How Spatial Information Infrastructures Support the Planning of Wind Farms

OER4SDI

Open Educational Resources for Spatial Data Infrastructures

In this learning material, we will use the real-world use case of planning the extension of a wind farm in the municipality of Lorup in Lower Saxony, Germany, to explore how geoinformation infrastructures support the availability and use of geospatial data needed in the wind farm planning process.

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1. Overview

In this learning material, we will use the real-world use case of planning the extension of a wind farm in the municipality of Lorup in Lower Saxony, Germany, to explore how geoinformation infrastructures support the availability and use of geospatial data needed in the wind farm planning process.

You will learn,

- Why wind farm planning requires easy access to up-to-date, high-quality geospatial data and what kind of data is needed,
- How SIIs facilitate the discoverability, accessibility, and usability of geospatial data that is needed for wind farm planning.

The structure of this tutorial is as follows:

We recommend that you first read the chapter with the background information and then follow the presented workflow for collecting and analyzing geodata with your own computer. Chapter 5 contains questions and tasks that can be used to test and deepen the knowledge acquired.

This tutorial is designed for students and professionals who want to improve their understanding of Spatial Information Infrastructures. We assume that you have some basic knowledge about geospatial data, QGIS and spatial data analysis. You will need about 60-90 minutes to work through this tutorial.

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2. Background

2.1 Wind Farm Planning

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The importance of wind energy as a renewable energy source is evident. Increasing the share of renewable and clean energy in the global energy mix is essential for achieving United Nations Sustainable Development Goals such as SDG 7 (Affordable and Clean Energy). The Federal Government in Germany has set itself a target of doubling the amount of electricity generated from renewable sources by 2030. Wind power will play a major role in this. 2% of the land area in Germany is to be made available for wind power use by 2032

(WindBG 2022)[1] . Expanding and repowering existing wind farms is a cost-effective way to increase energy production.

The planning process for building or expanding wind farms comprises the following steps:

- It begins with the **identification of areas suitable as sites for wind turbines**. Factors are for example the local topographical conditions, distance from residential areas and buildings, nature conservation areas and grid connection options.
- Once the planning area is determined, **wind turbine planning** involves selecting suitable turbines, determining their number, power and height, and optimizing their locations. Consideration of environmental impacts, such as bird protection or noise pollution, is important at this stage.
- The **connection to the power grid** requires a detailed planning of the lines in cooperation with the grid operator. Grid expansion may be necessary to feed the generated electricity efficiently and reliably into the grid.
- Finally, the **profitability analysis** of the project includes the investment costs, the expected energy yield, the operating and maintenance costs, and the expected income from the sale of electricity. Funding opportunities, such as the Renewable Energy Sources Act (EEG), can also play a role.

The wind farm expansion plan must comply with applicable laws and regulations and obtain various permits and approvals. In Lower Saxony, the Lower Saxony State Authority for Road Construction and Transport (NLStBV) is responsible for approving wind farm plannings.

The planning process relies heavily on high quality geospatial data, which is necessary to address the many constraints that apply to wind farm areas. The following are some of the exclusion criteria that are used to assess the suitability of areas for onshore wind energy use[2]:

- no intersection with nature reserves, bird sanctuaries, FFH areas
- no intersection with water protection areas (category I + II), smaller than 2000 hectares
- no intersection with wetlands (moors, swamps) 10 ha or larger
- minimal distance of 400 m from residential buildings outside of settlements
- minimal distance of 400 m from campsites, facilities for sports, leisure and recreation areas

[1] Act on the Determination of Area Requirements for Onshore Wind Energy Systems (Windenergieflächenbedarfsgesetz - WindBG). July 20, 2022, BGBl. I S. 1353.

[2] Lower Saxony Ministry for the Environment, Energy and Climate Protection (2023): Flächenpotenzialanalyse Windenergie an Land in NI (WiNiePot) - Erläuternde Präsentation. 2023-06-07. URL (accessed 2023-09-08): https://www.umwelt.niedersachsen.de/startseite/aktuelles/ergebniskarten-der-windflachenpotenzialanalyse-downloadmoglichkeit-220485.html

- minimal distance from roads and roadside areas (freeways +40m, otherwise +20m)
- minimal distance of 3000 m from Air traffic control facilities (radar and ground navigation facilities)
- […]

In our exercise, we will focus on the first step in the planning process which is the identification of areas that can be used for extending an existing wind farm. We will exemplarily investigate just two of the relevant exclusion criteria: the distance to nature reserves and the distance to buildings with residential use.

So, is the data available in the quality we need for our analysis? How can we find out? How can we get access?

This is where geospatial information infrastructures come into play. They should provide us with all the means to find the data we need, in the form we need it, so that we can easily download and process the data.

2.2 Spatial Information Infrastructures

Spatial Information Infrastructures (SIIs) can be considered as very large and distributed information systems that serve the information needs of large stakeholder groups, often on a regional, national, or international scale. A term used synonymously is Spatial Data Infrastructure (SDI), which puts more emphasis on 'data' as the carrier of information.

Many SIIs have a focus on public sector information. Their purpose is to make public sector data that is collected for a specific application (e.g., management of nature reserves) available and usable for further applications that are of interest for additional stakeholder groups such as other administrations, researchers, companies, and private individuals.

These infrastructures are always managed by one or more organizations on the basis of binding regulations and agreements between the respective stakeholders.

If we take a closer look at SIIs we can distinguish three levels of activities:

- At the **policy level** you'll find the bodies, procedures and artefacts that rule the objectives, the principles, the funding and the implementation of the respective SII (e.g. steering committees, vision statements, laws and regulations, funding instruments)
- At the **organizational level** you'll find the bodies, procedures and artefacts that coordinate the implementation and operation of the SII (e.g., coordination offices, advisory boards, technical working groups, architecture documents, guidelines, state of play reports, organizational agreements, roadmaps, etc.)
- At the **implementation level** you'll find the bodies, procedures and artifacts that make the SII happen in practice. These are, for example, government agencies,

companies, researchers and private individuals who provide and use data, metadata, technical services, portals and applications.

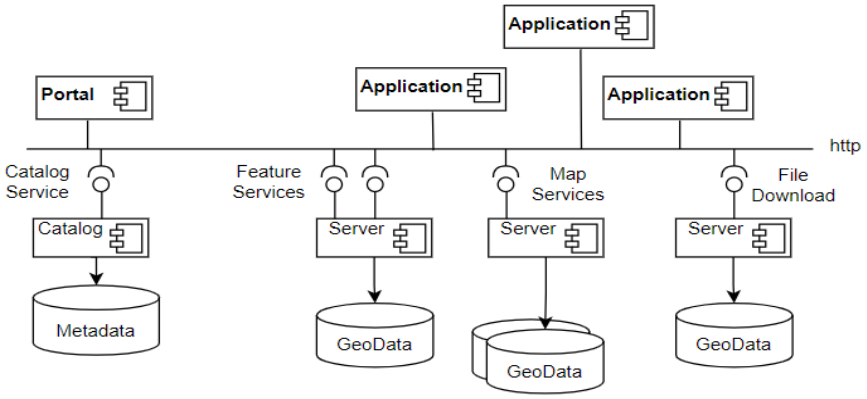

Fig. 1: Technical components of SIIs

The diagram (Fig. 1) shows a simplified overview on the components and interfaces of an SII. The core content is the geospatial data (GeoData) that is distributed over many organizations and information systems in the infrastructure. A mapping and surveying organization may provide topographic maps and data on administrative units, an environmental agency may provide data on protected sites, a XYZ office may provide access to data on 'whatever", and so on. In the best case the data is contributed in well-known data models and formats via web services (e.g. data access, data processing, data visualization) that can be accessed through well-known protocols free of charge from anyone, anywhere, and at any time.
All contributing parties register their datasets and services at one or more catalogs using standardized metadata models and encodings (Metadata). These catalogs may harvest metadata from other catalogs and thus form a system of federated catalogs with at least one central catalog and portal that provides access to all datasets and services that are available in that specific SII.

So far, so good. In practice, not all datasets are online accessible, accessible for anyone, accessible for free. Data may be outdated, with errors, offered with complicated data models and encodings, not meeting your requirements. The metadata may not answer the questions you have on the data, may be outdated as well. Portals may not be user friendly, leading to a low user experience.

So, what is the state of play?

Let's use the case of planning a windfarm in Lorup, Lower Saxony, to learn how we can take advantage from Spatial Information Infrastructures in Germany for acquiring and using data needed for the windfarm planning process.

As you will see, we will specifically address the following spatial data infrastructures:

- **Geodateninfrastruktur Niedersachsen (GDI-NI)**
  The Spatial Data Infrastructure of Lower Saxony (GDI-NI) aims at improving the availability and usability of high-quality public sector geospatial information. It is based on the Lower Saxony Spatial Data Infrastructure Act (NGDIG) that is aligned with national and European laws. It is coordinated by the GDI-NI steering committee, in which all state departments as well as municipalities, industry and science are represented. The central coordination office is located at the State Office for Geoinformation and Land Surveying of Lower Saxony (LGLN). The GDI-NI is also a contribution to the national SII in Germany (GDI-DE) as well as INSPIRE.
  Landing page: https://www.geodaten.niedersachsen.de/startseite/gdi_ni/

- **Marine Geodateninfrastruktur (MDI-DE)**
  The Marine Spatial Data Infrastructure is driven by German authorities with responsibilities for coasts and seas. They organize the provision of data and information services on basic marine data, coastal engineering, marine environmental protection and marine nature conservation in order to jointly fulfill their national and international information obligations.
  Landing Page: https://projekt.mdi-de.org/mdi-de/organisation/

- **Geodateninfrastruktur Deutschland (GDI-DE)**
  The National Spatial Data Infrastructure of Germany (GDI-DE) aims at improving the availability and accessibility of public sector geospatial data. It is organized by the federal government together with the state and local governments. The national geoportal is the central entry point for searching data offerings. Data and services are provided in a decentralized manner by public authorities. The GDI_DE Steering Committee is also the national INSPIRE contact point. The Federal Agency for Cartography and Geodesy (BKG) is responsible for the operation and further development of the national technical components.
  Landing page: https://www.gdi-de.org/

- **INSPIRE**
  The Infrastructure for Spatial Information in Europe (INSPIRE) is designed to support EU environmental policies by facilitating public access to spatial data. The INSPIRE Coordination Team consists of European Commission staff from DG Environment and the Joint Research Centre (JRC), as well as staff from the European Environment Agency (EEA). Its role is to coordinate the implementation and further development of INSPIRE and to coordinate with other EU policies.
  Landing page: https://inspire.ec.europa.eu/

All of these infrastructures have in common that they aim to improve the availability, accessibility, and usability of geospatial data held by public agencies. They always relate to a region and/or to specific topics. And all these infrastructures form a federation of systems

by exchanging metadata with each other as far as this corresponds to their respective goals. While the metadata are collected in centralized metadata catalogs, the data and data services are provided decentrally by the respective data providers.

3. Planning the extension of a wind farm in Lorup, Germany

In this section, we first present the real project of the extension of a wind farm in Lorup, a small community in Lower Saxony, Germany. Then, we will exemplify for this context how to find, download, and integrate the geodata needed for the identification of the expansion areas into the data analysis of the wind farm planning.

3.1 The Lorup Wind Farm Project

Lorup is a small municipality in Lower Saxony with about 3200 residents. Together with a local investor, Lorup built the "Mammoor" wind farm. The first four wind turbines (ENERCON E-66 / 18.70 with a hub height of 98 meters) were commissioned in December 2001. This was followed by a total of 10 more turbines by mid-2004. In 2010, the wind farm was expanded by 5 Enercon E 82 with a hub height of 108 meters.

Fig. 2: Aerial Photo of the Mammoor Wind farm

In 2022, Lorup has decided to plan for the extension of the Mammor wind farm. The consulting company Revento GmbH has been contracted to develop a concept for the extension and repowering of the existing wind farm and to identify potential areas for additional wind farms in the Lorup region.

In our tutorial, we take Revento's perspective and collect and analyze geospatial data to identify areas suitable for the expansion of the Mammor wind farm. More specifically, we'll focus on the following requirements:

- The extension area is located in the Lorup municipality
- Wind turbines (incl. rotor) must not be placed in protected sites
- Wind turbines (incl. rotor) must keep a minimum distance of 400 m to neighboring houses

The criteria refer to the methodology of the current wind area potential study of Lower Saxony[3]. To meet these criteria, we need data on administrative boundaries, protected sites, and buildings. It is also helpful to have data on the existing wind turbines in order to determine the status quo.

We will start with data acquisition. Here we will use Spatial Information Infrastructures to find and download the relevant data. We will then demonstrate how to analyze the data to identify areas that are suitable for wind energy use.

Please note at this point that we have considerably simplified the planning process as it is carried out in Lorup for practical reasons. Both the criteria and the results of the analysis may therefore differ to some extent.

3.2 Data Acquisition

Identifying the precise type of data needed for the task is crucial before looking for and downloading geographic data. Finding geographic data is made easier by using Spatial Data Infrastructures. They enable quick and easy access to a variety of data from many sources, saving time and effort while looking for information.

In this chapter we will explore how to search for and download the raw data that we need from spatial data infrastructures and discuss the experiences that we make.

> *Note: The websites we will be using are primarily designed for German-speaking users, with very limited English language support. To make navigation easier, you*

[3] Lower Saxony Ministry for the Environment, Energy and Climate Protection (2023): Flächenpotenzialanalyse Windenergie an Land in NI (WiNiePot) - Erläuternde Präsentation. 2023-06-07. URL (accessed 2023-09-08): https://www.umwelt.niedersachsen.de/startseite/aktuelles/ergebniskarten-der-windflachenpotenzialanalyse-downloadmoglichkeit-220485.html

can use a German keyboard and the translation function of your web browser to translate the content into English. The screenprints we use are always English translations of the German websites.

3.2.1 Administrative Boundaries

We need the administrative boundaries for our analysis because we want to ensure that the wind farm expansion area is within the boundaries of the municipality of Lorup.

We need up-to-date data that comes in the best case with a defined positional accuracy (e.g. +-5 m) so that we can take this into account in our analysis. To ensure the quality of the data, we want to use reliable sources, preferably government or official agencies responsible for maintaining such information. In Lower Saxony, the State Office for Geoinformation and Land Surveying of Lower Saxony (LGLN) is responsible for providing data on administrative boundaries - a very trustworthy provider. LGLN is also the state office that is responsible for coordinating the Spatial Information Infrastructure in Lower Saxony (GDI-NI).

We can expect that the data is part not only of GDI-NI but of the national Spatial Information Infrastructure (GDI-DE) and of the European Infrastructure for Spatial Information in Europe (INSPIRE) as well. We will use the geoportal of GDI-NI to search for and download the data.

1. Go to the GDI-NI website https://www.geodaten.niedersachsen.de/startseite/

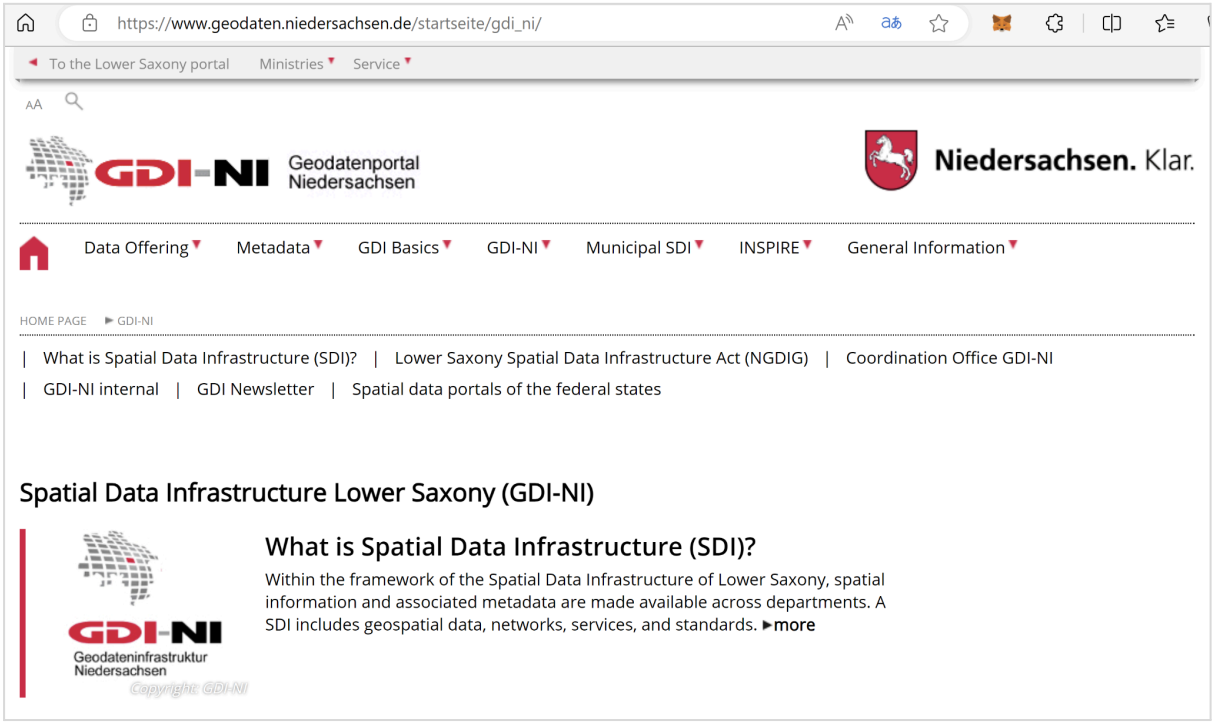

Fig. 3: Landing page of GDI Niedersachsen (GDI-NI)

At the GDI-NI landing page, use the options “Datenangebot” (data offering) and "Geodaten Suchen" (geodata search) from the main menu which will lead you to a website with search options for geodata. The option “Zentrale Geodatensuche”, “Niedersachsen” (central geodata search, Lower Saxony) on the right-hand side will take you to the search catalog, where you can explore the available geospatial datasets (https://geoportal.geodaten.niedersachsen.de/harvest/srv/ger/catalog.search).

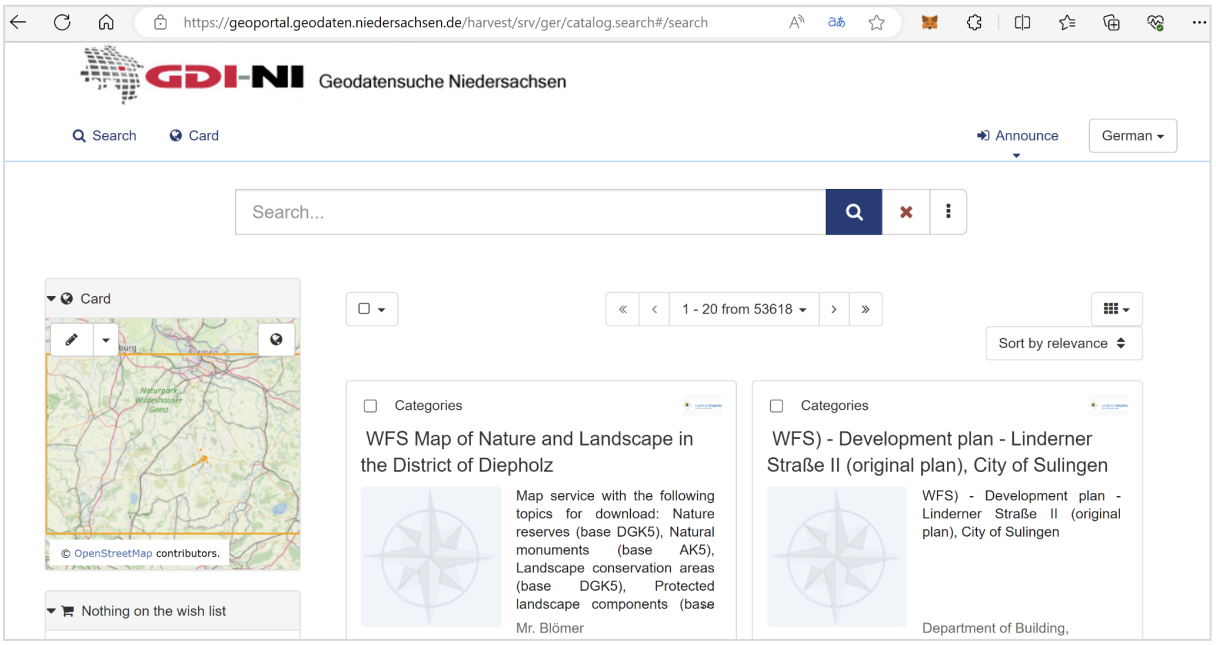

Fig. 4: User interface of the GDI-NI (translated)

Note: Different from other spatial data infrastructures, the metadata catalog of the GDI-NI is currently somewhat hidden and difficult to find. You will notice the difference when comparing the portal with those of GDI-DE or MDI-DE.

2. Use the German terms "Verwaltungsgrenzen" (administrative boundaries) and “Verwaltungseinheiten” (administrative units) to find all relevant records. Use the filter options to search for offerings that are related to the LGLN.

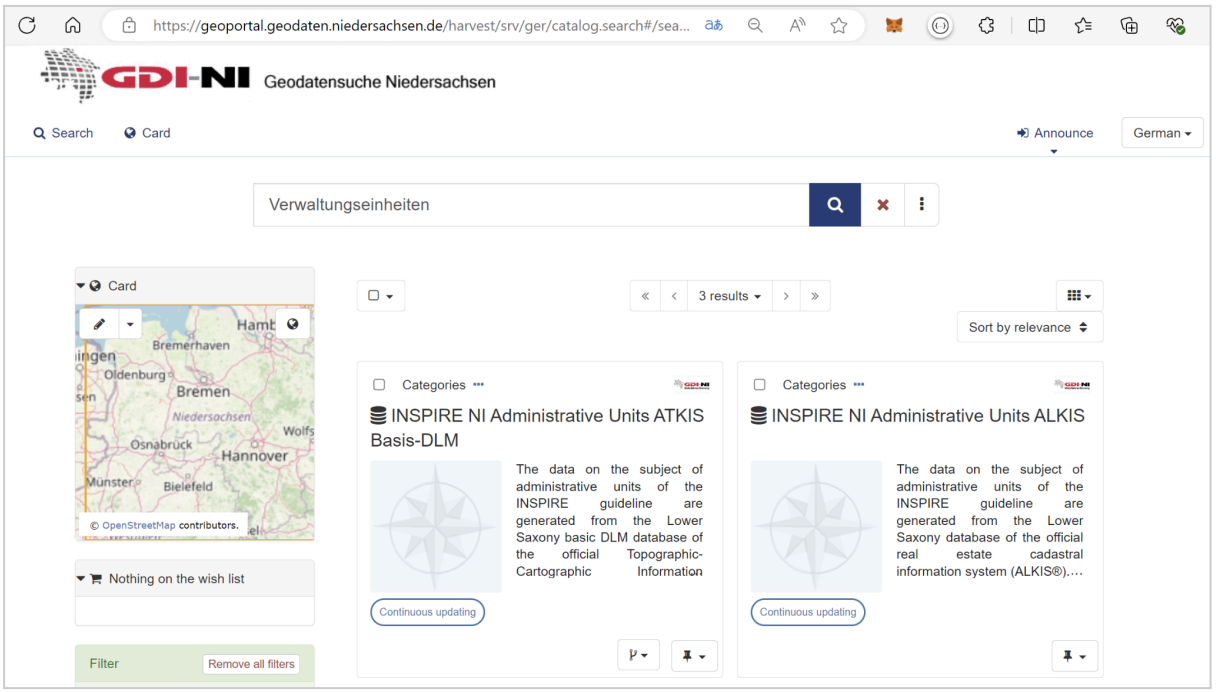

Fig. 5: GDI-NI geoportal, searching for “Verwaltungseinheiten” (administrative units)

To understand the differences between the data offerings, explore the metadata provided for each dataset. By examining the metadata, you can gain insights into the data's origin, its format, the geographic extent, and its temporal relevance. In the best case you’ll find links to extensive background materials that help you to achieve a deep understanding of the data.

> *Note: Knowledge of the supported keywords and the exact spelling is required for this search engine, as other languages or semantic or phonetic search are currently not sufficiently supported.*

> *Note: ALKIS is the Official Real Estate Cadastre Information System. ATKIS is the Official Topographic Cartographic Information System. The term “Basis DLM” (digital landscape model) refers to the model for topographic data in ATKIS which is complemented by the digital cartographic model. Both ALKIS and ATKIS are German standards for cadastral and topographic information and both contain data on administrative boundaries. INSPIRE data on administrative units are based on the ALKIS and ATKIS datasets, and their data model and encoding follow the INSPIRE data specifications. WMS (Web Map Service) and WFS (Web feature Services) are types of web services that can be used to directly interact with the data source and retrieve map images or feature data.*
> *You’ll find detailed background information on ALKIS and ATKIS on the website of the State Office for Geoinformation and Surveying of Lower Saxony (LGLN).*

3. Let's look into some details: Select the "WFS NI Verwaltungsgrenzen ALKIS" (Web Feature Service NI Administrative Boundaries Basic ALKIS) record and look up the metadata of this resource.

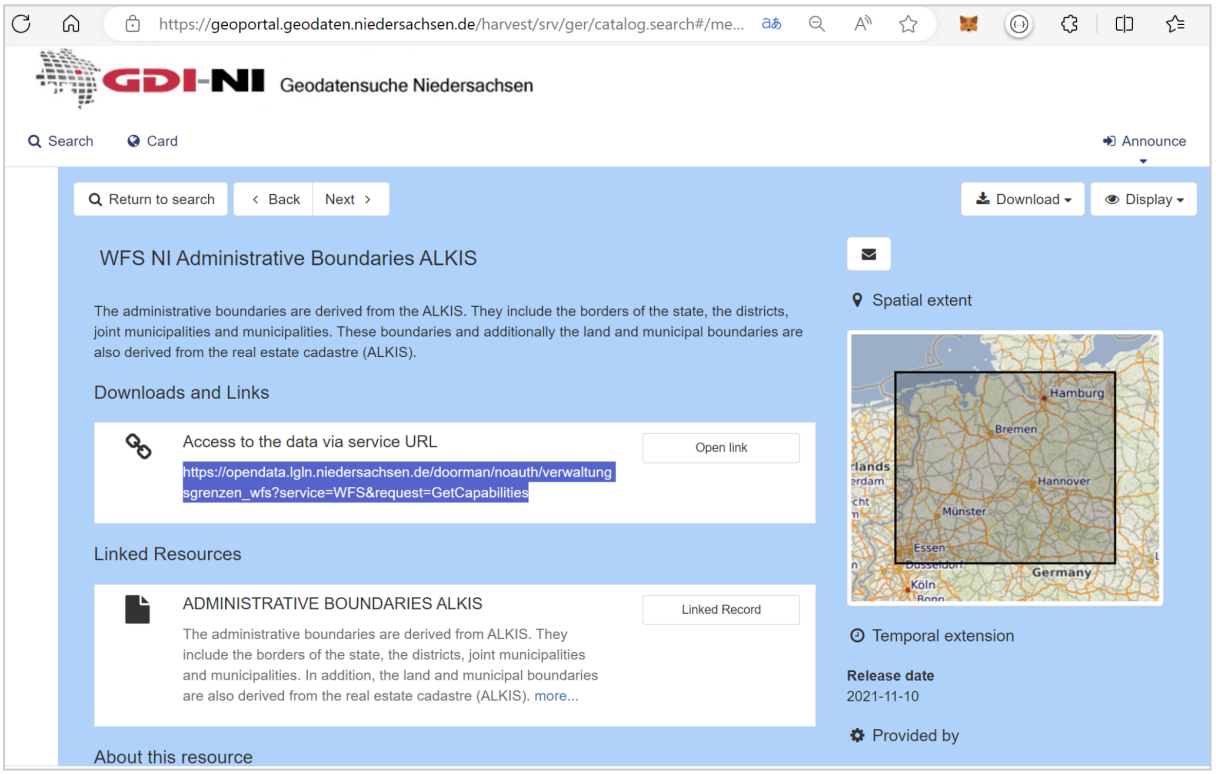

Fig. 6: GDI-NI Metadata on "WFS NI Verwaltungsgrenzen ALKIS" (WFS NI Administrative Boundaries ALKIS)

You will find information about the data offering, such as the spatial extent, the coordinate reference system (CRS), the data format, the license terms for accessing and reusing the data, and even the phone number of a contact person. The dataset is reported to be continuously updated and from other documentation we know that ALKIS provides the best positional accuracy of all authoritative datasets on administrative boundaries.

One metadata element is the link to the Web Feature Service that can be used for direct access to the data.

> *Note: if you use "download metadata" you'll get access to the XML formatted metadata set, which is stored in the metadata catalog. Both the data model and the XML encoding of the metadata are standardized in Europe, with some specifics in Germany and some further specifics in Lower Saxony. This allows sharing of metadata between metadata catalogs within Germany and across Europe.*

4. We decide to use the dataset "WFS NI Verwaltungsgrenzen ALKIS".

Now create a data directory in your local computer that shall contain all the downloads of raw data that you will use in this exercise (we refer to it as “your **project’s data download directory**”).

Copy the URL of the WFS to a text file and store it in the project’s data download directory. Later on we will use the link to access the data via QGIS.

3.2.2 Data on Existing Wind Turbines

We are interested in up-to-date data on existing wind turbines, as we would like to have this as information on the status quo, even though we will not use the data for calculations. In fact, some of the existing wind turbines will be replaced by larger, more powerful turbines at a later stage of the planning process (so-called repowering of the existing windfarm).

1. After inspecting the catalogs of GDI-NI and GDI-DE we find some resources in the Marine Data Infrastructure MDI-DE. Use your browser to find the nokis metadata catalog of MDI-DE and search for “Windkraftanlagen (Küstenländer)” (wind turbines (coastal countries)).

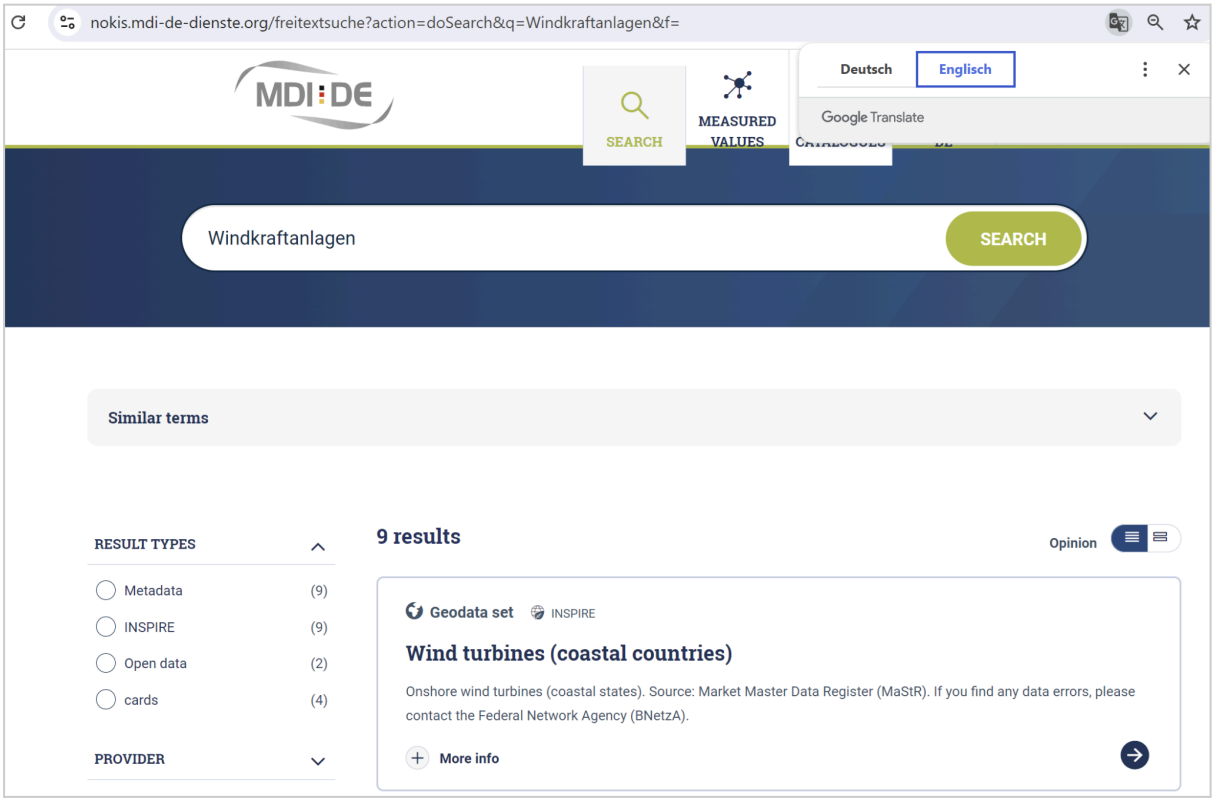

Fig. 7: MDI-DE - Metadata on wind turbines in coastal countries

Note: The metadata catalogs typically provide metadata records both for the datasets themselves and for data services such as view and download services. View services are often implemented as Web Map Servies (WMS), Download-Services are often

implemented as Web Feature Services or other types of data access services. Since the metadata of data sets contain links to the services and vice versa, this leads to inconvenient redundancies in the list of hits when searching.

2. Look up the metadata and familiarize with the data offering. Use the map-preview to get an idea about the data.

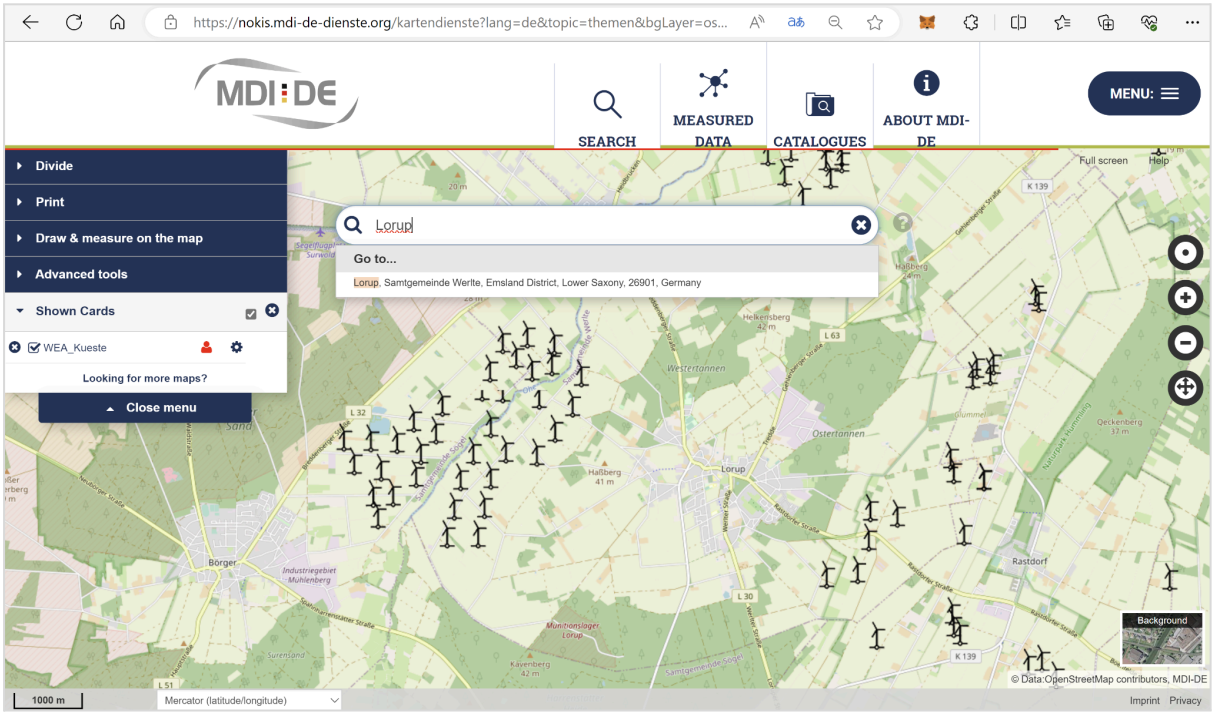

Fig. 8: MDI-DE geoportal, map preview of the datasets on wind turbines in coastal countries

Note: The original dataset is the so called "Marktstammdatenregister - MaStR" (see https://www.marktstammdatenregister.de) which contains data about renewable energy units and their operators. The data is being maintained on a daily basis and published under an open license (DL-DE->By-2.0) by the German Federal Network Agency (Bundesnetzagentur). Since the data set is currently not registered in one of the Spatial Data Infrastructures in Germany. MDI-DE and some other SDIs have decided to use the official dataset and re-publish subsets via standardized interfaces.

Note: Unfortunately, the MDI-DE metadata set does not include any information about the timeliness of the data republished here. For our exercise purpose, we ignore this point. In practice, one should contact the provider or, in case of doubt, use the original data of the Marktstammdatenregister, which can be downloaded from its website (see above).

4. Within the metadata, search for the link to the data download service that is offered as a Web Feature Service (WFS). Copy the URL of the WFS to a text file and store it in your project's data download directory. Later on we will use the link to access the data via QGIS.

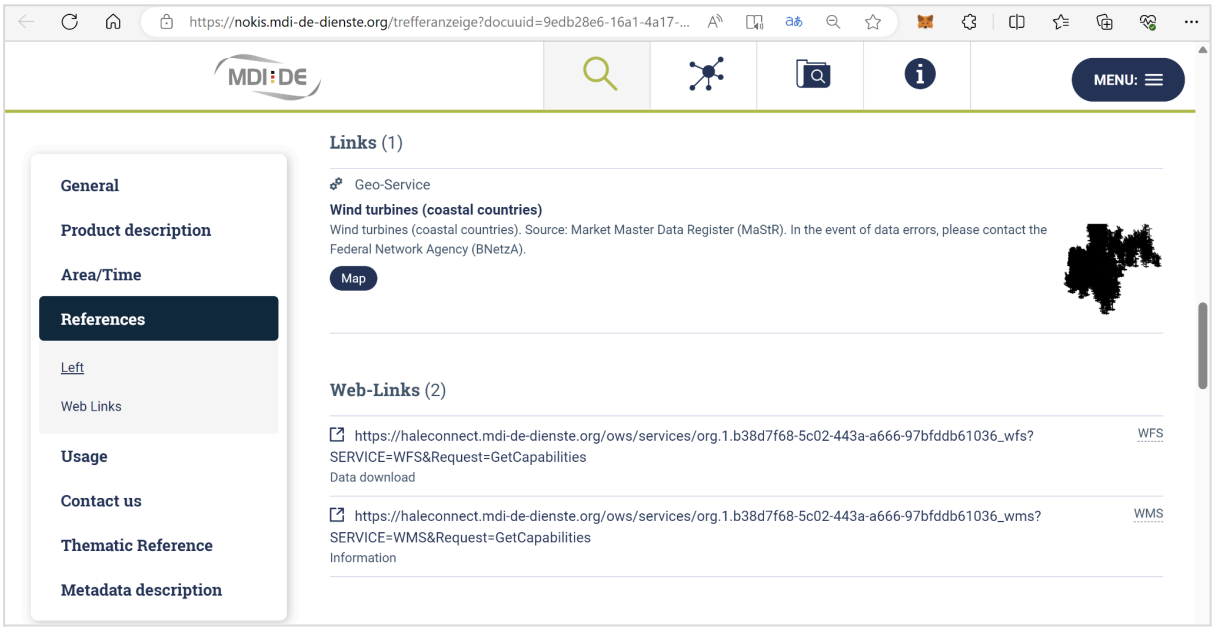

Fig. 9: MDI-DE geoportal, WFS URL of the data download service

3.2.3 Protected Sites Data

The term Protected Sites refers to areas that are designated under national or international legislation to achieve specific conservation objectives regarding natural or cultural resources. Depending on the legislation defining the protection status (e.g. the EU Habitats Directive 92/43/EEC or the EU Birds Directive 79/409/EEC, the Ramsar Convention, national laws, etc.), different rules apply to the use of wind farms within or near these protected areas.
Thus, in order to identify areas that are not suitable for wind turbines, we must consider the location and extent of designated protected areas and the associated rules for wind turbines. In our tutorial, we focus on nature reserves according to §23 of the Federal Nature Conservation Law in Germany (BNatSchG), since these exclude wind power use and can be found in our project area.

Since the data originate from public institutions and are relevant for any land use planning in Lower Saxony, we expect the data to be available in the Spatial Information Infrastructures in Lower Saxony (GDI-NI). Since they are also relevant for policy makers and users at national and European level, they should also be available in the GDI-DE and INSPIRE infrastructure.

1. Access the GDI-NI portal and navigate to the data search section. Use the search bar to look for "Naturschutzgebiete", which means nature reserves. Browse through the result set and locate the item "Naturschutzgebiete (NSG)." Based on the description, this dataset provides a digital state-wide overview map containing the geometries of all nature conservation areas (NSG) in Lower Saxony.

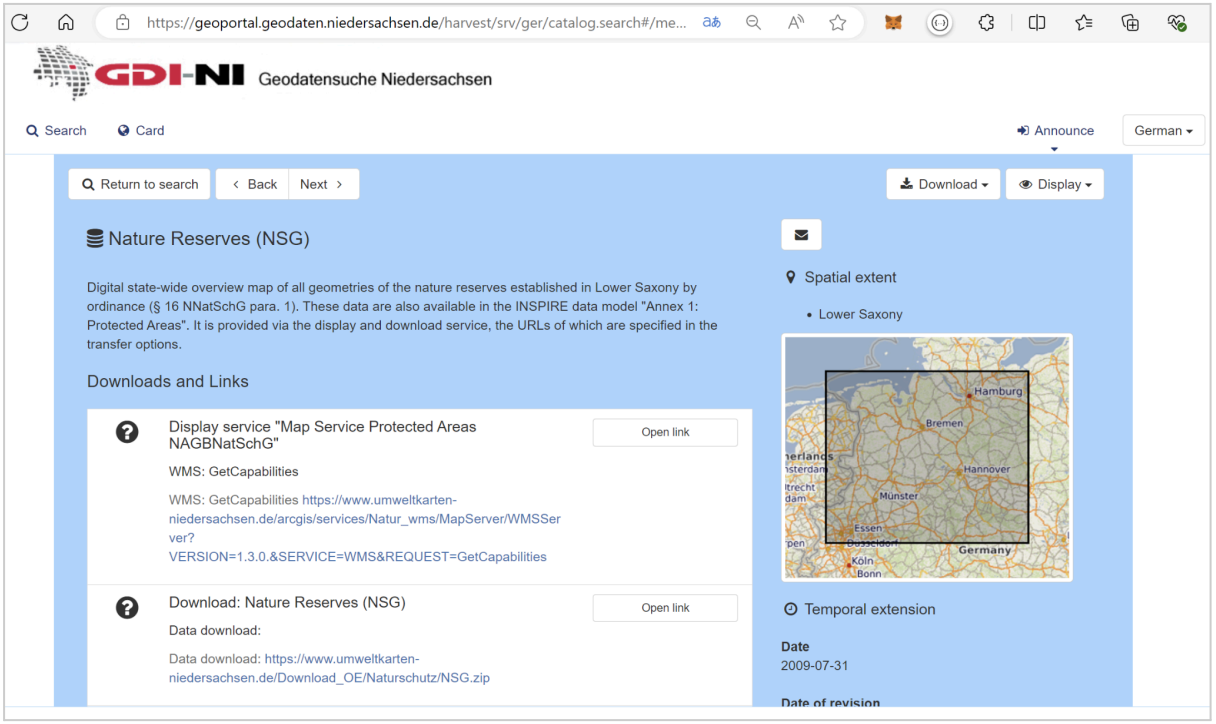

Fig. 10: Metadata on the dataset Nature Reserves (Naturschutzgebiete (NSG))

As you can see from the metadata, the data is provided by the Lower Saxony State Agency for Water Management, Coastal Protection and Nature Conservation (Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz - NLWKN).

Although the abstract announces only a statewide overview map, the metadata set provides links not only to view services (WMS), but also to download services (WFS and zip archive with Esri shapefiles). The INSPIRE view and download services comply with the INSPIRE data and service specifications (at least that is what the metadata promises).

Since currently the WFS services seem to have some technical issues just download the zip archive to your project's data download directory.

3.2.4 Data on existing Buildings

Data on existing buildings is essential for the planning of wind turbines. The proximity of buildings to wind turbines affects safety aspects, noise levels, and visual impacts. Outside of residential areas, wind turbines should be no closer than 400 m from residential buildings to

avoid noise impacts to residents. Actually, the distance criterion refers to the tips of the rotor blades. To determine which areas must be excluded for wind turbines based on this distance criterion, we need data on the location of buildings that are used wholly or partly for residential purposes.

The data should include accurate information about building locations (footprints), and types. Additionally, the data should be up-to-date to reflect any recent changes in building construction. Proper attribution of building attributes and metadata is also important to provide information about the building usage, and characteristics of each building.

In Germany, data on buildings and the use of buildings are recorded in the standardized Official Real Estate Cadastre Information System (ALKIS). Among other things, it also contains data on the parcels, the owners, and results of the official land value estimation. Only the data from ALKIS that do not have a direct personal reference are publicly accessible.

In Lower Saxony, the State Office for Geoinformation and Surveying (Landesamt für Geoinformation und Landesvermesssung, LGN) is responsible for the creation and provision of statewide geodata. The collection of ALKIS data is decentralized and carried out by regional directorates and local cadastral offices of the LGN.

Derived from ALKIS and other data sources, the LGLN also offers statewide building models in the detail levels LOD1 (block model) and LOD2 (simple roof forms). Up to 2023 accessing the ALKIS data has been subject to a fee but this has changed.

So, let’s search for data on buildings in GDI-NI.

1. Navigate to the GDI-NI geoportal that we have already used to search for the protected sites data. Use the German term “Gebäude” (buildings) and filter on “LGLN Landesamt für Geoinformation und Landesvermessung Niedersachsen” as Metadata contact.

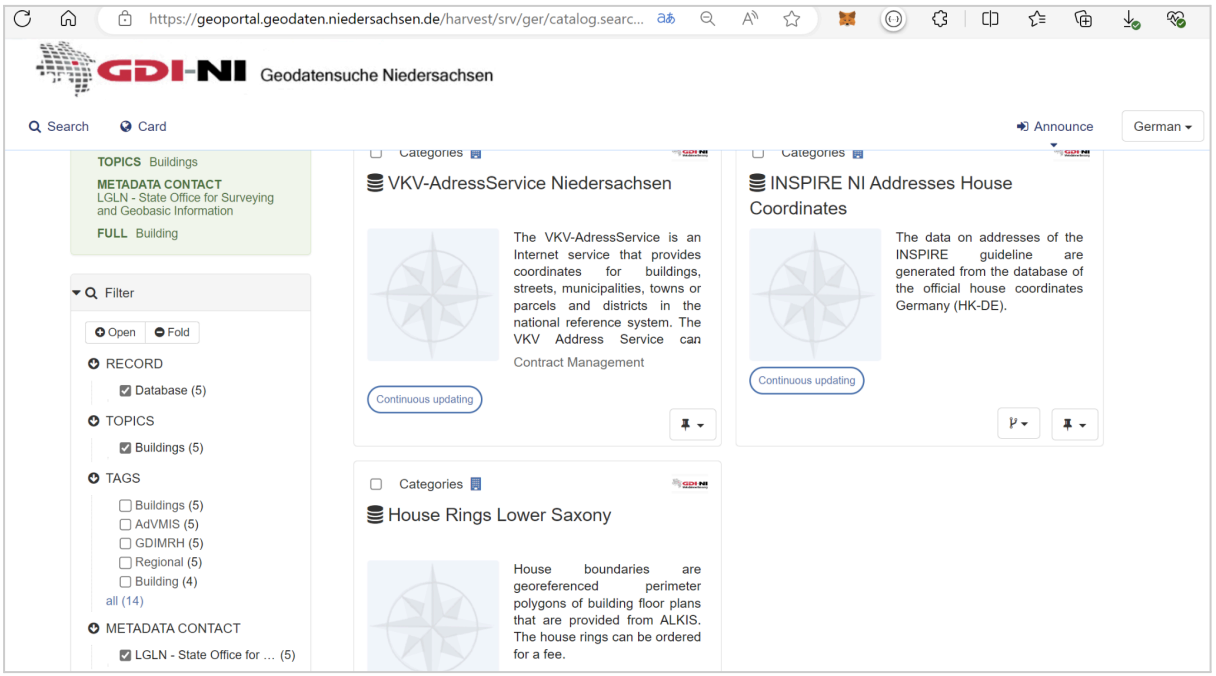

Fig. 11: Searching for data on buildings in the GDI-NI geoportal

Browse through the list of results and get an overview of the available data. Among others, you will find the following data and services, that contain the footprints of buildings:

- **Amtliches Liegenschaftskatasterinformationssystem (ALKIS)**
  (Official Real Estate Cadastre Information System (ALKIS))

  This catalog entry refers to a whole range of data products derived from the Official Real Estate Cadastral Information System ALKIS®. Building data is included in some of the products. The data is continuously updated and available through web services (WFS) in various data models (NAS, AAA, simplified). While the NAS and AAA model are more detailed and thus more complex regarding their data structure, the simplified data model is tailored to the limited capabilities of standard GIS software.

- **INSPIRE GDI NI Gebäude 2D ALKIS**
  (INSPIRE Buildings GDI NI 2D ALKIS)

  This dataset is derived from ALKIS® on-the-fly. It complies with INSPIRE data specifications, and is accessible through WMS and WFS.

- **Hausumringe Niedersachsen**
  (Building footprints Lower Saxony)

  The dataset which is derived once a year (1st of April) from ALKIS provides polygons representing 2D footprint of buildings. The data is available via the Open Data portal of Lower Saxony.

- **3D-Gebäudemodelle (LOD1 und LOD2)**
  (3D Building Models, Level of Detail 1 and 2)

  The dataset contains 3D building models that are derived from ALKIS® and laser scan point clouds. The data conforms to the European INSPIRE data specifications and is available as CityGML and 3DShape encoded data.

2. Since the most up-to-date building footprints are offered through the ALKIS data services we will use the web feature service “WFS NI ALKIS Vereinfacht (WFS NI ALKIS simplified)” for our purposes.

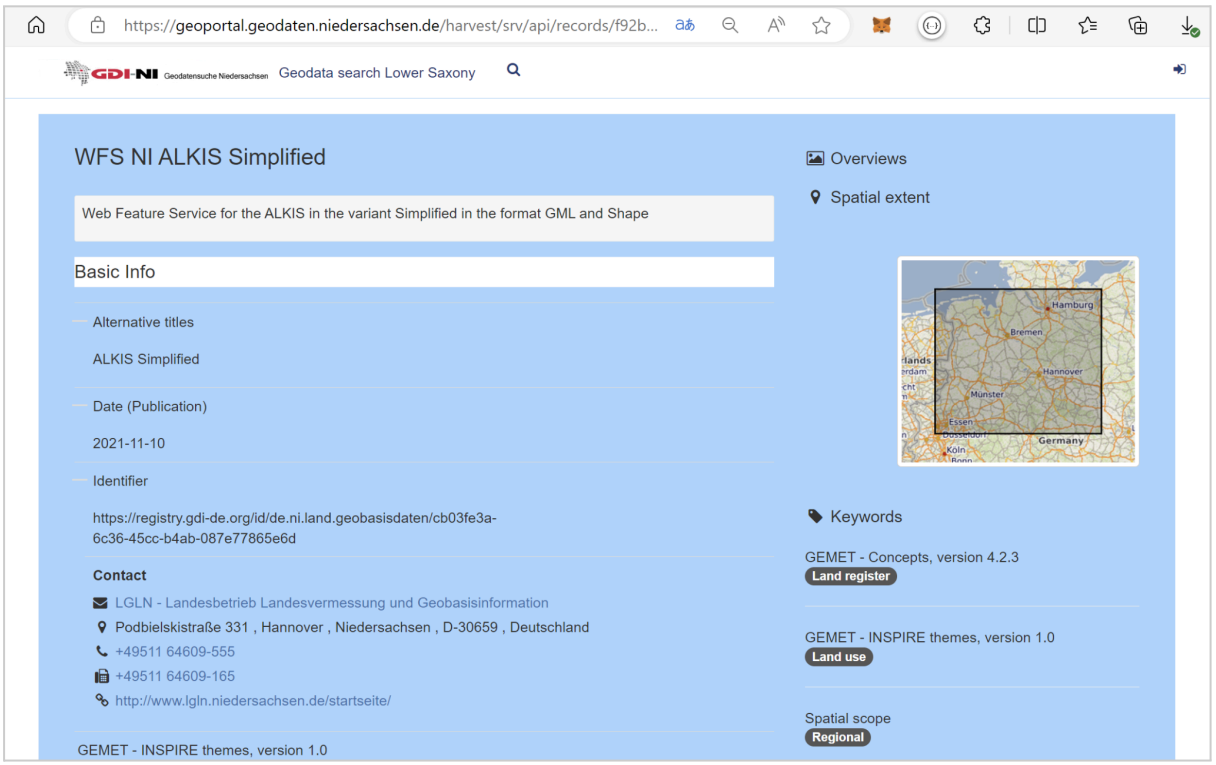

Fig. 12: GDI-NI geoportal - Metadata on the ALKIS WFS with simplified data model

Find the URL of the web feature service (don't confuse it with the URL of the metadata set), copy it to a text file and store it in the project’s data download directory. Later on we will use the link to access the data via QGIS.

3.3 Data Analysis

The data analysis aims to identify suitable areas for the development of the Mammoor wind farm in Lorup, taking into account that certain areas are to be excluded due to nature conservation areas (NSG) or due to the proximity to residential buildings. The workflow involves

- initializing the QGIS project,
- identifying exclusion areas due to existing nature reserves,
- identifying exclusion areas due to residentials buildings,
- identifying remaining candidate areas for further investigations and decisions.

We will use the open source software QGIS for our data analysis. If you do not have QGIS installed on your computer, please visit the official website of the QGIS project (https://www.qgis.org), download the latest stable release of QGIS and install it.

As spatial data infrastructures are constantly evolving, the portals, data and services used in the exercise may have changed or been supplemented by new offerings. In these cases, try to carry out the described workflow with the currently available resources. If necessary, you can also access the GeoPackage with the data used in the exercise, which you can download from the GitHub repository of this learning material:
https://github.com/oer4sdi/OER-SDI4WindFarmPlanning/tree/R240903/data

3.3.1 Initializing the QGIS project

So let's start up QGIS, create a new project (>Project, >New) and define some basic properties such as the title and the place where you want to store the project's data (>Project, >Properties, >General).

Now let's add OpenStreetMaps as a basemap.

A nice way to access useful basemaps is to install and activate the QGIS plugin QuickMapServices (>Plugins, >Manage and Install Plugins), which should be part of the QGIS distribution. Otherwise you can find it at https://plugins.qgis.org.

This plugin comes with two new icons in the web toolbar. Check the functionality and choose for example *OSM Standard* and *Google Satellite* as base maps.

Use the locate field in QGIS (lower left corner) to zoom to the municipality of Lorup.

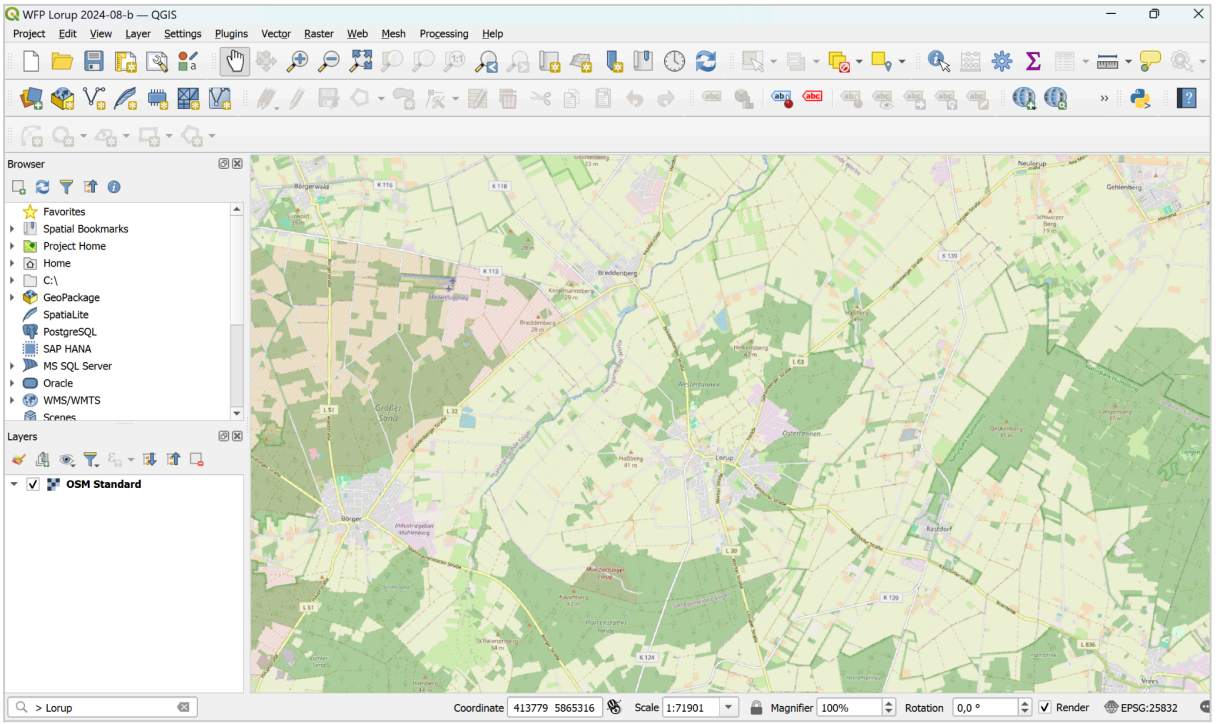

Fig. 13: QGIS - base maps and administrative boundaries of Lorup

Define the project's coordinate reference system and save the project

Now we define the coordinate reference system that we want to work with (>Project, >Properties, >CRS). In our case we chose EPSG:25832 which stands for ETRS89/UTM Zone 32N. This reference system is commonly used by public authorities for authoritative data in Lower Saxony.

Store the project (>project, >save as) to the data directory that you want to use for this project. Further on, we will refer to it as the **"project's data directory"**.

Load the administrative boundary of Lorup

Now we want to connect to the Web Feature Service that we found in GDI-NI to integrate data on the administrative Boundary of Lorup. Use >Layer, >Add Layer, > WFS/OGC API - Features and create a new server connection. Name it "NI ALKIS AdminBoundaries" and use the URL of the ALKIS service that you've stored in a text file in your project's download directory.

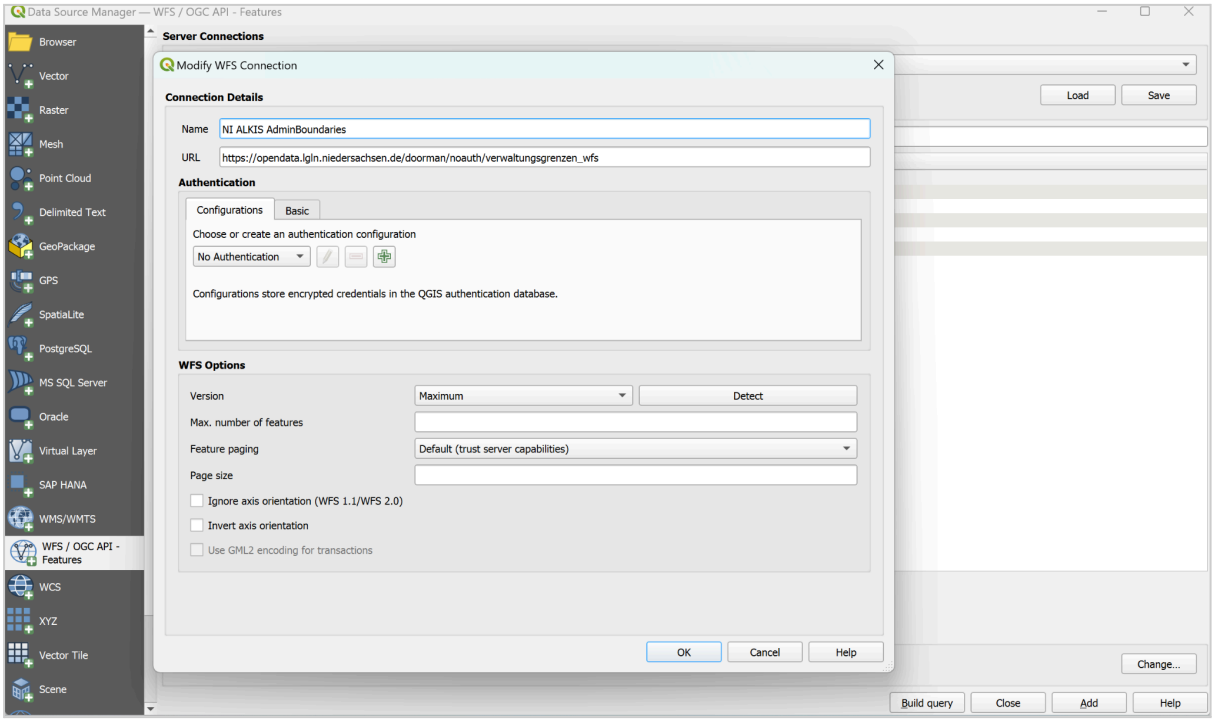

Fig. 14: Connecting to the WFS with ALKIS data on administrative boundaries from NI (Niedersachsen, Lower Saxony)

Connect to the server, select the feature type “Gemeinden” (municipalities) and add it to our QGIS project. Select the boundary of the Gemeinde Lorup by using “> Select features by Value” from the Selection toolbar. The Polygon of the Lorup municipality should be highlighted now.

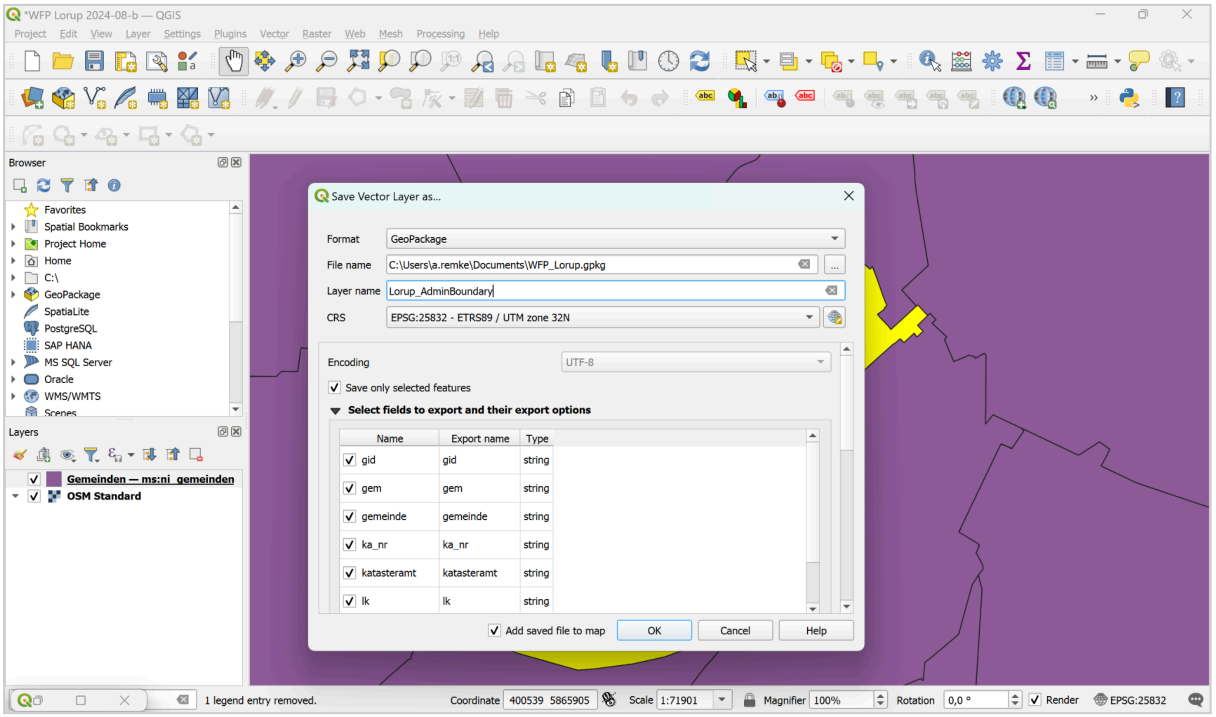

Fig. 15: Saving the project's data as GeoPackage

Use the context menu of the new Layer and export selected features (in this case just one polygon) as a layer "Lorup_AdfinBoundary" to a new GeoPackage that we will use to collect all the relevant data for our windfarm planning project. Use the CRS EPSG:25832, name the Geopackage "WFP Lorup" and store it in the **project's data directory**.

The stored layer appears as a new item in your layer list. Rename it to "Lorup_AdminBoundary", change the style of the layer to a transparent fill and the line color to red so that the boundary is easy to see when displayed on top of any base map. Remove the original layer group ATKIS_Verwaltungsgrenzen from your list of layers.

.

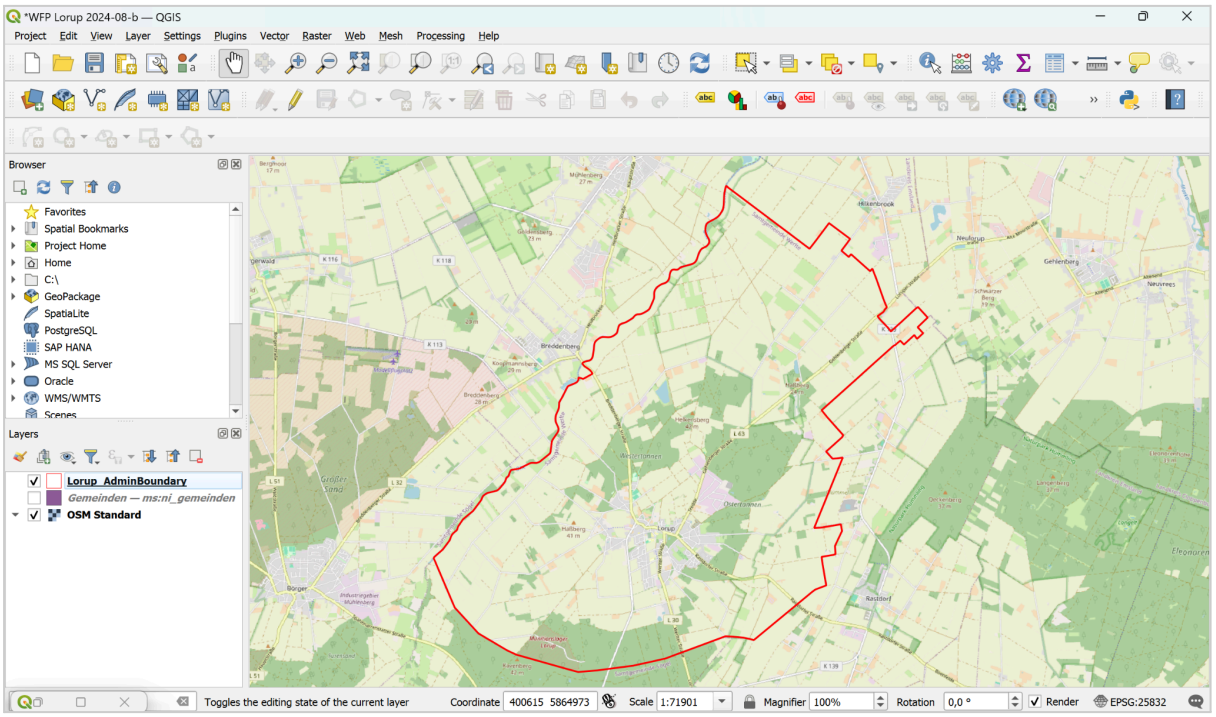

Fig. 16: Admin boundary of Lorup, taken from the ALKIS WFS

Save your project (>project, >save) to save the status of your work.

Define the Area of Interest (AOI)

In a next step, we define the area of interest for our project. This is the area in which we want to be sure that we consider all data that provide relevant information for our analysis. Within this area, our analysis should provide valid results. On the other hand, we can use the AOI to deselect all data that do not provide relevant information for our analysis, which saves computation time and costs.

One way to define the AOI is as follows: Adjust the map scale and map extent in the current canvas so that the map extent represents the project's area of interest. Lorup should be covered plus a certain extent (1km) N/W/S/E. Then use the “Create Layer From Extent” editing tool from the processing toolbox to create a temporary scratch layer that contains a polygon representing the map extent.

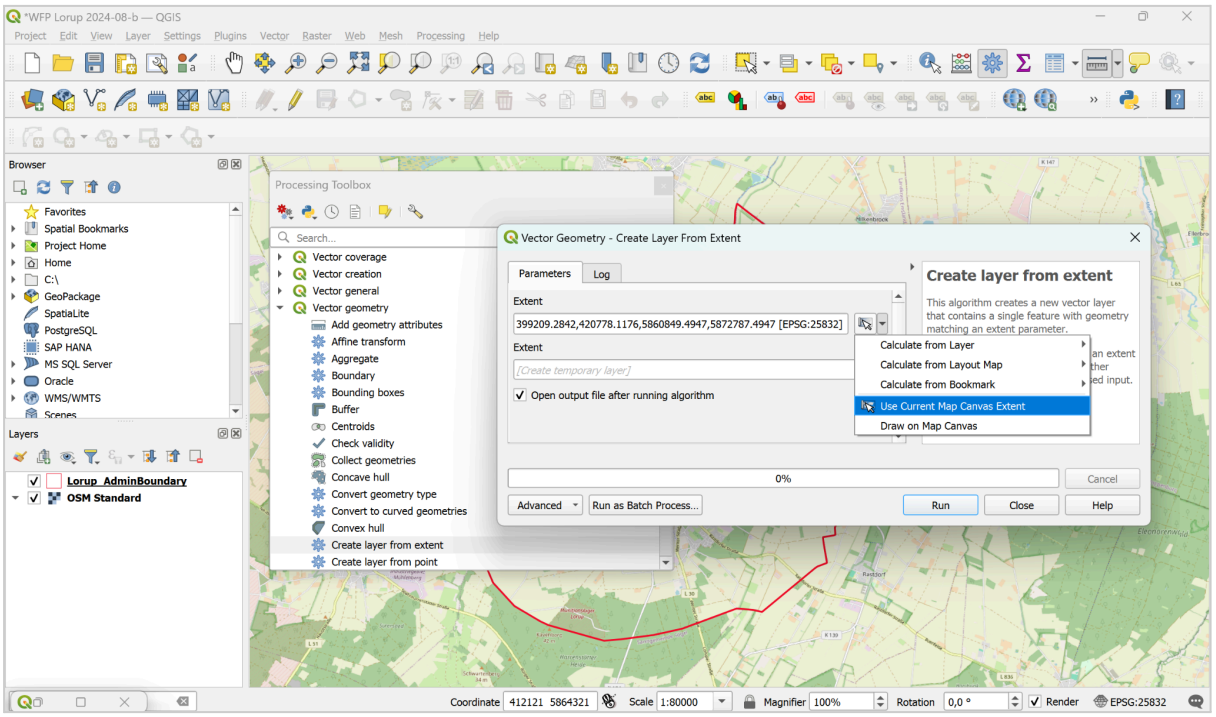

Fig. 17: Creating the AOI shape in QGIS

Save the temporary layer to the project's GeoPackage. The stored layer now appears as a permanent layer in your layer list. Rename it to “WFP_Lorup_AOI” and change the style of the layer to transparent fill.

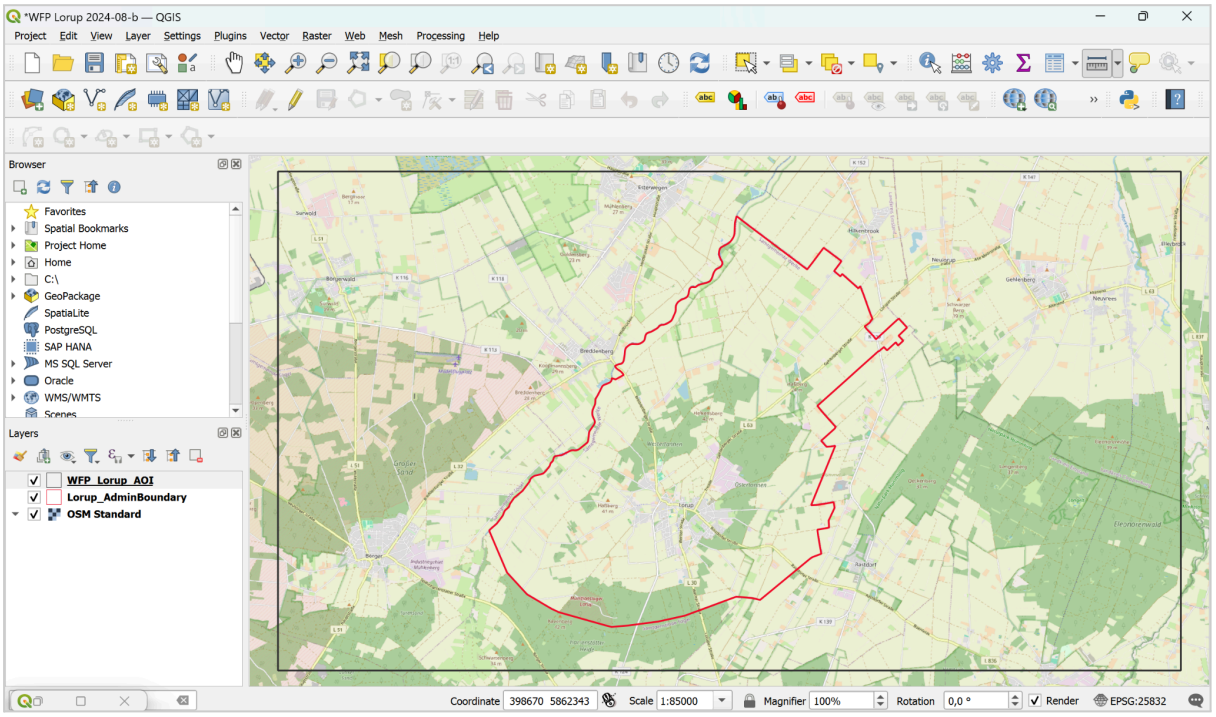

Fig. 18: AOI of the Lorup Wind Farm Planning Project

Save your project (>project, >save) to save the status of your work.

Add data on the existing wind turbines in Lorup

Now we want to connect to the Web Feature Service that we found in MDI-DE to integrate data on the existing wind turbines.
Use >Layer, >Add Layer, > WFS/OGC API - Features and create a new server connection. Name it “MDI-DE ExistingWindTurbines” and copy-paste the URL of the service that you’ve stored in a text file in your project’s download directory.

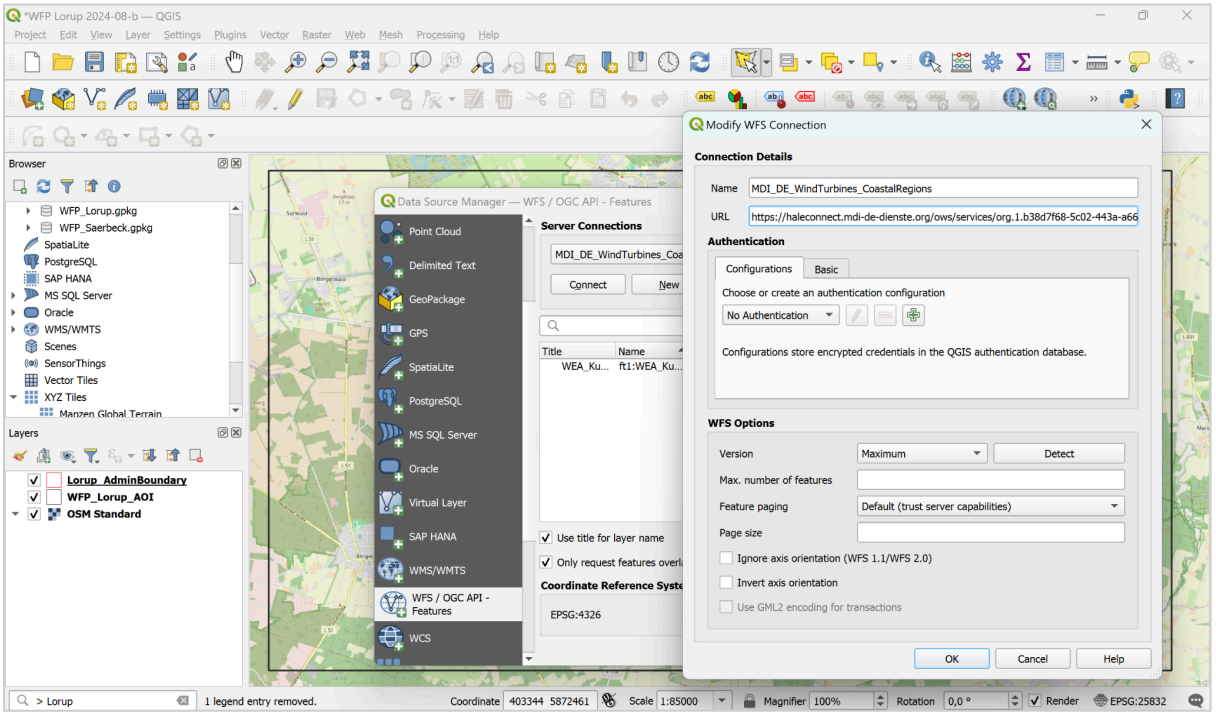

Fig. 19: QGIS, connecting to the MDI-DE WFS and retrieving the data on wind turbines

Then connect to the server and receive the list of feature types that are offered by the WFS. Select the one and only feature type “WEA_Küste”, which stands for Windenergieanlagen - Küste (Wind Energy Units - coastal region) and add it as a layer to your project.

The wind turbines represent the status quo of the wind farms in Lorup. The wind farm Mammoor is located in the northern part of Lorup. You can use the function "Identify feature" from the toolbar to retrieve the data of the existing wind turbines (see Fig. 23).

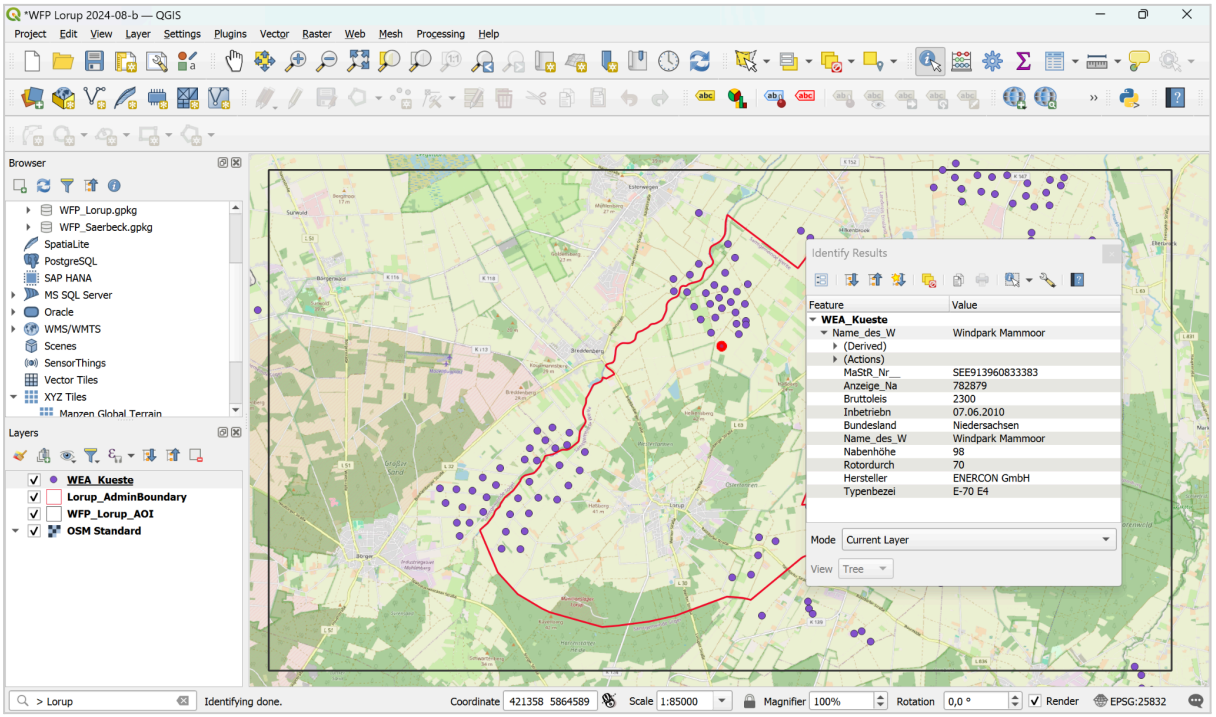

Fig. 20: Existing wind turbines, Mammoor wind farm in the north of the municipality of Lorup

Now use the tool "> Select by location" from the toolbar and create a selection of wind turbines that overlap with our area of interest WFP_Lorup_AOI.

Export the features from the WFS layer “ft1:WEA_Küste” to the project’s GeoPackage by selecting the layer and using >export, >SaveFeaturesAs from the context menu. In the dialog, set the coordinate reference system to EPSG:25832 and store the result in our project’s GeoPackage.

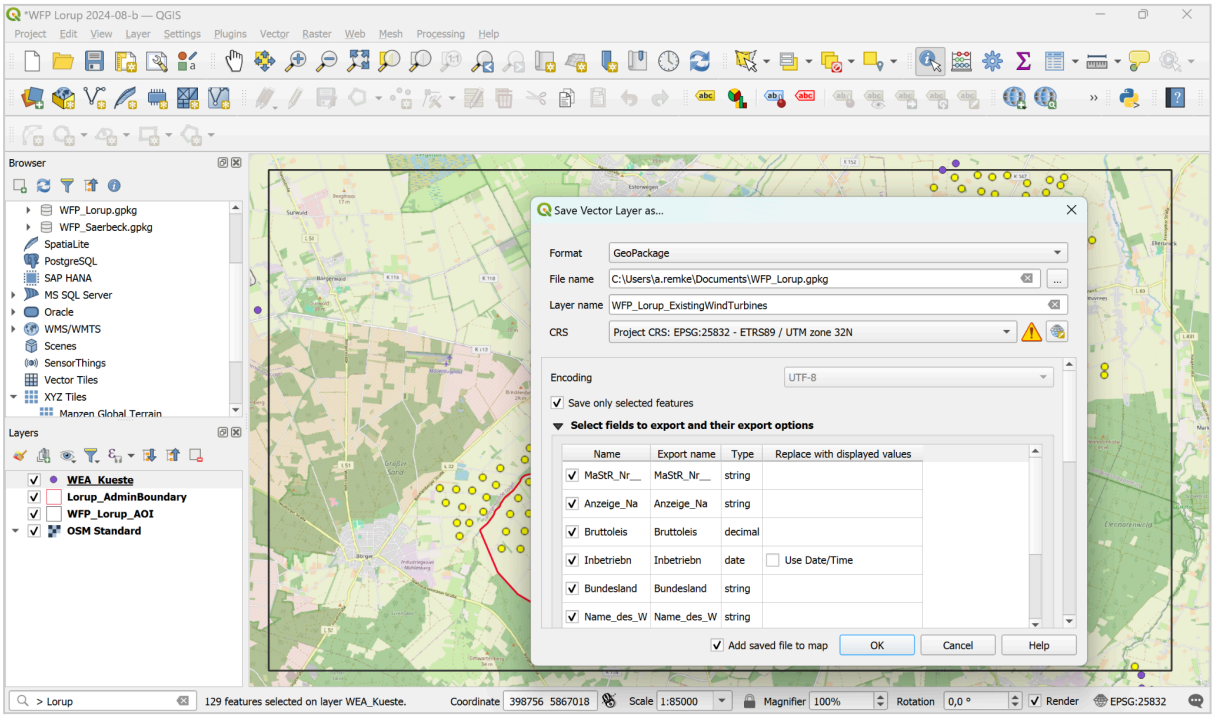

Fig. 21: Export wind turbine data from the MDI-DE WFS to our project's GeoPackage

The stored layer appears as a new item in your layer list in QGIS. Rename it to "WFP_Lorup_ExistingWindTurbines", change the style of the layer if needed and remove the original WFS layer "ft1:WEA_Küste" from the list of layers in QGIS.

The GeoPackage should contain three layers now: our project's area of interest (WFP_Lorup_AOI), the Lorup administrative boundary (Lorup_AdminBoundary), and the data about Wind turbines that are located within our area of interest (WFP_Lorup_ExisingWindTurbines).

Save your project (>project, >save) to save the status of your work.

3.3.2 Identify Exclusion Areas due to Existing Nature Reserves

In this step, we want to identify all areas that must be excluded from the planning of the wind farm expansion due to laws prohibiting the construction of wind turbines in or near nature conservation areas. In this criterion, we must consider not only the tower of the wind turbine, but also the rotor. In fact, we have to make sure that the wingtips of the rotor do not reach into the area of a nature reserve. Since the diameter of the rotors will in any case be smaller than 200m, we use a buffer of 100m around nature reserves to be sure that the locations of wind turbines in the remaining areas meet the distance criterion.

> *Note: Keep in mind that there are other types of protected sites, e.g. Landschaftsschutzgebiete (landscape protection areas), that have lower protection requirements and would not prohibit wind turbine construction generally.*

We start with loading the protected sites data “Naturschutzgebiete_DTK25.shp” that we have downloaded before. Use >Layer, >Add Layer, > Add Vector Layer and point to the zip_archive with the protected Sites data that you have found and downloaded based on the metadata in the GDI-NI geoportal.

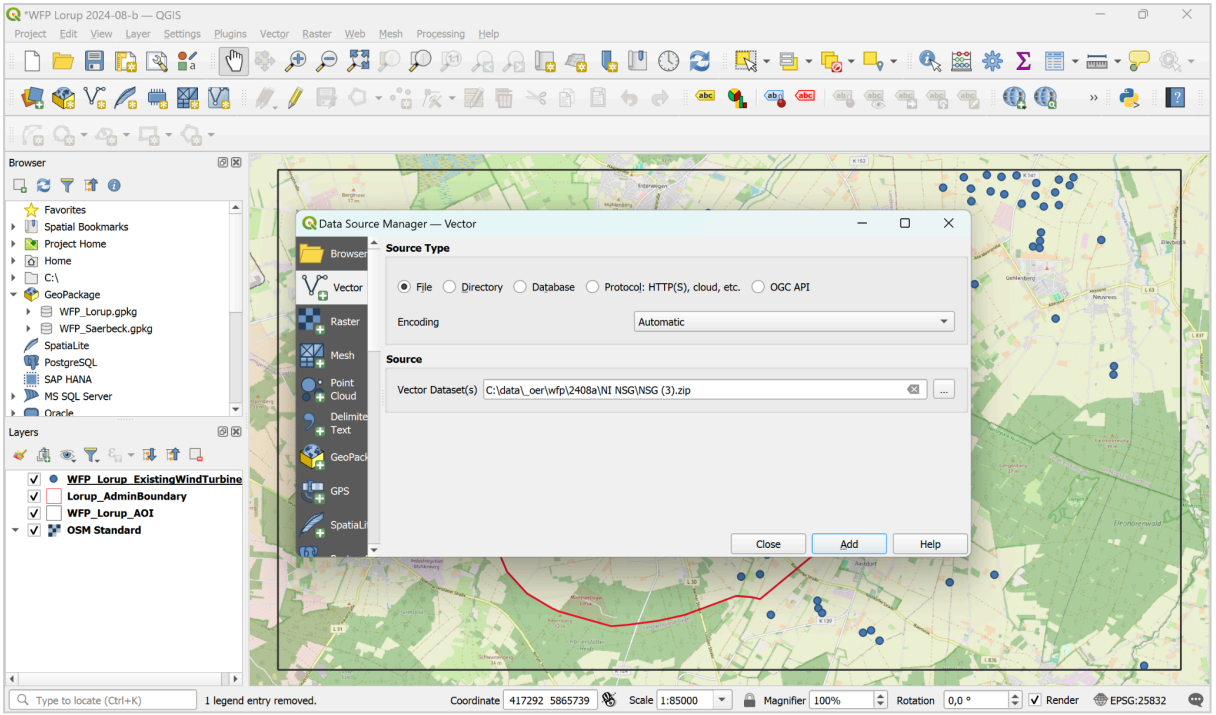

Fig. 22: Import protected sites data as downloaded via GDI-NI

We want to focus on those nature preserves that are relevant to our AOI, which means, they have to be in a distance of 100m or less to our AOI. We can use the processing tool “Vector

selection/Select within distance" from the processing toolbox to select all NSG within a distance of 100m to the AOI and to store the result in our project's GeoPackage.

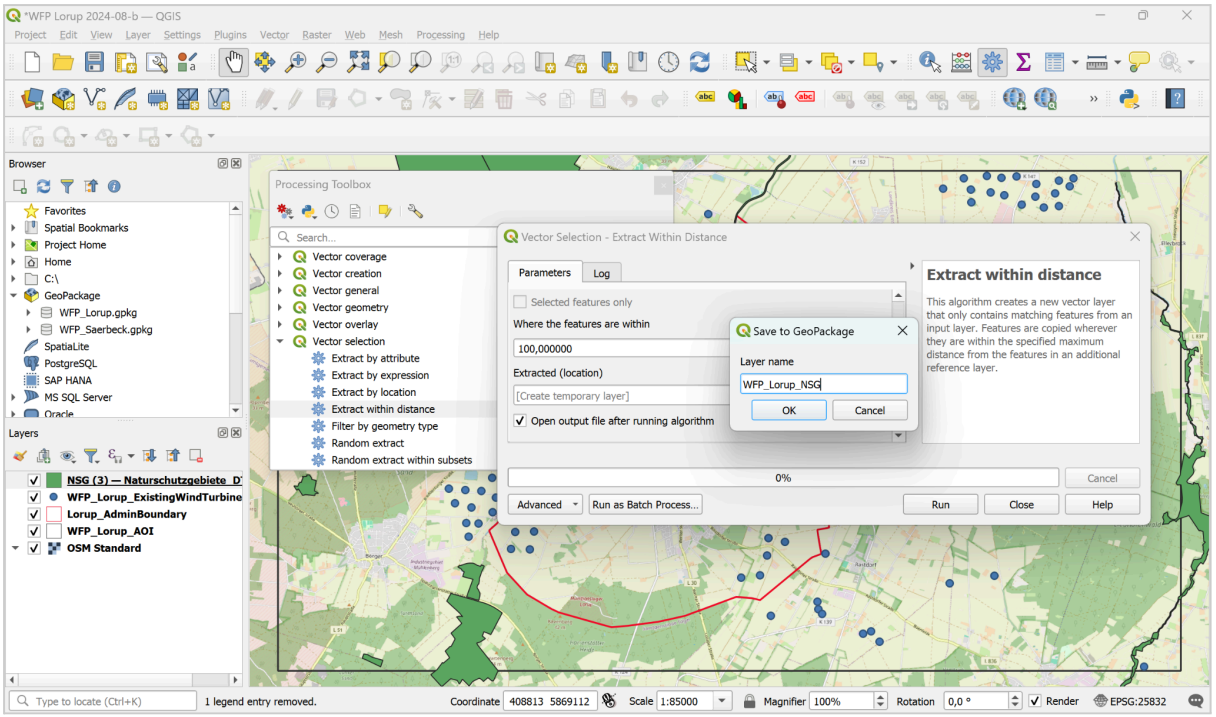

Fig. 23: Selecting nature reserves that may affect the project's area of interest (AOI)

The stored layer appears as a new item in your layer list. Change the style of the layer to green colored fill and remove the original layer from the list of layers.

Now we can use the processing tool "Vector geometry/Buffer" from the processing toolbox to compute the new NSG exclusion area by adding a 100m buffer to the NSG features and dissolving the result (check "dissolve result").

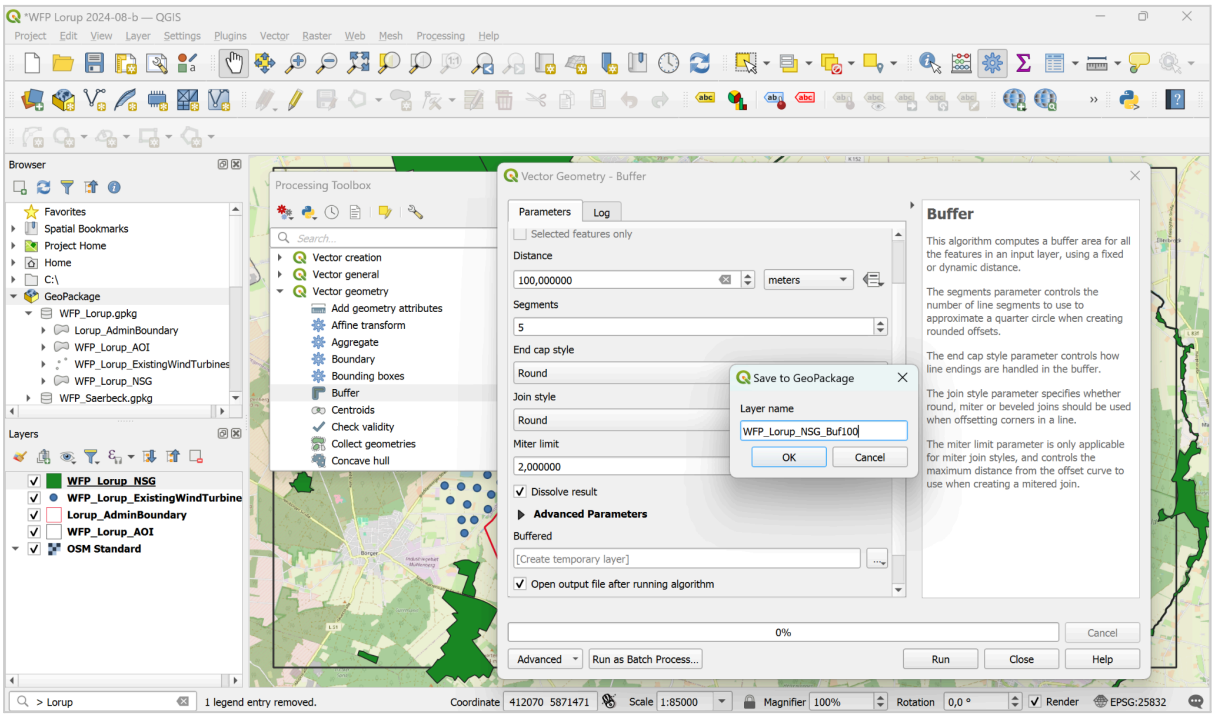

Fig. 24: Computing a 100m buffer around nature preserve areas

Save your project (>project, >save) to save the status of your work.

3.3.3 Identify Exclusion Areas due to Residential Buildings

In this step, all areas are to be identified that shall be excluded from the planning of wind farm development due to the minimum distance of 400m to residential buildings that must be maintained outside of settlements (see section 2.1). And again, we need to make sure that the rotor's wingtips meet this 400m criterion. Therefore, we add 100m to account for half of the rotor diameter, which in our planning case should not exceed 200m. So we'll compute a 500m buffer around residential buildings to identify all exclusion areas that relate to this distance criterion.

We start with downloading the building footprints using the ALKIS Web feature service that we've identified as a data source before (see section 3.2.4). We connect to the WFS and select the feature type "Gebäude (buildings)". Make sure that neither the maximum number of features is set to low nor the view extent is too small to miss out any relevant buildings.

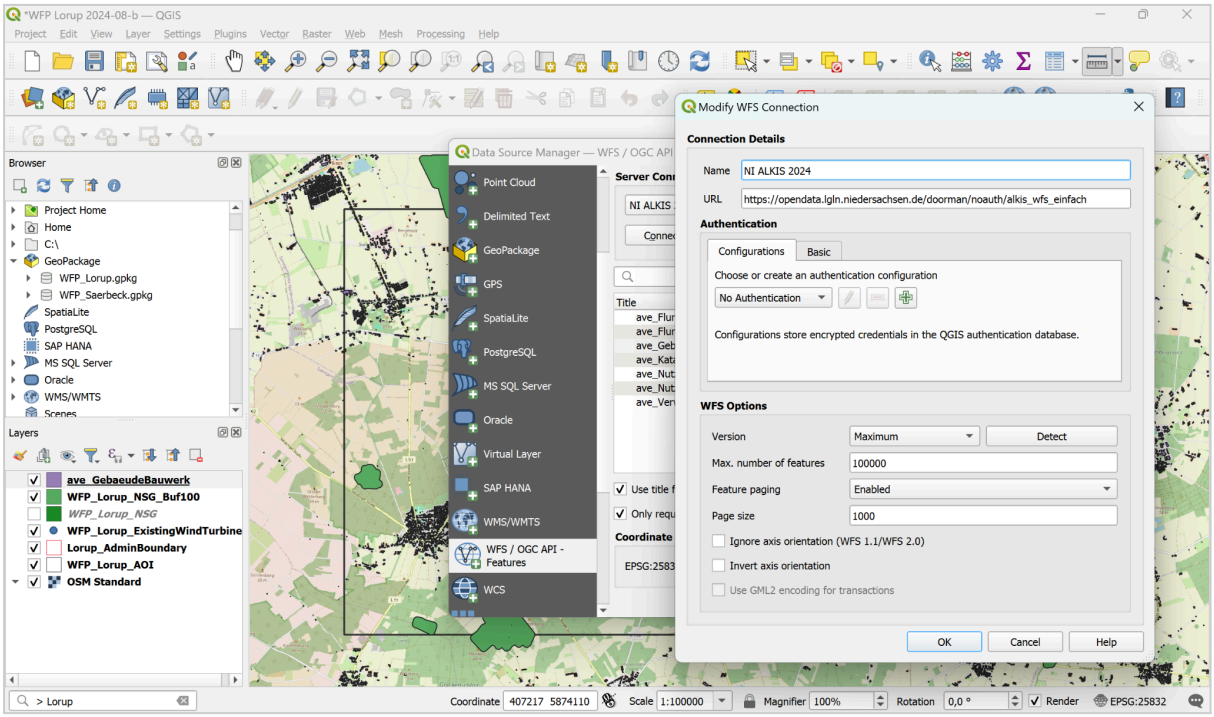

Fig. 25: Downloading building footprints from the ALKIS WFS provided by LGN

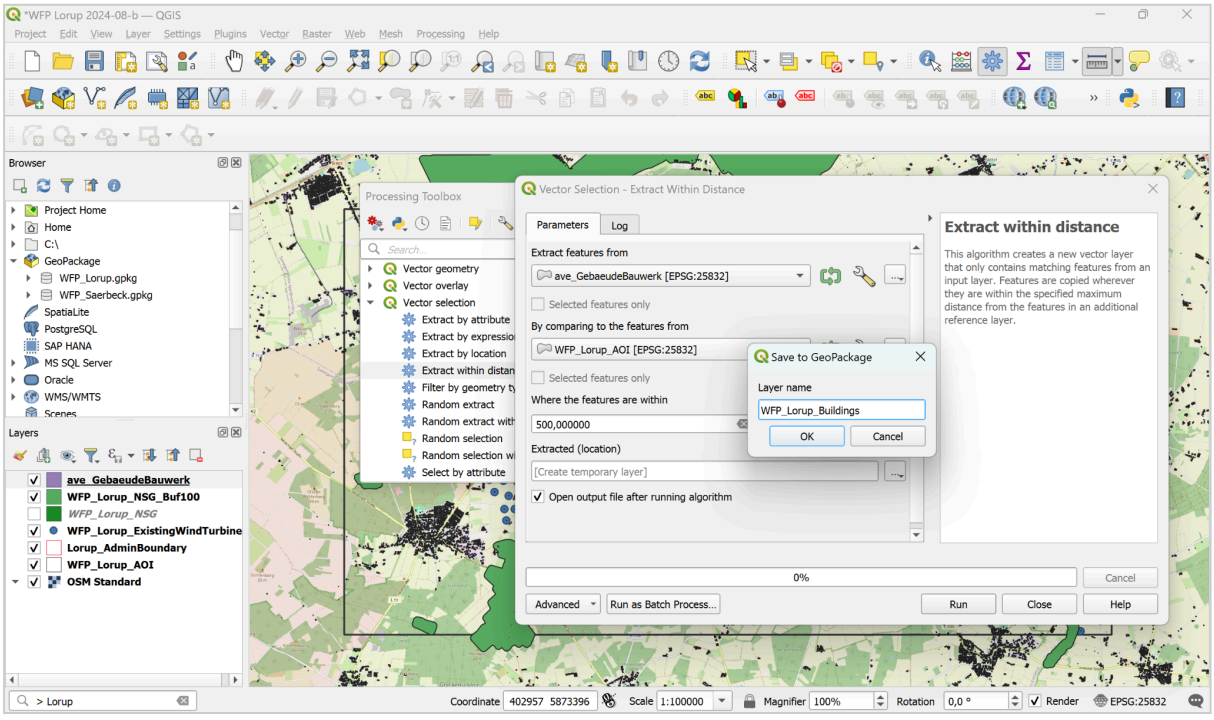

Fig. 26: Selecting and storing building footprints within a distance of 500m to the AOI

While the dataset contains the footprint of all existing buildings, we need to focus on residential buildings, as wind turbines only need to maintain a certain distance from residential buildings.

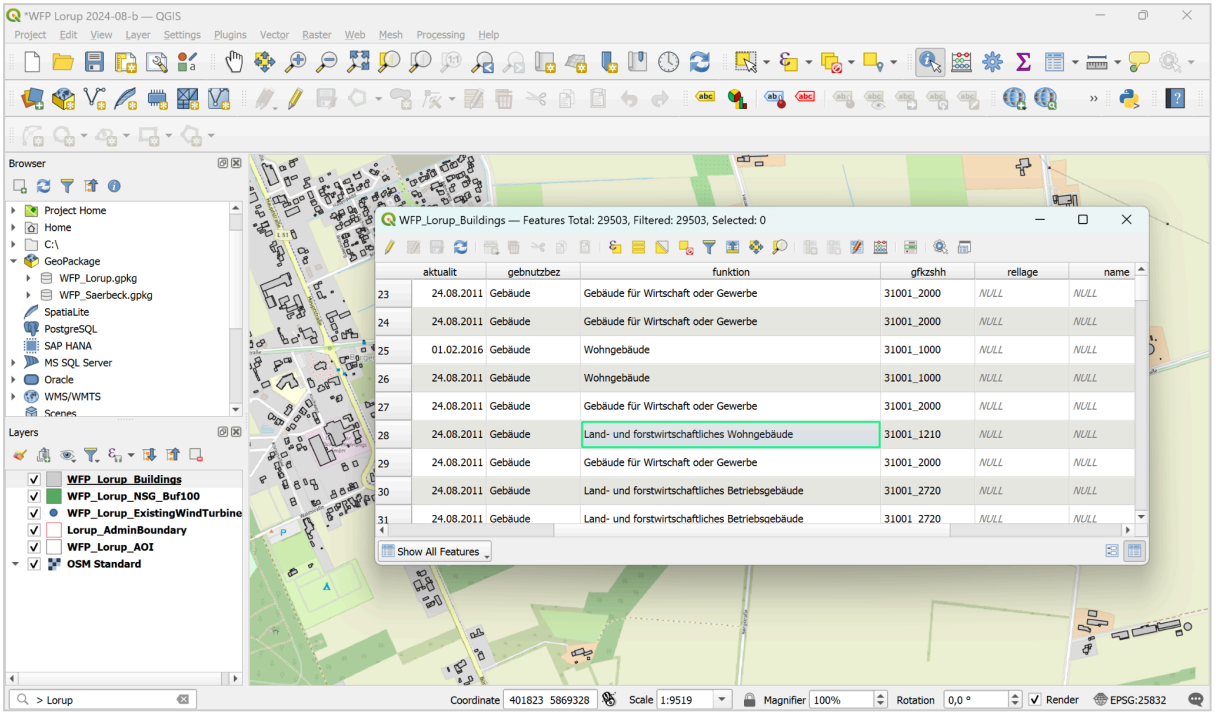

Fig.27: Building data, attributes “funktion” and “gfkzshh” indicating the function of a building

To understand the meanings of the function codes (values of gfkzshh), we need to look up the GDI-DE schema registry:
https://repository.gdi-de.org/schemas/adv/citygml/Codelisten/BuildingFunctionTypeAdV.xml

Fig. 28: Code List with ALKIS function codes describing the main usage of buildings

We have done the work for you and selected all the function codes that indicate that the building in question is used at least partially for residential purposes:

gfkzshh IN ('31001_1000', '31001_1010', '31001_1020', '31001_1021', '31001_1022', '31001_1023', '31001_1024', '31001_1025', '31001_1100', '31001_1110', '31001_1120', '31001_1121', '31001_1122', '31001_1123', '31001_1130', '31001_1131', '31001_1210', '31001_1220', '31001_1221', '31001_1222', '31001_1223', '31001_1310', '31001_1311', '31001_1312', '31001_2070', '31001_2071', '31001_2072', '31001_2073', '31001_2310', '31001_2320', '31001_2735', '31001_3048', '31001_3050', '31001_3051', '31001_3052', '31001_3064', '31001_3066', '31001_3070', '31001_3073', '31001_3075', '31001_3242')

Fig. 29: Query expression that compares the value of the gfkzshh attribute with a list of selected function codes

To select all buildings that are used in whole or in part for residential purposes use the processing tool > vector selection, > extract by expression. Use the query expression as defined above and store the result as Layer “WFP_Lorup_ResidentialBuildings” to our project’s GeoPackage.

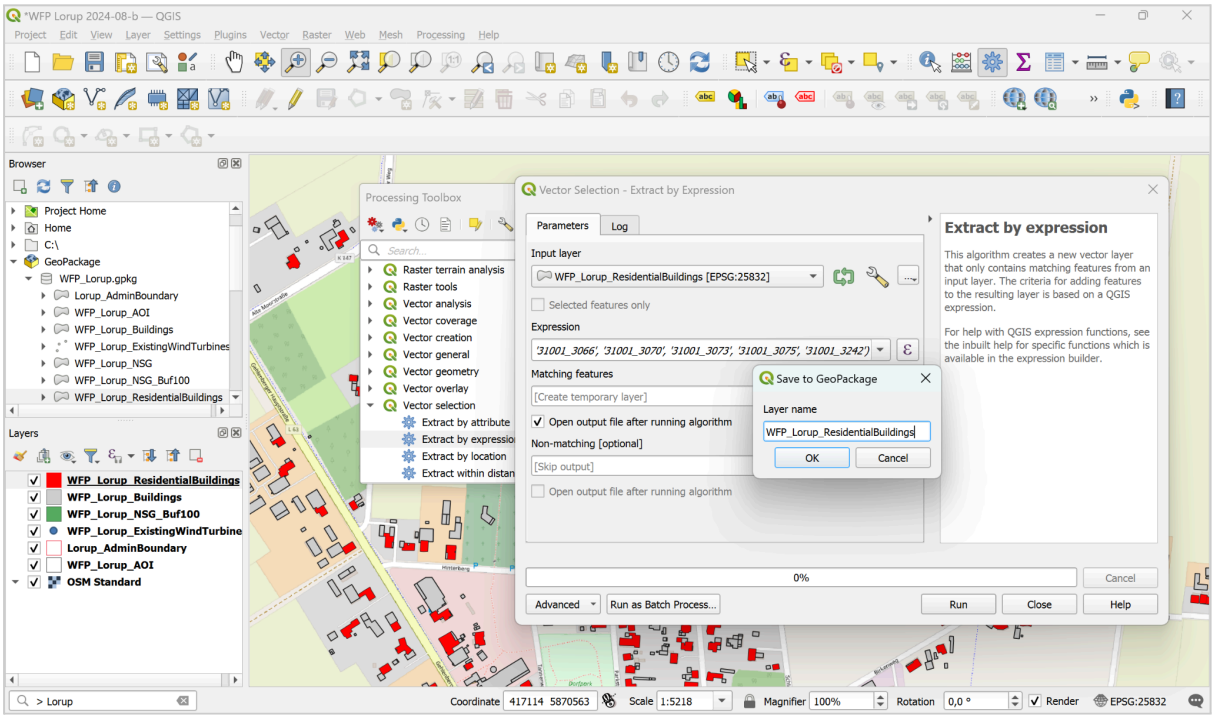

Fig. 30: Selecting Buildings with function codes that indicate residential use

Now we can compute the exclusion area for wind turbines due to the neighborhood to residential buildings. Use the buffer tool from the processing toolbox, make sure that “Selected Features Only” and “Dissolve” options are checked, specify the buffer distance to

be 500 meters, and choose the output to be stored as “Lorup_Buildings_Buf_500m” in your project’s data directory.

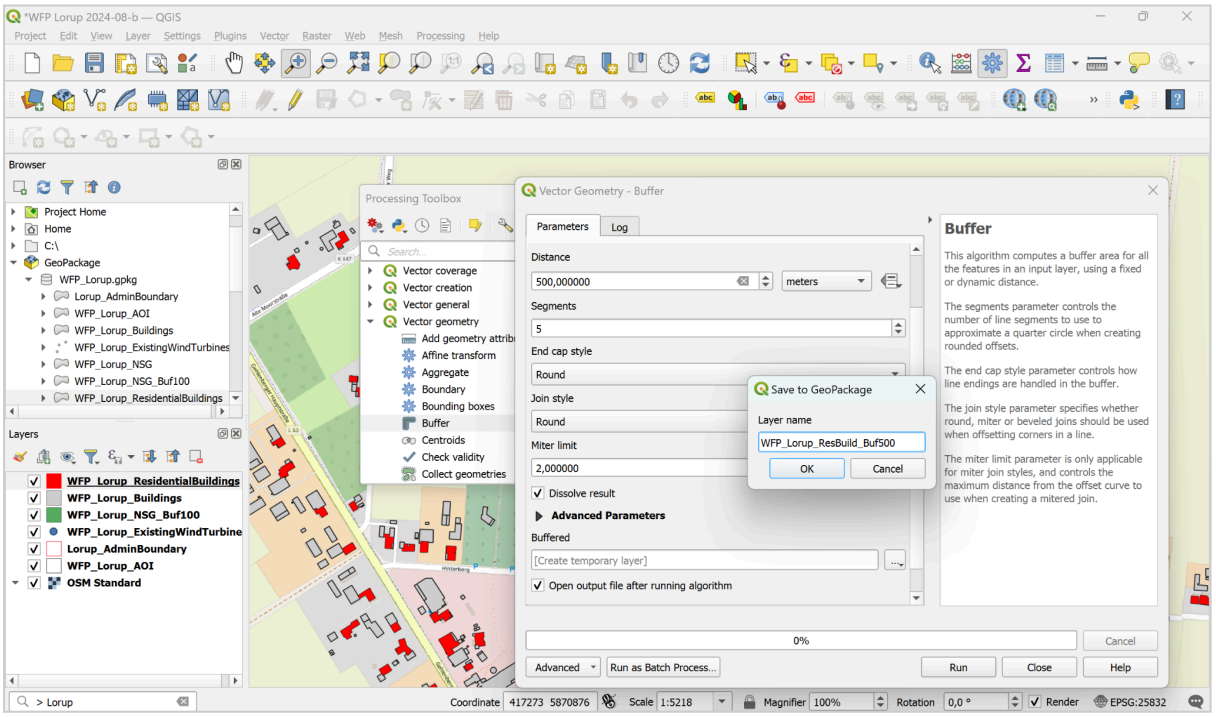

Fig. 31: Computing a 500m buffer zone around residential buildings in our project’s AOI

After you run the buffer calculation, you’ll see that not all existing wind turbines are actually outside the buffer zone around residential buildings. This is because the law stipulates that the actual distance from residential buildings must be at least twice the height of the wind turbine and most of the existing turbines do not reach this height.

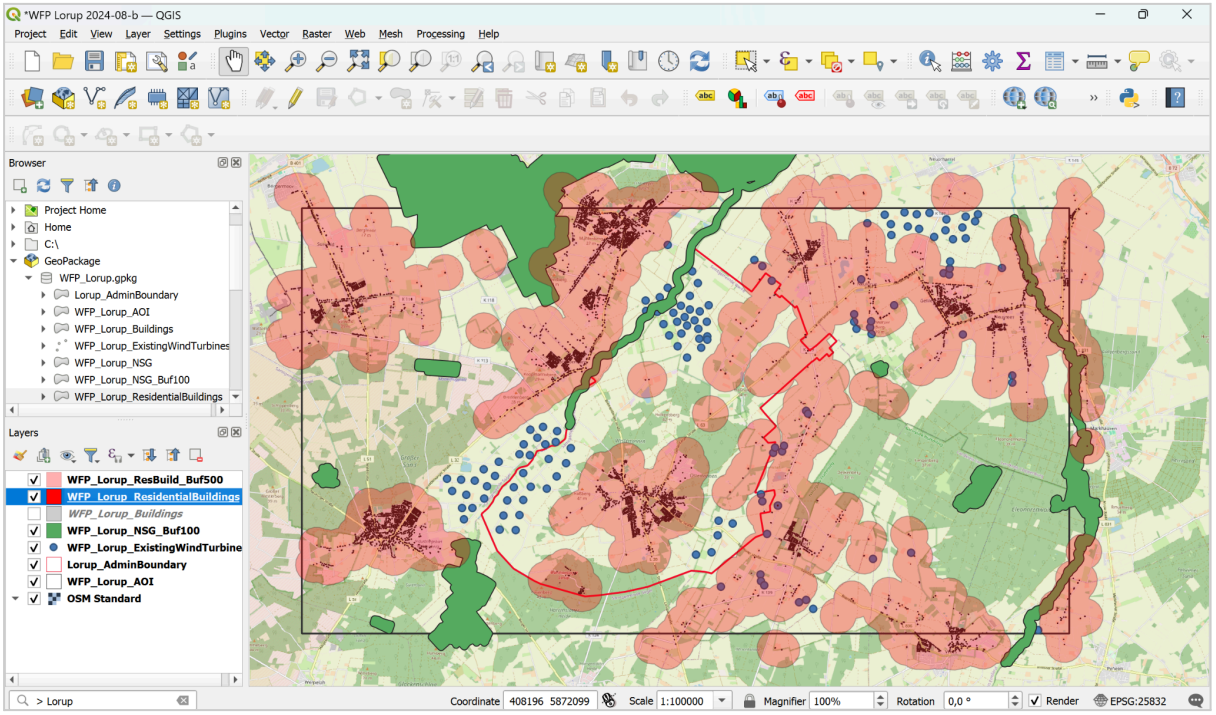

Fig. 32: Result of the buffer computation

Save your project (>project, >save) to save the status of your work.

3.3.4 Identify the candidate areas for the windfarm extension

In a first step we determine the area of the current wind farm Mammoor. For this we start with selecting the turbines, with the attribute "Name_des_W" = 'Windpark Mammoor' (> Select Features by Value..").

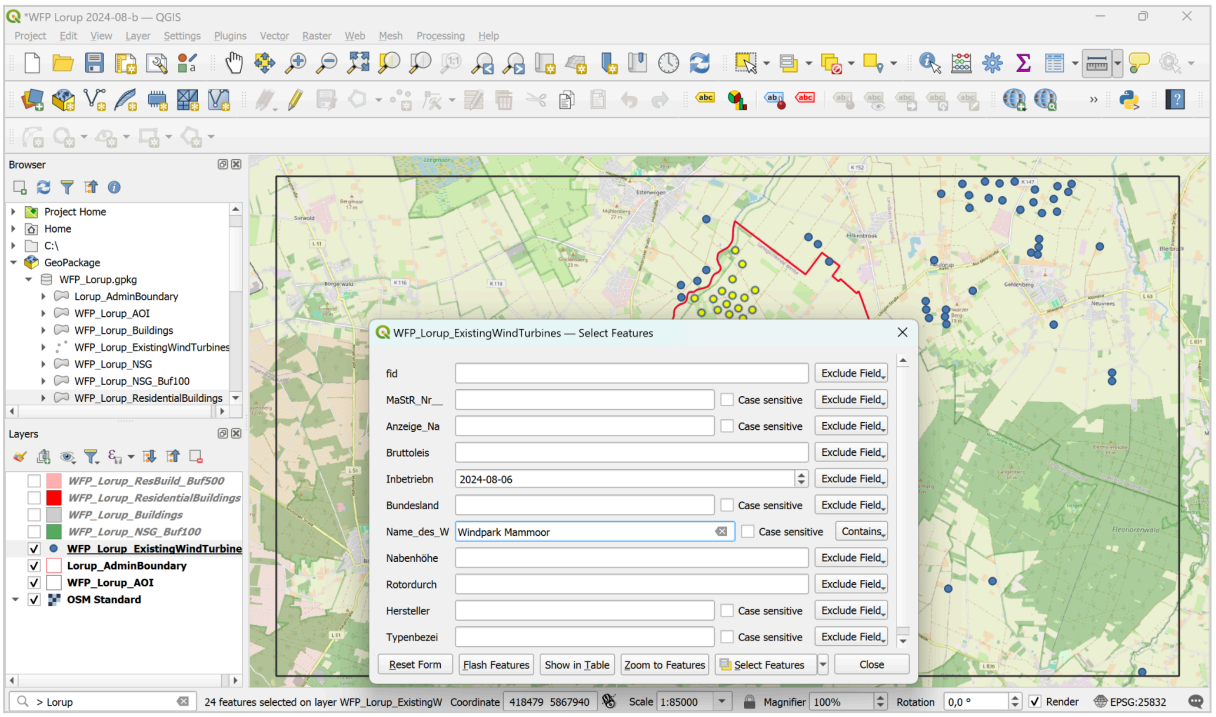

Fig. 33: Selecting the turbines of the Mammor Wind Farm

Then we calculate the concave surface that encloses all selected wind turbines of the Mammoor wind farm. For this we use the tool "Concave Hull" from the Processing Toolbox and apply it to all selected features. The threshold value 0.47 provides good results.

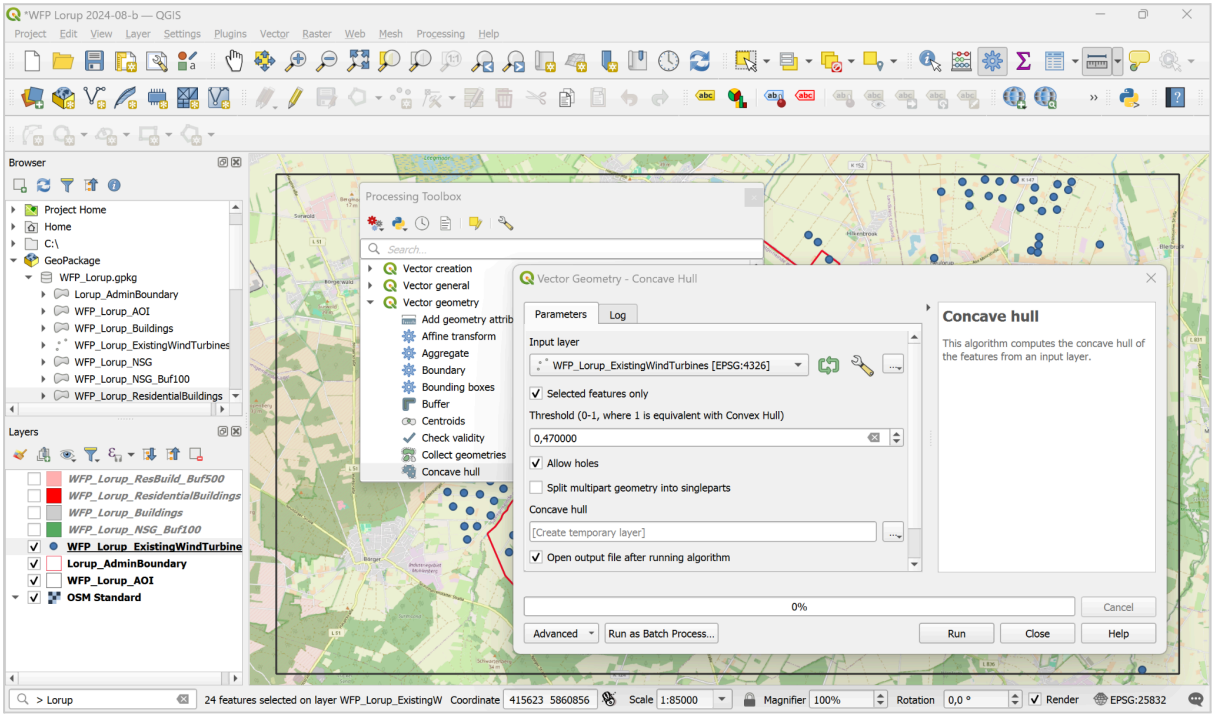

Fig. 34: Computing the convex hull of the selected features

Finally, we provide this area with a 100m buffer, so that the rotor diameters are taken into account. The layer with the resulting area is given the title "Mammoor Wind Farm" and saved in our project's geopackage.

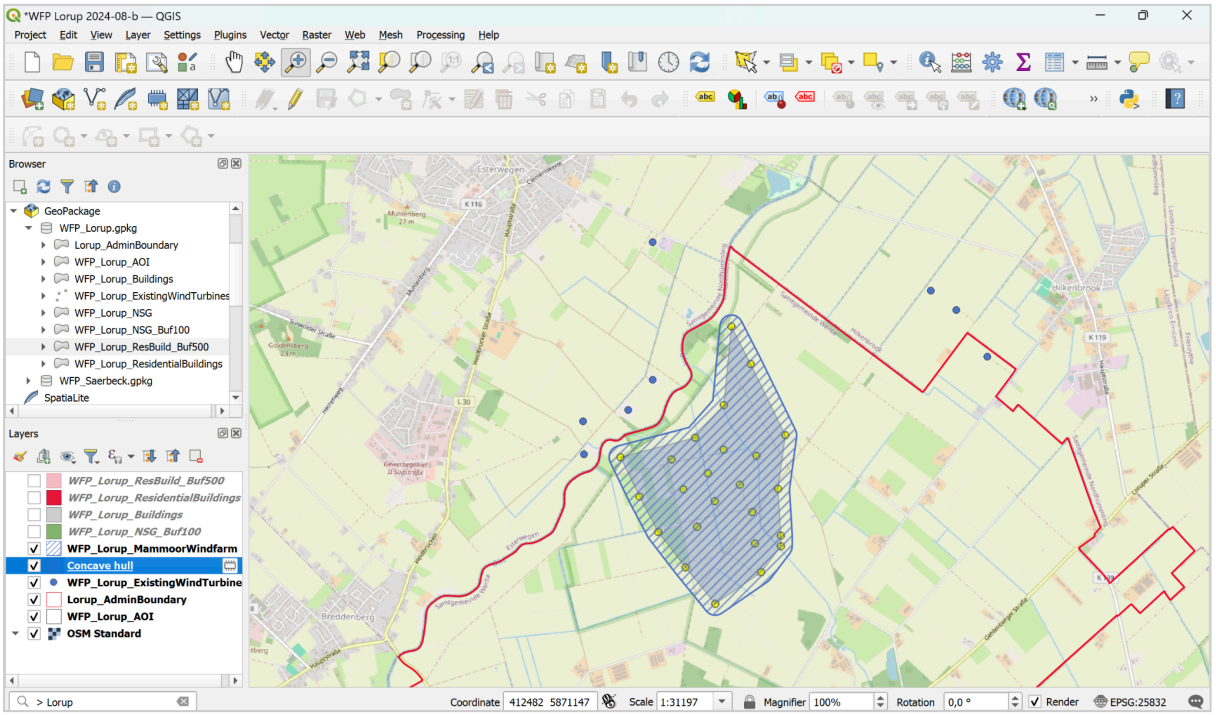

Fig. 35: Area of the existing Mammoor Wind Farm (blue hatched)

To determine the regions still eligible for the expansion of the Mammoor wind farm, we subtract the areas of the existing wind farm as well as the exclusion areas from the area of the municipality of Lorup.

For this we use the tool Difference (multiple) of the Geoprocessing Toolbox. Specify the administrative boundary of Lorup as input layer and then select the layers containing the polygons of the Mammoor wind farm, the buffered protected areas and the buffered residential buildings as overlay layers. The result should not be saved as a layer named "Suitable Expansion Areas" in our project's geopackage.

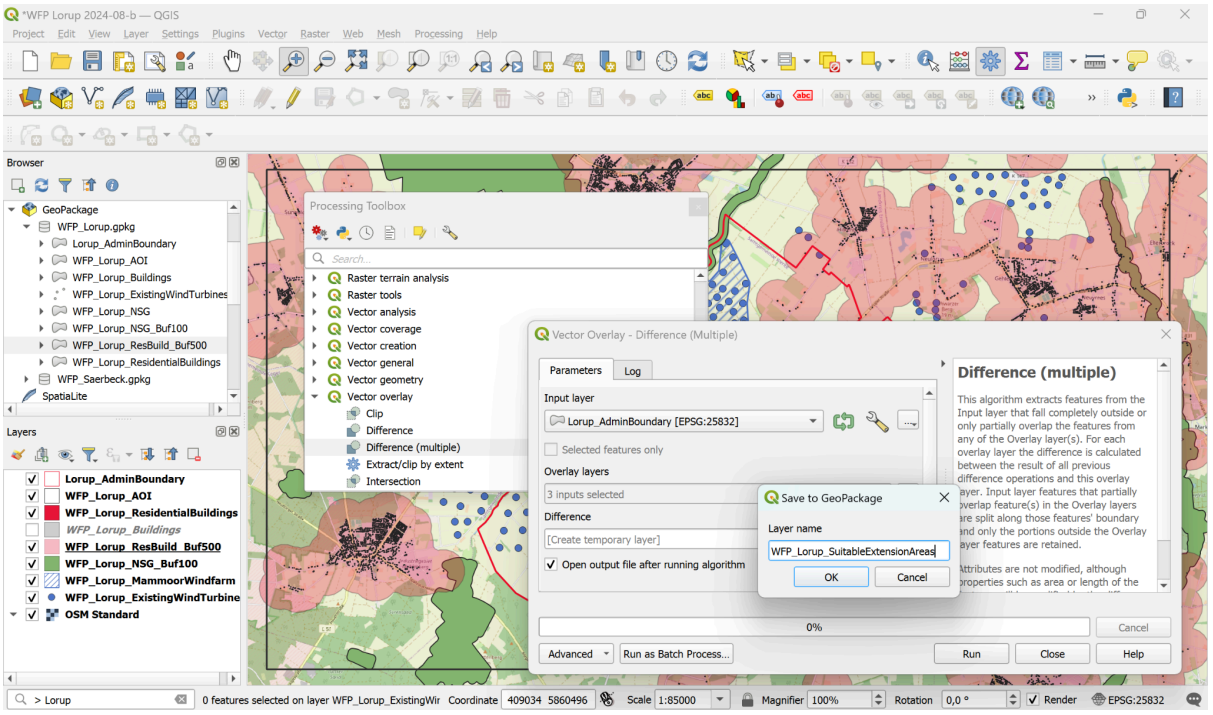

Fig. 36: Computing the area that may be suitable for extending the Mammoor Wind Farm

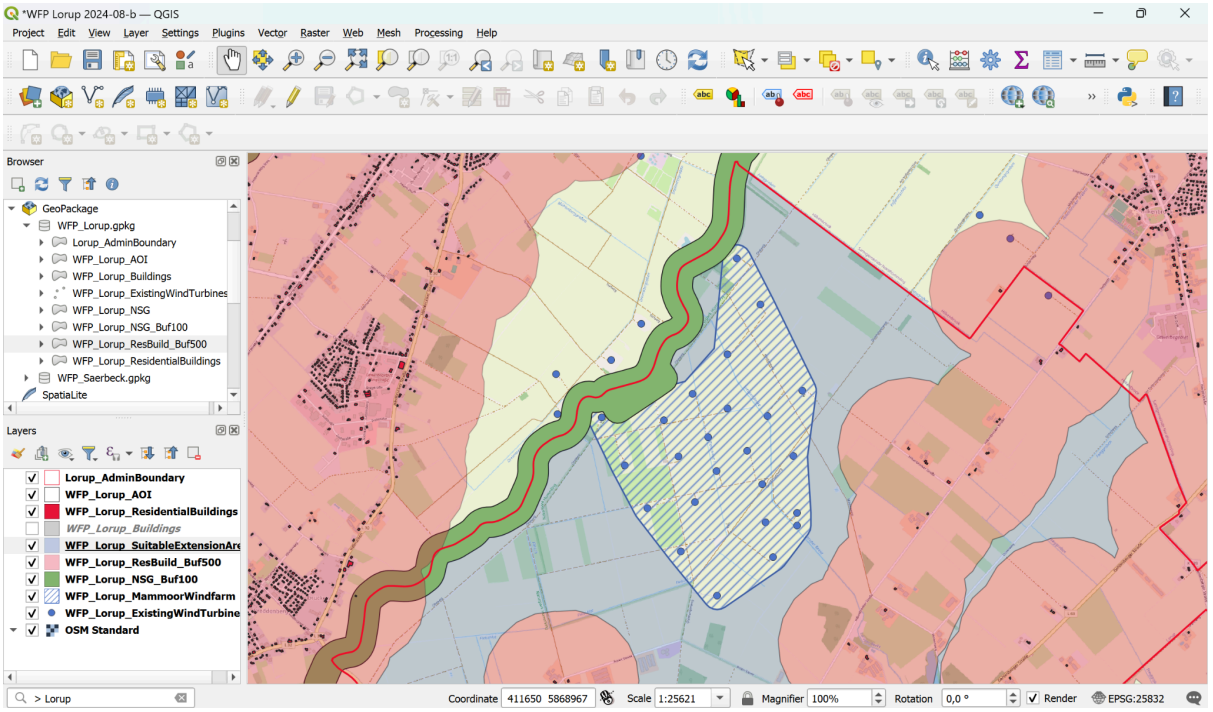

Fig. 37: Mammoor Windpark and potential extension areas within the municipality of Lorup

Save your project (>project, >save) to save the status of your work.

The generated layer now contains the area that is suitable for the expansion of the Mammoor Wind Farm, taking into account the location of nature reserves and residential buildings (outside settlement areas). At this point our exercise ends. In practice, further criteria, such as the location of buildings within settlement areas or the distances to roads, must be evaluated to further narrow down the usable area before the concrete expansion area can be determined.

4. Summary and Discussion

In this tutorial, we used the example of wind farm planning to investigate the extent to which spatial data infrastructures support the availability and usability of geodata.

We were able to use the geoportals of the GDI-NI and MDI-DE to find freely available geodata suitable for our use case. We were able to download the data as files or via web feature services and analyze the data with standard software - in our case QGIS. We were able to identify a potential extension area of the Mammoor wind farm according to the predefined set of criteria. I.e., we have achieved our goals!

By centralizing metadata in one place, SIIs make it easy for users to find and download the information they need without having to go to many sources. For example, the State Office for Geoinformation and Land Surveying of Lower Saxony (LGLN) provided valuable administrative boundaries and building data that allowed us to delineate the study area and consider the distance criteria for buildings. The Lower Saxony Ministry for the Environment, Energy and Climate Protection provided protected area data that helped us identify restricted areas for the construction of wind turbines. MDI-DE gave us access to data from the Federal Network Agency on existing wind turbines, which helped us understand the status quo of wind farms.

So, what was the contribution of the spatial data infrastructures?

- The stakeholders of the spatial data infrastructures coordinated their efforts to make geospatial data available in high quality, easy to use.
- They agreed upon standards for data, metadata, interfaces and licensing to improve the accessibility and usability of datasets and services.
- They have ensured that the metadata is stored in metadata catalogs that can be used via web based geoportals to search for and find geospatial data.
- They have ensured that the metadata catalogs are interconnected and that data from local authorities can also be found at the national and international level.

However, our overall impression was that there is still quite some room for improvement.
Here are some points for discussion:

- Searching for data in the geoportals turned out to be very tedious due to a) the very **limited capabilities of the search engines** and b) the often **poor quality of the metadata** provided.

  From google, Bing & co, we are used to find the most relevant items at the top of the result set. The simple search engines in the geoportals don't make use of concepts such as phonetic search, semantic similarities, or smart ranking mechanisms. Multi language support is very limited. Data and services are often registered with specific metadata records, resulting in unfavorable redundancies. Metadata is often inconsistent or incomplete, titles are not informative, and important questions e.g. on the up-to-dateness or on the spatial accuracy are often not answered. Filtering based on low-quality metadata leads to unusable results.
  However, the metadata sets are just the tip of the iceberg regarding the knowledge that is needed to make use of the data. The more critical the quality requirements are, the more information is needed on the data and on the application domain. Limited data understanding limits the ability to use the data in a meaningful way. Therefore metadata should always provide direct links to resources that provide more detailed information on the data and its context.

  High quality metadata and a good usability of the SDI's geoportals is not only nice-to-have regarding a good overall user experience, but it is essential to make geospatial data and services findable and therefore accessible and usable.

- The availability and usability of high-quality data plays a critical role in wind energy planning. But especially the most up-to-date and thus most **valuable data are often not offered as open data**. I.e., if you're not able to spend money on the authoritative data you have to use lower quality data resulting in lower quality results. An open data policy is important to facilitate the use of Authoritative Data to support the provision and use of renewable energy by fostering transparency and supporting informed decision-making.

- There are still **valuable geodata sets that have not been contributed to the spatial data infrastructures**. An example is the MaStR dataset of the Bundesnetzagentur (Federal Network Agency). As a work around, MDI DE offers access to an episodically updated subset for the region of the coastal countries. But the best solution would be to get the data directly from the provider of the original dataset.

Actually we could add some more aspects, which is a bit frustrating, given the fact that the history of developing these public sector SDIs spans more than two decades already. But the development does not stand still and the actors are all very committed to the further improvement of the spatial data infrastructures. Furthermore the concepts and technologies

hadvance as well so that it is easier to provide a better performance of the infrastructures. Many good reasons to be optimistic.

5. Check your Knowledge

You can use the following questions and the task to check and deepen your knowledge. Sample solutions to the questions and tasks can be found in the tutorial's GitHub repository: https://github.com/oer4sdi/OER-SDI4WindFarmPlanning/tree/R240903/sampleSolutions

Questions

- What bodies, processes and artifacts can you identify at the policy, organization, and implementation levels of the GDI NI?

	Bodies/Institutions	Processes	Artifacts
Policy	A1	B1	C1
Organizational	A2	B2	C2
Implementation	A3	B3	C3

Try to assign the following institutions, processes and artifacts to the correct positions in the table:

( ) State Parliament of Lower Saxony

( ) Technical coordination of GDI-NI

( ) WFS NI ALKIS (simplified)

( ) GDI-NI coordination office at the State Office for Geoinformation and Surveying of Lower Saxony (LGLN)

( ) Searching and accessing spatial datasets and services

( ) Guidance document on creating high-quality metadata

( ) Lower Saxony Spatial Data Infrastructure Act

( ) The Revento GmbH, consuming high-quality spatial data in the context of wind farm planning

( ) Transposing INSPIRE into state law in Lower Saxony

- What is the difference between the geoportal and the metadata catalog of a Spatial Data Infrastructure?

- What makes a metadata catalog a federated metadata catalog?

- What are the advantages of a web feature service over a simple file download?

Task

- The municipality "Saerbeck" in the district of Steinfurt, North Rhine-Westphalia would like to determine which areas are available for the extended use of wind power in their municipal area. In a first step, existing nature reserves (NSG) and residential buildings are to be considered.

  Use the Geodata Infrastructure North Rhine-Westphalia (GDI-NRW) to acquire suitable data on municipal boundaries, existing wind turbines, nature reserves and building footprints for your data analysis. Calculate the exclusion areas of the nature reserves (100m buffer) and the distance areas to residential buildings (500m buffer) as for Lorup and subtract them from the municipality area.