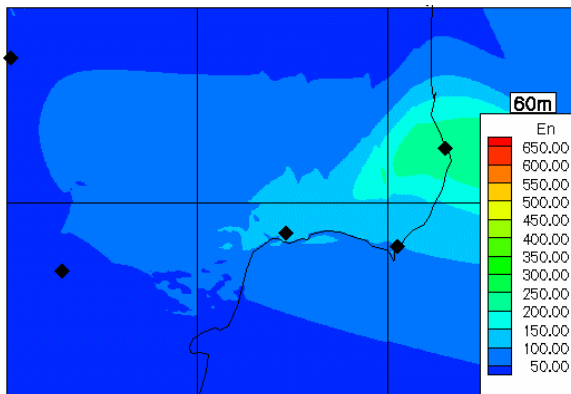




# Assessment of the Technical & Economical Potential of Wind Energy along the Black Sea Coast of Bulgaria & Romania

An OPET International Action  
Contract No NNE5/2001/733 – SI2.318354 - HECOPET





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## **Assessment of the Technical & Economical Potential of Wind Energy along the Black Sea Coast of Bulgaria & Romania**

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This work has been carried out by CRES, Center for Renewable Energy Sources, and its partners, with financial support from the European Commission, and national governments from Greece, Bulgaria and Romania.



Project Leader:

- HECOPET (CRES)

Project Partners:

- Balkan OPET (Sofia Energy Center)
- OPET Romania (ENERO)



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## **Introduction**

Decision makers and investors for RES projects need the appropriate information in order to decide if the potential RES projects are economically and technically viable.

The integrated information tool developed by CRES provides this information and gives a complete view in a specific region of the RES potential, assesses the expected energy production for given technologies, estimates the energy production costs and performs parametric analysis of RES investments (IRR, NPV, PP). The application of this tool for the wind potential of Black Sea coastal regions in Bulgaria and Romania provides to decision makers the methodology of use of this tool.

Moreover the results of the analysis give to potential investors a clear picture of the wind investing environment in a regional and also European level.

## **PART I**

### **CRES Wind Atlas Methodology and application results for the Romanian and Bulgarian Black Sea littorals**

## **1. Introduction**

When a number of measurements covering an area are available then it might be of interest to exploit these discrete data for an assessment of the wind potential, treating the area as a continuum instead of a grid of points. The methodology described in the following results in the assessment of the wind potential of a large area, without any limitations regarding its size. It was successfully used to predict the wind potential of Greece, yielding satisfactory results on a pretty fine mesh with surface resolution of 150m for the entire country.

The computational method developed by CRES achieves to establish an interpolation procedure that receives as input a substantial number of measurements and produces a prediction at an arbitrary point inside the area of interest. The procedure undertaken for the measurements is beyond the scope of the interpolation method, as long as there are sufficient points where wind data are available to describe the mesoscale effect.

## **2. Description of the methodology**

The methodology is derived from the assumption that the wind flow at high altimeters is inviscid, free from the influence of the surface boundary layer, governed strictly by meteorological mechanisms. On the other hand, the boundary layer phenomena are predominant close to the surface. There, the combined action of the topography and the boundary layer is enough to determine the wind speed and direction at any given point. In essence, a three-dimensional boundary correction method is introduced.

The whole calculation procedure is a two-step one. First, the three-dimensional space, which is defined by the surface and reaches up to a few kilometres in altitude, is analysed employing a potential flow code (mass conservation). The code works using normalized variables, imposing a unity velocity boundary condition at the upper side of the mesh. Because of the need to cover very large geographical areas, a multi-block approach is followed.

The area is divided into a large number of blocks, each of which is independently handled. Another set of blocks is generated from the first, defining a mesh of staggered with respect to the original series blocks. These two sets of blocks are used together to generate the final results, through extension, averaging and interpolation. Taking advantage from the fact that potential flow results far from the boundaries are insensitive to perturbations of boundary conditions, the above procedure yields a smooth and continuous solution at the block interfaces. Individual calculations are performed for each one of the chosen wind directions.

In a second step, a boundary layer correction is applied in order to introduce the viscous phenomena to the calculation. A simplified approach is followed for the viscous correction, derived from flat terrain boundary layer theory and the assumption of constant roughness (as long as roughness maps are not available). Correction is performed on a point-by-point basis. This simple method presents the significant advantage that mass rate is maintained. However, it is possible to substitute this by any boundary layer correction procedure.

At the end of this two-step procedure the flow field is completely defined, although still normalized by the wind speed at the upper bound. The normalization assumption that the wind speed at high altimeter is equal to unity is not equivalent to suggesting that it is constant too. On the contrary, it is known to exhibit significant variation. At this stage of the methodology, the intention is to calculate the wind speed at the upper bound. To this end, the available measurements are used.

For each point in the geographical area where measurements exist, it is possible to calculate the average wind speed for each direction of interest. Using this value, and the respective value at the computational grid node, the wind speed at the upper bound of the specific point can be predicted. This way, the measurements are used to predict the wind speed at a grid point at the upper bound. Interpolation of these values yields the wind speed at every point of the upper bound. The normalized values in the complete geographical area and at every height can then be converted to actual wind speeds.

The results attained up to this point still cover independently each direction. Using time-averaging information (probability density function of the wind direction), also yielded through the measurements, the average wind speed may be calculated at each point. Using this procedure the Weibull distribution shape factors can also be derived, which might be of interest for a better prediction of the electrical energy production by wind turbines in an area.

### **3. Results obtained for parts of the Romanian and Bulgarian Black Sea Coasts**

#### ***3.1. Data from meteorological stations and measuring sites***

For each of the six stations (four Romanian and two Bulgarian) where data were made available by the local project partners, the following information was provided:

- The geodetic coordinates of the site (latitude / longitude), and the elevation above sea level (a.s.l.).
- A brief description of the surroundings.
- The measuring and analysis of measurements procedures.
- The two Weibull distribution function parameters (as derived from the Wind Atlas standard procedure – WAsP Atlas LIB files), namely the scale parameter  $A$ , and the shape parameter  $k$ .

From the above-mentioned two Weibull function parameters, the mean wind velocity can be calculated as:

$$\bar{U} = A \cdot \Gamma\left(1 + \frac{1}{k}\right)$$

The above procedure was followed for all 12 sectors (of 30° each) that data existed, for five levels above ground (10, 25, 50, 100 and 200 m a.g.l.) and for four standard roughness classes (0., 0.03, 0.1 and 0.4 m).

The flow field for the area under investigation has been analyzed using the CRES Wind Atlas Methodology (3D Boundary Layer correction model) for the four main wind directions (north to south, east to west, south to north, west to east), and then an averaging procedure was followed. A pre-processing was necessary in order to derive from the data provided for each site the information required for the four primary directions. More specifically, the data used were those for the  $z_0=0.03\text{m}$  standard roughness class, at the standard level of 10 meters a.g.l. (except from two of the cases where the sites were located in the sea, for which  $z_0=0\text{m}$ ).

In concluding, as regards the six initially provided measuring stations the following data for wind speed and frequency were used for the calculations:

Station		North to South		East to West		South to North		West to East	
Name	Coordinates / Elevation	Speed (m/s)	Freq. (%)	Speed (m/s)	Freq. (%)	Speed (m/s)	Freq. (%)	Speed (m/s)	Freq. (%)
SULINA (RO)	45°10'N 29°44'E 3m a.s.l.	7.439	32.56	6.421	21.71	5.747	25.32	8.196	20.40
CORUGEA (RO)	44°44'N 28°20'E 219m a.s.l.	4.129	32.93	3.370	22.92	3.086	23.99	2.526	20.16
GLORIA Platform (RO)	44°32'N 29°34'E 30m a.s.l.	8.164	34.14	7.241	22.02	6.709	21.12	7.078	22.71
CONSTANTA (RO)	44°13'N 28°39'E 13m a.s.l.	4.075	37.43	3.199	19.27	3.579	19.66	3.760	23.65
SHABLA (BG)	43°32'N 28°37'E 16m a.s.l.	5.500	22.68	3.959	21.01	3.767	21.03	6.468	35.27
KALIAKRA (BG)	43°21'N 28°28'E 63m a.s.l.	5.109	44.87	1.902	11.97	3.222	26.05	2.640	17.10

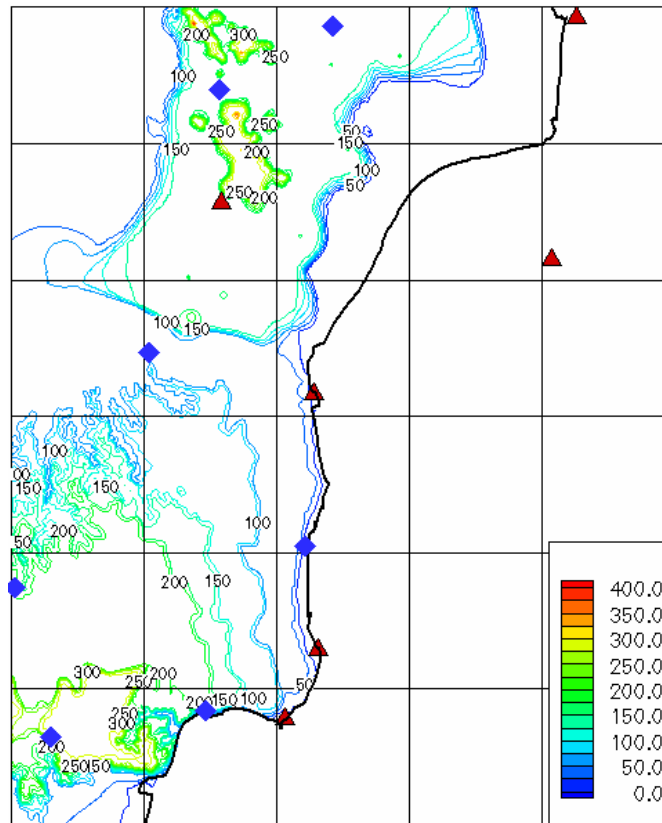
Unfortunately, the above data were not adequate in order for such a wide area to be covered satisfactorily. Thus, apart from the data provided by the project partners, and after direct contacts with active in the fields of RES and meteorology organisations in both Romania and Bulgaria, more data in the form of annual mean wind speeds and frequencies for 8 directions (N, NE, E, SE, S, SW, W, NW) over a 15 years period were obtained for the following meteorological stations:

- Romania:
  - Mangalia (43°49'N, 28°35'E, 6m a.s.l.);
  - Tulcea (45°11'N, 28°48'E, 33m a.s.l.);
  - Mircea Voda (45°02', 28°21', 185m a.s.l.);
  - Cernavoda (44°21'N, 28°02'E, 44m a.s.l.).
- Bulgaria:
  - Balchik (43°24'N, 28°11'E, 20m a.s.l.);
  - Suvorovo (43°21'N, 27°36'E, 202m a.s.l.);
  - Tervel (43°45'N, 27°25'E, 287m a.s.l.).

### 3.2. Application results



The topography contours of the Romanian and Bulgarian parts of the Black Sea coast along with the locations of the meteorological stations used in the calculations are presented in Figure 1. The computational grid was divided into 30 sub-domains each one of which had 201x201 surface nodes and grid spacing of 200m in each direction. This gives a domain size for the fine-scale calculations of 40 km. In this analysis two roughness length values were used, namely 0m at sea level and 0.03m at the land.



**Figure 1. Area under investigation elevation contours (triangles indicate the initial m.s. locations and rhombuses those of the new ones)**

Wind resource maps for the whole area under investigation are shown in Figures 2 and 3, the first one corresponding to the results at 40m a.g.l. above the roughness grid used for the simulations, and the second one to the calculation results at 60m a.g.l. These two heights were selected as representative of the hub height of two typical types of wind turbines, namely the 500 kW and 1 MW rated machines respectively.

The mean speed is shown at the left part of these two figures, while the power density, calculated as:

$$\frac{P}{A} = \frac{1}{2} \rho v^3$$

is provided in the right part ones, in [W m<sup>-2</sup>]. The wind speed of each simulation is weighted by the frequency of occurrence of the corresponding primary wind directions. The power density, for which the cube of the calculated wind speed was used and not the third moment of the wind speed (due to lack of adequate data), is calculated with a constant standard air density of 1.225 kg m<sup>-3</sup>.

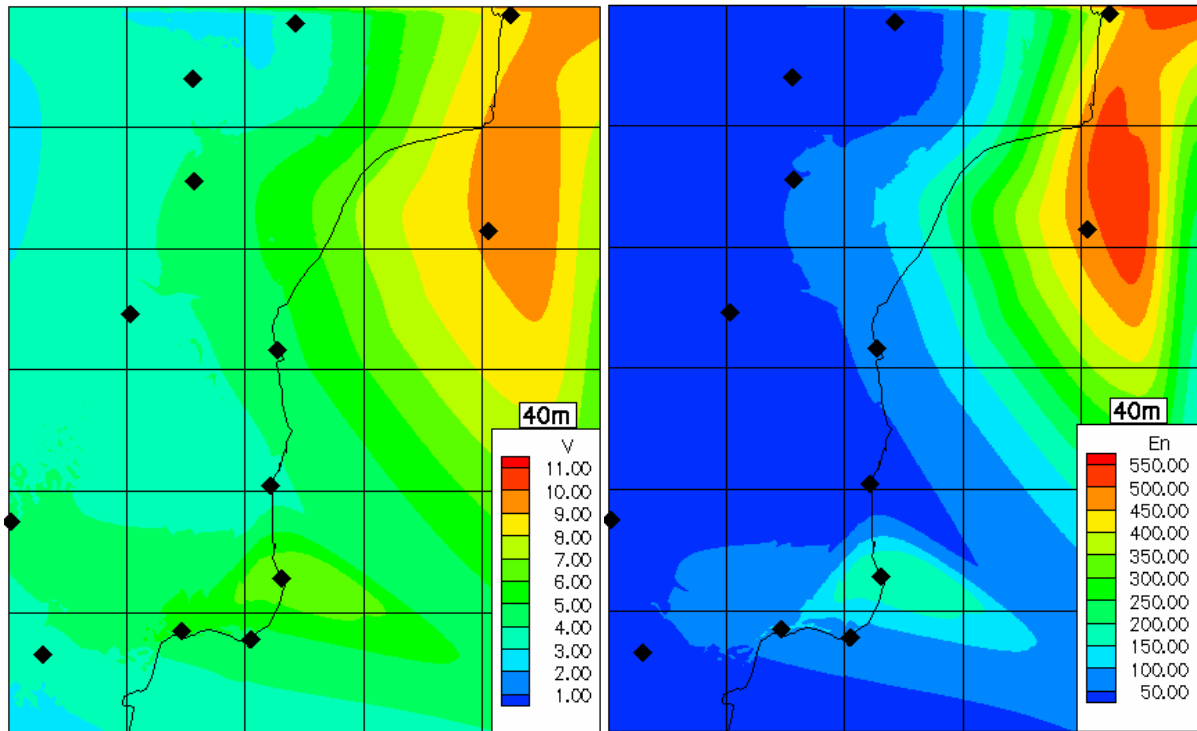


Figure 2. Resource maps of the mean speed and power density at 40m a.g.l.

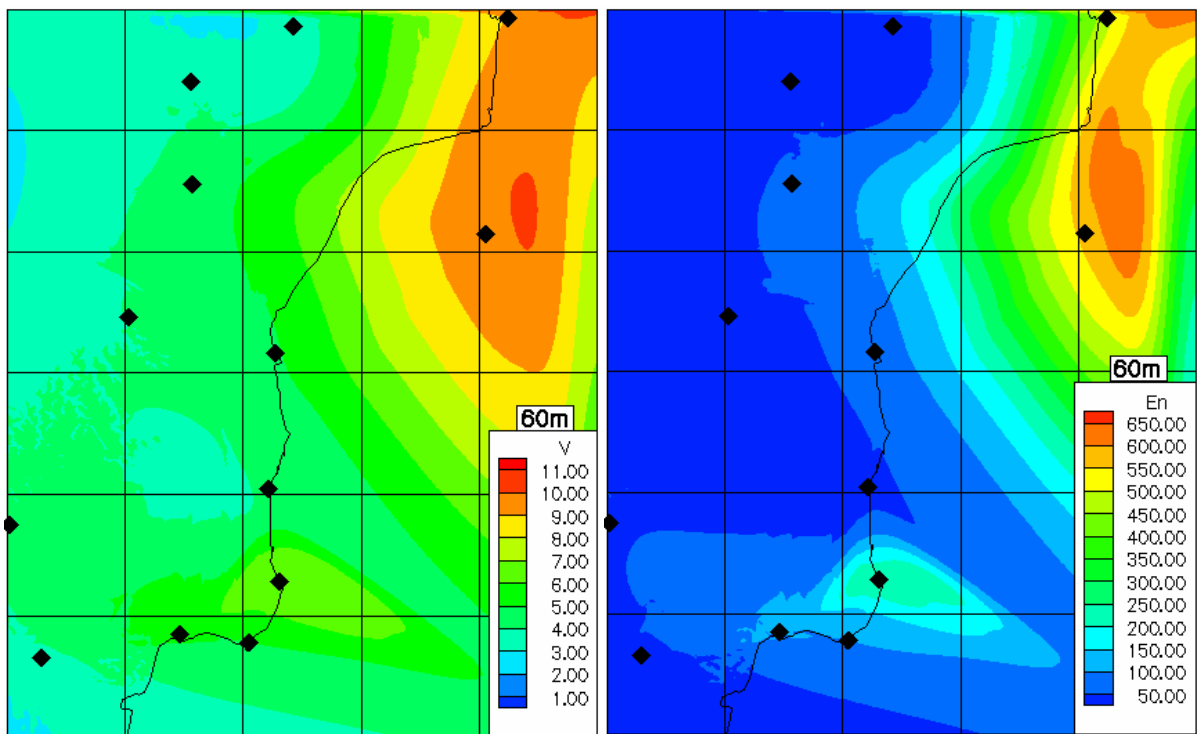


Figure 3. Resource maps of the mean speed and power density at 60m a.g.l.

The main features of these wind resource maps are the differences occurred between the sea and land areas. Moreover, a general weakening of the mean winds when going from the northern areas of the domain to the southern ones can be observed. On the other hand, lower values that the ones normally expected for the power density are observed in the figures that show this quantity's calculated values due to the above mentioned calculation approximation.

### 3.3. Results for the Romanian and Bulgarian areas of interest

The same as above wind resource maps have been produced individually for both the Romanian littoral and the Bulgarian Black Sea coast area of interest. These areas were considered as the most interest ones by the local partners (ENERO for Romania and SEC for Bulgaria) and are the following:

- The Romanian littoral excluding the Danube Delta, which is an area of preservation with weak grid connections;
- The Dobrutzha plateau (Northeast part of Bulgaria), where about 300 wind mills used to exist.

The calculation results for both 40m and 60m a.g.l. are shown in Figures 4 to 7.

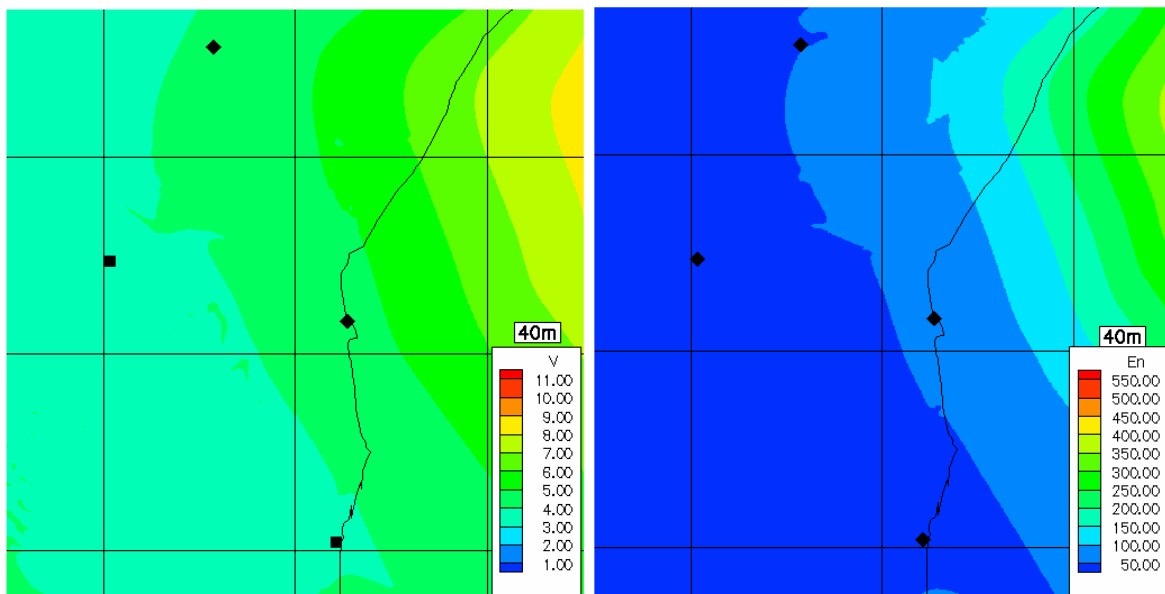


Figure 4. Resource maps of the mean speed [ $\text{m s}^{-1}$ ] and power density [ $\text{W m}^{-2}$ ] at 40m a.g.l. for the Romanian littoral area of interest

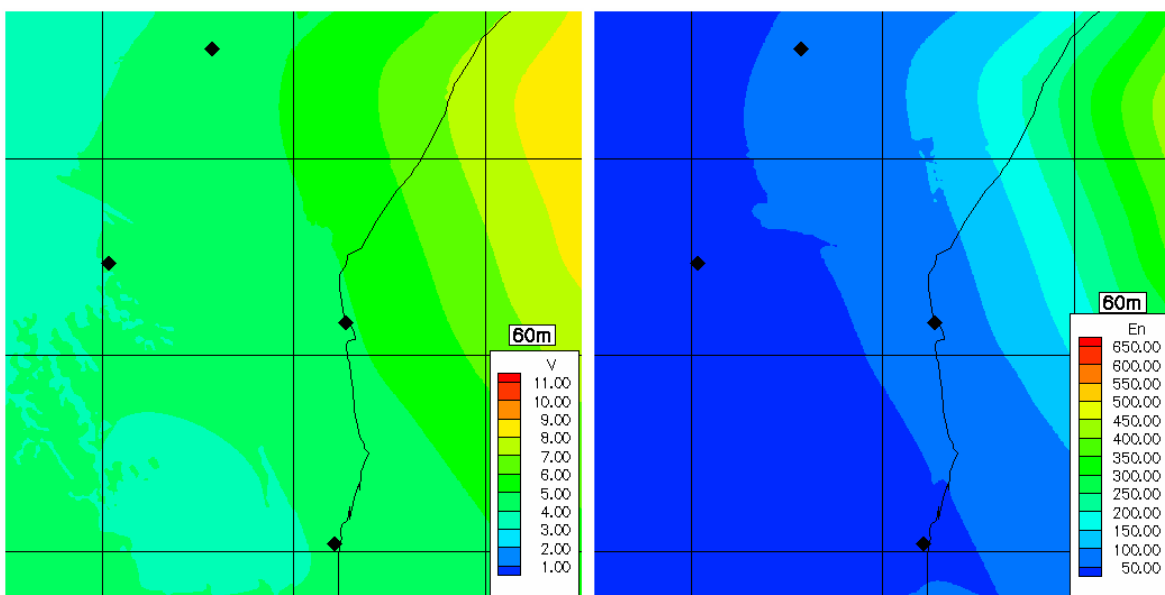


Figure 5. Resource maps of the mean speed [ $\text{m s}^{-1}$ ] and power density [ $\text{W m}^{-2}$ ] at 60m a.g.l. for the Romanian littoral area of interest

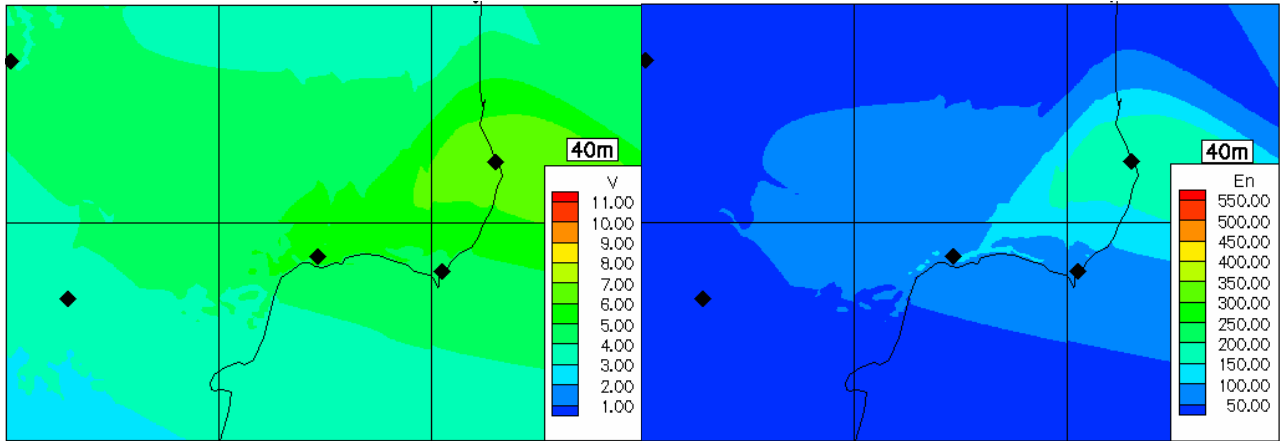


Figure 6. Resource maps of the mean speed [ $\text{m s}^{-1}$ ] and power density [ $\text{W m}^{-2}$ ] at 40m a.g.l. for the North-eastern part of Bulgaria

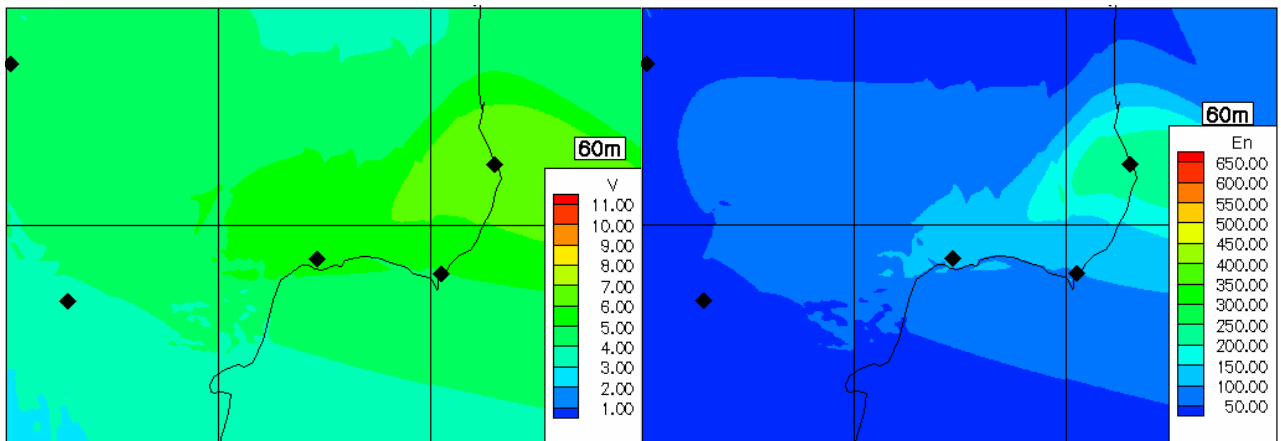


Figure 7. Resource maps of the mean speed [ $\text{m s}^{-1}$ ] and power density [ $\text{W m}^{-2}$ ] at 60m a.g.l. for the North-eastern part of Bulgaria

It must be mentioned that, due to the nature of the calculation procedure that is based in an interpolation of the wind velocity vectors procedure, it was necessary to introduce some “fictitious” data points in order to cover the areas of the calculation domain that are far away from locations where reliable data exist (in the upper-left and the bottom-right parts of the map of fig. 1). That’s why some irregularities of the flow fields (islanding) could be observed in some of the above figures. In a properly covered by stations where data are available computational domain such irregularities cease to exist and the results of the calculations are reliable and ready for use.

## **PART II**

### **A Geographical Information System For The Assessment Of The Technically And Economically Exploitable RES Potential**

This appendix outlines the methodological principles for the assessment of the technically and economically exploitable Renewable Energy Sources (RES) potential in wide geographical regions. The methodology, as well as the s/w tools developed by CRES, were demonstrated during this OPET action. Although the scope of the present action was the demonstration of wind energy potential assessment in the region of Romanian and Bulgarian Black sea coast, the methods for the assessment of small hydro, biomass and solar potential are also described, in order to provide a broad overview for all RES technologies.

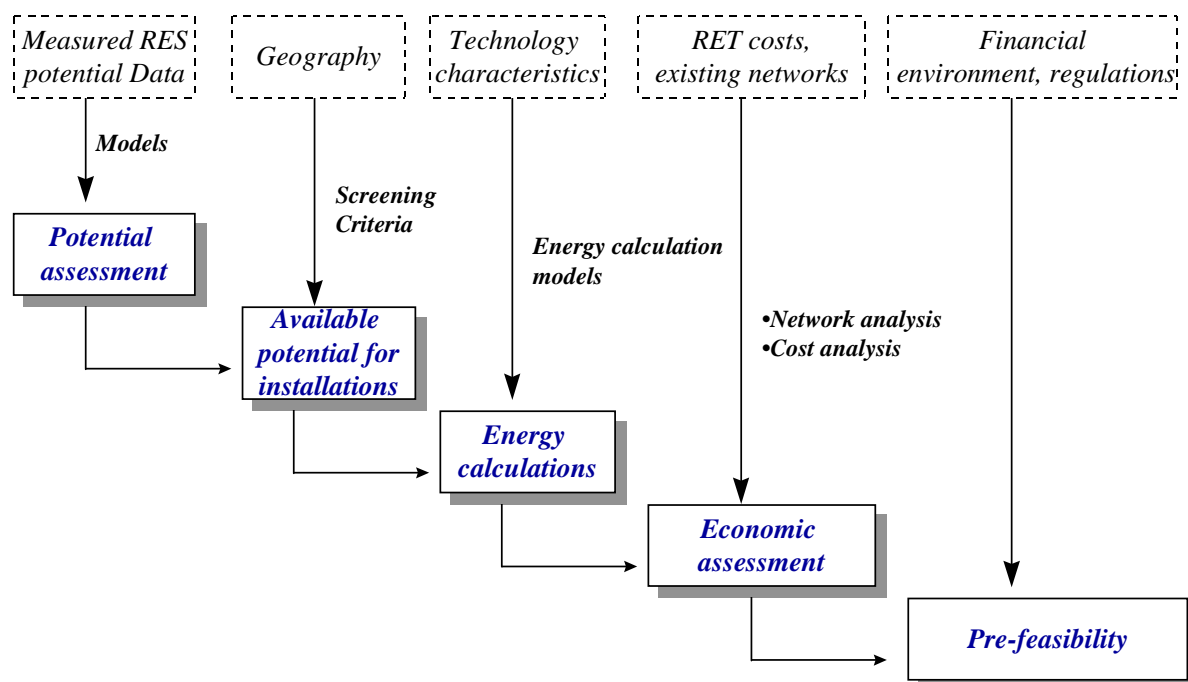
Aim of the methodology is to provide valid information for the availability, exploitability and economical efficiency of the electricity production from RES by using geographical information systems and computer models.

The information system is able to:

- Estimate the prevailing (theoretical) potential for each RES within the selected area
- Estimate the technically exploitable RES potential within the area
- Estimate the most economically attractive RET's (Renewable Energy Technologies) in each location
- Estimate the infrastructure required (electrical network, roads etc) for the RET's installation and the associated costs
- Analyse the impact of the existing legislative framework (mainly incentives, fiscal measures etc.) on the economic viability of private investments in RET's
- Evaluate the RES penetration in extended geographical areas for further use in strategic energy planning.

Where the required information includes

- The theoretical potential of each RES
- Geographical data
- Electricity network data
- Technical and economic data concerning existing RET's
- Legislative framework parameters
- Information for the financial environment for private RES investments



The analysis is focused on a specific geographical area . For each RES in a pre-selected region, the s/w tools report a variety of information which is either organised into a regional RES database or calculated by computer models. This information have been classified in the following five sections (*see figure above*):

1. Theoretical Potential
2. Available Potential
3. Technically Exploitable Potential
4. Economically Exploitable Potential
5. Prefeasibility Analysis of RES investments

The system is based on the idea that the portion of the energy content of renewables, which can be transformed into electricity, is constrained (hierarchically) by:

- The available potential (especially for wind energy installations when a number of issues regarding the use of land for wind energy development are usually under consideration).
- The mature technologies for RES exploitation and their efficiency (including their costs)
- The economic feasibility of RES investment, which is influenced by various factors such as the cost of RES installation the requirement for development of the electricity network infrastructure etc).
- The legal and financial framework regulating the RES sector, which has been proved to be a crucial factor for the RES's penetration into the energy system..

A short description of the above sections is presented here.

#### Section 1: Theoretical Potential: RES in nature

The primary energy of each RES is defined hereby as the Theoretical Potential. The objective of this module is the analysis and evaluation of the theoretical potential of each R.E.S., as well as the presentation of this potential on suitably defined maps.

For each RES, the following options are available:

##### *A. Wind*

- Isospeed curves
- Colour representation of different wind speed classes

##### *B. Hydro*

- Colour representation of different flow rate classes
- Colour representation of different gross energy content classes
- Colour representation of different land uses
- Colour representation of different slope ranges

##### *C. Solar*

Isometric curves in pre-selected solar radiation classes and Colour presentation of different solar radiation classes. The information of the solar potential can be retrieved as mean yearly, or as monthly data.

##### *D. Biomass*

For all available biomass types in the area the potential is presented using the following choices:

- The total area where biomass is collected
- Average value and moisture content of the biomass (TJ/tn)
- The mean quantity of biomass.
- The average expected value of energy produced (kcal/year)
- Monthly variations of the above quantities
- Determination of areas of interest (high biomass density areas by type)
- Classification of biomass by type on a geographical level

## Section 2: Available Potential: RES potential in relation with land planning and techno-economic constraints

The available potential demonstrates the energy by each RES, which is available for exploitation.

### *A. Wind*

- Legal and environmental constraints (land planning constraints, inhabited areas, protected areas, distance from airports, etc)
- General technical rules (i.e. maximum altitude, maximum land slope, etc)
- Other rough techno economic rules (i.e. minimum annual mean wind velocity, maximum distance from the grid and the road network, etc)
- Other rules imposed

### *B. Hydro*

- Legal and environmental constraints (land planning constraints, inhabited areas, protected areas, minimum environmental water flow, etc)
- General techno economic rules (i.e. minimum inflow rate, minimum net head, maximum distance from water inflow to power station, maximum altitude, gross power range, etc)
- Other rules imposed

### *C. Solar*

- Land use
- Upper and lower limit of solar radiation
- Altitude & orientation rules

### *D. Biomass*

The available biomass potential is defined as the biomass quantities that are available for energy uses, Input parameters for the assessment of biomass availability can be

- Legislation
- Biomass residues types
- Non-energy uses (i.e. forage, fertilizer, etc)
- Accessibility filters (i.e. maximum distance from road network, maximum slope of the area, etc)

## Section 3: Technically Exploitable Potential: RES to Power and Energy

The Technically Exploitable Potential is defined hereby as the capacity and expected energy production from a RES-to-Power stations (wind turbine, water turbine, PV etc...).

### *A. Wind*

- Type of Wind generator to be used (technology)
- General rules for the sitting of wind turbines.

The information system uses as input the dominating wind direction at the selected area, the turbine's power curve, and the mean wind speed at all available cells, and calculates:

- Total number of wind turbines in the area
- Total installed capacity (MW)
- Estimation of the energy produced, i.e.
  - Total annual energy production
  - Monthly variation of energy production
  - Energy density (MWh/km<sup>2</sup>)
  - Utilisation Factor of the Wind parks (in monthly and annual basis)
  -



### B. Hydro

In order to identify the location of the most profitable small and mini hydroelectric installations, separate algorithms are executed exhaustively, in order to calculate the following:

- Type of turbine
- Net head
- Nominal power
- Energy produced
- Utilization factor of the turbine
- Energy cost
- Installation cost and O & M cost
- Investment profitability (IRR, NPV, PBP)

### C. Solar

There are calculated

- Available area (km<sup>2</sup>)
- Size of solar system
- Total annual energy production
- Monthly energy production
- Density of energy produced (MWh/km<sup>2</sup>)
- Utilisation factor of the solar system

### D. Biomass

This module simulates the needed chaining processes in order to handle the biomass residues at a certain area, where projected biomass plant is to be installed.

In this process, are defined as input:

- The technologies used to collect each type of biomass (i.e. special vehicles, manually, etc)
- The pre-treatment procedures (i.e. chipping, pelleting, etc)
- The drying procedure (i.e. natural pre-drying, drying at the power plant)
- Transportation to the power plant
- Storage facilities
- Power plant technology (i.e. Grate firing, Fluidised Bed combustion, Co-firing, cogeneration option, etc) and location of the plant.

Main objective of this module is the estimation of:

- The final quantity of biomass at the plant, excluding mass losses during the pre-treatment and transportation processes.
- The electrical energy that can be produced, excluding the own-consumption.
- The installed capacity of the plant, depending on the desirable utilization factor
- The storage facilities needed

### Section 4: Economically Exploitable Potential: Production cost

The Economically Exploitable Potential is evaluated hereby, using estimations for the average cost of electrical energy produced by each RES and taking into account all the cost parameters affecting the economics of RET's such as installation cost, Operation & Maintenance (O&M) costs, cost of grid interface, cost for bulk network reinforcements, civil works, etc. The influence of each cost parameter (installation, O&M, network, civil works) to the final cost of energy is also estimated.

#### A. Wind, Hydro

There is calculated the mean energy production cost (GDR/kWh), the total installation cost and the yearly O&M cost. The breakdown charge of the energy production cost to all cost parameters (installation and O&M) is also calculated.

#### Section 5: Prefeasibility Analysis of RES investments: parameter analysis and evaluation of alternative policy schemes.

There is performed an analysis of the economic feasibility/profitability of private investments in the RES sector in order to analyse the behaviour of the market, keeping in mind the legal framework, the financial incentives and the financial environment.

The legislative and financial framework regulating the private investments in RES is taken into account in detail, in order to facilitate the application of various policy schemes and the evaluation of their impact, by calculating investment indices such as: internal rate of return (IRR), payback period, profitability cost, net present value, levelised cost.

Finally a parametric analysis for all major variables of RES investments (i.e. utilization factor, percentage of subsidy on investment cost, energy price, taxes, technology cost, interconnection cost, etc) is performed.

#### **4. Database description**

The RES database information could be categorised into the following five groups:

- Prevailing (theoretical) potential information describing the geographical distribution of the RES potential.
- Digital Elevation Models, describing the essential earth surface parameters, such as earth's elevation, slope and aspect.
- Cartographic information describing the existing infrastructures and the natural environment.
- Electricity network information describing the geographical distribution, topology and attributes of the high and medium voltage electricity network.
- Renewable Energy Technologies techno-economic data.

#### **Group A. RES potential information**

The RES potential is measured using a different method, for every RE source.

In the case of wind energy the potential database consists of

- Geographically located measurements (time series of wind velocity per direction)
- Normalised distribution of calculated wind velocity data (mean annual wind speed at specific heights) using a geographical matrix (grid).
- Time series and wind rose files.

In the case of small hydroelectric potential the database consists of measurements at specific river sites including

- Mean annual flow.
- Flow time series.
- Net head.

In the case of biomass potential the database consists of

- Agriculture land use maps.
- Estimations of agriculture residues per region.
- Forestry and energy cultivation maps.

In the case of solar energy potential the database consists of

- Geographically located measurements (time series of mean monthly total irradiation and air temperature)

- Normalised distribution of solar irradiation data (mean insolation per month, clearness index using a geographical matrix (grid)).

**Group B. Digital Elevation models**

The data of this group consist of Digital Elevation models (DEM's) presenting earth's surface information such as

- Elevation
- Slope
- Aspect

**Group C. Cartographic Information**

The data belonging to this group present basic cartographic and environmental information and consist of

- Road network.
- Urban centres
- Administrative boundaries
- Land use maps classified into land use classes.
- Protected areas.

**Group D. Electricity Network Information**

Electricity Network Information describes the attributes as well as the topology of high and medium voltage electricity network, including

- Generation units data
- Circuit data
- Bus data

**Group E. RES technologies information**

The data belonging to this group present information on RE technologies equipment such as

- Wind turbines power curves and related technical attributes
- Water turbines attributes
- PV systems attributes
- Biomass plants attributes

## **PART III**

### **Scenarios for the assessment of the profitability of Wind**

#### **Energy investments**

The following tables demonstrate the methodology for the assessment of the profitability of wind energy investments by evaluating the economical parameters of an hypothetical installation.

In the first part, an analysis of the associated to the installation as well as operation and maintenance costs is performed in order to calculate the cost of energy in the form of €/kWh. For this reason, a typical wind park comprising 10 wind turbines of 650 kW each one with a capacity factor of 35% (corresponding to approximately 7.5 m/sec mean wind velocity at hub height) is selected as a case.

In the second part, taking as input, standard parameters financial environment for a typical for the European Union are taken as a case in order to calculate the profitability indicators for the selected investment (Internal Rate of Return- IRR, Pay Back Period - PBP, Net Present Value - NPV).

It must be emphasized that the scenario selected includes a 30% subsidy to the capital cost while the discount rate is 5%.

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## **1. CALCULATION OF PRODUCTION COSTS**

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### ***A. Parameters***

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#### ***A1. LIFETIME***

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Wind park	20 years
Roads	50 years
Electrical grid	50 years
Infrastructure works	50 years

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#### ***A2. WIND PARK INSTALLATION COST FACTORS***

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Roads	146735 €/km
Electrical grid	0 €
Infrastructure works	1 % of wind turbine total cost
Consultants	1 % of wind turbine total cost
Technical equipment	1 % of wind turbine total cost
Training	1 % of wind turbine total cost
<b>Wind turbine acquisition cost</b>	<b>616287 €/WT</b>
Medium voltage electrical grid length	0 km
Medium voltage electrical grid cost	0 €/km
High Voltage Electrical grid Connection	0 €/km

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#### ***A3. OPERATION AND MAINTENANCE COSTS FACTORS***

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Land hiring cost	587 €/ha/year
Salary Cost	5869 €/WT/year
Maintenance ratio	2 % of install cost
Annual Insurance rate cost	0,15 % of install cost

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#### **A4. OTHER PARAMETERS**

Wind turbines	10	$P_{WT} = 650 \text{ kW}$
Roads	0 km	
Wind park cover area	1,8 ha /WT	
Electrical energy annual production	18396000 kW/year	

<b>Capacity factor</b>	<b>35 %</b>
<b>Discount rate</b>	<b>5 %</b>

#### **B. Costs**

##### **B1. INSTALLATION COSTS 6849596 €**

Wind turbines total acquisition	6849596 €
Roads	6162876 €
Electrical grid	0 €
Infrastructures	440205 €
Consultants	61628 €
Technical equipment	61628 €
Training	61628 €

##### **B2. Breakdown of annual operation and maintenance costs**

Operation and maintenance total cost	315040 €
Land hiring	105649 €
Salaries cost	58694 €
Maintenance cost	136991 €
Insurance rate cost	13705 €

##### **B3. SPECIFIC COST RATIO IN ENERGY PRODUCTION COST**

Wind turbines acquisition	0,025 €/kWh
Roads	0,012 €/kWh
Electrical grid	0 €/kWh
Infrastructures	0,00017 €/kWh
Technical equipment	0,00023 €/kWh
Consultants	0,00023 €/kWh
Training	0,00023 €/kWh
Land hiring	0,0053 €/kWh
Salaries	0,0029 €/kWh
Maintenance	0,0069 €/kWh
Insurance rate	0,00067 €/kWh

**ELECTRICAL ENERGY PRODUCTION COST 0,043 €/kWh**

## 2. INVESTMENTS ANALYSIS

### *A. Parameters*

#### ***A1. Investment Parameters***

Project economic lifetime	12 years
Discount rate or Reference rate	5 %
Annual interest	5,5 %
Payback credit years	9 years
Period of grace	1 years

#### ***A2. ELECTRICITY PRICE*** ***0,061 €/KWh***

Annual inflation of electrical energy price	0,35 %
Subsidization to kWh	0 €/kWh
Annual inflation subsidization kWh	0 %
Power cost	1,56 €
Power guarantee factor	50 %

#### ***A3. Investments subsidization ratio*** ***30 %***

Own capital ratio	30 %
Credit rate of interest subsidization ratio	0 %
Credit rate of interest subsidization years	0 years
Tax ratio	35 %
Beginning year of tax	1 year
Tax free reserve fund	0 %
Mean accountancy lifetime	12 years

#### ***A4. Parameters from previous analysis***

Number of Wind turbines	10	$P_{WT} = 650 \text{ kW}$
Roads length	0 km	
Wind park cover area	1,8 ha/WT	
Electrical energy annual production	18396000 kWh/years	
<b><i>Capacity factor</i></b>	<b><i>35 %</i></b>	
Energy losses	2,5 %	
<b><i>Annual net energy sale</i></b>	<b><i>189396000 kWh/year</i></b>	

### *B. Costs*

Roads	146735 €/km
Electrical grid	0 €
Infrastructures cost	1 % of wind turbine cost

Consultants	1 % of wind turbine cost
Technical equipment cost	1 % of wind turbine cost
Training	1 % of wind turbine cost
<b>Wind turbine acquisition cost</b>	<b>616287 €WT</b>

***INSTALLATION COST*** **6849596 €**

***WIND PARKS OPERATION AND MAINTENANCE COSTS***

Land hiring cost	587 €/ha/year
Salaries annual cost	5869 €/WT
Maintenance cost ratio	2 % of install cost
Insurance rate annual cost	0,15 % of install cost

***OPERATION AND MAINTENANCE TOTAL COST*** **311078 €/year**

**OWN CAPITAL INVESTEMENT ANALYSIS**

***Economical rates indicators***

<b>Internal Financial Rate of Return before taxes</b>	<b>(IRRbt)</b>	<b>31,48 %</b>
<b>Internal Financial Rate of Return after taxes</b>	<b>(IRRat)</b>	<b>21,63 %</b>
<b>Economic Rate of Return</b>	<b>(ERR)</b>	<b>15,83 %</b>
<b>Net present value</b>	<b>(NPV)</b>	<b>2265442 €</b>
<b>Pay back period</b>	<b>(PBP)</b>	<b>4,9 years</b>

**OWN CAPITAL AND CREDIT INVESTEMENT ANALYSIS**

***Economical rates indicators***

<b>Internal Financial Rate of Return before taxes</b>	<b>(IRRbt)</b>	<b>15,23 %</b>
<b>Internal Financial Rate of Return after taxes</b>	<b>(IRRat)</b>	<b>15,23 %</b>
<b>Economic Rate of Return</b>	<b>(ERR)</b>	<b>5,31 %</b>
<b>Net present value</b>	<b>(NPV)</b>	<b>566411577 €</b>
<b>Pay back period</b>	<b>(PBP)</b>	<b>8,4 years</b>