Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities

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Abstract

This research project investigated the potential impacts of the Sectoral Marine Plan for Offshore Wind Energy option N4 on island communities. Site N4 is situated adjacent the northern shore of the Isle of Lewis, with the closest edge of the plan's area being less than 5 km from the shoreline. As a result, adverse landscape and seascape changes are expected, which is expected to affect the local communities, who rely on small-scale economic activities, land ownership, and tourism as sources of income. To quantify these impacts, this project used a GIS-based methodology, including a viewshed analysis to assess visual impacts, multi-criteria analysis to assess the site's suitability for a commercial-scale offshore wind farm, and a participatory GIS session with community landowners to gain local knowledge and opinions on the large-scale development proposal. The conclusions of this project demonstrated the importance of considering different development scenarios and anticipated impacts, as well as the usefulness of visually and verbally communicating this knowledge to communities that may be affected by large-scale offshore wind development.

Keywords: offshore wind energy, multi-criteria analysis, viewshed analysis, participatory GIS, community impacts

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Abbreviations

API application programming interface

CRS coordinate reference system

DTM digital terrain model

GIS geographical information system

MCA multi-criteria analysis

SMP Sectoral Marine Plan for Offshore Wind Energy in Scotland

ZTV zone of theoretical visibility

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CHAPTER 1

Introduction

There have been efforts to decarbonise the energy system in line with the targets outlined in the Paris Agreement at various administrative levels worldwide, ranging from political unions such and individual countries, to states, cities, local authorities, and even communities. Offshore wind energy, which only contributed 2,000 MW of renewable electricity in early 2010 (Esteban et al. 2011), has seen major developments since, with the United Kingdom (UK) alone installing 1,764 MW of new offshore wind generators in 2019 (Wind Europe 2020).

The Sectoral Marine Plan for Offshore Wind Energy in Scotland (SMP) was published by the Scottish Government in October 2020, in line with their offshore wind policy statement commitments to reach a zero emission target by 2050 (Scottish Government 2020a). This plan details 15 potential Plan Options, or development sites, in Scottish waters for commercial-scale offshore wind farm development, derived through an iterative process involving spatial planning and stakeholder engagement. Once these sites are identified, Crown Estate Scotland starts a seabed leasing round, where developers can apply to receive approval for constructing new commercial-scale offshore wind farms in Scotland (Crown Estate Scotland 2021).

The smallest of these sites, referred to as "N4", is in the northern region of Scotland and has a total area of 200 km^2 and a maximum generating capacity potential of 1 GW (assuming a density of 5 MW/km^2), of which 100 % development is deemed realistic. As shown in Figure 1, this site is adjacent to the northern coast of the Isle of Lewis in the Outer Hebrides (also known as the Western Isles or *Na h-Eileanan Siar* in Scottish Gaelic), and is significantly close to the northern shoreline of the island, measuring just 4.5 km from the nearest vertex (Tilbrook and Lees 2020).

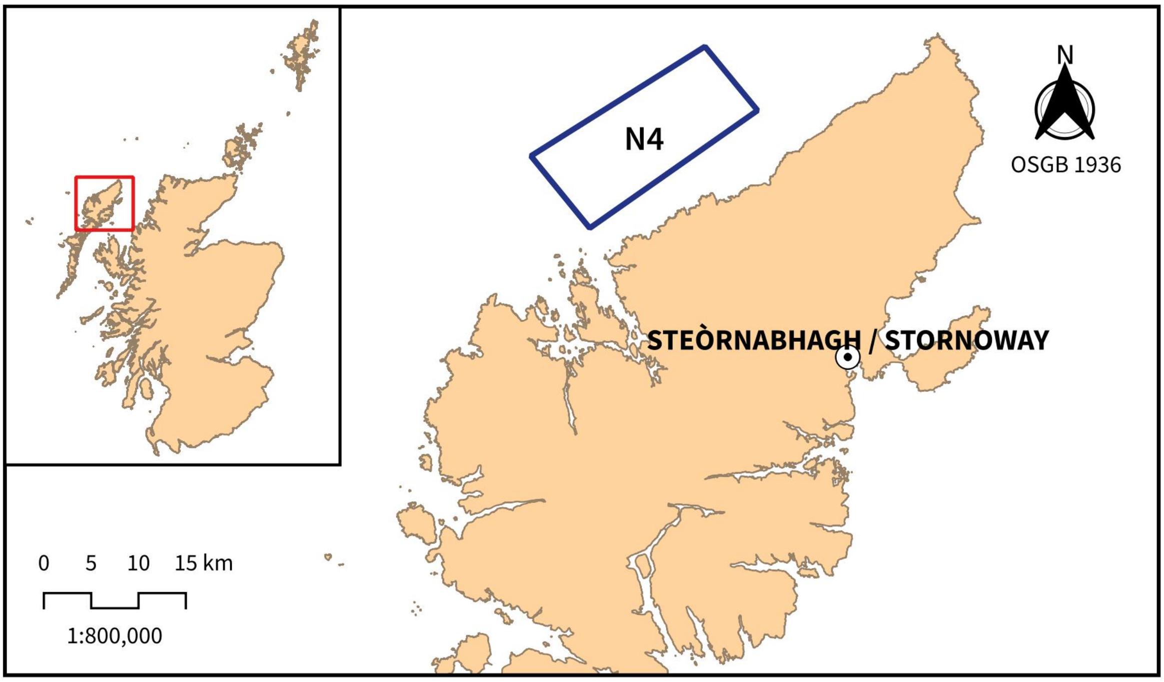


Figure 1: A map showing the location of Sectoral Marine Plan Option N4 within the Isle of Lewis. The location of the Isle of Lewis within Scotland is shown in the inset.

Based on responses to the draft SMP Plan Options by individuals and organisations (Scottish Government 2020b), there has been widespread opposition of Draft Plan Option SW1 (south-west region; outer Solway Firth), with over 300 negative responses (Scottish Government 2020a) from community members, local businesses, and fishers citing adverse impacts to the landscape, seascape, and socio-economic activities. As a result, SW1 was dropped from the final Plan Option. In contrast, there were very few responses pertaining to site N4, which indicates that Isle of Lewis communities have been generally unaware of the proposed site at the time of the government survey.

According to Comhairle nan Eilean Siar (the Outer Hebrides local government council) Local Development Plan, the Outer Hebrides is home to many cultural heritage and nature conservation sites, as well as communities that rely on tourism and small-scale economic activities (Comhairle nan Eilean Siar 2018). Housing in the Outer Hebrides is predominantly through crofting tenure, i.e. "a land tenure system of small scale food producers unique to the Scottish Highlands and Islands" (Scottish Crofting Federation 2021), with high levels of community land ownership (Comhairle nan Eilean Siar 2018). Despite this, Historic Environment Scotland neither supports nor opposes development at site N4, although they noted that adverse impacts are affected due to proximity to the shore, and mitigating these impacts is expected to be challenging (Scottish Government 2020b).

Considering the inshore location of site N4, developing the site into a commercial-scale offshore wind farm is expected to have adverse effects on the island communities. Therefore, it is crucial to quantify and analyse the potential impacts of this development on the island's landscape and industries. The results of this analysis can be used to increase awareness and understanding of these impacts in communities, helping them make informed decisions and participate effectively in future stakeholder meetings.

Aims and objectives

The aim of this project is to utilise geospatial methodologies to assess the impacts of commercial-scale offshore wind development at site N4, which is situated in the northern coastline of the Isle of Lewis in the Outer Hebrides.

The objectives of this project are to:

- generate a number of hypothetical commercial-scale offshore wind farm development scenarios to investigate the visual effects of varying the number and height of turbines installed;
- perform a viewshed analysis for each development scenario and compare the visual impacts in a number of identified viewpoints in the study area;
- identify environmental and socio-economic community impact assessment criteria and assess the suitability of site N4 using multi-criteria analysis (MCA);
- conduct a participatory geographical information system (GIS) session with community landowners affected by potential development at site N4 to gain their local knowledge and opinions; and

- propose an accessible method using GIS to improve public participation, understanding, and awareness of such large-scale projects.

CHAPTER 2

Literature review

Visual impact assessment

According to NatureScot's guidance on visual representation of wind farms, offshore wind farms are always expected to have a higher impact due to their relatively large sizes compared to onshore turbines (NatureScot 2017). While a height of more than 150 m is considered large for an onshore wind turbine, offshore wind turbines, based on current technological trends, always exceed this height. As a result, it is very important to quantify the visual impacts of a new offshore wind farm development, and what changes this could cause to existing landscapes and seascapes.

There are a number of mediums that can be used to assess visual impacts, which are geared towards different target audiences. Types of visualisations include wireframes, photomontages, and two-dimensional or three-dimensional maps. In a public participation study conducted by Berry et al. 2011, it was deduced that the public generally prefers realistic visualisations, such as photomontages (due to their true colour and photographic format), as opposed to more abstract representations, such as maps or three-dimensional models. However, it is worth noting that each individual would have a different sensitivity to visual impacts (Appleton and Lovett 2003; Falconer et al. 2013), so having different mediums of visualisations to complement each other are important. Additionally, although photomontages are seen as realistic, they tend to be inaccurate as well as subjective (Falconer et al. 2013), and also provide less information than a map with the appropriate symbologies.

When assessing visual impacts, visual receptors as well as the structure that causes the visual impact, must be identified. Falconer et al. 2013 conducted a study assessing visual, seascape, and landscape impacts of coastal aquaculture development, using the Outer Hebrides as a case study. The visual receptors identified in this study include tourists and local community members.

A digital terrain model (DTM) forms the basis of constructing these various visualisations. Based on NatureScot 2017, the same DTM is used to generate zone of theoretical visibility (ZTV) of wind farms, from which other visuals, such as photomontages and wireframes, are constructed. Viewshed analysis, which is defined as a widely-used objective approach to quantifying visual impacts, uses a raster DTM to calculate how visible each pixel is on its surface from a viewpoint (Falconer et al. 2013, citing Eastman 2012).

Viewpoint selection is also an important aspect of visual impact assessment. Falconer et al. 2013 considered various viewpoints, including buildings, roads, ferry routes, and points of interest in the Outer Hebrides to assess the visual impacts of land and sea aquaculture cages. Such level of detail would not be necessary for an offshore wind farm's visual impact assessment, as wind turbines are magnitudes larger than aquaculture structures both onshore and offshore.

Site suitability assessment

The basis of MCA, which may also be referred to as multi-criteria decision analysis (MCDA) or multi-criteria evaluation (MCE), is to consider multiple criteria, which are alternative choices, when making a decision (Dean 2020; Eastman 2005). In the context of spatial planning, Eastman 2005 defines MCA decisions as either being resource allocation or policy decision problems. Based on this definition, the direct allocation of Scottish waters to construct an offshore wind farm is part of the former, while the Scottish Government's wind energy commitments and the SMP Plan Options that influence the offshore wind development are part of the latter group. Both examples are the result of considering multiple criteria or alternative decisions.

MCA is widely-used in GIS for industrial site selection, and there have been many recent publications (in the last decade) that concern offshore wind site suitability assessment using MCA (Abdel-Basset et al. 2021; Deveci et al. 2020; Gavériaux et al. 2019; Mahdy and Bahaj 2018; Mekonnen and Gorsevski 2015; Tercan et al. 2020; Vasileiou et al. 2017). Many of these publications consider factors such as meteorology, technology, electricity grid networks, and geology in determining the suitability of an offshore wind site. Since the focus of this project is community impacts, these factors are omitted from the analysis. The analysis will also not quantify benefits such as clean energy generation, employment, and profits as a result of the development.

The criteria relevant to this project's impact assessment are socio-economic and environmental impacts. Gavériaux et al. 2019 broadly used marine data for their socio-economic criteria, including anchorage, restricted areas, fishing areas, and recreation zones. The former two are classed as constraints, as they physically prevent any development at the area of intersection. The latter two are classed as factors, where weights can be assigned to indicate their relative importance, but they do not necessarily prevent development on their coverage area. Similarly, for their environmental criteria, protected areas and marine reserves are classed as constraints, while commercial fishing resources, fauna, and flora are classified as factors.

Abdel-Basset et al. 2021 categorised the criteria into groups and subgroups of the same theme. For example, under the environmental group, three subgroups were present, which quantified the offshore wind farm's potential to cause damage to the marine ecosystem, water disturbances, and risk of collision to birds. However, the authors do not consider the socio-economic criteria as defined in the previous paper, such as fishing areas. Deveci et al. 2020 and Abdel-Basset et al. 2021 use qualitative inputs for determining the acceptance of local communities in their analysis.

A summary of the factors found in these sources can be found in Table 1.

Table 1: Summary of criteria used for offshore wind site suitability analysis in recently published literature (Abdel-Basset et al. 2021; Deveci et al. 2020; Gavériaux et al. 2019; Mahdy and Bahaj 2018; Mekonnen and Gorsevski 2015; Tercan et al. 2020; Vasileiou et al. 2017).

Criteria	Type	Theme	Frequency
Natural restricted areas	constraint	environmental	5
Socio-economic and defence restricted areas	constraints	socio-economic	5
Anchorage	constraint	socio-economic	1
Shore distance	factor	environmental; socio-economic	6
Shipping lines	constraint	socio-economic	3
Marine ecosystem	factor	environmental	4
Recreation zones	factor	socio-economic	2
Fishing areas	factor	socio-economic	2
Bird flight and habitat	factor	environmental	2
Public acceptance	factor	socio-economic	2
Population density	factor	socio-economic	1

Based on these publications, there are a number of methods for comparing criteria and assigning weights based on their relative importance. A Boolean mask is used when the outputs are binary; for example, restricted areas are constraints, so any area within the constraint is unsuitable. A pairwise comparison is when the criteria are assigned weights by direct comparison in pairs. Fuzzy memberships take into account correlations and relationships between variables of a criteria. Finally, an abundance rank is used as a simple means to aggregate the various criteria.

Participatory GIS

Using public participatory GIS in this project introduces a qualitative and mixed-method approach to evaluate impacts of the commercial-scale offshore wind farm development.

CHAPTER 3

Methodology

This project has a predominantly quantitative computing and GIS-based methodology, which includes the use of application programming interfaces (APIs) for automated data downloads, geostatistics and geovisualisation, exploratory data analysis, raster and vector data processing, viewshed analysis, and MCA. To supplement this data, qualitative inputs are obtained through a participatory GIS session with community landowners.

The data used in this project are predominantly derived from a number of UK or Scottish public sector data sources, including Ordnance Survey, Scottish Government, Marine Scotland, NatureScot, Improvement Service, and Historic Environment Scotland (Ordnance Survey n.d.; Scottish Government n.d.). Additionally, bathymetry data used is derived from the European Union's EMODnet Bathymetry portal (EMODnet Bathymetry Consortium 2020). All downloaded data are in the EPSG:27700 (Ordnance Survey National Grid reference system); except for data downloaded from Marine Scotland and EMODnet, which are in EPSG:4326. The output data produced are in the EPSG:27700 coordinate reference system (CRS) and two file formats: GeoPackage for vector data (points, lines, and polygons), and GeoTIFF for raster data.

This project uses a number of open-source software packages and dependencies, including the QGIS Geographic Information System, GDAL/OGR Geospatial Data Abstraction software Library, and the Python Programming Language and its geospatial libraries, including GeoPandas (GDAL/OGR contributors 2021; GeoPandas developers 2021; Python

Software Foundation 2021; QGIS Development Team 2021). The analysis can be performed cross-platform on a personal computer with 64-bit processing architecture.

The overall methodology used is summarised in the flowcharts in Figure 2. A full list of data and software used, as well as a link to view the Python scripts, can be found in Appendix A and Appendix B.

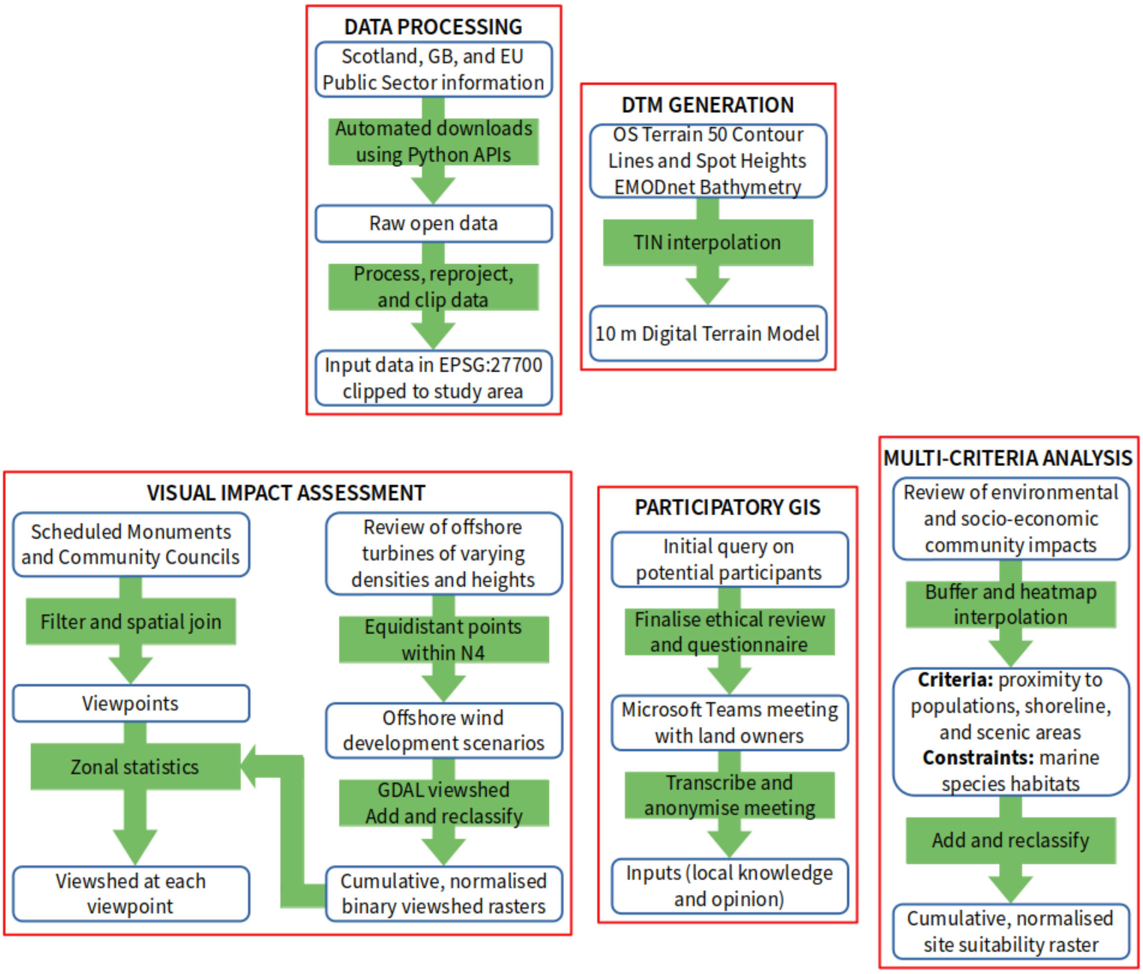


Figure 2: Flowcharts summarising the computational and GIS methodologies used.

Study area

The SMP Plan Option polygons were downloaded from Marine Scotland. Using the GeoPandas Python library, the dataset was filtered to include only site N4, and then reprojected into EPSG:27700. The resulting polygon was opened using the QGIS user interface, with Ordnance Survey's 1:250 000 Scale Colour Raster for the Isle of Lewis area, comprising of the NA, NB, and NG British National Grid 100 km tiles added as a basemap for context.

A study area around site N4 is determined to confine the analysis to a limited area, which enables the analysis to focus on the impacts on the communities closest to the shore, as well as improve the computational efficiency of the analysis by using a subset of all data available. An initial enquiry on the profiles of the landowners interested in taking part in this project was done to find their locations of interest. These locations were found on the basemap to be within a 15 km buffer from the edges of site N4; as a result, the area occupied by this buffer is selected as the final study area. The buffer was created and saved as a polygon using Python.

In order to provide additional context to the study area, boundaries representing community councils, which are statutory bodies independently run by volunteer residents representing communities (Comhairle nan Eilean Siar 2021), were used. These were downloaded, along with the Ordnance Survey Boundary-Line™ administrative boundary data, using a Python script, with the 15 km buffer serving as a mask to clip the data to the study area.

A map showing these community councils within the study area can be seen in Figure 3. Based on the map, eight community council areas are affected: Airidhantuim, Barvas and Brue, Bernera, Breasclete, Carloway, Ness, Shawbost, and Uig. It can be observed that the overlayed community council polygons do snap some areas, particularly the small islands close to Bernera and Uig, which was also noted in the data download source. As a result, if these polygons are used to cluster points, some data points will be out of bounds. This will be rectified in the sections below.

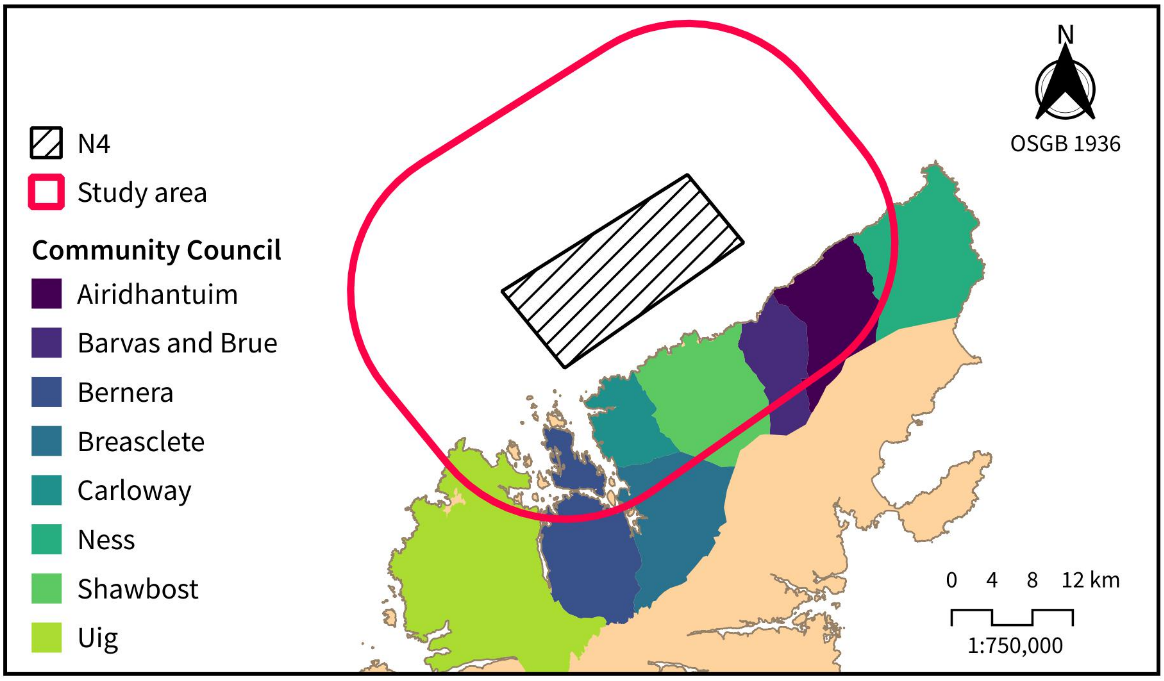


Figure 3: A map showing the location of Sectoral Marine Plan option N4 and the study area boundary relative to community council areas in the Isle of Lewis.

Digital terrain model

A DTM for the study area was then generated. A number of data sources were consulted, including high-resolution (50 cm to 2 m) LiDAR elevation models by the Scottish Environment Protection Agency (Scottish Remote Sensing Portal 2019). However, once merged, the DTM was 12 GB large and did not include part of the study area near Bernera and Uig. Ordnance Survey's OS Terrain® 50 dataset includes 10 m contour lines together with a number of spot heights, which can be interpolated to generate a much smaller DTM of 10 m resolution. However, this only covers the land area. Bathymetry data covering the study area was not available; as a result, the EMODnet Digital Bathymetry DTM in ASCII raster format was used. The bathymetry data had a resolution of 81 m and the EPSG:4326 CRS.

To derive elevation data from the bathymetry layer for the interpolation, the raster was first converted into points using QGIS's raster pixels to points algorithm. Then, the points were reprojected into EPSG:27700. After clipping the elevation datasets to the study area, a 10 m DTM (pixel size of 10) was generated using QGIS's triangulated irregular network (TIN) interpolation algorithm. The resulting DTM can be seen in Figure 4.

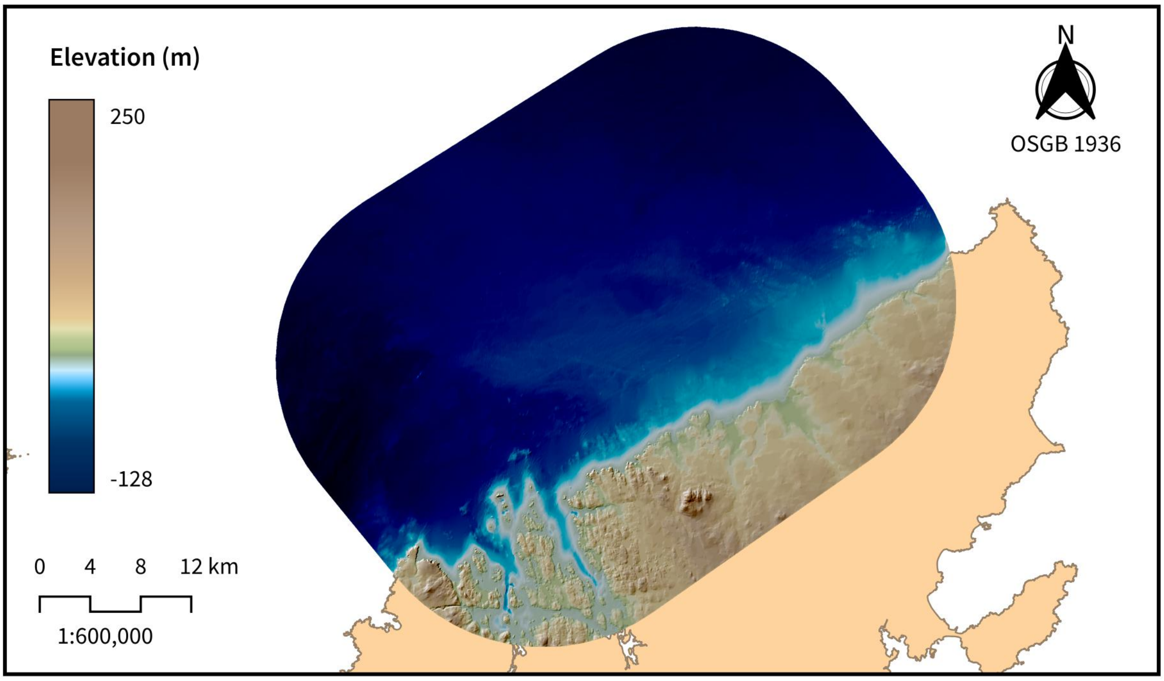


Figure 4: A map showing the digital terrain model of the study area.

Visual impact assessment

Scenario development

To assess the visual impacts of offshore wind turbines on the island communities, a number of scenarios representing wind farm development alternatives were constructed. Since there have not been any applications by developers to construct a wind farm at site N4 thus far, there is possibility to explore a large number of scenarios. To limit this, a number of constraints were first defined. This project's focus is on the impacts of development at site N4 on communities. Therefore, the site's suitability in terms of electricity grid connectivity, geology, meteorology, atmospheric conditions, etc. are deemed out of scope of the project.

The technological trends and learning curves, as well as downwind and crosswind spacing are also not within the scope of this project; approximate turbine specifications are used in line with recently established offshore wind farms in Scotland. A list of offshore wind farm projects in Scotland, both operational and under construction, are shown in Table 2. This table includes information about the capacity of turbines used, the height of these turbines, and the minimum spacing between turbines, compiled from publicly available development specification and layout plans available on Marine Scotland (Beatrice Offshore Wind Farm Ltd 2016; Department for Business, Energy & Industrial Strategy 2021; Inch Cape Offshore Limited 2021; Moray Offshore Windfarm (East) Limited 2020; Moray Offshore Windfarm (West) Limited 2021; Neart na Gaoithe Offshore Wind 2020; Seagreen Wind Energy Ltd 2020). The heights are measured to the tip of the turbine from either the lowest or highest astronomical tide, or both, depending on the specification document. The lowest astronomical tide measurements were around 5 m more than the highest astronomical tide measurements.

Table 2: List of offshore wind projects in Scotland in the last decade, compiled using development specification and layout plans available on Marine Scotland.

Name	Turbine capacity (MW)	Turbine height (m)	Turbine spacing (m)
Beatrice	7.000	187.0	945.5
Neart na Gaoithe	8.000	208.0	907.0
Moray East	9.525	198.9	1,128.0
Seagreen	10.000	205.0	1,042.0
Moray West	10.000	230.0	1,050.0
Inch Cape	15.000	291.0	1,278.0

Based on this table, offshore turbines up to 291 m and 15 MW are being erected in Scottish waters, with no turbine less than 187 m and 7 MW in the last decade. The spacing between turbines tend to increase with increasing turbine heights and rated power (which also means larger blades and rotor diameters). However, while the spacing is generally in the order of a 1,000 m, there is no clear correlation of the spacing with the height and capacity of the turbine. The spacing is additionally influenced by the total area available for the wind farm development.

The specification and layout plans also detail the water depths below the lowest astronomical tide at the development site, which ranged from 38-59 m. To gain a general understanding of the seabed's condition at site N4, a histogram showing the depth distribution of the area was obtained using the DTM's pixel values, which is shown in Figure 5. With a mean depth of 53 m and the entire range within three standard deviations, site N4's depth profile is similar to that of the other offshore wind farm projects.

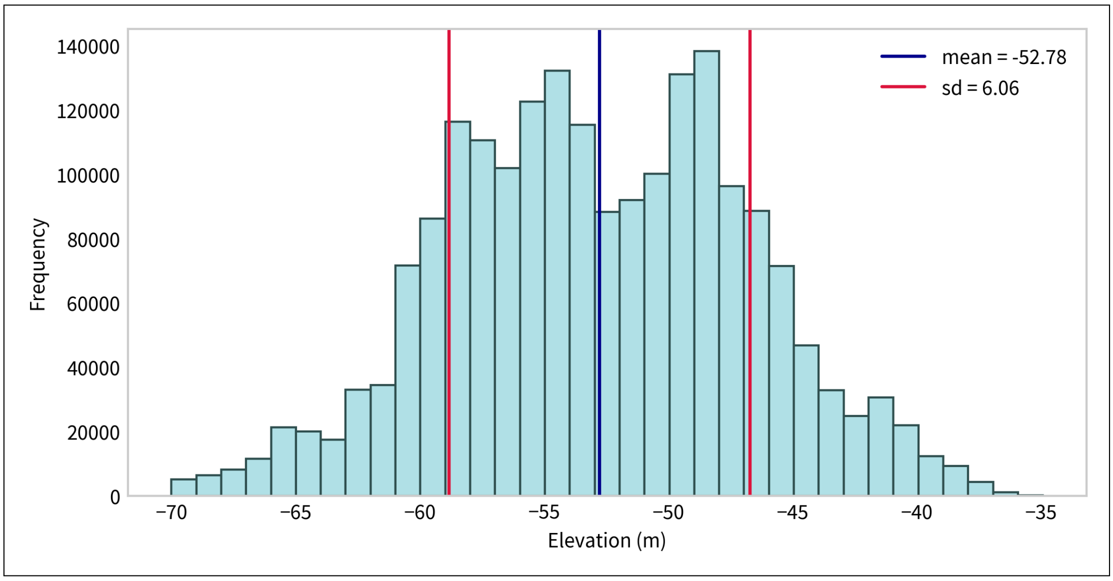


Figure 5: A histogram showing the distribution of water depth within site N4.

Once the draft SMP was released in December 2019, NatureScot published a response to their consultation with a design guidance for each Plan Option (Tilbrook and Lees 2020). In this document, they recommend wind turbines of heights less than 200 m to mitigate the significant changes to the landscape and seascape of the Isle of Lewis. Therefore, in this analysis, the maximum turbine height considered is 200 m, with an estimated power rating of 10 MW based on similar turbines in Table 2. Two additional heights are considered: 180 m (8 MW) and 160 m (6 MW). By keeping the number of turbines constant, the effects of turbine height on visual impacts can be quantified. A fixed number of 25 turbines are used for this analysis.

Additionally, scenarios with varying number of turbines are also used to simulate the visual impacts based on turbine density. A constant height of 180 m is used for these turbines, and the number of turbines used are 100, 75, 50, and 25. A summary of these scenarios is shown in Table 3. This gives a total of six unique scenarios, where four are used to compare the effects of varying turbine numbers, and three are used to compare the effects of varying turbine heights.

Table 3: List of scenarios to simulate different number of wind turbines at various heights and installed capacities.

Number of turbines	Turbine height	Turbine capacity (MW)	Wind farm capacity (MW)
100	180	8	800
75	180	8	600
50	180	8	400
25	200	10	250
25	180	8	200
25	160	6	150

For these scenarios to be used as geographical inputs for viewshed analysis, they must first be converted into points. It is assumed that the turbines are distributed in an array of equidistant points. During the actual project planning phase of an offshore wind farms, there will be additional constraints to consider when determining wind turbine placement, such as geological formations, wave conditions, and underwater cabling, which are all out of scope of this research project. There is no straightforward way to generate a certain number of equidistant points inside a polygon. With some trial and error using QGIS's regular points and intersection algorithms, points representing turbines at equal distance were generated. The distances are:

- 2,880 m for 25 turbines,
- 2,000 m for 50 turbines,
- 1,625 m for 75 turbines, and
- 1,400 m for 100 turbines.

All distances are above the 1,000 m range deduced from Table 2. The spatial distribution of these points within site N4 can be viewed in Figure 6.

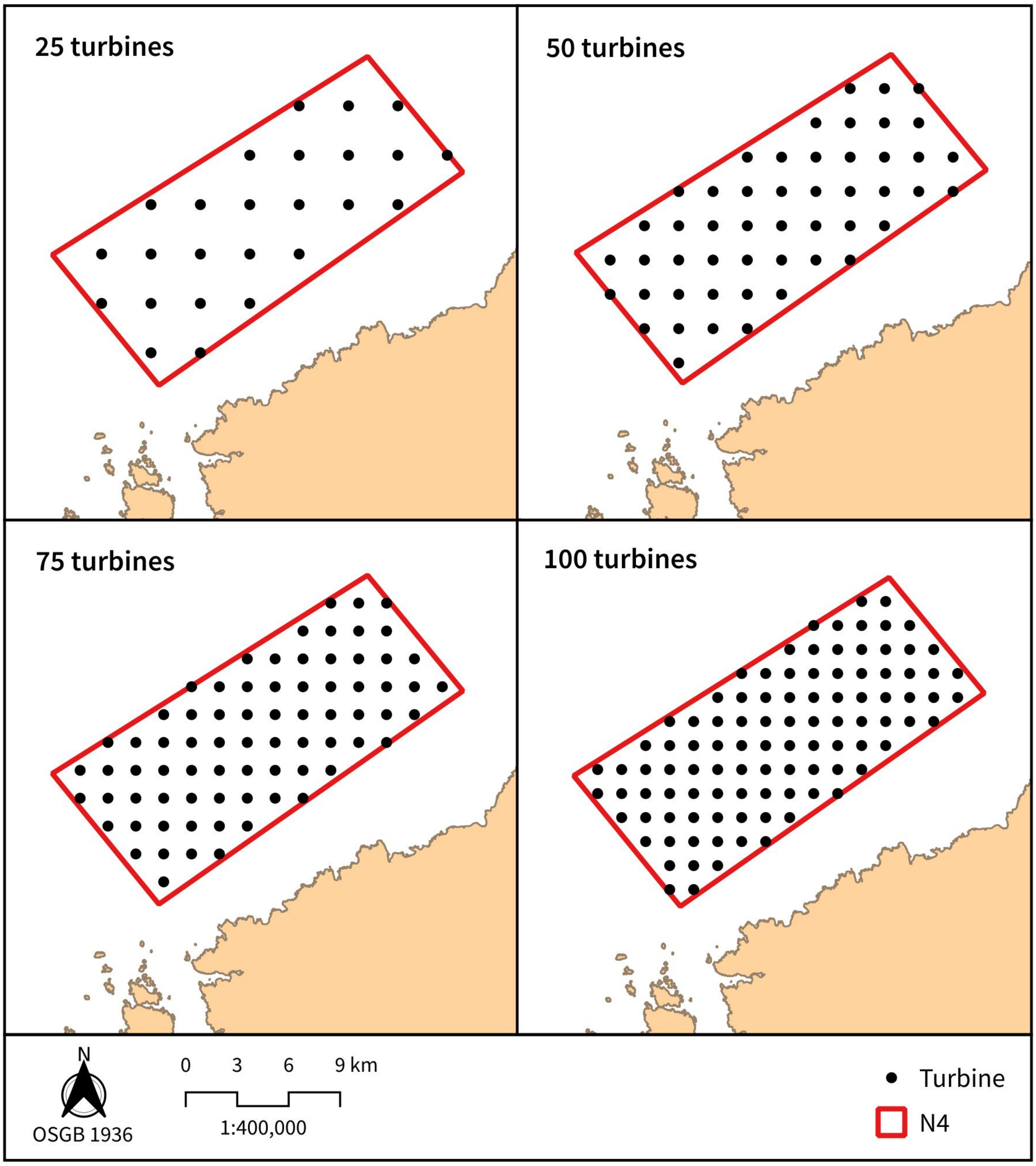


Figure 6: Maps demonstrating the offshore wind development scenarios in terms of number of wind turbines which are distributed equally within site N4.

Viewshed analysis

After the scenarios were developed, a binary viewshed analysis was conducted. This was done using GDAL's viewshed algorithm, which comes preinstalled with QGIS. A number of parameters are defined in this algorithm. The input raster provided is the DTM generated earlier. The observer locations are the wind turbine points. The observer height is the height of the turbine, plus 50 m to take into account the displacement between the seabed and the water surface. Finally, a visibility distance must be provided.

NatureScot's guidance on visual representation of wind farms (NatureScot 2017) recommends a distance of 45 km or more for wind turbines taller than 150 m and all offshore wind turbines in general, for performing ZTV calculations. This distance will cover the entirety of the study area, as it is confined to a 15 km buffer around the borders of the N4 site. A target height of 1.65 m was provided to represent a 1.65 m tall human on the terrain model.

This GDAL algorithm only accepts one observer point per run. Therefore, a Python script, which iterates across each point in the turbine array layer was written. This results in one binary viewshed output (GeoTIFF raster) being produced for each turbine.

To generate a cumulative raster for each scenario, QGIS's raster calculator to add all of the raster layers together. The results were then clipped to the land area using GDAL's clip raster by mask layer algorithm. The resulting raster files will have a continuous scale. To obtain discrete scales, showing areas with negligible, slight, moderate, substantial, and severe visual impacts (as suggested in Falconer et al. 2013), each cumulative raster was reclassified using five discrete classes with values between 0 and 1, where 1 represents severe impact and 0 represents negligible impact.

Viewpoints

To evaluate the visual impacts on specific viewpoints in the study area, cultural heritage data from Historic Environment Scotland was consulted. Scheduled monuments are monuments classed as being important nationally; designations are done by Historical Environment Scotland under Ancient Monuments and Archaeological Areas Act 1979, as well as the Designation Policy and Selection Guidance (Historic Environment Scotland 2021a).

The data was first downloaded from Historic Environment Scotland's API using Python. Using the study area buffer polygon, the data was clipped to the study area. To cluster the monuments into their respective community councils, a spatial join was performed using GeoPandas between the two dataframes, keeping the geometry attributes of the scheduled monuments data. When tested, it was found that two entries, namely Beinn an Teampuill, Little Bernera and St Peter's Church, Pabay Mor, were not assigned a community council area due to the gaps present in the community council boundary data. By cross-referencing these points with Canmore data (Historic Environment Scotland 2021b), they were assigned into Bernera and Uig, respectively.

The study area has a total of 41 scheduled monuments spread across the different community councils, as shown in the chart in Figure 7. There were no viewpoints available that intersected the study area and the Barvas and Brue community council. The types of scheduled monuments available include prehistoric standing stones, homesteads, and brochs. Due to the need to preserve these monuments in their original states and their positions in the outdoor landscape of the study area, one monument from each community council (except Barvas and Brue) will be chosen as the viewpoint to calculate zonal statistics.

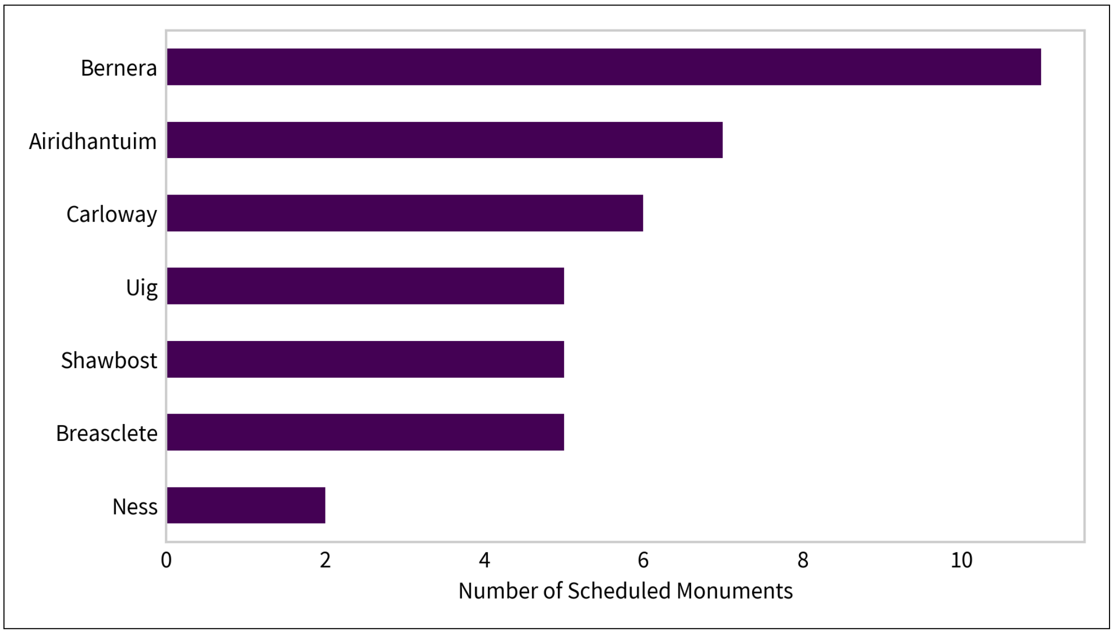


Figure 7: A chart summarising the number of scheduled monuments in each community council intersecting the study area.

The final viewpoints were selected based on the prevalence of photographic data available on Wikimedia Commons and Geograph (Geograph Britain and Ireland 2021; Wikimedia 2021) (which indicates the popularity of certain sites), as well as some inputs from community landowners during the participatory GIS session. These viewpoints were filtered from the scheduled monuments data using Python. The distribution of the viewpoints is shown in Figure 8, while photographs of viewpoints can be seen in Figure 9 and Figure 10.

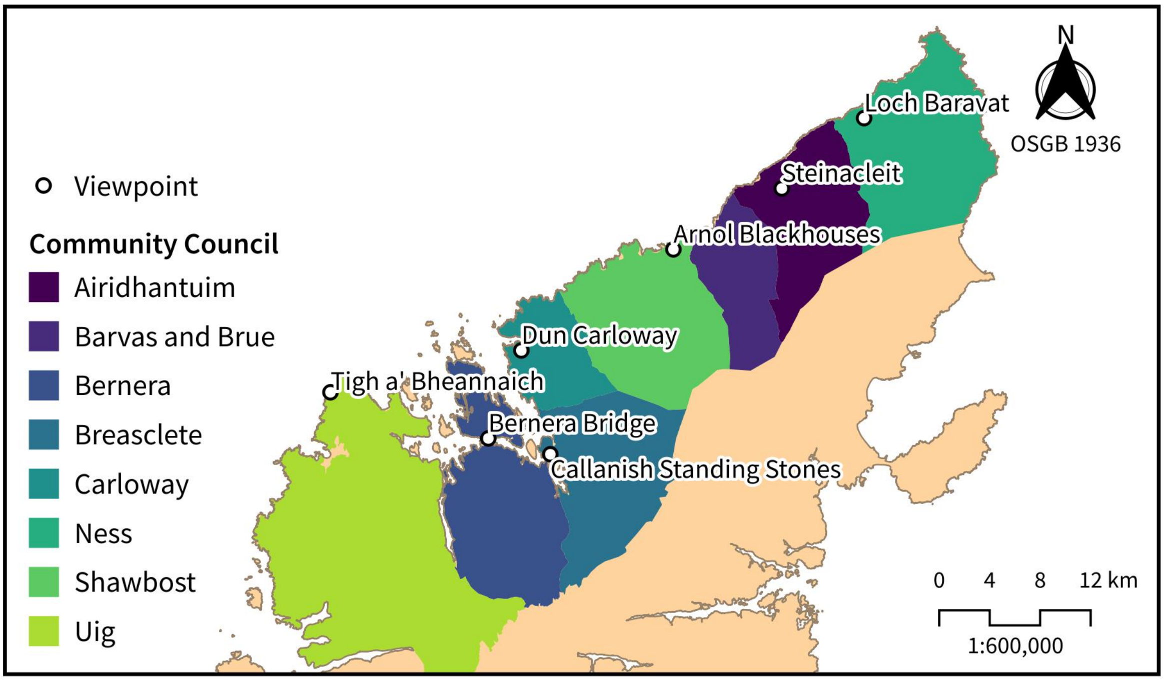


Figure 8: A map showing the location of viewpoints in each community council that intersects the study area.

The scheduled monuments data were polygon features, so the viewpoints must be converted to point features. This was done using QGIS's centroid algorithm. To calculate zonal statistics for each viewpoint, a buffer of 100 m was applied to each point. Finally, zonal statistics for each scenario at the viewpoints were calculated by iterating over the six normalised viewshed rasters and applying QGIS's zonal statistics algorithm. The statistics calculated are minimum, maximum, mean, and standard deviation.

Callanish Standing Stones, Breascelte (121301, 932992), SM90054. Photo: CC-BY-SA-3.0 - © Otter - Wikimedia Commons. 10 June 2009. https://commons.wikimedia.org/wiki/File:Calanais_Standing_Stones_20090610_01.jpg.

Bernera Bridge stone setting, Bernera (116385, 934255), SM5548. Photo: CC-BY-SA-2.0 - © F. Leask - Geograph. 8 June 2007. https://www.geograph.org.uk/photo/602195.

Arnol Blackhouse and associated croft houses, Shawbost (131057, 949253), SM90022. Photo: CC-BY-SA-2.0 - © M J Richardson - Geograph. 27 May 2016. https://www.geograph.org.uk/photo/4988136.

Loch Baravat dun, North Galson, Ness (146172, 959665), SM5454. Photo: CC-BY-SA-2.0 - © Dave Fergusson - Geograph. 29 September 2007. https://www.geograph.org.uk/photo/573109.

Figure 9: Photographs of viewpoints in Breascelte, Bernera, Shawbost, and Ness within the study area. All viewpoints are designated scheduled monuments.

Dun Carloway broch, Carloway (119002, 941231), SM90110. Photo: CC-BY-SA-2.0 - © Tom Parnell - Flickr/Wikimedia Commons. 25 February 2019. https://commons.wikimedia.org/wiki/File:Dùn_Chàrlabhaigh_(40814409303).jpg.

Steinacleit homestead and field system, Airidhantuim (139652, 954086), SM90284. Photo: CC-BY-SA-4.0 - © Andrew Gray - Wikimedia Commons. 11 April 2018. https://commons.wikimedia.org/wiki/File:Outer_Hebrides_-_Steinacleit_-_20180411114215.jpg.

Tigh a' Bheannaich chapel, Uig (103870, 937914), SM5390. Photo: CC-BY-SA-2.0 - © Marc Calhoun - Geograph. 31 May 2001. https://www.geograph.org.uk/photo/683286.

Figure 10: Photographs of viewpoints in Carloway, Airidhantuim, and Uig within the study area. All viewpoints are designated scheduled monuments.

Site suitability assessment

MCA was used to evaluate the suitability of the area within site N4 for commercial-scale offshore wind development. The suitability is analysed in terms of impacts on the community; the lower the impact, the higher the suitability. Based on the review of recent literature (Abdel-Basset et al. 2021; Deveci et al. 2020; Gavériaux et al. 2019; Mahdy and Bahaj 2018; Mekonnen and Gorsevski 2015; Tercan et al. 2020; Vasileiou et al. 2017), two categories of community impact assessment criteria were identified: socio-economic, such as population and recreational activities; and environmental, such as marine habitats and scenic views. As the focus is on community impacts, site N4's suitability in terms of geology, meteorology, and other natural conditions are omitted from this analysis.

The proximity to the shoreline, scenic areas, and populated areas are factors that influence visual and noise impacts. Meanwhile, installation of offshore turbines must be prohibited where marine species are present, as this is a constraint. A visual representation of the criteria used is shown in Figure 11.

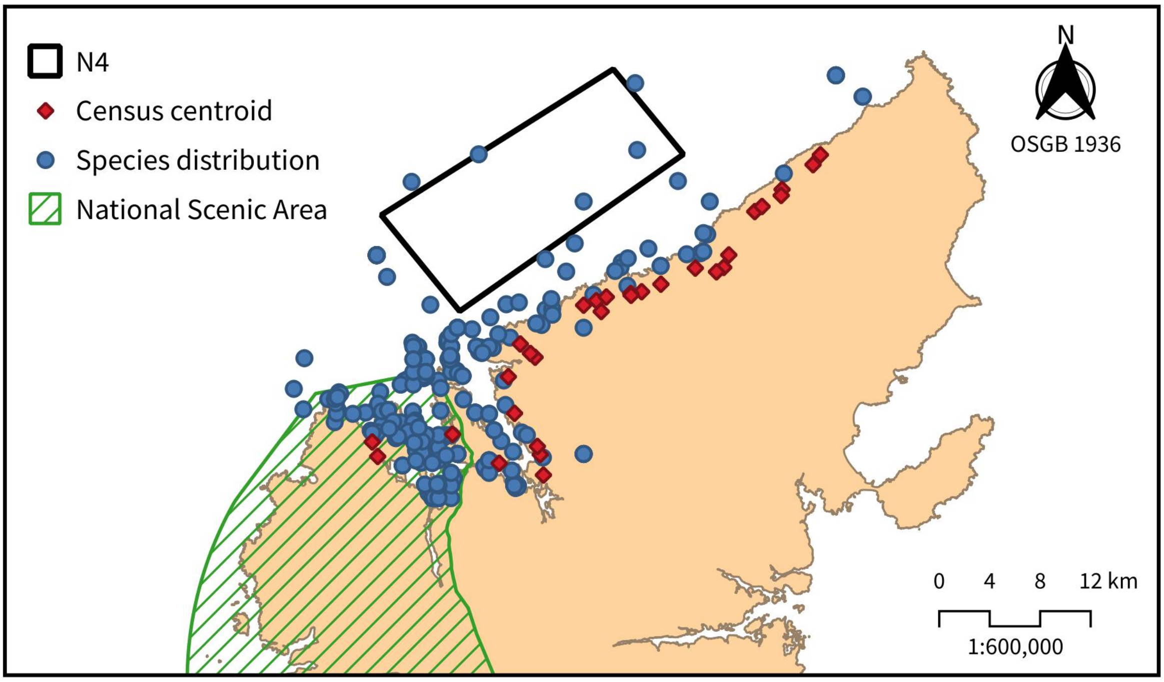


Figure 11: A map showing the locations of census centroids, species distribution, and National Scenic Areas relative to site N4. These are used as criteria, in addition to the coastline, in the MCA study.

Using QGIS, the OS Terrain 50 land-water boundary lines which use the mean low water levels were used as the shoreline. The National Scenic Areas dataset, which comprises of polygons, was used to represent the scenic areas. The multi-ring buffer algorithm was then used to calculate the proximity to scenic areas and the shoreline, using 5 km buffer intervals, which is based on the 3-mile value used by Mekonnen and Gorsevski (2015). The generated buffers were then rasterised to GeoTIFF files of the same resolution as the DTM. The population data was based on Scotland's 2011 census output areas and their population-weighted centroids. Heatmaps were used to interpolate the population data from the centroids, which also produces a raster layer.

After clipping the rasters to the study area, they were normalised to a scale of 0 to 1, where 1 is most suitable and 0 is least suitable. The normalised rasters were then reclassified into five discrete classes, which represent "very high", "high", "medium", "low", and "very low". The higher the distances to shore and scenic areas, the lower the anticipated impacts on the community; therefore, the higher the suitability for offshore development. Conversely, the higher the interpolated population value, the higher the anticipated impacts on the community; therefore, the lower the suitability for offshore development.

The reclassified raster layers were then added to produce a cumulative raster through the use of the raster calculator. Finally, buffers were created around marine species distribution points, which were weighted by their species count attributes. 1 km exclusion zones were then created to remove these constraints from the site suitability analysis.

Participatory GIS

A participatory GIS session was held to solicit local knowledge and opinions from a number of landowners within the study area who will be affected by offshore wind development at site N4. This was an online meeting for two hours done in a General Data Protection Regulation (GDPR) compliant manner using the University of Aberdeen-provided Microsoft Teams account. As a supplementary visual aid, a web map created using ArcGIS Online, containing layers of cultural, natural, and marine features in the study area, was presented to them. The local knowledge obtained through this session is used to complement and adjust inputs used for the visual impact assessment and MCA, such as viewpoint selection.

An initial consultation took place with a representative of the landowners to survey the number of participants interested, as well as whether there are any special accessibility requirements for the session. This survey was used to develop a full ethical review, which was then submitted to the university for approval. The university data protection office was also contacted for advice. Once approval was granted, the landowners were contacted and the meeting was arranged.

In line with the university's recommendations, the session was planned to be recorded using Microsoft Teams, which was then transcribed into qualitative data. The participants were informed of this beforehand, as well as notified that their participation is voluntary and that they may withdraw at any point. Once the necessary data was transcribed, the recording was securely deleted to minimise risks and protect the privacy of the participants.

The questions listed below formed the basis of the discussion during the participatory session:

1. Which settlement are you based in?
2. What are the most important economic activities, heritage sites, and scenic views in your settlement and the Isle of Lewis in general?
3. In your opinion, what are the biggest advantages and disadvantages of developing the N4 site into an offshore wind farm to your settlement and Lewis communities in general? Is there anything that concerns you the most?
4. Do you think the study area defined in this project is sufficient to capture the impacts on your settlement and community?
5. Can you rank the offshore wind farm development criteria for the N4 site from most to least important in the context of your settlement as well as Lewis communities in general? Criteria include proximity to heritage sites and protected areas.
6. Do you believe there are any development criteria that may have been overlooked or are missing from this analysis?
7. Based on the different development scenarios (in terms of number (density) and height

of wind turbines installed), which scenario do you believe is the most appropriate for Lewis communities?

8. What are the most important viewpoints to various visual receptors in the affected area (i.e. the people in your settlement, Lewis communities in general, and visitors)?
9. Are there any sites and important scenic viewpoints that you would consider more important than the others? What are the reasons for your choices?
10. What are the most important landscapes and seascapes in the affected area? Have there been any significant changes to these (both naturally and through human activity) over time?
11. Do you anticipate any other positive or negative impacts if site N4 was to be developed?
12. Were you consulted at any point during the development of the Sectoral Marine Plan for Offshore Wind (2020)? If yes, please provide some details on the consultation method, frequency, and information provided.
13. There is a significant change between the scoping area and final plan option of site N4 published in the Sectoral Marine Plan. What is your opinion on this?
14. Has there been any other public engagement once the N4 site was proposed? What are your expectations for future engagement?
15. What was your experience in using the web map provided during this session? Was it easy to use and interpret, and did it help you visualise the affected areas?
16. Do you have any feedback on how this session can be improved? Additionally, do you believe a participatory GIS framework can be used to improve public engagement in the future?

The landowners were informed that they may provide rankings to indicate the relative importance of factors (e.g. in a scale of 1 to 10, where 1 is least important and 10 is most important). Additionally, they were able to use the web map, which supports anonymous public data collection, to directly indicate locations of interests and optionally add points, lines, and polygons of important locations.

A participant information sheet and consent form was developed and provided to the participants ahead of the meeting. The participant materials can be viewed in Appendix C.

CHAPTER 4

Results

Participatory GIS

The following summary details the responses received from the community landowners during the participatory GIS session. The responses are by the group and not tied to any particular landowner that participated.

The session started off by showing the web map to the participants and asking them to explain which areas they are familiar with and can provide local knowledge. At that time, the Ordnance Survey Boundary-Line™ was used to provide a backdrop for the data points in the study area. The landowners suggested using the Deer Management Plan map (Association of Deer Management Groups, Scotland 2021), which shows land estate boundaries in the Isle of Lewis. Since community land ownership is an important part of the Outer Hebrides, these estate boundaries are highly relevant to their local knowledge concentration. The map is however in PDF format, so GIS data must either be digitised by hand or obtained through contacting Deer Management groups.

When asked about any existing consultations with stakeholders regarding the SMP, they stated that one public meeting was held, but there was very little awareness of the meeting actually taking place. Therefore, none of the landowners attended it. When asked about the factors that influenced the significant changes seen between the draft and final Plan Options, there were no comments, as there was even less awareness during which the draft plan was published in December 2019.

The landowners were then asked about the potential offshore wind farm scenarios. They were asked whether smaller turbines, which occupy less space, is less prominent, and produces less power output, is preferable to larger turbines, which will be more visible due to size, but produces more clean energy. They responded that the communities have not been consulted regarding any potential scenarios or plans for development, but they anticipate smaller turbines to have a lesser impact overall on the landscape and seascape and would be preferred. However, they usually expect some indications or projections of what different development options will look like from stakeholders. This include having some ideas about the turbine specifications. Since this has not been provided to them at this stage, they do not have much input to provide. They feel that the community are isolated, as apart from the realistic development quoted in the SMP of 1 GW in 200 km^2 of seabed area, no other idea of the scale of development has been provided, other than doing their own simple calculations on the power ratings of different turbines.

Regarding the impacts that they deem most important, they mentioned visual and noise, and that it would be interesting to visualise the effects of differing turbine dimensions on the magnitude of these impacts. They noted that there is potential for national and international interests and oppositions due to N4's proximity to the shore and changing coastal views.

The landowners were then asked about fishing activities. They mentioned that fishing usually takes place between the shoreline and the border to site N4, so the boats do not always intersect with site N4's border. During the summer, some boats travel out of Carloway to do this, and they may go further west to catch fish near the other islands. During winter, crustacean catching is done on the east side of the island. While site N4's boundary intersects with cockles, shellfish, and sandeel habitats where fishing is prohibited, stationary structures of the wind turbines are not expected to cause any adverse effects on these marine organisms; it may as well provide an artificial reef-like environment for them to live. With regards to aquaculture, all farms are inshore and in shallow waters, and there has not been any deep water farms.

When asked if there has been any interest in investing in site N4, they noted that there are some interested parties who are in discussion with the local council regarding the offshore wind development. However, there has been very little communication or publicly available documentation from these parties that can provide information and context to the community. The parties interested are all foreign companies or large, multinational corporations, or groups of companies established in the offshore wind industry. As a result, such a large scale investment is attractive to them, as they have the funds available within the short timeframe. In contrast, community groups usually take a long time to consult with each other and devise plans to raise money for an investment.

They noted that community targets are small in contrast to national targets, which are very ambitious. Since the Crown Estate is in charge of seabed leasing and management, community involvement in marine zones is non-existant. There is, however, a close relationship between the community and onshore wind development. Their biggest onshore wind farm thus far has a capacity of 9 MW from three turbines, which they consider large for community groups.

If N4 is developed, they anticipate that there will be no supply chain benefits during the construction phase of the wind farm, as labour and materials will likely be imported by the corporations involved. They expect there to be operation and maintenance jobs available to the locals once the wind farm is operational, and that the harbour will see collaborations and investments for transportation infrastructure.

They were then asked about important sites in the study area that may be affected by development at site N4. They anticipate ancient cultural heritage monuments, such as blackhouses, Gearannan, Calanais standing stones, and Dun Carloway, will have major impacts. The Calanais stones are an important monument and there are 11-15 other stones that, while not nationally-designated, are still important culturally and economically, as they are attractive to tourists. The entire coastline and beaches are large attractions for both tourists and locals, with the beach in Dalmore being frequently visited by local communities for leisure. There are other cemeteries and archaeologically-important sites around the study area.

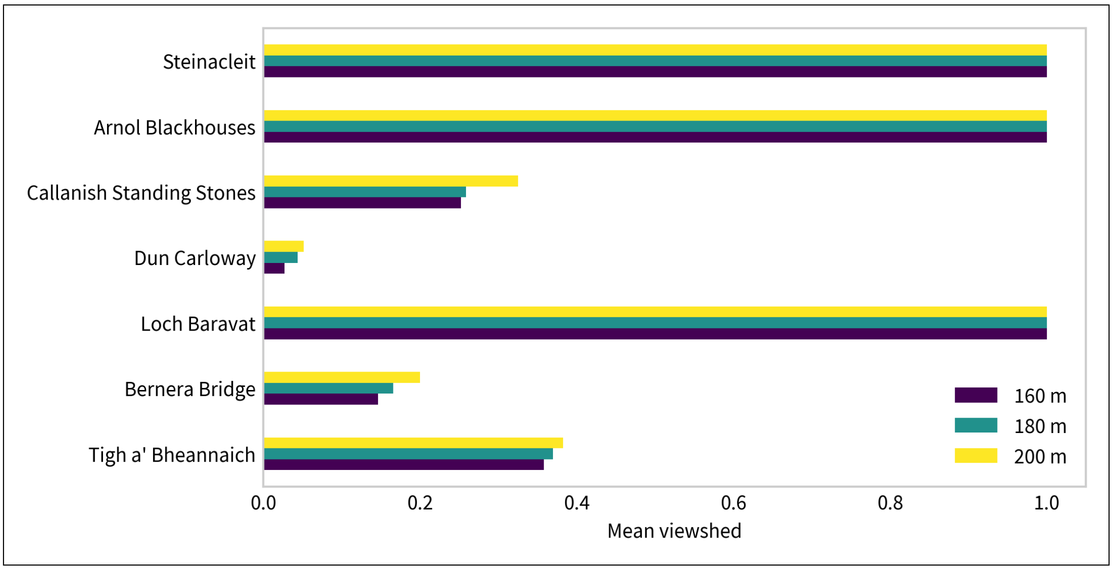
When asked if there are any natural spaces that are as significant as the historic monuments and coastal areas, they mentioned that the NatureScot designated protected areas on the island are land-based areas which are usually inaccessible to most visitors and people in general, but they are important to birds and other terrestrial wildlife. The coastlines have cliffs and sandy beaches that are deemed by the communities as being scenic views.

The landowners also suggested the possibility of quantifying visual impacts on coastal accommodation, to see how it could potentially overnight stays in these buildings which are valued for their views towards the sea. There is no accommodation catalogue that they know of, however, so the data has to be scraped from accommodation sites like AirBnB or approximated based on the Outer Hebrides tourism website.

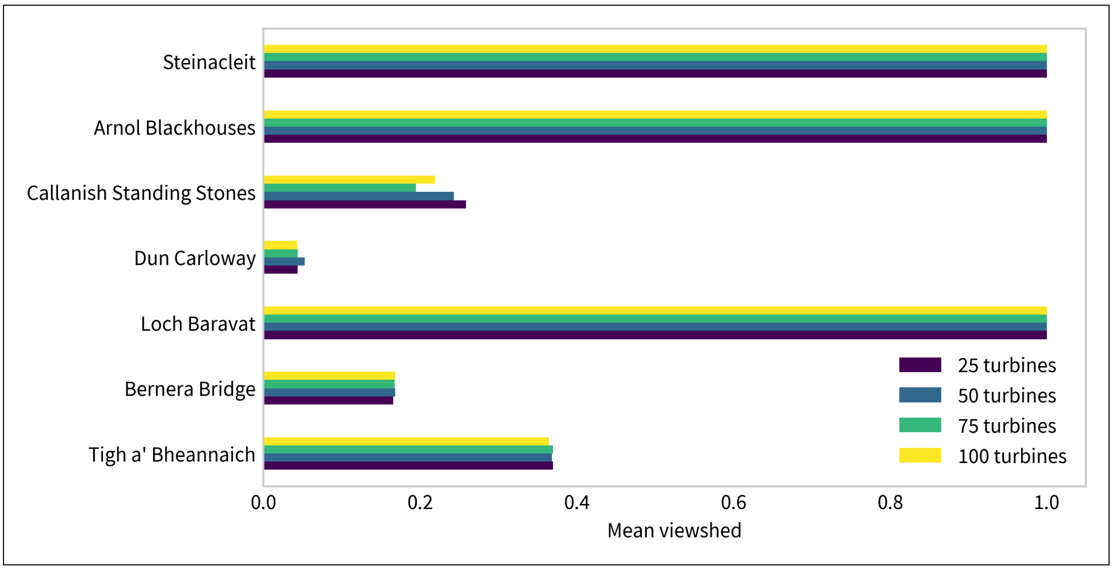
The landowners had favourable opinions regarding the use of the ArcGIS Online web map and found that it was easy to toggle on and off the various layers. They feel that any form of visual aid will greatly benefit community engagement in important policy decisions. They see benefits in using more sophisticated visualisations, such as three-dimensional representations of the different development scenarios from different perspectives, such as cycling route vantage points.

Visual impact assessment

Figure 12 compares the normalised mean viewshed values for each offshore wind development scenario at each viewpoint obtained through zonal statistics. Based on the first chart, which compares varying turbine heights, three of the seven viewpoints (Loch Baravat, Arnol Blackhouses, and Steinacleit) have the maximum viewpoint value of 1, regardless of scenario. From the other four viewpoints, a clear relationship between the turbine height and visibility can be deduced: the taller the turbine, the higher the visual impact. Of these four viewpoints, Dun Carloway had the lowest visual impact, regardless of turbine height. Based on the second chart, which compares varying turbine numbers (which correlates to the density of installation), no clear relationship exists between the number of turbines and visual impact. Similar to the previous chart, three of the seven viewpoints (Loch Baravat, Arnol Blackhouses, and Steinacleit) have the maximum viewpoint value of 1, regardless of scenario, and Dun Carloway has the lowest visual impact overall.



Scenarios comparing varying turbine heights.



Scenarios comparing varying turbine numbers.

Figure 12: Charts showing normalised mean viewshed values obtained through zonal statistics at each viewpoint for each offshore wind development scenario.

In order to compare the zonal statistics with the terrain condition at the viewpoints, the mean elevation at each viewpoint was also calculated, which is shown in Figure 13. Based on this chart, there is no clear relationship between the viewpoint's elevation and the visual impact. Dun Carloway, which had the lowest visual impact overall, has the third highest mean elevation of the seven viewpoints.

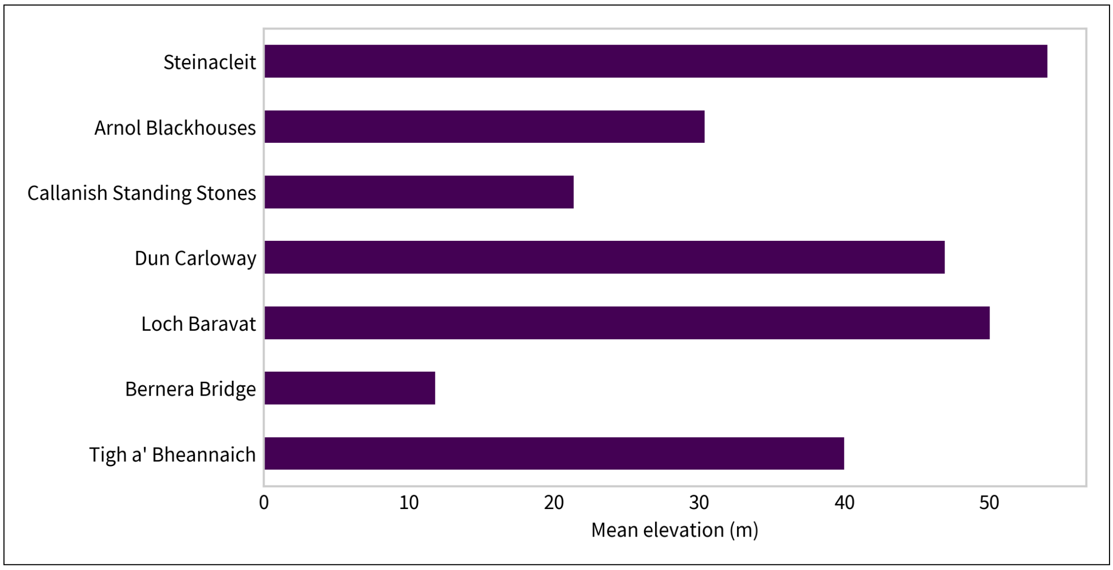


Figure 13: A chart showing the mean elevation obtained through zonal statistics at each viewpoint.

Site suitability assessment

Figure 14 shows the results of the MCA. From this map, the northern parts of N4 are the most suitable overall, while the areas in the south-western side, close to Loch Roag, National Scenic Areas, the coastline, and marine habitats, are the least suitable.

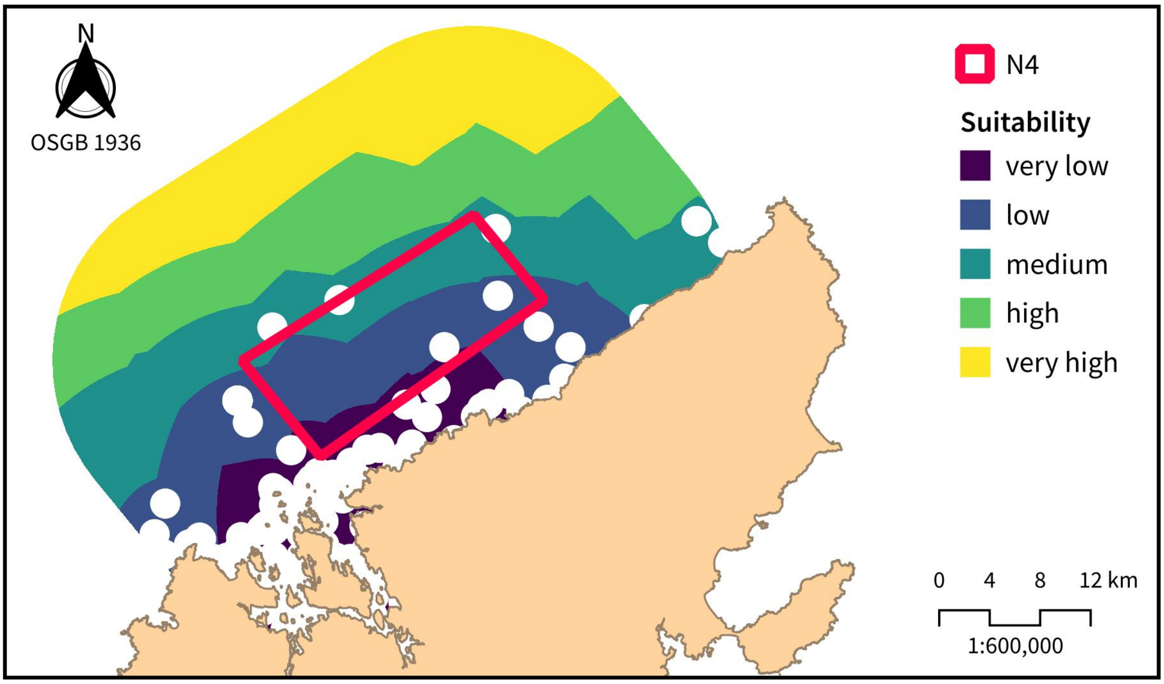


Figure 14: A map of the cumulative normalised raster of the multi-criteria analysis, showing suitability of the study area's waters for offshore wind development from very low to very high.

CHAPTER 5

Discussion

Participatory GIS

The landowners who participated in the discussion recommended the use of the Deer Management Plan map to represent each community. However, it was decided that the community council boundaries are more appropriate for this project, as these boundaries are available under an open-source license in a geospatial data format, which does not require manual digitisation or data requests. Additionally, community councils are statutory bodies, and are therefore more likely to be used in the public sector for spatial analysis.

Through this session, cultural heritage sites were identified as important sites in the study area. The visual impacts on these sites are important as they are present in the landscape and are frequented by locals and visitors alike. Therefore, choosing designated Scheduled Monuments in each community council area as viewpoints was suitable.

For this session, only five landowners attended. To gather public opinion from a wider range of community members affected by development at N4, there is the opportunity to use a web map with editable data layers for large-scale anonymous data collection, which is a form of crowdsourcing. To reach a wider audience, translation of the map elements into Scottish Gaelic will be necessary.

Visual impact and site suitability assessment

Zonal statistics are used, as the overall cumulative rasters generated for each scenario will have no noticeable differences when viewed at a small map scale. This is due to the size of the land area covered within the study area boundary. Additionally, the relatively large-scale of offshore wind farms compared to other marine structures, such as aquaculture sites, means that even the smallest offshore wind turbine will have a significant impact on the landscape and seascape. Zonal statistics provide the viewshed at each viewpoint, which allows for the scenarios to be compared more effectively.

Based on Figure 12 and Figure 13, no clear relationship is found between the elevation of the viewpoint sites and the visual impact. There could be other factors influencing the visibility of the turbines at these sites, such as the aspect, which is worth exploring in the future. Additionally, there is opportunity to repeat the analysis using a DTM generated using higher resolution data, or LiDAR elevation models, which will allow comparison of different interpolation methods and data quality on the results.

The scenarios investigated all occupy the entire space of N4 as equidistant points. By combining the site suitability assessment through MCA, further scenarios which concentrate the turbine installations in the northernmost vertex of N4 could be investigated. This will allow the evaluation of developing a small part of N4 which is deemed more suitable than the rest of N4's area.

This approach is also technologically-neutral, where turbine specifications are not defined in detail, apart from the height. Using turbine manufacturing trends and technology learning curves has the potential to develop many additional scenarios for comparison.

CHAPTER 6

Conclusion

The aim of this research project was to investigate the impacts of a commercial-scale offshore wind farm development inshore of the Isle of Lewis of the Outer Hebrides in Scotland on the island's communities. The site of concern is called site N4, which is one of the plan options outlined in the Sectoral Marine Plan for Offshore Wind Energy, published by the Scottish Government in October 2020.

Due to the close proximity of this site to the northern shoreline of Lewis, as well as the island being renowned for cultural heritage, scenic views, and a distinctive coastline, it is expected to cause a number of adverse impacts on the local communities. The communities rely heavily on tourism, land ownership, and crofting as main economic activities, which are in danger of being drastically impacted due to landscape and seascape changes pertaining to the wind farm development.

To assess the magnitude of these impacts, this project utilised open-source data and geospatial software packages to conduct a viewshed analysis for visual impact assessment, a multi-criteria analysis (MCA) to assess the offshore wind site suitability, and a participatory GIS session to gather opinions and local knowledge from community members regarding development at site N4.

Through the visual impact assessment, it was deduced that taller turbines are anticipated to produce a larger visual impact, while there is no clear correlation between the number of turbines and visual impact. From the MCA, the northern areas of site N4 were found to be the most suitable for commercial-scale offshore wind farm development, as they are furthest away from populations, the coast, and scenic areas. Developing a small portion of site N4 towards the northern areas may be a compromise between minimising community impacts and increasing renewable energy genration. The participatory GIS session with landowners affected by site N4 showed that the use of GIS tools, such as web maps and geovisualisations, in stakeholder sessions with community members can serve as useful visual aid to help them understand the scale and impacts of large-scale offshore wind farm development, as well as increase their engagement.

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APPENDIX A

Data

Dataset references

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Copyright information and disclaimer

Bathymetry data used in this project was made available by the EMODnet Bathymetry project, funded by the European Commission Directorate General for Maritime Affairs and Fisheries. The data originators are the United Kingdom Hydrographic Office (UKHO), Ocean-Wise Limited, and the General Bathymetric Chart of the Oceans (GEBCO).

All data used in this project are not to be used for navigation or for any other purpose relating to safety at sea.

APPENDIX B

Software

Python scripts

Python scripts used in the analysis are available in the following GitHub repository: https://github.com/nmstreethran/community-energy.

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APPENDIX C

Participant materials

The following pages contain the participant information sheet and consent form for the participatory GIS session.

The participatory session was in the form of a two-hour meeting with five landowners held online through Microsoft Teams.

The ArcGIS Online web map used during this session can be accessed using the following link: https://www.arcgis.com/home/webmap/viewer.html?webmap=43bce1bc4a9b4faabb250838d6d3ec3f.

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PARTICIPANT INFORMATION SHEET

Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities

My name is Nithiya Streethran. I am a Master of Science (MSc) student in Geographical Information Systems (GIS) at the Department of Geography & Environment, University of Aberdeen[1]. I would like to invite you to consider participating in the research project **"Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities"**. Below is some information about the project, to help you decide whether you would like to take part.

Participation in the research project is completely voluntary. You can withdraw from the project at any time, without having to give a reason.

AIMS

The Sectoral Marine Plan for Offshore Wind Energy[2], published by the Scottish Government in October 2020, shows a number of commercial-scale offshore wind development plan options around Scotland. One of these options, called N4, is significantly close to the northern/northwestern coast of the Isle of Lewis in the Outer Hebrides. According to the plan, N4 has a total area of 200 km^2 and can potentially generate a maximum of 1 gigawatt (GW) of wind power. The closest edge of the N4 site is less than 5 km away from the shore. The site is in close proximity to a number of towns with community land ownership, sites of historical and natural significance, and tourist attractions.

This study aims to evaluate the visual and environmental impacts of a number of offshore wind farm development scenarios in site N4 on the coastal areas affected in the Isle of Lewis. A number of GIS methods will be utilised, including multi-criteria analysis, viewshed analysis, and participatory GIS. The latter involves a session in which you will participate alongside other affected landowners to provide inputs as a group. The potential participants are landowners from [redacted].

Through the participatory GIS session, I aim to obtain your views and local knowledge on a number of scenarios of the proposed offshore development and the affected areas, including coastal activities, and scenic views. Your inputs will be valuable in improving my initial evaluation of the site and impacts. All of these will form the basis of an interactive and accessible web map to further improve community engagement, transparency in the decision making process, and inform all stakeholders should there be further discussion on the development of site N4.

[1] https://www.abdn.ac.uk/
[2] https://www.gov.scot/publications/sectoral-marine-plan-offshore-wind-energy/

Note: This research project will be submitted to the University of Aberdeen as my dissertation in partial fulfilment of the requirements for the degree of MSc in GIS.

WHAT YOU WILL BE ASKED TO DO

I will first distribute this information sheet and the accompanying consent form to you on Tuesday, 29th June 2021. Once you go through both documents, and if you are willing to participate in this research project, you may fill in and sign the consent form. If you have any questions or concerns regarding this project, you may contact me via email[3]. Please return the completed forms to me prior to the start of the participatory GIS session, if you wish to participate.

On Wednesday, 30th June 2021 at 14:00, we will have an online participatory GIS session where you and fellow landowners will be presented with scenarios of the proposed development and asked to provide your inputs as a group. This session will be conducted using an online video conferencing platform (Microsoft Teams[4]). Additionally, you will have access to an online map created using ArcGIS Online[5], which will allow you to visualise the development scenarios and affected areas, as well as add your local knowledge by drawing directly on the map.

The online meeting and web map can be accessed through a modern web browser (such as Mozilla Firefox, Microsoft Edge, and Google Chrome). You may alternatively choose to use the Microsoft Teams application for the online meeting. You will be sent an invitation with a link to the meeting and web map via email.

The session is expected to take approximately two hours of your time.

RISKS

To ensure that the discussion remains relevant to the topic, is within the scope of the project, and is not affected by differing views and opinions, the session will be structured with a series of questions, detailed maps, and visualisations. I will also provide you with instructions on how to access, view, interpret, and add data to the web map.

Note: You may refrain from providing answers to any particular question or withdraw from this session at any point. If you have made a mistake in the web map, please let me know and I will remove the incorrect inputs.

DATA MANAGEMENT AND STORAGE

The audio and video of our interactions will be recorded using Microsoft Teams, which is provided by the University of Aberdeen and is General Data Protection Regulation (GDPR) compliant. This data will only be stored securely offline on my computer's hard drive and will not be shared with other parties (other than the research team). I will use these recordings to produce an anonymised transcript, which I will share with you and your fellow participants

[3] n.streethran.20@abdn.ac.uk
[4] https://www.microsoft.com/en-us/microsoft-teams/group-chat-software
[5] https://www.esri.com/en-us/arcgis/products/arcgis-online/overview

for verification. You can request changes to this or request your data to be removed if you wish.

During the participatory session, you will be able to interact with the web map and add your local knowledge in the form of points, lines, and areas. This data will be fully anonymous and synchronised with the online map's database. You may refer to the ArcGIS Platform's GDPR guidance[6], published by Esri UK & Ireland, for more information about how the ArcGIS Online web map's data is protected. Once the session is complete, I will download the database and remove the data you entered from the online server.

At the end of the project and subject to your approval, a fully-anonymised database generated using your inputs may be published on the Aberdeen University Research Archive[7] and/or GitHub[8] with Zenodo[9], as an open dataset under the terms of a Creative Commons Attribution 4.0 License[10].

The project is expected to be completed on Friday, 6th August 2021. Any personal information collected (i.e. email exchanges, participant consent forms, and the Microsoft Teams meeting recording) will be deleted on this day.

CONFIDENTIALITY AND ANONYMITY

The University's Privacy Notice for Research Participants is available on the University of Aberdeen's website[11].

As mentioned above, raw data and the identity of participants will not be released to anyone outside the research team. The data you provide will be analysed and may be used in publications, dissertations, reports or presentations derived from the research project, but this will be done in such a way that your identity is not disclosed.

CONSENT

If you agree to take part in the research, you will be asked to indicate your consent by ticking boxes and adding your signature to the consent form enclosed below.

SPONSORS

In addition to the University of Aberdeen, this research is also done in collaboration with Community Energy Scotland (CES)[12]. CES is an independent registered charity in Scotland which provides support to communities for green energy development. I have not received any financial support from the University of Aberdeen, CES, or any other organisation or funder to conduct this research project.

[6] https://www.esriuk.com/en-gb/legal/gdpr/guidance-on-the-arcgis-platform
[7] https://aura.abdn.ac.uk/
[8] https://github.com/
[9] https://zenodo.org/
[10] https://creativecommons.org/licenses/by/4.0/
[11] https://www.abdn.ac.uk/about/privacy/research-participants-938.php
[12] https://www.communityenergyscotland.org.uk/

Thank you for considering taking part in this research.

If you have any questions about this research please contact me via email[3].

For any queries regarding ethical concerns you may contact the Convener of the Physical Sciences & Engineering Ethics Board at the University of Aberdeen[13].

This research project was approved by the Physical Sciences & Engineering Ethics Board on 28th June 2021.

[13] https://www.abdn.ac.uk/staffnet/research/ethical-review-10645.php

Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities

Consent form for participation in the research project "Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities".

Please complete the form below by ticking the relevant boxes and signing on the line below. A copy of the completed form will be given to you for your own record.

Please Tick Box

- ❒ I confirm that the research project **"Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities"** has been explained to me. I have had the opportunity to ask questions about the project and have had these answered satisfactorily.
- ❒ I consent to the material I contribute being used to generate insights for the research project **"Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities"**.
- ❒ I understand that my participation in this research is voluntary and that I may withdraw from the project at any time (until the point of data analysis) without providing a reason.
- ❒ I consent to allow the fully anonymised data to be used for future publications and other scholarly means of disseminating the findings from the research project.
- ❒ I understand that the information/data acquired (including audio/video recordings) will be securely stored by researchers, but that appropriately anonymised data may in future be made available to others for research purposes. I understand that the University may publish appropriately anonymised data in its research repository for verification purposes and to make it accessible to researchers and other research users.
- ❒ I agree to participate and provide my inputs as a group with the other landowners taking part in this participatory session.
- ❒ I agree to take part in the above project entitled **"Mapping the impacts of a proposed offshore wind development plan on Isle of Lewis communities"**.

Name of participant	Date	Signature
Name of researcher	Date	Signature