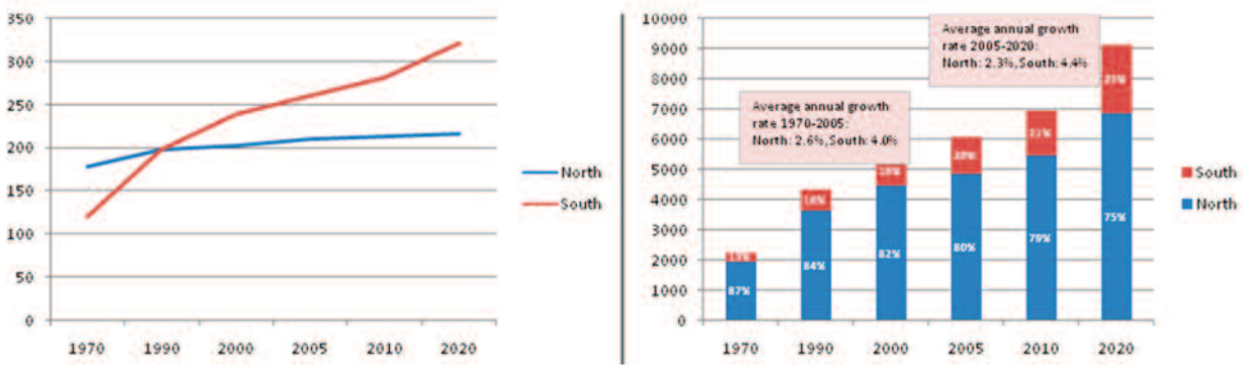
In this context, Mediterranean countries have an interest to prepare together for their long term future. It is a challenge as the obstacles to a better quality of life of an increasing population are numerous: energy and water scarcity, environment deterioration, etc. Gathering all competences and wealths will allow reaching a better path for sustainable development.

There is no unique or standard solution. But in general, a sustainable energy strategy imposes to preserve and use at best the non renewable natural resources, essentially oil and gas, and to promote renewable energy such as solar and wind for which the region is endowed with very abundant resources. This strategy for energy supply should be complemented by an energy efficiency program on both the supply and the demand sides. Such a global approach will bring access to energy, competiveness and security of supply while respecting the environmental constraints.

## 1.2. Global and regional socio-economic trends

In 2005, 470 million people lived in countries bordering the Mediterranean Sea — 45% in the Northern and 55% in the Southern Mediterranean shores. The South Mediterranean population is expected to reach 321 million by 2020, an increase of over sixty million inhabitants. Over the same period, the economic growth in the region is expected to surge at a rate of 4.4% per year on average. The main socio-economic trends illustrated above are summarized in *Figure 1*.

**Figure 1: Main socio-economic trends in the Mediterranean region**




Population growth
Population - million inhabitants

Economic growth
GDP - USD billion using 2000 PPPs

*Source: OME, 2008*

## 1.3. Current and future energy prospects

In its reference scenario, the *Mediterranean Energy Perspectives*[1] publication (OME, 2008) projects an annual growth rate of 1.4%, for a total final energy demand of 0.9 Gtoe in 2020. Most of this increase is expected to take place in the South Mediterranean countries (2.6% annual growth over the period). Through 2020, the South will account for about 36% of energy demand, compared with its current 29%.

The Mediterranean economies rely mainly on gas, oil and nuclear for their energy supply (*Figure 2*). By 2020, the share of gas is expected to further increase, while the share of oil should shrink. Although growing, renewable energy sources are expected to contribute marginally under the reference scenario.

**Figure 2:**
**Current and expected evolution of the primary energy in the Mediterranean region**

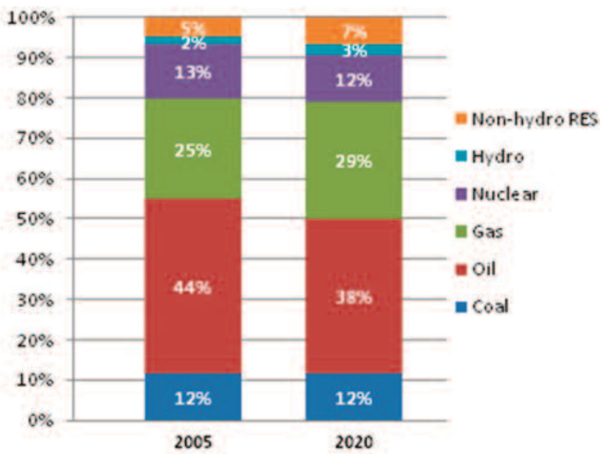
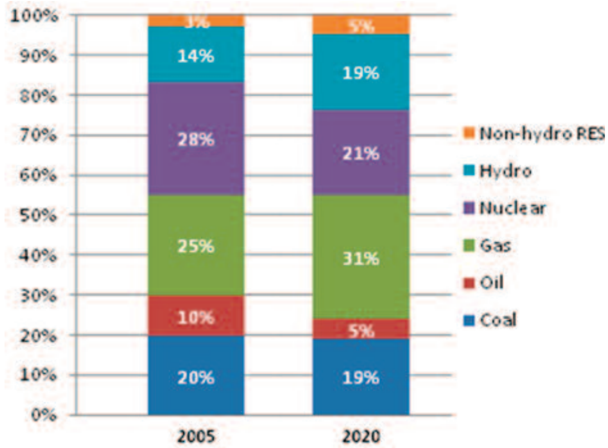



**Figure 3:**
**Current and expected evolution of the electricity production in the Mediterranean region**




*Sources: OME, 2008*

On the supply side, the Mediterranean region holds 4.6% of the world's oil and gas reserves. Over 90% of the total oil and gas reserves in the region are concentrated in three countries: Libya, Algeria and Egypt.

As a result of the energy demand increase, it is expected that in 2020 the Mediterranean region will be importing over 30% of its oil needs and 27% of its natural gas needs. Considering the burdens this will involve both on the economies and the environment, promoting energy efficiency and developing renewable energy is clearly a high priority and a win-win strategy for all countries. Electricity needs are growing more rapidly than energy demand in the Mediterranean (+ 53% by 2020). 191 GW net additional capacity will be installed in the Mediterranean region up to 2020 of which 84 GW in the North and 107 GW in the South.

As shown in *Figure 3*, natural gas and hydro shares in electricity generation are expected to increase significantly whereas oil and nuclear are expected to decline. Even though hydro and non-hydro renewable electricity production remains small in absolute values, these technologies are expected to be the fastest-growing energy sources throughout the projected period, with more than 5% per year average increase. In 2020, they should represent about 24% of electricity generation (653 TWh) in the Mediterranean.

[1] The MEP reference scenario is a business-as-usual model, which takes into account only existing policies and measures. It is not based on the potential of any given technology, but only on its actual exploitation. These aspects are particularly important for renewables, since several policies are currently under discussion or are being implemented in order to stimulate their contribution in the future energy supply mix. A successful implementation of these policies and measures should lead to a higher share of renewable in the region. The full version of the MEP 2008 is available at www.ome.org.

## 1.4. The current and potential role of renewables under a business as usual trend

The Mediterranean region is endowed with important renewable energy resources and particularly solar and wind, for which the region has some of the most promising sites in the world. In the South and East Mediterranean region, sunny hours vary from 2 650 to 3 400 hours per year and the average annual radiation varies between 1 300 $kWh/m^2$/year at worst to 3 200 $kWh/m^2$/year. Wind potential is also particularly high, with wind speed ranging between 6 and 11 m/s. The region has also an important potential in biomass, geothermal and hydraulic resources.

In 2005, renewables (excluding large hydro) installed capacity in the South Mediterranean countries was about 1 GW. According to the OME scenario, it would reach 14 GW by 2020 (7% of total installed capacity by then). Under this scenario, renewables would account for 4% of primary energy demand and 3% of electricity generation by 2020.

Tapping the potential for renewables in the Mediterranean region and promoting energy efficiency will require enhanced cooperation. Leading initiatives such as the Euro-Mediterranean Partnership (Barcelona Process) have already provided a framework for market integration and policy harmonization. However, the many challenges facing the region call for strengthening this integration in the energy field. To this end, the recent launch of the Union for the Mediterranean (UfM) represents a key step toward greater cooperation between both shores of the Mediterranean. The Mediterranean Solar Plan, one of the key priorities set by the UfM is a great opportunity for the strengthening of the regional cooperation around a common and shared sustainable energy future.

In this framework, the REMAP project provides better knowledge on the wind and solar resources available in the Mediterranean region and opportunities to invest in wind and CSP projects particularly in Algeria, Tunisia, Jordan and Turkey. Thanks to a close cooperation with national stakeholders, it brings information about the priorities given by these different countries to the implementation of CSP and wind power projects. The project develops adapted financing schemes for the implementation of the projects. According to the results of the project, the present Action Plan intends to give some guidance on how to promote CSP and wind in the Mediterranean region, which are detailed hereafter.

# 2. The REMAP Project and how to promote CSP and wind in the Mediterranean region

## *2.1.* Necessary Activities to Promote CSP Technologies in the Southern and Eastern Mediterranean Region - REMAP Action Plan

A number of CSP concepts are technically mature as it can be seen from the recently implemented projects in Spain and the USA. Getting CSP to work in the southern and eastern Mediterranean area needs to set up the right framework conditions to make such projects viable for investors. There are two main fields of action: The first one is to make available reliable planning data. The available solar resource is one of the most important input factors into the economic assessment. Secondly, projects need reliable economic frame conditions, either fixed feed in tariffs or long term power purchase agreements to secure the return on investment.

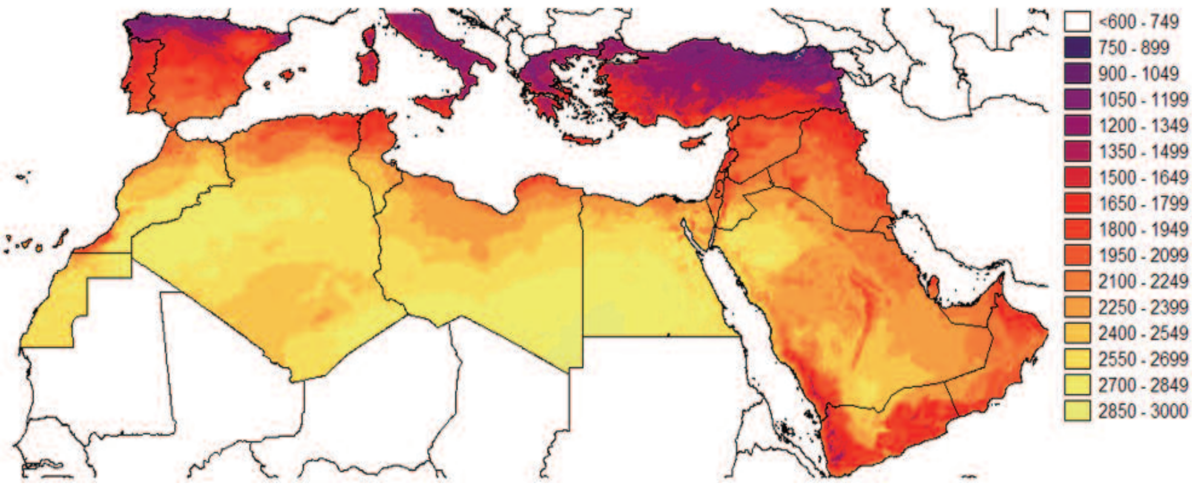
***a - High Quality Solar Energy Resource Assessment***

Solar radiation is the "fuel" of solar energy systems. Its availability directly determines the economic income of solar power plants; the knowledge of the resource is therefore a key for investment.

The direct normal irradiance is the amount of solar radiation arriving directly from the sun (ignoring radiation from the rest of the sky), and falling onto a plane perpendicular to the direction of the sun. It can be used for electricity generation via concentrating solar thermal power plants. Direct irradiance has the advantage that it can be concentrated with mirrors to reach high temperatures, and the disadvantage that it is only available in cloud free situations and in regions with high levels of solar radiation.

The available solar irradiance is mapped from remote sensing data. It is based on images from geostationary meteorological satellites, which are used to map the cloud amount. The methodology is described in detail for direct normal irradiance in (Schillings et al., 2004) and for global irradiance in (Hammer et al., 2003) and (Rigollier et al, 2004). On the other hand, global irradiance is an important parameter for photovoltaic systems and flat plate collectors.

**Figure 4:Annual direct normal irradiance in the Mediterranean region in the year 2002 in kWh/m²/y.**



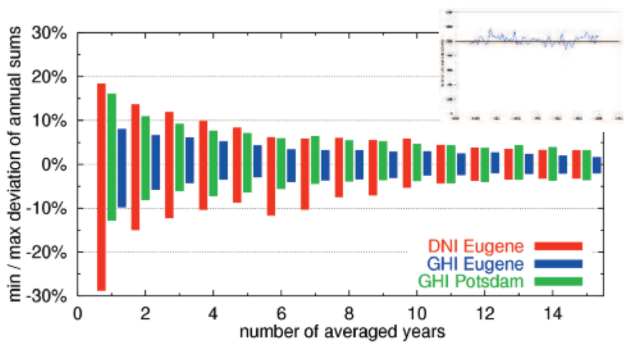

*Source: DLR*

*Figure 4* shows the annual sum of the direct normal irradiance in the Mediterranean Region in kWh/m²/y for the year 2002. This map gives a first indication for the assessment of potentials, but it is not enough for project development and investment decisions. The reason will be explained in the following chapters.

## b - Characteristics of Solar Energy

Solar radiation is highly variable in time and space. The annual sum of incoming solar radiation can change significantly from year to year due to varying weather conditions. *Figure 5* shows the annual variability of global horizontal and direct normal radiation at two sites in Germany and the USA. The small figure on top shows a time series of annual sums of global horizontal radiation in Potsdam from 1937 to 2000. The lower graph shows the maximum deviations of moving averages from 1 to 15 years compared to the long term average of all years in the data sets. It can be seen that at least 10 years of data are necessary to stay within the limit of ±5% of the long term average. This has nothing do to with the uncertainty of measurements or models, this is just natural variability. This curve shows that if a project is based on a short term measurements of only a year or two, the estimation of the resource may be far away from what can be expected at this site in the long term.

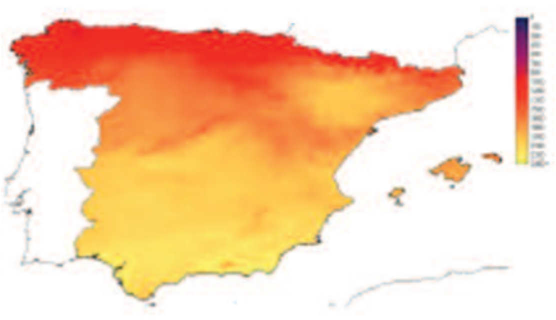
**Figure 5: Annual variability of solar radiation**



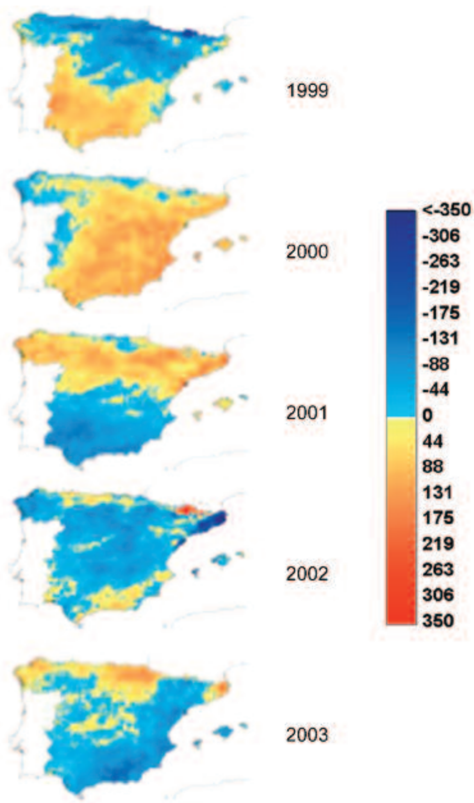

*Source: DLR*

*Figure 6* shows the spatial variability of solar radiation. The left figure is a five year average of direct normal radiation in Spain. The right figures show the annual differences in each year. The patterns are quite different each year and the deviation changes over a short distance. This means if one knows the deviation of data for the current year to a long term average on one site, one cannot transfer this result to the next site. Resource assessments have to be site specific.

**Figure 6:**
**Spatial variability of the solar radiation**



Average of the direct normal irradiance (DNI)
based from 1999 to 2003.




*Source: DLR*

These two examples show two important features of good solar energy resource assessment: it needs to be based on long term data (at least 10 years) and must have a high spatial resolution of a few kilometres. Satellite based resource assessments can provide both: satellite raw data is archived for many years and data from meteorological satellites in geostationary orbits has a very high spatial resolution.

But satellite data has limitations e.g. in temporal resolutions and sometimes cannot model all local effects as some of the input data sets (e.g. currently aerosols) are not available in high spatial resolution. Ground measurements are therefore a necessary and helpful addition to satellite base resource assessment. A major advantage is that ground-based instruments can register the solar radiation at very high temporal sampling rates of 1 min or even lower. Such data is very useful for modelling transient effects in solar thermal systems e.g. at sunrise and sunset or the passage of a cloud.

Ground measurements are a labour intensive task. High quality measurement systems use at least three sensors for global horizontal, diffuse horizontal and direct normal irradiance. The measurement of diffuse and direct normal radiation needs a precise tracking of the path of the sun. Especially in dusty regions such as deserts the instruments need regular maintenance and cleaning, at best every day. In addition, the measured data has to be quality controlled on a regular basis. Measurement of all three quantities will help to assure the highest quality as checking the sum of direct and diffuse which should equal the global radiation is one of the most strict quality control options. If the measurement is not checked and controlled regularly, the measured data will be meaningless. If such data sets are recorded successfully they will have a very high value for solar energy resource assessment but also for other scientific work such as climate research or development and validation of new remote sensing methods among others.

A true high quality resource assessment should provide both long term data with high spatial resolution based on remote sensing methods and ground measurements with high quality and high temporal resolution at selected sites within the resource assessment region. Such a data set will allow in-depth analysis of solar system performance for improvement of the systems or for reliable bankability of projects.

**Figure 7:**
**A high quality solar radiation ground measurement station. The tracker follows the path of the sun. The ball on the right hand side blocks out the sun for the diffuse radiation measurement.**

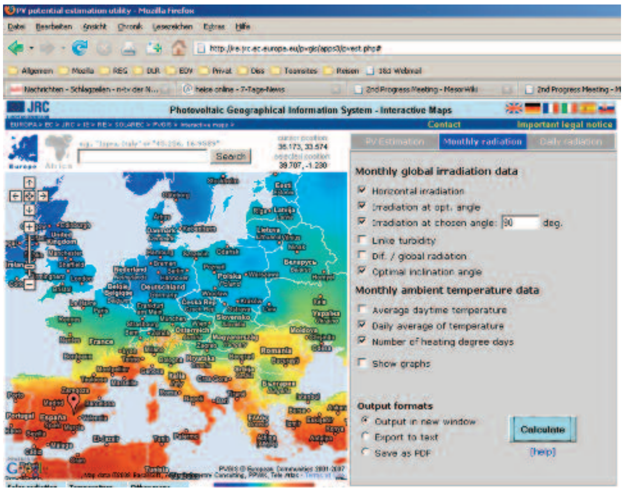
### *c - Access to solar resource data*

Creating high quality resource data is the first task in creating a database for the successful deployment of solar energy. Making it available to the users is the second task. Europe has several examples on how the data can be brought to users; two recent examples are PVGIS and the SoDa/MESoR portals.

PVGIS is a web service for global radiation in Europe and Africa. It brings an easy to use Google maps type interface. *Figure 8* shows a sample of this interface. The user can select a site of interest by moving through the maps. On the right hand side, he can select which solar radiation quantities he is interested in. PVGIS also includes simple performance models for the estimation of PV-yields. Users wanting to install PV systems can very quickly get a first estimate of what they can expect from a PV system at their site of interest.

PVGIS does not include direct normal radiation. It is therefore not usable in the first assessment of concentrating solar power.

**Figure 8: PVGIS Interface to solar radiation and simple PV-performance models.**



The SoDa and its successor prototype, the new MESoR portal, use a different approach in gaining access to solar resource data. They act as an agent who connects different sources and applications through the internet. The data source and applications are hosted by their providers. The portals connect different sources and models to derive user specific results. A user can select one source of data and a performance model of another provider to calculate the expected yield of a system.

*Figure 9* shows a sample of the MESoR portal. Data sources can be selected from a menu. In this way the user has the same look and feel in accessing the data for different sources. The window on the right shows a sample of an extracted time series. The connected sources use standard internet protocols; therefore an automated access to the data source from software is possible.

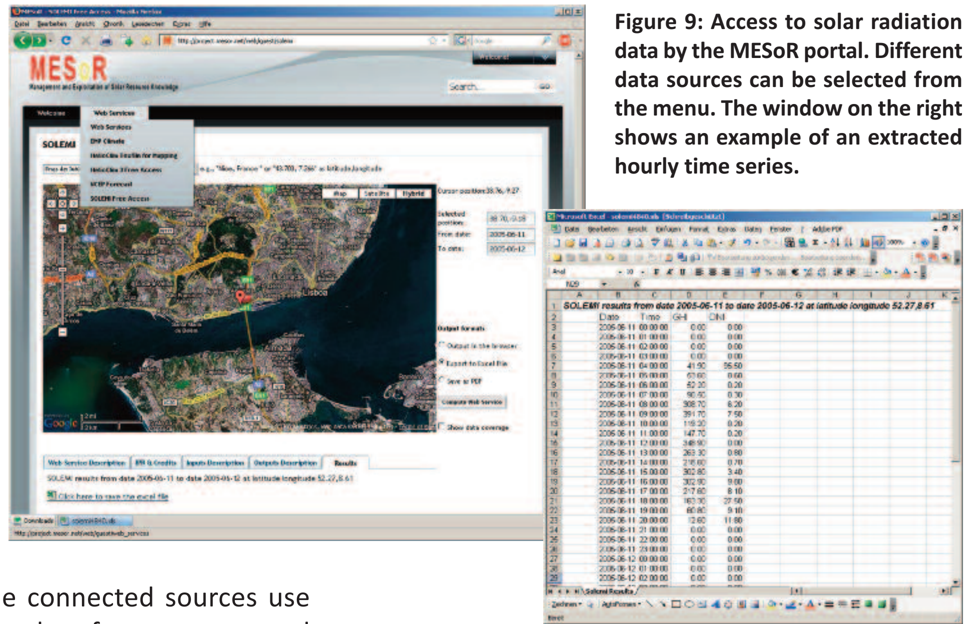


**Figure 9: Access to solar radiation data by the MESoR portal. Different data sources can be selected from the menu. The window on the right shows an example of an extracted hourly time series.**

### *d - How to finance CSP plants in the MENA Region*

The feed-in tariff systems established in Germany and Spain within the respective renewable energy act are very successful examples for the market introduction of renewable energy in the power sector. However, it is difficult to transfer those schemes to the Southern and Eastern Mediterranean region, due to the fact that Southern and Eastern Mediterranean utilities are often by law forced to offer electricity to their clients below the production cost.

However, there may not even be a contradiction, if real costs are applied to the electricity produced. Southern and Eastern Mediterranean countries see a growing peak electricity demand, which is due to increasing loads from air conditioning. Peak load is usually covered by electricity from oil-fired gas turbines that are quickly put into operation when the peak load occurs. Considering for example a long-term average spot price of 60 US$/MWh for heating oil (fuel #2) and efficiency of peaking gas turbines of about 20%, this translates into a peak electricity cost of 30 ct/kWh, not accounting for the capital and maintenance cost of the related gas turbines.

Concentrating solar power (CSP) stations can deliver solar electricity at costs between 20 and 30 ct/kWh depending on solar irradiation conditions. In the Southern and Eastern Mediterranean region even lower costs can be expected due to the high solar irradiation given in most countries. It can also be shown by time series analysis comparing the electric load with the power supply from such CSP plants, that a solar power station can cut off electricity peaks completely, totally substituting the need for peaking gas turbines, and at a lower cost than those.

Therefore, Southern and Eastern Mediterranean countries offering to CSP projects a long-term power purchase agreement (PPA) based on the real cost of peaking electricity would not only profit from introducing a new domestic, sustainable source of electricity, but would also save money starting with the first CSP plant installed and guard against any future fuel price escalation.

Because of the abundant availability of the sun as resource in the Southern and Eastern Mediterranean region, it is wise for these countries to start harvesting this sustainable resource and build the expertise locally by accepting JVs with external partners setting up a number of projects. Next to the transfer of knowledge it will initiate mass production of CSP-components, resulting in declining prices, which will make the technology even more competitive when the region is ready to roll it out en masse. Another element which will potentially make CSP even cheaper in the future is the fact that not all components of a CSP-installation are limited to the generally accepted useful life of 15 – 20 years resulting in lower repowering costs for a second life at the site.

As mentioned, general technical and economic advancement of CSP industry will allow for a step-by-step reduction of tariffs, thus really providing least cost electricity to Southern and Eastern Mediterranean consumers, in contrast to a fuel-based supply that may become more and more expensive. The establishment of long-term power purchase agreements for CSP-electricity has the following advantages for the Southern and Eastern Mediterranean region:

1 - Tariffs (PPA) for newly installed capacity can be adjusted year by year taking into account advancements of CSP industry, inflation rates, general cost escalation related to energy etc. to optimize the benefits for the region and to minimize the country's necessary investments for the market introduction of this new domestic energy source.

2 - Southern and Eastern Mediterranean governments or utilities can individually control the total capacity related to each tariff level and adjust the capacity to be installed year by year according to the needs of each country, thus optimizing the total cost of market introduction and maximizing the cost savings achieved by the CSP plants.

3 - The Southern and Eastern Mediterranean countries can tap a new, very large and sustainable source of energy that is domestic to the region with relatively low public investment.

4 - This new source can support economic development of the Southern and Eastern Mediterranean region and may also become a potential export product in terms of solar electricity (and later eventually solar hydrogen) for Europe.

We are convinced CSP has the potential to create a real win-win situation between foreign investors (industrial and/or financial) and the Southern and Eastern Mediterranean countries if lessons are learned from the support schemes in e.g. Europe:

1 - Introduction of the technology can be made cheaper by offering project investors a better visibility on project cash flows over a longer time period (countries adopting feed-in tariffs have obtained lower electricity production costs than the system of certificates).

2 - The possibility to sell electricity in neighbouring countries adds flexibility and lowers the risk for a project.

3 - Transparency for all project aspects (permits, legal advise, fiscal treatment, …) reduces perceived risk ("guichet unique").

4 - Commitment said and shown by all levels of policy making will credit to the believes for long term stability of the positive investment environment.

## e -Necessary conditions for successful CSP implementation in the South and East Mediterranean

**1 - Reliable resource assessments of direct normal irradiance :**

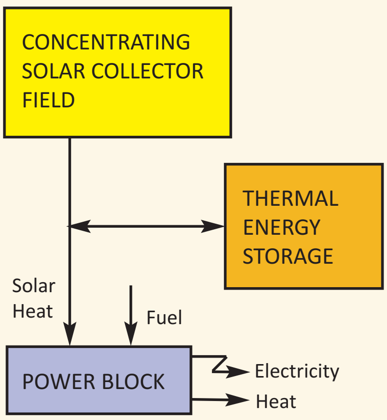
- The available resource is one of the most important parameters in the economic assessment.
- The resource assessments have to cover long periods of time (at least 10 years) and should have a high spatial resolution of a few kilometres.
- Remote sensing and modelling can provide high resolution long term maps helping project developers to successfully select sites for the most economic projects.
- A measurement campaign can complement the resource maps, giving site specific data in high temporal resolution for detailed system design studies and research and development for CSP technology.

**2 - Reliable economic conditions**

- Investors need a reasonable return on investment within the loan period.
- Fixed feed in tariffs or long term power purchase agreements can ensure the return on investment. These tariffs and agreements should be fixed for the loan period.
- Tariffs and power purchase agreements can be adjusted for new installations according to the cost development of CSP technology.
- CSP tariffs should be related to the real cost of conventional power plants they can replace. As a first economic market niche, they can replace daytime peaking plants. With thermal storage and/or hybrid solar-fuel operation, they can also provide night time peaking power on demand.

### Box 1: Solar Thermal Power Plants : Solar Collectors instead of Fuel

Solar Power Towers (left) and Parabolic Trough Power Plants (centre) as well as Linear Fresnel Systems (right) are concentrating solar power technologies. Parabolic trough plants with 425 MW of presently installed capacity are in commercial operation since many years and projects with several 1000 MW are under development. Power Towers (30 MW) and Linear Fresnel Systems (7 MW) have been demonstrated successfully.




The technical principle is quite simple: high temperature heat from a concentrating solar collector is used to operate a conventional thermal power cycle like e.g. a steam turbine, a gas turbine or Stirling engine. Solar heat can be stored during the day in concrete, molten salt, ceramics or phase change media. At night, it can be extracted from the storage to run the power block. Fossil and renewable fuels like oil, gas and organic waste can be used for co-firing the plant, allowing a granted power availability for base load or peak load demand. Co-generation of electricity and heat is particularly interesting as the high value solar input energy is used with the best possible efficiency, industrial process heat, district cooling and sea water desalination. Solar thermal power plants will have a considerable share on clean electricity generation. They are among the best suited technologies to achieve the global goals of emission reduction. Energy payback time of a solar thermal power plants is in the order of 0,5 years.

***Source: DLR***

## 2.2. Future activities in wind energy for the Mediterranean region REMAP Action Plan

### a - Barriers identified within REMAP

According to the results of the REMAP project, a number of barriers have been identified for the implementation of wind power projects in the Mediterranean region. These are:

#### 1 - Lack of resource data

*Type of data*: there is a general lack of valid data concerning the wind resources in Mediterranean countries. Data found in electronic format are mostly images (pdf, jpeg, etc) where no data can be extracted. Often there are only printed documents. Concerning GIS data sets, there is very limited coverage, and the data sometimes are very old (more than 10 years).

*Availability of the data*: very often data are not public or easily available. A number of country specific data sets are available but they are sometimes confidential or undisclosed.

#### 2 - Technical barriers

Wind power technology is mature and is in that sense well known to national stakeholders and widely accepted as a reliable alternative to conventional electricity generation technologies. But since wind is a variable energy source, and it is rather difficult to predict its variation, care has to be taken when integrating large wind farms in existing electric power grids in order to avoid grid failures. Also, it was observed that grids are generally weak in target regions, which could hinder development of wind power if the grid is not improved. And in case of small remote grids, electricity storage solutions could also be considered, even though such technologies remain expensive at the time of writing.

In conclusion, if no particular conditions are set regarding large-scale integration of wind power in countries with a low penetration of such technology, wind power development could be hindered by issues with grid management, grid instability and even grid failure.

#### 3 - Financial and political barriers

Even though it is one of the cheapest renewable energy based electricity generation technologies, wind energy is still expensive compared to conventional generation technologies and is highly dependent on the financial framework (i.e., feed-in tariff, grid integration cost, etc.) to become successful in regions where this technology is not currently widely developed.

Moreover; the legal and institutional framework is not always adequate in some countries. Barriers for investors include high capital costs, technical risks, financial risks, and competing fuels whose full costs are not accounted for (subsidies, environmental externalities etc), as well as uncertain policies, inadequate legal frameworks, lack of infrastructure, and lack of regional power sharing agreements and networks. Given the uncertainties of future business, the supply industries have operated on the basis of serving one-off customers instead of setting up complete R&D, large-scale manufacturing, and operations and maintenance programs. The result is very high cost, underexploited economies of scale, and limited investment in R&D leading to technology development and innovation.

### b - Future Action Plan - Wind

#### 1 - Resource atlas for the Mediterranean region

High quality resource assessments are part of the basic infrastructure for market development and investments into any given energy technology. From the experience collected through the REMAP project, there is a need to set up a Wind resource atlas for the Mediterranean region to attract foreign investors and industries.

The Wind resource atlas should consist of:

- maps and data created by remote sensing and numerical modeling, including detailed terrain models, land cover classifications to derive roughness for the whole region;
- high quality ground measurement network, measurement stations well characterized by its surrounding roughness;
- online access to the data;
- long term series of data.

Wind resource assessment usually uses the WAsP approach (Wind Atlas Analysis and Application Program) developed by the Riso National Laboratory in Denmark for the European Wind Atlas. WAsP uses a flow model to predict the wind behavior above the ground, including orography, roughness, obstacles and adjacent turbines. Local effects at the measurement stations have to be removed to derive a generalized wind climate. To do a site assessment at a different site, the generalized wind climate is taken and fitted back to the local site conditions.

An alternative is the use of Meso-Scale numerical weather models, which also need high quality input data.

**2 - Explore new sites possibilities:**

- *Second class sites*: In some Mediterranean countries, like Tunisia or Turkey, where the saturation point has already almost been reached for "first class" sites, and the technology is well known by national stake-holders, it is needed to study the possibilities of exploiting "second class" wind sites, in order to meet the demand needs. At medium-long term, technical developments and grid integration improvement will lower the costs and raise the operational profitability and return on investment of the projects.
- *Off-shore*: Off-shore development of wind power plants was out of the scope of REMAP project, which was based on existing data. But the off-shore potential of the Mediterranean region should be studied and needs a particular and different analysis, including wind resource assessment, technology development and financing schemes.

**3 - Financing schemes and local energy policies**

*Local energy policies* are key to trigger investments. They should be "custom made", tailored to the characteristics of the technologies, ensuring those will be profitable, functional and meet local energy needs.

- Future research should focus on a suitable "instrument mix" rather than opposing various tools;
- Prices reflecting overall investment costs;
- Control and command (standards and labels);
- PPP;
- Feed-in tariffs;
- Quality guarantee.

Mature technologies as wind require adapted financing schemes and effective support policies, which should provide reasonable financial incentives but also address non-economic barriers (installation permits, authorization procedures, grid access, grid design and operation and social acceptance).

Proposed wind power investments and project structure have to be better conceived to minimize risks. Future projects must show clear benefits and strong economic returns, while project developers must demonstrate how they can minimise risk better than other projects competing for finance. The level of predictability is more important than the incentive in itself. Government and stakeholder support will be essential to demonstrate risks are lower.

**4 - Know-how and technology transfer**

The lack of local skills is often a barrier for investors. Even mature technologies are not systematically deployed. Therefore, there is a need to rely on local skills rather than simply importing technologies from developed countries for design, operation and maintenance of the wind power plants.

Technology Transfer requires specific knowledge. Various possibilities can be studied for collaboration in terms of research between the North and the South regions; as for example establishing regional or international joint ventures to enhance competitiveness; and making the most of local capabilities and know-how.

Besides, joint research projects between European and Mediterranean partners can further improve the methods and develop new services.

The following points have to be addressed to foster technology transfer and guide future research initiatives:

- Improve the quality of energy policy;
- Share best practices;
- Foster innovation locally;
- Deal with power sector specificities regarding knowledge sharing, technology transfer and timeframe.

## Box 2 - Wind Energy - State of the Art

Wind energy is a power generation source with variable output, but turbines and farms have been designed to cope effectively with variations from both the supply and the demand side through their configuration, control systems and interconnection. Wind turbines are complex machines which consist of subsystems to catch the wind's energy, point the turbine into the wind, convert mechanical rotation into electrical power, and systems to start, stop, and control the turbine.

***Types of Wind Turbines***

Modern wind turbines fall into two basic groups: the horizontal-axis variety, as shown in the photo, and the vertical-axis design, like the eggbeater-style Darrieus model, named after its French inventor. Nowadays, the majority of commercial turbines are horizontal-axis wind turbines (HAWT). Horizontal-axis wind typically either have two or three blades. These three-bladed wind turbines are operated "upwind", with the blades facing into the wind.

**A modern wind turbine produces 180 times more electricity per year than its 1980s equivalent, as less than half the cost per unit.**

***Sizes of Wind Turbines***

Utility-scale turbines range in size from 500 kilowatts to as large as several megawatts. Larger turbines are grouped together into wind farms, which provide bulk power to the electrical grid. **One 1 MW turbine produces power for around 650 EU households**, the average size of turbines being manufactured today being around 2 MW.

The 3.6 megawatt wind turbine shown here is one of the largest prototypes ever erected, even though prototypes of up to 7 MW were designed. The common trend of these larger capacity designs are larger and larger turbine blades. Covering a larger area effectively increases the tip-speed ratio of a turbine at a given wind speed, thus increasing the energy extraction capability of a turbine system. Typical modern wind turbines have diameters of 40 to 90 meters.

For HAWTs, tower heights approximately two to three times the blade length have been found to balance material costs of the tower against better utilization of the more expensive active components. Hub height can therefore easily reach from 80 to 120 meters. Modern wind turbines are able to operate across a wide range of wind speeds from 3-4 meters per second up to gale force, and electricity grids are equipped to deal with uncertainties.

***Generator***

Typically wind turbines generate electricity asynchronous machines that are directly connected with the electricity grid. Older style wind generators rotate at a constant speed, to match power line frequency, which allowed the use of less costly induction generators. But never wind turbines often turn at whatever speed generates electricity most efficiently. This can be solved using multiple technologies such as doubly fed induction generators or full-effect converters where the variable frequency current produced is converted to DC and then back to AC, matching the line frequency and voltage. Although such alternatives require costly equipment and cause power loss, the turbine can capture a significantly larger fraction of the wind energy. In some cases, especially when turbines are sited offshore, the DC energy will be transmitted from the turbine to a central (onshore) inverter for connection to the grid. Nowadays, some large wind generators even use direct-drive generators with permanent magnets, thus reducing mechanical complexity, even though at higher cost. For large, commercial size horizontal-axis wind turbines, the generator is mounted in a nacelle at the top of a tower, behind the hub of the turbine rotor.

***Blades***

Current production wind turbines blades are manufactured as large as 90 meters in diameter with prototypes in the range of 100 to 120 meters. New materials and manufacturing methods provide the opportunity to improve wind turbine efficiency by allowing for larger, stronger blades. Carbon fiber reinforced blades have recently been identified as a cost-effective means for reducing weight and increasing stiffness.

***Grid Integration***

Understanding and predicting wind variations is essential for successfully integrating wind power into the power system and to use it most efficiently, and continuous advances are being made in improving forecasting techniques. Doubly-fed machines, or wind turbines with solid-state converters between the turbine generator and the collector system, have generally more desirable properties for grid interconnection.

***Source: ACCIONA***

## About REMAP

REMAP is an Action Plan for high-priority renewable energy initiatives in Southern and Eastern Mediterranean area. The Southern and Eastern Mediterranean Countries (SEMCs) involved in the project are Algeria, Tunisia, Jordan and Turkey.

The objectives of the project are to work with key stakeholders in order to achieve the following:

- State of the art and synthesis of the renewable Atlas in the SEMCs.
- Identification and prioritization of potential demonstration sites for wind and CSP in the SEMCs.
- Commitments by major stakeholders towards wind and energy CSP integration in the SEMCs.
- Proposal for adapted financing schemes for the identified priority demonstration projects.
- Elaboration of an Action Plan for a few well identified initiatives able to be implemented.
- Dissemination of the results of the project to a wide audience in Europe and in the Mediterranean region.

## The PARTNERS

| Participant name | Short name | Country |
|---|---|---|
| Observatoire Méditerranéen de l'Energie (coordinator) | OME | France |
| ACCIONA | ACCIONA | Spain |
| Agence de l'Environnement et de la Maîtrise de l'Energie | ADEME | France |
| Deutsches Zentrum für Luft- und Raumfahrt e.V. | DLR | Germany |
| General Directorate of Electrical Power Resources and Survey and Development Administration | EIE | Turkey |
| Energy For Sustainable Development | ESD | United Kingdom |
| Labein | Labein | Spain |
| National Energy Research Center | NERC | Jordan |
| Centre de Recherche et de Développement de l'Electricité et du Gaz | CREDEG | Algeria |
| Société Tunisienne d'Electricité et du Gaz | STEG | Tunisia |
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