Russian Journal of Earth Sciences

Special Issue: "Fundamental and Applied Aspects of Geology, Geophysics and Geoecology"

Software Tools for Evaluating Renewable Energy Sources

Pavel Yu. Buchatskiy[1], Semen V. Teploukhov[1], Stefan V. Onishchenko[1], Kirill K. Kuzmin[1], Timofey Yu. Bychkov[1]

[1] Adyghe State University, Maykop, Russia
* **Correspondence to:** Pavel Yu. Buchatskiy, butch_p99@mail.ru

Abstract: In this paper a review of existing software tools for the evaluating and modeling of renewable energy sources, which allow to determine various aspects, such as: the amount of incoming energy for a particular area, the economic feasibility of involving an alternative source, the impact on the environment, the cost of the projected system, the features of the terrain, etc. Programs for the evaluation of solar and wind energy, as well as solutions allowing the evaluation of several different types of renewable energy sources were considered. As a result, open-source software tools, such as: QGIS, SAGA GIS, which can be integrated into the implementation of a comprehensive assessment of renewable energy sources to perform certain functions, such as a preliminary assessment of the gross renewable energy potential in specific geographical conditions and identifying topographical features of the regions under consideration, were defined.

Keywords: potential assessment models, smart models, renewable energy, solar energy.

Citation: Buchatskiy P. Yu., Teploukhov S. V., Onishchenko S. V., Kuzmin K. K., Bychkov T. Yu. (2023), Software Tools for Evaluating Renewable Energy Sources, *Russian Journal of Earth Sciences*, Vol. 23, ES0202, https://doi.org/10.2205/2023ES02SI02

1. Introduction

At present, energy conversion technologies, based on renewable sources, are increasingly being developed around the world (Figure 1).

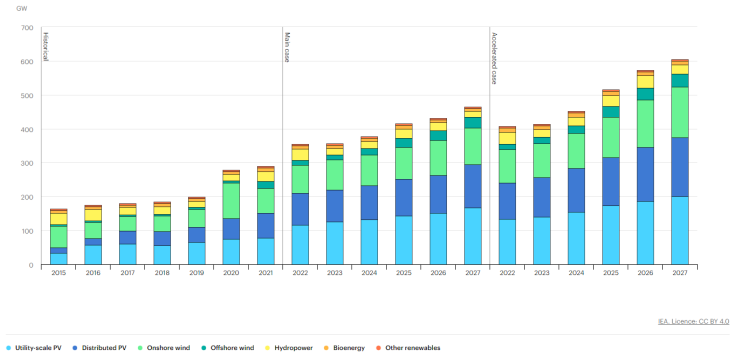


Figure 1. The trend of energy generation based on renewables.

In some developed countries, such as Germany, Norway, Sweden, New Zealand, the share of generation from renewable energy currently reaches about 50% of the total amount of energy produced (Figure 2) [*Enerdata*, 2009].

The use of energy systems based on renewable energy makes it possible to ensure high energy security and independence of the overall energy system and significantly reduce the amount of harmful emissions into the atmosphere arising from the use of traditional carbon resources [*Kotelenko and Ryabov*, 2018], which is an extremely urgent task in recent years.

Research Article

Received: 20 October 2023
Accepted: 27 November 2023
Published: 15 December 2023

To solve it, many states have developed and approved policies of energy transformation, involving maximum decarbonization of the entire energy and industrial sector, for which it is proposed to produce an active involvement of all types of renewable energy sources in existing energy systems and reduce the share of traditional hydrocarbon fuels [*Simankov and Buchatskiy*, 2019].

In this case, for the effective involvement of RES in the existing energy system or to create an autonomous system based on "green" energy, it is necessary to determine the theoretical values of the amount of energy produced and the gross potential of energy sources in the area where the planned location of the energy system [*Buchatskiy et al.*, 2019a,b].

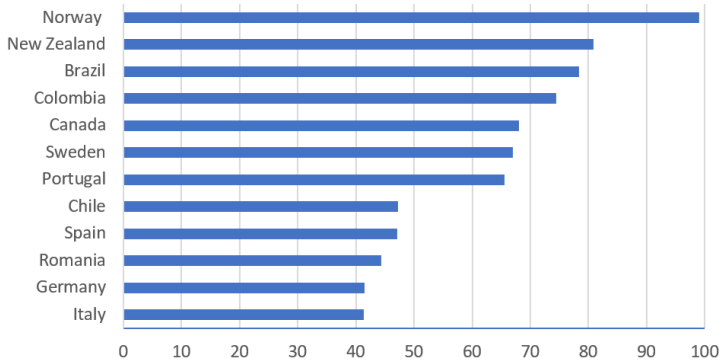


Figure 2. Percentage of renewable energy in electricity generation in different countries [*Enerdata*, 2009].

There is a large number of different mathematical models that allow calculating the potential of incoming energy, but their use is very difficult, especially in the presence of a large number of input data and a lot of points where it is necessary to perform modeling and forecasting [*Simankov et al.*, 2023]. For this reason, the development of automated tools that allow the user to perform such an analysis in a simplified mode, some of which allow a comprehensive assessment of the efficiency of the use of RES, not only the calculation of gross values of incoming energy.

One class of such tools are geographic information systems (GIS), which allow to analyze data on the location of solar panels, climate and other factors affecting energy production. Using GIS, it is possible to implement various models to forecast solar energy, taking into account the specific conditions of the region, as well as to integrate such solutions as part of the forecasting system. As a result, the problem of preliminary estimation of the theoretical values of renewable resources capacity can be solved.

In this connection, in this work, it is proposed to analyze the existing software tools for estimating and modeling the amount of energy obtained and to determine what functionality they can provide the user.

2. Materials and Methods

When implementing projects for the design and construction of energy systems involving renewable energy sources, a preliminary assessment of the energy resource potential of a particular area is of key importance [*Buchatskiy et al.*, 2020; *Simankov and Buchatskiy*, 2019], for which various software products are currently used. Since there are a large number of such software products, this paper proposes to analyze the existing software designed to assess renewable energy sources.

On the basis of this analysis, it is necessary to determine what functionality different technical solutions offer, and which of the existing solutions have the most universal application.

Thus, Table 1 presents various software products designed to assess the energy potential of solar energy and the design of solar power systems for private consumers.

As you can see, most of the reviewed systems are paid systems with the ability to provide trial access to the product to get acquainted with the features of its functionality. Some of the software products have extensive capabilities. For example, the system Aurora [*Aurora Solar*, 2023], is a universal tool for assessing and analyzing the effectiveness of the implementation of energy systems based on the use of solar energy (Figure 3).

This system allows not only to estimate the energy input and output, but also to carry out an economic analysis of the designed system and to select the most suitable composition of such a system, and to carry out a complete design of the implemented system for a particular consumer. The only disadvantage of this platform is that the system design can only be carried out for private consumers who are non-industrial energy consumers.

Table 1. Software tools for solar energy evaluation.

Software	Freeware (±)	Main functions	OS
Aurora [aurorasolar.com]	–	Assessment of solar energy potential; Economic analysis; Report generation; Data visualization; Designing solar systems for the individual consumer.	Web
BlueSol [bluesolpv.com]	– Trial version available	Economic analysis; Systems modeling; Writing documentation; Designing a photovoltaic system.	Windows
Helioscope [helioscope.com]	– Trial version available	Assessment of renewable energy potential; Assessment of technical potential; Systems modeling; Report generation; Data visualization.	Web
PV Sol Free & Premium [pvsol.software/en]	Trial version available	Systems Modeling; Data visualization.	Windows
PVGIS [joint-research-centre.ec.europa.eu]	+	Assessment of renewable energy potential; Assessment of technical potential; Economic analysis; Environmental impact assessment; Support for autonomous, networked systems; Data visualization.	Web
PVsyst [pvsyst.com]	–	Assessment of technical potential; Economic analysis; Systems modeling; Systems optimization; Data visualization.	Windows
Pylon Solar Design & CRM Software [getpylon.com]	– Trial version available	Economic analysis; Systems Modeling; Customer relationship management.	Web

An interesting solution is the PVGIS platform [*EU Science Hub*, 2023], which is open-source, making it possible to integrate this solution into some more universal system for assessing renewable energy potential. This platform makes it possible to assess theoretical and technical potential, assess economic aspects, and, unlike the other products considered, it also allows environmental interaction factors to be taken into account, as shown in Figure 4.

Both of these solutions allow a qualitative assessment of the amount of solar energy and an economic analysis, but the Aurora complex also allows the system to be designed

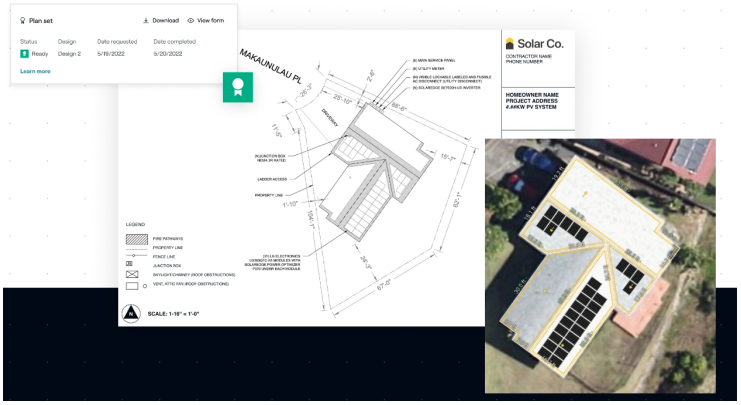


Figure 3. Solar power plant design feature in the Aurora app.

Figure 4. Functionality of the PVGIS application.

for the individual consumer. A similar solution to the PVGIS complex is PVsyst [*Photovoltaic Software*, 2023], which has similar functionality, but it is commercial and not freely available. Other software products such as BlueSol [*CadWare S.r.L. P.I.*, 2013], Helioscope [*HelioScope, an Aurora Inc. Company*, 2022], PV Sol Free & Premium [*Valentin Software*, 2023] have only some of the features of the AURORA and PVGIS tools.

Let us now look at some of the existing solutions for wind energy assessment and modeling. Table 2 presents a list of software products for wind energy assessment, with a description of the main functionalities.

Similarly, software solutions for the evaluation of solar energy, some of the presented are not available for free use. However, of the commercial solutions it is worth noting the system WindPRO [*EMD International A/S*, 2023], which allows a comprehensive assessment of the effectiveness of the implementation of wind power plants (Figure 5).

The presence of a large number of modules in this solution allows you to implement the following functionality:

- analysis of wind data;

Table 2. Software tools for wind energy assessment.

Software	Freeware (±)	Main functions	OS
Openwind [ul.com]	– On order only	Assessment of renewable energy potential; Assessment of technical potential; Economic analysis; Systems Modeling; Systems Optimization.	Web
Small Wind Economic Model Microsoft Excel [windex-change.energy.gov]	+	Assessment of technical potential; Economic analysis.	Cross-platform
AQUA [umass.edu]	+	Evaluation of energy potential; Report generation.	Windows; Linux; MacOS
WAsP [epa.gov]	+	Assessment of technical potential; Economic analysis; Systems Optimization.	Windows; Linux; MacOS
WindPRO [emd-international.com]	– Trial version available	Assessment of renewable energy potential; Assessment of technical potential; Economic analysis; Systems Optimization; Environmental Impact Assessment; Data Visualization.	Cross-platform
WInDS [umass.edu]	+	Data visualization; Simulation of wave-induced dynamics; Simulation of an offshore floating wind turbine.	

- mapping the location of wind resources;
- evaluation of energy production;
- power plant design and optimization;
- calculation of environmental impacts;
- visualization of results;
- implementation of calculations of electrical and economic indicators.

The main distinguishing feature from complex solutions aimed at evaluating the energy potential is the ability to assess the effectiveness of the implementation of the power plant not only at the level of the individual user, but also at the level of districts and regional entities.

At the same time, freely distributed solutions for the assessment of wind energy are not comprehensive, and are usually aimed at assessing a single indicator: determination of the energy potential [*University of Massachusetts Amherst*, 2016], economic analysis [*U. S. Department of Energy*, 2023], simulation of wave dynamics [*University of Massachusetts Amherst*, 2016].

Let's consider the complex solutions that allow evaluating several types of RES at once, in the table presented in Table 3.

The Table 3 presents solutions, the distinctive feature of which is the ability to work with several types of energy resources. The most interesting solution is HOMER Energy [*HOMER Software*, 2021], which consists of three large modules: the distributed grid optimizer, the energy system designer and the module for economic analysis. This product allows to design not only the energy system based on RES, but also to organize hybrid energy systems that combine traditional and alternative energy sources.

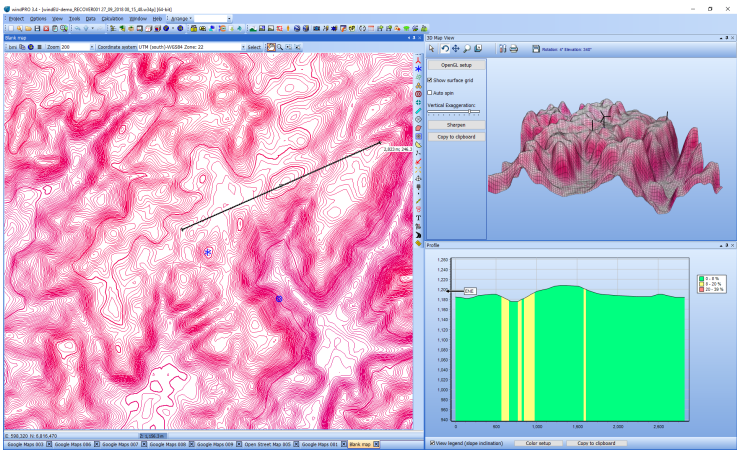


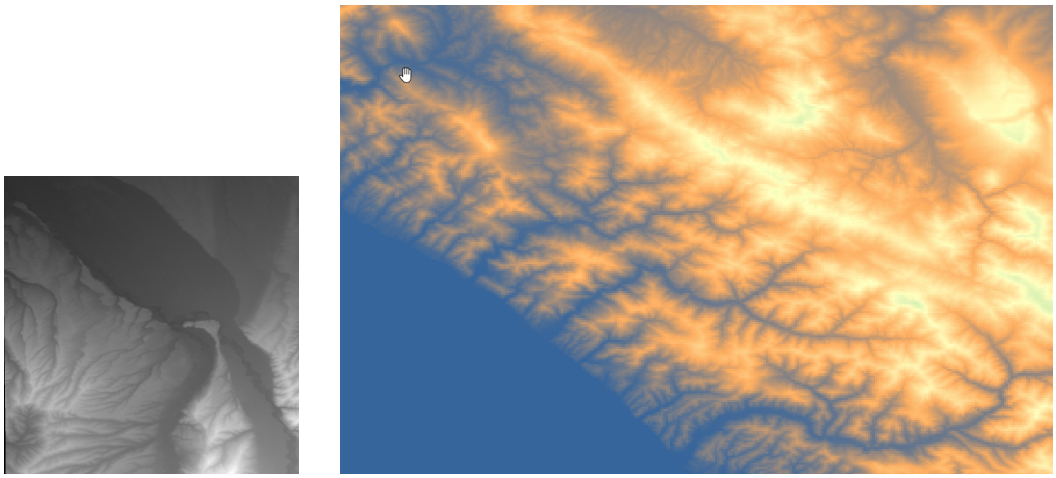
Figure 5. Mapping of wind resources in WindPRO software.

A distinctive feature of such solutions is their focus on the design of systems and optimization of existing energy complexes, in contrast to software tools aimed at assessing a particular energy resource.

Of the considered software products it should be noted the following solutions: SAGA GIS [*Institute of Geography Göttingen*, 2001] and QGIS [*QGIS*, 2023], which are modern geographic information systems, aimed at working with different spatial data and providing the ability to analyze the features of the topography of a particular area. These solutions are open source, which suggests the possibility of their integration in the development of more comprehensive solutions aimed at assessing renewable energy sources.

Thus, the QGIS software tool allows viewing data in different views (e. g., in the form of spatial tables in vector format, data in raster and graphical representation), as well as providing the ability to analyze the parameters required by the user. Consideration of relief features, which can be implemented through the use of this platform, is an important factor necessary for the implementation of RES forecasts, as it has a direct impact on the amount of incoming energy, and as a consequence on the power generated by power complexes used based on alternative energies. Figure 6 shows the result of the QGIS program, which resulted in a relief map for the city of Maykop and the coast near the city of Sochi.

Using the terrain map data, it is possible to determine the landscape profile, which is extremely useful for determining the existing altitude difference, which can have a significant impact on the efficiency of the operation of solar and wind energy converters.



(a) **(b)**

Figure 6. Relief display in the program QGIS: a) the outskirts of the city of Maykop, b) the coast near the city of Sochi.

Table 3. Software tools for wind energy assessment.

Software	Freeware (±)	Main functions	OS	Type of energy resource
EnergyPLAN [energyplan.eu]	+	Assessment of technical potential; Economic analysis; Systems optimization; Systems Modeling	Web; PC	Hydroresources; Petroleum fuels; Geothermal energy; Solar energy
Global Atlas IRENA [irena.org]	+	Assessing the potential of renewable sources; Demand forecasting; Data visualization	Web	The main types of RES; Traditional energy resources
HOMER Energy [homerenergy.com]	– Trial version available	Assessment of technical potential; Economic analysis; Systems modeling; Support for hybrid systems; Systems optimization; Data visualization	Windows; Web	Hydropower; Biomass; Traditional energy sources
RETscreen [retscreen.net]	– Trial version available	Assessment of technical potential; Economic analysis; Systems modeling; Benchmarking; Data visualization	Windows	Main types of RES
TRNSYS [trnsys.com]	–	Data visualization; Simulation of transient systems	Windows	Biomass; Solar energy; Hydrogen energy

The SAGA GIS [*Institute of Geography Göttingen*, 2001] software tool is a free GIS that contains a specialized module for the evaluation of solar power production, which allows the evaluation of the theoretical values of the incoming solar radiation. Like the QGIS software environment, this solution also has the source code, which allows you to talk about the possibility of integrating this tool to implement a system for assessing and modeling the efficiency of solar power plant involvement. The results of this program are presented in Figure 7.

The results obtained in this tool allow to generate data arrays containing theoretical values of solar insolation for a specified period, which is one of the necessary parameters when building evaluation and forecasting models of the amount of incoming energy or forecasting models of power generation.

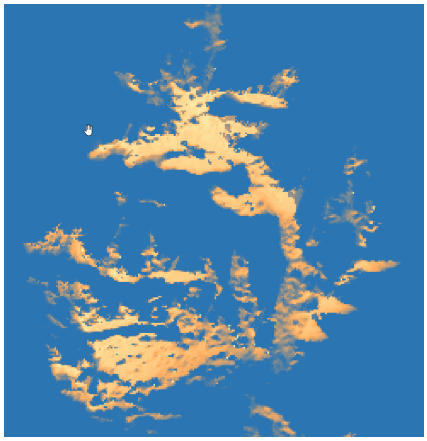


Figure 7. The arrival of solar insolation in the period for May 2023 near the city of Maykop.

3. Results

In this paper a review of some software tools for the assessment and modeling of renewable energy sources was conducted. Both commercial solutions and freely distributed products designed to evaluate wind and solar energy, as well as software that allows you to explore several types of energy resources were considered.

At the same time it was found that at the moment there are no comprehensive tools for assessing the main types of renewable energy that would not only evaluate the theoretical potential of energy, but also to determine the economic efficiency of the introduction of RES in the energy system and perform optimal energy system design, since each of the products performs only part of such functions for certain types of energy.

It was also determined that there are a number of open-source solutions, which allows the integration of such solutions when creating a more universal system for assessing renewable energy sources. The most suitable for integration are two software tools QGIS and SAGA GIS, which can be used to organize the modeling and forecasting subsystem.

The availability of such solutions allows us to talk about the possibility of creating on their basis a more advanced system for assessing the efficiency of renewable energy sources involvement, and the solutions themselves can be used when implementing one of its subsystems, namely the subsystem of forecasting and modeling of renewable energy sources.

References

Aurora Solar (2023), Aurora Platform, http://www.aurorasolar.com/, (date of access: 09/04/2023).

Buchatskiy, P. Y., S. V. Onishchenko, and A. S. Platonov (2019a), Development of a software and hardware complex for measuring wind speed on the Arduino platform, in *Distance educational technologies: materials IV All-Russian Scientific and Practical Conference (with international participation), Yalta, September 16-21, 2019*, pp. 250–257, IT "Arial", Simferopol (in Russian).

Buchatskiy, P. Y., S. V. Teploukhov, S. V. Onishchenko, A. S. Platonov, A. A. Avdzhiyan, and V. E. Avdeev (2019b), Implementation of the power assessment appliance for renewable energy sources, *The Bulletin of the Adyghe State University,the series "Natural-Mathematical and Technical Sciences"*, *4*(251), 103–108 (in Russian).

Buchatskiy, P. Y., S. V. Teploukhov, and S. V. Onishchenko (2020), Software and Hardware Complex for Evaluating the Potential of Wind and Solar Energy, in *2020 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, IEEE, https://doi.org/10.1109/ICIEAM48468.2020.9112028.

Buchatskiy, P. Y., S. V. Onishchenko, S. V. Teploukhov, and A. N. Lisova (2023), New Renewable Energy Conversion Technologies, in *Fundamental and Applied Aspects of Geology, Geophysics and Geoecology Using Modern Information Technologies. VII International Scientific and Practical Conference. Part I*, pp. 49–57, IP Kucherenko V. O., Maykop (in Russian).

CadWare S.r.L. P.I. (2013), BlueSol. Photovoltaic design software, http://www.bluesolpv.com/, (date of access: 09/04/2023).

EMD International A/S (2023), WindPRO is the industry leading software suite for design and planning of wind farm projects, https://www.emd-international.com/windpro/, (date of access: 09/04/2023).

Enerdata (2009), The share of renewable energy in the global energy mix has increased by 10 percentage points since 2010 to almost 30%, https://energystats.enerdata.net/renewables/renewable-in-electricity-production-share.html (in Russian), (date of access: 09/04/2023).

EU Science Hub (2023), Photovoltaic Geographical Information System (PVGIS), https://joint-research-centre.ec.europa.eu/pvgis-online-tool_en, (date of access: 09/04/2023).

Government of Canada (2022), RETScreen Clean Energy Management Software platform, http://www.retscreen.net, (date of access: 09/04/2023).

HelioScope, an Aurora Inc. Company (2022), HelioScope, https://www.helioscope.com/, (date of access: 09/04/2023).

HOMER Software (2021), HOMER (Hybrid Optimization of Multiple Energy Resources), https://www.homerenergy.com/, (date of access: 09/04/2023).

Institute of Geography Göttingen (2001), SAGA - System for Automated Geoscientific Analyses, https://saga-gis.sourceforge.io/en/index.html, (date of access: 09/04/2023).

IRENA - International Renewable Energy Agency (2023), Global Atlas, https://globalatlas.irena.org/workspace, (date of access: 09/04/2023).

Kotelenko, S., and A. Ryabov (2018), The advantages and disadvantages of alternative Energy, *Izvestiya Tula State University*, (12), 84–88 (in Russian).

Photovoltaic Software (2023), A powerful software for your photovoltaic systems, (date of access: 09/04/2023).

QGIS (2023), QGIS. A Free and Open Source Geographic Information System, https://qgis.org/en/site/, (date of access: 09/04/2023).

Saru Technologies Pty (2023), Pylon. #1 Solar Design & CRM Software for fast-growing solar businesses, https://getpylon.com, (date of access: 09/04/2023).

Simankov, V. S., and P. Y. Buchatskiy (2019), Methodological Basis for Assessing Effectiveness of Involvement of Renewable Energy in Regional Energy Balance, in *2019 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, IEEE, https://doi.org/10.1109/ICIEAM.2019.8742922.

Simankov, V. S., P. Y. Buchatskiy, S. V. Onishchenko, and S. V. Teploukhov (2023), Overview of models for estimating and predicting solar energy supply, in *Fundamental and Applied Aspects of Geology, Geophysics and Geoecology Using Modern Information Technologies. VII International Scientific and Practical Conference. Part II*, pp. 167–174, IP Kucherenko V. O., Maykop (in Russian).

Sustainable Energy Planning Research Group at Aalborg University (2000), EnergyPLAN - Advanced Analysis of Smart Energy Systems, https://www.energyplan.eu/, (date of access: 09/04/2023).

TRNSYS (2019), TRNSYS Transient System Simulation Tool, https://www.trnsys.com/, (date of access: 09/04/2023).

U. S. Department of Energy (2023), Small Wind Economic Model. Wind Energy Payback Period Workbook (v1.0), https://windexchange.energy.gov/files/docs/small_wind_economic_model.xls, (date of access: 09/04/2023).

U. S. Environmental Protection Agency (2022), WASP Model Tutorials, https://www.epa.gov/ceam/wasp-model-tutorials, (date of access: 09/04/2023).

UL Solutions (2022), Openwind. Wind Farm Modeling and Layout Design Software, https://www.ul.com/services/openwind-wind-farm-modeling-and-layout-design-software, (date of access: 09/04/2023).

University of Massachusetts Amherst (2016), The Wake Induced Dynamics Simulator (WInDS), https://www.umass.edu/windenergy/research/software/WInDS, (date of access: 09/04/2023).

University of Massachusetts Amherst (2023), AQUA, https://www.umass.edu/windenergy/research/topics/tools/software/aqua, (date of access: 09/04/2023).

Valentin Software (2023), PV Sol Free & Premium, https://pvsol.software/en/, (date of access: 09/04/2023).