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Wind energy in the natural and social environment

Research and Innovation action (RIA)

wimby

WIND IN MY BACKYARD

WIMBY

Wind in My Backyard: Using holistic modelling tools to advance social awareness and engagement on large wind power installations in the EU

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SHORT ABSTRACT FOR DISSEMINATION PURPOSES

Abstract This deliverable presents a step-by-step guide for implementing a framework based on the Multi-Criteria Satisfaction Analysis (MCSA) method to evaluate satisfaction for wind power plant projects. The framework proposes a systematic procedure to collect and translate the preferences of residents into quantifiable satisfaction levels for wind power production installations in their vicinity. Building on the inputs from D4.1 and D4.2, a tailor-made and transparent satisfaction analysis system has been developed that incorporates specific criteria, indicators, and factors influencing wind energy satisfaction. Satisfaction functions of participants are determined using a preference disaggregation decision analysis model called the MUlticriteria Satisfaction Analysis (MUSA) method, with the help of questionnaires. The aggregated preferences of participants across multiple criteria yield result in the satisfaction levels, which are then categorised per demographic groups to support targeted strategies for improving satisfaction.

The detailed guidelines provided in this deliverable support local authorities, analysts, and anyone else, seeking to apply a satisfaction analysis in their respective areas. The potential practitioners can also benefit and inspire themselves from the actual satisfaction questions, created as part of the WIMBY project. The satisfaction analysis framework and the developed questionnaire have been validated across four pilot sites in three countries, the results of which are presented and analysed in this deliverable. Insights from the case studies will inform recommendations in WIMBY D4.6.

TABLE OF CONTENTS

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ABBREVIATIONS

Acronym	Description
ADI	Average Demanding Index
AII	Average Improvement Index
ASI	Average Satisfaction Index
GDPR	General Data Protection Regulation
KM	Kilometre
MCDA	Multi-Criteria Decision Analysis
MCSA	Multi-Criteria Satisfaction Analysis (Framework)
MUSA	Multicriteria Satisfaction Analysis (Method)
MW	Megawatt

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Public acceptance is a critical challenge for wind energy deployment. Authorities and developers need a rigorous yet practical way to measure how residents perceive benefits and impacts, and to turn those insights into targeted actions. D4.3 (i) validates the guidelines for implementing the Multi-Criteria Satisfaction Analysis (MCSA) framework, (ii) tests their transferability across contrasting contexts, and (iii) presents common and site-specific public satisfaction/acceptance of wind energy on different aspects.

Building on D4.1–D4.2, we applied MCSA, which is centred on the preference-disaggregation method Multicriteria Satisfaction Analysis (MUSA), at four pilot sites in three countries: Pantelleria in Italy, Styria (Ennstal: Gröbming & Irdning) in Austria, Viana do Castelo and Torres Vedras in Portugal. A harmonised, consortium-validated questionnaire captured satisfaction/acceptance across twelve sub-criteria grouped into three dimensions (environmental, community, individual). MUSA produced criterion weights, satisfaction functions, and summary indices, visualised via action and improvement diagrams.

Fieldwork relied on in-person surveys adapted to each context. Through MCSA, we find the overall acceptance is strong and demand is low at all sites. Community aspects are most influential in Austria and Portugal, and personal aspects dominate in Pantelleria.

Applying the full workflow across four contrasting settings demonstrated the guidelines' usability and adaptability. From problem structuring through survey localisation, data processing, and interpretation, it provides a consistent pathway from raw responses to decision-ready evidence. D4.3 delivers a ready-to-use set of guidelines for integrating MCSA into planning and permitting. Results feed directly into D4.6 for the synthesis analysis.

All task objectives were successfully achieved within the planned timeline. Moreover, the scope of the study expanded significantly from the original plan, evolving from one to four pilot sites across three countries.

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1. INTRODUCTION

Amid the accelerating global shift to sustainable energy, the expansion and repowering of wind power installations are critical to achieving renewable energy targets [1]. However, these initiatives often face significant socio-economic and environmental challenges, including resistance from local communities, residents, and other stakeholders, which can hinder project success [2]. Addressing such challenges requires a structured decision-making approach that actively engages stakeholders, especially local residents, and systematically assesses their preferences and satisfaction levels. Specifically, regarding residential and commercial areas, local satisfaction often plays a critical role in the success of such projects.

Task 4.1 of the WIMBY project addresses these needs by developing a comprehensive Multi-Criteria Satisfaction Analysis (MCSA) framework. This framework builds on the principles of Multi-Criteria Decision Analysis (MCDA), which include defining explicit criteria, assigning weights to their importance, and aggregating performance scores to support transparent and balanced decision-making [3]. Central to the framework is the use of the MUlticriteria Satisfaction Analysis (MUSA) method, which quantifies satisfaction levels across multiple dimensions [4], [5]. MUSA enables the aggregation of individual preferences into a coherent assessment of overall satisfaction, providing transparent insights into the diverse factors influencing stakeholder satisfaction with wind energy projects. Building on the outcomes of Task 4.1(D4.1 and D4.2), the MCSA framework was applied in Task 4.2 to real-world pilot regions to demonstrate its applicability. This task produces a finalised set of guidelines for practitioners, along with actionable recommendations tailored to the needs and concerns of local residents. These outputs validate the MCSA framework developed in T4.1 and inform the creation of practical guidelines for its broader application, thereby supporting the integration of wind energy solutions into regional and local planning processes.

Building on the MCSA framework from D4.1 and D4.2. D4.3 translates it into a hands-on guide for practitioners to apply wind energy acceptance/satisfaction analysis. It advises integrating MCSA results into compliance plans, comparing real-world satisfaction with baseline expectations, and implementing targeted interventions when demands are not met. D4.3 provides a guideline for planning officers and community liaisons to ensure that MCSA outputs are correctly interpreted and acted upon, thereby embedding evidence-based, socially responsive decision-making into every stage of wind farm development.

The remainder of this report first revisits the MCSA methodology and the guidelines for practitioners, clarifying the scope, criteria design, weighting, data requirements, and the MUSA calculation procedure. It then describes the pilot sites and fieldwork, including survey localization and offline, in-person data collection. Subsequent sections present the MUSA modelling results for each site, followed by a cross-site comparative analysis that identifies common drivers of satisfaction, site-specific sensitivities, and priority areas for improvement. Then, we provide the outlook of the satisfaction analysis study in this project and the report concludes with further analysis and policy recommendations for planning authorities and developers.

2. SATISFACTION ANALYSIS FRAMEWORK AND GUIDELINES

The proposed satisfaction analysis framework is specified to adhere to the requirements of the MUlticriteria Satisfaction Analysis (MUSA). MUSA was initially designed to elicit customers' satisfaction based on the collective input from a group of evaluators. This approach ensures that diverse perspectives and priorities are considered in the assessment process, leading to a more inclusive and representative evaluation of products and services.

Building on the MUSA as the core methodological approach, we have expanded the analysis to focus on the satisfaction analysis for wind power plants. This framework aims to systematically capture the satisfaction levels of residents and stakeholders, thereby providing a comprehensive evaluation of diverse group responses and preferences. In the following subsections we introduce the MUSA method, and how it is integrated in the MCSA framework.

2.1 MUSA METHOD

The MUSA method is at the core of our satisfaction analysis framework because it translates individual resident ratings into a coherent, quantitative model of overall satisfaction. Traditional MCDA techniques often require users to assign explicit weights or utility values to criteria, which can introduce bias and inconsistency[3], [6]. MUSA, on the other hand, uses a preference-disaggregation approach. It infers the importance of the criteria and the shape of the satisfaction functions of the stakeholders directly from the responses to the questionnaires. This reduces respondent burden. Participants simply rate their satisfaction on criterion-specific scales, which ensures transparency because the underlying mathematical model is reconstructed from observed data rather than imposed ex ante.

As shown in Figure 1, the MUSA is applied to disaggregate overall global satisfaction into individual satisfactions across multiple criteria, effectively decomposing the complex evaluation into more manageable parts. This hierarchical breakdown allows for a detailed assessment of how each subcriterion contributes to the overall satisfaction level. By employing the MUSA method, the framework can quantitatively measure the impact of each criterion on a global satisfaction scale, enabling evaluators to identify areas of strength and opportunities for improvement within the satisfaction structure. This structured approach provides a transparent and comprehensive view of resident satisfaction for analysts, other external intermediaries, decision makers, or experts.

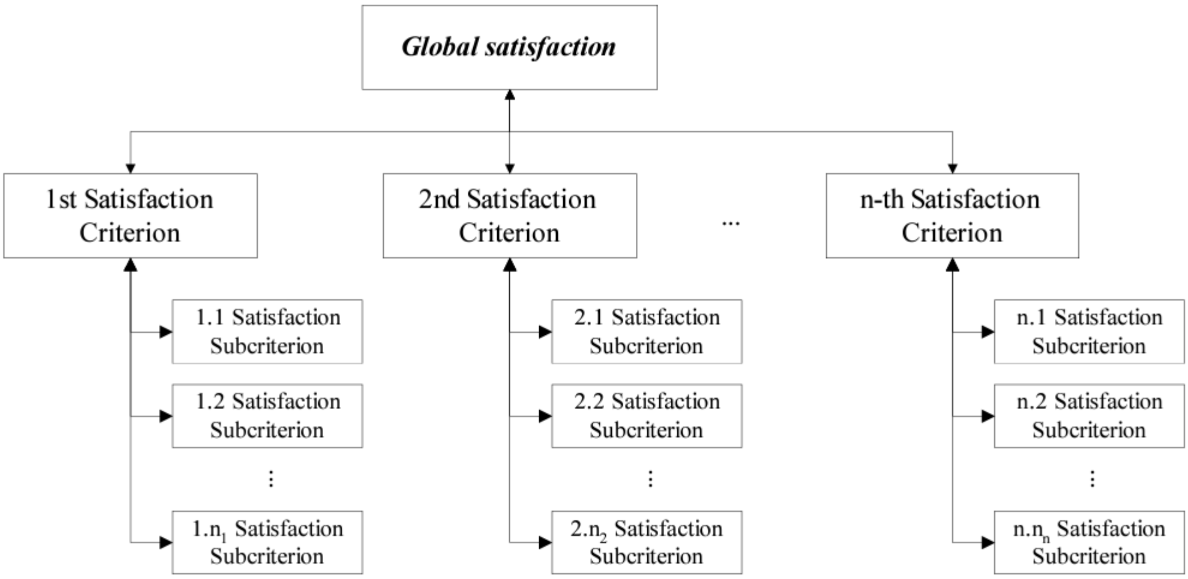


Figure 1 Structure of a MUSA problem. Respondents provide ordinal judgements at three levels: a global judgement (top), main criteria (middle row), and for each criterion, a set of subcriteria (bottom row).

By employing MUSA, we aim to derive detailed metrics on prioritising various attributes influencing wind farms' satisfaction, such as visual and noise impacts. This analysis will allow us to construct a comprehensive portrait of public sentiment towards wind farms, identifying both strengths and potential areas for improvement. The goal of our research is to provide policymakers and urban planners, including wind power developers, with actionable insights to facilitate the promotion of sustainable wind energy solutions.

In our study, residents were invited to participate in an online survey to express their judgments, encompassing both their overall satisfaction regarding wind farms installed nearby and satisfaction levels on specific criteria. A predetermined α ordinal satisfaction scale is used to capture these judgments, for example, in a 5-point Likert scale: (5) extremely dissatisfied, (4) somewhat dissatisfied, (3) neither satisfied nor dissatisfied, (2) somewhat satisfied, and (1) extremely satisfied. The scales can vary from different criteria or subcriteria. This scale simplifies the quantification of participant feedback, enabling clearer and more straightforward interpretation for citizens. Suppose there are n criteria denoted as $G = \{g_1, g_2, \dots, g_n\}$. In this method, the overall satisfaction function is represented by Y^*, while the partial satisfaction functions corresponding to each individual criterion i are denoted by X_i^*. The relationship between these variables is explained by an ordinal regression analysis equation:

$$Y^* = \sum_{i=1}^{n} b_i X_i^* - \sigma^+ + \sigma^-, \tag{1}$$

$$\sum_{i=1}^{n} b_i = 1, \tag{2}$$

where b_i is the weight of criterion i. Y^* and X_i^* are normalized in the interval $[0,100]$, where the satisfaction level $y^{*1} = x_i^{*1} = 0$ and $y^{*\alpha} = x_i^{*\alpha} = 100, \forall i = 1,2,\ldots,n$. σ^+ and σ^- are the overestimation error and underestimation error, respectively. Drawing upon the specified equation, MUSA constructs a Linear Programming (LP) model designed to discern how satisfaction across multiple criteria contributes to overall satisfaction with the service. The primary objectives are to minimize under- and over-estimation errors for all the respondents to the questionnaire (an illustration of the global satisfaction function for the j^{th} participant can be found in Figure 2).

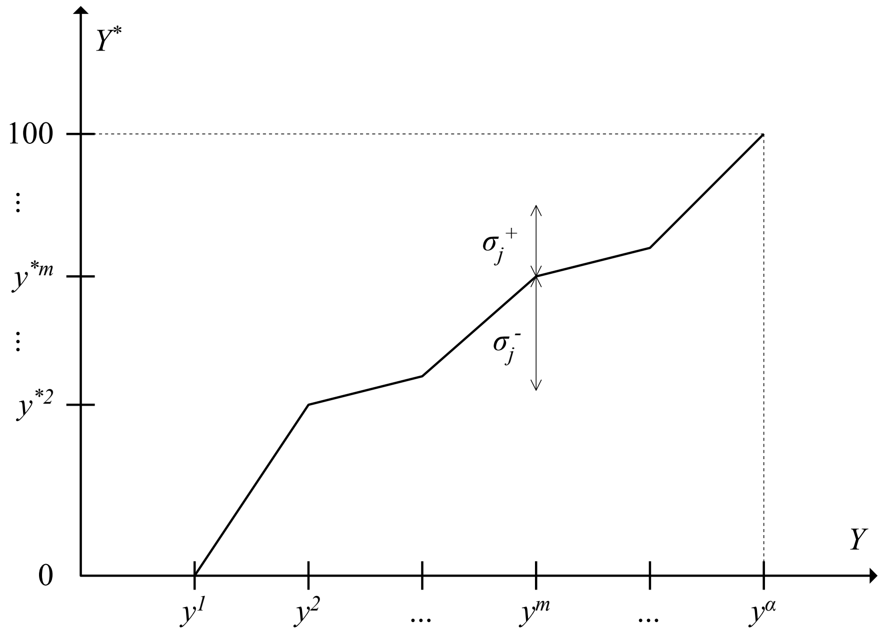


Figure 2 Error variables for the j^{th} participant. The horizontal axis shows the declared satisfaction category on an α point ordinal scale. The residual between the observed score and the model prediction is split into the non-negative error variables σ_j^+ and σ_j^-.

The output generated by MUSA includes a comprehensive set of results, detailing overall satisfaction, which is aggregated from partial satisfactions for individual criteria, weighted appropriately. Four metrics can be obtained from the model, which describe the characteristics of the participants. For the mathematical definitions of the metrics, please refer to [5]:

1. The **weight** quantifies a criterion's influence on the overall satisfaction score: larger weights denote greater impact within the weighted-sum aggregation.
2. The **Average Satisfaction Index (ASI)** measures how well each criterion meets stakeholder expectations, normalized within [0, 1], with higher values denoting greater satisfaction. It is calculated by averaging the satisfaction scores linked to the response levels chosen by all participants.
3. The **Average Demanding Index (ADI),** normalized within [−1, 1], gauges the stringency of stakeholder expectations. Technically, it captures the curvature of the satisfaction function: a concave curve (negative ADI) rises steeply, so respondents reach high satisfaction even at lower performance levels, indicating they are not very demanding. Conversely, a convex curve (positive ADI) climbs slowly, meaning respondents require top-level performance before they feel satisfied. An ADI of +1 means only the highest performance level suffices, whereas -1 indicates minimal requirements.
4. The **Average Improvement Index (AII),** scaled from 0 to 1, estimates how much overall satisfaction could rise if a criterion were improved. It blends two inputs: the criterion's weight and its current ASI. A heavily weighted criterion with a low ASI yields a high AII, signalling plenty of room and strong justification for improvement. In short, higher AII values point planners to the areas where targeted upgrades would deliver the greatest boost in overall satisfaction.

2.2 MCSA FRAMEWORK

While MUSA helps extract weights and satisfaction functions directly from stakeholder surveys, it does not by itself constitute a deployable process for real-world projects. That is why we have wrapped MUSA within the broader Multi-Criteria Satisfaction Analysis (MCSA) framework. This satisfaction analysis framework builds on MUSA's strength in data-driven preference disaggregation by adding the critical steps needed for consistent, transparent application: rigorous problem structuring, localized survey design, standardised data-processing, and clear guidance on interpreting and visualising results. The satisfaction analysis framework transforms

MUSA's raw mathematical outputs into actionable insights that planners and policymakers can apply directly.

Also, there is a need to account for divergent interests that may arise due to varying socio-demographic characteristics of participants. These variations are particularly relevant to this study. For example, the proximity of wind turbines to residents' homes can significantly influence their opinions. Residents living closer to wind turbines may have distinct preferences compared to those living further away, necessitating a tailored analysis. To address this, the satisfaction analysis framework captures these nuanced differences, focusing on the satisfaction levels of local residents regarding wind power plants.

In the previous deliverable D4.2, we introduced the MCSA framework based on the MUSA method, which is organised into several key steps. We detail the workflow of the satisfaction analysis framework, outlining the step-by-step process from problem structuring to data analysis. The workflow presented in Figure 3 serves as a practical guideline, ensuring consistency, accuracy, and relevance in applying the framework across diverse contexts.

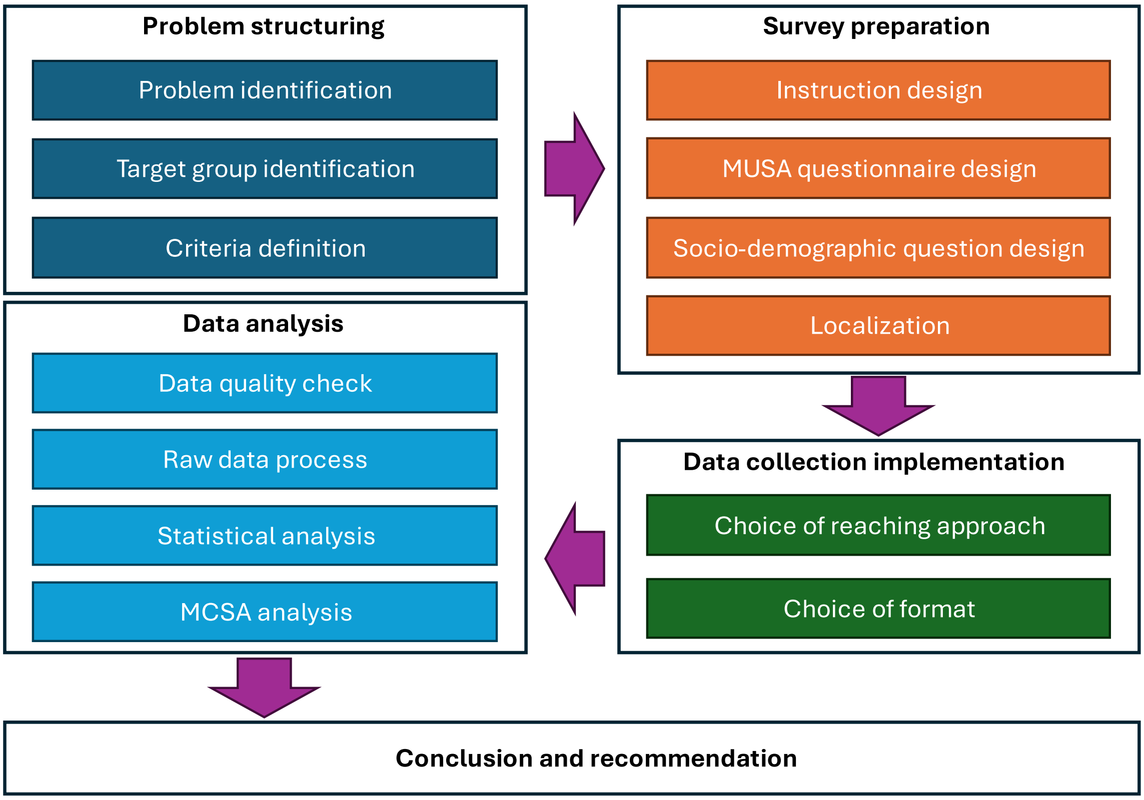


Figure 3 Satisfaction analysis workflow across five phases: Problem structuring, survey preparation, data collection, data analysis, conclusion, and recommendation

- **Problem structuring**: The foundation of the MCSA framework begins with a clear understanding of the problem and its context.
    - *Problem identification*: The first step is to clearly define the study's key objective. This involves pinpointing the specific subject about which satisfaction needs to be measured and analysed. In this study, this subject is satisfaction with wind power installations in the vicinity.
    - *Target group identification*: The identification of target groups is a crucial step in designing a satisfaction analysis, as it ensures that the study focuses on the perspectives of the most relevant stakeholders. In our study, the primary target group is local residents, as they are the most directly impacted by wind turbine installations in their vicinity. These residents may experience changes in their environment, such as visual or noise impacts, which significantly influence their satisfaction with the project. Additionally, secondary stakeholder groups may include tourists and visitors who may also have valuable perspectives.
    - *Criteria definition*: This step establishes the specific factors/criteria that are accounted for and included in the MCSA that affect the satisfaction levels of the participants. There is no strict maximum number of criteria for MUSA; however, it is important to maintain a balance between exhaustiveness and the level of detail. On the one hand, the criteria should be comprehensive to capture all relevant aspects, and on the other hand, they should be streamlined to avoid unnecessarily extending the answering time, which could reduce participants' willingness to engage.

- **Survey development and questionnaire preparation**: A well-structured survey is essential for capturing meaningful and actionable data. As such, a well-developed survey can help structure a comprehensive questionnaire that will be the means for the extraction of the required data by participants.
    - *Instructions Design*: Develop clear and concise instructions for survey participants to ensure consistency in understanding and responses.

- *MUSA Questionnaire Design*: Compile clear and straightforward questions that explicitly translate into each criterion and provide well-defined response options. These questions are fully aligned with the MUSA method within the MCSA framework and ensure consistent measurement of satisfaction across the complete set of criteria. Another important aspect is the definition of an appropriate point scale for the answers to each question. Odd- and even-point response scales serve different purposes: A five-point (odd) scale is best for bidirectional questions, because it offers two positive options, two negative options, and a neutral midpoint; A four-point (even) scale, which omits the neutral choice, is better suited to unidirectional questions that range only from low to high intensity. For example, noise impact might use a 4-point scale ranging from "No Impact" to "High Degree of Impact," while aesthetic integration could use a 5-point scale from "Strongly Negative" to "Strongly Positive." This is because noise pollution is assessed using a unidirectional question, where a 4-point scale suffices to capture varying degrees of disturbance (best case, no impact). In contrast, aesthetic integration is evaluated through a bidirectional question, acknowledging that it can have both positive and negative impacts. Therefore, a 5-point scale is employed, including a neutral option, with two positive and two negative choices to accurately reflect respondents' perceptions.
- *Socio-Demographic Question Design*: Incorporate questions to capture participants' socio-demographic attributes, such as age, education, income, and living location, to enable categorisation and clustering. These questions must comply with General Data Protection Regulation (GDPR) principles by collecting only the minimum data necessary to identify patterns and differences in opinions, while ensuring the essential information required for a demographic analysis is obtained.
- *Localization*: Adapt the survey to the specific context of the pilot site region, considering cultural, linguistic, and geographic nuances.

- **Data collection and implementation**: Effective outreach and data collection methods are critical for obtaining a good quantity of high-quality data.
    - *Choice of Reaching Approach*: Decide on the mode of distribution, such as online questionnaires, in-person interviews, or community workshops, based on the target group's accessibility and preferences.
    - *Choice of Format*: The choice of format for data collection should align with the specific characteristics of the location and the selected outreach approach. Depending on these factors, the method can range from structured questionnaires and polls to more in-depth extended interviews. Questionnaires and polls are ideal for efficiently collecting standardized data from a larger group of participants, while extended interviews allow for deeper exploration of individual perceptions and nuanced concerns.

In both formats, the MUSA questionnaire is essential, but the interview is optional. For example, in Pantelleria, some participants were approached in a café, and since they had adequate time to spare, they were also interviewed to provide further feedback. However, in Styria, where the survey took place over a single day in a museum, participants were less willing to answer additional questions, so only the questionnaire option was appropriate. Selecting a rational outreach format ensures that the data collection process is both effective and contextually relevant.

- **Data analysis**: Collected data is processed and analysed to derive meaningful insights. More details on how the collected data is verified, cleaned, and curated can be found in D4.1.
    - *Data Quality Check*: Review the raw data to ensure accuracy, completeness, and consistency. All incomplete survey responses were excluded from the analysis.
    - *Raw Data Processing*: Convert raw responses into a usable format for statistical and MUSA analysis, such as coding responses and normalizing scales.
    - *Statistical Analysis*: Conduct descriptive and inferential analyses to understand response patterns and identify significant trends across socio-demographic groups.

  - *MCSA Analysis*: Apply the MUSA method to quantify satisfaction and derive detailed insights into the satisfaction of wind turbines. The analysis includes identifying satisfaction levels for individual criteria and their contributions to overall satisfaction.

- **Conclusions and recommendations:** Upon completing the MCSA analysis, the final step is to transform the indices and value functions into clear, actionable conclusions and tailored recommendations. These findings are translated into site-specific guidance. In the WIMBY case, the outputs will serve as inputs to D4.6. By packaging the results into technical reports for planners, executive summaries for policymakers, and digestible briefs for local stakeholders, this step closes the loop between analysis and action, ensuring that the satisfaction analysis framework drives both practical improvements on the ground and informs wider policy and research through forthcoming scientific publications.

3. MUSA IMPLEMENTATION FOLLOWING THE GUIDELINES

After finalizing the guidelines, we applied the MCSA framework across four pilot sites in three countries: Pantelleria (Italy), Styria (Austria), Viana do Castelo (Portugal), and Torres Vedras (Portugal). These locations were selected to reflect a diversity of geographical, socio-economic, and planning contexts, providing a robust testing ground for the framework's applicability and adaptability:

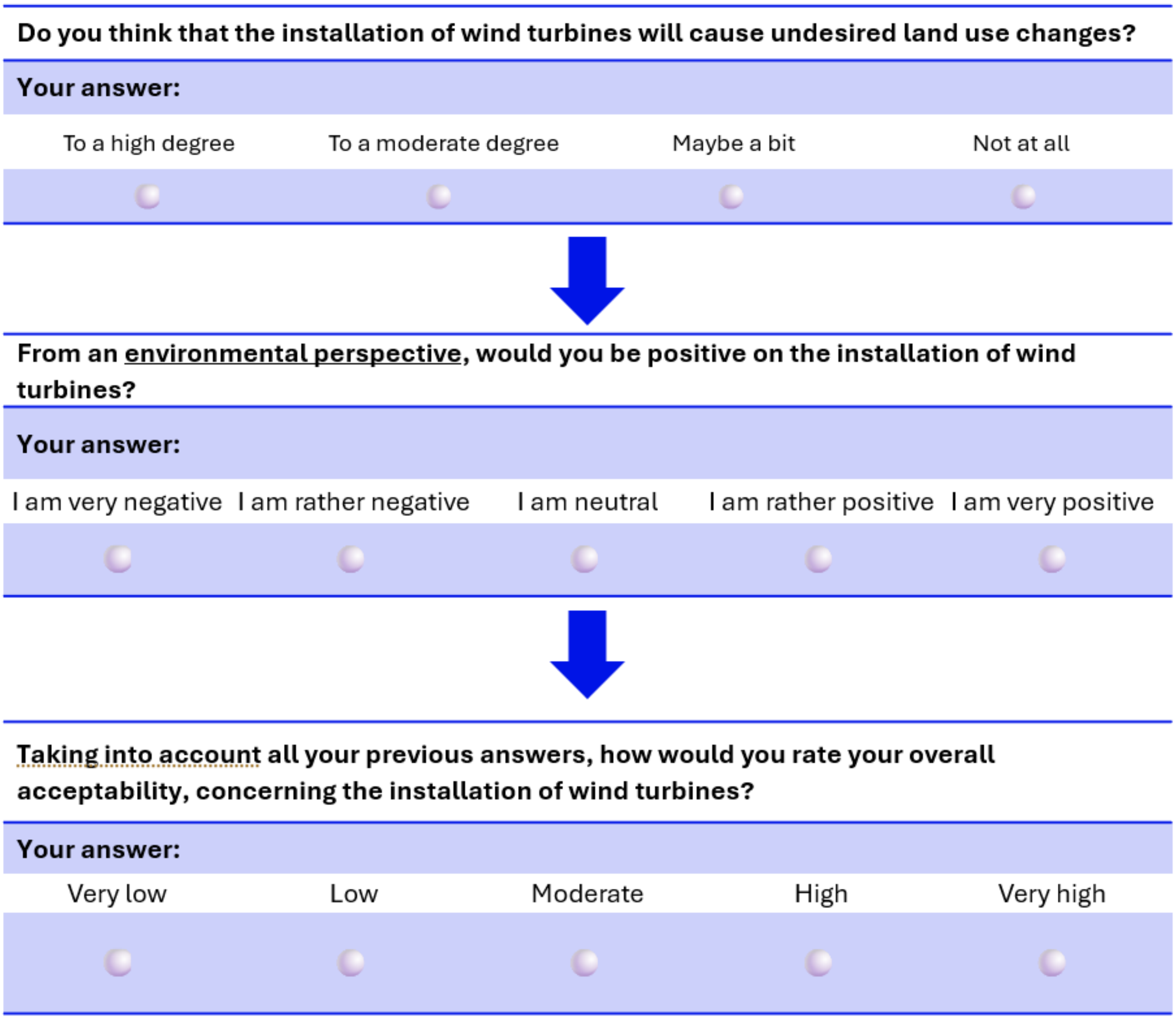
- Pantelleria is a remote volcanic island located 110 km off the coast of Sicily. The island's electricity grid is primarily powered by diesel generators, but due to its location in one of the windiest areas in Italy, wind energy is considered a viable option. There are no operational wind turbines currently on the island.
- Styria is a federal state of Austria, and our on-site surveys were conducted in the towns of Gröbming and Irdning. They were situated in a mountainous region of Styria, representing a rural context where landscape aesthetics and ecological conservation are prominent concerns. Public opinion here is often shaped by strong place attachment and cultural heritage values[7]. What should be noted is that, because Gröbming and Irdning lie only a few kilometres apart and share the same Styrian context, we treat them as a single pilot site. In contrast, the two Portuguese locations exhibit distinct settings and stakeholder profiles, so they are analysed as separate pilot sites.
- Viana do Castelo (Portugal) is a coastal municipality with existing wind farms. The region is home to the Alto Minho Wind Farm with a capacity of 240 megawatt(MW), Europe's largest onshore wind farm at the time of completion[8]. Additionally, the WindFloat Atlantic project, located 20 kilometres (km) off the coast, is Continental Europe's first floating offshore wind farm.
- Torres Vedras (Portugal), located closer to the Lisbon metropolitan area, reflects a semi-urban setting with diverse stakeholder groups. The region has several operational wind farms, including the Catefica wind farm, with a total nominal power of 18 MW.

To capture local residents' satisfaction regarding wind energy infrastructures, we defined a comprehensive set of criteria that spans environmental, community, and individual dimensions. Each dimension aggregates closely related sub-criteria to ensure that every major facet of wind energy impact is systematically assessed. Table 1 summarizes the identified dimensions and sub-criteria.

Table 1 Set of satisfaction criteria

Dimension (Criterion)	Sub-criterion
Environmental	Undesired land use changes
	Impact on biodiversity
	Reduce Greenhouse gas emissions (GHG)
Community	Economic impact on the community
	Negative effect on community lifestyle
	Safety risks to people and infrastructures
	Raise social awareness and political engagement
	Long-term maintenance and decommissioning plans
Individual	Impact on personal finances
	Negative effect on the landscape's aesthetics
	Disturbance from noise pollution
	Disturbance from shadow flicker

These criteria were selected through a combination of literature review, e.g., [9], [10], [11], [12], [13], and expert consultation, ensuring that they reflect both international best practice and site-specific concerns. Each survey question is carefully tailored with a scale type and set of response descriptions that best fit the nature of the underlying criterion, as illustrated in Figure 4. The complete, non-localised questionnaire (in English language), including all MUSA questions and socio-demographic questions, is provided in the Annex.


Do you think that the installation of wind turbines will cause undesired land use changes?

Your answer:

To a high degree	To a moderate degree	Maybe a bit	Not at all

From an environmental perspective, would you be positive on the installation of wind turbines?

Your answer:

I am very negative	I am rather negative	I am neutral	I am rather positive	I am very positive

Taking into account all your previous answers, how would you rate your overall acceptability, concerning the installation of wind turbines?

Your answer:

Very low	Low	Moderate	High	Very high

Figure 4 Different questions and scales for sub-criteria, criteria, and global satisfaction

We developed localized survey instruments tailored to the specific social and geographic contexts of each pilot site. For instance, since Pantelleria has no turbines at present, we could not measure residents' post-installation satisfaction; instead, we assessed their ex-ante acceptance of a proposed wind-turbine project. To ensure direct engagement with local communities and to capture both quantitative and qualitative insights, we conducted offline, in-person surveys. This method allowed us to explain questions in real-time, build trust with participants, and gather more nuanced perspectives on wind energy satisfaction. However, we should also acknowledge that, because participation depended on who happened to be present and willing during our short field visits, the sample may over-represent socially active or curious residents while missing less accessible or time-pressed groups. In-person interviews can also introduce interviewer effects, where respondents tailor their answers—consciously or not—to what they think the surveyor expects.

At each site, the survey team spent a minimum of two days in the location, with the data collection strategy adapted to suit local circumstances. Our extended stay in Pantelleria provided the opportunity to build closer contact with residents. Given the island's social dynamics and the popularity of local bars as gathering spaces, we conducted many interviews in these venues. This setting encouraged relaxed conversations and allowed us to probe deeper into individual attitudes, yielding detailed qualitative information in addition to the survey responses.

In contrast, data collection in Gröbming and Irdning posed different challenges. Located in a natural, less densely populated region, there were fewer opportunities for extended one-on-one interviews. We focused our efforts on areas with greater foot traffic. We were fortunate to receive support from a local museum, which kindly provided indoor space for survey distribution and participant engagement. It should be noted that although no turbines are currently operating in Gröbming and Irdning, many survey respondents came from surrounding areas where there are wind turbines. We therefore retained the term “satisfaction” rather than “acceptance”.

Meanwhile, in Viana do Castelo and Torres Vedras, we adopted a broader outreach strategy. In addition to distributing surveys in public spaces such as streets and squares, we targeted shopping centres, where we approached not only shoppers but also store owners and staff.

Figure 5 includes photos from our fieldwork across the pilot sites, capturing moments of interaction with participants and illustrating the diverse settings in which data collection took place. Overall, the guidelines ensured that the MCSA framework was applied consistently, while respecting each community's local realities and social dynamics.

Figure 5 Survey distribution activities at the pilot sites: (a) Pantelleria, (b) Styria (Irdning and Gröbming), (c) Viana do Castelo, and (d) Torres Vedras. All individuals pictured provided consent for their photographs to be used.

4. PILOT SITE RESULTS

This section presents the pilot site results of the MCSA, as obtained following the guidelines. By distributing an offline survey and having face-to-face discussions, we obtained the results shown in Table 2.

Table 2 MCSA survey overview and age statistics

Pilot Site	ITALY Pantelleria	AUSTRIA Styria (Gröbming and Irdning)	PORTUGAL Viana do Castelo	PORUGAL Torres Vedras
Nr. of responses	79	44	65	50
18-24	0	2	12	19
25-34	11	8	29	17
35-44	11	0	8	6
45-54	6	10	10	7
55-64	15	16	5	1
>=65	36	8	1	0

The age distribution highlights differences in respondent profiles across sites. For example, Pantelleria's sample was dominated by participants aged 65 and over, whereas the Portuguese sites drew a much larger share of respondents in the 18–24 and 25–34 age groups.

These differences in the population samples provide valuable context for interpreting site-specific satisfaction levels and preferences, which can be further analysed. On the other hand, a drawback of this is that the pools of respondents among the different countries are heterogeneous, a fact that does not facilitate the direct comparison and statistical analysis of the responses, as well the association of satisfaction with the demographic data.

To enable a systematic comparison across the sites, we present the resulting value functions and performance indices side by side. Figure 6 shows the global satisfaction functions for all pilot sites, illustrating how satisfaction levels vary among local residents. The satisfaction function is standardised, ranging from 0 to 100. It represents how satisfaction is reflected when residents select a certain option in the general question regarding wind turbine installations. The x-axis shows the five response options for the question. the green marker at level 2 in Figure 7 represents a Viana do Castelo respondent who chose “Low satisfaction” (the second step on the scale from “Very low” to “Very high”). The y-value of 53.9 indicates that this choice corresponds to an overall satisfaction score of 53.9. A concave function that quickly approaches a high satisfaction score indicates that residents are less demanding, as they have higher satisfaction on different levels compared to a convex function, meaning they require fewer improvements to feel satisfied[4]. Conversely, a slower rise in the satisfaction curve suggests greater expectation for improvements or changes. The satisfaction functions reveal that residents across all pilot sites exhibit comparable response patterns, suggesting similar levels of demand. Yet these piecewise functions only indicate how satisfaction changes with each response option; they do not disclose average satisfaction scores or the relative importance of individual criteria at each site. To uncover those finer distinctions, we must examine the detailed metrics and additional figures presented in the following sections.

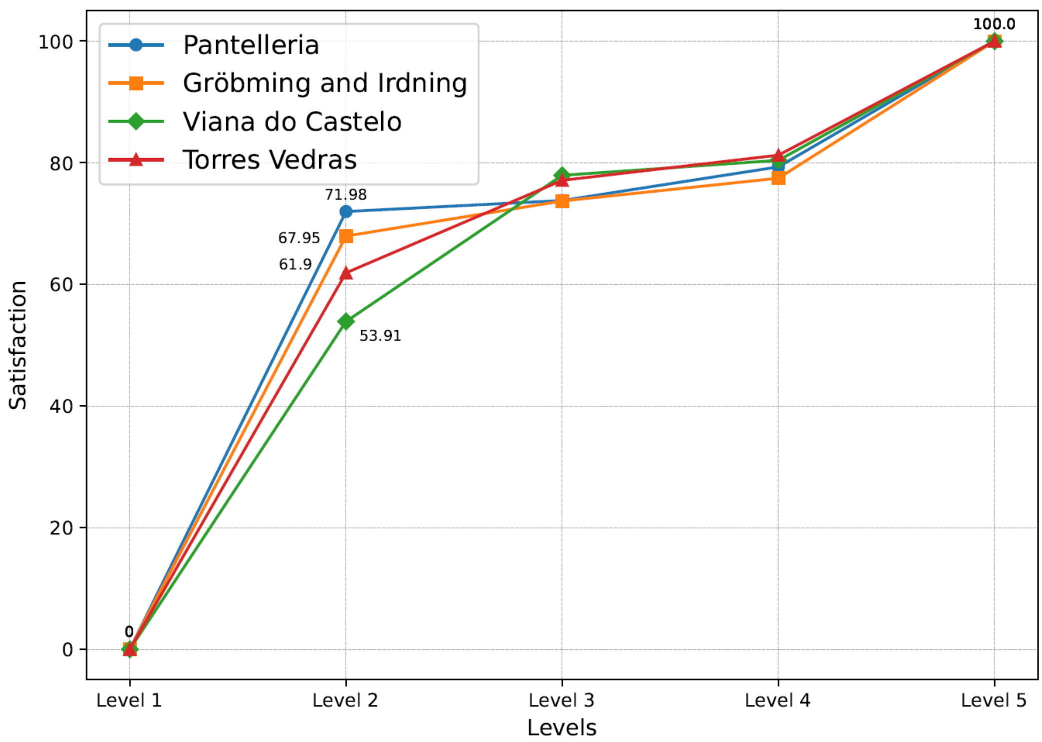


Figure 6 Regional global satisfaction function diagram

Table 3 and Table 4 complement the graphical comparison by reporting not only the overall satisfaction and demand indices but also the criterion-level metrics that underlie the MUSA analysis. The global satisfaction index reflects the mean satisfaction of the existing wind installation, except in

Pantelleria, where it represents the projected acceptance of a planned turbine. It is normalised between 0 (no satisfaction) and 1 (full satisfaction). The global demanding index conveys the same information as the slope of the value function **Error! Reference source not found.**: higher (more positive) values indicate stricter resident demand, while lower (or negative) values suggest a more relaxed level of demand.

Table 4 breaks down each evaluation criterion by four key metrics.

By plotting these indicies in two-dimensional "action" and "improvement" diagrams (Figure 7), practitioners can derive concrete strategies. The relative action diagram (Figure 7(a)) positions each criterion by its weight (x-axis) and ASI (y-axis), revealing which high-importance factors are under- or over-performing. The relative improvement diagram (Figure 7(b)) maps each criterion by its AII (x-axis) and ADI (y-axis), spotlighting the highest-priority areas for intervention. Together, these visual tools translate the MUSA outputs into a clear roadmap for enhancing the social satisfaction of wind farms.

Table 3 Global satisfaction and demanding across pilot sites

Pilot Site	Global Satisfaction	Global Demanding
Pantelleria	0.737	-0.501
Gröbming and Irdning	0.759	-0.461
Viana do Castelo	0.898	-0.415
Torres Vedras	0.818	-0.468

Table 4 Main criteria indices. ASI is obtained based on the average satisfaction value from the participants' satisfaction level. ADI is obtained based on the satisfaction function obtained from the optimization model. AII is the composite index based on weight and ASI.

Pilot Site	Criterion (Main perspective)	Weight	ASI	ADI	AII
Pantelleria	Environmental	0.157	0.840	-0.748	0.025
	Community	0.326	0.790	-0.628	0.068
	Individual	0.517	0.830	-0.720	0.088

Gröbming and Irdning	Environmental	0.231	0.847	-0.660	0.035
	Community	0.389	0.915	-0.798	0.033
	Individual	0.380	0.904	-0.695	0.036
Viana do Castelo	Environmental	0.248	0.927	-0.598	0.018
	Community	0.491	0.895	-0.573	0.052
	Individual	0.261	0.914	-0.505	0.023
Torres Vedras	Environmental	0.231	0.916	-0.498	0.019
	Community	0.389	0.923	-0.739	0.030
	Individual	0.380	0.883	-0.686	0.044

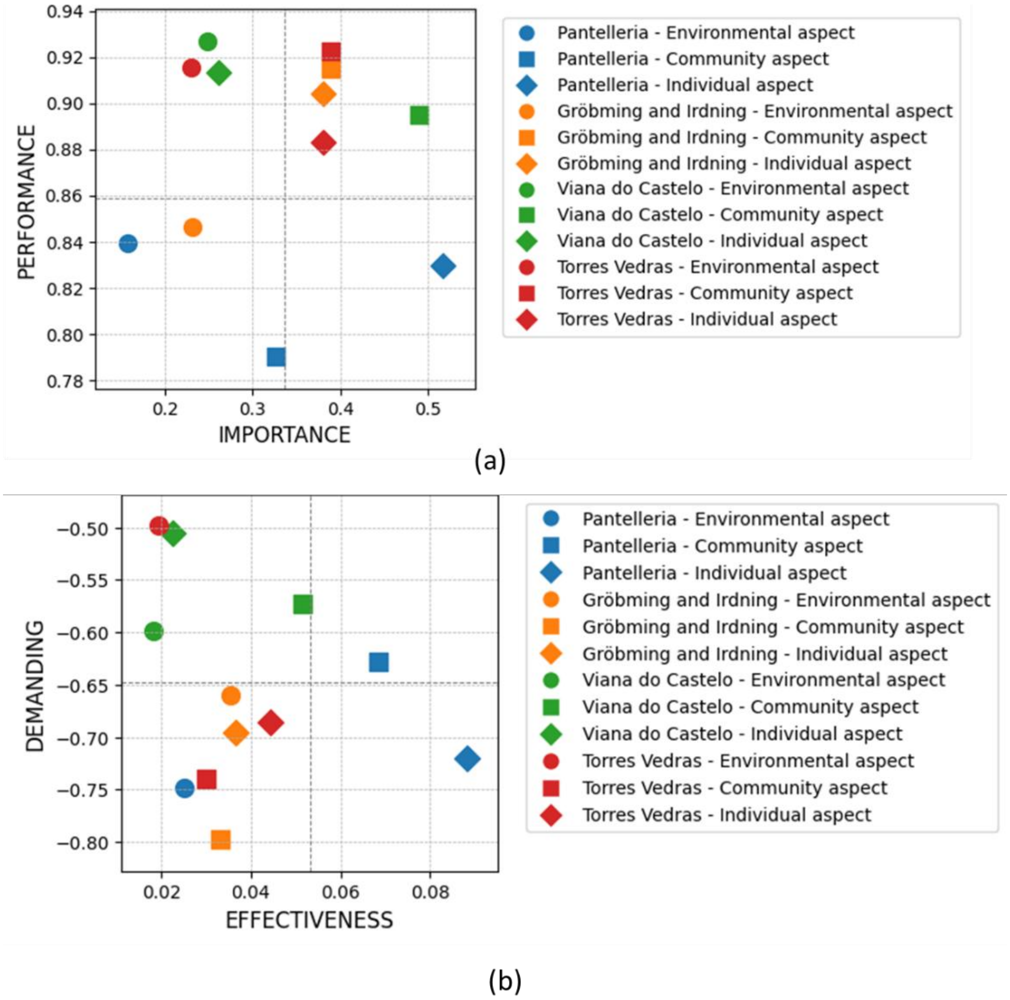


Figure 7 Regional action diagram (a) and regional improvement diagram (b)

The MUSA-derived results reveal both common patterns and notable differences in how communities across the four pilot sites perceive and demand satisfaction from nearby wind-turbine installations. Each measure can be represented by two straightforward scales. For ASI, weight, and AII, scores below 0.5 indicate a low level, and scores above 0.5 indicate a high level. The ADI is centred on zero: negative values show that residents are easy to satisfy, while positive values indicate stricter satisfaction thresholds. Overall, satisfaction/acceptance is strong at every pilot site, with global satisfaction ranging from 0.74 to 0.90, where Pantelleria and Styria (Gröbming and Irdning) sites present relatively lower satisfaction; the two Portuguese pilots present relatively higher satisfaction. One possible explanation is that the Portuguese sites already host large-scale wind farms, giving residents direct experience, and perhaps tangible benefits that can bolster their satisfaction. At all four pilot sites, the demanding indices are negative, meaning that people overall feel they do not need major improvements before granting their approval. Even so, the numbers reveal subtle differences. Pantelleria (-0.50) and the Styrian towns of Gröbming and Irdning (-0.46) are the most relaxed. Viana do Castelo (-0.42) and Torres Vedras (-0.47) are slightly less relaxed but still on the "low demand" side. These more urban Portuguese settings hint that residents look for higher service quality and community benefits before feeling completely satisfied.

Drilling down into the criterion-level metrics (Table 4) illustrates which dimensions drive these differences. Across all four sites, environmental aspects consistently receive the lowest weights (0.157–0.248) and the highest ASI (0.84–0.93), signifying that even though environmental impacts are not top priorities to the local residents, they are generally satisfied or find the performance of the wind farms on these criteria acceptable. Contrary to that, community aspects rank as the most influential criterion in Gröbming and Irdning (0.389), Viana do Castelo (0.491), and Torres Vedras (0.389). In Pantelleria, the community aspects present relatively lower weight (0.326) and carry less weight than individual factors (0.517). This divergence reflects each site's development stage: Pantelleria's hypothetical wind turbine installation does not deliver tangible community benefits, whereas Austria's and Portugal's more mature wind sectors have embedded robust engagement that resonates positively with residents[14], [15].

Personal aspects carry the highest importance in the criteria of Pantelleria (0.517), making them the single most influential driver of overall satisfaction there. Yet, despite its importance, Pantelleria also records a lower ASI = 0.83 for this aspect than the other pilot sites.

Translating these metrics into actionable insights is facilitated by the quadrant diagrams in Figure 7. The relative action diagram reveals that the Pantelleria individual perspective presents an action opportunity due to its relatively high importance and low performance. It is also regarded as the first priority to improve based on the improvement diagram due to its relatively low demand and high potential for improvement. In contrast, the action diagram places community factors for Gröbming & Irdning and the two Portuguese sites in the high-importance/high-performance quadrant, indicating they are "maintain momentum" items: residents already see tangible local benefits, and the focus should be on safeguarding transparency and continuity. But overall, only limited room for improvement remains, as confirmed by the low AIIs from all criteria.

In summary, however, the survey samples are small relative to the study-area populations and should not be treated as statistically representative. Even in Pantelleria, where the site with the highest coverage, respondents comprise only about 1% of permanent residents. The findings therefore provide indicative insights into residents' views rather than a complete picture of all subgroups.

5. OUTLOOK

With the framework now validated across four pilot sites, we have established a transferable approach for measuring social satisfaction with wind energy. The step-by-step guidelines contained in this deliverable allow planners, developers, and researchers elsewhere to adopt the method without repeating the trial-and-error phase. In general, a community wishing to gauge attitudes toward a new repowering program can adapt the questionnaire template, run the MUSA algorithm, and obtain a complete set of satisfaction, demand, and improvement indices within a few weeks using the same terminology. This harmonised workflow promises two distinct benefits. It accelerates local decision-making by turning stakeholder/resident sentiment into quantitative evidence.

It is important to mention here that the developed satisfaction analysis framework has already been reproduced in a case study, outside the WIMBY project. Specifically, the WIMBY questionnaire was adapted, translated into Greek, and distributed on the Greek island of Evia (Euboea) in a master's thesis study [16]. This approach aimed to utilize tools developed within the WIMBY project to measure residents' satisfaction with wind turbines. Evia was chosen because it is a region with substantial wind energy development, with over 500 MW of installed wind power capacity, making it a relevant case for assessing local perceptions of wind energy projects.

The 80 completed questionnaires from Evia indicated lower satisfaction levels compared to the four pilot sites of the WIMBY project. This difference could be attributed to the extensive wind energy development already present on the island, which has led to growing frustration among parts of the local population. Additionally, this lower satisfaction may stem from widespread distrust in the incentives and motives of the government, along with broader sociopolitical factors that influence public attitudes toward renewable energy initiatives. These findings underscore the importance of understanding local community perceptions and highlight the need for transparent communication and participatory planning in expanding renewable energy infrastructure.

In summary, the deliverable reports only the top-line results necessary to validate the framework. It does not delve into correlational analysis between sociodemographic attributes and MUSA outcomes yet, nor does it test the robustness of the indices under alternative weighting schemes or scale normalizations. These deeper statistical investigations are essential for unpacking questions such as whether age or income systematically influences the importance residents assign to personal versus community benefits, or how the index behaves in regions with very different turbine densities. Addressing such questions will require more extensive analyses. Moreover, we are currently exploring how demographics of a population, as well as other external factors (such as level of visibility and density of installed wind turbines), influence the satisfaction of citizens. To do that, we are combining the knowledge about the satisfaction of citizens, with the aid of the MUSA method, together with the demographic data of the citizens, using statistical tools. The results coming from the Greek case study of the island of Evia are also included in the analysis, together with the results from the four pilot sites of WIMBY. This synthesis will be presented in Deliverable D4.6 and will be published in a scientific journal.

6. CONCLUSIONS

This deliverable demonstrates that the Multi-Criteria Satisfaction Analysis (MCSA) framework, built around the data-driven MUSA method and supported by the guidelines developed in this project, provides a practical and transparent way to elicit stakeholder satisfaction with wind-energy projects. A single, neutral questionnaire was co-designed and validated by the full consortium; its wording was carefully cross-checked to ensure the same criteria apply in Austria, Portugal, and Italy. MUSA relies solely on respondents' answers, without any analyst-defined weights or other subjective inputs. It treats every response equally and keeps the entire evaluation model fully traceable.

Deploying the workflow in three countries and four pilot sites confirmed that the framework captures both broad patterns (such as consistently high global satisfaction) and site-specific priorities (for example, high personal perspective priority in Pantelleria, high community perspective priority in Austria and Portugal). MUSA's statistical process, based on ordinal regression, produces outputs which represent residents' preferences: criterion weights, value functions, and the ASI, ADI, and all indices detailed in D4.1. The resulting action and improvement diagrams convert these metrics into site-tailored priorities, giving planners and developers an evidence-based roadmap for enhancing stakeholder satisfaction with current and future wind-energy projects.

Equally important, applying the guidelines from problem structuring to survey localisation and data processing demonstrated that they can be adapted to diverse cultural and geographic settings. Although this first validation was performed by the framework's own developers, it confirms the guidelines' technical workability and sets the stage for external authorities and analysts to test, refine, and standardise satisfaction studies across Europe.

At the same time, the study's scope was intentionally pragmatic: it focused on establishing method viability rather than exhaustively exploring all statistical nuances. The deeper investigations, such as the correlation analysis of residents' satisfactions with socio-demographic variables and the classification of respondents are in progress and will be presented in D4.6 and a forthcoming peer-reviewed paper.

In summary, the work fulfils Task 4.2's objectives by (i) validating the MCSA framework in real-world settings, (ii) producing a practitioner-oriented guideline, and (iii) delivering initial empirical insights that inform WIMBY tasks T4.5 and T4.6.

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ANNEX

Questionnaire designed in WIMBY

The following section shows the questionnaire developed for the Styria pilot site. Please note that it is presented here in English and has not yet been translated into German.

Survey on the satisfaction with wind turbines in Styria

Part I: Introduction

Purpose

The aim of this survey is to establish personal opinions on wind turbines in order to investigate the satisfaction and opinions of the population with regard to the expansion of wind turbines in Styria.

The survey is part of the WIMBY (Wind in my Backyard) research project funded by the EU Horizon Program and has no connection with specific wind power projects.

The full survey will take approximately 5 minutes to complete.

Confidentiality

Your answers will be used exclusively for research purposes. All results will be published in an aggregated format, fully anonymized, ensuring that individual responses cannot be traced back to any participant. They will be treated confidentially, and under no circumstances will they be shared with third parties or companies outside the WIMBY initiative. The data processing policy is available in full on our website at: https://wimby.eu/privacy-policy/.

Instructions

The survey is divided into three sections, focusing on:

- Section A: Environmental aspects of wind energy
- Section B: Community aspects of wind energy
- Section C: Your individual opinion

At the end of the questionnaire, we ask you to provide personal information (sociodemographic data). For each question, select the answer that comes closest to your opinion or experience. Now, please look at the image of the wind turbine on the Sommeralm north of Graz. This image gives you a visual impression of what wind farms normally look like in Styria.

Sector A – Environmental aspects of wind energy

A1 Do you think that the installation of wind turbines in Styria will cause undesired land use changes?

▫ To a high degree
▫ To a moderate degree
▫ Maybe a bit
▫ Not at all

A2 Are you concerned that wind turbines will harm biodiversity in Styria?

▫ To a high degree
▫ To a moderate degree
▫ Maybe a bit
▫ Not at all

A3 Do you think that wind turbines can help produce clean energy in Styria?

▫ Rather negatively
▫ Slightly negatively
▫ No effect
▫ Slightly positively
▫ Rather positively

Summarizing question: Environmental aspects

A4 How do you assess the potential environmental impact of the construction of wind turbines in Styria?

- Rather negatively
- Slightly negatively
- No effect
- Slightly positively
- Rather positively

Sector B – Community aspect of wind turbines

B1 How do you think the installation of wind farms in Styria will affect the regional economy?

- Rather negatively
- Slightly negatively
- No effect
- Slightly positively
- Rather positively

B2 Are you concerned that the installation of wind turbines in Styria will negatively affect the community lifestyle?

- To a high degree
- To a moderate degree
- Maybe a bit
- Not at all

B3 Do you expect that wind turbines can pose a safety risk of people and infrastructure?

- To a high degree
- To a moderate degree
- Maybe a bit
- Not at all

B4 Do you agree that wind turbines in Styria can increase the social awareness and political commitment of the population?

- Strongly disagree
- Disagree

¤ Neutral
¤ Agree
¤ Strongly agree

B5 Do you think that wind turbines in Styria are a reliable technology in the long term?
¤ Strongly disagree
¤ Disagree
¤ Neutral
¤ Agree
¤ Strongly agree

Summarizing question: Community aspect
B6 From the community point of view, how do you rate the installation of wind turbines in Styria?
¤ Very negative
¤ Rather negative
¤ Neutral
¤ Rather positive
¤ Very positive

Sector C – Individual aspect

C1 How do you think the installation of wind turbines in Styria will affect your personal financial situation?
¤ Rather negatively
¤ Slightly negatively
¤ No effect
¤ Slightly positively
¤ Rather positively

C2 Do you think that the installation of wind turbines in Styria will negatively affect the aesthetics of the landscape?
¤ Strongly disagree
¤ Disagree
¤ Neutral
¤ Agree
¤ Strongly agree

C3 To what degree are you concerned about noise pollution from the wind turbines?
¤ To a high degree
¤ To a moderate degree
¤ Maybe a bit
¤ Not at all

C4 To what degree are you concerned about the shadow flicker from the wind turbines?
¤ To a high degree
¤ To a moderate degree
¤ Maybe a bit
¤ Not at all

Summarizing question: Individual aspects
C5 From an <u>individual point of view</u>, how do you rate the installation of wind turbines in Styria?
¤ Very negative
¤ Rather negative
¤ Neutral
¤ Rather positive
¤ Very positive

Final question
Taking into account all your previous answers, how do you rate your <u>overall satisfaction</u>, concerning the installation wind turbines in Styria?
¤ Very low
¤ Low
¤ Moderate
¤ High
¤ Very high

Socio-demographic Information

SD1 What is your age?
¤ *18* – 24 years
¤ 25 – 34 years
¤ 35 – 44 years

¤ 45 – 54 years
¤ 55 – 64 years
¤ 64 or older

SD2 What is your gender?
¤ Male
¤ Female
¤ Non-binary
¤ Prefer not to say

SD3 What is your level of education?
¤ Secondary schools or less (e.g., high school)
¤ College or vocational training
¤ Bachelor's degree
¤ Postgraduate degrees (Masters, PhD or higher)

SD4 Are you currently employed?
¤ Yes, full-time
¤ Yes, part-time
¤ No, not employed
¤ Retired
¤ Student
¤ Prefer not to say

SD4.1 If you are currently employed, what is your profession?
Plese fill in your profession.

SD5 Have you lived or are you currently living in Styria?
¤ I am currently living in Styria
¤ I have lived in Styria
¤ I have never lived in Styria
¤ Prefer not to say

SD5.1 In which municipality?
Plese fill in the municipality.

MUSA Results

The following figures present MUSA satisfaction functions on criteria and subcriteria.

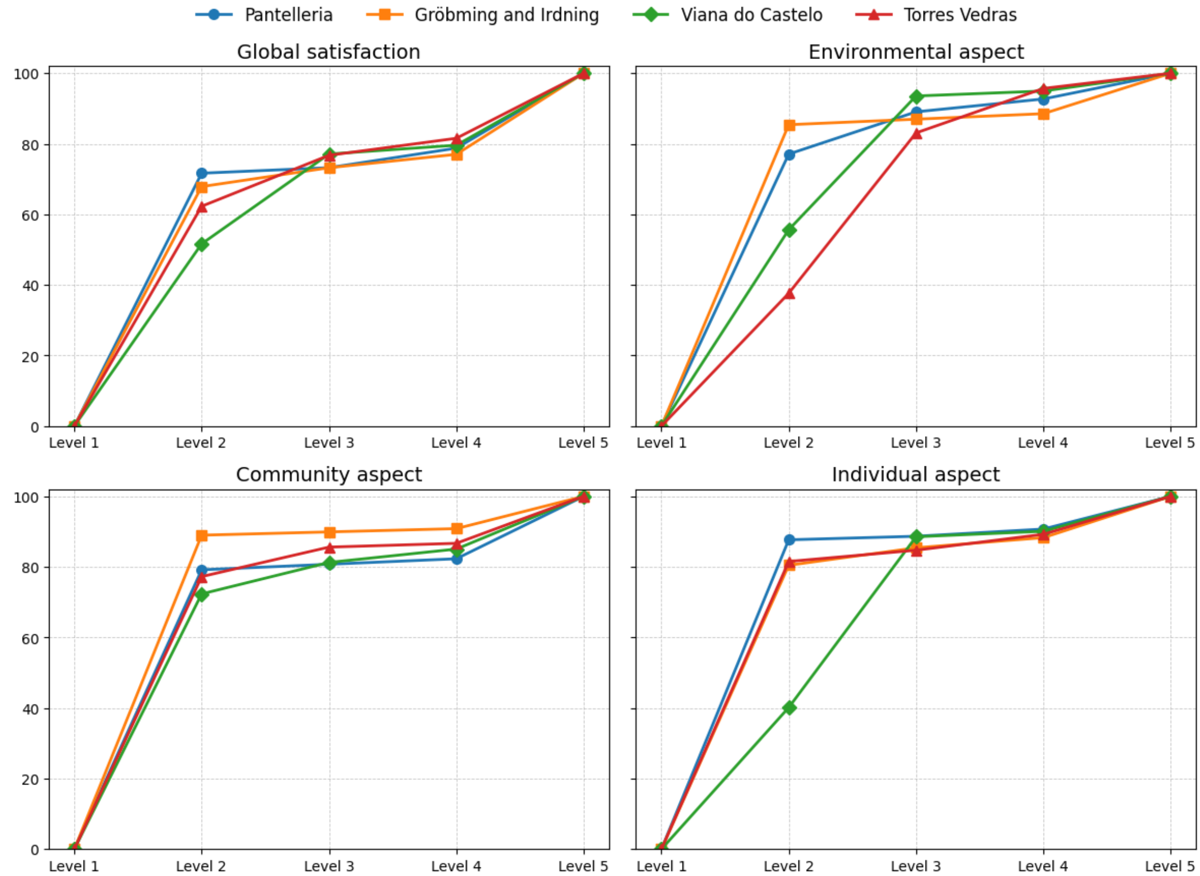

Figure 8 Global satisfaction function and criteria satisfaction functions on five pilot sites

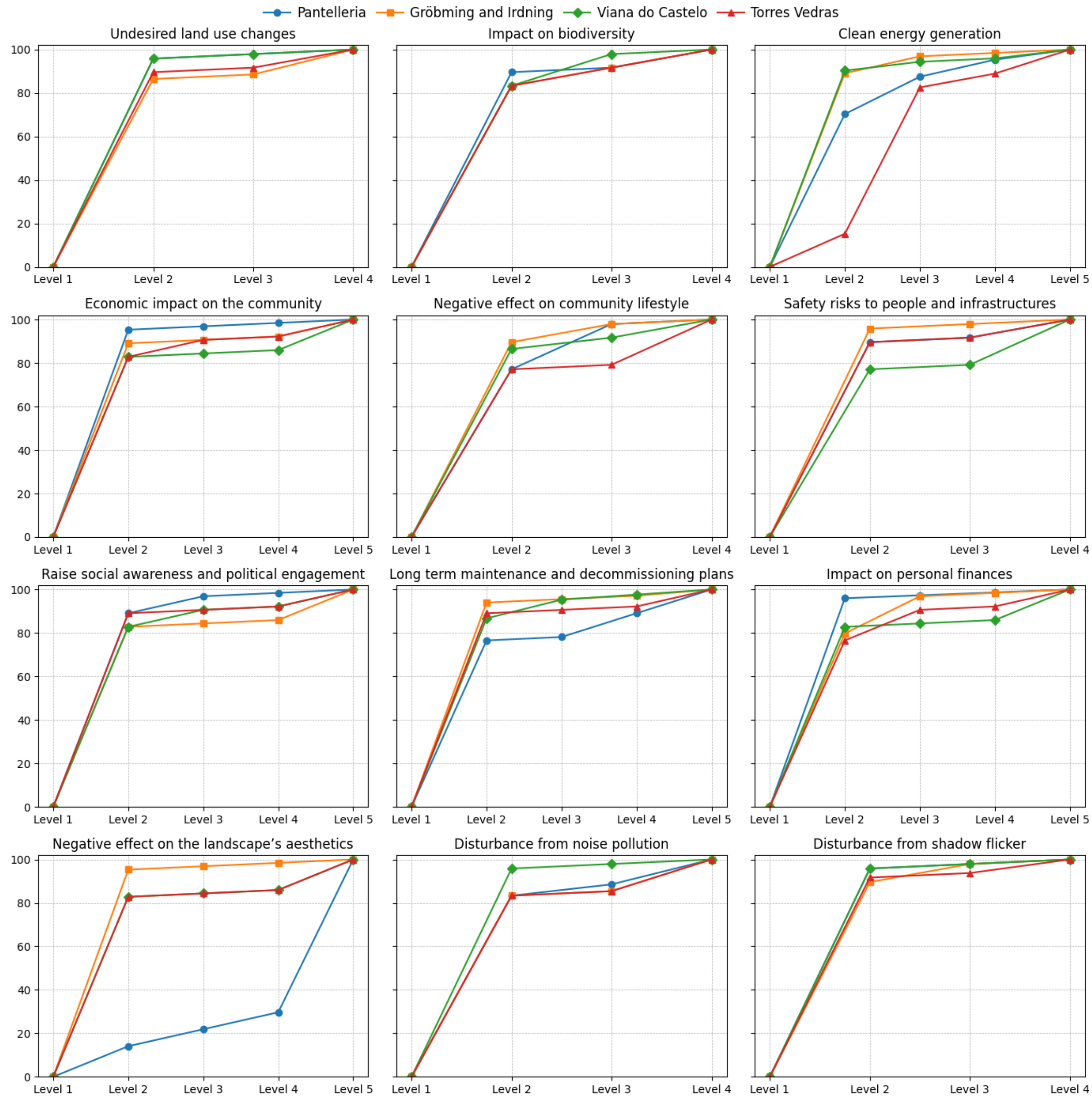

Figure 9 Sub criteria satisfaction functions on five pilot sites