GIS Odyssey Journal

2026 • Volume 6 • Number 2

https://doi.org/10.57599/gisoj.2026.6.2.37

Jakub Mroczko[1], Natalia Sajnóg[2]

ASSESSMENT OF THE SUITABILITY OF LAND FOR INVESTMENTS IN STANDALONE HIGH-VOLTAGE BATTERY ENERGY STORAGE SYSTEMS (BESS)

Abstract: The purpose of this article is to identify and attempt to prioritize the attributes of undeveloped land parcels in the context of their development potential as standalone high-voltage battery energy storage systems (BESS), distinguishing between those that are determining and those that are differentiating. It is assumed that "development potential" refers to the possibility and feasibility of implementing a BESS project on a given plot of land, understood, among other things, through the lens of planning, legal, technical, surveying and agricultural, environmental, and social factors, as well as the risks, time, and costs necessary to bring the plot to a state enabling the project's implementation. The following research methods were used in this study: (i) examination and evaluation of legal provisions, scientific and industry literature, including a critical review of the literature, (ii) the method of analysis and logical construction, and (iii) an expert scoring method.

Keywords: standalone BESS, investment potential, land suitability, defining characteristics, distinguishing characteristics

Received: 1 June 2026; accepted: 9 July 2026; revised: 23 July 2026

[1] Solarig Development Poland Sp. z o.o., Warsaw, Poland, email: jmroczko@solarig.com
[2] Warsaw University of Technology, Faculty of Geodesy and Cartography, Department of Cadaster and Land Management, Warsaw, Poland, ORCID ID: https://orcid.org/0000-0001-8758-4122, email: natalia.sajnog@pw.edu.pl

Introduction

The energy transition in the European Union and in Poland over the coming years will be driven by the need to simultaneously achieve climate goals and increase the share of renewable energy sources (Igliński et al., 2024), while simultaneously strengthening energy security (Kubiczek et al., 2025) and modernizing the power infrastructure to enable the integration of renewable sources (Sikorska-Pastuszka, 2025). The revised Renewable Energy Directive (EU/2023/2413) raises the EU's binding renewable target for 2030 to a minimum of 42.5% share of renewables in the energy mix, up from the previous 32% target, with the aspiration to reach 45%. It means almost doubling the existing share of renewable energy in the EU. This objective is part of the broader framework of the European Green Deal and the "Fit for 55" package, which aims to reduce net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels and aims for climate neutrality by 2050. As a result, the power system will face increasing pressure related to the integration of variable generation sources, particularly solar and wind power, whose development requires a parallel increase in system flexibility, balancing capacity, and energy storage capabilities (Shahzad & Jasińska, 2024).

As the share of renewable energy sources grows, ensuring the stability of the power system has become one of the key challenges of the energy transition. Energy production from renewable sources is variable, dependent on weather conditions, and does not always align with consumer demand patterns (Khalid, 2024). The literature emphasizes that energy storage systems are one of the key tools for increasing the integration of renewable energy sources into the power grid, as they help mitigate the effects of generation variability, support power management, improve power quality, and enhance grid reliability (Sakib et al., 2025). Battery Energy Storage Systems are of particular importance in this regard. Due to their ability to respond quickly to changes in grid operating parameters, their modular structure, and their capacity to provide system services, they are increasingly being considered as a technology that supports both the integration of renewable energy sources and the development of resilient power systems (Nazaralizadeh et al., 2024).

The Polish electricity sector is currently undergoing a period of rapid change driven by the energy transition, the growing share of renewable energy sources, and the need to increase the flexibility of the national power system. By the end of 2025, the share of renewable energy sources in Poland's installed capacity exceeded 50%, and for the first time, the share of electricity generated from renewable sources exceeded 30% for the entire year (MKiŚ 1, 2026). As this process unfolds, the importance of technologies that help balance the system and stabilize fluctuating energy production is growing, which is why energy storage is increasingly cited as one of the key prerequisites for the further development of renewable energy (MKiŚ 2, 2025).

As a result, BESS projects are becoming increasingly important. The level of interest in this type of investment is clear. The support program for large-scale energy storage facilities provides funding for 172 large storage facilities with a total capacity of 3,900 MW and a storage capacity of 14 500 MWh (MKiŚ 3, 2025). Although there is no single official statistic on the demand for land suitable for BESS projects, the scale of support programs and publicly disclosed projects – both those already connected and those planned for connection – suggests that such land is becoming an increasingly sought-after resource in the real estate market. Unlike storage facilities located at existing solar or wind farms, stand-alone BESS projects require the identification of land that not only meets basic area and construction requirements but, above all, possesses technical, grid, planning, environmental, and economic potential. The literature on the siting of energy storage facilities indicates that the choice of connection point has a direct impact on the ability to maximize system benefits, investment costs, and the effectiveness of grid services (Hameed et al., 2020). For BESS projects, key factors include proximity to power substations, distance from high-voltage lines, availability of connection capacity, feasibility of the connection, access to road infrastructure, land use designation in planning documents, environmental constraints, geotechnical conditions, and public acceptance (Ayyildiz & Yildirim, 2026).

GIS and MCDA (multi-criteria decision analysis methods) are, of course, effective tools for selecting the most optimal locations for various types of investments where a combination of spatial and multi-criteria analysis is necessary (Gao et al., 2022). The integration of GIS and multi-criteria methods creates a coherent approach that allows for the transformation of dispersed spatial and descriptive data into a structured decision-making model. Within this approach, it is possible both to exclude areas that do not meet the boundary conditions and to classify plots according to their suitability for investment. In the case of BESS projects, this is particularly important because high site potential does not result solely from the physical availability of land (Ping et al., 2025).

The purpose of this article is to identify and attempt to prioritize the attributes of undeveloped land parcels in the context of their development potential as standalone high-voltage electricity storage facilities, distinguishing between those that are determining and those that are differentiating. It is assumed that "development potential" refers to the possibility and feasibility of implementing a BESS project on a given plot of land, understood, among other things, through the lens of planning, legal, technical, surveying and agricultural, environmental, and social factors, as well as the risks, time, and costs necessary to bring the plot to a condition enabling the project's implementation.

Material and methods

From a functional perspective, a BESS project can be described as a set of interconnected components that collectively enable energy storage, as well as the withdrawal and injection of energy into the power grid. This breakdown is useful because each component involves specific spatial requirements, site layout, and service access, and may also impose constraints (e.g., safety zones, the need for access roads, and requirements for power infrastructure).

In this article, "BESS investments" refers to energy storage systems operating as standalone investment projects (i.e., not serving as ancillary components of photovoltaic or wind power plants) that require connection to the power grid at the high-voltage level. Figure 1 illustrates an example of this type of investment.

Fig. 1. An example of a large-scale battery energy storage system (BESS)
Source: Wikimedia Commons, 2025

This study focuses on identifying and attempting to prioritize the attributes of undeveloped land parcels in the context of their potential for BESS development. These attributes are categorized based on characteristics that determine and differentiate investment opportunities. For the purposes of the study, it is assumed that the assessment covers undeveloped land with an area of 1 hectare or more. This assumption allows the analysis to focus on industrial-scale investments, for which planning, legal, technical, surveying and agricultural, environmental, and social conditions are of particular importance. The geographical scope of the study refers to market realities and regulations in force in Poland. However, it does not cover the technical design of BESS installations or a detailed economic analysis of the project.

The following research methods were used in this study: (i) examination and evaluation of legal regulations, scientific and industry literature, including a critical review of the literature, (ii) the method of analysis and logical construction, and (iii) an expert scoring method.

Results

The investment potential of a plot of land designated for a standalone energy storage facility is realized in practice through the investor's ability to progress through the various stages of project preparation and implementation. Therefore, it is crucial to identify the areas that generate risk, time, and costs and ultimately affect the value of such land.

The risks primarily include uncertainty regarding the feasibility and conditions for implementing a project in a given location (e.g., environmental and planning decisions, constraints arising from the surrounding area, infrastructure conflicts), as well as the risk of delays in proceedings and approvals. For real estate market participants, this means that land parcels with greater uncertainty are perceived as less predictable from an investment perspective, which should translate into a lower price or influence the terms of the transaction in a way that limits the investor's exposure to risk, e.g., through phased payments, conditions precedent, or making the purchase contingent on obtaining specific decisions. Time matters because it delays the achievement of the investment objective and typically increases indirect costs (organizational and financial), as well as exposure to changes in the legal and market environment. In turn, preparation costs include not only the costs of carrying out the construction project but also expenditures incurred prior to the start of work, in particular analyses and studies, documentation, agreements, surveys, administrative and legal services, as well as site preparation costs. In the case of BESS, costs resulting from infrastructure and site conditions may also be a significant component, e.g., those related to options and the length of the connection infrastructure, the need to resolve conflicts, or the construction of additional land development elements.

A review of the relevant literature leads to the conclusion that the suitability of land for investment in a standalone high-voltage energy storage facility is not determined by a single characteristic, but rather by a whole range of attributes that influence the acceptability of the location, the predictability of the preparatory process, the feasibility of grid connection, and the level of investment risk. Consequently, the evaluation of land requires treating the identified elements as potential market characteristics that influence the attractiveness and value of the sites. These attributes can be categorized in terms of characteristics that determine and differentiate the investment potential of the land. Determining characteristics should be understood as those properties of the land that answer the fundamental question of whether a given plot of land can reasonably be considered eligible for an investment project in the form of a standalone high-voltage BESS. In turn, differentiating characteristics should be understood as those properties of the plot that no longer determine the very admissibility of the investment but influence the degree to which the land's suitability is enhanced by reducing the costs, time, and risk of project preparation.

Criteria for evaluating unbuilt land parcels in terms of their suitability for BESS investment The criteria for assessing the investment potential of undeveloped land parcels designated for BESS were classified into planning, legal, technical, surveying and agricultural, environmental, and social categories.

1. Planning conditions are of key importance, as they primarily determine whether the planned development can even be considered in a given area, and if so, under what conditions. In practice, a plot's potential is determined primarily by whether the project's location is provided for in the local zoning plan, by the possibility of adopting an integrated investment plan, or – in the absence of a local zoning plan – by a decision on development conditions, as well as by the role played in this case by the municipality's general plan.

It is essential to determine whether a local zoning plan applies to the property. The Act on Spatial Planning and Development (2003) stipulates that it is the local zoning plan that establishes the land use designation and specifies the methods of land development and construction, and that the provisions of the plan, together with other regulations, shape the manner in which property ownership rights are exercised. In the context of investment opportunities under BESS, this means it is necessary to verify not only the general land use designation but also whether the plan's provisions permit the location of a function corresponding to such an investment, particularly technical infrastructure, power facilities, or industrial or warehouse buildings. More detailed parameters and restrictions, such as building lines, development ratios, and height limits, are also significant.

Planning potential depends not only on the content of the applicable local plan, but also on the realistic possibility of amending it if the planned investment requires it. Amendments to a local plan are made in the same manner as the plan is adopted, and the local plan or its amendment can be prepared in parallel with the general plan or its amendment. Therefore, if the planned amendment to the local spatial development plan does not comply with the provisions of the general plan, the investor should consider the need for an earlier or simultaneous amendment to the general plan. Furthermore, after August 31, 2026, without an adopted general municipal plan, it will generally not be possible to adopt a new local plan or amend the existing one, or to issue a decision on development conditions.

It is also worth noting the possibility of adopting an integrated investment plan, which is adopted by the municipal council at the investor's request. This is a special form of local development plan and covers the area of the main investment and the supplementary investment. This procedure has been simplified by law compared to the traditional local development plan. A key element of this procedure is the urban planning agreement, in which the investor commits to implementing the supplementary investment on behalf of the municipality. The act also allows the investor to cover all or part of the costs of implementing the supplementary investment, including the price of the property designated for this investment, as well as all or part of the costs incurred by the municipality in adopting the Integrated Investment Plan, including the costs of settling claims for compensation for a decrease in the property's value. From the investor's perspective, adopting an Integrated Investment Plan can provide a faster and more flexible planning basis for project implementation than a traditional planning process, but it may also involve additional financial obligations. The possibility of adopting an Integrated Investment Plan is not dependent on the location of the land within the supplementary development area, which is relevant for the decision on development conditions (Kafar et al., 2025).

In the absence of a local development plan, a development decision may be the basis for the location, but obtaining one is not automatic. The Act (2003) stipulates that issuing a development decision is only possible when all statutory conditions are met, including, among others, at least one adjacent plot accessible from the same public road is developed in a way that allows for defining requirements for new development, the site has access to a public road, existing or planned utilities are sufficient for the intended development, the site does not require a change of use permit for agricultural and forest land or is covered by such a permit, and the decision complies with separate regulations. In the context of the project under consideration, this means that the lack of a zoning decision does not preclude its implementation, but increases procedural uncertainty. Furthermore, after the general plan comes into force, for new applications from August 31, 2026, issuing a development decision will generally only be possible if a general plan is in force in the given municipality and the site is located within a development extension area, which significantly narrows the area in which a development decision can be obtained.

2. Legal conditions are crucial when assessing the feasibility of successfully acquiring real estate or obtaining legal title to the land, which will allow for preparatory procedures to be carried out and, subsequently, for the investment in question to be implemented. In practice, one of the first steps should therefore be to verify the legal status of the property in the land and mortgage register and, in the absence of such a register, in other legal documents. This allows for the identification of the owner or perpetual usufructuary, co-ownership, mortgages, easements, claims, and indications that the legal status of the property may not yet be definitively settled. In practice, entries regarding encumbrances and claims, as well as notes or warnings, are of particular importance, as they may indicate ongoing changes or disputes concerning the property. Consequently, a property that is attractive from a planning and technical standpoint may be evaluated less favorably in the market if its legal status is complex, disorganized, or encumbered by third-party rights (Sokół & Sobolewska-Mikulska, 2024).

Another key aspect of a property's legal status is its ownership structure, including the number of co-owners. The Civil Code (1964) provides that ownership of the same property may be held jointly by several persons, and each co-owner may independently dispose of their share. At the same time, the consent of all co-owners is required to dispose of the jointly owned property and to perform other acts exceeding the scope of ordinary management. This means that in the case of jointly owned real estate, the effective acquisition of the entire property for the purpose of carrying out an investment requires the consent of all entitled parties. This has practical significance for the investor, as the acquisition of the entire jointly owned property, especially when there are multiple owners, usually requires negotiations with all entitled parties. This entails greater transaction risk and a longer acquisition period than in the case of a plot with a single owner.

The same applies to situations involving pending court proceedings, inheritance cases, partition cases, or cases seeking the dissolution of joint ownership. In inheritance matters, it is crucial whether the circle of heirs and their rights to the real estate have already been formally confirmed, as the absence of such clarification may prolong or complicate the transaction. In practice, this means that unresolved inheritance and legal issues increase transaction risk and prolong the time required for the effective acquisition of the land. It is also significant whether the real estate belongs to the State Treasury or a local government entity. Under the Real Estate Management Act (1997), real estate is generally sold through a tender process, unless there are statutory grounds for a non-tender sale. From an investor's perspective, this introduces an additional element of uncertainty, as mere interest in acquiring a plot of land does not yet guarantee the acquisition of ownership rights to it. Consequently, real estate owned by the State Treasury or local government entities may be viewed as less predictable in terms of transactions than privately owned land, as the procedure for their sale may prolong the investment preparation period and increase risk.

3. Technical conditions, including access to a public road, transportation accessibility, and connection options. Within this group of conditions, access to a public road is of particular importance. The Act (2003) broadly defines it as direct access, either via an internal road or through the establishment of an appropriate right of way. This means that the mere physical possibility of access is not sufficient; it is also essential that the access has a proper legal basis. Transport accessibility, on the other hand, should be understood as the actual ability to reach the plot of land in question via a road of an appropriate technical standard, taking into account the needs of construction and subsequent maintenance of the facility. For industrial-scale projects, this has direct organizational and cost implications, as it affects the logistics of equipment delivery, the conduct of construction work, and facility maintenance. If access exists but does not meet the appropriate technical standard, the investor may be forced to pave it or bring it to a condition that allows for the transport of equipment and the operation of the project, which entails additional project preparation costs. On the other hand, connection conditions depend on site-specific challenges, which translates into the cost-intensity of the connection infrastructure. The connection fee may depend, among other things, on the connection capacity, as well as the length and type of the connection. Consequently, the distance from the potential grid connection point and the feasibility of routing the connection in a practical manner – without excessive conflicts or terrain-related obstacles – become key factors in the assessment, as these factors affect the time and cost of project preparation.

4. The physical characteristics of the land should be assessed from the perspective of an industrial-scale investment, for which the site must allow not only for the installation of core equipment but also for the placement of supporting infrastructure, internal roads, maneuvering areas, and zones necessary for the safe operation of the facility. From this perspective, it is not only the plot's area that matters, but also its shape, width, and topography. A plot with a regular shape and favorable geometric layout typically allows for more efficient placement of equipment and simplifies site organization. In contrast, a narrow, irregular plot may limit the possibility of rational development, require a less favorable layout of infrastructure, or result in a larger portion of the site having to be allocated for access, maneuvering, and project operations. The terrain's slope is also of particular importance, as the steeper the slope, the greater the likelihood that earthworks, grading, drainage, or additional technical safeguards will be required. Consequently, a larger plot is not always more attractive than a smaller one if its geometry or topography hinders the use of the land. Industry materials on energy storage facilities indicate that relatively flat land is preferred – land that is not located in wetlands and is accessible via access roads both during construction and subsequent maintenance (Electrum, 2025). Physical characteristics also include soil and water conditions as well as the overall state of site preparation. Unstable, wet, or soil requiring additional reinforcement may result

in higher preparatory costs and increase construction risks. Similarly, the presence of terrain obstacles, such as ditches, slopes, trees, or other elements hindering the development of the site, should be assessed. In the case of unfavorable water conditions, it may also be necessary to obtain the required water law approval, in particular a water law permit or to file a water law notification, which may affect both the project preparation time and the cost level.

5. Geodetic and agricultural conditions. The starting point is the data contained in the real estate cadastre. The Regulation on the Land and Building Register (2021) stipulates that land use is classified, among other things, into agricultural land, for which soil quality classes are also indicated. Agricultural land includes, in particular, arable land, permanent meadows, permanent pastures, orchards, developed agricultural land, forested and shrubby land on agricultural land, land under ponds, and land under ditches. However, the cadastral classification alone does not fully capture the essence of the matter. The Act on the Protection of Agricultural and Forest Lands (1995) classifies as agricultural land not only land designated in the cadastre as agricultural land, but also, among other things, land under fish ponds and other reservoirs used exclusively for agricultural purposes, land under buildings and facilities used exclusively for agricultural production, peatlands and ponds, as well as access roads to agricultural land. At this point, it is also worth clearly distinguishing between two issues: the designation of land for non-agricultural and non-forestry purposes, and the exclusion of land from agricultural production.

The Act (1995) stipulates that the provisions of the chapter on restricting the use of land for non-agricultural and non-forestry purposes do not apply to agricultural land located within the administrative boundaries of cities. However, this does not automatically mean that there are no obligations related to the exclusion of land from agricultural production, as the Act regulates these matters separately. The stage of removing land from agricultural production is of particular importance to the investor. The Act provides that the removal from production of agricultural land of classes I, II, III, IIIa, and IIIb, as well as agricultural land of classes IV, IVa, IVb, V, and VI formed from soils of organic origin, may take place following the issuance of a permit. Of economic significance in this context are the fee and annual charge associated with the exclusion of land from production, and the fee itself is reduced by the value of the land determined according to market prices on the date of actual exclusion. This means that the agricultural nature of the property may translate not only into formalities but also into a concrete economic burden on the project.

Restrictions on the transfer of agricultural real estate warrant separate discussion. Under the Act on the Development of the Agricultural System (2003a), as a general rule, only an individual farmer may acquire agricultural real estate, and a purchase by another entity may require the consent of the Director General of the National Center for Agricultural Support (NCAS). However, land located in areas designated in the local zoning plan entirely for non-agricultural purposes is excluded from the definition of agricultural real estate. This means that a change in land use in the local zoning plan may exclude the application of the provisions of the Act (2003a), whereas the decision on development conditions itself, as a rule, does not have such an effect. It is also significant that, upon the sale of agricultural real estate, the right of first refusal is granted first to a tenant meeting the statutory conditions, and only in the absence of such an entitled party or their failure to exercise the right of first refusal may (NCAS), acting on behalf of the State Treasury, exercise it. Additionally, as a general rule, the acquired agricultural property may not be sold or transferred to other entities for a period of 5 years without the consent of the Director General of (NCAS). Therefore, the plot of land should also be analyzed to determine whether the seller acquired it within the last 5 years and whether, if applicable, the consent of the Director General of (NCAS) was obtained for the prior sale or transfer of the property into the possession of another party.

6. Environmental conditions can affect both the feasibility of a project's location and the scope of required analyses, approvals, and mitigation measures. Not every environmental factor automatically precludes a project, but each one can increase procedural risks, prolong the project's preparation, or raise its cost. Of particular importance is the environmental decision, required at an early stage of the investment process, prior to obtaining further administrative decisions, including the zoning decision and the building permit (Siwkowska, 2023). The starting point is to determine whether the property is located within or adjacent to nature conservation areas, such as national parks, nature reserves, landscape parks, protected landscape areas, Natura 2000 sites, natural monuments, ecological land, or nature and landscape complexes. The mere presence of a protected area does not automatically preclude the investment, but it requires particularly careful analysis. It is helpful to verify this in the Central Register of Nature Conservation Areas and materials from the General Directorate for Environmental Protection, although for legal purposes, the acts establishing a given form of protection remain key (Act, 2004).

From the perspective of environmental procedures, it is crucial to determine whether the planned project requires an environmental decision. The Act on Access to Information on the Environment and Its Protection, Public Participation in Environmental Protection, and Environmental Impact Assessments (2008) requires such a decision for projects that are always likely to have a significant impact on the environment and for projects that are potentially likely to have a significant impact on the environment. The project analyzed in this study, i.e., a standalone high-voltage BESS on land parcels exceeding 1 ha in area, will always require obtaining a decision on environmental conditions and preparing an environmental impact report.

Natura 2000 sites and ecological corridors are of particular importance. The Act (2003a) prohibits actions that could significantly adversely affect the conservation objectives of a Natura 2000 site, in particular by deteriorating the condition of the habitats or species for whose protection the site was designated, or by impairing the site's integrity and its connectivity with other sites. Ecological corridors, on the other hand, are legally defined as areas that facilitate the migration of plants, animals, or fungi. Therefore, the location of a plot of land within the boundaries of a Natura 2000 site, in a relationship that could have a significant impact on such a site or within an area critical for maintaining the continuity of ecological connections, increases procedural risk and may require a more comprehensive analysis of the project's impact.

This same set of characteristics includes whether a plot of land is located in an area at particular risk of flooding. The Water Law Act (2017) stipulates that the level of flood risk must be taken into account in decisions determining the location of public-purpose investments and in decisions on zoning conditions, and that drafts of such decisions and planning documents concerning areas located in zones of particular flood risk require approval by Polish Waters. Approval may be denied if the planned development or land use violates the provisions of water management plans or flood risk management plans, poses a threat to human health, the environment, or cultural assets, or hinders flood risk management. The significance of this characteristic is therefore not limited to the risk of flooding itself, but also encompasses the potential formal and design implications resulting from the location of a plot of land in such an area.

7. Social factors must be assessed not only from the perspective of general functional conflict, but also in terms of fire safety and acoustic impact. Fires in lithium-ion warehouses can be highly dynamic, long-lasting, and produce large amounts of smoke as well as toxic and corrosive chemical compounds, which underscores the importance of maintaining an adequate distance from sensitive structures. Additionally, permissible environmental noise levels are critical for this type of development. For single-family residential areas, these levels are 50 dB during the day and 40 dB at night, while for multi-family residential, farmstead, recreational and leisure, and residential-commercial areas, they are 55 dB during the day and 45 dB at night. Consequently, the location of a plot relative to sensitive developments must also be assessed in terms of the risk of exceeding permissible noise standards. Consequently, the location of the development may require maintaining appropriate distances from noise-protected areas or the use of additional noise-reduction measures, such as noise barriers, which further impacts the costs and preparation time of the development (Janik & Tępiński, 2025; Regulation, 2007).

An example tool for assessing the potential of unbuilt land parcels for BESS projects Based on the above considerations, the authors propose a simple tool for organizing the site evaluation attributes relevant to the investment in question, in the form of a "property card" based on an expert scoring method. The card should have a two-stage structure. In the first stage, qualifying characteristics "Card I" (Table 1) should be included – that is, those that allow one to determine whether a given plot of land is eligible at all for the implementation of a BESS investment. The second stage should include differentiating characteristics "Card II" (Table 2), i.e., those used to compare plots of land that were positively evaluated in the first stage. This structure of the process avoids mixing basic conditions with characteristics that affect economic attractiveness.

In the section on differentiating characteristics, a five-point scale from 1 to 5 is proposed, where a score of 1 indicates a very unfavorable characteristic, 2 – unfavorable, 3 – average, 4 – favorable, and 5 – very favorable. The advantage of such a scale is its greater ability to capture differences between plots of land that have already passed the first stage of selection and to identify those with the greatest potential for investment.

Table 1. Card I – Characteristics determining the suitability of a plot of land for a BESS project

Feature	Description	Scale
Planning conditions	Is the location of the BESS in accordance with the local zoning plan? Is it possible to amend or adopt a local zoning plan, adopt an integrated investment plan, or obtain a decision on development conditions?	0-2
Legal conditions	Is it possible to successfully purchase real estate or obtain the appropriate legal title to the land?	0-2
Technical conditions - access to a public road	Does the plot of land have formal access to a public road?	0-2
Physical characteristics of the ground	Does the plot of land provide sufficient space to set aside and designate for a BESS, along with the accompanying infrastructure?	0-2
Geodetic and agricultural conditions	Is the land use structure optimal? Does the agricultural status of the land prevent the investment from moving forward?	0-2
Environmental conditions	Are there any environmental restrictions that would significantly hinder the issuance of an environmental decision?	0-2
Technical conditions – connection specifications	Is there a valid basis for proceeding with the connection process, or has the connection status been confirmed?	0-2

Source: own study

Table 2. Card II – Characteristics differentiating the suitability of a plot of land for a BESS project

Feature	Description	Scale
Planning conditions	To what extent are detailed planning parameters and restrictions—including building lines, floor area ratios, height limits, and the predictability of the planning process—beneficial?	1-5
Legal conditions	To what extent do the legal status of the property, the method of acquisition, and the scope of formalities facilitate the smooth and predictable completion of the transaction?	1-5
Technical conditions – transport conditions	How important is transportation accessibility?	1-5
Physical characteristics of the ground	To what extent are the plot's shape, the terrain's slope, the soil and water conditions, and the site's readiness advantageous?	1-5
Geodetic and agricultural conditions	To what extent are the following factors beneficial: the structure of agricultural land, soil quality classes, soil types (organic soils), and the fees and charges associated with taking land out of agricultural production?	1-5
Environmental conditions	How extensive is the scope of additional analyses, agreements, and mitigation measures?	1-5
Technical conditions – connection specifications	How favorable are the terms regarding: the length of the service line, the number of conflicts, the scope of work, and the connection costs?	1-5
Social conditions	To what extent are the neighbourhood and the relationship to sensitive development beneficial?	1-5

Source: own study

Discussion

It should be emphasized that the proposed scales are intended as models. Each item on the form should be described not only by the name of the characteristic, but also by a brief explanation of how that characteristic is defined for the purposes of the assessment, along with an indication of the source for its verification. For example, formal access to a road should be assessed based on planning documents, maps, and the legal title to access; connection status – based on connection conditions or design documents; legal status – based on the land and mortgage register and other legal documents; and environmental conditions – based on environmental documentation. This ensures that the assessment of individual land parcels is based on uniform criteria and reliable sources of public, official data. Furthermore, since some of the information is spatial in nature, it is necessary to utilize GIS tools and publicly available geoportals (for example, when verifying distances from utility networks, nature conservation measures, or areas at particular risk of flooding).

It should also be noted that in the case of Card I, all features should be treated equally, although this may vary in a few cases depending on specific local conditions, for example, the municipal office's approach to BESS investments, which influences planning conditions, or the specificity of the terrain when considering a development site in mountainous areas. It should also be noted that if a feature is 0, the plot should not be considered for a BESS investment. However, in Card II, features may be considered with less emphasis depending on the investor's capabilities, such as access to newer technology, which allows for a reduction in the required land area due to the BESS's larger capacity, or existing infrastructure, which influences the local community's trust in the company.

Conclusions

The aim of this study was to identify and discuss the attributes of undeveloped land parcels in the context of their potential for the construction of a standalone high-voltage BESS. An analysis of these attributes revealed that planning, legal, technical, land surveying and agricultural, environmental, and social factors are of particular importance. The study also resulted in the systematization of the characteristics that determine and differentiate the suitability of land for this type of investment. Ultimately, the practical outcome of the study is a proposal for feature cards for land parcels intended for BESS, developed using an expert scoring method. The proposed tool for assessing the potential of land parcels within Card I (covering determining features) allows one to determine whether a given land parcel is eligible at all for the implementation of a BESS investment. In turn, under Card II (covering differentiating characteristics), it enables the comparison of land parcels in terms of their best potential and economic attractiveness.

Funding

This paper was funded by a subsidy from the Department of Cadastre and Land Management, Faculty of Geodesy and Cartography, Warsaw University of Technology.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Publicly accessible data, including research papers with their DOIs listed in the references, support this study's findings.

Use of Generative AI and AI-Assisted Technologies

No generative AI or AI-assisted technologies were employed in the preparation of this manuscript.

References

Act (1964). Ustawa z dnia 23 kwietnia 1964 kodeks cywilny (*Civil Code Act*) (t.j. Dz.U. 2025, item 1071, 1172, 1508, 2026 item 184, 507).

Act (1995). Ustawa z dnia 3 lutego 1995 r. o ochronie gruntów rolnych i leśnych (*Act on the Protection of Agricultural and Forest Lands*) (tj. Dz.U. 2024, item 82).

Act (1997). Ustawa z dnia 21 sierpnia 1997 r. (*The Real Estate Management Act*) (t.j. Dz.U. 2026, item 399).

Act (2003). Ustawa z dnia 27 marca 2003 r. o planowaniu i zagospodarowaniu przestrzennym (*The Spatial Planning and Development Act*) (t.j. Dz.U. 2026, item 538).

Act (2003a). Ustawa z dnia 11 kwietnia 2003 r. o kształtowaniu ustroju rolnego (*Act on the Development of the Agricultural System*) (t.j. Dz.U. 2025, item 1653, 2026, item 317).

Act (2004). Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody (*The Nature Conservation Act*) (tj. Dz.U. 2026 item 13).

Act (2008). Ustawa z dnia 3 października 2008 r. o udostępnianiu informacji o środowisku i jego ochronie, udziale społeczeństwa w ochronie środowiska oraz o ocenach oddziaływania na środowisko (*Act on Access to Information on the Environment and Its Protection, Public Participation in Environmental Protection, and Environmental Impact Assessments*) (tj. Dz.U. 2026, item 670).

Act (2017). Ustawa z dnia 20 lipca 2017 r. – Prawo wodne (*The Water Law Act*) (Dz.U. 2017, item 1566).

Ayyildiz E., Yildirim B. (2026). Strategic battery energy storage system site selection in Türkiye's Black Sea region using an intuitionistic fuzzy decision methodology. Journal of Energy Storage, vol. 155. https://doi.org/10.1016/j.est.2026.121459.

Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. http://data.europa.eu/eli/dir/2023/2413/oj [access: 04.04.2026].

Electrum (2025). Jaki grunt nadaje się pod magazyn energii? Mądre inwestycje w OZE. (*What kind of land is suitable for an energy storage facility? Smart investments in renewable energy*). https://electrum.pl/jaki-grunt-nadaje-sie-pod-magazyn-energii [access: 25.05.2026].

Gao J., Wang Y., Huang N., Wei L., Zhang Z. (2022). Optimal site selection study of wind-photovoltaic-shared energy storage power stations based on GIS and multi-criteria decision making: A two-stage framework. Renewable Energy, vol. 201, part 1, pp. 1139–1162. https://doi.org/10.1016/j.renene.2022.11.012.

Hameed Z., Hashemi S., Træholt Ch. (2020). Site Selection Criteria for Battery Energy Storage in Power Systems. In: Proceedings of 33 rd Canadian Conference of Electrical and Computer Engineering IEEE. https://doi.org/10.1109/CCECE47787.2020.925567.

Igliński B., Kiełkowska U., Mazurek K., Drużyński S., Pietrzak M.B., Kumar G., Veeramuthu A., Skrzatek M., Zinecker M., Piechota G. (2024). Renewable energy transition in Europe in the context of renewable energy transition processes in the world. A review. Heliyon, vol. 10, no. 24. https://doi.org/10.1016/j.heliyon.2024.e40997.

Janik P., Tępiński J. (2025). Bezpieczeństwo pożarowe magazynów litowo-jonowych – wyzwania i dylematy (*Fire safety of lithium-ion storage facilities – challenges and dilemmas*). Centrum Naukowo-Badawcze Ochrony Przeciwpożarowej im. Józefa Tuliszkowskiego – Państwowy Instytut Badawczy, Józefów.

Kafar D., Kornecka A., Kornecki J. (2025). Prawne aspekty uchwalenia zintegrowanego planu inwestycyjnego (*Legal aspects of adopting an integrated investment plan*). C. H BECK, Warszawa.

Khalid M. (2024). Smart grids and renewable energy systems: Perspectives and grid integration challenges. Energy Strategy Reviews, vol. 51, https://doi.org/10.1016/j.esr.2024.101299.

Kubiczek J., Kaliszuk A., Bochenek A. (2025). Dynamics of energy transition in the context of Poland's energy security. Frontiers in Energy Research, vol. 13. https://doi.org/10.3389/fenrg.2025.1701904.

MKiŚ 1 (2026). Ministerstwo Klimatu i Środowiska. Polska osiąga 50% mocy z OZE – historyczny przełom (*Ministry of Climate and Environment. Poland Generates 50% of Its Electricity from Renewable Energy Sources—A Historic Milestone*). https://www.gov.pl/web/klimat/polska-osiaga-50-mocy-z-oze--historyczny-przelom?utm_source=chatgpt.com [access: 25.05.2026].

MKiŚ 2 (2025). Ministerstwo Klimatu i Środowiska. Magazyny energii to klucz do skutecznej transformacji (*Ministry of Climate and Environment. Energy storage is the key to a successful transition*). https://www.gov.pl/web/klimat/magazyny-energii-to-klucz-do-skutecznej-transformacji [access: 25.05.2026].

MKiŚ 3 (2025). Ministerstwo Klimatu i Środowiska. Inwestujemy w wielkoskalowe magazyny energii (*Ministry of Climate and Environment. We are investing in large-scale energy storage facilities*). https://www.gov.pl/web/klimat/inwestujemy-w-wielkoskalowe-magazyny-energii [access: 25.05.2026].

Nazaralizadeh S., Banerjee P., Srivastava A.K., Famouri P. (2024). Battery Energy Storage Systems: A Review of Energy Management Systems and Health Metrics. Energies, vol. 17 (5). https://doi.org/10.3390/en17051250.

Ping D., Li C., Yu X., Liu Z., Tu R., Zhou Y. (2025). City-scale information modelling for urban energy resilience with optimal battery energy storages in Hong Kong. Applied Energy, vol. 378, part A. https://doi.org/10.1016/j.apenergy.2024.124813.

Regulation (2007). Rozporządzenie z dnia 14 czerwca 2007 r. w sprawie dopuszczalnych poziomów hałasu w środowisku (*Regulation on permissible environmental noise levels*) (tj. Dz.U. 2014, item 112).

Regulation (2021). Rozporządzenie z dnia 27 lipca 2021 r. w sprawie ewidencji gruntów i budynków (*Regulation on the Land and Building Register*) (tj. Dz.U. 2024, item 219).

Sakib S., Hossain Md.B., Zamee M.A., Hossain M.J., Habib Md.A. (2025). Role of battery energy storage systems: A comprehensive review on renewable energy zones integration in weak transmission networks. Journal of Energy Storage, vol. 128. https://doi.org/10.1016/j.est.2025.117223.

Shahzad S., Jasińska E. (2024). Renewable Revolution: A Review of Strategic Flexibility in Future Power Systems. Sustainability, vol. 16. https://doi.org/10.3390/su16135454.

Sikorska-Pastuszka M., Surowka M., Sliwinska-Grzegorczyk M. (2025). Modernization of electric infrastructure as a foundation for renewable resources transformation. Scientific Journal of Bielsko-Biala School of Finance and Law, 29(4). https://doi.org/10.19192/wsfip.sj4.2025.6.

Sokół K., Sobolewska-Mikulska K. (2024). Prawo rzeczowe w procesie wyceny nieruchomości (*Property law in the real estate valuation proces*). Politechnika Warszawska, Warszawa.

Wikimedia Commons (2025). File: Reid Gardner BESS.jpg. https://commons.wikimedia.org/wiki/File%3AReid_Gardner_BESS.jpg [access: 25.05.2026].