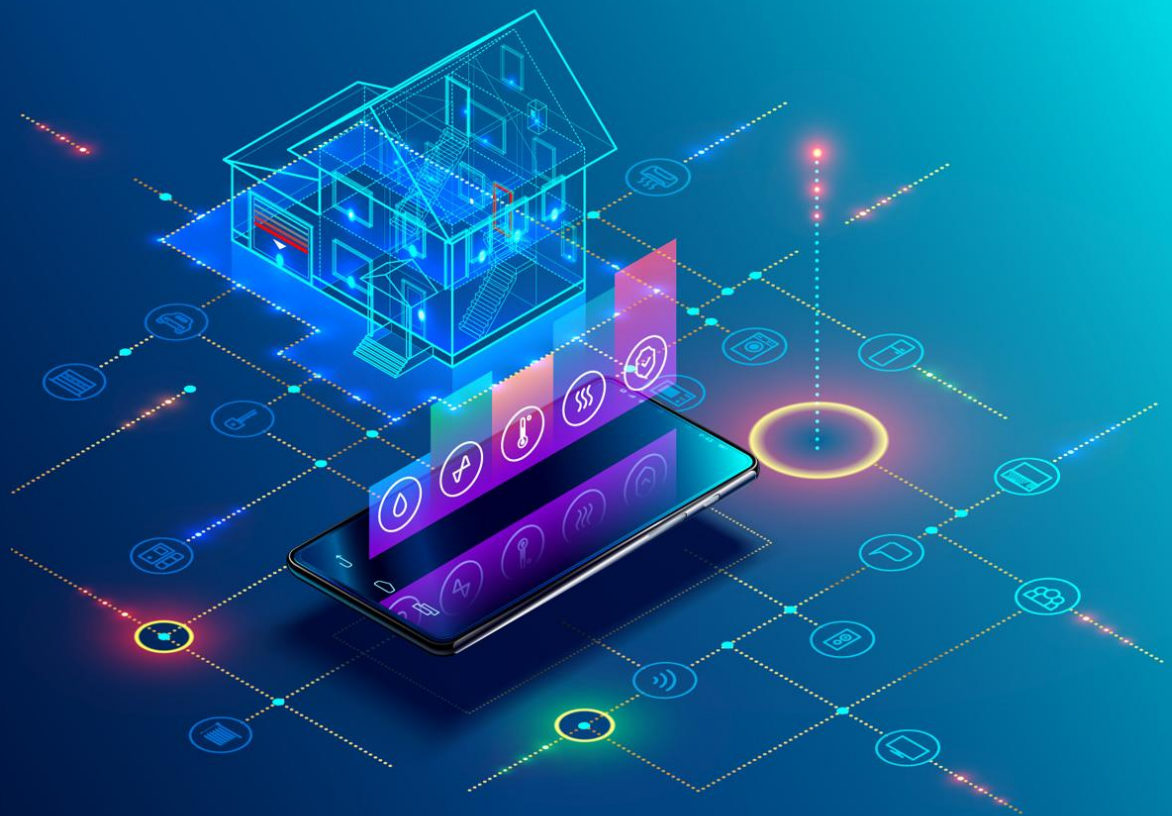


IT solutions to couple environmental, surroundings and weather data to BIM

Deliverable 1.4



Deliverable Report: D.1.4, issue date on 31.10.2020

BIM-SPEED

Harmonised Building Information Speedway for Energy-Efficient Renovation

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D1.4 - IT solutions to couple environmental, surroundings and weather data to BIM

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Publishable executive summary

Having a more comprehensive view of all factors influencing the planning, construction, and implementation of renovation projects is strongly suggested by many studies ([1], [2], [3], [4], [5]) and is the underlying purpose of the BIM-SPEED project. The urban context, including the urban geometry and form, land use, green and blue spaces in the neighbourhood, along with the environmental condition of the area regarding weather and microclimate conditions, pollution, and the acoustic characteristics can affect the renovation projects in different phases. Increasingly responsive HVAC (Heating, Ventilation and Air Conditioning) systems and the associated gains in energy performance require equally high-resolution real-time information on the building's surroundings. Numerous studies and projects tried to integrate surrounding GIS and environmental data into BIM data for construction and renovation purposes, outlining the use cases of such an integration.

This deliverable summarizes the results of Task 1.4: *Environment, climate and surrounding data*, and is meant to be used as a manual for the services implemented as part of this task. Two services have been implemented within this task of BIM-SPEED project: MEREEN (MEteo Reelle pour la simulation Energetique) weather service and BIM-SPEED GIS (Geographic Information System) data provider service. The former provides actual long-term weather data across Europe, while the latter retrieves the geospatial features in the surrounding of a building. The strategy for integration to BIM (Building Information Modelling) is coupling the weather and geospatial data with BIM via the selection of the data according to the location of the demonstration site extracted from the IFC file and retrieving the surrounding data via geoprocessing. As a result, the deliverable includes, firstly, recommendations on protocols and standards for retrieving and storing external data of GIS, and secondly, a description of the services integrated into the BIM-SPEED platform to simplify access to the weather and geospatial datasets via using the standards mentioned above. Lastly, an example workflow to utilize these services and apply the data for decision making for a specific demonstration site is presented.



List of acronyms and abbreviations

AOI: Area of Interest
API: Application Programming Interface
BIM: Building Information Model
BEM: Building Energy Model
CAMS: Copernicus Atmosphere Monitoring Service
EEB: Energy-efficient Building
EPW: EnergyPlus Weather Data
ESRI: Environmental Systems Research Institute
gbXML: Green Building XML schema
GFZ(DE): Floor Spec Ratio
GIS: Geographic Information System
GML: Geography Markup Language
GPS: Global Positioning System
ha: hectare
HVAC: Heating, Ventilation and Air Conditioning
IFC: Industry Foundation Classes
IT: Information Technology
KPI: Key Performance Indicator
MEREEN: MEteo REelle pour la simulation Energetique (EN: MEteo REal for ENergy simulation)
NDVI: Normalized Difference Vegetation Index
NOAA: National Oceanic Atmospheric Administration
OGC: Open Geospatial Consortium
OSM: Open Street Map
PM: Particulate Matter
WCS: Web Coverage Service
WFS: Web Feature Service
WMO: World Meteorological Organization
WMS: Web Map Service



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1. Introduction

Although buildings in urban areas are located in the urban context, get affected by the surrounding features, and affect their surroundings during the renovation process, the geospatial domain has not got enough attention within the renovation workflow. The surrounding and environmental data can affect the renovation process in different phases and for various use cases. As part of Deliverable 1.4: *IT solutions to couple environmental, surrounding and weather data to BIM*, to retrieve geospatial data, the BIM-SPEED GIS data provider service has been implemented and integrated into the BIM-SPEED platform. A prerequisite to implement this service was to structure the required data among an increasingly big pool of geospatial and environmental data which are provided by authorities, private sector organizations, and open-source initiatives, to be able to get access to the datasets that are required to support the building renovation process before commencing the planning phase. To this aim, firstly, an ontology has been developed. This ontology represents the surrounding built and natural environment of a renovation project. Detailed information about the ontology and its development is presented in an article¹. The ontology is also available online². An initial list of use cases (Figure 1) is defined to develop the ontology. Then, according to the literature review, expert’s knowledge and brainstorming, required data for each of the use cases are listed. With this approach, a knowledge system has been introduced to narrow down the broad domain of geospatial data into those that can support building renovation in different phases.

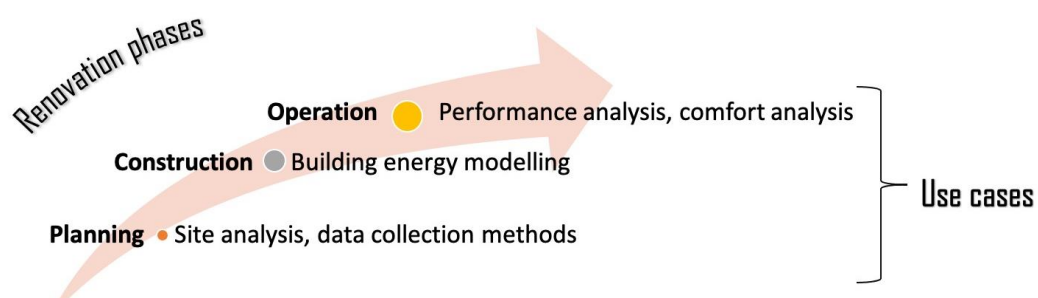


Figure 1: Renovation phases and relevant use cases of GIS and environmental data integration

On the other hand, building energy modelling, as one of the essential steps in the building renovation, requires weather data from the nearest weather station. To this end, MEREEN weather service has been implemented and integrated into the BIM-SPEED platform. This service provides access to historical actual recent weather data of the closest weather stations via web service access. Geospatial analysis has been used for the selection of the optimal weather station. The result includes the required weather parameters for energy modelling and provides the data in the EPW file format. This format is required for one of the most widely used energy simulation engines, EnergyPlus, which is also utilized in CYPE software applications, and is introduced in D3.2: *A set of support tools and standardised procedures for BEM creation as BEM tool*.

¹ <http://ceur-ws.org/Vol-2636/05paper.pdf>

² <https://depositonce.tu-berlin.de/handle/11303/11235>



Section 2 presents recommendations for protocols and standardization for retrieving GIS data. Following that, section 3 and 4 provide a description of the two mentioned services implemented within BIM-SPEED project and how to access them. Lastly, section 5 illustrates a proof of concept on a specific BIM-SPEED demonstration site.

1.1 Contributions of partners

Partners' contribution to the deliverable can be summarized as follows:

Table 1: Contribution of partners

#	Partner	Contribution
1	TUB	Leader of the deliverable, coordination of the overall task activity, development of the ontology, GIS data provider service specification
2	CSTB	Implementation of weather data service, implementation of GIS data provider service, internal reviewer of the deliverable
3	CYPE	Suggestions for developing the use cases for the ontology, which is used in GIS data provider service
4	UNIVPM	Suggestions for developing the use cases for the ontology, which is used in GIS data provider service
5	ASP	Collecting environmental and surrounding data for the two Bulgarian demonstration sites (Varna and Malko Tarnovo)
6	STRESS	Providing and managing GIS data for Frigento demonstration site
7	MTB	Suggestions for developing the use cases for the ontology, which is used in GIS data provider service, internal reviewer of the deliverable

1.2 Relations to other activities

This deliverable can be helpful in different stages of the renovation ranging from site planning to performance analysis. Thus, it can be connected to other tasks via the different use cases mentioned in Figure 2.

T1.4: *Environmental, climate and surroundings data*, is directly related to T3.3: *Integration of environmental and GIS data to BEM*, where the integration of GIS data with BEM is required. The services implemented for D1.4 shall directly be used in T3.3, as one of the use cases mentioned in D1.4 is building energy modelling. On the other hand, as the focus in D1.4 is the collection of 2D GIS vector data, it is worth mentioning that the integration of 3D GIS data with building data and providing the data for studying the solar mask on the building is discussed in D3.3 in enriching BEM with GIS data via CityGML to gbXML data conversion.

Moreover, it is indirectly related to other tasks within WP1: *Collecting and understanding BIM data from existing buildings*. It can be used for planners and decision-makers for selection of the methods for data collection related to the individual building in T1.1: *Architectural, structural, thermal 3D data acquisition and diagnostics*. T4.1: *Baseline, KPI and Use Case Definition* focuses on defining Key



Performance Indicators (KPIs) to measure the achievements of EEB goals through renovation. The KPIs will be verified against the building data and external data (environment and GIS) which are collected via D1.4. T4.3: *Acoustic, thermal comfort, and indoor air quality assessment*, T4.4: *Lighting and visual comfort analysis* and T4.5: *Holistic performance assessment* shall use the data provided in D1.4 as a basis for planning the comfort analysis considering the sources of noise pollution such as roads and railway, shading effect of surrounding buildings and solitary trees, CO2 emission, and other air pollution maps of the district respectively for acoustics, thermal and air quality assessment.

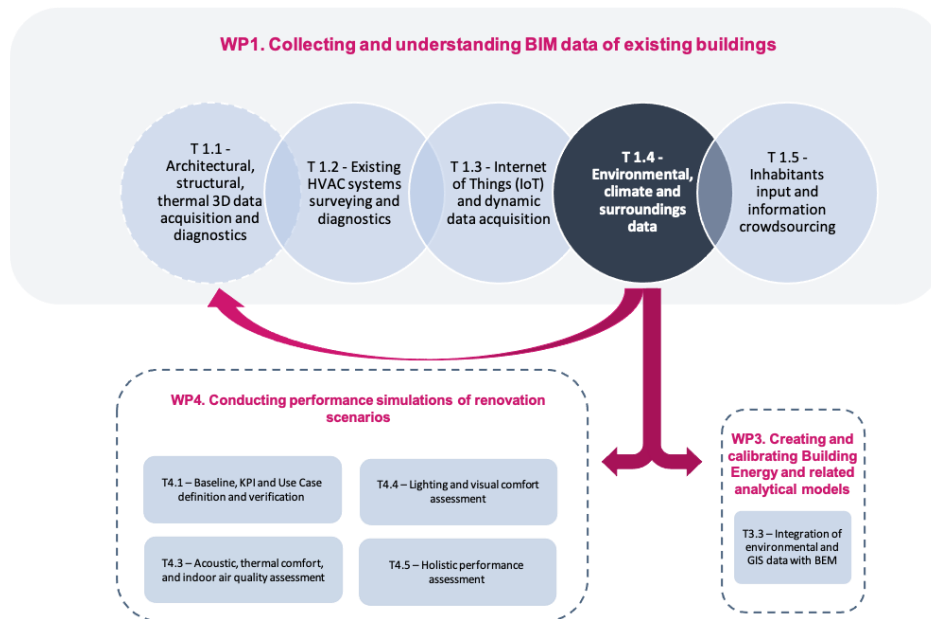


Figure 2: Relation between T1.4 and other tasks in BIM-SPEED project



2. GIS data, standards and protocols

Geographic Information System (GIS) is a computer system to capture, store, and display data related to positions on the surface of the Earth. GIS allows complex multi-layered geographic analysis and helps to understand, for instance, socioeconomic and environmental inter-dependencies. Different data types are utilized to represent GIS data, which can be categorized mainly into vector and raster data formats. Attributes and properties of the features can be assigned to the geometrical feature via an attribute table. GIS data can be provided in different spatial dimensions. The selection of the dimension to represent an object is relevant to the characteristics of that object and the application for which the data is required. 3D GIS represents the opportunity to depict objects more closely to reality, but for numerous applications and use cases, detailed 3D representation is often unnecessary. Different software solutions have been introduced to view and analyse geospatial data some of which are free and open-source (e.g., QGIS) and others are proprietary (e.g., ArcGIS Desktop from ESRI).

To realize the capabilities of utilizing GIS data in different applications, it needs to be sharable and interoperable. Open standards are introduced within this domain to facilitate the interoperability process. Evolving with technology, the GIS domain evolved in implementing interoperability. This has been started from implementing file format converters, to developing standards interchange formats such as GML, CityGML, to open data formats such as shapefile. Today the interoperability is achieved by the integration of standardized GIS Web Services such as WFS (Web Feature Service), WMS (Web Map Service), and WCS (Web Coverage Service) which are implemented by Open Geospatial Consortium (OGC), an international voluntary consensus standards organization, founded in 1994. Web services are currently considered as the best long-term solution for geospatial data interoperability. Some of the data formats and standards in the geospatial domain are introduced in Table 2.

Table 2: GIS data formats and standards

GIS data formats/standards	Description
Shapefile	Geospatial data format developed by ESRI as open specification which is used now in many GIS software applications. Shapefiles can describe vector features in point, polyline and polygon formats, but topologies meaning the spatial relation between the features are not represented in shapefiles.
Coverage	Coverage represents distribution of a specific phenomenon in space and time, which can contain topology.
GML	GML is an XML-based OGC open standard to express geographical features either by modelling geographical features or getting used



	as an open interchange format. GML can integrate all forms of geographic data such as vector and coverage.
CityGML	CityGML is an open standard data model and exchange format defined as an application schema for GML3 to store digital 3D cities and landscapes. CityGML defines different standard levels of detail for different purposes. It is an OGC XML-based standard and supports geometric descriptions, specification of semantics and topology information.
Web services	Web service interface standard provides an interface for allowing request for data across the web using platform-independent calls. The most important web service standards in geospatial domain are as below:
	WFS (Web Feature Service): allowing request for geographical features. When writing WFS, these operations should be implemented: GetCapabilities, DescribeFeatureType, GetFeature. When WFS provides the requested data, the format of the result can be zipped shapefile, GeoJSON, GML or CSV.
	WMS (Web Map Service): allowing request for georeferenced map images. When writing WMS, these operations should be implemented: GetCapabilities, GetMap.
	WCS (Web Coverage Service): allowing request for coverages. When writing WCS, these operations should be implemented: GetCapabilities, DescribeCoverage, GetCoverage.



3. IT architecture and processing steps for retrieving GIS and weather data

The approach which is used for retrieving GIS and environmental data related to a specific BIM dataset in IFC format is shown in Figure 3. The goal is to implement two services, one for collecting surrounding geospatial data: *BIM-SPEED GIS data provider service*, and another for collecting weather data: *MEREEN weather service*. The main information extracted from the IFC file is the GPS coordinates of the building (Figure 3, Step 1).

Next step for collecting geospatial data is to determine what are the use cases for collecting geospatial data and what are the data required for those use cases (Figure 3, Step 2). An initial list of use cases is provided as below:

- Site planning
- Building energy modelling (BEM)
- Acoustic comfort analysis
- Thermal comfort analysis
- Lighting comfort analysis
- Air quality comfort analysis

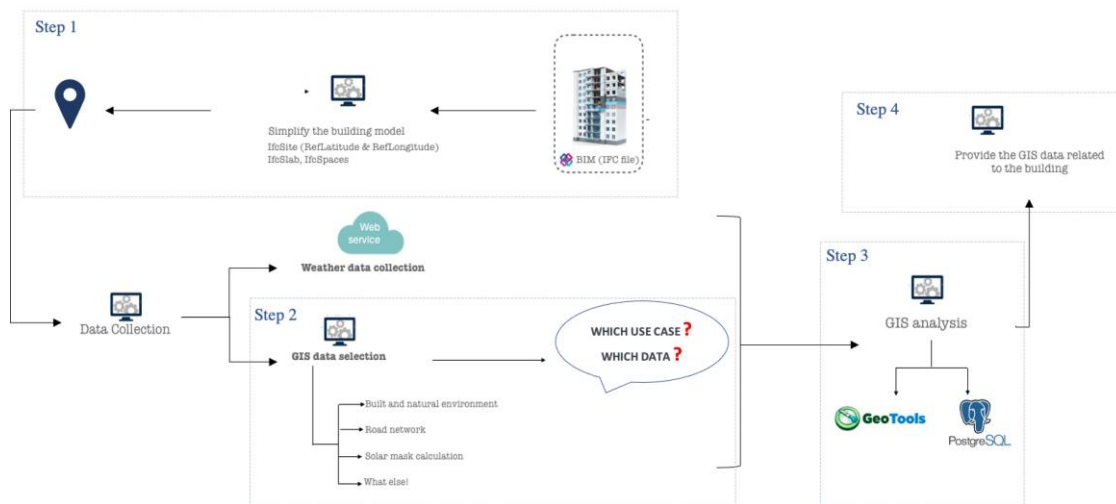


Figure 3: Processing steps for retrieving GIS and weather data

Different data layers may be required for each of these use cases. But these exhaustive list of data layers can be logically catalogued in different data categories which represent specific abstract concepts. For instance, for 'Railway' data category, different data layers related to railways such as 'railway_station' and 'railway_network' may be provided. A suggestion for the list of data categories for each use case is provided in Table 3. This is an initial list of use cases and categories; it can be expanded in future and accordingly, the prototype will be updated.



Table 3: Use cases and data categories required/suggested for them

Use case	Data category
Site planning	Building, Road, Walkway, Railway, Airport, Monument (Historical areas), Land use, District boundaries, Vegetation area, Tree, Parking, Population density, Population age, Population education level
Building energy modelling	Building, Road, walkway, Tree, Energy network, Energy consumption, Renewable sources of energy (Biomass energy potential, Wind energy potential, Solar energy potential, Geothermal energy potential), Energy consumption (if provided along with Building age, Population age, Population education level, Population density), weather data
Thermal comfort analysis	Building, Tree, weather data
Acoustic comfort analysis	Road, Railway, Walkway, Airport, Tree, Building, Pond, Lake, River, Park, Population density, Noise level
Lighting comfort analysis	Building, Tree, Road, Walkway
Air quality comfort analysis	Road, Tree, Vegetation area, CO2 emission, Fine particulate matter (PM) distribution

The mentioned data categories are also structured and represented in a form of ontology which has been already mentioned. Also, Figure 4 shows the same information in a graphical format.

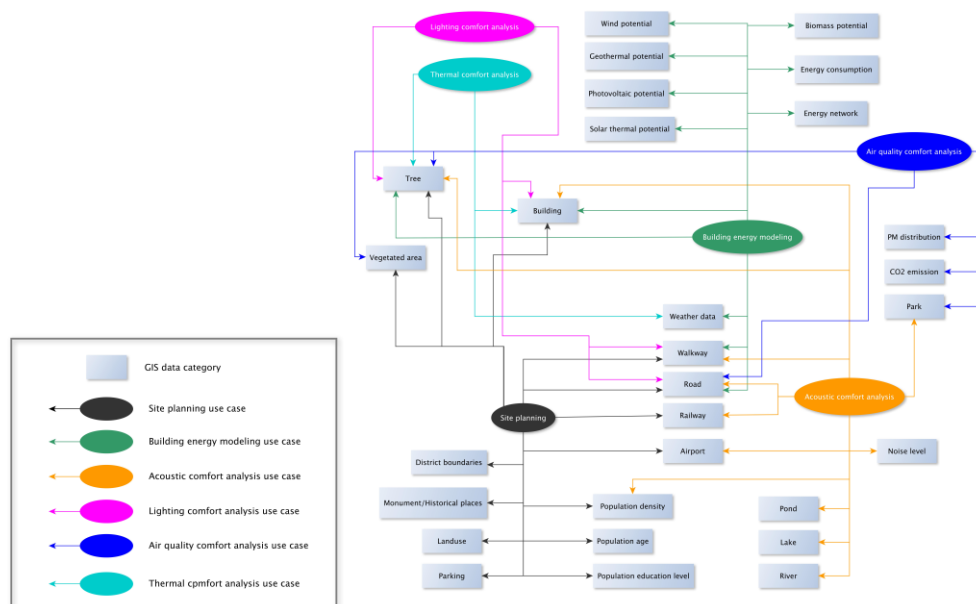


Figure 4: Required/Suggested GIS data categories for different use cases



GIS data are logical collections of geographic data (including data about location) that are used to create maps and are also the basis for geospatial analysis. It is possible to work with GIS data through layers in many GIS software applications. According to ESRI documentation³, each layer references a dataset and specifies how that dataset is portrayed. Table 4 shows the data categories and possible associated data layers. Selection of the data layer is dependent on the availability of data for a specific location.

Table 4: Data categories and possible relevant data layers for each of them

Data category	Data layers
Building	building, building blocks, including attributes related to the age, façade and roof of the building
Road	road network and attributes related to road type and width
Walkway	walkway network and attributes related to walkway type and width
Railway	Railway network and attributes related to railway type and width, railway station location and name
Airport	location of the airport
Monument	monuments and historical areas and places and attributes related to name, type and possible construction regulations
Land use	Land use type, GFZ
Boundaries	boundaries of districts, zip codes, city and attributes such as name, number, area
Vegetation area	green areas; public or private and attributes such as area
Tree	single trees, street-line trees and attributes such as tree height, tree crown size and tree species
Parking	parking lot, parking area
Park	park, playground and attributes such as name, area
Energy network	energy network and attributes such as energy type
Energy consumption	spatial distribution of energy consumption for each energy type

³ <https://doc.arcgis.com/en/arcgis-online/reference>



Biomass energy potential	spatial distribution of biomass energy potential (feed-in electricity and heating) in district or zip codes, location of existing biomass systems
Wind energy potential	spatial distribution of wind energy potential (feed-in electricity and heating) in district or zip codes, location of existing wind turbines
Solar energy potential	spatial distribution of solar thermal and photovoltaic (feed-in electricity and heating) potential in district or zip codes, location of PV and solar thermal systems
Geothermal energy potential	spatial distribution of geothermal extraction rate in different depths in district or zip codes
Population age	spatial distribution of population age in districts and zip codes
Population education level	spatial distribution of population education level in districts and zip codes
Population density	spatial distribution of population density in districts and zip codes
CO₂ emission	spatial and temporal distribution of Co ₂ emission
PM distribution	spatial and temporal distribution of PM
Noise level	spatial and temporal distribution of noise level

After selecting the use case and the data layer by the user, a geoprocessing analysis needs to be applied to retrieve geospatial data layers within a specific radius and to select the closest weather station to the demonstration site (Figure 3, Step 3). The last step is to store these datasets and provide access for the user (Figure 3, Step 4).

The next two sections are about these two services namely the BIM-SPEED GIS data provider service and MEREEN weather service. How to access the services from the BIM-SPEED platform is described in chapter 4. Figure 5 shows the IT architecture behind these services. The GIS data provider service provides the data by retrieving them from geodata servers, while MEREEN weather service uses NOAA and Copernicus archives to provide data for specific demonstration sites.



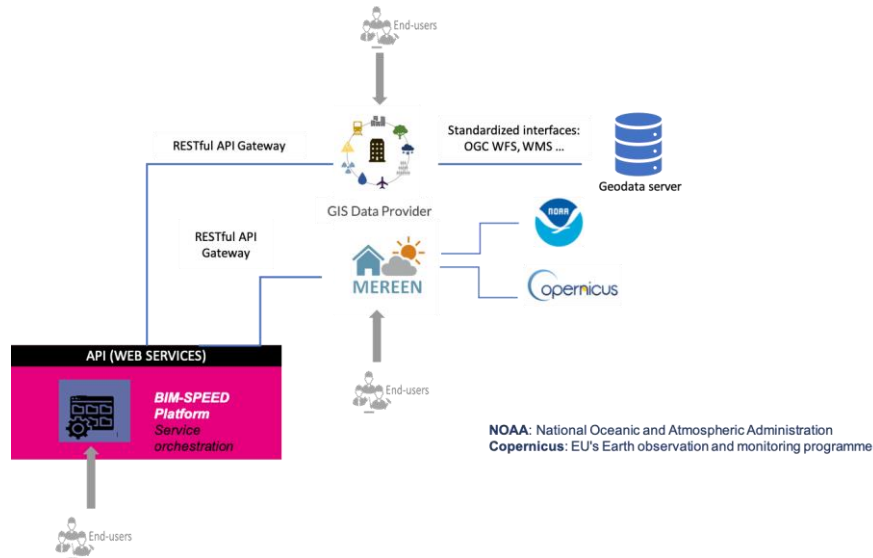


Figure 5: IT-architecture for retrieving surrounding GIS and weather data

3.1 The BIM-SPEED GIS data provider service

The objective of this service is to retrieve and provide accessibility to GIS surrounding data of specific demonstration sites. Two interfaces are implemented: one for the GIS administrator and another for the end-user. The GIS administrator is responsible for collecting, handling, and organizing the relevant GIS service endpoints (i.e., GIS data layers) for each specific demonstration site. GIS administrator shall use the list of data categories (Figure 4) as a framework to look for the required data. Realizing which data layers corresponds to which data category is the responsibility of the GIS administrator. The end-user interface is implemented for the end-users to simplify the access to these datasets to use them for the use cases mentioned before for building renovation purpose.

For different demonstration sites, GIS data layers are provided from organizations in different formats. Most of them are in shapefile format, some of them are provided via WFS, WCS, and WMS URLs, and even some of them are provided in CSV format containing longitude and latitude which make them transferable to geographic data. The BIM-SPEED GIS data provider service applies OGC web services, such as WFS. Web Feature Service (WFS) provides operations for creating, modifying, and querying feature instances from an underlying data store [6]. A feature is an abstraction of real-world phenomena. A real-world phenomenon can be a physical object such as a road or an abstract concept such as a district boundary. In general, a feature is considered as a 'spatial thing', meaning a thing which we can talk about in the universe of discourse and has spatial extent [7].

The proposal in this deliverable is to focus on utilizing available web services provided by authorities for two main reasons. Firstly, if the publishing organization updates the original data, the BIM-SPEED GIS data provider service will reflect those changes in real-time since it has a direct link to the service URL. Secondly, web services are more comprehensive, containing metadata that is retrievable according to different parameters such as bounding box.

The first version of the BIM-SPEED GIS data provider service utilizes a database which includes registry links to the WFS of different data layers and for different demonstration sites.



As mentioned, the BIM-SPEED GIS data provider service includes two interfaces, one for the GIS administrator and another for the user. Both interfaces use a backend which provides the following:

- A registry of Web Feature Services
- A registry of use case definitions
- A registry of data layers, organized in categories and connected to use cases (each data category can contain different data layers related to it)

The service also provides additional domain-specific functionalities which can be seen below:

- Obtain the list of GIS data layers pertaining to a given site (or location) in the context of a given use case
- Download the GIS data from the WFS server in GML/XML format
- Download the GIS data in shapefile (*.shp) format

Some metadata such as the bounding box of the data, a description about its content, the attribute table, which is assigned to its features, and so on can be extracted from the link. The administrator can then access these metadata, update information such as field names of the attribute table, add a description or translation to the names, and so on. Geospatial processing can provide the possibility of querying the data related to a specific demonstration site. The workflow from the user perspective is shown in Figure 6. By selecting the demonstration site and a specific use case, those WFS links relevant to the demonstration site and required for the use case will be selected. Selecting the location of the demonstration site can be either done from extraction from an IFC file or by selecting the location on a map. By selecting the use case, the data required for that use case will be selected and returned to the user. How to access both interfaces of this service is provided in section 4.1.

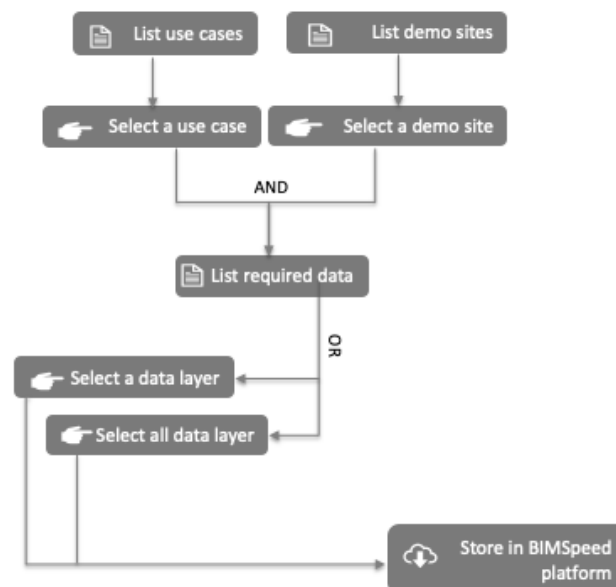


Figure 6: GIS data provider service from user perspective

API technical documentation for this service is available via this link:

<https://gisdata-provider-backend.dev.cpls.kroqi.fr/api/graphql>



The GIS data provider service utilizes GraphQL to interface software server and user interface. GraphQL⁴ is a query language for APIs. It provides an understandable description of the data in the API. The full documentation of the API is provided from the provided GraphQL link in a hyperlinked browsable form (Figure 7). This technical documentation about the API is directly generated from the schema defining the API and is usually provided with regarding to GraphQL APIs.

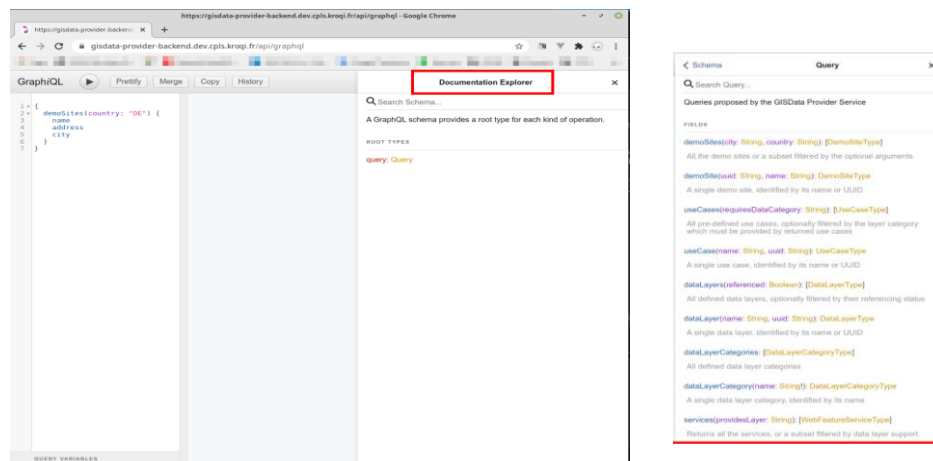


Figure 7: Technical description of GIS data provider service from GraphQL

3.2 MEREEN weather service

For extracting weather data, a separate service is implemented and integrated into the BIM-SPEED platform. MEREEN weather service was existing as a simple tool to collect and serve resampled weather data to be used by researchers. The extracted weather data needed reprocessing to be used for different applications. Many improvements have been made in the BIM-SPEED project to make this database operational and usable through the BIM-SPEED platform to provide a ready to use weather file for BEM simulation. Main development points within BIM-Speed project are:

- Fully operational web service that can read a BIM object and automatically select the best weather station for it.
 - Connection to BIM-Speed platform API
 - Diagnosis of data quality of stations to be able to select the nearest station that has data available to run energy simulation (diagnosis of the quality of all data required for energy simulation).
 - Fully functional map to get data.
- The most time-consuming part in retrieving the appropriate weather data is on the adaptation of raw weather data to files that can directly be used for energy simulation with softwares like EnergyPlus. This required development of the different sub-modules:
 - Different models to calculate variables that are not directly measured but can be estimated from the measured data:
 - Temperature of the ground
 - Direct and diffuse sun radiation

⁴ <https://graphql.org/>



- Height and azimuth of the sun
- Nebulosity of the sky
- Recalculation of pressure to the station level
- Calculation of absolute and relative humidity from dew point and outdoor temperature
- Representative temperature of the sky
- Adaptation and reformat of variables for specific file formats such as EPW format
- Decoding and processing of precipitation data to be properly provided for EPW files
- Advanced methods of substituting holes in the weather file. Simulations are not tolerant to holes. So, it was required to transform weather files from measurement (that have inherent holes) to data that are simulation compliant (without holes).
 - Development of simple substitution methods to fill short sequence of hole in the data
 - Development of advanced substitution methods, when a measurement is missing for more than 3 hours, using models that predict the missing variable using its previous relation to other variables of the station (usually linear relations but for sun radiation, more complicated models have been used inspired from some publications⁵)
- Backend improvements for the update documentation, performance indicator and overall quality of the database used.

The service provides data across Europe. It provides weather history for more than 15 years on more than 5000 weather stations. This service allows for providing weather data that are ready to be used for energy simulation. The target is the energy engineering team, working on a renovation project that can use these ready-to-use weather file for example to either calibrate BEM models using real weather data and compare them to real consumption data, or simulate renovation works impact with real weather input and evaluate their performance for the most extreme weather year. A benefit in this direction is that there is no need for reprocessing or building the weather file by the energy expert. This leads to gaining time, which is in line with BIM-SPEED objectives.

To provide weather data that are compatible with energy simulation needs, MEREEN weather service combines three main sources of data:

- Measured data for weather stations (World Meteorological Organization referenced weather stations) SYNOP/METAR data history.
- Solar radiations from Copernicus CAMS radiation services⁶
- Solar radiations from MERRA2 NASA services⁷.

MEREEN service can be requested using a post request with the following data:

```
{'properties': {'lat': {'type': 'number'},
```

⁵ <https://hal-mines-paristech.archives-ouvertes.fr/hal-00779714/document>

⁶ <http://www.soda-pro.com/fr/web-services/radiation/cams-radiation-service>

⁷ <https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/>



```
'lon': {'type': 'number'},  
'start_date': {'type': 'string', 'pattern': '^([0-9]{4}-[0-9]{2}-[0-9]{2})$'},  
'end_date': {'type': 'string', 'pattern': '^([0-9]{4}-[0-9]{2}-[0-9]{2})$'}}
```

It takes the GPS coordinates of the building, start and end date and provides the weather data of the nearest valid weather station to the building. Some stations referenced in the service may be obsolete and therefore do not have weather data for most recent years, so they are excluded from the query. GPS coordinates of the reference building can be selected via the selection of the IFC file and extracting location information from it. If the IFC file does not include the GPS coordinates of the reference building, the user will be redirected to the map of weather stations to select the nearest station manually. For a specific weather station, after sending the request to the service, the user will receive a weather data file in different formats. MEREEN can provide the output data at 1-hour timesteps for each station. The output format is either EPW which is compatible with the EnergyPlus engine or a French regulation specific format (RAY). The data includes general meteorological weather data as well as solar information coming from satellite imagery. Solar data are retrieved from CAMS (Copernicus Atmosphere Monitoring Service) radiation service for Europe. Since the service has a limitation in number of the requests per day, solar data are often delayed for about a month. The same delay applies to MERRA, the other satellite source of solar data from NASA. The currently provided data are recent actual data (for the past 15 years) that can be used for energy modelling for calibration purposes. Typical Meteorological Year data generation is currently under development and will be included in future versions of the service. Moreover, forecasting using climate change scenarios is also under development. How to access this service is provided in section 4.2.

More information about the data sources and variable description is available via this link:

<https://mereen.dimn-cstb.fr/doc/en>

API technical documentation can be found via <https://mereen.dimn-cstb.fr/api>



4. How to access the services

4.1 The BIM-SPEED GIS data provider service

Administration panel: Figure 8 shows the administration panel of the service. It consists of registries of demonstration sites, web feature services and use cases.

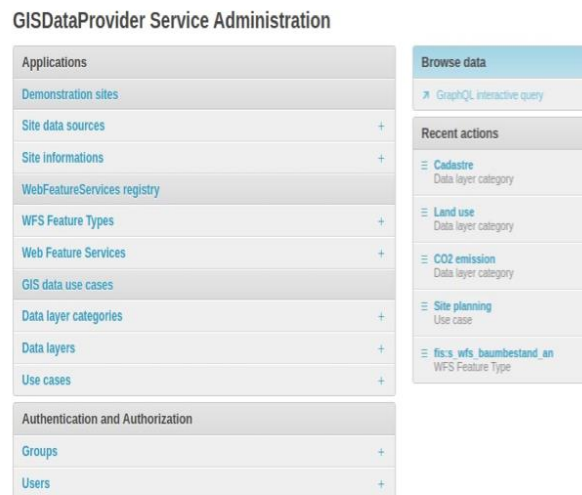


Figure 8: GIS data service – administration panel

It is possible to add a new demonstration site and assign attributes and the GPS location to the site (Figure 9). In the same manner, it is possible to add new use cases (Figure 10) and assign data categories to a use case (Figure 11).

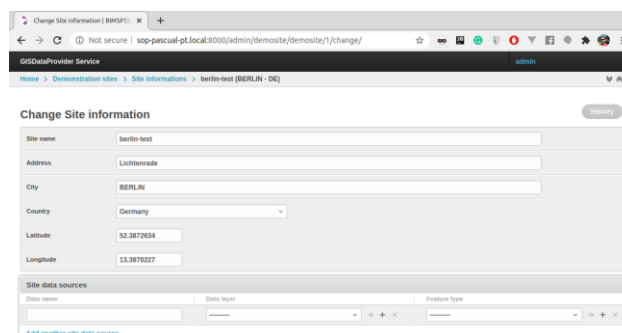


Figure 9: Adding/updating a new demonstration sit



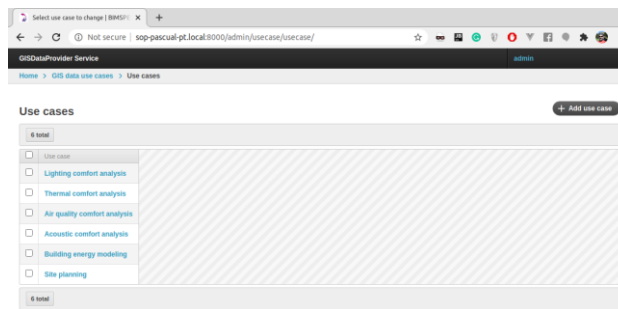


Figure 10: Adding a new use case

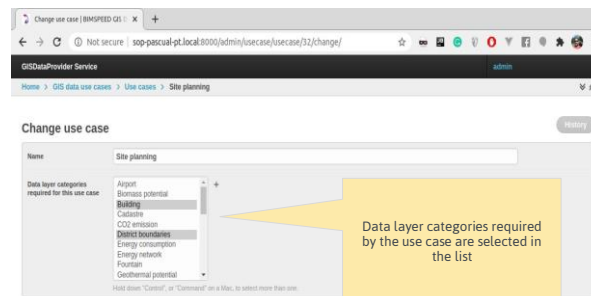


Figure 11: Adding/updating new layer categories to a use case

Adding a third-party web feature service is possible via adding the URL and a title. Figure 12 shows the list of some added web feature services. By clicking on the 'update' button (Figure 13) some information related to the data such as metadata and bounding box will be retrieved (Figure 14).

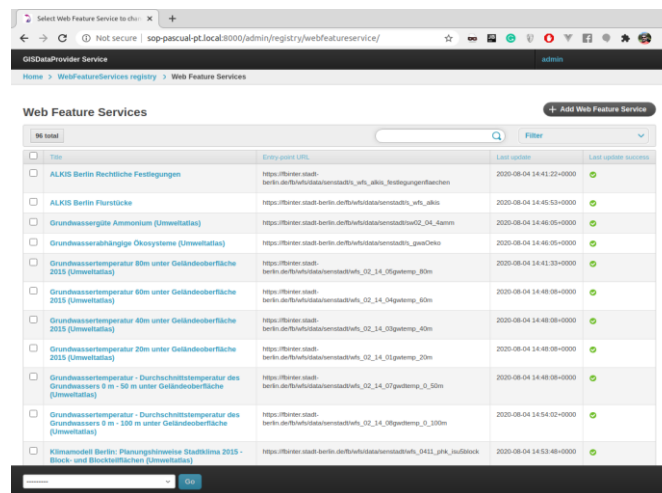


Figure 12: Web Feature Service list

Each WFS URL is a registry link to one or more specific data layer. As mentioned, each data layer belongs to a specific data category, and each data category may include several data layers. For instance, for energy network in the area, two data layers may be available, one layer representing the gas energy network and the other district heating.



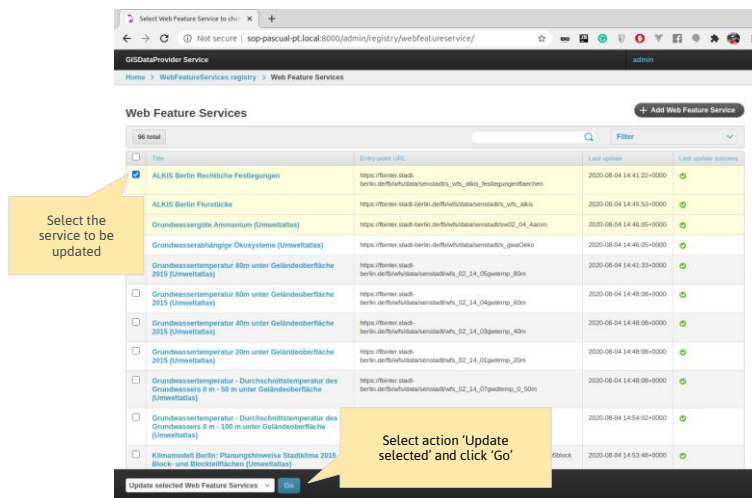


Figure 13: Updating the Web Feature Service

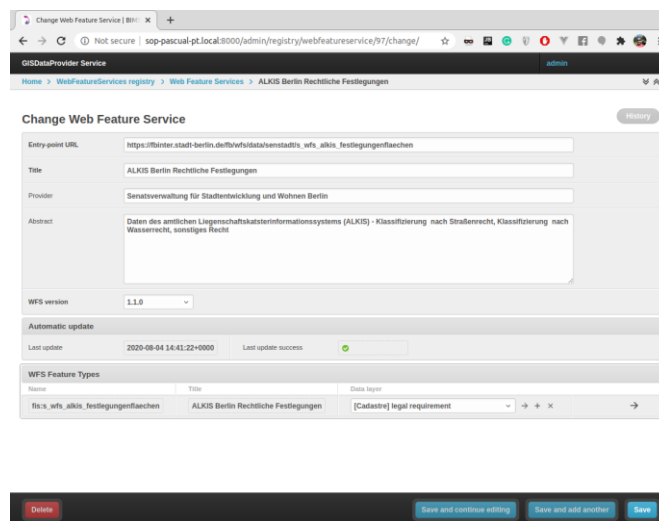


Figure 14: Updating the web feature service info

User interface: an explanation of the user interface is provided in a video⁸ for a better overview. More description is also provided in the following. The user can access the GIS data provider service from an IFC file in the BIM-SPEED platform. After opening the service, the procedure starts by clicking the ‘Extract features’ (Figure 15).

By selecting ‘Extract Feature’, the service checks the IFC file to find out the GPS location of the building from ifcSite (Figure 16). If the IFC file contains the GPS location of the building, it will be used for data extraction, otherwise, a map will show up, on which the user can select the location of the building. In addition, the user can select the AOI (Areas of Interest) radius for which the data collection is desired (Figure 17).

⁸ <https://vimeo.com/471457898>



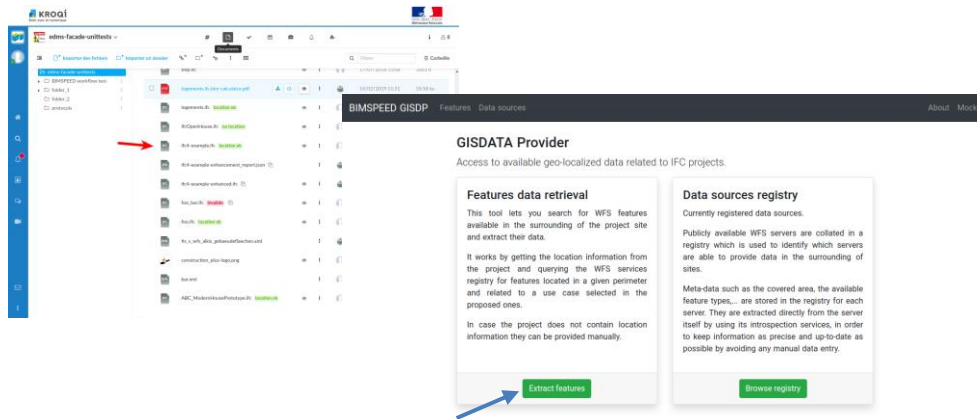


Figure 15: Access GIS data provider service from IFC file stored in the BIM-SPEED platform

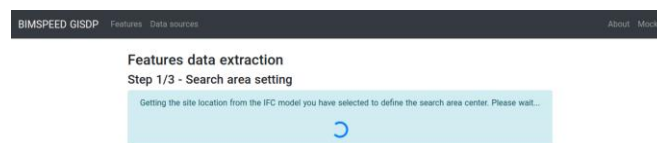


Figure 16: Retrieving data for a specific IFC file

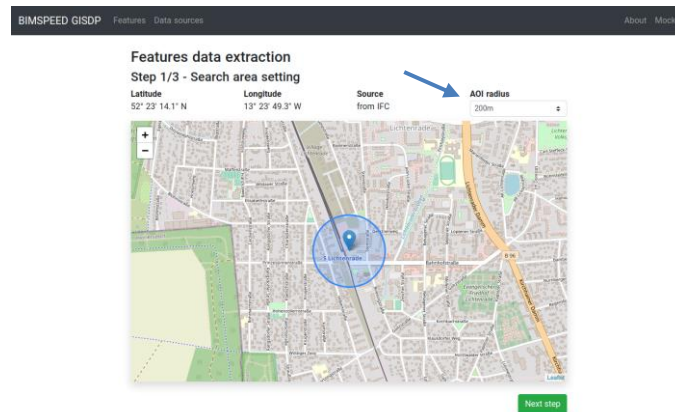


Figure 17: Selection of the building location and AOI radius

By clicking on 'Next' in previous step, a list of pre-defined use cases will be shown from which the user should select one (Figure 18).

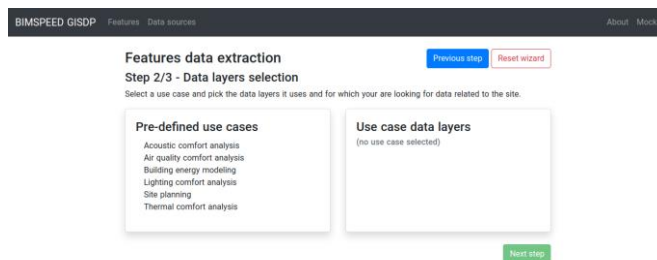


Figure 18: Selecting the use case by the user



By selecting the use case, a list of data categories suggested for that use case will be shown to the user (Figure 19). The user can select the desired data layers and click 'Next'.

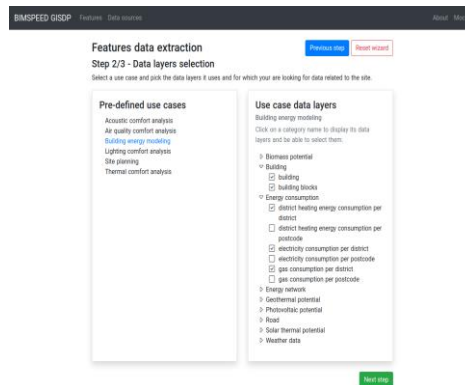


Figure 19: Selecting required data categories for a specific use

In the next step, a summary of the selections will be shown to the user. The user still has a chance to change the selections if required, by clicking on the 'Previous step' (Figure 20). Otherwise, the next step will show information about the layers and their sources for download.

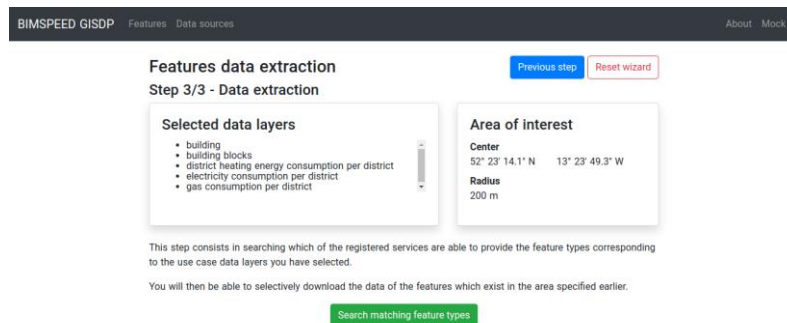


Figure 20: Summary of the user's selection

Figure 21 shows the layer's original name and their sources and provide some actions for them. Some details extracted from the WFS link will be shown by clicking on 'Details' (Figure 23). The 'Extract data' displays the dialog for specifying the extraction process options of features. The options include the data format (GML and Shapefile), the maximum count of features to be retrieved (limited to a reasonable value to avoid overloading all the server involved in the process, included the ones at the end of the chain), and the destination of the extracted data (Figure 22). Based on the selection in previous step the data is downloaded in the BIM-SPEED platform (Figure 24). Figure 25 shows the option for saving the data in a local folder.



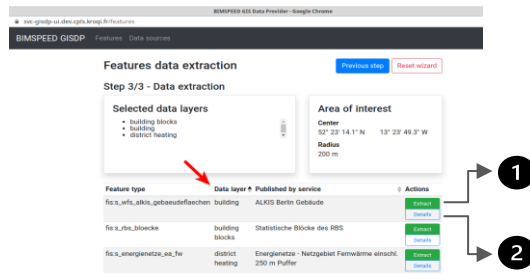


Figure 21: Information about the selected data layer

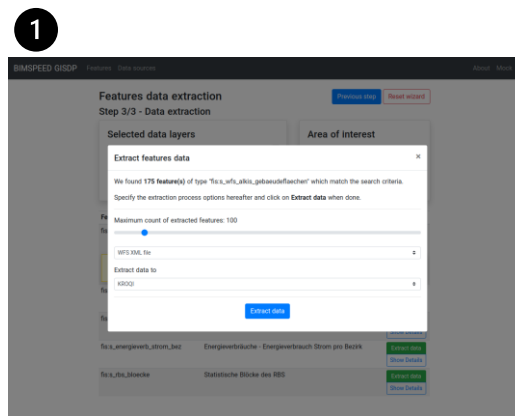


Figure 22: Select location for downloading the data



Figure 23: Information about source of data

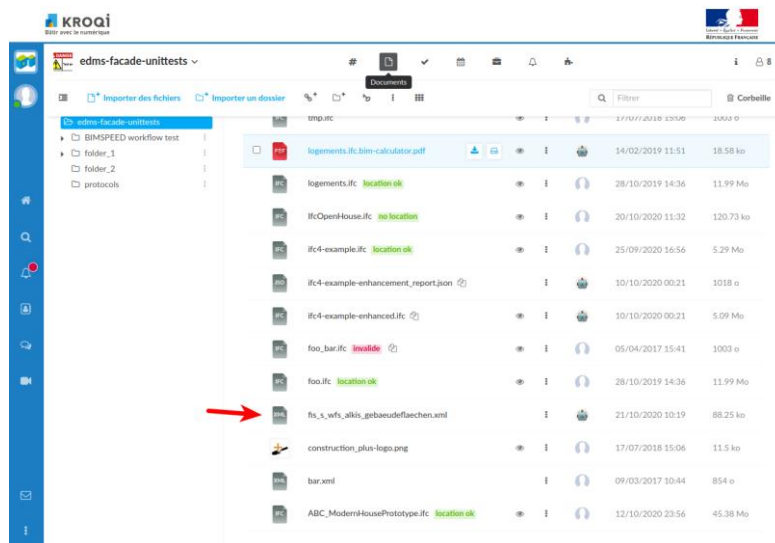


Figure 24: Access the downloaded GIS data in the BIM-SPEED platform



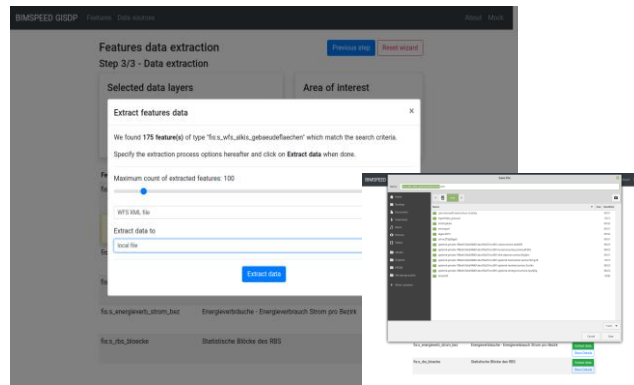


Figure 25: Downloading the GIS data in a local folder

4.2 MEREEEN Weather service

Accessing weather service is shown in Figure 26. The user selects the location of the building by selecting the IFC file which leads to the extraction of location from that file and opening the service from there. If the IFC file does not include the location information, the map of the weather stations will open to select a station manually (steps 1 and 2). In the next step, the weather data format and period should be selected by the user (step 3). Lastly, the data will be downloaded in the specific folder in the BIM-SPEED platform (step4).

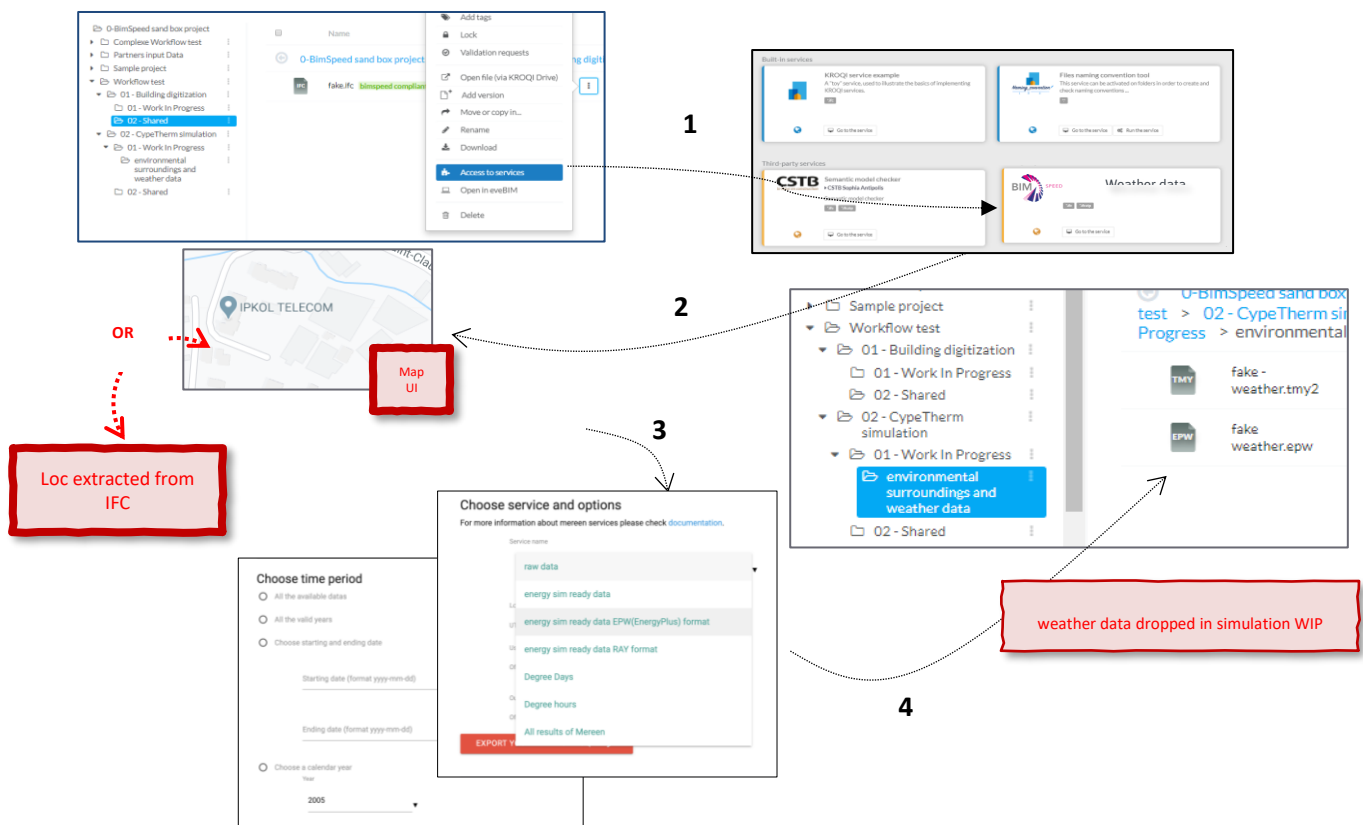


Figure 26: Weather data service from user's perspective



5. Illustration of a proof of concept on a specific demonstration site

This section shows how to use the IT solutions implemented in this deliverable to retrieve surrounding and environmental datasets and use them for decision-making purposes. Section 5.1 focuses on the use case of site planning for a selected demonstration site namely Berlin-Lichtenrade and uses BIM-SPEED GIS data provider service for collecting the required datasets. Following that, section 5.2 utilizes MEREEN weather service to collect required weather data for the building energy modelling use case for the same demonstration site.

As mentioned before, different software solutions allow the visualization and analysis of geospatial data. ArcGIS Version 10 and ArcGIS Pro Version 2.2.4, and ArcGIS Online have been selected for this purpose in this deliverable.

5.1 Site planning use case

To have a realistic view, it is very important to consider the location of the land and position of the building site. It is important to see the building in relation to sun, wind, water, electricity and other utilities, neighbours and preserving privacy, accessibility to the site via walkway and road, existing features such as surrounding buildings and trees and constraints such as construction site restrictions, topology, slope and so on. It is required to verify in advance the access road to the construction site, water, electrical and other utilities, as well as environmental factors such as drainage, groundwater, possibilities of floods, and so on [8].

Figure 27 shows the location of the Berlin-Lichtenrade demonstration site on a map (Google Maps). To extract geospatial data in vector format, BIM-SPEED GIS data provider service has been utilized.

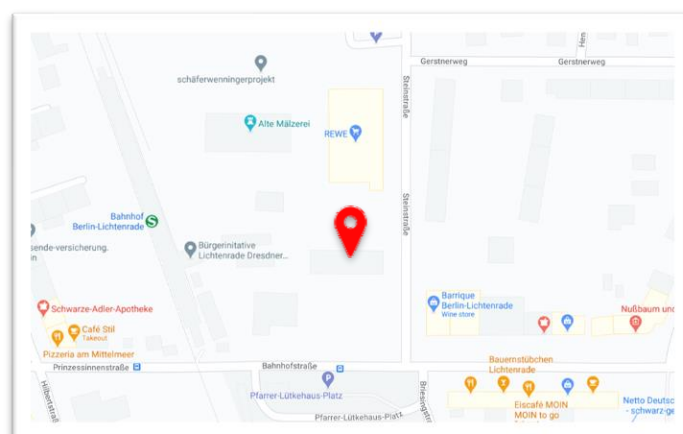


Figure 27: Berlin-Lichtenrade demonstration site



5.1.1 Data collection

A list of layers is provided for the specific use case of site planning. The query for the ‘Berlin-Lichtenrade’ demonstration site and ‘Site planning’ use case returns data categories as shown in Figure 28.

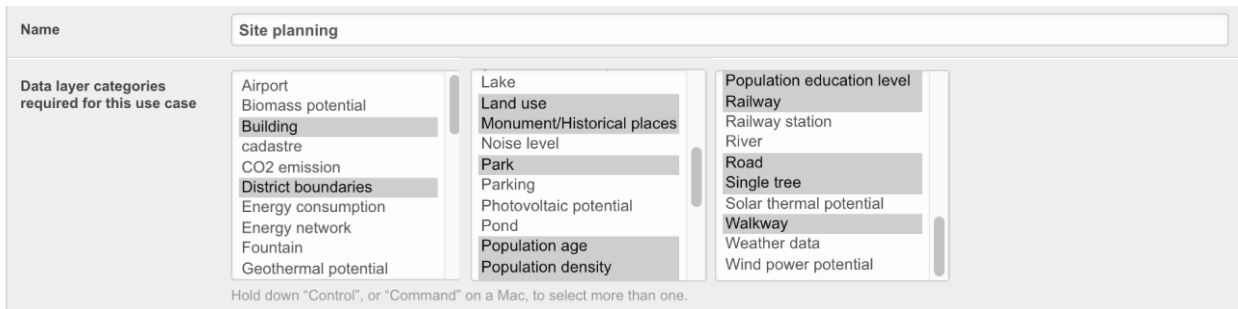


Figure 28: Data categories required for site planning use case

A radius of 200 meters is selected for retrieving the data. After retrieving the data, if there is lack of data in some area, it is also possible to use data from other data sources such as OSM (OpenStreetMap). For the current investigation, in addition to the data provided from BIM-SPEED GIS data provider service, single trees from OSM data have been added. Moreover, aerial imagery and satellite imagery has been used to check the data in the surrounding. Besides these 2D vector datasets, it is also possible to collect 3D GIS data for Berlin⁹. The data has been downloaded for a specific bounding box around the reference building in CityGML file format. Via ArcGIS Pro, it is possible to visualize the data along with the BIM data in the IFC file format.

5.1.2 Data visualization

ArcMap version 10.6 has been used to visualize these vector datasets which can be downloaded either in GML or Shapefile format via the service, or via accessing the OSM *.pbk file.

Figure 29 shows the single trees and street-line trees. As shown in the aerial imagery (Figure 30), in the backyard of the building, lines of trees can be seen which are not provided in the single tree layer. The reason is that the tree layer includes the data in the public area, while these trees are located in the private area. One way to include such data is by using the satellite imagery and extracting the vegetated area according to the infrared band of the image by calculating the NDVI (Normalized Difference Vegetation Index). An NDVI layer from Sentinel II imagery is available from ArcGIS Online data sources (Figure 30).

⁹ <https://www.businesslocationcenter.de/berlin3d-downloadportal/#/export>



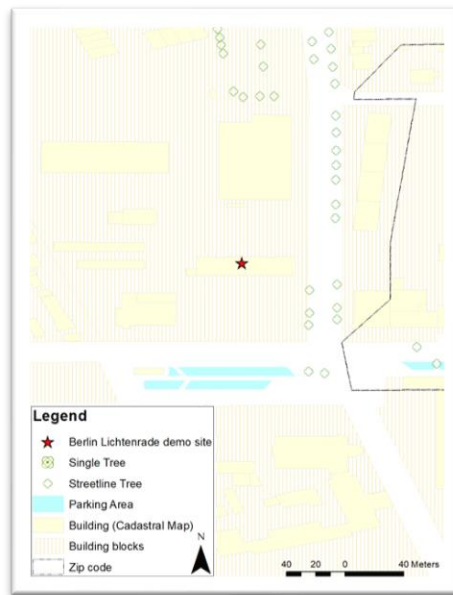


Figure 29: Single trees, buildings and parking areas in the surrounding

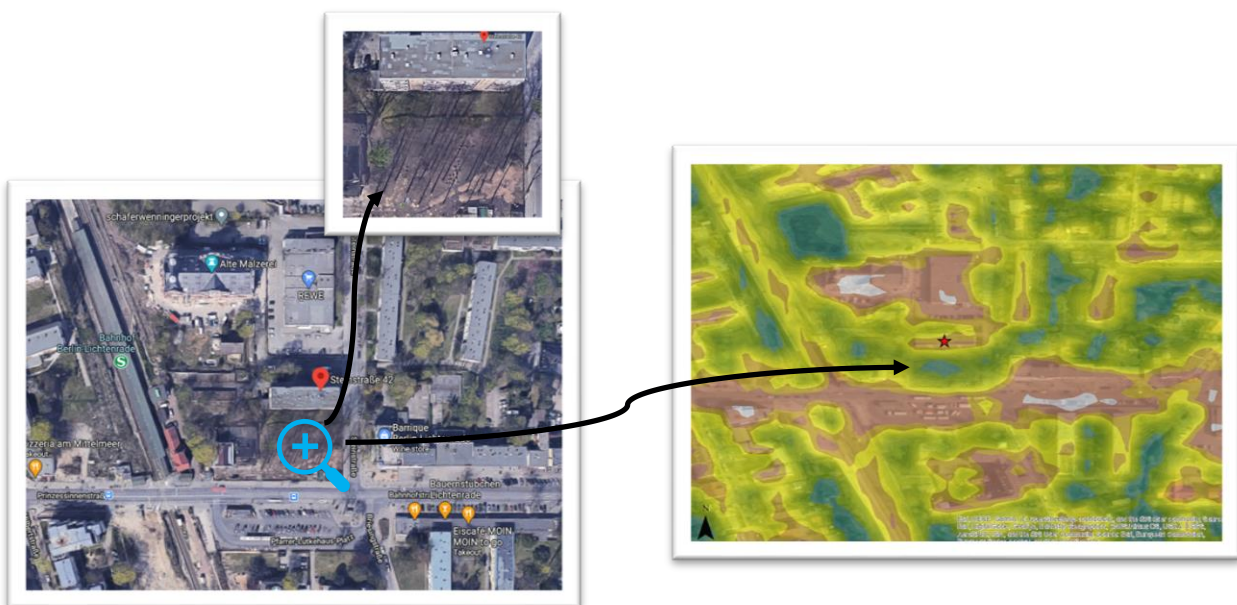


Figure 30: Aerial imagery of the demonstration site and NDVI of the area

In case, in some areas, there is overlap between the data features, spatial analysis and selection by location helps to select only those desired features, so that the result does not include redundant features in one location.

5.1.3 Interpretation

As shown in Figure 31, the reference building is surrounded by other buildings that can cause shading effects. To investigate the shading effect of the surrounding buildings, information about the height or number of floors of the surrounding buildings is required. Although, to have a better demonstration of the shading effect, 3D visualization is a more intuitive approach. This shading



effect can cause a cooling and heating effect and can influence the lighting and thermal comfort of the building. So, in the building energy modelling, it is important to consider this effect along with the physical structure of the building and weather conditions.

The 3D data of the Berlin-Lichtenrade demonstration site is provided from the Business Location Centre geoportal in CityGML data format. It is possible to view the CityGML file in a scene in ArcGIS Pro along with the IFC file of the site (Figure 31)



Figure 31: Integration of CityGML and IFC file in ArcGIS Pro

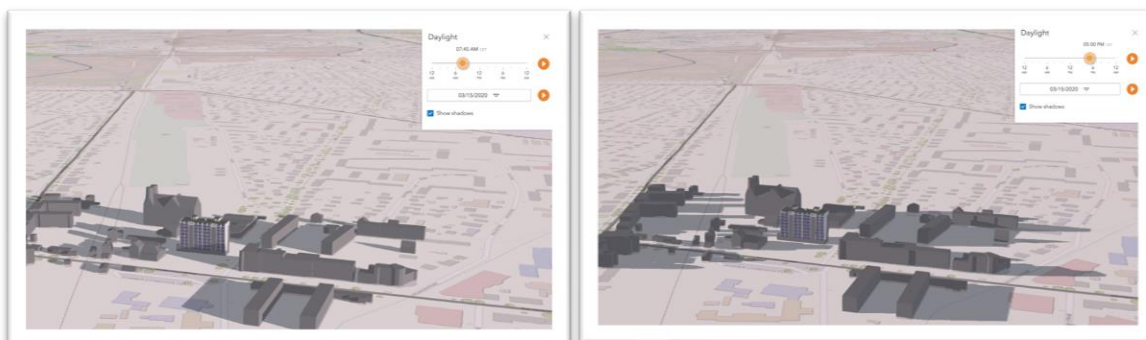


Figure 32: Shading effect of the buildings and daylight in different times of the day

Publishing this data via ArcGIS Online provides information about the day light and the shading effect on different dates and times of the year (Figure 32).

The tree layer reveals that there are solitary trees in the public area (Figure 29), which can affect shading on the building, or can cause disturbance in data collection. In addition, as shown in the aerial imagery, there are trees in the backyard of the building as well. Particularly as the trees are located closely to the façade of the building, 3D and thermal data collection via drone-flight will probably raise problems. Knowing in advance about the surrounding of the building, constant obstacles such as built area and solitary trees, as well as possible temporary obstacles such as parking areas help planners and data collectors to know in advance which data collection approach best fits the area. If drone-based approach needs to be utilized for a demonstration site, it is important to consider the location of airports in the vicinity of the building (Figure 33).



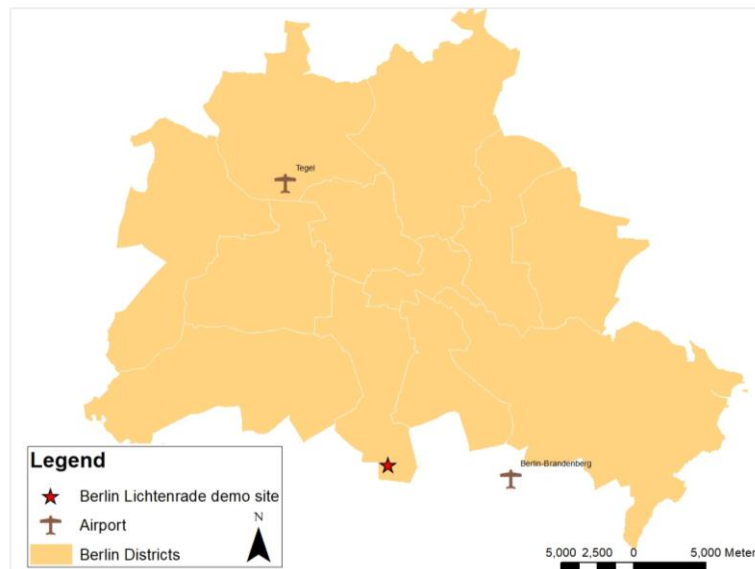


Figure 33: Location of airports in the city of Berlin

This is important because in many countries, there are regulations for flight close to the airport. In Germany, for instance, the drone may not fly closer than 1.5 km to the airport and may not fly higher than 50 m in the accepted zones¹⁰. In addition to airports, other regulations do not allow flight above or in lateral distance of 100 m from federal highways and railway facilities. Restricted areas of Berlin are provided online on a map¹¹.

Figure 34 shows that the building is located within a historical or monumental area. In order to have more information about the monuments in the area, a link has been provided in the attribute table of the layers. By clicking on the hyperlink, it is possible to open the related information.

Figure 35 shows the location of the building in a land use map. The building itself is of residential type, while it is located within a mixed type land use. In a very close distance of the building, the land use type is commercial and industrial, while in the west, railway transport infrastructure is located. In further distance in the surrounding the dominant land use type of the area is residential.

¹⁰ <https://www.drone-made.com/post/germany-drone-laws>

¹¹ [https://map2fly.flynex.de/a/map/fn/\(mapSidebarRight:mapInfos\)](https://map2fly.flynex.de/a/map/fn/(mapSidebarRight:mapInfos))



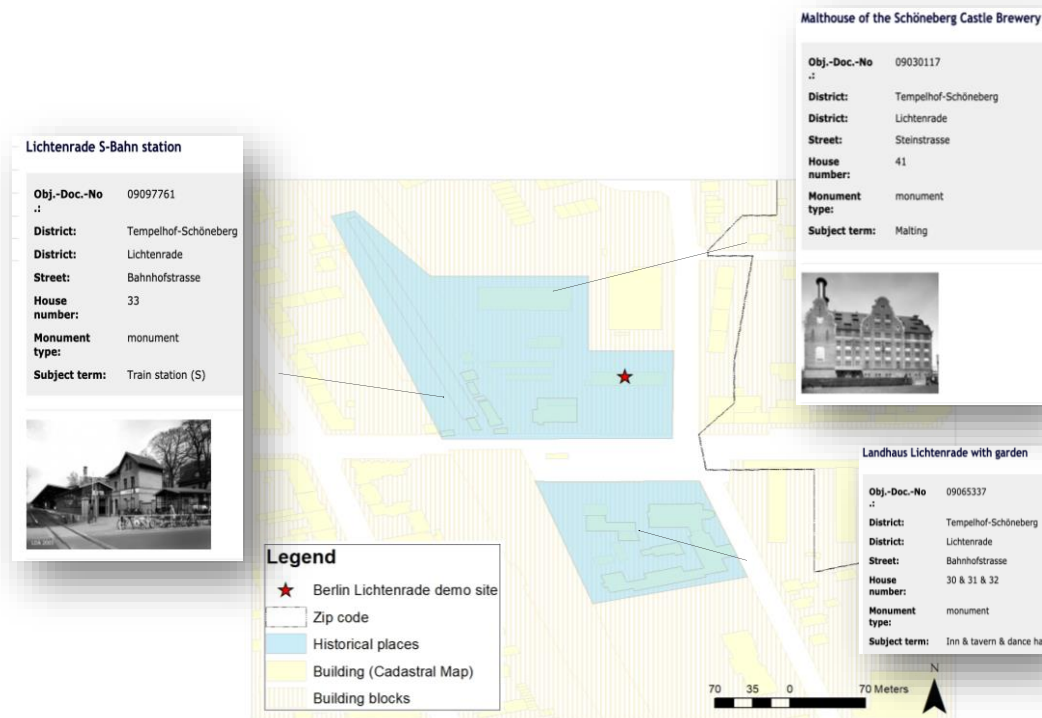


Figure 34: Monuments and historical places in the surrounding

Figure 36 shows the road network. The building is located close to the main roads, meaning that access to the building for the construction process is not problematic. On the other hand, the roads and the railway located at a very short distance to the building cause noise pollution as well as air pollution. This points out the fact that acoustic and air quality comfort analysis of the building should be included in the plan of the performance analysis. Also, for those purposes, it is possible to use noise data and CO₂ emission data that are already available from GIS sources. Vegetated areas, parks, lakes, ponds, or rivers and in general green and blue spaces in the district can have an impact in two ways. On the one hand, they change the microclimate in the area by causing a cooling effect, that can affect the thermal comfort of the building. That can be predicted via building energy modelling and comfort simulations. On the other hand, because these areas can be considered as public spaces where people gather, or where children's playgrounds are located, they can affect the acoustic situation of the area. As shown in Figure 37, such objects are not located in close distance to the building in the Berlin-Lichtenrade demonstration site.



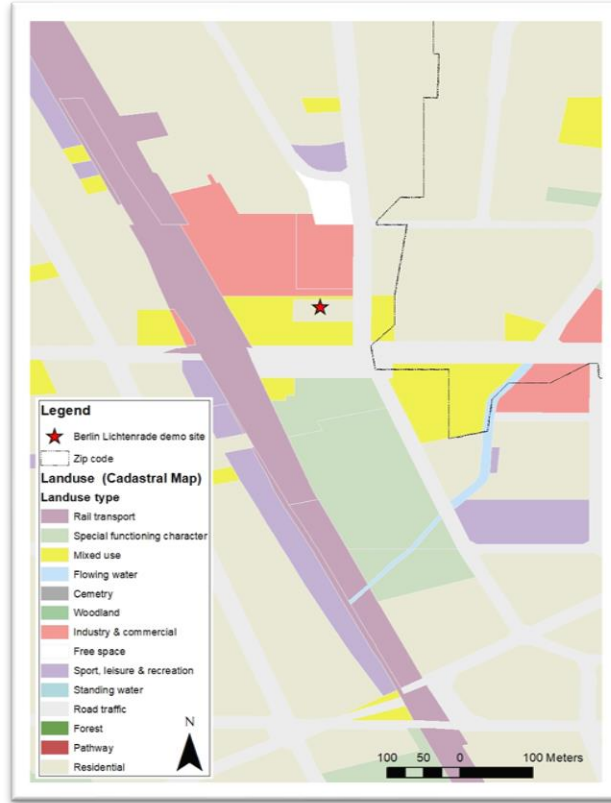


Figure 35: Land use map



Figure 36: Road network and railway



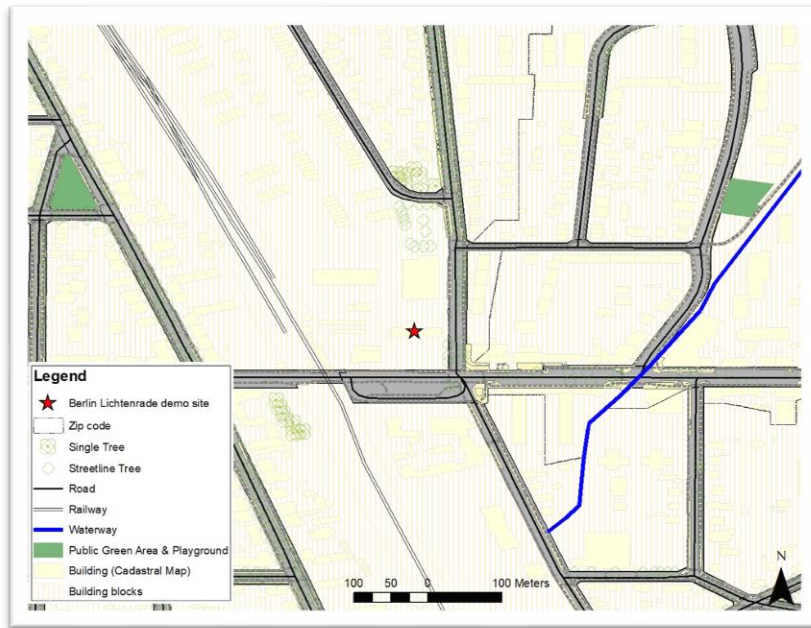


Figure 37: Green and blue spaces in the surrounding



Figure 38: Population density of the surrounding



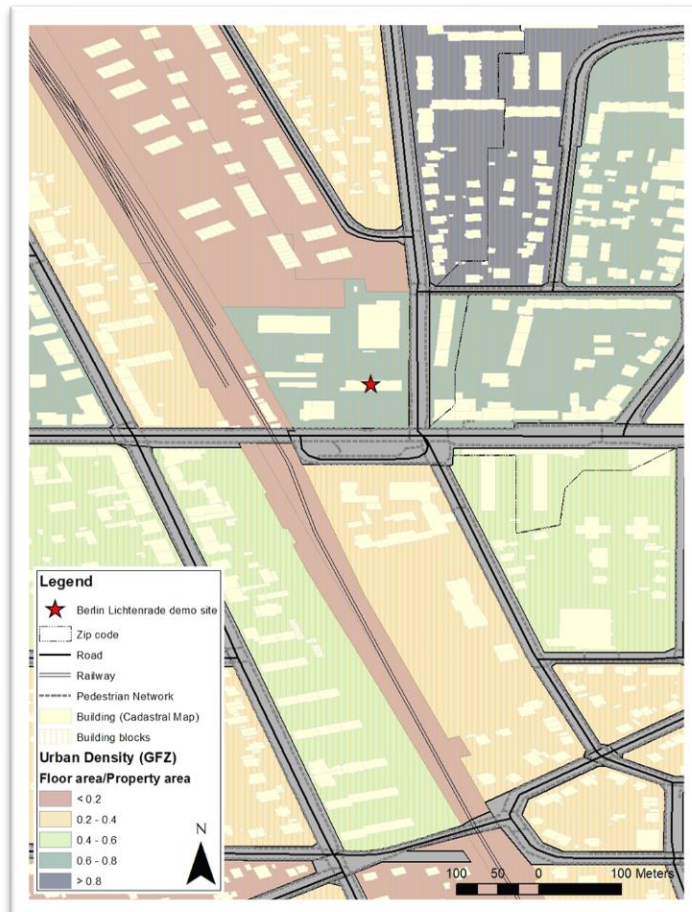


Figure 39: Urban density, Floor Space Ratio (GFZ) of the surrounding

The population density of the areas is shown in Figure 38. The building is located in an area where between 71-150 people are living per ha. In comparison to other building blocks in the surrounding of the building, population density is less. Many studies focused on the relationship between population density and efficiency in energy consumption ([9], [10]). On the other hand, urban density or Floor Space Ratio (GFZ) describes the ratio between the gross floor space of all floors of every building and the size of the area. As shown in Figure 39, the building is located in a denser urban area in comparison to other building blocks in the surrounding.

More information about the people living in the vicinity can reveal information about the people living in the reference building. A region is usually homogeneous regarding its cultural characteristic. Thus, if such data is available for the district and region, it can give some impression about the consumption behaviour of people living in the building under renovation. Population age, education, and cultural background can reveal some information that can help in this respect.



Not all the information provided in the ontology is available for all demonstration sites, but as shown, any possible information can help to understand the context of the building better. In order to have a more realistic plan, decision-makers need to have a more comprehensive view of the building situation. All the data mentioned above and more than that, can help in this respect.

5.2 Building energy modelling use case

The influence of surrounding GIS and environmental data in building energy modelling has been discussed extensively in D3.3: *Methods for integration of environmental and GIS data to BEM*. In addition to all geospatial data which can be retrieved for a specific demonstration site, weather data is a requirement for building energy modelling which can be retrieved from MEREEN weather service implemented as part of D1.4. The service is available directly from the BIM-SPEED platform and can be accessed from the IFC files (Figure 40 and Figure 41). Accessing from the IFC file provides the opportunity to extract the GPS coordinates of the demonstration site and retrieving the closest weather station to the site.

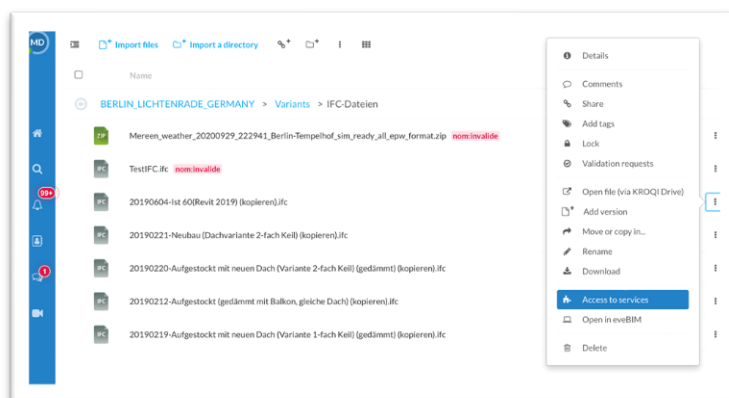


Figure 40: Accessing to MEREEN weather service from IFC file stored in the BIM-SPEED platform

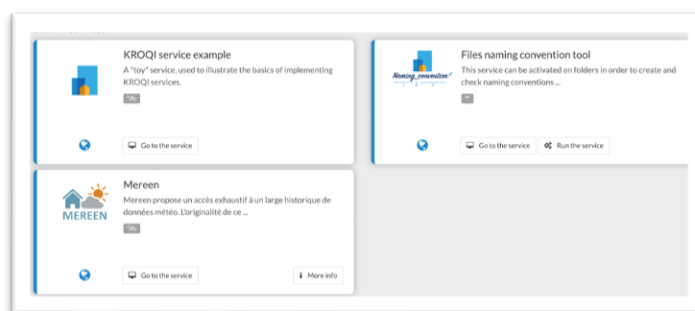


Figure 41: Accessing MEREEN weather service directly in the BIM-SPEED platform

By clicking on the 'Go to service' button, a pop-up will appear, which returns information about the closest station to the location of the demonstration site (Figure 42). Name and number of the station, data availability from different sources and in different periods are described in this section.



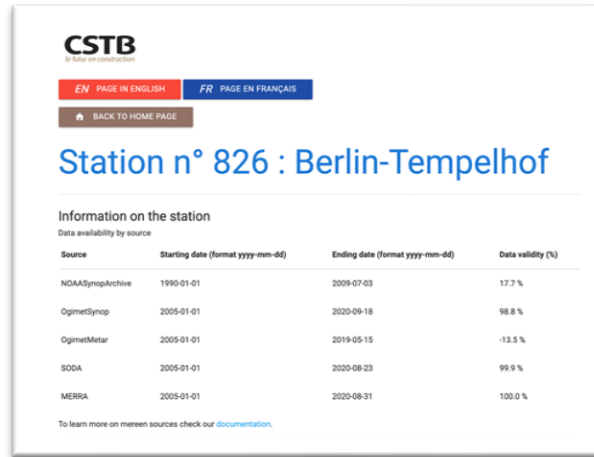


Figure 42: Information about the retrieved weather station

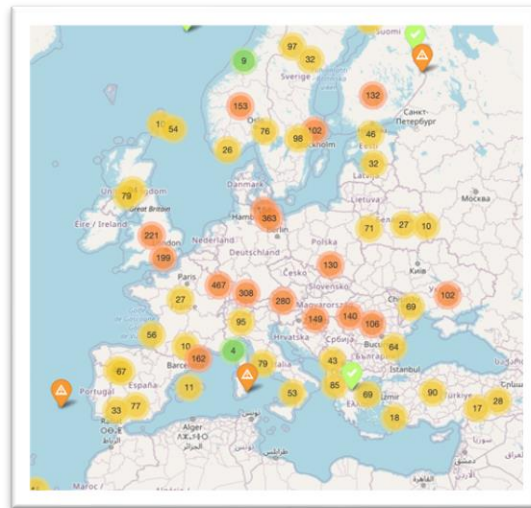


Figure 43: All weather stations in Europe visualized in MEREEN weather service

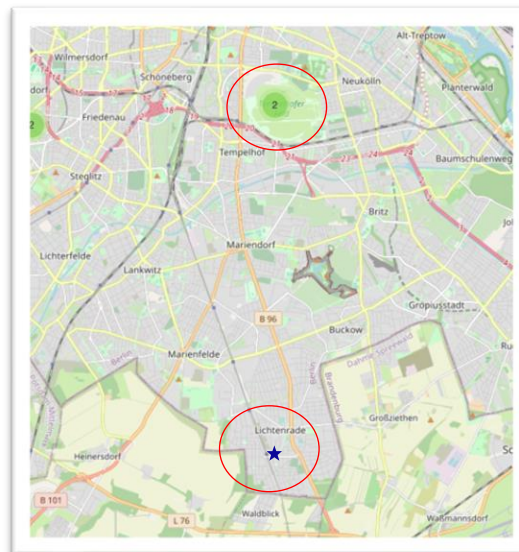


Figure 44: Distance of the weather station from the demonstration site



Closer look at the weather service map which is also available online¹² (Figure 43), shows that the distance from the weather station and the demonstration site is more than 9 km (Figure 44). The pop-up also includes sections for selecting the time interval for which the data is required (Figure 45). The user can select the whole datasets, a specific interval, or a specific year. It is also possible to select the output data format (Figure 46).

Then by clicking on ‘Export your data to the BIM-SPEED platform’, the service will download the data into the relevant folder in the BIM-SPEED platform (Figure 47). The zipped file includes both csv file and EPW file.

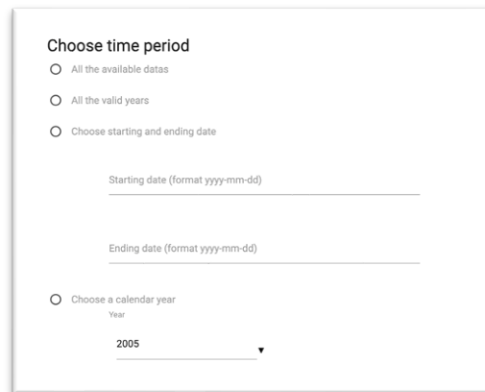


Figure 45: Choosing the time period in MEREEN weather service

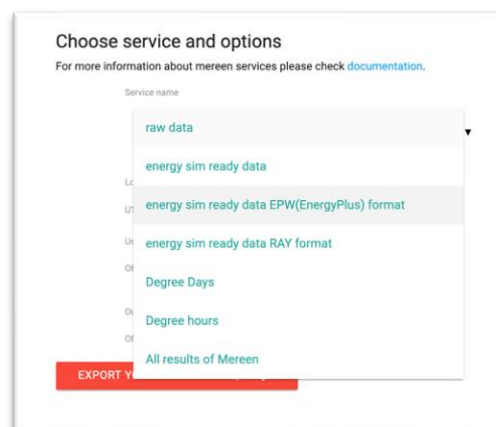


Figure 46: Selecting the weather data format in MEREEN weather service

¹² <https://mereen.dimn-cstb.fr/map/fr> (access requires authentication)



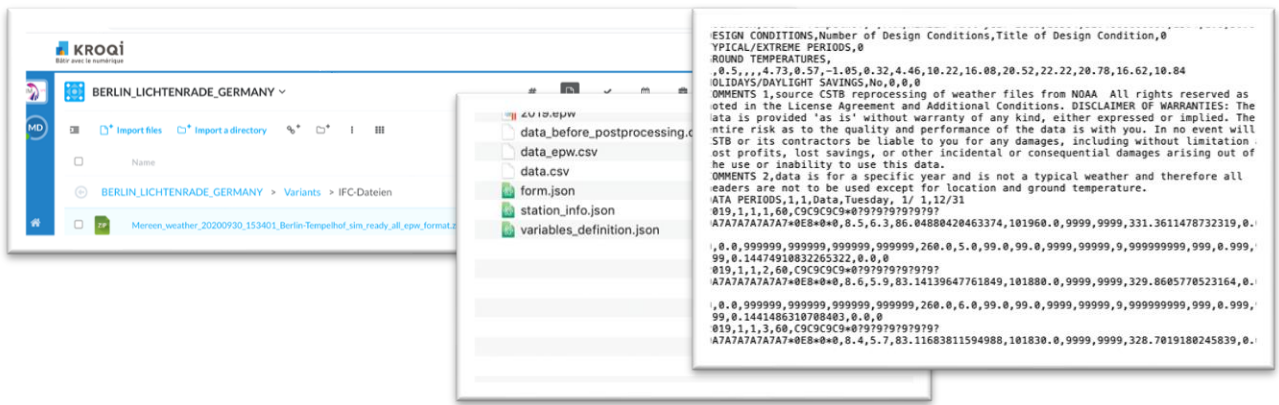


Figure 47: Downloading the weather data in the BIM-SPEED platform



6. Conclusions and future works

Deliverable 1.4 presents IT architecture and standardization for retrieving and storing GIS and weather data. Two services are implemented namely BIM-SPEED GIS data provider service and MEREEN weather data service. The former focuses on all features in the built and natural environment of a renovation project. Retrieving data from the service, currently only focuses on vector datasets via using WFS registry links, while retrieving maps and coverages from WMS and WCS is planned for future versions. The latter service focuses on the recent historical actual weather data, while the typical weather data is also expected in future versions.

While many EU projects mentioned and studied the effect of GIS data in the renovation process at the district level, this deliverable in the BIM-SPEED project addresses the practical usage of these datasets in the workflow of renovation at the individual building level, considering all the detailed accurate information collected for the building. The outcome of this deliverable can be used in the integration of GIS and environmental data in the energy modelling process (T3.3), also for the collection of exterior data required for KPI calculations and comfort analysis of the buildings.

The validation of the developed ontology for the surrounding and environmental data, which is used as the basis for implementing the BIM-SPEED GIS data provider service is considered as a future task. As this is a work in progress, changes in the use cases and data categories are expected and are predicted in the service implementation via the possibility for modifying use cases and their required data.

Another future task is to consider the as-built contextual data of the building in developing the BIM passport. Within BIM passport, any data that is used to fulfil BIM Use Cases, need to be checked to be available, and the quality of the data needs to be controlled. The attempt of this deliverable for organizing the related use cases and the relevant data categories can help in this respect as well.



7. References

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