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Lead author(s)	Thomas Schauppenlehner (BOKU)
Contributors	Karl Bitter, Eva Maria Konrad, Michaela Buchbauer (BOKU)

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SHORT ABSTRACT FOR DISSEMINATION PURPOSES

Abstract This deliverable describes the development of an immersive 3D platform for the integration of stakeholders and local population to identify trade-offs and social acceptance patterns in the context of wind energy development using a serious games approach and comprehensive interactive 3D visualisations and VR glasses. Data is derived from open and free repositories and processed to generate realistic 3D environments. An initial evaluation was carried out during a first series of workshops in the WIMBY pilot region of *Pantelleria*. It has been shown clear that the developed platform has great potential to support collaborative development approaches and is ready to be used in the WP3 workshops in the pilot regions.

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TABLE OF CONTENTS

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LIST OF PARTNERS

No	Logo	Name	Short Name	Country
1		VRIJE UNIVERSITEIT BRUSSEL	VUB	Belgium
2		DANMARKS TEKNISKE UNIVERSITET	DTU	Denmark
3		INTERNATIONALES INSTITUT FUER ANGEWANDTE SYSTEMANALYSE	IIASA	Austria
4		UNIVERSITAET FUER BODENKULTUR WIEN	BOKU	Austria
5		UNIVERSITETET I OSLO	UiO	Norway
6		NAZKA MAPPS BVBA	NAZKA	Belgium
7		KELSO INSTITUTE EUROPE GEMEINNUTZIGE GMBH	KIE	Germany
8		DEEP BLUE SRL	DEEP BLUE	Italy
9		UNIVERSITEIT UTRECHT	UU	Netherlands
10		POLITECNICO DI TORINO	POLITO	Italy
11		UNIVERSITA DEGLI STUDI DI PALERMO	UNIPA	Italy
12		APREN-ASSOCIACAO PORTUGUESA DE ENERGIAS RENOVAVEIS	APREN	Portugal
13		MULTICONSULT NORGE AS	MCN	Norway
14		EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH	ETH Zürich	Switzerland

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15		PAUL SCHERRER INSTITUT	PSI	Switzerland
16		UNIVERSITY COLLEGE LONDON	UCL	United Kingdom

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ABBREVIATIONS

Acronym	Description
OGD	Open Government Data
VGI	Voluntary Geographic Information
VR	Virtual Reality
nDSM	Normalised digital surface model
UI	User interface
ICT	Information and communications technology
API	Application Programming Interface
JSON	JavaScript Object Notation

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LIST OF FIGURES

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LIST OF TABLES

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EXECUTIVE SUMMARY

D5.3 aims to develop an immersive 3D platform for wind energy awareness raising, as participation, collaborative activities and knowledge transfer are important key concepts to consider and explore aspects of social acceptance for renewable energy development. The focus is on the integration of knowledge within a workshop-based serious games approach. This report presents the theoretical and methodological framework as well as the technical results and the finished 3D platform. It also provides a detailed overview of the hardware and software components for setting up the platform for the workshops in the different pilot sites regions. It also provides insights into the data used, primarily drawn from freely available open data sources, and presents initial results of a preliminary workshop series in the WIMBY pilot region of *Pantelleria* in May 2024. The results of this workshop have shown that the developed immersive 3D platform works stable and contains all relevant options for the participants to mark go and no-go areas for wind energy development at local/regional level and to test different wind turbine installations considering the adjustable parameters for the distance, size and number of wind farms and wind turbines. To enable a collaborative workshop, participants can use simple tokens to develop local wind turbine scenarios, change the viewing position and navigate on the map (zooming and panning).

<u>Attainment of the objectives</u>

The development of the immersive 3D platform has been completed. The individual software components and documentation are available on git (https://github.com/wimby-eu). Minor optimisations and bug fixes are an unavoidable part of the ongoing tests and implementation during the individual pilot site workshops. The final version of the 3D model based on geodata is available for the *Pantelleria* pilot site. For the other pilot regions, data sources are currently being collected and integrated according to the work tasks mentioned in the application. Further improvements to the data are also planned.

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1. STATE OF THE ART

This chapter provides an overview of the theoretical and methodological framework for the development of the immersive 3D platform. The focus is on participation, social acceptance, serious games approaches and the integration of ICT in collaborative planning and decision-making processes as foundation for the further development.

1.1 Citizen Participation in planning processes

All political and social practices are mechanisms through which individuals influence and shape public affairs beyond their private sphere are called civic engagement and citizen participation (Ampatzidou, et al., 2018). Public participation in planning and decision-making processes is generally acknowledged as a positive force for enhancing the quality and legitimacy of planning initiatives, as it promotes inclusive, sustainable living spaces and is a component of democratic governance. Despite these benefits, public participation often remains insufficient as it faces challenges such as meeting the needs of different stakeholders, facilitating effective communication between professionals and the general public or involving all social groups in a community (Delaney, 2022). In addition, public engagement in planning is influenced by conceptual and practical challenges. Citizens who are affected by the plans are often involved as a matter of priority and participation occurs within the specified timeframes of the planning processes and the commissioning organisation. As a result, many people are starting to view participation as futile and ineffective in resolving conflicts or influencing decisions (Ampatzidou, et al., 2018).

1.2 ICT in Citizen Participation

Information and communications technology (ICT) including visualisations, flythroughs, online discussion forums and digital questionnaires (Delaney, 2022), or "digital tools for online participation, such as e-democracy portals, online consultations, e-voting, crowdsourcing, blogging, social networking platforms, mobile apps, community GIS and online deliberation", are becoming increasingly important in various planning disciplines (Ampatzidou, et al., 2018). They have transformed communication and interaction and created new opportunities to involve and invite participation

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from citizens (Delaney, 2022), who may either be too occupied or disinterested in attending on-site meetings (Ampatzidou, et al., 2018). On the other hand, Web 2.0 as a medium for participation, interaction and democratization has also led to participation fatigue due to inequality, trolls, rudeness or hate speech (Porlezza, 2019), which require new strategies and mechanisms for the use of ICT as a participation tool.

1.3 Serious Games in planning

The use of games in planning, especially serious games, shows promising results in terms of participation, collaboration and innovation. While the concept of serious games for critical fields has a longstanding history, their integration into planning practices is still limited. The existing literature on game-based planning approaches contains numerous case studies, but offers little clear guidance for planners. However, games are recognised as supporting planning tools but require specific approaches, with serious games playing a crucial role (Sousa, Pais Antunes, Pinto, & Zagalo, 2022). The term 'Serious Games' was first coined in the late 1960s by the American engineer Clark C. Abt (Willenbacher, Lepiorz, & Wohlgemuth, 2017; Ampatzidou, et al., 2018). In his book 'Serious Games', he wrote that they combine thinking and action, thereby increasing learning success through a combination of physical and mental action (Willenbacher, Lepiorz, & Wohlgemuth, 2017). Serious games are therefore games that are not just for entertainment, but support creative tasks and decision-making processes through their educational aspect (Delaney, 2022). They are designed to teach, train (Willenbacher, Lepiorz, & Wohlgemuth, 2017) or generate awareness of real-world problems (Sousa, Pais Antunes, Pinto, & Zagalo, 2022). While the military, aerospace and medicine have been using serious games for training purposes for some time, they have also been increasingly used in schools, training centres and research in recent years (Willenbacher, Lepiorz, & Wohlgemuth, 2017).

The application of games promotes learning by enabling players to test different options without real consequences. They enable active participation and collaboration, while also encouraging innovation by incorporating the diverse perspectives of participants, thereby supporting civic engagement, expression, experimentation and co-creation. Serious

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games can make participants aware of how their individual and collective decisions are influenced by the combination of different elements, knowledge and experiences (Sousa, Pais Antunes, Pinto, & Zagalo, 2022). Gaming also offers numerous learning benefits for participation and civic engagement, such as awareness raising, improved knowledge of specific issues, complex problem-solving skills, the opportunity to test difficult scenarios in a safe environment, network and coalition building (Ampatzidou, et al., 2018).

Digital games can be used to create experimental situations that would not be possible in real life (Sousa, Pais Antunes, Pinto, & Zagalo, 2022), allowing researchers to tackle the problems to be solved directly through serious games. Therefore, attempts are often made to develop customised games in response to specific challenges. However, the creation of a quality, high value and entertaining digital game is often limited by logistical and financial difficulties (Delaney, 2022). For example, Ampatzidou et al. also found in their case study that the level of professional experience with games or gamified environments is currently low to limited, as games or gamified applications have only been used to design participatory processes by about a third of all respondents. Reasons that hinder the development and dissemination of games in planning practice are time and budget constraints, together with the assumption that games necessitate a more intricate development process in contrast to conventional methods such as offline surveys, interviews or focus groups (Ampatzidou, et al., 2018). Despite this, serious games are being developed across various research areas and are demonstrating their value as effective tools. Playability and player engagement depend on balancing complexity in such a way that players understand the game and remain interactive without losing touch with reality. Games must therefore have a clear set of rules that define goals and processes, as well as metaphors and narratives, game mechanics, interfaces, platforms and objects. The game mechanics are a central element, as they control the players' interaction with the game system. Clear goals increase motivation and ensure that outcomes depend on player decisions, not chance. Since the 1980s, storytelling has been used in participatory planning to actively involve participants, create context and motivate them to act. Serious games should not only be perceived as fun, but also as a meaningful investment of

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time. Both participants and planners should see the results of the game as useful. Planners use serious games to collect data that would not otherwise be available and expect them to generate planning solutions that are negotiated and accepted by the public (Sousa, Pais Antunes, Pinto, & Zagalo, 2022).

Using games as tools for complex decision-making requires the support of game facilitators. In addition to offering games as a learning and simulation environment for participants, planners or scientists have the opportunity to act as designers and facilitators, gathering information and connecting socially with participants. Similar to other participatory and collaborative planning approaches, moderation and debriefing are required to achieve the planning objectives of serious games. Games that are led by a moderator and where players come together in person seem better suited to tackle complex, uncertain, confrontational and ethical problems. This is because the games allow for extensive communication that can generate empathy. Game facilitators can react in a flexible manner to unforeseen behaviour and different player profiles while promoting balanced participation (Sousa, Pais Antunes, Pinto, & Zagalo, 2022).

To identify the effectiveness of a serious game, various evaluation methods are described in the literature, such as players reporting and explaining decisions or applying an evaluation framework before, during and after the game (Sousa, Pais Antunes, Pinto, & Zagalo, 2022). Using a literature review on serious games and spatial planning, Sousa et al. were able to identify groups of strengths and weaknesses (see Table 1) that planners should consider when utilising or creating serious games.

Table 1: Main strengths and limitations of serious games in descending order (based on data from Sousa et al., 2022)

Strengths	Limitation
Experimentation: Testing models/scenarios, mapping and trialling ideas – focus on problem solving and innovation	**Inconsistency:** Reticence of participants, incoherent and inconclusive solutions
Engagement: Involvement, motivation and encouragement for direct participation	**Oversimplification:** Deliver playable experiences and adapt to users' inputs, interactions, and outputs

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Collaboration: Interaction, negotiation, learning from other participants, compromise and joint decision-making	**Distrust:** Lack of trust and experience among planners and politicians, general prejudices against games and unpleasant situations
Complexity: Dealing with urban/spatial self-organisation, polarising and opaque problems	**Costs:** High resource requirements such as design expertise, data, tools (e.g. software, materials, facilities) and, time

In theory, serious games are mainly seen as educational tools. Although the game requirements for participatory planning and communication largely correspond to these groups, there are specific design considerations for planning games. The focus here is on participation and collaboration. Competition-oriented games with clear winners and losers are not suitable for such serious games, as the idea of participation would be undermined. On the other hand, planning games should aim to build a shared knowledge base, resolve conflicts of interest and achieve common goals. Role-playing games are particularly more suitable in this context, as they enable players to explore politically and socially relevant topics, understand other perspectives and think beyond personal interests (Bittner, 2022).

1.4 Game engines for visualisations

As video games and their technology matured, rendering and level creation tools became increasingly separable from the games they were used for. In the 1990s, games such as *Quake* and *Unreal* first allowed players to create custom games of a similar style. During the 2000s, fully-featured game engines such as the commercial *Unreal* engine became available as general-purpose video game creation tools. The low-level technology required for real-time 3D applications, such as efficient memory management, a render loop for smooth real-time rendering, camera projections, lighting, and physically based materials, as well as the technology for efficiently developing them (including scripting languages, debugging tools, etc.) thereby became reusable across game projects as well as for software outside of the domain of typical video games (Gregory, 2009).

One such domain is landscape visualisation. The ability to efficiently and realistically render large 3D environments is highly relevant both for video games and for landscape visualisation, and this synergy has been

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recognized and utilised ever since game engines first appeared (Herwig & Paar, 2002).

In the WIMBY project, we leverage cutting-edge game engine technology to develop realistic and interactive simulations of wind power installations. These engines enable us to render detailed 3D environments, simulate wind turbine operations, and visualise the potential impact of wind energy projects on the surrounding landscape. By harnessing the power of game engines, we aim to provide stakeholders with engaging and informative experiences that enhance their understanding of wind energy concepts and foster meaningful participation in energy transition initiatives.

2. TECHNICAL IMPLEMENTATION

The immersive 3D platform consists of three core components that interact with each other at different levels (see Figure 1 below).

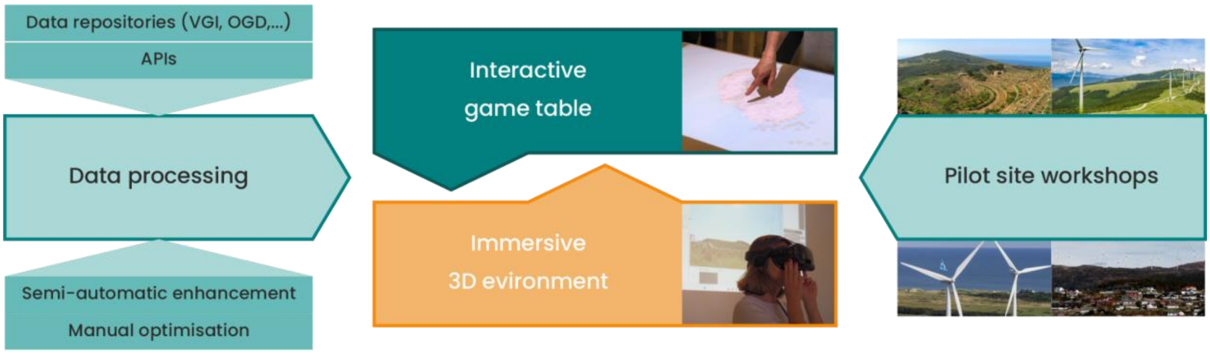

Figure 1 - Core components of the immersive 3D platform developed for the four pilot sites within the WIMBY project

The first component is the data processing component, which contains a compilation of free and open data sources for the individual pilot sites. The data is processed for each pilot site location and is supplemented by further manual and semi-automatic improvements and optimisations. This data forms the basis of the game board, the underlying game logic as well as for the creation of immersive 3D visualisations to convey the landscape effect of wind turbines. The result of the data processing component is a comprehensive *GeoPackage*,[4] that contains all the necessary data and structures for further processing in *Godot*[5] an open-source game engine on the basis of which both the visualization and the game table are created.

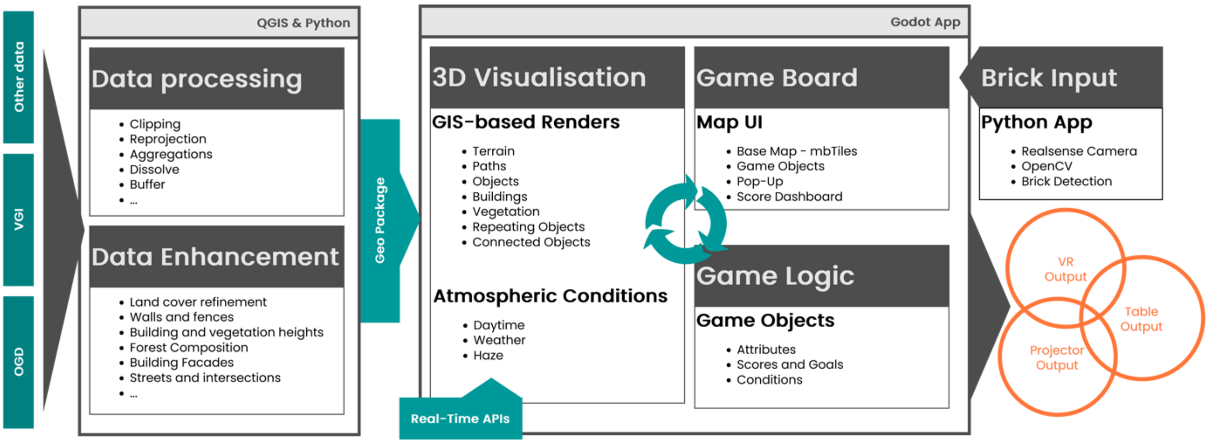

Figure 2 - Detailed representation of the immersive 3D platform components

Three visual output interfaces are delivered to support the serious game approach: The game table output (for game token placement to develop wind energy scenarios and perform map operations during a workshop), the projector output (to display a common dashboard with integrated 3D visualisation, indicators and environmental settings), and the immersive VR output for individual locations using VR glasses (see Figure 2 above).

2.1 Data Processing

Data from different data repositories and sources are compiled and processed to generate a comprehensive dataset for each individual pilot site.

2.1.1 Data Repositories and Application Programming Interfaces (APIs)

We access various sources of Open Government Data (OGD) and Volunteered Geographic Information (VGI) as a basis for the planning map

[4] https://www.geopackage.org (last visited on 18.06.2024)

[5] https://godotengine.org (last visited on 17.06.2024)

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and visualisation. The fundamental data sources for the 3D visualisation are shown in Figure 3:

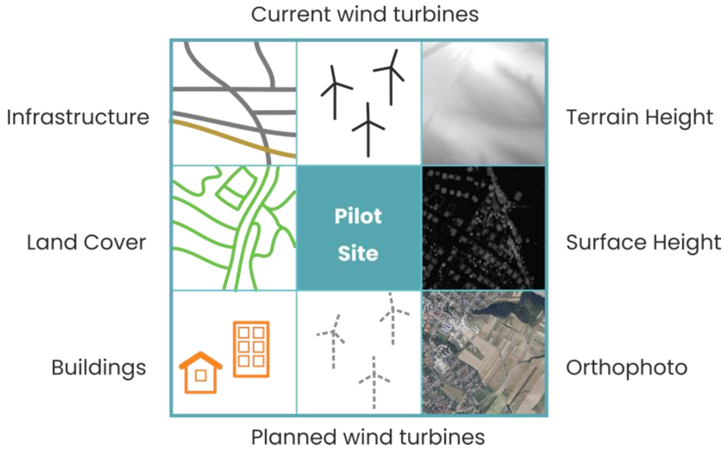

Figure 3 - Foundational data sources for the visualisation, schematic depiction.

In addition, we include potential scenarios for the future expansion of renewable energy in and around the given pilot site region. For example, a report[6] is available for a photovoltaic plant to be built at the *Pantelleria* airport, which we included in the visualisation. By visualising such scenarios along with the current custom plan, we can create a more holistic scenario.

In addition to the data for creating the 3D environment, data is also used for the game logic. This includes wind power potentials, allowed zones, as well as ecological data. Water depths are also considered for a realistic depiction of off-shore wind turbines and their anchoring.

A real-time weather API (*Open-Meteo*[7]) is used to match the atmospheric conditions in the visualisation with current weather. Further API implementations addressing real-time traffic (aeroplanes, vessels and cars) might be considered, depending on the available data and formats.

[6] https://clean-energy-islands.ec.europa.eu/system/files/2023-02/REPORT_Technical.Assistance_Gamechanger_Pantelleria.20230131.pdf (last visited on 20.06.2024

[7] https://open-meteo.com (last visited on 18.06.2024)

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2.1.2 Semi-automatic enhancement and optimisation

Some automated enhancements are similar or identical for all pilot site regions. For example, surface height data (nDSM) is calculated and analysed to identify solitary vegetation and to assign the correct height to plants and buildings. But by developing location-specific improvements to the data basis, the level of detail of the 3D visualisations is to be improved even further, thereby increasing the recognition value and orientation options. These improvements are dependent on the respective pilot site, as there are location-specific differences and the available data also varies from country to country. The focus of this optimisation is primarily on the design of transitions between different land uses, as very typical design elements such as walls, fences or transition strips are often found here, which are not present in the usual land use maps. As an example, for the pilot site in *Styria* (*Austria*) it is fences in the settlement or near-settlement area and in *Pantelleria* the walls and terraces that structure the rural area. They are of great importance for the scenic value of landscapes.

The process of deriving those sampled linear features for stone walls and terraces in *Pantelleria* is described in detail below as a representative example for this enhancement and optimisation process.

At the centre is an analysis of the microstructure of the elevation model in order to identify the position of the walls on the basis of significant gradients. This makes it possible to create a very precise data set for the walls and terraces on *Pantelleria*. Subsequently, this spatial differentiation makes it possible to improve the land cover data. Here, fallow land, meadows and heathland can be differentiated from agricultural patterns for wine, fruit and vegetable cultivation on the basis of slope gradients.

2.1.3 Data enhancement example: Stone walls and terraces in Pantelleria

Stone walls and terraces are important elements in the landscape of *Pantelleria*, but they are not available in any dataset. Therefore, we use nDSM data to derive them for the entire pilot site region. Figure 4 below shows the result of this process:

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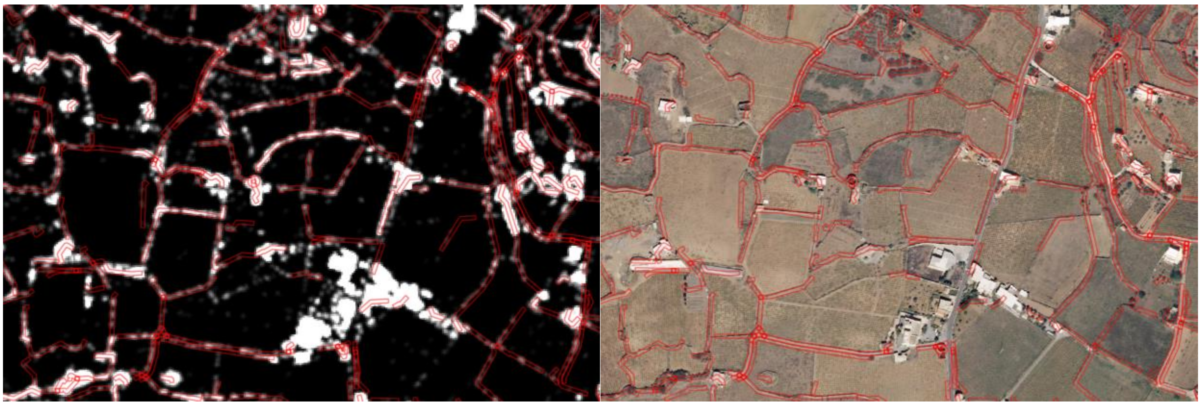

Figure 4 - Surface height map (nDSM) (left) and Orthophoto (right) of the same region, overlaid with the walls estimated using the process described below (vector lines, red outlines).

Workflow in GIS

The commands mentioned refer to *QGIS*[8] and its interfaces to *GRASS*[9], *SAGA*[10] and *GDAL*[11]. Other GIS programmes also enable these processes, but may use different terms and commands for them:

1. Calculate **Slope** for DTM
    a. Alternative: Calculation of the **Profile Curvature** to better distinguish the fences from natural slopes.
2. **Reclass** slope: 0 thru 5 to *NULL*, 5 and up to 1
    a. Note: if working with the curvature values, **Recode** is required
    b. For very flat areas, we want 0 thru 2 to *NULL*, 2 and up to 1. In less flat areas, this creates very large areas with 1 (after the next **Sieve** step) that needs to be removed by inverting the raster, buffering and separating from the rougher data:
        i. **Reclass** to turn 0 into *NODATA* and turn 1 into *NULL*
        ii. **Buffer** the result (range between 20-30m)

[8] https://www.qgis.org (last visited on 18.06.2024)

[9] https://grass.osgeo.org (last visited on 18.06.2024)

[10] https://saga-gis.sourceforge.io (last visited on 18.06.2024)

[11] https://gdal.org (last visited on 18.06.2024)

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   iii. **Reclass** to remove the classes introduced by buffer
   iv. **Polygonize** - the resulting polygon represents the area where we want to use the 0 thru 2 result, whereas everything outside of the polygon should use the 0 thru 5 result. In essence all polygons representing flat areas
   v. Use the resulting polygon to cut away the desired/undesired bits of each dataset
3. **Sieve** the result: remove everything smaller than 10 (note: *NO_MASK* must be True to use *NULL* instead of small areas)
4. If necessary: `r.null` to replace 0 with a *NODATA* value
5. **r.thin** to get lines with width of 1 pixel
   a. Note: Can cause artefacts (connections where there should be none), maybe another step is needed before
6. Filter some areas based on land cover (e.g. sealed areas)
7. **r.to.vect** to get vector lines from raster lines
8. **v.clean** (*rmdangle* and threshold 50) to remove short lines
9. **Smooth** the remaining lines (10 iterations, offset 0.5)

This process generates a line network that appear correct in general but contains a lot of gaps. For a more detailed subdivision of land cover, the polylines are converted to polygons

1. Extend the lines by 10m → first step towards closing gaps
2. Buffer the lines by 5m → second step towards closing gaps
3. Round end cap with 1 segment for sharp ends
4. Difference lines from base polygon → multiple individual polygons
5. Buffer result by 5m → first step towards generating polygons
6. Self-Intersect the polygons to remove overlaps
7. Difference result from base (space-covering) polygon → result are areas which are not yet filled
8. Merge Adjacent Polygons → small polygons (i.e. most space-filling clippings from above) are merged into larger adjacent ones

2.2 Interactive Game Table

The interactive game table is the core component for the practical operation of the game during the workshops. It allows the placement of game tokens for computer interaction and provides information about the

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game progress. This requires a stable mount for projector and camera as well as a software for game token recognition.

2.2.1 Projector and camera mount

In general, the transportability of the hardware is an important issue for the feasibility of the game in the pilot regions. The interactive gaming table plays a central role here, as a projector must be used precisely in different room situations and a correspondingly stable mount is required. The projector and the mount required for it must be adaptable to various situations. In addition, transportability by aircraft is a prerequisite for travelling to the pilot regions. A modular wooden construction was therefore developed that is easy to assemble and fits easily into airplane luggage in its individual parts (see Figure 5).

Figure 5 - Wooden construction for projector and camera mount and a classification of different table edges for their suitability

An installation with this mount is possible on almost all standard tables, with a corresponding triangular fixation under the table forming the counter bearing to the weight of the projector when mounted overhead. This means that the system can be set up and used in any environment and under different conditions (see Figure 6)

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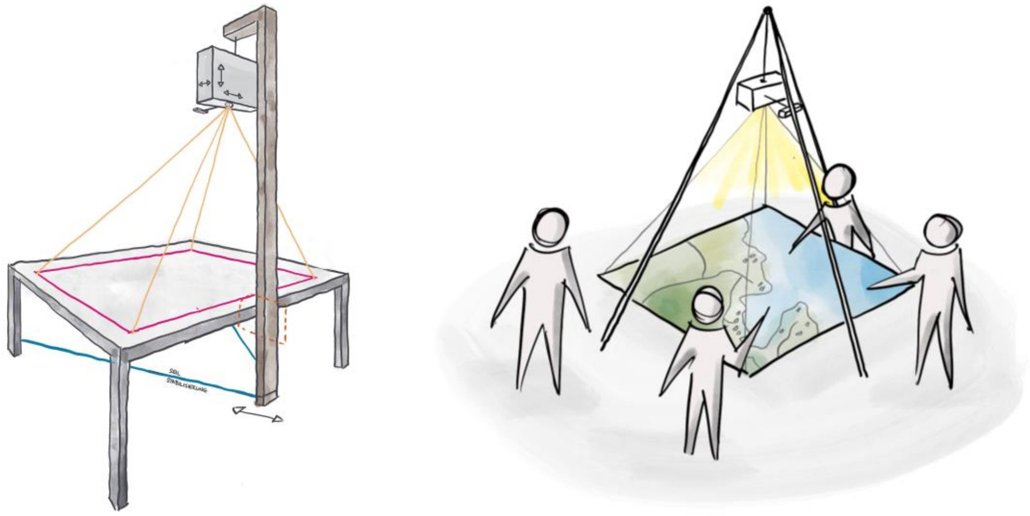

Figure 6 - Triangular fixation under the table to dissipate the lever weight of the projector (left) and a schematic sketch of the game table situation.

2.2.2 Game token recognition

As shown above, a projector is used to draw a large map on a table. Participants of the workshop can interact with this map, change the extent and zoom factor and develop local scenarios (see Figure 7). To do this, they place game tokens on the table, which are captured by a high-resolution webcam (Intel RealSense) mounted parallel to the projector. The captured video is then sent to a Python script for token recognition.

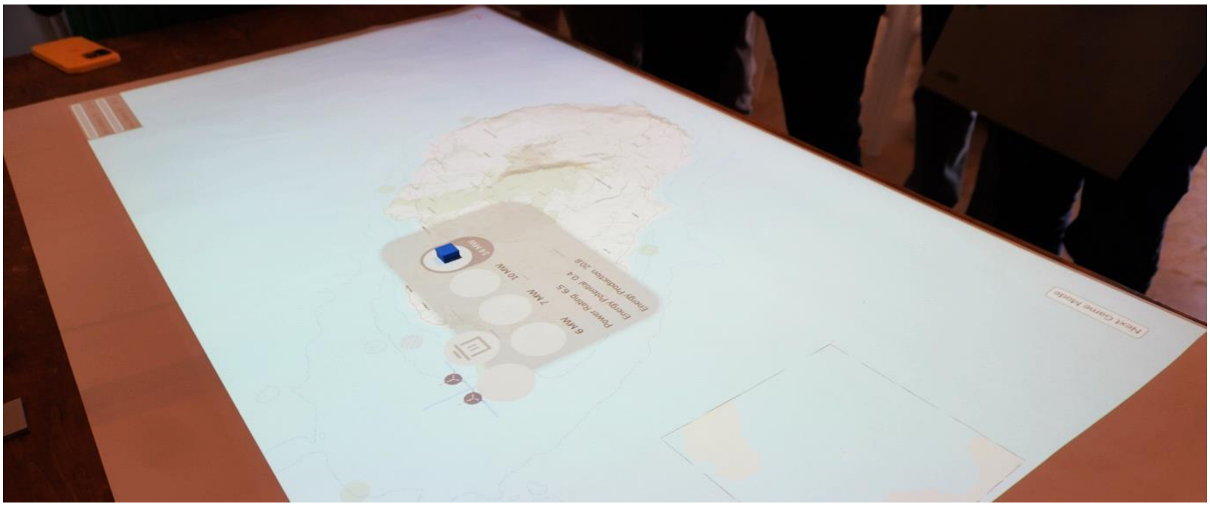

Figure 7 – A blue game token controlling a menu for wind turbine selection on the virtual game board (Image from the first *Pantelleria* workshop, taken by Rebecca Hueting-DBL)

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This recognition program uses the computer vision library *OpenCV*[12] to recognize shapes, sizes and colours. If a token is recognized, its position is calculated based on the map extent. The resulting data is then sent to the immersive 3D environment via a WebSocket connection as a JSON array.

Some challenges arise from this approach: firstly, the underlying map (which the camera inevitably also records) must not use shapes and colours which are too similar to the game tokens in order to avoid misrecognitions. The solution to this will be described in more detail in the next chapter. Secondly, the recognition software must be able to deal with varying light conditions. This is done by adapting camera parameters such as white balance and exposure based on a calibration process which runs at the beginning.

2.2.3 Game board map

The game board map is a cartographic representation of an individual pilot site region with the goal to explore different regions and make spatial decisions (potential wind park development zones and wind park layouts) during the game. The purpose of the map is to enable orientation in the pilot site region and to allow the placement of game tokens for computer interactions. This means that two aspects must be fulfilled with regard to the design of the map:

1. A **visual representation** that allows participants to orient themselves on the game board and navigate independently with local knowledge.
2. A **cartographic representation** that does not compete with the game token recognition and thus minimises or eliminates the risk of misrecognition of game tokens.

Regarding aspect 1, an emphasis was placed on the integration of a graphic topography by using a shaded relief. The shaded relief mimics the illumination and shadows caused by the sun on hills and canyons and

[12] https://opencv.org (last visited on 17.06.2024)

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provides a clear three-dimensional representation of the relief.Furthermore, local names (districts, viewpoints, landmarks, etc.) and facilities (companies, stores, restaurants, etc.) were integrated into the map. Depending on the selected zoom level, map contents are aggregated or displayed and described in greater detail (see Figure 8)

Figure 8 - Game board map representation for the *Pantelleria* pilot site in three different zoom levels

In order to avoid misrecognitions and errors during the detection process (aspect 2), a specific cartographic style was developed. This style is pale and desaturated on the one hand, but at the same time allows landscape features, compositions or hierarchies to be clearly and unambiguously recognized through slight differences in colour and brightness (see Figure 8).

2.2.4 Game UI

In order to interact with the projected game board on the planning table, a custom game UI was developed which is part of the same program as the game logic and 3D visualisation. The projects' visual identity was adopted to the most feasible extent such as font style or colour palettes.

As a base layer, the pilot region map described above is rendered. This is done with pre-rendered *mbtiles* which are loaded in real-time depending on the current zoom level and map extent (comparable to common web map services such as Google Maps or Open Street Map). Additional data is rendered on top of the base layer. Firstly, placed objects (wind turbines) are displayed on the game board using an icon representation.

Furthermore, UI elements are displayed as a top-most layer. One such UI element is a pop-up menu (see Figure 7) which appears when a game token

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(representing a wind farm) has been placed on the map. The menu allows participants to configure the wind farm in more detail, e.g. defining the number of turbines and their size. When placing a game token onto an existing wind farm, the same menu appears so that the users to make changes to the existing configuration. Individual wind turbines can also be changed by placing a game token on a specific wind turbine symbol. The schematic functions and processes of this UI are shown in Figure 9.

Additional UI navigation elements contain map controls for pan, zoom and center functions in the projected map extent. Lastly, score bars depicting the progress made towards certain targets:

- The **electricity generated** by the currently placed wind turbines
- The **required electricity generation** for that region.

When the game token recognition program sends data to the game UI, the UI first ascertains whether the token was placed on an UI element or on the map. If it was placed on an UI element, it is essentially interpreted as a mouse click on that element. Otherwise, it generates a new game object (i.e. a wind turbine) to be created at that location (see Figure 10).

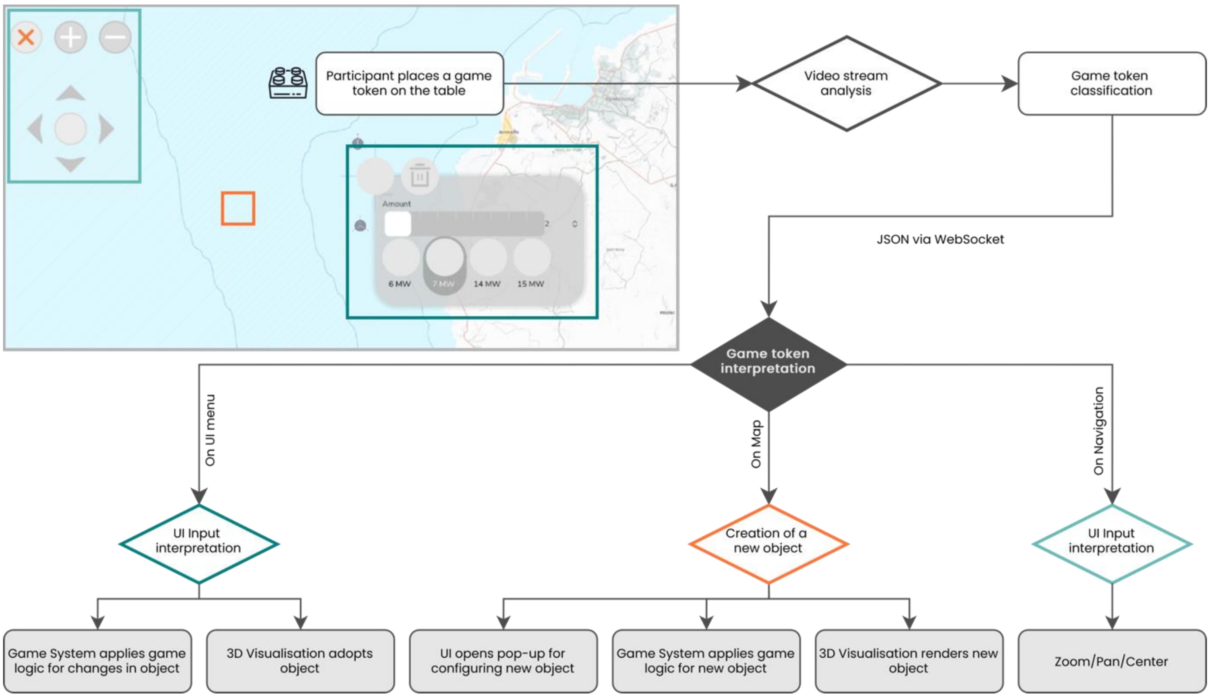

Figure 9 – Schematic depiction of the logic which the game UI traverses in order to turn a game token colour and position into the desired interaction outcome.

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Figure 10 – Workshop participant placing a game token on the interactive game board map (Image from the first *Pantelleria* workshop, taken by Thomas Schauppenlehner-BOKU).

2.2.5 Game logic

Placing a wind turbine on the game board causes the electricity generation score to rise appropriately. This is done by the game logic component. Four core concepts make up this game logic:

- **Game Objects:** abstract representations of GIS features coupled with game mechanics and interactivity.
- **Attributes:** values per *game object* based on GIS attributes or implicit connections (e.g. a raster value at its location).
- **Scores and Goals:** sums of multiple *attributes* of multiple *game objects*, compared to a target value.
- **Conditions:** restrictions of where *game objects* may be placed, e.g. to define zones where wind turbines may not be placed.

These concepts are used in the game definition, which is where geodata is transformed into a game. Formulas can be written for calculating complex attributes and for making multiple such attributes contribute to a score, and multiple conditions can realistically depict under what circumstances wind turbines may be built.

Finally, game definitions are related to the game board and game token recognition component. Token sizes and colours can be mapped to represent specific types of game objects (and therefore correspond to a GIS

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layer). For example, a red game token may represent an on-shore turbine, whereas a blue game token could represent an off-shore one.

2.3 Immersive 3D Environment

The immersive 3D environment is the third component of the planning and visualisation tool. This is where the changes made on the planning table come to life: it produces a highly realistic depiction of the given landscape (see Figure 11) with the changes currently made on the game board table.

Figure 11 - Visual comparison of the quality and reliability of the 3D visualisation (left) with a taken photo at the same location (right). (Image taken by Karl Bittner-BOKU)

Previous studies on the visual impact of wind turbines have predominantly used no visualisations or highly generic ones, even though dynamic and specific visualisations are a valuable tool for wind energy planning (Hevia-Koch & Ladenburg, 2019). They can create a “common language” (Kwartler & Longo, 2010) for the discussion and assessment. By fully immersing viewers in a full-spherical 360° landscape panorama, the possibility to view the visualisation on VR devices allows users to better grasp the overall perspective and scale of the landscape and changes within it (Schauppenlehner, Kugler, & Muhar, 2018).

The goal for our visualisation was to be highly interactive (arbitrary viewpoints and axes, adjustable atmospheric conditions) and immersive (viewable in VR). Current game engines offer sufficient real-time rendering technologies required for this: their value for landscape visualisation was already recognized in 2002 (Herwig & Paar, 2002), and the capabilities for realistic rendering including support for up-to-date VR technology (Edler, et al., 2019) has made this even more relevant.

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Our visualisation software is built with the *Godot* game engine. Similar previous studies have commonly used *Unreal* or *Unity* (Keil, Edler, Schmitt, & Dickmann, 2021; Edler, Keil, & Dickmann, From Na Pali to Earth: An 'Unreal' Engine for Modern Geodata?, 2020) but contrary to these engines, *Godot* is highly extendable and usable without licensing fees as it is licensed under an open-source license. This extendability was utilised for loading geodata into the engine: whereas the aforementioned earlier studies have usually used a complex pre-processing pipeline in order to bring the raw geodata into a format usable by the game engine, a plugin named *Geodot*[13] was developed for *Godot* to load geodata directly from standard formats such as *GeoPackages*, *Shapefiles* or *GeoTIFFs*. This data can be arbitrarily large: the visualisation loads only relevant parts for the current perspective, and level-of-detail techniques are employed to make the computational cost manageable. Therefore, pilot site regions can be as large as needed - up to hundreds of gigabytes per *GeoPackage*. In addition, by directly accessing geodata with no pre-processing, it is easy to experiment with additional or fine-tuned datasets as described in the data processing section. GIS changes are immediately visible in the visualisation, allowing us to make fine-tuned adjustments for pilot site regions as needed.

The game board and game system described above also access this same GIS dataset using the *Geodot* plugin. This way, there are no additional data formats, post-processing steps or incompatibilities: all visualisation and planning is directly reflected in GIS.

Different renderers are provided for different types of geodatasets. These are generic and can be used and configured depending on the needs of an individual pilot site region (see Figure 12):

- **Terrain renderer:** produces textured relief tiles based on heightmap, land cover, and orthophoto with different levels of detail.
- **Path renderer:** extrudes polygons or textures based on linear data. Used primarily for rendering roads.

[13] https://github.com/boku-ilen/geodot-plugin (last visited on 18.06.2024)

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- **Object renderer:** places 3D objects based on point data. Used for wind turbines and any additional detail with precise locations. These 3D ojects can be dynamic, so scenes like simulated bird swarms can also be placed at rough occurrence sites which they will then flock around.
- **Building renderer:** produces generic buildings with appropriate facades and roofs based on footprint polygons, height, and metadata.
- **Vegetation renderer:** pseudo-randomly scattering of 2D plants using land cover data or placement of 3D plants based on point data.
- **Repeating object renderer:** repeats a 3D object along a line. Used for rendering the stone walls, fences, etc.
- **Connected object renderer:** places 3D objects and connects them by extruding a different object in-between, e.g. power poles and power lines.

Figure 12 - Image of a settlement in *Pantelleria* showing all of the described renderers and how they combine to create a realistic depiction of the landscape.

These renderers give the virtual landscape its shape and form, both up close and in the far distance. But how the end result looks also depends on the atmospheric conditions and time of day. These can also be configured by the user. The configured date, time and location result in an accurate sun position, and weather settings define clouds, haze, rain, wind, and fog (see Figure 13). These settings can be defined arbitrarily in order to view different possible scenarios, or they can be set to the current outdoor conditions.

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Figure 13 - Comparison of different atmospheric and daytime conditions at the same viewpoint, showing how the landscape and the visibility of wind turbines is affected.

The result of these renderers and the surrounding lighting and atmospheric conditions is processes in two different ways. Firstly, a image rendering, either from a first-person (true to scale) or a top-down (flying) perspective, for the projector display. Adjustments to this view can be made by the workshop conductors using mouse and keyboard. Secondly, the same location visible in the projected view is sent to the VR glasses. This is an immersive first-person view controlled via VR sensors, placing users in a 1:1 scale virtual landscape. In order to connect these two outputs, a moving dot depicts the current view position of the VR device on the projected rendering.

This viewing position is also connected to the planning table: a specific game token (e.g., a green square token) is defined to be the *teleport token*. Placing this token sets the visualised position to exactly that position, making the view from that point visible both on the projector and in VR. This allows participants to intuitively control the visualisation while they are placing wind farms in order to see their visual impact.

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3. PRELIMINARY WORKSHOPS IN PANTELLERIA

In May 2024 (13 and 14 May), the first workshops related to the *CE4EU Islands* forum were held (see Figure 14). This series of workshops was not part of the original plan, but it provided an opportunity to test the 3D platform in real-life conditions, including discussions with stakeholders and exerts, modes of transport for hardware components and approaches to deal with language barriers. A total of three workshops were conducted. The first workshop included Italian participants (group A) with a connection to the island of *Pantelleria* and two workshops with stakeholders and experts (group B and C) from various European islands (visitors to the *CE4EU Islands* forum). In addition, the immersive 3D environment was set up for another day as an open lab where forum visitors had the opportunity to test the serious game method, play with different scenarios, explore the immersive 3D environment and contribute with ideas and/or questions.

Figure 14 - Impressions from the first workshop series in *Pantelleria* in May 2024.

The workshops were recorded using minutes and each participant completed a baseline and debrief questionnaire. The visual documentation of the workshop begins with an introduction to the game table and a clear

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explanation of the procedure. Participants actively engage in a hands-on activity, using game tokens to mark areas suitable or unsuitable for wind energy integration. They then place wind turbines or wind farms on these areas, observing immediate outcomes within an 3D environment, enhanced by the VR technology. This immersive aspect allows participants to virtually step into proposed wind energy landscapes, providing a vivid sense of scale and presence that deepens their understanding and engagement.

Through real-time visualisation, stakeholders can explore diverse scenarios and comprehensively understand potential impacts of wind energy projects. As participants interact with the game table, they collaboratively evaluate various environmental, economic, and social factors. Discussions cover topics such as landscape aesthetics, noise levels, biodiversity, emissions reduction, community impacts, personal considerations, social dynamics, safety concerns, and community engagement efforts.

By systematically addressing these dimensions, stakeholders can assess the sustainability and societal implications of wind energy initiatives. This interactive component of the workshop facilitates dialogue and consensus-building, fostering informed decision-making and active community involvement in developing sustainable energy strategies.

3.1.1 Materials, Recording and Observations

The workshop utilised colour-coded folders and stickers to streamline participant identification and data organisation. Each participant received a folder containing essential materials, such as a title facts page, info flyer with the agenda, a declaration of consent, and a baseline questionnaire to gather insights on renewable as well as wind energy perceptions. Debrief questionnaires were provided at the end of the workshop to collect feedback on the activities. This detailed organisation ensured a smooth and effective process, facilitating comprehensive data collection and analysis.

The colour coding system assured thorough recording and analysis of participant interactions. DEEP BLUE and POLITO staff recorded verbatim discussions and behaviours on individual laptops. Game table recordings captured valuable insights and decisions made during the workshop. Additionally, BOKU staff systematically recorded notes on participant interactions and workshop dynamics. This approach, consistently utilising

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the colour code system across all activities, ensured the collection of interconnected and comparative data, including both baseline and debrief questionnaires.

3.2 Evaluation

3.2.1 Participatory Observation of the game play

The three workshops were observed by the project team to identify obstacles during the gameplay caused by technical constraints or methodological issues.

Workshop Duration

One of the workshops lasted 3 hours, the two others were limited to 1.5 hours (due to the required embedding into the *CE4EU Islands* forum). It turned out that 3 hours is more suitable for a comprehensive discussion about the game and its objectives than just 1.5 hours. Collaborating without time pressure, allow reflections and feedback loops on the decisions made, which can increase the quality of the workshop's output. Time is also needed for the individual VR experiences because, unlike the projected 3D environment, these are individual experiences that can only be made one after the other.

Game board and navigation

Navigating on the map was mostly easy for all participants. The impression was that they had a very clear picture of which sites were suitable for wind energy and which were not - the map supported them in these assumptions and provided details on land use, exclusion zones, etc. No technical barriers were identified when using the game board either.

There were virtually no misidentifications of game tokens, but there were sometimes issues with the game token visibility because the participants covered the token with their hand or gave the object recognition process too little time. Object recognition takes place in real time and responds very quickly (there is a technical lag of a few milliseconds), but compared to the usual touch controls, the hand movements have to be slightly different. The participants adapted very quickly to this slightly different operation.

3D Experience

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It has been shown that group discussions can take place very well in front of the joint 3D dashboard projection. This dashboard shows the 3D visualisation as well as other indicators and the game goal status.

Nevertheless, "aha" moments occur after viewing in the VR glasses, as the actual dimensions and perspectives can only be experienced there. Since the Italian participants were familiar with the environment they were able to immediately recognise the coastline and the landscape, with situational awareness levels reported as very high. Nevertheless, they simultaneously reported the simplicity of some elements in the landscape, such as the buildings textures or the formal characteristics of the typical *Dammusi* houses. Furthermore, they experienced some minor differences in plant species and vegetation patterns.

Given the fact that the entire landscape was created exclusively from freely accessible geodata, the quality was nevertheless exceptionally high. Further improvements are planned based on the experiences of the first workshops.

By the "easy to use" teleport token, participants were able to quickly jump between different locations to assess the visual impact of scenarios created during the serious games process.

3.2.2 Analysis of evaluation questionnaire

This analysis presents the findings from the evaluation survey completed by participants at the end of the workshops conducted in May with attendants at the *Clean Energy for EU Islands* forum (*CE4EU Islands*). The primary focus was to assess participants' experiences, the effectiveness of the serious game component, usability, and the impact on their understanding and attitudes towards wind energy. A total of 29 questionnaires were analysed.

Overall Workshop Experience

The workshop garnered overwhelmingly positive feedback. Participants universally rated the quality and relevance of the content as excellent. Communication of workshop objectives received high approval ratings (97%), and a majority of participants (86%) found the interactive exercises and group discussions engaging and informative. Furthermore, the workshop facilitator received a positive rating from 97% of participants.

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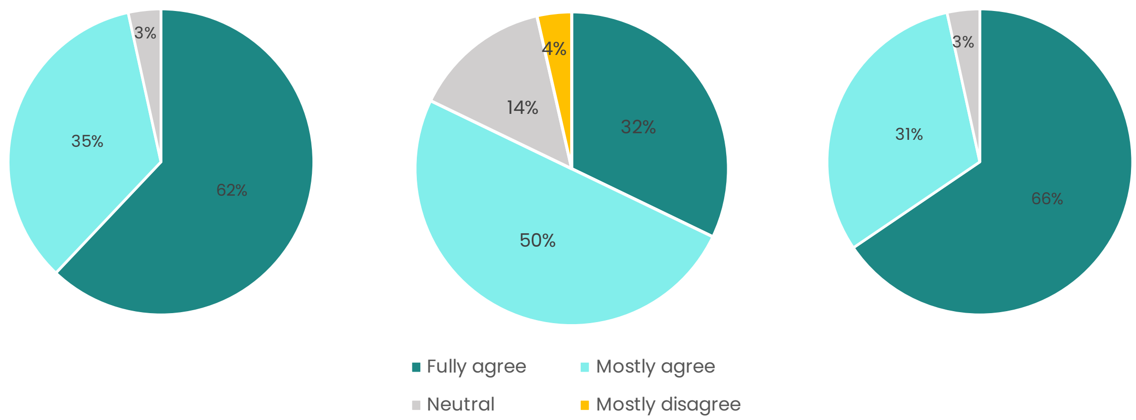

Figure 15 – Workshop Experience: Positive overall experience (left), engaging and informative group discussions and game activities (middle) and effective communication of the objectives (right)

Those who rated the communication of workshop objectives highly were more likely to also rate the workshop content positively, indicating a coherence between communicated goals and delivered content.

Game Experience

Participants exhibited a solid grasp of the game process, instructions, and user interface. Notable percentages affirmed clarity in game goals (86%) and ease of understanding in instructions (90%). The user interface was lauded as easy to use by 93% of participants. Additionally, the game's visual appeal was acknowledged by 97% of respondents, and 93% felt adept at orienting themselves on the game board map.

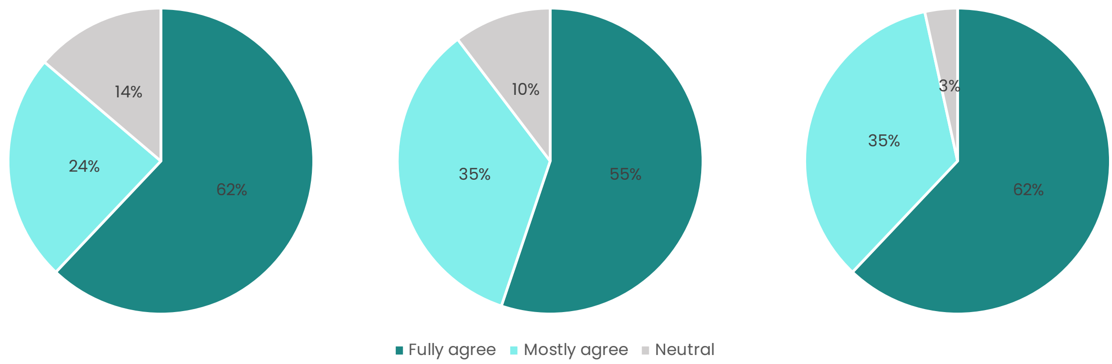

Figure 16 – Game Experience: Clarity of the game goals (left), Understanding the game instructions (middle) and the games visual appeal (right)

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While the game was deemed challenging by a significant portion (45%) of participants, some remained neutral (31%) or disagreed (24%), suggesting varied perceptions on its difficulty level.

Those who found the game goals clear were more likely to report a better understanding of wind energy concepts, suggesting a positive influence of clear objectives on educational outcomes. Moreover, there is a correlation between the perceived usability of the game interface and participants' ability to orient themselves on the game board map.

VR Experience

Participants displayed diverse levels of familiarity with video games and virtual reality (VR). Approximately 45% were not regular video game players, and a similar proportion had never used VR glasses before. Among VR users, leisure (38%) and educational/professional (17%) purposes were cited. This diversity suggests successful engagement across a broad audience, irrespective of technological background.

Participants with previous gaming or VR experience were more likely to find the 3D/VR environment interesting and useful, suggesting that familiarity with technology may influence engagement and perceived utility.

Learning Outcomes

The workshops notably augmented participants' comprehension of wind energy concepts. A majority (76%) agreed that the game contributed to a better understanding of wind energy initiatives, while 79% found group discussions engaging and informative. Moreover, 79% felt the game facilitated envisioning the future of wind energy in their communities.

The results suggest a synergistic relationship between interactive game elements and group dialogue in enhancing learning experiences.

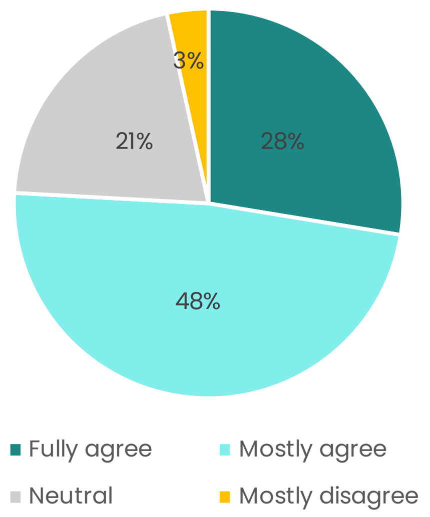

Figure 17 – Is the game helping to gain a better understanding of wind energy initiatives?

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Usefulness and Future Adaptations

The 3D/VR environment emerged as a valuable tool for discussing renewable energy, with 93% of participants endorsing its utility. Furthermore, 86% expressed interest in increased opportunities for participatory involvement in renewable energy initiatives within their communities, and a similar percentage indicated willingness to participate in similar workshops or events in the future.

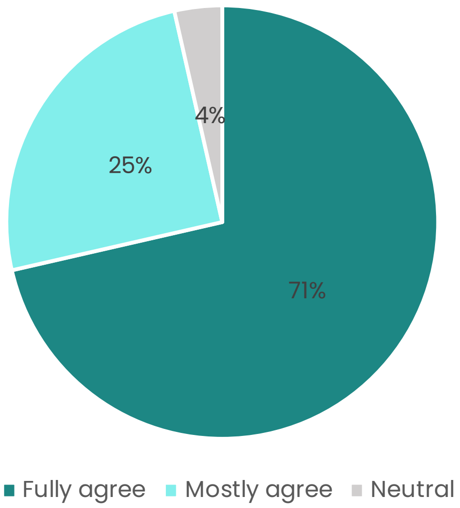

Figure 18 – Is 3D/VR useful for discussing renewable energy?

There is a positive correlation between participants' agreement on the usefulness of the game and their desire to see more opportunities for participatory involvement in renewable energy initiatives.

Efficiency and Impact on Attitudes

The workshops positively influenced participants' perceptions and attitudes towards renewable energy. Nearly half of the participants reported influence on their perceptions, with 21% noting partial influence. Moreover, 69% felt the workshop enhanced their understanding of wind energy concepts and potential impacts on their community, while 73% reported increased confidence in supporting wind energy initiatives.

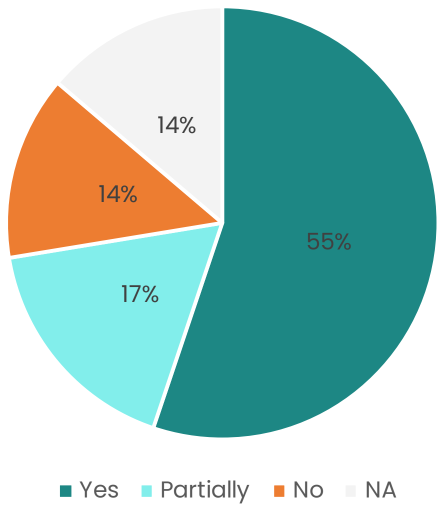

Figure 19 – Did the interactive workshop help improve participants understanding of wind energy concepts and potential impacts on their community?

The results indicate a positive association between workshop engagement and shifts in attitudes towards renewable energy.

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Suggestions and Feedback

Participants offered several suggestions for future adaptations of the platform, such as integrating photovoltaic technologies and providing training for community members to deliver the game. Positive feedback highlighted the informative nature of the game, its potential as an educational tool, and its strong engagement technology.

While the overall feedback was positive, some participants suggested improvements to the workshop duration and group size, noting issues in the trial run due to time limitations and large participant numbers. This is also consistent with the findings of participatory observation.

Some participants from the *CE4EU Islands* forum (group B and C) who had a broader knowledge base in terms of island regional development energy planning were also interested in a cost assessment for use on other islands and regions and noted the great potential for collaborative planning, decission making and communication.

Additionally, participants suggested adding more detailed data, such as information on the island's energy needs, economic benefits, wildlife impact, and detailed energy profiles. There were also recommendations for IT and quality improvements, including increasing VR resolution, enhancing map details, and providing more options within the 3D environment. As noted above, improvements will be made on the basis of the feedback. However, some aspects such as the resolution in the VR glasses are limited due to the current technical standards. With the Valve Index[14] headset, we are already using the best VR standard currently available in this respect.

Participants who provided constructive feedback were more likely to rate the workshop experience positively, indicating a link between engagement in the feedback process and overall satisfaction.

In summary, the workshops were well-received, with most participants expressing satisfaction with the content, delivery, and overall experience. The feedback and suggestions provided will be instrumental in refining and

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[14] https://www.valvesoftware.com/en/index (last visited on 18.06.2024)

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enhancing future workshops to better meet the needs and expectations of participants.

Evaluation Summary

Through the use of serious games, workshops effectively addressed knowledge gaps and cultivated positive attitudes towards wind energy, crucial for broader societal acceptance. The combination of positive feedback and insightful suggestions highlights the effectiveness of serious games in promoting social acceptance and enhancing educational experiences. Implementing these suggestions will enhance participant engagement and workshop efficacy. Additionally, the diverse technological backgrounds of attendees underscore the inclusive nature of the workshops, emphasising the importance of catering to varied demographics for broader social acceptance and stakeholder involvement. The feedback gathered will be instrumental in refining upcoming workshops to better engage stakeholders and further enhance social acceptance.

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4. CONCLUSIONS

This deliverable D5.3 is the central methodological and technical toolbox for conducting the pilot study workshops at the end of 2024 and beginning of 2025. Thanks to a very intensive exchange with the other work packages, a very comprehensive and flexible tool is currently available to carry out the workshop according to the work plan. An initial evaluation in *Pantelleria* has shown that the technology works very reliably, can be adapted to different situations and is very well received by the participants as part of the serious game. Until the upcoming workshops, the data from the other pilot studies will now be collected, integrated and processed in order to achieve a quality comparable to *Pantelleria*.

D5.3 is also closely linked to the General Forum (T6.3) and the Interactive Map (T5.3). On the one hand, qualitative contributions (from the workshops) and data content are provided, and on the other hand, data from the interactive map is also integrated directly into the game (e.g. wind potentials or the model for calculating noise)

The playful serious games approach and the technological implementation are very innovative and the initial results show great potential for collaborative planning and communication. This is possible above all through the integration of complex natural and social indicators and a new type of computer interface that emphasizes the group dynamic aspect. In addition, it can be shown that large regions can be rendered automatically in a very high and photorealistic quality if the appropriate geodata is available.

Initial searches have shown that the data availability for *Austria* and *Norway* appears to be suitable, but central data sets (relief and land use data) do not appear to be available in comparable quality for *Portugal*. However, this does not affect the realisation of the workshops. Differences are to be expected with regard to the level of detail and identification with the virtual space, which is a very exciting question from a research perspective and above all emphasises the need for high-quality and detailed data sets available throughout Europe if common goals are to be achieved.

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5. REFERENCES

Ampatzidou, C., Gugerell, K., Constantinescu, T., Devisch, O., Jauschnegg, M., & Berger, M. (2018). All Work and No Play? Facilitating Serious Games and Gamified Applications in Participatory Urban Planning and Governance. *Urban Planning, 3*(1), pp. 34-46. https://doi.org/10.17645/up.v3i1.1261.

Bittner, K. (2022). *Development of a Generic Toolkit for Creating Serious Games in Landscape Planning Based on GIS Data.* Master thesis. https://doi.org/10.13140/RG.2.2.27160.88329.

Delaney, J. (2022). Minecraft and Playful Public Participation in Urban Design. *Urban Planning, 7*(2), pp. 330-342. https://doi.org/10.17645/up.v7i2.5229.

Edler, D., Keil, J., & Dickmann, F. (2020). From Na Pali to Earth: An 'Unreal' Engine for Modern Geodata? In D. Edler, C. Jenal, & O. Kühne. Wiesbaden: Springer VS.

Edler, D., Keil, J., Wiedenlübbert, T., Sossna, M., Kühne, O., & Dickmann, F. (2019). Immersive VR Experience of Redeveloped Post-industrial Sites: The Example of "Zeche Holland" in Bochum-Wattenscheid. *KN-Journal of Cartography and Geographic Information, 69*(4), pp. 267–284. https://doi.org/10.1007/s42489-019-00030-2.

Gregory, J. (2009). *Game Engine Architecture (1st ed.).* A K Peters/CRC Press.

Herwig, A., & Paar, P. (2002). Game Engines: Tools for Landscape Visualization and Planning? In *Trends in GIS and Virtualization in Environmental Planning and Design* (pp. 162-171). Heidelberg: Wichmann.

Hevia-Koch, P., & Ladenburg, J. (2019). Where should wind energy be located? A review of preferences and visualisation approaches for wind turbine locations. *Energy Research & Social Science, 53*, pp. 23–33. https://doi.org/10.1016/j.erss.2019.02.010.

Keil, J., Edler, D., Schmitt, T., & Dickmann, F. (2021). Creating Immersive Virtual Environments Based on Open Geospatial Data and Game Engines. *KN - Journal of Cartography and Geographic Information, 71*(1), pp. 53–65. https://doi.org/10.1007/s42489-020-00069-6.

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Kwartler, M., & Longo, G. (2010). Visioning And Visualization: People, Pixels, and Plans. *Applied Spatial Analysis and Policy, 3*(1), pp. 67-68. http://doi.org/10.1007/s12061-009-9032-x.

Porlezza, C. (2019). From Participatory Culture to Participatory Fatigue: The Problem With the Public. *Social Media + Society, 5*(3), pp. 1-4. https://doi.org/10.1177/2056305119856684.

Schauppenlehner, T., Kugler, K., & Muhar, A. (2018). Anwendungserfahrungen von Virtual Reality als Kommunikationswerkzeug in partizipativen Planungsprozessen. *AGIT - Journal für Angewandte Geoinformatik, 4–2018*, pp. 15-24. https://doi.org/10.14627/537647003.

Sousa, M., Pais Antunes, A., Pinto, N., & Zagalo, N. (2022). Serious Games in Spatial Planning: Strengths, Limitations and Support Frameworks. *International Journal of Serious Games, 9*(2), pp. 115-133. http://dx.doi.org/10.17083/ijsg.v9i2.510.

Willenbacher, M., Lepiorz, R., & Wohlgemuth, V. (2017). Serious Games, Umweltbewusstsein und Nachhaltigkeit. *47. Jahrestagung der Gesellschaft für Informatik e.V. (GI) vom 25.-29.9.2017*, (p. http://dx.doi.org/10.18420/in2017_202). Chemnitz.

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6. ANNEX

The following supplemental documents are attached in PDF format:

A1: Workshop introduction text

A2: Baseline questionnaire

A3: Debrief questionnaire

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