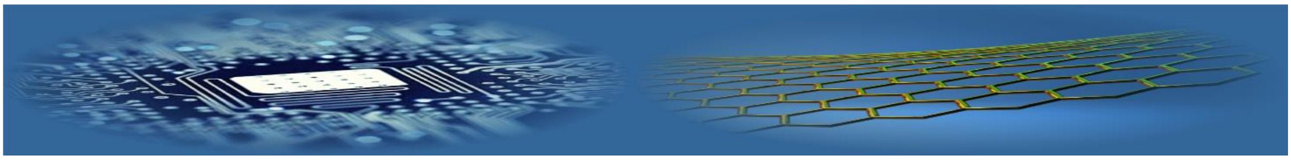

Factors and data for RES evaluation

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Abstract

Usage of renewable energy sources (RES) – is a modern powerful trend in energy development. "Green energy" technologies (technologies of gathering energy from renewable sources) are actively developed and will allow in the future significantly to reduce use of non-renewable resources (oil, gas, coal, peat), reduce the ecological impact of energy plants, improve the ecology around populated areas, reduce the cost of obtaining energy in some cases, increase the autonomy of life support systems and energy security of the country. RES are spatially distributed resources that depend on various factors. Thus, heterogeneous data and correctly defined factors are needed to evaluation of renewable resources. Paper considers the processes of RES potential evaluation, factors and data sources available for researchers. We discuss stages of RES potential evaluation, factors that can contribute to or hinder using RES and some data sources which can be used during the process. The Kazakhstan problems are briefly discussed.

Keywords:

Renewable energy resources, data sources, information systems, multiple-criteria decision making

1 Introduction

According the expert calculations the potential of the renewable energy sources in the Republic of Kazakhstan exceeds one trillion kWth yearly [1, 2], of which less than 0.1% are used (as mentioned below). The use of RES is associated with a certain complexity due to the dependence of the systems performance from random natural factors. Wind speed, solar radiation, hydropower resources can't be predicted exactly. Due to the depletion of the fossil fuel and ecological problems, the role of RES and of the more intellectual systems of energy distribution is going to increase. To solve the problem of RES evaluation we need collect several kind of data. Information system should collect weather, geographical, technical and social data. After analysing gathered data the system can support decision making process.

Despite large potential of renewable energy sources (RES) in Kazakhstan it might be economically indefensible to harness them in full. Consequently it is necessary to select the locations in the territory of the Republic where use of RES would be most useful. Although such a work has been performed in a range of projects mentioned above, purely engineering considerations are not sufficient for detailed analysis of the specified territories, as deployment of such facilities is influenced by a variety of different factors, which should be evaluated and consolidated in a generalized estimate.

Such factors encompass geographical (environmental, geomorphologic, location [3], ecological, technical, economical, social factors. Particularly, recent research show that there should be taken into account the problem of generator recycling [4] landscape and aesthetic limiting criteria, emerging in recreational area locations [5], etc.

This review discusses the evaluation of RES potential. We consider the factors and data affecting the evaluation process. The sources of such data and problems related to the conditions of Kazakhstan are briefly analyzed.

2 Evaluation of RES potential

RES potential evaluation approaches are considered in different research papers. The paper [6] defines basic stages of that process (Figure 1).

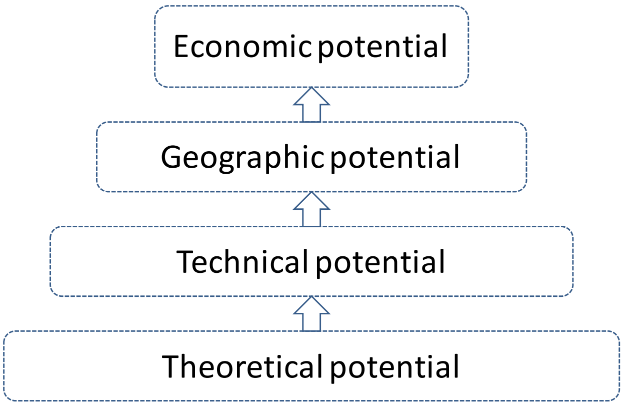

FIGURE 1 Stages of RES potential evaluation

It shows that the total scope of existing potential of a certain renewable (theoretical RES potential) is evaluated at the first stage. Technological potential, depending on parameters of the environment, generator effectiveness, service lines, etc., is evaluated at the second stage. Economic strength is evaluated at the third stage, based on greatest possible number of factors. As soon as RES depend mostly on geographic conditions, the paper [7] suggests an additional step – evaluation of geographic RES potential. Geographic potential is determined as a part of technological potential, being geographically available and necessary in a certain region.

Different methods are used for evaluation of theoretical

RES potential. For instance, the atlas describes techniques and results of potential estimates for natural resources and solar and wind energy, minor streams, peat, agricultural waste biomass, forestry and wood industry waste in the territory of Russia [8]. The detailed calculation of RES potential for one of Spanish regions is described in the paper [9].

Forest biomass potential of Italy was studied in detail in the paper [10]. The paper [11] represents an example of RES (solar and wind) potential estimation for rural regions. A technically related approach was applied in the thesis paper [12], where combination of factors, impacting deployment of power generators was classified by their significance for decision-making. Certain techniques of RES potential estimation in a range of papers were summarized with regard to establish information systems, supporting decision-making processes. The paper [13] describes the approach of information system establishment based on GIS and MCDM combination (abbrev. multiple-criteria decision making). MCDM method is also used in the work [14] where it helps in the selection of a suitable wind power plant project.

The mentioned papers use some non complicated mathematical models to evaluate energy volume that can be collected using RES. Examples of such mathematical models of energy systems are considered in the review [15]. Almost all papers discuss the factor and criteria that can contribute to or hinder the use of RES.

For example, in the above-mentioned work [14], the following 4 categories were considered: Benefits, Opportunities, Costs, Risks. Categories including criteria and sub-criteria are listed below.

Benefits

a. Wind availability
   - (a1) Geographical distribution of wind speed frequency
   - (a2) Mean wind power density
   - (a3) Annual mean wind speed

b. Site advantage
   - (b1) Influence of selected height of installation
   - (b2) Effect of wind gusting
   - (b3) Micro-siting of WEGs

c. (WEG functions
   - (c1) Real and technical availability
   - (c2) Affordable, reliable, and maintenance free
   - (c3) Power factor, capacity factor

Opportunities

d. Financial schemes
   - (d1) Switchable tariff
   - (d2) Discount of tax rate and duty rate
   - (d3) Other investment and production incentives

e. Policy support
   - (e1) Wind power concession program
   - (e2) Clean development mechanisms program
   - (e3) Other policy supports

f. Advanced technologies
   - (f1) Computerized supervisory
   - (f2) Variable speed wind power generation
   - (f3) Swept area of a turbine rotor
   - (f4) Static reactive power compensator, etc.

Costs

g. Wind turbine
   - (g1) Design and development
   - (g2) Manufacturing
   - (g3) Installation, maintenance

h. Connection
   - (h1) Electric connection
   - (h2) Grid connection

i. Foundation
   - (i1) Main construction
   - (i2) Peripheral construction

Risks

- Concept conflict Entrepreneurs, policy makers, residents
- Technical risks Technical complexity and difficulties
- Uncertainty of land Loyalty or lease agreement, geology suitability, etc.

Paper [13] considers the hierarchical set of factors including following elements:

(a) Environmental
   - Agrological capacity

(b) Geomorphological
   - Slope
   - Orientation
   - Area

(c) Location
   - Distance to road
   - Distance to power lines
   - Distance to villages
   - Distance to Substantions

(d) Climatic
   - Solar irradiation potential
   - Average temperature

In the work [12], the factors affecting the installation of RES are divided into natural, environmental, technical, economical and social. Here we propose taxonomy consist of six groups (Figure 2).

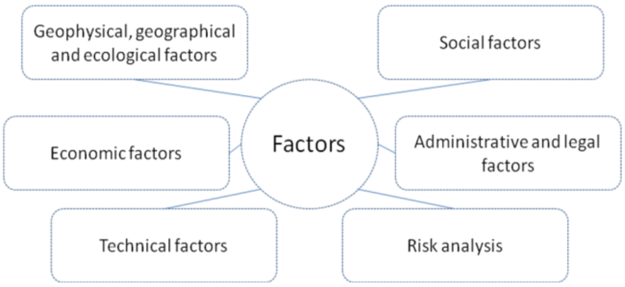

FIGURE 2 Groups of factor affecting the installation of power generators

Each of categories contains approximately 5-10 factors; the overall number of factors currently taken into account is 65.

Depending on type of RES generator, each parameter can be either an inhibitor or catalyzer. Some of inhibitors absolutely prohibit installation of generators in the area and are called hard inhibitors – they are not taken into account in further ranking of factors, and if hard inhibitor is present in the area, further calculations are terminated. The example of such hard inhibitor is national park.

Thus, to evaluate the theoretical potential of RES, it is necessary to determine the energy density for the territory, which depends on geophysical, geographical and weather characteristics of the terrain.

To assess the technological potential, it is necessary to know parameters of energy converters and factors that can limit the use of respective types of generators. We should mention that technologies development changes these parameters and influence of factors.

To gain assess to economical potential the information about factors are needed which contribute to or hinder the deployment of energy generators.

There are several methods used to heterogeneous factors estimation. AHP is method of factor weights calculation based on pair wise comparison process. AHP was proposed by T. Saaty [16]. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is considered in [13]. The paper [17] discusses integrated method based on fuzzy logic and AHP.

Categories of factors with possible methods of their evaluation are shown in table 1.

TABLE 1 Categories of factors

Group ID	Name	Possible method of evaluation
G	Geophysical, geographical and ecological factors	Computed evaluation
GN	Natural potential	Computed evaluation
GC	Consistency of energy source	Part is hard-threshold inhibitor, the rest – AHP
GG	Geographical and geophysical factors	Statistical evaluation
GGE	Unfavorable geotechnical conditions	Computed, hard-threshold inhibitors
GGW	Abnormal weather conditions	Statistical evaluation
GGN	Abnormal natural phenomena and disasters	Statistical evaluation
E	Economic factors	AHP
T	Technical factors	AHP
S	Social factors	AHP
A	Administrative and legal factors	AHP
F	Risk analysis	Statistical evaluation

The estimations obtained using these techniques are applied in decision-making support systems [13, 14, 18]. Geo-information systems visualize the results [8, 11, 12, 13, 19].

The accuracy of estimates and recommendations directly depends on quality of collected data.

3 Data sources

Energy resources evaluating tasks imply collecting data from different sources. Weather stations, autonomous sensors, remote sensing data, surface images from satellites, results of mathematical modelling can serve as the data sources for the parameters of the environment. Besides crowd source data-mining gradually becomes of more importance [20]. SETI@home, Galaxy Zoo, Citizen Weather Observer Program (CWOP) serve as the examples of such projects [21]. The latter is intended to collect meteorological data by the community of users, providing the data to the weather forecast services and to the security services, providing the feedback to the users in order to improve the quality of the collected data. The data received by the project is used in the universities, research centres, weather forecast services etc. The data collection in this systems is performed by the weather stations owned by the enthusiasts, by measuring the temperature of the mobile devices' batteries [22] etc. E.g. OpenWeatherMap [23] project uses the data from private weather stations in order to improve the accuracy of the weather forecasts as the number of measuring points is more important in predicting than the accuracy of the measurements.

For European researchers, several databases are available. For example, some databases present data for solar radiation of varying levels (global, continental). The Meteonorm [24] database is based on the 3D interpolation of solar radiation measured by meteorological stations. It includes data on global solar radiation, as well as direct and diffuse fractions.

The PVGIS database [25] includes month averaged values of solar radiation and ambient temperatures for Europe. It processes climatologically data that is available within the European Solar Radiation Atlas using interpolation methods and the r.sun model [26]. This model is implemented in GRASS GIS, an open source environment. Data is freely available at [27].

The HelioClim 2/3 databases contain long-term solar radiation data series for Europe and Africa. Satellite images of Meteosat are used to form global radiation maps on a horizontal surface [28]. The estimates are based on the Heliosat2 method [26, 29], who's software at the time of this writing was available at www.helioclim.net, but currently at [30].

Many researchers also use local data sources available in selected areas [9, 11, 13]. For example, in [11] the local data sources of the county of Vermont, the state of Poltney, were used. This approach allows a more balanced assessment of resources, especially for mountainous and remote areas.

The list of the main sources of the meteorological data consists of:

- NASA SSE (Surface meteorology and Solar Energy) [31]
- ECMWF (European Centre for Medium-Range Weather Forecasts) [32] archived sets of data
- NASA GSOD (Global Surface Summary of Day) [33]
- Some sets of publicly available data from NOAA (National Oceanic and Atmospheric Administration), NCEP (National Centers for Environmental Prediction) [34].

Currently, the data provided by numerous subsidiaries of NASA and NOAA are of the highest interest. This data is mostly results of remote sensing of earth's surface. NCDC (National Climatic Data Center) [35] should be noted out of these organisations also as the data can be ordered in a certified printed form and the authenticity is guaranteed [36].

In addition to the text and numerical information, spatial data may be stored in the form of maps (layers of maps). There is a significant amount of map sources on different subjects. Lately, online map suppliers such as OpenStreetMap (OSM) [36], OpenWeatherMap (OWM) mentioned above, Google Maps etc. become popular. E.g. OWM provides the maps of cloud coverage, air pressure, temperature, precipitation all over the world. Typically, the map suppliers have a well-documented API (which often is free of charge) using which it is possible to create own web-GIS with maps consisting of different layers, available from the map suppliers. However, the most of the spatial information is stored in the form of the map's files and satellite images. The most popular formats of map storage are Shape, GeoJSON for vector information and TIFF, JPEG for raster maps.

The problem of collecting data for the territory of the Republic of Kazakhstan is quite actual as data itself is not sufficient for full-scale analysis. E.g. in order to assess the energy potential of wind and solar energy it is necessary to get the data about the weather conditions on the territory of the whole country with the best possible resolution in the first place. This data should also contain information about time. The force of wind, illumination and temperature affect the performance of energy plants of the given type directly. In order to assess the parameters the weather stations are placed on the territory of interest.

But according to the NASA Global Surface Summary of Day (GSOD) [37] data for the year 2015 the territories of the Republic of Kazakhstan covered by the World Meteorological Organization (WMO) are about 1 for 7590 km2. This cannot be compared with the coverage in Europe and USA and does not allow assessing the weather conditions accurately enough.

Despite the fact that the number of automatic weather stations is gradually increasing, but this number still is very small for such a large territory (Figure 3).

The presence of a large number of the weather stations should allow improving the weather forecasting models assessing the energy potential more precisely. Currently, these models are mostly based on the data of the remote sensing and interpolation taking into account this data. The errors of the given models are assessed in ref. [8].

FIGURE 3 Automatic weather stations on Kazakhstan territory [38]

E.g. it is about 10% to 30% for the solar energy in comparison with the data observed on the surface, significantly increasing during the winter. Thus, the basis of assessment of renewable energy potential in Kazakhstan should become remote sensing data and ground-based meteorological data.

4 Conclusion

There are four stages of RES evaluation process:

1. To assess the theoretical potential of renewable energy it is necessary to determine density of energy for territory, which depends on geophysical, geographical, weather and other characteristics of terrain.
2. To assess the technological potential it is necessary to know parameters of energy converters, which change related to technology development.
3. To assess the economic potential the information about the factors is needed contributing or hindering generators installation.
4. At the end of evaluation process the possible location of generators is selected using some kind of decision support system.

The work lists the sources of information needed to perform three stages of assessing the potential of RES.

One of the main problems that apply to the conditions of the Republic of Kazakhstan is the low quantity of the data sources, especially the local one. Nevertheless, it is possible to use the remote sensing and global meteorological data for initial assessment of the resources.

For decisions on the use of various mechanisms of state regulation in the transition to renewable energy sources and the use of other useful resources a decision support system at national and regional levels is necessary.

It is expedient to develop a special information system to solve problems of estimating the potential of renewable energy sources and choosing the location of generators (power plants), such a system can greatly facilitate decision-making process on the use of renewable energy sources.

For the implementation of the system it is necessary to solve some important problems related to the detailed system architecture, services, data collection, integration and processing, functionality provided to users, aggregation of heterogeneous data and methods of their storing.

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