Configuration of prototypes

Integration of models and metrics in a holistic model

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List of Acronyms

Acronym	Description
API	Application Programming Interface
CIA	Cumulative Impact Assessment
CINEA	European Climate, Infrastructure and Environment Executive Agency
DEP	Danish Environmental Portal / Danmarks Miljøportal
EA	Environmental Assessment
EMODnet	European Marine Observation and Data Network
EU	European Union
FAIR	Findable, Accessible, Interoperable and Reusable
GA	Grant Agreement
GDPR	General Data Protection Regulation
GIS	Geographic Information System
HIA	Health Impact Assessment
INSPIRE	Infrastructure for Spatial Information in the European Community
LCA	Life Cycle Assessment
LCoE	Levelized Cost of Energy
MSFD	Marine Spatial Planning Framework Directive
MVP	Minimum Viable Product
OGC	Open Geospatial Consortium
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
OW	Offshore Wind
OWF	Offshore Wind Farm
QA	Quality assurance
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
S-LCA	Social Life Cycle Assessment
SO	Specific Objective
TRL	Technology Readiness Level
UX	User Experience
WFS	Web Feature Service
WMS	Web Map Service

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Keywords list

- Environmental sciences
- Environmental Impact Assessment (EIA)
- Strategic Environmental Assessment (SEA)
- Life Cycle Assessment (LCA)
- Cumulative Impact Assessment (CIA)
- Sustainability metrics
- Marine data space
- Open data

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Executive Summary

Purpose of D6.2

This deliverable defines the proposed configuration of the SUSTAINOW site identification and design tool prototypes and the information flows required to connect them to project data, models, metrics and sustainability measures. As D6.2 is delivered at Month 12, before the later integration and prototype deliverables, it establishes the architecture, decision-support logic, interfaces and requirements for subsequent development rather than presenting finished tools.

Throughout the report, a distinction is made between project commitments established in the Grant Agreement (GA), the prototype configuration proposed in D6.2, and implementation decisions that remain to be agreed during subsequent development.

Two complementary decision-support tools

SUSTAINOW develops two connected prototypes. The *site identification tool* primarily addresses *where* offshore wind development could be considered. It supports exploration of spatial conditions, constraints and selected sustainability considerations. The *design tool* primarily addresses *how* an offshore wind project could be designed, constructed, operated and decommissioned more sustainably, including through mitigation and enhancement measures.

The two tools are connected but support different decisions. Selected design measures may inform the siting tool where their spatial relevance and expected effects can be represented with adequate evidence.

The data foundation and holistic model

The WP2 data space provides the main data foundation, while WP3-WP6 contribute outputs on cumulative and transboundary effects, socioeconomic effects, and life-cycle and broader sustainability effects. WP6 brings relevant outputs together through the holistic model.

The holistic model is conceived as an integration framework rather than a single sustainability model or score. It connects different forms of evidence while preserving differences in meaning, scale, units, assumptions and uncertainty. The model organises information through a common effect pathway linking OWF elements, pressures, receptors, effects, metrics and mitigation or enhancement measures.

Prototype configuration

The proposed configuration establishes two distinct but connected decision-support functions. The site identification prototype is configured as a bounded, evidence-based interactive spatial tool rather than an optimisation tool identifying one objectively "best"

location. Its broader concept distinguishes between constraints-informed, mitigation-oriented and enhancement-oriented siting.

The design tool is configured primarily as a standalone plan and project-level decision-support tool. Its information foundation is the structured measures knowledge base developed through T6.3 with mitigation and enhancement measures. Building on this foundation, the prototype supports users in defining a design challenge, identifying relevant alternatives and comparing them across common decision-relevant attributes. Where compatible models, metrics or scenario results are available, these are incorporated into the comparison; where quantitative comparison is not methodologically justified, the tool provides structured evidence-based guidance. The purpose is therefore not simply to retrieve information, but to make alternatives, consequences, trade-offs and uncertainties more transparent for design decisions.

Open implementation decisions and next steps

The overall prototype functional architecture and decision-support logic are established in D6.2.

The next development phase will define the bounded implementation of this architecture through a limited set of agreed use cases and demonstrable interfaces. This involves defining the WP3-5 outputs to be included in the prototypes, the technical interfaces with the WP2 data space, the analytical functions that can be demonstrated with available evidence, and the subset of measures whose spatial effects can inform the siting prototype.

These decisions will be refined through partner coordination, development of the contributing methods and data, and stakeholder testing. The SUSTAINOW prototypes will demonstrate selected workflows at TRL5 through testing in real life cases of OWF planning in the North Sea by consortium partners and other key OWF stakeholders they engage with at the time of testing. A fully operational and maintained decision-support system remains a longer-term vision beyond the project.

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1. Introduction

D6.2 sets out the proposed configuration of the open-access site identification tool (also referred to as the siting tool) and the design tool prototype. It identifies the decisions each tool should support, their principal components and interfaces, and the inputs and outputs needed from the contributing work packages. It also defines requirements for WP3–WP5 that will allow their models and metrics to be brought together in the holistic model developed under T6.2.

At M12, D6.2 is a configuration report rather than a presentation of finished tools. It distinguishes between commitments established in the Grant Agreement (GA), the proposed prototype configuration, and implementation choices that remain to be agreed as methods, data and technical solutions develop.

In SUSTAINOW, a holistic approach means considering sustainability implications together and early in the planning and design process, rather than addressing them separately or only at successive stages of offshore wind development. This includes considering onshore and offshore implications, environmental and socioeconomic dimensions, cumulative and transboundary effects, and implications across the offshore wind farm life cycle. The holistic model supports this approach by organising information through a common effect pathway structure linking OWF elements, pressures, receptors, effects, metrics and mitigation and enhancement measures. The structure is intended as an integrative framework and accommodates discipline-specific terminology, including effect-category approaches used in LCA and S-LCA.

Through this structure of the model, data, assessment outputs and sustainability metrics can be related while maintaining their original meaning and context. Its purpose is to make different implications and trade-offs accessible together, without requiring all information to be converted into GIS layers or reduced to a single sustainability score. For the project prototypes, this broad perspective is translated into a bounded set of workflows and use cases with clearly stated coverage.

The configuration presented in this deliverable contributes to SO2 by establishing the framework for integrating relevant data sources and assessment outputs from WP2-WP5 (R2.3) and providing a basis for holistic assessment metrics (R2.4). The holistic model furthermore provides a central input to both the site identification tool (SO3) and the design tool (SO4).

The report distinguishes between the scope of a prototype, representations used to explore its interface, and its subsequent technical implementation, using different terms. A mock-up means a screen sketch or clickable interface used to test whether users understand a proposed workflow; it may use placeholder results. A minimum viable product (*MVP)* defines the smallest set of users, decisions, functions and real data needed to demonstrate a useful end-to-end workflow. A *prototype* is the functioning implementation of that bounded scope, using real inputs to produce results that can be tested. A *deployed IT solution* would add the coverage, governance, maintenance, support and reliability required for routine operational

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use. These terms describe different purposes and levels of implementation and are not interchangeable with Technology Readiness Levels. D6.2 focuses on the configuration of the prototype level, while distinguishing this from both exploratory mock-ups and a future operational solution.

D6.2 specifies the intended workflows and requirements for the SUSTAINOW prototypes. A fully deployed and maintained system remains a longer-term vision beyond the project.

The relationship between the work packages and the subsequent deliverables is as follows:

- WP2 develops the data space that will provide access to relevant environmental and socioeconomic data and past environmental assessment reports. Its configuration is addressed in D2.2; D6.2 identifies the data needs and access requirements of the siting tool and design tool.

- WP3, WP4 and WP5 develop methods and outputs concerning cumulative and transboundary effects, socioeconomic effects, and large-scale life-cycle and social sustainability effects, respectively. Their outputs differ in form and may be spatial, scenario-based, quantitative or qualitative. D6.2 specifies what WP6 needs from each work package and identifies requirements that still need to be agreed.

- WP6/T6.2 brings relevant models and metrics together in the holistic model to support consideration of different sustainability effects and trade-offs. The model itself is delivered later as D6.3.

- WP6/T6.3 develops the measures knowledge data, providing a common knowledge base of measures to mitigate negative effects and enhance positive effects across the OWF life cycle. The database is delivered as D6.4 and provides a central input to the design tool.

- WP6/T6.4 develops the site identification and design tool prototypes. The siting tool uses relevant spatial data and model outputs to support the exploration of potential development areas. The design tool uses relevant outputs from the holistic model and the measures knowledge base to support plan and project-level design decisions by identifying relevant alternatives, structuring comparison between them and, where suitable models and metrics are available, examining their implications. The comparison retains information on evidence, assumptions, uncertainty and trade-offs rather than reducing alternatives to a single sustainability score. The prototypes are delivered as D6.5.

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The purpose of this report is therefore to define a feasible configuration and the requirements that provide a basis for coordination and implementation across these work packages. Where data availability, model maturity, formats or implementation choices have not yet been agreed with the responsible partners, D6.2 identifies them as matters to resolve rather than presenting them as established capabilities.

Chapter 2 outlines the prototype concepts, their connections and the distinction between the project prototypes and the longer-term vision. Chapter 3 sets out the common requirements for input and integration, including the WP2 data-space interface. Chapters 4 describes the holistic model as the integration framework connecting the project's data, assessment outputs, metrics and measures. Chapter 5 and 6 specify the configuration, inputs and functions of the site identification and design tool prototypes, respectively. Chapter 7 brings together the main conclusions, priorities for subsequent development and next steps.

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1.1. Traceability between the Grant Agreement and D6.2

Table 1 shows how the Grant Agreement commitments most directly related to the holistic model and the two decision-support tools are addressed in D6.2. The table presents a short description of the project commitment and identifies where it is addressed in the report. Other relevant results, including a method for cumulative and transboundary effects (R2.1), a method for assessing large-scale effects (R2.2), and a method for fostering socio-economic benefits through stakeholder engagement (R4.2), are developed through separate tasks and may contribute inputs to the holistic model and prototypes where appropriate.

Table 1. Relation between grant agreement commitment, role of commitment, and where it is addressed in D6.2.

Grant Agreement commitments	Short description of commitment	Where addressed
SO1/R1.3/KER1. Cross-border OWF data space	Data foundation for planning and design	Separate deliverable (D2.2), but relations to tools mentioned in sections 2.1, 2.3 and Chapter 3
SO2/R2.3. Holistic model for understanding OWF effects	Integration framework connecting effects, metrics and sustainability measures	Core focus of D6.2; Chapter 4, supported by Sections 2.1, 2.3 and Chapter 3
R2.4 (KER3). Holistic assessment metrics	Common metric structure supporting planning and design decisions	Chapter 4, the integration requirements in Chapter 3; operationalised through the WP contributions described in Chapters 5 and 6
SO3/R3.2. Open-access site identification tool	Prototype supporting evidence-based site identification	Section 2.4; Chapter 5
R3.1. Configuration of site identification prototype	Definition of users, workflows, interfaces and required inputs for the site identification prototype	Chapter 5, supported by Chapter 3
SO4/R4.3/KER6. Open-access sustainable design tool	Prototype supporting plan and project-level sustainable OWF design decisions through identification and comparison of design options, mitigation and enhancement measures	Section 2.5; Chapter 6

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2. Configuration of the prototypes

This chapter sets out the proposed configuration of the siting tool and design tool prototypes developed in the SUSTAINOW project. It translates the project commitments into a functional architecture by defining the decisions each tool is intended to support, their data foundation, principal outputs and connections. It also distinguishes the scope of the project prototype from the broader longer-term vision. Specific implementation choices that depend on later work-package outputs, selected use cases or technical development are identified as open issues in the relevant sections. The subsequent chapters develop the input requirements and configurations of the individual components.

The terminology used for assessing effects differs across EIA, SEA, MSFD, LCA, SIA and HIA. Working across these disciplines and anchoring the terminology in established EU guidance requires alignment. Table 2 provides the working terminology in this deliverable.

Table 2. Working terminology used in D6.2.

Project Term	Definition	Examples
Activity	A human activity in any sector or geography	Construction activities, tourism activities, fisheries, mining, etc.
Offshore wind element	A technical component, activity or design choice associated with offshore wind development.	Rotor blades, wind turbine tower, piling, maintenance, operation, dredging, inspections, electricity grid, etc.
Pressure	Mechanism through which the activity interacts with the environment	Changes the noise field compared to pre-existing the activity, turbine visibility, sediment plume, change in water velocities, vibrations, electromagnetic fields, etc.
Receptor	Environmental or societal entity exposed to the pressure	Harbour porpoise, seabirds, benthic species/habitats, water column species/habitats, ell grass, physical parameters (e.g., water salinity and turbidity)
Effect	Receptor response	Mortality, change in population, scour, change in behaviour, displacement, change of habitat, reduced population viability, reduced conservation status, cumulative ecosystem effects, increased biodiversity
Metric	Quantitative measure used to describe an environmental pressure, effect, receptor or effect	Noise level (dB), area lost (km^2), water velocities (m/s), number of new jobs, number of species, number of adults of a species, electromagnetic field intensity (V/m)
Mitigation/ Enhancement	Measures envisaged to avoid, minimise, repair or offset adverse effects	Bubble curtains, curtailment during migration season, reduced speed of service boats, avoidance, establishment of new habitat etc.

In line with the terminology used in the EU EIA and SEA Directives, SUSTAINOW adopts effect as the common term for changes resulting from a plan or project. Within the holistic model, pressure describes the mechanism through which an activity interacts with the environment (e.g. underwater

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noise), while effect describes the resulting change for a receptor (e.g. behavioural disturbance of harbour porpoises). The term impact, used in several assessment traditions, is considered closely related to effect but is not treated as a separate element of the model.

Each element of the model can be described through relevant attributes. For effects, these may include likelihood, magnitude, spatial extent, duration, frequency, reversibility, and cumulative or transboundary character. Significance is considered an assessed attribute, reflecting both the characteristics of the effect and the sensitivity and value of the affected receptor in the relevant assessment context. These attributes, supported by appropriate metrics and evidence, provide a common framework while accommodating differences between assessment traditions.

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2.1. Overview of the tools and their connections

SUSTAINOW develops two connected decision-support prototypes that address different but related decisions. The **site identification tool** supports exploration of where offshore wind development may merit further investigation under specified spatial conditions, criteria and assumptions. The **design tool** supports plan and project-level decisions about how an offshore wind project can be designed and implemented more sustainably, including through relevant mitigation and enhancement measures. Both prototypes draw on data and assessment results produced or identified in the SUSTAINOW project, but the site identification tool focuses primarily on areas and spatial conditions, whereas the design tool focuses primarily on project, technology choices, and implementation choices. Spatial conditions include environmental, technical and socio-economic aspects where these can meaningfully be represented geographically. Other socio-economic findings may be included as non-spatial evidence.

The WP2 data space provides the principal data foundation by making relevant datasets, metadata and past environmental-assessment reports discoverable and accessible. WP3, WP4 and WP5 contribute methods and outputs concerning cumulative, socioeconomic and large-scale sustainability effects. Under T6.2, WP6 provides the common integration framework through which relevant data, assessment outputs, effects and metrics are related and can be brought together in the holistic model and made available to the two decision-support prototypes. WP6 is also responsible for extracting, interpreting, structuring and quality-checking records of mitigation and enhancement measures derived from past environmental-assessment reports. The relations are illustrated in Figure 1.

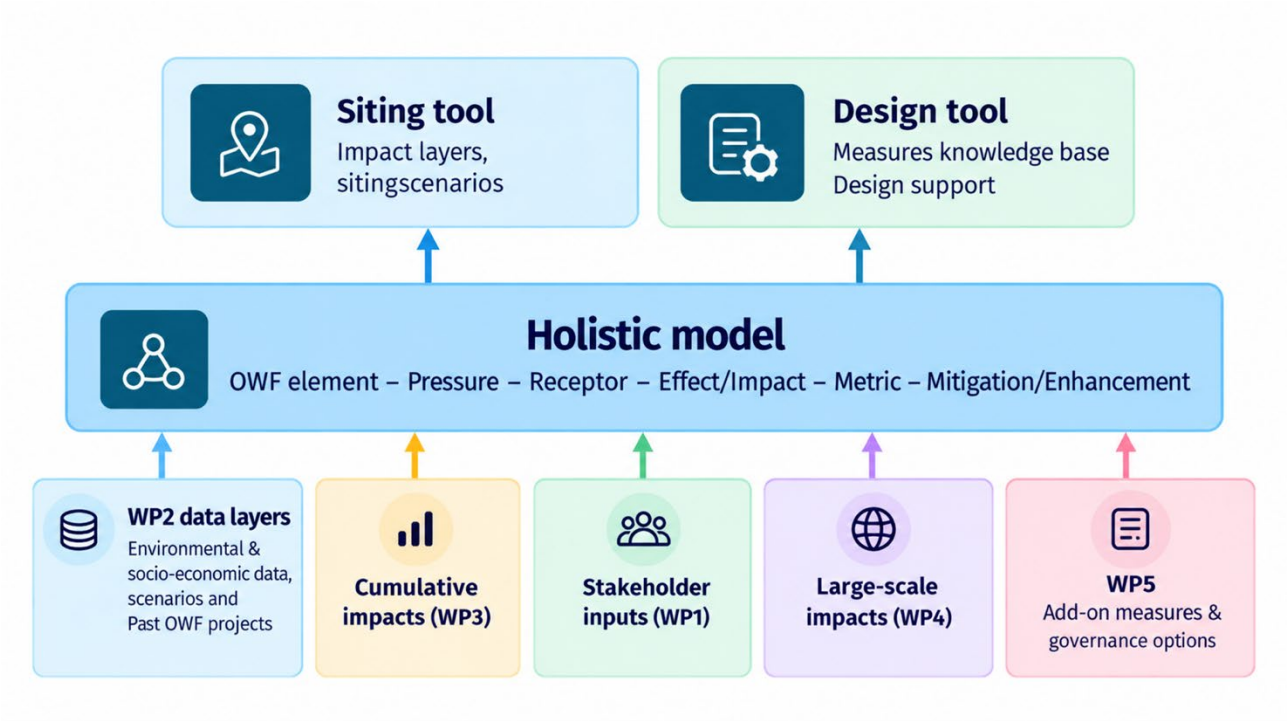

Figure 1 Proposed functional architecture and information flow for the SUSTAINOW prototypes.

The common measures knowledge base developed under T6.3 provides structured information on options to mitigate negative effects and enhance positive effects, principally for the design tool. Selected measures with an evidence-supported spatial effect may also inform selected siting scenarios.

The tools are therefore connected through the holistic model without requiring all design information to be spatially represented or the design tool to depend on use of the siting tool.

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2.2. Key innovations introduced through the prototype architecture

The innovations of SUSTAINOW primarily lie in the way existing data, assessment approaches, sustainability metrics and knowledge are brought together to support offshore wind planning and design decisions. Rather than replacing existing planning tools or assessment methods, the project aims to demonstrate new ways of integrating and applying them in decision-support workflows. The proposed prototype architecture introduces the following innovations.

Dynamic site identification

Many existing siting approaches focus primarily on identifying constraints, barriers and no-go areas. SUSTAINOW introduces the concept of dynamic site identification, where suitability is not treated as fixed but can be explored through changes in project specifications and evidence-supported sustainability measures. Rather than identifying a single optimal location, the prototype supports exploration of how different choices may change the areas that merit further investigation.

Mitigation-oriented and enhancement-oriented siting

The proposed siting concept extends beyond traditional constraint-based approaches. Users can explore how mitigation measures may reduce specific effects and how enhancement measures may create positive environmental or socio-economic outcomes. The purpose is not to override regulatory constraints, but to examine how project design and sustainability measures may alter the conditions and effects associated with potential development areas. This introduces a more proactive understanding of spatial planning by examining not only where effects occur, but also where design interventions could make locations more viable or beneficial.

Integration of site identification and project design

Traditionally, site selection and project design are treated as separate processes supported by separate tools. SUSTAINOW introduces an explicit connection between these decisions. Selected design parameters and mitigation or enhancement measures represented through the design tool can inform site-identification scenarios where sufficient evidence exists to represent their expected effects spatially. This enables users to explore the relationship between decisions about *where* offshore wind is considered and *how* a plan or a project might be designed, without assuming that every design choice has a spatial effect or that changes are transferred automatically between the tools.

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A holistic integration framework across assessment traditions

Offshore wind planning relies on a range of established assessment traditions, including EIA, SEA, CIA, SIA and LCA. The SUSTAINOW holistic model provides a common effect pathway structure through which these different forms of evidence can be related while preserving their methodological differences. The model links OWF elements, pressure, receptors, effects, metrics and mitigation or enhancement measures and thereby creates a common decision-support framework rather than a single integrated sustainability score. This allows site-specific, cumulative, transboundary and large-scale sustainability perspectives to be considered together.

An evidence-based knowledge base for sustainable design decisions

A structured and searchable knowledge base of mitigation and enhancement measures provides an evidence foundation for the design tool. Measures are documented consistently in terms of applicability, relevance in OWF life-cycles, expected effects, supporting evidence, uncertainty, implementation implications, potential benefits and trade-offs. The design-card concept provides a consistent user-facing representation of this evidence. The innovation lies not only in making measures searchable, but in using this structured evidence to identify decision-relevant alternatives, support comparison between them and, where compatible models and metrics are available, connect design choices to analytical or quantitative assessment results.

Supporting exploration rather than providing prescriptive answers

A final innovation concerns the overall philosophy of the prototypes. The prototypes are not intended to produce a single assessment result, ranking or prescriptive recommendation. Instead, they are intended to help users in identifying and comparing alternatives, examining consequences and trade-offs, and assessing the implications of different choices. The emphasis is therefore on supporting more informed and transparent decision support, rather than replacing expert judgement.

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2.3. Data foundation

WP2 is developing a data space targeted at offshore wind in the North Sea. The value and configuration are described in D2.2; this section focuses on its relationship to the siting and design tool prototypes. The data space is intended to support strategic planning and project development by providing access to relevant environmental, socioeconomic and technical information. Authorities, OWF developers and consultancies are considered priority user groups.

The data space is designed to improve the discoverability and accessibility of relevant information. However, access through the data space or through associated tool interfaces does not imply unrestricted redistribution of all underlying datasets. Access, download and API functions will remain subject to the licensing terms, access rights and other conditions defined by the original data providers.

The data foundation includes selected datasets from European and national sources, including EMODnet. The suitability of individual datasets will depend on the selected use case and factors such as geographic and temporal coverage, spatial resolution, collection method, quality, uncertainty, and licensing conditions.

The data space prototype focuses on common standards, data quality, interoperability, and governance principles, while also considering the governance, ownership and maintenance arrangements required for longer-term use. The data space is expected to give the prototypes access to data through standard interfaces, such as APIs and OGC web services (WMS/WFS), with metadata following established standards. The detailed configuration of the data space is described in D2.2. Particular attention will be given to ensuring that available quality information and known limitations accompany datasets used by the siting and design prototypes. Transparency regarding dataset provenance, version and retrieval dates will enable prototype results to be verified and differences between assessments to be more readily explained.

Other inputs, including assessment outputs from WP3-WP5 and sustainability measures developed through WP6, are connected through the holistic model and are addressed separately in the following chapters.

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2.4. Site identification tool: intended decisions and outputs

The site identification prototype is intended to help planners and other offshore wind stakeholders explore potential development areas in the North Sea. It should bring spatial information together and show how the interpretation of an area changes when different criteria, assumptions or project characteristics are considered. The purpose of the tool is not to maximise or optimise the capacity of OWF in a given area, but to allow the user of the tool to understand implications of design choices in a spatial and site-specific context based on a GIS interface.

The central proposition of the dynamic siting tool is that changing *how* offshore wind is developed can change *where* it could potentially be developed. Rather than treating site suitability as fixed, the tool explores how mitigation measures and changes in project design could expand the range of areas potentially available for offshore wind compared with an initial constraints-informed assessment, while enhancement measures may add positive environmental or socio-economic outcomes to otherwise relevant development areas.

The proposed concept distinguishes three complementary forms of exploration:

1. **Constraints-informed siting** considers existing environmental, technical, regulatory and socioeconomic conditions relevant to potential development.

2. **Mitigation-oriented siting** introduces selected measures to explore whether and how an identified effect or conflict could change through adjustments to project design or implementation.

3. **Enhancement-oriented siting** additionally considers opportunities for positive environmental or socioeconomic outcomes where the relevance and expected effects of enhancement measures can be supported.

These three levels of exploration describe the broader concept. Within SUSTAINOW, the prototype will demonstrate a limited set of parameters, measures and interactions using real inputs. The specific scope will depend on the selected use cases and the information available from the contributing work packages.

A user would select an area of interest and examine environmental, technical and socioeconomic information relevant to offshore wind development. The tool will show applicable constraints alongside selected parameters derived from the data space and the work of WP3–WP5. Where the underlying evidence supports it, the user is then supported in comparing scenarios—for example, how a change in project design or a specified mitigation measure affects an assessed effect and thus the feasibility of the site. The resulting maps and associated information should identify their sources, coverage, assumptions and limitations.

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The siting prototype will draw on WP3's methodological guidance to identify where cumulative effects and transboundary implications may be relevant. Where these cannot be represented using available data and models, they will be identified as limitations requiring further assessment rather than treated as resolved within the siting scenarios.

Two illustrative examples show how these interactions could work. Relevant mitigation and enhancement options would be informed by the design tool and its measures knowledge base.

Example 1: Exploring changes in turbine height

A user could adjust the turbine height of a proposed project and examine how the mapped results change. Where supported by appropriate data and models, the interface could display updated estimates of visual effects or bird collision risk alongside changes in electricity production, allowing the user to compare alternative configurations. The map could also show whether the revised configuration makes additional locations potentially suitable or changes the extent of an area under consideration. This illustrates how the tool could move beyond displaying existing constraints to exploring how design choices influence spatial opportunities for offshore wind development.

Example 2: Expanding potential areas through mitigation and enhancement

Figure 2 illustrates a hypothetical offshore wind development near nature protection sites, where piling noise and the sensitivity of nearby habitats and species influence the potential development area. The three panels illustrate how mitigation and enhancement could progressively broaden the area considered potentially suitable, subject to the evidence and conditions associated with each scenario. The example is illustrative; the specific parameters demonstrated in the prototype will depend on available evidence and models.

Level 1 - constraints-informed siting (Figure 2, top).

The initial assessment considers the proposed development in relation to existing environmental, technical and other relevant constraints. Noise modelling estimates the footprint of piling operations and identifies where exposure may give rise to adverse effects on sensitive receptors. For the initial project configuration, these considerations limit the area identified as potentially suitable for development.

Level 2 – mitigation-oriented siting (Figure 2, centre).

The user introduces a noise-reduction measure, such as a bubble curtain, identified through the design tool. In the illustrated scenario, effective mitigation allows an expanded development area to be considered compared to Level 1. The revised layout is assessed with the measure in place, so that the additional spatial opportunity is linked to the expected effectiveness of mitigation under that configuration. The map would identify the additional area as potentially suitable conditional on the specified mitigation measures, rather than simply removing the original constraint.

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Level 3 – enhancement and co-design-oriented siting (Figure 2, bottom).

Building on the mitigation scenario, the user explores whether enhancement measures could open further spatial opportunities. Through dialogue with relevant authorities and stakeholders, areas may be identified where an appropriately designed offshore wind project could contribute to positive environmental or socioeconomic outcomes. For example, nature-inclusive design or artificial reef structures (example of enhancement measure) could be considered where their ecological suitability and potential benefits are supported by evidence. Their assessment should compare the value of created habitats with that of natural habitats affected, taking account of the ecological context. Habitat creation alone does not demonstrate that adverse effects have been adequately addressed.

In the hypothetical scenario, combining effective mitigation with locally relevant enhancement enables further areas to be considered that were not identified as potentially suitable at Level 1. The development boundary therefore expands further in the illustration, with the additional area identified as potentially suitable conditional on the specified mitigation and enhancement measures. The comparison between scenarios should show the residual adverse effect after mitigation, and any trade-offs or displacement of effects. A useful outcome may also be that an area remains unsuitable or requires further investigation, rather than that the development area expands.

The three levels illustrate a possibility to be assessed, not a guaranteed progression towards increasingly large development areas. Mitigation may be insufficient, or enhancement may be inappropriate or unsupported in a particular location. Additional areas identified by the tool are therefore candidates for further consideration, not approved development areas. In particular, mitigation and enhancement measures do not, by themselves, establish the legal permissibility of development within nearby protected nature sites. Applicable protected-area requirements and other regulatory constraints require their own assessment.

The prototype can help users examine assumptions and potential effects, while making clear which conclusions remain subject to site-specific assessment and decisions by the competent authorities.

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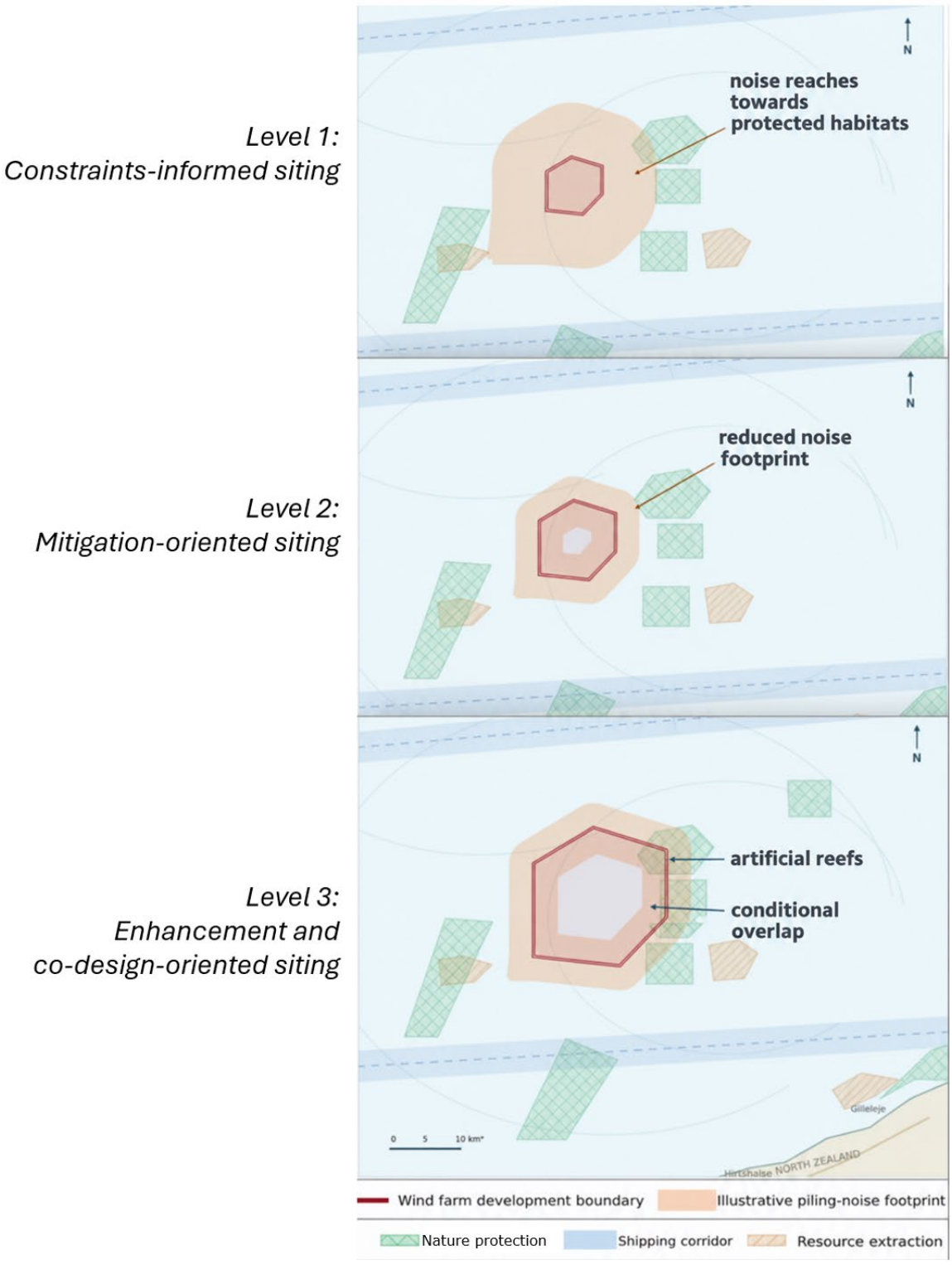

Figure 2. Illustrative siting scenarios considering constraints, mitigation and enhancement. The illustrated developed boundaries are hypothetical and do not imply regulatory suitability or approval.

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Users and value

For authorities and planners, the siting tool is intended to provide a more nuanced understanding of where offshore wind development could be considered and under which conditions. This includes exploring how project characteristics and mitigation and enhancement measures could expand the range of potentially suitable areas compared with an initial constraints-informed assessment.

For developers and their advisers, the tool could reveal additional spatial opportunities and support exploration of the design choices and measures needed to make these opportunities relevant to a particular project. The value lies not only in identifying potential locations, but also in understanding the conditions, effects and measures associated with them.

Access is envisaged through an open public interface, with the possibility of making relevant data and outputs available through application programming interfaces (APIs) or downloads for use in users' own siting tools. The specific access and reuse arrangements will depend on the agreed technical configuration.

Exploring user priorities

A further possible interaction is to allow users to adjust the relative importance of selected assessment criteria and examine how the displayed results change. Candidate criteria identified in the current concept include water depth, distance from shore and proximity to grid or port infrastructure, alongside relevant environmental and socioeconomic parameters. This functionality could be used within one or more of the siting scenarios described above; it is not a separate fourth scenario.

The purpose of weighting would be to explore how different priorities influence the relative performance against selected criteria of potential development areas. Changing weight would not change the underlying data or override legal constraints. The interface should therefore distinguish between changes in the comparison of plan or project scenarios resulting from user priorities and changes in assessed effect resulting from a different project configuration or the application of mitigation and enhancement measures.

Existing Danish Environmental Portal tools provide an example of this kind of weighted map exploration, as illustrated in Figure 3. Whether this functionality forms part of the SUSTAINOW prototype, and which criteria can be compared meaningfully, must be agreed with WP2 and the partners providing data about parameters. The figure provides an illustration of weighted map exploration rather than a commitment to a particular software platform.

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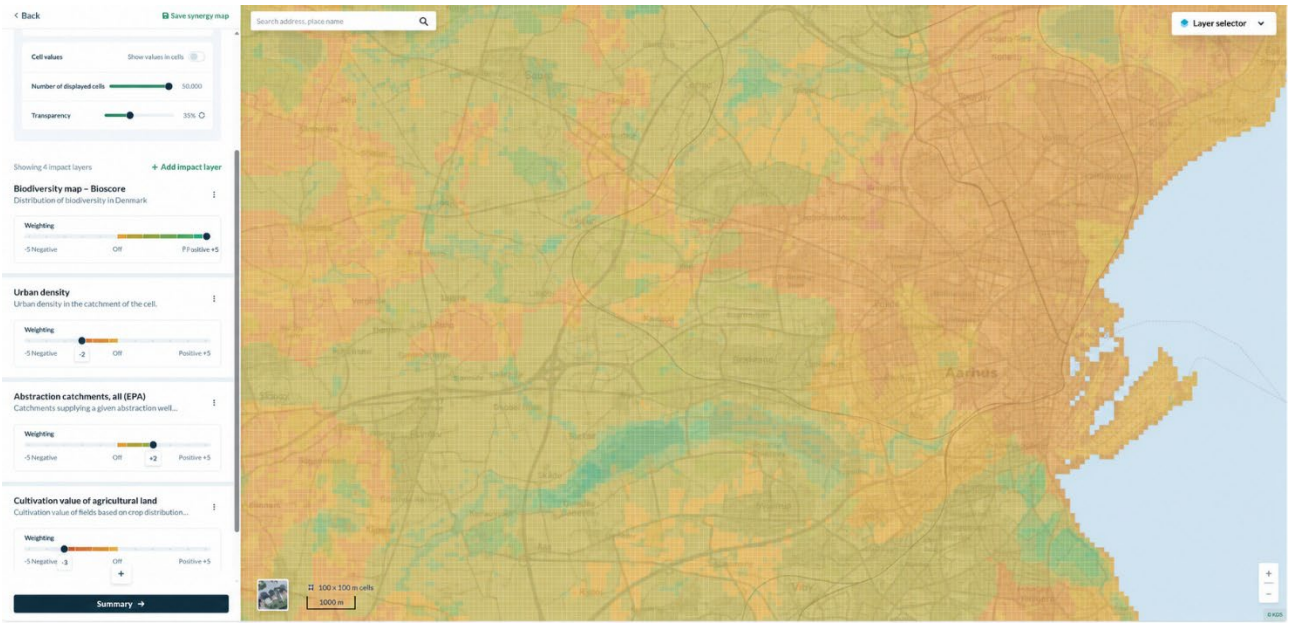

Figure 3. Example of an interface for weighted map exploration.

2.5. Design tool: intended decisions and outputs

The design tool prototype, developed under T6.4, addresses the question: how can an offshore wind farm be designed, constructed, operated and decommissioned more sustainably? It supports exploration and comparison of design alternatives and sustainability measures that may mitigate negative effects, enhance positive outcomes or otherwise improve sustainability performance. Its primary use is as a standalone plan and project-level decision-support tool, with selected measures also informing the siting tool where their spatial relevance and expected effects can be represented.

The report distinguishes between mitigation and enhancement measures:

> Mitigation measures address adverse effects following the mitigation hierarchy: avoid, minimise, repair and, where appropriate, offset for residual effects.
>
> Enhancement measures seek to generate or strengthen positive environmental, social or socio-economic outcomes beyond the baseline and beyond the reduction of project-related adverse effects.

A central input is the common measures knowledge base of sustainability measures developed under T6.3 and delivered as D6.4. It will bring together measures identified in past environmental assessment reports for OWF plans and projects, made accessible through WP2 and extracted and analysed by WP6, together with measures and supporting evidence generated and identified across WP3-WP6. These contributions include screened offshore wind solutions, life-cycle circularity evidence, citizen-inspired ideas and relevant knowledge concerning cumulative and transboundary effects. The detailed contributions are addressed in Chapter 6.

The measures knowledge base and the design tool serve different functions. The knowledge base stores and structures evidence about mitigation and enhancement measures, while the design tool uses this evidence to support a user in identifying relevant alternatives, comparing them and understanding their implications.

The prototype is expected to demonstrate three related decision-support functions:

1. **Identifying relevant options:** the user describes a design problem, or sustainability challenge (e.g. underwater noise affecting marine mammals) and is guided towards relevant design alternatives and measures.
2. **Comparing design choices:** the tool helps users compare selected options using common decision-relevant attributes, such as expected effects, applicability, uncertainty in the evidence, economic or implementation implications where available, and potential co-benefits and trade-offs. This function is based on existing knowledge.
3. **Connecting options to assessment:** where compatible models, metrics or scenario results are available, the tool can display analytical or quantitative results for the

alternatives. Where such comparison is not methodologically justified, it provides structured evidence-based guidance or links to relevant assessment methods.

Design cards provide a consistent user-facing representation of individual measures, including their purpose, applicability, expected effects, supporting evidence, uncertainties and potential trade-offs. They provide the evidence foundation for decision support but do not constitute the decision-support function on their own.

Users should be able to search and filter measures by technical system, OWF life-cycle phase (as identified in the Decision in OWF Report: site identification, tender, project design, construction, operation, repowering, decommissioning), effect or sustainability factor, and position in the mitigation-enhancement hierarchy.

The prototype will be developed as a generic concept and demonstrated to TRL5 through real-life cases of OWF planning in the North Sea by consortium partners and other key OWF stakeholders they engage with at the time of testing. Transferability to other sea basins is explored and the future uptake and development of the tool in other sea basins are guided through a set of recommendations for governance, tool transfer and development, and future maintenance. The prototype will be developed as a generic design and completed to TRL5 for the North Sea.

A possible future extension is an AI-supported dialogue interface that helps users describe a design challenge and navigate relevant measures and design cards. This is not part of the agreed prototype scope.

The project target is to integrate 50 design options into the design tool. The relationship between database records, cards and selectable design options will be specified through T6.3–T6.4.

Relevant assessment outputs from WP3-WP5 may support comparison of design alternatives where their methods, metrics and system boundaries allow meaningful comparison. The specific analytical functions to be demonstrated in the prototype are described further in Chapter 6.

Some measures may have spatial implications and could inform a scenario in the site identification tool. This connection requires information about where a measure applies and evidence of its expected effect; selecting a measure in the design tool would not, by itself, establish that an area is suitable or that an effect has been adequately mitigated.

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3. Requirements for inputs and integration

This chapter translates the prototype concepts in Chapter 2 into requirements for information supplied by WP2–WP5 and developed within WP6. It identifies what each output must describe for WP6 to use it, which prototype may use it, and what remains to be agreed with the producing work package. The requirements concern the meaning and usability of the outputs as well as their technical exchange.

3.1. Scope and status of requirements

Under T6.2, WP6 is responsible for defining requirements that allow cumulative, socioeconomic and large-scale sustainability outputs from WP3–WP5 to be integrated into a holistic model.

The site identification prototype also depends on relevant data from WP2, while the design prototype draws on the measures knowledge base developed under T6.3. At the time of D6.2, the contributing methods and datasets are at different stages of development. This chapter therefore defines the information WP6 needs without assuming that all outputs or technical interfaces have already been finalised.

The Grant Agreement establishes the project commitments; D6.2 translates them into proposed requirements for exchanging and using results. Requirements that depend on the methods, data or implementation choices of another work package must be agreed with the responsible partners. The handoff matrix in Table 3 therefore identifies the proposed requirements and the decisions still to be agreed.

The requirements will be refined with the contributing partners as their work progresses. For each handoff, WP6 should record the responsible partner, intended user decision, output definition, proposed exchange method, limitations and agreement status. Where an input is unavailable or unsuitable for a selected use case, the prototype should make that limitation clear and the partners should agree whether a narrower demonstration, a justified proxy or a different workflow can meet the project objective.

The following matrix consolidates the proposed input and interface requirements for the holistic model and the two tool prototypes. Section 3.2 defines the common information requirements. Chapters 4–6 explain how the inputs relate to the holistic model, siting tool and design tool. The exchange methods and uses below are proposed unless explicitly confirmed by the responsible partners.

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Table 3. Proposed inputs and interfaces for the holistic model and tool prototypes (handoff matrix)

Provider and input	Meaning and scale needed	Proposed exchange for the holistic model and prototypes	Used by	Status and decision needed
WP2: selected datasets and metadata	Dataset definition, units, geographic and temporal coverage, resolution, source, version, licence and quality. Cross-country differences and known gaps must be identifiable.	Dataset or reference with metadata, obtained through an agreed API, download or other access method. Spatial inputs must retain their geographic reference.	Siting tool; holistic model and WP3–WP5 assessments where relevant.	Agree priority datasets, coverage, transformations and access methods with WP2. The detailed data-space configuration remains in D2.2.
WP6: information extracted from past environmental assessments	Effect, project and location, technical setting, life-cycle stage, measure, reported effect and source passage, where available. Distinguish extracted statements from subsequently interpreted findings.	Structured records linked to the original report and extraction method, with a quality-check status.	Measures knowledge base; contextual evidence for the holistic model and both tools.	Agree extraction fields, checks and permitted reuse. Source linkage must be preserved when information is translated into a measure or design card.
WP3: cumulative and transboundary assessment framework and relevant outputs	Pressures, receptors, relevant activities, spatial and temporal boundaries, interactions, assumptions and limitations.	Documented methods and structured findings; assessment results where available. Spatial outputs only where produced or justified by the method.	Holistic model; design-tool evidence and guidance; methodological input to selected siting workflows.	Agree the demonstrable handoff with WP3 and how WP6 will represent it. Do not assume a ready-made GIS layer. Identify any cumulative or transboundary consideration that the prototype cannot assess.
WP4: site-specific socioeconomic parameters or model outputs	Affected activity or group, location, scale, parameter definition, direction of effect, method and limitations. State whether geographic coverage is complete, partial or absent for the selected case.	Spatial data or a documented relationship between a scenario (e.g. altered project configuration) and an outcome, where spatial representation is defensible. Exchange format agreed with the tool developer.	Holistic model; selected siting comparisons.	Agree which outputs can support the selected spatial decision. Do not require all parameters to be classified as constraints, mitigation or enhancement; distinguish assessed effects from measures and regulatory conditions.
WP4: location-independent socioeconomic results	Effect or benefit, affected groups, geographic scope, scenario, method and evidence. Preserve differences between groups and conditions affecting interpretation.	Qualitative or quantitative results with interpretation guidance and links to the relevant scenario or source.	Holistic model; design-tool comparison, contextual evidence or guidance.	Agree the decision relevance and presentation. Do not assign an artificial location or translate every finding into a measure.
WP4: citizen-inspired ideas and candidate measures	Proposed action, intended benefit, affected groups, stakeholder context, applicability and evidence. Identify life-cycle relevance and mitigation or enhancement purpose where applicable.	Candidate measure records linked to the original findings; contextual records where an actionable measure cannot reasonably be defined.	Measures knowledge base; design tool.	Agree translation and classification with WP4 and WP6. Preserve the original finding's meaning and limitations. Distinguish these records from WP4's site-specific outputs.
WP5/T5.3: LCA and S-LCA scenario results	Compared technology, material or design alternatives; functional unit or reference quantity; system boundaries; life-cycle stages; effect categories; results; assumptions and uncertainty.	Scenario-linked results with sufficient documentation to establish whether alternatives can be compared directly.	Holistic model; design-tool comparisons; selected siting scenarios only where a defensible spatial relationship exists.	Agree scenario identifiers, comparable outputs and presentation with WP5. Identify which results support quantitative comparison and which provide contextual guidance.
WP5/T5.3: screened solutions and sensitive parameters	Solution or parameter, affected effect, expected direction and magnitude of effect where	Structured findings linked to the underlying screening and scenarios; candidate	Measures knowledge base; design tool; selected spatial	Agree which findings become measures or selectable design options and their classification with

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	supported, applicable technical setting, life-cycle stage, evidence and trade-offs.	measure records where appropriate.	scenarios where justified.	WP6. WP5 checks the representation of relevant findings in D6.4.
WP5/T5.4: calculation method	Required design inputs, supported outputs, units, calculation boundaries, assumptions, applicability and limitations.	Documented method with an agreed implementation route: exchange of calculated results, or reference to an external assessment method or tool.	Holistic model; design tool.	Agree the integration route and input/output interface with WP5. Account for T5.4 continuing to M33, after D6.4 at M32.
WP6/T6.3: economic information associated with measures	Cost and benefit evidence, reference scenario, units, applicable setting, source and assumptions. Distinguish quantified information, qualitative implications and missing evidence.	Economic fields linked to measure or scenario identifiers, suitable for use alongside business modelling or LCoE calculations.	Measures knowledge base; design-tool comparison and external economic tools.	Agree sources and the valuation approach with relevant partners. Economic compatibility is a project commitment; quantified cost information must not be assumed available for every measure or supplied solely by WP5.
WP6/T6.3: sustainability measures knowledge base	Measure and purpose, affected effect, applicable technical setting, life-cycle stage, hierarchy position, expected effect, conditions, evidence, uncertainty, economic information and trade-offs.	Structured searchable records with stable identifiers, a consistent design-card representation and an agreed export or interface.	Design tool; selected siting scenarios where applicability and spatial effects are supported.	Agree the common schema and classification. Specify the relationship between database records, design cards and the target of 50 design options.
WP6/T6.2: integration, aggregation and presentation of assessment outputs	Relationships between inputs, effects, metrics and scenarios; conditions for comparison or aggregation; treatment of uncertainty, missing information and incompatible results.	Documented integration and presentation methods with traceable links to source outputs. Compatible results may be combined or summarised; other results are presented alongside each other with their differences visible.	Holistic model and both prototypes.	Agree presentation methods with the producing partners. Reduce complexity without removing information needed to interpret results or forcing unlike effects into one score.

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3.2. Common requirements for all inputs

WP6 needs enough information to interpret each input correctly and determine whether it can be used in the selected prototype workflow. These requirements apply to datasets, model outputs, measures and qualitative findings where relevant to the type of input. They do not require every contribution to be converted into a numerical value or GIS layer. To support transparency and fit-for-use assessment, metadata for all inputs should, wherever possible, follow established international standards (e.g. ISO 19115/INSPIRE, DCAT), so that they can be exchanged and reused through the data space. Each input should be accompanied by:

1. Meaning and unit: a clear definition of what is measured, modelled or described, including its unit, categories or qualitative interpretation. The direction of a scale must be explicit—for example, whether a higher value represents a greater negative effect or benefit.
2. Coverage and scale: the geographic area and time period to which it applies, together with its spatial and temporal resolution where relevant. Results for a particular project, technology or scenario should identify that context. Where relevant, inputs should also identify the planning or assessment level for which the evidence was developed, including whether it is suitable for strategic planning, project-level assessment, or both.
3. Method and assumptions: how the result was produced, including relevant boundaries, baseline, parameters and conditions for comparison. Outputs should have a stable identifier so that related inputs and results can be linked to the same scenario.
4. Uncertainty and limitations: the quality and completeness of the underlying evidence, known gaps, uncertainty where it can be assessed, and conditions under which the result should not be used. Missing data must be distinguishable from a measured value of zero or an absence of effect.
5. Source and version: the producing partner or source organisation, source dataset or document, date and version. Where information has been transformed or extracted, the link to the original source and the method used should be retained.
6. Access and reuse: how can the input be obtained, its proposed format and the applicable licence or access conditions. The producing partner and the tool developer should agree the practical exchange method for the selected use case.

Before combining inputs, WP6 and the producing partners should check whether they refer to comparable locations, periods, scenarios and definitions. Where they do not, the holistic model should present them separately or explain the limits of the comparison. Legal and planning requirements, assessment results and user-selected priorities should remain identifiable as different kinds of information.

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4. The holistic model

The holistic model serves as the integration framework connecting the SUSTAINOW data space, assessment methods, sustainability metrics, and decision-support prototypes. Its purpose is not to create a single sustainability score or replace established assessment approaches. Instead, it provides a common structure for organising and relating information generated across WP2-WP6 while preserving the meaning, assumptions, scale and uncertainty of the underlying evidence.

The model contributes directly to SO2, which aims to develop a holistic model for understanding offshore wind farm effects based on existing models and systems thinking. In particular, it supports result R2.3, Integration of data sources and models on environmental and socio-economic effects into a holistic model on OWF effects, and provides the basis for Result R2.4, Holistic assessment metrics. The model also functions as the conceptual bridge between the data space developed under SO1 and the site identification and design tools developed under SO3 and SO4.

The model has been developed around a common effect pathway structure:

OWF element → Pressure → Receptor → Effect → Metric → Mitigation/Enhancement

This structure provides a common language across the project while allowing different assessment traditions and evidence types to coexist within the same framework. It enables relevant information from environmental assessment, cumulative effect assessment, social effect assessment, life-cycle assessment and related approaches to be organised consistently without requiring all outputs to be converted into the same format.

The pathway starts with an OWF element, which represents a technical component, activity or design choice associated with offshore wind development. Examples include foundations, turbines, cable systems, installation activities or decommissioning operations. Each element may generate one or more pressures, understood as the mechanisms through which they interact with the environment. Pressures may affect one or more receptors. Receptors represent the environmental, social or economic entities that may be affected, such as marine mammals, benthic communities, local communities, fisheries, cultural heritage assets or global supply chains. Spatial receptor information may be drawn from the WP2 data space and associated data layers where available, while WP3–WP6 may provide additional spatial or non-spatial evidence and assessment outputs.

Effects describe receptor responses and their consequences in the relevant assessment context. Examples include disturbance of marine mammals, habitat creation, job creation, resource depletion or greenhouse gas emissions. To support the holistic scope of SUSTAINOW, effects are categorised according to relevant sustainability dimensions, including environmental, social and economic dimensions. The model further accommodates different assessment perspectives, including site-specific, cumulative, transboundary, regional and

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large-scale life-cycle perspectives. These perspectives are understood as ways of analysing an effect rather than fixed characteristics of the effect itself. A single effect may therefore be relevant to several perspectives simultaneously.

The holistic model will integrate assessment outputs from WPs 3-5 while avoiding unnecessary aggregation. Results that are compatible may be combined or summarised using transparent and documented methods. Results that differ in meaning, scale, unit of measurement, or assessment boundary will be presented side by side, with these differences made explicit. This enables the model to support decision-making across site-specific, cumulative, transboundary, and large-scale effects while maintaining transparency about what can, and cannot, be meaningfully compared or aggregated.

Metrics provide the connection between effect and decision support. Each effect may be associated with one or more qualitative or quantitative metrics. Examples include number of animals exposed, area of habitat affected, full-time equivalent jobs, greenhouse gas emissions or critical material demand. Metrics are intended to support the development of holistic assessment metrics under R2.4 while retaining traceability to their underlying data sources and assessment methods.

Where relevant, metrics and effects may be represented spatially through GIS layers. This functionality provides the primary connection between the holistic model and the site identification tool. However, spatial representation is not a requirement for all model components. Some WP4 and WP5 outputs are expected to remain non-spatial and can provide contextual evidence, especially for the design tool. The model may distinguish between spatial and non-spatial information while maintaining both within the same overall framework.

The final component of the model is the integration of mitigation and enhancement measures. Measures developed under T6.3 are linked to relevant activities, pressures or effects based on their applicability, evidence, expected effects, uncertainties, benefits, challenges and design considerations. They can act at different points in the effect pathway and follow the mitigation-enhancement hierarchy adopted by SUSTAINOW: avoid, minimise, repair, offset and enhance. This enables the model to support effect identification and management and establishes the connection to the design tool.

The role of the holistic model is therefore not to determine the optimal offshore wind solution. Instead, it provides a transparent structure through which data, assessment outputs, metrics and sustainability measures can be related and explored across different planning and design decisions. In this sense, the model acts as the conceptual centre of the SUSTAINOW architecture and the primary mechanism through which information from WP2-WP5 is made accessible and useful within the site identification and design tool prototypes.

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5. The siting tool prototype

This chapter sets out the configuration of the prototype of the siting tool. This includes the siting prototype's project scope, required inputs and functions.

The proposed prototype will support early identification of areas for further investigation and comparison of selected siting scenarios. Its baseline workflow will allow a user to examine an area against agreed spatial criteria, with data coverage and limitations visible. A selected dynamic workflow will demonstrate how a change in a project characteristic or an evidence-supported mitigation measure affects the assessment. The specific parameter, measure and calculation will be agreed with the contributing partners.

WP3's role in the siting prototype is methodological: its cumulative-effects framework may identify considerations, methods and limitations relevant to the siting process. No dedicated WP3 cumulative effect calculation or spatial layer is assumed for the siting prototype at this stage.

The SUSTAINOW siting tool prototype will demonstrate selected interactive mapping functions in an online sand box environment, using a limited number of parameters. These parameters will be selected for the agreed use cases based on decision relevance and the availability of suitable data and methods. Examples could include marine biodiversity, such as specific bird or mammal species, or selected socio-economic or climate-related parameters. Depending on the use cases, the parameters may draw on outputs from WP4 and WP5.

The siting tool prototype will support exploration of how changes in selected plan or project characteristics affect the area under consideration. For selected use cases, authorities, project developers and consultants may compare predefined project configurations where compatible data, models and metrics are available.

The prototype will also allow users to examine whether specific mitigation measures, identified and structured in the measures knowledge base and defined with sufficient evidence of their expected effect, could alter the assessed effect and, consequently, influence which areas are worth investigating further. Such assessments will present results before and after implementation of the measure, together with the available information on applicability, underlying evidence and key assumptions, and a clear indication where such information is missing or uncertain.

In addition, where supported by the selected use cases and available evidence, the prototype may illustrate enhancement opportunities by highlighting locations where beneficial measures may be relevant. Enhancement opportunities and their associated conditions will be presented separately from constraints and adverse effects to ensure a clear distinction between opportunities and potential risks.

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The siting tool prototype will distinguish between evidence relevant to plan-level and project-level decision-making. Information requirements for datasets, models and other evidence sources will therefore include the decision context for which the evidence was developed, together with its spatial and temporal scale, jurisdiction, source and version. This distinction will support the appropriate use of evidence by different user groups within the siting process. Spatial planners assessing broader areas for offshore wind development will be able to draw on evidence suited to strategic planning and SEA-related decisions, whereas project developers evaluating specific sites will be presented with evidence relevant to project-level assessment and EIA-related decision-making.

The prototype should support a bounded, evidence-based siting decision using real inputs and clearly stated limitations; it should not claim to identify an objectively optimal location.

5.1. Contributions to the siting tool prototype

The development of the siting tool has three main components with different WPs involved:

- Use case and user interface, including mock-up (WP6, primarily AAU)
- Software development of the protype in a sand box environment (WP6, primarily DEP)
- Simple spatial relationships for selected project characteristics and mitigation measures, where supported by evidence (WP4, WP5 and WP6, as relevant).

The scope of the siting tool prototype will be defined in a short scoping step led by WP6, building on the user needs identified in the project. This step specifies the target users, the decision to be supported, the parameters, the geographic area and the required data. The scope will be agreed with WP2 and the contributing work packages to guide prototype development.

The simplified models of spatial consequences are related to task 5.3 on modelling large-scale effects and OWF design solutions (M12-M30), task 6.2 on integration of models and metrics in a holistic model (M8-M34), and task 4.3 on models and metrics for incorporating site-specific socio-economic effects in strategic and project planning (M17-M30). A simplified model is a documented relationship between spatial data and an expected consequence that can be shown on a map, for example how an changes with distance to a given feature. Simplified does not mean easy to establish: each model still requires suitable data, a documented method and clearly stated limitations. WP4 will provide simple models on socio-economic effects, WP5 will provide simple models on climate or material-related effects, and WP6 will provide simple models on other types of effects.

Knowledge on cumulative and transboundary effects generated in WP3 will inform the context-setting and user guidance embedded in the siting tool prototype, supporting users in interpreting results and understanding relevant assessment considerations. In addition, WP3

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will contribute knowledge on mitigation and enhancement measures that can be incorporated into the siting tool prototype.

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6. Design tool prototype

The design tool (SO4), developed through T6.4, addresses the question: how can an offshore wind project be designed, constructed, operated and eventually decommissioned in a more sustainable way?

Whereas the siting tool primarily supports decisions about *where* OW development could take place, the design tool primarily supports decisions about *how* a project could be designed and implemented. The two tools are closely related but serve different decision contexts. As illustrated in Figure 4, the design tool supports two complementary uses of the same prototype. It is configured first and foremost as a standalone plan and project-level decision-support prototype. Selected design choices and mitigation or enhancement measures may also inform the siting tool, through the holistic model, where their applicability and expected spatial effects can be represented with sufficient evidence.

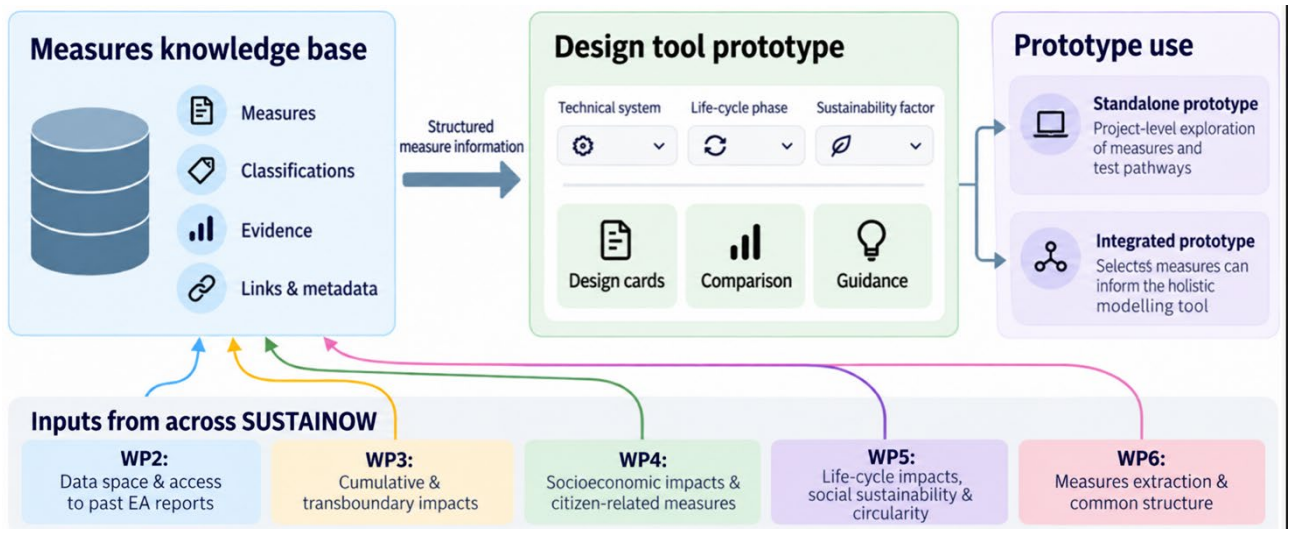

Figure 4. Design tool inputs and prototype use.

The design tool is not intended to replace detailed engineering, environmental assessment, LCA or other specialised assessment tools. Its added value lies instead in bringing together currently fragmented knowledge about design choices and sustainability measures and making the supporting evidence, applicability, expected effects, uncertainties, co-benefits and trade-offs accessible at the point where design alternatives are being considered. The design tool draws on the holistic model by relating design choices and sustainability measures to activities, pressures, receptors, effects and assessment metrics.

A central component is the common measures knowledge base developed through T6.3. It contains mitigation and enhancement measures across the OWF life cycle and across the sustainability factors addressed in SUSTAINOW.

Measures are classified according to the mitigation-enhancement hierarchy and linked, where relevant, to technical systems, project components, life-cycle phases, sustainability effects and supporting evidence.

The user-facing representation of this knowledge is provided through design cards (Figure 5). The design cards translate the structured information in the measures knowledge base into a consistent and accessible format and thereby form the principal interface between the knowledge base and the design-tool prototype. Depending on the available evidence, cards may support comparison between alternative measures or design choices, provide evidence-based guidance, or direct users towards relevant specialized assessment methods and tools.

The prototype will demonstrate this concept for a bounded set of design decisions and measures using research results and available real-project knowledge and data. Examples may include choices concerning foundation type, cabling, construction methods and sequencing, material choices, seasonal restrictions, vessel operation, measures to reduce effects on marine species or other users of the sea, and measures aimed at creating positive environmental or socio-economic effects.

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Figure 5. Illustrative design card presenting a measure and its supporting evidence.

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6.1. Decision-support logic and function

The design tool is not intended to function simply as a searchable repository of sustainability measures. The measures knowledge base and design cards provide the information foundation, while the design tool adds a decision-support layer that helps users move from a defined design challenge to relevant alternatives and understand the implications of choosing between them.

Decision support is provided at three complementary levels. First, the tool supports problem- and context-based identification of relevant options. Rather than requiring the user to know the name of a particular measure, the user can describe the design context or sustainability challenge, for example a foundation choice, underwater noise during construction, material demand, or interaction with fisheries. Structured information on life-cycle stage, technical system, affected effect, applicability and mitigation or enhancement purpose is then used to identify a decision-relevant set of measures or design options, whether the aim is to mitigate adverse effects, enhance positive outcomes, or understand interdependencies and cumulative effects as part of the design.

Second, the tool supports structured comparison of alternatives. Users can select relevant measures or design choices and compare them against common decision-relevant attributes, including expected effects, applicability and context dependency, strength of evidence, uncertainty, documented economic and implementation implications where available, and potential co-benefits and trade-offs. Implementation implications may include, for example, additional vessel time, material or energy demand, logistic requirements or operational restrictions. The comparison should make both differences and knowledge gaps visible. Information should only be compared directly where the underlying methods, boundaries and metrics are sufficiently compatible; otherwise, the results should be presented alongside each other with their differences made explicit.

Third, the tool provides analytical support where suitable models, metrics or scenario results are available. In such cases, a design option can be linked to quantitative or scenario-based results generated within WP3–WP5 or to relevant specialised assessment methods. For example, where WP5 provides comparable LCA results for alternative foundation, material or technology choices, the design tool can display how the alternatives differ across relevant metrics under the stated assumptions and system boundaries. Where quantitative comparison is not methodologically justified, the tool instead provides evidence-based guidance and makes the associated uncertainty visible rather than generating an artificial score.

The distinction between information retrieval and decision support is therefore important. Information retrieval answers the question *“what measures or evidence are available?”* Decision support additionally addresses *“which options are relevant to this particular decision, how do they differ, what consequences and trade-offs are associated with them, and how strong is the evidence for those differences?”*

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The purpose is not to identify a single objectively optimal design or replace specialist assessment and professional judgement. Rather, the tool should make alternatives, consequences, trade-offs, assumptions and uncertainties more transparent and traceable, enabling users to make better-informed and more explicitly justified design choices.

6.2. As a standalone tool

Used independently, the design tool primarily supports project and design-level decisions, while selected measures and evidence may also inform plan-level choices. Its basic workflow is to help a user to identify a design question or sustainability challenge, identify relevant alternatives, compare those alternatives using available evidence and metrics, and examine their potential consequences, co-benefits, trade-offs and uncertainties. Users can therefore enter the tool from different decision perspectives rather than having to know a particular measure in advance. Entry points may include:

- A technical system or project components, including fixed-bottom and floating OW technologies.
- An OWF life-cycle phase, including site identification, tendering, project design, construction, operation, repowering, and decommissioning.
- A sustainability parameter, effect or challenge.
- The mitigation-enhancement hierarchy, including avoid, minimise, repair, offset and enhance.
- Decision level (plan- and/or project-level relevance).

These dimensions can be combined to narrow the set of alternatives considered relevant to the decision. For example, a user considering installation of a fixed-bottom foundation could identify underwater noise during construction as the relevant challenge. The tool could first identify applicable mitigation measures and alternatives considered relevant to the decision. The user could then select relevant options for comparison and examine the differences in expected effectiveness, applicability, evidence strength, economic and implementation implications where available, potential effects on other sustainability factors and associated uncertainties. Where compatible model or scenario results exist, these can be added to the comparison; where they do not, the tool provides structured evidence-based guidance rather than implying a level of analytical precision that is not supported. Each measure or design option is documented through the design-card structure, including:

- Life-cycle stage
- Applicable technical system or project component
- Plan and/or project level relevance
- Sustainability effect addressed
- Position in the mitigation-enhancement hierarchy

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- Expected effect
- Conditions for applicability
- Evidence and uncertainty
- Economic and implementation implications where available
- Potential co-benefits and trade-offs

The design cards therefore provide the evidence behind the comparison, rather than constituting the decision-support function on their own.

6.3. Connection to the siting tool

The design tool may also inform the siting tool where a design choice or measure has a sufficiently clear spatial implication. This creates feedback between the questions of where and how without making the two tools identical.

The relationship between the two tools corresponds to the three levels of the dynamic siting tool described in Section 2.4 and further operationalised in Chapter 5:

- **Level 1 – Constraints-informed siting**: locations are assessed primarily against existing environmental, technical, regulatory and socio-economic constraints.

- **Level 2 – Mitigation-oriented siting**: selected measures from the design tool are introduced to explore whether and how an identified effect or conflict associated with a location can be avoided, minimised or otherwise mitigated. Effective mitigation may therefore change the range of areas considered to merit further investigation compared with a constraints-only assessment.

- **Level 3 – Enhancement- and co-design-oriented siting**: selected enhancement measures from the design tool are additionally considered to identify locations where project design may contribute to positive environmental or socio-economic outcomes.

Only a subset of the measures knowledge base will interact with the siting prototype. Some design choices, for example material selection or circularity strategies, may primarily affect plan and project-level sustainability and remain within the standalone design tool. Other measures, such as spatial configuration, seasonal construction restrictions, foundation choices with different environmental effects, nature-inclusive design or measures affecting interactions with other marine users, may influence the suitability of a location and can therefore become part of the dynamic siting assessment.

The design tool will categories mitigation and enhancement measures according to the level of decision-making they support, distinguishing between measures that are relevant at the planning level and those that are applicable at the project level, or at both levels. This can guide the presentation of measures to different user groups within the siting tool. For example,

measures relevant to strategic planning can be distinguished from those applicable to project design and implementation.

By making the decision context and limitation of the underlying evidence explicit, this approach may also support tiering between strategic planning and project-level assessment, without assuming that information is directly transferable between levels.

This interaction provides the link between the measures knowledge base and the siting tool's mitigation- and enhancement-oriented levels and makes the two applications different expressions of the same holistic model.

6.4. Contributions to the measures knowledge base and design cards

The measures knowledge base draws on contributions across SUSTAINOW (see Figure 4). Its organisation follows the sustainability factors established in D6.1 and provides a common structure through which environmental, social, socio-economic and cross-cutting knowledge can be connected.

The division of contributions is:

- WP4: measures and evidence related to Population, Human Health and Material assets, together with relevant citizen-inspired ideas that can be translated into actionable design measures.

- WP5: measures related to Climate mitigation, together with cross-cutting evidence from LCA, social LCA, large-scale effects and circularity. These results may both generate measures and provide evidence on life-cycle implications, co-benefits and trade-offs associated with measures elsewhere.

- WP6: measures related to the remaining sustainability factors identified in D6.1, including Biodiversity, flora and fauna, Soil and seabed, Land, Water, Air, Landscape and seascape, Cultural heritage, and is responsible through T6.3 and T6.4 for developing the common knowledge base structure, classification and design-card format.

- WP3: cross-cutting knowledge on cumulative and transboundary effects. Rather than constituting a separate category of design cards, these considerations should be incorporated into individual measures where they affect the applicability, effectiveness or consequences of a measure.

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This configuration allows the design tool to integrate knowledge from different work packages without requiring all contributions to take the same methodological form. The common denominator is therefore not a single sustainability score but the effect pathway structure of the holistic model, which provides a common decision-support framework while preserving the source, meaning, scale, assumptions and uncertainty of the underlying evidence.

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7. Conclusions and next steps

7.1. Main conclusions

D6.2 defines the proposed configuration of the SUSTAINOW site identification and design-tool prototypes, and the information flows needed to connect them to the project's data, assessment outputs and measures knowledge base. At this stage, the deliverable does not present completed tools. Rather, it establishes the decision-support logic, functional architecture, interfaces and requirements that provide the basis for the subsequent development of the holistic model and prototypes.

The configuration distinguishes two complementary decision contexts. The site identification tool primarily supports exploration of where offshore wind development could potentially take place. Its dynamic concept goes beyond a constraints-only approach by exploring how project characteristics, mitigation measures and enhancement measures may change which areas may merit further investigation and under which conditions they could be considered potentially suitable. The design tool primarily supports how an offshore wind plan or project can be designed and implemented more sustainably by helping users identify relevant alternatives, compare them using structured evidence and, where suitable assessment outputs are available, examine their implications analytically. It is configured primarily as a standalone plan and project-level tool, while selected measures may also inform the siting tool where their applicability and spatial effects can be represented with sufficient evidence.

A central conclusion is that the holistic model should not be understood as a single sustainability score or as a requirement to convert all results into GIS layers. The contributing work packages produce different forms of evidence, including spatial data, scenario comparisons, quantitative results and qualitative findings. The holistic model connects these contributions through a common effect pathway structure linking OWF elements, pressures, receptors, effects, metrics and mitigation or enhancement measures. This structure allows outputs from WP2-WP5 to be organised consistently while preserving their meaning, scale, assumptions and uncertainty.

The report also establishes that the prototypes must remain bounded and evidence-based. SUSTAINOW will demonstrate selected workflows with real inputs rather than attempt to create a fully comprehensive operational system within the project. Functions and connections that depend on later work-package results should therefore be distinguished from those that can already be demonstrated within the project scope.

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7.2. Next steps

The next phase translates the proposed configuration into agreed use cases and functioning prototype workflows. The input and interface requirements in Chapter 3 provide the basis for this work. Implementation will proceed through a bounded set of demonstrable decisions rather than attempting full integration of all available project outputs.

Priority next steps are to:

- **Agree the prototype use cases and MVP scope**, including the users, decisions, geographic scope, adjustable parameters and data needed for the siting and design-tool demonstrations.
- **Clarify the interfaces with the WP2 data space**, including priority datasets, metadata, access methods and how information from past environmental assessments is made available to the tools. The detailed data space configuration remains part of D2.2
- **Agree the demonstrable contributions from WP3–WP5**, recognising that their outputs differ in form and maturity. In particular, the project needs to determine which cumulative, socioeconomic and large-scale sustainability outputs can be represented spatially, compared across scenarios or used as supporting evidence.
- **Develop the common measures knowledge base and design-card structure**, including consistent classifications, evidence requirements and the relationship between measures, design cards and the project target of 50 design options.
- **Specify the interaction between the design and siting tools**, focusing on a limited number of mitigation and enhancement measures for which spatial implications can be represented and tested.
- **Define the testing approach**, covering both technical functioning and usefulness for real planning and design decisions. Testing should examine whether users can understand the source, assumptions and limitations of the information presented and whether the tools support meaningful exploration of alternatives.

The configuration should be refined as the contributing tasks progress. Where an intended input proves unavailable or unsuitable for a selected use case, the project should agree whether a narrower demonstration, a justified proxy or a different workflow can still meet the prototype objective.

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7.3. Future use

The SUSTAINOW prototypes are intended to reach TRL5 and provide a foundation for further development, rather than operate as fully deployed decision-support services at project end. Future use may take several forms. The site identification prototype could inform the continued development of existing public or sectoral spatial-planning tools, while the design tool and measures knowledge base could be further developed as plan and project-level decision-support for developers, authorities and consultants. The specific hosting and implementation pathways will depend on the results of prototype development and stakeholder testing.

Wider exploitation will require attention not only to technical development but also to governance, ownership, quality assurance, updating and maintenance of data, assessment methods and the measures knowledge base. Transfer to other sea basins or decision contexts will additionally require considerations of differences in regulatory frameworks, data availability, environmental conditions and user needs. The SUSTAINOW project will therefore use the prototype testing and subsequent exploitation activities to identify which components are sufficiently mature for continued use, which require further development, and which governance and maintenance arrangements are needed for longer-term operation. The aim is not to prescribe a single post-project implementation model at this stage, but to establish credible pathways for continued development and uptake of the SUSTAINOW results.

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