IMPACT ASSESSMENT OF RENEWABLE ENERGY IN THE REGION: A CASE STUDY OF THE ŠLUKNOV AGRIVOLTAIC POWER PLANT

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ABSTRACT

The ongoing energy crisis, the push for carbon neutrality, and the development of both European and national energy policies are driving significant changes in energy mix strategies. This is further supported by incentives, such as subsidies for operators of renewable energy sources (RES), which place municipalities and their mayors in a position to decide on the support for RES projects. The aim of the paper is to address the information asymmetry that exists among potential investors, mayors, and local residents through the introduction of an impact assessment tool. This tool, based on the multi-criteria analysis, is designed to help mayors and relevant stakeholders better comprehend the implications of RES and to evaluate their effects on local communities. The impacts of RES construction and operation are categorized into four key areas: environmental, social, economic, and innovative. The assessment process takes into account the unique characteristics of the local area, positioning the tool as a preliminary step before engaging in more resource-intensive methods such as feasibility studies and environmental impact assessments (EIA).

The effectiveness of the developed tool is demonstrated through a case study on the impact assessment of a proposed agrivoltaic power plant in the Šluknov region. Notably, compared to traditional photovoltaic power plants, agrivoltaic systems significantly mitigate a range of negative environmental impacts. Consequently, the implementation of such a power plant is anticipated to yield positive economic and social benefits for the micro-region.

Keywords: impact assessment; agrivoltaics; renewable energy sources; municipality

INTRODUCTION

The pressure to replace fossil fuels has led to the increased utilization of renewable energy in recent years (Jain *et al.*, 2021). According to the latest European Union directive, 42.5 % of total energy consumption should come from renewable energy sources (RES) by 2030 (European Parliament, 2023). With financial support from the EU, there is now a general increase in demand for the construction of new energy sources. Investors seeking profit propose the construction of renewable energy sources. In this context, many mayors have been recently faced with the decision of whether or not to support the construction of RES in their municipalities. Mayors, particularly those of smaller municipalities, face an increasing bureaucratic burden and often lack an energy manager to oversee energy and RES projects. As a result, mayors must take an interest in the impact of constructing and operating a new

RES in their municipality but usually do not have sufficient expertise to do so. They face the information asymmetry. Local residents often fear change, which leads to the NIMBY (Not In My Backyard) effect, where they resist the construction of new buildings in their neighbourhood (Rösch & Fakharizadehshirazi, 2024).

To facilitate understanding of the issue, a comprehensive impact assessment tool based on multi-criteria analysis has been developed to help the mayor assess the impact of RES construction and operation with knowledge of local specificities (Macháč *et al*., 2018). The aim of the paper is to present a method for addressing information asymmetry through an impact assessment tool on a specific case study of agrivoltaic power plant in Šluknov region. This assessment procedure is not intended to replace more commonly used and professionally more demanding analyses such as feasibility studies or Environmental Impact Assessments (EIA). The assessment presented below can be seen as a precursor to these more detailed analyses, which can follow in the case of a positive outcome. This tool can assist both mayors and potential investors during the initial decision-making phase of RES development. It can help determine whether the selected type of RES is suitable for a particular location and whether its construction would bring positive or negative impacts to the municipality.

However, as the demand for renewable energy grows, so do conflicts over land use. This problem can be mitigated and addressed through "agrivoltaics", which combines the energy production with the continuation of agricultural activities. While this concept is relatively new and innovative in the Czech Republic, it has already been implemented in Austria, Italy and France (Torma & Aschemann-Witzel, 2023).

Agrivoltaics and previous experiences

The literature review shows that the concept of agrivoltaic power plants has not been extensively studied, particularly in terms of impact assessment. Some recent studies have focused on social and economic impacts, with cost-benefit analysis (CBA) mentioned as a method used for the impact analysis of RES, according to the review by Agyekum (2024). Nevertheless, it can be said that a growing number of studies have emerged in recent months, analysing and comparing this new type of RES with others from a technical and environmental perspective. Guillot *et al.* (2023) point out that agro-PV allows for electricity production while using the land between and under the panels for cultivation. Although the output of this innovative type of power plant is lower in terms of energy production, this research suggests it enables food production and contributes to the decarbonisation of European energy systems. Agrivoltaics are also viewed as an effective solution to land use competition, as described by Jing *et al.* (2022), who explain that a growing population increases the demand for food and, consequently, the need for more agricultural land. At the same time, the demand for low-carbon energy requires more space for renewable energy installations. Their study examines urban rooftop agriphotovoltaic (APV) systems, which are seen as a hybrid ecosystem that can provide various ecosystem services, such as water purification, recreational space, and the production of local healthy food. Additionally, the system can protect crops from fluctuations in weather and climate, and the shade provided by the panels has the potential to improve water management and stabilize yields. Installing solar panels above crops can offer multiple benefits, as noted by Vélez *et al*. (2024), such as enhanced biodiversity, increased energy production and modified crop microclimates. The impact of agrivoltaics on the microclimate and soil ecology under the solar panels was studied by Tan *et al*. (2025). This study shows that agrivoltaics can improve water utilization, increase humidity, and buffer soil temperature due to the shading effect. From an economic perspective, agrivoltaics (combing energy production with farming) promotes the diversified development of the agricultural economy.

A comparison of the environmental and economic assessment of conventional and agricultural PV systems is presented in the work of Junedi *et al*. (2022), who also view this type of system as a good solution to the competition for land use (residential, agricultural, energy). Their research, which focuses on horizontal panels, found positive effects, including reduced radiation due to the shading effect, lower soil temperatures and evapotranspiration, and reduced need for irrigation. They point out that, from an economic perspective, although agrivoltaics involves higher costs than a conventional solar system of similar capacity, the system generally provides positive returns.

For example, Agostini *et al*. (2021) conclude that the cost of energy production is comparable for both conventional solar and agrivoltaic systems, with the advantage of APV being its contribution to the United Nations´ Sustainable Development Goals. Furthermore, agrivoltaics is seen as a type of renewable energy that increases energy self-sufficiency and reduces dependence on fossil fuels (Irie *et al*., 2019). However, the impact on the landscape and the reduced flexibility in land management regarding the choice of suitable production are perceived negatively by citizens living near the agrivoltaic power plant, particularly local farmers.

Jain *et al*. (2021) also consider this type of RES beneficial in terms of soil conservation, noting that in hot climates, growing shade crops under PV panels can increase yields while mitigating the negative effects of high temperatures. The study by Chalgynbayeva *et al*. (2022) presents different conclusions. The economic modelling in their paper shows that, under current economic and technological conditions, agrivoltaic systems cannot compete with conventional PV systems due to the higher investment costs.

In some countries, agrivoltaics are already widespread, e.g. France has made them a mainstay of its solar energy targets by 2022, as noted in the study by Torma & Aschemann-Witzel (2023). The authors point out that some respondents to their survey did not consider this type of RES to be a very good alternative. The results of their research revealed a major barrier to the development of APV, namely stakeholder concerns about change and transitioning to this type of PV. To improve social acceptance of new installations, the authors of the study recommended increasing the use of smaller installations and to involving key stakeholders (e.g. local communities and future operators) in decision-making processes.

Pascaris *et al*. (2021, 2023) examine the acceptance of agrivoltaics among US energy experts and local communities. Their findings show that local residents demand the preservation of the productive functions of agricultural land and that investors remain open to local demands. Agrivoltaics are gaining prominence in some countries as part of climate change mitigation strategies, a tool for sustainable development, and an option for supporting rural economies. Negatives aspects and barriers include the novelty of the approach, technological and economic challenges, and political feasibility. However, the authors highlight the benefits of agrivoltaics, such as increased crop yields, improved drought resilience, better water management, and a generally lower environmental impact compared to conventional PV.

MATERIALS AND METHODS

A new tool has been developed for assessing the impact of the construction and operation of renewable energy sources, which should be used in the initial decision-making phase (Macháč *et al*., 2018). It can be particularly useful for mayors of smaller municipalities who are faced with the decision of whether or not to support the construction of RES in their municipality. This comprehensive tool can help mayors to get an initial overview of the issue, to familiarise themselves with the type of RES and to use their knowledge of local specificities to assess whether the construction of RES will be beneficial for the micro-region. Similarly, the tool can be used by investors themselves to support their arguments in the approval processes required for construction permits. Based on a case-specific assessment, investors can influence the opinion of local government representatives and the attitude of the local residents, whose pressure may support the project or, on the contrary, jeopardise it. The tool can also help NGOs argue for or against a particular proposal.

The construction and operation of RES is associated with several direct and indirect impacts, both financial (e.g. changes in production) and non-financial (e.g. landscape). All these potential impacts need to be carefully considered prior to construction and included in the decision-making process. Several impact assessment processes are used in the Czech Republic. The impacts of legislative changes are analysed in Regulatory Impact Assessments (RIA), and these impacts are usually assessed at the national level. Economic, social and environmental impacts are the most relevant for RES development. The environmental impacts are assessed in more detail in an Environmental Impact Assessment (EIA), which examines and assesses the environmental impacts mainly associated with construction.

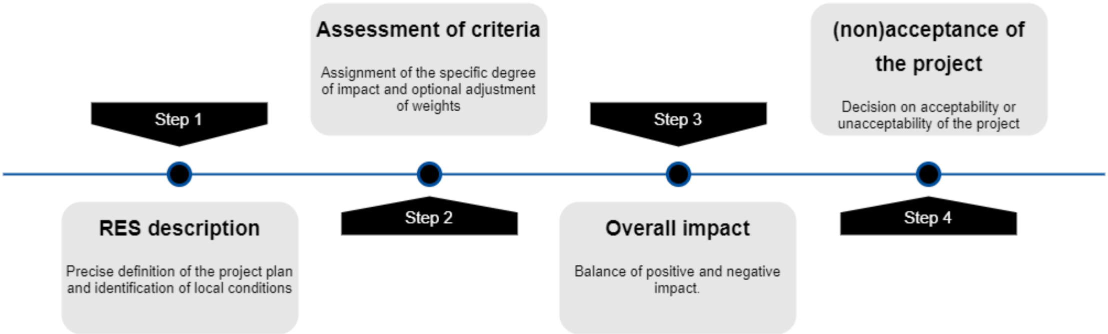
Multicriteria assessment

The literature review revealed the lack of a tool to assess all these impacts at a local level, using local knowledge. The principles of the so-called Local Impact Assessment (LIA) were used to incorporate local specificities (Whiteman & José, 2004) in the assessment of the impacts of RES construction and operation on the micro-region. The resulting overview of a wide range of impacts was divided into 4 pillars: economic, social, environmental and innovation impacts. In the last case, these are effects that do not directly affect the previous three pillars, but effects that usually have more development potential for the future, i.e. opportunities and potential threats for the micro-region.

The most appropriate method for a simple and time, technically and financially inexpensive evaluation of the overall impact of RES on the micro-region seems to be the use of the so-called multi-criteria analysis. This allows a comprehensive evaluation of a project using different forms of data, information and criteria and does not require a monetary expression of all impacts. The individual impacts described above are assigned impact scores by the user of the tool (e.g. mayor or investor), which can range from -3 (most negative impact) to +3 (most positive impact). In the next step, the importance of each criterion is decided, and weights (impact importance) are assigned. These weights are predetermined as shown in the methodology by Macháč *et al*. (2018), and their value is derived from expert studies that analyse survey among local public administration representatives. For indicators where it was not possible to determine the weight based on research, consultation and expert judgement were used. The final step is to calculate the overall impact of the project plan, which is the sum of the impacts of all criteria, considering their level of influence. The result is then a balance of positive and negative impacts in the form of a positive or negative number, which indicates the degree to which the project is beneficial to the whole region. In this case, the multi-criteria analysis can be used not only to give an opinion on whether to accept the project or not, but also to identify the most favourable project option or to reduce the number of options for further consideration.

The process of assessing the impact of the construction and operation of renewable energy sources on the micro-region is broken down into several successive steps, as shown in Figure 1. For a project to be considered suitable for support, its overall impact should be greater than zero. In the case of values close to zero, there is no clear outcome for supporting or rejecting the project, in which case it is advisable to revisit the assessment. For example, the project may be modified so that at least some of the impacts are positive.

Fig. 1: Process for assessing the regional impacts of renewable energy projects



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Identification of criteria

At the local level, economic impacts are mainly related to the area's economic growth, stability and economic efficiency. Thus, one of the key impacts in this group is Gross Domestic Product (GDP), which can be seen as an indicator of regional economic growth (Carroll, 2010). At the community level, maximising the involvement of local businesses will have significant positive benefits. The economic impact of the micro-region also includes the income and costs to the municipality, the impact on the agriculture, forestry and water management sectors, the potential use of waste heat produced, and the financial aspects related to the possibility of obtaining subsidies for the implementation of the project or related investments. If the municipality itself is the investor, the revenue and cost implications can be significant.

Social impacts include employment (Dvořák *et al.*, 2017), which should be divided into short-term impacts associated with the construction of the RES and long-term impacts associated with the operation itself. Social impacts include the possibility of reducing the cost of energy purchases, where more favourable energy prices for the community and its residents can be negotiated with the investor as part of the construction. It also includes education and human capital, municipality development and the appearance and perception of the community, which is often associated with concerns about noise, odour and increased traffic.

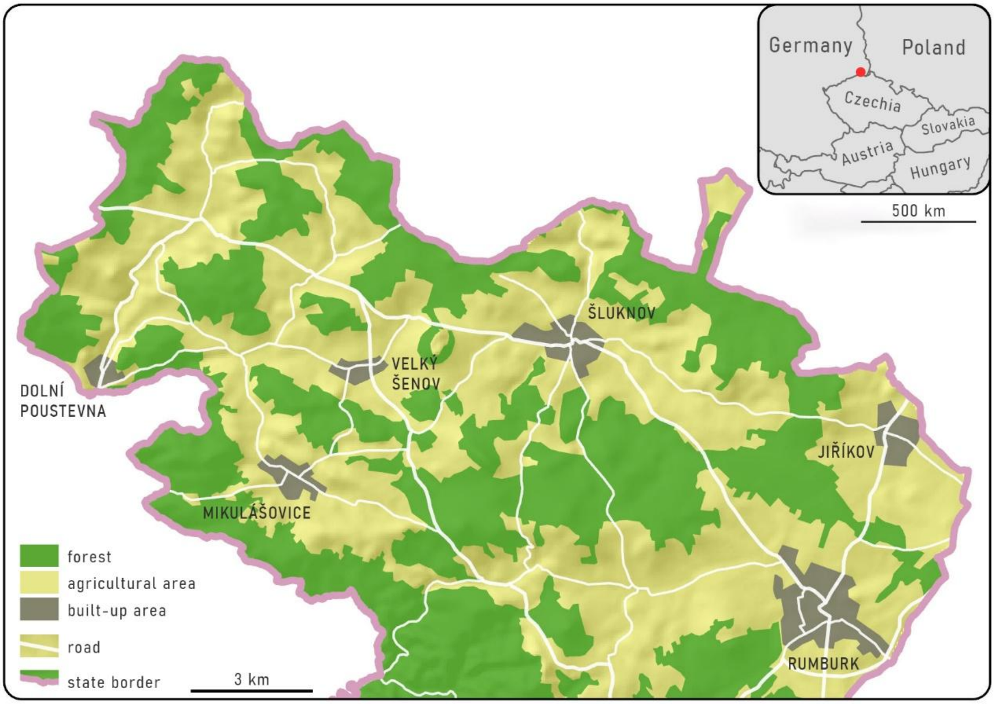
The environmental impact category is very diverse (Holma *et al.*, 2018; Lohse, 2018). Impacts vary according to the type of RES and local conditions. Relevant impacts are soil erosion and quality, biodiversity, water quality and consumption, air quality, CO2 emissions, noise, waste management and land use, which is most relevant for PV.

The last group consists of innovation effects (Bhattacharya *et al*., 2016), where infrastructure is included as a prerequisite for the construction of RES, and the business environment, where the involvement of local suppliers will have a significant impact on the micro-region.

Study area and planned project overview

The Šluknov promontory is located in the northernmost part of the Czech Republic and is surrounded on three sides by German territory. The location includes the towns of Šluknov, Dolní Poustevna, Jiříkov, Velký Šenov, Rumburk, Varnsdorf, Krásná Lípa and Mikulášovice (see Fig. 2). The project of agrivoltaic power plant building is planned in the rural area of one of the municipalities.

Fig. 2: The territory of the Šluknov region



Source: own

The designed output of the power plant is 50-80 MW, depending on the consent of the landowners and their interest in implementing this renewable energy source. The main concept of the system is the vertical installation of specific solar modules that are capable of utilizing light from both sides ("bifacial" modules). Both sides of the modules face east and west, which leads to peak energy production in the early morning and evening.

Therefore, energy is produced at times when it is most needed, compared to conventional panels. The production corresponds to the daily electricity price curve on the power exchange. The areas between the rows of modules can still be used for agriculture, and the resulting strips under the rows of modules provide space for endangered insects and many species of birds.

RESULTS

Based on the information provided by the project investor and considering local specifics, the individual criteria of the agrivoltaic power plant project in the Šluknov region were evaluated. To determine the overall impact, weights were assigned to the criteria based on the aforementioned literature review and then multiplied by the impact rate corresponding to the specifics of the project and the particular location. The overall impact of the entire project proposal is given by the sum of the total impacts from all four pillars. The team of authors reviewed the criteria and made an assessment based on the data provided by the potential investor of the project. Local aspects were included based on partial analysis of the area (e.g. proximity to settlements, landscape character, etc.)

Relevant impacts were divided into short-term and long-term impacts. The environmental pillar includes 8 basic criteria that can be affected by the construction and operation of RES, and the evaluated power plant project in the Šluknov region is neutral in this pillar. The agrivoltaic power plant significantly reduces the potential negative impacts associated with the construction of conventional photovoltaic power plants. For conventional off-roof projects, soil quality can be altered, disturbed and eroded, and construction is usually associated with negative impacts on biodiversity. Land is taken that has limited use. Unless these negatives are offset by other benefits, the overall impact is negative. However, as mentioned above, these impacts of conventional photovoltaic (PV) power plants on agricultural land are eliminated in the case of agrivoltaic power plants. The assessment of environmental impacts for the project under consideration is shown in Table 1.

Table 1: Environmental impact assessment of the agrivoltaic power plant project in the Šluknov region (compared to a conventional PV plant) (NR=not relevant)

Pillar	**Impact type/Criterion**	**Overall impact of the criterion**	
		APV	**Common PV**
Environmental	**Soil Erosion and Quality**	NR	-7
	Biodiversity	NR	-7
	Water Quality and Consumption	NR	NR
	Air Quality	NR	NR
	CO_2 emission	NR	NR
	Noise	NR	NR
	Agricultural Land Occupation	NR	-21
	Waste	NR	NR
Overall Impact		**0**	**-35**

Source: own

The comparison in Table 1 shows that the construction and operation of an agrivoltaic plant can be considered more environmentally friendly, with only a slight reduction in agricultural activity compared to the current situation.

A total of 8 basic criteria are also assessed under the economic pillar. These include impacts on regional GDP, costs and revenues for the municipality, agriculture, forestry and water management, energy cost savings through waste heat utilization and alternative financing sources. The values of the economic impacts depend strongly on the type of renewable energy source, but also on whether the investor is a private entity or a municipality; differences may also be caused by land ownership, the location of the company that will operate the renewable energy source, supply chains, etc.

In the economic pillar, the impacts of agrivoltaic systems are not very different from those of conventional PV systems. The more significant difference is in agricultural income, where a conventional PV plant would replace the landowner's income from agricultural use with rental income from the plant owner. Since it is possible to combine agricultural activities with the operation of a solar power plant, the landowner can receive a higher income from the combination of both activities. Other economic impacts are related to the income of the municipality if it owns part of the land. If the company operating the power plant is based in the micro-region, the taxes paid would generate revenue for the budget and the energy production would be counted in the regional GDP. Additional revenues may be generated by the municipality through contributions to the municipal budget for infrastructure maintenance and other activities. Overall, the economic pillar scores between 44 and 60, depending mainly on the location of the company's headquarters. The overall impact of the economic pillar is shown in Table 2 below.

A total of 5 main criteria are used to assess the impact of the social pillar. Impacts on short and long-term employment, energy prices for customers in the area, education and human capital, and impacts on the municipality or landscape appearance are assessed. Compared to conventional PV, the agrivoltaic type is less disruptive to the aesthetic appearance of the village, especially when viewed up close, but the impact is still assessed negatively. If local companies are involved in the construction of the plant, jobs can be created in the short term, and additional jobs in the long term are associated with the maintenance and operation of the RES, and there is also a demand for certain professions, thus potentially supporting education in the region. The implementation of both APV and conventional PV offers the opportunity to negotiate with the municipality and local residents for a potentially lower cost of electricity, which can lead to savings for households and possibly the municipality itself. A comparison of the social impact assessment for an agrivoltaic power plant and a conventional PV plant is presented in Table 3, which shows that the construction of both types of RES can be considered beneficial in terms of social impacts, with the impact values of the agrivoltaic plant slightly outweighing those of the conventional PV plant in a positive sense.

Table 2: Economic impact assessment for the agrivoltaic power plant project in the Šluknov region (NR=not relevant)

Pillar	Impact type/Criterion	Overall impact of the criterion	
		APV	Common PV
Economic	Regional GDP	0/4	
	Costs for the municipality	NR	
	Revenues for the municipality	24/36	
	Agriculture	20	
	Forestry	NR	
	Water management	NR	
	Waste heat utilization	NR	
	Alternative sources: subsidies	NR	
Overall Impact		**44/60**	

Source: own

Table 3: Social impact assessment for the agrivoltaic power plant project in the Šluknov region (compared to a conventional PV plant)

Pillar	Impact type/Criterion	Overall impact of the criterion	
		APV	Common PV
Social	Short-term employment	0/4	0/4
	Long-term employment	24	24
	Energy prices	0/10	0/10
	Education and human capital	0/4	0/4
	Impacts on municipality/landscape appearance	**-10**	**-20**
Overall Impact		**14-32**	**4-22**

Source: own

The innovation pillar covers the potential for further development of the municipality or micro-region and includes two criteria: the level of infrastructure and the business environment. However, in the case of the project in the Šluknov region, neither of these criteria is affected by the type of PV system (agricultural vs. conventional). In both cases, implementation would lead to increased grid stability, which would have a slightly positive impact on business development. Due to the innovative type of photovoltaic power plant, which is not yet used in the Czech Republic, the construction of the project would attract professional and media attention to the region. The overall impact of both criteria of the innovation pillar is shown in Table 4.

Table 4: Innovative impact assessment for the agrivoltaic power plant project in the Šluknov region

Pillar	Impact type/Criterion	Overall impact of the criterion	
		APV	Common PV
Innovative	Infrastructure level	7	
	Business Environment	4	
Overall Impact		11	

Source: own

DISCUSSION

As mentioned above, the impact assessment of agrivoltaics have not been studied a lot up to now. Cost-benefit analysis is supposed to be a commonly used method for evaluating the public projects which can raise an awareness about the positives and negatives of the project planned (e.g. Hekrle *et al*., 2023; Vejchodská, 2015). It can be also used in the field of agrivoltaics as in the study by Chalgynbayeva *et al*. (2022), who focused on the comparison of APV and PV systems from the economic and technical point of view. Anyway, authors of the study themselves see the limits of CBA method used for the agrivoltaics, because of the lack of data available, many important factors (such as very uncertain price of electricity, transportation costs etc.) have been ignored which makes the CBA not suitable for the impact assessment in agrivoltaics. Also Vejchodská (2015) points out that the method of CBA makes sense only in the cases where results are reliable, and the CBA process is supposed to be too complicated to be analysed by inexpert. An accurate data is missing at the project design stage and the mayor of the municipality mostly doesn´t have the knowledge needed for the precise method of CBA, which is also supposed to be time and money consuming. The new tool based on the principles of multi-criteria analysis with the local specifics included, presented in this study, can serve as a precursor to further precise assessments.

A comparison of the impact assessment of conventional PV and agrivoltaic power plant planned as a case study in the region of Šluknov showed a preponderance of positive results for the construction of an innovative type of RES using agrivoltaics. The difference was mainly due to the possibility of using the land concerned (less agricultural land taken) and less environmental impact (soil quality, biodiversity). The considered agrivoltaic power plant project in the Šluknov region has negative impacts, mainly in terms of aesthetic impacts on the appearance of the landscape, but an extensive literature search shows that these impacts are generally associated with the construction of RES. The problem is particularly exacerbated by the NIMBY (not in my backyard) effect (Rösch & Fakharizadehshirazi, 2024), where residents generally welcome the construction or project, but refuse to have it built near their own homes (or in their municipality). A common reason for opposition is the change in the appearance of the landscape and concerns about noise, smell, etc. The choice experiment method focusing on public perception of agricultural landscape made by Kim *et al.* (2021) showed the decreased value, people prefer the agricultural landscape view more than a view on agrivoltaic panels. In terms of environmental impact, the agrivoltaic power plant has a neutral impact, while in other pillars (economic, social and innovative) it has a significant potential for the development of the micro-region/municipality.

The municipality in the Šluknov region can gain an important partner in the power plant, which can generate revenues for the municipal budget if the company is registered in the municipality. There is scope for negotiating more favourable tariffs for energy consumption by local residents and farmers itself, as mentioned by Vidotto *et al*. (2024). The municipality may also receive additional funds from the lease of the land, which is expected to create new jobs related to the operation of the power plant and, due to the specificity of the job, there is also potential for the development of education in the locality. These benefits are also named as opportunities in the study about agrivoltaics made by Vidotto *et al*. (2024).

Concerning the increasing pressure to develop new renewable energy sources in order to meet national and European targets, the project plan to build an agrivoltaic power plant in the Šluknov region appears reasonable and can be recommended on the basis of the results of the impact assessment. Both the agrivoltaic and the conventional solar power plant come out positively in the assessed location, even without including potential benefits resulting from possible negotiations between the municipality and the investor. Compared to other conventional photovoltaic power plants evaluated in the article by Macháč & Zaňková (2020), very low negative environmental impacts can be expected in the case of the project plan for construction in the Šluknov region. On the contrary, there is a great opportunity to achieve additional economic benefits.

While agrivoltaics is already being utilized in neighbouring countries, in the Czech Republic there are only a few initial projects so far. If implemented, it can be expected to attract increased media coverage and attention from the professional public. This may indirectly lead to the development of other activities in the micro-region/municipality, including a significant strengthening of tourism and associated additional potential income for the municipal budget.

CONCLUSION

The EU aims to replace an increasing proportion of fossil fuel consumption with renewable energy. These transnational objectives are also reflected in national energy policies. As a result, the growing pressure to use renewable energy sources is driving the large-scale construction of such energy sources. In the absence of an energy manager position in smaller municipalities, the mayor of the municipality or micro-region takes on the responsibility of determining whether the implementation of a renewable energy project is appropriate for the area. However, mayors have been facing an increasing administrative burden in recent years and gaining insights into some of the more specialised or technical areas can be time and money consuming and difficult for them.

Following an extensive literature review and the realization that no simple methodology existed to assist mayors in this role, a comprehensive tool for assessing the impacts of RES construction and operation was developed using the multi-criteria analysis. This tool is primarily intended for use by mayors (but also, for example, by investors) to help them understand the issues and make an initial assessment of whether to support or reject a project in the area. Developing the assessment requires knowledge of local specificities, which mayors can undoubtedly apply. This paper presented both the tool itself and its practical application, using as an example the potential construction of a new type of photovoltaic power plant, the so-called agrivoltaic plant, which combines electricity production with agricultural production. The results of the evaluation showed that the predominant positive impacts support the implementation of the project, and thus, the project should therefore be endorsed.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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